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Market intermediation and its embeddedness – Lessons from the Finnish energy transition

S. Hyysalo [a], E. Heiskanen [b], J. Lukkarinen [c], K. Matschoss [b], M. Jalas [a], P. Kivimaa [c], J.K. Juntunen [d], F. Moilanen [c], P. Murto [a], E. Primmer [c]

[a] Aalto University, Department of Design, Finland
[b] University of Helsinki, Consumer Society Research Centre, Finland
[c] Finnish Environment Institute, Finland
[d] University of Vaasa, Finland

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ABSTRACT

Energy transitions are in many respects past the early exploration stages and moving towards the urgently needed mass market take-up. We examine the Finnish energy transition regarding how solutions – heat-pumps, deep retrofits and new district-wide solutions – that have demonstrated economic benefits and reasonable payback times have faced slow uptake and slow market development. We focus on the difficulties that suppliers and adopters face in establishing the value and singularization of goods when adopters need to act as calculative agents in the market. When the intermediation processes needed for market development do not cover the all the needed aspects, these market difficulties can persist until late in the transition process. We further elaborate how the intermediation takes place in ecologies of actors that become complex once the complexity of goods grows and the intermediation becomes tied to formalized arenas such as those found in urban development. Periodic assessment of the effectiveness of markets and ecologies of intermediation can inform policy interventions on market development.

1. Introduction

Energy transitions are in many respects past the early exploration stages and moving towards the urgently needed mass market take-up, albeit with slower speed than low-carbon scenarios would require (IEA, 2021). This calls for deeper understanding on how early technology experiments and actor networks turn into exchanges mediated by markets.

Standard economic theory downplays the political and institutional nature of establishing markets and the proliferation of new technologies. Transition research insists that markets do not unproblematically emerge to mediate between alternative goods and buyer demand (Dewald & Truffer, 2011; 2012; Ottoson et al., 2020; Boon et al., 2020). Markets are one aspect of the distributed process of system change (Geels & Schot, 2007; Bolton and Hannon, 2016; Saransini and Linder, 2018), and are seen to evolve over the course of the transition from early nurturing markets to later mainstream markets, enabling wide take-up of sustainable solutions (Geels & Schot, 2007; Safarzynska et al. 2012). Recent studies pay more focused attention to markets in transitions and the constituents of market formation in different transitions (e.g. Ottoson et al., 2020; DeWald & Truffer, 2011) and the geography of market formation (Dewald & Truffer, 2012), and call for further research on processes and different actors in market formation during transitions (Boon et al. 2020).

Increasing evidence points to the importance of not just producers, consumers and policy actors, but various intermediary actors being key facilitators, sometimes even drivers of, transition processes (e.g. van Lente, 2003; Guy et al. 2011; Kivimaa et al. 2019a,b;

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Mignon & Kanda, 2018; Kivimaa et al. 2020). Intermediaries are involved in creating new markets for innovative solutions through pooling knowledge and financial and human resources (e.g. Stewart and Hyysalo, 2008; Klerkx et al, 2009), sometimes concretely facilitating the emergence of new business models (Mlecnik, 2013; Brown, 2018), as well as challenging existing market structures and voicing demands (Boon et al., 2011; Kivimaa, 2014). Intermediaries influence the real and perceived availability, economic viability, dependability and appeal of different systems of provision for consumers, as well as advocate interests, deliberate and shape the ways in which information is transferred (Rohracher 2009; Moss 2009; Backhaus 2010; Bergek, 2020). Indeed, much hope has been placed on transition intermediaries in accelerating transitions (Kivimaa et al., 2019a,b; Kivimaa et al. 2020).

Close-up research on intermediaries in transition processes consistently underscores how intermediaries and their contributions emerge from complex, fleeting, uncertain and fragile positions (e.g. van Lente, 2003; Guy et al. 2011; Hargreaves et al. 2013). Rather than seeing intermediaries as just bearers of important system functions, their capacities should also be understood as being part of historically formed and contingently changing *ecologies of intermediation*, in which many actors mediate one or several aspects of the systems change, often in somewhat partial and imperfect ways (Stewart & Hyysalo, 2008; Hyysalo et al., 2018; Kivimaa et al. 2019a, b; Hyysalo, 2021). The relationship between ecologies of intermediation and markets is one of the important process aspects to clarify regarding markets in transitions, and thus our research question is:

How do markets for low carbon solutions emerge through patterned and fragmented intermediation?

To this end, we examine a decade of research on the Finnish energy transition regarding how 'readily available' solutions – heat-pumps, pellet burners, building energy efficiency improvements with added renewable production, and new district wide solutions – have faced protracted uptake due to adoption difficulties, despite their demonstrated economic benefits and reasonable payback times. After discussing the literature in section 2 and data and methods in section 3, section 4.1 elaborates how these adoption difficulties can continue until late into the transition process, when market actors cannot provide the needed information to consumers, and the intermediaries who could bridge gaps do so only partially. Section 4.2. shows how adopters' difficulties to act on the market can pile up when the nature of solutions in the market is more complex. Section 4.3 expands the analytical focus to urban development contexts, in which much of the intermediation has to take place in several differentiated formalized arenas. This adds to the demands intermediaries face regarding skill-sets, investment and commitment to particular arenas and strategies needed to realign actors therein. Sections 4.4 and 4.5. examine the possibilities that cross-linking of intermediation across formalized and experimental arenas in municipal and policy setting processes opens for market development. Discussion and conclusions follow in sections 5 and 6, explaining how the slowness of market development in energy transition owes in no small measure to the patterns of changing the intermediation in which markets are embedded.

2. Markets and Intermediation in transition processes

2.1. Markets in sustainability transitions

Sustainability transitions research underscores that the radical systems changes required for more sustainable production and consumption patterns do not result from simple market selection amongst competing goods (Geels and Schot, 2007; Köhler et al., 2022). Radical changes face the inertia of existing sociotechnical regimes in which shared rules and the intertwinement of the technology base, scientific research, logistics, raw materials access, investments, regulation, and consumption patterns have formed strong path dependencies and efficiencies through decades of sunken investment and learning effects (Geels & Schot, 2007; Köhler et al., 2019). Also, market structures and institutions are aligned with existing regimes, and market formation is one of key processes for alternative technological systems to emerge – alternative novelties cannot compete in the same markets from the start, and becoming competitive requires the formation of new markets and associated institutions (Bergek et al., 2008; DeWald & Truffer, 2011; Ottoson et al. 2020).

Recent years have seen increasing attention to the details of market formation in transitions. These conceptualizations share a process orientation to markets and a backdrop in the constructivist sociology of markets (e.g. Granovetter, 1985; Callon, 1998; Callon and Muniesa, 2005), albeit then differ regarding the details of the frameworks they propose. Dewald & Truffer (2011; 2012) concretize the 'market formation' function of the technological innovation systems (TIS) framework by examining German photovoltaic markets from early 'nursing markets' to 'bridging markets' to the verge of mass markets. They draw from social constructivist studies on markets (Möllering, 2009) to elaborate market formation sub-processes: formation of 'market segments' (through innovating, associating and institutionalizing); achieving and institutionalizing 'market transactions' (commodifying, communicating and competing); and formation of 'user profiles' through users determining consumer images, use patterns and preference structures.

Ottoson et al. (2020) depart from the observation that TIS, strategic niche management (SNM) and implicitly also the multi-level perspective (MLP) proceed through three distinct market phases in the course of the transitions: nurturing (niche), bridging (niche expansion) and mass markets (acceleration) (e.g. Smith & Raven, 2012; Bergek et al. 2008; Geels & Schot, 2007). They further observe that constructivist market-shaping research provides deeper understanding of markets as dynamic systems affected by distributed actions by the actors involved (e.g. Kjellberg & Helgesson, 2007; Nenonen et al., 2019 Callon, 1998; Callon & Muniesa, 2005). Ottoson et al. (2020) synthesize three key interacting processes for markets in sustainable technology. 'Proving the system' means material and organizational arrangements that show value creation being possible through production, distribution and use within the institutional constraints that are present. 'Constructing the narrative' refers to the discursive activities by proponents in positioning new goods favourably with respect to advocacy coalitions. 'Enabling exchange practices' refer to arrangements needed for determining the value

and exchangeability of goods, premised on value being an outcome of active and repeated exchanges in which negotiation of price, functionality, quality, payment and terms of delivery take place (Ottosson and Kindström, 2016).

Murto et al. (2019a, b) further analyze the enabling of exchanges for transition technologies by analyzing deep energy retrofits. They side with Dewald & Truffer (2012) in underscoring that technologies that are implemented in varying geographical, cultural, organizational or institutional settings require approximation of value in the particular adopter setting. They however go further and elaborate that to act in the market as calculative agents, adopters need to be able to singularize the value of goods among the competing offerings (Callon et al., 2002; Callon & Muniesa, 2005). This can require very complex calculations and recourse to reference sites, whose characteristics can be compared to one's own setting to determine realized value characteristics (Murto et al. 2019a, b), returns and risks, including projections of future technical and market developments, competition and sales volumes, as well as possible synergies and scale economies (Callon & Muniesa, 2005; Pollock & Williams, 2016).

A common thread across these explicitly market formation focused transition studies is the pursuit of more specific subprocesses to provide more concreteness to how markets change in transitions. They all also point to further research needs on details of how market development happens, and the roles different actors take particularly with respect to laying the ground for mass markets.

It is thus worth briefly recounting how the stylized 'middle' transition phases have been conceptualized to date. After early networks and experiments in the *exploration phase*, the *take-off phase* follows, wherein the alternative technology develops into a niche, with more developed technical characteristics and market availability, and gradual agenda-building around the niche (Safarzynska et al., 2012, Geels and Schot, 2007). The ideal-typical next phase is the *acceleration* phase, during which niches expand, institutionalize and become mainstream markets. The expansion of the adopter base is associated with structural changes in markets and institutions, and with the continued development of technological solutions, gradually improving their economies of scale (Safarzynska et al., 2012; Schot et al., 2016). Finally, in the *stabilization* phase of the transition it has become easier and more routinized for adopters to make a choice in the new regime than in the old, implying that also markets now favour the 'new' alternative (Geels and Schot, 2007; Schot et al., 2016). Comparably in TIS, bridging markets are assumed to give a way to mass markets roughly upon the beginning of the acceleration phase (Bergek et al., 2008; Dewald & Truffer, 2012). Different authors have indicated that the accelerated mass-market transition can begin someplace between 2%-15% of maximal market penetration (Meelen et al., 2019; DeWald & Truffer, 2012; Geels & Schot, 2007), albeit it is clear that in real-world transitions these stylized phases may play out differently, with some technologies stabilizing at low market penetration and others becoming integrated into each other (Lauttamäki & Hyysalo, 2019).

2.2. Transition intermediaries and ecologies of intermediation

Early transitions work on intermediaries focused on 'systemic intermediaries' (e.g. van Lente et al. 2003) and intermediaries in niche development (e.g. Geels & Deuten, 2006; Hargreaves et al., 2013). Subsequently, research has identified a range of relevant intermediary actors, such as governmental agencies (Kivimaa, 2014; Polzin et al., 2016; Barrie et al., 2017), urban development organisations (Guy et al., 2011), transition communities and networks (Ingram, 2015; Barnes, 2016; Lukkarinen et al., 2018), environmental NGOs (Rohracher, 2009), architects (Fischer and Guy, 2009), and internet discussion forums (Hyysalo et al., 2013, 2018; Meelen et al. 2019). Parallel research streams examine intermediaries between production and consumption (Howells, 2006; Stewart & Hyysalo, 2008; de Rubens et al., 2018; Bergek, 2020) and intermediation in the 'system building' of technological innovation systems (e.g. Mignon & Bergek, 2016; Lukkarinen et al., 2018). Regarding market formation, various intermediaries have been found to aggregate and abstract demands by end-consumers from idiosyncratic particularities into feasible business niches. Conversely, generic technical solutions are assembled and configured to serve particular needs of end-users and brought to operate in a given context (Guy et al. 2011; DeWald & Truffer, 2012; Kivimaa et al. 2019a,b).

Kivimaa et al. (2019a) synthesize the variety found in transition intermediaries into five distinct types of transition intermediaries, namely, systemic, regime, process, niche, and user intermediaries, and note how they can mediate within niche(s), within the regime or between niche and regime. A subsection of these actors have been given a specific remit to act as intermediaries in sustainability transitions, whereas many simply end up mediating in a transition (Kivimaa, 2019a; Beveridge & Guy, 2011).

Intermediaries seldom 'mediate at their will what they will', but their activities are tied by their own remits, business models, resources, access, materialities and infrastructures. As Guy et al. (2011) observe, intermediaries can instigate, momentarily steer or catalyse change, but they can hardly ever 'carry it through'. Intermediaries are also not functionally distributed in a sector or market and seldom cover all mediational needs, but tend to be clustered in positions and activities that are available, visible and sustainable for them (Guy et al. 2011; Stewart & Hyysalo, 2008). Following Stewart's & Hyysalo's (2008) work on innovation intermediaries, Kivimaa et al. (2018; 2019) stress that also in transitions, intermediaries tend to form 'ecologies' comprised of many actors and many ways of intermediating, and it is these multi-actor intermediation patterns rather than single intermediaries that need to be better understood for characterizing what intermediaries can (and cannot) do in transitions.

In order to understand intermediation patterns, some ambiguities need clarification regarding how intermediaries are addressed in transition scholarship. In closer view, the term 'Intermediary' is used as a shorthand that characterizes what a range of entities – e.g. people, organizations, physical locations, technical platforms – do in translating and transferring information and solutions, and facilitating exchanges and transactions between supply, regulation and use. Whilst the material and social makeup of many of these actors is complex, as well as consequential to what and how they mediate (Latour, 1987; Stewart & Hyysalo, 2008; Hyysalo, 2021; Contesse et al. 2021), this shorthand nevertheless addresses intermediaries as if they were organizational bodies, often as 'role holders' that 'do' 'intermediation'. But intermediation is foremost an activity or process and it can be carried out also by suppliers, consumers and policy actors as part of their other activities, or as an aside to it (Stewart & Hyysalo, 2008), e.g., suppliers' market oriented action may feature important intermediation. We thus from here on talk primarily of *intermediation*, and *ecologies of intermediation*, to denote

the activities involved, and reserve the term intermediary to actors/entities that primarily perform intermediation rather than do something else.

Yet, this calls for concepts to better address not just intermediaries but the other actors involved in intermediation. We propose that to this end two interrelated concepts from symbolic interactionist science and technology studies are helpful: *ecologies of actors* and *arenas*. Drawing on pragmatist tradition, symbolic interactionism sees *ecologies of actors* as a result of mutually defining lines of action by the actors involved in an event (Strauss, 1993), and more typically, the patterning of events that have resulted in more durable social institutions and topologies of power, resources, skills, materialities, constituencies and commitments (Strauss, 1993; Becker, 1982; Clarke & Star, 2003).[1] Ecologies are typically populated by a range of differing sociotechnical entities, some of which are nested and others that are not, or are so only partially. Organizations, social movements, professional and industry associations, start-up companies, internet platforms, families, and governmental agencies all have distinct characteristics and ensuing different capacities of action. Actors in these sociotechnical entities are typically somewhat aware of each other and the patterns of previous actions (Becker, 1982). They also tend to have complex interrelations that reach, in time and space, beyond a single event or arena (Clarke & Star, 2003). This has a propensity to result in many-to-many translations that extend over time rather than one-time contestation or translation of interests (Clarke & Star, 2003).

Arenas for social action refer to sociotechnically constituted social or physical 'spaces' wherein the current and renewed order between actors is negotiated (Clarke & Star, 2003). Arenas are thus patterned and often structured meeting grounds for ecologies of actors. In ecological sociology arenas are settings that feature some measure of stability and recognizability to the actors involved in them. Arenas can be in various stages of formation, from the emergent and fluid networks to formalized ones such as arenas of land-use planning (Heiskanen et al. 2018). The notions of arenas and sociotechnical space are already in varying use in research on transition processes and intermediaries (e.g. Guy et al., 2011, Jørgensen, 2012). Our more theoretically general notion of arenas and the ecology of actors populating an arena provides clarity to the common elements in specific references to experimental arenas, arenas of development, emerging arenas, policy arenas, or urban development arenas.

3. Research context, data and methods

We focus on technological solutions that, at the time of the study, were, or were becoming, cost-effective. In Finland, heat pumps became cost-effective in the early 2000s, solar PV for self-consumption in 2016, and several cost-effective combinations of new heating solutions were identified as readily available in 2015 (FINZEB, 2015). The technical advances have not, however, led to their automatic diffusion and transformation of the energy system. The energy transition has been piecemeal, as solutions for energy demand reduction (such as integrated energy efficiency services) have struggled to diffuse due to a range of barriers (e.g. Kangas et al., 2018).

We attempt to understand this situation by drawing on the results of a long-term research project that investigated the role of intermediaries in the energy sector transition. We cross-examine an eight-year span of 14 studies (Fig. 1) on intermediaries working to create new consumer markets (i.e., user-side intermediaries), intermediaries working to integrate these technologies in city energy systems and the built environment, as well as intermediaries attempting to create public policies for these technologies and markets.

The overall data assembled for this synthesizing analysis comprises 175 interviews with actors in the focal projects, 18 interviews with experts not directly involved in the projects studied, 11,000 pages of document materials, and approximately 50 months of ethnographic observation in the sites studied. Our first-stage data and analysis methods are detailed in In Appendix 1. The data analysis proceeded through a two-stage process. First-stage analyses were pursued for individual case analyses that have been reported elsewhere in altogether 17 research articles and one book (referenced in-text with each case analysis).

The second stage comprised of cross-case analysis to find patterns at the aggregated level reported in the present article. Our rich ethnographic data on user-side intermediation in emerging and mainstreaming markets for heat pumps and other retrofit technologies allows us to conceptualize *ecologies of intermediation*, with a focus on the type of competence that users and suppliers require, even in

[1] Abbott (2005, 248-249) articulates the position of ecological sociology within broader social theory: "When we call a set of social relations an ecology, we mean that it is best understood in terms of interactions between multiple elements that are neither fully constrained nor fully independent. We thus contrast ecology with mechanism and organism on the one hand and with atomism and reductionism on the other. The latter contrast is straightforward and general: ecology involves some kind of relation between units whereas atomism and reductionism involve only qualities of units themselves or of their aggregates. With mechanism and organism, the contrast is more specific. When we encounter complete and routine integration in the social world, we employ the metaphor of mechanics, as in the "rule-governed systems" of role theory, for example. When we encounter systems whose elements move together in flexible homeostasis, we use the metaphor of organism, as in structural functionalism. By contrast with these two, in ecological thinking the elements are not thought to move together at all; rather, they constrain or contest each other. "Ecology" thus names a social structure that is less unified than a machine or an organism, but that is considerably more unified than is a social world made up of the autonomous, atomic beings of classical liberalism or the probabilistically interacting rational actors of microeconomics.". Within theories popular in science, technology and innovation studies this epistemological stance is thus different to both either actor network theory (ANT) or multi-level perspective (MLP). ANT proceeds from actants and networks they form, leaving all issues of topology and structuration to be only empirically settled and does not have pre-existing or generic conceptual registers to address them ie it relies on what has become to be called 'flat' ontology. MLP, in turn, presupposes a pre-defined structural ontology to which study findings have to populate (Hyysalo, 2021). In contrast, the ecological views acknowledge the existences of previously identified social entities as *sensitizing concepts* that orient empirical inquiry towards topologies and ecologies, and suggests empirical points of entry, but do not assume that these take a necessarily take a pre-defined structure or shape, and thus leaves the outcome analysis of both ecologies and topologies to be empirically built for the topic at hand, not structurally pre-determined (Strauss, 1993; Star & Clarke, 2003).

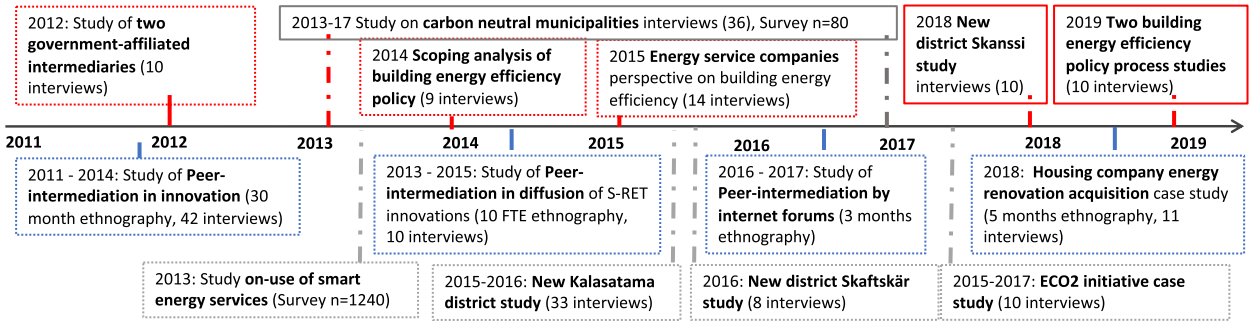

Fig. 1. The timeline of studies in on intermediaries in Finnish Energy transition

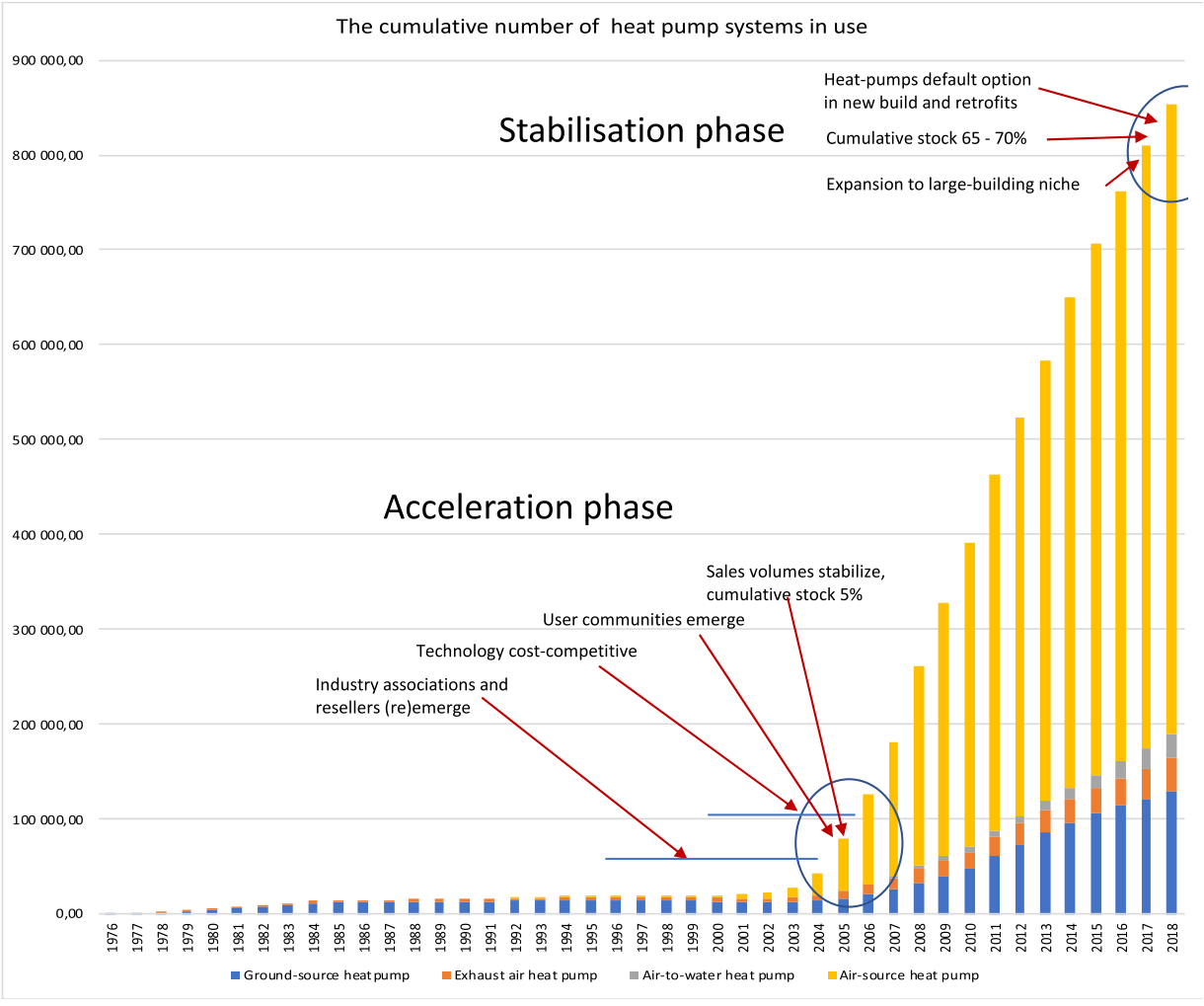

Fig. 2. The cumulative number of heat pumps in Finland, and markers for acceleration and stabilization phases of transition. Sources: SULPU, 2020, Hyysalo, 2021.

mainstream markets, and the kind of bridging across various arenas that is required for intermediation. Our case studies on city-level intermediaries, in turn, depict attempts to actively construct arenas to facilitate change, and how intermediation is required to both assemble and support new solutions and disrupt existing institutionalized practices. Finally, our analysis of intermediation in policy processes shows the important role of intermediaries in moving between different *market and policy arenas* for the articulation of feasible policy measures.

Cross-case analysis involved the author group working through all cases from the ecologies of actors perspective. Conceptualization and re-analysis of the original data proceeded through first identifying common themes and their incidence in different cases, then identification of more specific dynamics, constraints and intermediary capacities across the cases by tabulating the original data using the ecologies of actors concepts. For example, mutually defining lines of action by the actors involved in the relevant events were identified, along with their topologies of power, resources, skills, constituencies and commitments, as were arenas where temporary social orders are negotiated. We also tested for alternative explanations for the patterns found, for instance on what grounds can intermediation be observed and conceptualized to be biased, crowded-out or missing in different settings. The outcome analysis was then worked into a set of themes and organized into a presentational narrative shortened for the present article.

4. Results

4.1. Late emergence of mass-market conditions in heat pumps due to embedding of markets in intermediation

Taking an explicit adopter perspective to transition renders visible market deficiencies and the related contributions and limitations of different intermediaries (Rubens et al., 2018; Murto et al., 2019a, b; 2020). We discuss this first with data on heat pump purchases at three points in the transition, those at approximately 13%, 20-50% and 80% of estimated maximal market penetration (Heiskanen et al., 2011; Hyysalo et al., 2018; Hyysalo, 2021). Condensing the development into an empirical case summary illustration, we begin from the point when the heat-pump niche was arguably beyond the exploration and start-up phases in detached housing in Finland: Heat pumps were cost-effective in detached houses, industry associations had been formed over a decade earlier, there were tens of makes, models and resellers including large hardware chains, and sales had stabilized to about 50,000 units annually (Hyysalo et al., 2018; Hyysalo, 2021).

Case illustration: In 2007, when heat pumps were widely available and had reached around 13% of their estimated maximal diffusion potential in Finland, a residential association in a small town launched a joint purchase project. Despite frequent mentions in Finnish media at the time and availability of tens of models, the project champions concluded that reliable comparative information was not available in the market and contacted approximately 20 organisations with expertise in heat pumps, with minor help from only two organizations. Undeterred, the men applied for EU regional funding to run a nine-month €16k project comparing 82 heat pump models, resulting in a joint purchase of 120 heat pumps. Some months later the residential association was contacted by a government energy agency to help build information packages on heat pumps, but the market was developing fast and the association's information had become outdated (Heiskanen et al. 2011).

Other citizens solved this problem by setting up Internet discussion forums to aid in sizing, selecting, installing, maintaining, and improving heat pumps. In 2016, the largest forums featured 500,000 posts, and had been read over 150,000,000 times in a language

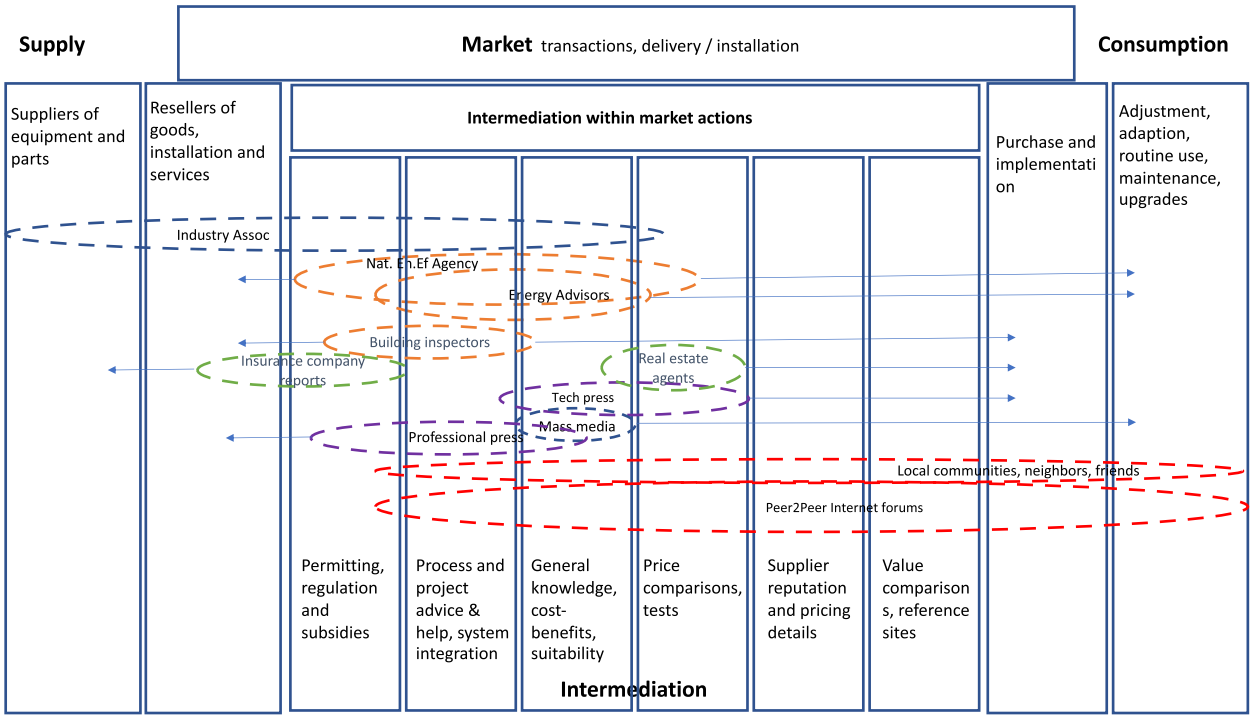

Fig. 3. Ecology of intermediation in heat pumps for detached houses in early acceleration phase. Semicircles indicate the area in which particular intermediaries intermediate and arrows to where the intermediation reaches.

area of 5.5 million people. At this point 750,000 pumps had been installed (55% of maximum diffusion) and for every purchased heat pump, the forums had been read around 130 times. A similar, up-to-date careful and informed comparison for which the two early project champions had to spend months of their time, could now be run from home in a matter of hours, including actual energy consumption data for comparisons (Hyysalo et al., 2017; 2018). By the end of our follow-on of heat-pump transition in Finland in 2020, many adopters no longer needed to visit the internet sites, as heat pumps had become such a common and taken for granted good that market offerings could be trusted and easily compared. In the detached housing segment, the heating system transition had by this time progressed to a point at which 80% of heating solution purchases included one or another type of heat pump (Hyysalo, 2021).

This comparison of how much work it takes for adopters to make an informed purchase choice, and thus be able to achieve the singularization and calculability between goods that characterizes acting in the market (Callon & Muniesa, 2005), draws attention to five interrelated issues. First, in an emerging market for low carbon solutions, the market transactions include information about goods and require context-specific evaluations. These include possible permitting needs; yield and payback estimates; the installation's suitability and costs; process and project management understanding; maintenance needs, costs, competencies and availability; supplier and installer reputation; and suitability to customers' preferences such as esthetics, noise, and heating levels. Second, suppliers face difficulties in providing this information in a trustworthy way, even when one or several reference sites exist, because more complex aggregation and site-specification is required (Jalkala & Salminen, 2010; Pollock & Hyysalo, 2014). Third, and consequently, users may (have to) invest much time and effort, in effect even turning themselves from consumers to user-side innovation intermediaries to fill in the knowledge gaps for themselves and for their peers (Stewart & Hyysalo, 2008; Barnes, 2016). Fig. 3 schematically represents the range of intermediary actors that mediated the new technology to consumers, but only with respect to some aspect, depending on the remit, interest, and time constraint of the actor. The result is an *ecology of intermediation* that builds up historically in response to the contingencies of technology, market and institutional development, rather than functionally, resulting in partial and piecemeal patterns of intermediation, where some aspects of the technology supply and markets are covered by several competing and complementary providers, whilst others remain devoid of the mediation that final beneficiaries need (Fig. 3).

Fourth, examining a rare case of a low carbon solution proliferation from its beginning to next-to-complete transition indicates that markets can remain remarkably underdeveloped even once the transition is well beyond its exploration and start-up phases. In this case, mass market conditions did not exist before approximately 25% maximal diffusion. Fifth, the patterns of intermediation also shift as technology options develop, new actors emerge to fill in gaps in knowledge or transactions, existing ones expand their repertoire or opt out of some activities, and at the verge of the stabilization phase, we indeed see that the requisite intermediation is found largely within market actions by suppliers and consumers (Fig. 4.

4.2. *Complexity of goods and needs in deep energy retrofits adding complexity to market formation and intermediation*

Whilst the heat-pump's technical complexity and fit to a particular detached house can be considerable, it is nonetheless a product

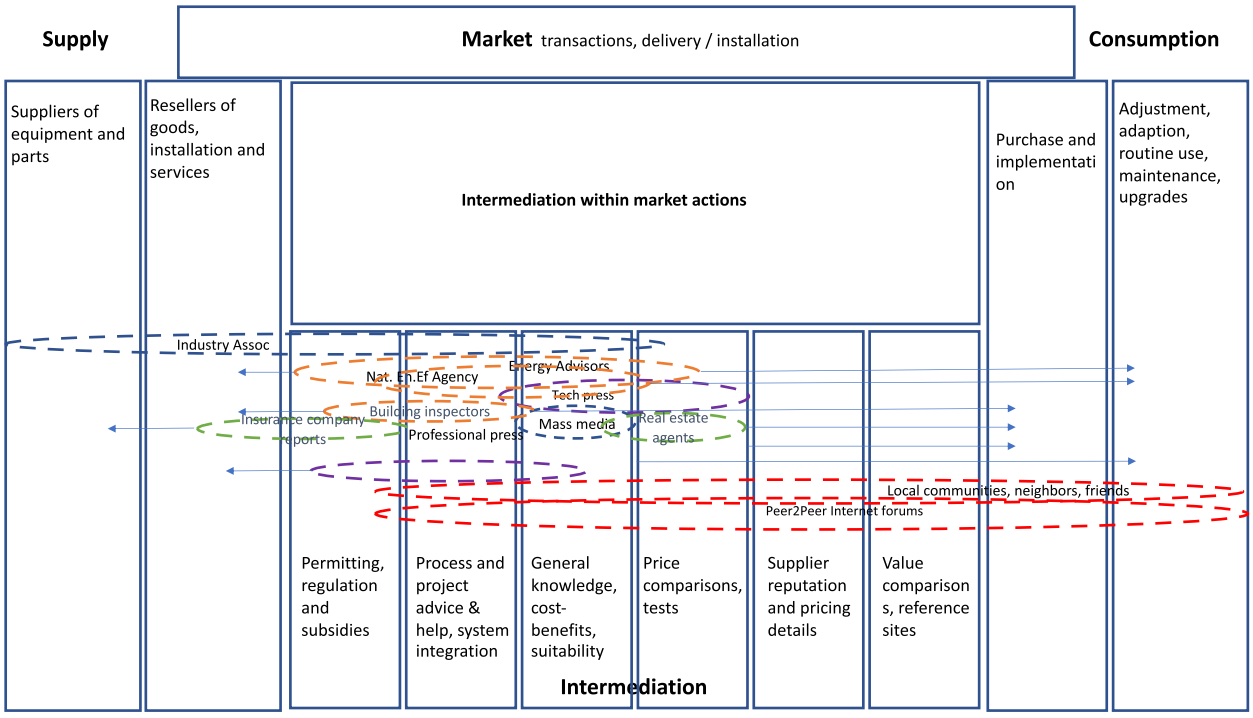

Fig. 4. Intermediation in the late diffusion stages of heat-pumps. Intermediation with market actions has supplanted other ways of intermediation

that can be installed in addition to or through the substitution of an old heating system – similarly to solar PV, solar collectors and biomass boilers. The market formation is more complex in the cases of goods that are not limited to single technology offerings, but are comprised of several complementary, but also competing, options. Such added complexity is common in energy transitions in larger housing units, such as apartment buildings, where high hopes have been placed widely deep energy retrofits combining energy efficiency measures and own energy production (e.g. Brown et al. 2018; Murto et al. 2019a, b,c). We again use a condensed empirical case summary of an investigation why this market still had not moved beyond exploration phase in 2017 despite clear economic incentives and off-the-shelf available technologies:

Case illustration: Housing associations A and B ran an investigation in 2018 to increase their share of renewable on-site generated energy and improved energy efficiency. As both houses are customers of local energy companies who offer solar PV and other renewable options, these were contacted first but with partial and lukewarm results and instructions to contact the installation companies to whom PV installations had been subcontracted. These too, only offered single solutions and could not offer an integrated energy retrofit or even planning for it. Continuing with contacts to national and local energy counsellors, referrals to technology providers as well as contacting potential suppliers found through internet searches resulted in gradually amassing the needed information over a 22-week time-span, in total requiring 83 hours of full-time work. During this process the suitability of ground-source heat, solar collectors, solar PV and additional energy efficiency improvements were assessed. As suppliers were able to offer contracts only on single options, the project champion gradually needed to establish altogether over 50 starting parameters of the buildings ranging from the expected ones such as exact façade orientation, type of ventilation, and annual energy consumption to complicated ones such as daily energy use profiles, incoming and outgoing district heat temperatures, and type of district heat exchangers. Moreover, the estimates on energy saving potentials and paybacks from different providers and with different technology options featured discrepancies as did the recommendations for actions taken. The energy planning consultants recommended by energy counsellors could not be reached despite considerable effort. A subsequent interview study of realized projects showed that such consultants did not serve the housing company market at that time. In all, the process of deep energy retrofit required the kind of investment of time and expertise to deal with market offerings and piecemeal intermediation that only exceptional housing companies had been able to handle it (Murto et al. 2019a, b).

This investigation into what it takes for a housing companies to proceed to a deep energy retrofit, first, underscores the splintering of offerings along technology boundaries and how this complicates market formation. The offerings may also be subdivided so that planning, sales and installation are handled by different suppliers and these, as well, are divided along narrow technology and task boundaries. Adopters face difficulties in acting on the market as calculative agents because of difficulties in singularizing the goods and offerings present (Callon, 1998; Callon & Muniesa, 2005). Second, as dysfunctional as this may be for adopters, providers may not be able to help it, since each of these product and/or service areas requires specific skills and assets, and solutions need to be tailored and calibrated to specific physical and geographical conditions of the buildings as well as local planning regulations, which have to be mediated by the solution providers (Heiskanen et al. 2011; Heiskanen et al., 2014; Lauttamäki, 2018; Lauttamäki & Hyysalo, 2019). Intermediary actors (and intermediary suppliers) would need to retain competency over several (often rapidly developing) technology areas and their interrelations – a costly business model that explains why less than a handful of companies had entered the energy

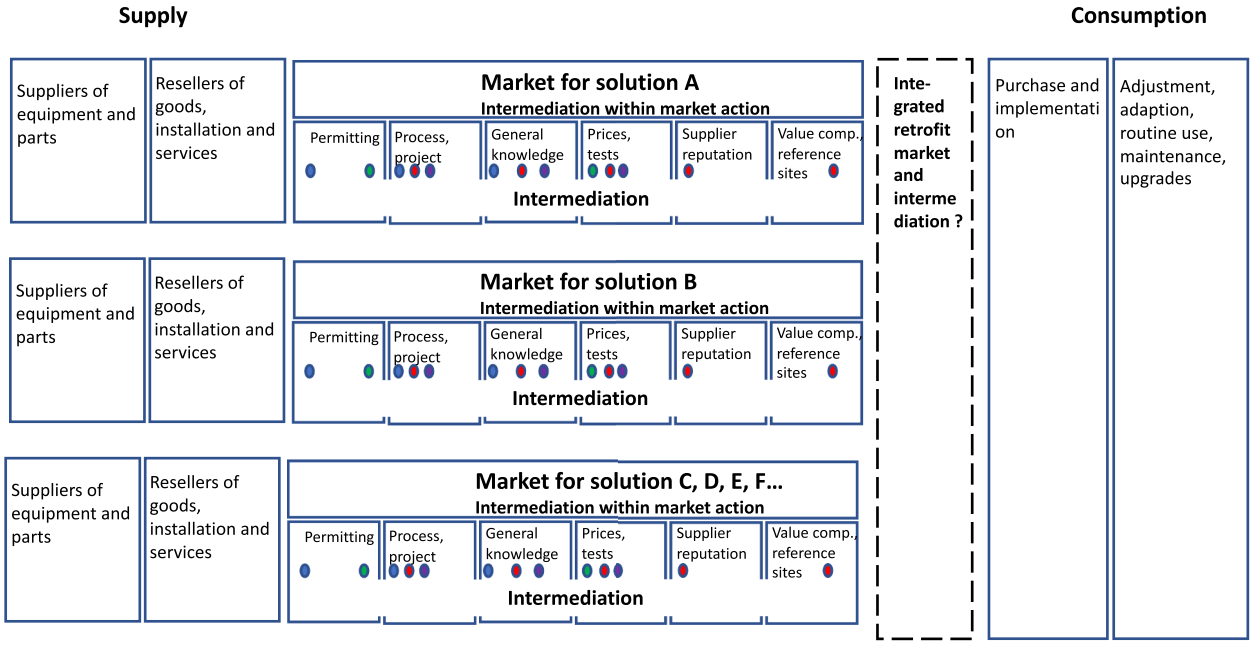

Fig. 5. Siloed ecologies of intermediation (coloured dots mark different intermediated aspects) and newly layered markets with combinatory goods in deep energy retrofits.

retrofit market among the 85,000 housing associations in Finland even by 2021 (Lazarevic et al., 2019). Third, phrased in more abstracted terms, the ability to intermediate across the resulting siloed suppliers requires bridging not only the technology fields, but also the arenas, in which each of these fields interface with regulatory actors (such as building permits, planning regimes) and different customer segments. (Fig. 5). The market is thus embedded in more complex and structured intermediation, which can further slow the market formation process in transitions.

4.3. *Urban development arenas as loci for intermediation of emerging energy market solutions*

Urban infrastructure is notoriously slow to change, thus obstructing the energy transition and markets for new energy solutions. In addition to the material obduracy of existing infrastructure, the introduction of new technologies is obstructed by layered urban planning procedures. These take place in arenas that are consistently more formalized than those found among technology suppliers or final consumers. Such arenas include ones for developing city and city-region strategies, including land use, transport, economic development and city services (e.g. city-owned energy companies). They also include *formalized arenas* for developing local master and detailed plans, as well as land use and land transfer policies. In these existing arenas, actor groups like city officials, construction developers, energy companies, and citizens have designated roles and responsibilities. The built environment also features several emerging and experimental arenas, often hosted by intermediaries, such as local innovation or sustainable development units. Such emerging arenas can focus on the development of new districts featuring experimental energy solutions, or the introduction of new topics such as sustainability and innovative ICTs into existing buildings, city services and the local economy (e.g., Mukhtar-Landgren et al., 2019; Edwards and Bulkeley, 2018; Matschoss & Heiskanen, 2017; Matschoss & Heiskanen, 2018). In these arenas, city-internal intermediaries seek to build on (or piggyback upon), but also to disrupt, existing planning procedures in order to introduce new energy solutions, novel traffic planning, and energy efficiency. Market creation for such novelties is 'bundled' with the sets of issues otherwise deliberated, negotiated and decided upon in each arena, each with its specific tools and procedures. The successes of intermediaries in these efforts in our cases are variable, and rarely cut across all arenas and goals. The promotion of building retrofits as part of the city-wide ECO2 project provides an illustration from one of our five cases:

Case illustration: As part of ECO2, and overlapping with several other urban development arenas in Tampere, the district of Tammela in central Tampere was selected as a target for urban densification. This enabled a local intermediary, EcoFellows Ltd, to piggyback onto the urban densification arena a plan for developing the market for building retrofit (a market that is lagging behind other energy transition markets, and where intermediaries are sorely needed as shown in section 4.2). Using several sources of funding (e.g. EU) and building on personal networks and relationships with service providers, Ecofellows organized a series of networking events for residents and local companies centering on retrofit planning, thus challenging a longstanding tradition of public officials not

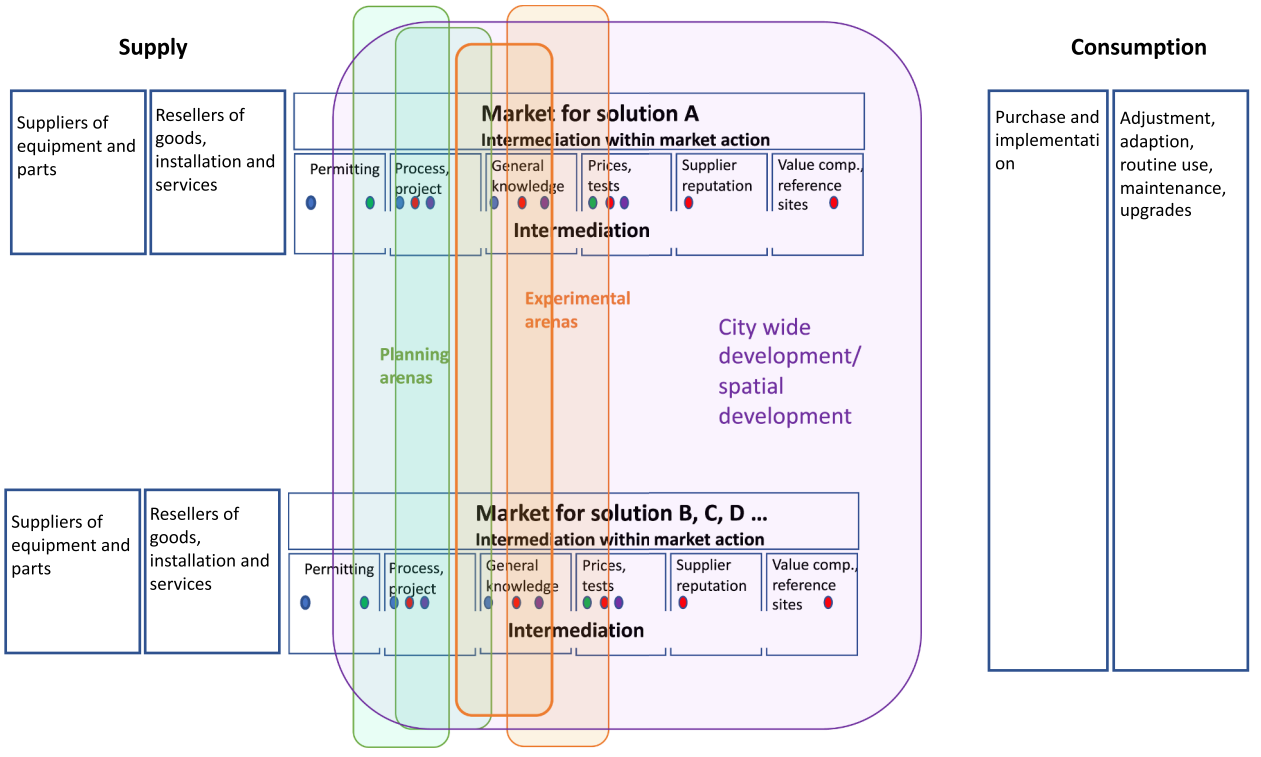

Fig. 6. Intermediation in urban development is tied onto several formalized and emerging arenas (green, orange and purple rounded rectangles) that can be partly overlapping and nested.

endorsing particular companies (i.e., "picking winners"). These events involved building owners in investigating and contracting various energy retrofit solutions, including insulation and other façade measures, solar power, and ground source and exhaust air heat pumps. The project was very successful, with several buildings conducting deep renovations resulting in as much as 50-75% energy savings, and local energy service companies gaining visibility and demonstration cases. These projects also resulted in a new line of business for the local energy company, which eventually launched a widely acclaimed 'two-way district heating' concept, purchasing heat from one of the renovated buildings with a hybrid heating system. (Heiskanen et al. 2018).

In each of our case studies concerning urban development arenas, we observed somewhat different arenas, and different patterns of intermediation. Yet taken together, our case studies show a pattern where intermediaries gain capacity to support the emergence of new markets by offering help and support to other players, for example, by offering technical support and creating networks involving new players. In this way, the intermediaries also gain access and credibility, and a legitimate role in various arenas. This has often been through *experimental arenas*, i.e., specific districts designated for experimentation in the city strategy development and land use planning arenas, where the intermediaries received their remit to do things differently (Fig. 6). The new goals and targets set by the city allowed intermediaries to introduce new performance metrics and bring new actors, such as startups or local service companies, into the energy field. In the experimental arenas, the intermediaries made themselves helpful by providing technical support, initiating partnerships, and providing visibility. These positive roles sometimes allowed them to disrupt existing business partnerships and provisionally challenge existing rules and practices that were seen as obstacles to the market entry of novel solutions. Along with city-level expectations for scaling up from the experiments, the intermediaries also gained a mandate for wider diffusion, the creation of more established networks, aggregation of experience, and provision of support for wider markets for the new companies involved. Experience gained in experimental arenas also provided them with a platform to challenge existing actor mandates and practices beyond the particular districts, such as the operating modes of city administrations or energy companies, as well as to advocate for a permanent reform to rules hindering a wider energy transition in the city (e.g. permitting rules and zoning provisions). The outcomes of these wider efforts, however, remain contested due clashes between different actors' powers and remits.

The district wide development processes show firstly that intermediaries hold varying presence in different arenas and hold varying capacities of action regarding the bundles of matters handled in them. They do not only involve an ecology of intermediaries, as discussed in the previous sections (cf. Kivimaa et al., 2019a), but are part of wider ecology of (inter)mediation of goods, services and knowledge that takes place in linked arenas. In such arenas of urban planning and energy provision, markets for new solutions are comprised of extended business chains and networks, which delays market formation in the course of the energy transition. Second, intermediaries can still play important roles in such settings. Sometimes intermediaries engage in supportive activities for new solutions and principles. Yet other moments and arenas are such that the major contributions by intermediaries to the transition have to do with disrupting the status quo with respect to actor constellations involved in an arena, issues brought into consideration, or the processes of preparation and decision making.

4.4. Cross-linked intermediation for low carbon solution markets

The embeddedness of market formation in intermediation – which we have argued to be characteristically partial, piecemeal, dynamically changing and tied to arrays and layers of pre-structured arenas – offers one explanation why market formation has proven so difficult in low carbon transitions. Guy et al. (2011) emphasize similar limitations and call for research on 'chains of intermediation' by which the piecemeal work by intermediaries may come to fruition. Instead of a 'chain' comprised of 'intermediaries', links are more plural. We hence suggest instead the spatial metaphor of 'cross-linked intermediaries' and a focus on the changes catalyzed by several intermediaries traversing different arenas and mobilizing different actors and materialities. Accordingly, proximity - either physical or social – facilitates intermediation, which in this view can be thought of as a coming-together of heterodox efforts and actors. To concretize such 'cross-linked intermediation' processes, we next examine a process of fostering and solidifying a novel idea of territorial carbon neutrality where the roles of several intermediaries, businesses, and municipal actors foster change. The vignette below captures the narrative of the CANEMU network that has emerged as an intermediary for municipal low-carbon actions.

Case illustration: The Carbon Neutral Municipalities (CANEMU) initiative aims at lowering carbon emissions in the participating municipalities, cities and regions by 80% by 2030. It was initiated in 2008 by five business managers who proposed action in their home municipalities. By 2021, 79 municipalities had joined the network, representing 39% of the Finnish population, with an average of 36% CO_2 reduction since 2007. Finnish Environment Institute has been a key intermediary since the beginning by giving the initiative visibility and legitimacy, setting the principles for carbon calculations and performing them annually as well as aiding in applying for funding, and identifying suitable actions in each municipality. Gradually the CANEMU network itself has become an intermediary: It has provided advocacy, knowledge exchange platforms (internet sites, newsletters, databases of solutions implemented); networking events for citizens, companies, politicians and civil servants; practical tools (carbon neutrality strategies, calculation schemes and roadmaps); and mobilization of co-procurement schemes for low-carbon investments. In turn, this has allowed other intermediaries such as consultants and development projects to join and concretize actions for business and citizens, for example, by arranging joint purchases of low-carbon technologies and solutions, arranging 'energy walks', updating building registries and improving procurement procedures and planning practices (e.g. Heiskanen et al., 2015; Jalas et al., 2018). This intermediary action within CANEMU has laid the conditions for market formation for low carbon solutions by creating a legitimating discourse for low carbon action as locally beneficial and doable – a counter force to common resistance to low carbon measures such as electric mobility often viewed as 'imposed' on rural populations. CANEMU has also mediated local perspectives to the national policy agenda, demonstrating the willingness and means of diverse municipalities to engage in ambitious low carbon development (Jalas et al. 2018; Lukkarinen et al. 2019).

Cross-linked intermediation helps to connect spatially embedded local planning arenas together (Fig. 7). The cross linked intermediation provides conditions for market creation in spatial contexts that might otherwise be difficult to achieve through traditional means. First, the advocacy and legitimation actions create the business and policy interest that is a prerequisite for the low-carbon solution providers to engage in planning and experimentation in new locations. Verification of climate and financial impacts through carbon calculation methods and procedures has been central, since those capabilities have traditionally been beyond the scope of municipalities and smaller companies. Second, the knowledge exchanges have enabled not only the abstracting of possible actions and impacts, but also a focus on concrete practices, such as integrating low-carbon targets into annual budgeting or utilization of public facilities to showcase and disseminate new solutions (Jalas et al., 2018; Karhinen et al., 2021). The link between financial savings and carbon reductions has had a measurable impact on the emergence of heat pump, solar-PV as well as wind energy markets in rural areas. Finally, the advocacy and verification activities have shown that low carbon actions can be handled by better management of local resources and services, and they expanded the realm of plausible futures also in the national policy discourse (Lukkarinen et al., 2018).

4.5. *Policy intermediation for market shaping in energy efficiency*

Intermediation in the policy interface has been necessary to gain more stringent regulations to support market development in building energy efficiency. As actors and established interest groups in the existing regimes often oppose such regulatory change, intermediation to achieve more ambitious policies has been and is still needed. Such intermediation has comprised, for example, creating new visions of what is possible, transferring knowledge to civil servants, and facilitating policy implementation (Fig. 8). As access to the arenas where public policy is being made is often limited to certain actors, intermediaries also need an entry to these

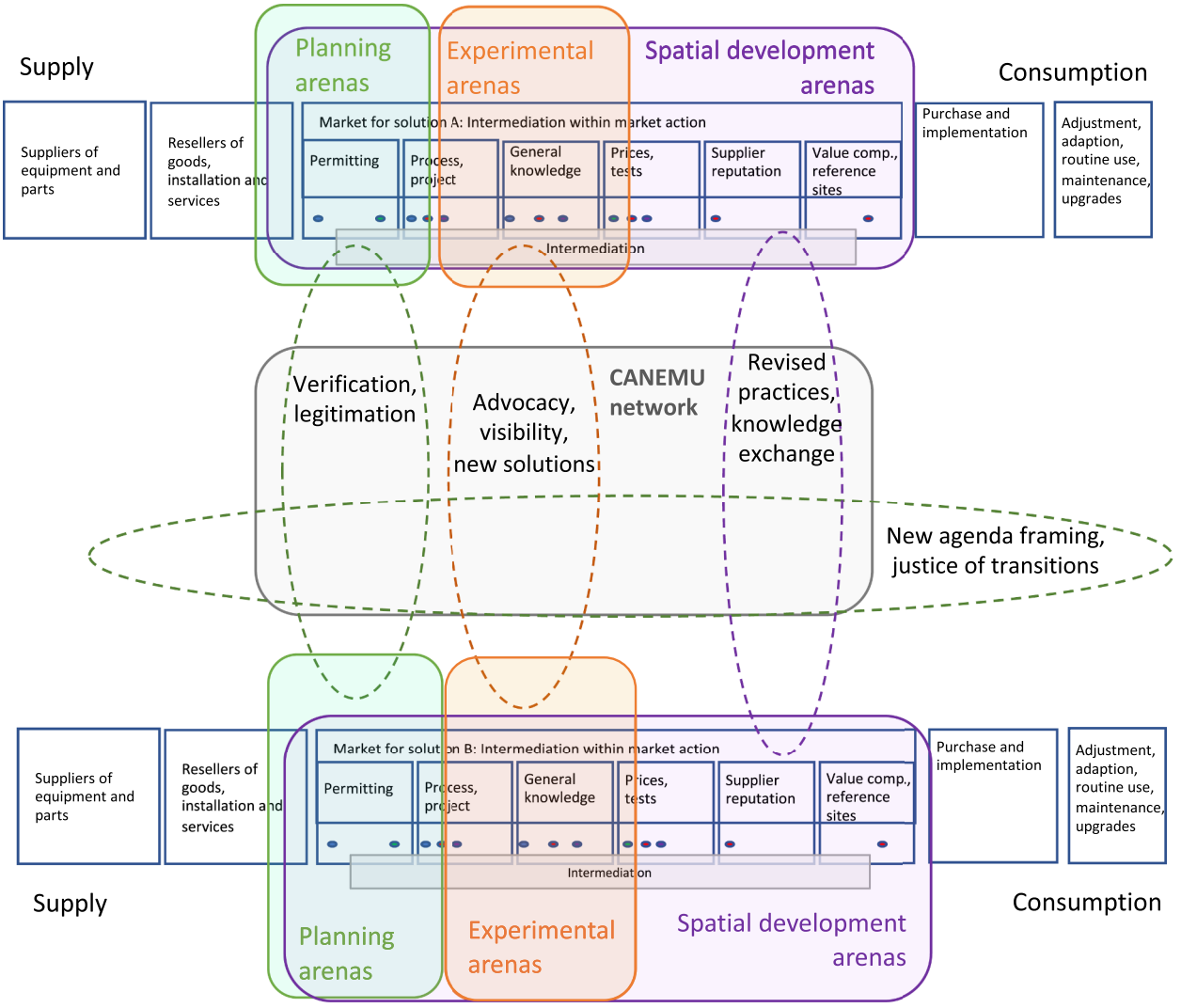

Fig. 7. Cross-linked intermediation across different arenas and locales in CANEMU.

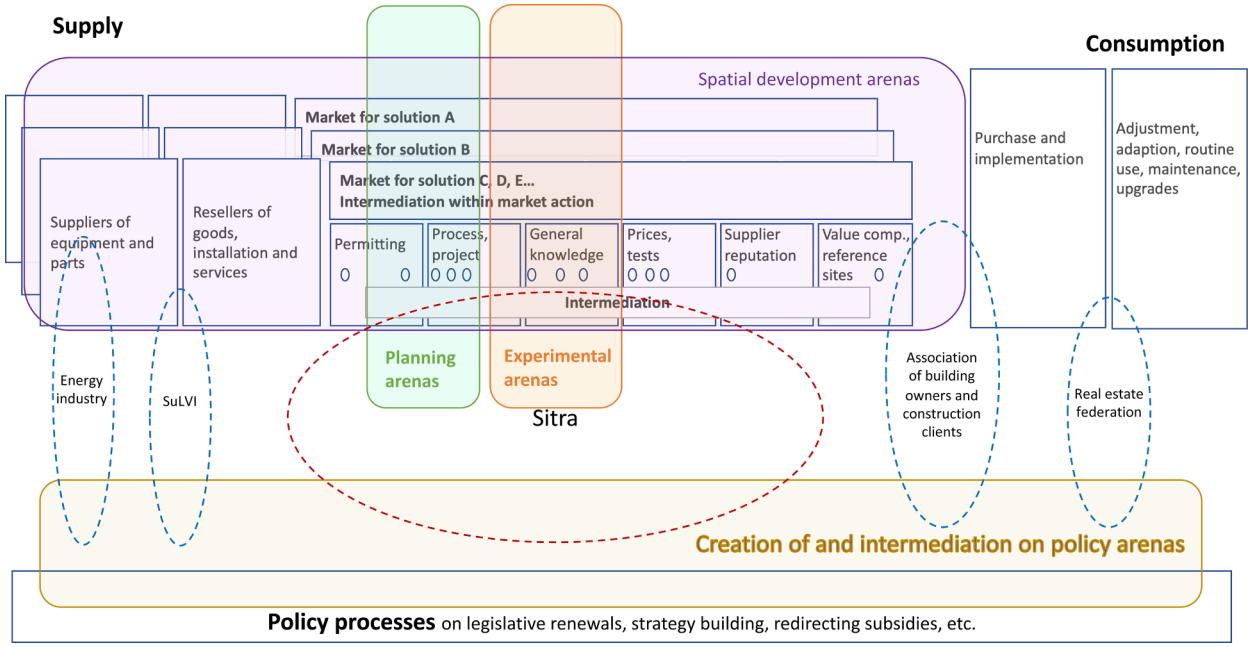

Fig. 8. Intermediating policy in building code renewal and movement of intermediaries across arenas to legitimate the policy setting process and its implementation.

arenas (e.g., high-level political interest). In the policy arenas, transition intermediaries compete with intermediation by actors that aim to safeguard the established (market) interests, and are required to promote environmental (or social) sustainability against conflicting values (e.g., pure market interests or anti-climate action). We examined two policy processes pertaining to building energy efficiency. The vignette below describes the process of renewing energy efficiency requirements for new buildings in the Building Code:

Case illustration: A policy process to renew the Finnish building code, seen as a large fundamental change and political alignment, began in 2008 and ended with regulatory change in 2012. Agenda setting focused on altering requirements for new buildings from 'u-values', prescribing minimum energy performance for diverse building components (e.g., windows, doors, walls), to total energy calculation, i.e., an e-value. The e-value is calculated as a building's use of purchased energy in one year. The shift from examining the insulating capability of building components (u-values) to total purchased energy (e-values) opened the doors for several novel solutions such as heat pumps as ways to meet building code standards, and it was supported by the building automation sector. Intermediation throughout the process was achieved in interaction between the Ministry of the Environment and the government-affiliated Innovation Fund Sitra, i.e., actors that already had an established access to the policy arena. The Ministry was effective in brokering messages between many building sector actors, some of which also acted as intermediaries within their own arenas. Particularly, The HVAC Association of Finland (SuLVI), was active in intermediating the changed regulation into practices by its members. Yet, some, such as the Finnish Association of Building Owners and Construction Clients, initially used their intermediary role to stall policy change. Sitra, meanwhile, conducted systemic intermediation to radically transform the policy system for new market creation by showcasing new possibilities to the Ministry at an early stage of preparation, when civil servants did not yet comprehend that total energy calculation was possible. Sitra translated a new vision from change agents in the sector to the Ministry, as well as mediated knowledge, skills and learning from experimental projects to the policy process (Kivimaa, 2014). Other actors in the ecology of intermediation agreed on the need for change and supported energy efficiency improvements rhetorically, while simultaneously opposing some of the new requirements. These actors (lobby organisations for the construction industry and energy industries, Finnish Real Estate Federation, etc.) effectively mediated details of the energy performance requirements for differing interests (each from their own stakeholder group), steering the direction of policy implementation and ensuing market-based transition in building energy efficiency (Kivimaa et al., 2020).

Table 1
Summary of data gathered from various types of intermediary cases examined

Data type	Incumbent related intermediaries	Governance intermediaries	User-side intermediaries	Total
Interviews of project actors	75	68 + 80 questionnaire replies	58	175
Interviews with experts	7	6	5	18
Document materials	1600 pages	600 pages	+ 10,000 pages	Approx. 11,000 pages
Ethnographic observation	16 events	2 events	Approx 48 months FTE	Approx. 50 months FTE

The policy arenas and intermediation therein highlight the depth of the embeddedness of markets in intermediation in low carbon transitions. Policy steering may be needed to catalyze market formation – here the shift to e-values supported solar and heat-pump installations – but the the idea of 'building a market by policy' is grossly simplified. Succesful policy steering required inputs from the actors in the market and required mediating tens of actor groups in several implicated arenas to become effective. The systemic intermediary Sitra synthesized knowledge and pragmatic lessons from a large number of actors over time (Kivimaa, 2014; van Lente et al., 2003), performing cross-linked intermediation across development arenas, market actors, and policy arenas. Equally, moving from policy arenas to implementation arenas, more 'classical' intermediation was needed in translating and interpreting new policies to stakeholders and facilitating the development of new skills to implement the changes required.

5. Discussion

5.1. How markets are embedded in intermediation that is patterned by arenas

The recently emerging cohort of studies on markets in transitions calls to question the sufficiency of broad-stroke assumptions made about market formation in transition processes (Dewald & Truffer, 2011; Dewald & Truffer, 2012; Ottoson et al., 2020; Boon et al,. 2020). To provide more focused insights, we analyzed the embeddedness of markets in intermediation in the energy transition. Market formation in the energy transition may be an even slower and more gradual process than assumed in the MLP and TIS models (e.g. Meelen et al., 2019; Bergek et al., 2008; Geels & Schot, 2007). In all our studied low carbon solutions, lagging market formation hampered the progress of transition even when the solutions were technologically ready and cost-competent. This condition could last far into what is commonly assumed to be the acceleration phase. In our analysis a (at least partial) reason for the slow market development lies in that the market actions related to novel decarbonization solutions require specific forms of sociality and technicality (Callon & Muniesa, 2005), which are embedded in complex patterns of intermediation. Moreover, even when established actors in principle support, for example, the energy transition, there is disagreement on the means to accerate market creation.

This required intermediation is, by default, only partially accomplished through the actions by suppliers and consumers in an emerging market. Other actors take on important intermediary activities that are key in overcoming the barrier that the underdeveloped market poses for adopters and suppliers. This intermediation is multifaceted, and spans from permitting to realized value and payback times; from installation suitability, process, and project management to maintenance needs, costs, competencies; and from supplier and installer reputations to the elaboration of customers preferences and needs (and so on). Beyond the activities that directly constitute markets, intermediation paves the way for progressive policies, embeds technologies in policy frameworks and affect pathways for policy implementation. The patterns of intermediation are dynamic as actors take on intermediating activities in a contingent fashion owing to the opportunities and constraints that open up (e.g. van Lente et al., 2003; Guy et al., 2011; Hargreaves et al., 2013; Hyysalo et al., 2018). This is to say that the remits of intermediation are not functionally divided, but seized by actors and built up historically in ongoing and changing patterns of participation in processes and arenas of intermediation.

A result of the historical formation of intermediation is that different actors intermediate overlapping aspects of markets, whilst other, functionally just as important, aspects may remain not catered for at all, or end up being duly intermediated only relatively late in the transition process, prolonging the market formation process. Our analysis stresses that actors who intermediate form 'ecologies of intermediation', which are shaped by the further embedment of intermediation in the other activities of the actors involved and the (pre)structuring of socio-spatial arenas in which intermediation happens. The arenas require credibility (sometimes also remit), competence and thus investment of time and resources to act in, thus limiting the possibilities that actors have in participating in the relevant arenas and the ways in which they can legitimately act in them.

The 'double embedding' – the embedding of markets in intermediation and embedding of intermediation in materially and socially shaped arenas and other activities of involved actors – results in several important dynamics of intermediation and market formation.

5.2. Implications for market development in transitions

The prolonged market formation processes commonly observed in low carbon transitions are not only an issue of availability and viability of offerings in the markets. Whilst the increased availability of alternative solutions and gradually lowering prices lay the ground for mass adoption, they can also create complex and difficult markets from the consumer's point of view. After the initial transition phases, much of the requisite intermediation in the market involves the very opposite of catalyzing solution emergence: reducing the complexity of goods and services and forming intermediary actor categories that simplify and stabilize the markets for final adopters (Callon et al., 2002; Stewart & Hyysalo, 2008), not least because the goods are appropriated by new customer segments as the transition progresses. Our findings thus lend support to Dewald and Truffer's (2012) insistence on the work done by users in market formation, and we extend this analysis beyond the early market formation performed by user-side intermediaries to intermediation that is needed when bringing the technologies of the energy transition into mainstream markets, urban planning arenas and policy processes which then multiply these technologies to new sites. Considerable efforts are needed for singularizing goods and enabling comparability across varying settings, and thus enabling the calculability that is needed to act in the markets (Callon & Muniesa, 2005).

Our analyses also underscore that it is rare for any one actor alone to find itself in a position to 'build a market' or to intermediate a novel a low carbon solution market (cf. 'long and fat intermediaries' in Stewart & Hyysalo, 2008). In section 4.6 we show that even policies that are commonly referred to as creating markets, factually require numerous actors and intermediation processes both in legitimately setting them and in implementing them, as in the established markets the novel policies need to overcome regime

resistance and reconfigure persistent practices across the contexts.

The form and complexity of both markets and intermediation varies greatly regarding the materiality of the goods exchanged (e.g. a discreet low carbon solution vs. infrastructural overhaul of a city district), adopter contexts (e.g. a detached house vs. a large housing company), the development stage of low carbon solutions (e.g. a packaged solution with installation, services and maintenance vs. an assortment of alternative technical sub-assemblines), and the mediums of intermediation (e.g. local peer advice vs. digital sharing vs. urban planning procedures vs. policy setting processes). The markets and intermediation can also evolve in tandem, such as becoming split into new business-to-business markets prior to the final consumers, as is presently happening in deep retrofits (Brown et al. 2016; Murto et al. 2019).

5.3. Implications for intemediation and intermediaries in transitions

Our analysis of intermediation in ecologies of actors makes five contributions to the theory and empirical work on intermediaries in sustainability transitions. First, our conceptualization and findings lend support to the emerging consensus in the studies focusing on intermediaries that the role and contributions of intermediaries in systems change cannot be adequately addressed by just identifying the system change functions they play (e.g. Guy et a., 2011; Kant & Kanda, 2019, Kanda et al. 2020; van Lente et al., 2020). Doing so bestows unrealistic capacities on intermediaries to foster systems change, and logically results in simplistic policy guidance of just setting up more intermediaries or a mix of different types of intermediaries to get all needed functions supported. Our findings stress the importance of viewing the emergence and evolution of interemediation as contingent processes, in which intermediaries (re) position and sustain themselves within a changing technological field and societal domains (Guy et a., 2011; Kant & Kanda, 2019, Kanda et al. 2020; van Lente et al., 2020).

Secondly, our conceptualization contributes to existing theory a deeper understanding of how the possibilities and constraints that intermediaries have are tied to historically formed ecologies of actors and arenas in which intermediation happens both in between single enties and within networks of actors. The evolution of intermediaries is not just a matter of positioning by the intermediary in the changing technological and societal and discursive contexts (Kant & Kanda, 2019; van Lente et al. 2020) but mediated through the evolution of arenas and ecologies of actors relevant to given low carbon solution. This observation leads to our third and most important theoretical contribution, an improved conceptualization of ecologies of intermediation. Our earier work has stressed that ‘ecologies’ are an adequate register to address how intermediariaries position themselves and how intermediation becomes patterned (as opposed to systems or networks or hierarchies or free atoms) (Stewart & Hyysalo, 2008; Hyysalo, 2010; Kivimaa et al., 2019a, b). We now clarify this view further: such an ecology includes the ‘ecology of intermediaries’ that is, the ecology of intermediary actors involved (Kivimaa et al., 2019a, b), but just as importantly the intermediating done by other actors in the ecology such as producers, consumers and government bodies, and the (range of) arenas in which intermediation (has to) happen[s].

Fourth, we add to conceptualizing the significance of the materialities of intermediation (or ‘non-human’ aspects of intermediation, cf. Contesse et al. 2020; Latour, 1987;2005). Such materialities – physical locales, Internet platforms, building code text, carbon calculation Excel sheets, comparison tableaus, et cetera – and related competencies are a reason why intermediation may remain deficient and why intermediaries tend to emerge from particular directions, engage in some rather than other arenas, and face difficulties in expanding their operations to further arenas and sets of actors. Our analysis also suggests that once markets mature, intermediation can become increasingly delegated from humans and organizations to digital sites, standards and calculation instruments.

Fifth, transition scholarship has recognized the importance of systemic intermediaries (e.g. van Lente et al. 2003; Kivimaa, 2014; Kant & Kanda, 2019, Kanda et al. 2020), formation of new actor groups and cross-fertilization of experiments (e.g. Loorbach, 2008; Smith et al. 2016) and placed hope in chains of intermediaries (Guy et al. 2011), but less so elaborated what the cross-linking requires and what all needs to become linked to support market formation. We add to this theorizing the capacity (or lack of) in crossing arena boundaries and limitations to act in them, as actors who have competency and means to bridge several arenas can both gain credibility and (re)align other actors in the arenas, and aid ‘cross-linked intermediation’, which can effectively lay the conditions for new markets. We saw examples of this in the policy intermediation processes of the building code renewal and in how CANEMU created a context for low carbon solutions.

Finally, in terms of policy advice, our analysis suggest that the market formation and ecologies of intermediation can be assessed on a periodic basis, and that this can be tasked to research institutes or consultants versed in the technology area, or alternatively to an industry association, should one exist for the low carbon solutions in question. On the basis of such assessment, targeted policy actions can be taken to rectify gaps or dysfunctional lock-ins in the shaping of markets or in the intermediation that embeds them. Policy intervention possibilities range from setting up new intermediaries, via tasking existing intermediaries with new actions, to setting experimental arenas in which new suppliers and intermediaries can affect the existing arena topology (by introducing or supporting the viability of novel ways of acting in the arena, diffusing novel technology options and by disrupting the customary ways and actor inclusions in the arena). Our depiction of cross-linked intermediation, for example, points to a form of intermediation which can mend existing gaps and create links among existing arenas, thus making new energy technologies and their markets more mobile and capable of entering multiple sites.

5.4. Limitations and further research

The current research was tightly focused on the temporal emergence of low-carbong transitions in the Finnish energy sector over the last two decades. As noted in the conceptualization, the ecologies of intermediation are highly context-dependent and thus limited

in terms of offering directly transferable empirical lessons. However, this also points towards need for detailed etnographic studies in transition sectors, where market intermediation is connected to different types of industrial histories and materialities. Another crucial point for further investigation is related to combination of different economic sectors with market actions, such as building sector histories and energy technologies in our case study, which merits more detailed studies regarding the role of intermediaries in the association and cross-linking of sectoral offerings.

6. Conclusions

Markets are always embedded in intermediation that allows users to qualify goods. Today's complex markets are multiply embedded in ecologies of intermediation spanning the production chains of complex goods like buildings or building retrofits, which moreover are embedded in local and national policy processes. The energy transition challenges these forms of intermediation and calls for new ecologies of intermediation, which emerge in a fragmented and piecemeal fashion, not least because intermediation occurs in diverse established arenas.

The findings of our decade-long research underscore how solutions used for renewing the built environment and energy production face particular and often complex sites of implementation. Their value and their valuable configurations in different adopter contexts and segments is knowledge intensive to establish. These conditions make not only adopters but also suppliers dependent on intermediary actors in establishing the value of goods for other actors in the market.

Intermediaries' capacity to act, in turn, depends on their access to and legitimacy in relevant arenas and ecologies of intermediation, which may take very different forms owing to the type of technology and adopter, and institutional contexts. Their capacity is further influenced by the degree of resistance from intermediation by actors that aim to safeguard the established market interests. Consequently, market formation and intermediation in transitions is unlikely to have a single identifiable pattern of evolution even within a single system such as energy. This calls for periodic assessment of market development and intermediation as a basis for informed policy intervention.

Declaration of Competing Interest

The authors have no conlicting interests to declare

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