How do intermediaries advance sustainability transitions? Conceptual insights on intermediary action in different transition phases

Paula Kivimaa[ab], Sampsa Hyysalo[c], Wouter Boon[d], Laurens Klerkx[e], Mari Martiskainen[a], Johan Schot[a]

a University of Sussex, UK

b Finnish Environment Institute SYKE, Finland

c Aalto University, School of Art, Design and architecture, Finland

d Copernicus Institute, Utrecht University, The Netherlands

e Knowledge, Technology and Innovation Group, Wageningen University, The Netherlands

Abstract

In recent years, increasing attention has been paid to *intermediaries*, i.e. actors connecting multiple other actors involved in transition processes. Previous research has highlighted that intermediary actors appear necessary and that they operate in many levels to advance transitions. We argue that such actions and the need for them vary during the course of transitions. Yet, little explicit insight is available on intermediary action in different transition phases, especially covering later transition phases. Thus, we draw on conceptual insights from the transitions literature to create a model of intermediary functions and activities and types of intermediaries in different transition phases. We empirically illustrate our model drawing on examples from car clubs, heat pumps and wind energy. We concluded that, in practice, both the functions taken by individual intermediaries and the ecology of intermediaries change over time, while the size and nature of the ecology is different in different contexts – size not necessarily equating with the success of the transition.

1. Introduction

In recent years, increasing attention has been paid to intermediaries, i.e. actors that connect multiple other actors, involved in sustainability transitions (e.g. Smith et al., 2016; Bush et al., 2017; Gliedt et al., 2018). There is an emerging body of literature on intermediaries in transitions that aims to clarify inconsistencies regarding which actors can be regarded as intermediaries and which activities are relevant for intermediation in the context of transitions (Gliedt et al., 2018; Kivimaa et al., 2018). Previously, it has been highlighted that intermediary actors appear necessary and that they operate on many levels to advance transitions; building from grassroots action (Hargrieves et al., 2013) to delegitimising existing institutional frameworks and lobbying for new ones within formal governmental structures (Smith et al., 2016). There is also a growing evidence of specific intermediaries playing crucial roles in certain phases of transition. For example, niche intermediaries have been important in the early stages of UK community energy (Smith et al., 2016), while in acceleration, systemic intermediaries may organise strategic workshops to align various perspectives and activities, and prevent strategic games by others (van Lente et al., 2003). Studying intermediary action in different transition phases is relevant for transition studies, because intermediary actions can be regarded an important contributor to explaining transition processes (e.g. Medd et al., 2012; Mignon and Bergek, 2016).

Yet, existing literature shows rather little *explicit* insight on intermediation in phases of transitions. Van Lente et al. (2012) has listed possible roles for *systemic intermediary* organisations in different phases. Building on van Lente et al. (2012), and taking stock of the most recent studies, we go beyond the focus on systemic intermediaries and discuss the functions and activities of different intermediary types (Kivimaa et al., 2018) in phases of transitions. We hypothesise that such intermediary actions and the need for them vary during the course of transitions. Thus, we draw on both conceptual insights from the transitions literature and illustrative empirical cases to create a model of intermediary functions and activities and types of intermediaries in different transition phases.

We also aim to complement the literature on the multi-level perspective (MLP) (Rip and Kemp, 1998; Geels, 2005) by drawing on the niche, regime and landscape levels of change. Regarding the MLP levels, intermediaries can pursue activities, for example, within emerging niches, they can work on destabilising and restabilising regimes, or they may translate or forecast landscape developments. They can also seek mediating roles that further the transition between a niche and a regime, or between different regimes and the regime-landscape relation.

We simultanously focus on the phases of transitions in which intermediary activity occurs and in which intermediary actors are established or emerge, building on previous work on transition phases. Although the start and finish of transitions are seldom explicitly addressed, a phasing of transitions has been proposed by Rotmans et al. (2001) and Safarzynska et al. (2012). They depict four transition phases: pre-development, take-off, acceleration and stabilisation (described in Section 2.3).

The conceptual model of intermediaries in phases and levels of transitions, and the illustrative case examples to concretise it, clarify the different roles intermediaries play in transition, and futher highlight the common shifts in the type, position and importance of intermediaries from one transition phase to another.

Section 2 sets a brief background on intermediaries in transitions, the multilevel perspective and phases of transitions. Section 3 builds a conceptual framework for intermediaries in transitions, and Section 4 illustrates this drawing on published empirical work. We empirically illustrate our

framework drawing on examples from UK low energy homes, Finnish heat pumps and Dutch automobility. Section 5 discusses the implications of such a framework and Section 6 concludes.

2. Conceptual background

2.1 Intermediaries in transitions

The literature on intermediaries in transitions originated in the early 2000s (van Lente et al., 2003; Geels and Deuten, 2006), but has only recently started to gain explicit attention in the sustainability transitions literature. An explicit definition for 'transition intermediary' actors has been lacking, and the literature has portrayed a diversity of actors and actions as intermediation in the context of sustainability transitions. Elsewhere, we have defined transition intermediaries as "*actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations*" (Kivimaa et al., 2018: 19).

Theoretically, the understanding of intermediaries in transitions has drawn from multiple origins, including empirical observations of transition and niche development processes (e.g. Geels and Deuten, 2006; Hodson and Marvin, 2009; 2010), the literature on innovation intermediaries (e.g. Howells, 2006; Steward and Hyysalo, 2008), and the literature on systems of innovation (Lundvall, 1992; Nelson, 1993; Edquist, 1997). Most attention has been focused on intermediaries in niche development (e.g. Geels and Deuten, 2006; Hargrieves et al., 2013), while intermediaries in the context of another stream of transitions literature, technological innovation systems, has been addressed only in a handful of studies (e.g. Lukkarinen et al., 2017). We, therefore, draw here on intermediation in the context of niches and regimes.

Depending on the empirical context, the literature describes a range of actors and platforms as intermediaries, including (but not limited to) governmental and institutional agencies such as innovation funders and energy agencies (Kivimaa, 2014; Polzin et al., 2016; Barrie et al., 2017), city-level organisations (Hodson et al., 2013; Kampelmann et al., 2017), community energy initiatives (Hargrieves et al., 2013; Barnes, 2017; Martiskainen, 2017), dedicated networks (Ingram, 2015; Lukkarinen et al., 2017), environmental NGOs (Rohracher, 2011), architects (Fischer and Guy, 2009), and internet discussion forums (Hyysalo et al., 2013; 2018). This list of actors should be complemented with innovation intermediaries that focus on technology transfer, including science parks, consultants, technology transfer agencies or local organisations that support technology use (Steward and Hyysalo, 2008; Kivimaa et al., 2017). The latter type of intermediaries continue to play a potentially important role in advancing new technologies as input to sustainability transitions. Part of all these organisations have a 'fixed' or 'prescribed' contribution as intermediaries due to their organisational form or identity (i.e. the type of organisation they are). However, in some cases, intermediation is more implicit and rather speaks from the functions and activities that define who is an intermediary in transitions (e.g. Martiskainen and Kivimaa, 2018). Thus, the label of 'intermediary' can be a temporary and fluctuating quality in actors and platforms especially regarding to specific transition efforts and sub-processes.

Intermediaries have been described as actors who carry out certain functions in innovation and transitions processes, including (F1) articulation of expectations, demands and visions; (F2) creating and brokering networks; (F3) exchange of knowledge and support of learning processes; (F4) innovation process management (e.g. mediation, resource procurement); (F5) translation function between different actors, interests and contexts; (F6) capacity building; and (F7) institutional

support (e.g., advocacy and lobbying support), for example, through aiming for policy change, and boundary spanning (van Lente et al., 2003; Klerkx and Leeuwis, 2009; Kilelu et al., 2011; Kivimaa, 2014; Bush et al., 2017). Each function requires different types of activities. For example, creating networks involves the identification of suitable network participants, motivating them to become part of the network. Innovation process management involves managing the discussions within the network – sometimes taking the role of a neutral arbitrator or mediator. Support for learning processes entails collecting information or knowledge of pilots, aggregating and modifying that knowledge, and communicating and translating that to different stakeholders.

Based on these functions and a systematic review of transitions literature, Kivimaa et al. (2018) illustrate five categories of intermediaries playing a role in transitions: systemic intermediaries, regime-based transition intermediaries, niche intermediaries, process intermediaries and user intermediaries (summarised in Table 1). This differentiation draws from the goals of intermediation, emergence of the intermediary actor (or of the intermediary quality of an actor) and the context in which it operates. We will below utilise this typology to address intermediation in different transition phases.

Table 1. Transition intermediary types (from Kivimaa et al., 2018)

Category	**Context/ level of action**	**Emergence**	**Goal of inter-mediation**	**Normative position**		**Examples**
				Position vis-à-vis niche	**Neutrality/ interest**	
Systemic intermediary	Inter-mediating on system level between multiple actors & interests	Typically established to intermediate	Pursues given (sustainability) goals on a system level; ambitiousness towards disruption to existing system	Outsider to specific niches, creating space for multiple, alternative niches	Typically regarded as a position of neutral, unbiased facilitator and broker, despite having an interest in stimulating transitions	Innovation Network Rural Areas and Agricultural Systems, Netherlands SITRA, Finnish Independence Fund Industrial Biotechnology Innovation Centre (IBioIC), Scotland
Regime-based transition intermediary	Inter-mediating on system level between multiple actors, within mandate given by dominant regime actors	Existing actor subsuming intermediary roles; or established by dominant regime actors to intermediate for transition)	Pursues given (sustainability) goals through typically more incremental solutions or political aims	Outsider to specific niches, creating space for multiple, alternative niches	Regarded as a player in the dominant system but pursuing or empowered for change	Motiva, Finland Forest Industries' Water and Air Pollution Research Foundation, Sweden Greater Manchester Climate Change Agency Religious congregations (sometimes)
Niche (or grassroots or user) intermediary	Intermediating between local projects, and/or higher level of aggregation	Often emerging to intermediate when a niche (or TIS) develops	Pursues given (sustainability) goals and solutions from a perspective of a given	Insider to a specific niche (or TIS)	Regarded as player advancing a particular niche (or TIS)	Community energy initiatives, England Wave Energy Association WAVEC, Portugal Living Community Challenge,

			niche (or TIS)			Canada/US Standardisation committees for new technology
Process intermediary	Intermediating within experimental projects or specific processes contributing to transitions	Typically established/ employed to intermediate day-to-day action in transition projects or processes	Implementing context-specific priorities, informed by broader transition trajectories	Typically outsider to specific niche	Regarded as a neutral, unbiased 'networker' that does not have specific 'agenda' in the process	Sustainability consultant Project manager Architect
User intermediary	Intermediating between technology (provided) and use, and/or niche technology and dominant configuration	Emerges from amidst users and consumers	Acts as facilitator, representative, or broker of end-use or end-users.	Insider or outsider to specific niche	Leans towards user interests (in some cases even as activists)	Internet discussion forum for heat pumps Car user clubs (in early phases) Advocacy groups Building manager (sometimes)

2.2 Levels of analysis for understanding sustainability transitions: niches and regimes

The MLP describes disruptive change in socio-technical systems to occur through interplay between three levels, including micro-level spaces in which we can observe radical innovations (so called 'niches'), relatively stable and shared technologies, practices and institutions ('regimes'), and slow-moving developments in the exogenous environment ('landscape') (Rip and Kemp, 1998; Geels, 2005). Associated and developing alongside the MLP has been the concept and literature of strategic niche management (SNM) (Kemp et al., 1998; Hoogma et al., 2002) that assumes that innovations aimed at sustainability can be facilitated in the context of socio-technical experiments that take place in niches and are nurtured to effect systemic change.

The interaction between niches and regimes has been studied using different concepts (Ingram, 2015), such as translation and anchoring (Elzen et al., 2012). For example, Smith (2007) looked at 'translation between niches and regimes' as the dialectic process between niche action and regime response. Later, the processes that occur between the development of niches and their becoming of part of the regime – either new or incrementally transformed – have been elaborated by Smith and Raven (2012) as two types of empowerment. 'Fit-and-conform' empowerment implies a process through which low-carbon technologies become "*competitive with mainstream socio-technical practices in otherwise unchanged selection environments*", not requiring far-reaching changes to institutions, infrastructures, skills and knowledge bases (Smith and Raven, 2012: 1030). The second type, 'stretch-and-transform' empowerment, more in line with niche-initiated transition, is regarded as a process through which mainstream selection environments are changed in a way (reframing and reforming institutions and rules) that makes them more agreeable for niche innovations that have emerged (Smith and Raven, 2012).

Elzen et al, 2012 attempted to provide what they position as a more fine grained meso-level understanding of translation process, by examining how niches and regimes interact in the embedding of new technologies through processes of institutional, cognitive and network anchoring,

supported by connectors between niche and regime which they call 'hybrid actors' and 'hybrid forums'. Recent studies have focused more on micro-level processes and explored agency in 'transitions in the making' studying the actions that actors employ to overcome barriers imposed by incumbent institutional structures in regimes (Farla et al., 2012; Fuenfschilling and Truffer, 2013). Here intermediaries between niches and regimes have been found crucial (Elzen et al., 2012; Smink et al., 2015).

The interface between niches and regimes is characterised by framing struggles and different storylines (Rosenbloom et al., 2016). Niche and regime actors interpret differently the need for transitions and the direction of change. In such struggles, intermediation may be relevant not only in connecting storylines of the niche and the regime (Hermans et al., 2016) but also in negotiating between different positions of actors within a niche or within a regime (between businesses, different government actors, etc.) in processes of demand and vision articulation. At the interface of niches and the regime, intermediaries link niche actors with regime structures through network brokering and innovation process management functions, aid in negotiating change by assisting in the building of alliances, and bring in supporters from within the regime (Diaz et al., 2013; Elzen et al., 2012; Hargreaves et al., 2013; Ingram, 2015; Smink et al., 2015; Hess, 2016).

To be able to bridge between distinct actors, transition intermediaries have a *translation* function. For example, consumer preferences are translated towards technology developers, citizen demands for sustainability are translated towards the government to inform policies, and business knowledge needs are translated towards academia to inform research agendas. The roles of transition intermediaries go beyond the facilitation of networks by brokering relationships that aim at creating institutional spaces (e.g. transition arenas, urban living labs) to support niche innovation. Further, they articulate expectations and visions for a transformed society on the basis of such innovations (e.g. Kivimaa, 2014). This implies that they play a role in terms of the *normative position* of niches and regimes, in view of strategic goals in transition processes.

2.3 Phases of sustainability transitions

Sustainability transitions have been described as long-term changes, the whole transformation process typically taking decades. Rotmans et al. (2001) conceptually depicted a transition to consist of four phases: pre-development, take-off, acceleration and stabilisation.

The *pre-development and exploration phase* is described as a dynamic equilibrium, where the status quo does not visibly change (Rotmans et al., 2001) but experimentation takes place (Safarzynska et al., 2012). Van Lente et al. (2012) describes this phase as a combination – and conflict – between eagerness to find out what is possible (articulation of societal needs) and reluctance to change existing configurations. In this context, experimentation that is typically defined as small-scale and temporary exploratory action (Kivimaa et al., 2017) can relatively easily take place even in change-resistant sociotechnical regimes. Niche technologies are not yet perceived as a threat by regime actors (Kanger and Schot, 2016).

In the *take-off phase*, the process of change begins (Rotmans et al., 2001) and novel solutions (niches) start to build up (Safarzynska et al., 2012). Niche development moves from experimentation to other forms of nurturing and shielding niches (Smith and Raven, 2012), and the strategic management of and agenda building around niches takes place. Change may still be slow due to dominant sociotechnical configurations and immature niche technologies.

Take-off is followed by the *acceleration and embedding phase*, which can take different forms, as described above in reference to 'fit-and-conform' and 'stretch-and-transform' strategies. In this

phase '*niches expand, attract more users, and become mainstream markets starting to compete with the incumbent regime*' (Kanger and Schot, 2016: 600). This phase differs from take-off as structural changes become visible through an accumulation of socio-cultural, economic, ecological and institutional changes, and collective learning and increasing returns take place (Rotmans et al., 2001; Safarzynska et al., 2012). Yet, it is not always clear when take-off is replaced by acceleration and embedding, and when sufficient reframing (Rosenbloom et al., 2016) or coalition building (Hess, 2016) occurs to be regarded as transforming a regime.

The *stabilisation phase* implies a decreasing speed of social change when a new dynamic equilibrium is reached (Rotmans et al., 2001) and '*a former niche has established itself as a new* regime' (Kanger and Schot, 2016: 600). Incremental change occurs to benefit from economies of scale. The cycle starts anew as experimentation in novel solutions commences again (Safarzynska et al., 2012). In reality, when different but connected sociotechnical systems change at different speeds, it may be difficult to know when stabilisation is reached.

The MLP and transition phases' literatures are interconnected, although this link has remained implicit. While the MLP literature has been less specific about phases of transition, Geels (2005) emphasised early phases being characterised by uncertainty and 'interpretive flexibility' around radical innovations. This corresponds to Rotmans et al. (2001) take-off phase. Safarzynska et al. (2012) have also elaborated on transition phases from the perspective of governance: "*the effectiveness, i.e. success, of the diffusion and adoption of innovations may depend on the extent of lock-in and path dependence, which vary in different phases of transition"* (Safarzynska et al., 2012). They also note that the notion of a multiphase transition puts emphasis on the timing of intervention in steering transitions. We interpret this to mean that the (required) activities, agency and normative position of intermediaries change in the different phases.

By assuming niche development as the starting point of transitions, the model of transition phases does not take into account other types of transition pathways (cf. Geels and Schot, 2007; Geels et al., 2016) in which change originates from landscape or regime level inducements. As such, it underplays the process of destabilisation (cf. Turnheim and Geels, 2012, 2013) that may either follow the acceleration and embedding of niches (acknowledged in the model), or precede it in cases where external shocks disrupt the system (ignored in the model) and pave the way for an era of niche pre-development or take-off. Regime destabilisation has been defined as processes that disrupt incumbent (industrial) regimes through weakening reproduction of core regime elements, including radical policy reforms and deliberate replacement of incumbents (Turnheim and Geels, 2012, 2013). Kivimaa and Kern (2016) specified this as significant changes in regime rules, removing support for non-sustainable technologies, changing network patterns and introduction of new key regime actors. To address disruption-oriented change, we take destabilisation into account as a phase that can happen simultaneously with, or before or after, niche specific processes of exploration, take-off and embedding.

3. Conceptual framework for intermediation in phases of transitions

We argue that the types, functions and activities of intermediaries can be conceptually differentiated based on their level and phase of operation (Table 2). With respect to levels, they can, for example, pursue activities within emerging niches or work on destabilising and restabilising regimes (or translating or forecasting landscape developments). They can also pursue intermediating roles that further the transition between a niche and a regime, or between different regimes and regime-landscape relation. This differentiation is important from an analytical perspective and in considering what the agency and roles of intermediaries are in governing transitions. As much of

existing transition intermediaries literature is not explicit about which transition phase is addressed, we drew on the literature on transition phases to provide indicators of different phases.

Table 2. Structure of the to-be-developed conceptual framework following phases and levels of transition.

Phases →	**Destabilisation (can precede or follow take-off / acceleration)** Indicators: Significant changes in regime rules, dismantling institutions, removal of support for non-sustainable technology, changing network patterns, introduction of new key regime actors, outlawing existing products and practices (Sources: Turnheim & Geels, 2012,2013; Kivimaa & Kern, 2016)			
Levels ↓	**Pre-development / exploration** Indicators: experimentation occurs, diverse (technological) options exist (Source: Safarzynska et al., 2012)	**Take-off** Indicators: explicit visioning & networking occurs; transition goals are set / emerge; new technologies / services accumulate & diffuse (Sources: Safarzynska et al., 2012; van Lente et al., 2011; Smith and Raven, 2012)	**Acceleration and Embedding** Indicators: Collective learning; institutional, cultural & economic changes accumulate; deconstruction & alignment of systems (Sources: Rotmans et al., 2001; Safarzynska et al., 2012; van Lente et al., 2011)	**Stabilisation** Indicators: Speed of change decreases; incremental innovation occurs; new cycle of experimentation and exploration of options (Sources: Rotmans et al., 2001; Safarzynska et al., 2012)
Niche level intermediary actors/activities/functions				
Niche-regime interface level intermediary actors/activities/functions				
Within regime level intermediary actors/activities/functions				

To connect the range of perspectives on intermediaries offered in previous literature with phases of transitions, we operationalised the phases in as much detail as possible. For the operationalisation we drew from the literature describing phases of transitions (Rotmans et al., 2001; Safarzynska et al., 2012; van Lente et al., 2011) and the recent literature on the concept of destabilisation in the context of transitions (Turnheim and Geels, 2012, 2013; Kivimaa and Kern, 2016). The operationalisation took into account overlaps between phases, and acknowledged that most articles were not specific about the phase they address, which required interpretation and iteration by the authors. Table 2 outlines indicators for such operationalisation. In the following sections we present the types, functions and activities of intermediaries belonging to each transition phase.

3.1 Pre-development and exploration

In the pre-development phase, the role of experimentation and exploration of options is important. Thus, early *niche intermediaries* are vital. They can operate both (a) at the grassroots level, having an important role in initiating and enabling pilots and experiments, and (b) on a broader niche level, connecting a range of experiments and pilots with each other, comparing and aggregating learning, and enabling new types of networks to contribute to novel vision building.

Niche intermediaries aggregate activities for joint vision building (e.g. Geels and Deuten, 2006). For example, in the case of wave energy, "*the early emergence of [niche] intermediary actors and formalization of arenas for debate favoured the conduction of field-level aggregation activities*" that guided the niche trajectory and articulated "*a compelling vision of future benefits*" (Fontes et al., 2016). While functions undertaken by niche intermediaries that pertain to the articulation of visions (F1), formation of networks (F2) and learning (F3) are imperative, there is less need for translation (F5), capacity building (F6) and institutional support (F7) in predevelopment, because the direction of development is unknown and the resistance of incumbents is low. Innovation process management (F4) may occur in individual projects.

A specific sub-type of niche intermediaries are grassroots organisations. They often overlap with user intermediaries, work bottom up to develop novel ideas and engage in a range of niche-specific experiments (F3). Such grassroots intermediation can occur before an explicit niche has formed, or exist at most at local scale (Kivimaa et al., 2018). This has been shown in the case of community energy initiatives in the UK (Hargreaves et al., 2013; Martiskainen, 2017), although community energy intermediaries may also play a role in the later stage of technology diffusion (De Vries et al., 2016). In predevelopment, grassroots intermediaries coordinate local projects (F2) that exist in spaces where 'the rules are different' from (and at times opposite to) the mainstream (Hargreaves et al., 2013), voicing expectations (F1) and engaging in learning activities (F3) (Martiskainen, 2017). In some cases, nascent *user intermediaries* form initial knowledge sharing networks in local contexts (F2, F3) and may become involved in innovating in their own equipment and sharing their insights among peers (Hyysalo et al., 2013).

Local experimental projects benefit from *process intermediaries* that have an important role in facilitating the project (F4), and sometimes the dissemination of the learning and vision of the project to others (Martiskainen and Kivimaa, 2017), fulfilling the intermediary function exchange of knowledge and support of learning processes (F3). At the niche-regime interface, process intermediaries translate (F5) context-specific regime priorities into the design and implementation of local projects (Hodson et al., 2013).

Systemic intermediaries are important in pre-development, as they can create institutional and social space for alternative technologies, models and social constructs to emerge, through the functions of demand articulation (F1) and institutional support (F7). Intermediaries have been described to open us spaces in local, policy, market or social contexts (Hargreaves et al., 2013) to a diversity of options and activities rather than a single technology, successful approach or strategy (van Lente et al., 2003; Hargrieves et al., 2013). Klerkx and Leeuwis (2009) regard systemic intermediaries as catalysts of innovation, for example, in setting up niche experiments, linking to innovation process management function (F4) (see also Kivimaa, 2014).

Regime-based transition intermediaries are likely to have a small role in predevelopment. However, R&D and innovation funders can help to find new sources of funding for basic and applied research (Polzin et al., 2016), through supporting network building (F2) and innovation process management (F4) that benefits niches development.

3.2 Take-off

During take-off, the visioning and network activities started during predevelopment become more explicit, alongside new technologies accumulating and diffusing. Actors, including regime-level policymakers, begin to set transition goals. In the literature, take-off connects to the idea of strategic management of sustainability niches (e.g. Hargreaves et al., 2013; Kivimaa, 2014).

In the beginning of take-off, local experiments and the learning they generated become more aggregated, gradually forming a niche on a regional, national or global level (Geels and Deuten, 2006; Hargreaves et al., 2013; Seyfang et al., 2014; Fontes et al., 2016). In these aggregation processes, *niche intermediaries* are again vital, both within the niche and in the niche-regime interface. Niche intermediaries improve knowledge flows between local experiments and the niche (F3), increasing the production and circulation of knowledge that is not intended for use in specific local practices but for the field as a whole (Geels and Deuten, 2006) (i.e. knowledge brokering). In addition, they can develop shared institutional infrastructure, for example, supporting the creation of new standards and rules (i.e. institutional support, F7).

Grassroots intermediaries, who in pre-development acted as niche intermediaries, may not have the capacity or ambition to be central actors in take-off. Not all grassroots innovations wish to grow and diffuse, and may exist without major transition visions (Hargreaves et al., 2013). They may seek to pool and connect with other grassroots initiatives to form broader networks, as has happened in the organic food movement (Durrant, 2016; Smith, 2012) and in community energy through ReSCOOP initiative that links millions of European citizens in community energy initiatives (Alarcón Ferrari and Chartier, 2017). This may mean that other niche intermediaries come to supplant some functions grassroots intermediaries previously played (Hyysalo et al., 2018).

As much experimentation still takes place during take-off, the role of *process intermediaries* is similar to predevelopment. What is different is that the context-specific regime priorities (cf. Hodson et al., 2013) may have changed through the increased diffusion of new solutions and, thus, process intermediaries need to adjust to them, i.e. through functions such as innovation process management (F4) and translation (F5), supporting this renegotiation process. Moreover, a larger number of actors (such as architects, planning officials or consultants) may expand their expertise to fit sustainability transition (cf. Martiskainen and Kivimaa, 2017), effectively becoming process intermediaries supporting transitions.

Regime-based transition intermediaries may take a more visible role during take-off, beginning to take practical action supporting niches (e.g. contributing to vision formation (F1), knowledge exchange and learning support (F3), innovation process management (F4), and translating between the regime interests and alternative niches (F5). They also form networks with other transition intermediaries (F2). The government may even establish new intermediary organisations with a transition orientation. For example, the UK government set-up the Sustainable Buildings Task Group which resulted in a draft Code for Sustainable Homes to encourage practice going beyond the minimum standards for energy efficiency in the building regulations (Pickvance, 2009), i.e. institutional support (F7). This task group was a prime example of a regime-based transition intermediary forming a core of a network of other intermediaries. In addition, some social housing associations have become active intermediaries in supporting a transition towards more sustainable buildings through piloting new solutions (contributing to vision formation, F1), while about 95% is estimated to be inactive (Pickvance, 2009).

Systemic intermediaries also become more important, as they engage in in market creation for alternative niches (e.g. through constructing broader future visions (F1) and institutional support (F7)) and evaluate potentially promising niches (F3). Linking to the destabilisation phase, they may also try to change the regime from within by articulating societal needs for change (F1), and create new political and institutional space (F7). For example, a Finnish Independence Fund Sitra has systematically intermediated to change building regulations to allow for innovation in low energy buildings to diffuse (Kivimaa, 2014).

User intermediaries are active in co-constructing the market and its related institutions, including the formation of market segments and transactions (Moors et al, 2018). Besides institutional work on market formation (F7), user intermediaries also contribute to facilitating early user practices effectively translating between users and suppliers (F5) and helping other peers to configure their technical systems (F3). User intermediaries further link users' need and solution information to resellers and manufacturers, thus contributing to demand articulation (F1) regarding new settings and new uses (Heiskanen et al. 2014; Hyysalo et al. 2018).

3.3 Acceleration and embedding

Following Smith and Raven (2012; see Section 2), embedding pertains to the empowerment of niches to gradually form part of the new regime. In the literature, much attention is paid to niche development (and to some extent also destabilisation), rather than niche-regime interaction and the role intermediaries play in such interaction. Therefore, our conceptualisation here is a proposition, highlighting a need for further empirical research.

Many *niche intermediaries* and *systemic intermediaries,* that operated during take-off, still need to continue operating, possibly strengthening some activities (e.g. for creating new institutions and markets, F6-F7) and weakening others (e.g. vision building, F1, and aggregation and distribution of project knowledge, F3). *Niche intermediaries* can try to lobby for recognition and resources in political strategies for accelerating the niche (F7, White and Stirling, 2013). If acceleration is successful, some niche intermediaries gradually become new regime intermediaries (Orstavik, 2014), and others cease to exist.

Intermediaries become less visible as technology matures; a relevant function for *regime-based transition intermediaries* and *process intermediaries* during commercialisation and diffusion being the mitigation of uncertainty and risk between firms or research institutes and potential financiers (Polzin et al. 2016). This can be addressed by effective innovation process management (F4), translation function between the parties concerned (F5), and institutional support (F7). A diffusion of maturing technology may also create new intermediaries to emerge at supply and user sides, as shown in the case of heat pumps (Hyysalo et al., 2013; Heiskanen et al. 2014). Intermediaries can continue to seize novel business opportunities in a newly stabilised regime, simultaneously shaping or transforming the regime (Rohracher, 2009) to the pursuit of their own and common objectives.

User intermediaries increasing the size and stability of the accelerating niche (Kanger and Schot, 2016) carry out new regime building. They also act as watchdogs to the expanding market and new market entrants, providing relatively unbiased information on the transition technologies and producer offerings on the market (i.e. aggregating, disseminating (F3) and translating (F5) knowledge. They try to re-emphasise the vision behind the transition (F1) and keep the transition on the 'right track'.

Systemic intermediaries help in articulating, negotiating and aligning the various perspectives to be more compatible with each other (F2-F3), advancing standardisation (F7) and preventing strategic games (van Lente et al., 2003, 2012; Rohracher, 2009).

Regime-based transition intermediaries, such as government or local authority intermediary agencies, can raise public awareness and create legitimacy for the new pathway (F6), if they have the resources and capabilities to do so. In stretch-and-transform (Smith and Raven, 2012), regime building and negotiation are likely to be prevalent activities, while in fit-and-conform, intermediaries may aim for raising public awareness rather than for letting users actively influence the transition (Mattes et al., 2015).

Rather than in supporting experimental projects, as in predevelopment, *process intermediaries* have a role in facilitating the embedding of niches (that they are outsiders to) to particular contexts of application through a translating function (F5). This is particularly important in transitions, where a solution is not an easily diffused technology applicable in multiple contexts, but rather requires context-specific fitting to operate optimally (zero-carbon buildings being a case in point).

3.4 Destabilisation

Destabilisation as a phase can precede or run in parallel to phases of predevelopment, take-off, and acceleration; being particularly closely related to the latter. It departs from the perspective of an extant regime that is shifting either stimulated by niche developments or influenced by landscape changes, while change can also originate from within the regime (see work on transition pathways by Schot and Geels, 2007).

The timing of destabilisation vis-à-vis the other phases influences the kind of intermediaries that emerge and take action. The existing literature shows how intermediaries may originate because of destabilisation (Backhaus, 2010; Fischer and Guy, 2009; Moss, 2009; Rohracher, 2009) or somehow influence destabilisation (Klerkx and Leeuwis, 2009; Orstavik, 2014). Intermediary actos may also deliberately *"attempt to destabilise dominant regimes…by aiming to decrease public legitimacy for and endogenous commitment to an existing regime, or unintentionally disrupt existing structures"* (Kivimaa, 2014).

Systemic intermediaries (e.g. van Lente et al., 2003; Klerkx and Leeuwis, 2009) can be seen as important actors in this phase. They may aim to disrupt existing institutional frameworks or markets (Nielsen, 2016) or destruct existing networks, and set-up new networks that disturb existing structures (F2, Klerkx and Leeuwis, 2009; Hodson and Marvin, 2009). In that sense, they can simultaneously facilitate a take-off of a broader niche and try to destabilise the regime from within. The function of 'destabilisation' is something that is previously unrecognised in literature on intermediary functions. Systemic intermediaries face other kinds of intermediaries as a counterforce that may "*thwart rather than promote potentially useful but disruptive innovations*" (Orstavik, 2014).

Niche intermediaries may also play a role in destabilisation for their own niche's benefit. This is part contradictory to how, for example, systematic intermediaries aim to open up space through destabilisation for multiple niches, key focus being the disruption of the unsustainable regime. Thus, niche intermediaries probably combine this function with functions for articulating their vision (F1) simultaneously building capacity (F6) and creation of new institutions for the niche (F7). Such activities need new networks to form between the niche and the regime (F2).

Destabilising regimes, exemplified through transforming infrastructure systems, generate demand for new forms of coordination and intermediation not previously required or recognised (Backhaus, 2010; Moss, 2009; Rohracher, 2009). If destabilising policy measures are carried out (Kivimaa and Kern, 2016), *regime-based transition intermediaries* can translate such new forms of regulation into practice (Fischer and Guy, 2009; Moss, 2009) or make sense of a complex and changing policy environment to niche innovators (F5), while they are unlikely to drive as drastic reforms as systemic or niche intermediaries. Importantly, both Moss (2009) and Rohracher (2009) argue for the emergence of intermediary organisations that liaise between producers/suppliers and consumers in the changing market context, i.e. new *user intermediaries*. While Rohracher is focused on the role of non-governmental organisations, Moss describes a range of intermediaries (advisory groups, information campaigns, educational programmes) that can take on this role.

4. Illustrative examples from UK low energy homes, Finnish heat pumps, and Dutch automobility

In this section, we will draw on three illustrative cases (Table 3) to support our conceptual analysis above. The illustrations are based on previously published research by the authors (Kanger and Schot, 2016; Hyysalo et al., 2018; Kivimaa and Martiskainen, 2018), have emphasis on different phases of transitions, and cover different geographical contexts and innovation contexts. The UK low energy homes and Finnish heat pump examples address attempts to transition towards sustainable energy system. The Dutch automobility illustration provides a historical comparison case, because we know of no sustainable energy cases having reach a stabilisation phase.

Table 3. Illustrative cases

Niche/transition	**Country**	**Time period**	**Phases covered**	**Intermediaries covered**
Low energy homes	United Kingdom	1970-2016	Predevelopment & take-off	Significant diversity (>70)
Heat pumps	Finland	1980-2018	Pre-development, Take-off & acceleration	Growing diversity (> 20) and stabilization
Automobility	Netherlands	1896-1970	All phases	Focus on a single central actor

4.1 UK low energy homes: a large number of intermediaries but failing to reach acceleration

The UK zero carbon homes niche traces back to the 1970s, experiencing a long predevelopment phase until the turn of the millennium, and take-off phase that turned into backtracking from 2009 (see full account in Kivimaa and Martiskainen, 2018). Upscaling did not take place: today a limited number of new low energy homes exists in the UK. For example, the Low Energy Buildings Database lists only 132 residential (public and private) new builds (LEBD 2018) against a housing stock of 28 million.

Predevelopment (1970-1998)

The predevelopment was characterised by multiple local experiments with new housing materials and concepts such as autonomous houses (Vale and Vale, 1975) and solar houses (McVeigh, 1983). The Centre for Alternative Technology (CAT), established in 1983 and still existing today, can be regarded as a *niche intermediary* for novel housing concepts. Through its low energy building pilots, it has contributed to articulating expectations and visions (F1), that had a long-term influence on both policy (Kivimaa and Martiskainen, 2018) and building projects in practice (Martiskainen and Kivimaa, 2018). It also developed, advocated and shared learning (F3) and undertook new capacity building (F6), by running environmental masters courses and acting as a location for many visits, e.g. for other students across the UK.

Other important intermediaries in predevelopment included the *regime-based transition intermediary*, Building Research Establishment, a government agency from 1972 until its privatisation in 1997, that was regarded as influential in exchanging knowledge and supporting learning processes through aggregating and disseminating a lot of information on zero carbon building (F3, Kivimaa and Martiskainen, 2018).

Milton Keynes Development Corporation (MKDC), set up as a government agency and in charge of developing a new 'garden city', was also an important *regime-based transition intermediary* that

from 1976 incorporated an energy consultative unit. It contributed to the articulation of expectations and visions (F1), exchanging knowledge and supporting learning processes (F3), as well as stimulated the emergence of new intermediaries in the area. MKDC developed, piloted and tested energy efficient housing concepts at a larger scale (Byrne, 2015). Research and development of MKDC fed into the development of low energy standards by National Energy Foundation (NEF), *niche intermediary* and an independent charity, in the 1990s. NEF, in turn, articulated expectations, visions and demands through practical projects (F1), developed of a national home energy-rating scheme (F7), and supported learning for low-energy building (F3) (Kivimaa and Martiskainen, 2018). NEF also took a *further intermediary* role, in recommending installers for zero carbon solutions to users (Caird et al., 2008). NEF managed a network of 30 Energy Advice Centres on behalf of Energy Saving Trust (EST, *regime-based transition intermediary*) that gave information on home energy efficiency (NEF, 2014).

EST was set up in 1993 and received funding from the government until 2012. During the time of its governmental mandate, EST provided institutional support for home energy efficiency policy (F7). It was also at the forefront of home energy efficiency advice (Mallaburn and Eyre, 2014), creating networks via the Energy Advice Centres (F2). EST also exchanged knowledge and supported learning processes (F3) via its research activities, e.g. in the form of providing guidance (EST 2006) and field trials of energy efficient heating technologies (EST 2013).

The predevelopment phase was characterised by fluctuating, and at times weak, policy support. In periods of weak policy, new non-state intermediaries emerged to create demands and expectations for stronger policy, and show possibilities through pilots (Kivimaa and Martiskainen, 2018).

Take-off (1999-2008) and backtracking (2009-present)

Take-off started in 1999 through new vision building, influenced by international and national climate change commitments and the 2002 EU Directive on the energy performance of buildings towards “nearly zero energy” (Kivimaa and Martiskainen, 2018). Learning was generated in new networks and high profile projects (Lovell, 2007). This lead to substantial policy commitments during 2006-2008: the 2006 announcement towards zero-carbon new homes from 2016 and the 2008 Climate Change Act (Kivimaa and Martiskainen, 2018).

The WWF-UK was particularly active as a *systemic intermediary* in creating expectations and visions. In 2002, WWF-UK’s ‘One Million Sustainable Homes’ campaign demanded a public commitment from the UK government to develop a million ‘sustainable homes’ (HM Government, 2014) and standardise the practice by 2012 (WWF-UK, 2006), i.e. articulating a vision and demand (F1). WWF took an intermediary role, having an insider role in policy processes, being the only NGO in government-set Sustainable Buildings Task Force and auditing sustainability progress in 12 large building firms (Pickvance, 2009).

In 2006, the UK government announced an objective to have all new homes zero carbon from 2016 onwards, creating a long-term vision for new build homes (DCLG, 2006). A specific *regime-based transition intermediary* Zero Carbon Hub (ZCH), partly funded by the government, was given the task to work a plan for the delivery of zero carbon homes with key stakeholders, effectively translating the broader aims to a plan of practice (F5). ZCH created and brokered a network of key stakeholders (F2) to work towards articulating expectations for zero carbon homes (F1). They supported learning processes (F3) by undertaking projects on issues such as performance and overheating of buildings (Zero Carbon Hub, no date). While it gave institutional support for the build-up of zero carbon policy

(F7), some have argued that it did not achieve the changes required for a zero carbon transition, and it was abolished in 2015 at the same time that the zero carbon homes target was removed.

After the zero carbon homes target was announced in 2006, new non-state *niche intermediaries* emerged, such as the UK Green Building Council (UKGBC), wanting to create cohesion, in the form of a joint vision (F1) for a disparate sector, effectively consolidating the niche (Kivimaa and Martiskainen, 2018). UKGBC became active in networking (F2), policy lobbying (F7), aggregating learning, and disseminating experiences from completed projects (F3) (Kivimaa and Martiskainen, 2018). Towards the end of the take-off phase, the global financial crisis resulted in reduced focused on climate change in government policy (Gillard et. al, 2017), affecting the construction sector as a whole.

Besides policy development, multiple intermediaries worked to advance the niche on the ground. Bioregional, an environmental charity and a social enterprise took multiple different intermediary roles. It acted as a *niche intermediary*, developing low energy housing concepts through piloting them in practice (most importantly the BedZED development in London in 2002) and forming visions, expectations (F1) and learning (F3) that influenced policy development locally and nationally (Kivimaa and Martiskainen, 2018). Bioregional later developed a One Planet Living concept that articulates a vision for future homes that goes beyond energy, and takes a whole, sustainable, lifestyle approach (Bioregional, 2018). In its building projects, Bioregional also employed *process intermediaries* to realise this vision in practice (Martiskainen and Kivimaa, 2018).

User intermediaries, such as the Eco Open Houses events in Brighton who facilitated the opening up of low energy homes for others to visit (improving also networking, F2), have exchanged knowledge from completed projects (F3), supported learning and helped to build visions of what is possible (F1) but with concrete attention to users' needs. Local authority sustainability officers, meanwhile, have acted both as important *regime-based transition intermediaries,* providing institutional support for projects at a local level (F7), and *process intermediaries* translating between novel solutions in the projects and the planning regime requirements (F5).

In the UK low energy housing case, intermediaries have changed over time and their initial roles have evolved. Niche intermediaries such as CAT and Bioregional, for example, have prevailed and become more systemic over time, while regime-based transition intermediaries have ceased to exist (ZCH) or weakened (EST) due to reduced government policy and mandate. Following the removal of the zero carbon homes policy, niche (UKGBC) and user intermediaries (Eco Open Houses) have become more central in continuing to advocate and lobby for the sector and help maintain a vision for low energy homes in the UK. Since the removal of their government funding in 2012, EST has continued to act as a *systemic-intermediary*, by for example articulating a vision for energy efficient homes as a national infrastructure priority (Frontier Economics, 2015).

4.2. Finnish heat pumps: Evolution of ecology of intermediaries from take-off to the brink of stabilization

Pre-development

First heat pumps entered Finland from Central Europe and Sweden at the turn of the 1980s in response to the 1970s oil crises. The early heat pumps used horizontal collecting fields on the ground or water and were introduced and endorsed by researchers, interested companies and forerunner citizens following examples elsewhere. A handful of companies introduced heat pumps to their offerings and around 2,000 installations emerged during the 1980s. The market development remained tainted by technical shortcomings, uncertain payback times, maintenance

problems and adverse appraisals from the energy field experts and energy incumbents in public media. One of the reasons was a lack of coordination, knowledge sharing and common voice in the media and towards customers, which followed from having only scattered and weak spokespeople (Louhija et al. 2017; Lauttamäki, 2018).

The continued proliferation of heat pumps in the neighbouring country Sweden and the development of vertical borehole techniques led to a second wave of ground source heat pump (GSHP) installations in early to mid-1990s. This time the involved companies formed an industry association, Finnish heat pump association (SULPU), a *niche intermediary* to avoid the first round problems. SULPU mediated information about heat pumps to media, planners, policy makers, and experts in the energy field, i.e. was involved in articulating a vision (F1) and translating knowledge (F5). It further shared best practices (F3), educated its member companies (F6) and policed the quality of installations, helping to raise the reliability of the field (F7) (Berninger et al. 2017; Lauttamäki, 2018).

Take-off

By early 2000s Finland had about 30,000 heat pumps and the market approached take-off, which happened through a slow linear growth in GSHP from 1995 and a surge in the uptake of air-source heat pumps (ASHP) since 2002. Whereas incumbent experts continued to express doubts about the suitability of ASHPs to the cold climate similarly to GSHPs in early 1980s, the ASHP's low consumer price ranging from hundreds to few thousands Euros drove purchases. An increasing variation in makes and models became available in both dedicated small installation companies and larger retail stores (Heiskanen et al., 2010; Heiskanen et al., 2014).

This development was accompanied by several actors, besides SULPU which continued the activities started in predevelopment stage (F1, F3, F5, F6, F7), to mediate information and skills about heat pumps, slowly forming an *ecology of intermediation* (Hyysalo et al. 2018). Intermediaries contributing to this ecology were numerous. Local energy advisors and the national energy efficiency agency, as *regime-based transition intermediaries*, included heat pumps to their lists of recommendations (F6, F7). Research institutes and polytechnics, as *regime-based transition intermediaries*, ran and published evaluations and cumulated expertise on heat pumps (F3). Coolant equipment firms included heat pumps to their offerings and began to offer information about heat pumps and their benefits (F7). Technical press, mass media, professional press relayed basic information to the public (F1, F3). In addition, the growing number of users acted as *user intermediaries* to their friends and neighbours, articulating the benefits of new technology and the ways in which it differed from previous heating solutions in everyday life (F1, F6). Some of these actors acted as regular intermediaries, without specific transition-functions but benefited the overall take-off.

Yet, there were considerable gaps in the market mechanisms that final consumers faced. As late as in 2008, it took months for two users to establish reliable information for particular siting location for a joint purchase (Heiskanen and Lovio, 2011; Martiskainen, 2014): market information on ASHP was mostly based on supplier and installer (potentially self-interested) proclamations, rather than unbiased information provided, for example, by regime-based transition intermediaries or user intermediaries.

Acceleration and embedding

The acceleration phase heat pump diffusion grew from 130,000 units to 750,000, which is 50% of the total residential building stock to which heat pumps are applicable in Finland. Hardware retail chains

included them as standard offerings with active marketing and information provision and some energy companies began to offer heat pumps as solutions for customers beyond the reach of district heating networks. The *niche intermediary* SULPU gained an increasingly legitimate position, continuing its existing functions.

Just as importantly, however, the acceleration was associated with the emergence of new *user intermediaries*, namely Internet discussion forums that became to have an important influence on market development with over 200,000,000 reads during 2006–2018 (Hyysalo et al. 2018). Local case-specific, isolated comparisons were insufficient in keeping pace with the rapidly evolving markets and ASHP technology. The Internet forums, as user intermediaries, accumulated information on sales, scaling, installation, maintenance, troubleshooting, efficiency, and on the reliability and credibility of suppliers and installers (i.e. contributed to aggregation of knowledge and learning, F3). In doing so, the forums provided qualifying market information, acted as a backchannel for complaints and improvement needs and provided evidence of value against counter claims from outside the niche (i.e. translated interests between different parties F5, and added institutional support F7) (Hyysalo et al. 2018). These *user and niche intermediary activities* helped in re-contextualise the standard technology to national specifics of colder and seasonally more varied use than elsewhere.

4.3 Dutch automobility: The intermediary role of the Dutch Tourist Organization (ANWB)[1] in transition

This history of the automobile in the Netherlands captures four main periods: the pre-development/exploration phase from 1896-1910 in which the car was mainly used as an racing and touring machine; the take-off phase from 1910-1920 in which the car was tamed into an utilitarian automobile; and the interwar period of acceleration and embedding, in which the car became used for many purposes. Finally, the stabilisation phase covers the period after World II up until the end of the twentieth century, in which the car became the dominant mode of transport. This entire process should not be pictured as a simple diffusion process of growing adoption but as a process of developing new user practices, institutions, regulations, production methods and new automobiles. Intermediary activities were a central plank in this process, and in this case became largely concentrated in the hands of one actor: the Dutch Tourist Organization (ANWB).

Pre-development/exploration (1898-1910)

Early car use was associated with racing, which generated a lot of publicity. In 1898, two years after the first automobile was purchased in the Netherlands, the first car race was organised by the newly founded Dutch Automobile Club (Nederlandse Automobiel Club, or NAC, later to become the Royal KNAC). The club consisted of car users and importers (Mom, 1997). This club functioned as a *niche intermediary* forming networks (F2), promoting experimentation through racing and early expectations, which articulated the car as an adventure machine, and a plaything for the rich (F1). This messaged the exciting masculine combination of fear and pleasure in the experience of speed, and in addition an opportunity to explore the landscape traveling without a fixed schedule (as with trains or trams) (Mom, 2001). Other supportive intermediaries were absent at the time.

Take-off (1910-1920)

In the take-off phase, a new actor moved into the automobile domain and became a significant *niche intermediary* actor: the Dutch Tourist Organisation ANWB, originally formed to promote cycling. The

[1] This case study draws extensively on Mom, Schot and Staal (2008).

ANWB's vision was that the car as a racing and luxury machine should be turned into a utilitarian machine, addressing needs of doctors, salespersons and shop owners. The organisation began to articulate demand for a new type of automobile (F1).

In 1907, the editor-in-chief of *De Kampioen*, the ANWB's membership magazine, complained in an editorial that the automobile had *"grown into a machine that competes with express trains in speed."(*Meijer, 1907: 2). And, he continued, arguing that this was regrettable because many people travelling long distances would be enthusiastic buyers of a reliable automobile with an engine to give a speed of 15-20 kilometres per hour (Meijer, 1907).

As a crossover between a *niche and user intermediary*, the ANWB helped formulate standards (F7) and translate user demands (F5). The utilitarian affordable and reliable automobile, which the ANWB called for, became more prominent after the First World War with the arrival of Ford's Model T.

Acceleration and embedding (1920-1940)

In acceleration, the ANWB adopted additional functions of the *process intermediary*. It also played a crucial role in shaping the competition with public transportation promoting the view that the future was for the car (F1), since it was a multi-functional machine that could be used for many purposes. It formed a network (F3), but aimed at confronting the competitor and playing strategic games, effectively taking over and continuing the *niche intermediary* role.

In 1927, ANWB was one of the first organisations to forecast the future diffusion of automobiles. In *De Kampioen* (4 March 1927, 193-194), the ANWB pointed out that at that moment 2.5 million bicycles were in use and that a comparable number of cars was to be expected for 1950. The envisioned wider diffusion meant that the drivers of the car had to be educated in relation to participating in daily traffic, e.g. passing other cars, taking curves, and braking while simultaneously signalling with one's hand. Therefore, the ANWB not only acted as representative of users, but also tried to educate and discipline them, i.e. building capacity (F6). Concerns about car accidents and traffic casualties (often widely expressed in newspapers) were important motivations for these educational efforts.

A national infrastructure was gradually created to support car and bus use. Until 1920, most roads were local or regional, linking different cities. In the 1920s, a powerful road lobby emerged, which lobbied for a new kind of road, highways, which were restricted to motor vehicles only. Members of this road lobby were: the Royal Institute of Engineers, ANWB, the (K)NAC and construction companies. They also lobbied for a national infrastructure to accommodate the expected car growth (F7). The ANWB also developed a new discourse, which presented cars as an economic and social necessity (F1). These forecasts and surrounding discourse underpinned the need for new roads. Rijkswaterstaat (RWS), the engineering and building department of the Ministry of Traffic and Transport, supported this idea and developed the first National Road Plan (1927), which the government accepted. This plan envisaged a national network of 2,800 km of primary roads, involving both new roads and upgrading of existing roads. The government plan also entailed the creation of a Road Fund to collect and coordinate money from the Road Tax Law.

The creation of new road infrastructures, which required huge investments (only partly paid from car taxation) led to questions about relationships with existing rail infrastructures (tram inside cities and trains outside cities). In the 1930s, this resulted in the co-called 'coordination crisis', which was related to infrastructure junctures and to investment decisions. The ANWB, and other car proponents, portrayed rail as technology of the past, which often needed subsidies, and cars as the

way of future. The ANWB began articulating a new vision of the automobile user, aimed at the 'nuclear family'. In 1935, the *Autokampioen* (14 September, p. 1253-1255) expressed a desire for:

> "*a people's car (…) that due to its price and economy will enable each family … to travel by road … The motorist of our age is … the father of a family who takes his wife into the country to be free in heath lands and grasslands, to beaches and lakes*".

Stabilisation (1945-1970)

After World War II, the people's car arrived. The automobile lost its exclusively middleclass character. The ANWB turned into a regime intermediary promoting and facilitating car use for everyone. To convince (actual and potential) car buyers, the ANWB campaigned for the rationality of car purchases. The ANWB promoted on the one hand a new do-it-yourself culture, especially amongst lower middle class and working class users, while it also recognized that not everyone wanted (or could) repair his own car, and carry the required tools along. Hence, the ANWB created a new maintenance-technical infrastructure. Already in 1946, the ANWB founded its nationwide road service organisation, *Wegenwacht*, especially tailored at roadside breakdowns.

Social-recreational car traffic also increased substantially during 1963-1993, becoming one of the most important functional categories in the late 20th century. The car was increasingly used for visits to relatives and friends, weekend outings, and holiday trips. The ANWB vision of the car as a multi-functional and in fact universal machine to be used for all transport needs of the entire population had come true, with the ANWB as its guardian.

5. Discussion

5.1 Functions of intermediaries in transition phases

Table 4 summarises the functions of different types of transition intermediaries over the transition phases. Many functions are based on our literature review (Section 3.1) and some on empirical cases (Section 4). Given the lack of research in this area, some other functions are deduced propositions, in the absence of literature or empirical evidence. These are marked with asterisk (*).

Systemic intermediaries have important roles throughout the transition, while other intermediaries, particularly *process* and *user intermediaries* may have more temporal and limited roles and experience shifts in the role they play in transition. *Niche intermediaries* may cease to exist after take-off or acceleration, or transform their role to a *regime intermediary* (even resisting change) in the new stabilised regime. *Systemic intermediaries* are likely to look out for new issues requiring their attention and pulling off from activity related to a particular sociotechnical system or subsystem after some time has elapsed (cf. Kivimaa, 2014) or at latest in the stabilisation phase.

In all, the proliferation of heat pumps in Finland and automobility in the Netherlands highlight the importance of intermediation in transition and illustrates how it changes as transition progresses. Even the UK low energy housing transition, which has not advanced to acceleration, showed the importance of different types of intermediaries in moving from pre-development to take-off. For heat pumps, pre-development was associated with scattered and weak intermediaries, a central niche intermediary and a nascent (even if gap-ridden) ecology of intermediation greatly supported the take-off phase. The acceleration stage was associated with maturing of the ecology of intermediaries, such, that a relatively mature market, technology and stable intermediation was in place for stand-alone residential GSHPs by around 2010 and for ASHPs by roughly in 2015. Similarly, the UK low energy homes transition involved fewer and less connected intermediaries in pre-development, while a strong systemic intermediary (WWF-UK) significantly influenced the beginning

of take-off. Take-off was characterised by the establishment of new niche intermediaries for strengthening the vision of the niche and adopting multiple intermediary functions, and regime-based transition intermediaries were involved in translating and institutional support building. The core intermediaries for Dutch automobility, while fewer, adopted similar functions in both take-off and acceleration. Overall, the cases show that systemic intermediaries, while important for sustainability transitions (van Lente et al., 2003; Kivimaa, 2014) do not play a direct part in every transition.

Table 4 Summary of classification of innovation intermediaries' activities, differentiated by level, origin and phase.

Phase of transition	**Destabilisation (can precede or follow take-off / acceleration)**			
	Systemic intermediaries decreasing public legitimacy for and endogenous commitment to an existing regime; destructing existing networks, markets and institutions; translating new forms of regulation to practice. *Niche intermediaries* aiming for destabilisation (coupled with functions for vision articulation, new network formation, capacity building and institutional support). *Regime-based transition intermediaries* translating destabilising policies into practice or making sense of a complex and changing policy environment to niche innovators.			
	Pre-development / exploration	**Take-off**	**Acceleration & embedding**	**Stabilisation**
Niche level intermediation	*Niche, user, process & systemic intermediaries* promoting experimentation & coordinating projects. *Niche intermediaries* forming networks, sharing best practices and creating reliability for new technology.	*Niche intermediaries* aggregating knowledge, guiding local experiments, replicating projects and pooling resources. *User intermediaries* configuring systems and uses, qualifying claims by producers and resellers; articulating demand for niche producers.	*Process intermediaries* facilitating embedding of niches (that they are outsiders to) to particular contexts of application *User intermediaries* fill in information missing in the emerging markets and in technology use and maintenance.	*Niche, user, process and systemic* intermediaries promoting experimentation & coordinating projects.
Niche-regime intermediation	*Process intermediaries* connecting context-specific regime priorities and local projects.	*Regime-based transition intermediaries* supporting incremental niche build up through practical action & forming networks	*Niche intermediaries* supporting niche embedding (aiming to increase size and stability) or seizing to exist / changing roles*	*Process intermediaries* connecting context-specific local priorities and local projects *Regime & systemic intermediaries* finding and directing funding for niche R&D activities.

	Regime-based & systemic intermediaries finding and directing funding for niche R&D activities. *Niche intermediaries* articulating early expectations.	with other transition intermediaries. *Niche intermediaries* developing shared institutional infrastructure (e.g. standard bodies). *Systemic (& regime) intermediaries* engaging in market creation and identification / evaluation of promising niches.	*Systemic intermediaries* aligning different perspectives and preventing strategic games *User intermediaries* facilitating technology adoption and reconfiguration by users	
Regime level intermediation	*Systemic intermediaries* articulating societal needs for change and making a variety of technological options more visible.	*Systemic intermediaries* articulating societal needs for change and creating political and institutional space.	*Systemic intermediaries* maintaining/ strengthening political and institutional space* *Regime intermediaries* raising public awareness and creating legitimacy for the new pathway* *Niche intermediaries* lobbying for visibility and resources in political strategy making	New *regime intermediaries* emerging to fill institutional gaps, in response to new governance modes or to market restructuring *Niche intermediaries* transforming into new regime intermediaries* *Systemic intermediaries* looking out needs for change*

5.2 Insights and future research needs pertaining to ecologies of intermediaries

The review and illustrative cases underscore that intermediaries tend to form ecologies, which vary from technology and industrial domain to another, and change in the course of the transition process both with respect to the role of particular intermediaries as well as the ecology overall. These shifts are particularly salient in between transition phases as intermediary activities move from local and often championing intermediaries (Martiskainen and Kivimaa, 2018) to trans-local/national/international scale, which asks for different data aggregation and communication styles and capabilities from the intermediaries.

The adequacy of such an ecology is difficult to assess. A relatively strong single intermediary mediated the successful Dutch automobility transition. As a whole, much fewer intermediaries were involved in that transition than in the UK low energy housing transition, which has been unsuccessful despite a significant number of intermediaries operating with different mandates and at different levels. Meanwhile the Finnish heat pumps greatly benefitted from a strong niche intermediary, an industry association specifically set to support it, but also emerging user intermediaries who filled in missing functions related to the new technology and market. The tentative evidence, thus, suggests that more is not necessarily 'merrier'. Further, highly concentrated intermediation may leave

dysfunctional holes in the emerging technology fields. The causality in transition processes is often difficult to assess, because the processes are complex and multidimensional (e.g. Geels, 2005). Is the failure of UK low energy homes transition to accelerate, partly, because of the absence of sufficiently strong single intermediaries, or a gap in the overall ecology? Or, are other factors making the transition so difficult, that this difficulty has led to an extremely high number of intermediary actors (cf. Kivimaa and Martiskainen, 2018) extending over different functions and levels of action?

We can also conjecture whether reaching adequate intermediation is easier in contexts that are characterised by one focal alternative technology such as an automobile or a heat pump, rather than in more varied socio-technical configurations such as low-energy housing, which feature multiple alternative technology options and highly localised variation at user sites. This paper highlights a need for further comparative research to examine the ecologies of intermediaries in successful transitions, and taking into account whether the transitions engage single or multiple technologies and/or technology-service combinations.

The policy action related to intermediaries has usually been one of founding new intermediary actors in cases of apparent need or adding new roles or areas of intermediation to existing intermediary actors, for example, when new preferable technologies enter markets (van Lente, 2003; Kivimaa and Martiskainen, 2018). Our analysis suggests that policy (or niche actor) intervention could go beyond such cases of obvious lack, through mapping whether relevant intermediaries exist in the ecology and whether their remits and interlinkages are functional enough. It further suggests paying attention to the changes needed in intermediary activities when the transition phase changes, given the likely changes in the market and technology characteristics that are associated with it. In particular, to address pressing social and environmental challenges, we need to consider how to get local or nascent intermediaries typical to early stages of transition to broaden their attention into 'growing' or 'diffusing', or, if also other types of intermediaries are needed, when these upscaling functions go against the grain of the typical grassroots activities.

6. Conclusions

Our paper made a new opening to study intermediaries and their functions – and how these alter – in different phases over the course of socio-technical transitions. It developed a conceptual model on what different types of intermediaries do in different transition phases, also including destabilisation as a specific phase. It then illustrated empirical examples comprising UK low energy housing, Finnish heat pump and Dutch automobility transitions. The cases demonstrated in practice that both the functions taken by individual intermediaries and the ecology of intermediaries change over time, while the size and nature of the ecology is different in different contexts – size not necessarily equating with the success of the transition. It also showed how a specific intermediary might alter its role from a niche intermediary to a regime intermediary or from a regime-based transition intermediary to a systemic intermediary. It appears that pre-development is typically associated with fewer intermediaries and a scattered ecology. Instead, take-off and acceleration are characterised by the emergence of new (possibly stronger) intermediary actors, or existing actors subsuming intermediary functions benefitting the transition.

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References

Alarcon Ferrari C, Chartier C. 2017. Degrowth, energy democracy, technology and social-ecological relations: Discussing a localised energy system in Vaxjö, Sweden. Journal of Cleaner Production, in press.

Backhaus J. 2010. Intermediaries as Innovating Actors in the Transition to a Sustainable Energy System. Central European Journal of Public Policy 4(1):86-109.

Barrie J, Zawdie G, Joao E. 2017. Leveraging triple helix and system intermediaries to enhance effectiveness of protected spaces and strategic niche management for transitioning to circular economy. International Journal of Technology Management & Sustainable Development 16(1):25-47

Bioregional 2018. One Planet Living: http://www.bioregional.co.uk/oneplanetliving/ [Accessed 26.04.2018].

Bush R, Bale C, Powell M, Gouldson A, Taylor P, Gale W. 2017. The role of intermediaries in low carbon transitions – Empowering innovations to unlock district heating in the UK. Journal of Cleaner Production 148:137-147.

Byrne A. 2015. Our Ian Byrne celebrates 25 years at NEF and looks back over his quarter century. Accessed 30.03.2017: http://www.nef.org.uk/about-us/insights/our-ian-byrne-celebrates-25-years-at-nef-and-looks-back-over-his-quarter-ce

Caird S, Roy R, Herring H. 2008. Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low- and zero-carbon technologies. Energy Efficiency 1:149.

DCLG 2006. Building A Greener Future: Towards Zero Carbon Development. Consultation. December 2006. Department for Communities and Local Government.

de Vries GW, Boon WPC, Peine A. 2016. User-led innovation in civic energy communities. Environmental Innovation and Societal Transitions 19:51-65.

Diaz M, Darnhofer I, Darrot C, Beuret J.-E. 2013. Green tides in Brittany: What can we learn about niche–regime interactions? Environmental Innovation and Societal Transitions 8:62-75.

Edquist C. (ed.) 1997. Systems of Innovation. Technologies, Institutions and Organization. London: Pinter.

Elzen, B., van Mierlo, B., Leeuwis, C., 2012. Anchoring of innovations: Assessing Dutch efforts to harvest energy from glasshouses. Environmental Innovation and Societal Transitions 5:1-18.

EST 2006. Solar water heating systems – guidance for professionals, conventional indirect models. Energy Saving Trust, London.

EST 2013. The heat is on: heat pump field trials phase 2: http://www.energysavingtrust.org.uk/sites/default/files/reports/TheHeatisOnweb%281%29.pdf [Accessed 26.04.2018].

Farla J, Markard J, Raven R, Coenen L. 2012. Sustainability transitions in the making: A closer look at actors, strategies and resources. Technological Forecasting and Social Change 79:991-998.

Fischer J, Guy S. 2009. Re-interpreting Regulations: Architects as Intermediaries for Low-carbon Buildings. Urban Studies 46(12)*:*2577-2594.

Fontes M, Sousa C, Ferreira J. 2016. The spatial dynamics of niche trajectory: The case of wave energy. Environmental Innovation and Societal Transitions 19:66-84.

Frontier Economics 2015. Energy efficiency: An infrastructure priority. September 2015: http://www.energysavingtrust.org.uk/sites/default/files/reports/Energy%20efficiency%20as%20infrastructure%20September%20Final.pdf [Accessed 26.04.2018].

Fuenfschilling L, Truffer B. 2013. The structuration of socio-technical regimes-Conceptual foundations from institutional theory. Research Policy 43:772-791.

Geels F. 2005. Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. Technological Forecasting & Social Change 72: 681-696.

Geels F, Deuten J. 2006. Local and global dynamics in technological development: a socio-cognitive perspective on knowledge flows and lessons from reinforced concrete. Science and Public Policy 33:265-275.

Geels F, Kern F, Fuchs G, et al. 2016. The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). Research Policy 45:896–913.

Geels F.W., Schot J. 2007. Typology of sociotechnical transition pathways. Research Policy 36:399–417.

Gillard R, Gouldson A, Paavola J, Van Alstine J. 2017. Can national policy blockages accelerate the development of polycentric governance? Evidence from climate change policy in the United Kingdom. Global Environmental Change 45:174–182.

Gliedt, T., Hoicka, C.E., Jackson, N., 2018. Innovation intermediaries accelerating environmental sustainability transitions. Journal of Cleaner Production 174:1247-1261.

Hargreaves T, Hielscher S, et al. 2013. Grassroots innovations in community energy: the role of intermediaries in niche development. Global Environmental Change 23:868–880.

Heiskanen E, Hyysalo S, Jalas M, Juntunen J, Lovio R. 2014. User involvement and radical innovation: The case of heat pumps in Finland. In Juninger S, Christensen P. (Eds.), Highways and Byways of Radical Innovation: The perspective of design. Kolding Design School: Kolding, pp. 171-192.

Hermans F, Roep D, Klerkx L. 2016. Scale dynamics of grassroots innovations through parallel pathways of transformative change. Ecological Economics 130:285-295.

Hess, D. 2016. The politics of niche-regime conflicts: Distributed solar energy in the United States. Environmental Innovation and Societal Transitions 19:42-50.

HM Government 2014. Approved Document L1A: Conservation of fuel and power in new dwellings, 2013 edition. Department for Communities and Local Government, Published by NBS, part of RIBA Enterprises Ltd.

Hodson M, Marvin S. 2009. Cities mediating technological transitions: Understanding visions, intermediation and consequences. Technology Analysis and Strategic Management 21(4):515-534.

Hodson, M., Marvin, S. 2010. Can cities shape socio-technical transitions and how would we know if they were? Research Policy 39:477–485.

Hodson M, Marvin S, Bulkeley H. 2013. The Intermediary Organisation of Low Carbon Cities: A Comparative Analysis of Transitions in Greater London and Greater Manchester. Urban Studies 50(7):1403–1422.

Hoogma R, Kemp R, Schot J, Truffer B. 2002. Experimenting for Sustainable Transport: The approach of strategic niche management. Spon Press: London/New York.

Howells J. 2006. Intermediation and the role of intermediaries in innovation. Research Policy 35:715–728.

Hyysalo S, Juntunen J, Freeman S. 2013. Internet forums and the rise of the inventive energy user. Science and Technology Studies 26(1):25–51.

Hyysalo S, Juntunen J, Martiskainen M. 2018. Energy Internet forums as acceleration phase transition intermediaries. Research Policy 47(5):872-855.

Ingram J. 2015. Framing niche-regime linkage as adaptation: An analysis of learning and innovation networks for sustainable agriculture across Europe. Journal of Rural Studies 40: 59-75.

Kampelmann S, Van Hollebeke S, Vandergert P. 2016. Stuck in the middle with you: The role of bridging organisations in urban regeneration. Ecological Economics 129: 82-93.

Kanger L, Schot J (2016) User-made immobilities: a transitions perspective. Mobilities 11 (4): 598 - 613.

Kemp R, Schot J, Hoogma R. 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technology Analysis & Strategic Management 10:175–195.

Kilelu, C. W., Klerkx, L., Leeuwis, C. & Hall, A. (2011). Beyond knowledge brokering: an exploratory study on innovation intermediaries in an evolving smallholder agricultural system in Kenya. Knowledge Management for Development Journal 7(1): 84-108.

Kivimaa, P. 2014. Government-affiliated intermediary organisations as actors in system-level transitions. Research Policy 43(8): 1370–1380.

Kivimaa P, Boon W, Hyysalo S, Klerkx L. 2018. Towards a typology of intermediaries in sustainability transitions: a systematic review. Under review.

Kivimaa P, Kern F. 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Research Policy 45(1): 205-217.

Kivimaa P, Martiskainen M. 2018. Dynamics of policy change and intermediation: The arduous transition towards low-energy homes in the United Kingdom. Energy Research and Social Science 44:83-99.

Klerkx L, Leeuwis C. 2009. The emergence and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. Technological Forecasting and Social Change 76: 849-860.

LEBD 2018. Low Energy Building Database. Available online: http://www.lowenergybuildings.org.uk/projectbrowser.php [Accessed 26.04.2018].

Lovell H. 2007. The governance of innovation in socio-technical systems: The difficulties of strategic niche management in practice. Science and Public Policy 34(1):35–44.

Lukkarinen J, Berg A, Salo M, Tainio P, Alhola K, Antikainen R 2018. An intermediary approach to technological innovation systems (TIS) - The case of the cleantech sector in Finland. Environmental Innovation and Societal Transitions 26:136-146.

Lundvall B.A. (ed.) 1992. National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning. London: Pinter.

Mallaburn P, Eyre N. 2014. Lessons from energy efficiency policy and programmes in the UK from 1973 to 2013. Energy Efficiency 7(1):23–41.

Martiskainen M. 2017. The role of community leadership in the development of grassroots innovations. Environmental Innovation and Societal Transitions 22:78-89.

Martiskainen M, Kivimaa P. 2018. Creating innovative zero carbon homes in the United Kingdom – intermediaries and champions in building projects. Environmental Innovation and Societal Transitions 26:15-31.

Mattes J, Huber A, Koersen J. 2015. Energy transitions in small-scale regions – What we can learn from a regional innovation systems perspective. Energy Policy 78: 255-264.

Medd, W., Marvin, S., Guy, S., & Moss, T. (2012). Intermediaries and the Reconfiguration of Urban Infrastructures: An Introduction. In *Shaping Urban Infrastructures* (pp. 15-28). Routledge.

McVeigh JC 1983. Sun Power. An introduction to the Applications of Solar Energy. Second edition. Oxford: Pergamon Press.

Mignon, I., Bergek, A., 2016. System- and actor-level challenges for the diffusion of renewable electricity technologies: an international comparison. Journal of Cleaner Production 128, 105–115.

Moors, E H, Fischer, P K, Boon, WP, Schellen, F, & Negro, S O, 2017. Institutionalisation of markets: The case of personalised cancer medicine in the Netherlands. Technological Forecasting and Social Change 128: 133-143.

Moss T. 2009. Intermediaries and the governance of sociotechnical networks in transition. Environment and Planning A 41: 1480-1495.

NEF, 2014. The National Energy Foundation. Celebrating 25 years. Accessed 13.05.2017: http://www.nef.org.uk/themes/site_themes/agile_records/images/uploads/NEF_25_Year_Concertina_Leaflet_June_2014.pdf. [Accessed 13.05.2017].

Nelson R.R. (ed.) 1993. National Systems of Innovation. Oxford: Oxford University Press.

Pickvance, C., 2009. The construction of UK sustainable housing policy and the role of pressure groups. Local Environment, 14(4):329–345.

Polzin F, von Flotow P, Klerkx L. 2016. Addressing barriers to eco-innovation: Exploring the finance mobilisation functions of institutional innovation intermediaries. Technological Forecasting and Social Change 103:34–46.

Orstavik F. 2014. Innovation as re-institutionalization: a case study of technological change in housebuilding in Norway. Construction management and economics 32(9): 857-873.

Rip A, Kemp R. 1998. Technological change. In S. Rayner & E. L. Malone, eds. Human Choice and Climate Change: Volume 2: Resources and technology. Columbus, Ohio: Battelle Press, 327–399.

Rohracher H. 2009. Intermediaries and the governance of choice: the case of green electricity labelling. Environment and Planning A 41: 2014–2028.

Rosenbloom D, Berton H, Meadowcroft J. 2016. Framing the sun: A discursive approach to understanding multi-dimensional interactions within socio-technical transitions through the case of solar electricity in Ontario, Canada. Research Policy 45:1275-1290.

Rotmans J, Kemp R, van Asselt M 2001. More evolution than revolution: transition management in public policy. Foresight 3: 15 - 31

Safarzynska K, Frenken K, van den Bergh J. 2012. Evolutionary theorizing and modeling of sustainability transitions. Research Policy 41(6): 1011-1024.

Seyfang J, Hielscher S, Hargrieves T, Martiskainen M, Smith A. 2014. A grassroots sustainable energy niche? Reflections on community energy in the UK. Environmental Innovation and Societal Transitions 13: 21-44.

Smink M, Negro SO, Niesten E, Hekkert M. 2015. How mismatching institutional logics hinder niche–regime interaction and how boundary spanners intervene. Technological Forecasting and Social Change 100: 225-237.

Smith A. 2007. Translating Sustainabilities between Green Niches and Socio-Technical Regimes. Technology Analysis & Strategic Management, 19(4):427–450.

Smith A, Hargrieves T, Hielscher S, Martiskainen M, Seyfang G. 2016. Making the most of community energies: Three perspectives on grassroots innovation. Environment and Planning A 48(2): 407-432.

Smith A, Raven R. 2012. What is protective space? Reconsidering niches in transitions to sustainability. Research Policy 41(6):1025–1036.

Stewart J, Hyysalo S. 2008. Intermediaries, users and social learning in technological innovation. International Journal of Innovation Management 12: 295–325.

Turnheim B, Geels F. 2012. Regime destabilisation as the flipside of energy transitions: lessons from the history of the British coal industry (1913–1997). Energy Policy 50, 35–49.

Turnheim B, Geels, FW., 2013. The destabilisation of existing regimes: confronting a multi-dimensional framework with a case study of the British coal industry (1913–1967). Research Policy 42: 1749–1767.

Vale B,Vale R. 1975. Autonomous House: Planning for Self-sufficiency in Energy. London: Thames & Hudson Ltd.

van Lente, H., Hekkert, M., Smits, R., & van Waveren, B. 2011. Systemic intermediaries and transition processes, in Guy, S., Marvin, S., Medd, W. & Moss, T. (Eds.) Shaping Urban Infrastructures: Intermediaries and the Governance of Socio-Technical Networks. London, Earthscan, 36-52.

White R, Stirling A. 2015. Sustaining trajectories towards Sustainability: Dynamics and diversity in UK communal growing activities. Global Environmental Change 23(5): 838-846.

WWF-UK, 2006. One Million Sustainable Homes, moving sustainable homes from the fringes to the mainstream of UK housing. Project number 2236/December 2006. WWF-UK.

Zero Carbon Hub (no date.) Zero Carbon Hub. Who we are, what we do. Available online: http://www.zerocarbonhub.org/sites/default/files/resources/reports/Zero_Carbon_Hub-Who_we_are_What_we_do.pdf [Accessed 27.04.2018].