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Assessing transitions to sustainable housing and communities in the UK

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ABSTRACT

We discuss work that is underway in the EU Framework 6 project MATISSE to develop the science and application of Integrated Sustainability Assessment (ISA) in EU policy-making. Many problems in the urban environment are persistent and intractable in nature, or *wicked problems*. Energy inefficient building stocks, growing energy, water and resource use, social exclusion and growing household numbers on limited land are complex, structural issues – deeply rooted in, and reinforced by, patterns of behaviour, technologies, infrastructures and social institutions. They make housing and communities in the UK *unsustainable*, environmentally, socially and economically. We focus on systemic shifts, or *transitions*, as an analytical framework for understanding these types of persistent problems, and aim to simulate the complex, dynamic processes within and between the different levels – niche, regime, and landscape – of societal systems. Using our empirically and theoretically based conceptual framework, we have developed a general modelling tool, which draws on agent-based modelling, as well as behavioural and economic theory, and explores the dynamics of and the barriers to transitions. Here we use this tool to explore the possibility of a transition to sustainable housing and communities in the UK. We look at the interdependency of institutions and infrastructures including the mainstream and 'green' building sectors, planners, house owners and other actors, and explore how the housing sector regime has created various types of lock-in, which stifle large-scale innovation. We review the current unsustainability and map it onto the transition framework. We then present two plausible future narratives for the housing sector: in the first climate change and energy are addressed in a top-down manner, and in the second a broader sustainability agenda is addressed both top-down and bottom-up. Finally, we take steps to tailor our general model to this case study.

Key words: Transitions, Sustainability, Communities, Housing, Modelling, Complex systems

1 INTRODUCTION

The Sustainability in housing and communities in the UK is a long-term, cross-sectoral issue, involving social, environmental and economical aspects. Here we report on research currently underway in the EU Framework Six MATISSE project[1] to model and assess transitions, or long-term systemic shifts, to sustainable development. We use concepts from the transitions literature (e.g., Geels 2005a; Rotmans et al. 2001) to consider the prospects and policy options for transitions to sustainable communities in the UK. We do not present an exhaustive review, but an attempt to get to grips with the main issues of sustainable homes and communities, and analyse them using transitions theory and the evolving MATISSE conceptual framework (Haxeltine et al., in prep.) within that theory. This paper starts with an overview of transition theory, which we then use in an assessment of the unsustainable situation of housing and communities in the UK at present and the barriers to transition. We then present two narratives of future housing and community scenarios under different policy options. Finally we introduce our prospective modelling work.

1.1 Transition theory

There are some nation-wide or EU-wide problems, such as road transport or unsustainable communities, which are persistent and intractable in nature. The systemic nature of these problems suggests that they are complex, uncertain and cut across a number of sectors, and indicates a need for more radical technological and behavioural solutions. Furthermore, these are structural issues – deeply rooted in, and reinforced by, patterns of behaviour, technologies, infrastructures and social institutions (Geels 2005a). This highlights the need to address the underlying structural determinants of the problems. Increasing attention is being given to radical, systemic innovation, or transitions as a means of tackling these types of persistent problems; a transition can be seen as a long-term (order of 25–50 years) systemic shift, which changes the systems infrastructure and dominant culture, as well as the behaviour of actors (e.g., Rotmans et al. 2001).

We use concepts from the transitions literature (e.g., Geels 2005a; Rotmans et al. 2001) to consider the prospects and policy options for a transition (systemic shift) to sustainable development. We introduce an innovative model of transitions, and demonstrate how we will apply it to the case study of transition to sustainable housing and communities in the UK. While Geels (2005a, 2005b) focus on *(socio-) technical* transitions, which look at disruptive new technologies and the surrounding institutions, we are also interested in *societal* transitions (Rotmans et al. 2001), which look at the broader picture of shifts in behaviour and societal functions as well. The model is not meant to be predictive, but rather to assist the user in thinking about the

[1] Methods and Tools for Integrated Sustainability Assessment (MATISSE). See: www.matisseproject.net

dynamics of change towards sustainability, as part of MATISSE's remit to improve the tool-kit available to policymakers and other stakeholders for evaluating sustainability policies. Stakeholder engagement is another part of this research.

Regimes and regime change Transition theory literature highlights the interdependency of institutions and infrastructures constituting societal systems and subsystems. These societal systems comprise interlocking social, cultural, economic, infrastructural and regulative subsystems, which are associated with a range of social groups (Geels 2005a), and result in various types of lock-in that stifle innovation (Smith et al. 2005). The stability and cohesion of societal systems is established and reinforced through cognitive, normative and regulative institutions (Geels 2005b), which in transition theory are represented by the concept of a *regime*. A regime can be understood as a particular set of practices, rules and shared assumptions, which dominate the system and its actors (Rotmans et al. 2001). Importantly, regimes typically focus on system optimisation rather than system innovation, because habits, existing competencies, past investment, regulation, prevailing norms, worldviews and so on, act to lock in patterns of behaviour and result in path dependencies for technological and social development (Smith et al. 2005; Geels 2005b). However, transitions require organisation-exceeding, qualitative innovations, realised by a variety of participants, which change the structure of the system (Loorbach and Rotmans 2006). Researchers have therefore highlighted niches – individual technologies and actors outside or peripheral to the regime – as the loci for radical innovation (Geels 2005a; Geels 2005b; Rotmans et al. 2001; Smith et al. 2005). The regime may be threatened from the niche level, or from changes at the broader landscape level of economic, ecological and cultural trends, or from internal misalignment amongst regime actors (Geels 2005a). Once a threat is recognised, regime actors will mobilise resources from within the regime, and in some cases from within niches, to respond to it (Smith et al. 2005; Geels and Schot 2005). A transition occurs when a regime is transformed or replaced.

The multiphase and multilevel concepts The analysis above uses the multilevel concept of macro-, meso-and micro-levels (Kemp and Rip 1998, Rotmans et al. 2001). The macro-level is the slow changing landscape of world views and paradigms, macro-economy and material infrastructure, as well as the natural environment and demographics. The meso-level refers to the regime and its structure, culture and practices, which are dominant within the system, and can sometimes affect the landscape as well. The micro-level refers to niches, i.e., individuals or small groups of actors, with local practices which sometimes differ from the regime. Innovation and alternatives, both social and technological, tend to emerge from this level. In our conceptual framework we have added the notion of an empowered niche, a niche or aggregate of niches which has grown powerful enough, in terms of resources and support, to be a threat to the regime; we place it between the micro-and meso-levels (Haxeltine et al., in prep.).

The multi-level concept is complemented by the multi-phase concept. Building on the s-shaped (sigmoid) diffusion curve (Rogers, 1995), four phases of a transition can be identified: pre-development, take-off, acceleration, and stabilisation (Rotmans et al., 2001; Geels, 2005a). In the pre-development stage, there is uncoordinated experimentation at the niche level but no visible change in the status quo. By the take-off stage, a coordinated network of niche actors (an empowered niche) forms and a dominant concept of the innovation they are developing emerges; the technology/idea is used in niche applications and rapidly improves. The acceleration phase occurs when there is a convergence of pressures on the regime, which allows the innovation to diffuse rapidly. As the niche enters the mainstream, it challenges the incumbent regime and the structure of the system visibly changes. Finally, in the stabilisation phase, the speed of change decreases and a new dynamic equilibrium is reached once the old regime is replaced. In some transitions the regime is not replaced, but adapts to the changing landscape through different mechanisms (e.g., Geels and Schot, 2007).

1.2 (What we mean by) Sustainable houses and communities

Sustainability in the housing sector does not refer merely to energy efficiency and combating climate change; rather, it refers more broadly to environmental, social and economic sustainability of houses, households and communities. Sustainable communities may be thought of as places where people want to live and work, which promote environmental sustainability and social inclusion, and which hold similar promise for future generations.

While we began investigating sustainable housing, we soon found the case study broadening to look at communities as well. Sustainable housing refers to energy and material resources used in building houses, and to energy and material resources used, and waste produced, from households. Sustainable communities refers to environmental, social and economic sustainability of the built (residential) environment, including land use, transport and connectivity, satisfaction with neighbourhoods and communities, etc. Sustainable housing and communities are connected through policy, stakeholders and various processes, especially when looking at long-term trends and possible transitions. Planning energy efficient houses goes hand-in-hand with planning communities which are land-efficient, with community recycling schemes, and easy access to public transport. In large scale developments, planners and architects design both the individual houses and the layout of the neighbourhoods, including public spaces and other community facilities. Users (i.e., residents) care both about their own home and about the communities they live and work in. Providing affordable housing is not only about cheap, decent homes, but also about the neighbourhoods and communities in which they are situated.

The connection is also evident in the schemes already in existence for promoting

sustainable development. For example, the BedZED scheme includes not only sustainably built houses, but also a high-density yet pleasant layout, with a neighbourhood CHP and facilities to minimise the need for commuting – designed to be an 'urban village' (Sommerhoff 2003). Co-housing schemes are neighbourhoods composed of private and public spaces, with individual dwellings and the whole layout designed to increase communal interactions, encouraging a sustainable community dynamic (Field 2004).

The Egan review[2] (ODPM 2004, page 18) defines sustainable communities as follows: "*Sustainable communities meet the diverse needs of existing and future residents, their children and other users, contribute to a high quality of life and provide opportunity and choice. They achieve this in ways that make effective use of natural resources, enhance the environment, promote social cohesion and inclusion and strengthen economic prosperity.*"

Other studies highlight different aspects of sustainable housing and communities. The WWF promotes sustainable development of communities in a fashion which reduces global environmental impact and increases worldwide equity in resource use, and uses indicators such as the ecological footprint (e.g., WWF 2006). Studies such as *40% House* (Boardman et al. 2005) focus on housing, addressing climate change and the many changes in policy, market and skills development necessary in the residential housing stock if the UK is to reduce its CO_2 emissions by 60% by 2050, in order to mitigate global warming.

In MATISSE we choose not to add another definition of 'sustainable development' to the many existing ones. We recognise that it must be defined in a way relevant to each case study by the relevant stakeholders, but that it broadly includes environmental, social and economic pillars (Weaver and Rotmans, in press). We therefore take the above definitions and comments as guidelines for sustainable communities for our case study.

2 THE CURRENT SITUATION

In this section we start by showing how the current situation of housing and communities in the UK is unsustainable. We then analyse the different actors and stakeholders from a transitions theory perspective.

2.1 The current unsustainability

Evidence for unsustainability in the housing sector can be found in various sources looking at different aspects of sustainability. We do not review them exhaustively, but

[2] The Deputy Prime Minister invited Sir John Egan to undertake a review of the skills and training that built environment professionals require to deliver sustainable communities. The Review included professionals, planning authorities and developers and looked at how they can work together in achieving measurable improvements to the communities they serve. It also considered how any skills gap can best be bridged.

look at a few different perspectives of sustainable housing and communities.

DCLG perspective The Office of the Deputy Prime Minister (ODPM, now Department for Communities and Local Government, or DCLG) action programme *Sustainable communities: building for the future* (ODPM 2003b) lists the sustainability problems facing communities in England in four areas:

1 There is a lack of affordable housing in decent surroundings, with vulnerable people occupying homes in poor conditions, and some urban areas requiring sustained effort for regeneration.
2 There is a housing shortage in some parts of the country, with new build in decline, and a growing gap between supply and demand of new housing. Meanwhile, there is a collapse of the housing market in other places.
3 There is wasteful use of greenfield sites in a densely populated country; new developments taking more land than they need, and extensive suburbs creating urban sprawl.
4 The planning system is slow and unresponsive in the face of changing needs and demands. Long-term planning of communities is inadequate, and many are built with poor design.

The above list focuses on the macro-economics of building communities, but does touch on environmental and social aspects. Other sources focus more on ecological and environmental unsustainability caused by resource and energy use, and the social and environmental unsustainability of households; two are detailed below.

An ecological footprint is a measure of the resources we require, or the mark we leave behind on the environment in order to sustain us. It is often measured in the area of land per capita we require to sustain our lifestyle, including food, energy, clothing, transport etc. The available productive land around the world gives an area of 1.8 global hectares (gha) per person (WWF 2004). The UK has an ecological footprint of 5.4 gha per person and rising, with regional and local variations (WWF 2006). This is three times the available per capita worldwide, and therefore unsustainable in a global perspective.

Housing is itself only a small portion of the ecological footprint, with energy taking up more than half of the footprint (WWF 2006), but environmental impact from housing includes energy for heating, household appliances and travel (direct energy) and energy required to produce goods and services (indirect energy). The ecological footprint is therefore a measure of environmental sustainability on a global scale, and while it measures more than housing, a significant reduction in the overall footprint would require a reduction in our housing and household footprint. The ecological footprint has already been adopted as an indicator of movement towards sustainable development in the Welsh Assembly Government, and case studies of the footprint and future development have been carried out in York and other places (ibid).

Climate change is one of the greatest challenges of our time, and averting the worst climate change is both a global issue as well as an environmental and economic issue for the UK. The threat from climate change to both present and future generations makes it a sustainability issue, and therefore reducing greenhouse gas emissions in an effort to combat the worst effects of climate change must be part of a sustainability agenda. CO_2 is the primary greenhouse gas, and contributed 85% of the UK's emissions in 2004 (HMG 2006). The UK's long-term target of reducing CO_2 emissions by 60% compared with 1997 levels by 2050 (DTI 2003) is a difficult target. The UK, like all industrialised nations, is locked in to a high carbon emissions economy, with carbon intensive lifestyle and consumption patterns co-evolving with CO_2 emitting technology and energy supply (Anderson et al. 2005). Approximately 27% of the UK's emissions in 2004 came from direct energy use in homes, of which about 60% was used for space heating, 20% for water heating, and the remainder for lighting, cooking and other appliances (HMG 2006). More emissions are related to indirect domestic consumption. While energy consumption for heating and cooking has decreased, the consumption related to appliances and lighting has increased (HMG 2006). Household ownership of electronics, such as televisions, domestic IT and other gadgets, has increased dramatically, and is expected to continue to rise over the next few years: by 2010 consumer electronics is predicted to become the biggest single sector of home electricity consumption (EST 2006).

Considering climate change in long term housing sustainability requires not only reducing the housing impact on climate change, but also adaptation to climate change which is already inevitable or highly likely. This includes changing regulations and practices to suit future climate which may vary across the UK, and addressing issues such as urban drainage with increased flood risks and changing patterns of urban heat islands (e.g., Environment Agency 2006, UKCIP 2003).

The number of households in the UK is growing, as the population grows and the average size of households shrinks, causing an increased environmental burden, and introducing social sustainability issues as well. Of interest are the increase in the over 65 population to roughly one quarter of the population, and an increase in single-person households.

One-person household numbers have grown from 18% of households in the UK in 1971 to 30% in 2001 (ODPM 2003a), and are predicted to constitute 38% of households in 2026 (ODPM 2006). Williams (2006) reviewed the state of one-person households and found a shift in their makeup from pensioners, mostly women, to mostly working age men and women, with single men aged 35-44 being the fastest growing group. Williams also finds that while the economic profile of one-person households is currently mostly in the lower decile groups, this is expected to diversify, and that most people who now live alone will never live with other people again. These findings have environmental, social and economic consequences.

While energy usage per household has gone down by 3% from 1970–2001, the number of households has increased by 36%, resulting in a 32% increase in energy

consumption (Shorrock and Utley 2003; Boardman et al. 2005). However, new appliances could counter the energy savings in efficient appliances (e.g., plasma televisions). Moreover, Williams (2006) found that current trends of increase in one-person households in England and Wales could cause an increase in domestic consumption of energy, land and household goods. This group has a higher environmental impact than larger households in (direct and indirect) energy consumption and waste production: one-person households used 1600kg of products per capita per year versus 1000kg in large (4 person+) households, i.e., 60% more; and the energy consumption in one-person households is 190GJ per capita per year, versus 80GJ per capita in large households, or 138% more (INCPEN 2001). Moll et al. (2005) also found that in the UK and other countries small households had higher direct and indirect energy requirements per person than larger households. As the profile of one-person households changes, this trend is expected to increase. While rising property and energy prices may constrain one-person household numbers, household goods are not usually an economic constraint (Williams 2006). This could mean an increase in energy use and waste production per household (reversing the current trend) as well as a growing number of households.

The increase in one-person households has social implications as well. Williams (2006) divides the single-householders into “happy independents” (elective singles) and “regretful loners” (forced singles), and investigates how the latter group might benefit from alternative living arrangements, such as collaborative or communal living, which would also reduce environmental impact. Her study highlights the social benefits as well as the environmental benefits of these arrangements.

In summary, we conclude that housing and communities in the UK are unsustainable in that available land is limited, while there is a housing shortage and the number of households is predicted to grow; material and energy consumption are likely to increase through the growing number of households and houses, and through increased number of appliances per household, increasing the average ecological footprint and threatening continued climate change; there is a lack of affordable housing, with vulnerable people needing better houses and surroundings, and there are a growing number of people who live alone, who would benefit socially, and reduce their environmental impact in other living arrangements.

2.2 The housebuilding and planning sector – the current regime

The mainstream construction and planning sector is the meso-level regime in the transition theory framework. It includes planners, developers, architects, etc, as well as various other bodies such as local and regional authorities and government planning bodies. Most houses in the UK are built by large volume builders, in mass production from large suppliers, with little innovation. Local authorities, who define places for development and decide on planning applications can be seen as part of

the regime as well.

There is much evidence that the mainstream building sector in the UK has practices and a culture which are incompatible with sustainability on various levels, and that sustainability issues require not only a technological shift in the building industry, but a complete paradigm shift: changes in structure, communication, strategy and actors (Boden 1996; Rohracher 2001). For example, Rohracher (2001) found that this sector traditionally has low levels of innovation, mass production from large suppliers, and separation of design from construction, whereas ecological optimisation requires some high-tech components supplied (as yet) by specialised companies, and high levels of cooperation between different experts to deal with complex problems. Moreover, the building industry in the UK is largely unaware of the potential for user input.

The regime is locked in to its current practices and culture, and fights to maintain them: in the UK volume house-builders lobby hard to influence energy efficiency and other regulations, but even so as many as one third of new developments fail to comply with them (Smith 2006). This can be seen as the regime using its power to resist change and maintain the status quo, or as an internal misalignment between different regime actors (Geels 2005b).

In another example of lock-in, in a study of commercial office building, Pett and Ramsay (2003) found that “conservatism and vested interest across the property professions inhibit provision of the kinds of workplaces occupiers actually want” (Pett and Ramsay 2003, p. 732). Williams (2006) engaged developers as stakeholders on various environmentally friendly designs. She found that developers favoured statutory controls for higher environmental standards, concerned that without them such building would suffer from competition with cheaper, lower standard building. This also points to entrenchment, as developers do not see the house-building sector changing of its own accord.

The regime’s approach poses barriers to changes in the housing sector. For example, Pett (2004) claims that forward-thinking builders sometimes have trouble promoting sustainable housing because it fails to meet targets or requirements of, for example, a local building committee. The planning system is slow and unresponsive in the face of changing needs and demands (ODPM 2003b), which could be interpreted as a ‘blindspot’ on the part of the regime. Nonetheless, speculative house builders are incorporating some energy efficient and renewable energy technologies into new build (Williams 2006).

Finally, it must be stated that there are a variety of actors in the mainstream building sector, and there are some initiatives facing the sustainability challenge, e.g., the European Construction Technology Platform, which is attempting to mobilise the whole sector to more sustainable practice, in which they include contractors, planning authorities, architects and other designers, purchasing bodies, suppliers, clients and users (ECTP 2005).

2.3 Sustainable housing and communities – innovative niches

A variety of developments and communities around the UK, both mainstream and alternative, have appeared over the past years and decades, as examples of more socially, economically and environmentally sustainable communities. There have also existed various pressure groups and NGOs pressing for more sustainable practices. These micro-level niches include a variety of small initiatives by individuals or groups: alternative housing schemes and neighbourhoods, such as the 'green building activists' studied by Smith (2006); demonstration projects like the Earthships in Fife and Brighton, in which the South Ayrshire Council has taken interest (ECRP 2004); local community groups including faith groups trying to improve their quality of life regardless of government policy (Darnton 2004); or pressure groups such as WWF. These have had a variety of levels of success.

Smith (2006) reviews eco-housing and green building activists (sic.): "activists have been trying to create more sustainable practices for over 35 years, with mixed success ... Wider recognition of these green niches by society, government and business has fluctuated over this period." While eco-housing remains a small niche in the UK, Smith asks how these actors and the eco-housing experience can inform the increased interest in sustainable homes and communities among policymakers and the mainstream. Smith claims 'strategic creation of innovative, greener niches' is a possible approach for sustainable technology governance in general, and specifically shows that interest in niche housing developments suggests there is a desire to learn from them; he stresses the importance of 'room for failure as well as success' in supporting innovative niches.

Innovative urban development Many actors are pressing for urban development and renovation to be more environmentally sustainable. One of the most prominent attempts at sustainable urban developments in the UK is the Beddington Zero Energy Development, or **BedZED**. BedZED is a housing and workspace development in Beddington, Sutton (South London), built to be environmentally friendly and energy efficient. This development of 82 homes and 18 live-work units is an urban village designed to meet environmental, social and economic needs. The flats look and feel modern, in an attempt to shake the 'hairshirt' image of environmentally friendly housing. It combines various proven methods of reducing energy, water and car use in one development, built from local and reclaimed materials wherever possible, and has an energy-efficient design and appliances enable ongoing resource and energy savings for residents. The community-focused design promotes social well-being as well, and BedZED received an EcoHomes rating of Excellent (Sommerhoff 2003, see also www.bedzed.org.uk). Architect Bill Dunster says, "A lot of people marginalise this as a study in green technologies. It is actually a serious study in high-density, contemporary urban living" (Sommerhoff 2003). This is an example of a project initiated by a forward thinking architect.

Another actor to consider is the World Wildlife Fund in the UK (**WWF-UK**), a

prominent example of an independent organisation promoting environmental sustainability. WWF is the world's largest privately financed conservation organization. WWF-UK has put itself forward as an actor in sustainable communities through reports on reducing ecological impact of housing (WWF 2006), and their 'One Million Sustainable Homes Campaign', with research into case studies such as the Thames Gateway development (WWF 2003). This and other NGOs focus on (global) environmental sustainability.

While individual developments and NGOs can be seen as niches on their own, we choose to group them together in our analysis as a single niche promoting environmentally sustainable urban development, often through innovative technologies, and trying to build socially sustainable communities as well.

Social sustainability – communities Another group of actors, although there are overlaps, focuses on improving quality of life in existing communities and creating new, sustainable ones. **Local community groups** are one example: Darnton (2004) reviews how the large number of local community groups in the UK act to improve sustainability or otherwise improve their communities; their local and voluntary nature often puts them outside the control of the state. These individual groups or networks of such groups are niches focusing on social and sometimes economic sustainability.

Co-housing is a sustainability-focused development, an example of collaborative living, which is the work of a group or community. The principles of Co-housing are consensus decision making, pedestrianised estate, and a combination of private and communal space. Commonly the last of these would be private self-contained units, with shared utilities and recreational facilities such as kitchens, dining halls, workshops and children's play facilities, and possibly shared evening meals. Co-housing residents comprise an *intentional community*. They choose to live together and to share property and resources, and develop a rich social life, aspiring to a strong 'sense of community' (Meltzer 1995; Field 2004). Field (2004) stresses the community aspects, which are important to social sustainability: co-housing neighbourhoods are of a certain type of design and the residents number within a certain range to encourage a community with a 'sustainable dynamic'. Field sees it as crucial that all decisions are made by the members, rather than an outside authority, from the designing and building stage onwards; this is a major departure from mainstream development. Co-housing addresses both resource consumption and social sustainability, "minimising private dwelling space in order to maximise shared facilities and collective opportunities." (Meltzer, 1995). Furthermore, "[F]ollowing its remarkable success in Denmark, co-housing attributes seen to encourage and facilitate social and environmental sustainability have been incorporated into mainstream public and private housing." (Meltzer, 1995). The social sustainability aspect of co-housing is also evident in Williams (2006), as an example of collaborative living, which she sees as a possible solution for 'regretful loners'. In Denmark co-housing schemes are a successful niche, with many different schemes in existence, and their influence on the mainstream housing paradigm evident. In the

UK the schemes are few. Networks of Co-housing schemes, housing cooperatives and other collaborative or communal dwellings can be considered a niche focusing strongly on social and often environmental sustainability as well.

However, we choose in our analysis to group together these various community oriented groups, and NGOs and planners supporting them, as a niche promoting social sustainability, stressing a community-based, bottom-up approach. These groups often focus on social innovation rather than technological fixes. Environmental and economic sustainability at the community level are also part of the agenda for at least some of the actors in this niche.

2.4 Policy and paradigm – the landscape

The landscape of the housing and communities sector includes increased pressure from climate change and the change in attitudes towards it; global and UK resources limitation, including energy and land; changing attitudes towards social sustainability and communities; changing demographics including the increase in the elderly population and the decrease in average household size.

The increase in sustainability rhetoric from the EU and ODPM/DCLG increases landscape pressure on the regime. The landscape changes can be expressed within the system as the legal and regulatory framework of the EU and the UK, with planning system and policy implementations at national, regional and local level[3]. Pett (2004) reviews the complexity of international conventions, UK and EU laws and policies, and local by-laws, in setting targets, limits and regulations. She also distinguishes between the clear procedure for changing UK legislation, compared with the murkier task of policy development. The situation is also complicated by the different laws and regulations in England, Wales, Scotland and Northern Ireland.

Background – supporting the regime On 'Green buildings', Rohracher (2001) claims that as a result of varying political interests, such as climate policy, energy policy, environmental policies, as well as social and economic policies, "most countries currently do not have coherent policy strategies to promote the transition to a more sustainable building stock."

On planning, Pett (2004) considers the UK to have a patchy legislative framework for sustainable development in general, and sustainable housing and construction in particular, with most legislation favouring add-on or end-of-pipe solutions, rather than sustainable development, which requires good design to prevent problems arising in the first place. Pett further states that planning and building regulations have a long way to go to catch up with the aims of sustainability, and in recent years "stakeholders have pointed to the planning systems as a major barrier to their

[3] We broadly group central government as landscape, and local authorities as actors in the regime, working within the centrally dictated framework. However, one could argue that some local authority or even central government actors belong in the niches when they act to change the system and promote sustainability.

implementation... Speed of obtaining planning permission [was also a major failure] for sustainable housing."

On social sustainability, Pett (2004) states that while local policies may refer to certain types of housing, such as 'affordable housing', it is left up to the developers ('the market') to address specific needs, such as adaptable housing, single-person units etc. Similarly, economic sustainability seems in practice to be restricted to financial sustainability or 'profitable growth', and does not refer to the impact of companies on communities or their surrounding environment (ibid). Environmental sustainability legislation is more advanced, but focuses on concepts of preventing or limiting damage, e.g., protecting habitats, reducing energy use, preventing pollution, waste management and recycling. It does not promote a better way of developing housing, such as promoting healthy and stable natural and human environmental systems (ibid). To summarise, there was little pressure on the regime to change its practices and culture until recently.

Recent developments – a change in the landscape Recent and planned changes to planning and building regulations and sustainability targets have effectively changed the landscape. Rydin (2006) reviews the huge reform agenda in the planning system over the last few years, which comprise cultural and procedural changes to spatial planning including the Local Development Framework, the Sustainable Communities Agenda, and others. She considers how these changes could promote sustainable development, but it is debatable whether sustainable development is being prioritised in this reform. Pressures on local authorities to deliver services including planning services put pressure on planners through time constraints; the sustainable development agenda has high intellectual demands on local authorities, hence the need to clarify how local authorities can learn about sustainable development.

Rydin (2006) concludes that the situation is more positive than in 2003 but more complex: while sustainable development is higher on the political and planning agenda, there is no guarantee that the reforms will deliver more sustainable communities due to the great effort in changing processes. However, she sees great potential to use the reforms to further the sustainability agenda.

Recent government papers put sustainable housing and communities higher on the agenda, putting pressure on the regime – the conservative building sector. For example, in a recent consultation paper, DCLG (2006a) proposes improved energy and carbon performance in building regulations, requiring new build homes from 2016 to be 'zero carbon', an ambitious target set to combat climate change and fuel poverty, and improve the UK's energy independence. The Code for Sustainable Homes (DCLG 2006b) presents a wider range of sustainability parameters, developed "to enable a step-change in sustainable building practice for new homes".

There is pressure on the regime from local authorities as well, which increasingly set out legal requirements, e.g., percentages of energy requirements from new developments to be supplied by renewable resources (Pett 2004). Meanwhile, the

Barker Review (Barker 2006) recommends major changes to land use planning, which will have serious implications for planners and local government.

From a transition theory perspective, all of these recent changes amount to a landscape change putting pressure on the regime. While these changes will inevitably cause some change in house-builders and planners practices, we propose to research under what conditions this pressure might result in a transition, and if so whether this results in more sustainable housing and communities.

3 NARRATIVES

We present two narratives (or 'scenario storylines') for the future of the housing and communities sector in the UK over the first half of the 21st century. The narratives are not meant to be predictions, but plausible futures used for heuristic purposes. In the next section, we will draw on elements from these narratives in order to apply a general transition model to the housing and communities case study.

The first of our narratives is based on government regulations, market power and new technologies, which lead to a housing sector which is more energy efficient in build and use. This is a shift to a low energy / low carbon emission housing stock, but without significant changes to economic or social sustainability, nor to environmental issues other than climate change. The second narrative covers a broader and more radical perspective of sustainability, a top-down and bottom-up transition to a housing sector and communities which are more sustainable, environmentally, economically and socially.

3.1 Narrative 1: government, markets and technology

This narrative is based on the UK government planning to tackle climate change through a combination of measures including harnessing new technology, stricter building regulations, and the power of the market. In the housing sector, the focus is on low carbon technologies, energy efficient houses, and low energy appliances. The narrative describes a successful shift to a low carbon emission, energy efficient housing sector. However, while we use transition multi-phase language in the narrative, we argue that this shift is not a transition: it does not describe a systemic shift including cultural values and paradigm changes; the regime is not significantly altered, with the same players and only changes in certain practices; and the changes are almost entirely top-down.

In the pre-development phase, at the beginning of the 21st century, the mainstream building sector and 'green' building were incompatible at various levels (Rohracher 2001): This sector traditionally had low levels of innovation, mass production from large suppliers, and separation of design from construction, whereas ecological optimisation required some high-tech components supplied at the time by specialised companies, and high levels of cooperation between different experts to

deal with complex problems. Moreover, the building industry in the UK was largely unaware of the potential for user input. Over the next few decades, the building sector was slow to change, and only did so following government regulations and subsidies for low carbon emission buildings and retraining skills. While new types of building were taken on board, there was no significant shift in the builder / consumer relationship: the overwhelming majority of new build was still carried out by a few constructing agents, which begrudgingly accept changing regulations and norms; the housing stock otherwise remained standardised, with consumers having little input into house design.

The Egan review (ODPM 2004, p. 29) discussed broad implications for new skills needed for sustainable communities, "*to make this work we need a wide range of skills from the technical such as designing high quality townscapes, to the more generic such as strong, informed leadership*". However, in practice, the government pressured for change in the building sector only in the field of technical skills, following recommendations such as The 40% House (Boardman et al. 2005, p.101): "*the 40% scenario also implies a huge program of training in the skills needed to design, construct and maintain a low-energy building stock, the appliances within it and the technologies on which it will all depend.*" Moreover, the government's housing agenda was geared towards reducing carbon emissions, introducing stricter emission targets in the pre-development and take-off phases (DCLG 2006a), with emission reduction and energy saving measures forming a stricter part of the Code for Sustainable Homes than other environmental or social issues (DCLG 2006b).

Refurbishment to improve the existing housing stock increased, following the success of the Warm Front and other schemes in the pre-development phase in reducing fuel poverty and energy bills and increasing the percentage of homes meeting the thermal comfort criterion. Such schemes received an extra push in the take-off phase when it was shown they had knock on effects in terms of quality of life and other social sustainability indicators, such as improved use of living space and even improved physical and mental well-being (Gilbertson et al. 2006). By the acceleration phase, energy companies and others competed in offering 'energy efficiency services' which provided assessment of energy efficiency in the home, refurbishment and installation of low carbon energy micro-generators, besides their traditional role of supplying energy.

Demolishing and new build of the housing stock also played an important part in improving house energy efficiency. The rate of demolition increased, targeting the least energy efficient of the housing stock in the early 21st century, some 14% of the houses at the time, so that by 2050 one third of the housing stock was newbuild, i.e., built in 2004 or later (Boardman et al. 2005). This was combined with an increase in environmentally responsible demolition, in which materials were reused or recycled, e.g., concrete reused for new structures or rest crushed for aggregate, wood beams and other lumber were recovered and resold; parts unsuitable for recycling as aggregate reused as road sub-base, etc. This greatly reduced landfill use from demolition. The construction sector objected at first to responsible demolition,

claiming it was not economically viable, as demolition projects took longer. However, they were proved wrong as it emerged that the demolition was cheaper due to reselling materials and reduced landfill payments, and the longer, more labour intensive demolition projects provided more employment (von Weizsäcker et al. 1997, chapter 2.12).

The environmental sustainability of the increased turnover rate came from the new-build being comprised of highly energy efficient and low material impact houses, from reduced material flow through responsible demolition, and through careful planning of newbuild which considered future refurbishment options and demolition of the houses.

Following the Stern Review (Stern 2006, chapter 16), the UK government accepted that some new alternative technologies were bound to fail, but that this failure could still create valuable knowledge. In the take-off phase, the government supported small scale eco-housing experiments, fostering a wider range of possible technologies than the market would do by itself (ibid.). Thus, while the 'eco-housing' niche never grew large, throughout the take-off and acceleration phases ideas for low-carbon, energy efficient housing were developed, and the more economically viable ones were incorporated into the mainstream building sector, as ideas for new technologies and building techniques were sought to meet with ever-stricter building regulations. The most successful became standards by the stabilisation phase.

Reduction in household energy usage was achieved partly by changes in consumer behaviour. While this seemed implausible in the pre-development phase, landscape changes including rising oil prices and fear over energy security, as well as increasing effects of climate change being felt in the UK caused a enabled a shift in energy usage. This was complemented by higher consumer energy prices and intense campaigning by the government and energy sectors. In the take-off phase revisions to energy labelling regulations to reflect total energy consumption encouraged purchase of smaller appliances (Boardman et al. 2005); these especially helped reduce consumption in the growing number of single-person households, as this group embraced smaller refrigerators and washing machines, which used less energy. Other measures, such as feedback on energy consumption, through 'smart meters' displaying current energy consumption, interactive electricity meters and better information on energy bills also encouraged energy savings in the home (Boardman et al. 2005). By the acceleration phase, consumers seeking out how to maintain their lifestyles while minimising their energy usage was becoming the norm.

The decrease in average household size was nonetheless a setback. One-person household numbers grew from 30% of households in 2001 (ODPM 2003a) to 38% in 2026 (ODPM 2006), as the average size of the household continued to drop from about 2.3 in the early 21st century to 2.1 in 2050 (Boardman et al. 2005). The make up of one-person households shifted from pensioners, mostly women, to mostly working age men and women, with single men in their 30s and 40s being the largest group (Williams 2006). Small households, especially one-person households consumed more energy, land and household goods, and produced more waste per

person (Moll et al. 2005; Williams 2006). In the pre-development phase the energy consumption in one-person households was 138% more then large (4 person+) households (INCPEN 2001), and this grew in the take-off phase as the economic profile of one-person households diversified from mostly people in the lower decile groups to people of different incomes (Williams 2006). As one-person households became the norm, not the exception, by the 2030s, previous energy efficiency measures were less effective in reducing CO_2 emissions from houses, requiring a greater reduction per household.

Despite these difficulties, take-off phase investment in and subsidies for low-carbon technology and energy efficient buildings led in the acceleration phase to a housing sector in which it was common to have two low and zero carbon technologies per household, including neighbourhood and micro-CHPs, solar water heating, photovoltaics, biomass generation and wind turbines; by 2045 the stabilisation phase was reached, with residential electricity generation became a net exporter of electricity (Boardman et al. 2005). Carbon emission reduction from the housing sector only just met its 60% reduction targets by 2050: public acceptance of the need for mitigation of further climate change made this possible, but it was a continuous struggle to offset increasing household numbers and appliances per household with energy efficiency measures and public campaigns to conserve energy. There were also knock-on effects and improvements to other sustainability agendas, for example, energy efficient buildings and micro-generation reduced fuel poverty with public health benefits (Gilbertson et al. 2006). However, there were no significant systemic shifts to solve the persistent problems of socially unsustainable communities, and environmental problems from land and resource use and waste generation remained unsolved.

3.2 Narrative 2: from green niches to sustainable communities

This narrative is based on the UK government plan to tackle climate change through a combination of measures including harnessing new technology, stricter building regulations, the power of the market, and investing in ‘green’ niches; but there is also investment in other sustainability measures. The focus is not only on low carbon technologies and energy efficiency, but also on social innovation. These policies enable the bottom-up change from alternative housing and community niches, which together with pressure from the landscape results in a transition in the housing sector to a new planning and building regime, with benefits to communities in increased social, environmental and economical sustainability.

Government regulations and subsidies push for change as in narrative 1, but there was also legislation helping smaller builders experiment with alternative designs and technologies, as the government left room for failure as well as success not only in technological innovation (Stern 2006, chapter 16) but also in social innovations in niches (Smith 2006), and recognised the benefit of enabling housing associations

and even individuals more say in planning and design (Dewick and Miozzo 2004). A large number of alternative builders appeared at first, and after years of experimentation a smaller number of construction methods became more widespread. The result was a paradigm shift in the building sector, with some new construction and architect names appearing and some of the old ones disappearing. In the emerging new paradigm, there was a process of iteration between local authorities, housing associations, builders and architects/engineers in planning residential areas for environmental, social and economic benefit (Dewick and Miozzo 2004). Refurbishment and demolition were similar to narrative 1, although the changes in building sector paradigm affected this too: consumers had more say over what type of refurbishment or improvements they received under Warm Front type schemes, contributing to empowerment in communities (Gilbertson et al. 2006), and the many newbuild opportunities allowed a variety of alternative living schemes to be tested, such as co-housing.

In rural areas, a variety of alternative eco-housing projects emerged in the pre-development phase in the early 21st century. The earthship in Fife, which demonstrated the idea of self-built low impact earth-sheltered housing, drew the interest of South Ayrshire Council (ECRP 2004). In 2010 the South Ayrshire council invested in “a self-build housing project of 12 houses based on Zero Waste Zero Energy principles demonstrating earthships as low cost social housing” (ECRP 2004). The project also generated a source of income, as interested parties visited, and some stayed in an overnight accommodation earthship. This later led in the take-off phase to “a Scottish-wide Earthship national development and support network” (ibid) which supported earthships and other earth sheltered accommodation and helped spread information. While the number of people living in such accommodation was never very large, the network played a part in the spread of the self-build concept, which played a part in the acceleration phase in increasing user input into all stages of house planning and building in the mainstream, and also spread the word of low-impact earth-sheltered accommodation throughout the UK.

In more densely populated urban areas, schemes such as co-housing and other collaborative or communal schemes formed ‘intentional communities’; these appeared in the pre-development phase and encouraged a sustainable community dynamic and ‘sense of community’ (Meltzer 1995; Field 2004). Although average household sizes continued to decline, similarly to narrative 1, the take-off phase saw Scandinavian style co-housing schemes take hold and become popular among various sectors of the population, including both ideologists and single people who were “regretful loners”, i.e., forced singles (Williams 2006). Some characteristics of co-housing and other schemes had a significant impact on sustainability of mainstream housing and communities in the acceleration phase, as “attributes seen to encourage and facilitate social and environmental sustainability have been incorporated into mainstream public and private housing” (Meltzer, 1995). While in the pre-development phase developers saw co-housing as a grass-roots phenomenon, at an embryonic stage in the UK, even then some were keen to get

involved in projects already underway (Williams 2005, 2006). At the time this was a lifestyle choice in a select group, but as demand increased in the take-off phase, collaborative housing was seen as a viable choice by mainstream culture and builders. In the acceleration phase a variety of co-housing schemes, urban villages and other collaborative and communal living styles flourished, offering people more environmentally friendly, economically cheaper, and socially sustainable ways of living. These communities received a push when it was shown they could contributed to economic sustainability as well: substituting social capital for built capital enabled a higher quality of life on a lower income, alleviating poverty (Mulder et al. 2006). Many otherwise “regretful loners” joined such groups, improving their quality of life, thereby contributing to overall social sustainability. While the number of households still grew, these living arrangements offered a more energy and material efficient lifestyle through communal facilities, making CO_2 emission reduction targets easier. Intentional community developments emphasised and enhanced both social and environmental sustainability.

On another front, the pre-development phase saw a variety of local groups to improve their quality of life (Darnton 2004), while local government sought ways to produce more sustainable social housing. In the take-off phase synergies began to appear between these local groups and other changes. Social and environmental sustainability attributes of co-housing and other alternative developments gave fresh new ideas for addressing problems in social housing and deprived neighbourhoods: energy and water efficient housing lowered bills, helping to alleviate poverty, and community dynamics were strengthened. In the take-off phase, consumers had more say over what type of refurbishment or improvements they would receive under Warm Front type schemes, contributing to empowerment and quality of life in deprived communities (Gilbertson et al. 2006), and long-term cooperation between local authorities, housing associations, constructors and architects/engineers in planning social housing also yielded social and economic benefits (Dewick and Miozzo 2004). By the acceleration phase, local community groups became part of this equation, further strengthening communities, and the resulting synergies brought about mainstream lifestyle changes, which made stronger environmental regulations more viable. There were also knock on effects, such as reduced transport needs and more effective public transport, through uptake of ideas from ‘urban villages’, contributing to sustainable transport. While poverty was by no means eradicated, by the stabilisation phase fuel poverty was nearly eliminated and deprived communities were fewer in number and generally better off.

The changing nature of the housing sector and the building regime resulted in a more diverse sector with more involvement from users and communities in both new build and refurbishment, with more communication between various stakeholders, and constructing companies diversifying into consultancy for self-build or self-refurbishment. This shift was part of a more locally led social and economic sustainability of communities. While a variety of low-carbon technologies and energy efficiency measures abound as in narrative 1, government regulations and standards

were more difficult to set due to the increased diversity, making carbon emissions more difficult to estimate. By the 2040s, however, a smaller number of social and technological innovations had taken hold, and the increased standardisation enabled CO_2 emission reduction targets to be met, while the new housing regime and changes in lifestyles and values increased social, environmental and economic sustainability in communities and households.

4 MODELLING

Our work includes producing transition models, aimed at capturing the dynamics of socio-technical transitions. The models in question are not meant to be predictive, but heuristic: a tool for exploring transition dynamics under different assumed circumstances and policy measures. In this section, we briefly introduce our general transition model, which we are already using to look at different pathways towards a transition (Bergman et al., submitted). We then use our conceptual framework (Haxeltine et al., in prep.) and our review of sustainable housing communities to present a preliminary implementation of the model for this case study, as well as plan a more robust implementation. Details of our general model, as well as analyses of run results and parameter dependencies can be found in Bergman et al. (submitted), and the theoretical framework behind it is detailed in Haxeltine et al. (in prep.). Here we review only the principles and main features of the model.

4.1 The general model

The transition model combines agent-based modelling and a systems dynamics approach. There are a small number of (aggregate) *agents*, which can be one of three types: A *regime*, which is by definition the most powerful agent in the system, and whose culture and practices are dominant. There can be only one regime agent at any time (although periods without a regime are possible). A *niche* agent represents a small collection of actors whose local practices and culture differ from those of the regime. Finally, an *empowered niche* is a niche which has grown strong enough to be a threat to the regime. These aggregate agents represent a large number of actors, and are programmed as complex agents: they have an internal metabolism, as well as interactions with other agents, and with the landscape.

Each agent has *culture* and *practices* parameters, the former representing the agent's norms and values, and the latter expressing the agent's behaviour and decisions. These are implemented as axes in a multi-dimensional space, each axis representing one type of practice. For example, an axis could represent the expected carbon emissions from newbuild homes. The regime of mainstream house-builders would have a high practice score on this axis, whereas a niche of eco-house builders would have a much lower score. Each agent's combination of practices is a vector, or set of coordinates, in the practice space. In the general model, we use only two abstract axes for simplicity, but in case studies we would use the minimum number

we felt adequately captured the dynamics.

Each agent also has *structure*, representing physical infrastructure, production capacity and institutional capacity. The structure largely determines the agent's power over other agents, consumers, and the system as a whole. Agents' metabolism includes *resources*, broadly representing cash flow, investment and borrowing capability. Resources are needed to maintain structure and ultimately power. Agents' resource generation is determined by their practices and by consumer/citizen *support*.

This support is represented by a *support canvas*, a distribution of individual actors, which could represent ordinary consumers, celebrities or politicians or small aggregate actors, such as NGOs. The canvas appears as a consumer 'cloud' in the practice space. Consumers choose which agent to support based on their proximity to the agents in the practice space and the agents' power. In other words, individuals and organisations support the niche/regime which represents similar actions and values to themselves and/or is most powerful.

Landscape changes in the model are expressed either as a change in the resource generation functional dependency on practices, i.e., the same combination of practices might generate more or less resources as the landscape changes; or as changes in consumer preferences, i.e., a change in the consumer support attracted by different practice combinations.

Agents' behaviour includes decisions on changing their practices, and interacting with other agents. Changing practices can be the result of the agent seeking to increase resource generation or consumer support, or to undermine another agent's consumer support.

The dynamic model sees consumer support and power fluctuate as agents move and interact. However, if there is no landscape pressure, or if the pressure is weak, the regime will usually maintain its power and support with minimal practice change, which would not equate to a transition. However, the regime cannot easily make great changes to its culture or practices, due to its rigidity and entrenchment; it is locked in to its ways, through infrastructure, finance, and culture. Transition through regime change (i.e., replacement) occurs when the landscape pressure leads to the regime weakening as an innovative niche, or cluster of niches, gain power to become an empowered niche, and eventually challenge the regime and replace it. In some cases transition occurs without regime change, as the regime agent manages to adapt its culture and practices significantly to maintain power, sometimes by adopting practices of innovative niches (see also Bergman et al., submitted).

4.2 Modelling transitions to sustainable housing and communities

We present here preliminary results of application of our transition model to the case study of sustainable housing and communities, following our first application to sustainable transport (Köhler et al, submitted) as well as how we plan to expand this modelling exercise. We cannot represent the entire complexity of this case study

within the model. Rather, we will try to capture key indicators of sustainable communities, and major events and processes through careful selection of parameters, drawing on our transitions theory analysis and our narratives.

As a first step, we attempt to create a model which can capture two different stories, which are consistent with our narratives. The first is a shift to low carbon housing, in which the only substantial change is designing and refurbishing individual houses for higher energy efficiency and lower carbon emissions. The second is a systemic shift – a transition – to more sustainable housing and communities in a broader sense; in this preliminary model we capture this broader transition by choosing a parameter representing increased density and mixed zoning of communities, which could both reduce carbon emissions through reducing daily transport, and increase social sustainability through improved access to services and increased social interaction. Other stories can also emerge from this preliminary model – it is central to our modelling effort that this is possible.

Defining agents In a first attempt to map the sector, we define aggregate agents – a regime and three niches. This differs from our analysis earlier in the paper, but we thought it more consistent with transition modelling approach, where a niche or regime is defined not only by participating actors but also by a set of practices, culture and paradigm.

- **The regime** represents the mainstream property developers, house-builders, architects, city planners and property sellers. The actors of the regime have an economic, business-as-usual agenda, and tend to resist innovation. The regime promotes home ownership with high levels of car ownership. Sustainability agendas including problems of urban sprawl, lack of access, and climate change mitigation are only addressed when consistent with economic aims.
- **Niche 1** includes making houses and appliances more energy efficient and reducing CO_2 emissions from houses. This is done primarily through technology – better insulation and energy efficient houses, energy efficient appliances. Limited behaviour change is expected, i.e., skills for construction and maintenance of low carbon houses, consumers preferences moving towards more efficient houses and appliances, installation of smart meters, etc. On sustainability issues other than energy and CO_2 emissions, niche 1 follows regime practices. The 40% House study (Boardman et al. 2005) is an example of niche 1.
- **Niche 2** includes practices of change to the larger built environment, such as mixed-use zoning, integrated spatial planning and integrated public transport. Housing developments such as BedZED, and energy saving schemes such as community CHPs would be in this niche, as would some alternative urban builders, architects and planners, such as the ECTP, and organisations such as the WWF. Niche 2 puts more emphasis than the regime on social

sustainability and environmental sustainability beyond climate change prevention. However, it includes no change to the existing power structure, with such initiatives coming from local authorities or otherwise top-down.

- **Niche 3** also looks at changes to the built environment, but in contrast to niche 2 it stresses community-based, bottom-up initiatives and fundamental behaviour change. Power is shifted down from local authorities to community level for much decision making, although some individual power may be lost to the community. Co-housing projects which are planned, developed and managed by the residents are an example of niche 3, as are networks of local community groups. Niche 3 has a strong social sustainability agenda, as well as an environmental and economic sustainability agenda.

Choosing practices In a first attempt to capture interesting dynamics which relate to the two narratives, we chose two aggregate practices:

1. **Energy efficiency and CO_2 emissions:** This covers energy use in houses, including insulation measures, energy supply and appliance efficiency, and applies both to newbuild and renovation. It will be used in projecting total carbon emissions from the residential sector. The regime has low/medium efficiency, all the niches have higher efficiency (i.e., lower emissions).
2. **Density and Zoning:** This parameter was chosen as a proxy for broader (social) change than mere reduction of emissions. It includes density of built environment and single or mixed-use zones. Low value of this parameter means suburban sprawl; middle value means medium density, but mostly single use (as many neighbourhoods in the UK are now); high value means medium to high density with high mixed use. Higher density and mixed use zones improve accessibility and social interaction/support, can reduce daily transport, and have implications for green belt land. The regime has low to medium values (with enough urban sprawl to affect different sustainability indicators), and niche 1 is similar. Niches 2 and 3 have a higher value, supporting medium to high density and more mixed use zones; the latter is especially true in niche 3.

Landscape signals In this prototype, we define three landscape changes to be represented as signals in the model, to fit in with the narratives and the model so far. These are *climate change*, *fuel (oil) price rise*, and *demographic change*. The climate change signal will be used in all simulations; this signal can modestly shift consumers' preferences, and can also result in increased regulations (see below). Fuel price rise directly affects consumer preferences, shifting them strongly towards more energy efficient behaviour, i.e., along the energy efficiency / CO_2 emissions practice. Demographic increase reflects a rise in population and number of households (we do not cover details at this stage); this increases overall CO_2 emissions from the housing sector, and can result in regulations for higher density and more mixed zones (see below). Different combinations of demographic change

and fuel price rise will be tested.

Complementing landscape signals, we include two 'policy events', which affect the agents. The first represents subsidies or regulations encouraging higher energy efficiency and lower CO_2 emissions in houses. This is represented by giving agents with lower CO_2 emissions / higher energy efficiency an advantage. The second represents regulations and subsidies which empower experimental technologies, buildings and communities in order to encourage innovation, ultimately leading to more sustainability. As many of these innovations are consistent with higher density and especially mixed use zones, this policy event is represented by giving an advantage to agents with a higher density / zoning parameter. The first policy event will be used in all runs, the second in some for comparison.

Figure 1 shows the model components schematically, showing the direct effects of the landscape signals and policy events used. Consumers are divided into a large majority of 'mainstream', and a small group of 'others'; the latter group have preferences which make them support one of the niches from the start.

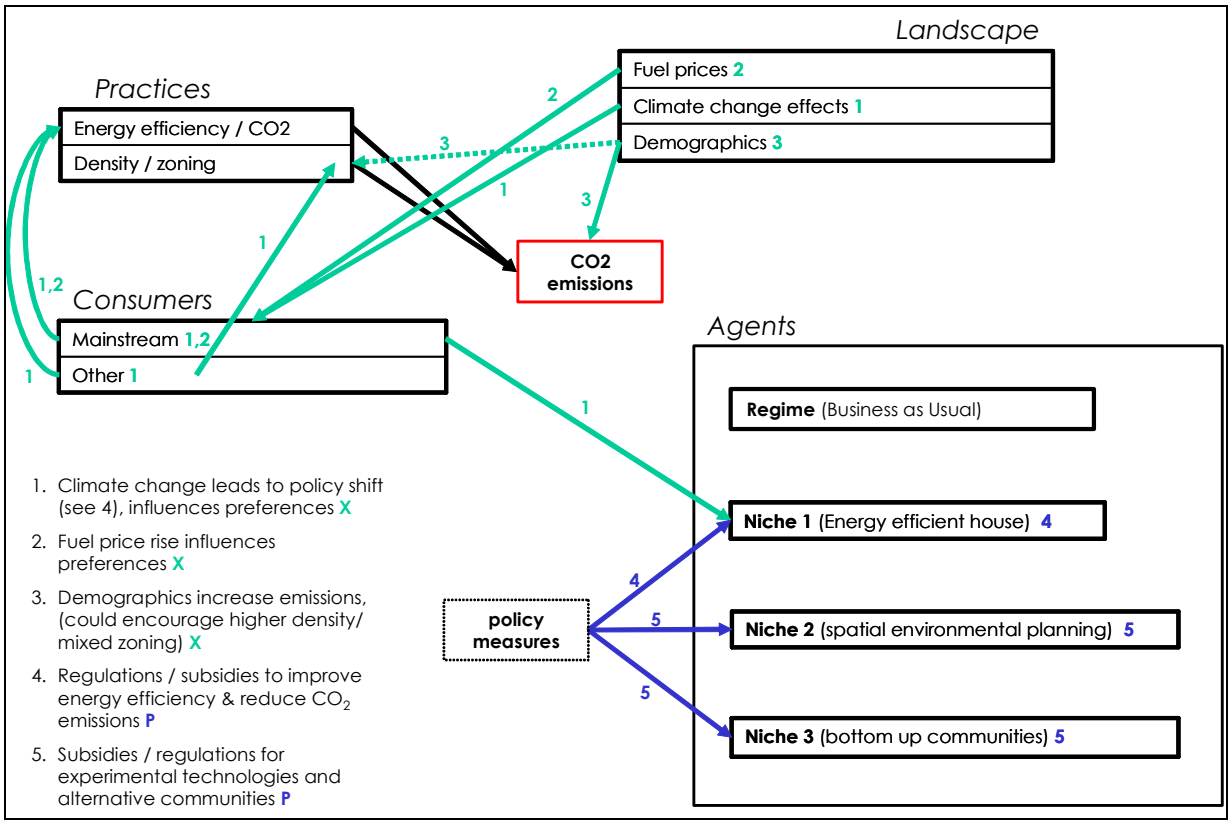

Figure 1: Model schematic showing potential effects of landscape signals and policy events. The different boxes show the four agents, the landscape signals, the two chosen practices, and the two consumers groups. Direct (programmed) effects of the external landscape signals (X) are marked in green arrows, and those of the policy events (P) in blue arrows.

There are several points of interest in model run dynamics, in terms of sustainability and transition. In this preliminary model, sustainability will be judged by a semi-quantitative estimate of overall CO_2 emissions from the housing sector. CO_2 emissions will be estimated from the energy efficiency and CO_2 emissions practice, and to a lesser extent the density and zoning practice of each agent, modified by the agent's respective support from consumers.

The model can be said to show a transition in one of two cases: if there was regime change, i.e., the regime agent was overthrown and another agent rose to take its place; or if the regime adapted its practices significantly over the model run (Bergman et al., submitted). In this case study, a slight shift in the regime's practices towards lower CO_2 emission houses would not constitute a transition. However, a significant shift to lower CO_2 houses and more mixed use zones, which resulted in a significant overall reduction in CO_2 emissions from the housing sector (i.e., comparable to climate change targets), and arguably represented more socially sustainable practices as well, would indicate a systemic shift which we could call a transition.

Finally, we are interested in model dynamics as well as outcomes. The series of events in a model run leading to a successful or failed transition can be interpreted as narratives. We ultimately hope to create interesting narratives, including counterintuitive stories, ultimately to be use as a tool by policy makers.

4.3 Preliminary Results

The model is not deterministic, so many model runs with different parameterisations are needed to analyse the results. Here we only cover some qualitative analysis from several runs. Figures 2 and 3 illustrate some of the visualisations we use, showing one sample run in which niche 1 was empowered and replaced the regime. Figure 2 demonstrates non-linear behaviour of the system – after a long, slow change, the incumbent regime suddenly loses power and the challenging agent becomes a very strong regime very quickly.

The results show, as expected, that stronger landscape signals, which change consumers' preferences, force a transition over time: the agents rely on consumer support, they cannot get enough support without meeting the preferences of the consumers. Niche 1, which offers the smallest change from the regime and enjoys the largest support among the niches, is most likely to replace the existing regime. A closer look at some of the runs reveals some interesting behaviour:

1. The subsidies and regulations help the niches compete with the regime, as expected, but this is a complex process. For example, in model runs where both policy events are used, there was a higher chance of a regime change, with niche 1 replacing the old regime. This may seem counterintuitive, as niche 1 gets a smaller subsidy in these runs; however the subsidies enable niches 2 and 3 to grow stronger, weakening the regime, thereby giving niche 1 an edge.

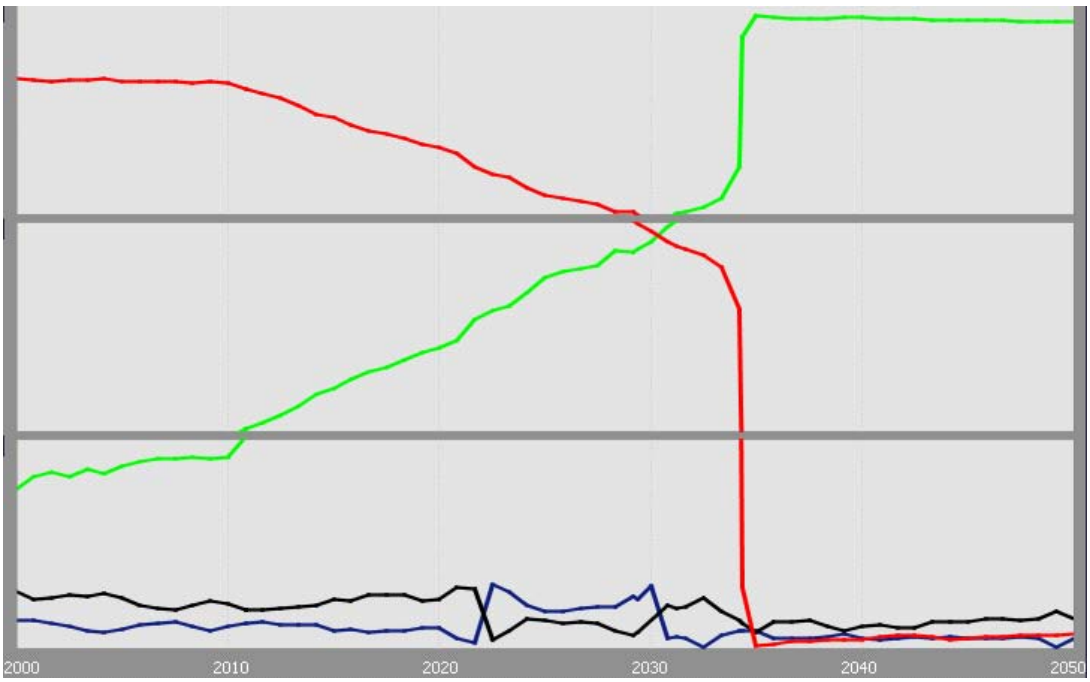

Figure 2: Graphs of agents in a transitions: the panels show the strength of the agents over time, where the top shows regime agents, the middle empowered niche agents, and the bottom niche agents. Red line is business-as-usual regime; green is niche 1 (energy efficient houses), black is niche 2 (changed build environment) and blue is niche 3 (bottom up communities). In this run niche 1 becomes empowered at around 2012, overpowering and replacing the regime around 2030.

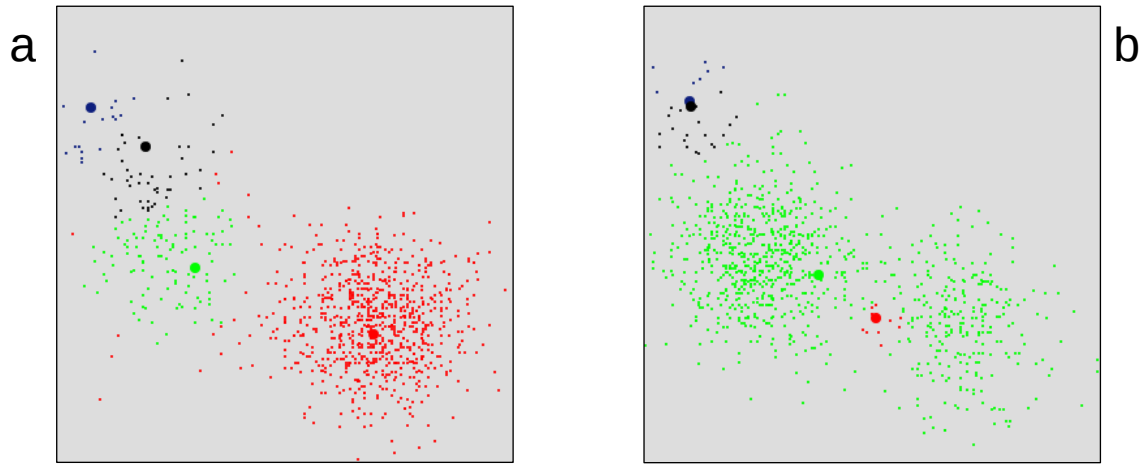

Figure 3: Support canvas: Complementing figure 2, this figure shows the two-dimensional support canvas at the beginning (a) and end (b) of the same run. Consumers are in the colour of the agent they support, the agents are the larger circles. The x-axis is the efficiency/CO2 emissions practice, further left = lower emissions; the y-axis is density/zoning practice, further up = high density and mixed use. From (a) to (b) we can see the shift of support from the red agent to the green; the shift of the consumer cloud left and up; and the movement of the agents, putting green and red closer together.

2. The CO_2 emissions (a simplified, qualitative calculation) did not drop by as much as expected even after transition: different runs showed 0-20% drop in total housing sector emissions, equivalent to 20-35% per capita decrease (after correcting for demographics). The reason is that the niches adapt their practices to be somewhat similar to that of the regime to gain support. For example, figure 3 shows the two agent's practices (old and new regime) are much closer at the end of the run than at the beginning. The interpretation of this is interesting: actors who plan and build energy efficient houses tone down the efficiency in order to appeal to the mainstream.
3. Weaker landscape signals led to more variation (i.e., less predictability) in model dynamics. In some runs the regime stayed in power, in others it was replaced by niche 1 or niche 2. The CO_2 emission reduction was also highly variable. These runs are perhaps the most interesting, and the dynamics will be explored further.

While our results and analysis are not complete, and we have not yet reproduced the narratives as originally hoped, we have already produced some interesting dynamics, as listed above. We hope further development of the model will make it a useful and relevant tool.

4.4 Future modelling

The model presented above reports on a preliminary implementation of our housing and communities case study in our transition modelling framework. In order to better capture real world dynamics, and generate more interesting narratives from model results, we are currently in the process of a more robust implementation. This would include the following:

A more comprehensive list of **practices** to capture the dynamics of the system. This could include splitting *density* and *zoning* into two separate practices. Other practices we are considering adding include *(de)centralisation*, as a measure of the balance of power in taking decisions and imposing plans for local communities between national government and regional authorities, local government, and communities implementing their own decisions. *Resource use efficiency*, as a measure of environmental sustainability other than climate change, an aggregate measure of land use, material flows, water and sewage flows, etc. Finally, *public transport provision and use* could be added as a quantifiable measure of public infrastructure provision with environmental, social and economic consequences. With this broader list of practices we hope to capture a more robust list of sustainability indicators, economic, social and environmental.

In addition to consumers, we plan to explicitly resolve group **stakeholders**. These could include local authorities, construction firms, community groups and NGOs. At first these would be abstract, but could later include, for example, semi-quantified representation of the largest construction firms or of a few local authorities.

More **landscape** signals will be added, such as environmental degradation in urban regions, or increase in inequality. More policy events and other events would complement this, enabling more scenarios to be explored. Ultimately, suggested policies and other events could be suggested by stakeholders.

A **market** module will be added as well. This would enable exploring the effects of prices on newbuild, refurbishment and built environment design on the dynamics of the system, and add realistic price differences between houses with innovative design and standard houses which benefit from economies of scale.

Finally, some real world data will be included to give semi-quantified indicators. This could include energy use in different types of houses and related CO_2 emissions, prices for different technologies, estimated daily travel distance in different scenarios, etc. With this full implementation, we hope to produce a prototype of a heuristic tool in which the user can specify different policy options, predicted landscape pressures, or price futures, which will be useful for policymakers and other stakeholders in exploring different possible futures for the UK's housing sector.

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