Supply and demand for low energy housing in the UK: insights from a science and technology studies approach

Supply and demand for low energy housing in the UK: insights from a science and technology studies approach

Heather Lovell

School of Geosciences
University of Edinburgh
Drummond Street
Edinburgh, UK
EH8 9XP

Supply and demand for low energy housing in the UK: insights from a science and technology studies approach.

Abstract

Economic theory about supply and demand suggests that if consumer demand for a product increases, then producers respond by increasing supply. In the UK housing market there is emerging evidence of consumer demand for low energy housing, yet little has been built to date by private sector housebuilders: existing low energy housing is largely within the social housing and self build sectors. Ideas from science and technology studies (STS) are introduced to help further understanding of why the housing market might be slow to respond to changing consumer preferences. Although standard economic concepts concerning costs and price are able in part to explain the situation, greater attention to socio-technical issues highlights some of the reasons why innovation and change are difficult to effect. The housing market is best viewed as a socio-technical system, whereby the social and the technical are interlinked (Berkhout 2002, Bijker 1995, Latour 1991, Pinch and Bijker 1984, Rip and Kemp 1998).

KEY WORDS: Low energy housing; science and technology studies; supply and demand theory.

Introduction

Economic supply and demand theory suggests that private sector housebuilders would increase supply if there was significant consumer demand for new housing products, such as low energy housing. This is because increased consumer demand for a

product leads to a rise in its price, thus acting as an incentive for producers to increase production, because higher profits can be obtained. Over time, markets reach equilibrium, with supply matching the level of demand. A key assumption of supply and demand theory is that consumers and producers have perfect knowledge of the costs and benefits of their actions. In practice this is rare, particularly in complex markets, and market failure is common. It is suggested that in the UK housing market a type of market failure has occurred whereby supply of low energy housing remains largely unresponsive to evidence of increasing consumer demand. Ideas from the science and technology studies (STS) literature about the relationship between humans and technologies are introduced to help better understand the reasons for market failure. An STS perspective highlights how housing is an atypical consumer good, thus making the application of economic supply and demand theories problematic. Economic theory does not pay sufficient attention to the characteristics of the product being exchanged, and the influence these characteristics have on market operations. In particular, more attention needs to be focused on how the material and technical characteristics of products affect the decision making of producers and consumers. For example, consumers do not have perfect knowledge of the housing product, because they have little experience of living in different types of dwelling: the net effect is to reduce demand for innovative housing.

A low energy house is defined as a dwelling (house or flat) that exceeds the current UK energy building regulations (DTLR 2002). Low energy housing typically incorporates one or more of the following features: passive low energy design, a thermally efficient built form, and use of renewable energy technologies. The analysis is restricted to what housebuilders produce, and for this reason discussion is

limited to new housing, rather than refurbishment of existing housing. The paper is based on the findings of a three year doctoral research project examining the production and consumption of low energy housing in the UK (see Appendix One).

Since the late 1990s, there have been many environmental policy initiatives in the UK housing sector, particularly policies aimed at lowering energy consumption in light of growing concerns about climate change. As private sector housebuilders produce nearly ninety percent of new housing in the UK (Barker 2003), and nearly three-quarters of UK housing is privately owned (ODPM 2003a), it is primarily within the private sector where changes are required. The 2003 Energy White Paper had a strong emphasis on the residential sector, outlining policies to bring about household carbon reductions of approximately five megatonnes of carbon (MtC) by 2020, accounting for a quarter of total UK carbon reductions (DTI 2003). More recently, a Sustainable Buildings Task Group was established to identify cost-effective environmental improvements to buildings, including energy reductions (DTI 2004). There have also been a host of policy measures aimed at modernising the UK construction industry and encouraging innovation, most notably via the government-sponsored Rethinking Construction programme (Egan 1998, The Housing Forum 2003).

The paper is structured as follows. Firstly, a brief summary of key concepts from the STS literature is provided. The following sections discuss decision making about low energy housing from consumer and producer perspectives, drawing on ideas from economics and STS. In conclusion, the implications for policy makers are considered, and the potential contribution of the STS literature to housing studies is discussed.

Concepts from science and technology studies

The STS literature focuses on the relationship between humans and technologies, and its defining feature is a belief in the inseparability of social and technical systems (Bijker 1995, Bijker *et al.* 1987, Bijker and Law 1992, Guy and Shove 2000, Hughes 1983, Rip and Kemp 1998). Thus:

> "The point is that whilst technology is a thoroughly social construction, society is a technological construction as well"
> (Kirsch 1995, p. 531).

In other words, politics, economics, and culture are critical to the development (or not) of certain technologies, and likewise, technologies are important in shaping culture and society. The literature seeks to avoid technological determinism, whereby the development and dissemination of certain technologies is seen as inevitable. It similarly seeks to avoid misrepresentation of technologies as 'neutral actors', with little or no influence on their users (Cowan 1987, Street 1992, Winner 1977).

These ideas can be usefully applied to housing because housing is an atypical consumer product: it is durable, high capital cost, and of fixed location. The material and technical characteristics of housing thus have a strong influence on its patterns of production and consumption. Taking an STS approach in striving to understand supply and demand of low energy housing thus balances economics approaches, which focus primarily on the social sphere, in particular costs and price.

Two important STS concepts are actor-networks and socio-technical systems. The main idea of actor-network theory is that material objects possess agency (Callon 1986, Latour 1991, Law 1992, Law and Hassard 1999, Murdoch 1997, Murdoch 2001). It thus attempts to overcome traditional dualisms between human and non-human entities, or society and nature. Actor-networks are viewed as 'heterogeneous networks', in that society is comprised of more than just human actors:

> "... the social is nothing other than patterned networks of heterogeneous materials…these networks are composed not only of people, but also of machines, animals, texts, money, architectures …"
> (Law 1992, p.2).

By assuming no *a-priori* distinction between human and non-human entities, the interactions between technologies, individuals and institutions are able to be explored in innovative ways. As Murdoch states, one of actor-network theory's main advantages is that it is a new, creative analytical framework, thus forcing people to:

> 'look afresh at the categories, divisions and boundaries that frequently divert our attention away from the nonhuman multitudes which make up our world."
> (Murdoch 1997, p. 753).

A key idea of the literature on socio-technical systems concerns the 'momentum' possessed by mature socio-technical systems (Davies 1996, Graham and Marvin 2001, Hughes 1983, 1987, Moss 2001). The term is used to describe the tendency of large socio-technical systems, such as energy and telecommunications, towards

stability, or inertia. A socio-technical system possesses momentum because numerous interrelationships develop over time between social actors and technologies, which serve to reinforce the status quo: choices and decisions are influenced by past investments and established practices, and thus there is a bias against new innovations (Hughes 1987). Innovations in socio-technical systems are therefore conceived as more likely within protected innovation niches, where close collaboration between producers and consumers takes place, and risks are therefore reduced (Kemp 1994, Kemp *et al.* 1998, Rip and Kemp 1998, Smith 2002). Innovation niches are learning spaces for new technologies, which usually comprise a single experiment or project, or a cluster of several experiments (Weber 2003). Thus:

> "… a niche..protects [new technologies] against too harsh selection and provides space to grow."
> (Schot *et al.* 1994, p.1061).

Ideas from the STS literature help further understanding of the low energy housing market by focusing on interactions between the social and the technical, and, crucially, by seeing the housing product as possessing agency. An STS approach highlights two issues which significantly shape consumer demand: firstly, the invisibility of low energy technologies and building materials, and, secondly, the idea that the housing product is embedded within a local actor-network, and therefore consumer purchase decisions are commonly made not just on the features of the dwelling. From a producer perspective, the STS concept of system momentum is useful in understanding how innovation can be costly for producers. In addition, theories about innovation taking place in niches help explain why the majority of low

energy housing in the UK has so far been built in the social and self build sectors. These issues are explored in further detail below.

Theorising consumer demand for low energy housing

According to economic supply and demand theory, as consumer demand for a product increases, its price rises, because of its scarcity in the market. There is some evidence of increased consumer demand raising the sale price of low energy housing, discussed below. However, the relationship between demand and price in the housing market is complex, because of the particular socio-technical characteristics of the housing product, and it is through focusing on these socio-technical issues that the STS literature adds significant depth to economic supply and demand theories.

A recent online survey of nearly one thousand home owners found eighty-seven percent were willing to pay a premium for an energy efficient house, with most saying they would pay an extra two percent (CABE *et al.* 2004). Further, a consumer survey of ten thousand UK householders revealed that for the majority of consumers who were aware of the energy efficiency features of their new home, it was an important factor in their decision to buy it (MORI 2001). These willingness-to-pay surveys might, however, overestimate consumer demand, as there is the risk that people will tend to say what they perceive to be the right thing, i.e. that they are interested in energy efficiency. Actual purchasing patterns therefore provide a more reliable indication of the level of demand, but to date there has been little low energy housing built in the UK for private sale, as most has been constructed within the social housing or self build sectors (see Figure One). However, the low energy housing that has been built does appear to have sold for a higher price compared with local

averages. For example, homes at the low energy BedZed development in south London are estimated to have sold for premium of nine to twenty percent (Bioregional 2004). In addition, the only commercial housebuilder in the UK to specialise in sustainable low energy housing - Gusto Construction - have been able to sell their houses at a premium of approximately ten percent (Wright 2002 pers.comm.).

Despite the emerging evidence of consumer demand for low energy housing, an STS approach suggests two reasons why demand is likely to remain muted. Firstly, the housing product is not purchased in isolation, but rather is embedded within geographical space. Thus there is a complex relationship between demand and price: even if low energy housing was identical in price to 'normal' housing, sales may not significantly increase, because a host of other factors influence demand. In other words, consumer purchasing decisions are not related solely (or even primarily) to the quality of the housing product, but incorporate consideration of the social and material characteristics of the surrounding locale, such as provision of parks, the quality of local schools, and employment opportunities. Hence, instead of a dwelling being conceptualised as a discrete, uniform product - as in economic supply-demand theory - it is perhaps better understood as a more disparate and complex actor-network. The situation increases risk for housing producers because consumer demand for low energy housing will remain difficult to quantify: energy issues will always be just one factor in housing purchase decisions.

Secondly, an STS approach highlights how consumer preferences for new products are unlikely to fully develop unless individuals have had the opportunity to interact with different types of housing. This is particularly the case for low energy housing

technologies, such as thermal wall insulation or heat recovery ventilation systems, which are invisible (Guy and Shove 2000). A period of actually inhabiting a house is therefore necessary in order for consumers to interact with the technologies. Socio-technical relations are slow to form, thus constraining more active consumer demand. Without sufficient experience of different house types, consumers have imperfect knowledge of the housing product, and market failure is a likely outcome. The situation is exacerbated because housing is a durable and expensive product, meaning people tend to move infrequently, and therefore have limited experience of different types of dwellings. Consumer preferences are latent, or subconscious, as Barlow and Ozaki explain:

> "Defining user requirements and adding value to increase 'satisfaction' *pre-supposes that people know what they want* and that their needs can be captured and translated into realisable [housing] products."
> (Barlow and Ozaki 2003, p.91, emphasis added).

Thereby suggesting the private sector market for low energy housing might remain muted, because consumer preferences are not well formed. Qualitative research undertaken with residents of a private sector low energy housing development near Newark, in the East Midlands, appears to confirm the idea. The research revealed how the residents' preferences have developed over time as they have adjusted to living in their new homes. The housing development, called Millennium Green, was built by Gusto Construction. The company is unique in the UK in building private sector housing with a range of sustainability features (BSHF 2002, Jones 2002). The energy efficiency of the houses at Millennium Green is approximately three times

above the current UK energy building regulations, and the houses have solar thermal panels, a heat recovery ventilation system, and passive solar design (Gusto 2004). Focus groups were conducted with groups of Millennium Green residents to explore the ways in which they have adapted to living in their new homes, and also their original motivations for purchasing (see Appendix One). It emerged that the residents have significantly altered their preferences since moving to Millennium Green. About half of the current occupants bought their homes because they liked the location, whilst the other half were motivated primarily by the sustainability features (Gusto residents 2003, Wright 2002, pers. comm.). But interestingly, for those not initially motivated to purchase for sustainability reasons, the experience of living in a better quality house has been crucial in altering their preferences, as one resident explains:

> "We didn't move for environmental reasons. We were downsizing…[we wanted] a less hassle property… I'm not an environmentalist by any means… I will say, however, having moved into the house and enjoyed the benefits – the solar hot water panel, the rainwater tank - *that if I moved again, I would be looking for something similar*".
> (Interview, May 2003, emphasis added).

For another resident, simply experiencing the quality of building in the Millennium Green show home had an important influence:

> "To be honest we drove past quite a few times and weren't sure about the look of the homes… but once we got into the show home, the whole thing just sort of took off."
>
> (Interview, May 2003).

Thus indicating the importance of consumers actually physically interacting with housing in order to form preferences. Even visiting show homes may be sufficient to help develop preferences, as the director of a national charity involved in building low energy housing elaborates:

> "Now most people…every show house they walk into smells the same, feels the same, so what's the difference? So that's one of the main things we want to demonstrate out of our project, is that the houses are not marketed as different, *but as soon as you walk through the show home hall, you're sold*. And that's what will start to drive the market, because when [consumers] move on from that first house to the next one they'll be looking for that element. And they'll reject houses which don't [have it]."
>
> (Interview, July 2002, emphasis added).

As more low energy housing is built, the interviewee reasons that consumers will act as an increasingly important catalyst for change. Conversely, the current lack of consumer experience of low energy housing is likely to be one factor curbing low energy housing supply and demand in the UK: an example of a socio-technical issue not considered within conventional economic supply and demand theory.

Theorising producers' decision making about low energy housing

Following economic supply and demand theory, one might expect housing producers to have increased supply of low energy housing in response to signs of increased consumer interest. Diversifying their portfolio with low energy housing would also allow housebuilders to maintain a competitive advantage by keeping in advance of changes to the UK energy building regulations, which are likely to be significantly upgraded in 2005, and beyond (DTI 2003, ODPM 2003b). Low energy housing production has increased during the 1990s, but not significantly, and it has been constructed largely outside of the private sector free market, in social housing, and by self builders. STS concepts, including socio-technical momentum and innovation niches, are used to help explain low energy housing supply from a producer's perspective.

An internet-based survey of low energy housing revealed that over one hundred and fifty low energy housing developments have been built or planned in the UK since 1990, comprising over twenty four thousand dwellings (see Appendix One). Further, a case study of low energy housing in the East Midlands region identified over twenty low energy developments built or planned in the region over this time period (see Table One). Moreover, certain housing producers, including a small number of large private sector housebuilders, have started to diversify their product range to include low energy sustainable housing. A survey of the thirteen largest UK housebuilders by WWF found ten to have dedicated environmental reports (WWF 2004). The company Countryside Properties, ranked first by the WWF survey, now builds all its homes to an EcoHomes 'Good' standard - the government-sponsored sustainability rating scheme for housing (BRE 2001, Countryside Properties 2002). The private

sector housebuilder Gusto Construction, discussed above, only builds sustainable housing, and has now completed three developments for private sale within the East Midlands. However, despite these various initiatives, in overall terms private sector housebuilders have not significantly invested in increasing the supply of low energy housing. More detailed research revealed that the large majority of existing low energy housing in the UK is located within the social housing and self build sectors. Figure One illustrates who has initiated low energy housing in the UK, and shows that over a third of developments have been initiated by Registered Social Landlords, and some twenty percent by self builders.

According to economic supply and demand theory, one of the principal reasons why producers might not increase supply of a product in response to escalating demand is because the costs of increasing production are high. There is mixed evidence about whether this is the case for low energy housing. Debate on the issue has been contentious (see for example TCPA and WWF 2003, Yates 2001), in part because of the difficulty of obtaining commercially sensitive building cost information. Furthermore, building costs are only one component of producers' costs, with the cost of land comprising approximately one third of overall development costs (UK Land Directory 2004). Furthermore, building costs vary considerably across the UK according to the cost of labour (BICS 2004). An investigation into the costs of obtaining EcoHomes accreditation concluded that building housing to an Ecohomes 'Excellent' standard incurs extra costs of up to £3,000 per dwelling (Sustainable Homes 2002). In addition, the building costs for some specific low energy housing developments are known. For example, the Bedzed development in south London, the largest low energy housing development in the UK to date, cost £1,135 per square

meter to build (BRECSU 2002) - above the London average of £1,000 per square metre (BICS 2004) - although it does include the cost of an on-site combined heat and power plant. Likewise Millennium Green, the first housing development built by Gusto Construction, is estimated to have cost an extra ten percent to build (BSHF 2002, Sustainable Homes 2003). With these two developments though, the extra production costs do appear to have been recouped through higher sale prices, as discussed above. There are examples of other low energy housing developments that have not cost more to build, although they are self build developments, and savings were achieved through reduced labour costs: the Hockerton self build development of five terraced houses cost £450 per square metre in 1996 (BSHF 2002), and the nearby Vales's 'Autonomous House' completed in 1993, cost the same (BRECSU 1996). Overall, the evidence does suggest slightly higher building costs for low energy housing (Sustainable Homes 2002, TCPA and WWF 2003), and, coupled with uncertainty about whether consumers are willing to pay a price premium, appears to provide an explanation as to why the supply curve for low energy housing remains flat. However, application of supply-demand concepts also oversimplifies the housing market. Factors other than costs and price are important in the decision making of housing producers, and ideas from the STS literature are explored here to help deepen understanding of the production and consumption of low energy housing.

The UK housing market can be seen to exhibit significant momentum, or low rates of innovation (Ball 1983, Barlow 1999, Gann 1996). Momentum is high in the housing sector because of the durability of the housing product, and the considerable capital cost of production. It means that innovating with new products like low energy housing is more costly and higher risk, because they do not fit easily within the

existing socio-technical system (Hughes 1983, 1987). Technical knowledge, regulations, and production methods are all aligned towards building dwellings in a particular way. Increases in production costs therefore include less easily quantifiable factors in addition to more straightforward monetary costs, such as the time and effort spent in changing company procedures, and changes in habits and attitudes. An extract from an interview with the managing director of a small, innovative company building low energy housing illustrates how the institutional structure of the UK housing industry can impact negatively on innovation and product development:

> "The volume housebuilders…they think that we are doing something that is partly unnecessary, because they can sell houses anyway, so why bother to do it? … You've been doing it for donkey's years and you've made good profits, and got away with it, so why not continue treading that same path?" (Interview, August 2002).

His comments indicate the momentum of the housing market, whereby over time change is more difficult to effect, because certain norms and market patterns become embedded within the socio-technical system. Change is particularly difficult to effect if there are not perceived to be critical problems within the existing socio-technical system (Hughes 1983, 1987), and, as the interviewee points out, housebuilding in the UK continues to be a profitable sector. Another issue currently exacerbating momentum in the housing sector is the undersupply of new housing in the UK (Barker 2004), meaning housebuilders are virtually guaranteed to sell what they produce, and the quality of the housing product becomes less critical (Ball 1983, Barlow 1999, Mathiason 2002).

The concept of momentum also helps further understanding of why the low energy housing that has been built in the UK is largely located within the social housing and self build sectors. As previously discussed, innovations in socio-technical systems are conceived as more likely to occur within protected innovation niches. In the social housing and self build sectors, producers and consumers have a closer relationship than in the private sector, and hence it is easier for learning to take place: there is a relatively protected niche environment. Close collaboration can help to overcome the conservative tendencies of the existing housing socio-technical system, because the risk of new products failing is reduced if consumer preferences are better known and understood. In contrast, private sector housebuilders are predominately speculative, that is, they do not build housing for a specific client. There is hence no ongoing relationship between the housing producer and consumer, either before or after the house purchase, and the commercial risks of innovation are increased.

The concept of innovation niches also provides a conceptual basis for understanding Government policy aimed at encouraging innovation in the housing sector. An implicit cornerstone of the Government's social housing environmental policy is that innovations promoted in the social housing sector will diffuse over time into the private sector (see for example Sustainable Homes 2004). Government-sponsored initiatives, such as the Housing Forum Demonstration programme (Constructing Excellence 2004), and the Millennium Communities programme (English Partnerships 2003), also embody the idea of innovation niches; encouraging and celebrating certain innovative projects in the hope that other housing producers will learn from them, and be inspired. There are many advantages of this type of policy

approach, which allows housing producers and consumers to interact with new technologies. However, one potential problem, highlighted by applying STS ideas, is that the effectiveness of innovation niches in social housing may be limited, because the private, social and self build sectors are in effect different housing markets, with different socio-technical characteristics. In other words, it is not necessarily the case that innovation niches within the social housing sector will diffuse easily into private housing.

Conclusions and Recommendations

In summary, economic supply and demand theory suggests that private sector housebuilders would increase supply if there was significant consumer demand for new housing products, such as low energy housing. This is because the price of a product rises as it is increasingly sought after, and producers therefore have an incentive to respond. There is tentative evidence of this type of standard market response for low energy housing in the UK, with some consumers paying a premium for low energy housing, and some producers increasing supply and launching new environmental initiatives. However, economic supply and demand theory, with its primary focus on price and costs, overlooks more complex socio-technical issues that exert a strong influence on the operation of the low energy housing market, tending to suppress the emergence of new products. These include the embeddedness of the housing product in local 'actor-networks', the formation of consumer preferences through interacting with housing technologies, and the momentum of socio-technical systems.

Neither STS nor economic theories have a strong focus on role of government. Nonetheless, there are some implications of the discussion for policy makers. Firstly, and most importantly, it must be recognised that governments are embedded within socio-technical systems. Policy making to stimulate radical innovation is hence more difficult for governments to effect, because they also experience momentum (Pierson 2000, Smith 2002). Perhaps a greater recognition of the influence of the material characteristics of housing on the operation of the housing market, and on the process of policy making, will help generate more effective policies to encourage low energy housing. Secondly, policy makers must take into account that the housing sector in effect comprises a range of housing markets, as discussed above, each with slightly different socio-technical characteristics, and that policies must be tailored accordingly.

The article has attempted to introduce some of the main concepts of the STS literature into housing studies, and it is hoped it will stimulate further exploration and debate. In the case of low energy housing, combining STS ideas with economic supply and demand theory has provided an alternative explanation of the operation of housing markets, which is not exclusively focused on cost and price. STS concepts have been shown to have particular value in conceptualising housing because it is so embedded within our society, and hence the ways in which its material characteristics influence the decision-making of producers, consumers, and governments tends to be overlooked.

Acknowledgments

The paper is based on doctoral research funded by the Economic and Social Research Council (ESRC), grant number R422000134546. I would like to thank all those interviewed for their time, in particular those at Millennium Green. Also, thanks to my PhD supervisor, Professor Susan Owens, for her help and encouragement.

Appendix One – Research Methodology

The paper is based on the findings of a three year ESRC-funded doctoral research project, examining the production and consumption of low energy housing in the UK. Semi-structured interviews have been conducted with over seventy experts involved in low energy housing from a range of housing sectors (social, private and self build), non-governmental organisations, and Government. Interviewees were primarily selected using a 'snowballing' technique (Bryman 2001, Schoenberger 1991), in order to identify networks of actors involved in low energy housing. Key issues explored include: motivations for building or initiating low energy housing, the role of Government policy, and the ways in which new household energy technologies have been adopted. One component of the research was an internet-based survey of existing databases of sustainable and low energy housing in the UK, corroborated by a wide-ranging grey literature review. The survey, carried out over a three month period in 2002, identified one hundred and fifty low energy housing developments constructed or planned in the UK, equivalent to some twenty four thousand dwellings. Another component of the research has been a detailed case study of low energy housing in the East Midlands region. The case study was undertaken in order to explore in-depth questions regarding why low energy housing has been built, and by whom. In particular, the reasons behind the growth of a cluster of low energy housing

in Newark and Sherwood region have been explored. The cluster includes two self build developments (the Vales's Autonomous House and the Hockerton Housing Project), and one private sector development (Gusto Construction's Millennium Green). Two focus group interviews with groups of six to eight residents of Millennium Green were conducted in May 2003 to investigate the residents' motivations for purchasing their dwellings, and how they have interacted with the energy technologies in their homes.

References

Ball, M. (1983) *Housing Policy and Economic Power: The Political Economy of Owner Occupation* (London & New York, Methuen).

Barker, K. (2003) *Review of Housing Supply - Securing our Future Housing Needs. Interim Report - Analysis* (London, HMSO).

Barker, K. (2004) *Review of Housing Supply - Securing our Future Housing Needs - Final Report* (London, HMSO).

Barlow, J. (1999) From Craft Production to Mass Customisation: Innovation Requirements for the United Kingdom Housebuilding Industry, *Housing Studies* 14 (1) pp. 23-42.

Barlow, J. & Ozaki, R. (2003) Achieving 'Customer Focus' in Private Housebuilding: current practice and lessons from other industries, *Housing Studies* 18 (1) pp. 87-101.

Berkhout, F. (2002) Technological regimes, path dependency and the environment, *Global Environmental Change* 12 (1) pp. 1-4.

BICS (2004) *House Rebuilding Cost Assessments for Insurance Purposes*, Building Cost Information Services (BICS) (http://www.bcis.co.uk/costass.html, accessed 23rd November 2004).

Bijker, W. E. (1995) *On Bikes, Bakelite and Bulbs: Towards a theory of Socio-Technical Change* (Cambridge MA, MIT Press).

Bijker, W. E., Hughes, T. P. & Pinch, T. J., (Eds) (1987) *The social construction of techological systems: new directions in the sociology and history of technology* (Cambridge MA, MIT Press).

Bijker, W. E. & Law, J. (1992) General Introduction, in: W. E. Bijker and J. Law, (Eds) *Shaping technology/Building society: studies in sociotechnical change* (Cambridge MA, MIT Press).

Bioregional (2004) *Predicted sales premiums for future ZED developments*, Bioregional, FPD Savills (http://www.bioregional.com/programme_projects/ecohous_prog/bedzed/bz_monitoring.htm., accessed 3rd November 2004).

BRE (2001) *EcoHomes - The Environmental Rating for Homes*, Building Research Establishment (www.bre.co.uk/ecohomes, accessed 17th Jan 2003).

BRECSU (1996) *General Information Report 53: Building a sustainable future - homes for an autonomous community* (Watford, Energy Efficiency Best Practice Program; BRECSU).

BRECSU (2002) *General Information Report 89: BedZED - Beddington Zero Energy Development, Sutton* (Watford, BRECSU; BRE; the ZED team).

Bryman, A. (2001) *Social Research Methods* (Oxford, Oxford University Press).

BSHF (2002) *Environmentally Sustainable Housing in the East Midlands - Draft Version* (Coalville, Building and Social Housing Foundation).

CABE, WWF & Halifax (2004) *87% of people want environmentally friendly homes* (http://www.wwf.org.uk/sustainablehomes/index.asp, accessed 26th July 2004).

Callon, M. (1986) Some elements in a sociology of translation: domestication of the scallops and fishermen of St. Brieuc Bay, in: J. Law, (Eds) *Power, Action, Belief* (London, Routledge and Kegan Paul).

Constructing Excellence (2004) *Why become a demonstration?*, Constructing Excellence (http://www.constructingexcellence.org.uk/bpknowledge/why.jsp, accessed 25th November 2004).

Countryside Properties (2002) *Environmental, Social and Ethical Report* (Brentwood, Countryside Properties).

Cowan, R. S. (1987) The Consumption Junction: a proposal for research strategies in the sociology of technology, in: W. E. Bijker, T. P. Hughes and T. J. Pinch, (Eds) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge MA, MIT Press).

Davies, A. (1996) Innovation in Large Technical Systems: The Case of Telecommunications, *Industrial and Corporate Change* 5 (4) pp. 1143-1180.

DTI (2003) *Energy White Paper 'Our Energy Future - creating a low carbon economy'* Department for Trade and Industry (London, HMSO).

DTI (2004) *Sustainable Buildings Task Group*, DTI, ODPM, DEFRA (http://www.dti.gov.uk/construction/sustain/sbtg.htm, accessed 22nd November 2004).

DTLR (2002) *Approved Document L1 - The Building Regulations 2000 (Conservation of fuel and power in dwellings)* Department for Transport, London and the Regions (London, HMSO).

Egan, J. (1998) *Rethinking Construction: the report of the Construction Task Force* (London, HMSO).

English Partnerships (2003) *Millennium Communities Programme*, English Partnerships (www.englishpartnerships.gov.uk, accessed 21st May 2003).

Gann, D. (1996) Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan, *Construction Management and Economics* 14 pp. 437-450.

Graham, S. & Marvin, S. (2001) *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition* (London, Routledge).

Gusto (2004) *Gusto Homes Features*, Gusto Construction (http://www.gustogroup.biz/new/features.php, accessed 23rd November 2004).

Gusto residents (2003) *Gusto residents' focus groups - Collingham* (personal communication, 29th & 30th May 2003).

Guy, S. & Shove, E. (2000) *A sociology of energy, buildings and the environment: constructing knowledge, designing practice* (London, Routledge).

Hughes, T. P. (1983) *Networks of Power: Electrification in Western Society 1880-1930* (Maryland, The John Hopkins University Press).

Hughes, T. P. (1987) The Evolution of Large Technological Systems, in: W. E. Bijker, T. P. Hughes and T. J. Pinch, (Eds) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MIT Press).

Jones, N. (2002) Does energy efficiency sell houses? *Show Homes* (January 2002) pp. 26-27.

Kemp, R. (1994) Technology and the Transition to Environmental Sustainability, *Futures* 26 (10) pp. 1023-1046.

Kemp, R., Schot, J. W. & Hoogma, R. (1998) Regime shifts to sustainability through processes of niche formation: the approach of Strategic Niche Management, *Technology Analysis and Strategic Management* 10 (2) pp. 175-195.

Kirsch, S. (1995) The incredible shrinking world? Technology and the production of space, *Environment and Planning D: Society & Space* 13 pp. 529-55.

Latour, B. (1991) Technology is Society made Durable, in: J. Law, (Eds) *A Sociology of Monsters: essays on power, technology and domination* (London and New York, Routledge).

Law, J. (1992) Notes on the Theory of the Actor Network: Ordering, Strategy and Heterogeneity, *Systems Practice* 54 pp. 379-393.

Law, J. & Hassard, J., (Eds) (1999) *Actor Network Theory and After* (Oxford, Blackwell Publishers & The Sociological Review).

Lovell, H. (2005) *The governance of emerging socio-technical systems: the case of low energy housing in the UK* PhD thesis (Department of Geography, Cambridge University).

Mathiason, N. (2002) Builders 'plot to keep house prices high', *The Observer* 5th May 2002 pp. 12.

McGill, J. (2001) *Planning for Efficient Environmental Resource Use in the Housing Sector* MPhil thesis (Faculty of the Built Environment, University of the West of England).

MORI (2001) *National Customer Satisfaction Survey 2001* (London, The Housing Forum).

Moss, T. (2001) Battle of the systems? Changing styles of water recycling in Berlin, in: S. Guy, S. Marvin and T. Moss, (Eds) *Infrastructures in transition: urban networks, buildings, plans* (London, Earthscan).

Murdoch, J. (1997) In human/nonhuman/human: actor-network theory and the prospects for a nondualistic and symmetrical perspective on nature and society, *Environment and Planning D: Society and Space* 15 pp. 731-756.

Murdoch, J. (2001) Ecologising Sociology: Actor-Network theory, Co-construction and the Problem of Human Exemptionalism, *Sociology* 35 (1) pp. 111-133.

ODPM (2003a) *Housing Statistics 2003*, Office of the Deputy Prime Minister (www.odpm.gov.uk, accessed 9th April 2004).

ODPM (2003b) *Possible Future Performance Standards for Part L* Office of the Deputy Prime Minister (London, HMSO).

Pierson, P. (2000) Increasing returns, path dependence and the study of politics, *American Political Science Review* 94 (2) pp. 251-267.

Pinch, T. J. & Bijker, W. E. (1984) The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology might Benefit Each Other, *Social Studies of Science* 14 (3) pp. 399-441.

Rip, A. & Kemp, R. (1998) Technological Change, in: S. Rayner and E. Malone, (Eds) *Human Choices and Climate Change Volume 2 - Resources and Technology* (Columbus Ohio, Battelle Press).

Schoenberger, E. (1991) The corporate interview as a research method in economic geography, *Professional Geographer* 43 (2) pp. 180-189.

Schot, J. W., Hoogma, R. & Elzen, B. (1994) Strategies for Shifting Technological Systems: the case of the automobile system, *Futures* 26 (10) pp. 1060-1076.

Smith, A. (2002) *Transforming Technological Regimes for Sustainable Development: a role for Alternative Technology niches?*, SPRU (http://www.sussex.ac.uk/spru, accessed September 2002).

Street, J. (1992) *Politics and Technology* (Basingstoke, Macmillian Press Ltd).

Sustainable Homes (2002) *EcoHomes Costings* (London, e2s).

Sustainable Homes (2003) *Sustainable Homes Ecodatabase* (http://www.sustainablehomes.co.uk/, accessed 23rd April 2003).

Sustainable Homes (2004) *Sustainable Homes - What we do*, Sustainable Homes (http://www.sustainablehomes.co.uk/, accessed 25th November 2004).

TCPA & WWF (2003) *Building sustainably: how to plan and construct new housing for the 21st Century* (London, Town and Country Planning Association (TCPA) & World Wide Fund for Nature (WWF)).

The Housing Forum (2003) *The Housing Forum - About us*, The Housing Forum (www.thehousingforum.org, accessed 17th Jan 2003).

UK Land Directory (2004) *Record shortage of land to fuel continued property price boom*, UK Land Directory (http://www.uklanddirectory.org.uk/land-for-sale-prices-shortage.htm, accessed 24th November 2004).

Weber, K. M. (2003) Transforming Large Socio-technical Systems towards Sustainability: on the Role of Users and Future Visions for the Uptake of City Logistics and Combined Heat and Power Generation, *Innovation: the European Journal of Social Science Research* 16 (2) pp. 155-175.

White, N. (2002) *Sustainable Housing Schemes in the United Kingdom* (Hockerton, Hockerton Housing Project).

Winner, L. (1977) *Autonomous Technology: technics-out-of-control as a theme in political thought* (Cambridge, MIT Press).

Wright, S. (2002) *Interview - Director of Gusto Construction* (personal communication, August 2002).

WWF (2004) *Building towards sustainability: performance and progress among the UK's leading housebuilders* (London, WWF).

Yates, A. (2001) *Quantifying the Business Benefits of Sustainable Buildings* (Watford, Building Research Establishment).

Figures and Tables

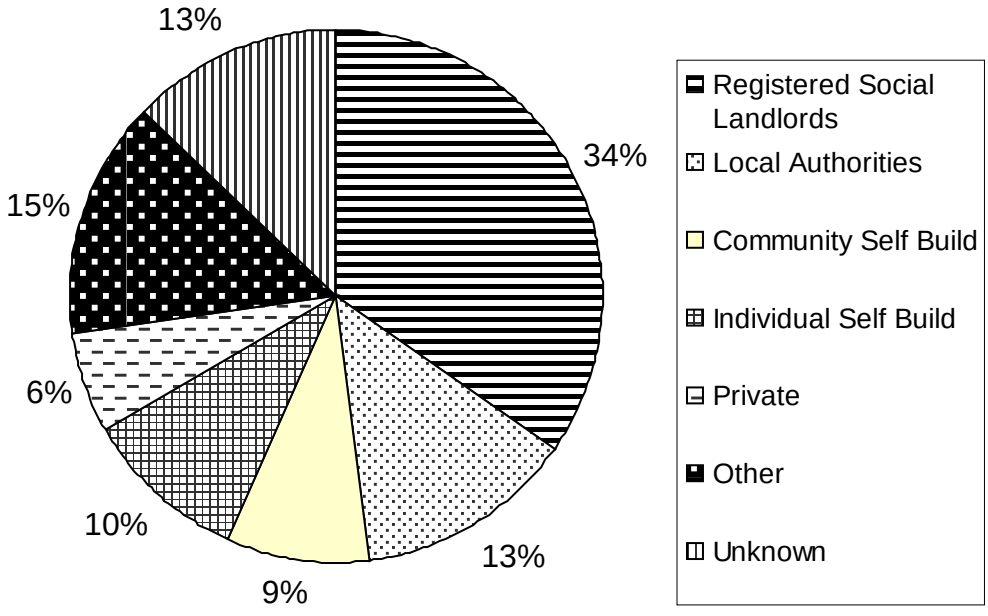

Figure One – Initiators of UK Low Energy Housing Developments by Housing Sector (various sources, including: Lovell 2005, McGill 2001, Sustainable Homes 2003, White 2002).

Name of development	Location	Type of Initiator	Number of dwellings	Date completed	Low energy features
The Eco-House	Leicester	Local authority	1	1990	photovoltaic (PV) panels, mechanical heat recovery, well insulated
Albert Hall Memorial Housing	Coalville, Leics.	Social housing	7	1990	well insulated, passive solar design, mechanical heat recovery
Ashtree Cottage	Westbury, Northants.	Individual self build	1	1993	well insulated, passive solar design, solar hot water
The Autonomous House	Southwell, Notts.	Individual self build	1	1994	super insulated, PV panels, energy self sufficient
Underhill Houses	Derby	Local authority	2	1997	well insulated, solar hot water, mechanical heat recovery
Hockerton Housing Project	Hockerton, Notts.	Community self build	5	1998	earth sheltered, super insulated, passive solar design, wind turbine, solar hot water, PV panels, heat recovery
Concept Cottages	Donnington, Lincs.	Local authority	2	1998	well insulated timber frame, mechanical heat recovery
Sinfin	Derby & Mapperly, Notts.	Social housing	5	1998	well insulated, high thermal mass, mechanical heat recovery
Fosse Estate	Newark, Notts.	Social housing	33	1999	well insulated timber frame, passive solar design
Millennium Green	Collingham, Notts.	Private sector	24	2001	solar hot water, passive solar design, well insulated
The David Wilson Millennium Eco House	Nottingham	University /private sector	1	2000	PV panels, passive solar design, heat pump, wind turbine
Beaconsfield Street	Nottingham	Social housing	7	2000	well insulated timber frame
Green Lane	Clifton, Notts.	Social housing	44	2002	PV panels
Plain Tree Court	Nottingham	Social housing	10	2002	timber frame, geothermal, heat pump, well insulated, covered walkways
Garendon Road Eco Life	Loughborough	Social housing	17	2003	Low energy features not yet finalised, likely to include passive solar design and timber frame
TEK Haus	Nottingham	Social housing	2	2004	well insulated lightweight modular construction, mechanical heat recovery, solar hot water
Sherwood Energy Village	Ollerton, Notts.	Community self build/ private sector	c.125	c.2007	Low energy features not yet finalised, likely to include on-site renewable energy generation and energy efficiency measures
Ashton Green	Leicester	Local Authority	3500	2010-2015 (phase 1 by 2004)	As above
Wellingborough East	WellingboroughNorthants.	Local Authority	3000	2010-2015	As above

Table One – Low energy housing in the East Midlands
(source: Building and Social Housing Foundation (BSHF 2002)).