Why do builders innovate?
A review of the international literature on home-builder innovation

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Summary

This report reviews the international literature on home building innovation. It draws a distinction between home building and construction, and focuses mainly on the former.

The report starts by characterising the home building sector, noting the common view that it is not particularly innovative but also reporting that some researchers disagree with this assessment. It then reviews definitions of innovation applicable to the home building sector showing that it is necessary to make distinctions between ideas, actions and outcomes. Defined in terms of degree of change in concept and links, the more sophisticated definitions identify five types of innovations: incremental, modular, systems, architectural, and radical.

The report builds on these definitions to show that there are two main strands of theory in building innovation – one strand that focuses on the individual and one strand that focuses on supra-individual context or structures. The former includes the adoption-diffusion model, the S shaped curve which charts the rate of innovation over time, the use of survey methods, and studies of firm characteristics. This approach appears to be more relevant to smaller and discrete technologies. The latter approach includes more complex models of home-builder innovation, locating the decision maker in a context that includes both influencing and enabling agents. It also includes a broad range of participants in the building sector, each with particular motivations and constellations of predispositions (habitus), arranged in networks that directly influence innovation. Since networks are important in home-builder innovation the report includes some other literature which has this focus.

The conclusion of the report is framed in terms of policy implications. It makes the general point that those policies recognising the system background and networked nature of innovation are more likely to be effective. The key policy messages are:

1. The home building sector may not be as backward in innovation as some commentators suggest.
2. For those working with an adoption-diffusion model, policy should focus on information sources and improving their familiarity in order to decrease uncertainty. Innovation policies should encourage firms to support multiple functions and engage managerial staff with trade experience.
3. For those working within the macro-level approaches, policy needs first to recognise that the home building system is dynamic and open to influence. Policy at a general level should be comprehensive and synergistically target each part of the system, and work to link the different parties.


**Introduction**

The main research objective of the Technology Users’ Innovation (TUI) research programme is to increase our fundamental knowledge of (1) technology users as a source of innovation, (2) how socio-technical networks work to help or hinder innovation, (3) the unique technology governance factors in New Zealand and (4) the distinctive cultural qualities of New Zealand innovation. In addition to these main objectives, the research will contribute to BRANZ’s knowledge of home building innovation. This report directly addresses this latter goal.

The original research objective of this report was to review the international literature on home building innovation in order to make comparisons to the situation in New Zealand. Our extensive literature review revealed no articles or books concerning building innovation within New Zealand. Duncan’s (2005) examination of the performance-based building code in New Zealand, while not disconnected from the topic of innovation, focused on evaluating the effectiveness of the code and is not relevant to this report. Thus, in this report it is not possible to make direct comparisons to New Zealand by referring to New Zealand-specific literature. However, the findings of this review are able to inform our knowledge about home-builder innovation generally and can be used to develop and understand policies relevant to the New Zealand situation. Accordingly, this report concludes with general policy recommendations for encouraging home-builder innovation.

The literature on innovation often does not discriminate between the home building sector and the construction sector, in which construction means large-scale infrastructural projects or facilities involving many companies and teams of workers. Thus, some construction literature was examined and has been included in this review with the assumption that there are sufficient similarities between the two sectors to justify this inclusion. In some cases there are studies of small and larger home building firms and the latter have been included because they contribute to our understanding of home-builder innovation, if only by showing how the larger firms are distinctive.

One of the main motivations for research on home-builder innovation is growing concern over sustainability. Home building activities have an effect on energy use, greenhouse gas emissions, and contribute to the waste stream. The resulting houses, themselves, have ongoing effects on energy consumption. Further, in many countries, house building is a large sector of the national economy. For these reasons, sustainability in the home building sector is of growing importance and reflects the ‘greening’ of the sector. This pro-environmental emphasis is in response to imperatives to develop the natural environment for the benefit of humans while, at the same time, conserving natural resources for the future. The concern over home building sustainability leads to interest in the use of new or different technologies, and this drives interest in the question of why do builders innovate.
In this review all relevant and available literature has been included regardless of focal country. The main search strategy was to use the keywords of ‘innovation’ and ‘build*’ in Web of Science, plus ‘innovation’ and ‘house or home building’. Some of the literature is located in conference proceedings and theses and some of these could not be accessed.

The approach used in organising this review was to structure the literature into two groups – the literature that takes a micro-level perspective and the literature that takes a macro-level perspective. The micro-level perspective focuses on the builders themselves, including personal characteristics that influence innovation. Some of this literature does focus on firm-level characteristics but does not fully transcend the micro-level. The macro-level perspective focuses on the broader context in which builders operate, including social networks beyond the builders. These approaches bring two different perspectives, or theories of home builder innovation, to the process of innovation within the building sector. Different theories convey different understandings of innovation and have different policy implications.

This review starts with some general observations about the home building sector before considering definitions of innovations and the two main theories of innovation.

**Characteristics of the home building sector**

The building sector is generally considered to not be particularly innovative (see, e.g., Koskela and Vrijhoef (2001), Koebel (1999) and Duncan (2002)). Koebel (1999) documents the popular assessment that there are a number of impediments to innovation, including the:

- Cyclical nature of construction.
- Dominance of small firms.
- Lack of integration and heavy reliance on subcontractors.
- Diverse building codes.
- Lack of product approval systems that establish and certify to well recognised performance criteria.
- Lack of access to information about new products.
- Inadequate education and training on products and materials, installation techniques, and methods of operation and maintenance.
- Exposure to liability.
- Required acceptance by finance and insurance companies.
- Limited funding for research.
- Resistance to innovations from home buyers.

In a similar vein, Hassel et al. (2003) describe the housing sector as having low barriers to entry, cyclical changes in demand, and builders operating in small to medium-sized firms. With these structural characteristics, fragmentation slows information sharing, and the benefits of innovations are hard to protect.

However Koebel (1999), Hassell et al. (2003), and Duncan (2002) caution that it is premature to conclude that the industry is highly resistant to change. Koebel (1999)
points to work showing that the diffusion of innovations was similar in speed and process to comparable innovations in other sectors. He also argues that a lack of research studies has contributed to the widespread assessment that the homebuilding sector is slow to innovate. Similarly, Slaughter (1991) found more innovation than was suggested by previous studies, and Slaughter (1993) found many examples of builder-sourced innovations. Hassell et al. (2003) report that the evidence regarding building sector innovation rates is mixed with some studies supporting this claim and others showing that the productivity trends in housing are not unlike trends in other industries (Slaughter, 1993; Rosefielde and Mills, 1979).

Duncan (2002) suggests that the traditional view of innovation, with its basis in individual ownership of an idea, is the reason for apparently low rates of innovation in the residential construction sector. Instead, he argues that the unique, day-to-day problems that face builders require types of innovation that frequently occur but may or may not diffuse through the building community and are not carried on to market in a manner that is captured well by current methods of innovation measurement.

It may be that perceptions of innovation rates in the building sector reflect differences in perspective. Slaughter (2000) takes a macro-level view of the sector and assesses its level of innovation favourably. It seems plausible that those taking the micro-level view look mainly to the builders themselves to explain the rate of innovation and in seeing that it is not ideal, they conclude that innovation is wanting. It may also be the case that the popular but critical view of home building sector innovation has gained support because it has been a convenient justification for work in this area.

**Definitions of innovation applicable to the home building sector**

Different meanings are sometimes given to the terms ‘invention’ and ‘innovation’ so some care is necessary to establish viable meanings. Invention and innovation involve people doing something new. This newness involves three stages of development: ideas, actions, and outcomes. Hassell et al. (2003: 17) see the key steps of innovation as invent, design, and adopt, which correspond to these three stages. Each of these stages is a position along a continuum, and each is a necessary condition for the subsequent stage. When all stages occur there is a fully-fledged innovation and a new technology is used to such an extent that there are material changes and social and/or economic effects. Definitions of each of these three stages will be given before going on to consider house building innovation.

**Ideas.** The origin of an invention is an idea and this idea may or may not be taken to the next stage of action. Someone can invent something in an abstract sense, in the realm of ideas, and not want to or be able to take it beyond the idea. For example, Da Vinci thought out the idea of a helicopter and other mechanical devices which were not expressed in action. In some cases these inventive ideas precede the availability of suitable materials essential for their construction. For some people, these new ideas are sufficient in themselves to constitute an invention.
**Actions.** The next stage of development is taking an inventive idea and using it to guide actions that take the idea on to material development. An important part of the action is developing or refining the invention to make it work well, putting aside those (few) instances when the first prototype is close to the final prototype. An important element of success in invention is getting the prototype to work. Presumably there is ongoing interaction between artefact and idea as the reality of the artefact, and its relative success, is interpreted and the original idea modified accordingly. It is here that design plays a critical part in the development of the invention.

**Outcomes.** Having a new technology that works does not mean that it is fully successful as an innovation. The third stage involves taking the new technology and managing its growth so that others use it. This can occur through either a market or a non-market mechanism. By either means, when others use the new technology it can be seen as a successful innovation.

A number of definitions of innovation in house building have been found and they range from basic to sophisticated. Examples of basic definitions include Toole (1994: 10) who defines technology innovation as ‘...application of technology that is new to an organization and that significantly improves the design and construction of a living space by decreasing installed cost..., increasing installed performance..., and increasing construction business performance’. While this definition is perhaps prosaic, it nevertheless characterises the improvements meant to derive from innovation, in this case all tied to economic benefits (efficiency, performance, cost). Most agree that newness is an essential part of innovation but, as indicated in the above definition, and noted elsewhere, e.g., Hassell et al. (2003), an invention can be entirely new, a new application of an existing idea, or a reintroduction of an out-of-use idea. Beerepoot and Beerepoot (2007), in their review of definitions, indicate that innovation is largely regarded as an incremental process that is firmly based on existing technologies or processes.

More sophisticated definitions better reflect the complex nature of building. For example, Koebel (2008: 46) defines innovation as the commercialization of new products and identifies two types. **Disruptive innovations** (e.g., geodesic domes or manufactured housing) typically combine multiple complementary changes while **incremental or sustaining innovations** (e.g., nail guns) involve improvement in existing products that have relative advantages over previous method in efficiency, performance or cost. Similarly, Harty (2004) classifies innovations into those that are **bounded**, where the implications of the innovation are restricted to a single, coherent sphere of influence, and those that are **unbounded**, where the effects of implementation spill over beyond this and the collaboration of many firms is required for successful implementation.

A definition that reflects these distinctions and appears to be comprehensive has been provided by Slaughter (2000:2) (Figure 1). She defines an innovation as a ‘non-trivial improvement in a product, process, or system that is actually used and which is novel to the company developing or using it’. She applies this definition to
construction in general, noting that any introduced change can have ripple effects throughout the various systems comprising the construction, and therefore potentially generates risks. To assess these risks she introduces five categories of innovations and then considers the implementation stages of innovation for each category. The strength of this definition is that it is comprehensive and acknowledges the complex nature of house building.

Figure 1: Slaughter’s categories of innovations

The five categories of innovations derive from the degree of change in concept and degree of change in links. An *incremental innovation* is a small improvement in current practice with minimal impact on other components or systems. An *architectural innovation* is a small improvement within a specific area or core concept but requires significant modification in other components or systems in order to function. A *modular innovation* is a significant improvement within a specific region but requires no changes in other components or systems. A *system innovation* is a set of complementary innovations which work together to provide new attributes or function and together can significantly advance the state of knowledge or practice. A *radical innovation* is a completely new concept or approach which often renders previous solutions obsolete.

These five categories of innovation appear to include a wide variety of innovations including those that include changes to organisational and management routines, creativity in marketing, and modifications to production processes (Beereport and Beereport 2007). Further, the five categories clearly acknowledge the complex networks in which building innovation occurs. This context can have particular

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1 These same categories are also defined by Goverse et al. (2001) with reference to the earlier work of Henderson and Clarke (1990) and Tushman and Anderson (1986). Slaughter (2000) also cites Henderson and Clarke (1990) but only with respect to some of the categories.
implications for builder innovation. For example, Koebel (2008: 78) explains that it is difficult for home builders to appropriate the benefits of innovation given that they have to balance the characteristics of supply against market demand.

Most product innovation are commercialised upstream from the builder... Manufacturers protect their rights through patents, trademarks and copyrights. They also increase market share by expropriating the knowledge produced by builders who field test new products. Any net gains by innovative builders who achieve higher productivity, sales, or customer satisfaction by using a new product are likely to be momentary, as the manufacturer and supplier benefit from sharing the knowledge with other builders... The builder also receives little benefit when innovation improves building performance... Many buyers only live in new house for relatively short periods, and are not directly involved in material and product decisions.

In effect, there is a contested environment or context to innovation decisions. Koebel (1999: 78) states that decisions about innovations in the built environment are often a complex blend of government, business, and consumer decisions. Builders are a critical part of this mix. Not only do they make the final decision with regards to the practical value of an innovation, but they must also anticipate what the consumer will support. Similarly, Hassell et al. (2003) in their list of three primary motivations for innovation (seeking competitive advantage, improving technology efficiency, and meeting external requirements) show that builder innovation is embedded in a diverse network which includes competitive relationships with other builders and demands stemming from consumers or regulators.

The above outline of definitions of home-builder innovation sets the scene for more explicit consideration of the nature of innovation theory, that is, theories which offer explanations of what it is and how it works.

Theories of innovation

Binder (2008) sets out a number of important questions relating to innovation. He sees the literature as not being clear about innovation and raises three questions about the innovation process.

1. What is the precise nature of innovation? Is it continuous or discontinuous, bounded or unbounded?
2. Where does innovation occur? Does it lie with creative individuals, interacting individuals, groups, creative cities, knowledge clusters, networks, or governance structures?
3. At what level does it occur? Is it a property of individuals (such as openness to new ideas, tacit knowledge, roles, leadership), groups (such as group learning, cooperation, collaboration) or contextual factors (such as crisis, complexity, regulation, government)?
The definitions above show that with respect to question 1 this distinction is recognised and both types occur. The definitions also show that with respect to questions 2 and 3, there are a variety of perspectives. Some approaches start with the individual and may or may not consider the context, while others start with the individual in a context. Thus, there are two main strands to the theory of innovation as it has been developed and applied in studies of housing. First, there are those which focus on the individual as the unit of analysis and look at the pattern of change over time in the use of available technologies. Common to this approach is the use of the adoption-diffusion model of innovation. Second, there are those which focus on the supra-individual context or structures within which innovating individuals operate. This latter approach explains innovation in terms of networks or relationships between entities, rather than the individuals themselves. These approaches include a focus on the individual but conditionally as an individual within a context. Each approach is now considered.

1. Innovation theory with the individual as the unit of analysis

Many researchers base their work on applying the adoption-diffusion model to the process by which housing innovations work their way through a population of builders. This approach is exemplified in Koebel’s (1999) description of the process. Initially, a small group of potential adopters are motivated to learn more about an innovation and use it on a trial basis. If it is judged to be successful, word spreads and others adopt it. Increased demand reduces costs of adoption and there is further spread of the innovation. The result is an S-shaped curve which charts the rate of innovation over time.

Diffusion theory, based on considerable research in a variety of settings, shows that the rate of adoption is affected by five factors: relative advantage, compatibility, complexity, trialability, and observability. In terms of relative advantage, builders favour innovations that are easily understood, have immediate or near-term benefits, and have benefits which are highly visible to the consumer. They prefer innovations that are compatible with their existing technology. In terms of complexity, a modern house is a complex system of component subsystems and this high complexity (especially where there are many distinct relationships) works against innovation. Trialability poses a problem for house builders since low volumes and working with many subcontractors limit opportunities for trials. For this reason, it is often research centres which operate demonstration parks. However, these have high costs and low portability. Observability poses a problem since many innovations are invisible to the consumer.

The adoption-diffusion model does provide a framework for good questions about innovation (Koebel, 1999). How do builders assess relative advantage? What information do builders and consumers lack? Who serves as information brokers for each? What is the relative importance of industry sources and independent sources of information?

A number of general observations of the adoption-diffusion model can be made. Proponents of this approach do not ignore larger-scale entities. However, these
entities do not figure strongly in their explanations of innovation. Further, this theory emphasises barriers to innovation and therefore most attention is given to the individual, and those that do not innovate are labelled as laggards. The danger here is that rational decisions on the part of apparent laggards are interpreted in psychological terms, drawing attention away from structural factors which have important influences in decision making. In addition, the term is mildly and unjustifiably pejorative. Further, while all innovations are, by definition, new, not all are good. Also typical of the adoption-diffusion model is the assumption of economic rationality on the part of the adopter, hence the emphasis given to efficiency, performance and cost in some of the definitions of innovation. However, the general view of the rational decision-maker has come under increasing fire from several quarters (see, e.g., Ariely, 2008; Tversky and Kahneman, 1992). This model also assumes the linear model of innovation – the process of moving from research to development through to demonstration and then deployment.

The adoption-diffusion model may be more relevant for smaller and discrete technologies that are not critically linked to other aspects of the construction process. One example of this type of technological change is the use of the nail gun. Such innovations are able to be adopted by a builder by way of a relatively simple and personal decision. But the model may not be so applicable to complex, system-related innovations in which numerous parties have a stake.

In its focus on the individual and using the adoption-diffusion model, the research on innovation has tended to employ survey methods. For example, Thorpe and Ryan (2007), aware of the need for improved sustainability in building, surveyed 20 smaller residential building construction firms in Queensland to understand why innovation occurs. There were 50 innovations covered by the 20 firms. Most of the innovations were related to sustainability and improved design practices, and most were new to the business rather than new to the industry. They found that builders sourced innovation ideas from industry contacts rather than research organisations, and that industry associations, training events, suppliers, journals, magazines, advertisements, designers and subcontractors were the main source of innovation knowledge external to the firm. The main perceived benefit was improving the industry’s reputation, while improved profit was the lowest ranked benefit. This finding immediately calls into question the economic rationality assumption of the adoption-diffusion model. The main motivations were knowledge that it was good practice and legislative requirements but not client demand. Overall, Thorp and Ryan (2007) interpret their survey results as indicating a generally positive view among home-builders regarding sustainable design and construction practices in the residential building sector.

Builders are influenced by suppliers of products and these suppliers are important sources of innovations. Fell et al. (2002) cite research by Cohen and Sinclair (1990) which found supply firms which adopted more innovations performed better. Further, research by West and Sinclair (1980) found innovator companies employed more manufacturing and production engineers and were technically more progressive.
Fell et al. (2002) surveyed 196 single-family house builders in California, Oregon and Washington to ask about their use of six innovations, including engineered wood products and wood substitute building materials. The builders were grouped into early adopters (16%), majority adopters (68%) and late adopters (16%). The early innovators built more houses, were more likely to build luxury homes, had higher incomes, generated more of their revenue from single family home construction (rather than from repairs or remodelling), and were more likely to be members of the National Association of Home-builders. More of the late adopters were located in counties with high populations (over 500,000). For all types of builders the main communication channels were building product magazines, trade magazines and journals, and talk between builders. There were few differences across adopter types in terms of communication channels although early adopters rated communications with manufacturers’ field representative as more important.

Scheur (2007) investigated green building practices in order to understand how familiarity plays a role in the adoption of these practices. Interviews with 19 builders in Michigan and 32 in Oregon showed that increased green building experience was linked to a shift in familiarity from building and project issues to conceptual and human behavioural issues. Results from a subsequent survey of 171 US builders showed, using structural equation modelling, that familiarity was strongly linked to the use of green building practices. Further, familiarity was found to mediate various sources of information on the use of green practices. Scheur recommended that communications to builders be designed to improve familiarity. Familiarity can be fostered by increasing the availability of experiences that develop familiarity and by finding ways to develop builders’ familiarity with the system-level dimensions of green building. It would seem that familiarity is related to the compatibility factor in adoption-diffusion theory.

Another strand in this literature is that which takes the building firm as the main unit of analysis. While some of this literature is critical of the adoption-diffusion model it does not really transcend it and does not give full attention to the macro-level of analysis. In other words, the firm-level characteristics are taken for granted rather than explained. Thus, while this literature does not cover strictly micro-level processes, and in this sense is more sophisticated, it does not fully develop its macro-level approach.

Toole’s (1994) assessment of the literature focuses mainly on industry-level factors such as firm size, management intensity and profit margins. These are explained as resulting from the sector characteristics of cyclical sales and fragmentation. Further, Toole (1994) explains that innovation adoption for organisations is quite different than for individuals, and for this reason the existing adoption-diffusion literature is lacking. It is different because there are many organisational variables that act over and above the aggregate of individual variables. Further, the situation in which technology innovations are introduced is complex. The number of individuals and organisations with which firms interact is much greater than is the case for individuals. Thus, the relative advantage of an innovation derives from how well it
can be expected to fit with a potential adopters’ task, and is a function of how well it allows an organisation to match its innovation. With this basis, Toole (1994) puts forward a theory of task uncertainty to explain home-builder innovation. This theory notes how home buyers, regulations and subcontractors contribute to uncertainty, and how early adopters have better capabilities for gathering information to reduce uncertainty or have higher tolerance of uncertainty.

Toole (1998) interviewed over 100 home-builders throughout the USA and found that those who were more innovative accessed more sources of information about new products from their organisational environment. Information processing significantly differentiated earlier adoption builders from innovation laggards. There was no relationship between company size, years in business, or market segment served. However, the results showed that there were differences between builders who adopted high uncertainty innovations compared to those who adopted low uncertainty innovations. The former had a higher numbers of functions (e.g., top management, office administration, sales, design or site supervision), and had at least one individual with a building trades background involved in innovation activities. The latter had at least one individual with an architectural or engineering background (they applied engineering principles to reduce uncertainty relating to physical performance but could not reduce uncertainty relating to market acceptance). Toole’s (1998) results support the hypothesis that uncertainty reduction plays a key role in the adoption of technological innovations. For those builders who believe in the profitability of using new building products prior to wide diffusion, he recommends the establishment of appropriate staff, procedures, and norms within their organisations to more effectively gather and process information about innovations. This will insure that the innovations they adopt are appropriate and more acceptable to homeowners, subcontractors and regulators. Builders who believe that early adoption can never pay off should reconsider their position since the evidence indirectly suggests that it is feasible and effective.

In a survey of US builders, Blackley and Shepard (1996) used firm-level data to measure diffusion of innovations in home building and identified factors explaining this diffusion. As context to the study they note that a number of factors influence diffusion in home building. They take the view noted earlier that the structure of the industry, consisting largely of highly competitive, small to medium-sized builders who rely on independent subcontractors, deters research and development. Further, variable or highly cyclical sales, small average size, vertical or horizontal fragmentation of the industry, and the absence of significant barriers to entry all make for a lack of technological progress. In addition, institutional factors such a local code requirements and the strength of unionisation may affect innovation. These factors mean that the risks associated with innovation are high, the costs associated are high and the benefits to individual firms are reduced.

In a survey of 417 home-builders, ten innovations were selected and respondents were asked to indicate the extent to which they used the innovation. A range of

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2 This finding is consistent with results reported in Rinne et al. (ND).
independent variables considered to influence innovation were formulated, and these were analysed with an ordered probit model to show that firm size (measured with construction revenues) and the number of counties in which the builders operated were key determinants of innovation. Also, industrial-type builders, building modular, panelised or pre-cut units, were more likely to innovate. Geographical location, reflecting building code and climate was a significant determinant of innovation. There was partial support for some demographic characteristics being related to innovation such as characteristics of the firm head, and the age of the firm head but education and years of experience were not related. Factors having a negative effect on innovation were higher prices of the typical unit and greater management intensity; that is, having relatively more non-construction employees. There was no evidence that fragmentation affected innovation.

Careful consideration of innovation among home-builders in the US has been provided by Koebel et al. (2003) and Koebel and Cavel (2006). In the former study the focus was on smaller building firms: nearly two-thirds of those surveyed built fewer than 25 houses in 2001, and three-quarters built fewer than 50 houses. The key findings were that:

- At the early stage of adoption, national and regional firms, multi-family and modular builders, and single-family custom builders were more likely to adopt innovations than single family builders.
- Sales and suppliers, subcontractors and trade shows were important sources of information about new products and materials. However, early adopters relied on technology transfer programmes and universities more than middle or late stage adopters.
- Less established businesses were often the first to introduce new products, but innovation adopters tended to rely on established manufacturers who stand behind their products.
- Higher levels of adoption were associated with having a technology advocate in the firm (most often the owner), a company emphasis on being creative, the use of union labour, and explicit demand from informed homebuyers.
- Low levels of adoption were associated with local production builders and those who emphasised marketability and profit. These builders associated firm success with land development and emphasised the tried and true rather than risking new materials and methods.

In further work on diffusion of specific technologies Koebel et al. (2003) found variable patterns. Some were spearheaded by larger firms; others by smaller firms. Some technologies entered the market in more expensive homes while some entered in low cost homes. Large builders stressed cost saving, improvement in production, reduced callbacks or reduced exposure to liability. By contrast, smaller builders stressed high consumer awareness and were less concerned about price or impact on the production process.

Koebel and Cavel (2006) conducted a national survey of 200 production builders—those who build over 200 homes a year. The key findings were that:
• Larger firms were more innovative.
• Decentralisation contributed to innovation.
• Purchasing departments had significant influence on innovation.
• Building technology innovation was seen as risky (innovative products and material were seen to cost more than those they replace and subcontractors were resistant to new products) but also as having the potential to improve quality and performance. Those with aggressive growth plans were more likely to innovate.
• Typical information sources were local offices within the company, subcontractors, manufacturers, wholesalers and supplier, and technology transfer programmes.
• Preferred innovations were those that reduced construction defects, improved subcontractor dependability, and improved the style and attractiveness of the homes. Less than half rated investments in technology as a means to improving market share. However, building technology was an important part of production builders’ business models although it was considered just one of many important factors.
• The main barriers to innovation were building codes, the risk of increased call backs when using new building products, and resistance among construction workers.
• The main benefits of innovation were increased quality, meeting customers’ expectations, increased competitiveness, better image and decreased call backs.

The character of the home building industry has been more recently assessed by Koebel (2008). He argues that the traditional small-firm builder, orchestrating the construction of a house with supply and labour inputs from other firms, has been able to respond quickly to changes in demand and building cycles, but may not be able to make longer-term capital investments needed for innovation. Custom homebuilders may be innovative but this represents only a small part of the industry. On the other hand, production builders may resist innovation if it requires production line stoppages. Further, since they rely on subcontractors, any changes require the subcontractor to endorse the innovation. On the other hand, larger production builders have the capital and human resources to promote innovation.

In summary, innovation theory with the individual as unit of analysis often employs the adoption-diffusion framework model. It therefore draws on a model, having been developed extensively in other settings, to identify factors that affect the adoption rate. It emphasises barriers and laggards, economic rationality, and the linear model of innovation. Firm-level variables are sometimes included but macro-level factors do not receive significant attention. Using this approach, researchers use survey methods and find that they can explain innovation by examining a range of individual and firm-level independent variables. These include information sources, perceived benefits (not necessarily economic), familiarity, uncertainty and firm characteristics. The research shows that there are distinctive but quite variable characteristics of innovators: they build more houses, they have higher incomes, and they are more familiar with or have less uncertainty about innovation. Further, the character of the firm head is linked to innovation. Innovative firms have more
diverse people with fewer managers, are larger in size, and operate in more counties.

It is fair to say that some of the literature in this grouping considers firm characteristics and sector characteristics, and these are used to explain innovation, or lack of it, among home builders. In this sense, some proponents in this grouping recognise macro-level factors in home-builder innovation. However, these are taken for granted rather than explicitly theorised or examined. They examine the consequences of these macro-level factors rather than their causes. It is in recognition of this distinction that we turn to the other theoretical approach to home-builder innovation.

2. Innovation theory with networks, relationships, or systems as the unit of analysis

Proponents of macro-level theories of innovation reject the linear model of innovation. Hassel et al. (2003) note that the linear model best applies to complex science and technologies such as atomic bombs, where the government requested, funded and purchased the products. In general, the linear model has the following weaknesses:

1. It fails to match real world innovation processes which often have a complex, circuitous path.
2. It does not deal well with innovation that results from intuition, experimentation, and trial and error rather than rigorous theoretical understanding.
3. It does not recognise that non-technical considerations, such as lack of consumer interest, can stop innovation.

Specifically for the housing sector, the fragmented nature of the industry means that some innovations are resisted. Instead of the linear model of innovation Hassel et al. (2003) propose a dynamic model. This model separates invention from research, and links research, knowledge and market forces to each step in the innovation process, including invention, development, demonstration, and deployment (Figure 2). This model reflects that research typically leads to knowledge rather than invention, and that the knowledge base may not be sufficient to allow for the development of the innovation. The inclusion of market forces reflects the need for funding, for consumer demand, and for the product to meet regulatory requirements. Each of the above elements is linked with two-headed arrows to reflect the feedback and interactions that occur.
In addition to their new model, Hassel et al. (2003) show that in terms of motivation for innovation, there are three broad types:

1. To gain competitive advantage — as more firms adopt the advantage decreases and the innovation becomes a requirement.
2. To improve technological efficiency — improving efficiency can motivate adoption even if there is no clear need but because it is likely to lead to a better product or service. These innovations may be resisted until the decision maker has sufficient information.
3. To meet external requirements — this typically happens after an innovation has come in to wider use.

However, they also state that additional factors must be considered to fully understand adoption decisions. These are the knowledge base of the decision maker, the influence agents (people who try and influence the decision maker) and the enabling agents (people who expand the decision maker’s knowledge base through invention and research and by sharing knowledge with the decision maker). In the housing sector, Hassel et al. (2003) recognise that the homeowner is the ultimate decision maker but that he or she is influenced by builders and designers. Further, the builder and the designers are influenced by suppliers and subcontractors who provide information about products and processes. Beyond these are researchers, managers, and investors. Thus, the successful deployment of an invention requires many industry participants to learn about and accept the invention. Also, participants, at different times, are thrust into the different roles of decision agent, enabling agent, and influence agent. Further still, they acknowledge that beyond the economic considerations of inventions, the particular historic
context or ‘technological frame’—that is the decision maker’s time, place, past experiences and professional training—shapes how they think about technology. All these additional factors clearly show that this approach acknowledges that many more factors other than those of the builder or the firm are at work in the home-builder innovation process.

In keeping with their broad perspective on the home building sector, Hassell et al. (2003) note that different participants in the home building sector have different motivations. These participants correspond to the different stages in the process from land development to post-construction and include:

1. Land development – developers, planning officials, community interest groups.
2. Design – architects and engineers, homebuyers, testing and evaluation groups.
3. Pre-construction – model code organisations, regulatory agencies, material producers, suppliers.
4. Construction – builders, trade contractors,
5. Post-construction – real estate agent, mortgage brokers, appraisers, lenders, insurers.

Hassell et al. (2003) thus have developed a sophisticated model of home building sector innovation and acknowledge the complexity of participants in the sector. In articulating such a comprehensive view of innovation, they are acknowledging that builders work within a network of relationships.

Turning to recent work in Australia shows a similar, fully-fledged social theory of innovation. Binder (2008) uses this new theory to interpret his case study of a recent building innovation in Australia. What the case study showed was that the innovation resulted not only in change and but also resistance to change, and that there were not just a few creative entrepreneurs that drove change. Further, the innovation attracted the attention of people involved in local politics whereby potentially affected groups worked hard to defend their interests. Binder (2008) therefore broadens the focus even further than Hassell et al. (2003). Also, there was evidence that there were unexpected changes beyond the immediate parties. The core innovation was used by others, some builders took it up (but in a relatively modest way), and some did not take it up at all. For Binder (2008) these are the characteristics of innovation that must be explained by the new theory.

To explain these characteristics of innovation, Binder (2008) argues that innovation can best be seen as an example of social learning where humans develop in interaction with others and these lessons stabilise and coalesce in habits of activity, language and meaning. Drawing from Bourdieu, these lessons take the form of ‘habitus’, defined as disposition or orientation to action (Johnston et al. 2000) which establish our tastes, preferences and predispositions. Habit allows many things to occur without attention but the associated habits do not over-determine human behaviour. Events can provoke a challenge and humans can learn and change creatively. Change is bounded by the possibilities of habitus but is stimulated by

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3 A pertinent question is to ask: is this a typical case of innovation?
interacting with others. Thus, a powerful source of adaptation and innovation is the introduction of a practice from others, that is, by interaction between one habitus and another. The fundamental problematic here is not one built on creative individuals but a relational one – innovation occurs as the outcome of a process by which actors, habits and the process of change are played out.

The tension that drives this change is the clash between one habitus and another. Binder (2008) explains that humans occupy a number of ‘activity systems’ in which they have niches of necessary relationships that sustain, define, and challenge life physically and culturally. These activity systems or communities of practice also define gender, class and identity, that is, who we are and who we are not, what we like and what we do not like. In other words, our niches provide familiar ways of doing things that are linked to identity. However, these ways can be challenged by changes in relationships and from others’ acts that can be intentional or non intentional. These challenging relationships demand a response beyond habit. Such challenges do not necessarily result in a fundamental change. They may lead to a defence of faith and practice, or to learning and adaptation, or to innovation and modification. Accordingly, innovation is a socio-political phenomenon pursued and resisted by groups defined by their distinctive habitus. Where change fits with existing habitus it will be pursued or at least accepted. Changes that are not consistent with habitus will be resisted. The limits of a particular innovation are not set by innovators but by the habitus of others and the path of innovation can be understood as a product of resistance to and pursuit of countervailing habitus in a particular context. The tacit knowledge of habitus, co-operation, risk taking, collaboration, regulations, leadership and timing are all relational phenomena that are elicited by the innovation process rather than discrete phenomena that can be deployed to engender innovation. This importance accorded to relational phenomena is consistent with Hassell et al.’s model.

Binder’s relational theory makes it clear how non-innovation can be rational and this is an advance on adoption-diffusion theory. The theory implies that different groups, each with a particular habitus, form a network. This view implies that the networks themselves have a role in building innovation. Adopting this approach, Lutzenhiser (1994) also sees technology innovation as a socially-regulated process rather than as the product of rational economic actors. Among the actors are firms, regulators and financiers who form a socio-technical system, which evolves fitfully by building upon pre-existing knowledge, technologies and social institutions. The building sector is a local ensemble of tools that work together and is dependent on other more distant networks. Following Bijker (1989), Lutzenhiser (1994) suggests emergent events may make innovation desirable but not in any predetermined way, as numerous case studies and international comparisons show. Innovation is shaped by ways of thinking about technology problems, or frames, and these frames are challenged and changed in the innovation process. Each possible invention is not equally satisfying to every interest involved. There can be public and private struggles between relevant interest groups often resulting in political negotiation of ultimate designs, which may lead to stabilisation and closure, further limiting future change. These
theoretical characteristics clearly parallel the key elements of building sector innovation identified by Binder (2008).

In applying this perspective to energy efficiency in housing construction, Lutzenhiser (1994) sets out a number of constraints to innovation. Business cycles and market uncertainty force some firms to consider other activities such as land development, rental housing, the provision of ancillary services, or quitting the industry. In addition, it leads to subcontracting in which suppliers may stimulate technology innovation in a social struggle to attract adherents, but local competition between builders may inhibit innovation. Consequently, risk taking and cost reduction may only appear in certain odd niches of housing markets. The dynamics of information flow through industry networks may affect innovation.

More recent work using a network approach focuses on innovation as a product of the coordination between contributing organisations. Dewick and Miozzo (2004) contend that the literature is still struggling to understand these linkages. Innovation studies of this type have found that the success of innovation relates to long-term relationships and close interactions with agents external to the firm, and that user-supplier relationships play an important role. Dewick and Miozzo (2004) note that emphasis has tended to be on scientific infrastructure and there has been little elaboration of how different parties in the network interact. Other studies focus on comparing different sectors but these have similar limitations. However, the recognition of networks in innovation has led to a large body of literature working under the rubric of ‘systems of innovation’ to reflect the importance of networks.

Dewick and Miozzo (2004) apply their network approach to the study of innovation in social housing in Scotland. Although there is demand for green building techniques there are still many barriers. The main barrier is high capital cost, but there are additional barriers from perceived risks, shortage of suppliers, uncertainty about the actual benefits given the complexity of making full life cycle assessments, and lack of expertise relating to new technologies. Scottish Homes, which assists approximately one-third of all house building in Scotland, has been actively encouraging sustainable technologies, but their policy aims are difficult to achieve because of the barriers imposed by inter-organisational relationships in the building sector. For example, members of the housing associations believed that long-term relationships helped overcome conservative tendencies among contractors, and ‘design-and-build’ contacts allow the contractor to be involved earlier in the building process which was believed to be advantageous. However, architects and engineers believed that innovation was facilitated by the traditional contract form and that the ‘design-and-build’ approach stifled innovation because contractors prefer to settle for building to meet minimum regulatory standards. They argued that traditional contracts allowed the specialised knowledge of architects and engineers to facilitate integration between them and the contractors. Dewick and Miozzo (2004) argue that many of the differences in the interests of the various stakeholder groups could be reconciled if there was more specific funding channelled to integrating innovative products and processes, and if successful demonstration projects were repeated. They also
conclude that it may be useful to include the project coalition at an early stage in the construction process.

A systems of innovation perspective has been applied to home building (Beerepoot and Beerepoot, 2007). Supported by results from Miozzo and Dewick’s (2002) analysis of the construction sector, they show that contractors are constrained in their level of innovativeness. Because innovations in construction are not implemented in a firm itself but as part of the projects in which many firms are engaged, most innovations have to be negotiated with one or more parties in the project coalition. Further, construction jobs are unique so there is little scope for economies of scale, and little incentive for contractors to be innovative. Contractors have limited capital, and price competition and awarding contracts to the lowest priced contractor also constrain innovation. Further, Miozzo and Dewick (2002) argue that the development of strategic innovations depend on the structure of ownership, management of contractors, the creation of institutions within the firm to facilitate diffusion of new processes, long-term relationships between firms and collaboration with external sources of knowledge.

Specifically for the Dutch home building sector, Beerepoot and Beerepoot (2007) explain why it is hard to achieve energy efficiency innovations. Such investments generate advantages for home buyers not builders. Apparently, the demand for such houses is weak, householders have relatively low levels of expenditure on energy, and there is a lack of transparency in energy efficiency.

Our last example in the literature that takes a macro-level perspective is one that provides an important supplementary point about the role of discourse. Lovell (2008) examines the role of discourse in innovation journeys and argues that the politics and power struggles highlighted by a focus on discourse are integral to the innovation process. Discourse both constrains and enables innovations. She interprets the development of low-energy housing technologies in the UK from the 1970s to show that while new technologies were originally part of the sustainable housing movement they were reframed as part of low-carbon housing in the late 1990s. This amounted to a remapping of the innovation journey which in turn influences the contemporary pathway of low-energy housing. In effect, Lovell posits an ongoing interaction between discourse and innovation, cautioning that any account can retrospectively reframe a history and omit inconsistent parts.

The advantages of discourse theory are that it can provide structure to the innovation journey showing how apparently disparate parts are related, and that it shows how a discourse can selectively reframe the innovation journey. Drawing from the political science concept of policy networks, Lovell focuses on ‘discourse coalition’, whereby members, while not necessarily sharing the same values, are united by their shared use of language. In particular, ‘discourse framing’ is a process whereby new ideas are presented and problems and solutions are simplified. This framing is a way of making sense of complex situations, and is a technique used by discourse coalitions to help define their boundaries of activities and lend coherence to their discourse. It can include identifying a problem and making sense of a
problem. Discourse may speed up an innovations journey by creating cohesion among actors and through presenting technologies in a way designed to appeal to policy makers. However, narrow framing may create problems because key issues are left out.

Lovell’s (2008) research usefully complements the network and innovation literature by emphasising discourse. Her work corresponds to work by Hassell et al. (2003) and Lutzenhiser (1994), which refer to frames, and to work by Binder (2008), which refers to habitus.

To summarize these examples of innovation theory, networks, relationships and systems are the main unit of analysis. Proponents of network theory emphasise the complex situation in which innovative builders operate and discount the adoption-diffusion model. In addition to the decision maker, they identify influence agents and enabling agents, including a wide range of participants in the home building sector. Further, they point to participants’ framing or interpretation of technology and how this reflects past experience. Innovation is therefore a product of dynamic interaction between parties who have distinctive frames or habitus. The outcome of this clash is contingent and the outcome may reinforce the status quo or it may lead to change. Fundamentally, it is the outcome of this social process which leads to innovation or a lack of innovation, rather than the innovation being explained by reference to individual decision making. This is true even if the outcomes of the social dynamics are expressed in decision making. Thus, the theory locates innovation as a characteristic of a sector not of individuals within a sector. Therefore understanding why home builders innovate requires focusing on characteristics and dynamics of the home building sector, in particular, its network characteristics. With this emphasis in mind we briefly consider literature which makes a contribution to this topic, including construction, networks and socio-technology regimes.

Learning about networks from other literature

1. Construction literature.
In the construction sector, the completion of typically large-scale and distinctive projects requires that many contractors come together for the project. They then disband and may or may not work together in future. The home building sector appears to be similar in that the typical building involves many subcontractors. It differs, however, in that builders may use the same subcontractors repeatedly as they know and understand them. If we assume that there is similarity between the construction sector and the home building sector on the topic of networks then we can learn from the construction literature about how these networks operate.

Anderson at al. (2004) report how a lead firm configured a network of influential partners to induce solar energy projects in the Sydney Olympic village. Important factors in success were configuration of resources, commitment of actors, and translation of activities. Their theoretical approach was to recognise the level of the firm within the network, the overarching business context, and the rules of the game
to which all players must adhere\textsuperscript{4}. Importantly, they recognised that builders rely on established cognitive frames to manage coordination successfully, and by following ‘traditions’ or patterns of use, operate using established practices. (These concepts fit nicely with the concept of habitus mentioned earlier.) A number of practices work against collaboration, including: the short term and diverse nature of projects, task dispersion and competitive bidding processes, and weak appropriation regimes for benefiting from first mover advantages.

By configuration of resources they refer to the role of a consortium in the selection and management of partner networks throughout all phases of the project. This included sharing information, collaborating, and selecting suppliers willing to share some of the risks in return for exposure (i.e., being identified as innovative in a public setting). Commitment of actors required knowledge brokers to work with firms from different industries to achieve innovations. Translation of activities involved knowledge dissemination in order to develop new ways of doing things. Energy efficient benefits derived from using already developed technologies.

The attention to relationships in building networks was the explicit focus of Holmen at al. (2005) in their study of multi-storey, timber-frame residential housing in Denmark and Norway. They recognised that many government policy initiatives try to address the lack of innovation in housing by attempting to increase co-operation between firms. They theorise the nature of relationships as activity links, actor bonds and resource ties. Innovation results not from the efforts of a single firm but from the interplay between different firms. Therefore, degree of firm innovativeness is related to the extent to which a firm engages in relationships comprising co-operation and development. While the existing structure of a network acts as a brake on innovation, the activity links and actor bonds are important in bringing about innovation. They empirically test these ideas with case study data from government-led projects which intended to stimulate innovation. The resulting data showed that firms did try to co-operate and did aim at creating actor bonds, resource ties and activity links. However, these bonds, ties and links were loose not strong, reflecting uncertainty inherent in technology innovation. They interpret the results as supporting existing findings that innovation is difficult in the construction sector characterised by shifting coalitions working on unique projects.

Bossink (2004) specifies four categories of drivers of innovation in construction, including environmental pressure, technology capability, knowledge exchange and boundary spanning. Empirical research shows that innovation drivers are used by authorities, clients, architects, consultant and contractor to stimulate and facilitate innovation. Innovation occurs at the trans-firm, intra-firm, and inter-firm level.

\textsuperscript{4}They acknowledge a body of literature which operates at this higher level, for example, Dosi (1982), and this literature is briefly reviewed in the next section.
2. Networks literature

The literature reviewed immediately above suggests that the number of nodes and characteristics of the links in a network can have an impact on the uptake of an invention. It can be argued, for example, that complex networks make innovation difficult since any one change necessitates changes in many others. This would, of course, hamper the spread of the invention. On the other hand, successful diffusion through a large, widespread network is, by definition, a mark of greater innovation than diffusion through a small, more localised network. The impact of the innovation will be greater in the former case, with “all other things being equal”; a circumstance that is so rare as to be almost non-existent in the real world. What other network characteristics should we then consider?

In some home building situations where there is less involvement of an on-site builder and more involvement of subcontractors, we understand that on-site interactions are minimal, even to the extent that subcontractors do not have ‘smoko’ together. In social network parlance, this is an example of cliques within a network. Cliques are groups of people (or organisations, depending on the unit of analysis) that have a greater number of links to each other than they do to other members of the larger network (see Figure 3 for an example of such a network). A prototypical example of this is a remote workgroup that has a single line of communication back to the home office.

Figure 3: Example of a Clique Network

Not surprisingly, clique formation can work against innovation by limiting the number of links and by reducing perceived similarity amongst all nodes in the larger network. However, as Granovetter (1983) has shown, so-called “weak links” may, in fact, have a disproportionately large effect on change within a network. His argument is that those with whom we frequently interact are less likely to supply us with novel information. This follows from the observation that a human being will tend to prefer to associate with those who are similar to him or her in values, attitudes, cultural practices, and other such characteristics. Weak links, on the other hand, are those that are used infrequently and are generally formed with people who are somewhat dissimilar to the person. These sources are more likely to supply radically new perspectives and information to that person by virtue of their dissimilarities.
The discussion above leads to some interesting implications for the uptake of innovation. Cliques with few bridges to the larger network are less likely to change. However, the information that does come in, if acted upon, is likely to lead to quick and radical changes throughout the clique. Thus, in a ‘network of cliques’, innovation will not be a smooth and gradual process but rather one that leaps, then slows, only to leap ahead again.

We will end this section with a somewhat surprising finding in the literature. The preferential forming of certain links over others (i.e., the differentiation of weak and strong links) makes sense but, counter-intuitively, such preferential attachments may not lead to the best possible networks for the spread of innovation. In a computer simulation comparing networks of randomly generated links to those that were created more systematically, Noble et al. (2002) have shown that the higher the proportion of random links, the greater the spread of innovation. Thus, in light of Granovetter’s (1983) and Noble et al.’s (2002) findings, it may not be “who you know” that helps innovation; rather, it may be “who you are (slightly) acquainted with”.

3. Literature on socio-technological regimes

So far we have given attention to innovation theory that has a focus on the networks, relationships or systems. There is an interesting body of literature that takes and even wider view of context and examines long-term patterns of innovation that occur as part of ‘innovation fields’ or ‘socio-technical regimes’. This literature is briefly considered to acknowledge the broader context to networks.

A leading exponent of this approach is Geels and Schot (2007) who have developed a typology of multiple socio-technical transition pathways. Their approach is to take a multi-level perspective on transitions, including niche innovations, socio-technical regimes, and the socio-technical landscape. Niche innovations form at the micro level where radical innovations emerge. Initially, these are unstable socio-technical configurations with low performance, carried and developed by small networks of dedicated actors, often outsiders or fringe actors.

Socio-technical regimes refer to shared cognitive routines in an engineering community and includes the broader community of social groups and their alignment of activities. These regimes include markets, user preferences, industry policy, technology, culture, and science. The socio-technical landscape forms the exogenous environment beyond the direct influence of niche and regime actors and in which change takes place slowly. Overall, the multi-level perspective argues that transitions come about through interactions between processes at these three levels. Niche innovations can merge into the socio-technical regime, bringing about adjustments in the regime. Over time changes in the regime influence the landscape.

An important point is that the multiple-level perspective acknowledges the contingent nature by which niches innovations may become stabilised within a socio-technical regime. This point is developed by Konrad et al. (2006) who use the socio-technical regime approach to consider the contingent nature of innovation pathways.
which are influenced by developments in the context of the innovation, and to considering how regimes may be changed with radical technologies to lead to more sustainable ways of fulfilling societal functions. They consider the prospects for smart buildings, those that allow for regulation and communication between building services and appliances. Their approach is to not to set a normative starting point of wider diffusion of an innovation but in exploring a range of possible futures which may or may turn out to be more or less favourable for an innovation. To do this they follow the four steps of analysing an innovation field, examining the context of the field, exploring the range of different possible variations in the shape and provision of the innovation, and then elaborate scenarios on how the innovation, the socio-technical regimes and the landscape may change.

Conclusion – how best to encourage home-builder innovation?
The findings of this literature review inform our knowledge about home-builder innovation generally and can be used to develop policy relevant to the New Zealand situation. In addressing this topic we use two strategies. The first is to note what other countries have done to support builder innovation, and the second is to show how awareness of different theories of innovation can guide policy formation. Our general view is that the literature review of innovation theory indicates that policies recognising the networked nature of innovation are more likely to be effective.

The challenge for policy discussion is to take a viable position between conservatism and enthusiasm. The former position is often taken or advocated by academics reluctant to speculate. However, if taken to the extreme this position can result in banal findings. The latter can be dangerous for academics not fully familiar with the home building sector. It is not the role of academics to presuppose that their knowledge of the sector is sufficient to allow for strong policy recommendations. In taking a position between conservatism and enthusiasm we are leaving space for those with expert insight into the home-building sector to develop their own policy but in ways that are informed by knowledge of home-builder innovation.

1. Recent government policy initiatives
In considering the implications for policy, Hassel et al. (2003) reviewed federal policies in the USA and observe that they have repeatedly recognised the benefits of innovation and they have sought to learn from past experiences. The three major changes in recent times have been a move from top-down to bottom-up approaches, a broadening interpretation of technology and innovation (from direct engineering advances to information technology), and an increased focus on broader whole-house and systems approaches.

More specifically, Koebel (1999) provides a summary of relevant US policy. The building industry supports federal assistance for building technology. It does this through national construction goals, the Building America Program, and the Partnership for Advancing Technology in Housing (PATH). The Building America Program is sponsored by the US Department of Energy to reduce energy use in new homes. Partnership for Advancing Technology in Housing is designed to improve quality, cost-effectiveness, durability, safety, and the disaster resistance of housing.
It has numerical targets to meet, and provides new product information through the NAHB Research Center via the internet.

The national construction goals for homebuilding are reducing production costs through improved technology, shortening production cycle time, and improving product durability. The seven strategies to achieve these goals include:

- Establish and maintain an information infrastructure responsive to the needs of builders, designers, subcontractors, manufacturers, code officials, and consumers.
- Develop and implement improved methods for assessing and increasing the durability of specific types of building products.
- Improve the efficiency of the housing production process.
- Improve the efficiency of the regulatory and new product approval process.
- Develop an improved understanding of the performance of conventional light frame structures.
- Foster the development and commercialisation of innovative products and systems based on input from the building community.
- Expend markets and marketability for products and systems that reduce cost and improve durability.

In terms of policy, Koebel (2008) recommends that a two-fold strategy is used to differentiate policies for small, custom builders from those for large, production builders. Since the technology champion in the smaller firms is often the owner, who may use innovation to establish a niche, smaller firms are more likely to be partners in demonstration projects. Since they are responsive to customer needs, they would favour environmental innovations rather than innovations designed to increase affordability. To support innovation in production firms, policies should target regional and corporate-level R&D and purchasing personnel, with a view to convincing them that manufacturers and suppliers will stand behind new products. It is important to show that innovation will not disrupt efficient production. These builders have limited opportunity to test innovative products or processes so other institutions should provide this service, such as governments, research organisations or universities.

2. Policy implications deriving from theoretical perspective

2.1 Micro-level theory
If one uses the adoption-diffusion model, one is constrained to focus on the builder as the source of innovation. Policy deriving from this perspective will therefore look to the builder and ways to directly influence him or her. One of the main themes here is the attention given to information. This is not surprising as the adoption-diffusion model relies on individual builders finding out about an innovation as a precondition to innovating. Research shows that builders get information from a variety of sources. In Queensland it was mainly by personal contacts. In the US, it was building product magazines, trade magazines and journals, or suppliers, subcontractors, and trade shows. Clearly, information sources play an important part in builder innovation by providing opportunities for builders to consider different
technological artefacts or processes. This information is more effective if it can be communicated in ways that improve familiarity or decrease uncertainty.

At the firm level, this research showed that innovative firms have staff who play multiple roles within the company, many with backgrounds in trade. These firms also have either lower management intensities or a technology advocate. Firms need to have staff to gather and process information about innovations or need to promote creativity. This suggests that policy should advocate that building firms, especially larger ones, should attempt not to become overly bureaucratised.

Generally, innovative firms have been found to be either larger and to operate in more counties, be national or regional firms, or multi family. They engage in industrial, modular, panelised, pre-cut house construction. This suggests that large house building firms can play an important role in innovation and perhaps could be considered as targets of particular policies.

2. Macro-level theory
If one uses a macro-level model of home-builder innovation, one is constrained to focus on the context of the builder as the source of innovation. Policy deriving from this perspective will therefore look to the context of the builder and indirect ways to influence him or her. This is illustrated by Hassel et al. (2003) when they suggest ways to improve innovation promotion by invoking their model of home-builder innovation. They suggest strategies that address each part of the system that the model represents. Among these strategies is the enhancement of research activities through provision of sustained research support. They support strengthening the knowledge base by supporting networking across the horizontal and vertical boundaries of the sector, coordinating government efforts, encouraging sharing of knowledge, and supporting education and training. Hassell et al. (2003) also support the process of innovation by supporting exploratory and applied research, changing the R&D tax credit, supporting development and demonstration, explaining the regulatory process to innovators, providing technical and standard development support, and advocating public procurement. Improved market linkages can be achieved by identifying market trends and opportunities, supporting product performance monitoring and evaluation, rewarding important innovations, creating linkages among markets, and creating financial incentives such as subsidies for end users of innovations.

Similarly, in terms of policy, Binder (2008) argues that change requires understanding the habitus of important stakeholders. Those seeking change need to gain support from natural allies. They need to bring together like-minded people and organisations around a particular project in order to develop alliances to deal with inevitable resistances. Further, in recognising that people have good reasons for their actions, change needs to focus on transforming practices, something that will take time. Binder observes that it is an open question as to whether the rate of

5 But having developed theory about innovation it appears that it is still difficult to manage.
change among builders is fast enough to meet impending environmental imperatives or whether more radical change is needed, such as regulation.

A networks perspective invites distinctive policy considerations. Lutzenhiser (1994) argues that understanding the functions of, and interactions between, markets (costs of credit, labour, materials, land, resale values), institutional/cultural processes (builders’ and buyers’ design preference, knowledge (trust, risk perceptions, definitions of quality, status and stigma), and organizational network dynamics (codes, design standards, appraisal, financing, insurance, supplier interests and macro-level-political imperatives) are essential to effective policy intervention. She states that:

- Building codes and regulations work fairly well in creating change and these can be coupled with inducements and relaxation of regulations.
- Barriers to design innovations should be removed from the secondary mortgage market.
- Energy prices can be increased to reflect the true marginal costs of supply.
- Cost savings are a poor incentive to status conscious buyers and builders.

The potential of regulation as a policy instrument to effect change in the home building sector appears to be limited. Beerepoot and Beerepoot (2007) show that Dutch energy policy did not contribute to really new innovations in hot water production technologies, and at best only improved efficiencies of conventional technologies. They show that the project-based nature of the home construction industry and the complex nature and defensive character of the building process means that builders are generally unable to be flexible in using different technologies so as to comply with the energy performance standard.

In another Dutch study that examined the potential to increase the use of wood in house construction, a clear link was found between sector characteristics and potential for, and resistance against, innovation. Goverse et al. (2001) showed that innovations in wood fit into the types of innovation identified by Slaughter (2000) and could be used in standard production processes without too much difficulty. However, material suppliers, a group with a significant impact, do not think in terms of using wood. Cost competitiveness, the emphasis on efficiency and standardisation, and the project-based co-operation prevents diffusion of knowledge about using wood. They concluded that policy needs to include public construction projects requiring use of wood, increasing information about wood and wood construction, supporting research on wood technology, and strategic alliances between wood and construction firms with research organisations. (These functions appear to currently be in application in New Zealand. NZWood is providing useful information about wood, FRST is funding research at the University of Canterbury on the use of wood in multi-story buildings, and there is a government policy requiring new state buildings to use wood where possible.)

Macro-level theory implies that innovation can be supported by changing the home building sector itself. This level of change can appear daunting. However, Gan (2000) indicates a way to initiate change. He recommends that the construction system not
be seen as an intentional, planned and controllable environment but rather as the product of dynamic interactions between technological progress, economic activities, and strategies of firms and institutions governing decisions and expectations. It is inherently changeful and changing. Therefore the introduction of new technology results in competing organisational forms and there is scope for new policies to manage change. This approach injects an optimistic note into policy debate which accepts the macro-level approach.

Finally, we note that these policy findings fit quite well with our emerging results from case studies of successful and unsuccessful technology users' innovation. In some cases, lack of capital or insufficient business network connections prevent or make difficult the goal of achieving innovation success. The small scale of many of these inventors heightens the effects of these network factors. Further, any policy intervention must do more than address individually the important factors inhibiting innovation success.

3. Implications for innovation centre(s)
The adoption-diffusion model lead to questions about information, such as what information do builders lack, and who serves as information brokers. These questions suggest that in independent innovation centre could play an important role in delivering these functions. Network theory of home building innovation emphasises the importance of influence agents and enabling agents, and this suggests a potential role for innovation centres. When Hassell et al. (2003) recommend supporting networking across horizontal and vertical boundaries in the building sector this also implies that there is a role for an innovation centre.

A general policy point from network theory si that innovation requires discourse coalitions – the sharing of ideas on the problem and its resolution and a multi-pronged policy platform aimed at key elements in the building network. These requirements for successful policy point to the need for an innovation centre.

4. Other observations
The US research illustrates more adoption diffusion model and theory, and is the home of survey research. The European research uses broader range of theory, typically taking the macro view. The Netherlands demonstrates exemplary work in home building innovation. It also has leading researchers on technology and innovation generally.
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