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What are the risk-related barriers to, and opportunities for, innovation from a business perspective in the UK, in the context of energy management in the built environment?☆

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ABSTRACT

Conventional prediction techniques have not performed well in anticipating changes in building services technology. An alternative theory based on the concept of a technology trajectory offers a better retrospective account. Used prospectively, this theory highlights the future role of integrated management system technologies, the vertical integration of markets, and the need for more effective focused interventions.

1. Introduction

The questions posed to this review are:

- How can government, business and academia aid a transition from research and development to proof of concept and finally to application, that stimulates innovation in energy management and in construction materials?
- What is the role of the energy markets and their business and regulatory network in energy-related innovation?
- What are the risk-related barriers to (and opportunities for) innovation from a business perspective in the UK, in the context of energy management in the built environment?

This paper uses the innovation literature to offer partial answers.

2. Services innovation: historical evidence

Building services have changed radically over the last 30 years. Conventional forecasting techniques (e.g. Department of Energy, 1977; RCEP, 1976) made a poor job of anticipating these changes. These techniques used a paradigm, still current, of new technology rolling out throughout the building stock as it becomes 'cost-effective'. But despite the failure of these predictions, the changes that have taken place show no overt sign of anything unusual. For example, data provided by the Building Research Establishment (BRE) for the domestic sector shows the characteristic S-shaped logistic curves associated with the normal penetration of consumer products in mass markets (Hitchin, 2007). We have to be cautious not to assume that the forecasting problem was the result of hidden 'barriers' to innovation, rather than just the wrong economic model. Indeed, a recent review of innovation in construction (Gann, 2000) shows the developments to be largely consistent with an application of mainstream innovation theory.

Banham (1969) argued that building services innovations showed a characteristic over the first half of the 20th century that we would now call a 'technology trajectory'. In this process, innovations in services were imported from industry into premium buildings and then migrated to commercial buildings, then to premium housing and finally to general housing. As in modern technology trajectory theory (Dosi, 1982), there is no pipeline from lab bench to market (the so-called linear theory). Instead a strong two-way interaction between 'first customer' and 'innovation supplier' marks the transition at each market sector boundary (Von Hippel, 1988). Recent NESTA reviews (Georghiou, 2007; Leadbeater, 2006) affirm this interaction as characteristic of mass-market innovation behaviour. The reasons for persistence of the 'linear theory' in public sector thinking (even in this review's terms of reference), when Gann identifies it as obsolescent in the 1970s, is beyond the present paper's scope.

What first pulls through innovations from industry to start them on their technology trajectories? Addressing construction innovation more generally, Bowley (1966) argued that this does not happen through technology push, but in response to external disruptions to building function. In modern terminology, the building together with its context forms a self-organising system. As externally applied stresses start to build up, a weak 'systems lock-in effect' between components retains the current paradigm

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for a while under increasing pressure, but eventually an innovation relaxes the stressed system to a fresh, if temporary, equilibrium. Relief through innovation in one part of the 'system' then redirects the external pressure to another component. This often creates a cascade of innovations that Hughes (1983) in a broader innovation theory context called a salient. The classic example is pressure from mounting central business district ground rents. Physical constraint on building height was released by the invention of the safe passenger lift. But with the height restriction removed new technology was then needed to condition occupied spaces high above the ground without inducing large updrafts.

3. Does the trajectory work prospectively?

Gann (2000) has recently reviewed this area and largely reaffirms the Banham–Bowley model, though he does discern one new mechanism shaping the direction of innovation in construction at the top end of the market—the adoption of rapid prototyping techniques. Building services' adherence to a single technology trajectory has a rationale that makes it more than just a historical curiosity. This trajectory minimises the distribution of risk, with the highest development costs occurring where the profit margins are largest. It matches learning curves in performance and production to the price and performance demands of the developing market. It also aligns with aspirations. Buildings carry a large esteem value as products. The trajectory introduces innovations to a sector's occupants from the sector to whose values they can most realistically aspire. This review has found no innovation in building services introduced to social housing that has ever migrated 'upwards'. In this respect, services innovations have more in common with innovations in private cars than in other construction products or construction techniques. For low-energy or low-carbon technologies to diffuse in this way requires that they become premium products. However, on an argument first advanced by Veblen (1899), and now deeply embedded in the 'sustainable consumption' critique (Jackson, 2006), we might fear that the signifier of a premium building in the late 20th century was that it was conspicuously wasteful to match its luxurious finishing. If energy-efficient devices have penetrated the market at all they seem to have done so through other virtues such as lasting longer or being quieter, smaller or cooler.

The trajectory model predicts a strong dependence on effective performance and capital cost, but only a weak dependence on running costs. This is because energy costs, in contrast to system performance, are well below the threshold of concern in most buildings. Indeed, 'fuel poverty' policies aim to make the whole market use energy without any service compromise. This is not strictly a 'market failure,' since it is the high transactional costs of making optimal choices that are steering purchasers to suboptimal solutions. In theory, consumers can welcome some regulation or standard setting because it still provides a better outcome overall (Stern, 2006, pp. 380–382).

The model offers a rationalisation for two elements of the building services market that defied the 'cost-effectiveness' projections. Formal investment appraisal saw double glazing as poor value. In fact it provided conspicuous esteem, acoustic privacy and visible value to property. BRE figures show its rapid market penetration from private to social housing. In contrast, investment appraisal made a case for district heating in social housing, but without a marketing precedent in the private sector it simply became a stigma of Class D deck access living. Electric storage heating, kept alive with a little help from energy policy, remains stubbornly in Class C/D.

4. The diffusion of soft technologies

Does the trajectory apply to soft technologies like energy management? Computerised building management systems (BMS) give some encouragement that the answer is a qualified yes since they have followed the classical trajectory. The technology was introduced into premium commercial buildings from process control in the 1970s, to solve problems with managing widely dispersed plant rooms. It is now common for a commercial building to be fitted with 'integrated BMS' combining space conditioning, security and fire (Levermore, 2000). It is in this form that the technology is entering the top end of the housing market. It seems almost inevitable that as domestic services integrate (e.g. home entertainment and security), interfaces will emerge to the security, space conditioning, hot water and lighting systems. A first premium application might be in housing with relatively complex service systems, for example housing that uses fuel cells or micro-CHP, or demand management tariffs.

However, while BMS energy management technology is following the standard trajectory, its diffusion is largely about the delivery of a better service, such as fan or pump failure alarms, rather than running efficiency. Yet in truth, the energy consumption of a modern complex building such as a hospital is more an emergent property of its original design than one which is determined by it. So BMS technology has significant potential in low-carbon energy management. But, as was argued before, there is little incentive today to follow through efficiency strategies once satisfactory conditions are attained. Building energy labelling based on performance and used in a 'post-Stern' context where low carbon is a premium attribute would change the situation. It remains to be seen whether the UK's proposed asset-based performance certificate based on design criteria has enough traction.

The outsourcing of facilities management is now a widespread 'soft' technology that has diffused down as far as housing complexes, but again the performance contracts are currently in the form of service provision rather than energy economy. It has frequently been suggested that 'energy services companies' (ESCOs) might form a business model where the service contract remained in place but the facilities management company had the opportunity to reap the reward of improving the efficiency of its provision. An analogy of this business model exists in IT where an outsourced contractor would provide software services but also own and operate some hardware. It is hard to convincingly eliminate an ESCO model from energy management in the next 50 years but to date the business model seems to have difficulty surviving. In one recent review (Dayton et al., 1998), the ESCO is seen as vulnerable to absorption by 'retail energy companies' (RESCOs). The argument runs that if savings are to be made in energy supply then some will also relate to issues such as peak demand and energy storage, so the retail company might be better buying the ESCO than trading with it.

5. New disruptors

While we can use existing trajectories to project further innovation uptake, it ought to be possible to identify candidate new disruptors that will trigger new trajectories within the Foresight horizon. The rationale of the current Foresight exercise hints that over this period, conspicuous waste of fossil fuels will cease to be an effective Veblen 'signifier' as climate change moves from conjecture to reality and governments look for revenue sources to fund adaptation expenditure. Tipping points in mass markets tend to be very rapid, and few building services have a lifetime much over 10 years.

When looking for other 'disruptors', possibly the most obvious is that the UK becomes a net energy importer for the first time in its history in the next 50 years. Historically, energy-efficiency innovations have occurred predominantly in countries that are sensitive to energy import vulnerability or extreme weather events. Energy security is vital in buildings, and building users pay a high price to ensure the availability of supply. Indeed, Gann's complex buildings of the 1990s are even more dependent on reliable energy than Banham's of the 1960s. This argument suggests that new technology aimed at managing load is more likely to be pulled through into building energy management than technology focused only on annual energy consumption. It is impossible to disentangle whether renewable energy and distributed distribution are not synonyms for local and hence secured energy, and that energy management really implies a future in which we survive on what was once designated 'standby' supply (Patterson, 2007). This disruption scenario is one where ESCOs are likely to be absorbed by 'RESCOs'. It also accelerates the integration of security and building services management.

6. Implications

What are the implications of this analysis for business, government and academia? A number of factors, such as prevarication in regulation and conservative public procurement practices, have disadvantaged the UK in the past as a first market of choice for innovations in environmental technology (BERR, 2007, pp. 1–22). Matters are exacerbated in construction, where a long tradition of aiming for cheapness makes it difficult to foster robust innovation. At the premium end the industry is now able to handle complex projects at world-class standard, but at the low end it is rapidly building some of the worst housing since the 1960s (Sustainable Development Commission, 2007). Evidence of mixed signals that might make investors nervous is that while proposed regulatory targets for all housing in 2016 are so ambitious that they have never been achieved even in enthusiasts' 'eco-homes' a statutory building energy label display scheme is only to apply to large public buildings. These issues are not fatal, but if not addressed they may divert risk takers to open first in other markets.

What does the technology trajectory theory suggest would make for more rapid transitions and diffusion in UK buildings? First, it cautions against placing too much reliance on theoretical 'cost-effectiveness' calculations for setting priorities unless they are developed into much more sophisticated techniques (e.g. Ellingham and Fawcett, 2006). Second, while setting a carbon price is good discipline, on its own it is likely to have only a weak effect in energy management investment. Tradable permits might give a different outcome but only if over-allocation could be avoided. Third, the theory would try to bury (again) the linear theory of innovation, cautioning against the siren call of funding innovations for vast low income housing markets before getting ideas to work in smaller but more profitable niches earlier in a technology trajectory. Fourth, it would focus effort on accelerating the transitions between sectors.

Government regulatory regimes need to avoid creating sector boundaries. 'Cost-effective' regulation that equates marginal costs across the sectors of a regulated market, while well intentioned, fails to recognise that innovation is easier to seed in the premium sectors (BERR, 2007, pp. 34–37). So-called 'dynamic' regulation would involve the migration of standards down the technology trajectory on a predictable basis rather than setting long-term, uniform aspirational targets. Public domain academic scholarship could be profitably directed at understanding how a device actually works in one sector before it is re-engineered for the next. Public procurement needs to be innovation focused, with an emphasis on pulling innovations along the innovation trajectory rather than 'trying out' wild ideas.

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