DEVELOPMENT OF THE SUSTAINABLE BUILDING AND CONSTRUCTION PRODUCTS INDUSTRY IN AUSTRALIA

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Abstract

This paper draws on a major study the authors conducted for the Australian Government in 2009. It focuses on the diffusion issues surrounding the uptake of sustainable building and construction products in Australia. Innovative sustainable products can minimise the environmental impact during construction, while maximising asset performance, durability and re-use. However, there are significant challenges faced by designers and clients in the selection of appropriate sustainable products in consideration of the integrated design solution, including overall energy efficiency, water conservation, maintenance and durability, low-impact use and consumption. The paper is a review of the current state of sustainable energy and material product innovations in Australia. It examines the system dynamics surrounding these innovations as well as the drivers and obstacles to their diffusion throughout the Australian construction industry. The case product types reviewed comprise: solar energy technology, small wind turbines, advanced concrete technology, and warm-mixed asphalt.

The conclusions highlight the important role played by Australian governments in facilitating improved adoption rates. This applies to governments in their various roles, but particularly as clients/owners, regulators, and investors in education, training, research and development. In their role as clients/owners, the paper suggests that government can better facilitate innovation within the construction industry by adjusting specification policies to encourage the uptake of sustainable products. In the role as regulators, findings suggest governments should be encouraging the application of innovative finance options and positive end-user incentives to promote sustainable product uptake. Also, further education for project-based firms and the client/end users about the long-term financial and environmental benefits of innovative sustainable products is required. As more of the economy's resources are diverted away from business-as-usual and into the use of sustainable products, some project-based firms may face short-term financial pain in re-shaping their businesses. Government policy initiatives can encourage firms make the necessary adjustments to improve innovative sustainable product diffusion throughout the industry.

Keywords: sustainable products, innovation, construction industry, Australia

INTRODUCTION

World economic activity is expected to increase five-fold and global manufacturing activity to triple by 2050 (Matthews et al., 2000). With this predicted growth, increased importance is being placed on the development of sustainable products that minimise environmental impact, but also maximise performance, durability and re-use (Terry et al., 2007).

As a result of increasing public awareness of sustainable development and legislative and financial drivers, manufacturing firms are developing sustainable building and construction products to meet growing demand. Simply, sustainable products in the built environment refer to building and construction components that have environmental attributes or a lower environmental impact than alternative products (Terry et al., 2007). Sustainable products can be stand-alone, but are mostly used as a part of an integrated sustainable design strategy; and selection is rarely made in isolation. For example, the selection of a spectrally sensitive glazing product (that reflects radiant heat) would be used in conjunction with an external shade product to maximise energy efficiency.

Thus, a major challenge for designers and clients is the selection of appropriate sustainable products that are compatible in an integrated sustainable design solution. In selecting a suitable product, design considerations for the entire system should be considered such as: energy efficiency, water conservation, maintenance and durability, low-impact use and consumption (Terry et al., 2007). Construction and manufacturing considerations should also be taken into account such as distribution, efficiency in production and recycling.

This paper presents a review of the current state of sustainable energy and material product innovations in Australia. It highlights four case products, as examples of cutting edge development and discusses their proposed innovative contribution towards improving building and construction sustainability in Australia. Given the significant breadth of the topic, it has been necessary to profile selected innovations from across the full range available. However, despite the subjective nature of selection, authors sought advice from subject matter experts to confirm selection.

SUSTAINABLE PRODUCT INNOVATIONS

Case product types are now presented followed by a discussion of the system dynamics surrounding these products. The drivers and obstacles of product diffusion across the Australian construction industry are then discussed. The four case product types namely: solar energy technology, small wind turbines, advanced concrete technology, and warm-mixed asphalt, are presented in light of their expected system-wide impacts.

Solar energy technology (Photovoltaic)

Solar photovoltaic (PV) arrays generate electricity through solar energy with very little aversive environmental effects such as pollution or waste. Generally, they are also reliable products as they do not have moving parts, translating to ease of maintenance and long life spans.

Although PV solar panels are not a new technology to the building industry (the base concepts of the technology date back to the early 1900’s), the technology is constantly evolving and is currently offering considerable benefits over earlier innovations. One of the major barriers to the widespread use of this technology has been its limited efficiency in converting light energy into electricity. But as the technology has developed, so has its efficacy, which is continuing to improve. The latest performance from a photovoltaic cell device saw 40.8% of light energy converted to electricity, achieved in August 2008 (NREL, 2008). In Australia, the key market for this technology has been for 'off-grid' systems in the industrial, telecommunication and agricultural industries, followed by off-grid building residential systems (ABCSE, 2006). The off-grid applications for residential buildings include supplementing standard utility power and electricity backup. Large PV arrays have also been used in commercial buildings for offsetting power distribution during off-peak times. Recent cutting-edge research by scientists at the Australian National University (ANU) has developed transparent 'printable' PVs on a thin film polymer (Stohr, 2009). It is expected this innovative manufacturing process will not only significantly increase PV's cost-effectiveness, but open up a range of applications on buildings such as glazing integration.

Another emerging application of PVs is Building-integrated Photovoltaics (BIPV). Simply, BIPV refers to the use of photovoltaic materials as a replacement to conventional building materials, such as roofs, façades and glazing, thus improving aesthetics and integration within the architectural features of a building (Bhargava, 2007). In the Australian building industry, this innovative approach has been successfully trialled and has proven to achieve valuable electricity generation under Australian conditions (Prasad and Snow, 2004). It is expected the market for such products will expand as the PV technology further evolves.

Small wind turbines

Australia is known to have abundant and powerful wind resources, unrivalled in most of the world, which have yet to be fully tapped (Herbert et al., 2007). Wind technology has seen rapid growth worldwide (Price, 2006) and wind power currently attracts the most investment in the renewable energy resource sectors across the globe (Boyle et al., 2008). The investment in wind power generation has mainly focused on large wind farming, but an emerging area of innovation is small wind turbines that can be used to supply remote, off-grid electrical loads on various built assets.

Currently, the wind energy generation industry has invested heavily in large wind turbine aerodynamic profiling, with much less emphasis on the smaller wind turbines (Ackermann and Söder, 2000). However, small wind turbine research groups are emerging due to the increasing government emphasis on self-sufficient energy generation. For example, the Australian Government announced in August 2008 it would provide funding for a 'small wind turbine' test centre at the Research Institute for Sustainable Energy at Murdoch University in Perth, Western Australia (Garrett, 2008). Such research will assist in the development of small wind turbine technology to be used in the residential and commercial building sector. According to a global market report on small wind turbines by the American Wind Energy Association (AWEA, 2008, p.9), the recent technology advances globally in this field include:

- active pitch controls to maintain wind capture during high winds and automatic adjustments to blade pitch for best angles of attack
- vibration isolators and slower rotor speeds to lessen sound (wind turbines are traditionally very noisy)
- advanced blade design
- operational capabilities in low wind
- self-protection mechanisms during extreme wind conditions

- single models for on-grid and off-grid use
- wireless display and software support
- integrating turbines into existing structures such as utility poles, and
- aesthetically more attractive designs.

Wind turbines can be used not only for energy generation on residential buildings but also to power central air extraction/ventilation systems in large commercial or industrial buildings. A successful example of this latter approach is the CO2 building in Melbourne. The CO2 building has six wind turbines to power an air extraction system through ducts on the building's north façade. The wind turbines were purpose-built and replace the requirement for electric fans that would traditionally power air circulation systems (ABSJ, 2006).

Advanced concrete technology

Concrete technology has advanced rapidly over the last ten years. These advances have been in the areas of mixture proportions, aggregate materials, structural design, durability requirements and testing. However, many of these advances remain outside standard practice worldwide (Vanikar, 2004).

One product that has gained greater acceptance in the construction industry is High Performance Concrete (HPC). HPC contains specialised aggregate and admixture materials that are combined with traditional Portland cement (with generally high cementitous levels) to assist in achieving high durability and strong compressive performance. According to Vanikar (2004), emerging refinements include:

- the development of advanced chemical admixtures such as accelerators, retarders, corrosion inhibiters and water reducers
- advanced supplementary cementous materials such as fly ash and silica fume
- extended use of recycled materials in concrete, which are generally used as concrete and slag aggregates
- new concrete mixture proportions, as a result of improvements in concrete batch trailing and research, where continuous grading and workability tests are gaining greater acceptance
- new variations in concrete structural and durability properties suitable for specific conditions, e.g. high strength concrete for bridge design and durable concrete mixes for pavement design
- advances in concrete test procedures (such as shrinkage and air-void testing), which improve strength and durability outcomes, and
- improved concrete construction control – including advances in curing processes and the use of software to monitor concrete strength development and prevent cracking.

A recent innovation in supplementary cementous materials is a product called 'Eco-cement' developed by TecEco in Australia. Eco-cement replaces the calcium-base lime ingredient that is traditionally found in Portland cement with reactive magnesia (a form of magnesium oxide). The traditional manufacture of Portland cement requires high kiln temperatures to form calcium carbonate (and thus high energy use). However, Eco-cement can be kilned at around half the temperature (Pearce, 2002). This decrease in energy consumption can be quite significant as it is estimated the manufacture of cement accounts for approximately 7% of total man-made carbon dioxide emissions (Pearce, 2002).

According to Pearce (2002), the greatest benefit of Eco-cement over traditional Portland is its ability to rapidity absorb carbon dioxide from the air when it has been cured through a carbonation process. Therefore, if Eco-cement is used to produce masonry blocks, it has the potential to remove carbon dioxide from the air much like the function of a growing tree. Other benefits include incorporating recycled materials as the aggregate without losing structural strength. To date, this product has not gained wide acceptance within the construction industry and the base source materials remain expensive (e.g. magnetite).

Warm-mixed asphalt

An interesting and emerging product innovation in the road construction sector is a road surface application called Warm-Mixed Asphalt (WMA). Traditionally, hot-mix asphalt is created by heating a bitumen binder and aggregate to very high temperatures (around 170 degrees Celsius), which is then laid on the road surface hot and cures while it cools. Warm-mix asphalt (developed in Europe in the early 2000s), uses a two-stage process, where firstly, the asphalt is made using a specialised soft binder that allows the binder/aggregate mix to be heated at much lower temperatures (approximately 120 degrees Celsius); and secondly, a second binder is added (mainly a foam bitumen) that forms a combined mixture in similar grade to standard hot asphalt (AAPA, 2001). The use of WMA can significantly reduce cost as it uses up to 30% less fuel (a major ingredient in bitumen). It also produces a third less carbon dioxide emissions and dust than traditional methods (Whelan, 2009). Although testing is continuing to evaluate enduring performance, it is expected the warm mix may become a new benchmark for road construction worldwide (Whelan, 2009).

This paper now presents the product system dynamics surrounding the uptake of these innovative sustainable products; followed by a discussion of the issues impeding sustainable product diffusion in the Australian construction industry.

PRODUCT SYSTEM DYNAMICS

Project-based firms (such as contractors and consultants) are increasingly becoming aware of the importance of Ecologically Sustainable Design (ESD) for their future commercial viability, with many contractors expecting ESD and the use of sustainable building products to be mainstream in the next five years in Australia (Crabtree and Hes, 2009). Also, as a result of the increasing emphasis placed on ESD by construction clients and government, product supply networks (i.e. manufacturing firms and distributors) are focusing on the production and distribution of sustainable products to meet increasing demand. Currently, this demand is creating specialised markets, comprising small to medium-sized manufacturing and project-based firms in many cases.

The promotion of sustainable products is focused on the activity of the supply network (i.e. manufacturing firms and distributors). However, the development and implementation of innovative products in the marketplace is strongly driven by demand from clients and owners, and by users/facility managers who are concerned about long-term asset efficiency (e.g. life cycle cost savings). The uptake of sustainable products is also driven by project-based firms through a facilitation role. Project-based firms facilitate the diffusion of these products by prescribing to their clients the benefits that can be gained. For example, cost consultants can play a key role in promoting sustainable building options by quantifying the financial rewards and life cycle costing benefits to their clients and the design team (Clark, 2003). Also, technical support infrastructure actors (such as industry associations) play a role in promoting the benefits of the innovative products at an industry level, and drive advances in product technology through research and development.

Regulatory and institutional actors (e.g. government authorities) within the product system assist in driving technological development and in increasing diffusion rates. The use of innovative finance options and positive government incentives are currently major drivers for the uptake of sustainable products in the Australian construction industry – particularly the residential building sector. It is expected that once the incentivised products gain market penetration and the technology advances, economies of scale will potentially bring prices down. For example, the Australian Government Solar Credit scheme offers a financial rebate for home owners, small business and community groups on the purchase of energy production systems up to 1.5 kilowatt capacity. This includes photovoltaic arrays, wind turbine and micro-hydro electricity generation (DEWHA, 2009). It is expected that increased demand, competition and production volume may bring prices down.

Government regulation also has a major role in the development and uptake of sustainable products. The Building Code of Australia (BCA) has incorporated minimum mandatory energy efficiency requirements for buildings, and Australian Standards dictate the minimum performance standards of products and new technology (such as minimum standards for the manufacturing of residential photovoltaic arrays). Also, Australian local and state governments have their own building environmental performance standards to encourage ESD in their regions. The combination of these regulatory and financial incentive approaches has been successful in promoting the uptake of innovative sustainable products in Australia; however, further education for project-based firms and the client/end users about the benefits that can be achieved may be beneficial. This would include both residential home buyers and commercial and government infrastructure clients.

SUSTAINABLE PRODUCT DIFFUSION

Innovation awareness is critical to the 'technology transfer' process. Many construction industry commentators agree that despite the increasing importance placed on ESD and sustainability, there remain barriers to wide spread adoption of these principles (and thus the acceptance of new products) (McGee et al., 2007, Crabtree and Hes, 2009). The levels of diffusion of sustainable products that are commercially available (and are set to be rolled out) is partly influenced by regulatory and pricing mechanisms in the industry (Crabtree and Hes, 2009). For example, a recent move towards the ratification of a uniform 'feed-in tariff' scheme in Australia potentially could improve the adoption of renewable energy-producing products (such as solar photovoltaic arrays) in the residential building sector. Currently, all Australian state governments have their own feed-in tariff schemes that offer residents the opportunity to be paid a premium for their locally generated electricity, to be fed back into the main power grid. Usually, locally generated electricity is metered separately from household energy usage, and is offset at a higher rate than the retail cost of the electricity from the utility company. In 2008, the Council of Australian Governments agreed to develop a set of national principles for new feed-in tariff programs (COAG, 2008). Regulatory improvements to the feed-in tariff systems in Australia have the potential to increase the cost-effectiveness of local energy production (as a part of a building system).

According to Terry, Walker-Morison et al. (2007, p.12), some of the real or perceived barriers to the diffusion of sustainable building products and materials in Australia include:

- sectoral conservativeness and slow building turnover, limiting exemplar projects to showcase new products
- diversity of rating tools resulting in confusion over the evaluation processes
- inconsistency in the industry's response due to a lack of mandatory sustainability standards
- high perceived costs, as cost evaluation is erroneously based on up-front costs, rather than on 'whole of life' costs
- inadequate in-depth knowledge to understand and assess new products and their integration and broader implications within the building system, and
- the need for new mindsets including a willingness to revise design and construction processes and timeframes to accommodate new product 'constructability' requirements.

The development of innovative sustainable products and processes are driven by the involvement of organisations large enough to absorb R&D and implementation costs. However, a major barrier to the development of these products is that the majority of the industry is made up of small to medium-sized firms who do not have the capacity to develop and implement such innovations in an emerging market. The industry needs to see the formation of new alliances between manufacturing and project-based firms to overcome cultural and resource obstacles to the development and diffusion of sustainable products and processes (Binder, 2008).

According to Crabtree and Hes (2009), a consistent approach is needed for dissemination of building product information (characteristics, costs and performance) to Australian designers and contractors. This includes improved collaboration and knowledge sharing to 'dismantle the myths and confusion perceived to be surrounding the financial implications of widespread implementation of sustainable design aspects' (p.223). It is expected that once the industry matures (and sustainable products gain greater acceptance), environmental performance will become a key consideration in the design and construction process and a consolidation process will occur (Terry et al., 2007). As more of the economy's resources are diverted away from business-as-usual and into sustainable products, some firms will face short-term pain in re-shaping their businesses. Government policy initiatives can help firms make the necessary adjustments.

CONCLUSION

This paper has profiled emerging sustainable product innovations offering significant performance improvement across the Australian building and construction products industry. These innovations contribute in a significant way to creating a more sustainable built environment in Australia. Given the significant breadth of the topic, it has been necessary to profile selected innovations from across the full range available. This selection has been necessarily subjective, but is nevertheless based on the advice of subject matter experts. It is expected future research will be able to quantify the relative promise of the profiled innovations, but as a starting point, this paper has mapped the product system dynamics surrounding the uptake of these innovative sustainable products; and identified key obstacles impeding their wider uptake.

Overwhelmingly, this paper points to the important role played by Australian governments in facilitating improved sustainable product adoption rates. This applies to governments in their various roles, but particularly as clients, regulators, and funders of education, training, and research and development. In their role as clients, Australian governments can better facilitate innovation by reviewing their specification policies and adjusting them to encourage the uptake of advanced sustainable products and associated innovations. As a result of a major shift in government policy towards this goal, it is expected private sector clients would follow suit. In their role as regulators, Australian governments face particular challenges associated duplication and uncertainty in how sustainable products are approved for use. This means that innovators often face high costs associated with gaining approval for products across multiple government jurisdictions. Also, regulatory and pricing mechanisms to encourage sustainable product use by consumers/clients require ongoing ratification across government jurisdictions. In relation to the BCA, recent reforms in environmental standards/benchmarks have helped to encourage the uptake of innovative sustainable products, yet greater emphasis on environmental performance, mandatory sustainability standards and performance-based regulations is encouraged.

Finally, in relation to education, training, research and development, the literature and subject matter experts agree that there is a lack of adequate understanding of the net benefits associated with particular sustainable product innovations. It is recommended Australian governments place further emphasis on education programs, training and demonstration initiatives to encourage a cultural shift towards decision-making based firmly on the consideration of long term whole-of-life costs and wider environmental benefits.

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