Institution: University of Aberdeen

Unit of Assessment: 15 (General Engineering)

Title of case study: Dynamic Insulation in Buildings

1. Summary of the impact

Ground-breaking research in the field of Dynamic Insulation (DI) at Aberdeen University has contributed to international efforts to combat climate change through the reduction of the carbon emissions associated with the heating, ventilation and air conditioning of buildings. Through the establishment of a spin-out company and the development of the world's first modular DI product, jobs have been created and developers have been able to use the first commercially available DI products and systems to meet strict new environmental targets. The success of such projects has led to greater public awareness of the issues around global warming.

2. Underpinning research

According to the Carbon Trust, emissions from buildings generate more than 45% of the UK's annual carbon footprint, and better insulation is critical in the fight against climate change. This is true for buildings in colder climates (where heating can account for around a third of total energy use) and those in hotter climates (where air conditioning can boost energy consumption - and the associated carbon emissions - to more than 2/3 of total energy use). Research led by Dr Mohammed Salah-Eldin Imbabi (at the University of Aberdeen since 1990) and his team at the School of Engineering has focused on the development of materials and technologies based on the properties of "dynamic insulation" to reduce energy use and de-carbonise the built environment.

Dynamic insulation (DI) is a technology that combines insulation and ventilation in which the heat energy escaping from a building is used to pre-warm incoming air through an insulation layer in the fabric of the walls, effectively turning the building envelope into a heat exchanger. In hot climates the same principle applies, with the insulation layer pre-cooling incoming air. Having established the basic science of how DI works in 1996 [1], the Aberdeen team went on to develop a basic prototype DI wall-element [2]. Using lab tests and simulation modelling they were able to quantify and fine-tune its performance and study how it operates as part of an overall building system [3].

At the next research stage, two different types of DI were tested and compared in the lab: permeodynamic insulation (where the wall-element is air-permeable and the air flows through the insulation material) and parietodynamic insulation (where the wall-element is air-impermeable and air flow is restricted to channels within the plane of the wall). Researchers found that the permeodynamic model also exhibited potential to function as a filtration system, removing potentially health-damaging nano-particulates from the air passing through it into the building [4].

As a result of the research findings, in 2004 a spin-out company, Energyflo Construction Technologies Ltd, was established with the aim of providing an investment platform for the development of a commercial DI building product. Field trials using specially built apparatus followed. Information from these was used to develop production prototypes for a new modular dynamic breathing wall system for use in new and retrofit building projects including the world's first modular DI product, the EF04 Energyflo® cell for commercial-scale construction of dynamic breathing buildings [5].

Between 2006 and 2008, in what were the first full-scale trials, the original Energyflo® cells were used by the house building company CALA Homes in the construction of a 4-bedroom detached

dwelling in Balerno on the outskirts of Edinburgh, and an Eco-Villa in Abu Dhabi. Heating, ventilation and air conditioning energy use was monitored in both projects and then quantified against existing standards in both regions. Results suggested a potential saving of 50% of the energy used to heat/cool domestic buildings, and up to 75% for commercial edifices [6].

3. References to the research

1. Taylor, B.J., Cawthorne, D.A. and **Imbabi,** M.S., "*Analytical investigation of the steady-state behaviour of dynamic and diffusive building envelopes."* Building & Environment, 31(6), p519-525, 1996. *This paper establishes and sets out the fundamental difference between diffusive and dynamic insulation and introduces the theoretical basis for quantitative modelling of the complex heat transfer effect that occur in permeodynamic insulation systems.*

2. ***Imbabi,*** *M.S., "Modular breathing panels for energy efficient, healthy building construction."* Renewable Energy, 31(5), p729-738, 2006. *The concepts underpinning development of the world's first modular dynamic insulation product, the Energyflo cell and the thinking behind it were first outlined in this paper.*

3. *Taylor, B.J. and* ***Imbabi****, M.S., "Environmental design using dynamic insulation."* ASHRAE Transactions, 106(1), p15-28, 2000*. The paper explores and defines the performance envelope for use of dynamic insulation as part of a system – i.e., building + dynamic fabric + HVAC plant.*

4. ***Imbabi****, M.S. and Peacock, A.D., "Allowing buildings to breathe."* Sovereign Publications, p85-95, 2004. *Introduces the concept and the basic underlying science that underpin the use of dynamic insulation as a filter of airborne particulate matter from the built environment.*

5. *Brown, A.R.,* ***Imbabi****, M.S. and Peacock, A.D., "The transforming technology of dynamic breathing building."* Ecocity World Summit 2008, San Francisco (USA). 24-26 April 2008. *This paper presents the key findings from Carbon Trust project, featuring a dynamic insulation roof incorporating the Energyflo cell, the world's first modular dynamic insulation product.*

6. *Elsarrag E., Aboulnaga, M., Peacock, A. and* ***Imbabi****, M.S., Dynamic insulation for energy conservation and improved indoor air quality in hot humid climates.* Invited keynote paper, ASHRAE 5th Chapter Regional Conference (CRC), Dubai (UAE), 1–3 November 2006. *This seminal paper presents the results from the first trial application of dynamic insulation in a hot-humid climate, to reduce air conditioning energy use and associated CO_2 emissions.*

Relevant research grants

1. *Collaborative research project on the application of dynamic insulation in the UAE, Dubai Municipality.* M S Imbabi (PI) and K Al-Sallal, 4 months commencing August 2007 (AED 140k).

2. *Carbon Trust RD&D Grant ARP 051-233, Full-scale performance evaluation of energy use and emissions reduction in dynamic breathing building construction*. M S Imbabi (PI), 2-years commencing July 2006 (£250k).

3. *SMART: Scotland* Stage (I) feasibility study grant to develop the "Environmental Building System".* M S Imbabi (PI), Scottish Executive and Industry, July 2004 (£60k).

4. *EPSRC Grant GR/K23461, The use of diffusive and dynamic insulation for combined heat recovery and ventilation in buildings*. M S Imbabi (PI), D Cawthorne, 3 years from September 1995 (£112k). The dynamic insulation technology stemming from the research is protected by several patents, patent applications registered designs and trademarks.

4. Details of the impact

In December 2006, the UK Government promised that all new homes would be 'zero carbon' from 2016 and introduced the Code for Sustainable Homes (CSH) against which all new homes would

be rated on a range of sustainability measures. The announcement had a galvanising effect on the house building industry and supply chain.

By August 2008, Aberdeen's monitoring results from the CALA Balerno-project were showing a 16% reduction in the total space heating energy requirement compared to a conventionally insulated building, resulting from the use of dynamic insulation solely in the roof – the walls, windows and doors were conventional [1]. Since December 2008, the Aberdeen spin-out company, Energyflo Construction Technologies (ECT), has attracted more than £2.5 million in additional venture capital investment [2]. In 2009/10, 9 new jobs were created at ECT, including the full time employment of a CEO, four product design engineers, a sales manager and a business design manager, followed by DI commercial developments (2008-2010), including a 47-house retrofit in Kirkwall for the Orkney Housing Association (2009); the Fair Isle Bird Observatory, which was fitted with Energyflo wall, roof and floor insulation (2009); and the “Eco-House” in Cranford, Northamptonshire, where DI was used in SpeedDeck’s roof construction (2011) [3].

All new building products must meet strict compliance frameworks, one of which is the assigning of a "U-value", indicating how much heat is conducted. As there was no recognised way of assigning a U-value to a DI product, Aberdeen researchers in partnership with the National Physics Laboratory and the Building Research Establishment (BRE) devised and designed a hot-box test capable of determining net heat transfer (2009/2010). This data, together with BRE's input, enabled a dynamic R-value for Energyflo dynamic insulation (used to calculate the dynamic U-value of the wall construction) to be assigned and written into the Standard Assessment of Performance (SAP) methodology in early 2011m meaning that house builders can use Energyflo products to meet the Government's 2016 environmental standards [4].

In 2010/2011, ECT completed three new licensing agreements with major manufacturers and received new expressions of interest from major clients, including national house builders and manufacturers using modern methods of construction. Among the development projects that followed are:

- Chorleywood Homes (2011): main contractor DBC Contracting and Architects PFG Design built detached four-bedroom homes in traditional masonry cavity using Jablite Dynamic Insulation [5];
- Wilmot Dixon (2011): DI retrofit to homes built in the 1950s and ‘70s at South Cambridgeshire Council's Rampton Drift properties in Longstanton [6];
- Stewart Milne (2011) : AIMC4 Developments 17 homes designed to meet Level 4 of the Code for Sustainable Homes on three sites: Portlethen, East Lothian in Scotland and Preston in Lancashire;
- Lovell Partnership (2012): dwelling at Bassaleg, South Wales fitted with DI partial cavity insulation.

In May 2012, two houses featuring Aberdeen's DI technology and product were completed by Lomond Homes as part of the Housing Innovation Showcase in Dunfermline. During 2012, over 2,500 construction and housing professionals visited the Fife showcase. Five hundred local people were also given the chance to tour the homes during a family day in May. [7]

The DI products that were developed and inspired by the original research have won a number of UK awards and professional accolades, including in 2011 the Green Apple Award for Lomond Homes developments using DI [8]; the 2011 International Green Awards (Dynamic Insulation in Best Green Production Innovation category); and the 2012 EEF Future Manufacturing Awards (Winner of the Climate Change Opportunity Award for Jablite's Dynamic Cavity Products).

As a result of DI research, development of energy-saving products and evolution of successful private public partnerships, Imbabi is regularly invited to speak about the Aberdeen research at non-academic meetings worldwide, including Ecocity World Summit (San Francisco, April 2008, 1,500 attendees included members of the public, representatives of international governments and business); the European Environmental Bureau Brokerage Event (Brussels, July 2012) and the Housing, Carbon Reduction and Climate Change Conference (Edinburgh, Oct 2012, attended by Government ministers and key stakeholders from the house building industry, its suppliers and associated professional members).

Media coverage of Aberdeen University's research and Energyflo has appeared in many technical and trade journals including in-depth articles in "Eco-Construct" magazine (Winter 2011) and "Timber and Sustainable Building" (Spring 2011).

Since 2010, Imbabi has been a member of the Technical Standards Committee of the Emirates Green Building Council (EGBC). In this capacity, he assesses the environmental impact of various construction projects and sits on the judging panel of the EGBC Awards.

5. Sources to corroborate the impact

1. The former Technology Director at the Carbon Trust who sits on the Technology Strategy Board) – http://www.dbb-project.com/ can confirm the results of research stemming from the Balerno project.

2. An Investment Director at Sigma Capital Group PLC can confirm the investment of ~£2.5 million by SCGP into Energyflo Construction Technology.

3. The Technical Director at SpeedDeck, http://www.youtube.com/watch?v=6VCPXFtZVaM can confirm that SpeedDeck was licensed by Energyflo to produce and market a parietodynamically insulated roof system.

4. Dynamic Insulation included in SAP Appendix Q - http://www.sap-appendixq.org.uk/page.jsp?id=43. *The BRE consultant who oversaw the process leading to inclusion of dynamic insulation and a range of Energyflo products in SAP Appendix Q can confirm the impact.*

5. Jablite Dynamic Cavity Insulation build in Chorleywood - http://www.jablite.co.uk/. Richard Lee, Sales Director from Jablite speaks of his experiences with Energyflo at Ecobuild 2011, confirming that Jablite was licenced by Energflo to produce and market a range of parietodynamically insulated wall products. http://www.youtube.com/watch?v=KgUMaTLg504

6. The Principal Consultant (Energy Services) at Willmot Dixon can speak to their use of Energyflo's dynamic insulation technology for retrofit of the Rampton Drift project.

7. Housing Innovation Showcase, Dunfermline 2012: http://www.housinginnovationshowcase.co.uk/10801.html *The website gives details of the innovative Energyflo dynamically insulated dwelling design.*

8. Lomond Timber Frame win a Green Apple Award with Energyflo's Dynamic Insulation: http://www.lomondgroup.com/Main/News/1842/Zero+heat+loss+delivered+by+Lomond+Breathing+Wall+system/ and http://www.thegreenorganisation.info/.