Institution: The University of Edinburgh & Heriot-Watt University (the Alliance)

Unit of Assessment: 16 Architecture, Built Environment and Planning

Title of case study: 4: Radically improving built assets through reduced CO_2 emissions

1. Summary of the impact

Alliance researchers have demonstrated that it is possible to refurbish existing buildings, which make up over 90% of our stock of over 26m buildings, to achieve a reduction in CO_2 emissions of up to 80% (domestic properties) and 50% (non-domestic). The research has underpinned a shift of emphasis by UK government from new to existing buildings and the formulation of incentives to encourage building owners to make energy-saving improvements. In partnership with not-for-profit, public and private stakeholders, it has been used by national and local agencies to highlight the potential of improving the energy performance of traditionally constructed, timber-framed and residential mobile homes and incorporated into practical guidance by the Chartered Institution of Building Services Engineers. It is also the technical foundation for an educational software package developed with 100 school children and teachers and praised as exemplary by Education Scotland.

2. Underpinning research

In the UK, the built environment accounts for 46% of total carbon emissions. As new buildings make up less than 1% of stock each year, and at least 75% of current buildings are estimated to be still standing twenty years hence, radical action needs to be taken with existing built assets if current government targets on reducing emissions are to be met (at least 34% below the 1990 baseline by 2020 and 80% by 2050). In 2004, the Engineering and Physical Sciences Research Council (EPSRC) and The Carbon Trust took steps to meet this challenge, as the UK moved towards passing the Climate Change Act 2008. Under its Carbon Vision Buildings (CVB) programme, the partnership funded three research projects tackling CO_2 emissions and the built environment, including Tarbase (Technology Assessment for Radically Improving the Built Asset Base) led by the Alliance's Urban Energy Research Group at Heriot-Watt University (HWU).

The aim of the £1.4M Tarbase project was to investigate the potential for significant reductions in CO_2 emissions from existing buildings in the period to 2030. The work considered potential reductions from different perspectives, including end use equipment, building fabric, heating, air conditioning and ventilation equipment, on-site generation of heat and power and the carbon intensity of network electricity. Crucially, it also considered the effect of climate change on building energy needs and user acceptance and behavioural trends regarding building use. It ran from 1 July 2004 to 31 March 2009 under the leadership of Prof Phil Banfill (1995-present) and Co-Investigators Prof Marcus Newborough (2002-2008) and Dr Gillian Menzies (2000-present), supported by Andrew Peacock, Research Associate and Project Manager (2003-present), Dr David Jenkins, Research Fellow (2005-present), and various researchers from the Universities of De Montfort, Warwick, Surrey, Nottingham and Glasgow.

The Alliance research bridged the gap between building stock models (which provide information for policy but insufficient detail for the occupant or building energy manager) and detailed case studies (which provide very specific data that is too finely grained to provide generic guidance). It did this by modelling the energy performance of a number of buildings expected to be prominent in the stock in 2030 – from domestic properties to offices, supermarkets and schools – before and after the application of CO_2 reducing measures. The buildings were fully specified in terms of construction and location, internal activity, and HVAC (heating, ventilation and air conditioning) systems, with other inputs from hourly climate files in 2005 and 2030. The effect of 'demand-side' measures on emissions was assessed by bespoke models of IT/end use equipment and appliances, lighting, building fabric, glazing and alternative HVAC systems, while the effect of 'supply-side' measures was assessed by models developed for photovoltaics, micro-combined heat and power, micro-wind, solar thermal, air- and ground-source heat pumps, heat recovery and battery storage.

The project found that it was possible to refurbish buildings to achieve a reduction in CO_2 emissions of up to 80% (domestic buildings) and 50% (non-domestic buildings). For dwellings, the cost could be as much as £30k per home, therefore financial 'payback' was unlikely to incentivise home owners, who would require subsidies to be able to undertake the optimum range of refurbishments. While internal activity in buildings significantly affects energy use and governs the choice of refurbishment methods, building energy demand is generally poorly understood and satisfying that demand on-site through renewables - e.g. wind, photovoltaics and Combined Heat and Power (CHP) - problematic, because the energy is often available when there is no demand and vice versa. The study also found that a warming climate could significantly affect comfort and energy use in buildings without air-conditioning, possibly leading to a rise in CO_2 emissions, were the installation of cooling plant to become more widespread.

3. References to the research

Publications

Peacock A.D. and Newborough M., 'Effect of thermal demand side measures on the CO2 savings attributable to micro-combined heat and power systems in UK dwellings', *Energy*, 33 (4), 2008 http://dx.doi.org/10.1016/j.energy.2007.10.016

Jenkins D.P., Tucker R. and Rawlings R., 'Modelling the carbon-saving performance of domestic ground-source heat pumps', *Energy and Buildings*, 44, 587-595, 2009 http://dx.doi.org/10.1016/j.enbuild.2008.12.002

Peacock A.D et al, 'Reducing CO_2 Emissions Through Refurbishment of Non-Domestic UK Buildings', 5th International Conference, *Improving Energy Efficiency in Commercial Buildings* (IEECB'08), Frankfurt, 10-11th April 2008. http://sunbird.jrc.it/energyefficiency/pdf/IEECB08/IEECB08%20proceedings/028_Peacock_final.pdf

Jenkins D.P., Peacock A.D, Banfill P.F.G., Kane D., Ingram V. and Kilpatrick R., 'Modelling carbon emissions of UK dwellings – the Tarbase Domestic Model', *Applied Energy*, 93, 2012, 596-605 http://dx.doi.org/10.1016/j.apenergy.2011.11.084

Pellegrini-Masini G, Bowles G, Peacock A.D., Banfill P.F.G. and Ahadzi M, 'Whole life costing of domestic energy demand reduction technologies: householder perspectives', *Construction Management and Economics,* 28, 217-229, 2010 http://dx.doi.org/10.1080/01446190903480027

Funding

Tarbase (Technology Assessment for Radically Improving the Built Asset Base) was funded in 2004 by a partnership of The Carbon Trust and the Engineering and Physical Sciences Research Council (EPSRC) under its Carbon Vision Buildings (CVB) programme. The funding totalled £1.4M, awarded to Banfill as Principal Investigator (GR/S94285/01). In 2008, the EPSRC awarded follow-on funding of £104,532 to Principal Investigator, Dr Kate Carter (2003-present), for the Partnership Public Engagement project, From concrete to cookers (*Fromconcrete2cookers*) (EP/F066589/1). Banfill was Co-Investigator.

4. Details of the impact

At Ecobuild 2011, the [text removed for publication] Chartered Institution of Building Services Engineers (CIBSE) gave a presentation in which he described the UK's existing building stock as "*the elephant in the room*". Emphasising that there were "*no magic bullets*" in meeting CO_2 reduction targets, he stressed the need for managing, maintaining and improving the existing stock using an honest measurement of actual energy use ("*metering; measuring; monitoring*"). The sentiments sum up the focus and spirit of Tarbase and, as a long-term supporter of the project, it was CIBSE [text removed for publication] who suggested that Banfill join the Publication Working Group developing the Institution's Technical Memorandum on *Low-carbon Refurbishment of*

Buildings (2013). Banfill was involved in the development of the Memorandum over a four-year period and the publication proposes a range of practical solutions to address the issues highlighted by his research into Technology Assessment for Radically Improving the Built Asset Base (see 5.1, below).

Impact on, and with, CIBSE demonstrates how Tarbase has levered the support of industry professionals to drive forward change. Similar gains have been made at policy level using a similar, publication-based pathway, including the *Final Report of the Low Carbon Construction Innovation & Growth Team* published, in Autumn 2010, by the Department for Business, Innovation and Skills (BIS) which uses data provided by (Tarbase sponsor) The Carbon Trust, and states that "*members* [of the Team's Buildings Work Group] *have agreed that the emphasis needs to be on measures to address the existing stock* [which has] *far greater potential for reducing its carbon footprint in the short to medium term*" (see 5.2). The Buildings Work Group involved [text removed for publication] Tarbase's non-academic partner, BSRIA, who has confirmed that Tarbase informed the Group's deliberations in their work on improving the performance of non-domestic buildings through refurbishment. He has said "*I have been impressed with both the management of the Tarbase work and the quality of output and I commend the team for their work… In particular the analysis of carbon intensity of electrical supply was helpful in identifying the urgency of policy in this regard*". (See 5.3).

The pathway to policy-level impact was secured in December 2007 with the publication of a report by the independent, industry-led, UK Green Building Council (UK-GBC; see 5.4). This report, *Carbon Reductions in New Non-Domestic Buildings*, was commissioned by the Department for Communities and Local Government. The document makes multiple references to the research and to the subsequent application of its modelling techniques by the Alliance team to three generic new building types (a £30k package of work referred to as "*leading edge*" in the publication). The report concluded that "*a challenging yet achievable timeframe for achieving zero carbon new non-domestic buildings is needed*", underpinning the UK Government target of 2019 (announced by The Labour Party in 2008 and reiterated by the current Coalition government in December 2010).

For buildings in the domestic sector, we established a consultancy service, offering advice on comprehensive CO_2 emissions reduction in dwellings. Aimed at a range of clients, from individual homeowners to developers, housing associations and local authorities, it utilises the domestic Tarbase model, which is better able to be tailored to the individual circumstances of a dwelling than other packages currently available on the market. As one of twenty new innovations that "*creatively address the carbon reduction challenge*", the service was showcased at the Innovation Future Zone at Ecobuild 2010 (London, March 2010), having been selected by a panel of industry experts from a competition run by the Modern Built Environment Knowledge Transfer Network (MBEKTN). At this event, it attracted interest from both public and private sector stakeholders, including UK Future Homes, Fulcrum (now part of the Mott MacDonald Group), Artica Technologies and Chapterhouse Architects. (See 5.5).

Commissions arising out of the consultancy include Energy Modelling in Traditional Scottish Houses (EMITSH) for Historic Scotland. For this £30k commission, undertaken in 2008, our researchers modelled and assessed three building variants to establish the potential for CO_2 reductions in traditionally-constructed Scottish dwellings. The methodology was also applied to the refurbishment opportunities afforded by Swedish-style, pre-fabricated timber houses in Edinburgh, with the Alliance reporting to the Scottish charity, Changeworks, as part of the Technology Strategy Board's 'Retrofit for the Future' initiative. Sub-contracted to Alba Building Sciences, we assessed options for the refurbishment of 'park homes' (residential mobile homes). Alba has described our contribution (worth £23.5k) as being "*of substantial benefit*" to them and independent reviewers, AEA Energy & Environment, reported to funders, OFGEM, that it was "*very thorough*" and that "*the theoretical results derived from the TARBASE model accord well with the savings realised in practice*". (See 5.6).

One of the most publicly accessible offshoots of Tarbase has been *Fromconcrete2cookers*, a

Partnership Public Engagement project led by Carter, with Banfill as Co-I, funded by the EPSRC. Launched at the Edinburgh Science Festival in 2009 by [text removed for publication] the Met Office's Chief Advisor to Government in Scotland and Northern Ireland, the project's main output was a web-based educational game exploring, through character-based play, how different measures change energy use and CO_2 emissions in schools. Tarbase constitutes the technical foundations of the game, which was designed by the eLearning specialist, Junction-18, in close collaboration with the academic researchers, teachers and c.100 pupils from four Edinburgh schools: Forrester High; Portobello High; Towerbank Primary; and Blackhall Primary. Promoted by STEM Scotland as "*exciting and timely*", the game has been cited as "*a fantastic resource*" by Education Scotland (formerly Learning Teaching Scotland), which lists the project as "*to be exemplified*". (See 5.7).

5. Sources to corroborate the impact

5.1 Contact details for the [text removed for publication] Chartered Institution of Building Services Engineers (CIBSE) and the [text removed for publication] CIBSE's Publications Working Group developing the Technical Memorandum on *Low-carbon Refurbishment of Buildings* have been provided separately. The former's Ecobuild 2011 presentation can be made available in pdf format, on request.

5.2 *Final Report* of the Low Carbon Construction Innovation & Growth Team's Buildings Work Group to the Department for Business, Innovation and Skills (BIS). See p 141… https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31773/10-1266-low-carbon-construction-IGT-final-report.pdf

5.3 A factual statement from [text removed for publication] BSRIA has been made available in support of this case study.

5.4 *Carbon Reductions in New Non-Domestic Buildings,* the UK Green Building Council. See pp 13,20,25,30-32,34,37,43-45,84,87-88... http://www.ukgbc.org/resources/publication/uk-gbc-report-carbon-reductions-new-non-domestic-buildings

5.5 For information on the Tarbase showcase at the Innovation Future Zone, Ecobuild 2010, see... https://connect.innovateuk.org/web/innovation-future-zone/innovation-future-zone-at-ecobuild

5.6 A factual statement from [text removed for publication] Alba Building Sciences has been made available in support of this case study. It quotes from a report by independent reviewer, AEA Energy & Environment, prepared for funders, OFGEM, a copy of which can also be made available, on request, in pdf format.

5.7 Contact details for [text removed for publication] STEM Scotland have been provided separately. See also STEM Scotland's factsheet on *Fromconcrete2cookers*, which corroborates the project's listing by Education Scotland (Learning Teaching Scotland, at the time of publication)… http://www.stemscotland.com/files/concrete2cookers.pdf