Institution: Plymouth University

Unit of Assessment:C16 Architecture and Built Environment

Title of case study: Simulating Buildings' Performance: impact in the facility and energy management sectors

1. Summary of the impact (indicative maximum 100 words)

The Environmental Building Group (EBG) is making an internationally-recognised impact on industry practice using building performance simulation research to look at the relationship between building use scenarios and building performance. In particular, research in building energy data analysis and the prediction of the impacts of climate change on UK building stock has enabled: C3Resources to increase turnover by 28%, double its workforce and win new international clients; Cornish Lime to develop a new product; RTP Surveyors to increase service provision; and Lend Lease and Wates Construction to change their strategies in relation to what/how they may build in the future.

2. Underpinning research (indicative maximum 500 words)

Within the EBG, research undertaken by Dr de Wilde (2005-present) focusses on building performance simulation; in particular, the interrelation between various buildings' complex use scenarios (occupant behaviour, climate conditions) and aspects of performance such as energy use and thermal comfort. At Plymouth, through an Engineering and Physical Sciences Research Council (EPSRC) First Grant (2009-2011), de Wilde developed specific expertise on handling these complex scenarios, applying it to the study of the risks climate change poses to the future operation of buildings. The research involves the propagation of uncertainties in weather conditions, control settings and changes in building component properties (subject to deterioration over time) to generate likely thermal performance profiles as output, thus moving from deterministic to probabilistic simulations. de Wilde's international recognition in this field is demonstrated by his joint guest editorship of a special issue of Building and Environment (55, 2012) and by his role as challenger at a Chalmers University of Technology's PhD defence in Sweden (25 May 2012).

Dr de Wilde's research has helped establish the expertise of the EBG in computational assessment of the energy performance of buildings and to enter into a Knowledge Transfer Partnership with company C3Resources (February 2010- April 2012), which has been externally assessed as 'outstanding' by the Technology Strategy Board KTP Assessment Panel, the result of which has been the company's increased growth and profitability, Follow-up research is now turning towards guiding occupant behaviour to reduce energy demand in buildings via the EPSRC 'eViz' project (2012-2015), and further investigation of the gap between predicted and measured building performance via a Royal Academy of Engineering and Leverhulme Trust Senior Research Fellowship (2012-2013). EBG research has already had some impact in raising awareness of the potential cost efficiencies and environmental benefits the 'eViz' project offers, evidenced by multiple partners from both industry and the not for profit sector having invested in the project with financial and /or in-kind contributions.

Dr de Wilde's research has involved cooperation with other researchers at Plymouth, especially with Dr Wei Pan (Reader: 2008 -2012) in the area of construction management. Dr Pan's research typically takes place in collaboration with large construction companies, e.g. Lend Lease and Wates, and focusses on improving industrial practice. The dialogue with these partners has included the need to reduce the future impact of climate change on buildings, with a direct impact on the companies' long term strategies, and ongoing joint projects between Pan and de Wilde address some of these concerns, yielding further benefits to the companies. The probabilistic approaches de Wilde developed to deal with climate change are also guiding analysis of field data in monitoring and measurement research undertaken by Dr Brian Pilkington and Professor Steve Goodhew, which has enabled new product development (Cornish Lime Company). By extending the simulation work to instruments, EBG's Matthew Fox's EU-ESF-CUC-funded research on

transient thermography has increased the rigor of surveyors' assessments. This has expanded/ improved the services offered by RTP Surveyors and the Cornwall Development Company.

3. References to the research (indicative maximum of six references)

Publications that support the research impact are as follows:
(1 to 5 are in field-leading, archived, peer-reviewed, international academic journals with Impact Factor; 6 is a commissioned report).

1. de Wilde, P. and W.Tian, 2012. Management of thermal performance risks in buildings subject to climate change. *Building and Environment*, 55, 167-177. International, peer-reviewed journal, ISI Impact Factor 2.400.

2. de Wilde, P., W. Tian and G. Augenbroe, 2011. Longitudinal prediction of the operational energy use of buildings. *Building and Environment*, 46 (8), 1670-1680. International, peer-reviewed journal, ISI Impact Factor 2.400.

3. de Wilde, P. and W. Tian, 2011. Towards probabilistic performance metrics for climate change impact studies. *Energy and Buildings*, 43(11), 3013-3018. International, peer-reviewed journal, ISI Impact Factor 2.386.

4. Tian, W. and P. de Wilde, 2010. Predicting the performance of an office under climate change: a study of metrics, sensitivity and zonal resolution. *Energy and Buildings*, 42 (10), 1674-1684. International, peer-reviewed journal, ISI Impact Factor 2.386.

5. de Wilde, P. and W. Tian, 2010. The role of adaptive thermal comfort in the prediction of the thermal performance of a modern mixed-mode office building in the UK under climate change. *Journal of Building Performance Simulation*, 3 (2), 87-101. Peer-reviewed, official journal of the International Building Performance Simulation Association, ISI Impact Factor 0.718.

6. Goodier, C.I. and Pan, W. (2010) *The Future of UK Housebuilding*, Commissioned by the Royal Institution of Chartered Surveyors (RICS), London. ISBN 978-1-84219-645-8. Downloadable at: http://www.isurv.com/site/scripts/download_info.aspx?categoryID=1026&downloadID=1289

All authors were, at the time of publication, academics at Plymouth University, except:
- G. Augenbroe, Georgia Institute of Technology, USA
- C. Goodier, Loughborough University, UK

This co-authorship demonstrates the close links maintained by Plymouth academics with leading institutions worldwide.

4. Details of the impact (indicative maximum 750 words)

The work of the EBG impacts the construction industry, mainly within the building services engineering and facilities management sector. The impact is demonstrable in the following ways (reference to evidence is indicated in brackets):

The research has enabled substantial growth and savings for local SME, C3Resources (1, 2, 3). The KTP project with the company has helped it to increase its turnover by 28% and double its workforce by automating data analysis that previously depended on manual processing. C3Resources estimates to have achieved an additional 1920 tonnes of CO2 savings. The project also increased service levels and improved cost management. Furthermore, the company has partnered with the University on a collaborative £967K project, which was awarded to the University by the HEFCE Revolving Green Fund 2 to develop integrated energy management and ICT for all campus buildings. C3Resources was an integral partner in the application and will act as the independent verifier of energy savings. Other industry partners are Schneider Electric and

Cisco who will work closely with the Principal Investigator, Paul Lumley of the University's Procurement and Sustainability Department (4). The project has also given the company 'international exposure' and credibility enabling it to 'expand its client base/market share' and has led to 'cultural change within the business' (1,3).

Plymouth research, via the EPSRC KTN, is supporting The Cornish Lime Company's, development of a novel, competitive product for thermally efficient renovation of existing buildings; the project is also critically assessing the building regulations for fabric upgrades in renovation cases, which is presently pushing/crossing the boundaries of the physical possibilities (3).

Work on thermography with Penwith Housing Association, RTP Surveyors and the Cornwall Development Company investigates the use of infrared cameras in building surveying. Through the use of transient thermography It has been possible to increase the rigor of existing building assessments to give a 'picture' of a building over a period of time rather than a snapshot taken from a single visit and the businesses are now assessing the feasibility of adding this technology to their service portfolio'. Additionally, the work has advanced the surveyors' 'understanding of thermography' and ways of 'improving thermal properties of existing premises, [for] both the company and…clients' (3).

Commercial companies, Lend Lease and Wates Construction have used the research to plan their strategies in terms of building design and building management in order to prepare for the impact of climate change (3). Lend Lease took part in the inaugural seminar for the Institute for Sustainability Solutions Research (ISSR) as keynote speakers on 'Maximizing Business Opportunities in Sustainable Building and Development' (21 April 2011) due to the positive impact of the research on its business (6). The event was held in association with the EBG and the University's business school and brought together representatives from business, not-for-profits, academia and government.

The eViz project, funded by EPSRC (1 September 2012 - 31 August 2015), has already raised awareness of the opportunities/benefits the research offers to industry and the Third Sector. This is demonstrated by the letters of support and investments made by various industrial/charitable partners: Carnego Systems, Scheider Electric, CISCO, TEKLA, C3Resources, Energy Saving Trust, Eden Project, RegenSW, Carbon Action Network, Plymouth City Council, Cornwall Development Company, the Building Services Research and Information Association, Doddiscombsleigh Community School, GreenerTeign (a climate action group) and Transition Newton Abbot (3). Impact will continue to emerge in this project over the next few years.

To ensure the research benefits the maximum number of industry practitioners, the EBG disseminates findings through the International Building Performance Simulation Association (IBPSA), the Royal Institution of Chartered Surveyors (RICS) and others (4). Hard measurement of the impact is difficult, but it has ensured a wide reach for the findings, promoted practitioner/public debate and had some impact on changing/informing opinion. For instance, the RICS-commissioned 'Future of UK Housebuilding' report (a joint publication by Plymouth and Loughborough Universities) was lauded by industry press: 'the research highlights a series of low-cost housing solutions which could significantly ease national shortages and ensure that affordable housing is more readily available to both local authorities and first-time buyers'; illuminates the likely 'elements of success or failure [for the housebuilding industry] in the future'; and pushes 'government and industry [to] consider more innovative solutions to development' (4). Indeed, MP Nick Raynsford 'agreed … more must be done to ensure that sustainable developments are correctly valued to encourage their development' (www.makeoffer.co.uk), while other industry voices believe the report will boost the growth of new types of house design/construction companies (4).

5. Sources to corroborate the impact (indicative maximum of 10 references)

(1) Final Report from KTP C3 Resources.
Confirms that C3 Resources have grown turnover from £166k to £532k, 40% of which is attributed

directly to the actions of the KTP.

(2) Assessment by TSB KTP Panel of the project with C3Resources.
The KTP has been externally assessed as 'Grade A': 'outstanding' by the TSB Assessment Panel.

(3) Written statement from Director, C3 Resources Ltd., confirming that the project with the EBG has led to substantial growth and savings for the company.

(4) Written statement from Managing Director, Cornish Lime Company Ltd., confirming that Plymouth research has enabled the company to develop a novel, competitive product for the thermally efficient renovation of existing and aided the company's 'understanding of the UK's Building Regulations 2010'.

(5) Written statement from Practice Manager, RTP Surveyors, confirming that EBG research has led to advances in the company and they are assessing the feasibility of adding this technology to its service portfolio.

(6) Written statement from Sustainability Manager, Wates Construction, confirming that the research has provided Wates with 'some useful and cost effective technologies.

(7) Written statement from Director, Carnego Systems Ltd., confirming that the work of the EBG has helped extend the range of approaches that can be developed and applied.

(8) Written statement from Lead, Climate Change, Eden Project., confirming the organisation has found EBG research helpful in assisting project development.

(9) Written statement from Sustainability Officer, Plymouth City Council, confirming that directly due to eViz involvement, the Council has launched a Behaviour Change pilot in one of [its] largest buildings.

(10) HEFCE Revolving Green Fund 2 Bid document.
Document outlines the project with industry partners.