

**Impact case study (REF3b)**

<p><b>Institution:</b> Plymouth University</p>
<p><b>Unit of Assessment:</b> C16 Architecture and Built Environment</p>
<p><b>Title of case study:</b> Building Monitoring and Preservation: Impacting Homebuilders and Households</p>
<p><b>1. Summary of the impact</b> (indicative maximum 100 words)</p> <p>This study presents the impact of research by Plymouth’s Environmental Building Group (EBG) and Centre for Earthen Architecture (CEA) on industry and regulatory bodies. These interconnected groups research the manufacture, construction, preservation and performance (thermal, hygral and acoustic) of new and old buildings of diverse construction, including earth, straw-bale and hemp-lime. EBG/CEA research has impacted the energy consumption of 690+ homeowners (21st Century Living; DECC/Eden) and contributed to national standards for construction and conservation (BRE/DEBA/English Heritage). Industry partnerships/projects include: Zero Carbon House, Kevin McCabe Ltd; Carfrae Sustainable Design; Hukseflux; Cornish Lime Company.</p>
<p><b>2. Underpinning research</b> (indicative maximum 500 words)</p> <p>In 1992, following a 60-year decline in earth-building and loss of skills/buildings, Plymouth University established the CEA. This initiated research into the performance of earth (particularly cob) as a building material in the light of new Building Regulations/certification. CEA field and laboratory research is supported by and contributes to the work and guidance of key organisations: DEBA (Devon Earth Builders Association), English Heritage, CRATerre (International Organisation for Earth Buildings), DHBT (Devon Historic Building Trust), BRE (Building Research Establishment) and ICOMOS-ISCEAH (International Scientific Committee on Earthen Architectural History). Initial work investigated cob’s composition, structural performance, failure, repair and maintenance. Presently, key researchers (Watson, Mackie, Brocklebank, Bradbury), work in a broader context, with heat, moisture, legislation, sustainability and culture, exemplified in the ongoing international Cordiale project on managing landscape change producing a series of online tools influencing the building related choices that construction professionals and occupants take.</p> <p>The EBG was established by the CEA to focus on the wider field of sustainable construction (degrees from 1995, accreditation in 1996). Today, the EBG complements the CEA by looking at environmental issues in the building industry. Initially researchers such as Goodhew and Pilkington, focussed on earth walls to establish a methodology that can be used to measure the in situ thermal properties of mass building materials. This has expanded to a spectrum of (predominantly natural) materials, such as straw bale and hemp-lime, as well as hygral and acoustic performance establishing a series of numerical values that characterise the moisture and sound insulation performance of natural materials.</p> <p>A key line of research uses thermography to assess the thermal performance of buildings in situ, (The Telegraph, March 2006). Based on findings that characterised the relationship between viewing thermal images and occupant behaviour, the work has impacted the domestic energy consumption of 690+ homeowners: 61 homes were assessed in the 21st Century Living project with Homebase and the Eden Project, while ‘Cornwall Together’ with the Department of Energy and Climate Change (DECC) has added 620. EBG thermography expertise benefits industry/academia further through a presence on the International Standard Organisation’s ISO 9869-1 TC 163 on thermal performance/energy use in buildings.</p> <p>EBG has also developed thermal probes for measuring materials in situ. Working with Dutch instrument manufacturer, Hukseflux sophisticated prototypes are being tested through a programme of measurements in real buildings [1, 2, 3]. Further work has developed moisture probes, specifically designed for monitoring the conditions in straw bale walls. Again, these have been tested in live building environments establishing the technique as a valid approach to inter-</p>

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wall moisture monitoring for contractors and building owners alike. Research has supported the Zero Carbon House design, Kevin McCabe Ltd, and Carfrae Sustainable Design has been launched by EBG staff for best practice sustainable construction [4].

Finally, since 2008 a project on internal insulating renders has investigated the combined effects of heat and moisture transfer, specifically in the context of renovation of the existing building stock in the Southwest. This research has led to Cornish Lime changing the composition of its products.

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

All are in field-leading, archived, peer-reviewed, international academic journals with Impact Factor.

1. Carfrae, J.; de Wilde, P.; Goodhew, S.; Walker, P.\*; and Littlewood, J.\* (2010). A cost effective probe for the long term monitoring of straw bale buildings. *Building and Environment*, 46 (01), 156-164. International, peer-reviewed journal, ISI Impact Factor 2.400.
2. Goodhew, S. and Griffiths, R. (2005). Sustainable earth walls to meet the building regulations. *Energy and Buildings*. Vol. 37 (5) pp. 451-459. International, peer-reviewed journal, ISI Impact Factor 2.386.
3. de Wilde, P.; Griffiths, R. and Goodhew, S. (2008). Validation of data analysis routines for a thermal probe apparatus using numerical data sets. *Building Simulation. An International Journal*. vol 1 (1) , pp. 36-46. International, peer-reviewed journal, ISI Impact Factor 0.815.
4. Keefe, L.; Watson, L.; and Griffiths, R. (2001). A proposed diagnostic survey procedure for cob walls. *Proceedings of the Institution of Civil Engineers Structures & Buildings*, 146 (1) pp. 57-65. ISI Impact Factor 0.573.
5. Pilkington, B.; Griffiths, R.; Goodhew, S.; de Wilde, P. (2010). In situ thermal conductivity measurements of building materials with a thermal probe, *ASTM Journal of Testing and Evaluation*, v.38 (3). International, multi-disciplinary journal for applied science and engineering, ISI Impact Factor 0.349
6. Pilkington, B.; Griffiths, R.; Goodhew, S.; de Wilde, P. (2008). Thermal probe technology for buildings: the transition from laboratory to field measurements. *ASCE Journal of Architectural Engineering*, v14 (4) pp.111-118. International, peer-reviewed journal for civil engineering, ISI Impact Factor 0.183

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Professor Peter Walker, University of Bath  
 Dr John Littlewood, Cardiff School of Art & Design (WIRAD)

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

Building preservation and monitoring research by the CEA and EBG is having significant impact on professional bodies, charities, individual homeowners and industry.

Work at Plymouth has helped instil confidence in cob as an exemplary, sustainable form of construction and has allowed the material to reach a wider audience, impacting industry and homeowners in the Southwest. Plymouth is known nationally for the CEA and Plymouth's research on earth building, presented at various national and international conferences, is cited in guidance documents, making a strong contribution to the standards produced by bodies such as the BRE [1] and DEBA [2]. Additionally, Prof. Goodhew of the EBG is a member of the International Standard Organisation's ISO 9869-1 TC 163 (a working group which feeds into the main ISO panel on Thermal performance and energy use in the built environment) impacting international thermography standards that detail what is required to ensure

materials/products/processes/services are safe and fit for purpose and which are used by both industry and academia. Due to Plymouth's membership on the panel there is now a Part 3 to the ISO/DIS9869-3 detailing the use of thermal probes [3]. Researchers from Plymouth helped start up a thermographic thread focused upon methodologies to improve build quality before practical completion stage at Ecological Built Environment Research and Enterprise (EBERE) at the Wales Institute for Research in Arts and Design (WIRAD) [4].

Whilst the work with industry detailed below inevitably impacts homeowners, this can be measured directly in two projects with the Eden Project, a Cornish charity/social enterprise::

More than 690 households have been impacted by thermography research in relation to their domestic energy consumption. Thermography research at Plymouth has had national coverage, with key images by Goodhew supplied to the *Telegraph* often showing up in the context of thermography of buildings [5]. This work led to collaborations with a number of social housing groups, e.g. Sovereign Homes, and the community-facing, 21st Century Living Project, a collaboration with the EBG, Homebase, EST, and the Eden Project. This initiative influenced the lives of 61 households in England using thermography as a tool to change their behaviour in relation to domestic energy use [6]. Work under the 'Cornwall Together' scheme led by the Eden Project and supported by the DECC (January-March 2013) has provided 200 further homeowners with custom thermography of their own homes, which is being contrasted to control groups that were given general thermographic images (sample size 200 households) or generic advice (sample size again 200 households). Comprehensive walkthrough thermography was conducted for 20 homes, yielding a total of 620 households impacted [7].

The research has also had a demonstrable impact on industry in the following ways:

Staff supported and enabled the design of a Zero Carbon House, Keppel Gate, Ottery St. Mary (builder: Kevin McCabe Ltd.) through soil testing by Clark and thermal monitoring by Goodhew, and the company confirms that the research 'has had a significant impact on the work of Kevin McCabe Ltd , allowing us to expand and improve the services we offer' [8].

A company, Carfrae Sustainable Design (<http://www.carfrae.com>), has been set up using EBG research as a basis for best practice: the development and refinement of a low-cost monitoring system used to indicate the moisture content of the interior of walls made from non-food-crop materials has enabled Carfrae's clients (householders) to be sure of the condition of one of the largest financial investments that they will make. This monitoring system has been applied in 10 domestic-scale mixed use buildings.

Hukseflux, a Dutch instrument manufacturer, is using Plymouth research to change and improve the design of its latest series of specialist thermal probes for measurement of the thermal properties of buildings and building elements. The research 'form[s] a significant part of Hukseflux's progress, in terms of developing the company's existing products, knowledge and understanding for new markets'. Currently, new innovative 'guarded' probes are undergoing testing at Plymouth within the dissertation research of Rolf Engels (2012-2013), with initial results being encouraging. And in the category of emerging impact, if proved accurate, these will be made available globally by Hukseflux [9].

Cornish Lime, a local SME that supplies mortar, lime putty and related products, has developed a new understanding of ' the difficult problem of moisture transport...and the moisture and heat transfer effects of various matrixes in the mix' and has changed the matrix of its Hemptulate product for internal application on the basis of research carried out in collaboration with Plymouth researchers, improving the product's performance and thereby benefitting 'the company, practitioners and homeowners'. [10].

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

1. BRE, 2008: Earth Masonry: Design & Construction Guidelines.

The BRE (Building Research Establishment) document was produced with the support of the former Dept. of Trade and Industry and provides guidelines for building inspectors to facilitate the use of earth masonry in contemporary construction, focusing on new-build applications. EBG research on 'The Thermal Characteristics of building materials' is used and acknowledged.

2. DEBA: "Cob Dwellings: Compliance with the Building Regulations 2000. The 2008 Devon Model". Available at: <http://www.devonearthbuilding.com/leaflets.htm>

The DEBA (Devon Earth Buildings Association) document offers practical guidance on how traditional cob can satisfy current Building Regulation requirements with respect to low-rise residential properties. It makes extensive use of EBG thermography

3. Report of ISO/TC 163/SC 1/WG 16 "In-situ measurement of thermal resistance and thermal transmittance of opaque building elements" to ISO/TC 163/SC 1 for its meeting on 2013-09-12 in Stockholm, Sweden.

The International Standards Organisation (ISO) has now added a part 3 to this particular standard. This addition had been made due to EBG's research into probes and Prof. Goodhew's membership of the committee.

4. Taylor, T.; Littlewood, J.; Goodhew, S.; Geens, A.; Counsell, J.; Hooper, J.; Blanch, T.; and Sharp, D. In -construction testing of the thermal performance of dwellings using thermography. In: Third International Conference on Sustainability in Energy and Buildings 2011 (SEB'11), Marseille, France, 1-3 June 2011.

5. *Daily Telegraph* (25 Mar 2006) Red alert. Available at: <http://www.telegraph.co.uk/property/3348650/Red-alert.html> (Accessed 10 January 2013).

An article about using thermal imaging to see energy loss in houses including EBG images and an interview with Prof. Goodhew.

6. 21st Century Living Project. Weblink: <http://www.edenproject.com/whats-it-all-about/climate-and-environment/climate-revolution/21st-century-living-project>

Summary and final report of the 21<sup>st</sup> Century Living Project.

7. 'Cornwall Together' project, funded through DECC. Overall £750k, UoP £65k. Jan 2013-Apr 2013.

The final project report outlines the findings of the thermal imaging research project 'Cornwall Together', jointly undertaken by Plymouth University and the Eden Project, which tested thermal imaging as a motivational tool to engage householders and motivate behaviour change

8. Letter of reference corroborating impact/new buildings: Owner and Director, Kevin McCabe Ltd.

The letter confirms that EBG research has 'had a significant impact on the work of Kevin McCabe Ltd , allowing us to expand and improve the services we offer'.

9. Letter corroborating impact Owner and Director, Hukseflux.

The letter confirms that the research continues to form a significant part of Hukseflux's progress, in terms of developing the company's existing products, knowledge and understanding for new markets.

10. Letter corroborating impact Managing Director of Cornish Lime Company Ltd.

The letter confirms that work with the EBG has helped the company understand the difficult problem of moisture transport when using internally insulating plasters with resultant changes in the company's products.