

Institution: University of Plymouth		
Unit of Assessment: UoA13		
Title of case study: Energy visualisation interventions for reducing carbon emissions from buildings		
Period when the underpinning research was undertaken: 2007-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Pieter De Wilde	Prof. in Building Performance Analysis	01.05.2006- present
Professor Steve Goodhew	Prof. of Environmental Building	01.09.94-31.12.2007 & 01.04.2014 - present
Dr Alba Fuertes Casals	Ass.Prof. in Construction Technology and Management	01.04.2014 - present
Dr Rory Jones	Lecturer in Built Environment	15.05.2017 - present
Dr Matthew Fox	Research Fellow	05.07.2015 - present
Period when the claimed impact occurred: 01.08.2013 – 31.12.20		
Is this case study continued from a case study submitted in 2014? N		
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Through the use of energy visualisation interventions, including thermal imaging and digital games, householders in the UK, Europe and Canada have altered their energy related behaviours and taken action to insulate their homes. The University of Plymouth research methodology for reducing energy use was implemented by:</p> <p>(i) UK Department of Business, Energy & Industrial Strategy (BEIS) to train smart meter installers to deliver energy efficiency advice to households. As of March 2020 this equates to advising 17.3 million households through smart meter installations.</p> <p>(ii) Vancouver's Greenest City Action Plan for a large-scale thermal imaging programme of 15,000 homes which contributed to the development of the city's 2019 Deep Emissions Retrofit Strategy and was drawn on by other municipalities in the Province of British Columbia.</p> <p>(iii) UK and international business. The research opened new opportunities for business enterprise, including: the development of C3NTINEL™ software; the games EnergyCat and EkoSmart for the energy provider Électricité de France (EDF); a UK based spin out consultancy; and a novel arts-focused social enterprise.</p>		
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>Energy visualisation research at the University of Plymouth (UoP) responds to the global necessity to reduce CO₂ in the atmosphere by focusing on reducing carbon emissions from homes. Reducing emissions from existing homes has proved a challenge because residents require expert advice to invest in changes to their properties and dynamic information on their home energy if they are to use energy more efficiently. This challenge has been addressed by UoP researchers through two major research projects:</p> <ul style="list-style-type: none"> • 2012-2016 <i>Energy Visualisation for Carbon Reduction (eViz)</i>, funded by the EPSRC (£908,746), led by UoP Principal Investigators Prof. Pieter de Wilde (School of Art, Architecture and Design) and Prof. Sabine Pahl (School of Psychology) with Newcastle, Bath and Birmingham universities, and international partners at the University of British Columbia (UBC) in Vancouver and the Technical Universities in Eindhoven and Vienna. • 2015-2018 <i>Energy Games for Awareness of Energy Efficiency in Social Housing Communities (EnerGAware)</i> funded by EU Horizon 2020 (€2,000,000) led by Universitat Politècnica de Catalunya with UoP research lead Dr Alba Fuertes Casals (PI) and UoP researchers Prof Pieter de Wilde, Prof Sabine Pahl and Dr Rory Jones. <p>The research builds on long standing expertise in thermography and building performance in the University with thermal cameras first used in 1998 for defect detection in buildings [3.1 & 3.2]. In 2007, in collaboration with the School of Psychology, thermal energy visualisations were successfully used as an intervention to engage households with energy-saving home retrofits, such as wall insulation and draught proofing, and to encourage energy efficiency. Findings from</p>		

a series of four studies established a methodology which was unique at that time in using energy visualisation interventions as a catalyst to bring together homeowners, tenants and housing managers with energy providers, low-carbon materials suppliers and technical expertise. The research was led by Prof Goodhew (School of Art, Architecture and Design) and Prof Pahl (School of Psychology). Results from the series of four studies are detailed in the table below. In the first three studies (Table 1) UoP thermography researchers conducted internal and external imaging surveys of individual homes and discussed practical energy saving solutions with occupants, while in the fourth study the only intervention was a letter sent to each household containing generic thermal images or text. Study 1 tested the effectiveness of a thermal survey versus a non-visual energy audit and found that the group who received personalised, or tailored, thermal images made a 14% reduction in carbon emissions from energy use in their homes [3.3]. Study 2 (the *21st Century Living Project*) did the same but included a £500 incentive to spend on energy saving products. The households receiving thermal surveys and follow-up tailored images were nearly five times more likely to draught proof their homes [3.3]. Study 3 tested energy saving beliefs, finding households receiving thermal surveys and follow-up tailored images recalled the communication better, showed further engagement with energy efficiency and were more likely to share the information with others [3.4]. In Study 4, the only intervention was a letter sent to each household containing generic thermal images or text. Letters with images elicited lower uptake of energy savings enquiries, indicating the importance of tailored images and talking to householders.

Table 1 Details of the four thermal imaging research studies. [R3,4]

Year	#Homes	Partners	Findings
Study 1 2007	43	Bovey Climate Action Group	The thermal survey group made carbon savings of 14.29%. The control group made no carbon savings and made fewer energy saving actions.
Study 2 2008	100	The Eden Project, Homebase, University of Surrey	26% draught proofed homes compared to 6% in the control group.
Study 3 2013	980	eViz, Cornwall Together (DECC), The Eden Project, Homebase	40% of households receiving tailored thermal images made improvements (compared to 20% and 17% in non-tailored image groups) and were twice as likely to share advice.
Study 4 2015	4736	eViz, Behavioural Insights Team, Plymouth Energy Community	No observable increase in retrofits from letter communication with no thermal survey.

The *Energy Visualisation for Carbon Reduction* research project (2012-16), 'eViz', fostered a breadth of visualisation experiments, including virtual reality gaming and partnerships with social housing providers, energy providers, tech companies and creative industries. The studies were unique in their scientific approach to measuring energy efficiency behaviour and provided the evidence base and methods to support public investment in the UK and Canada. The eViz research was extended through the Europe-wide EnerGAware research project (2015-18) for which UoP researchers surveyed 4000 social housing tenants in Plymouth and co-developed the tablet-based computer game EnergyCat with Devon and Cornwall Housing Association, the transnational energy supplier EDF and the software development company Fremencorps. EnergyCat guided users to save energy by modelling household energy-use scenarios linked to actual energy consumption, providing tailored information on how to save energy and reduce heating bills [3.5 & 3.6].

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

- 3.1 Fox, M., Coley, D., Goodhew, S. & De Wilde, P. (2014) 'Thermography methodologies for detecting energy related building defects'. *Renewable and Sustainable Energy, Reviews*, 40, 296-310. <https://doi.org/10.1016/j.rser.2014.07.188>
- 3.2 Goodhew, S., Fox, M. & de Wilde, P. (2016) 'Building defect detection: External versus internal thermography' *Building and Environment*, 105, 317-331. <https://doi.org/10.1016/j.buildenv.2016.06.011>

- 3.3 Goodhew, J., Pahl, S., Auburn, T. & Goodhew, S. (2014) 'Making heat visible: Promoting energy conservation behaviours through thermal imaging'. *Environment and Behaviour*, 9, 1-30. <https://doi.org/10.1177/0013916514546218>
- 3.4 Boomsma, C., Goodhew, J., Goodhew, S. & Pahl, S. (2016) 'Improving the visibility of energy use in home heating in England: Thermal images and the role of visual tailoring'. *Energy Research and Social Science*, 14, 111-121. <https://doi.org/10.1016/j.erss.2016.01.005>
- 3.5 Casals, M., Gangoells, M., Macarulla, M., Forcada, N., Fuertes, A. & Jones, R.V. (2020) 'Assessing the effectiveness of gamification in reducing domestic energy consumption: Lessons learned from the EnerGAware project'. *Energy and Building*, 210, 1-12. <https://doi.org/10.1016/j.enbuild.2019.109753>
- 3.6 Hafner, R., Pahl, S., Jones, R.V. & Fuertes, A. (2020) 'Energy use in social housing residents in the UK and recommendations for developing energy behaviour change interventions'. *Journal of Cleaner Production*, 251, 1-12. <https://doi.org/10.1016/j.jclepro.2019.119643>

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

i. Influencing UK Government guidance on delivering energy efficiency advice

Energy visualisation interventions developed by eViz informed a Government commissioned pilot conducted December 2015 to February 2016. Its aim was to understand how best to deliver energy efficiency advice to households during smart meter installation visits, and thereby reduce carbon emissions from existing homes. The approach developed for delivering tailored advice is now intrinsic to the roll-out of smart meters in the UK through the Smart Meter Implementation Programme. The Smart Meter Installation Code of Practice now obliges energy suppliers to provide energy efficiency advice and promote engagement with energy efficiency advice at point of installation. As of March 2020, 17.3 million smart meters had been installed in homes in Great Britain by the trained installers. UoP researchers were consulted and presented their work to the Department of Energy & Climate Change (now BEIS) in 2014 for the research phase of the pilot. UoP research is cited in the UK Government's advisory publications available on the Department for Business, Energy & Industrial Strategy (BEIS) webpage of 'Best practice guidance for the delivery of energy efficiency advice to households during smart meter installation visits' [5.1, 5.2]. The publications comprise a toolkit guide to help energy suppliers develop training with guidance for their installers and ten factsheets covering a range of energy advice that installers can pick from to match customers' circumstances. UoP provided exemplar thermal images, which are included in two Factsheets: 'Draught proofing, It's a Breeze' and 'Keeping the heat in: A simple guide to wall insulation' [5.2]. An eViz case study is included in the 'Review of Energy Efficiency Advice Best Practice' prepared by Ipsos MORI and the Energy Saving Trust (2017, p.18) [5.1]. Specific references include:

- Review of Energy Efficiency Advice Best Practice (eViz case study pp.18-19)
- Toolkit Guidance (e.g. reference to thermal images as engagement 'hooks', pp. 7, 10)
- Draught proofing Factsheet (UoP credited content)
- Wall Installation Factsheet (UoP credited content)

ii. Contribution to the Vancouver City Council's Greenest City Action Plan

With a longstanding reputation for environmental leadership going back to the founding of Greenpeace in Vancouver in the early 1970s, the city has a reputation as an early adopter and influencer, spurred by the inception in 2011 of the Greenest City 2020 Action Plan and more recently in 2019 by an ambitious Climate Emergency Declaration. In addition, Vancouver is unique in Canada as the only city with the power to set its own building regulations ('Lessons from the BC Energy Step Code', 2019). In the context of the Greenest City Action Plan, UoP research informed a large-scale thermal imaging programme involving 15,000 homes [5.3] which contributed to the development of the city's 2019 Deep Emissions Retrofit Strategy [5.4] and was drawn on by other municipalities in the Province of British Columbia (BC) [5.5]. UoP researchers first outlined a thermal imaging approach to household engagement in energy efficiency for the context of BC through a co-authored invited White Paper with partners at the University of British Columbia (UBC) for the Pacific Institute for Climate Solutions, which drew on eViz research [3.1-3.4]. Following this, Vancouver City Council commissioned a thermal imaging report 'Exploring the use of thermal imagery for the promotion of residential energy efficiency' (2016) from UoP

and UBC researchers outlining a programme. The report, alongside regular consultations with UoP and UBC researchers, provided a robust methodology that framed the City of Vancouver's thermal imaging pilot of 15,000 homes in January 2017 [5.5, 5.6]. The Council invested over CAD150,000 (01-2017) in the programme and followed up UoP recommendations with a city-wide media campaign, letter communications tailored to households and neighbourhood engagement. The Green Buildings Manager reported: *"The energy visualisation research helped us make the problem of carbon emissions from homes much more visible and it raised the issue of thermal insulation for our many historic detached family dwellings much more prominent. The Thermal Imaging Pilot Program was one of the major homeowner engagement projects that has helped us plan how best to tackle GHG from homes in Vancouver. The City voted to invest Can\$20M for retrofit programs in 2019 and we now have a Deep Emissions Retrofit Strategy which is part of our ambitious and newly approved Climate Declaration Action Plan"* [5.5]. The Thermal Imaging Programme was one of four city-wide pilots stated in the Council's Administrative Report (2019, p.5) as contributing to the 2019 Deep Emissions Retrofit Strategy [5.4], which updates the 2014 policy 'Energy Retrofit Strategy of Existing Buildings,' and feeding into the Vancouver Building ByLaw 2019 update. Following the pilot, Vancouver updated its approach for existing housing to provide incentives as well as put in renovation requirements and neighbouring cities have adopted their policies [5.5]. The sustainable building consultancy Integral Group (co-authors on 2016 thermal imaging report) state they: *"drew on this research in making recommendations to a group of municipalities in the Lower Mainland of BC"* and that consequently the Township of Langley has *"developed a pilot program that draws on a combination of subsidised energy advisors, household engagement and financial support that has drawn interest and support from the Province of BC"* [5.6].

iii. New opportunities for energy-saving business enterprise

The eViz research project included a number of business collaborators including the Plymouth-based energy management company C3Resources. As an eViz collaborator, the opportunity to experiment, observe, share and discuss findings with eViz researchers was key to the development of the architecture, design and functionality of the company's energy data visualisation software tool C3NTINEL™, which monitors energy use in buildings. As a result, C3NTINEL gained industry recognition and in December 2015 the company was acquired by the multinational ENGIE, a global benchmark company in low carbon energy and sustainability for the facilities management sector, employing over 170,000 people across the world. C3NTINEL is now used worldwide to deliver Engie Management and Energy Efficiency [5.7].

Two start-up companies formed following interactions with the eViz project. The consultancy Thermal Imaging IR was established in 2017 by an eViz thermographer and provides unique expertise in the South West in the novel use of thermal imaging for energy efficiency in architecture and construction sectors. The social enterprise Art and Energy was founded in 2013, inspired by meeting with eViz researchers, and has directly engaged over 1500 participants and 114 artists in making energy efficient, awareness-raising artworks [5.8]. The digital game EnergyCat was developed through the EnerGAware research project with energy provider Électricité de France (EDF) and the software company Fremencorp to encourage home based energy saving behaviours. EnergyCat led to a 5.34% reduction in energy use in the survey group with 3.46% electricity savings and 7.48% gas savings, which is higher than the 2% saving from the government's roll-out of smart meters. Subsequently, Fremencorp went on to develop two further games for household energy saving based on EnergyCat - Smartn for individual homes and EkoSmart for neighbourhoods, both available as apps and online [5.9]. EkoSmart was released as a pilot study by EDF Méditerranée in Montpellier, France in 2017 to 500 households. It attracted investment of EUR180,000 (04-2018) by EDF and EUR65,000 (04-2018) from the French Government's Investing for the Future Programme [5.10]. The pilot was run by EDF in partnership with the Montpellier Institute of Management and social housing landlord ACM Habitat. EDF found that EkoSmart influenced customer's energy saving habits with the app communicating more effectively with young people and the link to the games' software developer revitalising the energy supplier's image. For Fremencorp, the proof of concept for their product opened markets for the app as a training and awareness solution for energy efficiency [5.10].

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

- 5.1 GOVERNMENT GUIDANCE. Evidence of UoP contribution to consultation for UK pilot study which led to an approach to deliver tailored, energy efficiency advice during smart meter installation visits: Ipsos MORI and Energy Saving Trust., (2017) *Review of Energy Efficiency Advice Best Practice: Smart Metering Energy Efficiency Advice Project* [online]. London: Department for Business, Energy & Industrial Strategy. (Viewed 31 January 2021). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/587341/Review_of_Energy_Efficiency_Advice_Best_Practice.pdf
- 5.2 GOVERNMENT GUIDANCE: Evidence of UoP contribution to guidance for training smart meter installers and FACTSHEETS for householders: UK. Department for Business, Energy & Industrial Strategy., (2016) *Toolkit Guide: Supporting the delivery of energy efficiency advice to consumers during smart meter installation* [online]. London: BEIS. [Viewed 31 January 2021]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/587307/Toolkit_25.11.16_v27_high_quality_PRINT.pdf
- 5.3 Report evidencing the role of UoP eViz research in the City of Vancouver's Greenest City 2020 Action Plan: Canada. City of Vancouver Council., (2017) *Greenest City Action Plan 2016-17 Implementation Update* [online]. Vancouver: Vancouver City Council. [Viewed 31 January 2021]. Available at: <https://vancouver.ca/files/cov/greenest-city-action-plan-implementation-update-2017.pdf>
- 5.4 City of Vancouver Administrative Report, April 2019 to the Standing Committee on City Finance and Services from the General Manager of Planning, Urban Design and Sustainability referencing the role of the "City-led thermal imaging": Vancouver. Vancouver City Council., (2019) *Building Retrofits for Deep Carbon Reductions* [online]. Vancouver: Vancouver City Council. [Viewed 31 January 2021]. Available at: <https://council.vancouver.ca/20190424/documents/cfsc3.pdf>
- 5.5 Testimonial from the Green Buildings Manager, City of Vancouver Council detailing benefits to the city's Thermal Image Pilot Program in January 2017.
- 5.6 Testimonial from the Principal, Climate and Sustainability Policy, Integral Group, Vancouver detailing benefits to Vancouver's Greenest City Action Plan and Province programmes.
- 5.7 Testimonial from C3Resources CEO stating how research collaboration with UoP led to the success of its C3NTINEL software and its acquisition by global organisation Engie.
- 5.8 Testimonial from Founder and Director of Art and Energy CIC testifying that UoP research and the eViz project were an essential cornerstone in the establishment of the company.
- 5.9 PowerPoint presentation by CEO of Fremencorp 'Projects arising from EnergyCat – Smartn and EkoSmart' (2019) evidencing benefits to the company from UoP research.
- 5.10 Testimonial from the Directeur EDF, Montpellier Area, France detailing benefits from the EkoSmart game deployed by EDF as part of its remit to help customers save energy.