Institution: Oxford Brookes University

Unit of Assessment: 13, Architecture, Built Environment and Planning

Title of case study: Improving housing energy performance through domestic energy mapping

Period when the underpinning research was undertaken: 2005–2020

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 Rajat Gupta	Professor of Sustainable Architecture and Climate Change Director of Oxford Institute for Sustainable Development	[text removed for publication]
Matthew Gregg	Senior Research Fellow in Architecture and Climate Change	

Period when the claimed impact occurred: August 2013–December 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

DECoRuM® is an award-winning Geographic Information System (GIS)-based domestic energy mapping software. It can rapidly and accurately identify appropriate dwellings for area-based energy retrofits at a neighbourhood or city scale. It does this by combining a spatial-mapping-based, data-driven approach with innovative data-reduction techniques. DECoRuM® creates energy models and assesses the potential for energy retrofit measures on a house-by-house basis, which is then scaled up to cover a much larger urban area.

The DECoRuM® model has provided a range of environmental, public policy and practice benefits to low-carbon community organisations, local authorities, architects and householders. These local, national and international benefits have been achieved through:

- influencing the United Nations Environment Programme (UNEP)'s refined Global Common Carbon Metric (CCM) approach
- enabling the development of British Standards Institution (BSI) standards
- facilitating a range of powerful public engagement initiatives
- making real energy and CO_2 emission reductions (over 50%) through energy retrofit measures in existing housing.

2. Underpinning research

Professor Rajat Gupta, Director of both the Low Carbon Building Research Group and Oxford Institute for Sustainable Development at Oxford Brookes University, combined energy modelling and spatial mapping to create the RIBA-award-winning (2006) Domestic Energy, Carbon Counting and Carbon Reduction Model (DECoRuM®). DECoRuM® is unique in bringing together GIS techniques (based on MapInfo GIS) and the Building Research Establishment's Domestic Energy Model (BREDEM-12). It can rapidly measure, model, map, manage and track domestic CO_2 emissions house by house, and also collect and visualise results on an urban scale, to help local authorities plan area-based energy retrofits.

The background calculations of DECoRuM® are performed by BREDEM-12 and Standard Assessment Procedure (SAP 2009), which are dynamically linked. To inform the model, actual home characteristics are gathered from historic and current maps, on-site street surveys, occupant

questionnaires and literature describing home characteristics based on age and typology. DECoRuM® uses data reduction techniques to assess baseline energy use and evaluate energy savings. It can also assess CO_2 reductions and the cost-effectiveness (using life-cycle costing) of applying best-practice energy efficiency strategies and low/zero-carbon technologies in existing housing for current **(R1)** and future climate **(R2)**.

As part of the **ESRC/EPSRC** EVALOC low carbon communities project (PI: Gupta, Researcher: Gregg, 2011–2015, GBP1,144,509, ES/I006664/1) led by Professor Gupta in collaboration with Oxford University's Environmental Change Institute, the researchers worked in partnership with six communities who took part in the Department of Environment and Climate Change (DECC)'s (now DBEIS) GBP10,000,000 Low Carbon Communities Challenge (LCCC) programme. EVALOC assessed and explained changes in energy use in the participating communities as a result of their LCCC activities, looking at individual dwellings and the wider community. To help community groups reduce energy use, DECoRuM® was used to measure, visualise and communicate energy use for over 1,800 dwellings, both before and after community energy projects. It was also used to predict future carbon savings across the six communities **(R3)**. The carbon maps created by the DECoRuM® model gave the local community energy group, local authority and householders visual feedback about energy use. It also provided evidence of community action, and presenting carbon maps at workshops showed that others were also engaged in energy action **(R4)**. The EVALOC project also created an EVALOC eNergy And Communities Toolkit (ENACT) to enable better public access to briefings, case studies and technical reports arising from the project, including the DECoRuM® approach and results.

Later, in the **Innovate UK**-funded LEMUR (Local Energy Mapping for Urban Retrofit) project (PI: Gupta, Researcher: Gregg, 2015–2016, GBP161,531, project ref: 132027), the DECoRuM® model was further enhanced. It was adapted to use publicly available national and local datasets on housing and energy to quickly identify suitable city neighbourhoods for particular retrofit measures, based on relative energy use and fuel poverty ratings **(R5)**. The DECoRuM® model was then used to estimate energy use and potential for energy reduction on a house-by-house basis. This approach was successfully tested in the town of Bicester, Oxfordshire.

Building on the LEMUR project, the DECoRuM® model was applied as part of the **EU ERDF**-funded OxFutures project (Co-I: Gupta, 2017–2020, the total value GBP1,599,810) to identify fuel-poor neighbourhoods with high energy use, covering over 2,000 dwellings in five district councils of Oxfordshire **(R6)**. The findings were used by community organisations such as Low Carbon Hub to increase take-up of home energy improvements. Findings from the DECoRuM®–LEMUR project have been used to develop a county-wide future energy planning tool in collaboration with Oxfordshire County Council as part of the **Innovate UK** Local Energy Oxfordshire (LEO) project (Co-I: Gupta, 2019–2022, the total value GBP13,788,087, project ref: 104781).

DECoRuM® research is being adapted for use in India, to build community energy models of 2,000 homes across five cities. It will be used to evaluate the potential for deployment of energy-saving measures and rooftop solar, as part of the **EPSRC/Indian Department of Science and Technology (DST)**-funded RESIDE project (PI: Gupta 2017–2022, GBP1,300,000 million: GBP772,178 from EPSRC and the remainder from DST, EP/R008434/1) on residential building energy demand reduction in India.

3. References to the research

R1. Gupta, R. (2009) Moving towards low-carbon buildings and cities: experiences from Oxford, UK. *International Journal of Low-Carbon Technologies*, 4(3), 159 -168.
DOI: 10.1093/ijlct/ctp028

R2. Gupta, R., and Gregg, M. (2013) Preventing the overheating of English suburban homes in a warming climate, *Building Research and Information*, 41(3), 281-300.
DOI: 10.1080/09613218.2013.772043

R3. Gupta, R. and Gregg, M. (2014) A quiet revolution: mapping energy use in low carbon

communities *Proceedings of the 30th International PLEA Conference: Sustainable habitat for developing societies - Choosing the Way Forward Vol 2, 49-56,* 16-18 December 2014, Ahmedabad, India. (Best Paper Award).
http://www.plea2014.in/wp-content/uploads/2015/01/PLEA2014_Proceedings_Vol_2.pdf

R4. Gupta, R., Barnfield, L. and Gregg, M. (2018) Exploring innovative community and household energy feedback approaches. *Building Research & Information,* 46(3), 284–299.
DOI: 10.1080/09613218.2017.1356130 (Gold open access, 2235 downloads to date, Impact factor: 3.7)

R5. Gupta, R. and Gregg, M. (2018) Targeting and modelling urban energy retrofits using a city-scale energy mapping approach, *Journal of Cleaner Production,* 174, 401-412.
DOI: 10.1016/j.jclepro.2017.10.262 (5-year Impact factor: 6.2)

R6. Gupta, R. and Gregg, M. (2020) Domestic energy mapping to enable area-based whole house retrofits, *Energy and Buildings*, 229, 110514.
DOI: 10.1016/j.enbuild.2020.110514

4. Details of the impact

The DECoRuM® model, EVALOC and subsequent research projects have had a considerable and sustained impact on environmental policy. They have also improved community and public engagement. Both of these things have improved housing energy performance. The following examples demonstrate these benefits.

Informing policies and practice

Principles of the DECoRuM® research have underpinned the development of tools, protocols and practices. Through his role as technical advisor, Professor Gupta piloted and refined UNEP's Global Common Carbon Metric (CCM) approach through the Sustainable Buildings and Climate Initiative. The CCM protocol has been developed as an ISO standard on carbon metrics of buildings (ISO/TC 59/SC17) **(S1)**. As a member of the steering committee, Professor Gupta applied DECoRuM®'s principles of accounting carbon emissions from all energy end uses in dwellings in the BSI's 'UK PAS 2060 Specification of the demonstration of carbon neutrality' **(S2)**, and this was taken up by nearly 100 organisations.

The EVALOC project was profiled as an exemplar case study in the DECC's National Community Energy Strategy (2014), and DECoRuM® was highlighted as a carbon mapping tool that is key to helping community groups reduce energy use by measuring, visualising and communicating house-by-house energy use and the potential for carbon savings **(S3)**.

Findings from DECoRuM®'s research within the EVALOC and LEMUR projects have been presented regularly (2014, 2015 and 2016) to senior members of the Energy Efficiency Deployment Unit (EEDO) in DECC, and used to inform policy development in the field of community/local energy and household energy use. In September 2015, Professor Gupta was invited by Scottish Government officials working in the community energy sector to share the evaluation approach adopted in the EVALOC project. The action research approach influenced the Scottish Government's evaluation protocols for measuring the impact of community energy initiatives.

The Construction Leadership Council's Green Construction Board's report **(S4)** explicitly highlighted the EVALOC tools and datasets (created by the DECoRuM® model on monitoring and evaluation of household energy use) and awarded them the highest score (four out of four) for future usefulness in understanding housing energy use.

Improving community engagement

The findings from the EVALOC–DECoRuM® research have been used by community organisations and community energy projects. Community-based organisations involved in the Eco-Easterside project used evidence from EVALOC to support a successful funding bid worth £1 million. The

participants who were provided with energy feedback in the six carbon mapping workshops were more motivated to adopt energy-saving behaviours and to undertake further retrofit measures (from draught-proofing and re-dressing the mortar joints in external walls, to fitting solar PV panels). EVALOC fed directly into a collaborative Knowledge Exchange project (Monitoring and Evaluation for Sustainable Communities), which trialled a variety of EVALOC's monitoring and evaluation tools to enable rapid learning among members of Transition Network and Low Carbon Communities Network **(S5)**.

The community engagement and household recruitment methodology developed in the EVALOC project were applied in an Innovate UK-funded project, Energy Resources for Integrated Communities (ERIC), to encourage householders to store and share solar-generated electricity. The ERIC project installed solar photovoltaic (PV) systems and smart batteries in 82 dwellings in a neighbourhood in Oxford, resulting in generation of 117 MWh per year (over 25 years) of solar electricity and increased self-consumption of PV electricity from 51% on average to 65% per year. The project also won two prestigious national energy awards in 2016 **(S6)**.

Extending public engagement

Many public engagement activities, including workshops, advice stalls and open exhibitions, were undertaken throughout the EVALOC project. For a national interactive exhibition, 'A Sense of Energy', the EVALOC installation used thermal imaging and DECoRuM® carbon mapping to 'visualise' energy **(S7)**. Airbrushing the colours normally seen in a thermal image on to a doll's house was an innovative way of demonstrating heat losses from a typical Victorian terrace, as well as providing recommendations on how to reduce them. DECoRuM® carbon mapping showed the changes in a community's estimated domestic household energy use, before and after local community energy action. The public exhibitions ran in London in July 2014 and in Cardiff from September to October 2014. In Cardiff, the exhibition included workshops and gave visitors the chance to talk to researchers. The EVALOC thermally imaged doll's house installation has been used in local public events in Oxford, including the 2015 OUTBURST festival, where it attracted attention as part of the welcome exhibit aimed at designers, managers and developers in the construction industry.

The ENACT toolkit on the EVALOC website was devised to promote public access to the findings in easy-to-understand briefings, case studies and technical reports **(S8)**. The EVALOC website was viewed 5,231 times, with 612 returning visitors between March 2015 and March 2016. This is in comparison to only 2,645 total views prior to the ENACT toolkit being launched (April 2012 to February 2015). The visitors to the site are believed to be a mix of community practitioners and building industry personnel who are interested in monitoring and evaluating the impacts of community energy initiatives and energy retrofits.

Achieving real CO_2 emission reductions

The DECoRuM® approach has been applied in advanced low-carbon refurbishments of three Innovate UK-funded 'Retrofit for the future' projects by Oxford Brookes University. Of these, one project (Oxford Whole House Carbon Reduction) achieved 80% carbon emission, with wide media coverage, and was the only case study profiled by Innovate UK (formerly TSB) in its 'Retrofit analysis' report **(S9)**. Through the DECC-funded Local Energy Assessment Fund (2012), DECoRuM® enabled a local community in Bicester to prepare for the National Green Deal programme. During the assessment period, it allowed the community to assess the potential for applying costed refurbishment packages, based on a combination of best-practice energy-saving measures and low-carbon technologies. Findings from the DECoRuM®–Bicester model were used directly to install cavity and wall insulation in 42 dwellings, resulting in CO_2 savings of least 50tCO_2 per year **(S10**).

Since 2018, DECoRuM®–India models in the RESIDE project have been developed to target the deployment of energy demand reduction measures (insulation, shading, low-energy cooling/heating systems) combined with rooftop solar, across five Indian cities. Findings are being used to inform the assessment of the residential energy code that will impact the energy performance of 100 million homes in the next 10 years.

5. Sources to corroborate the impact

S1. ISO/TC 59/SC17: Environmental performance of buildings - Carbon metric of building in-use stage http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=322621

S2. British Standards Institution's (BSI) '*UKPAS 2060 Specification of the demonstration of carbon neutrality'*. (Oxford Brookes University is mentioned as the only University on the steering group committee.)

S3. Department of Energy and Climate Change's Community Energy Strategy, page 49 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/275163/20140126Community_Energy_Strategy.pdf

S4. Green Construction Board report on GCB Project 430 Knowledge Capture and Dissemination, Page 34

S5. Project summary, Monitoring and Evaluation for Sustainable Communities - https://www.geog.ox.ac.uk/research/technologies/projects/monitoringandevaluation/monitoringandevaluation_HEIF_summary_report.pdf

S6. ERIC project energy awards - https://www.brookes.ac.uk/about-brookes/news/energy-saving-community-project-wins-prestigious-energy-awards/

S7. EVALOC *A sense of energy* exhibition - http://www.evaloc.org.uk/news-energyexhibition

S8. ENACT toolkit - http://www.evaloc.org.uk/enacthomepage

S9. Technology Strategy Board (2013) *Retrofit revealed* http://www.retrofitanalysis.org/retrofit-revealed-by-technology-strategy-board.pdf

S10. BioRegional Development Group (2012) report on the outcomes of the Insulating Highfield project, which, in the assessment period, enabled the Bicester Eco Town Team to prepare for the National Green Deal programme