Institution: De Montfort University		
Unit of Assessment: 13		
Title of case study: Localisation of Electricity Generation and Use		
Period when the underpinning research was undertaken: 2009–2016		
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:**
Mark Rylatt	Professor of Intelligent Energy Systems	2011–2017
Peter Boait	Senior Research Fellow	2009–2018
Richard Snape	Senior Lecturer	2010–present
Rick Greenough	Professor of Energy Systems	2009–present
Period when the claimed impact occurred: 2014–present		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Domestic energy technology and practices must change as large-scale adoption of electricity generation from renewable energy sources (wind, sun), combined with electrification of heat and transport, presents challenges in matching supply and demand, and also in distribution. Investigation of scope and methods for dynamic management of domestic electricity use led to field trials, combining novel technology with a practical business model which incentivises both local renewable generation and the optimum local use of that resource when it is available. Driven by start-up enterprises Exergy Devices Ltd and Energy Local CIC, further commercial realisations of these innovations have reduced electricity cost for the consumer, mitigated stress on the distribution network, and improved the potential for community-based renewable energy projects, as recognised in the 2020 Energy White Paper.

2. Underpinning research

Through 2009–2013 Rylatt and Boait worked on methods to improve domestic energy efficiency, and reduce consumer energy costs, by applying machine learning and optimisation techniques to heating controls and the use of electricity from household electricity generators such as micro combined heat and power (CHP) and rooftop photovoltaics (PV). This work was supported under [G1] (2009–2012), with publication in R1 and R2. Research performed under this grant included small-scale field trials of the heating control automation technology in R1. These trials provided detailed data on domestic energy appliance performance, and also included collaboration with social scientists leading to valuable behavioural insights.

The radical nature of the prospective changes in electricity generation and use under climate change led Rylatt, with Boait and Snape, to investigate larger-scale interactions between domestic energy use and renewable generation, using a complexity science approach and agent-based modelling, under [G2] (2010–2013). Each agent was a household with energy generation and use patterns simulated using findings from [G1]. Because the non-dispatchable and intermittent nature of renewable generation implies that demand must be managed to match supply, the modelling, using thousands of agents, sought to explore the scope for exploiting domestic energy stores such as water tanks and thermal mass of building fabric, and methods for signalling the availability of renewable energy resources.

A key concern addressed by the modelling was preserving system stability when demand is varied dynamically in response to the state of supply. From this work, techniques for realising a stable control loop matching demand to supply were published in R3. A follow-on grant [G3] (2013–2016) supporting the agent-based modelling allowed further work focused on behavioural

aspects of domestic energy systems acquisition and use, leading to the policy-oriented publication at R4.

The team then sought an opportunity to test the accumulated modelling findings in field trials. A consortium was built in 2014 with 5 commercial enterprises (detailed in section 4) and Oxford University's Environmental Change Institute to bid into an Innovate UK competition entitled 'Localised Energy Systems – A Cross Sector Approach'. This was successful (TSB grant 101999) leading to an Engineering and Physical Science Research Council (EPSRC) grant [G4] for the DMU work package with Greenough as PI. The concept of the project was to recruit about 50 households in or near Shrivenham, Oxfordshire, including some with rooftop PV, and deploy novel 'smart home' control devices that would manage energy stores including water tanks, storage heaters and batteries, and regulate operation of schedulable loads such as washing machines. These control processes were informed by signals indicating the availability of local PV generation, and a time-of-day electricity tariff, but prioritised user needs as expressed through an interface provided on their phone or tablet. The DMU work package comprised targeted modelling and technical advice to support the design and operation of the fielded technology.

The trial was successfully executed during 2015–2016, leading to publications R5 and R6 and ongoing impact as detailed in section 4.

3. References to the research

The journal references are all in high-quality peer-reviewed scientific journals. In 2014 the research described in R3 led to a team comprising Snape, Boait and employees of Exergy Devices Ltd winning the Nesta Dynamic Demand Challenge (https://www.nesta.org.uk/project/dynamic-demand-challenge-prize-finalists-and-winner/), a competition set up by Ofgem and National Grid.

[R1] Boait, P.J. and Rylatt, R.M. (2010) 'A method for fully automatic operation of domestic heating', *Energy and Buildings*, 42(1): 11–16; http://dx.doi.org/10.1016/j.enbuild.2009.07.005

[R2] Boait, P.J., Fan, D. and Stafford, A. (2011) 'Performance and control of domestic ground-source heat pumps in retrofit installations', *Energy and Buildings*, 43(8): 1968–1976; http://dx.doi.org/10.1016/j.enbuild.2011.04.003

[R3] Boait, P.J., Ardestani, B.M. and Snape, J.R. (2013) 'Accommodating renewable generation through an aggregator-focused method for inducing demand side response from electricity consumers', *IET Renewable Power Generation*, 7(6): 689–699; http://dx.doi.org/10.1049/iet-rpg.2012.0229

[R4] Snape, J.R., Boait, P.J. and Rylatt, R.M. (2015) 'Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent based modelling', *Energy Policy*, 85: 32–38; http://dx.doi.org/10.1016/j.enpol.2015.05.008

[R5] Boait, P.J., Snape, J.R., Darby, S.J., Hamilton, J. and Morris, R.J.R. (2017) 'Making legacy thermal storage heating fit for the smart grid', *Energy and Buildings*, 138: 630–640; http://dx.doi.org/10.1016/j.enbuild.2016.12.053

[R6] Boait, P.J., Snape, J.R., Darby, S., Hamilton, J. and Morris, R. (2019) 'The practice and potential of renewable energy localisation: results from a UK field trial', *Sustainability*, 11(1): art 215; http://dx.doi.org/10.3390/su11010215

The four research grants referenced in section 2 were awarded by the EPSRC following a competition and rigorous process of review.

Full titles of the grants are as follows.

[G1] EP/G000395/1 Carbon, Control and Comfort: User-Centred Control Systems for Comfort, Carbon Saving and Energy Management; https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/G000395/1

[G2] EP/G059969/1 Complex Adaptive Systems, Cognitive Agents and Distributed Energy (CASCADE): A Complexity Science-Based Investigation into the Smart Grid Concept; https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/G059969/1

[G3] EP/K033492/1 Agent-based Modelling of Electricity Networks (AMEN); https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/K033492/1

[G4] EP/M507210/1 Localised Energy Systems: Community Energy Generation, Aggregation and Demand Shaping (LES-CEGADS); https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/M507210/1

4. Details of the impact

A spin-out company Exergy Devices Ltd (https://find-and-update.company-information.service.gov.uk/company/05831393) was founded by Boait to commercialise the work on smart heating controls from [G1]. This progressed to real-life implementation of the findings from the agent-based modelling grants (cited above) in a domestic energy control unit given the name 'Hestia'. The team sought a route to realise matching of local demand with local generation with many potential benefits – lower-cost electricity for consumers, improved business case for small-scale renewable generation, reduced impact of local generation on distribution network voltage regulation and improved community coherence through participation in a shared enterprise. However, at the time there was no clear method within extant electricity market regulation allowing a small generator to sell directly to a local consumer.

Boait with Gillie, Morris and Parkinson founded a company Energy Local Ltd (https://find-and-update.company-information.service.gov.uk/company/08775150) in November 2013 with the goal of bringing this research concept into practical operation and having a tangible impact on consumers and the energy industry. During 2014 the company began by engaging with the Department of Energy and Climate Change, Ofgem and Elexon to find an acceptable operating model. At the same time it recruited Exergy Devices Ltd, Moixa Technology Ltd (www.moixa.com, a domestic battery systems manufacturer), Westmill Sustainable Energy Trust (http://westmillsolar.coop/partners/) (a community energy co-op), Co-operative Energy Ltd (www.cooperativeenergy.coop/, an energy supplier), DMU and Oxford University to bid into the Innovate UK 'Localised Energy Systems' competition as a consortium with Energy Local as the lead partner.

With the grant from this competition, in 2015 the consortium recruited 48 homes, of which 14 had rooftop PV totalling 45 kWp, in an area local to the Westmill co-op. All the homes were equipped with Hestia units, while 9 received battery systems from Moixa. Co-operative Energy operated a bespoke time-of-day dependent tariff scheme which sold electricity exported from the PV-equipped homes to the participating consumers for 6.5p/kWh. Because of the regulatory issues this novel peer-to-peer trading scheme did not replace consumers' existing contracts but gave credits for savings achieved in the form of supermarket vouchers. Participants made an average financial gain of GBP109 per annum and network benefits (e.g. flattening of demand peaks) were demonstrated as detailed in R5 and R6.

In 2016 the success of this trial persuaded Co-operative Energy to work with Energy Local Ltd to deliver a fully commercial scheme in Bethesda, Wales [C1], using a regulatory loophole known as a 'complex site' which permits local generation to be netted off local consumption where both consumers and generation are on the same low-voltage distribution. This scheme allows 100 consumers to use the output from a 100 kW hydro generator at a tariff of 7p/kWh. The ongoing benefit of 45% of the cost of a kWh in a deprived location was highlighted by a *Times* newspaper report in January 2020 [C2], and led to recognition by Ofgem of the Energy Local concept as an exemplary local energy archetype [C3: 5].

This experience (with Energy Local now reconstituted as a social enterprise Energy Local CIC; https://energylocal.org.uk/) has resulted in a business being built based on the creation of 'local energy clubs' that recruit local consumers and generators to form their own local energy social enterprise, deploying the Energy Local regulatory model in collaboration with Octopus Energy who have taken over Co-operative Energy. There are now 17 clubs [C4], mostly in Wales due to support given by the Welsh government, at varying stages of development.

DMU (Snape) has continued to support Energy Local with modelling and analysis tasks, including work on a winning bid in the Department for Business, Energy & Industrial Strategy (BEIS) supported Domestic Demand-Side Response Competition [C5]. Evidence of the past and prospective impact has been provided by Energy Local in a letter of support [C6]. This ongoing collaboration continues to widen the impact of the underlying research as the localisation scheme proposed in the research is applied to a wider range of scenarios, encompassing technologies that are gaining prominence including electric vehicles and domestic heat pumps. This work includes modelling the benefit to Scottish Power Energy Networks of having Energy Local clubs in their network.

In 2018 Energy Local won the prestigious Ashden Award for their impact on climate change and fuel poverty [C7]. The award particularly noted the average saving of 24% on electricity bills in the Bethesda club, the benefit of 52% of electricity demand being matched with local hydro generation in Bethesda and the positive environmental impact that led to grant funding being obtained for 20 further communities. The wider potential of this business and technical model has been recognised by Government in the 2020 Energy White Paper, where it is presented as a case study in delivery of consumer benefit through community energy [C8: 25].

A parallel strand of impact has arisen from work by Exergy Devices Ltd to develop the Hestia system which drew on the modelling research. Exergy Devices took out three patents, GB2518365, GB2534553 and GB2514128 [C9]. All these relate to 'smart' control of domestic heating and energy stores such as water tanks and storage heaters in the context of local renewable energy sources. GB2518365 was purchased in 2019 by Centrica plc to strengthen their IP behind the Hive smart heating product (www.hivehome.com). GB2534553 and GB2514128 were purchased in 2019 by Boxergy Ltd (www.boxergy.com) to underpin their marketing of innovative domestic heating systems combining heat pumps with smart energy storage using phase change materials.

To summarise, the research described in section 2 led to four different areas of impact:

1 Commercial activity in the form of the start-ups Exergy Devices Ltd and Energy Local CIC, and the uptake of innovation by Co-op Energy, Octopus, Centrica and Boxergy.

2 Electricity consumers have made actual financial savings and learned the practices necessary to make effective use of dynamic time-of-day electricity tariffs.

3 Demonstration of improved returns on investment in smaller renewable electricity generators through peer-to-peer trading that will motivate further projects contributing to climate change goals.

4 Policy and regulatory influence has arisen from the novel exploitation of existing regulation, and demonstration of the consumer benefits of community energy, leading to the citation in the 2020 Energy White Paper.

5. Sources to corroborate the impact

[C1] *BBC* report on Bethesda Energy Local scheme; http://www.bbc.com/news/uk-wales-38236414

[C2] *The Times* report on Bethesda Energy Local scheme; https://www.thetimes.co.uk/article/times-christmas-appeal-green-power-runs-on-river-water-and-welsh-community-spirit-mz57ng75w

[C3] Ofgem, 'Future Insights – Local Energy in a Transforming Energy System'; https://www.ofgem.gov.uk/publications-and-updates/ofgem-future-insights-series-local-energy-transforming-energy-system

[C4] Energy Local clubs – list at 3 December 2020; https://energylocal.org.uk/clubs

[C5] Department for Business, Energy & Industrial Strategy Innovative Domestic Demand-Side Response Competition winners, 2019; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment

	_data/file/783338/BEIS_innovative_domestic_demand-side_response-competition_phase_2.pdf
[C6]	Letter of support Director of Energy Local CIC, December 2020
[C7]	Ashden award 2018 to Energy Local; https://ashden.org/winners/energy-local/
[C8]	Energy White Paper 2020 'Powering Our Net Zero Future'; https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[C9]	Consolidated evidence from Espacenet and UK Intellectual Property Office for patents GB2518365, GB2534553 and GB2514128 in a single PDF.