Institution: Nottingham Trent University (NTU)

Unit of Assessment: C13 - Architecture, Built Environment and Planning

Title of case study: Developing Sustainable Energy Solutions for Existing Housing

Period when the underpinning research was undertaken: 2013-2020

Details of staff conducting the underpinning research from the submitting unit:

Name:	Role	Period employed by submitting HEI:
Anton Ianakiev	Professor	1998-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

The research team at NTU has developed an innovative co-simulation tool, coupling an energy system model built on the Dymola-Modelica and EnergyPlus model of buildings, which evaluates and optimises retrofit solutions for existing homes. The team also pioneered a new low temperature district heating solution, in collaboration with Nottingham City Homes. The research has been applied during the retrofit of 463 homes and has achieved real world impact in multiple aspects: (1) enabling Nottingham City Council to access £26m in EU and UK Government funding and establish the city as a world leader in sustainable urban regeneration; (2) improving the living conditions of a large group of vulnerable residents and reducing their fuel costs by up to 73%; (3) influencing housing policy of local authorities; and (4) contributing to the broad national debate on retrofit of existing housing.

2. Underpinning research

Existing homes will account for 80% of the total housing stock in 2050 and most of them have an energy performance rating of Band C or worse. Large scale retrofit of existing housing is needed to achieve the UK's carbon reduction goal of the 2008 Climate Change Act. Despite numerous successful pilot retrofit programs, there are still significant technical, economic, and social barriers for scaling-up retrofits. Professor Ianakiev addressed some of the key issues of retrofit, in partnership with Nottingham City Council (NCC), Nottingham City Homes (NCH) and Nottingham Energy Partnership (NEP), in a large EU H2020 project (2014-2020) (**G1**).

Ianakiev investigated different levels of retrofit interventions, from simple external wall insultation to the deep retrofit 2050 home standard, for the main types of housing (**R1**). He developed sustainable energy solutions that include both measures to improve building fabrics and reduce energy demand and innovations to increase the use of renewable energy and improve the efficiency of community-level energy supply. These varied solutions have been implemented and tested for economic sustainability, scalability and impact on CO2 reduction in a large-scale renovation project, involving 463 properties.

A highlight of Ianakiev's work is centred on efforts to achieve near-zero-energy homes by offsetting the energy consumption with local energy microgeneration through ground source heat pumps, photovoltaic panels, and electric, as well as thermal, energy storage devices. The management of such a complex hybrid heating system requires a suitable new control system. Ianakiev developed a co-simulation tool, which is capable of evaluating parameters of both the building envelope and controlling the operation of the energy system, to optimise the fluctuations in energy demand, and improve overall system efficiency. This dynamic energy management system maximises the utilisation of sustainable energy sources, through energy capturing and thermal storage, distributing surplus energy between properties to meet the varying daily

demand in order to minimise energy consumption from the national grid at peak times (**R2**).

District heating to replace individual gas boilers is a route to a fossil fuel-free future and Low Temperature District Heating (LTDH) offers advantages of improving efficiency through reducing heat losses, utilising heat surplus of existing systems and integrating renewable energy sources. Ianakiev led the first large scale LTDH study in the UK, involving 94 low-rise flats in four buildings in Nottingham. His innovative LTDH control solution maximises the utilisation of low temperature heat by combining measured data in homes, 'live' weather data and modelling of the dynamic heating system. It also addresses legionella related risks and peak loads during hot and cold weather (**R3**).

Hydraulic balance within the heating network is a critical pre-condition for the efficient implementation of an LTDH network. Ianakiev developed a novel thermo-hydraulic model, to investigate the hydraulic imbalance in the LTDH network, using real weather and monitored operational heating data from an existing boiler-based building (**R4**, **R5**). Hydraulic imbalance was analysed for four different control scenarios with the aim of finding an optimum strategy with minimum head-loss, pumping power, and energy consumption (**R5**).

3. References to the research

The quality of the underpinning research has been evidenced by the following externally peer reviewed outputs and grant:

References:

R1. Cui, J.M., Ianakiev, A. and Garcia-Fuentes, M. (2017) To examine appropriate deep-retrofit practice using simulation results in an EU-funded urban regeneration project. *Energy Procedia*, vol. 105, pp. 2549-2556. ISSN 1876-6102 http://doi.org/10.1016/j.egypro.2017.03.733

R2. Cucca, A. Ianakiev, (2020) Assessment and optimisation of energy consumption in building communities using an innovative co-simulation tool, Journal of Building Engineering, Available online 3 August 2020. ISSN: 2352-7102. https://doi.org/10.1016/j.jobe.2020.101681

R3. Ianakiev, A., Cui, J., Garbett, S., Filer, A. (2017) Innovative system for delivery of low temperature district heating. *International Journal of Sustainable Energy Planning and Management*, Vol.12, pp.19-28. ISSN 2246-2929 http://dx.doi.org/10.5278/ijsepm.2017.12.3

R4. Ashfaq, A., Ianakiev, A. (2018) Cost-minimised design of a highly renewable heating network for fossil-free future**,** *Energy, vol. 152, pp. 613-626 ISSN 0360-5442* http://doi.org/10.1016/j.energy.2018.03.155

R5. Ashfaq, A. Ianakiev, A. (2018) Investigation of hydraulic imbalance for converting existing boiler based buildings to low temperature district heating**,** *Journal of Energy, vol. 160, pp. 200-212, ISSN 0360-5442* https://doi.org/10.1016/j.energy.2018.07.001

Grants

G1. REgeneration MOdel for smart URBAN transformation (REMOURBAN) Future Cities Demonstrator. 5-year (2014-2019) EU Horizon 2020 Lighthouse Project involving 22 partners and 5 cities across the EU. Total budget of 25M Euros. 1M Euro awarded to NTU. Principal investigator: Professor Ianakiev.

4. Details of the impact

Shaping retrofit practice of social housing provider(s)

NTU's research directly informed the retrofits of 463 properties owned by Nottingham City Homes, which is an arm's length management organisation of Nottingham City Council. It provided "[a] *valuable contribution*" to the task of selection and evaluation of different retrofit solutions (**S1**), including 10 properties to '2050 deep retrofit' standard (the first demonstrator of its kind in the UK); 94 properties with solid wall insultation and LTDH solutions; 312 properties for solid wall insulation and Light-Emitting Diode (LED) lighting retrofit; the remaining with LED

lighting intervention only. The success of this retrofit development is considered a key component of Nottingham City Council's strategic objective of becoming a carbon neutral city by 2028.

The co-simulation system, developed by the NTU team, provided the baseline modelling for ventilation, temperature, insulation values, energy use/savings for each of the eight property archetypes, including deep retrofit 2050 homes, LTDH, and solid wall insultation retrofit properties (**S1**). The system enabled NCH and its supply chain partners to optimise the retrofit solutions for different types of properties (**S2, S3**). The NTU team also developed and installed monitoring systems in 41 selected properties, covering all archetypes, to evaluate the impact of retrofit measures. "*NTU's contribution was fundamental to capturing and analysing the in-situ monitoring data, playing a critical role in simulation validation to prove actual energy savings across the different retrofit interventions and property types*" (**S1**).

The partners have benefited from collaboration with the NTU team with new knowledge of technical solutions for utilising sustainable energy, as well as supply-chain procurement and innovative financing models (**S5**). The collaboration enabled NCH to secure £12m follow up ERDF funding to scale-up the deep retrofit solution to an additional 155 social houses in Nottingham, including 29 properties in Sneinton (**S2**) and £14m funding from the Department of Business, Energy, and Industry Strategy (BEIS) for retrofitting 262 houses in the Radford and Lenton areas in Nottingham. Melius Homes has developed knowledge of the 2050 home/Energiesprong concept during the collaboration, and the experience enhanced their skills and knowhow in delivering this model more efficiently/effectively. Its Technical Director stated that "*NTU enhanced our capacity to implement more effective/efficient energy management systems within a deep retrofit environment to 2050 standards, which we are currently applying to the extra 155 homes within the current contract and intend to replicate in a further potential 500 other publicly owned properties.*" (**S5**).

Improving quality of life of over 450 families

The work improved the quality of life of 463 families through reducing fuel poverty and improving in-door environment conditions. "*Homes are warmer, lighter, with better air quality and beautiful redesign that has created more internal space. Residents indicated that they felt healthier and their wellbeing had improved because of living in more comfortable and safer homes*" (**S3**). The average cost saving on energy use is £866 per household per year. The saving for 2050/Energiesprong homes is greater, from £1850 down to £500, equivalent to a 73% saving (**S2**, **S4**).

A post-retrofit survey and interviews with 92 participants, during January to May 2020, found that 85% reported improvement to the quality of their home, with 71% indicating a significant improvement (**S4**). 69% reported homes were warmer during winter. 85% of residents receiving solid wall insulation reported an improvement in comfort, with 68% of all residents indicating a significant improvement in the warmth of their home in winter. 87% of households had cheaper energy bills while 100% of residents reported the appearance of their homes improved, with 69% indicating a significant improvement. 100% of The Court's residents confirmed the internal space within their homes had increased (**S4**). In addition to improvements in warmth and cheaper bills, resident testimonies also evidenced enhanced health and wellbeing. "*Before the refit I had the gas heater (front room) and the central heating on all day and night. The house was freezing. Now I have the heating on only 1 and ½ hours a day and it stays warm all night too. I'm much happier cause I can wear less layers of clothing*". "*The cold didn't help my arthritic knees. Going to the toilet/bathroom at night is so much easier [now]. My body is so much more relaxed cause I'm not cold anymore. I'm free to walk around the whole home. I sleep better, before it was freezing but now it's much warmer*". "*I had damp and mould in the bathroom before they made changes. […] But when they had a new double-glazed window, they put in a fan. I've not seen any signs of mould since*". (pages 28-30, **S4**).

Influencing national debate on retrofitting

The NTU team published a White Paper - "Scale up Retrofit 2050", jointly with the Institute of Engineering and Technology in 2018 (**S6**). It calls for a nationwide programme to boost the energy efficiency of existing homes through deep retrofit; urges both national and local

government to take the lead in encouraging systematic change; identifies policy recommendations to overcome current barriers in order to implement more effective housing retrofit policy and practice. The report has generated a broad impact on the on-going national debate on retrofit of existing homes, evident by: (1) it triggered a written question by Lord Jones of Cheltenham in the House of Lords "to ask Her Majesty's Government what assessment they have made of research carried out by the Institution of Engineering and Technology and Nottingham Trent University published in their report Scaling Up Retrofit 2050". In a written answer, Lord Henley confirmed that the government agrees with the main thrust of the White Paper (**S7**); (2) it was used as a reference in the BEIS Select Committee report into 'Energy efficiency: building towards 'net zero' (**S8**); (3) it was acknowledged by Alan Whitehead, the Shadow Energy and Clean Growth Minister (Department for BEIS) in his article, "The big retrofit challenge: Is ECO up to it?" (**S9**); (4) it was referenced by Energy UK in their "The voice of the energy industry – Energy and the environment: a ten-point action plan on tacking climate change" paper. They referenced the White Paper in their recommendation (no 4) for government to reinstate zero-carbon homes initiatives to avoid the need for future retrofitting (**S10**).

5. Sources to corroborate the impact

S1: Nottingham Energy Partnership Testimonial from the Chief Executive. Sept 2019.

S2: **Nottingham City Council Testimonial** from the Smart Cities & European Project Manager. Jul 2019.

S3: Nottingham City Homes Testimonial from the Strategic Energy Lead. Sept. 2019.

S4: A joint report by Nottingham City Council, Nottingham City Homes, Nottingham Energy Partnership and NTU, Retrofit 2050 for Social Housing – Better Homes Improve Lives. Available at: https://cordis.europa.eu/article/id/418439-retrofit-social-housing-better-homes-improve-lives

S5: **Melius Homes Testimonial** from the Technical Director, Sept. 2019

S6: **Scale up Retrofit 2050 Whitepaper** - A joint report by Nottingham Trent University and The Institute of Engineering and Technology. It was published at a launch event at the Science Media Centre on 10 October 2018 and was reported by many public and professional media outlets, including the Guardian, BBC Nottingham, Architects Journal, etc.

S7: Written question by Lord Jones of Cheltenham in the House of Lords and a government response https://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Lords/2018-10-22/HL10882

S8: House of Commons, BEIS, Energy Efficiency: Building Toward Net Zero report, July 2019. https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/1730/1730.pdf; (reference on page 53, footnote 299).

S9: **Alan Whitehead MP, Shadow Minster (DBEIS)** article "The big retrofit challenge: Is ECO up to it?", published in *Business Green*, October 17th 2018, https://www.businessgreen.com/opinion/3064547/the-big-retrofit-challenge-is-eco-up-to-it

S10: **Energy UK,** Energy and the environment: a ten-point action plan on tackling climate change. https://www.energy-uk.org.uk/publication.html?task=file.download&id=6924