London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

ANNUAL COLLOQUIUM 2018

Thursday 8 November 2018
The Building Centre, LONDON

About the Centre

The London–Loughborough EPSRC Centre for Doctoral Training in Energy Demand (LoLo) is the premier centre for energy demand research in the built environment in the UK. It was set up in 2009 with funding from EPSRC for 50 studentships over 5 years, with a renewal of funding in 2014 of 60 additional studentships over the next eight years.

LoLo currently has over 40 PhD and MRes students working on a range of topics of profound practical importance spanning energy technology and systems, policy, economics and human behaviour along with a growing community of over 20 alumni who have gone on to attain research positions and lectureships along with technical and professional roles in external organisations.

Both UCL and Loughborough are committed to cross-faculty collaboration in energy research, which enables the Centre to offer truly innovative, multi-disciplinary training. Our students experience a novel learning structure which enables them to make connections across academic disciplines.

Before embarking on their three-year PhD, students undertake a one-year MRes programme, which allows them time to absorb the context of energy demand studies and to pick up the rules, tools and methods that can support innovative, high impact research. For their PhD, students join large and active research groups that can support a wide range of research projects. Students work in partnership with a range of industrial stakeholders and collaborators and their work is disseminated both directly and through national and international networks.

We aim to create a unique, vibrant, student-focused environment with excellent support from stakeholders, a Centre that will train the energy leaders and pioneers of tomorrow who will take on senior roles in academia, industry, commerce, and policy formulation.

Prof Robert Lowe (Director UCL)

Prof Kevin Lomas (Director Loughborough)

Programme

13:00	*Registration – tea and coffee, light lunch available* Vincent Suite, Lower Ground Floor
14:00	**Opening address** Professor Robert Lowe, Director, LoLo CDT *(Director, UCL Energy Institute, UCL)*
14:15	**LoLo highlights from the year** Professor Kevin Lomas, Director, LoLo CDT *(Professor of Building Simulation, Loughborough University)*
14:30 – 15:00	**Final year student presentations**
14:30	Catherine Willan – UCL Energy Institute *Life in the gap: How does a construction team respond to targets for energy and Carbon use?*
14:40	Ben Roberts – Loughborough University *Summertime overheating in UK homes: can occupants keep cool without using air-conditioning?*
14:50	*Coffee, networking*
15:20 – 15:40	**Final year student presentations**
15:20	Matej Gustin – Loughborough University *Prediction of Internal Temperatures during Hot Summer Conditions with Time Series Forecasting Models*
15:30	Frances Hollick – UCL Energy Institute *Developing a dynamic method to assess whole house thermal performance requiring minimal inputs*
15:40 – 17:00	**Poster Session** (Vincent Suite & Lower Ground Floor Foyer)
17:00	**Closing Remarks** Professor Robert Lowe, Director, LoLo CDT
17:10	*End of main conference*
17:20	**Keynote** (Vincent Suite, Lower Ground Floor)
18:20	**Poster Competition Winners** Professor Kevin Lomas and Professor Robert Lowe Director, LoLo CDT
18:30 – 19:30	**Drinks reception** (Main Gallery Ground Floor)

Keynote session

Paul Deane – MaREI Centre, Environmental Research Institute, University College Cork

Opportunities and challenges in decarbonising heat

Climate change is unequivocally underway due to the burning of fossil fuels, manufacturing and intensive agriculture. Decarbonising the energy system requires radical changes to how we generate and utilise electricity, heat and transport posing significant technical, political and societal challenges. Addressing climate change also provides many opportunities for cleaner air, reduced illnesses and improved energy security.

The challenges associated with climate change mitigation are sometimes oversimplified, but pretending it is easy just makes it harder. One of the main simplifications is that the solution is to maximise efficiency, decarbonise electricity and electrify everything. Most least cost decarbonisation analyses indicate that electricity will grow from 20% of energy use currently to 30% – 40% by 2050. Some recent studies point to a possible increase to 60% of energy end use.

This presentation will explore options for decarbonising heat encompass demand reduction measures, energy efficiency measures (new building regulations and retrofitting), and decarbonising thermal energy supply (electrification plus decarbonisating electricity, renewable gas, hydrogen, etc.). It will highlight a number of key challenges and opportunities.

Biography

Paul Deane is a Research Fellow the MaREI centre in University College Cork, Ireland. He is also a fellow at the Payne Institute, Colorado School of Mines and is the 2018 Royal Irish Academy's Speaker in Computer Science He has been working in the energy industry for approximately 15 years in both commercial and academic research. He has published over 80 papers and is a co-author of a Book-Europe's Energy Transition. His research focuses on clean energy and methods to understand future energy systems with a focus on EU climate and energy policy. He is a member of a number of European multidisciplinary think-tanks and scientific advisor to European energy projects. He is an active contributor to European policy thinking on renewable energy.

Paul's research interests are Energy and Power systems modelling, Energy Economics and Policy, Energy storage and Wind Resource Assessment. Follow his research and blogs by joining him on LinkedIn.

A full list of Paul's up-to-date publications can be seen at his google scholar page.

Poster session

Ayooluwa Adewole	Adopting Solar PV for Back-up Electricity in Nigerian Residential Estates
Charalampos Angelopoulos	Design and control of mixed-mode cooling and ventilation in low energy residential buildings
Minnie Ashdown	Airtightness testing in the UK during the introduction of regulatory testing: an inferential approach
Rayan Azhari	Energy performance evaluation of the TfL Headquarters in Stratford, London
Kostas Chasapis	Early-Stage Design Decision-Making for Community Energy Schemes
Rami El-Geneidy	Delivery of Contracted Energy Flexibility from Communities
Lauren Ferguson	The Effect of an Energy-Efficient Retrofit on Childhood Exposure to Indoor $PM_{2.5}$
Jessica Few	Studying Ventilation in Occupied Case Study Dwellings with Trickle Vents
Joseph Forde	Multi-objective optimization of Passivhaus buildings in a UK social housing context
Daniel Franks	Fuel Poverty; changing the definition, the groups suffering and influencing factors.
Duncan Grassie	An investigation of feedback & feedforward energy efficiency mechanisms from a UK school crowdsourced stock model
Naomi Grint	Hygrothermal characterisation of solid brick walls and the impacts of internal wall insulation
Clare Hanmer	How flexible is home heating demand?
Suneina Jangra	Evaluating the in-situ thermal performance of loft insulation in residential buildings: determination of R-/U-values and opportunities for minimising heat loss.
Seb Junemann	Occupant-driven Mitigation Strategies for Poor Indoor Air Quality in UK Homes
Anneka Kang	Investigating the reduction of domestic heating emissions brought about by 1 PVT series system used to power a row of terraced houses
David Kenington	Innovating with smart meters to improve energy management in retail and hospitality
Harry Kennard	Observational evidence for the variation in experienced temperature
Matthew Li	Measuring whole building thermal performance in occupied homes
Anthony Marsh	How hot is too hot? Overheating in student accommoda4on
Nathan Moriarty	Heat Pump DSR Potential for Imbalance Payment Mitigation
Murat Mustafa	Natural Ventilation Effectiveness in Single and Multi-Storey Residential Buildings
Giorgos Petrou	Modelling assumptions and how they impact overheating compliance.
Salman Siddiqui	Efficient Integration of Heat Networks with Low-Carbon Power Generation
Benjamin Simpson	Predicting Ventilation Effectiveness for Natural Ventilation
Luke Taft	Perceptions of Thermal Comfort in an Office During a Heatwave
Zack Wang	Heat pumps with district heating for the UK's domestic heating sector
Stephen Watson	Increased electricity demand from heat pumps, taking user behaviour into account
Daniel Wright	Zonal Controls: A home heating revolution?

In loving memory of Susanna Ala-Kurikka
1983-2018

Susanna joined the LoLo CDT in 2017 following previous roles in EU policy, journalism and economics. She tragically passed away on May 12th May 2018 following a sudden illness. She is missed by her LoLo colleagues, and she will be remembered as a wise, humble, highly intelligent and motivated member of our community. She was a brilliant student and a dedicated mother; her passionate commitment to being both of these things at once was inspiring. Our thoughts are with Susanna's family.

PhD students

Charalampos Angelopoulos – PhD, Loughborough University

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BSc in Mechanical Engineering from the Technological and Educational Institute of Piraeus, Athens, Greece in 2013, graduated with distinction. I continued my studies at Technical University of Denmark (DTU) where I obtained an MSc in Sustainable Energy. It was a 2-year program with a specialization in thermal energy. My MSc dissertation examined diverse energy storage technologies with a novel system of thermo-electric energy storage system. Afterwards, I continued my studies at LoLo CDT in Loughborough University where I obtained my MRes in Energy Demand with distinction. My PhD research focuses on design and control of mixed-mode buildings.
Research interests include design and control of natural and mixed-mode ventilation systems, model predictive control, self-learning control algorithms, thermal comfort.

Design and control of mixed-mode cooling and ventilation in low energy residential buildings

The aims of this project are to develop control algorithms for mixed-mode buildings in hot climates. The sophisticated algorithm will optimally select between natural and mechanical ventilation in order to constantly maintain thermally comfortable internal environments as well as to minimise the energy consumption of the building. For the purpose of this research, dynamic thermal modelling simulations will be performed alongside with CFD simulations. The sophisticated control algorithms will be developed in Modelica which will be coupled with EnergyPlus to assess the performance of its control algorithm under a variety of scenarios.

Minnie Ashdown – PhD, UCL

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Prior to starting at UCL in 2017, Minnie worked in local charities and community development, and became particularly interested in housing. Minnie has an MSc in Climate Change Management, and a BSc Hons Astrophysics, and has recently completed the MRes in Energy Demand Studies from UCL. Her MRes research project focussed on a mathematical model of airtightness testing in new dwellings, and made use of Bayesian methods to generate inferences about the process of airtightness testing in new dwellings.

An investigation into the dynamic airflow characteristics of existing UK dwellings with a focus on probabilistic methods and inverse statistical modelling.

Understanding airflow within buildings is crucial to being able to both control heat and regulate pollutants in buildings. Airflow can also impact odour, mould spores, and sound transmission throughout spaces as well as occupants comfort and health through pollutant exposure, exposure to drafts, and condensation.
The difficulty of direct measurement of characteristics associated with ventilation, and an associated lack of data, means that a dynamic understanding of a buildings airflow characteristics is relatively lacking.
This work will attempt to facilitate a holistic understanding of airflow within buildings using a data driven and probabilistic approach, requiring fewer assumptions than conventional methods and enabling a dynamic understanding of the ventilative characteristics of a building. This will further help to establish whether buildings are consistently meeting the needs of occupants, and generate a better understanding of the energy efficiency of the building

Rayan Azhari - PhD, UCL

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Rayan studied architecture (BSc) in Latakia-Syria from 2003 to 2008. He worked in Syria and Saudi Arabia before coming to the UK to do an MSc in Sustainable Buildings Performance and Design at Oxford Brookes University. After that Rayan carried out some research at Nottingham University on “Minimising Thermal Discomfort and Energy use in Houses”. Then he worked for 3 years at Richard Morton Architects in London prior to joining the UCL as part of the LoLo CDT programme.

Investigating the effectiveness of the Design for Performance programme for commercial buildings in the UK

This research project will attempt to investigate the energy performance of office buildings in the UK and compare the predicted energy use with the actual in-use energy performance as well as with similar buildings in Australia. Potentially this project will identify some key points causing the performance gap, assess the potential value increase of highly energy efficient buildings, and suggest ways to move from a design for compliance culture to design for performance.

Kostas Chasapis - PhD, Loughborough University

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Kostas is Electrical Engineer and holds an MSc degree in Renewable Energy Systems (2004) and an MRes in Energy Demand in Built Environment (2016), both from the Loughborough University. Kostas has working experience in the Energy sector and particularly in Renewable Energy projects and Electricity trading. Through his career he got involved in the design and installation of wind farms and PV projects. He got also involved with the analysis of the Electricity market and the day-ahead electricity trading. He has worked with small regional companies and international firms and has cooperated with several public authorities and organizations. He is currently studying at Loughborough University as a member of LoLo CDT and started the second year of his PhD.

Early-Stage Design Decision-Making for Community Energy Schemes

Community Energy Schemes (CES) are energy generation, distribution, storage and consumption systems involving local community ownership and participation. They promote the combination of locally owned production and consumption of energy. They can combine different energy technologies, comprising generation from intermittent sources, base loads and dispatchable sources. However, there is lack of methodological principles that lead from potential analysis to sustainable implementation strategies and to the planning of energy-efficient neighborhoods.

This research compares the energy saving and carbon emissions reduction potential as well as the cost effectiveness of different energy technologies and business model options for Community Energy Schemes at the concept design/planning stage. For this, a tool has been developed to analyze the costs, emissions and energy balance of CES and enhance informed design decisions

Rami El-Geneidy - PhD, Loughborough University

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I did my bachelor's and master's degrees in the Energy Technology programme under the wings of Aalto University. There I dug deep into energy system studies, modelling and simulation. My master thesis was about studying potential of novel energy conservation methods in passenger ships. Before ending up in the CDT I worked in the wind power industry in sales and market analysis.

I am keen to finding problems that span over different disciplines and have maximum impact. As my MRes research project I did a project on how control strategies could be designed for populations of buildings to allow their use for demand response.

Delivery of Contracted Energy Flexibility from Communities

Role of aggregating parties managing distributed and granular energy assets in buildings and communities has been established to deliver high value flexibility services, like contracted demand response (DR). The model-predictive control (MPC) framework, where thermal response modelling meets control and automation, provides a promising solution to address the challenges of forecasting and implementing flexibility in real-time over multiple buildings. As a MRes dissertation project three MPC heuristics, centralised, decentralised and hierarchical strategies, aimed at delivering contracted DR were developed. Their operation was compared with co-simulation of case studies in a UK-specific case community of ten houses.

In the PhD the aim is to explore the intersection of theory and practical implementation of energy flexibility strategies. Intention is to do this by testing and designing strategies to harness energy flexibility in real buildings and study the implications within the building.

Lauren Ferguson – PhD, UCL

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Having graduated with a Bachelors Degree in Biology in 2017, I first worked at the Wolfson Institute of Preventative Medicine using Bioinformatic strategies in cancer prevention. I joined LoLo in Autumn 2017 on the MRes course Energy Demand Studies. My MRes research project modelled the effects of a home energy-efficient retrofit on childhood exposure to indoor $PM_{2.5}$ across income groups, finding that the energy upgrade did increase exposure to indoor $PM_{2.5}$ from some sources.

My future PhD will look at the contribution of a number of both indoor and outdoor environments on childhood exposure to air pollution: Overall personal exposure is dictated by not only time spent in the home but a number of other micro-environments, such as the school. Using a number of modelling techniques, the work will investigate how changes in the UK energy market may impact national pollution levels and how exposure varies for children across different socio-economic groups.

Jessica Few – PhD, UCL

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I studied Physics at Durham University and graduated in 2013 with a first class MPhys. Being keen to work on addressing climate change, I then worked for three years as a research scientist at the National Physical Laboratory, focusing on identification and quantification of atmospheric emissions of gases from industrial processes. I joined LoLo in 2016 after deciding I wanted to work on something more relatable to everyday life while keeping an environmental aspect to my work.

Ventilation in Dwellings with Trickle Vents.

In recent decades, buildings have become increasingly airtight to improve energy efficiency by reducing unplanned ventilation. The building regulations require that planned ventilation strategies are incorporated into buildings since ventilation is required for good indoor air quality. The most commonly used ventilation strategy uses trickle vents for background ventilation and mechanical extract fans for point extraction. However, there has been little research on the ventilation rates achieved in dwellings with trickle vents. Additionally, the intention stated in the approved documents to the building regulations is that trickle vents should be left always open, however existing research suggests that trickle vents are often kept closed in occupied dwellings.

This research will focus on understanding the ventilation rate in dwellings with trickle vents. This will include developing a method for measuring ventilation in occupied homes as well as interviewing the occupants about their engagement with trickle vents in their home.

Jospeph Forde – PhD, UCL

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Joe is a physics graduate who has also worked as an energy consultant. Joe is interested in early design practices and how optimisation tools can be used to maximize the potential energy reduction impact at early design decision making stages. This interest led to the development of Joe's MRes project where a tool has been developed to optimize Passivhaus designs within appropriate design software. Further broad interests include: fuel poverty, policy, low-zero carbon design and building performance simulation.

Multi-objective optimisation of Passivhaus buildings in a UK social housing context

The UK is experiencing a housing crisis with wide calls for the construction of more affordable homes. This has inevitably led to demand for more social housing to be built in tandem with new developments. However, the need for more home building is not in a vacuum, with the UK still required to meet its international climate obligations and help alleviate domestic issues such as fuel poverty. The Passivhaus concept has been explored by local authorities in the UK as a future ready concept that can drastically aide those at risk of suffering from issues such as fuel poverty. The concept offers a comprehensive low energy standard but has been thought to incur a cost premium compared to traditional construction methods. Driven by this, a tool has been developed using multi-objective optimisation to search for optimal trade-offs between either of the heating criteria required for Passivhaus certification and construction cost.

Daniel Franks - PhD, Loughborough University

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Studied mathematics from 2012-2017 at the University of Birmingham. My dissertation was on modelling wave power devices. It was this that sparked my interest in energy demand and motivated me to join the LoLo CDT in 2017. During the MRes year, my dissertation focused on fuel poverty in English households.

The changing household environment

The PhD research will use large, rich data sets to analyse how internal wintertime temperatures, electricity demand and fuel poverty has changed over the last seven years in England. Three hypothesises will be tested:

1. There no significant change in the way English households are heated from 2011 to 2018
2. Fuel poor households in each socio-economic and dwelling group have lower internal temperatures and use less fuel.
3. Elderly and vulnerable groups (unable to work) heat to significantly higher temperatures.

And further questions will be answered, such as what trade off fuel poor households make with regards to energy consumption and which socio-economic and dwelling groups are particularly high or low users of energy and why. The research is crucial for energy policy formulation, the design of new controls and heating systems, for accurate stock modelling and fuel poverty prevention schemes.

Gabriele Gessani – PhD, UCL

gabriele.gessani.15@ucl.ac.uk – on interuption of studies

I pursued my BSc in Environmental Engineering and the MSc in Environmental Sustainability in Italy. I completed the MSc in Construction Economics & Management in UCL in 2015 and Before ending up in the CDT I worked as business developer and relationship manager in London.
In my MRes research project I developed an optimization tool based on the concept of the Energy Hub in order to understand which technologies can minimize carbon emissions in the UK residential sector. During my PhD I will explore the energy demand in the non-residential sector and sub-sectors and their implication on the economy of the UK.

Techno-economic assessment of energy systems compatible with sustainable economic growth for non-domestic sectors

The PhD research has the objective to create robust energy demand profiles for the sub-sectors of the UK non-domestic buildings. The result will be assessed by the economic point of view and energy policies will be technically assessed in an iterative way. The approach will integrate bottom-up engineering approach with top-down macroeconomic approach. Two contrasting modelling types will be utilised in order to solve the problem of fulfilling energy demand in an economical sound fashion; the bottom up demand approach and the top-down macroeconomic approach. The engineering approach is to develop bottom-up models with thorough descriptions of technologic aspects of the energy system and how it can develop in the future. Energy demand is typically provided exogenously, and the models analyse how the given energy demand should be fulfilled in a cost-optimal fashion. The economic approach is to build top-down models that describe the whole economy and emphasize the possibilities to substitute different production factors in order to optimize social welfare.

Duncan Grassie – PhD, UCL

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I have been aware of the decline in fossil fuel resources first hand throughout a decade of modelling secondary recovery mechanisms for hydrocarbon resources. My personal interest is now in determining whether realistic models of energy reduction scenarios can be constructed which include human interactions.
Although previously a chemical physics graduate, I see the role of how people interact with their surroundings as an essential input into energy simulation models of schools. My research investigates the possibility of motivating and informing participants to provide data on the operation of their buildings which can be aggregated to national level.

An investigation of feedback and feedforward energy efficient mechanisms from a UK school crowdsourced stock model.

National construction and energy datasets coupled with batch building performance simulation techniques have made feasible the construction of a stock building simulation model of over 16,000 schools. Although this should provide insights for targeted energy efficiency measures, discrepancies between measured and calculated performance limit predictive powers.
Discrepancies in calculated performance have been demonstrated when standardised variables are assumed for schedules, setpoints and equipment over the entire school stock. This makes it difficult to distinguish between poorly operated and poorly built buildings as well as determine causes for differences between identically constructed buildings.
This research will test whether feedback mechanisms can be designed as a means of recruiting school building users to facilitate future data provision for the school stock model. The work will also investigate how data can be aggregated from individual school models to inform the work of regional and national policy makers to track progress towards emissions reduction.

Naomi Grint – PhD, UCL

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Naomi has been involved in environmental building projects in various different roles since 2003. Alongside her studies she now works part time on the certification of Passivhaus building projects with Will South at Etude (passivhaus.etude.uk, formally as part of Cocreate), where she also undertakes moisture monitoring of building fabric in energy retrofits, including EnerPHit projects. She also contributes to the UK Centre for Moisture in Buildings Technical Working Group on measuring and modelling moisture in buildings (www.ukcmb.org).

Hygrothermal characterisation of in-situ solid brick walls and the impacts of internal wall insulation

Internal wall insulation is among the most effective retrofit strategies for existing buildings, but there is uncertainty surrounding moisture risk. This research firstly addresses a lack of long term datasets by measuring in-wall humidity in three walls for at least one year before and after the installation of internal wall insulation. This data is used to monitor the effect of the insulation, but also to investigate our current assumptions about these walls, and explore new ways to characterise them.
Sensitivity analyses on a hygrothermal simulation of one wall indicate that in-wall moisture predictions are influenced by uncertainty in material properties, particularly liquid transport and storage functions. Parameter estimation, using UCL's in-house Bayesian optimisation software, will then attempt to infer appropriate moisture transfer and storage properties of the walls under study, given the data and simplified hygrothermal models developed. An outcome may be the potential to estimate some simplified hygrothermal properties in-situ.

Matej Gustin – PhD, Loughborough University

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Matej studied at the University of Trieste in Italy. He got a Bachelor's Degree in Building Engineering in 2009 and a Master's Degree with honours in Civil Engineering in 2013. After his Master's Degree he worked for two years as a project engineer in the civil department of a multinational company in the field of steel and aluminium plant-making. He got a Master of Research in Energy Demand Studies in 2016.

Predicting overheating risk in UK homes

Overheating in the UK homes is a recognised existing problem for house builders, home owners, landlords and tenants. Climate change projections indicate that the UK is expected to experience more frequent and more intense heat wave periods over the coming decades. Thus, the problem will intensify as the climate warms and as homes become even better insulated, resulting in discomfort, health complaints and even mortality. For these reasons, predicting the overheating risks in UK homes is of utmost importance in order to identify the homes, locations and occupants that are most at risk. The aim of this research is to develop and compare different statistical black-box models (e.g. linear ARX and semi-parametric GAM models) to forecast the impending risk of overheating and the short-term evolution of the internal air temperatures in the UK dwellings.

Clare Hanmer – PhD, UCL

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Clare worked for 10 years at the Carbon Trust, contributing to innovation support programmes and strategy development across a wide range of low carbon technologies. She managed a programme investigating the challenges and opportunities for low carbon refurbishment of non-domestic buildings and les the Carbon Trust input to a European strategy for wave and tidal energy deployment. Clare has a degree in engineering from Cambridge University and worked initially in the industrial gases industry. She gained an MSc in Renewable Energy from the University of Reading in 2003 and an MSc in Energy and Society at the University of Durham in 2015.

How flexible is home heating demand?

Most future scenarios for decarbonizing the UK energy system include a high proportion of homes with electric heat pumps. If current heating demand patterns persist, this will lead to a peak in electricity demand in the morning. Demand management to reduce this peak can only be achieved if households are prepared to accept flexible running times for their central heating.

The research investigates the factors that shape the patterns of home heating demand in the UK. The aim is to provide a picture of how people actually use their heating and how flexible they are to accept changes in heating patterns. A mix of qualitative and quantitative methods is used, combining analysis of data from heating controllers in more than 3,000 homes with qualitative interviews with case study households.

A theoretical framework, which draws on adaptive thermal comfort and social practice theories, has been developed to situate heating operation within the multiple practices taking place in the home and to consider the reasons why some households may be resistant to changes in heating patterns. Recommendations will be made on the design of heating systems and controls to encourage flexibility.

The findings about factors that restrict the potential for heating load management will be relevant for policy-makers, electricity network operators and organisations providing Demand Side Response services.

Frances Hollick – PhD, UCL

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Frances completed an undergraduate Masters in Physics at the University of Warwick in 2015. During this she studied a multidisciplinary module on the challenges of climate change and decided she wished to work on helping to solve these. The LoLo CDT's focus on energy and buildings provides a real-world way of achieving this. Frances enjoys thinking about different ways of accounting for various physical effects in buildings. She is participating in IEA EBC Annex 71, 'Building energy performance assessment based on in-situ measurements'.

Developing a dynamic method to assess whole house thermal performance requiring minimal inputs

In order to address the performance gap and improve the efficiency of the domestic stock, it is important to have a widely applicable method of assessing the in-use performance of dwellings. This project aims to develop such a method, working on lumped thermal capacitance models of dwellings analysed using Bayesian techniques. A dynamic approach was chosen to enable shorter monitoring periods and year-round assessment of houses, with the grey-box method allowing estimated parameters to be physically interpretable whilst not excluding any data trends reflecting, for instance, occupant behavior. Using Bayesian optimisation provides extra information on the parameters, and allows model comparison including the Occam's razor principle. Data from five sites of various constructions is being used in this project in order for the method to be as widely applicable as possible.

Suneina Jangra – PhD, UCL

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Suneina is a doctoral candidate at the UCL Energy Institute. Her research focuses on the characterisation of heat flow through domestic roofs and aims to quantify the technical performance gap associated with loft insulation. Suneina holds an MRes in Energy Demand Studies from the UCL Energy Institute, an MScR in Civil Engineering, Architecture and Building from Coventry University, and a MEng in Civil Engineering from the University of Bristol.

Evaluating the in-situ thermal performance of loft insulation in residential buildings: determination of R-/U-values and opportunities for minimizing heat loss.

This project investigates the thermal performance of the insulation in cold-pitched roofs of standard construction using site surveys and in-situ monitoring. Measured heat flux and temperature data are used to estimate point R-/U-values which are compared against expected R-/U-values based on assumptions about the building fabric. The results suggest that there is a 'performance gap' whereby the expected energy and cost savings associated with loft insulation are not realised in practice due to variable environmental conditions and the quality and/or coverage of the installed loft insulation. In particular, it emerges that the effects of solar gains and ventilation on the heat flow mechanism through the loft cavity are significant and could contribute to an overall performance difference across the wider UK residential stock.

Sebastian Junemann – PhD, UCL

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Previous to joining the LoLo programme, Seb worked in social research, having been part of the delivery of the ETI's Consumer Response and Behaviour Project and DECC's evaluation of the Renewable Heat Incentive. He has seven years' experience in the UK social housing sector and has specialised in qualitative and sociotechnical research.

Seb's primary interest is in understanding the relationship between people and the places where they live. Understanding the complex interactions between residents, homes and energy systems continues to drive his research surrounding ventilation and how occupant behaviour can make homes healthier, more comfortable places to live.

Occupant-driven Mitigation Strategies for Poor Indoor Air Quality in UK Homes

Poor indoor air quality in homes is a growing concern to the building research sector as evidence and modelling show that the internal environments in many UK homes can be detrimental to the health of their occupants. Furthermore, evidence suggests that improving the energy efficiency of homes can reduce the natural ventilation pathways and increase the need for new ventilation strategies.

This research builds on Masters-level research to work with occupants to co-create solutions to the myriad problems surrounding poor indoor air quality and identify the potential for behavioural strategies to mitigate these. The MRes work has highlighted a gap in the evidence base around behaviour-led solutions. An action research approach will be used to design interventions, test them and examine the efficacy and impacts using social and technical monitoring data.

As a result of this work, case studies will be developed to provide rich empirical data to give a stronger understanding of the potential for behavioural interventions to overcome poor indoor air quality, such that improved, targeted advice can be provided to occupants. While the work will not involve the installation of physical measures it will consider the way that physical factors provide constraints and enablers for behaviour to make recommendations for potential physical improvements to be made in homes in future.

Anneka Kang – PhD, UCL

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Anneka is a researcher at UCL Energy Institute, her research studies the potential for solar heating in future urban areas. With a background in Mechanical Engineering, Anneka has worked as an Energy Consultant for several large fast-moving consumer goods factories, and as a Mechanical Design Engineer for hybrid energy storage units. She specialised in stress analysis and heat/cooling flow simulations on units, seeing them through production. Anneka's research interests are currently in the field of renewable energy, domestic heating, simulation and design/optimization.

David Kenington – PhD, UCL

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I graduated from Imperial College London with an MSc in Environmental Technology in 2003. Since then I have had a varied background in policy, social research and evaluation on a broad range of issues, but with a focus on energy and resource efficiency. I worked at the Energy Saving Trust for 8 years (2003-2011) in a range of roles including research and evaluation.

Most recently I worked at Databuild Consulting Ltd (2011-16) delivering research-based consultancy work for public sector clients including Department of Business, Energy and Industrial Strategy (BEIS), DEFRA, Energy Saving Trust and others.

Using smart meter-based innovations to improve energy management in the retail and hospitality sectors

The UK has committed to roll-out smart meters to all small businesses by 2020. It is envisaged that by providing them with accurate, near real-time energy use information will help them improve energy management, leading to improvements in efficiency and other benefits. Retail and hospitality businesses tend to be energy intensive, so comprise key targets for the policy.

To kick-start innovation in the energy management market for these sectors, UK Government is funding the Non-Domestic Smart Energy Management Innovation Competition (NDSEMIC). The aim of the Competition is to support development of innovative smart meter data based tools to help improve energy management.

This project partners with one of the NDSEMIC Competition winners. The project aims to use participatory research methods (action research) to help deliver successful tools and achieve the competition's aims. A range of principally qualitative research methods (interviews and focus groups/workshops) will be employed to deliver the project.

Harry Kennard – PhD, UCL

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Harry is a Physics graduate and energy researcher from mid-Wales. After completing an MPhil in Applied Mathematics he studied for an MA in Linguistics, in order to better understand social scientific research techniques.

Alongside academic research, he has worked in journalism as a consultant for Greenpeace's Energydesk and most recently with the Open University on the AHRC funded project 'Stories of Change' as a researcher for the BBC's Roger Harrabin.

Experienced Temperature and Health

Heating and hot water demand account for around 40% of total UK energy demand. Cutting emissions from heating is essential if the UK is to meet its legal obligations. However, concern about the rate of excess winter deaths (the ratio of winter to summer mortality) has led to questions surrounding what the minimum internal healthy temperature for homes should be and what the exact mechanism are which underlie the health impacts of cold homes.

This study makes use of UK Biobank data (a large longitudinal health study), in particular temperature data taken from an activity wristband worn by 100K Biobank participants for a week. Pilot studies showed that the temperature recorded by the wristband is a mixture of ambient environmental temperature and heat from the wrist – a quantity which has been called 'experienced temperature'. Following a large data processing exercise to down-sample the 100k data files to produce experienced temperature time series, associations between demographic/health status data and the experienced temperature will be tested. It is hoped that these any revealed relationships will form the basis of future studies into the health impacts of cold homes.

Matthew Li – PhD, Loughborough University

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Following completion of an MMath degree in 2008, Matt spent five years (2010-2015) teaching mathematics at Seoul Global High School, South Korea. Matt's research interests include whole building thermal performance, load profile analysis, and agonizing over whether to learn R or Python.

In-Use Building Thermal Performance of UK Homes

The project aims to evaluate the potential value of in-use energy performance monitoring data for assessing the thermal performance of the UK housing stock. A selection of steady state and dynamic methods will be explored to gain understanding of the uncertainties associated with using monitored data gathered from occupied dwellings. Use of synthetic data generated for a range of building typologies and boundary conditions will allow identification of appropriate methods for different scenarios and use-cases

Anthony Marsh – PhD, UCL

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In 2013 I graduated from the University of Leeds with a 1st class masters degree in Energy & Environmental Engineering.
Since then I have gained experience working as a technical consultant in the commercial solar industry, and as an energy efficiency consultant within the retail sector.
My research examines the energy and environmental performance of student accommodation in the UK.

Indoor Environmental Quality in Student Accommodation

In order to reduce emissions the UK requires that all new buildings meet emissions targets, as mandated under the EU Energy Performance of Buildings Directive. However, in the drive to decarbonize buildings it is important that sufficient attention is paid to the potential risks from unintended consequences. Two particular concerns are the increased risk of new (more thermally efficient) buildings overheating, and indoor air quality (IAQ) problems associated with reduced ventilation rates. The combined issues of energy performance and indoor environmental quality are investigated in this project by conducting post-occupancy studies of student accommodation developments to help understand how these buildings are performing in practice.
Two case study developments were monitored for 8 months over the 2017-18 academic year. Over 80% of the bedrooms monitored failed all the empirical tests for overheating. This was due to poor ventilation, a lack of solar shading, and high internal gains. Indeed, many participants reported finding their rooms to be "unusable" in warmer weather, which they judged to have negatively impacted on their studies. Meanwhile those bedrooms without continuous mechanical ventilation extract were found to have serious IAQ issues, as they routinely exceeded 3000PPM carbon dioxide overnight.
These findings raise concerns over whether overheating risk is being adequately assessed at the design stage in student accommodation developments. It also has implications for how these residences are likely to perform in the years ahead as the UK climate continues to warm.

Nathan Moriarty – PhD, UCL

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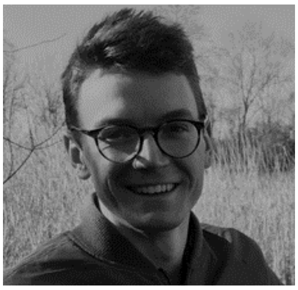

After studying Mathematics BSc at UCL 2010-13, I joined Fidessa - a financial services software company. I went on to complete an engineer training program at National Grid - GB System Operator - alongside a sponsored foundation degree in Electrical Power Engineering at Aston University. After a further year of experience at UKPN - Distribution Network Operator - within the innovation team, I'm now enrolled at the LoLo CDT in Energy Demand Studies.

Demand Side Response Dynamics in a Future Market with Transparent Fortnight Ahead Prices with Near Real Time Price Lock In

No significant market reform is anticipated despite the burgeoning smart meter programme. The physical rollout is not a panacea and the originating promises may not actualise. Developments are required in future relationships between consumer and producer. Neither the rules of engagement nor language have been defined.

We will develop an agent based model (ABM) informed by the growing body of empirical research on demand side response (DSR). We will incorporate this to instruct automated trading agents (ATAs) to act on behalf of the consumer. Sensitivity analysis of objective metrics (e.g. revenue) will hopefully elucidate the important set points in the ATAs. The objective metrics will be assessed across a range of environment scenarios (e.g. price profiles). Visualisation, agent based modelling, and language will ultimately aid informed consent. This tool is a visual user interface that places the consumer at the heart and helm of the machine of machines.

Murat Mustafa – PhD, Loughborough University

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Murat has a first degree in electrical and electronics engineering. After graduating, he worked in construction industry as an electrical building services design engineer for ten years in Cyprus, Turkey and the UK. In 2016 he graduated from MSc program of “Low Energy Building Services Engineering” and his MSc dissertation project had been awarded as the best research in building energy theme in 2016 by Energy Institute of the UK. Consequently, he continued to further study in London-Loughborough Research Centre. Subsequently, he successfully finished his MRes program in energy demand in built environment and currently, he is a PhD student in LoLo Research Centre interested in low energy ventilation and cooling solutions.

Natural Ventilation Effectiveness in Single and Multi-Storey Residential Buildings.

The aim of this research is to propose new year-round ventilation effectiveness (VE) values for naturally ventilated domestic buildings, based on achieving a robust trade-off between IAQ and energy efficiency.

George Papachristou - PhD, Loughborough University

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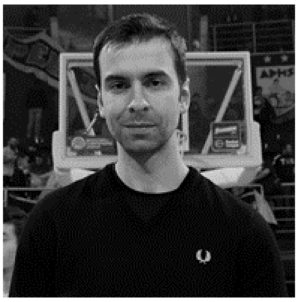

George is a Building Physicist, who is currently working for BDP in Manchester. He has multi-disciplinary building engineering studies, as he has obtained an Meng in Civil Engineering from Aristotle University of Thessaloniki, an MSc in Low Carbon Building Design and Modelling from Loughborough University and an MRes in Energy Demand Studies also at Loughborough University. For his MSc dissertation he received the Energy Institute East Midlands MSc Student award. His PhD focuses on utilising real-time data streams to calibrate dynamic building performance models of existing dwellings

Reducing the Energy Performance Gap - improving building simulation tools through data-driven and real-time approaches

Digital innovations and technologies are growing and becoming integral to many sectors. For existing buildings this means that multiple sensors and controls will be recording a wealth of real-time time series measurements on all aspects of building performance. However, the current range of building performance models are not easily able to react to these measurements, as they were primarily developed for early stage design work.

The aim of the project is to develop a methodology for calibrating dynamic building performance models which utilises real-time measurements from Smart Home equipment to improve performance predictions for existing dwellings. The overall goal is to reduce the Operation Performance Gap. Among the expected outcomes is a calibration methodology that can utilise real-time performance data and which can improve the predictions of thermal models of existing buildings

Giorgos Petrou – PhD, UCL

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After graduating with a Physics BSc degree from the University of Warwick in 2016, I joined the LoLo CDT with the goal of employing my skills in a new and exciting research field. I'm currently in the second year of my PhD and my research focuses on the prediction of indoor overheating risk. Over the last two years, I've questioned whether the choice of Building Performance Simulation tool and algorithms can influence the indoor overheating risk predicted by TM59. For the near future, I will try to establish whether occupancy can influence summer indoor temperatures and how to accurately capture it within our models.

Calibration of building performance simulation tools for individual building and stock-level modelling of indoor overheating risk.

The accurate prediction of building indoor overheating risk is critical in order to mitigate its possible consequences on occupant health and wellbeing. Current efforts are commonly based on the use of Building Performance Simulation tools which allow for a prediction under various possible weather scenarios. However, the modelling assumptions associated with such assessments can prove detrimental to the estimated overheating risk. This work focuses on evaluating the importance and validity of input assumptions in the overheating risk procedure described by CIBSE's Technical Memorandum 59. The use of test cell data will be used to determine whether the indoor temperature can be accurately predicted based on the information available at the design stage. Data from the Energy Follow Up Survey will then be used to determine the influence of household characteristics on the indoor overheating risk. The derived relations will feed into the creation of stochastic models that will allow the possible extremes of indoor overheating risk associated with occupant diversity to be estimated.

Ben Roberts – PhD, Loughborough University

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Mitigation of summertime overheating in homes is my PhD research area. Before my PhD I completed an MRes where my research focused on zonal heating controls.
Before joining LoLo I was Compliance Manager for an insulation and heating company. I coordinated the daily operation of the Green Deal finance scheme for the company. Prior to that I was a Knowledge Transfer Associate at Anglia Ruskin University, researching ways to effectively market the Green Deal to new customers.I hold an MSc in Energy Policy and BSc in Geography, both from the University of Exeter. I am an Associate Fellow of the Higher Education Academy.

Summertime overheating in UK homes: can occupants keep cool without using air-conditioning?

Summertime overheating is a growing health problem in the UK. Overheating is worsening due to a warming climate, better insulated homes, urbanisation and an ageing population.
My research is exploring simple mitigation strategies such as daytime shading and night ventilation to keep UK homes cool, healthy and comfortable, without air-conditioning. I have used a matched pair of test houses to experimentally investigate different mitigation strategies.

Zareen Sethna – PhD, UCL

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Zareen studied Civil, Structural and Environmental Engineering at the University of Cambridge and graduated in 2008. After graduation she joined the engineering consultancy Buro Happold, first working in their London office and subsequently based in Berlin. She joined the MRes in Energy Demand Studies at UCL Energy Institute in September 2013.

Understanding the uptake of energy efficiency measures in the private rented sector

The private rented sector is the second largest tenure in the UK, accounting for 20% of households, and has the lowest levels of energy efficiency measures. The aim of this study is to improve our understanding of the uptake of energy efficiency measures in the private rented sector, using social practice theory as a guiding framework and using an explanatory sequential mixed methods research design. The quantitative phase will use data from the English Housing Survey to analyse the associations between rates of uptake of energy efficiency measures and dwelling, household, landlord and geographical characteristics within the private rented sector. The qualitative phase will explore landlords' practices and how these relate to the uptake of energy efficiency measures through interviews, walk-through interviews and focus groups with landlords and other stakeholders.

Salman Siddiqui – PhD, UCL

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Salman holds a MEng in Mechanical Engineering and an MSc in Earth Sciences. After spending four years as an engineer and analyst in the Oil and Gas industry, his interests in sustainability and energy economics led him to join the LoLo CDT to work on the challenges of transitioning away from a fossil fuel-based supply. His current works focuses on national scale energy modeling of heat and power networks and optimisation of heat dispatch and storage

The Integration of Heat Networks with Low-Carbon Power Generation

District heating networks and the electrification of heat have been identified as key technologies in facilitating the decarbonisation of heat supply in the UK. The decarbonisation is dependent on the growth of renewable power generation which is largely intermittent. To balance the grid, heat storage is a means of decoupling demand from supply and can be practically integrated into district heating networks. This work will focus on optimising district heating energy loads and supplies, as well as heat storage capacity for a for an economically effective transition from the current energy mix to a decarbonised system. To integrate a thermal grid with an electrical grid at various stages of decarbonisation, control algorithms and optimisation techniques will be developed to efficiently manage heat generation, distribution and storage and in doing so, uncover the economic value of heat storage and optimise the size of heat storage investment.

Ben Simpson – PhD, Loughborough University

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Ben has completed an Undergraduate in physical Geography, an MSc in Climate Change and has just completed the MRes in Energy Demand Studies. His MRes thesis used CFD techniques to predict ventilation effectiveness values for a range of mechanical and natural ventilation strategies. With the aim of providing evidence of natural ventilation effectiveness value for the inclusion in ASHRAE Standard 62.1. Ben is currently working on identifying a PhD topic and plans on continuing with the use of CFD and natural ventilation. Ben has an interest in the use of CFD for ventilation and building design optimization.

Predicting Ventilation Effectiveness for Natural Ventilation

There is currently very little information regarding ventilation effectiveness values for natural ventilation in both CIBSE Guide A and ASHRAE Standard 62.1. This project aims to predicted ventilation effectiveness values, as well as other ventilation performance metrics, for a range of mechanical and natural ventilation strategies. The ventilation effectiveness metric used is the zone air distribution effectiveness (E_z) metric currently used in ASHRAE Standard 62.1 which follows the Contaminant Removal Effectiveness (CRE) method. This project has used Computational Fluid Dynamics (CFD) to simulate a simple single zone office space. The ventilation strategies that have been modelled include, mixing and displacement systems for the mechanical ventilation and both single-sided and cross-ventilation strategies, using window openings, for the natural ventilation systems. The preliminary results from the CFD simulations have predicted E_z values ranging from 0.13 to 2.05 for the mechanical ventilation strategies and from 0.4 to 1.36 for the natural ventilation strategies.

Zack Wang – PhD, UCL

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I am a PhD student at the UCL Bartlett School of Environment, Energy and Resources. I studied BSc Environmental Geoscience at the UCL Earth Sciences Department. After that, I had one year working experience in petrochemical industry in China. I completed my MSc in Economics and Policy of Energy and the Environment at the UCL Energy Institute focusing on energy and environmental economics, policy assessments and energy modelling. My research interests include energy and environmental policies, business and sustainability, and low carbon technologies especially decarbonisation in power and heating sectors.

What are the economic and environmental advantages or disadvantages of integrating heat pumps with district heating for the UK's domestic heating sector through different topologies: individual, district level, both, or neither?

Electric heat pumps and decarbonised electricity are proposed as promising technologies that could replace gas heating and contribute to the future low-carbon heat mix. District heating networks have been transforming from fossil fuel-based to renewable-based energy over several generations to meet space heating and domestic hot water demand. Both technologies have been well developed, with abundant scientific research and industrial experiences in some European countries over the past few decades. However, the market shares of heat pumps and district heating networks are low in the UK, and there are technical, social, and economic challenges for their deployment.

The aim of this project is to better understand heat consumptions in domestic buildings and the role of heat pumps and district heating by assessing the topological configurations of heat pumps, district heating networks, and thermal storage solutions for various types of buildings on different scales. This study investigates heat pumps in individual households versus district heating networks through techno-economic models, in order to further explore their comparative advantages based on different aspects, including technical performance, carbon emissions, financial practicability, and policy uncertainties.

Stephen Watson – PhD, Loughborough University

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Stephen studied Engineering (MEng) at Durham University from 2009 to 2013. His final year specialisation was in New and Renewable Energy, which consisted mostly of Mechanical Engineering with some Electrical Engineering, and his final year project was on recovery of heat from domestic graywater. At Loughborough, his MRes project was about overheating of artifical sports pitches and the possibility of removing heat.

Stephen is interested in heat pumps and the role they might play in future UK domestic heating. Stephen has recently been analysing data as part of the DEFACTO project on smart heating controls.

Increased electricity demand from heat pumps, taking user behaviour into account

In order to meet CO2 reduction targets, it is commonly envisaged that heat pumps will play a significant role in the UK's future domestic space and water heating. Most of the UK's space heating demand currently is met by the gas network, whereas meeting this demand from the electricity grid could prove challenging. However, electric heat pumps respond differently to gas boilers, having lower water temperatures and lower maximum heat output, thus possibly leading to different user behaviour.

In order to be able to make predictions about possible future national electricity demand under a widespread uptake of heat pumps, an empirical approach is being used, based on half-hourly demand data from real houses with heat pumps and gas boilers. These data are being analysed to investigate patterns of heating, the relationship to the type of house and occupants, and the degree of simultaneous usage, in order to obtain estimates of future national electricity consumption of heat pumps.

Catherine Willan - PhD, UCL

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Prior to joining UCL, Catherine worked for eight years in the low carbon sector. At the Carbon Trust, she worked in policy, strategy and business planning. Projects included: the development of PAS2050 and carbon labeling; research into global carbon trading mechanisms; greenhouse gas reporting; carbon-saving strategies for large corporates; and many other product and policy development areas, working with a wide cross-section of government and industry stakeholders. Subsequently, she joined the EOI business school in Madrid, where she taught and supervised international postgraduate students.

Life in the gap: How does a construction team respond to targets for energy and Carbon use?

Performance targets for energy and carbon in building use pose a significant adaptive challenge to UK construction companies. However, they also hold the potential to drive significant improvements in the efficiency and environmental impact of the national building stock. Unfortunately, practical implementation of these targets has so far met with mixed success. This research uses concepts from Science and Technology Studies (STS) to explore a case study of a construction company seeking to adhere to ambitious targets for energy and carbon emissions in use in a large non-domestic project. It draws on a rich variety of qualitative sources, including interviews, observation and documents. This research demonstrates the value to policy makers of a situated understanding of how construction companies respond to new incentives

Dan Wright – PhD, Loughborough University

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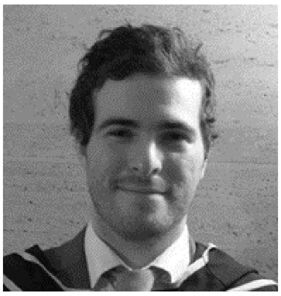

Dan's background is in psychology, sustainable business practice and project coordination. Since joining LoLo CDT in late 2016, he has been developing his skills using mixed-methods research designs (combining engineering approaches with psychological and sociological analysis), applying this approach in the fields of overheating risk assessment and developing evidence-led advanced heating controls optimisations. Dan is collaborating with Simble, an innovative SaaS (software-as-a-service) specialist, to produce media content aimed at engaging public and business with the latest energy demand-related policy and technology news strengthened with insights from academia and industry.

People, Energy and Zonal Control Applications

Since the mid-1970s, infrequently used spaces in UK homes, such as bedrooms, continue to be heated despite being vacant, thus wasting energy and increasing bills. Zonal space heating controls (ZCs) support occupants to choose when and how much they heat individual spaces. Existing research shows that energy use in houses fitted with ZCs either reduces or increases compared to a baseline. This novel research aims to understand *why* some occupants save energy using ZCs, *what* the barriers may be to saving energy, and *how* barriers can be overcome to save energy. A mixed-methods research design will be employed to investigate a set of homes (n = 20) in the midlands, UK. The outcomes will inform policy regarding the potential of ZCs to reduce domestic energy demand, support evidence-based design of interfaces and contribute to the growing understanding of how people interact with energy.

Aligned PhD students

Ayooluwa Adewole – PhD, UCL

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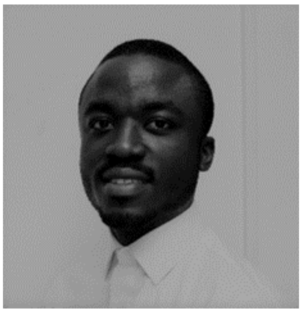

Ayooluwa is an energy economist with interests in renewable energy. With a background in Economics, He obtained an M.Sc. in Energy Economics and Policy from University of Surrey with Distinction in 2015. Before commencing His PhD at UCL, He previously worked as a researcher at the MacArthur Foundation Funded, Centre for Petroleum, Energy Economics and Law, University of Ibadan, Nigeria. As an ORACLE Certified Database Administrator, He contributed to building the first online open database on Nigerian Energy Data. He is currently a Doctoral researcher at the Energy Institute of the University College London, focusing adoption decisions for solar energy in Nigeria.

Adopting Solar PV for Back-up Electricity in Nigerian Residential Estates

Nigerians in urban cities face unreliable and erratic grid electricity supply. This has led to a reliance on self-generation through back-up (diesel and petrol fired) generators to meet electricity demand. The associated global pollution from these generators in the form of greenhouse gas emissions and local environmental, noise and air pollution pose challenges to residents. By adopting solar energy, residents can enjoy benefits such reliability, clean air and serene environments, provided the adoption is carried out collectively such as in neighbourhoods where generators are banned. Using both qualitative and quantitative methods, this study seeks to investigate how these clean and quiet benefits of collectively adopting solar PV can enhance its attractiveness among residential homeowners in Nigeria. Furthermore, it seeks to understand if homeowners will be drawn to such clean estates if they can trade energy.

Luke Taft – PhD, UCL

luke.taft.17@ucl.ac.uk

Having completed an MSc in energy policy at SPRU (the University of Sussex) in 2017 my ESRC funded studentship is allowing me to continue my interest in the role heating technology plays in shaping our everyday lives. My masters dissertation focussed on the role of change agents within developmental niche clustering of low-energy social housing and attempted to highlight the now sadly dwindling value of investments in this area. Prior to this I completed a BSc in Physics (University of Reading, 2006) and worked in various roles across the musical instrument industry.Abstract (current students only)Reconfiguring thermal comfort in offices

Reconfiguring thermal comfort in offices

This project takes an unconventional 'bottom-up' and anthropological view to thermal comfort in office spaces through ethnographic methods and a spread of applied academic disciplines. The work is aiming to synthesise a view of offices as people in their environment, as opposed to the more objectively formed view of offices as people and an environment that has been implicitly presented within the literature to date. This project is intended to make a contribution towards our understanding of how our use of technologies in the built environment creates and shapes overall energy demand, and the role this environment and the technologies employed play in energy consumption

MRes students

Ahmed Ahmed – MRes Energy Demand Studies, LU

a.ahmed-18@lboro.ac.uk

Graduated from the University of Birmingham with a degree in Electrical Engineering. Several years of working experience doing industry work, and also worked as a teacher having taught both in the UK and abroad. Gained MSc in Renewable Energy from the University of Nottingham, 2017. Current – LOLO student.

Zero energy building (ZEB). Studying and investigating the extent to which integrated renewable energy resources generated onsite balances with a building's energy demand, covering and assessing technology efficiencies, space and system integration limitations, energy generation, transmission, equipment and building losses.

Ashanafi Araya – MRes Energy Demand Studies, UCL

A.Araya-18@student.lboro.ac.uk

I did my undergraduate degree at Lancaster University in Sustainable Engineering in 2016. I studied Sustainable Engineering because of my interest in renewable energy and in technologies that deliver an integrated sustainable benefit to communities in terms of social, economic and ecological aspects. I did my final year project on '*Analysis of the dependence of wind turbine performance on the characteristics of the atmospheric boundary layer*'. I then did my master's degree in Water and Waste Engineering at Loughborough University, WEDC, in 2017.

I am looking forward to getting involved in a research related with air conditioning systems in non-domestic buildings.

Kinan Al Zayat – MRes Energy Demand Studies, UCL

k.zayat@ucl.ac.uk – on interruption of studies

Kinan worked as a research assistant at University College London analysing aircraft operating cost and performance as part of the SAECA project. He built a model simulating the costs occurring for different airlines around the world. His thesis at City University London focused on evaluating the environmental impact caused by extra-atmospheric intercontinental travel. He recently graduated with an MSc in Aerospace Vehicle Design from Cranfield University. Prior to Cranfield, Kinan worked as a service engineer, providing support for pharmaceutical lab equipment.

Paul Drury – MRes Energy Demand Studies, UCL

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Paul is a graduate in Mechanical Engineering from Nottingham University. He has over 18 years industry experience working within manufacturing and production development. In 2017 he completed an MSc in Energy and Sustainable Development from De Montfort University, Leicester.
Research interests include sustainable and low energy buildings, social aspects of energy use and whole systems approach.

Anna Gorbatcheva – MRes Energy Demand Studies, UCL

anna.gorbatcheva.17@ucl.ac.uk

Anna holds a BEng in Engineering with Business Administration and an MSc in Engineering with Innovation and Entrepreneurship.During her undergraduate degree, she completed a work-study placement at the company Bosch in Germany. There she had the opportunity to experience the automotive industry. By interning in different departments over the course of three years, she gained insights into manufacturing and plant coordination processes.
She then joined UCL to complete her master's degree with her final project based on modelling a blockchain-based peer-to-peer energy trading platform. With a great interest in this highly innovative topic, she decided to continue her research in Energy and Blockchain by joining the LoLo CDT.

Benjamin Halls – MRes Energy Demand Studies, UCL

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I graduated from Nottingham Trent University with a master's in physics in 2016. For the past two years I have been a pricing analyst in the financial sector where I gained a real interest in modelling to optimise insurance pricing. I hope to continue to develop my modelling skills and apply this to the built environment. Interest in modelling/simulation of built environment.

Zaki Iqbal – MRes Energy Demand Studies, UCL

Zaki.iqbal-18@student.lboro.ac.uk

Zaki Iqbal has been working as a Senior R&D engineer at RAK Research & Innovation Center, UAE. He has over 11 years+ of experience. He developed a micro-grid to power Solar Outdoor Lab (SOLAB). He has been active in the field of hybrid energy production. Under his supervision, a 96 MWhr Hybrid system was successfully implemented. He has written various papers in scientific journals and presented his work in international conferences in US, Japan and Europe. Iqbal is a certified PV Associate of North American Board of Certified Energy Practitioners. He holds a master's degree from the University of Leicester-UK with distinction.

Elizabeth Francis – MRes Energy Demand Studies, UCL

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My background is in Humanities, having studied History, Literature and Culture and then Poverty and Development, both in Brighton.

Giulia Ragosa – MRes Energy Demand Studies, UCL

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Before joining the Lolo CDT, Giulia completed an MSc in Global Governance and Ethics at UCL's School of Public Policy, through which she developed a strong interest in climate and energy policy. In her research, she hence explored issues related to attracting private capital into renewable power generation projects in developing countries. Previously, she trained and worked as a journalist and gained experience in the field of corporate social responsibility. Giulia's research interests lay in the role played by the private sector in the transition towards a low-carbon economy.

Eleonora Ruffini – MRes Energy Demand Studies, UCL

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Eleonora holds a MSc in Energy and Nuclear Engineering from the Polytechnic University of Turin. As affiliate at the Lawrence Berkeley National Laboratory, she worked on the cost analysis of sustainable transportation technologies. Before starting the MRes, she worked as research intern at Joule Assets Europe, supporting the research in the context of two H2020 funded projects (FLEXICIENCY and SEAF). She also collaborates with Joule Smart, assessing potential energy savings from improved lighting, HVAC and building management systems in order to draw proposals for viable projects. Her interests range from demand response and demand side management to electric vehicles.

Chameli (Niki) Sahabandu – MRes Energy Demand Studies, UCL

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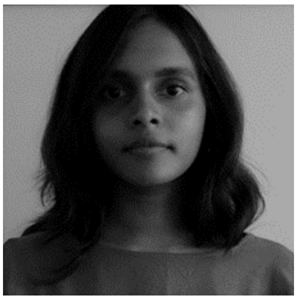

Niki graduated from the University of Liverpool where she completed a Masters degree in Physics. She has worked as a research intern for the 'Muon g-2' group at UoL, which is part of a wider experimental group looking to gather high precision particle data in order to determine the structure of The Standard Model. She completed her final year project, a simulation based study of the ideal environment for particle trackers, within the same group. An interest in growing as a researcher in an interdisciplinary environment as well as the drive to apply physics to help resolve real-life energy demand problems lead her to join the LoLo CDT.

Cairan Van Rooyen – MRes Energy Demand Studies, UCL

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I have 14 years experience as a Building Physics Engineer and Chartered Building Services Engineering (MCIBSE) consultant. I have held senior positions in a small and medium multi-disciplinary consultancies, working as a designer in the education and commercial sectors in the UK.

Much of my experience has revolved around the technical design and analysis of the internal environment. All these design decisions have a direct impact on energy use, the way people interact with spaces and the health and wellbeing of building users.

My research interests involve ventilation systems and practices in buildings and how this impacts noise levels, indoor air quality and overheating, whilst also considering how this affects the health and wellbeing of the occupants.

Nicole Watson – MRes Energy Demand Studies, UCL

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After graduating from the University of Exeter with a BA in English and German, Nicole completed an MSc in Global Governance and Ethics at UCL, with particular focus on energy and climate policy and quantitative research methods. Alongside her MSc, she worked as a publication editor for a climate change adaptation consultancy and undertook an internship in metadata enhancement with CLOSER (Cohort and Longitudinal Studies Enhancement Resources). Her research interests include public attitudes towards demand-side policies and the use of behavioural insights to understand and incentivise consumer uptake of new initiatives.

Letitia Zainea – MRes Energy Demand Studies, UCL

letitia.zainea.18@ucl.ac.uk

I have a bachelor's degree in Economics and Management and a master's degree in Computer Science. I have spent one year working as a Business Operations Analyst and then as Program Coordinator at General Electric. My research is focused on exploring how Distributed Ledger Technologies could be used to tackle issues in energy trading and decarbonisation. During my PhD, commencing next year, I will focus on how demand side response can be verified, authenticated and optimised using non-intrusive load monitoring techniques with machine learning and blockchain technologies.

Alumni

Alexandros Adam (PhD, UCL)
Energy Analyst, National Technical University of Athens

Alexandros received his undergraduate diploma in Mechanical Engineering from the National Technical University of Athens. He then came to London and obtained an MSc in Building Services Engineering with Sustainable Energy from Brunel University. He worked as a building services engineer for a consultancy in London. In 2010 he joined the London – Loughborough EPSRC Centre for Doctoral Training in Energy Demand from which he obtained his MRes in Energy Demand Studies. In 2011 he joined the UCL Chemical Engineering department for a PhD degree in collaboration with the UCL Energy Institute. In 2015 Alexandros passed his PhD viva on the topic: "System Modelling and Optimisation Studies of Fuel Cell based micro-CHP for Residential Energy Demand Reduction". Alexandros is now working as an Energy Analyst at the National Technical University of Athens.

Joynal Abedin - PhD, Loughborough University

Joynal is an Electronic Engineer by professional training and has substantial industrial Research & Development experience. He was awarded a prestigious industrial sponsorship by Thorn EMI Electronics Defence Group (now Thales) and studied MEng & BEng (Hons) degrees in Electronic and Electrical Engineering. He completed a two year IEE accredited post- graduate industrial training programme at Thales. Joynal has over eight years industrial R&D experience and held senior design engineer posts at Marconi Communications and Filtronic Comtek. Joynal has completed a Master of Research (MRes) degree in Energy Demand Studies at Loughborough University. Joynal's PhD research project title is 'Thermal Energy Storage in Domestic Buildings: A study of the benefits and impacts', and his research interests include short-term thermal energy storage technologies, building energy modelling & simulation, Demand side management and thermal energy storage materials.

Carrie Behar (PhD, UCL)
Senior Sustainability Consultant, Useful Simple Projects

I completed my PhD in spring 2016 and am currently working as a Senior Sustainability Consultant at Useful Simple Projects. We are a group of sustainability professionals providing strategic and technical consultancy services for the built environment. I enjoy the challenge of working across a broad set of environmental, social and economic themes on projects ranging from developing corporate sustainability strategies for well-known brands, to reviewing sustainable development opportunities for exciting new infrastructure and construction projects.

I also teach a module on Post Occupancy Evaluation for the MSc Environmental Design and Engineering course at UCL and am visiting sustainable design tutor on a number of university courses.

Francesco Babich - PhD, Loughborough University

Francesco is currently working as Senior Researcher at EURAC Research within the Energy Efficient Group (Renewable Energy Institute) and is about to complete his PhD at Loughborough University. During the last two years, he worked also as University Teacher at Loughborough University His field of interest is numerical modelling, including CFD, human thermal regulation and dynamic thermal modelling, and measurement techniques that are used to validated the models. Alongside his research activity, Francesco organized the second LoLo student-led conference, which had over 100 registered participants mainly from UK universities, is working as a University Teacher mainly in Investment Appraisal.

Previously, Francesco studied at the University of Trieste (Italy), where he obtained his Bachelor and Master Degree in Building Engineering. Having completed his Master, he was allowed to take the exam for the professional engineer license in July 2012 in Italy. He worked as an engineer and as a project manager for one year and half in Italy and Germany before joining LoLo in September 2013. He completed with distinction his MRes in September 2014.

Thermal comfort in non-uniform environments: real-time coupled CFD and human thermal-regulation modelling and validation

Mechanical systems such as built-in air conditioning consume a lot of energy because they cool down quite evenly the entire space. On the other hand, personalised systems such as air movement generated by a fan in warm environment improve occupants' thermal comfort while using less energy, but generate transient and asymmetrical environments. Traditional thermal comfort models (PMV-PPD, adaptive) have limited use for complex transient and asymmetrical conditions. A more advanced model, such as the IESD-Fiala model, may provide with better results. The IESD-Fiala model has been successfully and entirely coupled with a CFD code. This research aims to test and validate the coupled model.This research project includes field studies, computer based modelling and thermal chamber studies, and it is linked with a wider project that involves Loughborough University (UK), University of California Berkeley (USA), CEPT University Ahmedabad (India) and De Montfort University (UK), allowing for wider application of the developed models.

Arash Beizaee (PhD, Loughborough University)
Research Associate (DEFACTO Project), Loughborough University

Arash graduated as a mechanical engineer in Iran and then continued his studies in the UK to obtain MSc in Building Services Engineering (with distinction) from Loughborough University. He joined LoLo CDT in 2011 and completed MRes in Energy Demand Studies (with distinction) before starting his PhD in 2012.

Arash is now working as a research associate on the DEFACTO research project at Loughborough University. DEFACTO is a 6 year interdisciplinary project started in 2012. The project examines the way that hundreds of households heat their homes and how the use of digital control enables reduction of energy use.

Nafsika Drosou – PhD, Loughborough University

With a Civil Engineering background (University of the Philippines 2003, DMC Inc. scholarship) and diverse work experience, Nafsika completed an MSc in Low Carbon Building Design & Modelling at Loughborough University in 2010. Her dissertation employed simulation tools to examine the trade-off between visual and thermal comfort in a vernacular education building. She then joined Portsmouth University, School of Architecture, as a Research Assistant for SILCS (Strategies for Innovative Low Carbon Settlements) an EU Interreg IVC project. Returning to Loughborough University, she completed the MRes in Energy Demand Studies in 2013, with a dissertation project investigating IAQ compliance of refurbishment designs for a Victorian classroom, through CFD modelling.

Assessing actual daylighting performance of classrooms in use

Daylight is a non-depleting energy source with the potential to reduce lighting energy and contribute to the health and wellbeing of building occupants. The latest daylight design regulations for UK school buildings employed the new Climate Based Daylight Modelling (CBDM) metrics to specify daylight compliance, instead of using the traditionally and internationally used metric. However, knowledge that will allow assessing whether this move improves the daylighting performance of classroom designs is sparse. The project at hand addresses this gap by providing evidence of the visual needs, the user behaviour (electric light and blind use) and the subsequent operational daylighting performance from the day-to-day reality of four modern learning environments. A mixed method research approach associates the measured quantitative parameters with users' subjective views, revealing the underlying reasoning of observed behavioural responses and enabling an estimation of the potential held within daylight specifications and metrics to shape operational daylighting performance.

Özlem Duran – PhD, Loughborough University

After Özlem held her undergraduate degree in architecture, she worked in various design and construction companies in Istanbul, such as Arup. In 2007, she started MSc. in Istanbul Technical University (ITU), and completed her dissertation in the Applied Sciences University of Stuttgart (HFT) where she worked as a researcher later on. Currently, she is studying at Loughborough University as a member of LoLo CDT where she completed MRes in 2013 and writing up her PhD. She is also a part-time lecturer in Architectural Technologies at Nottingham Trent University

Optimised retrofit strategies for post-war office buildings

The aim of the project is to optimize the retrofit process of post-war non-domestic modernist buildings focusing specifically on office buildings, by applying dynamic energy simulations to typical building model that represent this defined building stock.

Multiple combinations of energy saving refurbishment measures were applied to representative models of post-war office buildings. Based on energy consumption, thermal comfort and costs, a range of heating and cooling refurbishment features were evaluated under a parameter study. The initial evaluation shows that although retrofitted post-war offices with high insulation consume negligible amounts of heating energy, thermal comfort could only be provided by additional active cooling in future weather conditions as a result of over-heating which results in higher costs and lower greenhouse gas reductions.

Mike Fell (PhD, UCL)
Research Associate, Buildings (Domestic Energy & Behaviour),
UCL Energy Institute

Mike Fell researches the public acceptability of domestic demand-side response (DSR).

Prior to joining the London-Loughborough CDT Mike was the energy commissioning editor at Earthscan (a leading publisher of books and journals in sustainability). He graduated from the University of Southampton in 2004 with a BSc in Marine Science with French.

Mike has a keen interest in research/policy engagement, and regularly organize events bringing academics and policymakers together. From March to June 2013 he undertook a POST/EPSRC Fellowship in the House of Commons Library, briefing Members of Parliament on subjects in science and the environment.

Together with colleagues Mike also set up and coordinates the UCL-Energy Social Sciences Group which aims to bring together researchers across UCL with an interest in people and energy. After finishing his PhD Mike is now back at UCL Energy Institute, working as a research associate at the RCUK Centre for Energy Epidemiology. His focus is on behaviour and energy use in homes.

Pamela Fennell – PhD, UCL

After studying engineering at Cambridge University, and a Masters in the Management of Construction Enterprises at the ESTP, Paris, I worked for 14 years in the procurement of public private partnership projects. During this period, I led projects in a wide range of sectors, focusing in recent years on the education sector. Most recently, I spent 4 years leading a partnership between Southwark Council and Balfour Beatty which invested £250m in the refurbishment and rebuild of 13 schools. I obtained an MBA with distinction from Imperial College in 2007 and an MRes with distinction from UCL in 2014.

Energy Performance Contracting – is it time to check the small print?

In an Energy Performance Contract, the installer of an energy efficiency measure guarantees the expected savings which means EnPCs potentially have a key role to play in increasing levels of investment in energy efficiency.

Understanding the detail of how performance will be measured or "reading the small print" is essential if the parties are to understand their full risk exposure and their likely financial returns.

This study uses a stochastic modelling approach to investigate the effect of risk allocation on financial returns for clients and contractors and finds that the choice of measurement boundary for a lighting upgrade project has a significant effect on the level of protection that clients can expect from the guarantee. The effects vary depending on the client's underlying patterns of lighting use.

Louis Fifield – PhD, Loughborough University

Louis Fifield is a mechanical engineering graduate from the University of Manchester. He completed his final year project on hospital energy consumption and saw the CDT as way to further his interest in on the topic.

Being one of the first cohorts on the program he enjoyed completing an MSc in Low carbon building design and modeling where his research focused on monitoring Leicester city's urban heat island.

Louis has just passed his PhD viva with corrections, his project combined his interest in hospitals and monitoring to carry out an investigation of energy consumption in UK hospital buildings.

Stephanie Gauthier (PhD, UCL)
Lecturer in Energy and Buildings, University of Southampton

Dr Stephanie Gauthier is Lecturer in Energy and Buildings within Engineering and the Environment at the University of Southampton.

Stephanie Gauthier is a lecturer in Energy and Buildings within the Faculty of Engineering and the Environment. Her degree and diploma were in Architecture followed by an MSc in Environmental Design and Engineering from UCL. Her PhD developed a new method to assess human thermal comfort using ubiquitous sensors, and introduced an extended model of behavioural responses to cold thermal discomfort.

Stephanie has over eight years of consultancy experience mostly focused in building and infrastructure, working at Arup, HOK, Atkins and ADPi. As an architect and project manager in multi-disciplinary design teams, she has collaborated on schemes in Abu Dhabi, UK, France and China; including the Oriental Art Center in Shanghai, the King Alfred Development in association with Gehry Partners, BSkyB broadcast center in London and Abu Dhabi National Stadium.

Virginia Gori (PhD, UCL)
Research Associate, UCL Energy Institue

Virginia is a Research Associate in the physical characterisation of buildings at the RCUK Centre for Energy Epidemiology (UCL Energy Institute) and part of the Physical Characterisation of Buildings group. Her PhD thesis, entitled "A novel method for the estimation of thermophysical properties of walls from short and seasonal-independent insitu surveys", combined Bayesian statistics, building physics and physical monitoring of insitu buildings to evaluate the thermophysical performance of building elements. The method developed showed the ability to provide robust estimates of the thermophysical properties of building elements using shorter monitoring campaigns than the incumbent method and collected at all times of the year.

Virginia has a keen interest in exploring the thermal performance of buildings by means of monitoring campaigns, building physics, modelling and data analysis. Virginia's research interests build on her engineering background, her MRes in energy demand studies, and previous research on the energy demand of urban neighbourhoods.

Sven Hallin - PhD, Loughborough University

I originally qualified with an Economics degree at Trinity College Dublin and on completion joined a UK multinational and was trained in the development and manufacture of a variety of surface coatings. After originally working in the UK, I then worked as an expatriate in Africa and the Far East before returning to the UK and starting my own manufacturing business specialising in the production of screen printing ink. This business was sold after eighteen years, and after a short period of retirement I undertook an MSc in Real Estate at Nottingham Trent University which was completed in 2010.

After completing a MRes in Energy Demand Studies in 2012, my PhD project entitled "Reducing residential sector dependence on fossil fuels: a study of motivating factors" was completed in 2015.

Currently, along with my supervisors, Professor Thomas Weyman-Jones and Dr Elizabeth Hooper, I have been working on a research paper entitled "Why the Green Deal failed: Case Study evidence and behavioural analysis." I'm also involved in some non-academic writing projects, specifically a second novel (which so far is around one third complete). I have also written a number of short stories. However, I am keen to have the opportunity at some time in the future to do some further academic research as a counterbalance to my interest in writing popular fiction.

Richard Jack (PhD, Loughborough University)
Energy Solutions Engineer, Willmott Dixon Energy Services Limited

I completed my PhD in 2015, having had a (mostly) fun and enlightening time in Lolo. Completing a PhD is necessarily an introspective process at times, but being a part of the Lolo really helped me to keep an outward-looking perspective which helped to make my work more relevant to others and generally made life more interesting.
After completing my PhD I worked as a research associate at Loughborough University for a year, and then moved to Willmott Dixon Energy Services as an energy solutions engineer in March 2015. I specialise in performance measurement and assessment of buildings and building systems, and continue to apply the research that I completed during my time in Lolo.

Paula Morgenstern (PhD, UCL)
Building Performance Manager, BAM Construct UK

I completed my PhD in summer 2016 and am now working as Building Performance Manager at BAM Construct UK. We are a company handling all aspects of the building lifecycle, i.e design, construction, FM and property development.

My role involves implementing a process for post occupancy evaluation within all our projects, so that experiences from past projects can be used to improve the performance of future buildings – for the occupants, the client and the environment.

Ashley Morton – PhD, Loughborough University

Ashley has a background in Chemistry and Energy after completing a MChem (with industrial experience) and an MSc at Heriot Watt University. She joined the LoLo CDT in 2011.

For her Master's Ashley has undertaken dissertations in computational chemistry (MChem), fuel poverty (MSc) and temperature variation in homes (MRes). In 2012 she joined the EPSRC funded DEFACTO: Digital Energy Feedback and Control Technology Optimisation project to undertake her PhD. She submitted her thesis "Heating use in UK homes" for examination at the start of Oct 2016. Currently Ashley is working as the Cohort Interaction Research Associate on the DEFACTO project.

Heating use in UK homes

The aim was to examine household space heating use and to identify the reasons behind heating use in homes. Two main investigations were carried out to understand and identify the how, what and why with regards to heating use. The first investigation being a qualitative focused study on how people currently use their heating within their home and the reasons behind such heating practices. A new taxonomy of heating characters relating to heating use drivers was then developed. The second investigation was a small scale monitoring study of homes for ten months after new heating controls were installed. A mixed method approach was taken to uncover what people did with their heating, how they interacted with the controls, the reasons why they did what they did and the evolution of use through seasonal shifts. The benefits of adopting mixed method approaches within heating use research are also presented.

Thomas Neeld – PhD, UCL

After graduating with a first class master's degree in Physics I went on to spend two years working with IBM as a Technology Consultant in their Business Analytics unit, working closely with some of the biggest energy companies. After which I aimed to go back into university and pursue a PhD within the broad field of Energy in order to specialize. In my spare time I am a keen rower and row for London Rowing Club along the Embankment at Putney with the ultimate aim of winning at Henley.

Moira Nicholson (PhD, UCL)
OFGEM

Moira has recently submitted her PhD thesis on consumer participation in demand-side response. She now works in the Behavioural Insights Unit at Ofgem.

Using behavioural science to increase consumer adoption of time of use electricity tariffs: evidence from survey and field experiments

A challenge for realising the benefits of smart meters, promoting energy security and decarbonising electricity is encouraging domestic consumers to switch from flat-rate electricity tariffs to a new generation of time of use (TOU) tariffs.

In a marked departure from the existing literature, this thesis argues that opt-out enrolment (a type of 'nudge') is unlikely to be a suitable method of recruiting consumers onto TOU tariffs, even though it could achieve almost universal enrolment.

The first study shows that half of British energy consumers are unable to make informed choices about the cost-effective tariff for them, particularly those in low socio-economic grades. Consumers are therefore unlikely to opt-out of being switched onto a TOU tariff, even when unsuitable. Results from three further studies covering a collective sample size of 16,000 participants, show that tailoring the marketing of TOU tariffs towards electric vehicle (EV) owners increases demand for TOUs amongst EV owners whilst reducing demand amongst non-EV owners, who pose less of a burden to the electricity network and are less likely to save money from switching. Unlike opt-out enrolment, tailored marketing is an 'effective and selective' nudge (Johnson, 2016). Unlike personalised defaults, tailored marketing can achieve informed consent.

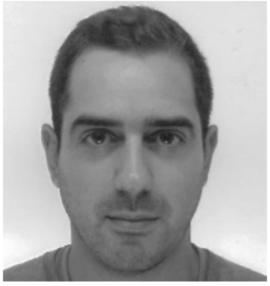
The results have implications for multiple 'smart' energy programmes, from signing up to TOU tariffs or direct load control contracts to participating in vehicle-to-grid services. In each case, a decision will need to be made about whether consumers will be left to opt-in or opt-out of such services, and to what extent it matters that consent is informed.

Jenny Love (PhD, UCL)
Research Associate, Energy & Buildings, UCL Energy Institute

Prior to her appointment as a Research Associate, Jenny worked for two years as a Consultant at Element Energy, a low carbon energy consultancy carrying out rigorous mathematical analysis to help provide a sound evidence base for clients to make decisions on low carbon strategy. Jenny was hired as a built environment specialist and carried out modelling and analysis for clients including DECC, the CCC, energy companies and charities. Example projects included: creation of a dynamic model of a micro-CHP system interacting with a house, zonal simulation of different heating systems in a historic palace to protect the building without a high energy penalty and technoeconomic modelling of the integration of heat pumps in district heating networks.

Jenny's training in the field of energy demand came from her PhD at the LoLo Centre for energy demand reduction in the built environment, where she studied how energy efficient building retrofit might change occupants' heating behaviour. Her work focussed on integrating technical evidence from sensors and social data from occupants to discern how increase in internal temperature comes about when homes are retrofitted. She was able to challenge the conventional physics-based and economic approaches to retrofit, proposing a socio-technical approach instead. Jenny holds an MSc in Environmental Design and Engineering at UCL and a Physics degree at the University of Oxford. Between these courses she spent a year volunteering with a Christian Organisation.

Argyris Oraiopoulos – PhD, Loughborough University



Argyris joined the LoLo CDT in 2012 where he completed his MRes on Energy Demand and his PhD on the development of an empirical model that is able to predict overheating in UK homes using descriptive time series analysis. He then worked as a Research Associate at Loughborough University looking at urban scale energy modelling. Currently he is employed as a Research Officer at the Association for the Conservation of Energy (ACE) working on energy policy.

Argyris' research interests include:

Overheating (criteria & predictions); Time Series Analysis & Empirical Modelling; Dynamic Thermal Simulation Modelling; Occupant Behaviour & Attitudes; Energy Policy; Public Engagement & Education (STEM & EWB Ambassador)

Sofie Pelsmakers (PhD, UCL)
Assistant Professor, ARHUUS School of Architecture

I am an architect and environmental designer with more than a decade of hands-on experience designing, building and teaching sustainable architecture, including at the University of East London where I lead a masters programme in sustainable design. I finished my doctoral research at the Bartlett, UCL's faculty of the Built Environment, where I also lead a low energy housing retrofit module. I now co-lead the MSc Sustainable Architecture Studies with Aidan Hoggard. My PhD was titled "Pre-1919 suspended timber ground floors in the UK: estimating in-situ U-values and heat loss reduction potential of interventions" and I currently undertake research and consultancy in this area.I am co-founder of Architecture for Change, a not-for-profit environmental building organisation and author of The Environmental Design Pocketbook. Alongside my research interests, I am interested in environmental context as a generator of architectural design.

Daniel Quiggin (PhD, Loughborough University)
Renewable energy analyst, Investec Asset Management

My PhD covered supply-demand modelling of future energy scenarios and the quantification of household demand adaptations via demand side management. Energy demand research is difficult because its the interplay between economics, people, technology, social norms and buildings.
LoLo students benefit from the diverse research interests of the teach staff and PhD students alike.

My background is in Particle Physics, holding a Masters of Physics and moved into his current area of research via a Research Masters in Earth System Science.

Currently I model and analyse global supply – demand of renewable energy technologies for a Commodities and Resources team of an asset management group to inform the investment strategies of the groups funds.

Ella Quigley – PhD, Loughborough University

I have a background in mechanical engineering but I have long been interested in building energy use and sustainability. This led me to join the LoLo CDT at Loughborough University, where I undertook an MSc in Low Carbon Building Design and Modelling, followed by a PhD concerning the energy and thermal performance of steel modular residential buildings in the UK. I completed my PhD in August 2016; I am currently writing research papers about energy use and overheating in my case study buildings, and beginning to look for an interesting career in building performance and sustainability

Ed Sharp (PhD, UCL)
Research Associate: Spatiotemporal Energy Modelling, UCL Energy Institute

I am a geospatialist and energy modelller researching the spatio-temporal variation of renewable weather driven supply, domestic energy demand, non domestic stock models and air pollution in Great Britain. My overall aim is to improve aggregated scenario modelling by introducing spatial and temporal variation at a fine resolution using knowledge and methods from data science, GIScience and industry.

Examples of recent work I have done as part of my PhD and elsewhere can be seen on my blog at esenergyvis.wordpress.com.

Kate Simpson – PhD, Loughborough University

Kate recently submitted her PhD thesis; a mixed methods study aiming to identify whether eenergy-efficiency refurbishment of UK owner-occupied homes were successful from the householders' perspective, and according to physical measurements. Following this study, Kate has been granted funding from the Association of Colleges to undertake a study titled 'Energy-efficiency refurbishment of UK homes: The installers' perspective, from which she hopes to gain industry reflections on the thesis results. These findings are intended to inform policy, training within Colleges and further research on post-occupancy evaluation following domestic refurbishment. In addition, Kate recently started a literature review on the health impacts of alternative construction materials for Smart Shelter Research. During the thesis write-up stage she undertook a 12 month internship with the research team at the Centre for Sustainable Energy where she worked on a number of valuable qualitative and quantitative projects. Kate's background is in Building Surveying, and 'traditional' building maintenance and refurbishment, which has informed her recent teaching on a HNC in Construction and the Built Environment, for part-time students working in industry (from whom she is learning a lot!), at the University Centre of North Lindsey College, Scunthorpe.

Sam Stamp (PhD, UCL)
Teaching Fellow in Building Performance,
UCL Institute for Environmental Design & Engineering

Sam completed a four-year MSci in Physics at the University of Bristol in 2009, including a thesis exploring the potential for small-scale tidal stream technologies. This work on small-scale energy generation led to a position at LIRE, the Lao Institute for Renewable Energy, in Southeast Asia. Work here focused on delivering a demonstration project to provide off-grid electricity, through pico-hydro generators, to remote villages in Laos.

Sam returned to the UK in 2010 to undertake a Masters in Energy Demand. Having submitted his PhD in September 2015, Sam has now started to work as a Teaching Fellow in Building Performance at the UCL Institute for Environmental Design and Engineering.

Vicki Tink – PhD, Loughborough University

Vicki is a researcher currently writing up her doctoral thesis. Prior to her doctorate she completed the Master of Research in Energy Demand Studies. Her background is as a technologist, graduating in 2011 from Loughborough University with a degree in Product Design Technology BSc. Vicki's research interests are centred around domestic buildings, in particular those in need of renovation to make them more energy efficient. She is also interested in the design and manufacture of building components; overheating in energy efficient dwellings; collection of measurements from dwellings; and the improvement of simple modelling techniques (e.g SAP) to inform decision making.

The effect of internal wall insulation in solid wall dwellings on energy demand, thermal comfort and overheating

Approximately 30% of the UK's housing stock is comprised of older, solid wall buildings. These buildings are expensive to heat, inefficient and can be uncomfortable for occupants throughout the winter. Solid wall buildings can be made more energy efficient and winter thermal comfort can be improved by the installation of internal wall insulation (IWI). However, there are concerns that IWI could lead to overheating in the summer.

Through the course of this doctoral research Vicki had sole access to a unique facility comprised of a matched pair of solid wall semi-detached houses. The houses were characterised (co-heating test, airtightness test, U-value measurements) and monitored (continuous measurement of thermal comfort parameters and energy consumption) both before and after the left house was retrofitted with IWI. The outcome of this research is empirical evidence into the debate over whether IWI is an appropriate retrofit technique to provide comfortable and energy efficient dwellings.

Faye Wade (PhD, UCL)
Career Development Fellow in Energy & Society, University of Edinburgh

Faye Wade is a PhD researcher, adopting in-depth qualitative methods, including semi-structured interviews and observation, to explore the installation of domestic central heating systems. Aside from her PhD, Faye has gained experience in applying qualitative methods and social theories during short- term projects, including the use of focus groups and interviews to investigate residents' experiences of fuel poverty. Prior to the PhD, Faye completed a Master's degree in energy demand studies as part of the London-Loughborough EPSRC Centre for Doctoral Training, and a master's degree in chemistry at the University of York. Faye has just accepted a position at the University of Edinburgh as a Career Development Fellow in Energy and Society, in the Department of Science, Technology and Innovation Studies.

Peter Warren (PhD, UCL)
Senior Scientific Officer – Technical Energy Analysis,
Department for Business, Energy & Industrial Strategy

Peter completed his PhD on the mechanisms behind the success and failure of global energy efficiency and demand response policies. The PhD covered 30 countries, 36 sub-national states and 12 different types of demand-side policy. He worked at the IEA in the energy efficiency unit whilst finishing his PhD, and now works in the UK's Department of Energy and Climate Change.

Peter enjoyed his experience in the LoLo centre, particularly the multi-disciplinary nature of the course and regular access to energy experts from a range of disciplinary backgrounds.

In October 2015 Peter joined the Department of Energy and Climate Change (DECC) as a Senior Scientific Officer – Technical Energy Analysis, now the Department for Business, Energy and Industrial Strategy.

Selin Yilmaz – PhD, Loughborough University

Selin's research aims to develop a high resolution residential electricity demand model to provide insights into the amount of flexible demand that can be available for shifting in the UK residential sector. She has MSc on Renewable Energy Science and Technology from Ecole Polytechnique in France where she worked on organic photovoltaics. She has graduated from the Chemical Engineering Department from Middle East Technical University in Turkey.

Household Appliance Usage model to quantify the demand response potential in the UK residential sector

My research develops a novel modelling framework of bottom-up stochastic model that is able to generate realistic electricity demand profiles for domestic appliance use that are based on measured data. The aim is to use the model to provide insights into the amount of flexible demand that can be available for shifting, when aggregated across a number of homes. The results of the model were analysed to address the key findings and challenges in modelling high-resolution electricity demand from measured data. It is shown that the model realistically reproduces electricity demand profiles for a large number of households. Finally, amount of flexible load available provided by different households types and appliance types are shown.

Appendix: Posters

London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

ANNUAL COLLOQUIUM 2018

Adopting Solar PV for Back-up Electricity in Nigerian Residential Estates

Ayooluwa Adewole 2nd Year PhD Student, UCL Energy Institute
Supervisors: Michelle Shipworth, Xavier Lemaire, Danielle Sanderson
a.adewole.17@ucl.ac.uk

Current situation

- Unreliable grid electricity
- Leads to reliance on back up electricity from petrol/diesel generators

Global pollution: ↑ GHG Emissions

Local environmental pollution:
- Noise
- Air – Has health risks

Future picture

- Estates with homes using back-up Solar PV
- Homebuyers enjoy clean and quiet benefits
- Localised benefits from collective adoption
- Global benefits of reduced carbon emissions

Research Questions

1. Can clean and quiet electricity increase the adoption/appeal of solar PV among residential homeowners in Nigeria?
2. Can blockchain enabled energy trading increase the appeal of clean estates?

Methods

1. Qualitative: Interviews with real estate agents, estate developers, home buyers
2. Quantitative: Choice experiment with homebuyers of new residential estates

Choice Experiment

		Existing electricity grid infrastructure	With blockchain enabled energy trading
Petrol/ Diesel Generators Allowed (status quo)		Option A (control): Regular estates: Dirty and noisy	Option B: Regular dirty and noisy estates blockchain enabled energy trading
Petrol/ Diesel Generators NOT allowed		Option C: Clean and quiet estates (solar/inverter + battery)	Option D: NEW Clean and quiet estates with blockchain enabled energy trading

Initial Results from Interviews with estates agents

1. Homebuyers are interested in clean and quiet areas.
2. Some are willing to pay a little more for clean and quiet homes

Next steps

1. More interviews with estate developers and homebuyers to design and pre-test choice experiment instruments.
2. Carry out choice experiment

UCL
Loughborough University
EPSRC Engineering and Physical Sciences Research Council

ANNUAL COLLOQUIUM 2018

Design and control of mixed-mode cooling and ventilation in low energy residential buildings

Charalampos Angelopoulos 3rd year PhD Student [C.Angelopoulos@lboro.ac.uk]
1st supervisor: **Professor Malcolm J Cook**, Loughborough University UK
2nd supervisor: **Dr. Eftychia Spentzou**, Loughborough University UK
3rd supervisor: **Dr. Yash Shukla** , CEPT University India

London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

Introduction

Why this research now?

- Residential sector
  - 27% of total energy consumption in UK[1] and 50% in India[2]
- Exponential increase in floor space
  - Expected 500% increase by 2030[3] in India
- Higher comfort expectations
  - Economic growth
- Increased urbanization
  - x 3 current population in cities by 2030
- Future cooling strategies
  - Utilize natural ventilation/cooling to achieve long term sustainable growth

Gaps in literature review

- Lack of knowledge on control of mixed-mode buildings
- Absence of studies focusing on residential mixed-mode buildings

Aim

The aim of this research is to investigate the impact on thermal comfort and on energy savings of novel and sophisticated control algorithms in mixed-mode residential buildings in hot climates (i.e. India)

Methodology

Demonstration case

Control strategies for natural and mixed-mode ventilation

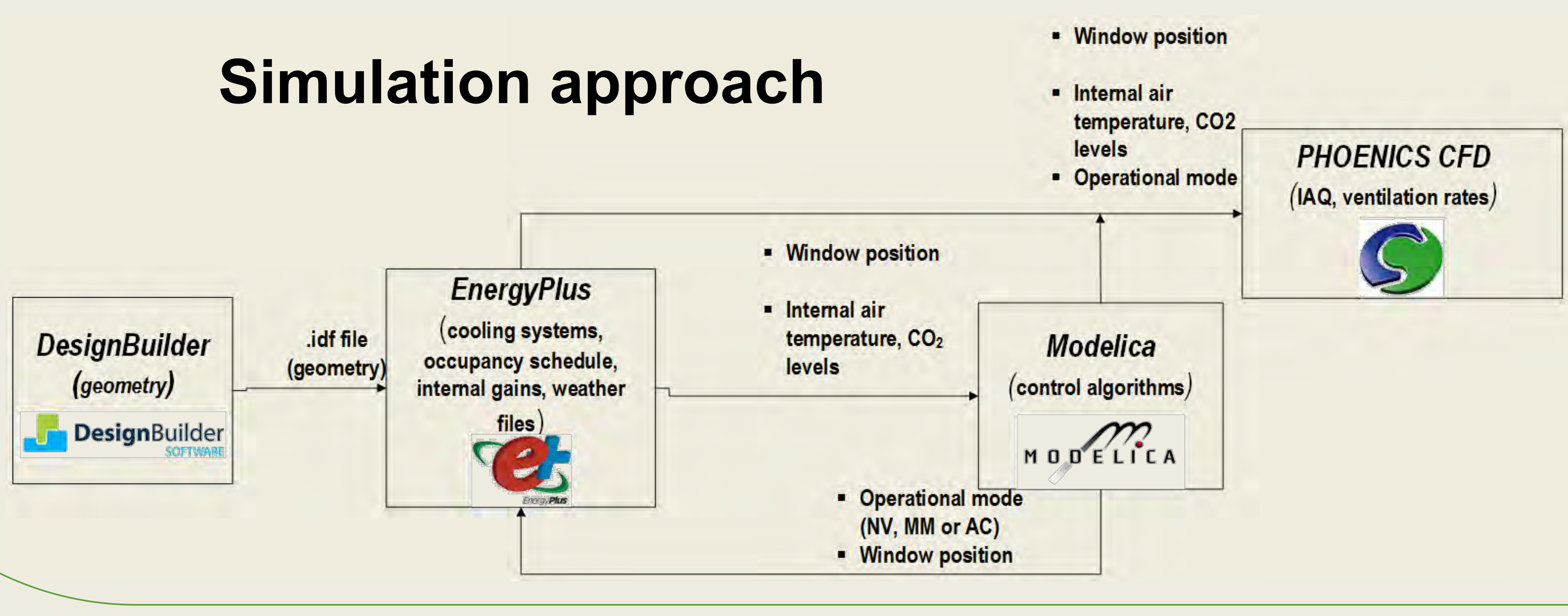
i. **Ventilation and Cooling Strategy 1 (VCS 1):** Natural Ventilation with split AC.

ii. **Ventilation and Cooling Strategy 2 (VCS 2):** Natural Ventilation with ceiling fan and split AC;

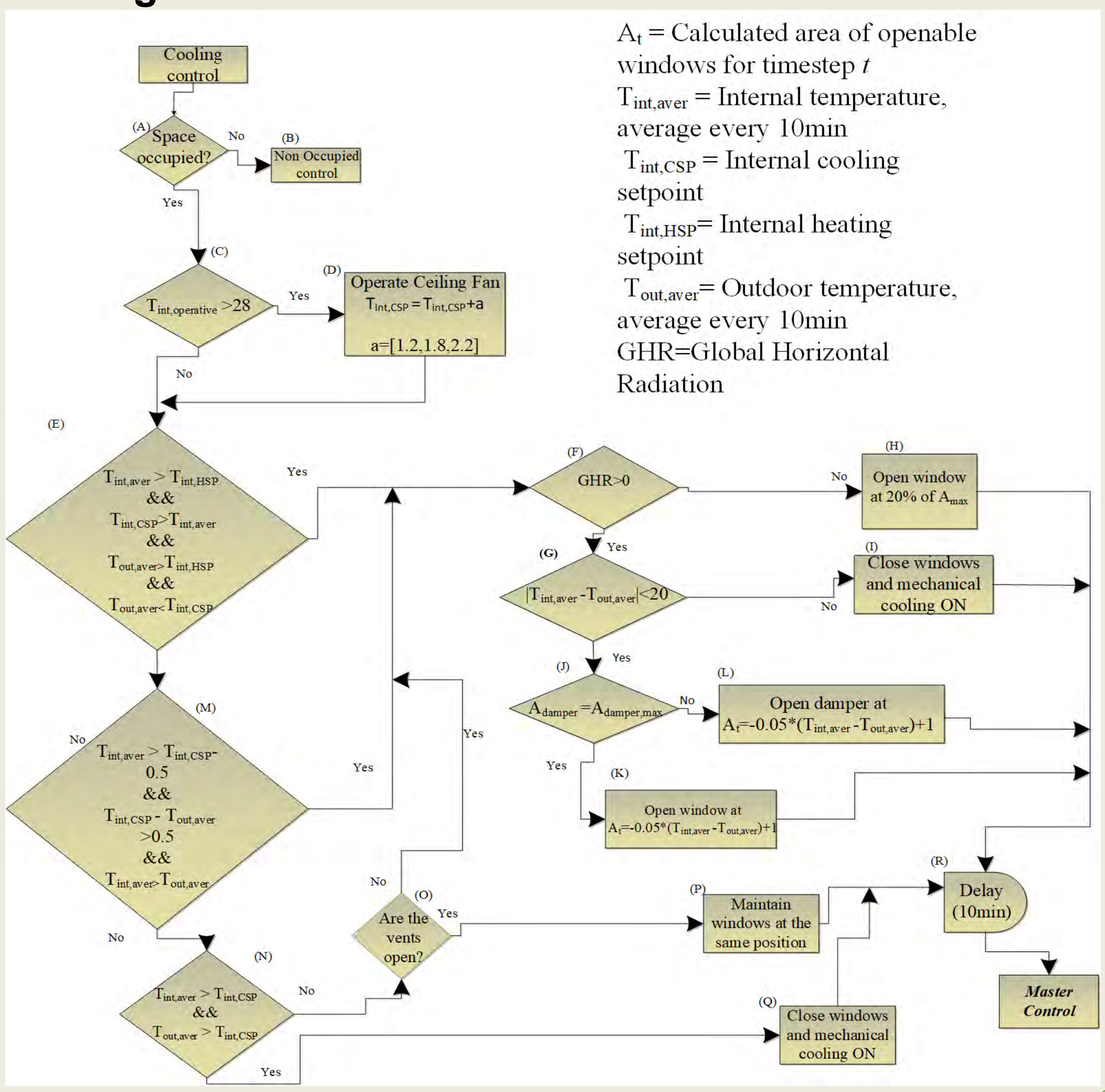
iii. **Ventilation and Cooling Strategy 3 (VCS 3):** Natural Ventilation ceiling fan, mechanical ventilation, humidification, dehumidification and split AC;

iv. **Ventilation and Cooling Strategy – Base Case**: Mechanical systems to maintain thermal comfort conditions.

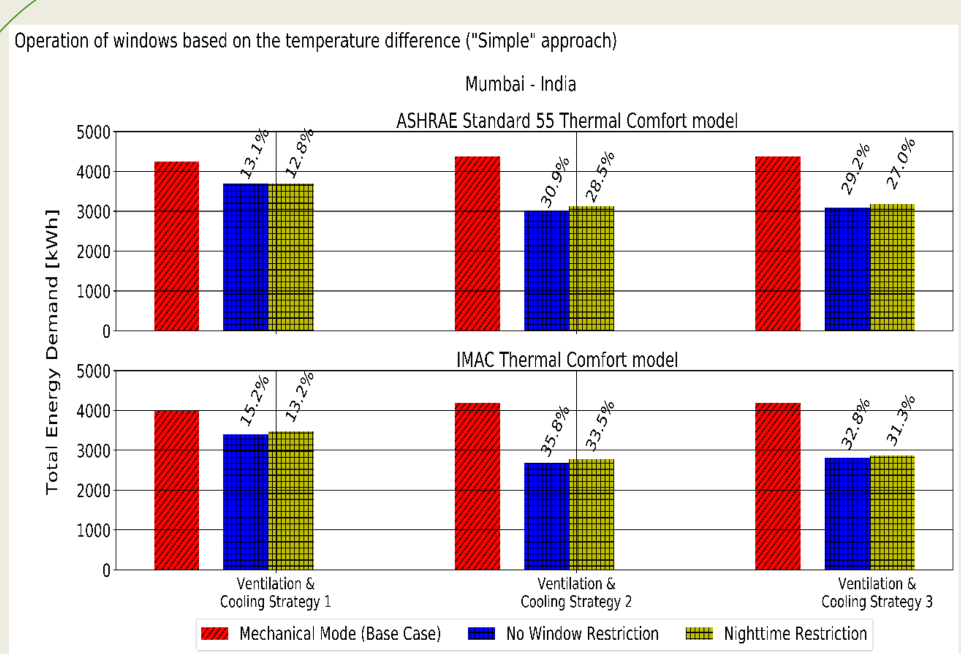
Simulation approach

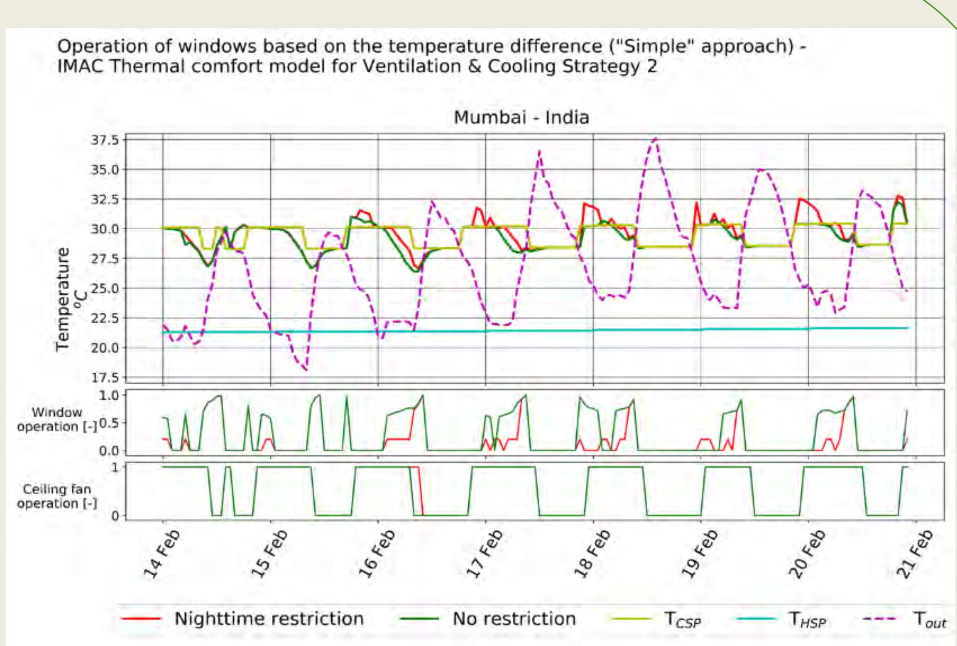


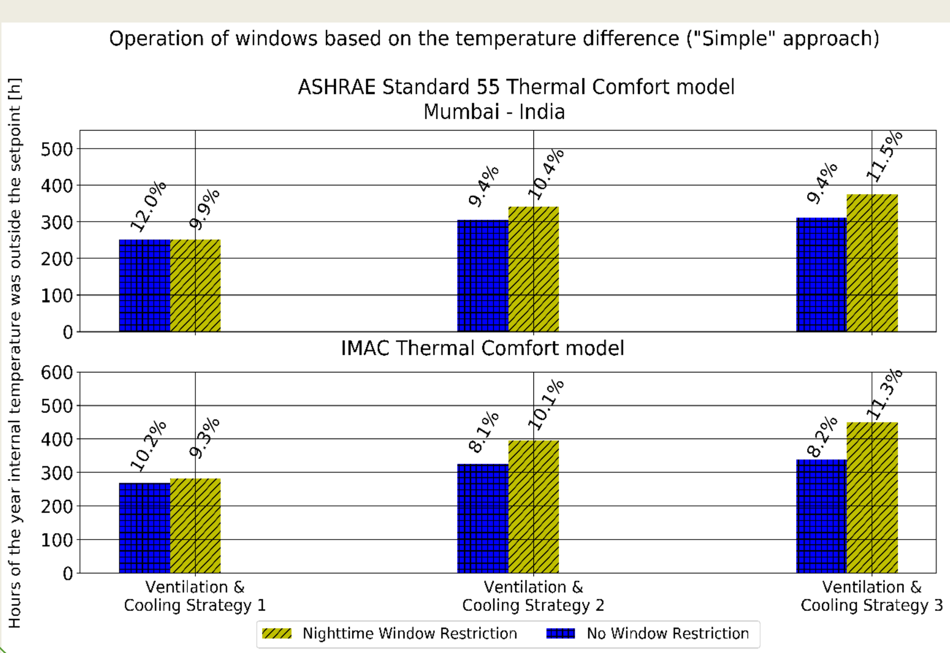
Flexible control algorithms for low energy mixed mode buildings

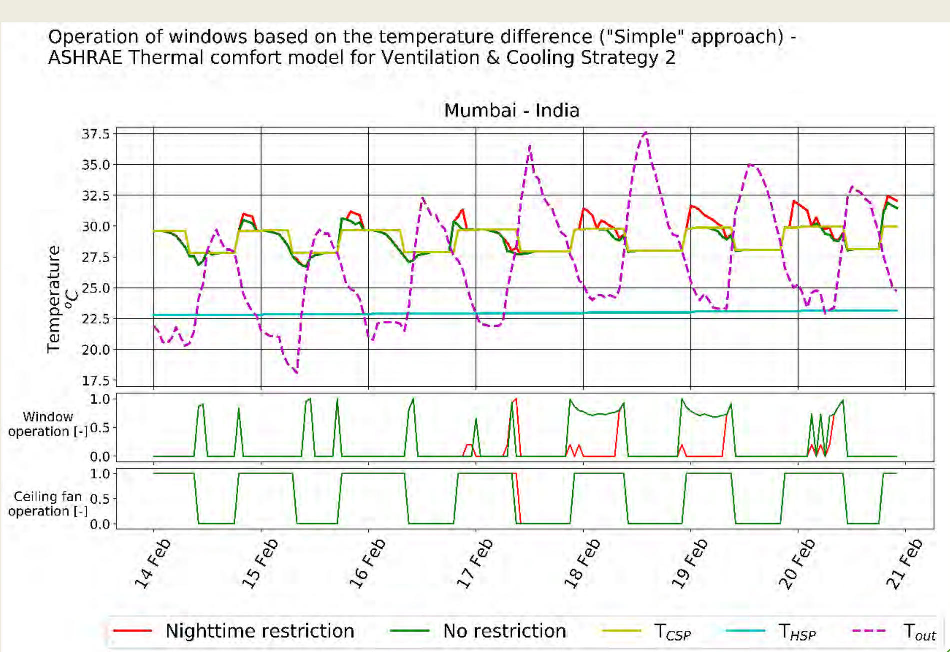


Results









Conclusions

- 13%-36% energy saving potential by operating a building in mixed-mode;
- 90% of the year internal temperature within comfortable limits;
- 5% higher energy saving potential by IMAC thermal comfort model compared to ASHRAE Standard 55;
- 15%-20% higher energy saving potential by using ceiling fan and elevate the setpoint temperatures; and
- 2%-5% lower energy saving potential by imposing night-time window opening restriction at 20% of their maximum allowable opening area.

References

1. DECC. (2016). Energy Consumption in the UK. London: UK Government.
2. Kapoor, R., Deshmukh, A., & Lal, S. (2011). Strategy Roadmap for Net Zero Energy Building in India. USAID ECO-III Report. New Delhi, India: International Resource Group.
3. Rajan, R., & Shukla, Y. (2014). Residential Buildings in India : Energy Use Projections and Savings Potentials. Ahmedabad, India: CEPT University.

Acknowledgements

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ANNUAL COLLOQUIUM 2018

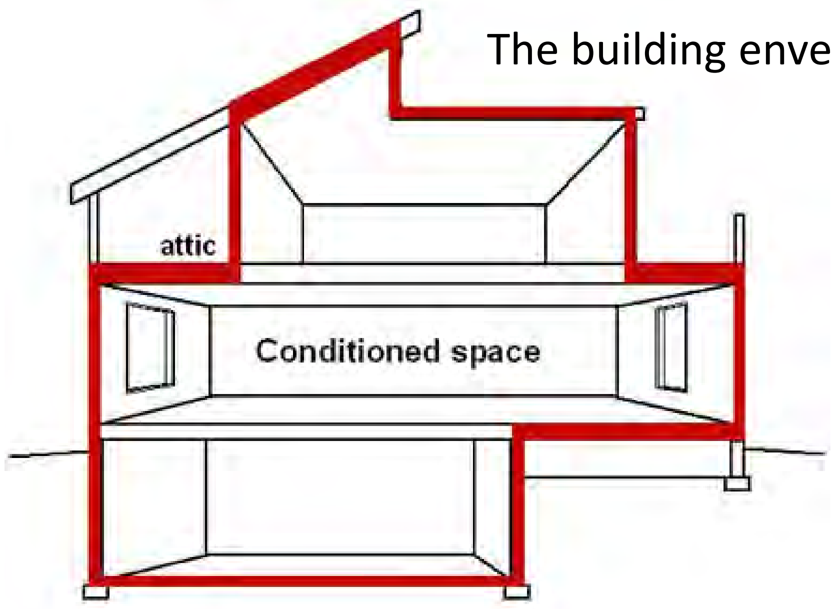
Airtightness testing in the UK during the introduction of regulatory testing: an inferential approach

Minnie Ashdown 1st year MPhil/PhD **Supervisors:** Cliff Elwell and Jenny Love

Background

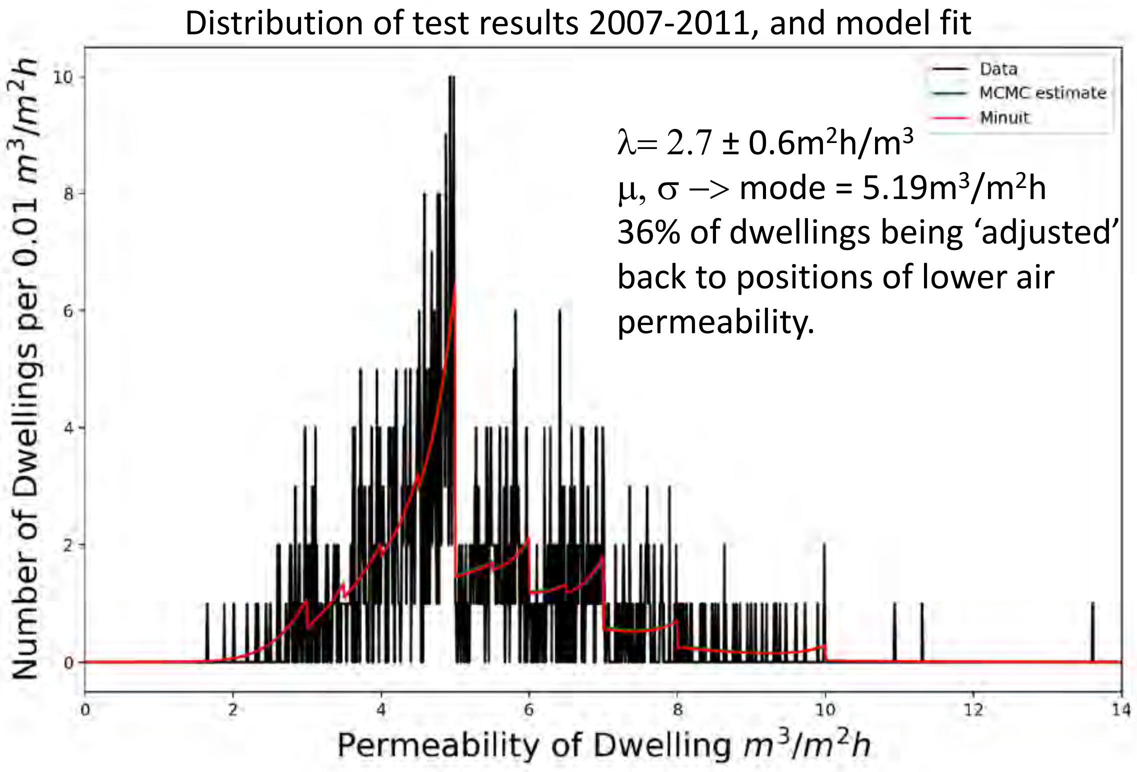
Airtightness is the "resistance of the building envelope to infiltration with ventilators closed" (Part F 2013), and air permeability is "the physical property used to measure the airtightness of the building fabric" (Part F 2013).
Airtightness is related to many elements of building performance, especially thermal efficiency, but also performance of the ventilation system, occupant comfort, heath and wellbeing.
As of 2006, in recognition of the importance of airtightness for building performance, it became mandatory to perform an air tightness test on a dwelling at the end of the building process (or on a subset of the buildings on a large development).
It was hoped that this would lead to an overall reduction in air permeabilities of new dwellings, which would increase the energy efficiency of the building stock and improve occupant comfort.

The building envelope



Data and Model

Distribution of test results 2007-2011, and model fit



A mathematical model was developed previously and applied to this new data set. As can be seen above, it provides a good fit to the data. Monte Carlo methods and Bayesian analysis were performed to estimate model parameters from the data.

This analysis focusses on 901 airtightness test results generated by a private developer between 2007 and 2011. Similarly to results previously analyzed within the Energy Institute, an unexpected distribution is observed. The data is characterized by sharp peaks and rapid drops in the regions of common design target air permeabilities.

Mathematical model

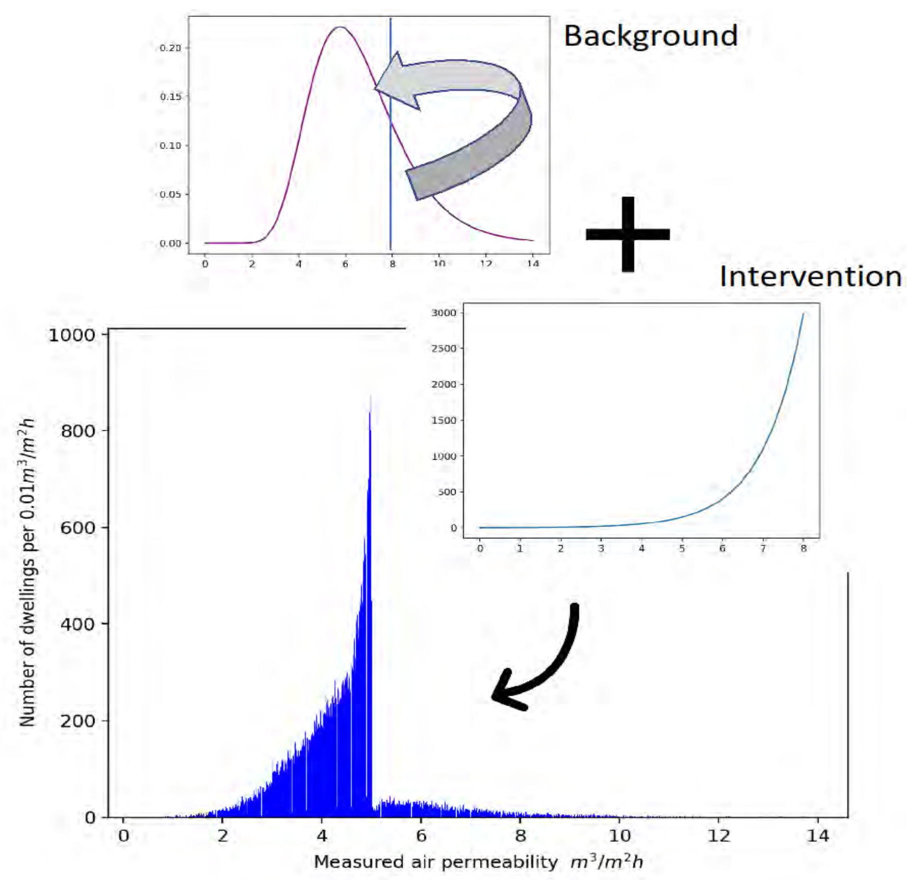
$$P_{back}(0 < perm <) = \frac{1}{\sigma\sqrt{2\pi}\,perm} e^{-\frac{1}{2}(\frac{ln(perm)}{\sigma}}$$

$$P_{adj}(t_n < perm) = \frac{1}{2}(1 + erf[\frac{\mu - ln(t_n)}{\sigma\sqrt{2}}])$$

$$P_{int}(0 < perm < t_n) = \lambda(1 + e^{-\lambda t_n})e^{-\lambda(t_n - pe}$$

$$P_n(0 < perm < t_n) = P_{back} + P_{adj} P_{int}$$

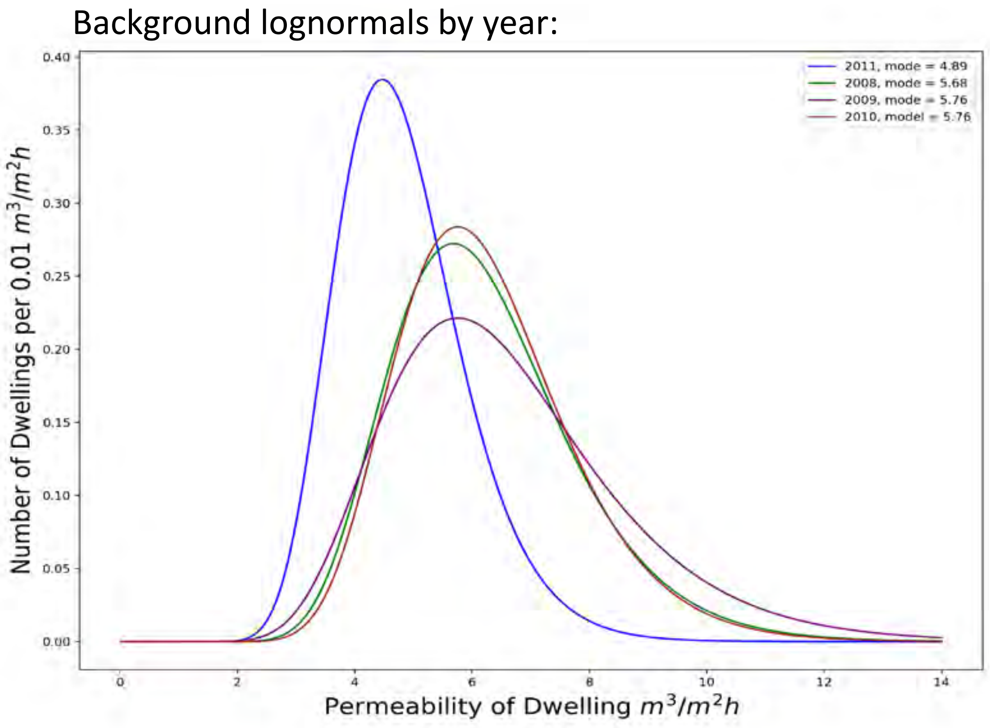
$$P(0 < perm) = \sum_{n=1}^{15} f_n P_n + f_c P_b$$



Parameter	Description
μ, σ	background lognormal parameters ($ln(m^3/m^2h)$)
λ	Intervention parameter, common to all design targets, ($m^2/m^3/h$)
$f_1, f_2 ... f_n$	Fraction of dwellings aiming for a design target t_n
f_c	Catch all fraction of dwellings with a design target not included in t_n
t_n	Design targets, taken from the meta data associated with the ATTMA data set

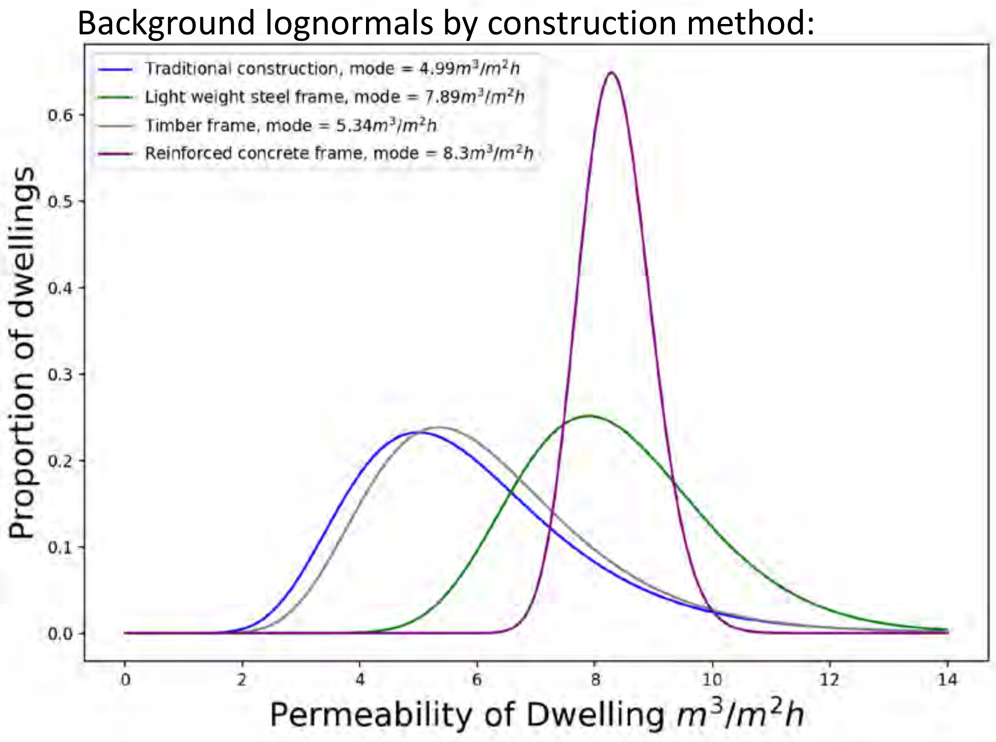
Effect of construction year and method

Background lognormals by year:



- Between 2008 and 2001, the mode (most probable value) has shifted from 5.68 to 4.89 m^3/m^2h.
- Background 'as built' permeability of dwellings is improving.
- $\lambda = 4 \pm 2$ m^2h/m^3 in 2008
- $\lambda = 2.5 \pm 0.1$ m^2h/m^3 in 2011
- Scale of interventions is reducing.

Background lognormals by construction method:



- Disaggregating the data by design target and again estimating the background lognormal parameters allows an assessment of the effect of construction method on as built permeability.
- Traditional and Timber frame perform best.
- Encouraging for brick and mortar!

Conclusions and further work

The model performs well for this new data set, however, more data would allow a more accurate estimate of parameters.
The data indicates that airtightness standards are being met, but that a large number of small interventions are being performed at the end of the building process.
Uncertainty analysis would help to better understand these results.
An ideal further analysis would retest the dwellings featured in this data set, to understand the lasting impact of the airtightness interventions being performed, and the long term energy efficiency of the buildings.

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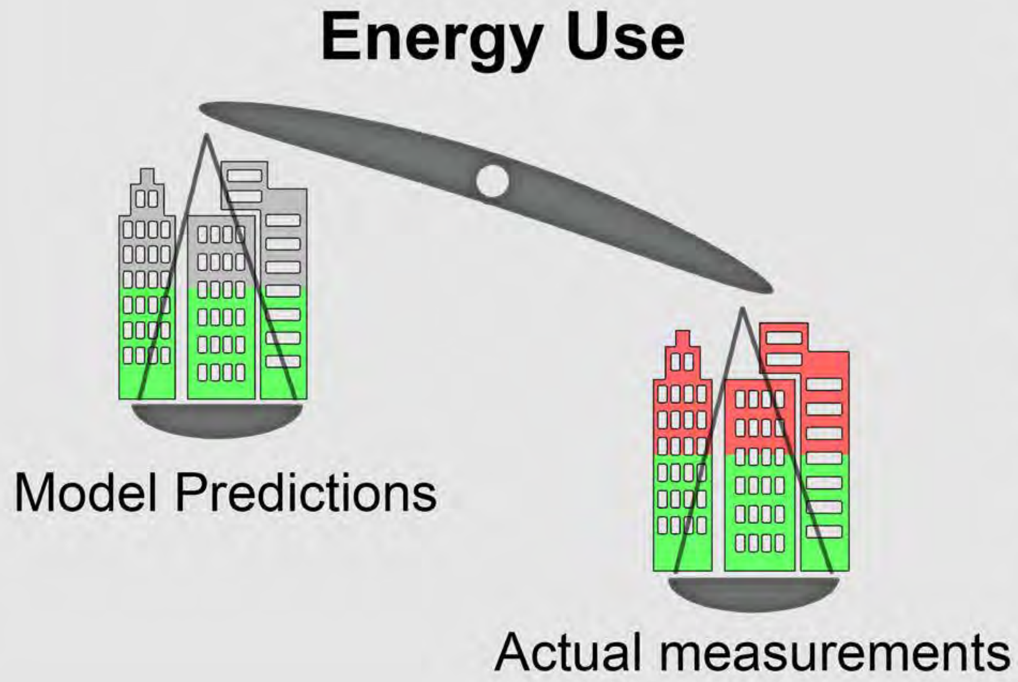
Energy performance evaluation of the TfL Headquarters in Stratford, London

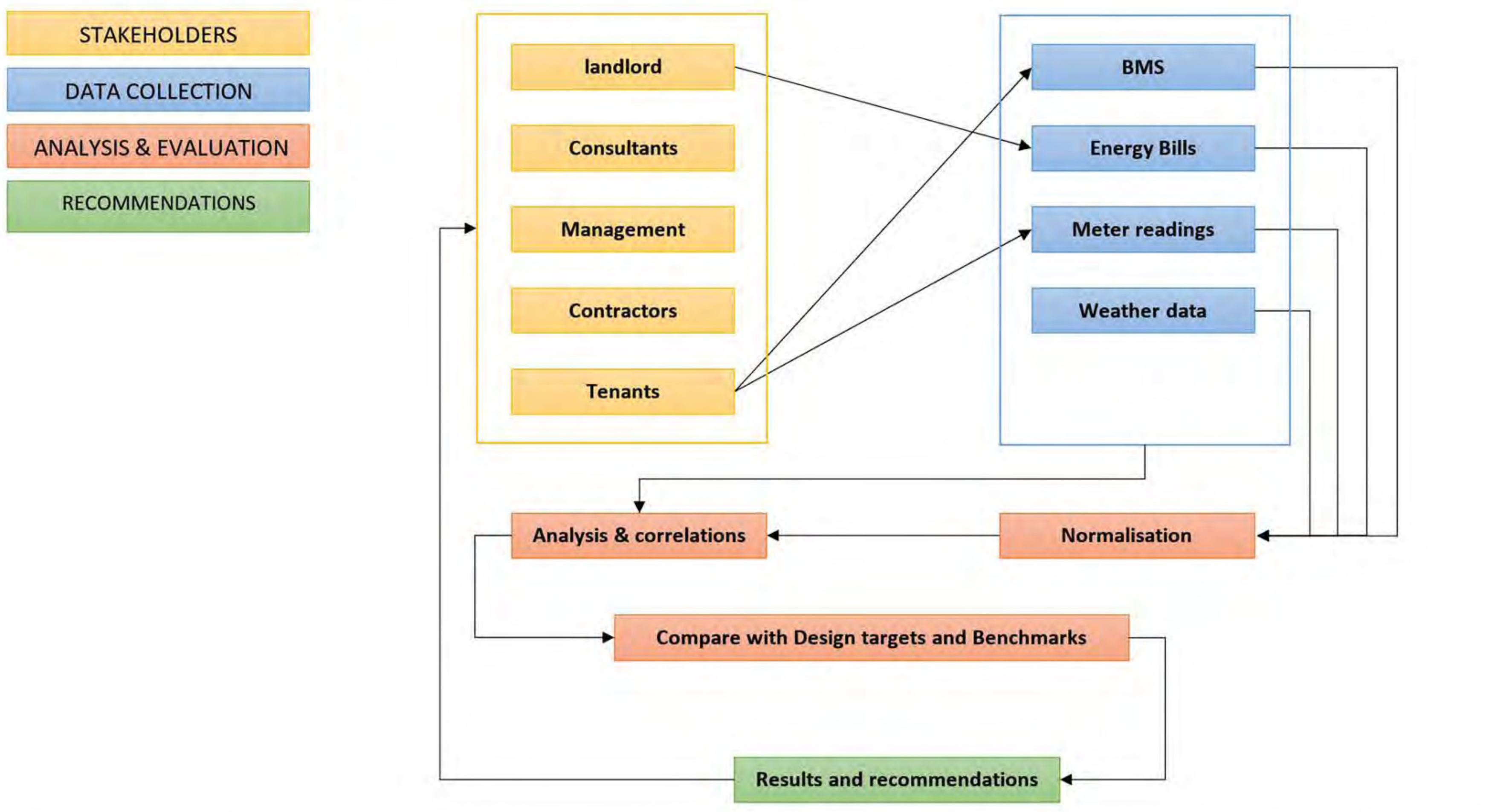
Rayan Azhari MRes Energy Demand 2017-18 Email: rayan.azhari.17@ucl.ac.uk
Supervisor: Prof. Paul Ruyssevelt



Aim:

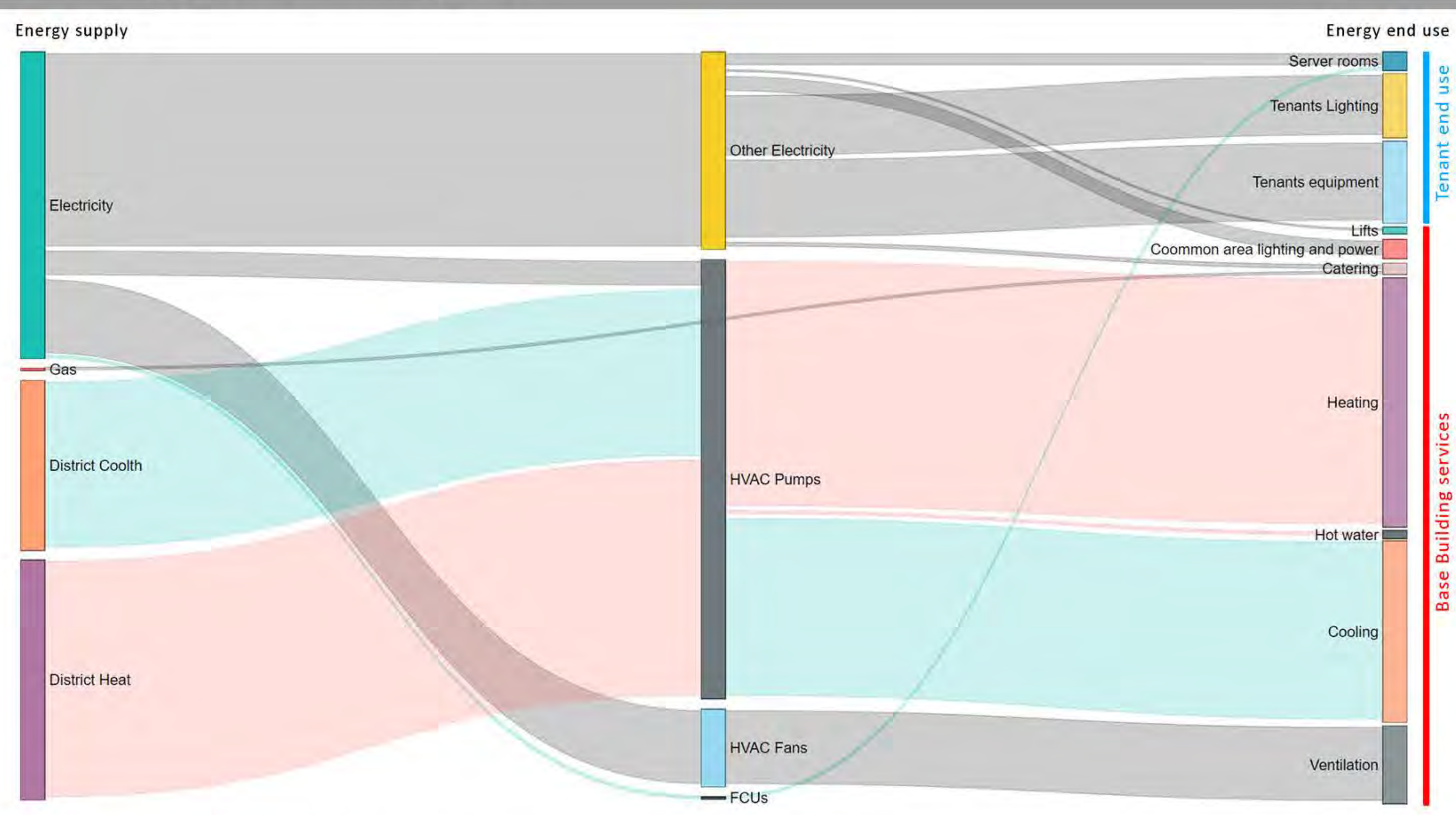
The aim of this project was to compare the actual energy use measurements in the case study (5ES) with advanced dynamic model predictions to identify all the significant differences and to understand their causes.
This study is trying to make an addition to the Design for Performance pilot case studies which aims to change the way we design new office developments in the UK, from design for compliance to design for performance.

Methods and data collection process



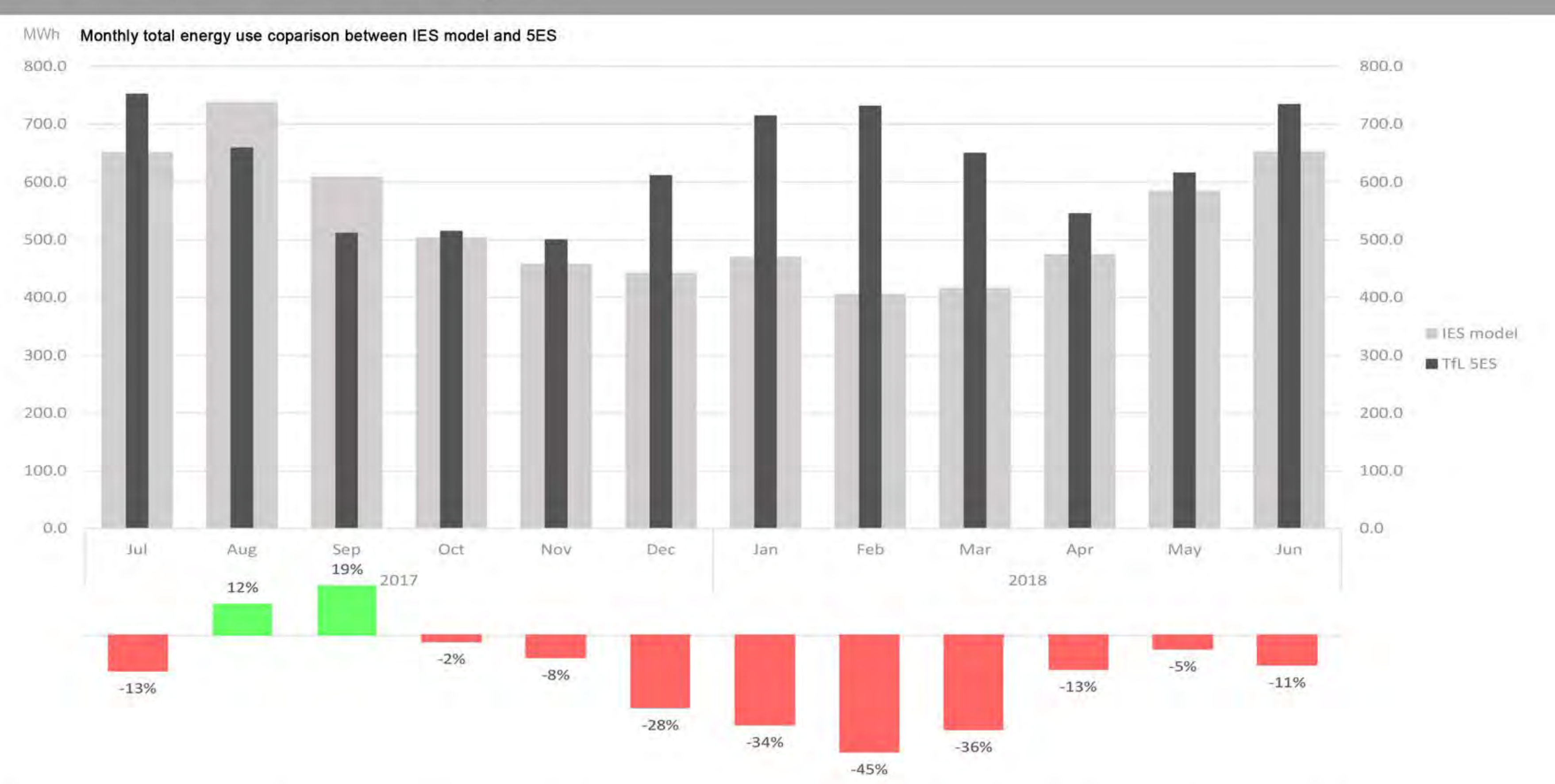
This research uses a secondary dataset which contains; half-hourly readings of (119 Electricity, 39 Heat, 36 Coolth and 2 Gas) meters and sub-meters collected by the BMS (Building Management System). The dataset includes manual meter readings and energy bills provided by the tenant (TfL).

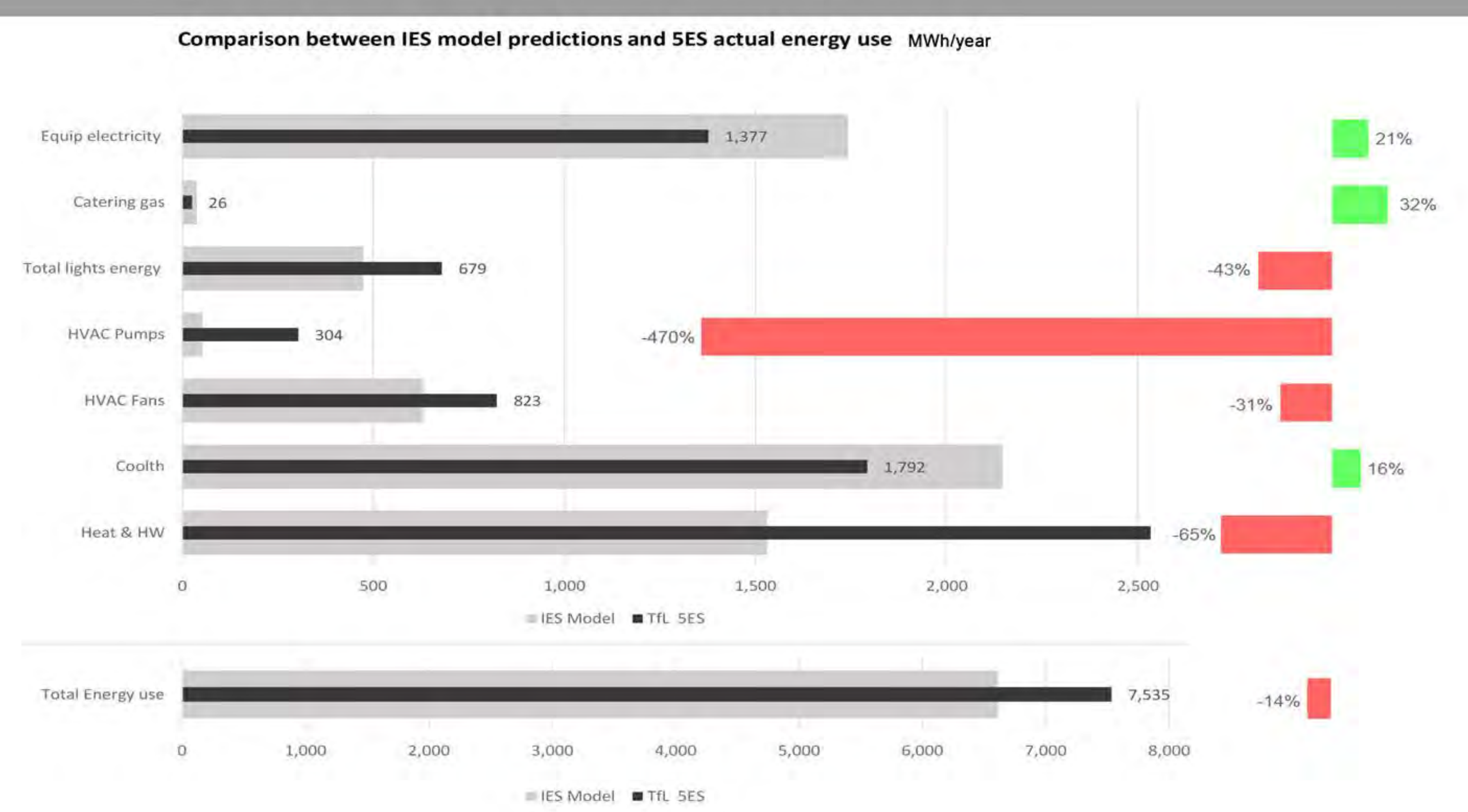
Energy flow diagram



The Sankey diagram shows how the incoming energy flows into the building's systems to provide different services based on the actual energy use and covers the period from November 2017 to May 2018.

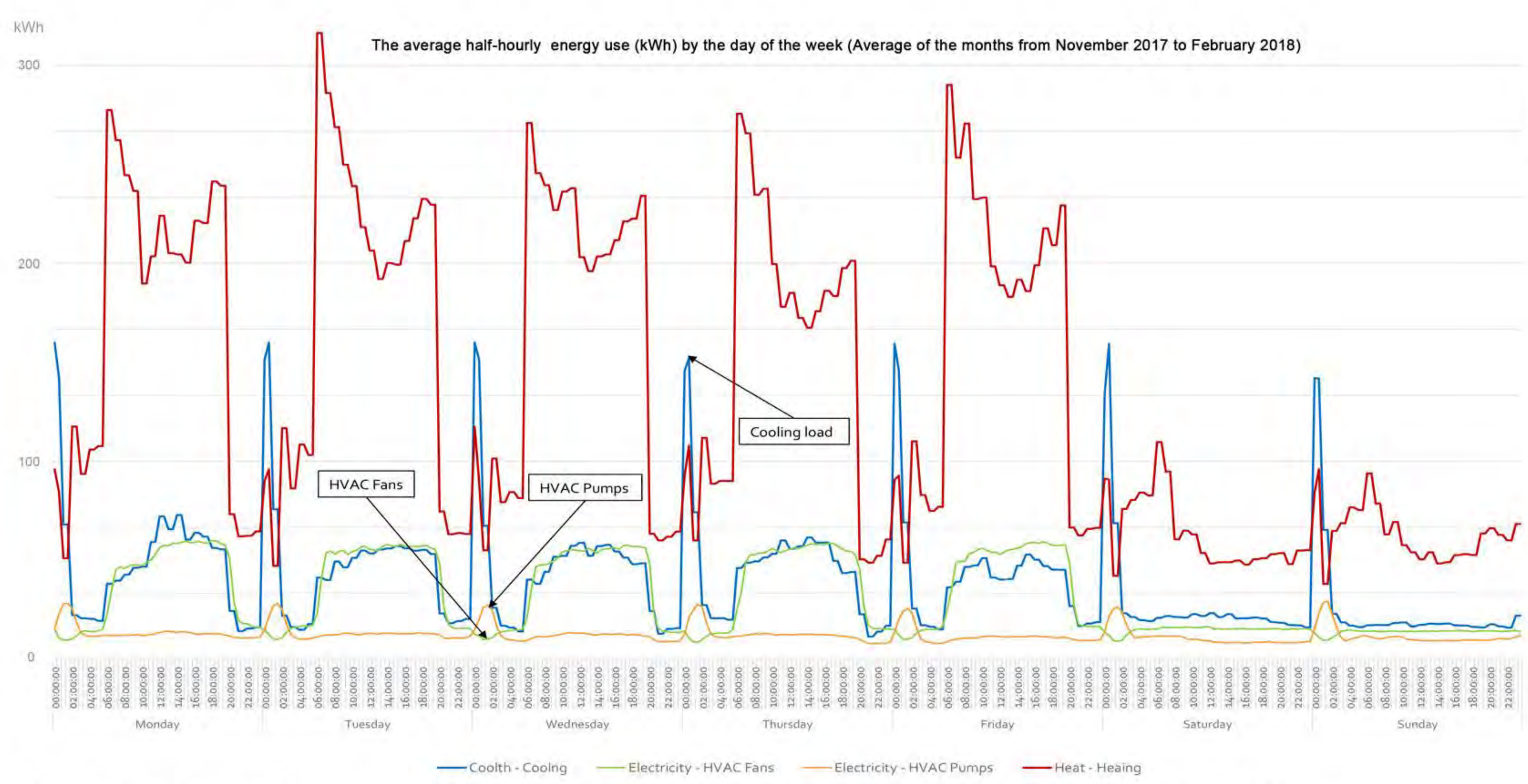
Results and analysis





The energy performance of the 5ES building was only 14% higher than the IES model predictions. Underestimating the energy for heating (by 65%) in the IES model was the main contributor to this gap is performance (2,533 MWh/yr actual energy use against 1,531 MWh/yr IES mode prediction).

The HVAC pums were running 24/7 which explains the 470% variation.
The HVAC fans energy use was underestimated due to the lower heating load which was predicted by the IES model



The spikes in cooling, heating and HVAC pumps loads were due to the routine water circulation at midnight to stop the build up of micro-organisms

Conclusion

-The half-hourly data was not reliable in general, especially at the sub-meters levels.

-Some of the sub-meters didn't add up to match their parent meter's energy use, in some cases, it was even higher than the parent meter. This indicates that the meter may need to be calibrated, or there may be some errors in assigning sub-meters.

-HVAC pumps were running 24/7 regardless of the heating/cooling loads.

-The IES model does not allow for the unregulated loads such as the routine water circulation at midnight to stop the build up of micro-organisms. The same applies to the unregulated hours of use.

-The IES model predict the energy demand based on specific HVAC systems. However, the actual HVAC systems installed in the building may not match the ones used in the model and may have different efficiencies. This may lead to higher energy demand.

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ANNUAL COLLOQUIUM 2018

"Early-Stage Design Decision-Making for Community Energy Schemes "

Kostas Chasapis – 3rd Year PhD
Supervisors: Dr. David Allinson, Prof. Kevin Lomas

Background:

Community Energy Schemes (CES) are:

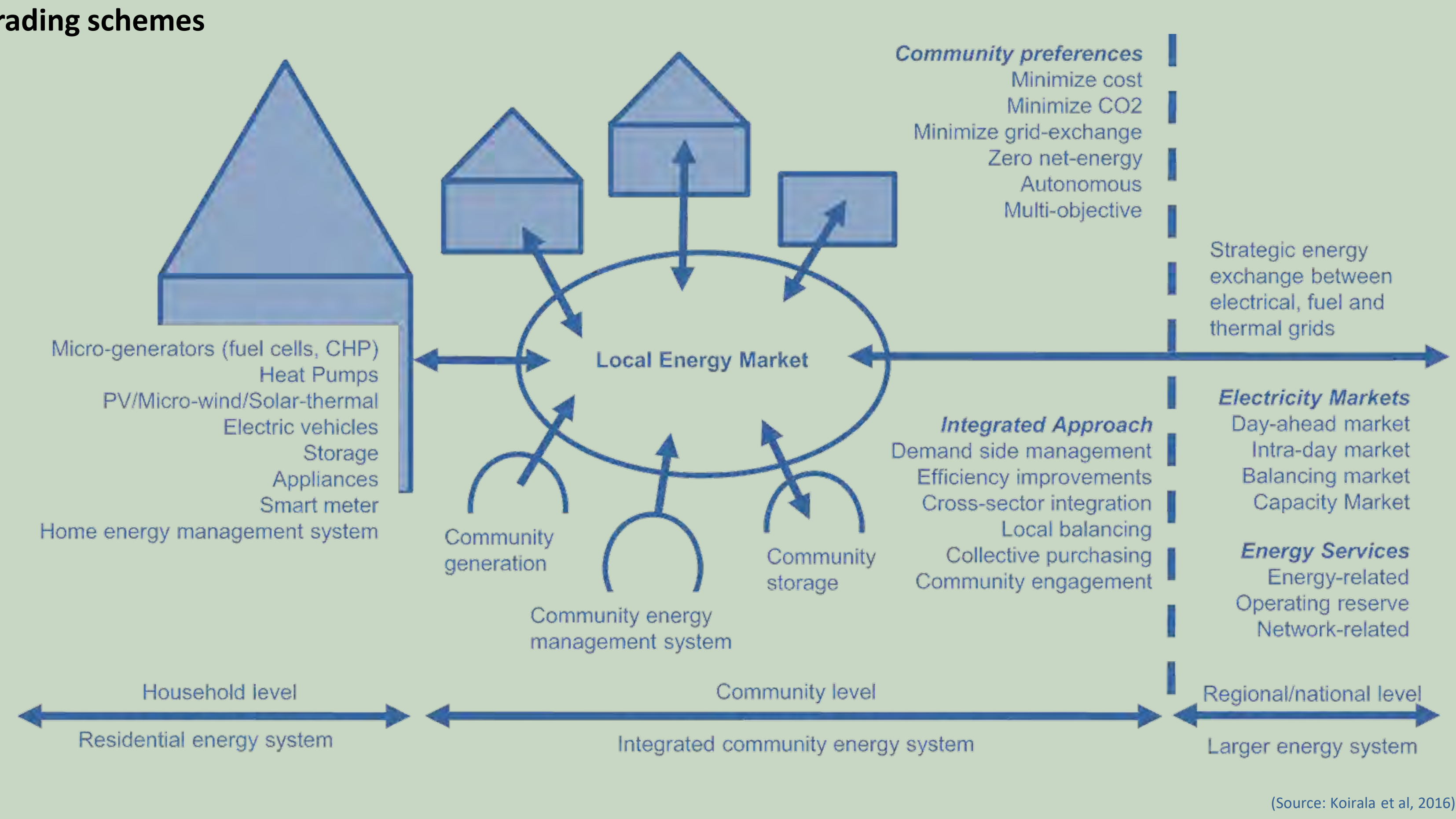
- Multi-source local energy generation, distribution, storage and trading schemes
- Involve local community ownership and management
- Governed by or for local people
- Size from a few households to an entire district
- Participants are prosumers instead of consumers

Purposes of CES:

- Economic
- Environmental
- Social
- Technical

Benefits of ICES:

- Wealth retention within the community
- Initiation of green circular economy
- Use of local renewable energy
- Active engagement of people
- Energy efficiency
- Coordinated demand-side management
- Improved energy security



(Source: Koirala et al, 2016)

Aim:

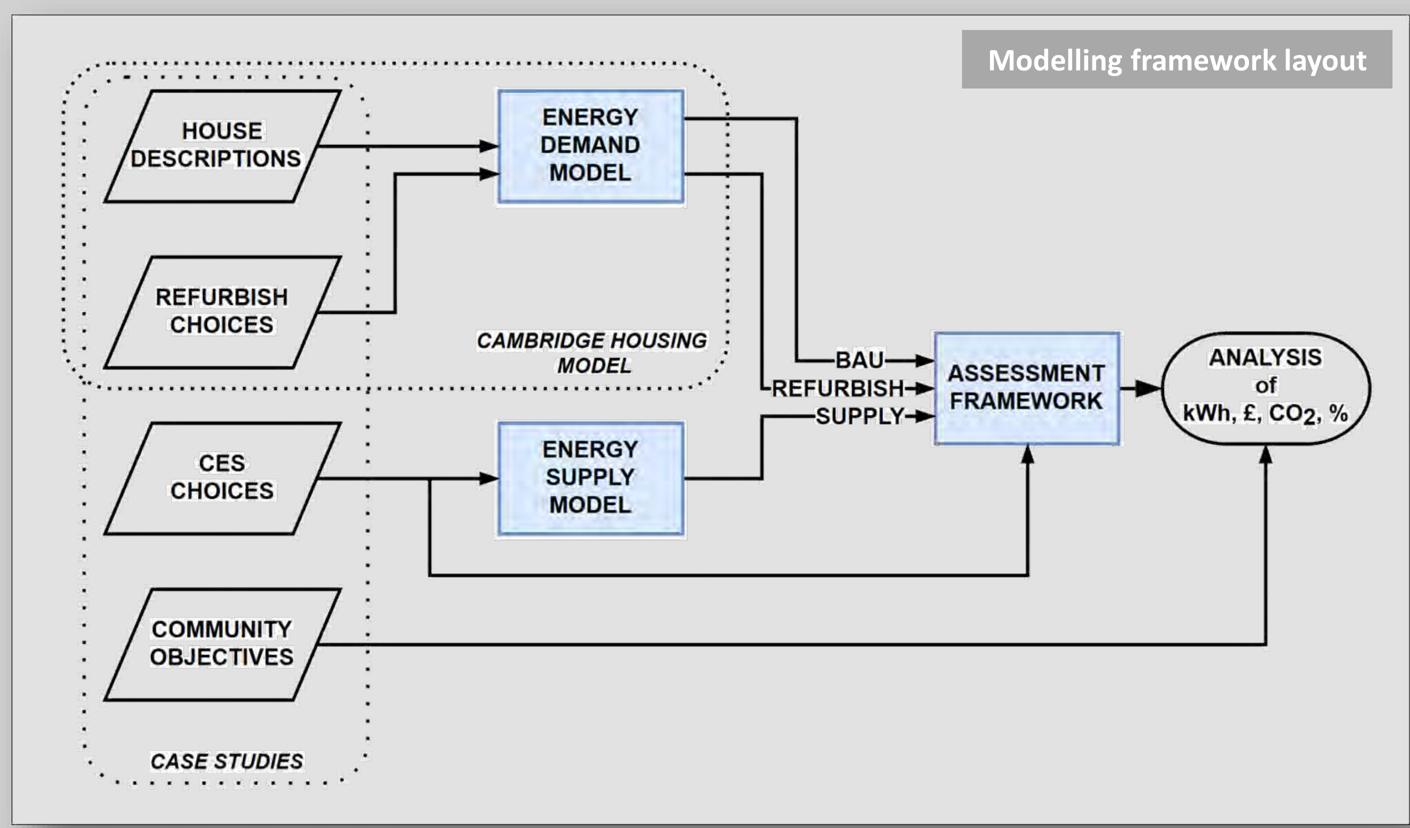
To compare the energy saving and carbon emissions reduction potential and the cost effectiveness of different energy technologies and business model options for Community Energy Schemes at the concept design/planning stage.

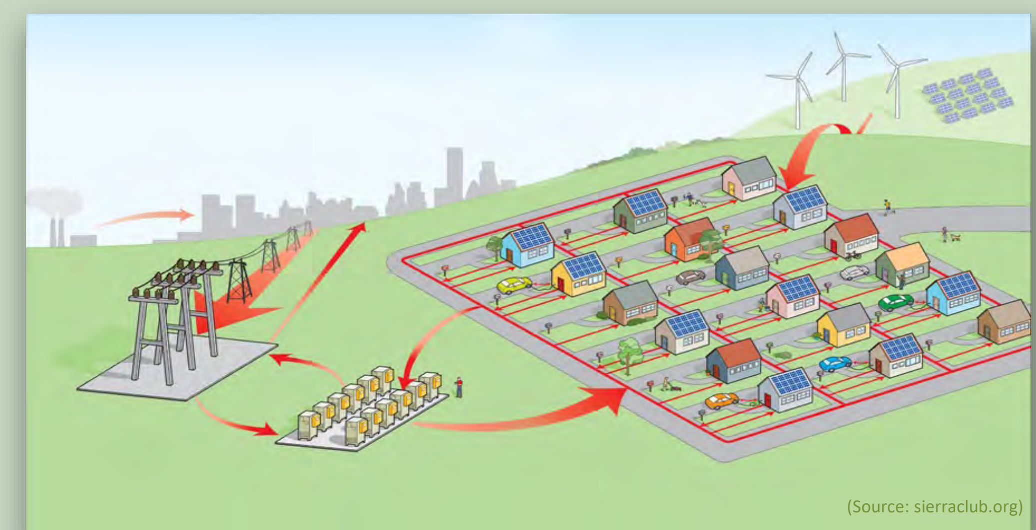
Research Question:

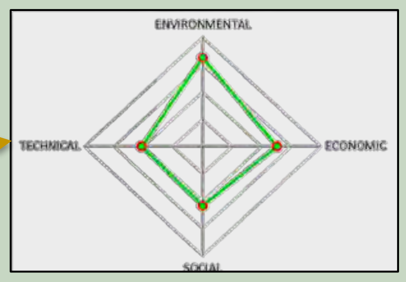
How can community energy schemes be modelled at an early design stage in a straightforward and reliable way to explore, assess and compare the technoeconomic options that achieve community-set objectives for energy, emissions and costs?

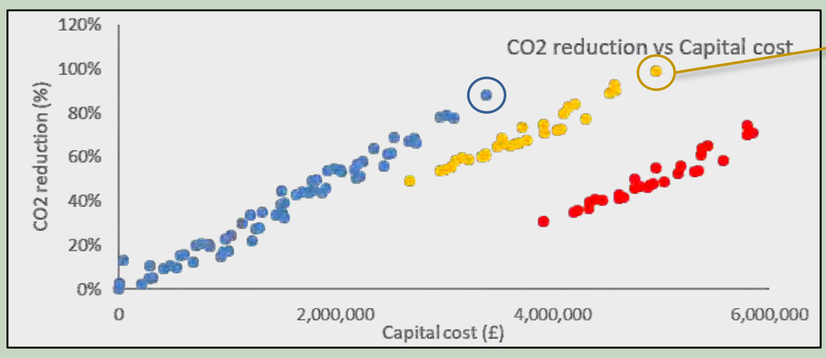
Why early-stage design?

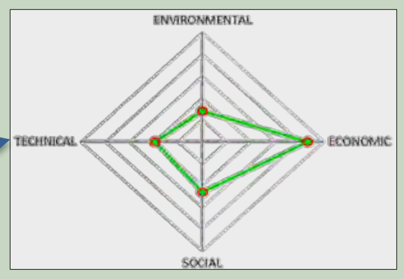
- Timely identify opportunities and challenges
- Narrow-down the vast combination of possible scheme setups
- Communicate valuable insight to the next steps of the project's development

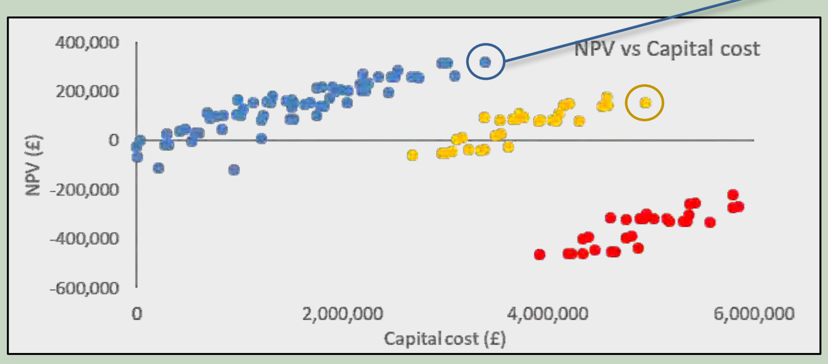












Methods:

- Bottom-up approach
- Mathematical modelling based on building physics
- Quasi-steady-state
- Established economic analysis methods
- Sensitivity and uncertainty analysis
- Multi-criteria decision analysis
- Modular structure

Further work:

- Identify the relative importance of input parameters
- Investigate community energy business models
- Decision-making analysis of different CES alternatives

Anticipated Outcomes:

- Identification and categorisation of the main CES viability drivers
- Quantitative assessment of the different community energy setups
- Consolidation of the model to a systematic framework for informed early-stage CES design decision-making

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ANNUAL COLLOQUIUM 2018

Delivery of Contracted Energy Flexibility from Communities

Rami El Geneidy
Supervisor: Bianca Howard, Ph.D.

Why Contracted Energy Flexibility?

Utilising aggregated flexibility of buildings is a key part in visions of future *smart grids*.

Potential benefits of increasing flexibility in the UK energy system are estimated to be *tens of billions of pounds*.

Contracted flexibility or demand response can be performed by reducing energy demand according in a pre-agreed fashion according to an agreement between the provider and recipient.

Model-Predictive Control

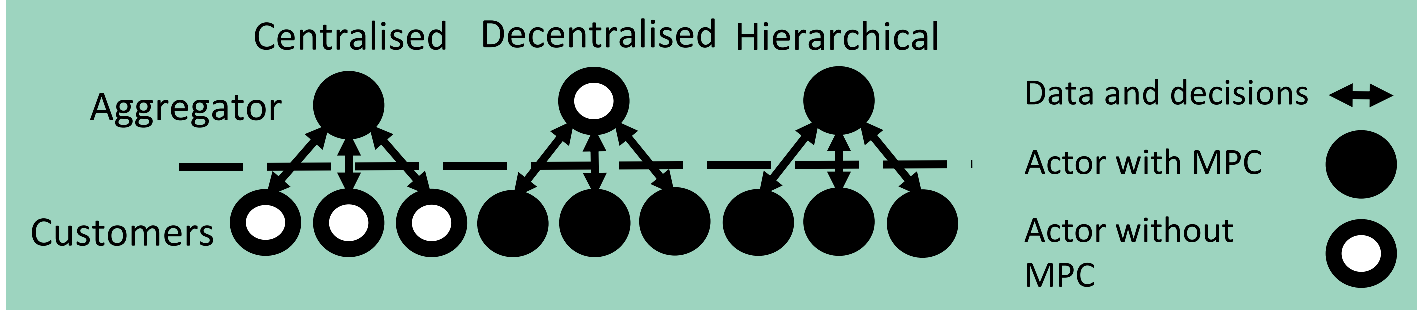
Model-predictive control (MPC) was chosen to deliver contracted flexibility with heating systems in buildings.

In MPC building models are used to derive *optimal* control decisions by using techniques of optimisation.

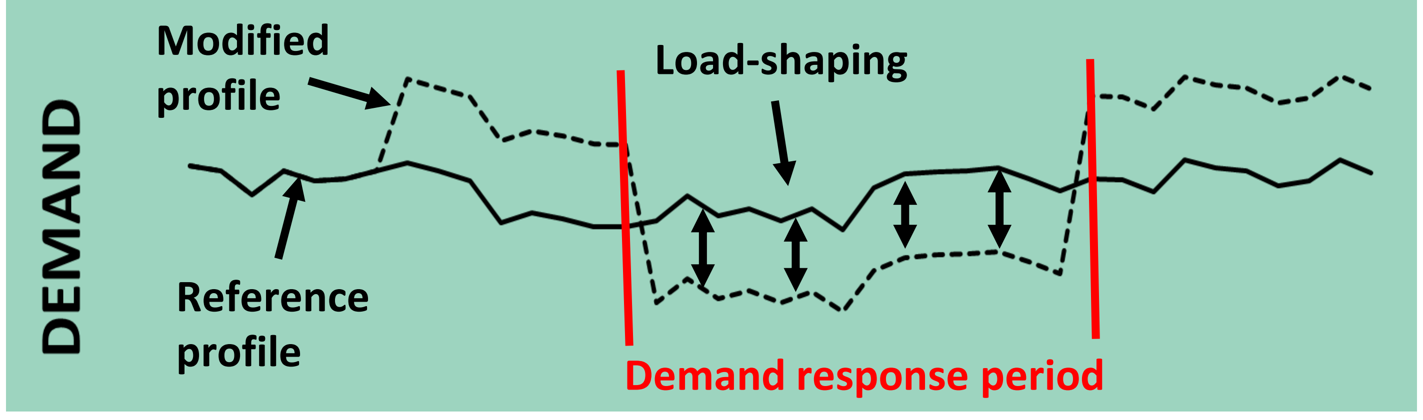
The energy demand forecasts provided by MPC could be used to utilise flexibility in real-time with *load-shaping*.

Development of Community-Scale Flexibility Strategies

Three community-scale economic MPC strategies were developed for aggregator-led demand response:



Forecasts of energy demand by the MPC were utilised in load-shaping to determine reference profiles to follow over demand response periods.

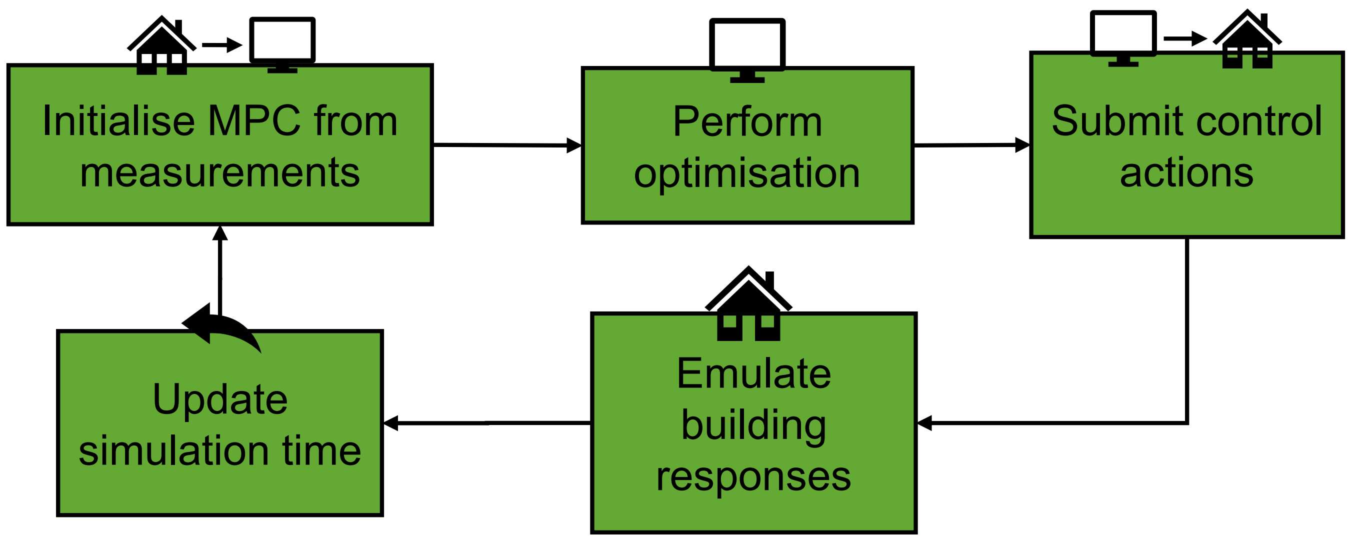


Methodology

A community model consisting of *ten homes* constructed based on typical house archetypes in the English building stock.

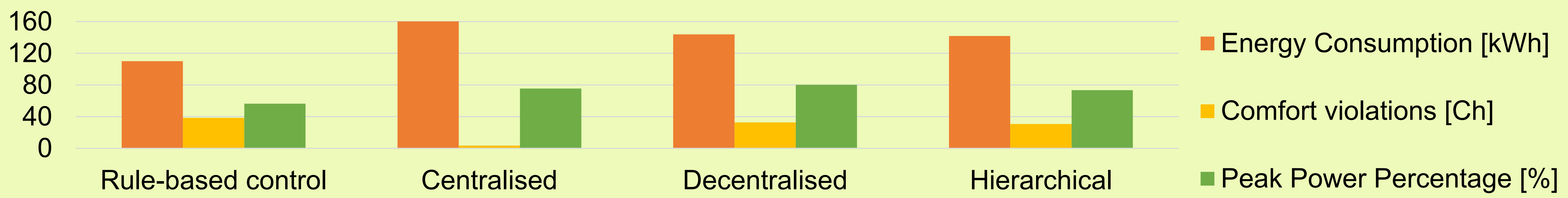
Thermal responses of houses predicted in the MPC with low-order resistance-capacitance models.

MPC operation and real building response simulated over a call for demand response of three hours.



Key Outcomes

Comparison of control strategies' performance under dynamic electricity pricing



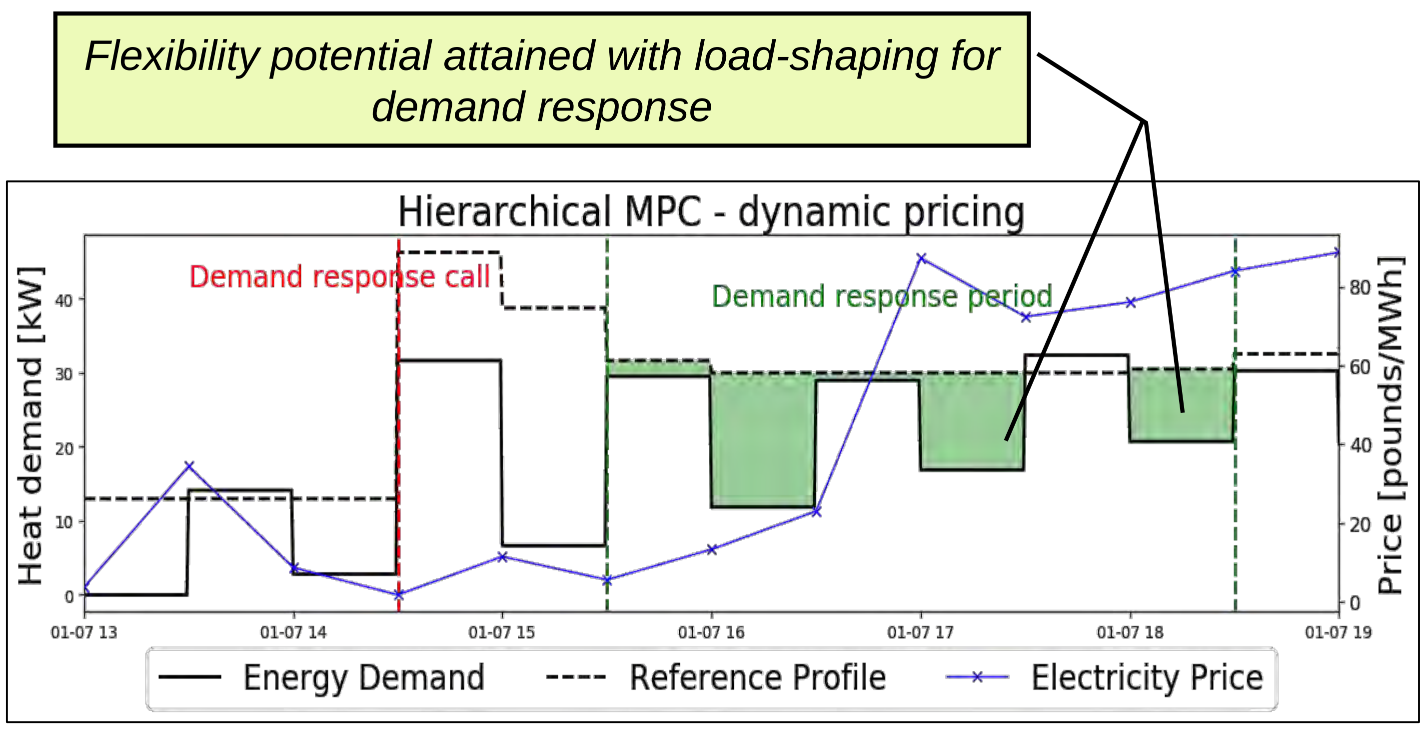
Conclusions

MPC proved to be a *potential method* to provide contracted energy flexibility but several challenges still hinder its scalability.

Trade-offs observed between guaranteeing comfort, minimising energy demand and providing demand reductions.

Control strategies and pricing schemes affected the flexibility obtained for demand response.

Achieving *sustained demand reductions* over long time periods was challenging.



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ANNUAL COLLOQUIUM 2018

•The Effect of an Energy-Efficient Retrofit on Childhood Exposure to Indoor $PM_{2.5}$

•**Lauren Ferguson,** MPhil Student

Background: In order to meet national carbon targets, sizeable reductions have to be made in the UK buildings sector, which has only seen very modest declines in carbon emissions since the Climate Change Act was established in 2008. Given that existing buildings are expected to account for 70-80% of the 2050s building stock, much of the necessary energy-efficiency improvements must be achieved by retrofitting existing dwellings. Retrofitting modifies a dwelling by tightening the building envelope and reducing the heat loss of a home via the installation of measures such as double glazing. However, a by-product of this is a reduced number of air exchange rates which can have a detrimental effect on indoor air quality. Children typically spend a greater amount of time in the home compared to adults and are therefore at greater risk of developing negative health effects associated with poor indoor air quality. Likewise, their immature immune and lung systems mean they have a higher rate of O_2 consumption per unit of body weight, making them more susceptible to air pollution-induced effects.

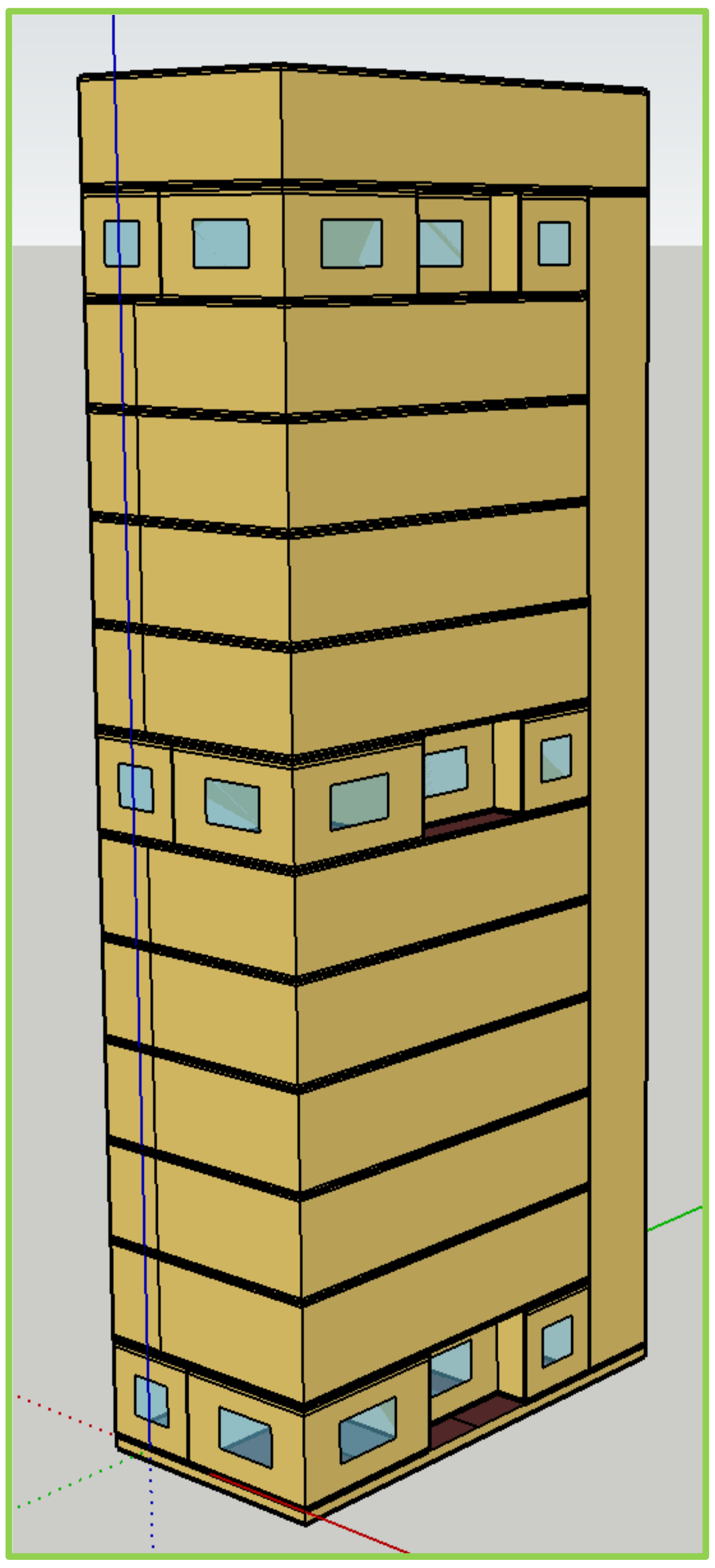


Figure 1. High-rise flat.

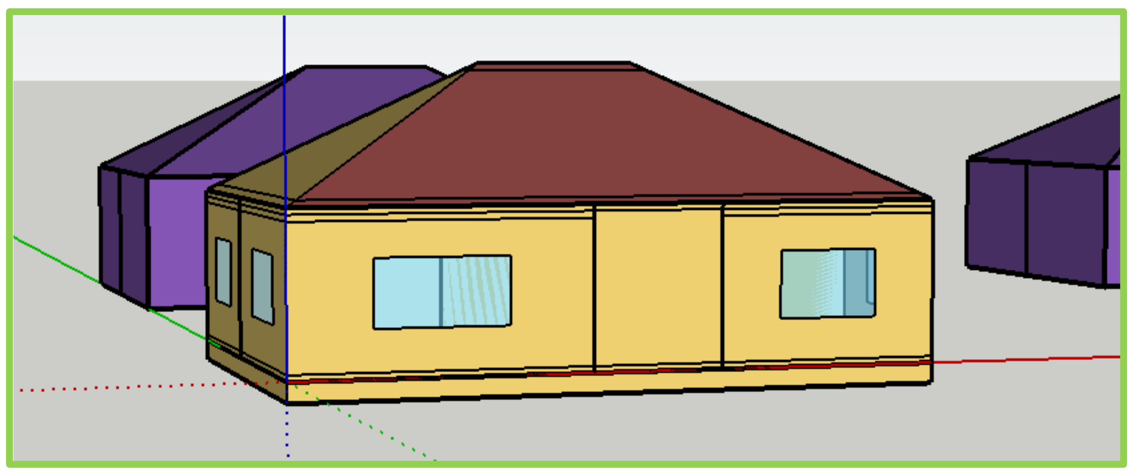


Figure 2. Bungalow.

- **Methods:**
- The building simulation software, *EnergyPlus,* was used to construct 6 building archetypes, broadly representative of the London housing stock (**Table 1**).
- Each archetype was given a retrofitted and non-retrofitted scenario, as outlined in **Table 2**.
- Sources of $PM_{2.5}$, a pollutant with known health impacts, were then introduced into the dwellings from three origins; cooking, indoor smoking and infiltration of outdoor air.
- Childhood occupancy patterns were derived from empirical data produced by the NatCen Time-Use Survey and this was used to calculate annual average childhood exposure to $PM_{2.5}$ from each of the three sources independently.
- Socio-economic information was introduced into the model using data from the 2016 English Housing Survey (EHS). The EHS identifies the occurrence of different dwelling archetypes per tenure group (owner occupied homes, private-rented, local authority dwellings and housing association). The survey also identifies all homes which fall below the low-income threshold (LIT), which are households with an annual income is 60% or less of the median income in England and Wales for that year.

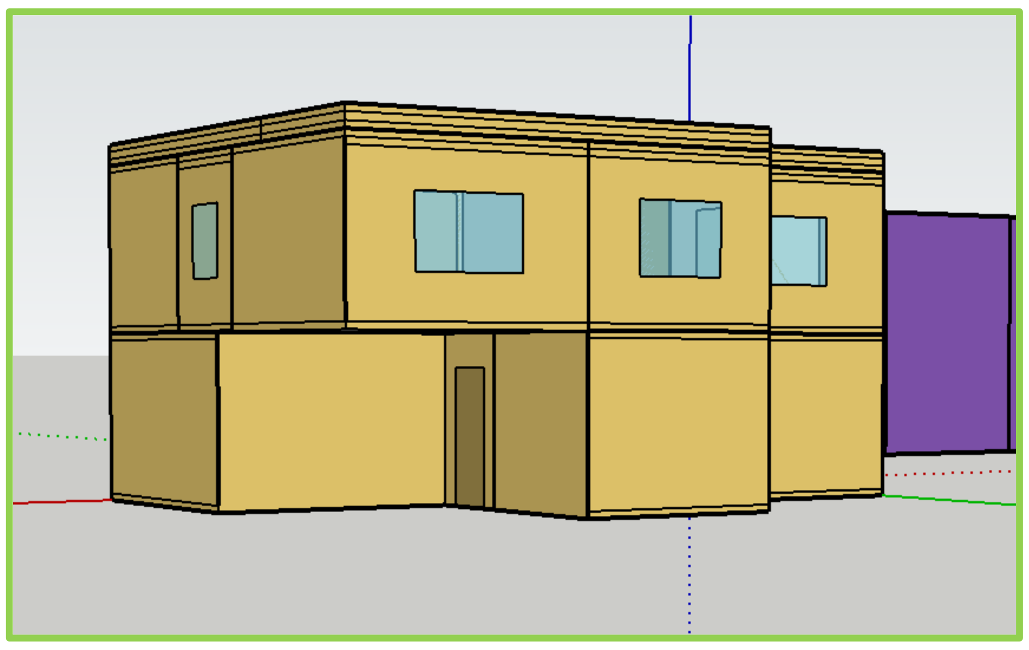


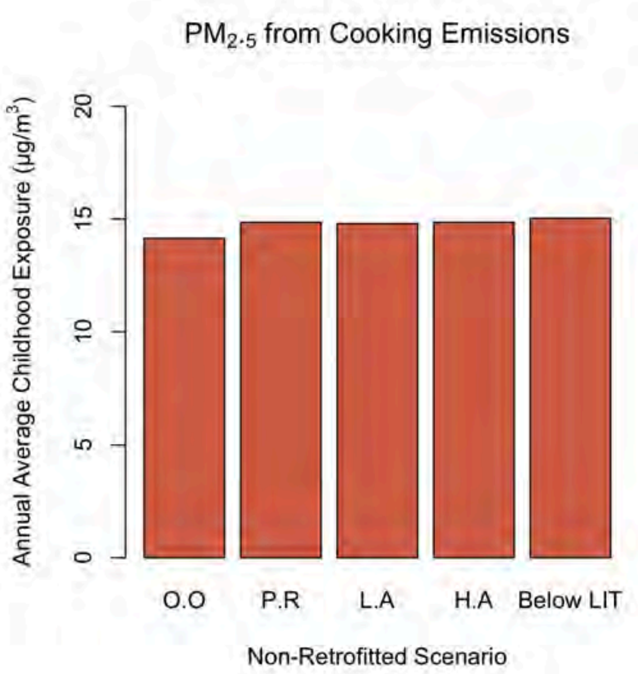
Figure 3. Detached dwelling.

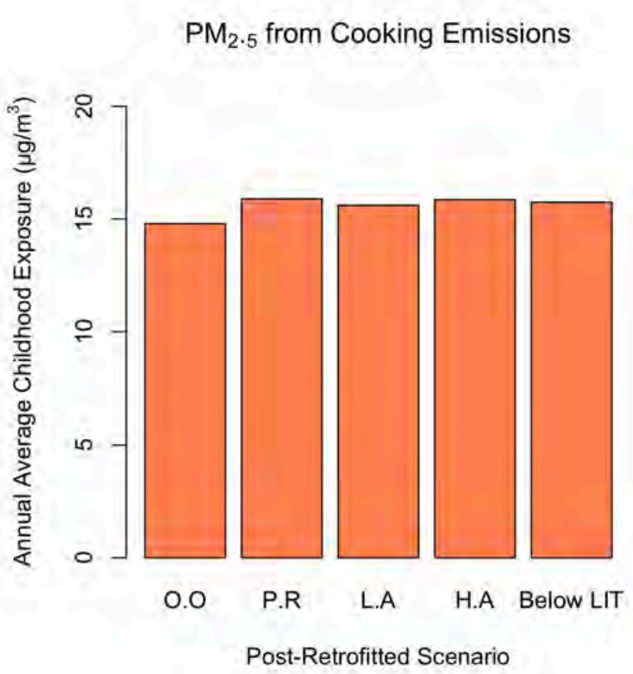
Building Archetype	Frequency in London Stock (%)
Semi-detached	11.9
Converted Flat	10.0
Detached	2.6
Bungalow	1.3
Terrace	27.0
High-rise Flat	47.2
Total	**100**

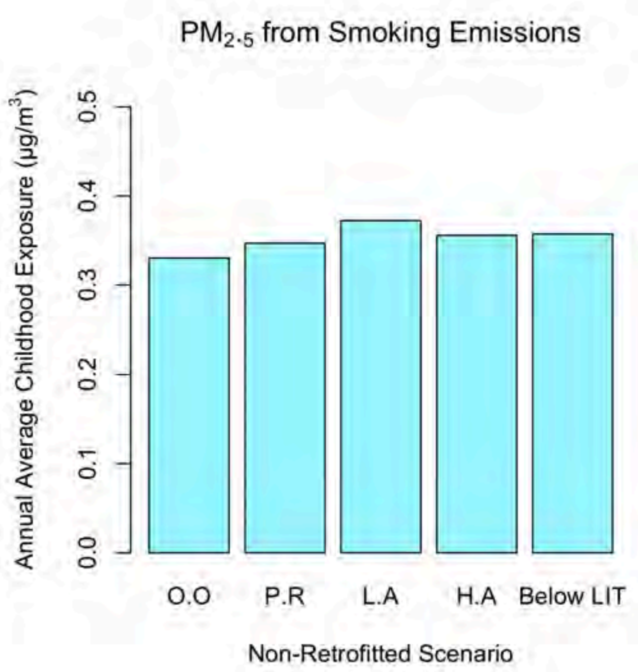
Table 1. Frequency of the six archetypes in the London Stock (EHS, 2016).

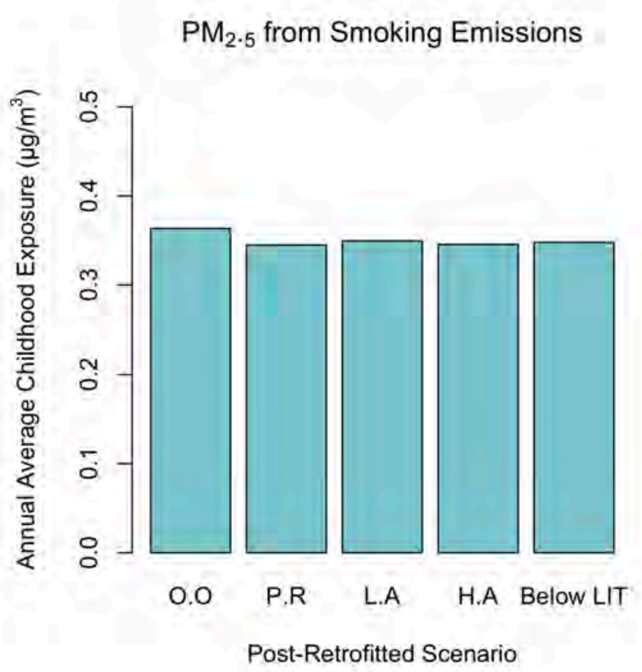
	Pre Retrofit	Post Retrofit
Wall U-Value	2.9	0.28
Window U-Value	4.6 (single glazing)	1.1
Roof U-Value	2.5	0.18
Floor U-Value	1.2	0.25
Permeability	15	5

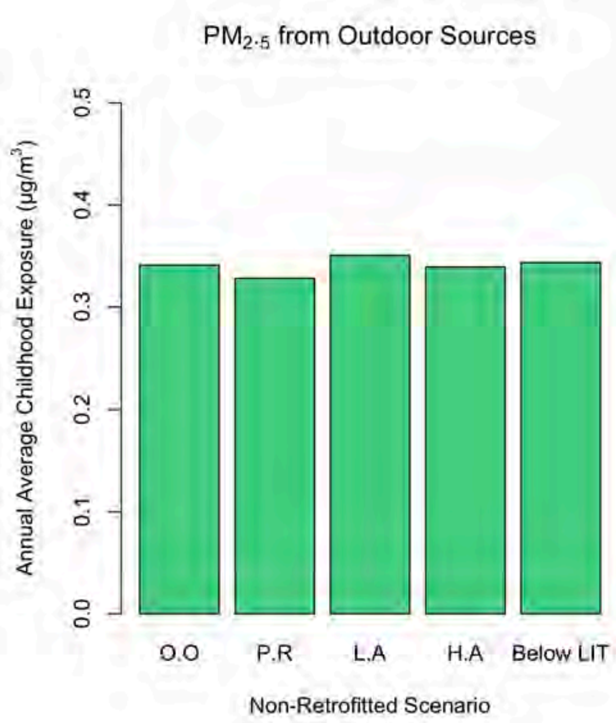
Table 2. U-Values and permeabilities for a retrofitted and non-retrofitted scenario.

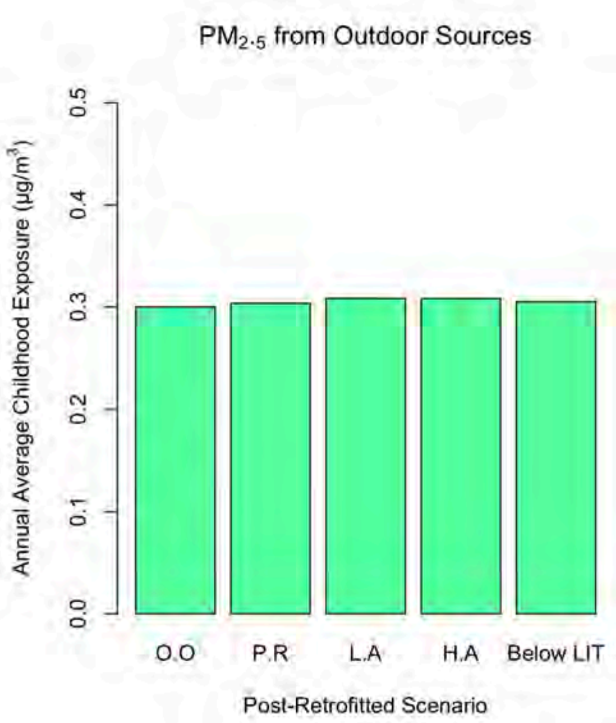












Results: Bar charts in all graphs represent Owner Occupied dwellings, Private Rented, Local Authority, Housing Association and homes which fall below the Low-Income Threshold from left to right. Results found that $PM_{2.5}$ levels from cooking activities increased (shown in orange), whilst $PM_{2.5}$ from indoor smoking did not change (shown in blue) and outdoor sourced $PM_{2.5}$ decreased following the retrofit (shown in green). This highlights the dual role of a home retrofit on indoor air pollution: Although the energy upgrade increased indoor exposure to $PM_{2.5}$ from cooking emissions, retrofitting tightens the building envelope, reducing the ability of external polluted air to infiltrate the dwelling. Results confirmed that only owner occupied dwellings were significantly different from all other tenure and income groups, across all three sources. Increase of exposure to $PM_{2.5}$ from cooking emissions following the retrofit has some implications for childhood health: The World Health Organisation (WHO) cautioned $PM_{2.5}$ exposure in the home is responsible for over half of all childhood deaths from pneumonia (WHO, 2016).

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ANNUAL COLLOQUIUM 2018

Studying Ventilation in Occupied Case Study Dwellings with Trickle Vents

Jessica Few: 2nd Year PhD Student. **Supervisors:** Cliff Elwell & Michelle Shipworth

London-Loughborough EPSRC CDT

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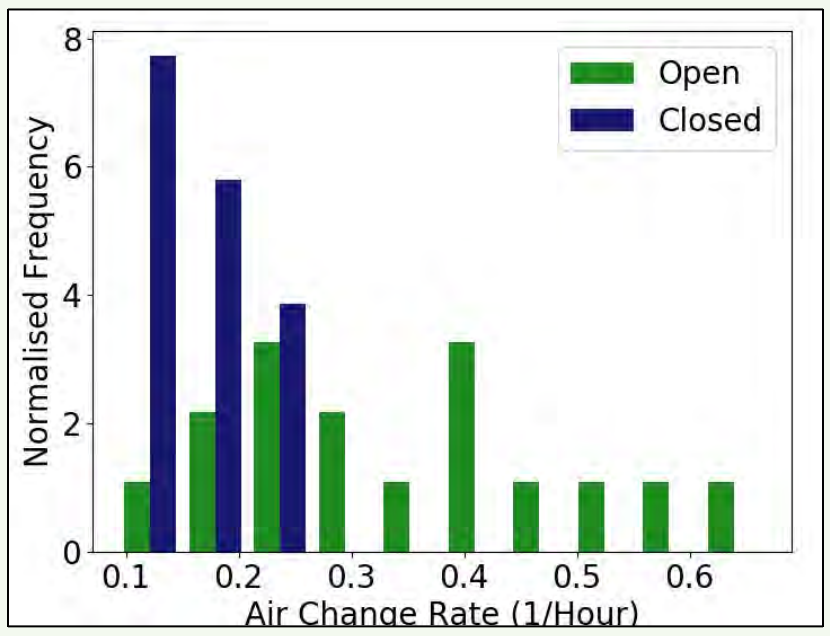
Airtightness and Ventilation Provision

Newly built dwellings are increasingly airtight due to regulations around airtightness.
However, sufficient ventilation is required to provide adequate indoor air quality.
The simplest way to adhere to ventilation provision requirements is to install trickle vents and mechanical extract fans.

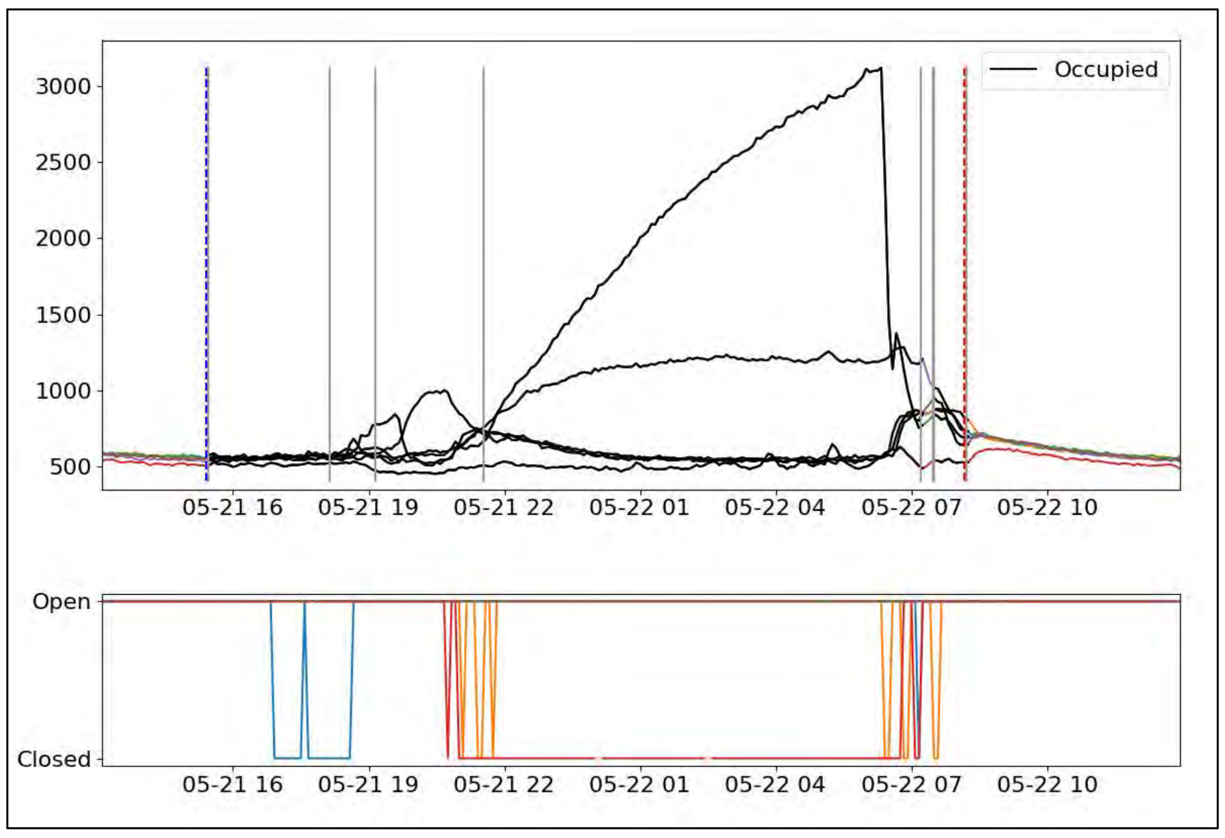
Trickle Vents Are Not Left Open

Building Regulations Approved Documents state that trickle vents should be left always open.
Existing research suggests that this is not the case in most dwellings (Sharpe et al., 2015).

Closed Trickle Vents Reduce Ventilation – A Pilot Study



Measurements of ventilation rate were carried out in a single room of an unoccupied test house with trickle vents open or closed.
0.5 air changes per hour is usually considered a 'good' ventilation rate.



What about Ventilation in Occupied Homes?

In occupied homes, ventilation can be measured using the concentration decay tracer gas technique with metabolically generated CO_2. For this to be valid, the space must be unoccupied.

An algorithm has been developed for this project using data collected from an occupied case study dwelling where CO_2 and door opening were measured for all rooms.

Compared to reported occupied times, this algorithm is correct in 86% of cases.

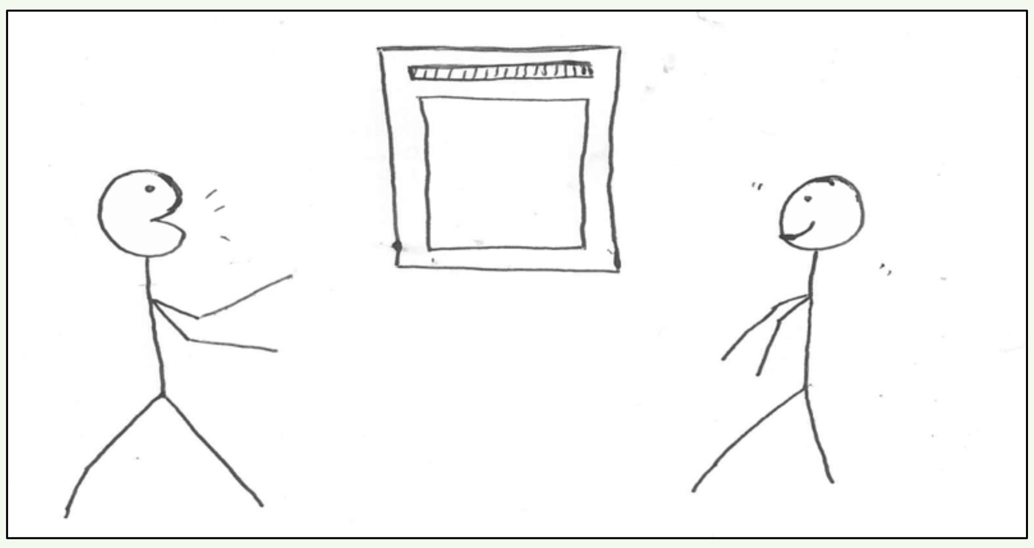
Next Steps…

This project will measure ventilation in occupied case study dwellings with trickle vents.

Accommodating the assumptions of the tracer gas technique in the context of an occupied home will require development of the measurement and analysis methods. Issues to be addressed will include:

- Homogeneity: how is the CO_2 distributed?
- Zoning: how do the occupants use internal doors to divide the house into different zones?
- Variability: how much does the ventilation rate vary and over what time scale can it be assumed to be constant?

What about the Occupants?



Interviews will be carried out with the occupants to understand how they are engaging with the trickle vents, and how this compares to the intention stated in the building regulations.

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References: Sharpe, T. et al., 2015. Occupant interactions and effectiveness of natural ventilation strategies in contemporary new housing in Scotland, UK. *International Journal of Environmental Research and Public Health*, 12(7), pp.8480–8497.

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ANNUAL COLLOQUIUM 2018

Multi-objective optimization of Passivhaus buildings in a UK social housing context

Joseph Forde 1st year PhD student, Loughborough University
Supervised by: Dr Christina Hopfe & Dr Rob McLeod

Introduction:

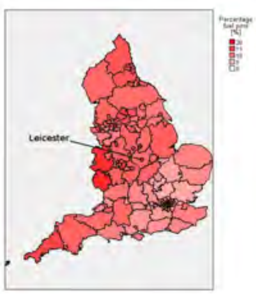
The UK is currently facing a housing crisis with wide ranging calls for new construction particularly in the social housing sector to match demand [1]. However, these new builds need to be completed in an environment under ever increasing threat from climate change. Hence, these new homes must be future ready and comply with overarching strategy. The Passivhaus standard offers a comprehensive low-energy standard suitable for this future, but is often seen as cost prohibitive [2]. The PH standard offers two heating criteria for certification – heating load and annual heating demand.

Research Aim:

The aim of this research is to identify cost optimal design solutions that meet the Passivhaus standard for a certain location within the UK for the present and the future climate.

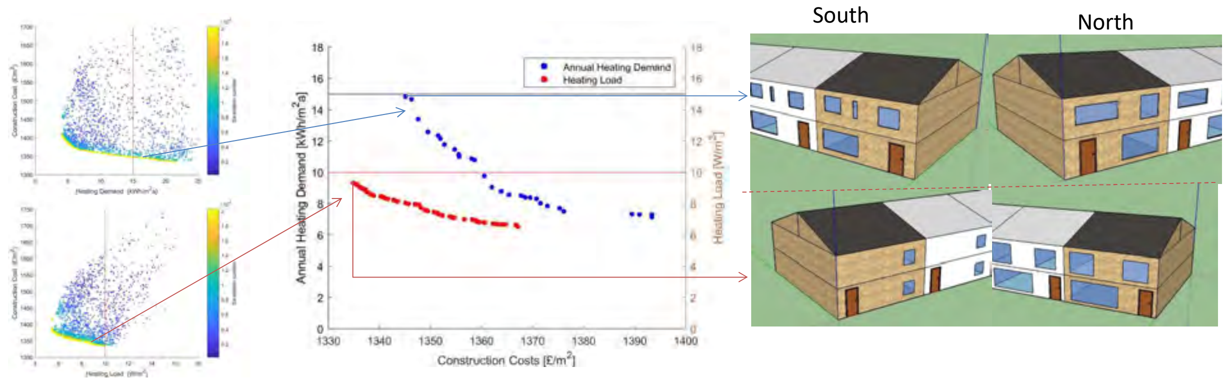
Methodology:

- A study region was selected using a sub-regional fuel poverty data-set.
- A building typology was selected based on standard characteristics of buildings in the selected study region.
- A range is defined for each component variables, these include the roof, wall and floor insulation levels, and geometric variables such as floor area.



- A selected genetic algorithm (GA) will be used for the multi-objective optimisation [3]
- Objective functions for this GA, which are to be optimised for, are defined to be either heating load or annual heating demand and construction costs.
- Constraints are defined for factors including minimum window area.

Results:



- The heating load criteria offers solutions at a lower construction cost than solutions optimised to the annual heating demand objective.
- The driver for this difference in cost is mostly (54%) created by differences in glazing percentage on the south façade.
- The glazing selected for the south façade tended towards higher cost, high-g glazing to maximise solar gains.
- Finding significant as annual heating demand often used as heating criteria for PH certification [4]
- Optimised cost solutions for heating load significantly more cost effective than non-optimised in design space.
- For future climate conditions, the heating load objectives produced more resilient designs, with overheating risk less likely to be exceeded until much later in the century.

Conclusion:

- Heating load offers a lower cost heating criteria in this instance compared to annual heating demand.
- The use of multi-objective optimisation allows the identification of solutions in the design space that are much lower cost. than non-optimised solutions, whilst still meeting the PH standard.
- Main driver for the cost differences between cost optimal solutions from heating load and heating demand is glazing area, particularly south facing glazing area.

References:

[1] – A. E. Holmans, "Housing need and effective demand in England A look at the big picture ," Cambridge Centre for Housing and Planning Research, April, 2014
[2] – J. Barnes, AECOM, and P. Trust, "Passivhaus Capital Cost Research Project," 2015. [Online]. Available: http://www.passivhaustrust.org.uk/ UserFiles/File/TechnicalPapers/150128PHCapitalCosts.pdf
[3] – R. Evins, P. Pointer, R. Vaidyanathan, and S. Burgess, "A case study exploring regulated energy use in domestic buildings using design-ofexperiments and multi-objective optimisation," Building and Environment, vol. 54, pp. 126–136, 2012.
[4] – I. Ridley, J. Bere, A. Clarke, Y. Schwartz, and A. Farr, "The side by side in use monitored performance of two passive and low carbon Welsh houses," Energy and Buildings, vol. 82, pp. 13–26, 2014.

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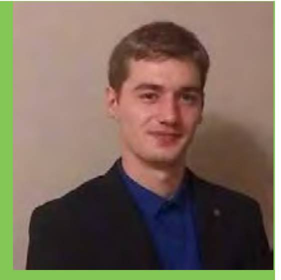
ANNUAL COLLOQUIUM 2018

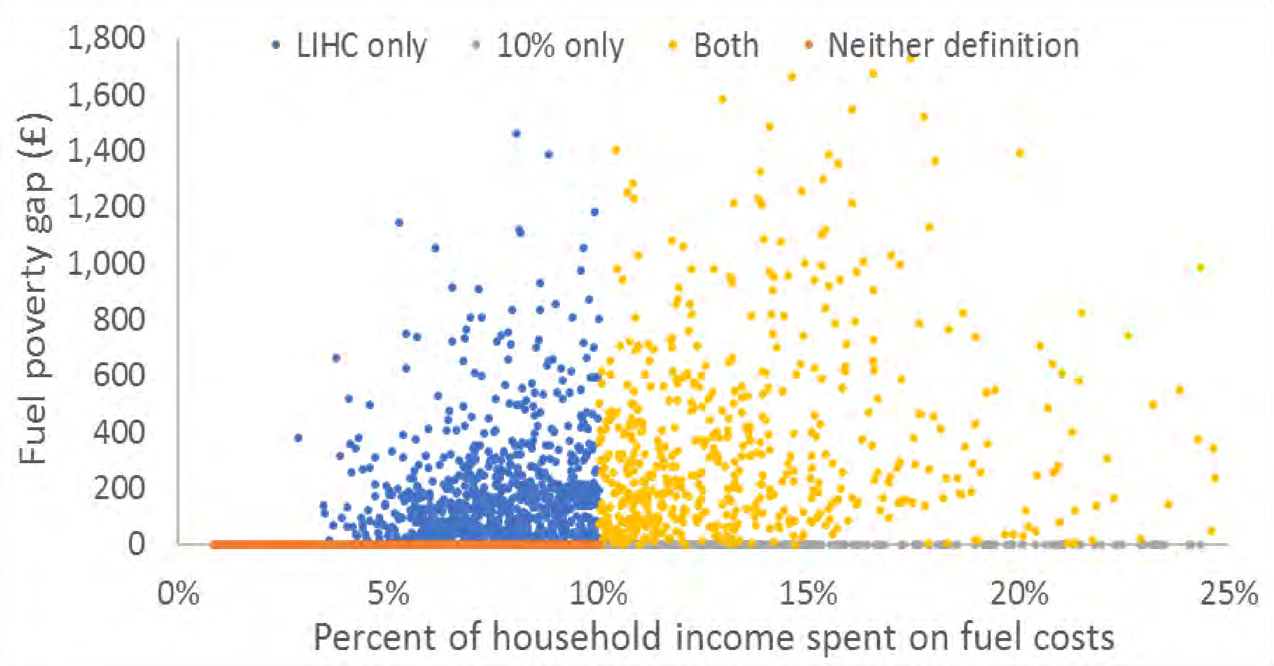
Fuel Poverty; changing the definition, the groups suffering and influencing factors.



Daniel Franks: 1st year PhD student **Supervisory team:** Prof Kevin Lomas, Dr David Allinson

Introduction

Fuel poverty affects 2.5 million households in England. These are households who would fall below the poverty line, were they to have a warm, well-lit home, with hot water for everyday use, and the running of appliances. There are severe consequences to leaving people in fuel poverty with 34,000 excess winter deaths recorded in 2017. The way England identifies fuel poor households has recently changed from the 10% indicator to the low-income high-cost (LIHC) definition. This research uses the 2012 and 2015 English Housing Survey (EHS) to compare the fuel poverty definitions, establish the socio-economic and dwelling groups most at risk to fuel poverty and understand what causes households fuel poverty status to change.



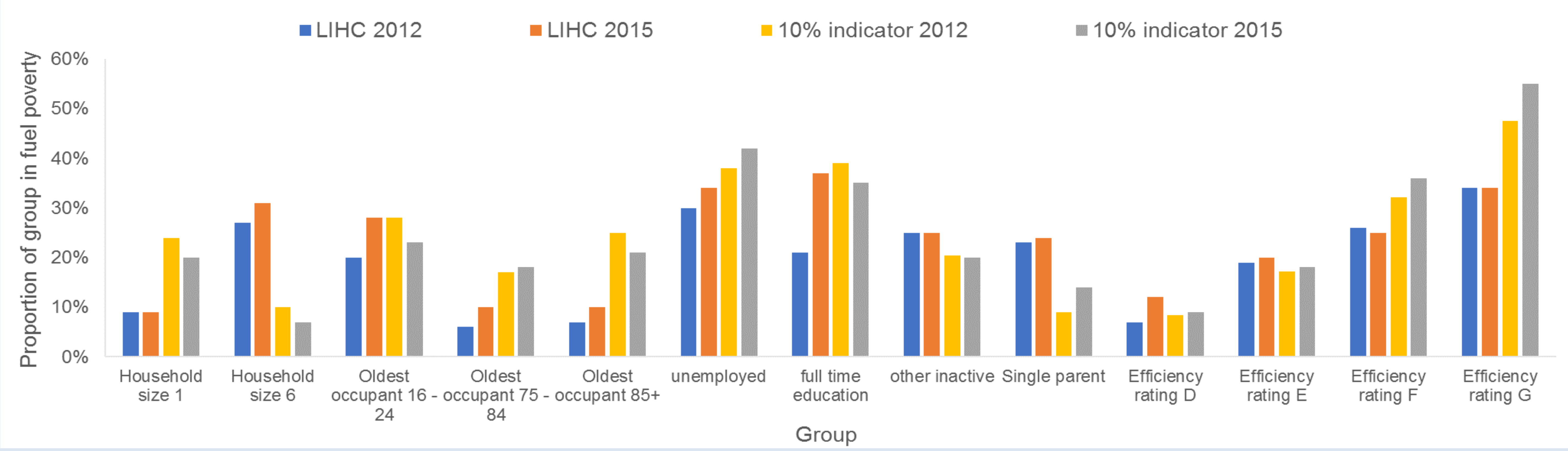
Compares the two fuel poverty definitions for 2015.

Comparing the fuel poverty definitions

The 10% indicator defines a household in fuel poverty if it spends more than 10% of it Income from all sources on fuel: $\frac{Required\ fuel\ cost}{Household\ income} > 0.1$

The LIHC defines a household in fuel poverty if:
-They have required fuel costs that are above the median level; and
-Were they to spend that amount they would be left with a residual income below the poverty line.

A Large discrepancy between the definitions was observed, with some households are spending over 20% on fuel costs, yet not classed as fuel poor by the LIHC indicator. Similarly, some household has a fuel poverty gap of over £500 yet not classed as fuel poor by the 10% indicator.

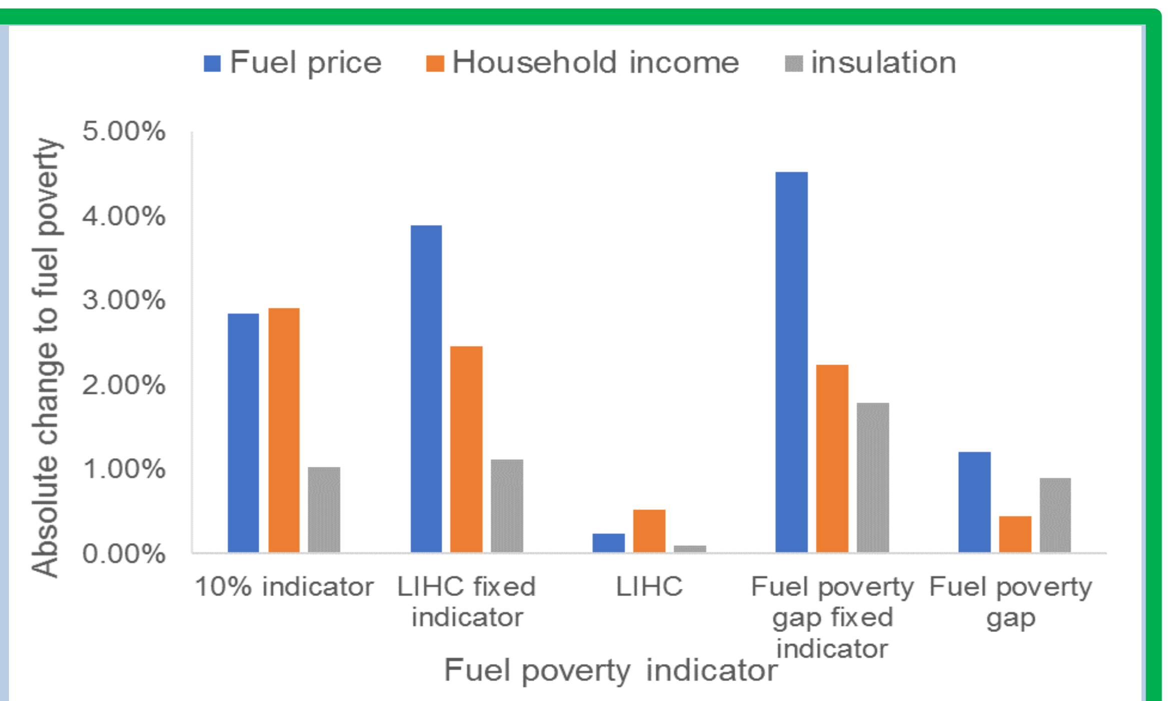


Proportion of fuel poor households by Group for both definitions and for the years 2012 and 2015.

The sensitivity of fuel poverty

A fuel poverty sensitivity analysis was carried out which consisted of adjusting, in turn, the fuel price, household income and insulation of all households in the EHS one percentage point at a time; while recording the change to fuel poverty. This was done to both fuel poverty definitions as well as the LIHC fixed indicator. The final indicator used to demonstrate the sensitivity of the LIHC indicator for an individual or group of households, where a change to their fuel price or household income, has a negligible effect on the national median fuel cost or household income.

The LIHC definition is insensitive to national changes to household income, fuel cost or insulation. However, for individual households or small groups, fuel poverty status can easily change. Thus, the group's that are targeted with fuel poverty prevention measures should observe a notable drop in the number of households in fuel poverty, if the measures are effective.



Demonstrates fuel poverty sensitivity to household income, fuel price and insulation

Conclusion

Changing from the 10% indicator to the LIHC definition, led to a small difference in the total number of households in fuel poverty; although approximately half of the fuel poor households are different. The groups that saw significant reductions due to the definition change were: single occupied households, households with an efficiency rating of F or G, households with an elderly member and low-income households.

The socio-economic and dwelling groups that show a high proportion of people in fuel poverty, and considered to be particularly susceptible to the effects of fuel poverty, are: Households where the HRP is unemployed or other inactive, households made up of a lone parent and child(ren), and households with an efficiency rating of G or F. Thus, the current fuel poverty strategy, targeting the fuel poor by SAP rating, could miss or delay reaching many socio-economic and dwelling groups considered to be at greater risk, to the effects of fuel poverty.

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ANNUAL COLLOQUIUM 2018

An investigation of feedback & feedforward energy efficiency mechanisms from a UK school crowdsourced stock model

Researcher: Duncan Grassie 2nd Year MPhil/PhD
Supervisors: Dr. Ivan Korolija, Prof. Dejan Mumovic, Prof. Paul Ruyssevelt

Motivation for research

CIBSE
TM 57: School Design

SALIX

1999 No. 2
EDUCATION, ENGLAND AND WALES
The Education (School Premises) Regulations 1999

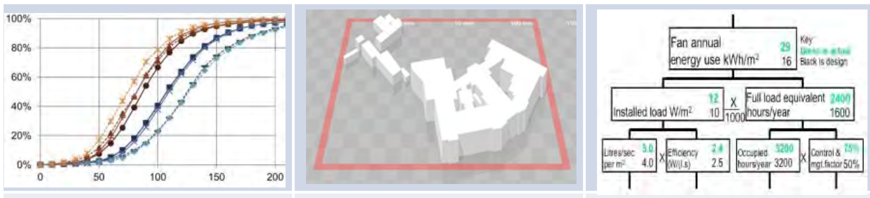
In wider **context:**

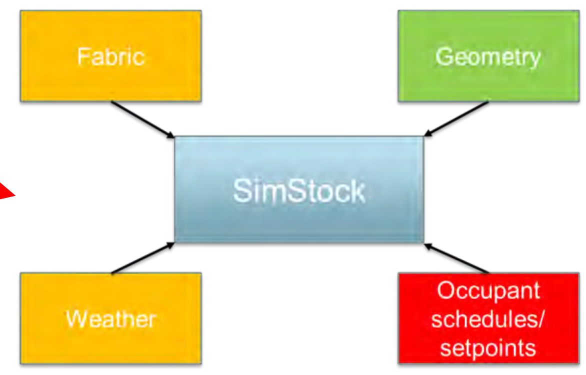
- **80% reduction** in Carbon emissions required by 2050 from 1990
- **Non-domestic** energy demand responsible for **18% of UK total**
- **Schools** sector buildings – relevant sector for investigation
  - **Standardised** by function, guidelines, regulations & funding

Urban scale building stock models to track/reduce emissions:

- Involves **auto-generation** of 1000s of simulation models
- Combines **top-down** and **bottom-up** methodologies
- Utilises national level datasets for **geometry, fabric & weather**
- Previous work showed **generic schedules & setpoints** for heating, lighting, occupancy, ITC & catering **cannot be used**[1]

1 Grassie, D. et al., Feedback and Feedforward Mechanisms for Generating Occupant Datasets for UK School Stock Simulation Modelling.

Top-down	Stock model	Bottom-up
		
Covers population	Covers population	Detailed sample
Benchmarks - no causal	Show causal relationships	Show causal relationships



Research Questions

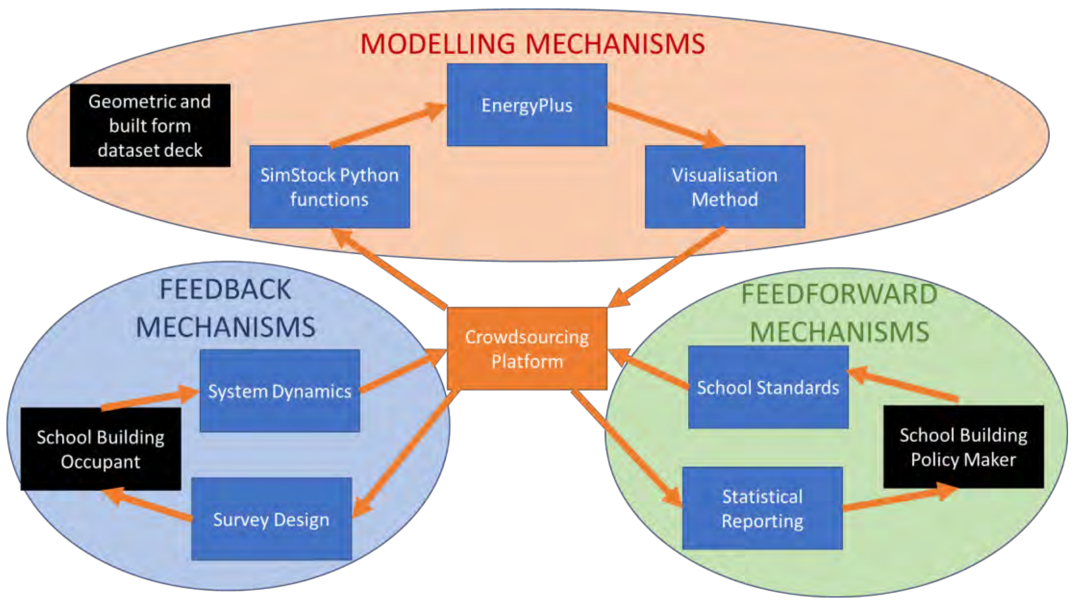
Stock model of 22,000 schools in England /Wales

Can a national occupant dataset be constructed?

Can it feedforward progress on regional & national CO_2 targets?

Can it feedback performance improvement to individual schools?

Role of platform



Structure of research and methods to be used

Stage gate process	Scoping		Development		Testing	
Deliverable	Summary of previous attempts to build national school occupant datasets	Design required for individual schools / policy makers to engage	Crowdsourcing platform which defines variables required for occupant datasets	Comparison of updated model sample of sub-metered schools	Effect of sample size and format of feedback on veracity of dataset	Effect of a national occupant dataset on aggregated data
Method(s)	Comprehensive literature review	Semi-structured interviews / workshops	Interface building	Calibration of Energy+ models to metered data	Analysis of variance	Descriptive statistics

Results - Example School A

Solar: "Is it generating electricity? Who is getting the benefit of that?"

"We had to buy some **fans** for classes because it was just like **extreme heat** earlier on in the year."

"it's a single **pre-fab build**, with two little rooms ... as additional teaching space."

Calculated (EPC):
C 51-75 — 62
A 0-25 — 25
C 51-75 — 55

Actual (DEC):
E 101-125 — 111

"The caretaker will put the **heating on and off** and we often have to **prompt one way or the other** at times."

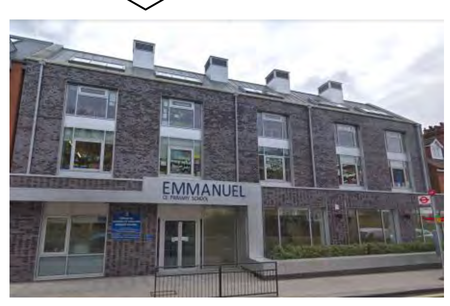
Results - Example School B

"We've got a **big kitchen** which is **currently being used** by a secondary school, theirs is out of action."

"quite often the **front** bit of the building is **cooler than the back... We've put some stuff on the glass"**

"The **ground source heating** costs more money because we have to get it serviced annually"

"there's **so many systems**... that... our site services manager has quite a **punishing schedule** "



Calculated (EPC):
B 26-50 — 37

Actual (DEC):
E 101-125 — 118

Discrepancies between actual and calculated performance are considerable for both example schools shown.
Reported comments demonstrate there are a plethora of operational factors which could be responsible.
Investigating if factors are significant at a population level requires development of methods to gather data directly from building users.

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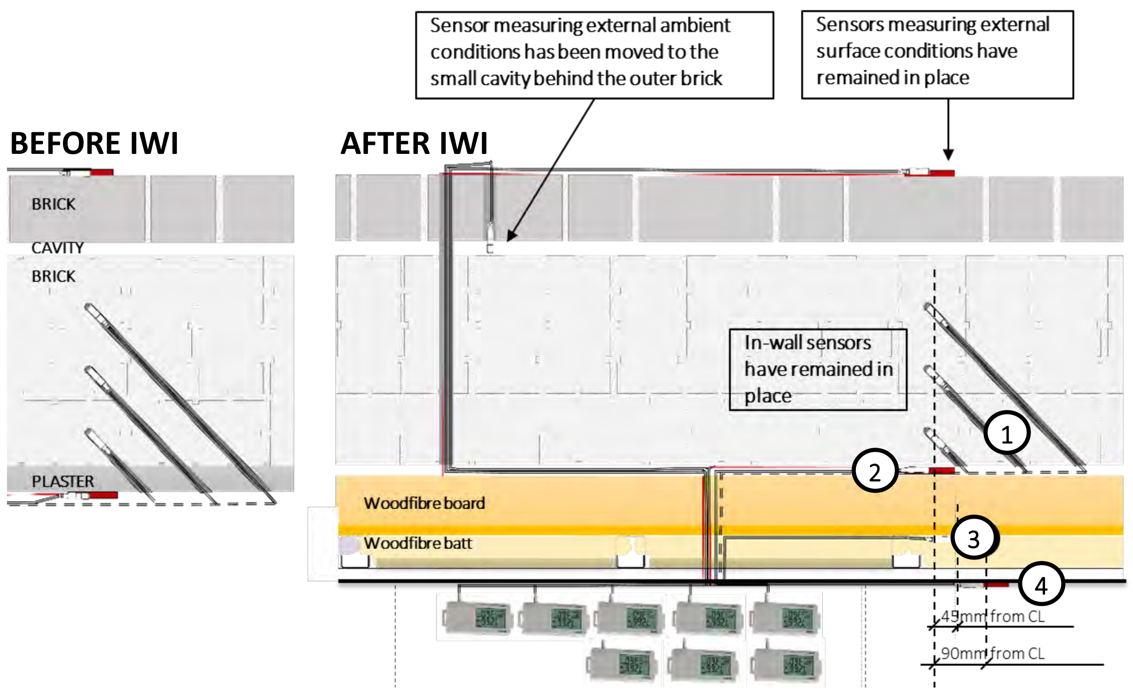
ANNUAL COLLOQUIUM 2018

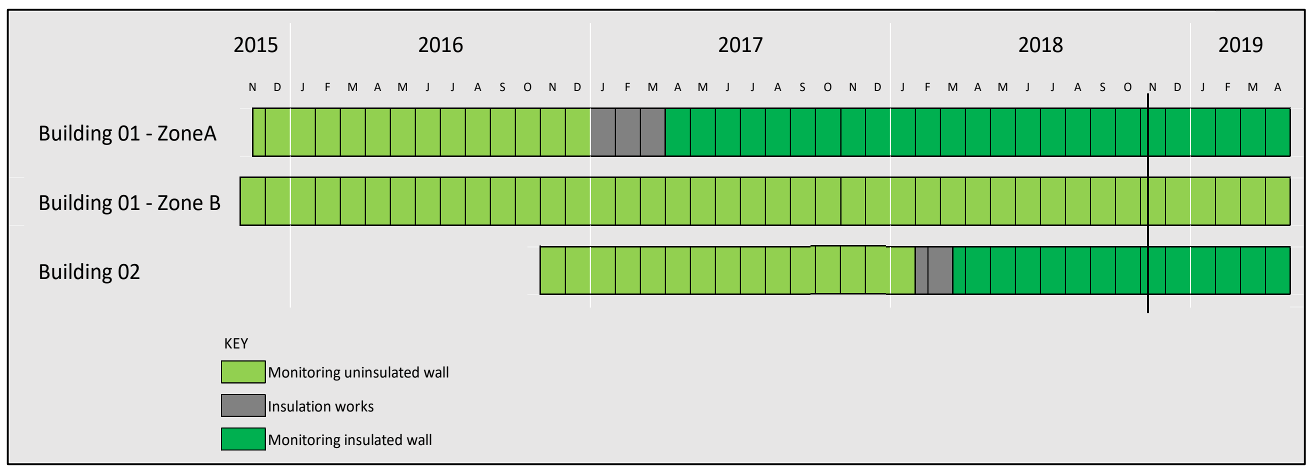
Hygrothermal characterisation of solid brick walls and the impacts of internal wall insulation

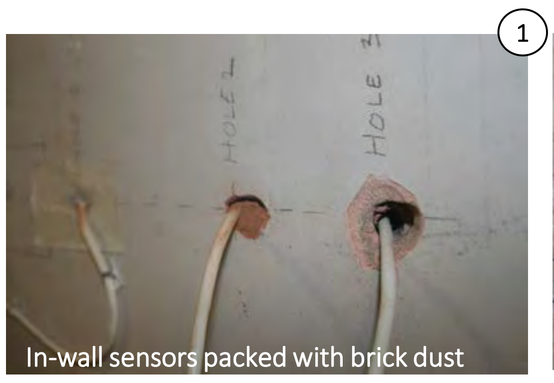
Naomi Grint 3rd Year PhD student (part time) **Supervisory team:** Cliff Elwell & Mike Davies

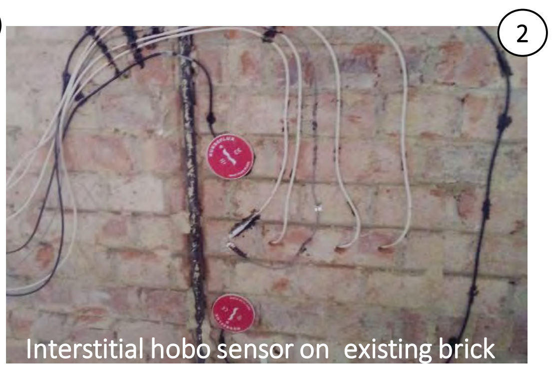
Data collection

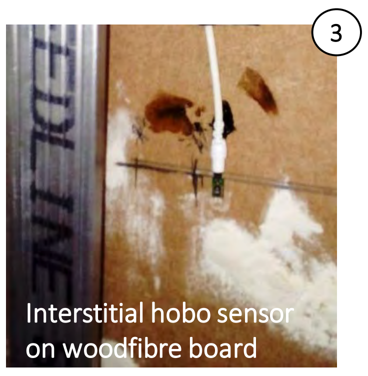
Internal wall insulation (IWI) may contribute significantly to reducing energy demand, but there are potential unintended consequences. 'Before and after' data is rare. High resolution data is rare.

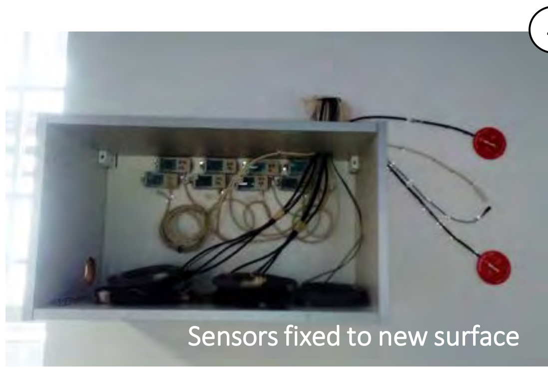





1 In-wall sensors packed with brick dust


2 Interstitial hobo sensor on existing brick

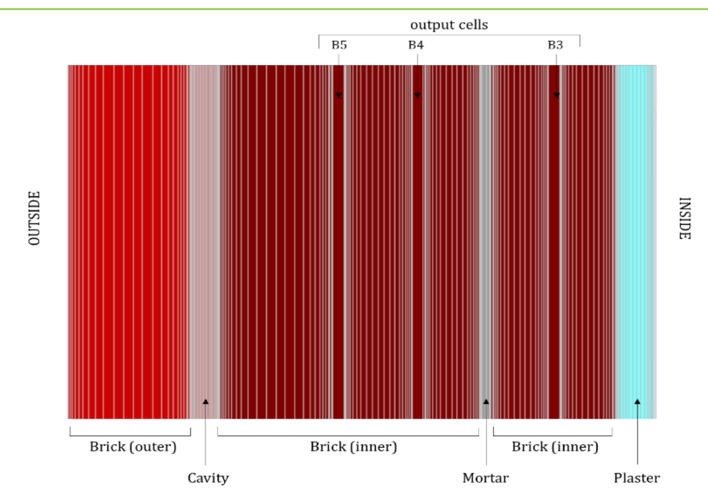

3 Interstitial hobo sensor on woodfibre board


4 Sensors fixed to new surface

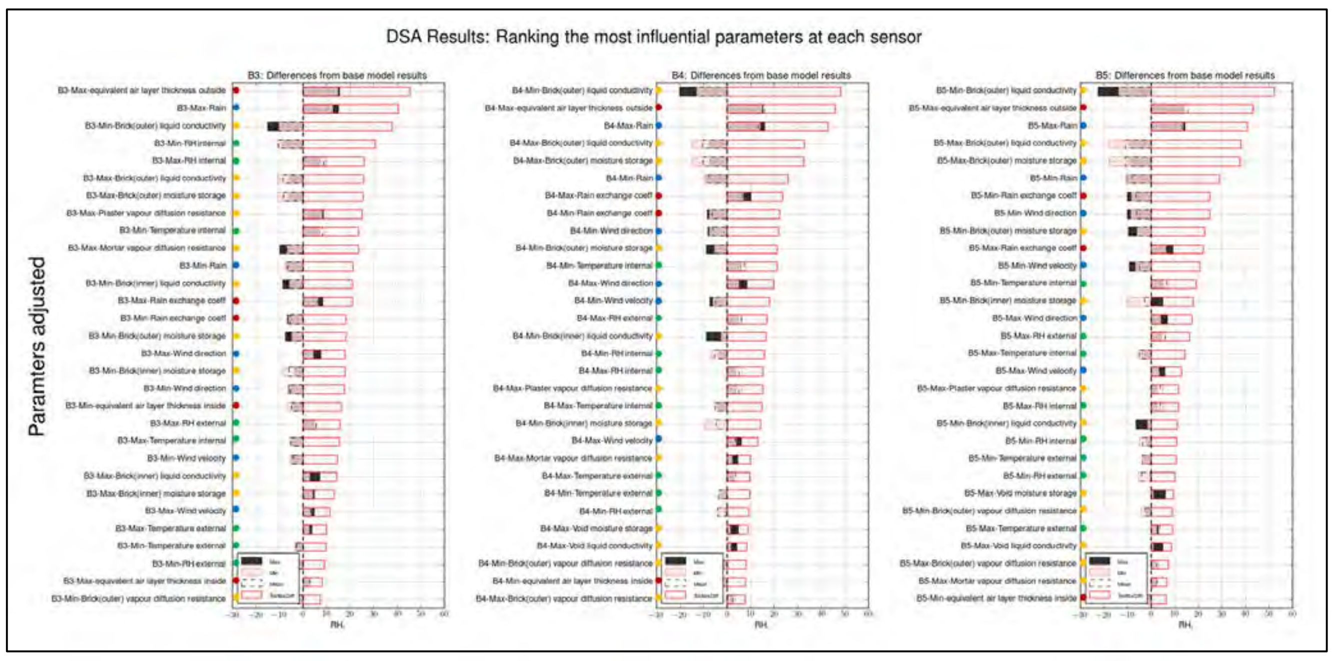
Climate monitoring equipment on external wall

Sensitivity Analyses

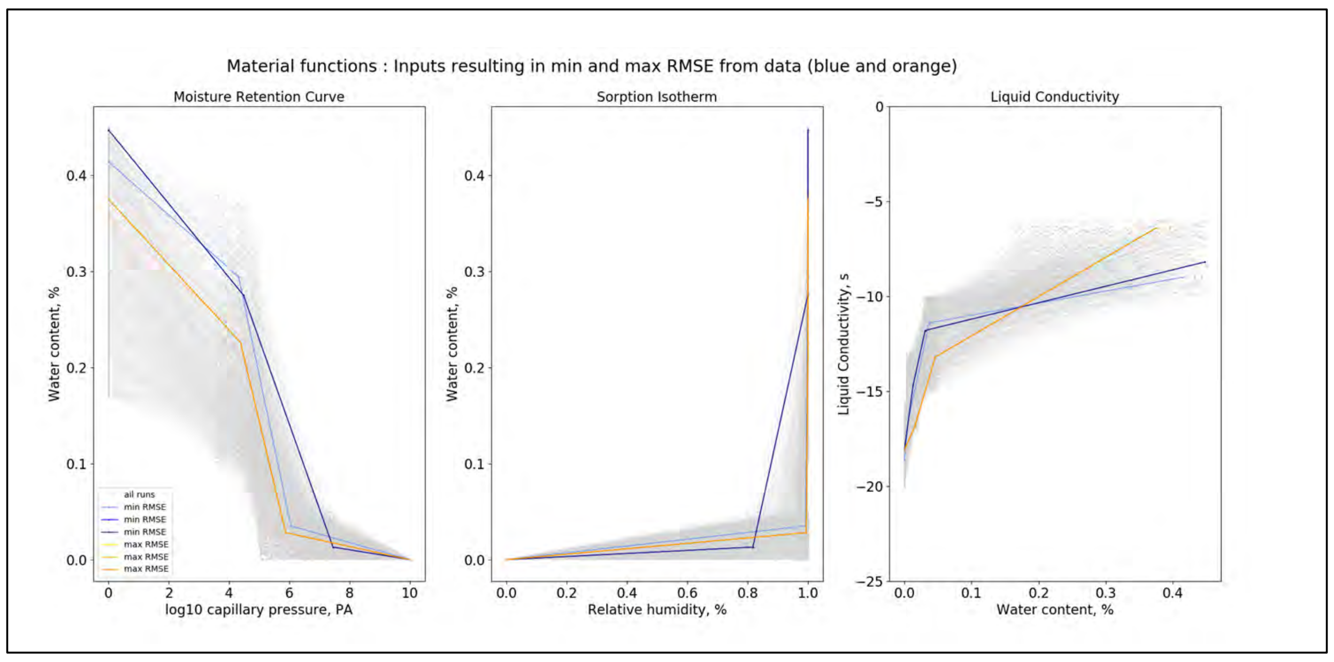
Uncertainty in material properties impacts on in-wall model results of Relative Humidity. Especially liquid conductivity and storage in the outer brick.

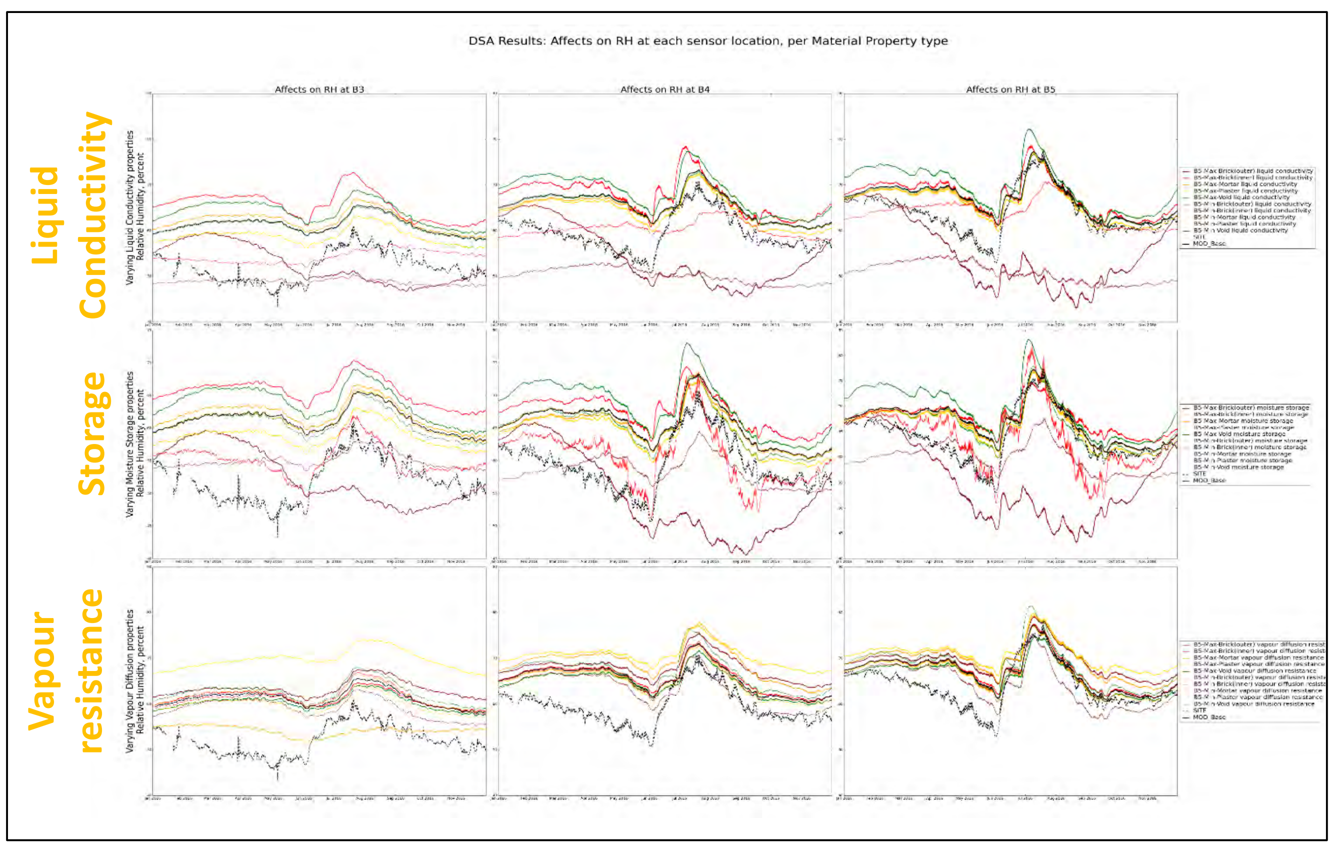


DIFFERENTIAL SENSITIVITY ANALYSIS:
ASSESSING IMPACT OF ONE PARAMETER AT A TIME



MONTE CARLO ANALYSIS:
FINDING CLOSEST FIT TO SITE DATA



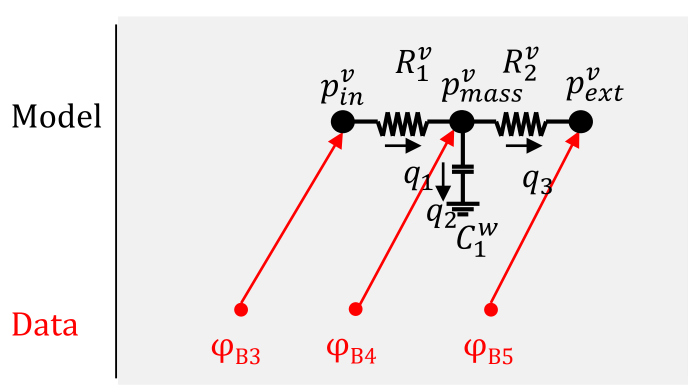


Parameter Estimation

It may be possible to infer some material properties using the in-situ data and simplified models. This may provide a more useful way to characterise in-situ walls.

FIRST MODEL:
NEGLECTING LIQUID TRANSPORT

$$\frac{\partial w}{\partial \phi}\frac{\partial \phi}{\partial t} = \frac{\partial}{\partial x}\left(\delta_p \frac{\partial p_v}{\partial x}\right)$$



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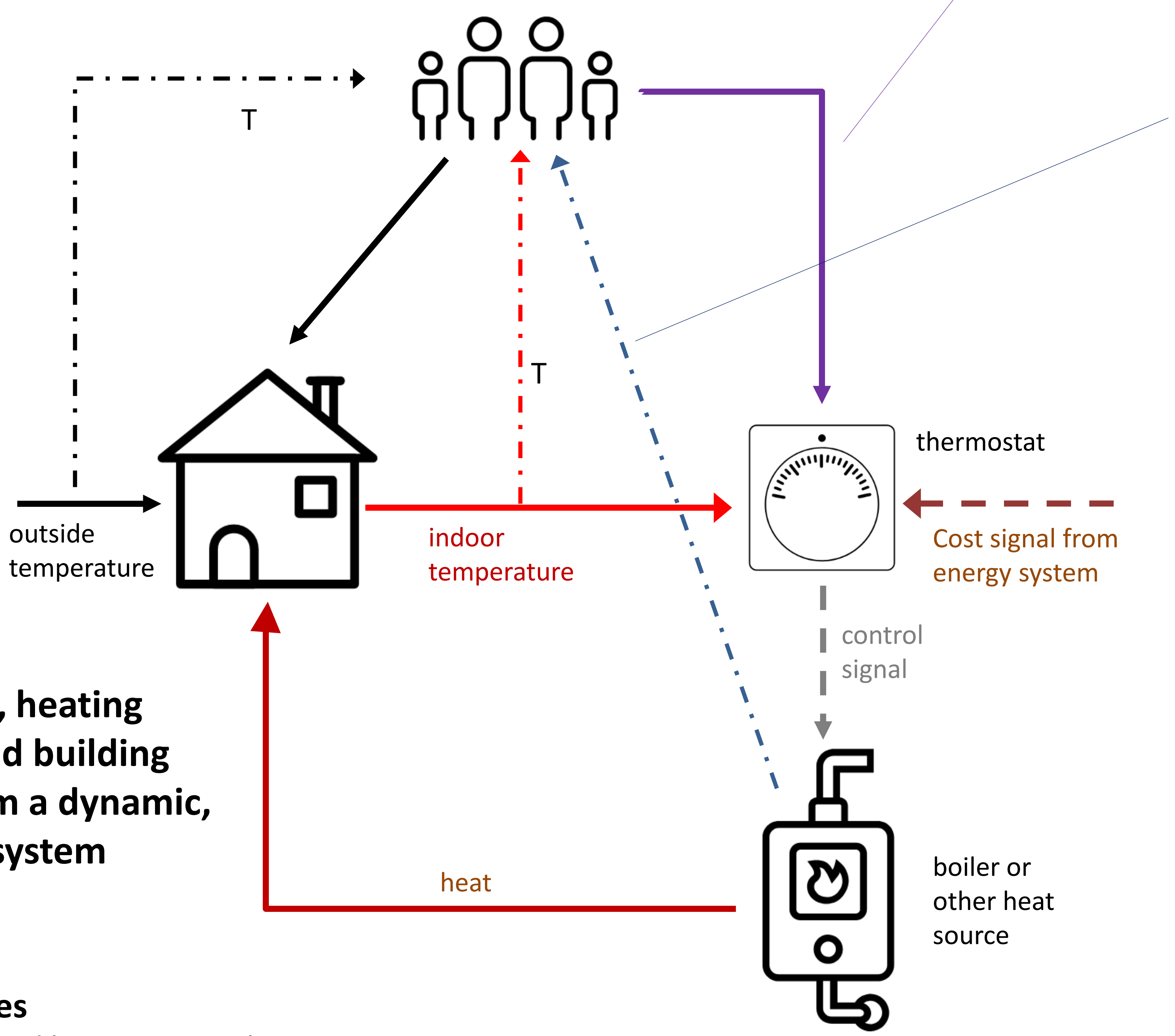
ANNUAL COLLOQUIUM 2018

How flexible is home heating demand?

Clare Hanmer Third year PhD clare.hanmer.15@ucl.ac.uk
Supervisors: Prof David Shipworth; Ms Michelle Shipworth; Dr Charlotte Johnson
Industrial Partner: PassivSystems Ltd

Understanding patterns of heating demand is important

- What will the additional peak load on the electricity network be if electric heating (heat pumps) replaces gas boilers?
- Will low carbon heating be acceptable to users if operating patterns have to change (e.g. heat pumps run at night time)?
- How flexible is heating demand? Can it be used for load management?



Residents, heating system and building fabric form a dynamic, adaptive system

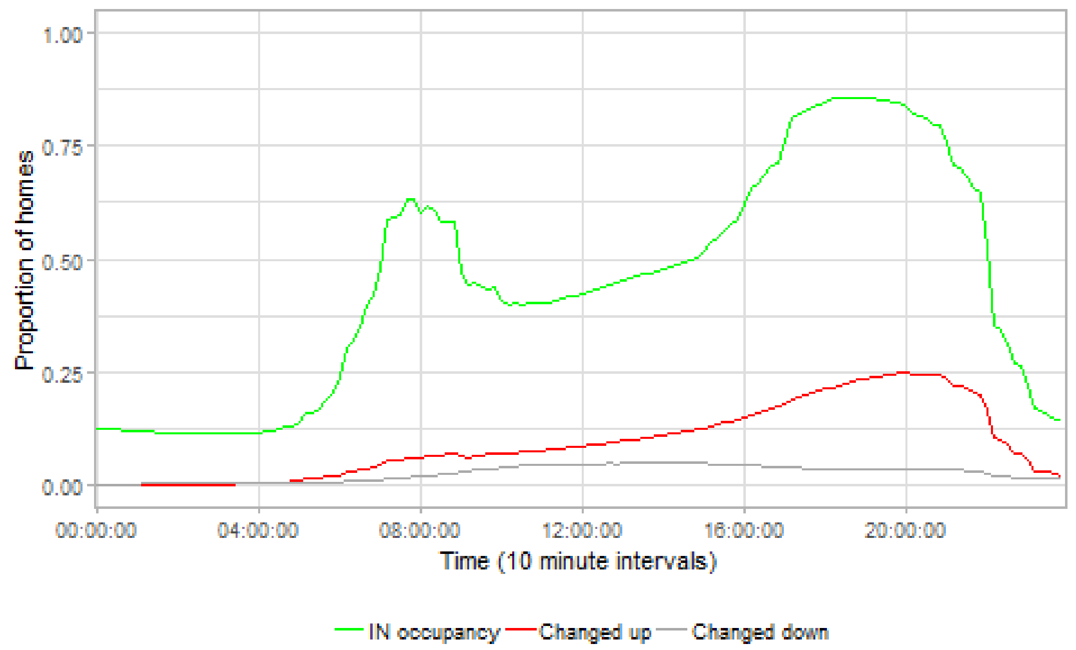
Data sources

Freedom hybrid heat pump trials:
Private homes interviews: 12 before trial started, 8 spoken to during trial
Social housing interviews: 4 during trial
Data analysis for 71 homes Nov 17 –Apr 18

Bulk data analysis: 3,579 homes with PassivSystems heating controllers

Residents' temperature requirements are not constant

- Households not running heating all time home occupied (and occupants awake)
- Changing temperature setpoints through the day
- Varying expectations associated with different practices in home



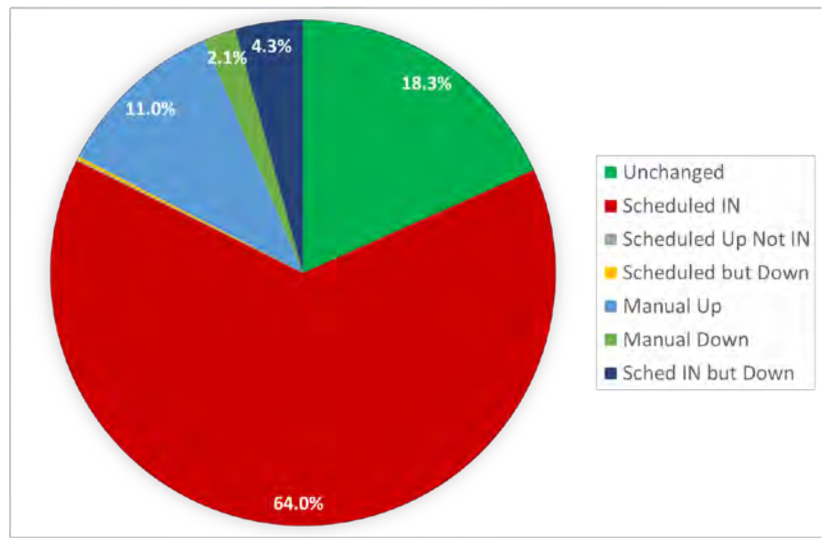
Proportion of homes which have changed their IN setpoint compared to earlier in the day: mean across 3,579 homes 3/1/16 to 27/2/16

Room temperature is not the only goal that matters

- Thermal comfort not only objective for residents
- Complaints about noise (boiler, heat pump, gurgling in pipes)
- Heating running "when it shouldn't": loss of control / agency
- Worries about costs and lack of direct control
- Additional feedback loop: direct from equipment

Some households are resistant to demand management

- In many cases households were happy with (or did not notice) new operating patterns
- But 13% of first morning setpoint changes were made manually and so not available for load shifting
- One interviewee had reverted to manual control because of concerns on cost of operation, effectively opting out of demand management



First setpoint change after 5am: proportion scheduled, manual and unchanged for 71 homes in Freedom trial 1/11/17 to 19/4/18

Key challenges for algorithm and control interface design

- Recognising the full range of potential user requirements. This may mean additional inputs to specify preferences apart from temperatures.
- Providing information to the residents sufficient for them to understand how to specify their requirements and build their trust in the system.

Messages for energy policy

- There's more to heating demand shifting than maintaining "same heating service" (interpreted as reaching user-specified minimum temperature when house is occupied).
- People need encouragement and information in order to adapt to new heating patterns.

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ANNUAL COLLOQUIUM 2018

Evaluating the in-situ thermal performance of loft insulation in residential buildings: determination of R-/U-values and opportunities for minimising heat loss.

Suneina Jangra, 2nd year PhD student, UCL Energy Institute (Supervisors: Dr Cliff Elwell & Prof Bob Lowe) suneina.jangra.16@ucl.ac.uk

CONTEXT & MOTIVATION

- Loft insulation is one of the most common household energy efficiency upgrades but the expected energy and cost savings are not always realised in practice.[1,2]
- Incorrect assumptions about the impact of energy efficiency upgrades can lead to misinformed energy demand policy.
- Measured data is needed to improve the accuracy of thermal performance estimates and reduce uncertainty in models.[3]
- There is little evidence to confirm that the in-situ thermal performance of loft insulation is in line with the expected performance under design assumptions.
- The impact of air flow and solar gains on heat flow around roofs is not currently fully understood.

METHOD & ANALYSIS

- Measured heat flux and temperature data to estimate in-situ R-/U-values.
- Design U-value estimates based on standard assumptions about the thermal conductivity of building materials.
- Infrared thermography and site surveys to contextualise quantitative results.

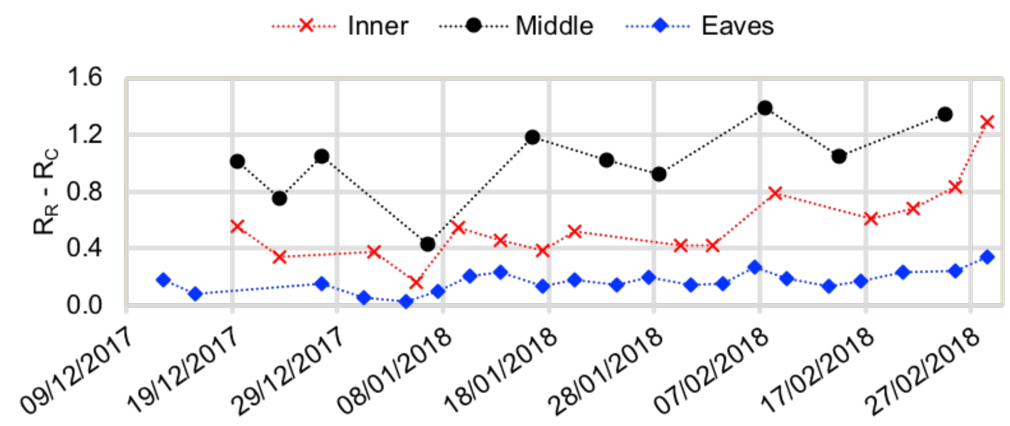


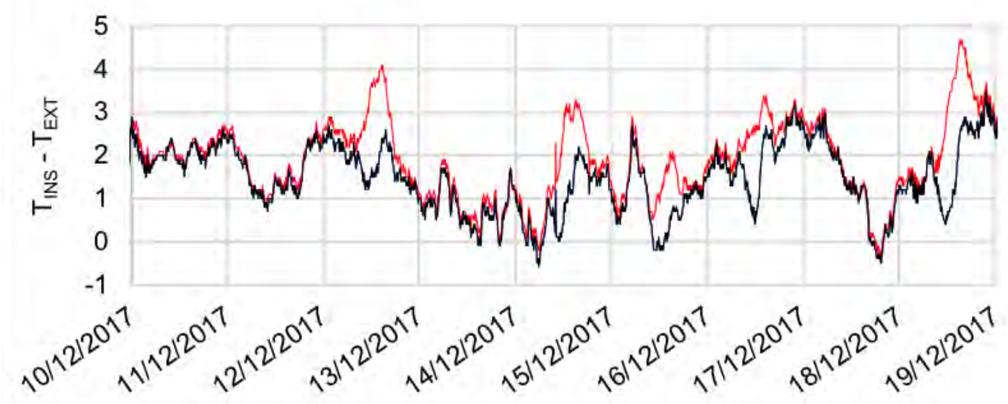
FUTURE WORK

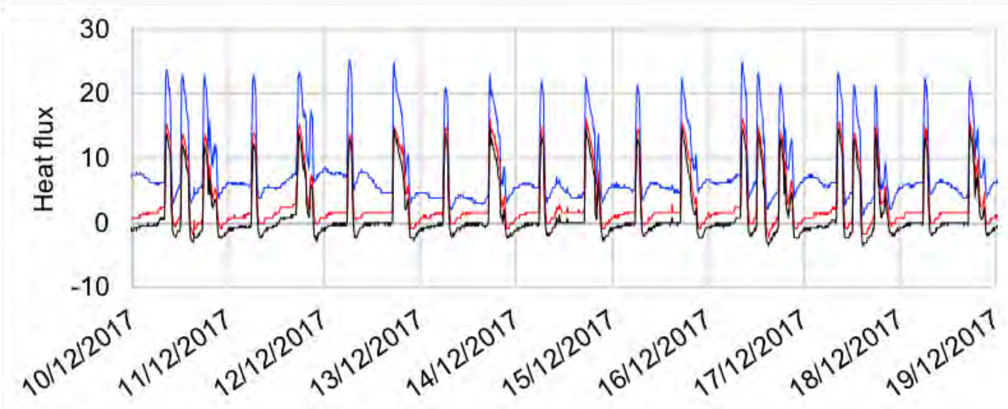
- Test the validity of a dynamic Bayesian probabilistic method[4] for estimating R-/U-values.
- Further characterise the effects of ventilation and solar gains on heat flow in roofs.
- Characterise perimeter effects/impact of defects on the performance of installed insulation.

[1] S.H. Hong, T. Oreszczyn, I. Ridley (2006) The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings. Energy and Buildings 38 (10).
[2] C.A. Elwell et al. (2017) The thermal characteristics of roofs: policy, installation and performance. Science Direct 132.
[3] D. Crawley et al. (2006) Contrasting the capabilities of building energy performance simulation programs, Building and Environment 43 (4).
[4] P. Biddulph et al. (2014) Inferring the thermal resistance and effective thermal mass of a wall using frequent temperature and heat flux measurements. Energy and Buildings 78.

PRELIMINARY RESULTS





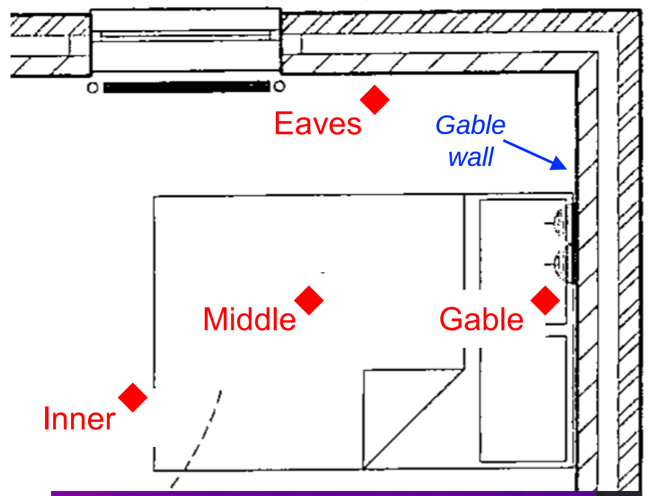


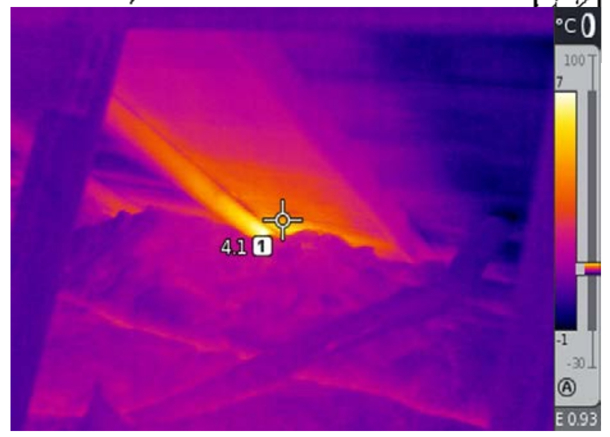
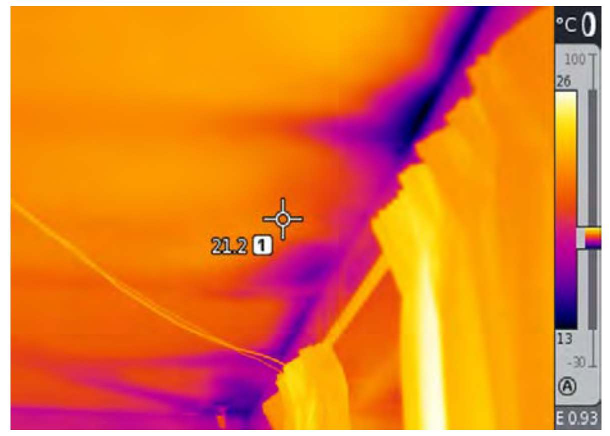
Resistance of the loft cavity is consistently lowest at the eaves:

- No significant difference between ΔT at eaves and middle location;
- however, heat flux is much higher at eaves due to gaps in the insulation.

Resistance of the loft cavity at inner location consistently lower than middle location:

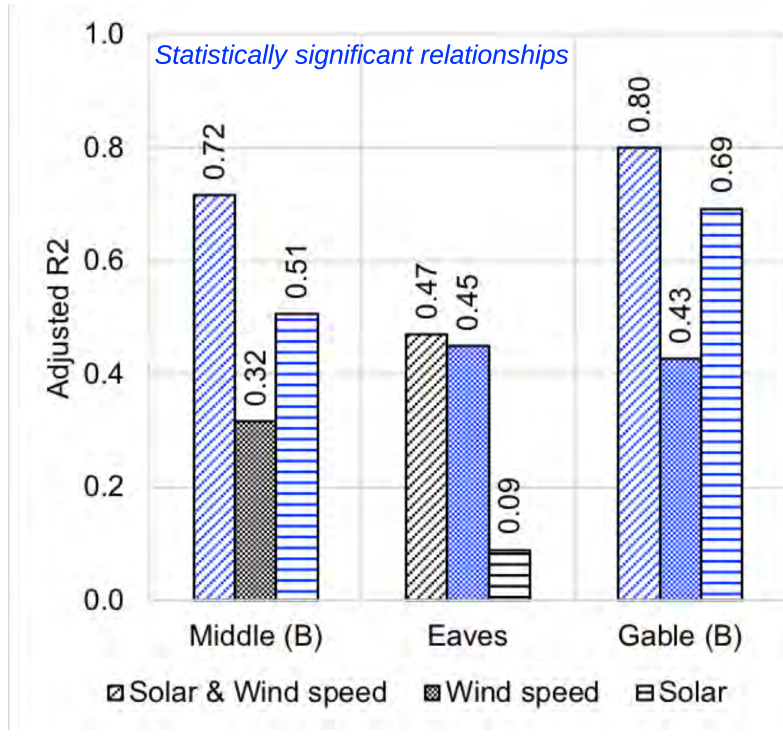
- ΔT is more variable and peaks higher at inner location;
- But heat flux is consistently higher possibly due to occupant intervention in this area of the loft.



What is the impact of solar radiation and/or wind?

- **Middle:** R^2 is only statistically significant for relationships including solar radiation – the more solar radiation on the roof, the higher the resistance of the loft cavity.
- **Eaves:** Only wind has a statistically significant effect on the resistance of the loft cavity – wind penetrating nearby vents draws in cooler air and the resistance of the loft cavity decreases.
- **Gable:** Wind and solar are both significant – proximity to building perimeter increases dependence of observed R-values to external weather conditions (solar is the dominating factor, wind is not as important because there's less impact of air flow through vents).



This research was made possible by support from the Engineering and Physical Sciences Research Council (EPSRC) Centre for Doctoral Training in Energy Demand (LoLo), grant numbers EP/L01517X and EP/H009612/1.

This project is also sponsored by the British Board of Agrément (BBA).

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ANNUAL COLLOQUIUM 2018

Occupant-driven Mitigation Strategies for Poor Indoor Air Quality in UK Homes

Efforts to understand the interactions between people and the spaces they live have, in recent years, been dominated by studies focused on energy consumption and heat. However, indoor air quality is an area in real need of empirical, real-world data on how and why people behave in the way they do with regard to ventilation. As we make progress towards improving the energy efficiency of our housing stock we are changing the natural ventilation profiles of dwellings. This project aims to better understand the way people ventilate their homes and, using an action research approach, determine what scope there is to improve air quality in their homes through behaviour change.

Action research is a cyclical process. It involves working with participants to understand their specific problems, design suitable interventions and reflect on the impact of the interventions.

This project will consist of a longitudinal study of 6-8 social housing households using mixed methods (including qualitative interviewing and environmental monitoring).

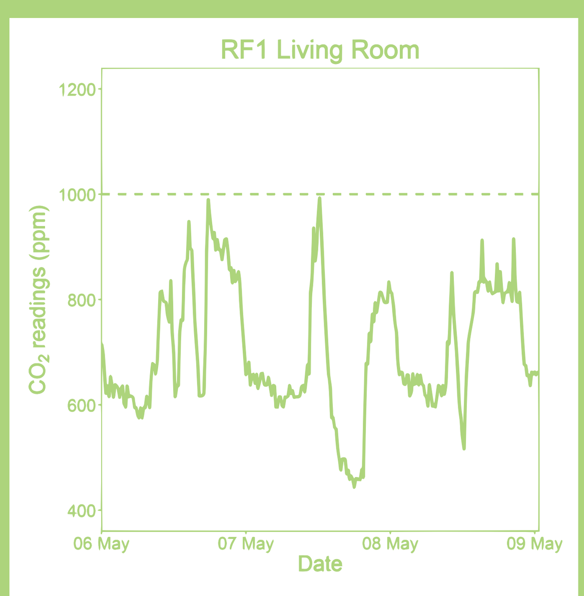
Understand the problem

Q Methodology

A quant-qual hybrid method based on sort cards and factor analysis to understand complex attitudes and behaviours

Depth Interviews

Detailed interviews to fully understand the specific situation of the household and examine their needs and behaviours



Observe & Reflect

Monitoring

In-home monitoring will capture the impact of interventions. Monitored data will include CO_2, temperature, RH and window opening events

Co-creation

Following the explorative element of depth interviews, a co-creation activity will take place with participants to design interventions that are suitable to their lives and situation. Participants will then carry out interventions during the period between researcher visits.

Design & carry out interventions

Vector image of flat by "sceneit" via "Vecteezy"
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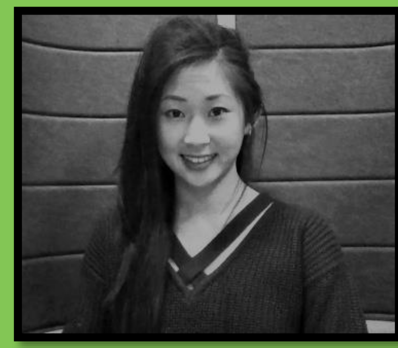
ANNUAL COLLOQUIUM 2018

Investigating the reduction of domestic heating emissions brought about by 1 PVT series system used to power a row of terraced houses



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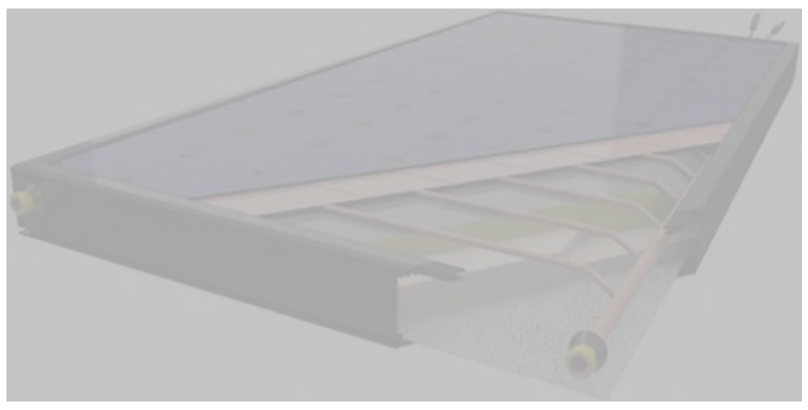
Anneka Kang 1st Year PHD Student. Supervisors: Dr Ivan Korolija and Dr Dimitrios Rovas

What percentage of space heating and domestic hot water could be provided by 1 PVT system with thermal and electrical storage across the roof area of a series of terraced houses?

Motivation

- 70% of the world's population are projected to live in urban areas by 2060; therefore reducing urban area domestic emissions is key.
- Low-rise purpose built flats, converted flats and terraced houses comprise 68% of London's accommodation buildings, so this initial study investigated emissions reduction amongst terraced houses.
- Photovoltaic-thermal (PVT) are a promising high energy density technology; simultaneously producing electricity and heat whilst increasing the PVT efficiency with cooling.



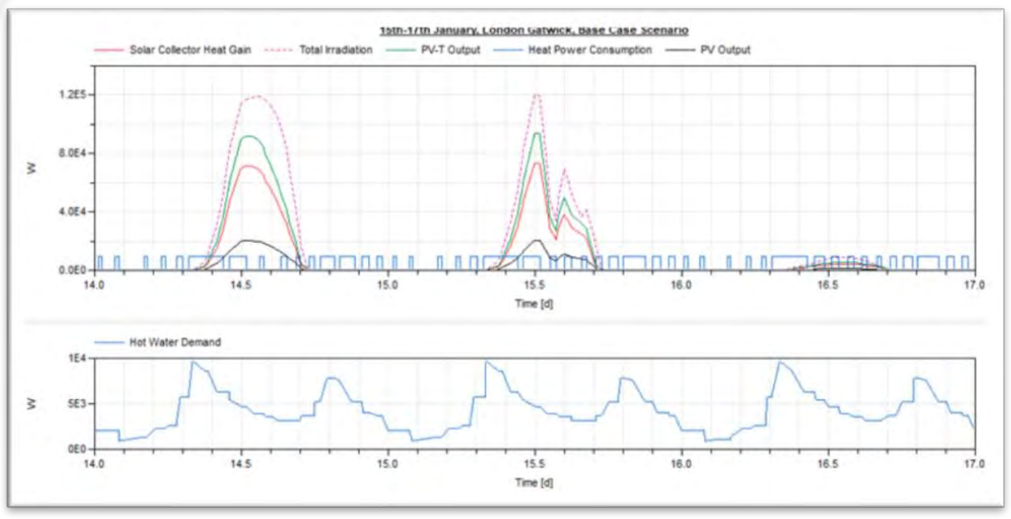


Figure 1: Example of system result output in January

Method

- The high-level system modelled in Dymola/Modelica comprised of: weather, PVT, hot water tank, auxiliary heater and terraced house heat demand sub-systems.
- 5 system configurations were modelled with various setups such as altering tank temperature, closed/open loop PVT configurations, varied hot water demands and differently sized auxiliary heaters.
- Modelled over 1 year, at 1 second increments, with an area of 160m^2 PVT, based on a row of 10 houses in a terraced row.
- Pump control and tank set point control was implemented.

Key Findings

- *Pre-heating mains water* in the PVT increases both the PVT thermal efficiency and utilisation, and electrical efficiency (Figure 2).
- Closed loop PVT configurations had *a* compensated performance. The auxiliary heater and PV electrical output *matched only 13-29%* of the time, making a case for battery storage to reduce grid dependency. (Figure 3)
- With lithium-ion battery storage, the PVT system could meet all hot water demands and almost all the electricity demands (~91%), or 80% space heating during winter.
- The study highlighted the importance of carefully designed control systems.
- For pre-heating scenario, ~3.2 tonnes CO^2 reduction if previous gas heated, ~4.5 tonnes CO^2 reduction if electrically heated previously.

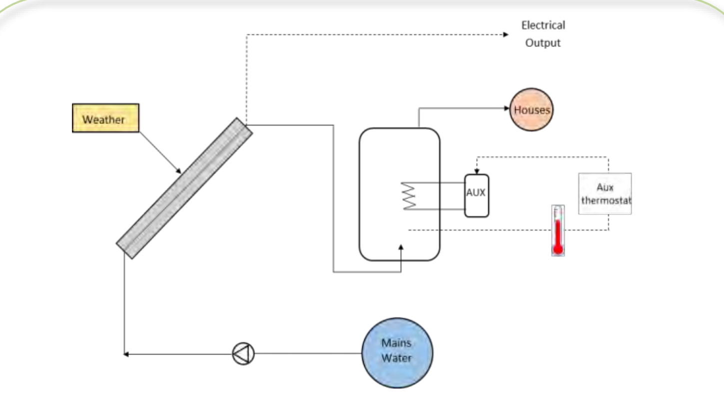


Figure 2: Pre-heating configuration

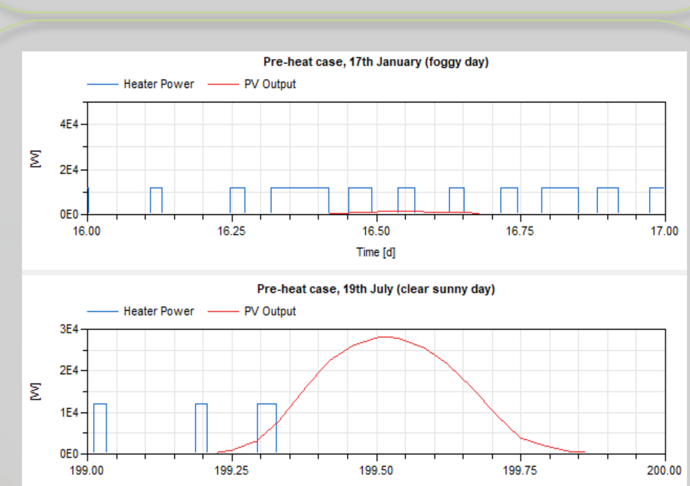


Figure 3: Foggy and sunny day

Future Work

- Low and high rise buildings, groups of rows of terraced houses.
- Implement heat zoning and co-simulation methods.
- GSHP's and PVT potential for space heating.
- Phase change materials potential with PVT in urban scenarios.

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David Kenington

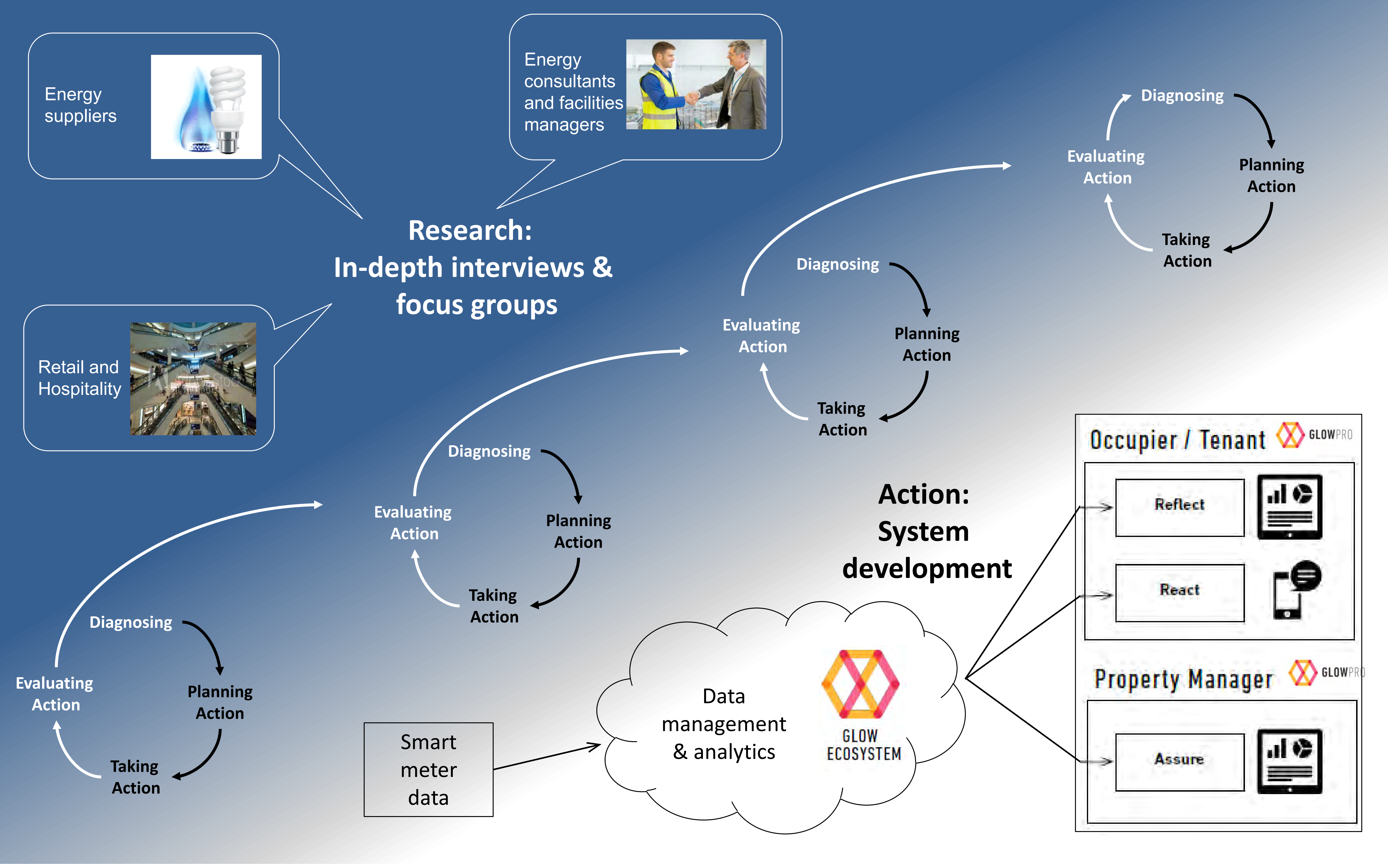
Innovating with smart meters to improve energy management in retail and hospitality

The UK has committed to roll-out smart meters to all smaller businesses by 2020. It is envisaged that by providing them with accurate, near real-time energy use information will help improve energy management, leading to improvements in efficiency and other benefits. To kick-start innovation in energy management using smart meter data, UK Government is funding the **Non-Domestic Smart Energy Management Innovation Competition** (NDSEMIC).

GLOWPRO

This project partners with one of the Competition winners, **Hildebrand Technology** Ltd. Hildebrand's **GlowPro** project is developing an easy to use (across a range of user roles) digital ecosystem for energy management that will engage and support **retailers** and **restaurants** (independents and chains) within shopping centres and high streets, delivering a **positive impact on energy efficiency, energy procurement and operational management**.

Using cycles of action research to develop successful energy management tools



Key outputs will be a platform/ecosystem, property manager web application, business manager energy management application, a mobile application for front line managers, research reports evaluating what is working, a thermal model of non-domestic premises and four test interventions around lighting, heating, cooling and refrigeration.

We will be using an **action research** approach to help deliver successful tools and achieve the competition's aims. By using action research cycles the project, aims to build innovations which are attractive to customers, improve energy efficiency and deliver other benefits.

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An open solid fuel fire (2304

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ANNUAL COLLOQUIUM 2018

Observational evidence for the variation in experienced temperature

Harry Kennard 3rd year doctoral researcher in PACE research group

Supervisors: Prof. David Shipworth. Dr. Gesche Huebner

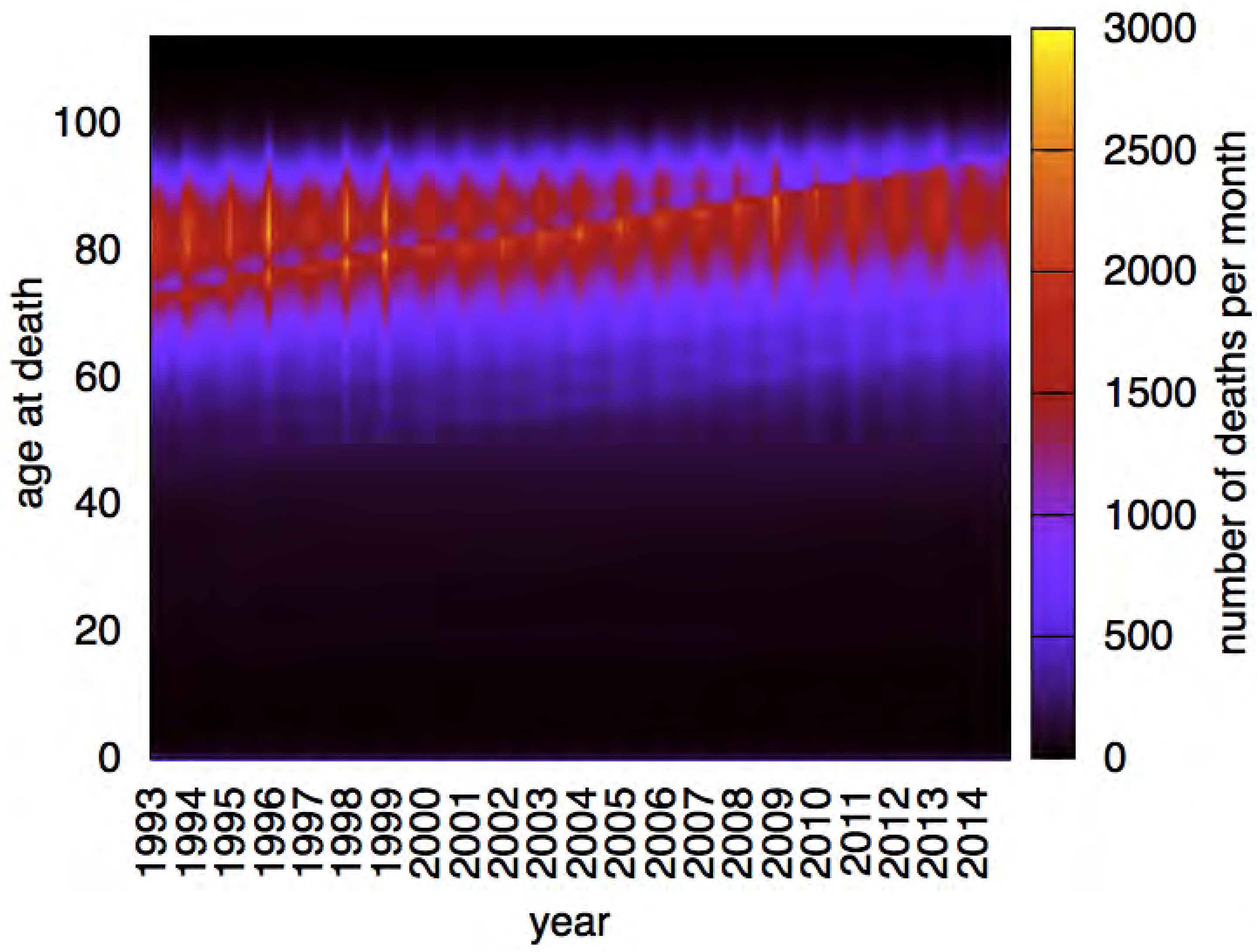

Fig 1. Number of a deaths each month in England and Wales as a function of age. Seasonal variation is evident.

Background

- Domestic ambient temperature demand strongly influences energy demand.
- Seasonal variation in mortality and morbidity has been linked to cold ambient temperature (see fig 1).
- Exact way in which people are exposed to cold is unclear – necessitating the concept of 'experienced temperature'.
- This study uses data set from the UK Biobank of 100 thousand adults age 40-80, who wore a wristband temperature/activity monitor for a week.

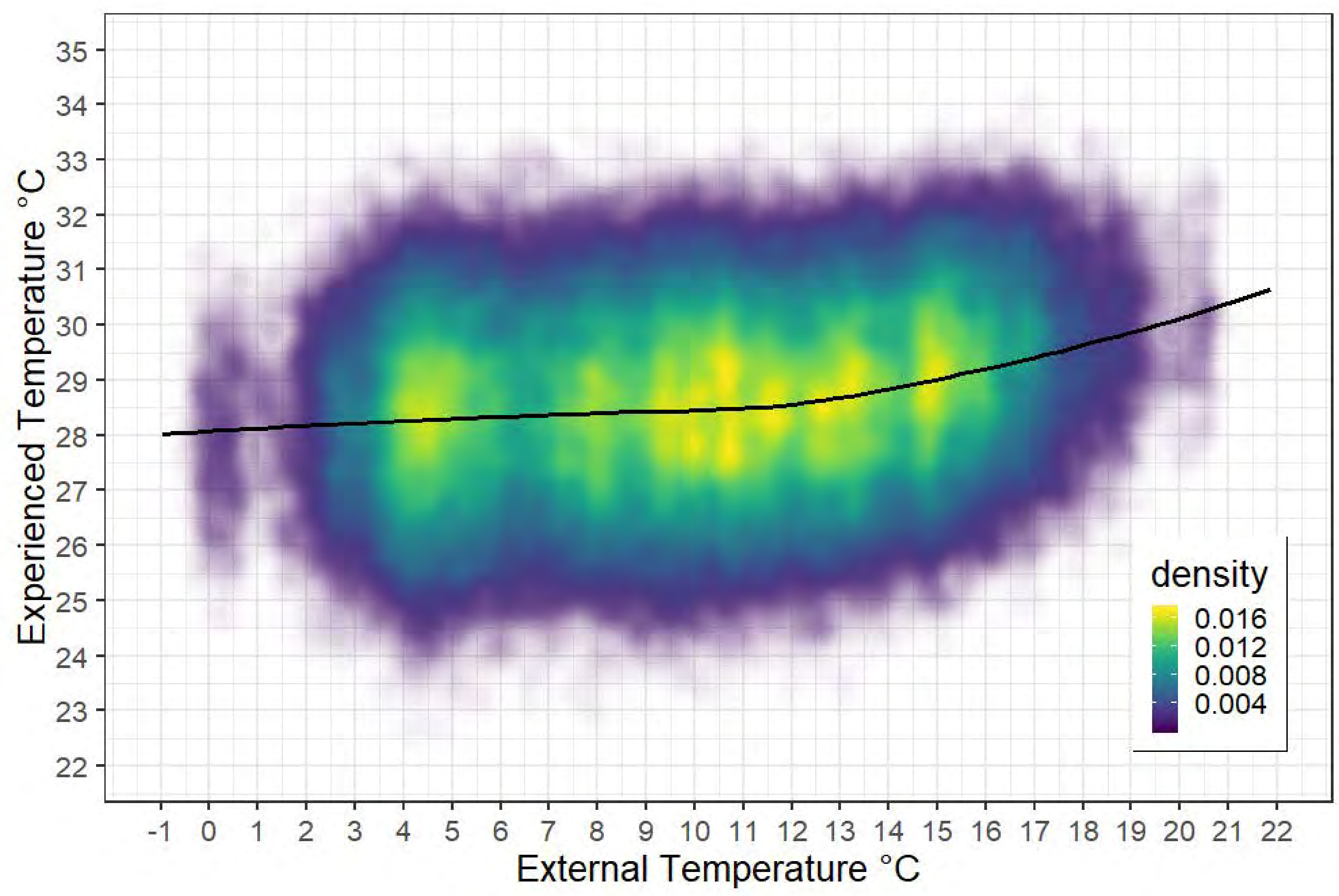

Fig 2. The relationship between external and experienced temperature for sedentary individuals. 77,794 participants data visualised as a density plot. LOESS smoothed trend line shown in black.

Experienced Temperature

- Measured using wrist worn monitors.
- Demonstrated to be a mixture of ambient temperature and heat from the wrist.
- Associations with external temperature help understand the extent to which winter is experienced in the UK (see fig 2).
- Demographic and housing type differences help identify at-risk groups.

Results of multiple linear regression (p<1%)

- Coldest days are experienced as approximately 1.8°C lower than warmest days, on average.
- Experienced temperature of those living in flats is significantly warmer than those in houses/bungalows (0.10°C)
- Slight increase (0.02°C/year old) as a function of age.
- Experienced temperature of those who use open solid-fuel fires for heating were 0.15°C colder than those who did not.

Next step…

- Model the associations between experienced temperature and health outcomes.

biobank uk
Improving the health of future generations

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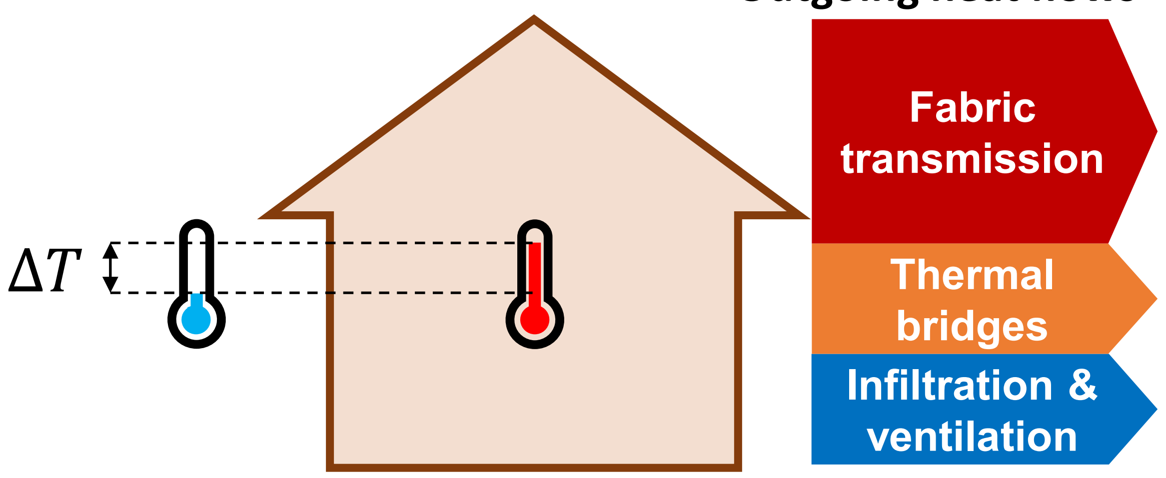
ANNUAL COLLOQUIUM 2018

Measuring whole building thermal performance in occupied homes

Matthew Li (1^{st} Year PhD) **Supervisors** Dr David Allinson, Prof Kevin Lomas

@LoLoMattL

The heat transfer coefficient (HTC)



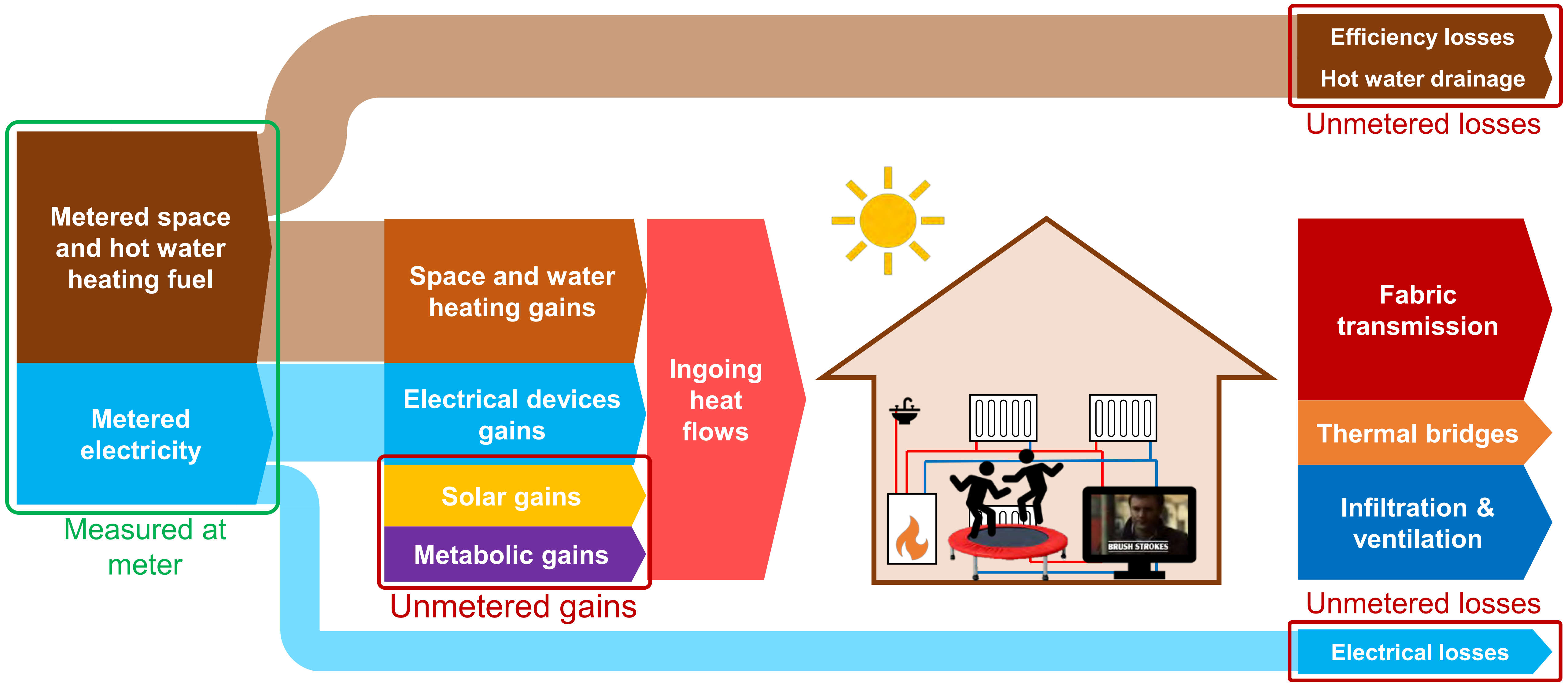
$$\text{HTC} = \frac{\text{total outgoing heat flow rate (Watts)}}{\text{indoor-outdoor temperature difference (Kelvin)}}$$

Research questions

- What are the uncertainties associated with evaluating building thermal performance using in-situ monitored data?
- Which methods are suitable for individual building types? When are steady-state approaches sufficient, and when are dynamic analyses necessary (or otherwise beneficial)?
- What is the potential value of smart-meter-like data for evaluating the thermal performance of the UK domestic stock?

Measuring heat flows in occupied dwellings: a steady state approach

- Assuming a steady state heat balance, measured ingoing heat flows may be equated to the outgoing heat flows.
- While gas and electricity are metered, it is necessary to account for unmetered gains (solar and metabolic) and unmetered losses (boiler efficiency, hot water drainage, electrical losses).



Relative magnitudes of individual heat flows will vary between building typologies and boundary conditions

PhD research project outline

1. Establish a theoretical physical framework for assessing building thermal performance.
2. Identify existing methods for measuring building thermal performance.
3. Evaluate uncertainties in a selection of steady-state and dynamic thermal performance calculation methods, using data representing a variety of building typologies and boundary conditions.
4. Apply appropriate methods (as identified in 3) to data from a sample of UK homes, and explore applicability from various stakeholder perspectives.

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ANNUAL COLLOQUIUM 2018

How hot is too hot? Overheating in student accommodation

Anthony Marsh - UCL PhD Student

London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

Background

Overheating can affect the health and wellbeing of occupants, particularly if sleep is degraded. New student accommodation buildings contain a number of design characteristics that can make them particularly susceptible.

Research Questions

- Do new student accommodation provide comfortable conditions all year round?
- How do students adapt the environment to suit their thermal requirements, and is it effective?

Data Collection

Technical Data

1. IEQ conditions

- Internal temperature (in 3 locations)
- Relative humidity
- Carbon dioxide

2. Occupant Control

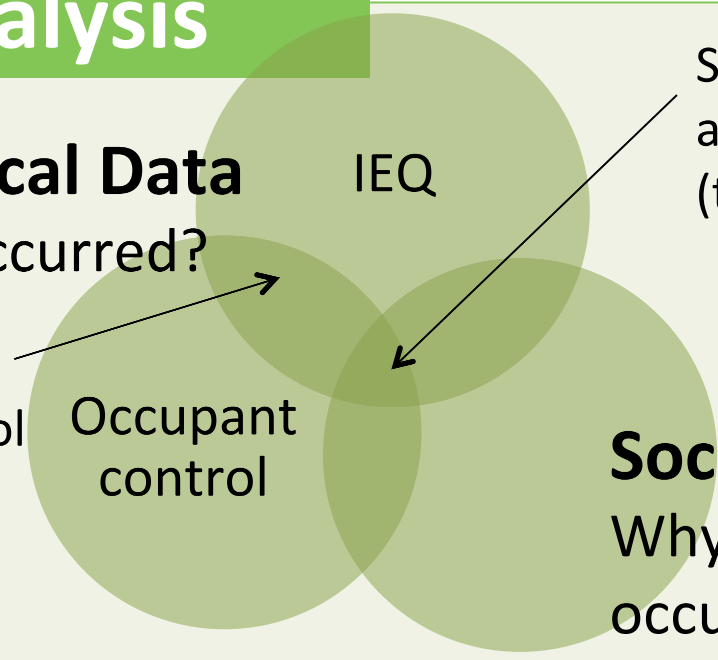
- Window opening
- Heating
- Blind control (lux)

Social Data

1. Semi-structured interviews in winter and summer
2. Building survey for all residents
3. FM interviews (post initial analysis)

Data Analysis

Technical Data
What occurred?



Social & technical analysis (triangulation)

Analysis of how occupant control influences IEQ conditions & vice versa

Social Data
Why it may have occurred?

Overheating Analysis

Technical

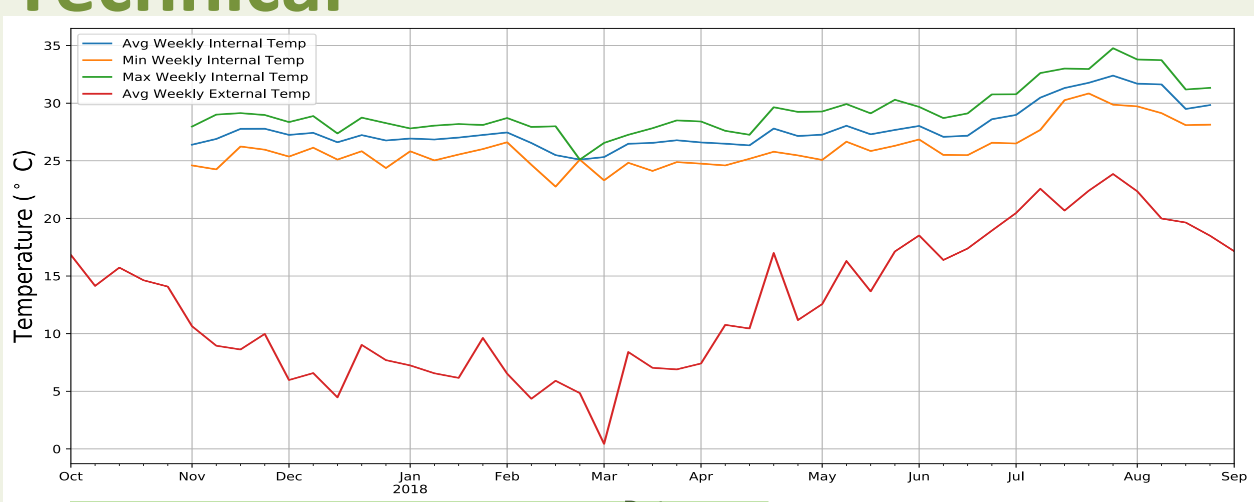


Fig 1: Average weekly temperature profile

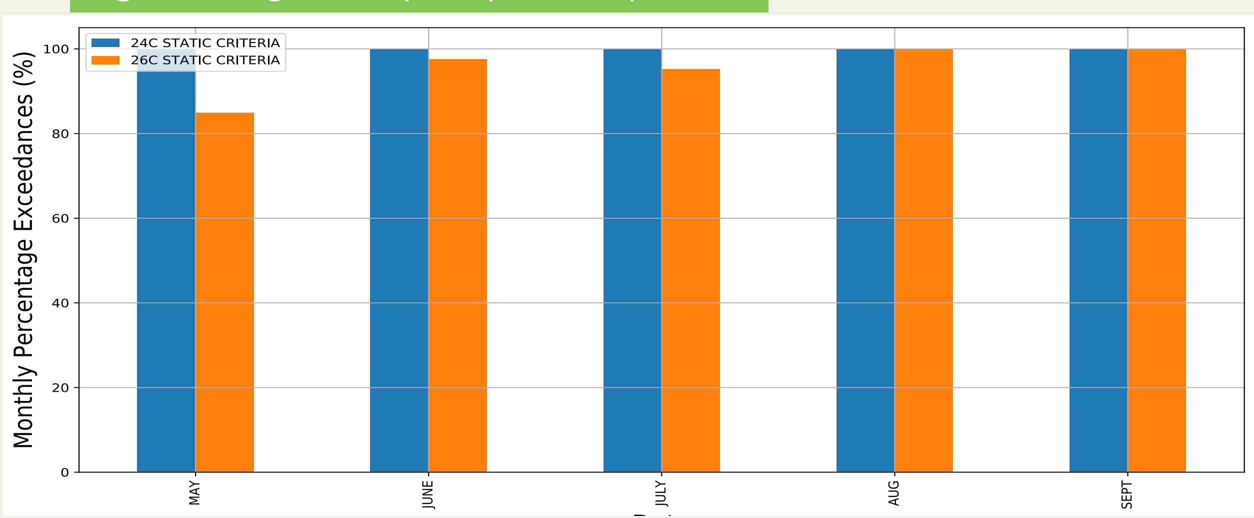


Fig 2: CIBSE Guide A static overheating criteria

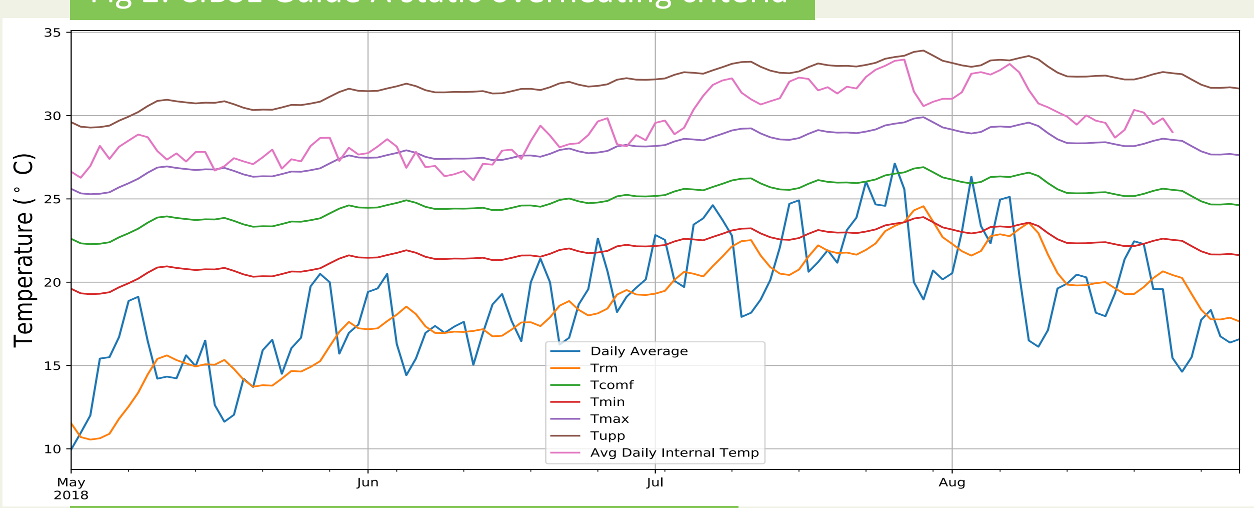


Fig 3: TM52 adaptive overheating criteria

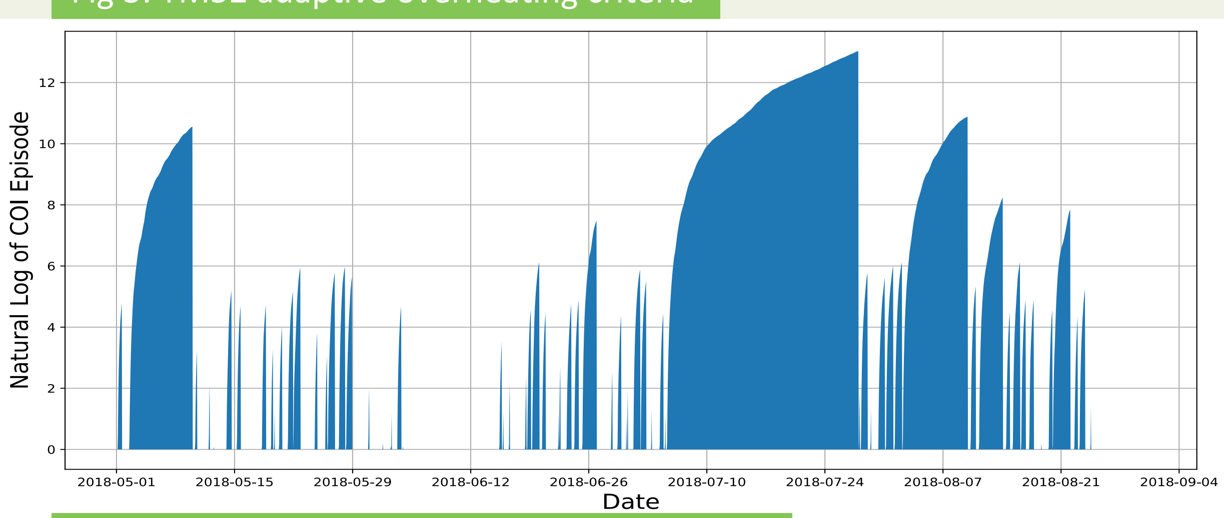


Fig 4: Continuously Overheated Intervals (COI)

Social

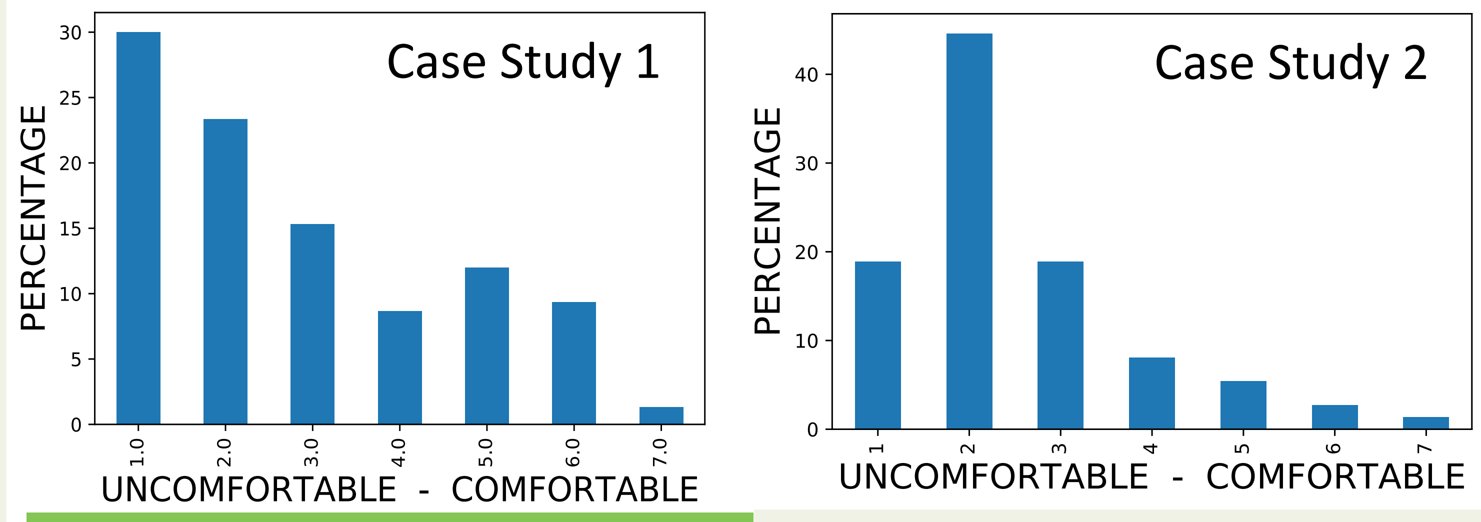


Fig 4: Building surveys summer comfort plots

"WAY too hot in the summer, during heatwave there was no air flow, even with the window open was way too hot. Felt sick from the heat."

"There is no air coming through in the summer when the weather is really hot and the windows are quite small meaning that not much air can get in"

"Unbearably uncomfortable "

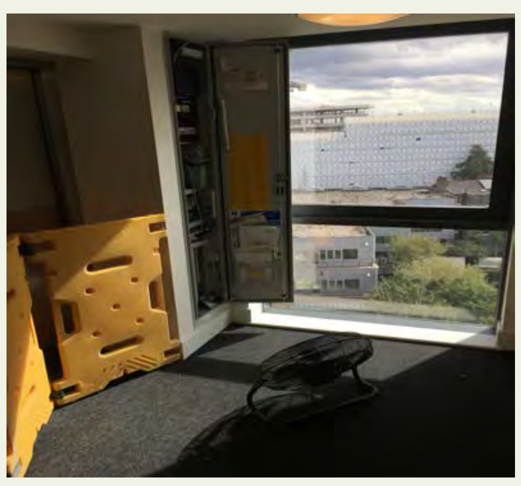
"The rooms are unbelievably hot and the windows can only be opened a fraction of an amount."

"The corridors are hell. If I didn't have a fan and air purifier this place would have been awful. Windows barely open, after a couple of minutes in the bathroom it becomes unbearable."

Fig 5: Selection of comments on summer conditions

Key Findings

Over 80% of bedrooms monitored in two student accommodation developments failed all the empirical tests for overheating. Why? Poor ventilation, poor solar shading, and high internal gains. Many participants reported finding their rooms to be "unusable" in warmer weather, which they judged to have negatively impacted on their studies.



Electric lift equipment breaks down due to heat

Fully glazed south & west facing stairway exceeded 40°C

Participant attempts to increase ventilation

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ANNUAL COLLOQUIUM 2018

Heat Pump DSR Potential for Imbalance Payment Mitigation

Email me @:
nathan.moriarty.10@ucl.ac.uk

Nathan Moriarty 1st yr PhD
MRes Supervisors: Andrew Smith and Jenny Love

We investigated revenue potential (£) and shift patterns (kW) for time-of-use optimisation DSR considering heat pumps and system price.

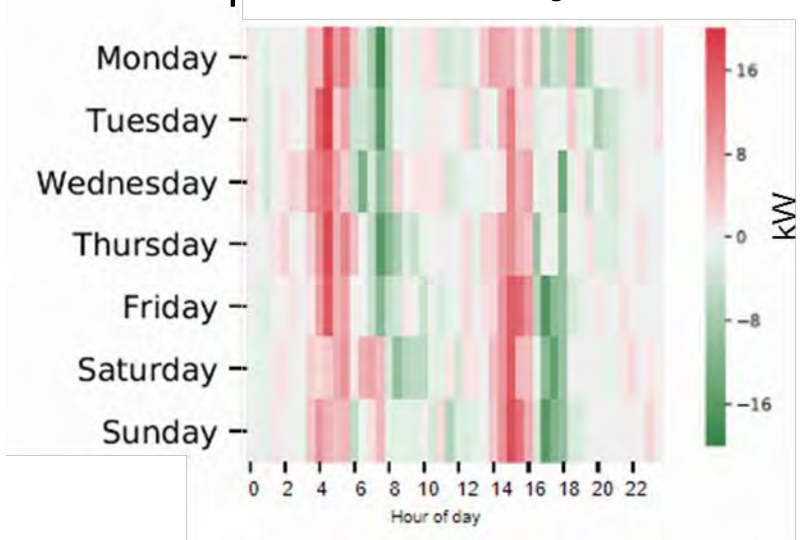
Key Findings

- **Three hours flexibility enough for 30 minutes of Heat Pump Demand**
- Low Revenue for two 30 minute DSR events a day (<£5 over Nov-Feb per site)
- **Significant flexibility of (+20, -20) kWe per 100 appliances against baseline**
- There was little benefit from up-sizing a Heat Pump / use of BESS for flexibility.

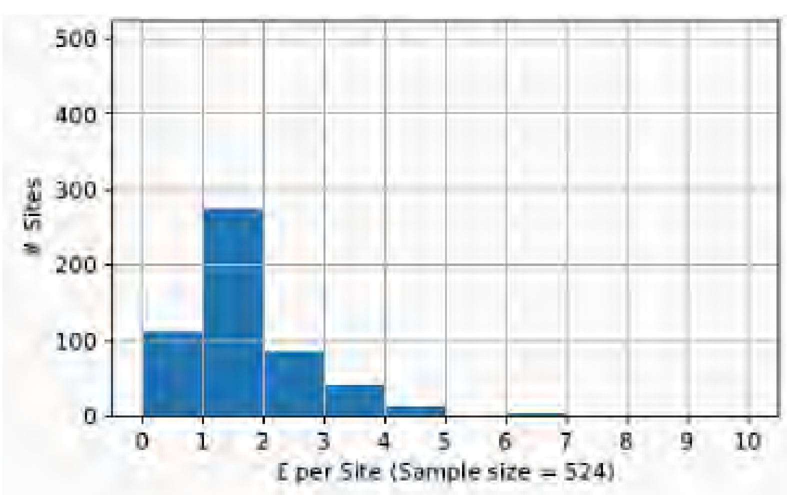
Results

- **Effect on Baseline Consumption (kW and £)**

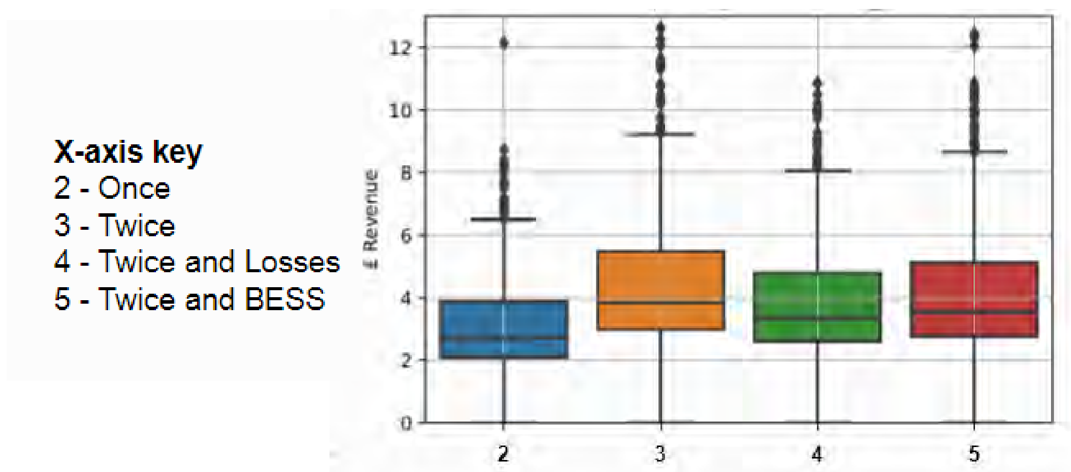
Power Shift per 100 sites Algorithm 4 – Cold Months 2014 (Nov-Feb)



Revenue per Site Algorithm 4 – Cold Months 2014 (Nov-Feb)



Revenue Sensitivity per Algorithm Cold Months 2014 (Nov-Feb)

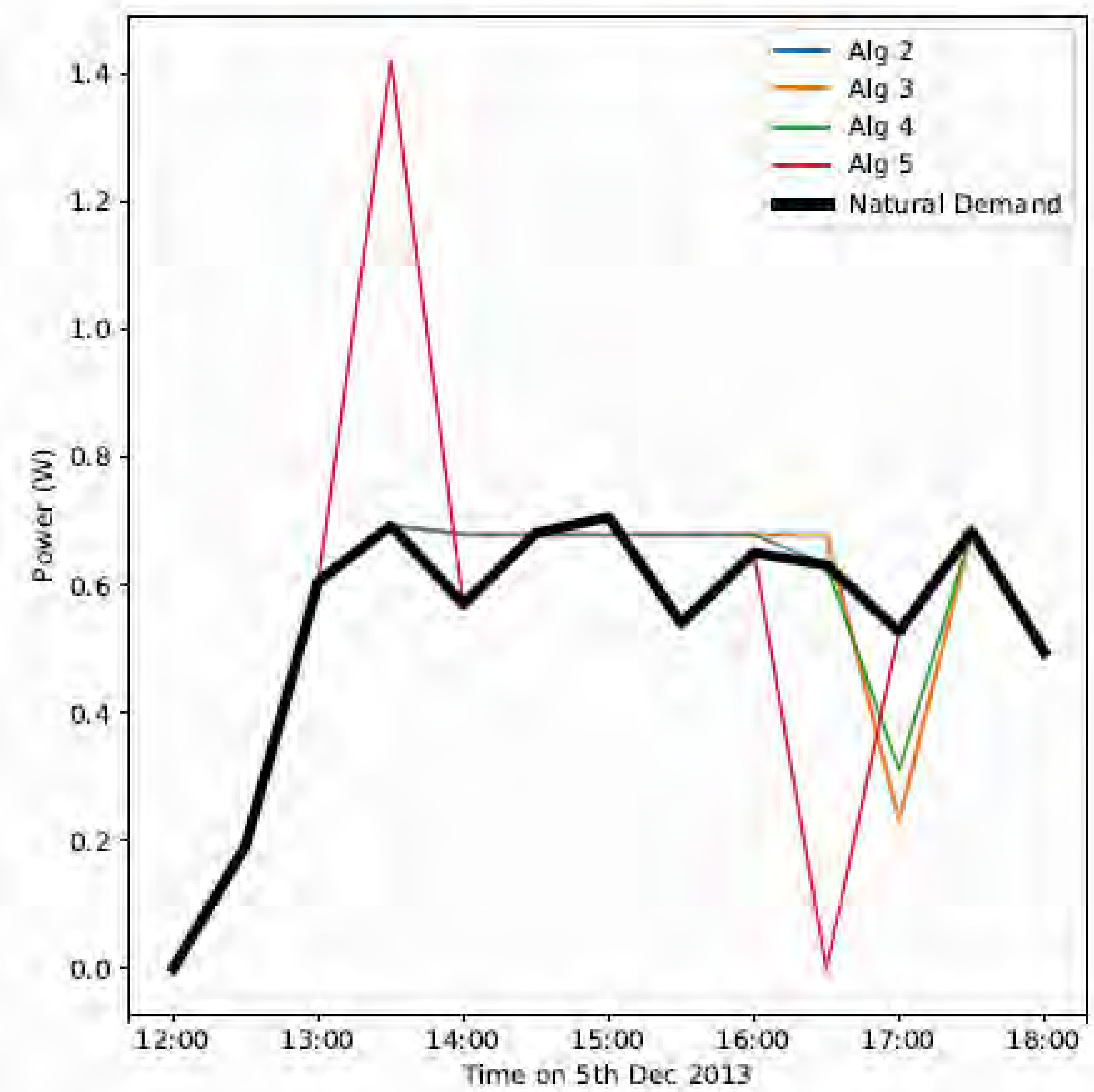


Method

Five algorithms implemented to investigate four sensitivities

- Time Window Flexibility (1-9) hours
- Frequency per day
- Storage Losses and Price Elasticity
- Upsizing Heat Pump

Algorithms "in action" for single site



(RHPP Dataset)

Further Work

We did not consider:

- Forecasting
- Future Electricity Prices
- Effect of Crowding
- Diffusion of Market Interventions
- Lower Security of Supply
- Consumer Reaction

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ANNUAL COLLOQUIUM 2018

Perceptions of Thermal Comfort in an Office During a Heatwave

1st Year PhD Pilot Study by Luke Taft, UCL Energy Institute

Primary Supervision: Michelle Shipworth

Secondary Supervision: Dr. Hannah Knox

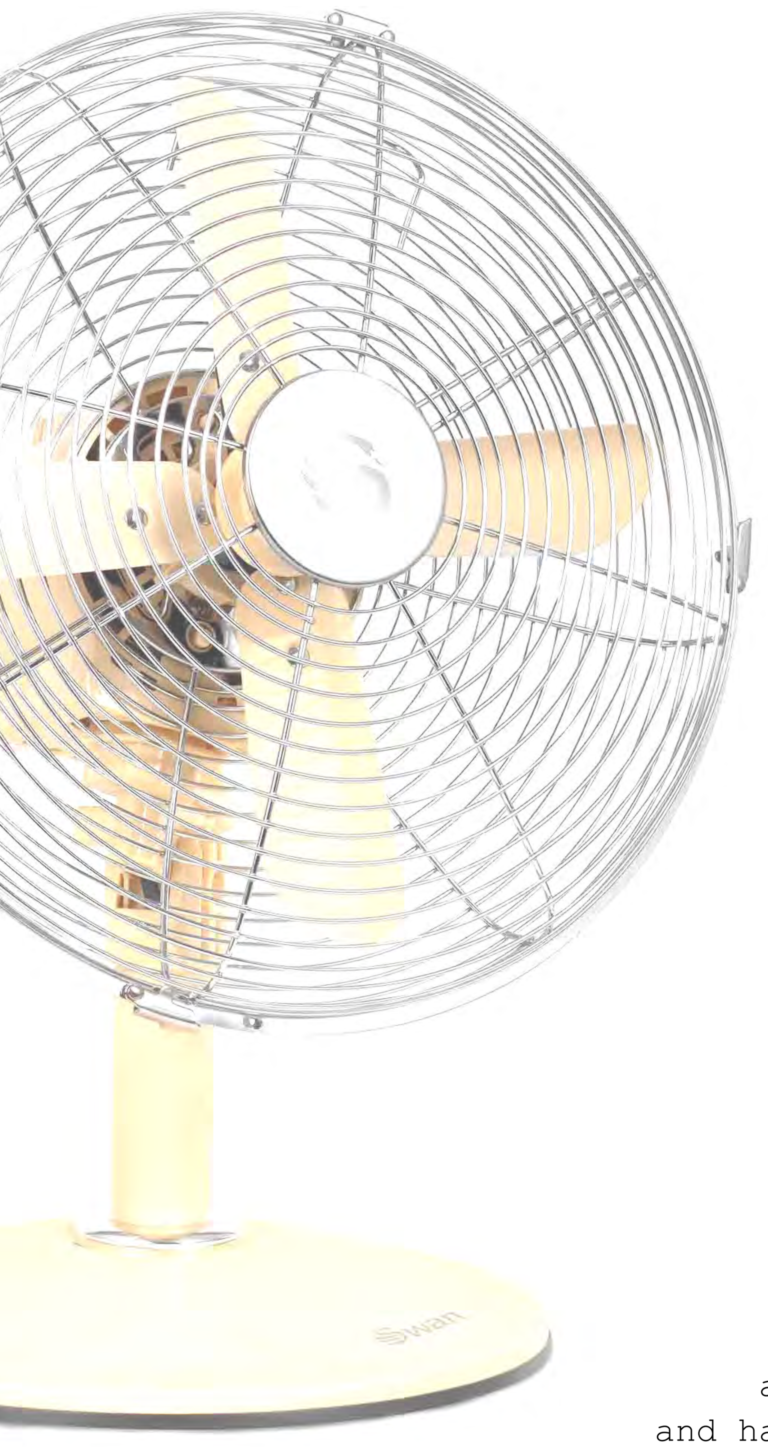
Background

1) ***70%*** of the total energy supplied to a non-domestic building is used in cooling and ***19%*** of GHGs are attributable to the '*built environment*'. Field studies have shown that ***75%*** of these buildings may be *missing current thermal comfort targets*

2) Within the literature on thermal comfort there is a tendency to explain comfort outside of specified ranges as on account of various '*cultural factors*'

3) Comfort is often taken as an implicit requirement based on what may be an incomplete and insufficient understanding of how to achieve it

This project is the first step in a larger project to explore *potential future comfort [re]configurations*



Method

During the *Summer 2018 UK heatwave* a London office was observed for a total of 9 days stretching over a three week period

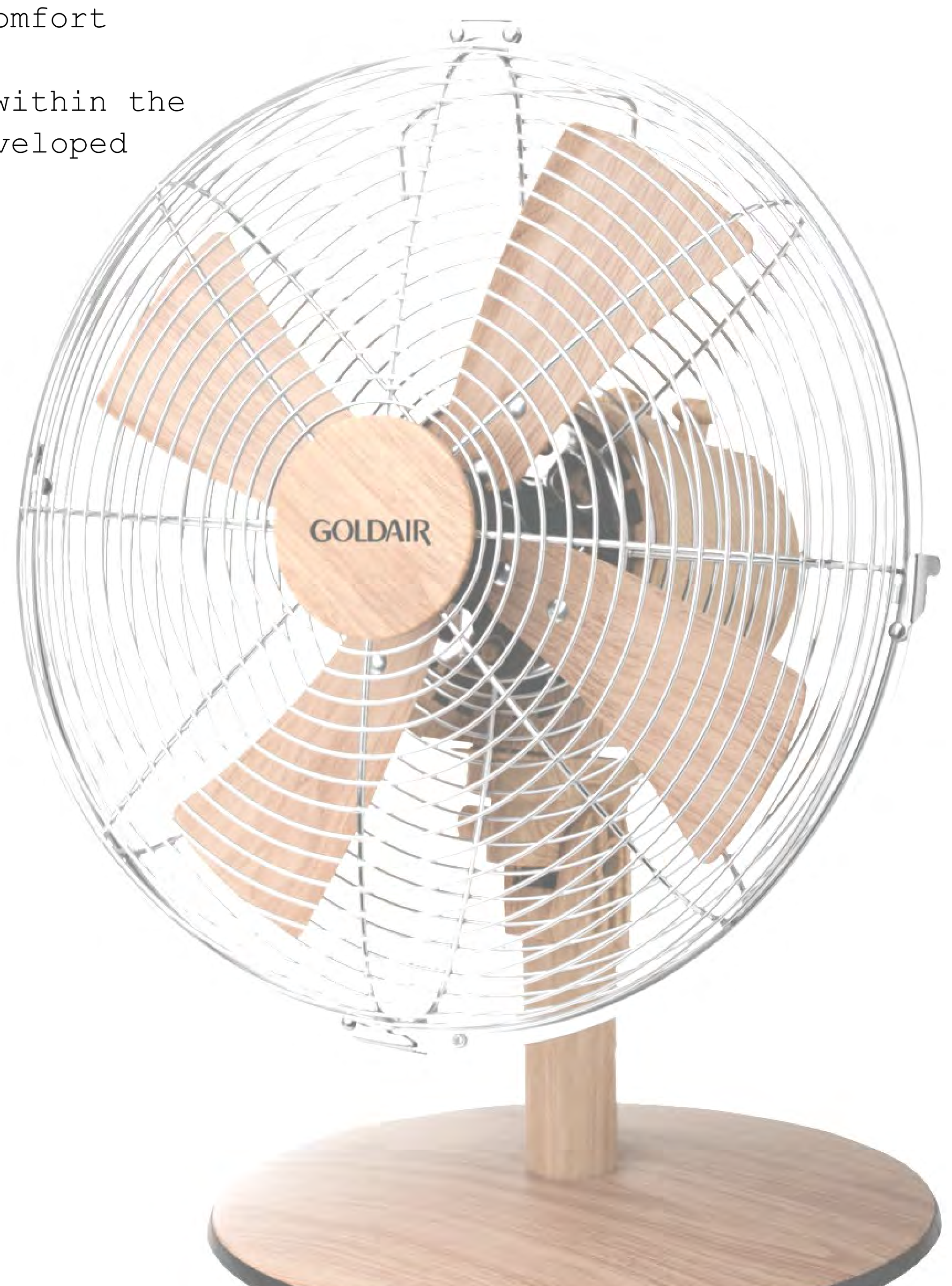
As a process of '*surfacing the mundane*' ethnography was employed so as to allow an inside view of these often taken-for-granted aspects of comfort

This research is largely situated within the '*Sensory Ethnography*' approach developed by Sarah Pink

Theory

Current thermal comfort models are based within cognitive psychology and have, to date, continued along the lines of the study of the parameters of '*indoor climate*'. These models are then further based on body and mind as separate entities with the mind subject to culture and body subject to nature

An alternate perspective is that both entities are embodied within the same perceiver. It may also be important to demarcate the difference between 'climate' and 'weather', where *climate* is that which is *enumerated* and *abstracted* and *weather* is that which is *experienced*



Emergent Themes

Team Hot & Team Cold: Quiet Conflicts

Participants often identified as either '*hot*' or '*cold*' people with '*thermal teams*' emerging thereafter. People and teams interacted through different understandings of the processes of local set-point control creating intra and inter *thermal team tensions*

'..we have team hot and team cold...someone explained it to me, and from that point I was aware of it...if it [HVAC System] ***adapted back to the hotter weather, we wouldn't be thought as the culprits of the hot office'***

'...it was really funny, there is a sort of quiet conflict between us [the research participant and the office manager/team cold member]***'***

'I think it's unfair to make someone hotter cos there's very little they can do about it...you're never going to please those people are you, so you've got to go with the lower temperature and say "you've got to wear a cardigan"'

At no point during this research did members of team cold articulate the '*you've got to wear shorts/sandals*' reverse of the final quote above. The first quote also summarises the view of technology as participating in the conflict

Close Air and Distance Science: Inner Confusions

This is the tension between subjective perceptions and objective expectations of cooling with participants associating cooling with a decreasing room temperature. Despite delivering respite a portable fan was deemed insufficient as it failed to decrease the room temperature

'..I don't really get the benefit of that [a medium sized floor-standing fan located in the middle of the office]***, but it is a lot cooler'***, then later, ***'cos moving air around doesn't really cool the room down, it just...gives you the perception of coolness..'***

'..a fan is just, changing the, you know, same temperature, so if they really want it to be cooler, then they should go downstairs and do the A/C..'

'..They say that that doesn't really cool you, it's just blowing the, but it does make you feel, even if it isn't, feel cooler..'

Within the final quote the '*they*' was undefined but represents a distant scientific voice that runs counter to the participant's experience of her own environment

Implications

Thermal Comfort is not as individualistic as currently understood - but exists within a *deeper web of social relations*

'*Overcooling*' may partly result from office social relations - opening up alternative approaches to increasing comfort and reducing energy demand

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Natural Ventilation Effectiveness in Single and Multi-Storey Residential Buildings

Murat Mustafa 1st year PhD student

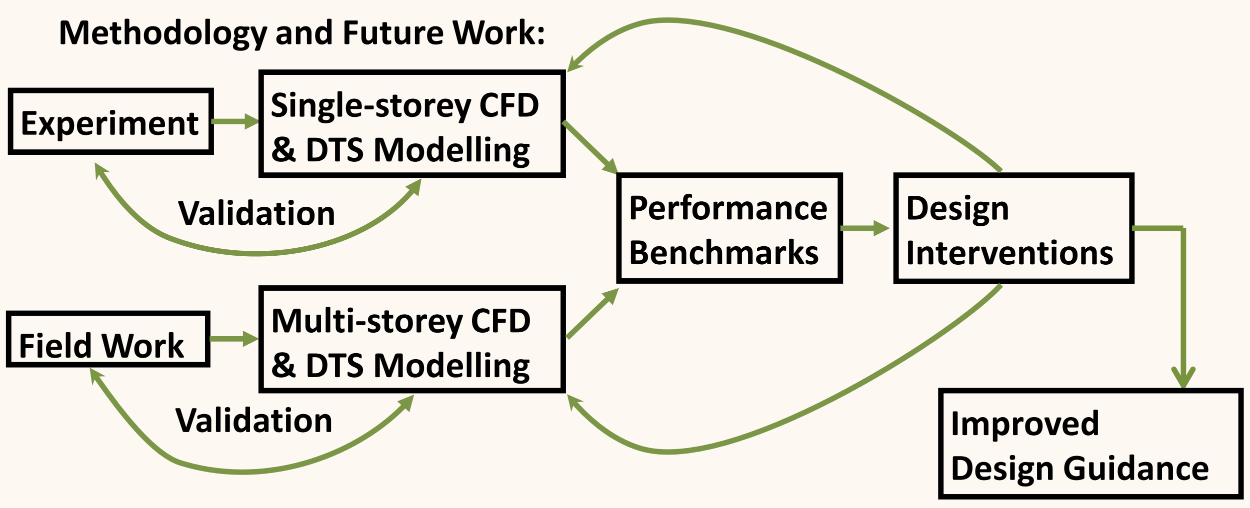
Background: Air-conditioned (AC) buildings have been historically associated with insufficient indoor air quality (IAQ), poor thermal comfort, and energy inefficiency (Finnegan et al., 1984; Burge et al., 1987); whilst conversely, naturally ventilated (NV) buildings have been widely associated with the provision of good IAQ, enhancement of thermal adaptation possibilities for occupants and energy efficiency (De Dear et al., 1991; Cook et al., 1999). It is expected that the impacts of the climate change and the urban heat island (UHI) effect, coupled with rising thermal comfort expectations, are likely to increase the proliferation of AC buildings further which could result in more frequent power failures and subsequent mortalities (Changnon et al., 1996; Sailor, 2014). To date, much of the work on indoor environmental ventilation design has concentrated on defining a definitive relationship between minimum acceptable supply air flow rates and occupant health, productivity, well-being and thermal comfort. However, the confounding factors and a lack of evidence-based results have led to international guidelines and researches advocating a wide range of minimum fresh air flow rates (ranging from 6l/s p to 50l/s p) (Burge et al., 1987; Godish & Spengler 1996; Carrer et al., 2015). As a design criterion, the use of a minimum supply air requirement becomes an ineffective and uncertain target because of these conflicting suggestions. It is proposed instead that, ventilation effectiveness (VE) could be considered as a more objective method of assessing the performance of a ventilation system. VE is a measure of the ability of a ventilation system to remove contaminants or heat from the domain (Mundt et al., 2004). It is postulated that providing a highly efficient NV system based on the use of an appropriate VE metric will result in clearer guidance and a more robust trade-off between good IAQ and energy efficiency.

The research Problem: Earlier researches in the ventilation effectiveness field mostly concentrated on mechanical ventilation (MV) systems and studies focusing on NV performance are very limited. Furthermore, commonly used performance metrics in NV performance assessment studies were unable to quantify the local ventilation performance of a NV system in terms of the provision of the IAQ and the effective removal of heat from the occupied region. It is hypothesised that the quantification of NV ventilation effectiveness with relevant metrics is an essential requirement to advance the understanding of NV systems. Moreover, the quantification of NV ventilation effectiveness with relevant metrics will allow a direct performance comparison between the efficacy of different NV and MV solutions. A key outcome of this work will be to contribute to more effective NV system design principles based on evaluating different ventilation solutions in accordance with quantified VE values.

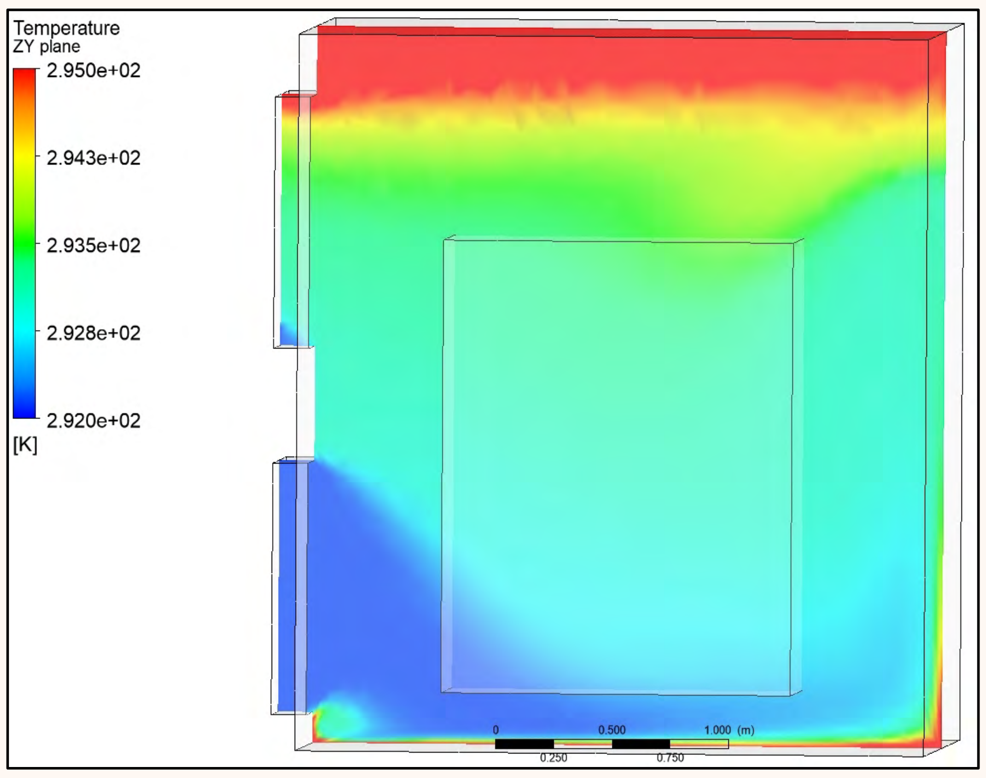
Aims of the Project:

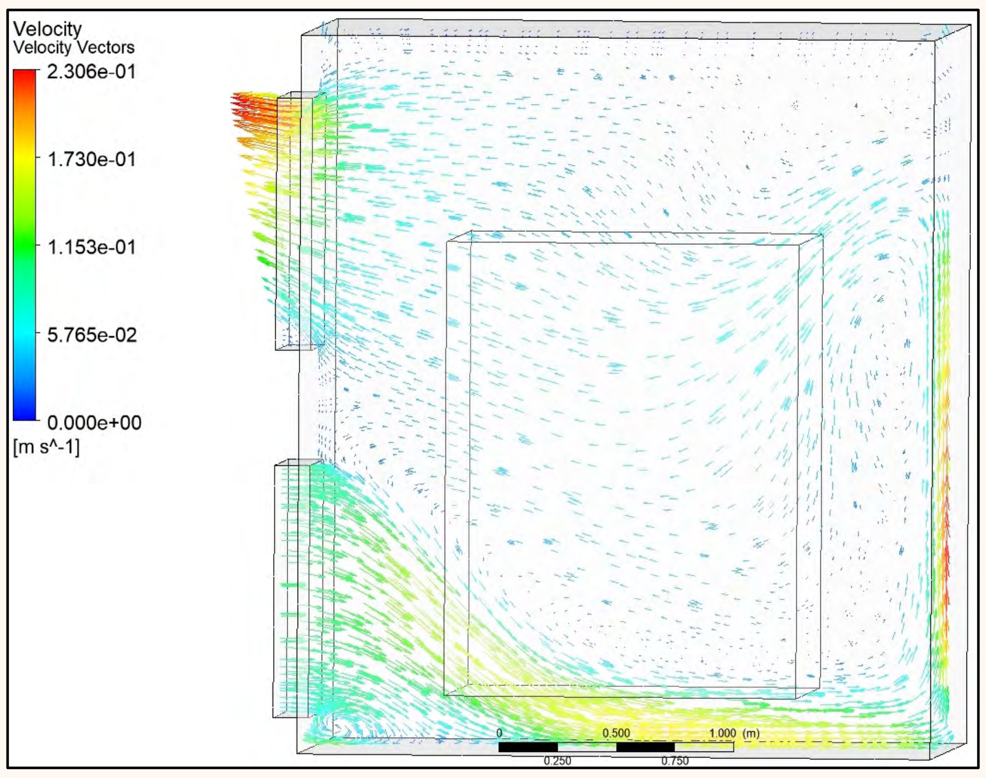
- **Aim:** The aim of this research is to propose new year-round ventilation effectiveness (VE) values for naturally ventilated domestic buildings, based on achieving a robust trade-off between IAQ and energy efficiency.

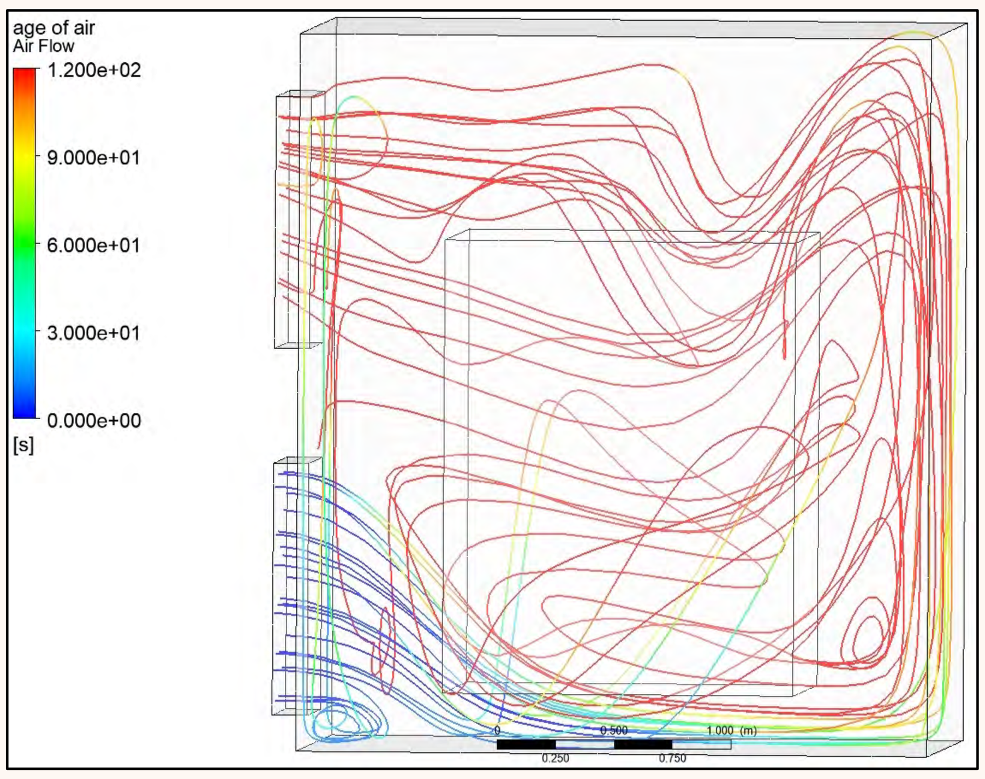
Methodology and Future Work:



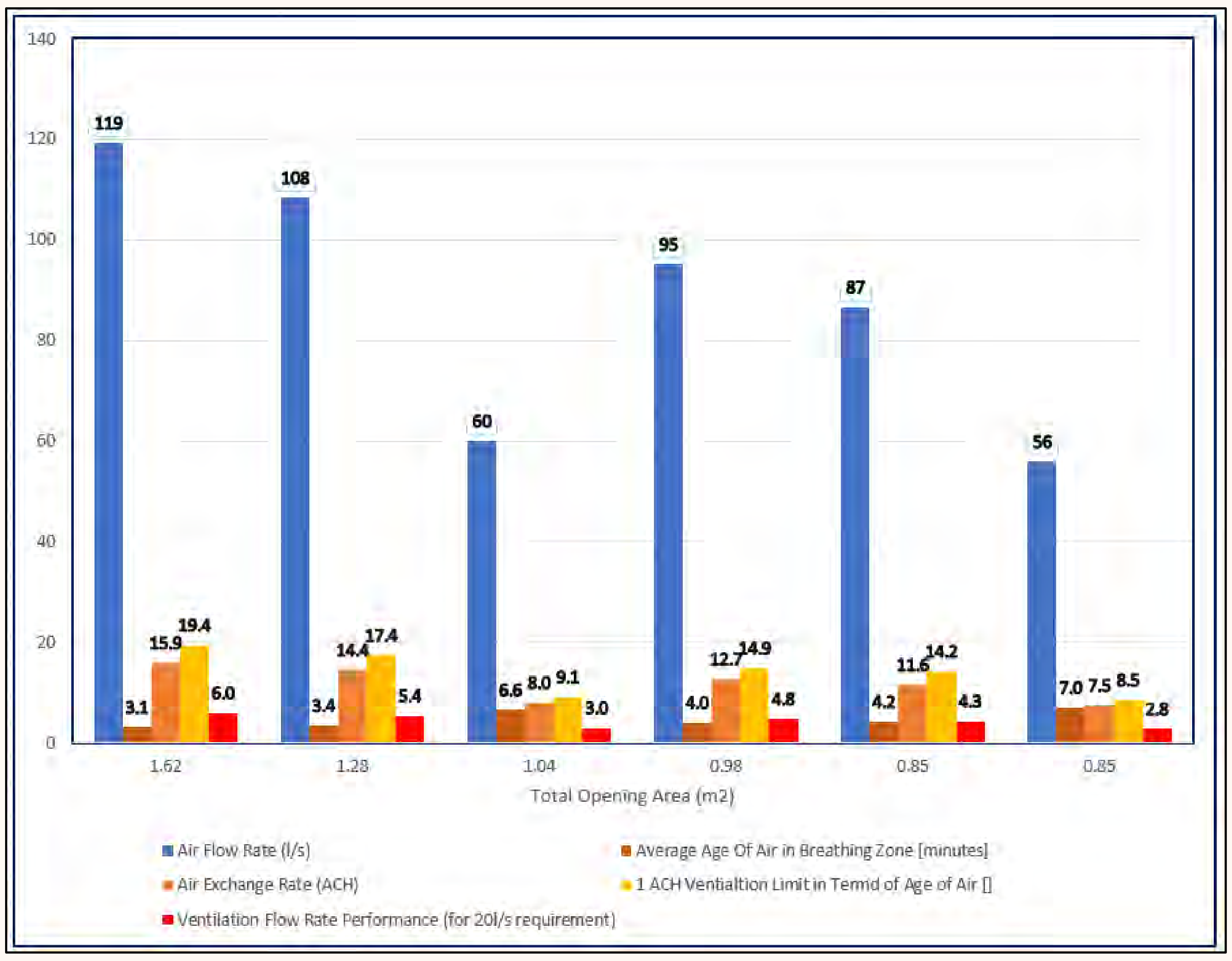
Preliminary Model:







There is no significant short-circuit airflow from inlet to outlet as it can be seen from air flow models. This is further confirmed by quantitative results from the graph. Please note that similarity of ACH performance values (pink bar) to the age of air performance values (yellow bar). The theory says, if the air is well mixed within a domain (no short-circuit between an inlet and outlet), ACH performance metric will give the same result with age of air performance metric. However, in reality, the air within a domain is rarely well mixed. Thus, local performance metrics are necessary. As expected, energy loss from the domain and ventilation rates are positively corelated. However, even by employing the smallest opening (0.82m²), the IAQ performance is 2.8 to 8.5 times higher than minimum requirement while heat loss kept at minimum.



References:

Finnegan, M.J., Pickering, C.A. and Burge, P.S., 1984. The sick building syndrome: prevalence studies. *Br Med J (Clin Res Ed)*, *289*(6458), pp.1573-1575.

Burge, S., Hedge, A., Wilson, S., Bass, J.H. and ROBERTSON, A., 1987. Sick building syndrome: a study of 4373 office workers. The Annals of occupational hygiene, 31(4A), pp.493-504.

De Dear, R.J., Leow, K.G. and Foo, S.C., 1991. Thermal comfort in the humid tropics: Field experiments in air conditioned and naturally ventilated buildings in Singapore. International Journal of Biometeorology, 34(4), pp.259-265.

Cook, M.J., Lomas, K.J. and Eppel, H., 1999. Use of computer simulation in the design of a naturally ventilated library. In Proceedings of the PLEA (Vol. 99, pp. 597-602).

Changnon, S.A., Kunkel, K.E. and Reinke, B.C., 1996. Impacts and responses to the 1995 heat wave: A call to action. Bulletin of the American Meteorological society, 77(7), pp.1497-1506.

Sailor, D.J., 2014. Risks of summertime extreme thermal conditions in buildings as a result of climate change and exacerbation of urban heat islands. *Building and Environment*, *78*, pp.81-88.

Godish, T. and Spengler, J.D., 1996. Relationships between ventilation and indoor air quality: a review. *Indoor Air*, *6*(2), pp.135-145.

Carrer, P., Wargocki, P., Fanetti, A., Bischof, W., Fernandes, E.D.O., Hartmann, T., Kephalopoulos, S., Palkonen, S. and Seppänen, O., 2015. What does the scientific literature tell us about the ventilation–health relationship in public and residential buildings?. *Building and Environment*, *94*, pp.273-286.

Mundt, M., Mathisen, H.M., Moser, M. and Nielsen, P.V., 2004. Ventilation Effectiveness: Rehva Guidebooks.

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Modelling assumptions and how they impact overheating compliance.

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Introduction

- The summer of 2018 was the warmest recorded in England [1].
- Higher summer ambient temperatures can **drive thermal discomfort**, impacting the occupants **health** and **wellbeing**.
- **Building Performance Simulation (BPS) tools** can be used to predict indoor temperatures and assess the risk of indoor overheating.
- **Technical Memorandum 59 (TM59),** released by CIBSE, aims at providing a common procedure for predicting the overheating risk at the design stage [2].

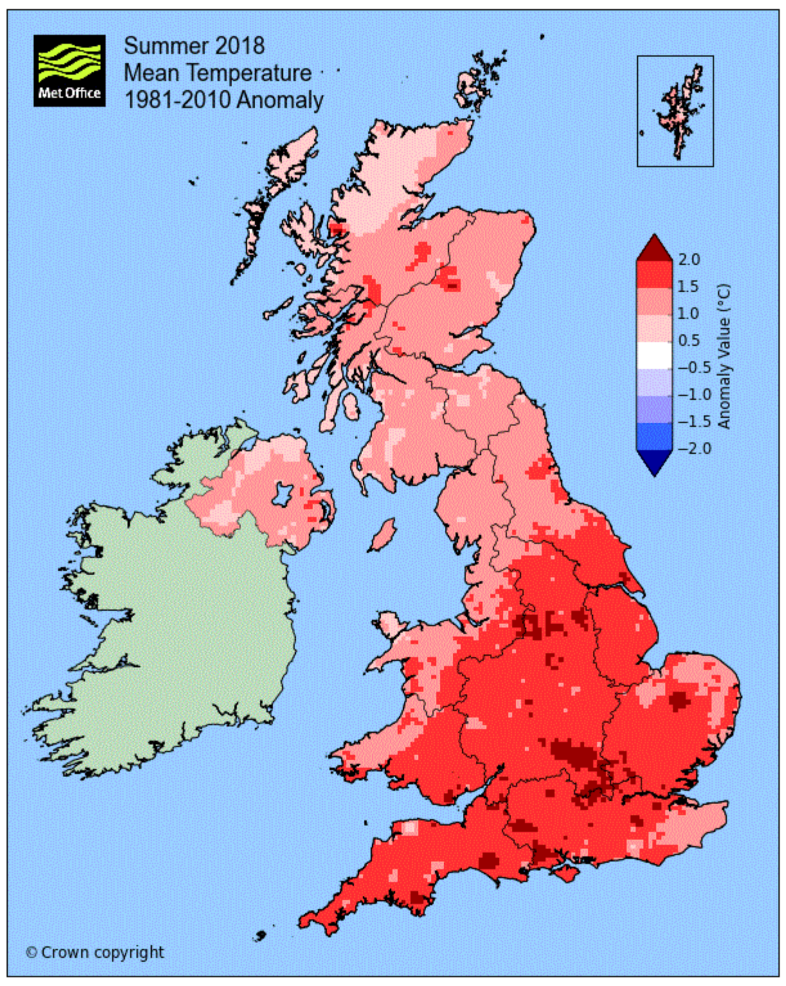

Figure 1: *Mean temperature anomaly [1].*

Motivation

- BPS tools are based on **approximations** of physical laws.
- TM59 does not specify a tool or algorithms.
- Choice of algorithms/tool might not be informed.
- Default algorithms are commonly used.

Table 1: *Algorithms assessed.*

	No. of options	
Process	**Tool A**	**Tool B**
Conduction	2	1
F.D. Discretisation	2	1
Exterior Convection	5	2
Interior Convection	4	4
Ext. Longwave Radiation	1	2
Int. Air Emissivity	1	2
Solar Rad. Distribution	5	2
Air Heat Balance	3	1
Total	**1200**	**64**

Method

- Free-running and naturally ventilated dwelling model.
- High level of thermal insulation and airtightness.
- Vary (full-factorial analysis) algorithms in two BPS tools while thermal properties were kept constant.
- ANOVA analysis to determine statistically significant influence of algorithms and interaction effects.

Results

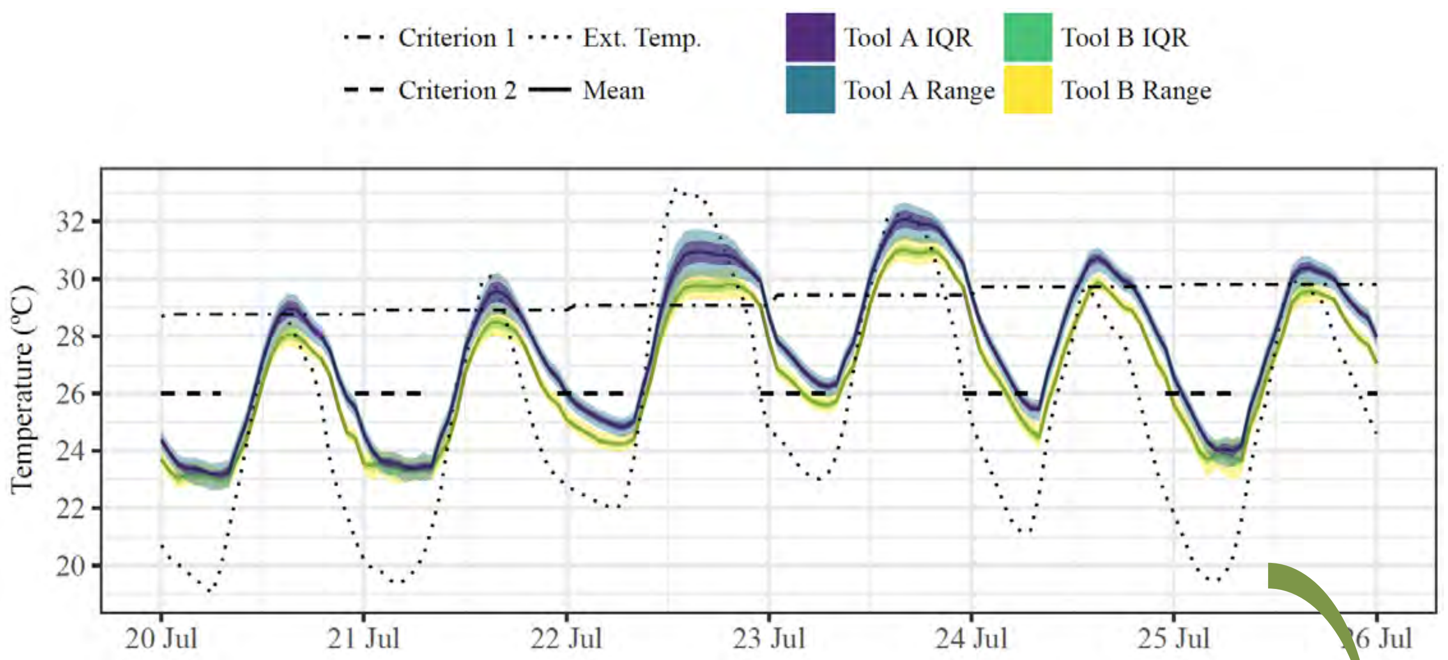

Figure 2: *Indoor bedroom temperatures predicted by both tools during the hottest period. The shaded areas indicate the range and inter-quartile range (IQR) of the distribution of predicted hourly indoor operative temperatures due to the choice of simulation options.*

TM59 Metrics

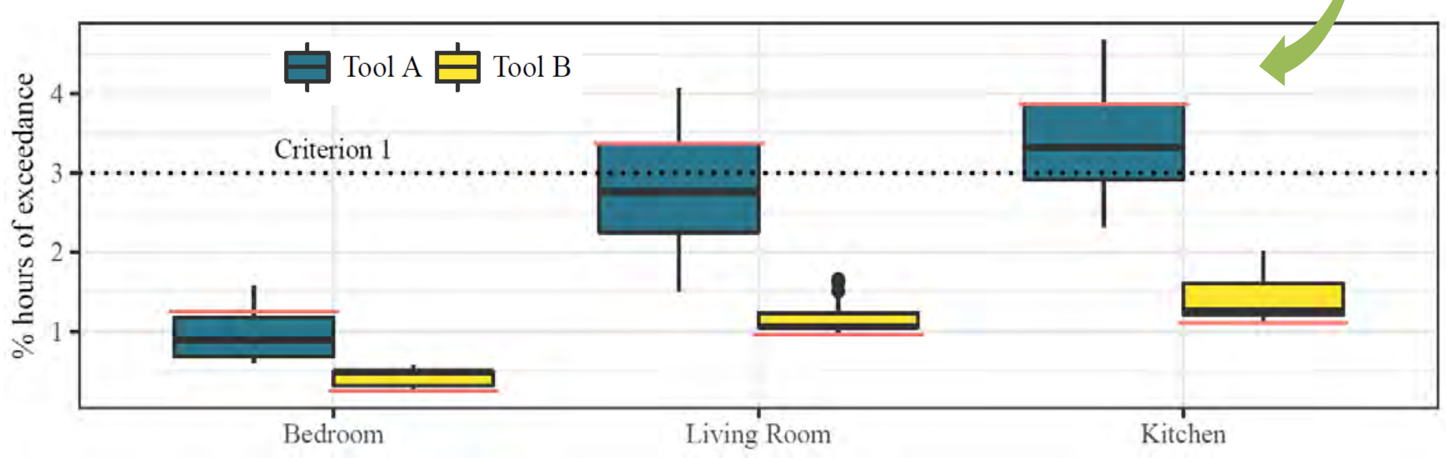

Figure 3*: Distributions of the percentage of occupied hours that the CIBSE TM59 Criterion 1 was exceeded. Each box plot is comprised of the individual predictions resulting from every combination of simulation options of each tool [3].*

- Hourly indoor temperature **varies up to 2.5°C** due to algorithm choice.
- This leads to a spread of predicted overheating risk.
- More likely to **randomly select algorithms** that are in closer agreement than the default between the tools.
- Taking the default options as the reference point for tool A, **65% of the algorithm combinations** would alter the overheating risk prediction from high to low for the living room.
- This allows for, **deliberate or unintended choice of algorithms that result in lower overheating risk prediction.**

Discussion & Conclusions

Modellers:

- Different tools = Different abstraction of reality.
- Treat defaults as the **pre-selected not the best options**.
- Different algorithms for different tasks – **know your tool!**
- **Publish the tool and algorithms used**.

Tool Developers:

- Detailed description of algorithms used.

Best practise guidance:

- **Standardisation of the assessment** by accounting for differences in tools and algorithms.

Future work

Empirical Validation & Calibration: Given the uncertainties at the design stage, can the indoor temperature of a naturally ventilated test cell be predicted?

Occupancy: The effect of household characteristics on the predicted overheating risk according to the TM59 metrics will be quantified using the 2011 **Energy Follow-Up Survey (EFUS).**

Workshop: What do the above mean for the prediction of indoor overheating risk using TM59?

References

1. https://www.metoffice.gov.uk/climate/uk/summaries/2018/summer
2. CIBSE, 2017. Design methodology for the assessment of overheating risk in homes, TM59: 2017. Chartered Institution of Building Services Engineers, London.
3. Petrou G, Mavrogianni A, Symonds P, Korolija I, Mylona A, Raslan R, et al. What are the implications of building simulation algorithm choice on indoor overheating risk assessment? In: Building Simulation And Optimization 2018. Cambridge; 2018.

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Vision and leadership for a sustainable built environment

ANNUAL COLLOQIUM 2018

Efficient Integration of Heat Networks with Low-Carbon Power Generation

Salman Siddiqui 2nd year PhD

BACKGROUND

Several options exist to decarbonise heat demand in the built environment, some which include a high degree of electrification of low temperature heat demand.

With the high level of electrification, it is expected that a large share of this will be of renewable origin which is generally intermittent.

District heating networks are a technology that allow centralised heat generation to be distributed and allows a more diverse range of heat sources to be used taking advantage of the efficiency and economy of scale as well as the integration of thermal energy storage due to its potential in peak load shifting.

Integration of heat and power networks are an encouraging opportunity to manage and mitigate temporal imbalances of supply and demand in energy systems with a high fraction of intermittent renewables such as wind energy.

Supply and demand follow different patterns in different domains and integrating them can lead to synergies in generation, storage and consumption. Resulting in a higher reliability, flexibility and efficiency for the enegy system.

As district heating is a distribution technology, CHP units and heat pumps are not mutually exclusive but the operation schedule is critical and heat storage provides a level of flexibility between the two.

Both the carbon intensity and cost of power generated hour by hour will vary depending on the amount of renewable generation available and stored.

Hence the size of heat stores to minimise fossil fuel usage and to economise district heating plant operation will be critical.

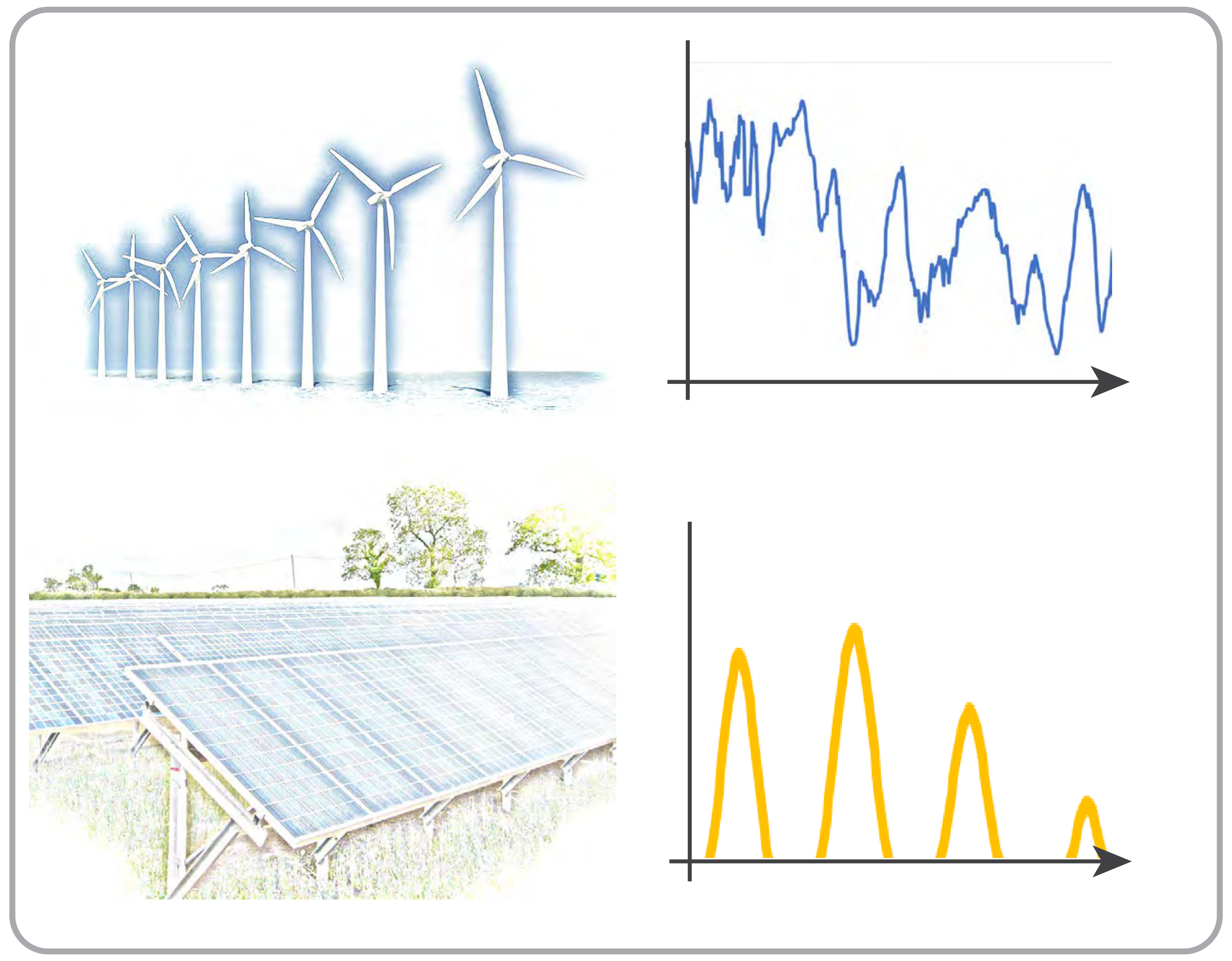
Research Questions

A. What operation algorithms minimise life time costs and carbon emissions for district heating networks in a renewable energy system with large scale district heating and combinations of heat storage, heat pumps and CHP?

B. What combination and sizes of district heating components, in terms of heat plant and storage is optimal economically in terms of capital investment and to mininise operating costs.

C. What is the economic value of thermal energy storage for power grid balancing compared to conventional storage technologies and how much can this replace conventional energy storage?

NATIONAL SCALE RENEWABLE POWER GENERATION MODEL



LEGACY BASELINE GENERATION

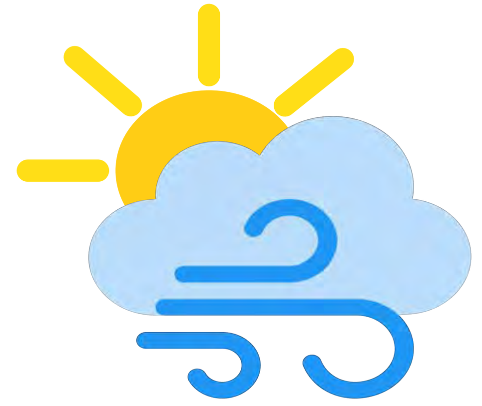
+

CHP POWER

POWER FOR HEAT

£ CO_2

USING NATIONAL CONSUMPTION DATA, THE MARGINAL SYSTEM COST OF ELECTRICITY GENERATION IS CALCULATED FOR A CAPITAL INTENSIVE SYSTEM - i.e. THAT WHICH CONTAINS LARGE FRACTIONS OF OFFSHORE WIND AND GRID STORAGE



METEOROLOGICAL DATA USED TO PREDICT HEAT LOAD AND RENEWABLE POWER GENERATION COUPLING HEAT DEMAND WITH INTERMITTENT POWER GENERATION

DISTRICT SCALE HEATING LOADS MODELLED

BUILDING ARCHETYPES

BUILDING THERMAL MODEL SPECIFIC HEAT LOSS AND THERMAL MASS

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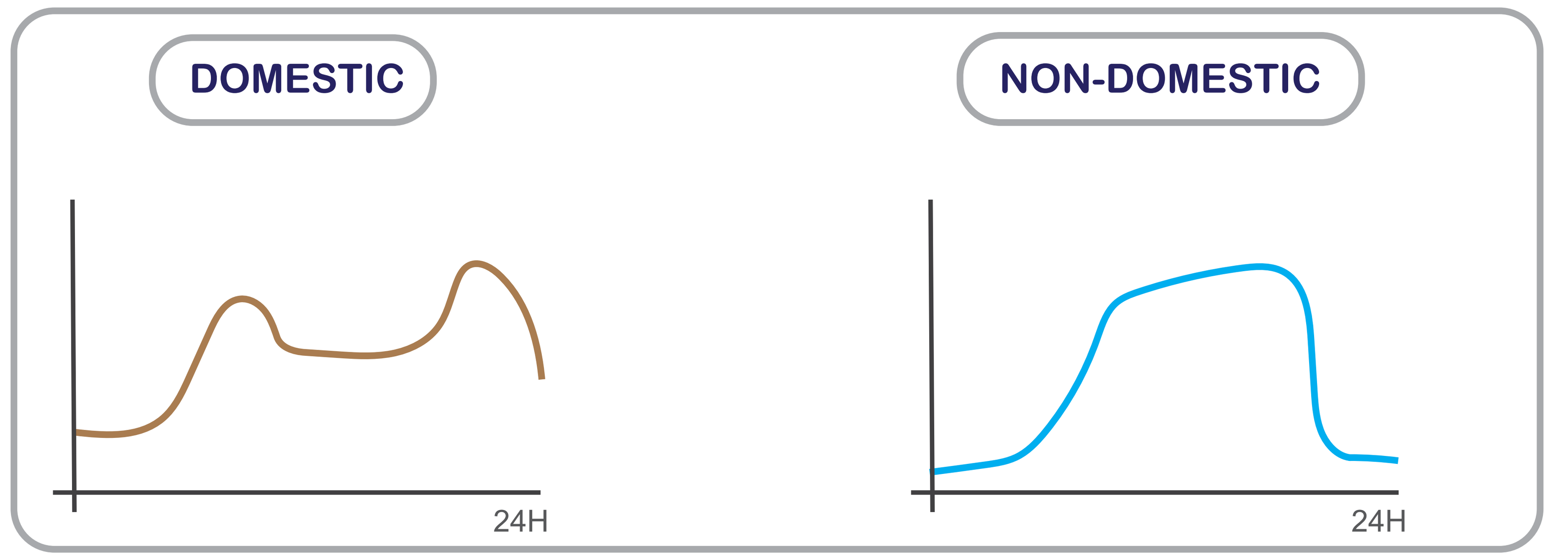
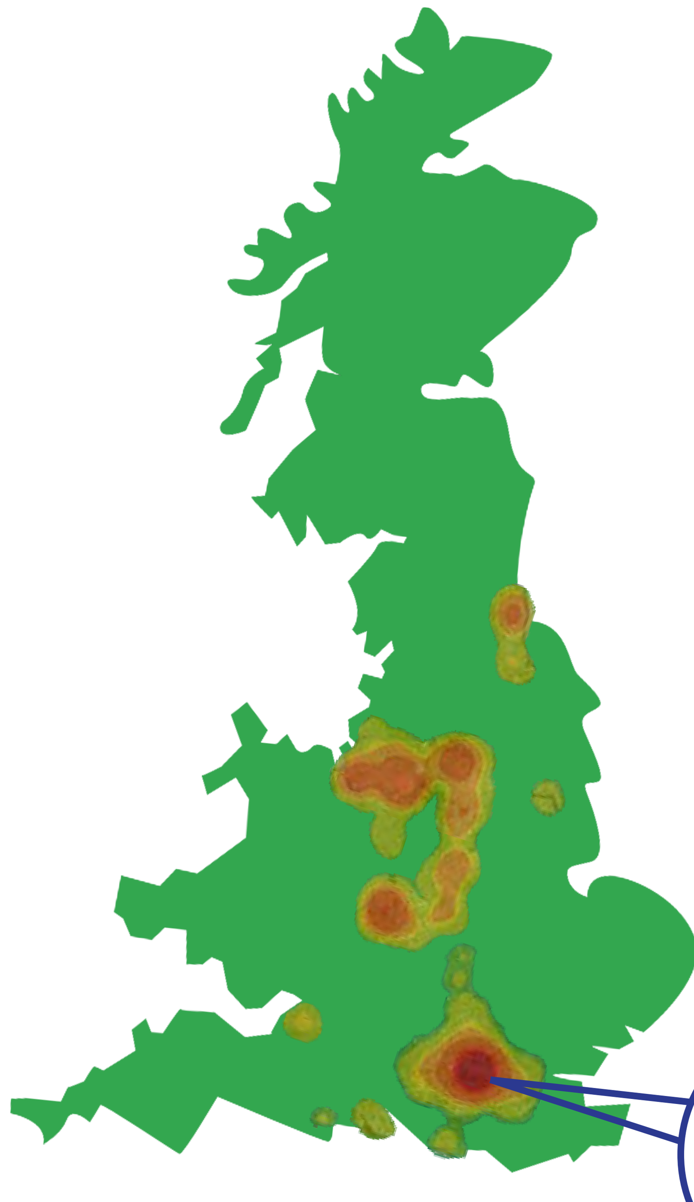
HOURLY ACTIVITY LOAD PROFILES





DISTRICT HEATING NETWORK MAPPING

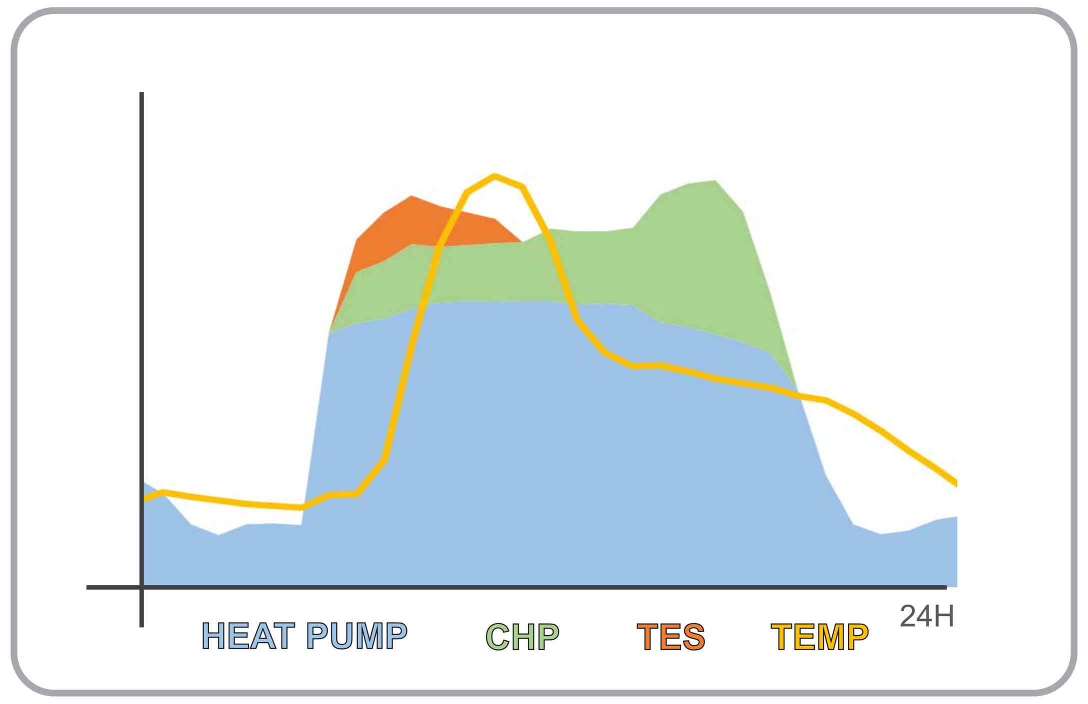
DISTRICT SCALE HEATING LOADS MODELLED HOURLY FOR BUILDING COMPOSITION OF URBAN DISTRICTS HEATING NETWORK

DISTRICT HEATING POWER PLANT OPERATION

HEAT PUMPS
COMBINED HEAT POWER
THERMAL ENERGY STORAGE

HEAT DEMAND

HEAT SUPPLY



OPTIMISATION ALGORITHM

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Predicting Ventilation Effectiveness for Natural Ventilation

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Supervisor: Prof Malcolm Cook

Background

Currently in ventilation standards (ASHRAE Standard 62.1 [1], CIBSE Guide A [2]), zone air distribution effectiveness (E_z) values are provided for a rage of mechanical ventilation systems. These values are used to calculate the volume of outside air required for the zone being designed.

While these standards provide E_z values for mechanical ventilation systems, they do not currently provide values for any natural ventilation strategies. This project aims to use CFD techniques to provide evidence for the inclusion of natural ventilation E_z values.

Objectives:

- Compare mechanical ventilation predicted E_z values against the values provided in ASHRAE Standard 62.1 [1]
- Predict E_z values for a range of natural ventilation strategies
- Identify key natural ventilation design characteristics that influence ventilation effectiveness

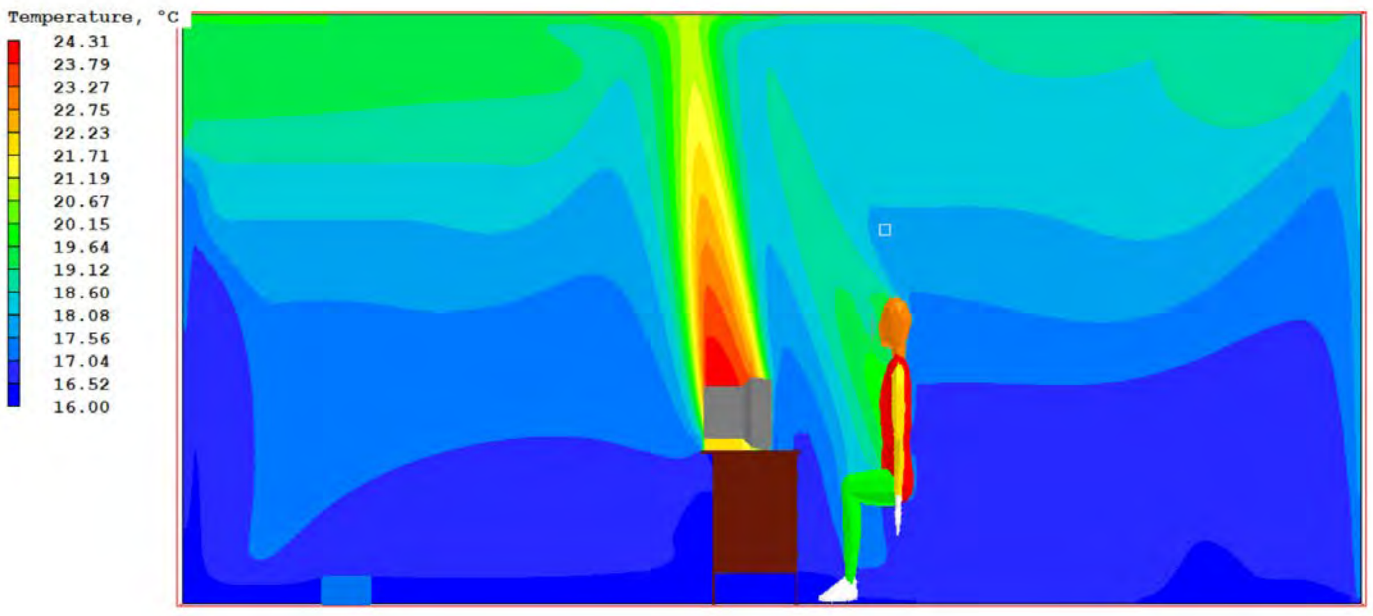
Ventilation Effectiveness (Zone Air Distribution Effectiveness, E_z):

Ventilation effectiveness, defined in Lee [3] as:

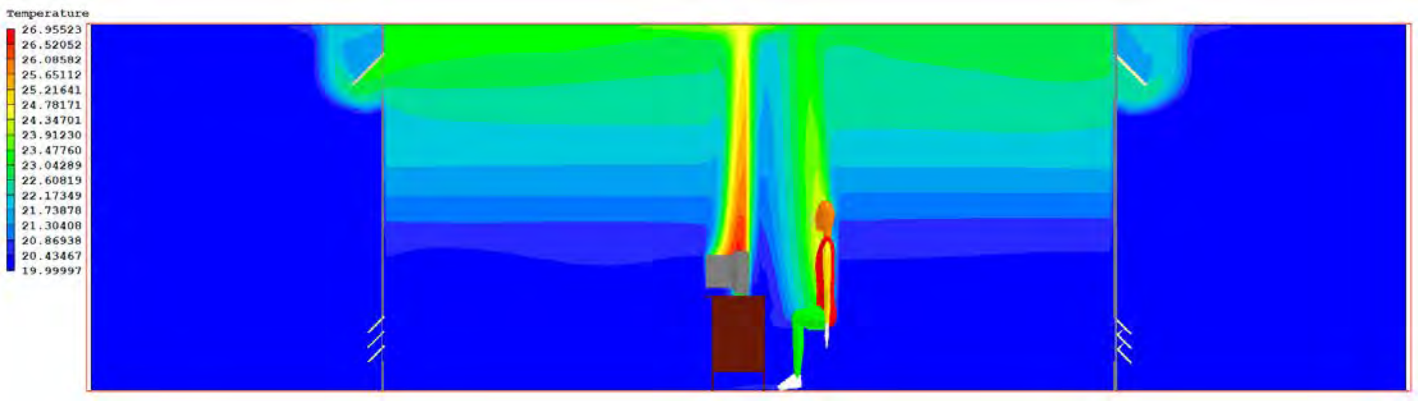
$$E_z = \frac{C_e - C_s}{C - C_s}$$

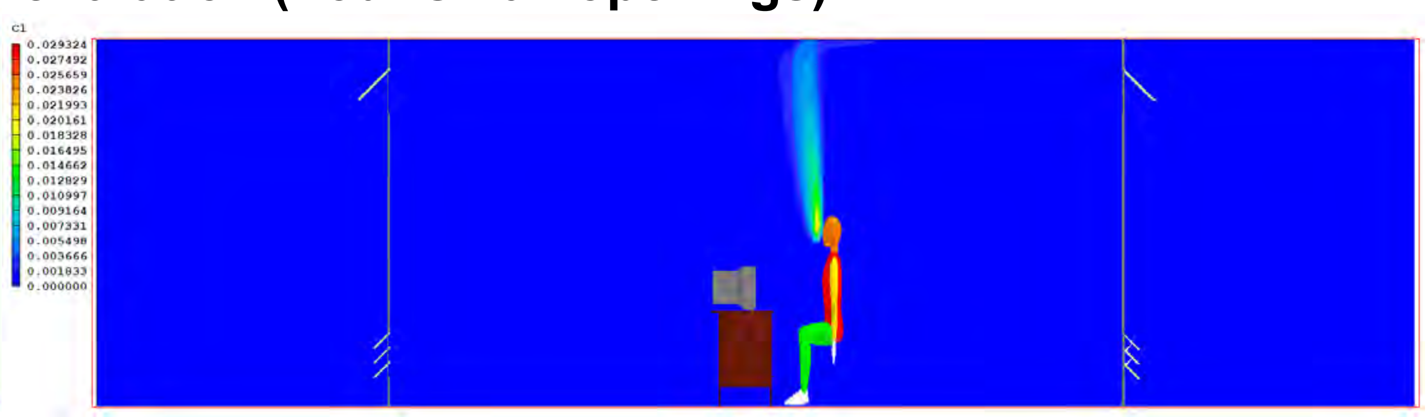
Where C_e is the total contaminant concentration at the exhaust; C_s is the total contaminant concentration at the supply and C is the averaged contaminant concentration in the breathing zone.

Case 3 – Mechanical Displacement Ventilation

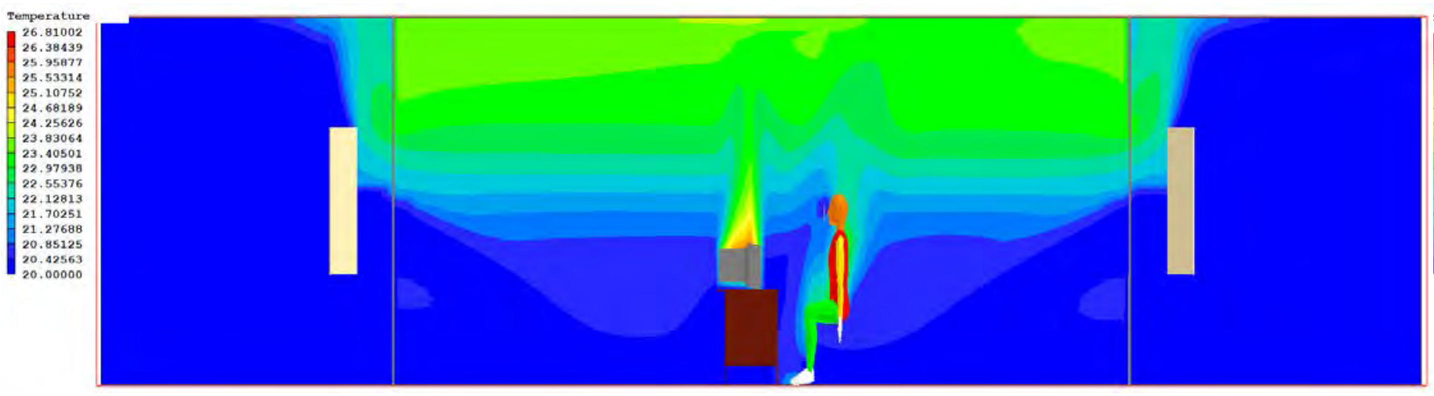


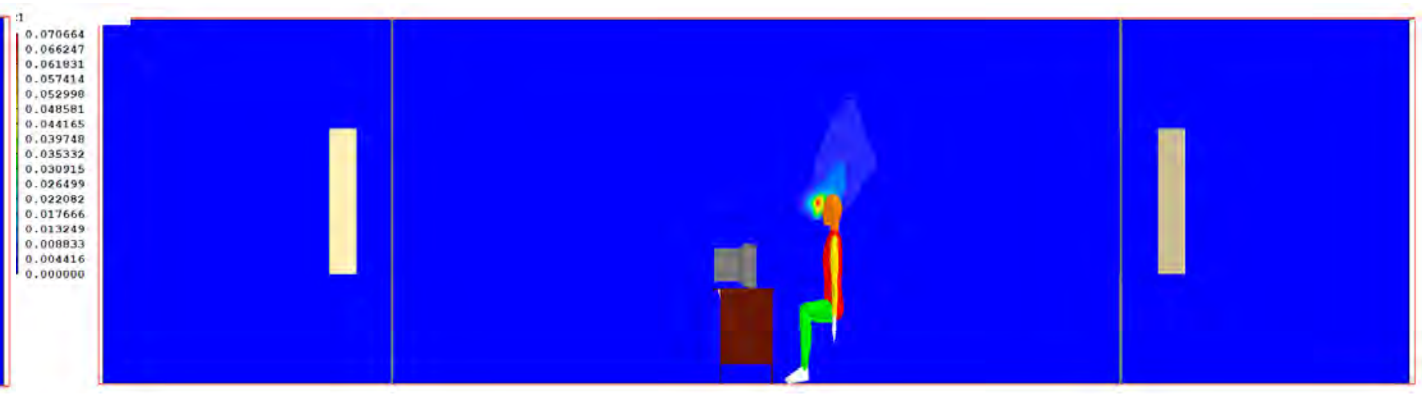
Case 5 – Natural Cross-ventilation (Four small openings)





Case 7 – Natural Cross-ventilation (Two large openings)





Case	Supply/External Air Temperature °C	Air Supply Rate m^3/s (ACH)	Ventilation Effectiveness E_z
Case 1	16	$2.5x10^{-1}$ (28.8)	0.7
Case 1	20	$2.5x10^{-1}$ (28.8)	1.4
Case 2	16	$2.5x10^{-1}$ (28.8)	0.3
Case 3	16	$1.0x10^{-1}$ (11.52)	2.05
Case 3	16	$2.5x10^{-1}$ (28.8)	0.13
Case 3A	16	$1.0x10^{-1}$ (11.52)	0.72
Case 3A	16	$2.5x10^{-1}$ (28.8)	0.21
Case 4	20	$3.3x10^{-2}$ (3.8)	0.94
Case 5	20	$5.3x10^{-2}$ (6.1)	1.36
Case 6	20	$3.6x10^{-2}$ (4.1)	0.4
Case 6A	20	$3.8x10^{-2}$ (4.3)	0.46
Case 7	20	$5.4x10^{-2}$ (6.3)	0.67

Outcomes:

- Mechanical displacement ventilation systems can provide the highest E_z values
- Cross-ventilation strategies utilising two small low level and two small high level openings provide the highest E_z values for natural ventilation
- The location of the openings on the external walls has more impact on the E_z values than the total opening area of the windows

Reference:

[1] - ASHRAE. Ventilation for acceptable indoor air quality. ASHRAE Standard, (STANDARD 62.1):1 - 70, 2010.
[2] - CIBSE. Environmental design CIBSE Guide A. 2017.
[3] - Lee, K., Jiang, Z., and Chen, Q. 2009. Air distribution effectiveness with stratified air distribution systems. In ASHRAE Transactions, 2009.

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Heat pumps with district heating for the UK's domestic heating sector

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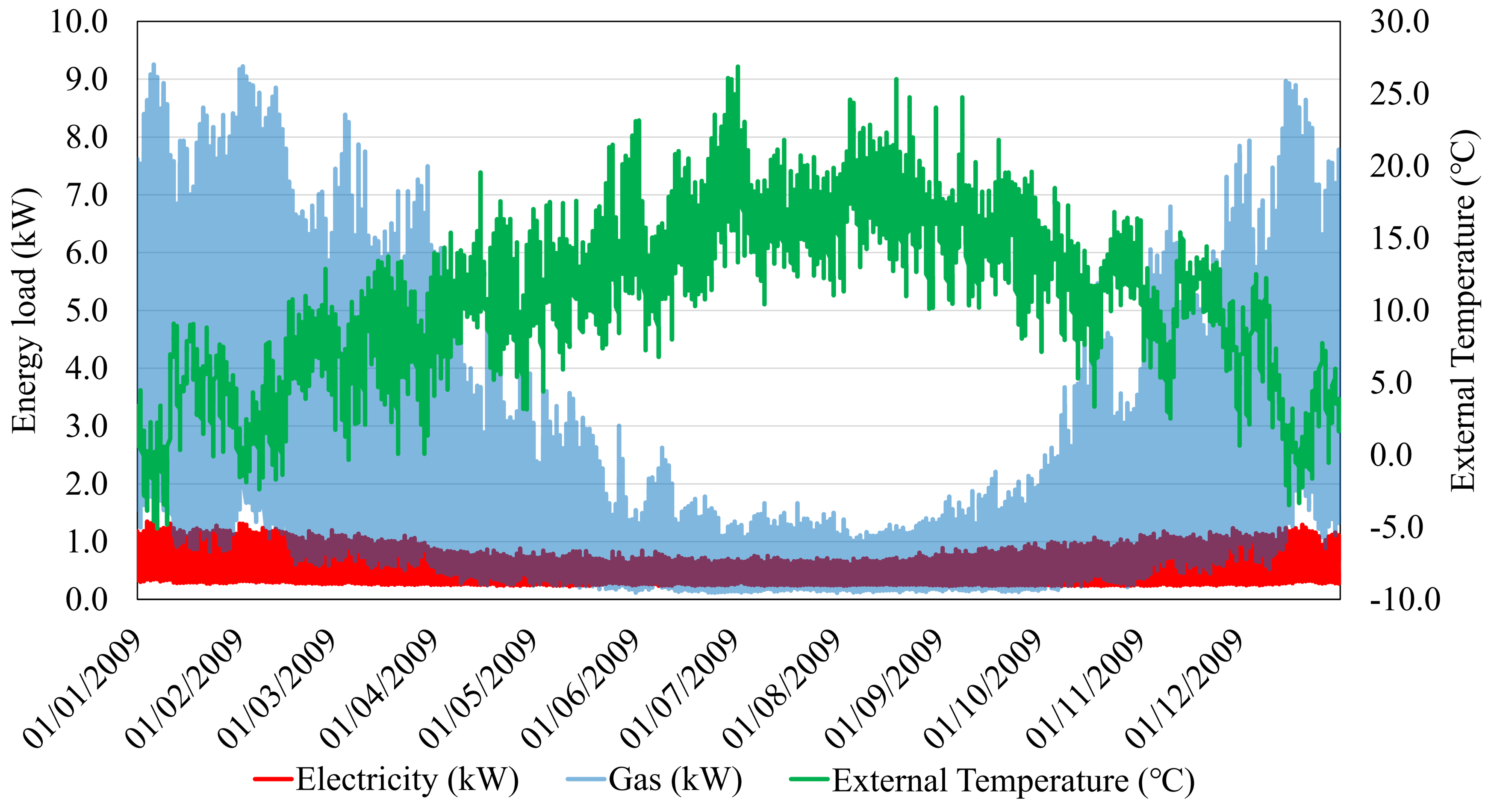
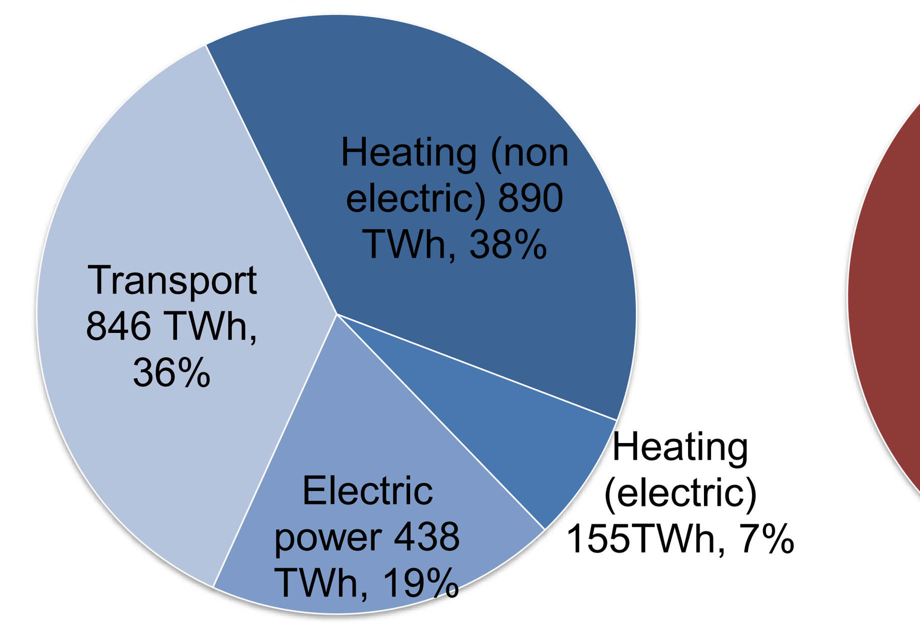
Heat demand in the UK

The UK has set ambitious targets to reduce carbon emissions, improve energy efficiency and affordability, encourage renewable energy generation, and reduce dependency on imported fossil fuels. It is possible to achieve deep cuts in carbon emissions from British dwellings with the potential for future improvements in building performance, decarbonising the electricity, and re-engineering the heat supply. Currently, nearly **half of the final energy demand** in the UK is consumed to provide heating. Heat demand is much more **volatile** than electricity demand overtime. **Gas boilers** are the principal way supplying heat in over **85% of British households**.

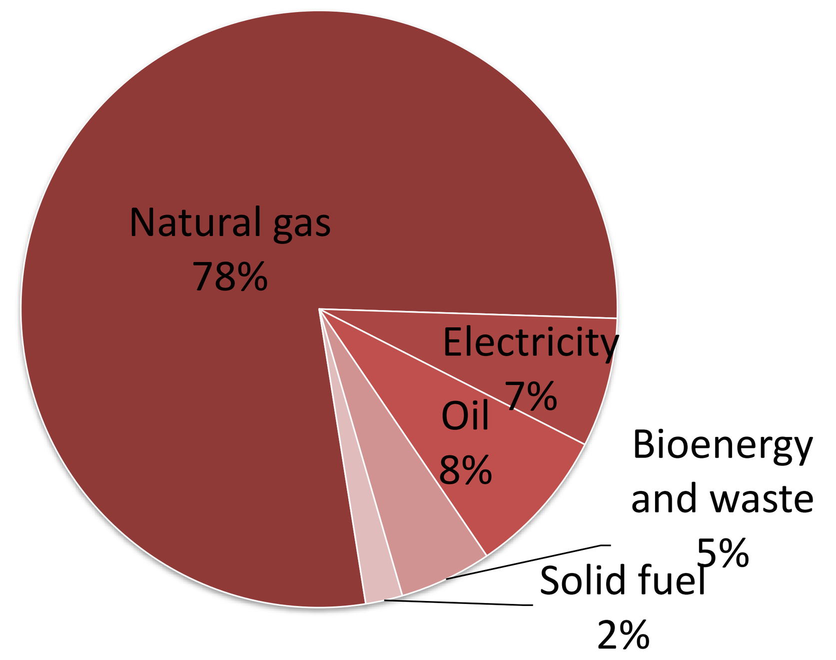


Average hourly domestic electricity and gas demand versus external temperature in 2009

At present the best balance between different heat supplying technologies is **unknown**. Electric **heat pumps** together with **decarbonised electricity** could replace gas heating and contribute to the future low-carbon heat mix. **District heating networks** have been transforming from fossil fuel based to renewable based over several generations. However, **the market shares** of heat pumps and district heating networks **are very low in the UK**.

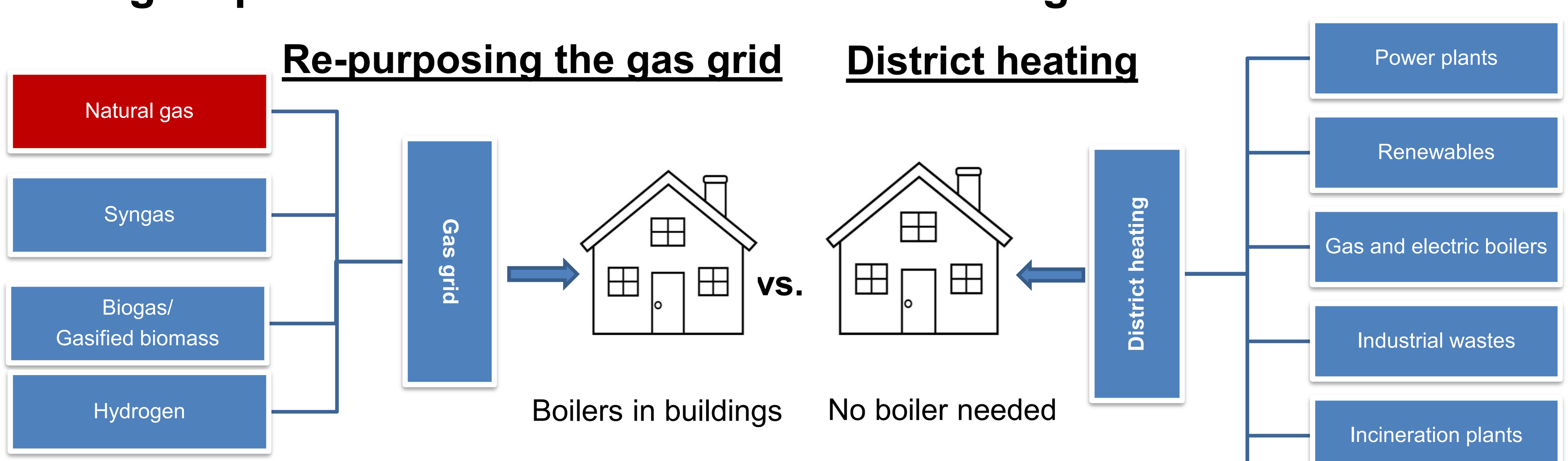


45% of final energy demand is consumed to supply heat



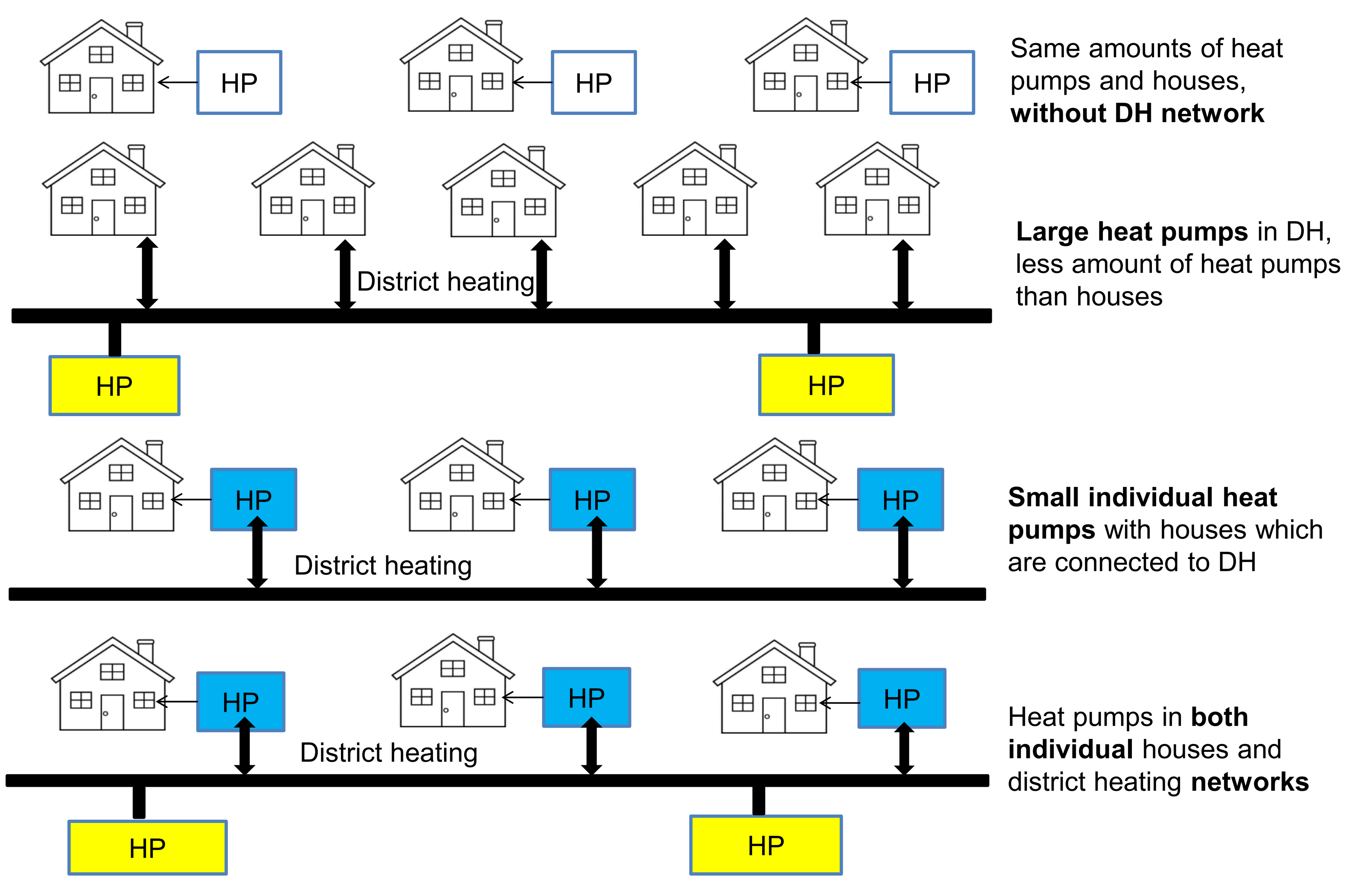
78% of heat is supplied by natural gas

Strategic options to decarbonise the UK's heating sector



The cheaper approach is re-purposing the gas grid through **substitution of natural gas** to biogas or syngas. The second one is to develop district heating networks, which could offer **higher flexibility and efficiency**. Unlike the gas grid that uses high-quality energy resources for a low-quality demand, district heating could **utilise different types of sources** including fossil fuels, renewable resources, and waste energy.

Individual heat pumps vs. heat pumps in DH

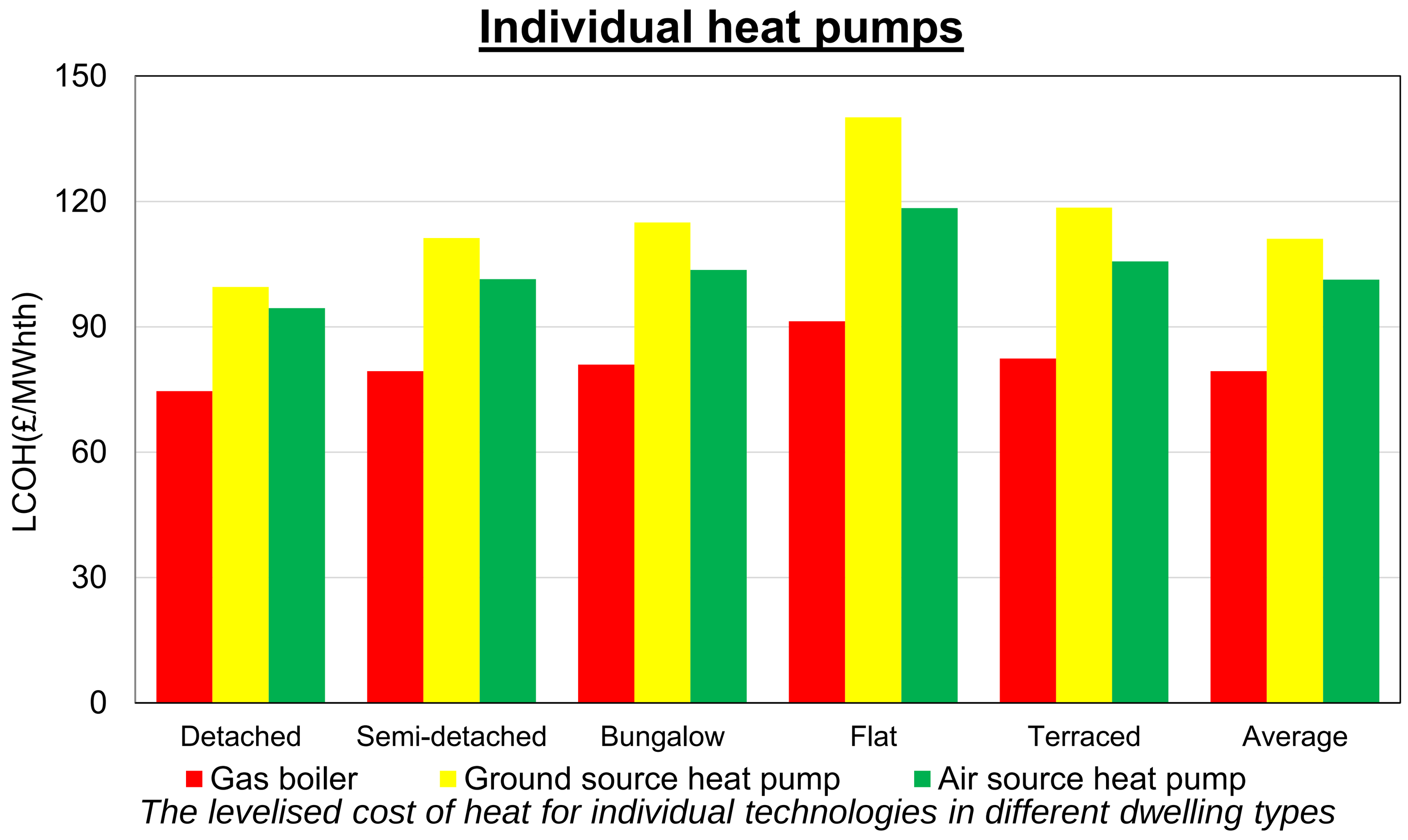


Topological configurations of buildings, heat pumps and district heating networks

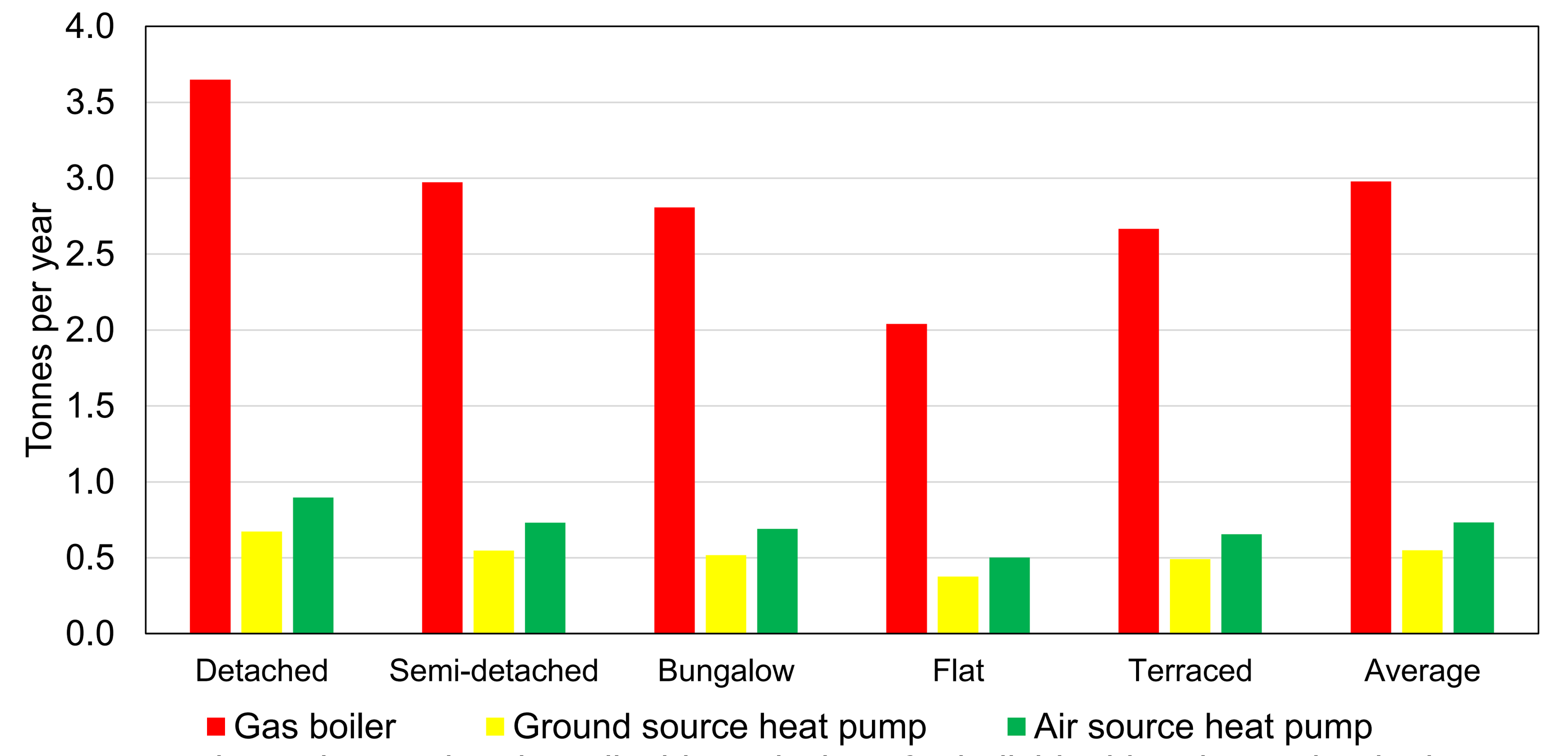
The **well-developed natural gas networks** and **cheap natural gas** are the most substantial challenges for the future deployment of electric heat pumps and district heating networks in the UK. This study proves that **economies of scale arise** in the UK's district heating networks with large heat pumps. Although **heat pumps with decarbonised electricity** could **reduce domestic carbon emissions** from heat intensively, **the levelised costs** for heat pumps and district heating are **significantly higher** than individual gas boilers.

The **mass electrification of the heating sector** and the deployment of the heat networks on large scales will require intensive **investment**, alterations in **supply chain** practices, and **public acceptance**. Further studies are desirable to better understand the role of district heating and heat pumps in the UK's energy system and transform district heating **from a strategy into reality**.

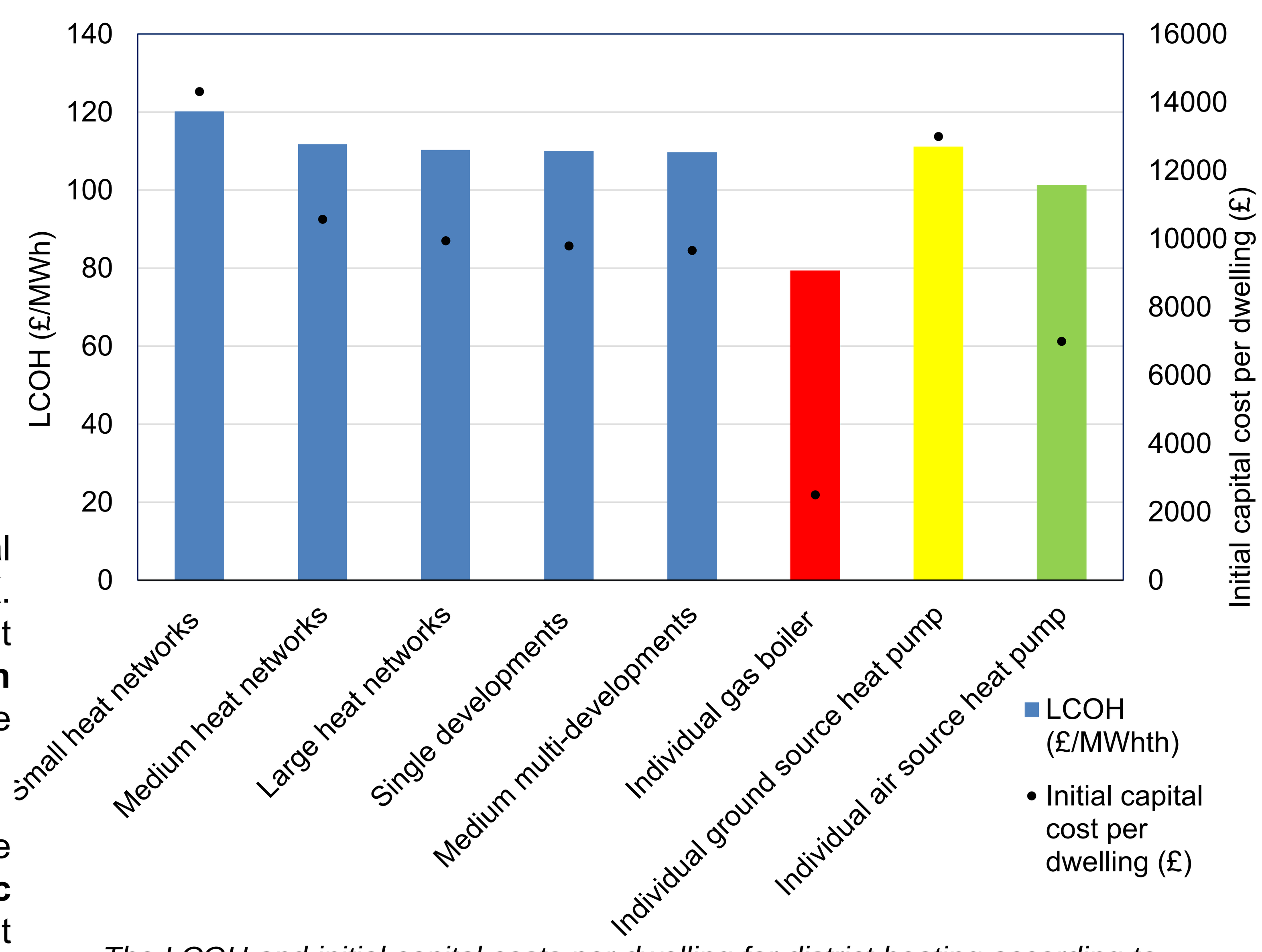
Individual heat pumps



The levelised cost of heat for individual technologies in different dwelling types

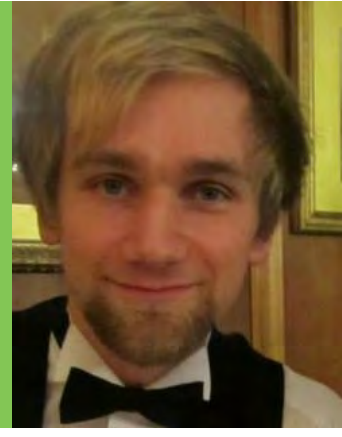


Estimated annual carbon dioxide emissions for individual heating technologies



The LCOH and initial capital costs per dwelling for district heating according to five scales, compared to individual heating technologies

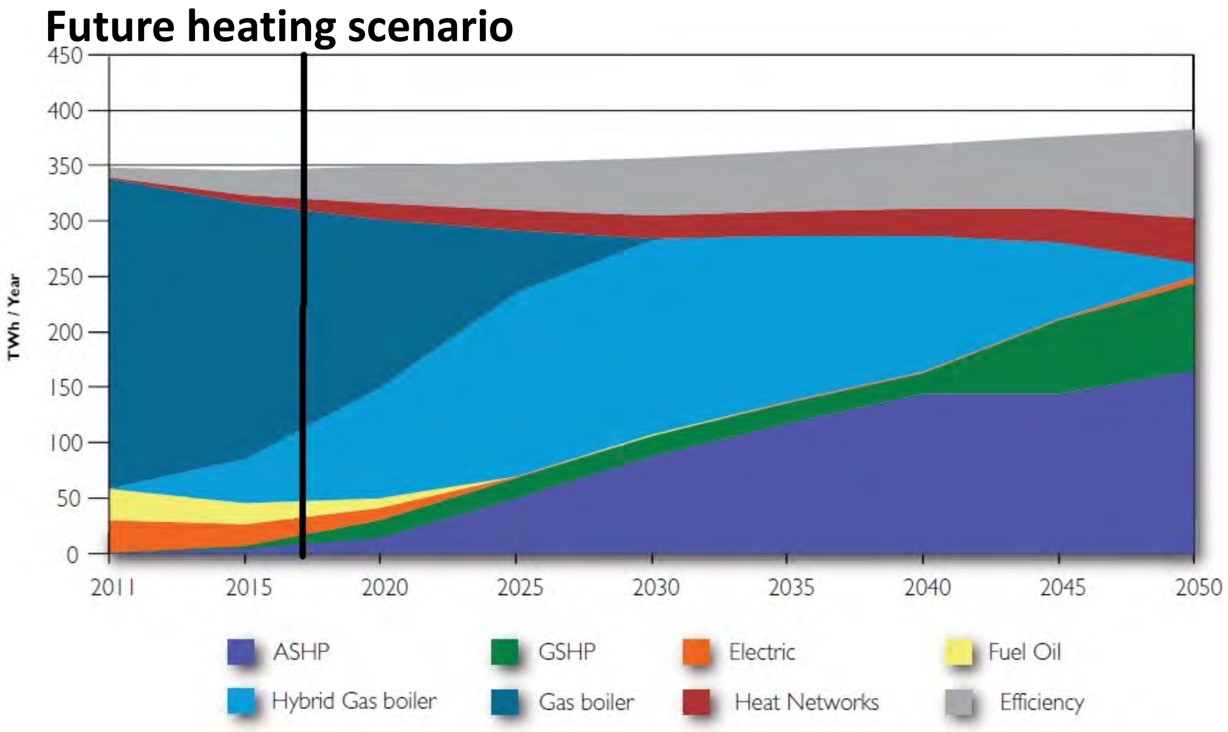
Increased electricity demand from heat pumps, taking user behaviour into account



Stephen Watson PhD Student (Loughborough University)
Supervised by **Dr Richard Buswell**, **Dr Jenny Love** and **Prof Kevin Lomas**

Background:

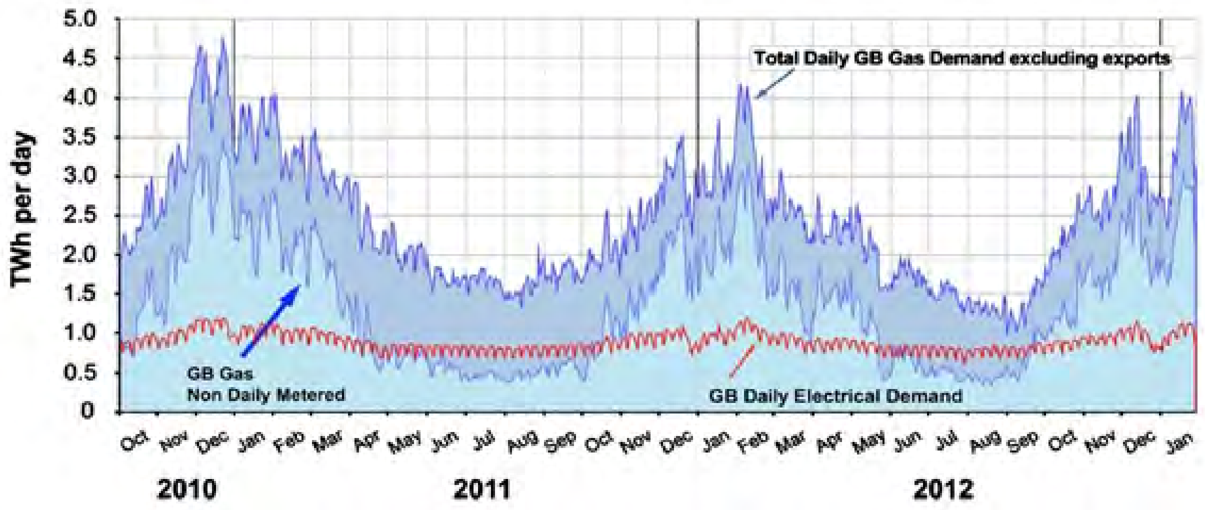
Future heating scenario



Heat pumps are expected to play a significant role in domestic heating by 2050. (Source: DECC (2013))

- Heat pumps are expected to play a role significant role in domestic heating in most future heating scenarios.
- The number of houses heated by heat pumps varies between scenarios.
- A widespread introduction of heat pumps would introduce a significant new demand for electricity.
- This increased demand for electricity, especially during cold weather, is considered to be one of the main challenges associated with a widespread use of heat pumps.

Gas and electricity demand



There is a large variation in the demand for heat over a year. Peak heat demand is considerably greater than current peak electricity demand. (Source: Wilson et al (2013))

Aim:

To quantify the additional electricity demand resulting from a widespread introduction of heat pumps for space and water heating in UK homes, and to determine the implications for future UK energy policy.

Chapters:

1. Estimate current GB half-hourly domestic heat demand.
2. Investigate heating patterns and factors affecting these, for gas boilers and heat pumps.
3. Produce estimates of national heat/electricity demand under various scenarios of mass heat pump uptake.

References:

DECC, 2013. *The Future of Heating : Meeting the challenge*,
Wilson, I.A.G. et al., 2013. Historical daily gas and electrical energy flows through Great Britain's transmission networks and the decarbonisation of domestic heat. Energy Policy, 61, pp.301–305. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421513004655.

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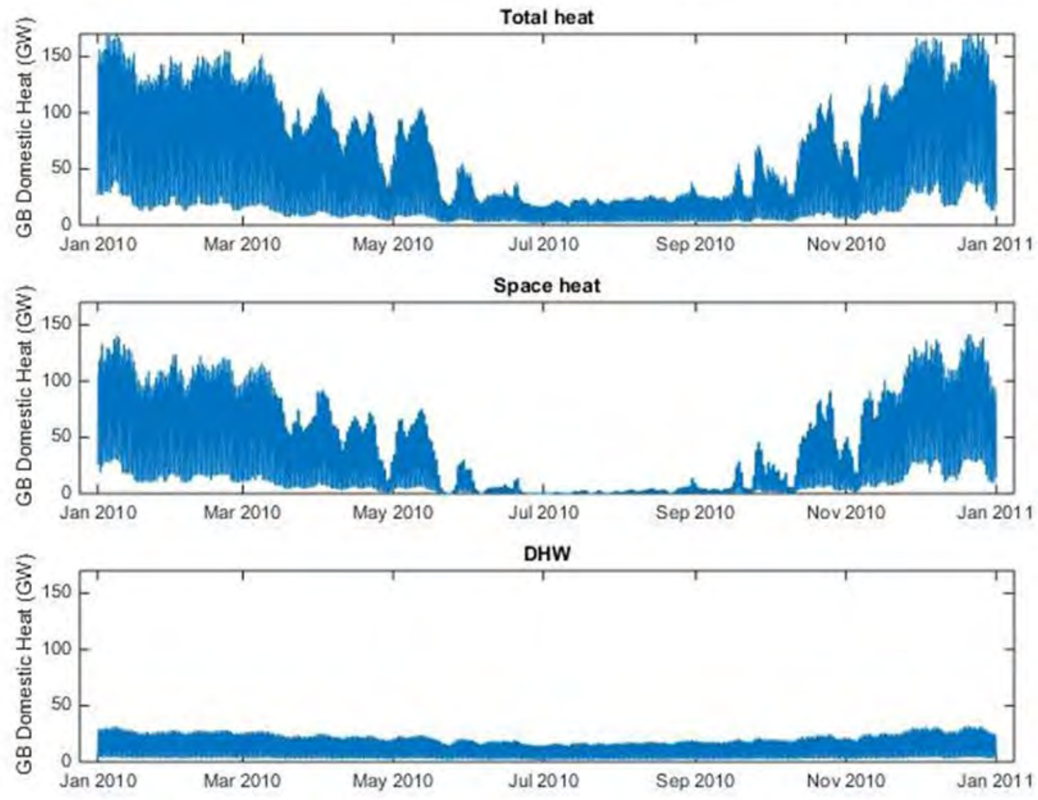
Results:

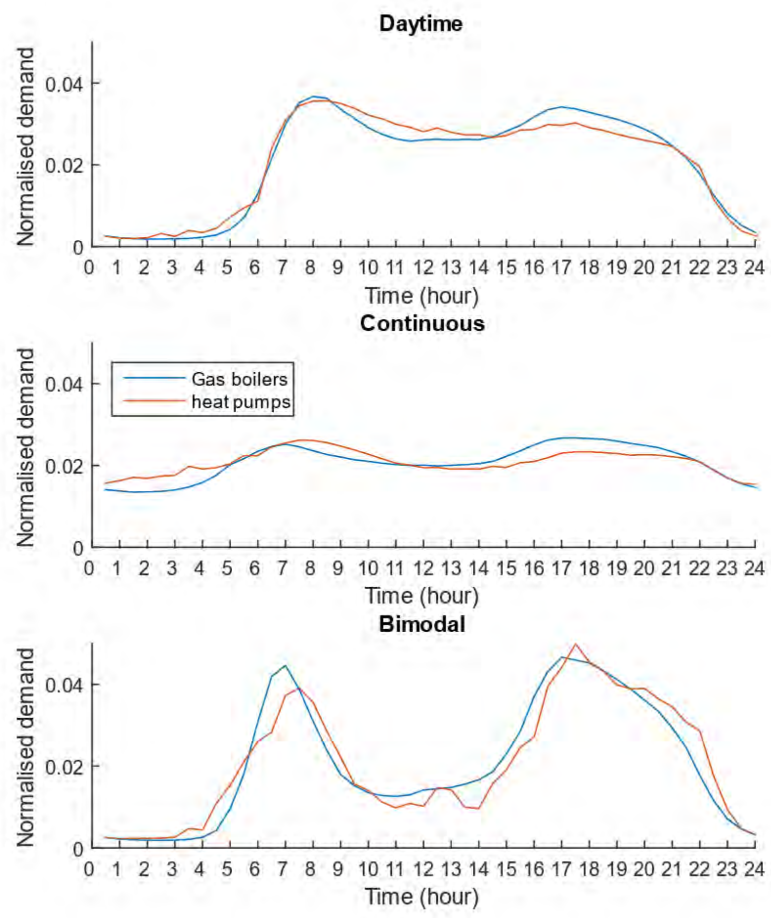
Current GB domestic heat demand



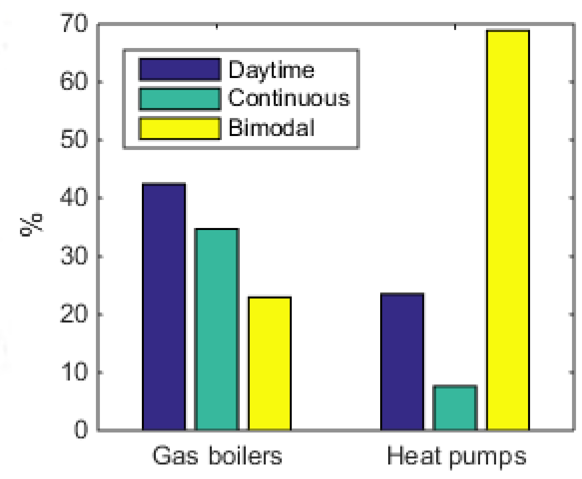
Half-hourly GB domestic heat demand for 2010, giving total heat, space heat and DHW

- Lower peaks than previous estimates
- Based on monitored data (around 6000 homes)
- Shape of heat demand varies with outdoor temperature.

Heating patterns



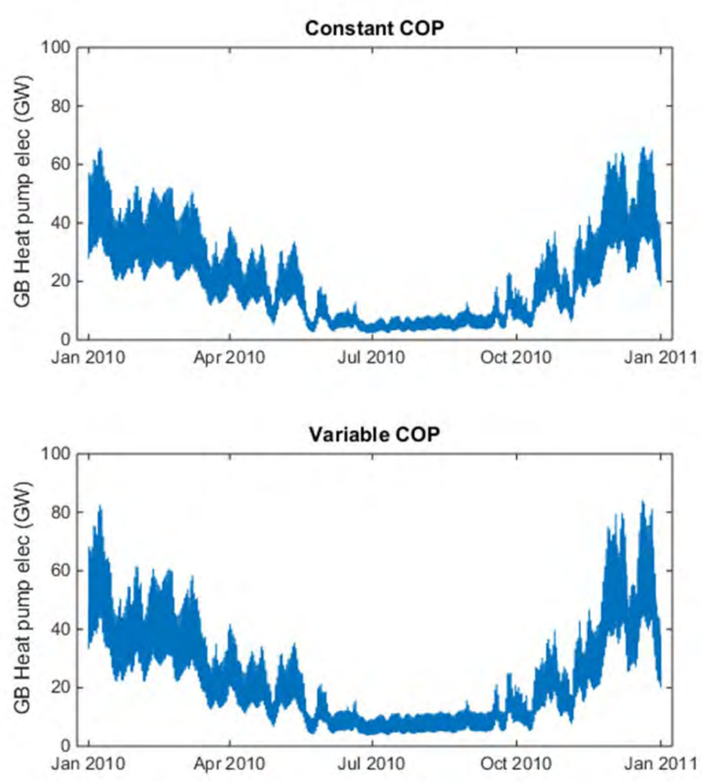
Heating pattern clusters found for heat pumps and gas boilers



Proportions of different heating patterns found for gas boilers and heat pumps

- Clustering is applied to mean wintertime profiles.
- Three types of use found, both for heat pumps and gas boilers.
- Different proportions for heat pumps and gas boilers.
- Heating patterns affected by emitter type and socio-demographics.

Future GB heat pump electricity demand



Half-hourly heat pump electricity demand, when 100% of domestic heat demand supplied by heat pumps

- Assuming 100% of domestic heat demand met by heat pumps
- If COP is fixed at 2.5, peak demand is 65 GW.
- If COP varies with outdoor temperature, peak demand is 85 GW.
- Peak total electricity demand approximately doubled.

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ANNUAL COLLOQUIUM 2018

ZONAL CONTROLS: A HOME HEATING REVOLUTION?

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Introduction

Heating in UK homes contributes to 83% of total energy consumption in the residential sector (Committee on Climate Change 2015). Smart energy metering will move consumption of energy in the home from being imperceptible and abstract to being tangible and manageable (Fischer 2007; Faruqui et al. 2010; BEIS 2018).

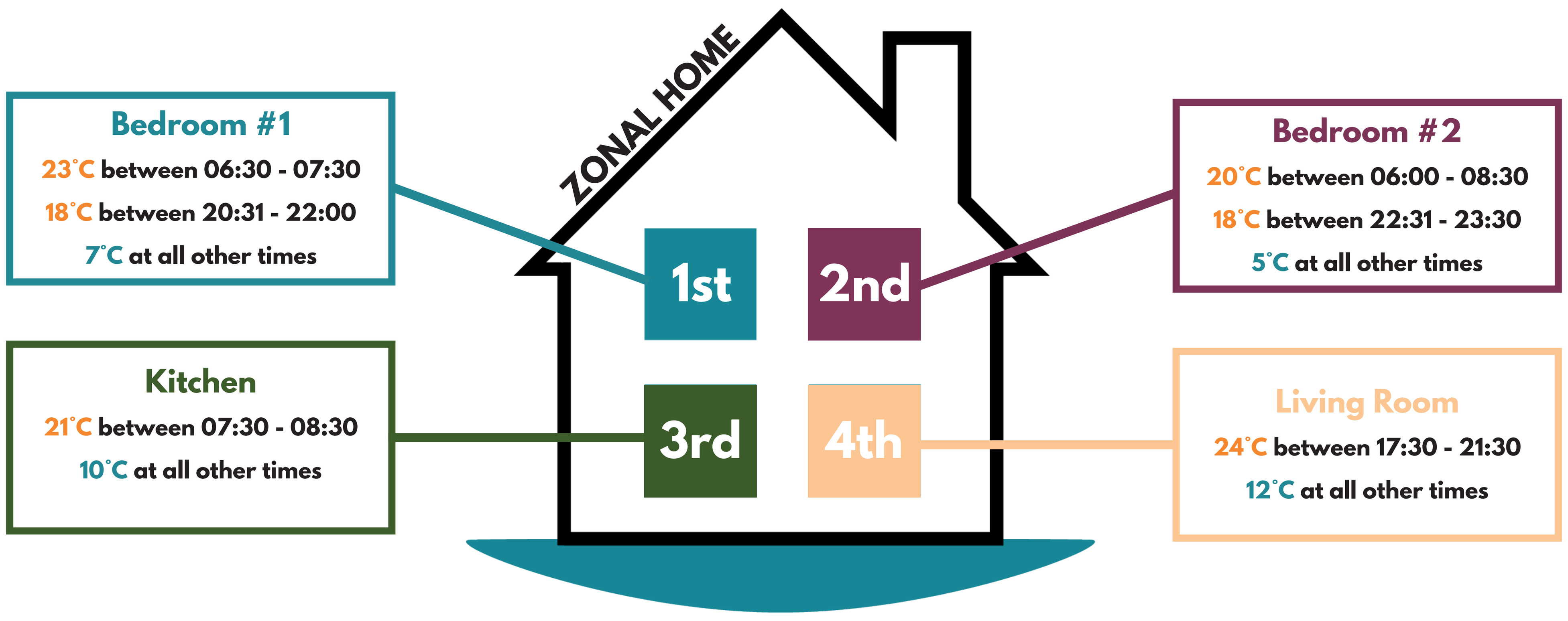
Through pioneering lab studies and cutting edge field studies, we understand that zonal controls can be used to save energy. It is not understood how occupants interact with these controls and what factors might be limitations to occupants getting the full energy-saving and thermal comfort benefits.

Research Aim

To evaluate how occupants can be supported to operate zonal space heating controls to facilitate energy-saving and thermal comfort.

What are zonal controls?

Zonal controls give occupants the ability to control the temperature in every part of their home... So that the heating only comes on when required, at the temperature preferred and in the room(s) desired:



Mixed Methods

1. Critically review evidence from psychology, design, and engineering on how occupants interact with their home.
   - Literature review
2. Quantitatively analyse monitored gas use, electricity use, room temperature and interaction with zonal controls.
   - Data analysis (Python)
3. Collect qualitative data through interviews and questionnaires to contextualise home energy use.
   - Home interviews (semi-structured)
   - Sociotechnical survey (online)
4. Develop and test interventions to support interaction with zonal heating controls and improve outcomes.
   - Design, prototype and test

Progress

44 households recruited!

Gas-use monitoring and zonal control interaction logging is underway in 44 households located across the Midlands, UK.

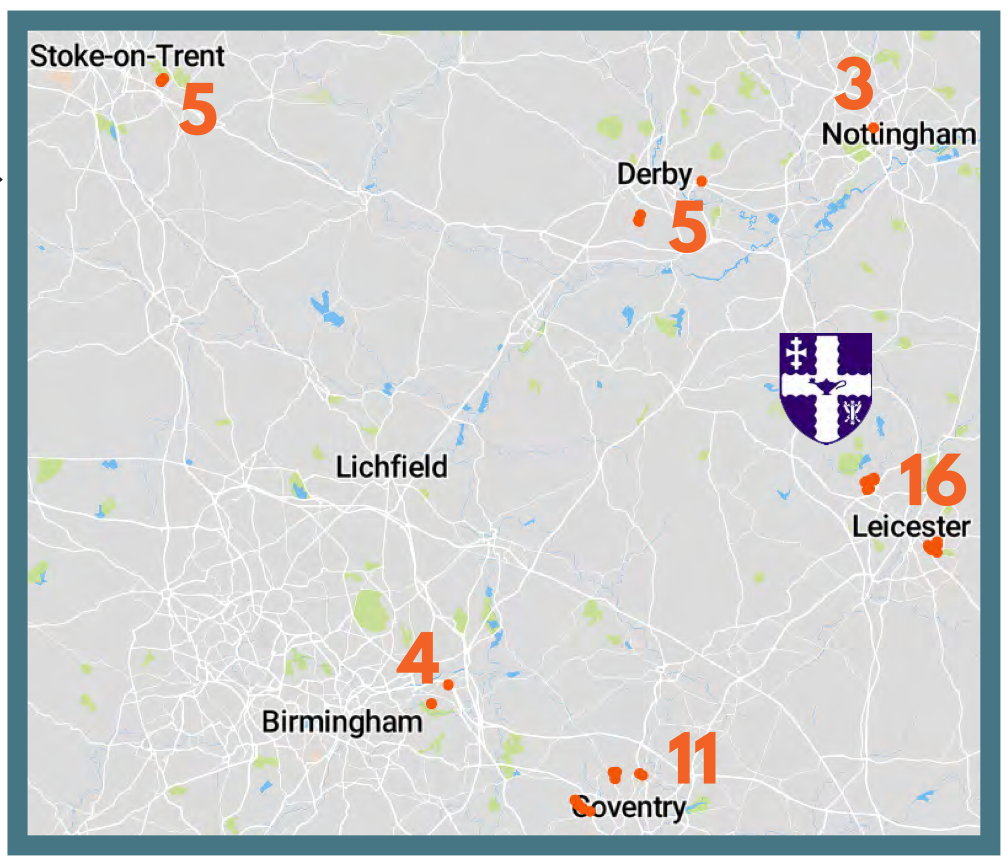
Number crunching...

The huge datasets that come with three years of *half-hourly* gas monitoring, *two-minutely* electricity monitoring, *five-minutely* room temperature monitoring, and *as-and-when* zonal control interaction data are being analysed. Data is being reformatted, cleaned and wrangled to enable insights into how zonal controls are (or are not) being used.

Our survey said...

In collaboration with the DEFACTO team at Loughborough University, a questionnaire has been circulated to 150+ households to investigate how and why heating systems are used. This provides insights to be explored further and also updates the records of house improvements for participating homes to help explain any difference in energy use.

Participating households



Projected outcomes

- To *innovate* through a mixed-method approach to investigating end-use energy demand.
- To *support* a transition towards clean home energy by maximising effectiveness of existing gas and electric heating systems.
- To *raise awareness* of the benefits of zonal controls for reducing demand and even helping to combat fuel poverty.
- To *strengthen* the legacy of the EPSRC-funded DEFACTO research programme.

REFERENCES

- **BEIS, 2018.** Smart Meters Implementation Programme 2017 progress update.
- **Committee on Climate Change, 2015.** Sectoral scenarios for the Fifth Carbon Budget.
- **Faruqui, A., Sergici, S. & Sharif, A., 2010.** The impact of informational feedback on energy consumption.
- **Fischer, C., 2007.** Influencing electricity consumption via consumer feedback: a review of experience.

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