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 30 PhD 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 50 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 undertook one-year MRes programme, which allowed 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 *(Chair of Energy and Building Science, UCL)*
14:15	**LoLo highlights from the year** Professor Kevin Lomas, Director, LoLo CDT *(Professor of Building Simulation, Loughborough University)*
14:30 – 15:00 14:30	**Final year student presentations** Zack Wang – UCL Energy Institute *Sizing of district heating systems based on smart meter data: Quantifying the aggregated domestic energy demand and demand diversity in the UK*
14:40	Dan Wright – Loughborough University *A socio-technical assessment of the energy saving potential of domestic zonal space heating controls*
14:50	**Coffee, networking**
15:10 – 15:40 15:10	**Final year student presentations** Harry Kennard – UCL Energy Institute *Thermal Variety and Health: Evidence from the UK Biobank. Using a wrist-worn temperature sensor to understand participant's thermal environment*
15:20	Matthew Li – Loughborough University *Quantifying in-use thermal performance of UK homes*
15:30	Clare Hanmer - UCL Energy Institute *How flexible is UK home heating demand?*
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

LoLo Alumni:

Dr Paula Morgenstern (Building Performance Manager – BAM Construct UK Ltd)

What does net zero carbon in operation mean to construction teams?

New buildings must be net zero carbon in operation by 2030 (at the latest) to help address the climate emergency. This challenge will require involvement and contributions from all actors across the building life cycle as well as insights from academia / industry engagement. An important role in avoiding gaps between intended and actual building performance falls to contractors and small supply chain partners who built out low carbon designs.

Dr Daniel Quiggin (Senior Policy Advisor in the EU Exit, Energy and Climate directorate – BEIS)

How do different actors, from investment banks, think tanks and the civil service view the challenges and opportunities of negative emission technologies?

Questions need to be asked as to the validity and risks of relying on negative emissions technologies (NETs), such as bio-energy with carbon capture and storage (BECCS). The timing is pertinent; as countries move towards 'net zero' national targets, and we approach COP26 in 2020, the nationally determined contributions (NDCs) are being revised, as part of the Talanoa Dialogue. In the recent 1.5C IPCC report, 81 of the 90 scenarios investigated all required NETs.

Biography

Paula has a background in building services engineering and now works as the first building performance manager for BAM Construct UK, who are largely a main contractor but to a smaller extent also handle building design, facilities management and property development. Her role aims to develop the companies' strategy and capability to deliver buildings that perform in practice; avoiding performance gaps on energy, carbon as well as other building objectives. Post occupancy evaluations and the feeding back of lessons into new projects are key tools for this.

Daniel is a Senior Policy Advisor at the Department for Business, Energy and Industrial Strategy (BEIS), working in the EU Exit, Energy and Climate directorate. Prior to this, Daniel was a Research Fellow in the Energy, Environment and Resources department of Chatham House, working on a wide range of projects, such as; advising the Chinese government on global energy governance policy, analysis of macro electricity sector trends impacting the business models of utilities, assessing the evolution of mobility (focus on EVs) and the potential resource scarcity of critical metals.

Since completing her PhD through LoLo in 2016, Paula moved on to become the first building performance manager for BAM Construct UK, who are a large main contractor for non-domestic buildings. The role aims to develop the companies' strategy and capability to deliver buildings that perform in practice; on energy, carbon as well as other building objectives. Post occupancy evaluations and the feeding back of lessons into new projects are key tools for this.

In this keynote, Paula reflects on her time at UCL and how it prepared her (or not) for the task of promoting zero carbon in operation to construction teams. She will also share some observations on challenges in decarbonising the built environment from a contractor perspective, including quality in building information modelling (BIM) and working together across fragmented supply chains.

Prior to Chatham House, Daniel was an Analyst at Investec Asset Management on the second largest Commodities and Resources investment fund in the City of London, responsible for global oil and renewable energy modelling and company analysis.

Since completing his PhD through LoLo in 2014, Daniel has worked for the second largest energy investment fund in the City of London, a global think tank advising the Chinese Government on climate policy, and the UK Government on Brexit energy and climate policy. In this keynote, Daniel will reflect on the dynamics between these three key actors in shaping climate action, and specifically on the role academia has played in shaping these actors' views and approach to BECCS.

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Poster session

Ayooluwa Adewole	Adopting Solar PV for Back-up Electricity in Nigerian Residential Estates
Ahmed Ahmed	Forecasting low winter temperatures in dwellings to detect excess winter mortality risks in real-time
Minnie Ashdown	An investigation into the dynamic air exchange characteristics of existing UK dwellings with a focus on dynamical systems.
Rayan Azhari	Investigating the metering configurations in the commercial buildings in the UK
Paul Drury	No escape from the heat? Bedroom temperatures during England's hottest summer
Rami El-Geneidy	Flexineering buildings: design and implementation of control strategies for demand response
Lauren Ferguson	Incorporating socio-economic information into building physics models
Jessica Few	Understanding Ventilation in Occupied Homes
Joseph Forde	A framework towards the delivery of volume zero-carbon homes in the UK
Daniel Franks	Heating patterns in English homes
Gabriele Gessani	Techno-economic assessment of energy systems compatible with sustainable economic growth for non-domestic sector
Anna Gorbatcheva	Analysis and design of a peer-to-peer energy trading system to support local electricity grid balance
Duncan Grassie	An investigation of feedback and feedforward energy efficiency mechanisms from a UK school crowdsourced building stock model
Benjamin Halls	Occupant Behaviour: A data driven modelling approach for occupancy presence in residential buildings
Frances Hollick	Developing a dynamic method of assessing whole house thermal performance: exploring the inclusion of 4 effects
Suneina Jangra	Evaluating the in-situ thermal performance of loft insulation in cold-pitched domestic roofs: 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	Opportunities for Communal PVT Heating?
David Kenington	Can energy management be improved within retail and hospitality organisations using opportunities provided by smart meters?
Giorgos Petrou	How hot will it get? Predicting the summer indoor temperatures of English homes
Giulia Ragosa	Governing electricity distribution networks for the low-carbon energy transition in Great Britain
Niki Sahabandu	Closing the UK district heating performance gap: A case study performance assessment using real-operational data
Salman Siddiqui	The integration of heat networks with low-carbon power generation
Benjamin Simpson	Multi-criteria optimization of building design for natural ventilation
Luke Taft	
Cairan Van Rooyen	Ventilation practices in UK homes in relation to indoor air quality, noise and overheating.
Nicole Watson	Cognitive biases and consumer engagement with local energy in a multiple supplier model: Survey experiments in Britain

PhD students

Ahmed Ahmed – PhD, Loughborough University

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Ahmed graduated from the University of Birmingham with a degree in Electrical Engineering. He has gained several years of experience working in the industry and has also worked as a teacher having taught both in the UK and abroad. He gained an MSc in Renewable Energy and Architecture from the University of Nottingham in 2017 and joined the LoLo CDT ESPRC program in 2018.

Ahmed's MRes dissertation focused on forecasting internal temperatures of dwellings in the winter. His research interests are to explore novel approaches to reduce energy consumption and greenhouse gas emissions in the built environment.

Research interests

- Time series forecasting and machine learning
- Access to affordable energy and mitigation of fuel poverty
- Hybrid energy systems and energy consumption in buildings

Forecasting Low Winter Temperatures in Dwellings to Detect Excess Winter Mortality Risks in Real-Time

Excess avoidable deaths occur each winter in temperate climate countries. According to the Office for National Statistics, 50,100 excess deaths were recorded in 2017/2018 winter in England and Wales. Excess winter mortality is strongly linked with cold homes which is associated with inadequate heating, poorly insulated homes and fuel poverty. This study develops a time series forecasting model using AutoRegressive with eXogenous inputs (ARX) to provide reliable multi-step ahead predictions of internal temperatures of homes in the winter. The model was validated using a case study home located in Loughborough, UK. Internal temperature forecasts with a 95% prediction interval during periods of cold weather were produced. The ARX model achieved Mean Absolute Error (MAE) of 1.22°C for 72 h prediction horizon. This study demonstrated the potential for using time series forecasting as an early warning system to detect low winter temperatures; reduce EWM, promote energy efficiency and highlight fuel poverty.

This study intends to investigate and propose a new approach to detect and reduce excess winter mortality and morbidity risks in the winter. Excess seasonal death occurrences is a significant public health problem in the UK, particularly death occurrences related to cold weather which considerably exceeds the number of deaths recorded during non-winter seasons. The aim of this research is to explore statistical predictive modelling tools in general and in particular focus on the selection and implementation of the most appropriate time series forecasting model for the purpose of achieving multi-step ahead predictions of low internal temperatures of dwellings in the winter with acceptable accuracy

Minnie Ashdown – PhD, UCL

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Minnie graduated from Edinburgh University in 2010 with a degree in Astrophysics. After completing her undergraduate degree Minnie went on to complete an MSc in Climate Change Management, and has worked in the community sector setting up sustainable projects including a local food co-op, and with the local council and community to create entrepreneurial opportunities for local people. She is interested in improving the quality and efficiency of the building stock. Her research is focused on understanding dynamic airflow characteristics in domestic buildings through empirical measurement and inverse statistical methods.

An investigation into the dynamic airflow characteristics of existing UK dwellings with a focus on non linear dynamical systems.

Understanding building air exchange is challenging because of the spatial and temporal variability associated with parameters needed to calculate it, and the unpredictability of their combined effects. This leads to limitations around when specific methods can produce reliable results, and static values and assumptions are often used. However, use of static values, and the associated underlying assumption that they're representative of the ventilation within a space is now being shown to be erroneous, as measured ventilation rates are rarely concordant with those required by the building regulations and guidance documents. This is leading to spaces appearing to be both over and under ventilated. It is also becoming clear that this variance does not exist solely between dwellings, but also in time in a single dwelling. This work focusses on developing a method to characterise the dynamic variation of air exchange in buildings, making use of indoor and outdoor CO2 variation.

Rayan Azhari - PhD, UCL

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Rayan graduated in 2008 from Tishreen University (Syria) with a degree in Architecture. After that he completed a Master in Sustainable Buildings Performance and Design at Oxford Brookes University. He worked in Syria, Saudi Arabia and the UK in architecture as well as carrying out some research at Nottingham University on "Minimising Thermal Discomfort and Energy use in Houses". Then he joined UCL as part of the LoLo CDT programme.

Energy meter configuration in office buildings in the UK

Rayan is researching the metering structures and configurations in office buildings and the complex relationships between landlords and tenants and their responsibilities in office buildings using data from the 3DStock model and case studies with the help of members of the Better Buildings Partnership (BBP).

Paul Drury – PhD, Loughborough University

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Paul is a graduate in Mechanical Engineering from Nottingham University. He has over 18 years industry experience working within manufacturing, metrology 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, Building Performance Evaluation through monitoring methods as well as wider interests in the justice issues of energy transitions.

No escape from the heat? The frequency and intensity of indoor overheating during England's hottest summer

There is growing research interest in domestic indoor overheating in the UK. Despite increasing empirical evidence, very few studies have collected data during a hot summer or from multiple rooms. Indoor temperature data for up to five rooms in 33 semi-detached houses across the English Midlands were analyzed for a 122-day period over the hot summer of 2018. Overheating analysis was carried out using existing static criteria and the adaptive comfort guidelines defined within CIBSE's Technical Memorandum 52. All master bedrooms with monitored data had more than 5% of occupied hours exceeding 24°C-a temperature that is determined to impact sleep. The concept of a cooler room, or 'safe haven' was introduced and analyzed. Results showed that the reduction in the number of homes categorized as overheating considering the coolest living and bedroom space was only slight-although the number of hours exceeding fixed temperature thresholds was reduced, suggesting some respite from the heat.

Rami El-Geneidy - PhD, Loughborough University

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My whole career has so far been built around working with energy. During my bachelor and master's studies in Aalto University, I dug deep into energy systems and their modelling and simulation. My master thesis was about studying potential of novel energy conservation methods in passenger ships. Before ending up in the CDT to work with energy demand in the built environment, I worked in the wind power industry in sales and market analysis.

I am interested in solving practical problems in the intersection of control, computer and energy engineering in the urban built environment. I am currently exploring how buildings and communities could be made into resources of energy flexibility for demand response. 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.

Flexineering Buildings: Design and Implementation of Control Strategies for Demand Response

Increasing flexibility of the electricity system through demand-side measures can help in meeting challenges brought by the transition to a future low-carbon energy system with more electrified heating and intermittent power generation. Buildings with electric heating, ventilation and cooling systems could act as sources of flexibility by participating in demand response programmes. These programmes can act as alternatives to building new power plants or new grid infrastructure when managing peak demands. In my PhD I will introduce novel model-predictive control (MPC) strategies for buildings to deliver reserve capacity services. The capability of these smart predictive buildings to provide demand response is explored through simulations and full-scale experiments in buildings. The experiments are done in three buildings owned by Loughborough University, two domestic test homes and a commercially operated teaching building.

Lauren Ferguson – PhD, UCL

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Lauren holds a first-class Bachelor's degree in Biology from Queen Mary, University of London and worked briefly as a bioinformatician at The Wolfson Institute of Preventive Medicine before joining the LoLo Doctoral School at UCL.

Her MRes project studied the unintended consequences of an energy efficient home retrofit on childhood exposure to air pollution using modelling techniques. Lauren's PhD collaborates with Public Health England and will further study childhood exposure to indoor air pollution in the home and other indoor environments, across socio-economic groups.

Modelling Childhood Exposure to Indoor Air Pollution Across Socio-economic Groups

The effect of air pollution on health are now well-documented, especially that of vulnerable groups. Children are particularly susceptible to the health effects induced by exposure to air pollutants because of their immature immune and lung systems: Infants and young children have a higher rate of oxygen consumption per unit of body weight, therefore experiencing more pronounced health effects from exposure. Both physical characteristics of the environment and behavioural difference influence the level of air pollution we are exposed to and may vary according to socio-economic status. Children from low-income backgrounds are a population group potentially exposed to high levels of air pollution and most at-risk of developing adverse health effects. Whilst much of the existing literature has attempted to quantify the overall personal exposure of children to outdoor air pollution, the indoor environment is often excluded from these analyses despite the significant amount of time children spend indoors.

Jessica Few – PhD, UCL

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I studied at Durham University and graduated in 2013 with a first class Master of Physics degree. 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.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 Occupied Dwellings with Trickle Vents.

New buildings have become increasingly airtight in an effort to improve energy efficiency by reducing unplanned ventilation. The building regulations require adequate ventilation in new buildings for good indoor air quality. This research will specifically investigate homes where trickle vents are part of the ventilation strategy. Little research exists on the performance of trickle vents in practice despite their widespread prevalence in ventilation systems. Additionally, the stated intention according to the approved document to the building regulations is that trickle vents should be left always open, but existing research suggests that trickle vents are often closed in occupied dwellings.

There has been little research which investigates the ventilation rates achieved in occupied dwellings. This is partly because available ventilation measurement methods have several practical issues, this project will develop a method for measuring ventilation in occupied homes to address some of these. Understanding ventilation in real homes is complex, given that ventilation can be highly variable, depending on weather, building characteristics and occupant behaviour. This project will combine technical measurements in occupied case study homes and qualitative interviews with the occupants to give a detailed insight into how ventilation is manifested in these occupied homes

Jospeph Forde – PhD, UCL

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Following the successful completion of a MPhys Master's degree in Physics with Nanotechnology in 2015, Joe spent two years working as an Energy Consultant working mostly on the domestic housing new build sector. An interest in the role of the construction industry in meeting future emission targets led Joe to join the LoLo CDT in 2017.

Joe's interests include sustainable building design, the role of the planning system and local policy in delivering future ready homes, resilience and how issues relating to land impact the future of affordable housing and carbon reduction contributions of new homes.

A framework for the delivery of affordable, volume zero-carbon homes in the UK

The UK faces a dual challenge of climate change mitigation and housing affordability. Typically, low-zero carbon homes incur a cost premium for development. Under typical speculative housing development this premium would need to be paid by the home buyers decreasing affordability. Alternatively, the price paid for the development land can be decreased to cover the premium. However, this may limit the availability of development land or risk a developer being outbid by builders not applying a low carbon building standard. Local authorities can require such standards and therefore premiums to land costs by creating a regionally level playing field through the application of local plans. This work will explore at the role of local authorities in delivering low-zero carbon homes sensitive to local contexts. This will be achieved through initial qualitative work, before applying a quantitative methodology for the maximisation of low-zero carbon homes whilst attaining local affordability targets.

Daniel Franks - PhD, Loughborough University

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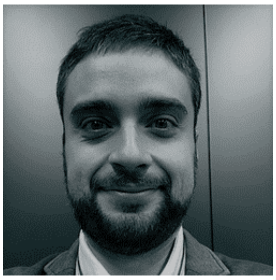
Studied mathematics from 2012-2017 at the University of Birmingham. My dissertation was on modelling wave power devices. It was this that sparked my interest in energy demand and motivated me to join the LoLo CDT in 2017.

My board interests are Human/environment interaction, Indoor climates, end-use energy demand in domestic buildings, detailed energy monitoring studies.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.

In England, as in many other Western countries, one-quarter of all energy is consumed directly in households, and the main part of this relates to maintaining a comfortable indoor climate. Research and policy efforts over the last 30years have mainly focused on more energy-efficient buildings and technologies. However, the actual energy consumption for space heating is determined not only by the efficiency of the equipment but also by inhabitants' use. Consequently, this research focuses on how different social and dwelling groups regulate their indoor climate on a national scale. This is primarily done through examining, using existing data, the internal temperatures of 1500 English homes. Conclusions will/are drawn on, the methods used to estimate heating schedules, the common temperatures and heating schedules observed in English households, the reasons behind the variation in temperatures and heating schedules between households, and how households heating habits and internal temperatures have changed over the last decade.

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 at UCL in 2015 and before joining the CDT I worked as an energy manager delivering EPCs in the domestic and commercial sectors.
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 iteratively. The approach will integrate bottom-up engineering approach with top-down macroeconomic approach. Two contrasting modelling types will be utilised 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 the 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 to optimize social welfare.

Anna Gorbatcheva – PhD, UCL

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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 gaining insights into manufacturing and plant coordination. She then joined UCL to complete her MSc with her final project modelling a blockchain-based peer-to-peer (P2P) energy trading platform.
Anna's MRes thesis focused on the analysis and design of a P2P energy trading system to support local electricity grid balance. As part of her PhD, Anna will be focusing on scalability issues of P2P energy trading systems.

Analysis and Design of Peer-to-Peer Energy Trading Networks for System Scalability

The growing number of distributed energy resources in the UK is rapidly transforming the operation of electricity grids. Installing PV and battery storage turns energy end-consumers into energy prosumers, which challenges the traditional operation of electricity networks at the distribution level.
New mechanisms are developed to include small-scale energy producers in the energy market called P2P energy trading. P2P energy trading allows individual households to trade surplus energy with neighbours and utility companies.
When conducting energy transactions on the network, physical constraints of the electric grid such as the volume of electricity injected into the network have to be considered. At the same time, P2P energy trading platforms should be designed to allow scalable market participation.
The research aims to analyse which system characteristics are required to allow dynamic scaling of P2P energy trading networks taking into account constraints from the physical electricity network layer and the financial energy trading layer.

Duncan Grassie – PhD, UCL

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I was motivated to take on my PhD in 2016 through the first hand experience of a decade as an engineer in the oil sector and the realisation that many of the fields I helped develop should be mothballed in a bid to stem climate change.

I am keen to define new methods of transferring knowledge on how buildings can be operated to reduce energy demand over time- not only to those who construct and pay for buildings, but also those who operate them. I hope that the methods tested in my PhD could help improve the links between occupant and policy maker to achieve the energy revolution required.

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

Energy demand in non-domestic buildings makes up around 17% of the UK's total carbon emissions. Although the UK school stock is more homogeneous than other sectors with available datasets for geometry and condition, there is a need to improve quality of stock level building simulation modelling by sourcing more reliable data on fabric and operation of building services.
This project tests a crowdsourcing method by first deriving the needs of stakeholders to engage through workshops, followed by local sensitivity and database analyses to determine the criticality and availability respectively of data. Finally a study of a handful of schools in the Greater London Authority is required to demonstrate the effectiveness of the base modelling required in building stock models as well as what datasets occupants are able to reliably contribute towards.

Benjamin Halls – PhD, Loughborough University

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I previously graduated from Nottingham Trent University with a master's in physics and worked within the financial sector as a pricing analyst before joining the course. My MRes was focussed on occupant behaviour, developing a better understanding of occupancy presence in domestic buildings. My PhD will continue to focus on developing a better understanding of occupant behaviour in the built environment

Occupant Behaviour: A Data Driven Modelling Approach for Occupancy Presence in Residential Buildings.
The presence and movement of occupants in a building can have a significant influence on energy demand. This is due to the requirement that occupants need to be present to interact with buildings systems such as lighting, heating and appliances. Building simulation tools use standard and repeatable occupancy schedules to simulate occupants. This may not represent the stochastic nature of occupants in a building environment, contributing to the performance gap. This study investigates occupancy presence in domestic buildings with monitored data from 20 houses. The study aims to develop a better understanding of occupancy presence and develop a stochastic model to integrate into building simulation tools which may aid in improving energy demand predictions. Results suggest occupancy presence varies noticeably by household, time of week, age and number of occupants in a household. The stochastic model performs well at reproducing and predicting occupancy presence, suitable to integrate into building simulation tools.

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 cold-pitched domestic roofs: determination of U-values and opportunities for minimising heat loss.
This project investigates the thermal performance of the insulation in cold-pitched roofs of standard construction using a combination of in-situ monitoring, visual inspection and infrared thermographic surveys. Estimated U-values based on measured heat flux and temperature data in four case study dwellings are compared against predicted U-values based on standard assumptions about the thermal conductivity of the installed building materials to determine whether or not the expected energy and cost savings associated with loft insulation are realised. The project also seeks to characterise the effects of solar gains and ventilation in roofs and test the validity of a statistical-based dynamic method for the estimation of the thermophysical properties of roofs using in-situ measurements.

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. However, empirical studies exploring the relationship between occupant behaviour and domestic indoor air quality are few and far between.

This research builds on Masters-level research to work with occupants to explore behavioural impacts on air quality, co-create solutions to any problems surrounding poor indoor air quality and identify the potential for behavioural strategies to mitigate these. An action research approach will be used to design interventions, test them and examine the efficacy and impacts using social and technical monitoring data.

Furthermore, a novel social research technique, Q Methodology, will be used to explore participant subjectivity around ventilation beliefs and behaviours to understand the complex factors that may influence existing behaviour.

Anneka Kang – PhD, UCL

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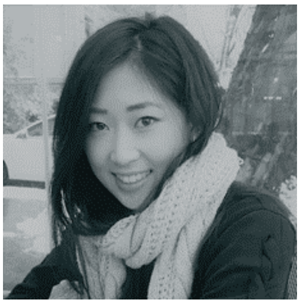

Anneka is a researcher at UCL Energy Institute, her research studies the potential for solar heating in future urban areas. With a background in Mechanical Engineering, Anneka has worked as an Energy Consultant for several large fast-moving consumer goods factories, and as a Mechanical Design Engineer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

Opportunities for communal photovoltaic-thermal heating systems with storage

With 70% of the world's population projected to live in urban areas by 2060 and 67% of current energy related emissions produced in urban areas, there is a compelling case to investigate the reduction of CO2 emissions from heating in densely populated areas in the UK or other regions with heating requirements. This study investigates how multiple dwellings sharing one PVT system with thermal and electrical storage could reduce heating emissions in densely populated areas. Initial findings carried out in Dymola/Modelica were that there is potential for greater thermal and electrical output with larger PVT systems and shared communal electrical and thermal storage. Also pre-heating a hot water tank mains water supply increases both the PVT thermal and electrical efficiency.

David Kenington – PhD, UCL

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David is a social scientist, specializing in researching organizational behaviour and its implications on energy demand. Prior to commencing his PhD, he worked at the Energy Saving Trust in research and evaluation roles and at Databuild Consulting Ltd (now Winning Moves) undertaking research-based consultancy for clients including BEIS, DfT, TfL, Defra, WRAP, Carbon Trust and Energy Saving Trust.

Can energy management be improved within retail and hospitality organisations using opportunities provided by smart meters?

This project centres around the question of 'how can energy management be improved within retail and hospitality organisations using opportunities provided by smart meters?', with the broader goals of improving energy efficiency and delivering other benefits, such as reducing costs and improving productivity.

This action research PhD study is supporting the design of a new energy management system for retail and hospitality organisations called GlowPro. The study aims to understand whether energy management can be improved using opportunities provided by smart meters.

Non-domestic energy demand is a complex, under-researched socio-technical issue and a participatory action research approach using principally qualitative social research methods is being employed. The researcher is working with the GlowPro consortium (led by Hildebrand Technology Ltd) undertaking research with target customers and other involved actors to help inform the design and deployment of GlowPro.

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

Giorgos Petrou – PhD, UCL

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I joined LoLo in 2016, following the completion of my Physics BSc degree at the University of Warwick, with an interest in the complex interaction of Climate Change with the built environment, health and wellbeing. Initially, I explored the influence that the choice of simulation tool and algorithms can have on the CIBE TM59 overheating assessment while now my focus has shifted to the assessment of indoor temperatures at the housing stock level. Besides my own work, I've enjoyed participating in other health-related projects and delivering tutorials for the Advanced Building Simulation module offered by the MSc EDE course.

Bayesian calibration of the UCL English Housing Stock model for indoor temperature prediction

As the high temperatures experienced during the summers of 2018 and 2019 will likely become commonplace by 2050, adaptation to higher indoor temperatures while minimizing the need for mechanical cooling is required. This can be achieved by understanding the factors that influence indoor temperatures and capturing them effectively in a model. The 2011 English Follow-Up Survey was used to analyse the interaction of 11 dwelling and 9 household characteristics with summer indoor temperatures. Factors such as the main heating system, tenure and occupant vulnerability were all found to have a statistically significant association with the indoor thermal environment. Following these findings, the same dataset is now used to develop a Bayesian calibration framework that will validate and improve the UCL archetype-based English housing stock model. The calibrated thermal simulation model could be used to predict the housing stock's indoor temperatures under future climate scenarios, inform the uptake models of mechanical cooling and enable the costs/benefit analysis for heat adaptation measures

Giulia Ragosa – PhD, UCL

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After studying and working as a journalist, Giulia undertook an MSc in Global Governance and Ethics at UCL. During this time, she conducted and published quantitative research into the policy drivers of renewable energy investment in the context of developing countries. Since joining LoLo in September 2018, her main focus has been on the role of public institutions in fostering the innovation of electricity infrastructure to enable the integration of low-carbon energy technologies in the low-voltage network. In her MRes, she drew insights from political science to study the governance of the distribution grid in Great Britain.

Governing the electricity distribution grid for the low-carbon energy transition

Giulia has now started her PhD, in which she is comparing the UK experience with that of countries with different institutional environments to see whether lessons can be drawn from their policy and regulatory strategies to steer change in networks industries and unlock the value of distributed energy resources. Giulia's research relies on qualitative analysis and the solicitation of key energy system stakeholders

Chameli (Niki) Sahabandu – PhD, UCL

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Prior to successfully completing the MRes in Energy Demand Studies at UCL, Niki completed a Masters degree in Physics at the University of Liverpool where she also worked as a research intern for the 'Muon g-2' group which is part of a global experimental group that deals with high precision particle data.

An interest in growing as a researcher by learning in an interdisciplinary environment as well as a drive to understand and solve real-life energy demand problems lead her to join the LoLo CDT.

Closing the performance gap in UK district heating: a multiple case study performance assessment

There are around 2000 DHS in the UK; a number that is expected to increase because of the role that DHS have been given in UK climate strategies due to their emissions saving capabilities. Troublingly, studies indicate that DHS in the UK are underperforming and, in some cases, producing more than double the emissions of the individual boiler counterfactual. Furthermore, government reports show that some consumers are having to pay unfairly high heating costs due to the misaligned economic incentives of the developers that lead to high operating costs. This is especially a concern in social housing (where heat networks are seen as an attractive means of supplying heat) where consumers are at a higher risk of fuel poverty.

To address the above socio-economic and environmental issues, the UK government has been urged to consider regulating heat networks such that their standard of performance is improved and resulting heat costs are reasonable. A Code of Practice (CP1.2) developed by industry are being considered as the basis for such regulation. The research proposed attempts to aid the application of CP1.2 as a regulatory framework to facilitate the performance improvement of DHS. The research is a multiple case study that aims to collect operational data, carry out performance analyses, and identify and develop solutions for performance issues for a representative set of DHS.

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. For his PhD, Ben is continuing with CFD and natural ventilation. Particularly looking into the use of CFD for ventilation and building design optimization. His project title is "Multi-Criteria Optimization of Building Design for Natural Ventilation"..

Multi-Criteria Optimization of Building Design for Natural Ventilation

With the performance of natural ventilation being influenced by the building design. It is crucial that the natural ventilation strategy being used is sufficiently considered into the early stage design of a building. In this project, multi-criteria optimization techniques will be investigated to identify the natural ventilation performance improvements that can be achieved by optimizing the buildings design. The performance metrics used include PMV, PPD and draft for thermal comfort and ventilation effectiveness for IAQ. Acoustic comfort is also being investigated as a design criteria.

An Evolutionary Algorithm (EA) will be used to generate the different design possibilities, with the fitness evaluation being conducted by Artificial Neural Networks (ANN) acting as surrogate models. The ANN's will be trained by the use of Fast Fluid Dynamics (FFD) and Computational Fluid Dynamics (CFD) simulations. These different modelling techniques are being used to reduce the high computation time requirements compared to using only CFD simulations for the fitness evaluations.

Cairan Van Rooyen – PhD, UCL

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A Chartered building services engineer and building physicist with 14 years experience as a senior consultant in multidisciplinary consultancies.

Research interests involve occupant ventilation practices and how this impacts and determines the quality of the indoor environment, specifically overheating, indoor air quality and noise.

Ventilation practices in UK homes in relation to indoor air quality, noise and overheating risk, and their impact on health and well-being

Europeans spend most of their time indoors. Ventilation practices have a direct influence on the indoor environment and are of central importance for our understanding of the health and well-being of building occupants. Changes to the climate alongside trends in urbanisation, densification, urban heat island effect, airtight dwellings, and a growing and ageing population are all factors that influence IEQ and present an increased risk to the health of the UK population. This research sets out to understand the relationships between IEQ and ventilation practices, and specifically to understand how ventilation practices impact and determine IEQ holistically.

Nicole Watson – PhD, 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 policy and quantitative research methods. Alongside her MSc, she worked for a climate change adaptation consultancy and undertook an internship in metadata enhancement for longitudinal studies. In addition to energy research, Nicole is interested in open science, research methodology, and scientific communication..

Beyond the supplier hub: Understanding consumer engagement with multiple supplier models

Multiple-supplier models (MSMs) have been proposed as a solution to the challenge of integrating renewable distributed energy resources into the centralised grid. MSMs would allow consumers to retain their contract with their current (national-level) supplier whilst taking on additional contracts with local suppliers or engaging with other business models, such as peer-to-peer energy trading or electric vehicle charging schemes. Whilst this model offers a promising alternative to the supplier hub principle for facilitating innovation in the energy market, evidence of how domestic consumers might respond to MSMs is sparse.

This PhD project applies behavioural economics as a framework and uses experimental methods to understand consumer attitudes towards MSMs and new business models enabled by distributed energy resources. The project builds on the results of MRes work, which focused on consumer engagement with local energy suppliers in an MSM.

Dan Wright – PhD, Loughborough University

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Dan's background is in psychology and sustainability, having worked for an international conservation charity for three years before joining the LoLo CDT at Loughborough University. His MRes research (supervised by Prof. Kevin Lomas and Dr Victoria Haines) focused on the adaptive opportunities, actions for, and barriers to, mitigating overheating in vulnerable UK dwellings such as bungalows.

He is in the second year of his PhD research (supervised by Dr Victoria Haines and Dr David Allinson) which builds on the legacy of the EPSRC-funded DEFACTO research programme by investigating further into the potential of zonal space heating controls as means of reducing domestic space heating energy demand. This is being approached through a mixed-method analysis of both physical data and occupant experiences with the system and user-interface, with outcomes supporting the growing evidence-base related to the role that zonal space heating controls could play in reducing UK domestic energy demand.

Dan's research is part-funded by Simble, an Australian software-as-a-service company who are moving into the UK domestic energy market. Dan has been collaborating with Simble on a series of blog articles synthesising the latest research and news in the energy space. Dan is also a co-host of the Building Energy Research Group podcast (BERGcast) available for free on Spotify, Google Podcasts and other sources..

Nathan Moriarty – PhD, UCL

on interruption of studies

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 –

on interruptionof Studies

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.

Letitia Zainea – UCL –

on interruption of studies

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.

Zareen Sethna – PhD, UCL

on interruption of studies

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.

Final year PhD students

Charalampos Angelopoulos – PhD, Loughborough University
Research Engineer in Mitsubishi Electric R&D Centre Europe B.V – UK Branch.

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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 at Loughborough University where I obtained my MRes in Energy Demand with distinction. My PhD research focused on the 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 was to develop control algorithms for mixed-mode buildings in hot climates. Initially, it was important to identify all the control parameters that were important to be included in the control algorithms. Then the control algorithms were designed and presented in flow charts. To analyse the performance of the proposed control algorithms, computer simulations were performed, whilst a validation analysis was conducted to provide evidence of the validity of the control algorithms. Computer modelling comprised of co-simulations, using Dynamic Thermal Modelling (DTM) (EnergyPlus) and equation-based tools (Dymola using the Modelica language). The coupling of these was achieved using the Functional Mock-up Interface (FMI) for model exchange. The co-simulations enabled to examine the energy saving potential that can be achieved by the proposed control algorithms. In order to evaluate the ventilation performance of the proposed control algorithms, the ventilation rates and ventilation effectiveness of the systems were analysed using Computational Fluid Dynamics (CFD). This allowed the final analysis which included the evaluation of the ventilation performance of the control algorithms by calculating the ventilation effectiveness. To provide evidence of the proposed control algorithms and simulation approach, a validation study was done using data from an experimental chamber in India.

This research contributed to the existing body of knowledge by providing the four main conclusions with regards to the design and control of mixed-mode ventilation and cooling systems: i) to delivery of comprehensive guidelines on the design and control of mixed-mode buildings, and the ways in which the co-simulations can be implemented to improve the existing control algorithms that can be found in the literature; ii) the use of the co-simulations showed that the developed control algorithms, when dampers/windows and ceiling fans are used, can improve the predicted hours of thermal comfort by up to 1900h compared to base-case scenarios while achieving up to 55% energy reduction depending on the city; iii) The CFD simulations predicted that cross ventilation with the maximum opening areas for windows and dampers in combination with the operation of the ceiling fans can dissolve the contaminants and/or heat in the building resulting in comfortable internal environments resulting in ventilation effectiveness of up to 1.65; and iv) the accurate and validated control algorithms that were developed in this research can be used for any study that requires control of mixed-mode buildings regardless of the geometry of the building. The use of co-simulations provides great flexibility since the same control algorithms can be used in any geometry or building location without the need for any modification of the code.

Konstantinos 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 a doctoral researcher at Loughborough University as member of the LoLo CDT and is at the writing-up of his PhD thesis.

Investigation of effective paths for community energy at the concept design phase

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 model has been developed to analyze the costs, emissions and energy balance of CES and enhance informed design decisions.

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

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's MRes dissertation in 2016 was on the subject of How household thermal routines shape patterns of heating demand. She is in the final stages of completing her PhD looking at the flexibility of home heating demand. In November 2019 she starts work as a Senior Research Associate at the Tyndall Centre, UEA.

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 led 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. In 2003 she gained an MSc in Renewable Energy from the University of Reading and in 2014-15 she pursued her interest in the social aspects of energy demand by studying for an MSc in Energy and Society at the University of Durham..

How flexible is home heating demand?

Most future scenarios for decarbonising the UK energy system include a high proportion of homes with electric heat pumps. Shifting current heating demand patterns to the electricity network would increase peak demands. Demand management to reduce this peak can only be achieved if households are prepared to accept flexible running times for their central heating. Clare's PhD investigated what this flexibility looks like from the perspective of the households involved.

The case study is a trial of hybrid heat pumps (gas boiler and electric heat pump in parallel) with smart controllers to enable demand management. Hybrid heat pumps have the advantage of fuel switching between electricity and gas as well as shifting electricity demand in time.

The investigation is multidisciplinary, analysing both quantitative data from heating controllers and qualitative data from interviews in trialists' homes. This enables both quantifying the running patterns of heating and asking the residents why they have chosen them. The PhD explores how residents adapt to a new heating system with algorithmic control and unfamiliar running patterns. 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 studied Physics at undergraduate level, before joining the LoLo CDT in 2015. Addressing energy demand seemed a real-world and relevant way of aiming to combat dangerous climate change..

Developing a dynamic method of assessing whole house thermal performance

Accurately assessing the thermal performance of dwellings is vital to achieving a reduction in emissions from the domestic sector, however most current methods require an unoccupied home or a lengthy dataset. These conditions can respectively affect the accuracy and applicability of a method, and thus this project aims to accurately characterise occupied dwellings using a dynamic method. Lumped thermal capacitance models are used, using Bayesian parameter estimation techniques.

Harry Kennard – PhD, UCL

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Harry is a Physics graduate and energy researcher from mid-Wales. He is most interested in the health impacts of climate change and energy use in the built environment. Before his LoLo PhD, he got an MPhil in Applied Mathematics and MA in Linguistics. Alongside academic research, he occasionally works in journalism. His most recent work appeared online at Slate.com

Experienced Temperature and Health

Dangerous cold exposure contributes to winter mortality rates in the UK. However, determining when, where and for whom this exposure occurs is challenging. Rather than using static measures of ambient temperature, this study makes use of experienced temperature – a novel measure of the immediate thermal environment of an individual. The relationships between experienced temperature and sociodemographic, housing and health factors were examined using data from a longitudinal observational health study of over 100,000 participants (the UK Biobank). Each participant wore an activity monitor, which also measured temperature. The coldest times of the year were found to be associated with lower experienced temperature. Experienced temperature increases with age and decreases with activity level, health satisfaction and whether a solid-fuel open fire is used for home heating. There is clear evidence that low standard deviation of experienced temperature, named thermal variety in this study, is associated with poor health.

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.

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

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.

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..

Management of electric heating through heat pumps: A systematic exploration of comparative advantages of individual scale versus district level.
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.

This study aims to better understand heat consumption in domestic buildings through analysing empirical data from a large group of dwellings and evaluate the role of heat pumps and district heating by assessing the topological configurations of heat pumps and district heating networks for various types of dwellings at 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 from different perspectives, including technical performance, carbon emissions, and financial practicability.

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.

Aligned PhD students

Ayooluwa Adewole – PhD, UCL

a.adewole.17@ucl.ac.uk

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. He is currently a Doctoral researcher at the UCL Energy Institute, exploring adoption decisions for solar energy in Nigeria. Prior to 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.

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 reliance on self-generation through noisy and polluting back-up (diesel and petrol fired) generators. By adopting solar energy, residents can enjoy benefits such as reliability, clean air and serene environments, provided the adoption is carried out collectively such as in neighbourhoods where generators are restricted. Using both qualitative and quantitative methods, this study investigates 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. Initial findings suggest preference among respondents for alternative clean energy sources over conventional generators. The clean and quiet attributes of back-up energy and the ability to trade energy are also found to have significant and positive influence on the likely decisions of respondents.

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

Appendix: Posters

NOTES

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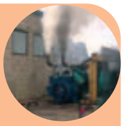
Adopting Solar PV for Back-up Electricity in Nigerian Residential Estates

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

Ayooluwa Adewole 3rd Year PhD Student, UCL Energy Institute
a.adewole.17@ucl.ac.uk
Supervisors: Michelle Shipworth, Xavier Lemaire, Danielle Sanderson

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

Choice Experiment

1. Qualitative: Interviews with real estate agents, estate developers, home buyers
2. Quantitative: Choice experiment with homebuyers of new residential estates: 650+ respondents

Attributes of the house	Option A	Option B	Option C
Backup	Inverter	Solar	Generator
Pollution	None	None	Yes
Energy Trading	Selling	Selling	Not available
House price	₦10M	₦10M	Same price of your home
Backup price	₦2M	₦2M	Same price of your current gen
Most preferred type (Choose one among 3)	Option A ☐	Option B ☐	Option C ☐

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

Initial Results from Choice Experiment

1. There appears to be relatively high degree of interest in replacing generators with cleaner alternatives
2. Respondents seem to have some interest in energy trading

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Forecasting low winter temperatures in dwellings to detect excess winter mortality risks in real-time

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

Ahmed Ahmed (1st Year PhD) **MRes Supervisor: Rob McLeod**

Background:

- Cold homes in the winter lead to an increase in heart diseases, stroke, circulatory and respiratory problems.
- There is a strong relationship between temperatures and health related problems.
- The World Health Organisation (WHO) recommends 21°C in living rooms and 18°C in other occupied spaces
- This study investigates a new approach to detecting and reducing excess winter mortality and morbidity

Aims of the study:

- To explore statistical predictive modelling (time-series) to forecast internal temperatures of homes
- To assess the potential for AutoRegressive with eXogenous inputs (ARX) models to make reliable multi-step-ahead predictions

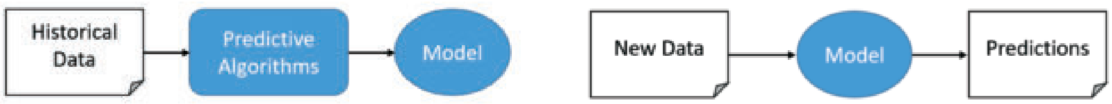
Case Study: Refit Smart Homes

- Temperature data collected in 20 homes in Loughborough, UK, from 2013 to 2015

Model validation:

- **Forecasting** error $\mathcal{E}_t = y_t - \hat{y}_t$
  - $\mathcal{E}_t$ is the forecasting error
  - y_t is the actual internal temperature
  - $\hat{y}_t$ is the internal temperature forecast
- **Mean Absolute Error (MAE)** = average($|\mathcal{E}_t|$)
- **Root Mean Squared Error (RMSE)** = $\sqrt{\text{average}(\mathcal{E}_t^2)}$

Time Series Forecasting: Statistical modelling

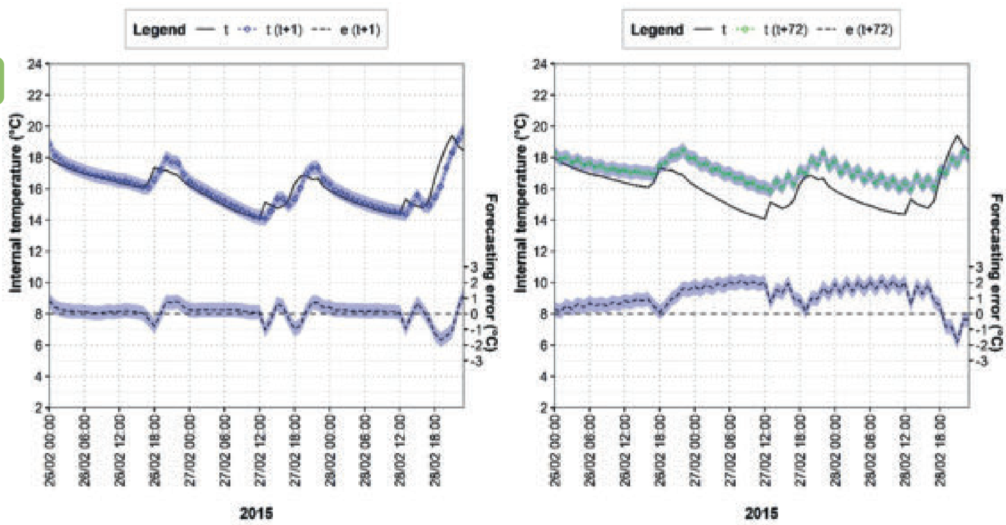


$$Tint_{(t+1)} = f\,(Tint_{(t)}, Tint_{(t-1)}, Tint_{(t-2)}, Tint_{(t-3)}, \dots Tint_{(t-n)})$$ → next hour = *f*(present hour, previous hour, 2-hours ago etc.)

ARX model achieved an accuracy for MAE of 1.22°C for 72h forecasts.

Conclusions

- ARX model achieved an accuracy of MEA of 1.22°C for 72h forecasts.
- Forecasting models could be used:
  - as an early warning system
  - Promote energy efficiency, and
  - highlight fuel poverty.



Observed temperature (t), temperature forecast for prediction horizon h, t (t + h), forecasting error, e (t + h), and the 95% prediction interval (shaded area)

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An investigation into the dynamic air exchange characteristics of existing UK dwellings with a focus on dynamical systems.

Minnie Ashdown, 2nd Year PhD Student. Supervisors: Cliff Elwell and Jenny Crawley

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Centre for Doctoral Training in Energy Demand

Background

- Airflow impacts odour, mould spores, and sound transmission throughout spaces as well as occupants comfort and health through pollutant exposure, exposure to drafts, condensation, and heat loss.
- Building air flow characteristics are understood in terms of air changes per hour (ACH) or permeability (resistance of a building to infiltration).
- Building regulations specify static values for new dwellings Air Change Rates based on the ventilation system and required level of airtightness.
- BUT: Air exchange is the result of many complex processes in a dynamic environment, with both non linear and stochastic effects present

Model

CO_2 dynamics are often used to calculate a time varying Air Exchange Rate (λ) based on a simple mass balance:
(No internal source of CO_2 present)

$$\frac{d}{dt} < C(t) > / \, (C_s - < C(t) >) = \lambda$$

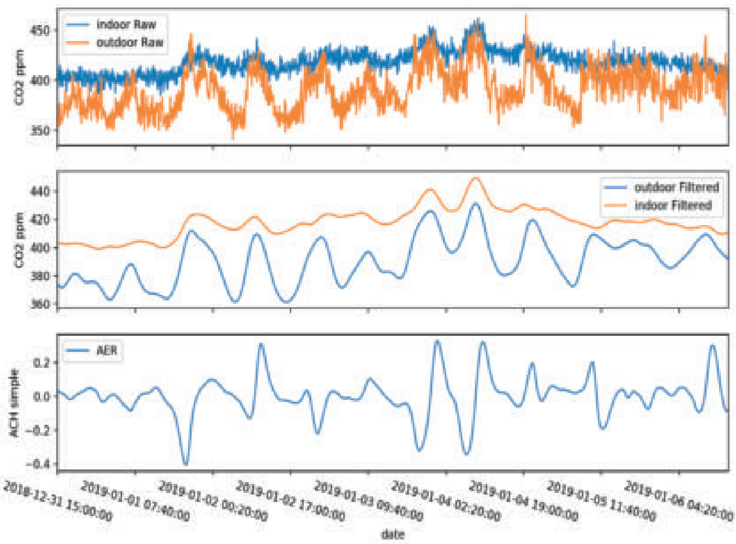
$< C(t) >$ = spatial average of concentration inside room
C_s = Concentration of CO_2 entering room.
λ = Air Exchange rate
BUT: If $C_s \rightarrow C_s$ (t)
A time varying Air Exchange Rate may be calculated using $C_s(t) = external\ CO_2$ concentration

Caveat: This is still a very simple model that needs additional terms to cope with more system variability.

Method

- Internal and external CO_2 time series data from unoccupied properties is collected
- The data is noise filtered using a low pass Butterworth filter at 4.78E-5Hz (approximately a 6 hour period). This removes unwanted effects
- Then the mass balance equation is either used directly (simple method) to calculate the Air Exchange Rate,
- A time varying Air Exchange rate is then available.

CO_2 data from an unoccupied dwelling in winter 2019 is shown, with a vertical offset, along with noise filtered data used and the AER calculated



Comments

- Time varying AER with peaks in the expected range.
- Resembles a random walk as expected
- Better cross calibration needed to better assess offset: AER sensitive to offset
- Results highly sensitive to the filter cutoff frequency
- Bulk air exchange rates should not be negative, hence the flow dynamics described above are not sufficient to described the granular air exchange rates

Going Forward

- How much time does a particular building spend in various air exchange 'regimes'. What is the variation within and between buildings?
- Extend the basic model to account for further system dynamics including wind (stochastic effect), thermal effects, and pressure fluctuations
- Understand uncertainty

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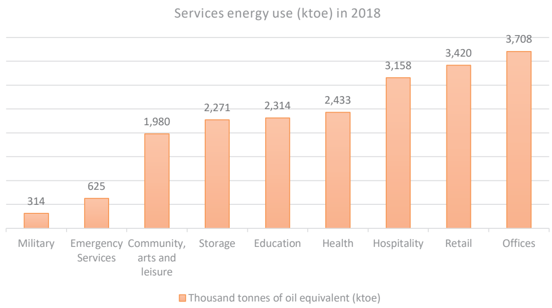
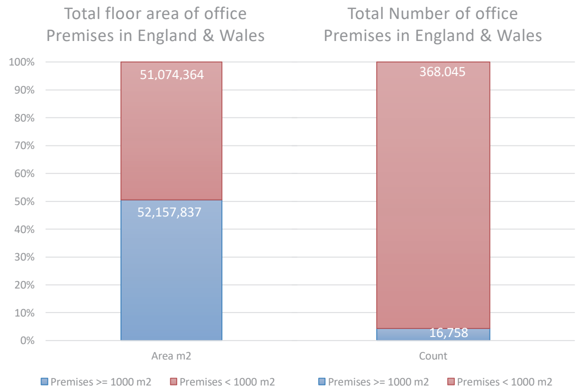
Investigating the metering configurations in the commercial buildings in the UK

Rayan Azhari (2nd year PhD) Email: rayan.azhar.17@ucl.ac.uk

Background

- The Design for Performance Pioneers (13) committed to trial the design-for-performance approach on (at least) one new office development starting in 2019 for 3 years (similar to NABERS).
- DfP Commitment Agreement seeks to guarantee the energy performance of the 'Base Building' (services under landlords control such as; HVAC, hot water, of the whole building, light and power in communal areas, and lifts)
- The UK committed to reducing its greenhouse gas emissions to net zero by 2050 (BEIS, 2019), compared with the previous target of at least 80% reduction from 1990 baseline under The Climate Change Act 2008 (DECC, 2008).





Gaps in the literature

- tenant energy use and the variety arrangements for metering provision in tenanted offices 'split incentive'.
- Lack of information on the commercial office building meter configurations
- Lack of information on the tenants energy use

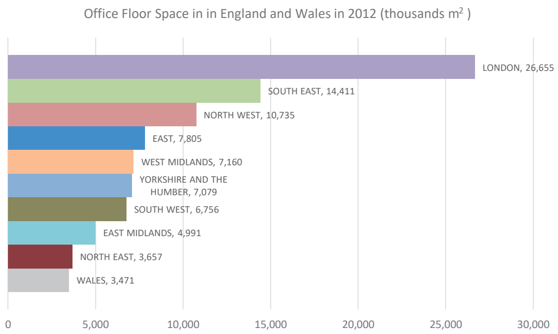
Aim

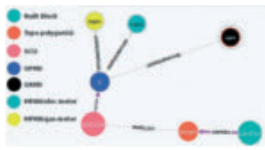
This project aims to provide a classification of metering configurations and their distribution in the commercial office building stock; and establish the scale of the challenge to introduce metering arrangements for accurate accountability.

Research Question:
What are the metering configurations in commercial office buildings in the UK?

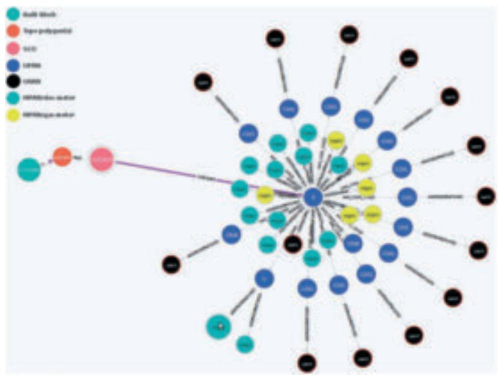
Methods:

- Statistically analyze meter data in SCUs from the 3DStock model to classify and understand the metering structure and energy use the office building stock.
- Case studies: analyze the actual energy performance and the tenant/landlord energy split and responsibilities and their contractual relationship.

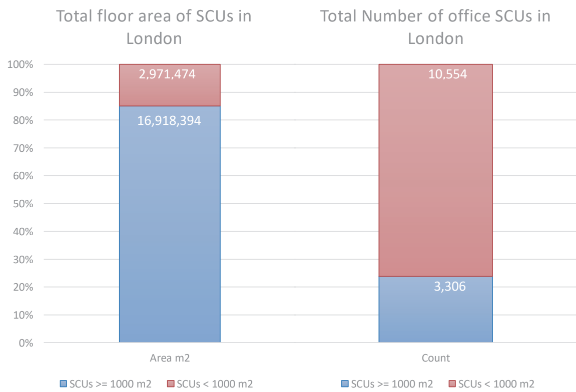




This show real examples of different relationships between meters, premises and footprints in Self Contained Units. The key distinguishes urban blocks (BuiltBlocks), building footprints in the OS Topo layer (Topo polygons), SCUs, Unique Property Reference Numbers (UPRNs), VOA hereditaments (UARNs), electricity meters (MPANs) and gas meters (MPRNs). This figure relates to a single-storey shop. (Evans, Liddiard et al. 2017)



Relationships between meters, premises and footprint in a large multi-storey SCU containing 14 office hereditaments. (Evans, Liddiard et al. 2017)



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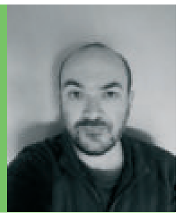
No escape from the heat?
Bedroom temperatures during England's hottest summer



Paul Drury Year 1 PhD, Loughborough University P.Drury@lboro.ac.uk
Supervised by **Prof Kevin Lomas**

Introduction and Objectives

Context

- Elevated bedroom temperatures can degrade quality of sleep and impinge on health and wellbeing.
- Indoor overheating requires "urgent action" (HM GOVT, 2017).

Research Question

- In hot summers, do people have a '*safe haven*' especially for sleeping?

Method

- Measurements in 2018 - the joint hottest UK summer on record.

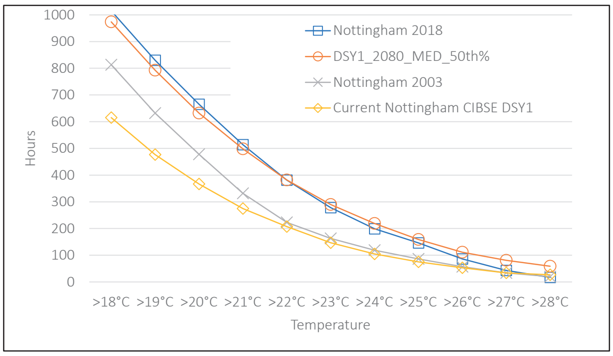


Figure 1 Temperatures across midlands **comparable with 'near-extreme' summers of 2080** under a medium emissions scenario

Key findings

The CIBSE static overheating criterion was exceeded in 78% of master bedrooms and 74% of other bedrooms.

In half of the master bedrooms, temperatures exceeded 24°C for more than a third of sleeping hours.

Even if all occupants slept in coolest bedroom, 70% would still experience overheating.

Homes with an EPC rating in Band E had lower incidence of overheating.

Discussion points

- Is overheating assessment in existing buildings to determine moment-by-moment comfort of occupants or the overall perception that a building overheats?
- Are the methods developed for predicting overheating applicable to monitoring studies?
- How can the weather during a monitoring study be 'normalised' for region and year?

Methods and Analysis

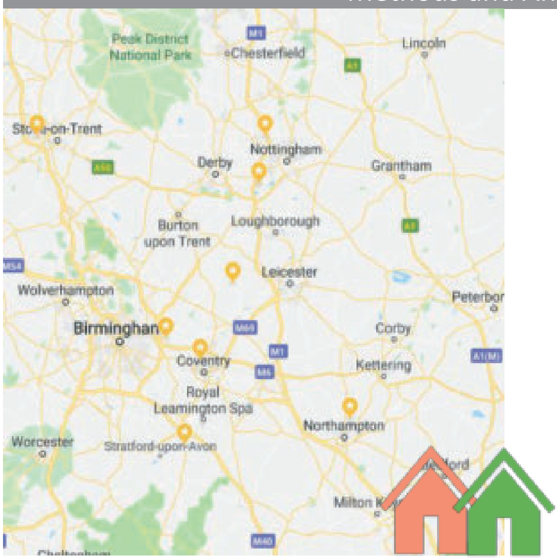


Figure 2 (Source: Google maps)

- **33 Semi-detached** houses in the English Midlands.
- **Monitoring** in up to five rooms for **122 days** over **summer 2018**
- **Building and household surveys**
- **Overheating** evaluated using **CIBSE TM52 static criteria** and adaptive comfort criteria.
- **Influence of dwelling and household** on overheating evaluated
- **Master bedroom** temperatures **compared** against **coolest bedroom.**

Finding a safe haven

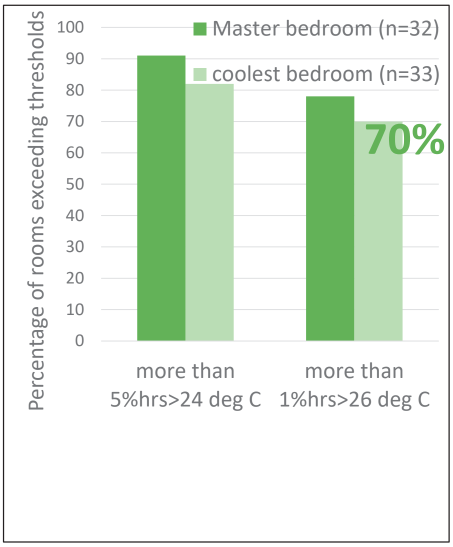


Figure 3

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References
HM GOVT (2017) *UK Climate Change Risk Assessment 2017.* London: HMSO

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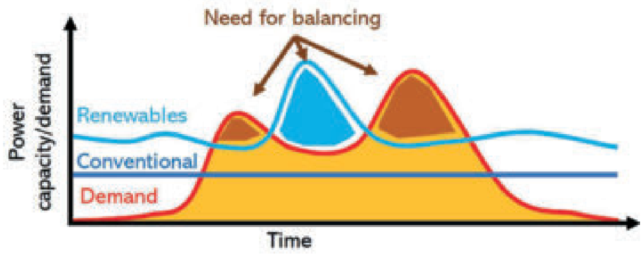
Flexineering Buildings: Design and Implementation of Control Strategies for Demand Response

Rami El Geneidy, Dr. Bianca Howard, Dr. David Allinson

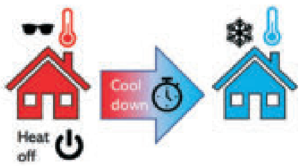
The Balancing Challenge

- Transition to low-carbon energy systems creates a challenge for **balancing energy systems**.
- **Energy flexibility** means the ability to modify energy demand or supply to reduce imbalances.
- Flexibility is in practice realised through **demand response** programmes and intra-day markets.



Building Energy Flexibility

- **Thermal mass and heating systems** provide flexibility potential.
- To participate in demand response, scalable **aggregation** of building flexibility is needed.

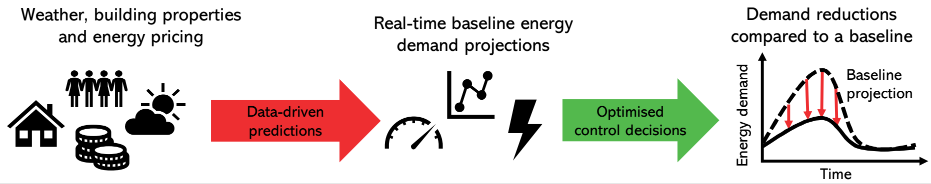


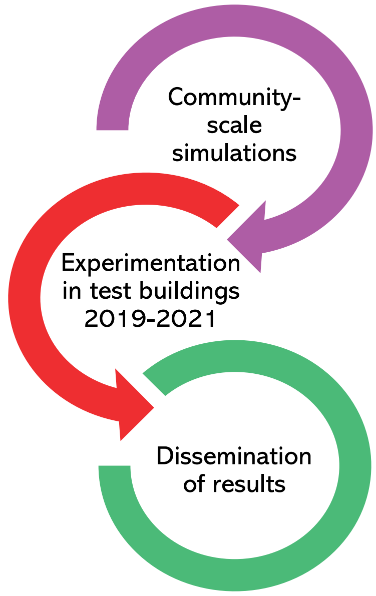
Research Aim

Design, implement and evaluate a scalable community-scale control strategy allowing buildings to access demand response schemes with their energy flexibility.

Design and Implementation of Novel Controls

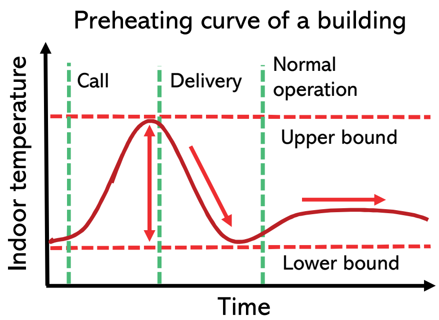
- **Model-Predictive Control** produces optimal control decisions in real-time using information about the building and weather forecasts.
- A data-driven control strategy based on **ARX-models and linear programming** has been developed.
- The control strategy can be used by **aggregators** to request for demand modifications when demand response is needed.
- **Dynamic heat demand projections** are used to incentivise buildings to meet demand modification requests by aggregators.





Results and Further Work

- Control algorithm validated with **co-simulations.**
- Potential to deliver **a fixed demand reduction** from an English community varies between 5-30 min.
- Flexibility is characterised by **physical, contractual and behavioural** elements.



Back-to-back repeated experiments

Full-scale experiments with the MPC in two test homes and one campus building.

Days	1-2	3-4
Demand response	None	Evenings + mornings

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Project in GitHub:

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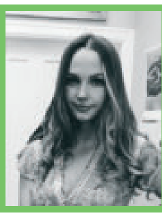
•Incorporating Socio-economic Information into Building Physics Models



•**Lauren Ferguson** MPhil/PhD 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. Policy-mediated modifications to the built environment are associated with compromised health, comfort and wellbeing (Shrubsole et al., 2014). One way this can occur is through the emerging dichotomy that arises between increased building airtightness and the maintenance of optimal indoor air quality. Given their limited resources to adapt to changing conditions, vulnerable populations within society, such as those of low socio-economic status (SES), may be disproportionately affected by the unanticipated effects of policies which are implemented without consideration of the wider socio-economic processes governing the space. Indoor environment modelling (IEM) is a growing area of research offering a methodology through which evidence regarding adaptions to the built environment can be robustly examined before implementation (Shrubsole et al., 2016), preventing impacts falling disproportionately on those of low SES and reducing inequalities. This may be achieved by incorporating socio-economic information into indoor environment modelling, but this is not yet widely explored in the literature.

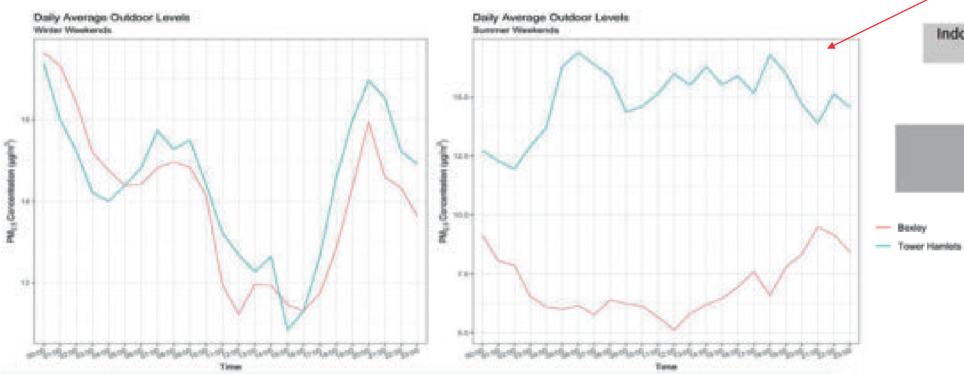


Figure 1. Outdoor weekend concentrations, averaged over the Winter and Summer seasons for Tower Hamlets (low socio-economic case) and Bexley (control).

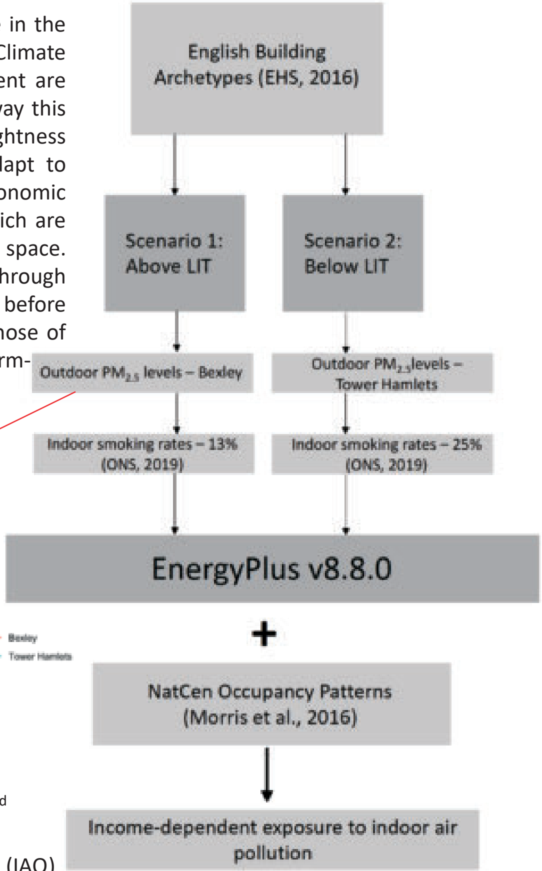


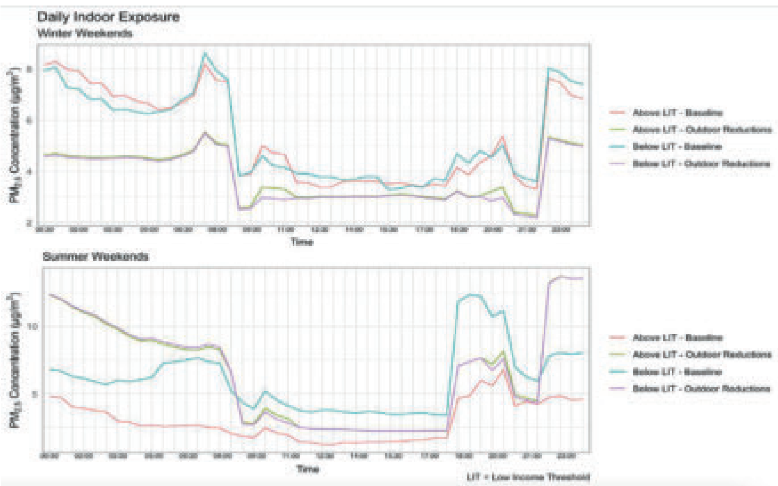
Figure 2: Flow chart outlining data inputs and sources for the modelling framework.

Methods: The building physics model, *EnergyPlus,* was used to model the indoor air quality (IAQ) of two socio-economically different populations. Two policy interventions; energy efficient building modifications and reduced outdoor air pollution concentrations, were evaluated as a proof of concept. Exposure was modelled for populations identified by the English Housing Survey as above and below the low-income threshold (LIT), defined as households which live on less than 60% of the UK's median income (Francis-Devine et al., 2019).

Socio-economic effects were introduced into the model via:

- **Outdoor concentration levels** (Figure1)**;**
- **Building archetype composition;**
- **Indoor smoking prevalence.**

Data inputs are outlined in Figure 2.



Results: For the home retrofit, as no additional ventilation features have been provided, the energy upgrade has increased exposure to $PM_{2.5}$ in the home for both cases, by reducing the extent of background ventilation, this was particularly pronounced in the low socio-economic model as indoor levels were higher due to higher indoor smoking rates and smaller dwellings which have a lower volume for the distribution of indoor-sourced particles. When outdoor concentrations were reduced, both homes above and below the LIT had similar levels of indoor $PM_{2.5}$ of outdoor-origin on winter weekends. In summer, average diurnal levels were higher in households below the LIT due to the higher baseline outdoor concentrations (shown in Figure 1) and the higher summer air exchange rates – higher levels of infiltration due to window opening.

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Understanding Ventilation in Occupied Homes

Jessica Few
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Supervisors: Dr Cliff Elwell & Michelle Shipworth

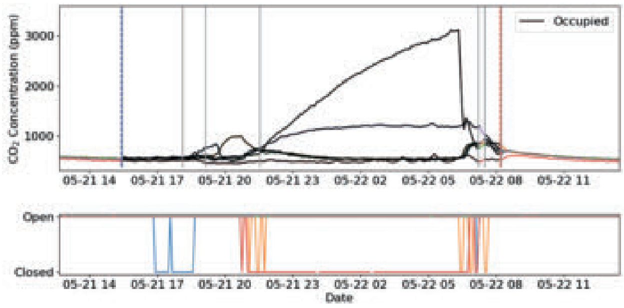
London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

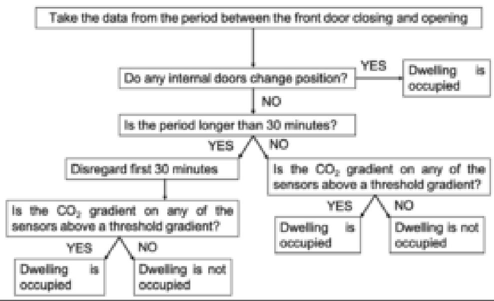
Context and Aims

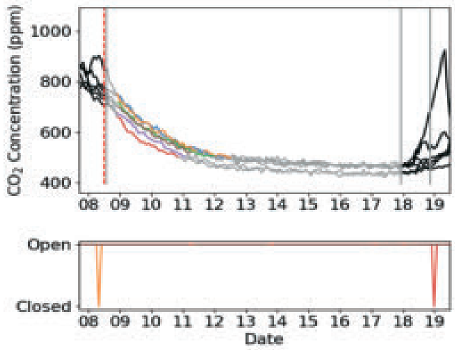
- **Ventilation** is required to maintain good **indoor air quality**, but too much can reduce the **energy efficiency** of a building. In the UK, building regulations require adequate ventilation for the people in the building.
- However, understanding ventilation is challenging because of the wide variety of factors which affect it, including **building characteristics, weather and occupant behaviour**.
- This project takes a **sociotechnical** approach to give detailed insights into ventilation in occupied case study homes. This will involve developing a method for measuring ventilation in occupied homes so the **ventilation rates that occupants experience** can be assessed in a series of case study homes, as well as **semi-structured interviews** so that the **occupant's influence on and experience of ventilation** in their home can be investigated.

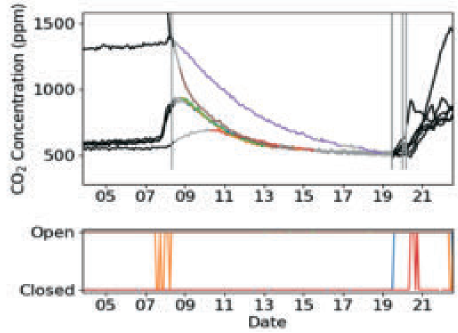
Developing a method for ventilation measurement in occupied homes

- CO_2 based ventilation measurement methods require knowledge of when the occupants are present.
- An algorithm has been developed for estimating when a building is occupied, this algorithm achieved an **87% agreement** with occupant records of occupancy periods.





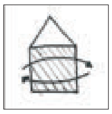
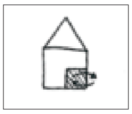




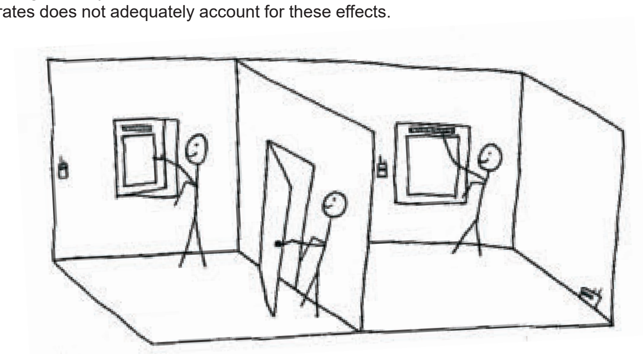
- These figures demonstrate that **configuration of internal doors** have a significant impact on the CO_2 decay and the resulting interpretation of the ventilation rate.

Results of investigations on door closure and trickle vent use

- An investigation was carried out in an unoccupied test dwelling, ventilation rates were measured using the CO_2 tracer gas decay method.
- The building regulations recommend a whole dwelling ventilation rate, but these results show that **ventilation rates measured on different spatial scales can be significantly different**.
- The single room ventilation rate was well below recommended levels, despite an overall air permeability of **15.5 m³/hr/m²**: very leaky by modern standards.

Trickle Vents	Whole house 	Individual room 
Open 	0.8 ach	0.3 ach
Closed 	0.7 ach	0.2 ach

- These results show that occupant use of internal doors, windows and trickle vents is likely to significantly affect ventilation rates. Current discussion and measurement of ventilation rates does not adequately account for these effects.



Implications for building regulations

- **Trickle vents did not raise individual room ventilation rates to sufficient levels, and increased the overventilation of the whole house, worsening heating inefficiency.** Research already shows that trickle vents are often closed in homes.
- Undercuts beneath doors or vents between rooms may help to increase airflow without increasing whole building ventilation rates.

Further work

- **Monitoring** is on-going in four occupied case study flats.
- **Semi-structured interviews** with occupants are planned for December
- Early analysis suggests **significantly different behaviours and ventilation rates experienced**.

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A framework towards the delivery of volume zero-carbon homes in the UK

Joe Forde (j.forde@lboro.ac.uk)

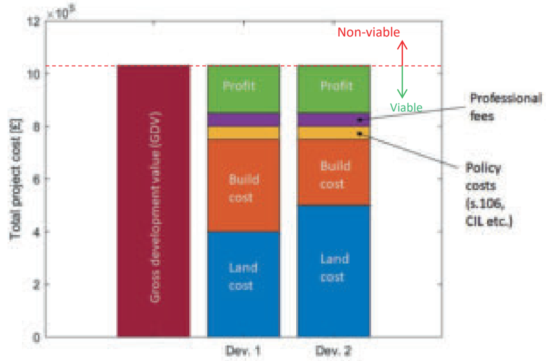
London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

Why do we not already build zero-carbon homes in volume?

The UK does build highly energy efficient, zero-carbon homes. But not in volume. The reason for this is fundamental to many systematic issues within UK housing. Highly efficient new-build homes are often built as part of self-build projects, or as part of schemes with low volume. This can happen as typically these homes will be sold for a higher value on the basis of better quality and size. However, market saturation of these homes is quickly reached if all of the same tenure type to maximise value. Therefore, for high volume development this is not possible. Beyond the implications for affordability, competition to a fundamental asset in the construction process – land – will inevitably drive down non-required costs to enable developers to secure this vital resource.

Research aim: Develop a new methodology which will provide cost-effective solutions to the challenge of volume zero-carbon housing development at a local authority level.

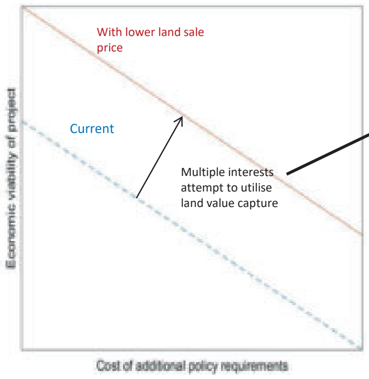


Developer 2 has a more competitive land bid due to lower building costs. Developer 1 can only compete through raising GDV, lowering build costs or accepting lower profit. This situation difference regionally and sub-regionally.

Geographic variation: Large difference are seen within residential land value between regions and even sub-regions. This affects differences in GDV and may effect ambition within local planning policy.

Developing more zero-carbon homes

- Multiple potential policy frameworks to enable increased development (i.e. via planning policy or local authority led housing delivery)
- Any potential uplift from policy change (i.e. land value capture) likely to be subject to trade-offs between interests.
- Therefore, decision support required to help optimise outcomes and support the development of further zero-carbon homes.



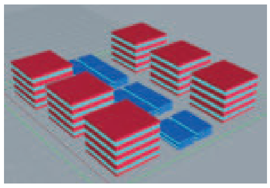
For example:

Option One – Maximise:
- Affordable housing delivery

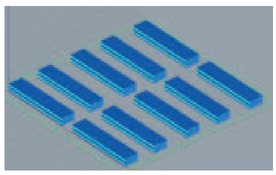
Option Two – Maximise:
- Life-cycle carbon

Option one allows for the attainment of affordable housing targets which is maximised through higher GDV. However, this is at the cost of life-cycle carbon (masonry for high-rise) and increased energy demand (more shading). To achieve zero-carbon offset must be paid for.

Option two land value capture allows developer to meets low carbon requirements on-site, but lower housing delivery and therefore lower GDV. Affordable housing must be offset.

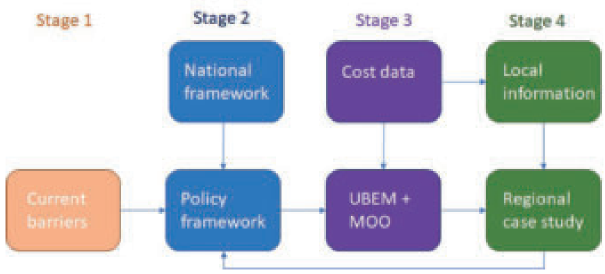


Option One:
High GDV
FAR = 1.14
Occupancy = 330
Mixed construction
High lifecycle carbon
sDA = 27



Option Two:
Low GDV
FAR =0.68
Occupancy = 180
Lightweight construction
Low lifecycle carbon
sDA = 55

Methodology:



- Qualitative data collection from stakeholders to further explore barriers and mechanisms to zero-carbon homebuilding.
- Exploration of potential framework options from feedback to enable zero-carbon homebuilding (i.e. local authority led social housing delivery, through local plan targets, etc.).
- Develop a quantitative framework to support decision making and facilitate interaction between stakeholders using building energy simulation and multi-objective optimisation (MOO).
- Test methodology for a proposed region.

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LoLo Student conference 2019
Heating patterns in English homes

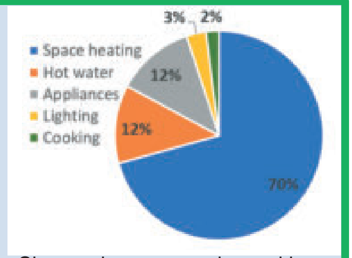
Daniel Franks: 1st year PhD student **Supervisory team:** Prof Kevin Lomas, Dr David Allinson

Problem

Space heating accounts for approximately one-eighth of the UK total carbon emissions as well as being the most sensitive parameter in building stock models. Research; have estimated heating times, patterns and duration of heating through temperature monitoring. However, in each case, a different method is used, and different assumptions made. This unsurprisingly results in different findings.

Research paper/report	Mean (Hours)
Shipworth et al.	8.2
Huebner et al.	10
Kane et al.	12.6
UK statistics	9.4
UK Standard Assessment Procedure	11
Energy supply company	8

Compares previous research estimates for the average hours a dwelling is heated per day, during winter.



Shows where energy is used in a UK home.

Aims

1. Establish whether temperature sensors can capture household heating on/off times.
2. Determine a suitable method and algorithms to estimate heating on/off times.
3. Discover the common heating patterns in English households.

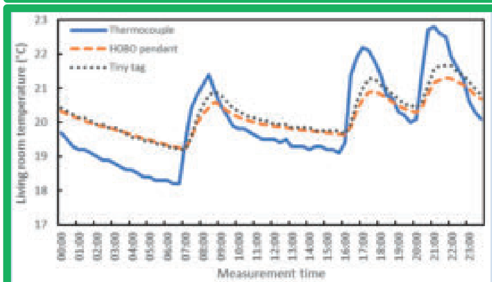
Method

1. A short temperature monitoring study was carried out using three different temperature sensors (HOBO pendant, Tiny tag and a type T thermal couple) in two dwellings; where the temperature profiles were compared to the heating pattern, which for both dwellings was on from 7am-9am and 4pm-11pm.

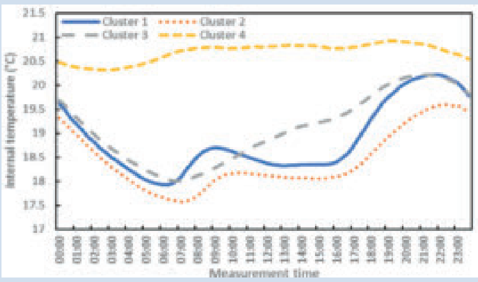
2. Each past and suggested method to estimate heating on/off times from temperature data was calculated for the two monitored homes and compared against household's actual heating times. Additionally, a dozen homes from the EFUS dataset (a 2011 study which monitored the temperature of 823 households for a year) was used to compare the predicted heating on/off times according to each method to the heating on/off estimated by visual inspection.

3. The heating times of all the homes in EFUS 2011 was estimated using the most suitable method. This was followed by using cluster analysis, grouping households of a similar heating pattern together. To ensure no common heating pattern is missed the cluster analysis is carried out for 2-9 clusters noting the variance and graphically viewing the visual difference for weekdays and weekends separately.

Photo of temperature measuring equipment



The graph compares the temperature of three sensors for a dwelling with a heating pattern 7-9am and 4-11pm.



The graph illustrates the internal temperature of each cluster for weekdays

Results

1. Observe as soon as the heating system switches on, the temperature increases, no time lag observed. Similarly, internal gains appear to have a negligible impact. However, in the evening heating period their notable oscillations caused by the temperature reaching the thermostat setpoint, resulting in the boiler switching off and the temperature significantly decreasing before switching back on.

2. Most methods struggled to capture the heating patterns for all households. The method most suitable was one that focused on the length of time the temperature decreases to determine on/off times.

3. Four common heating patterns are observed; two-peak pattern, daytime pattern, 24hour pattern and an irregular pattern. The two-peak pattern was most common on weekdays with 40% of the sample heating in this way.

Conclusion

1. Temperature sensors can estimate heating patterns if algorithms that limit the impact of the thermostat setpoint dead-band are applied.
2. None of the current methods captures heating patterns perfectly, but time method offers the best approximation.
3. Four common heating patterns are observed; two-peak pattern, daytime pattern, 24hour pattern and no pattern.

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

Gabriele Gessani – Doctoral Researcher at UCL Energy Institute; **Dr Catalina Spataru** – 1st Academic Supervisor, BSEER; **Dr Alvaro Calzadilla** – 2nd Academic Supervisor, BSEER

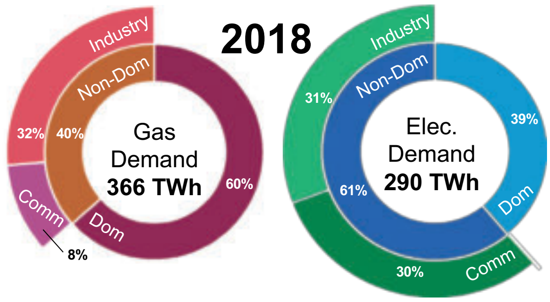
Aims and Objectives

- Develop demand profiles for non-domestic buildings in the UK
- Develop scenarios for non-domestic sector
- Establish a link between an economic global model (**CGE**) and a dynamic energy model (**DEAM**)

IMPACT on environment, society and economy

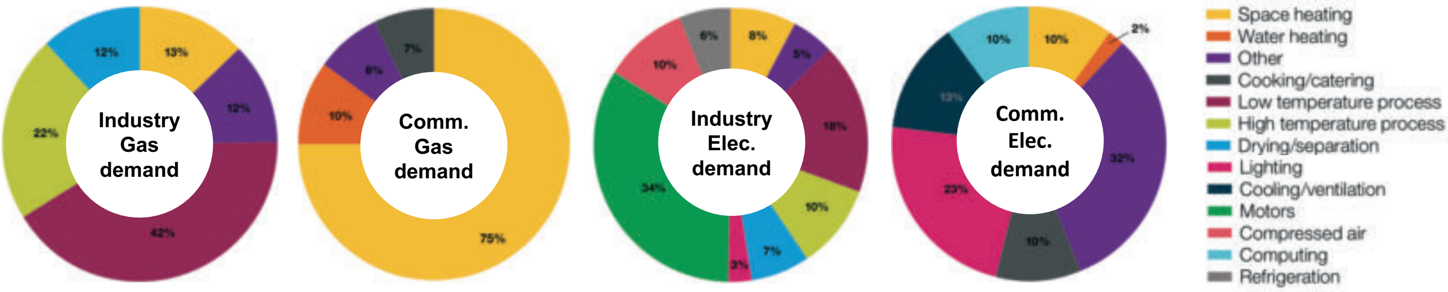
IMPACT on CO_2 emissions, employment and GDP

RISKS, **CHALLENGES** and **OPPORTUNITIES** in future energy scenarios



Introduction and Background

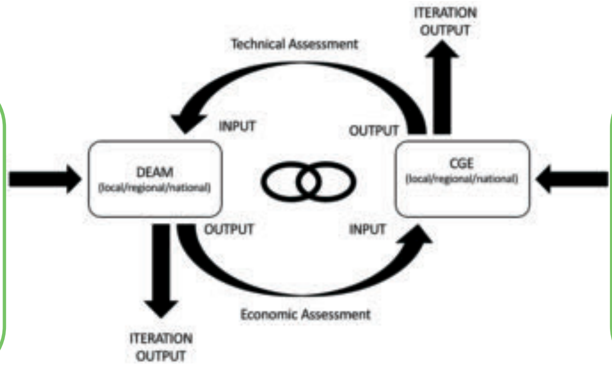
- UK building stock responsible for **30%** of total carbon emissions (456MtCO_2e)[1]
- Non-domestic buildings accounted for **9%** of the UK total carbon emissions[1]
- UK non-domestic buildings are **poorly understood**[2]
- Non-domestic sector energy consumption is driven by many **different end-uses**[3]



Methodology

DEAM[4]

- Dynamic energy model
- Domestic and non-domestic agents
- Electricity and Gas demand
- Simulations at individual agent, DNO or aggregation at regional and national level
- **Does not capture the constraints of the economy**



CGE[5,6]

- Analysis of policies and their effects on economy
- Interaction between agents (enterprises, households etc.)
- How agents responds to a certain change
- **Energy supplied and demanded are not captured**

Results – Commercial Sector – ASHP

2050
18.5 $MtCO_{2[ele]}$
3.5 $MtCO_{2[gas]}$

6000 MW_e installed capacity by 2050

Conclusions

- Investing in efficient technologies stimulates economic growth
- Investment in capital and energy efficiency gains is essential to delivering economic growth
- In further studies will be assessed the impact on jobs, and income per capita
- It serves as key support for policy effort and investment in efficiency measures

[1] CCC. 2019. Reducing UK emissions
[2] Evans et al. 2017. Modelling a whole building stock: domestic, non-domestic and mixed use, Building Research & Information
[3] HMG. 2017. The Clean Growth Strategy
[4] Spataru C. & Barrett M. 2015. DEAM: A Scalable Dynamic Energy Agents Model for Demand and Supply
[5] HMRC. 2013. HMRC 's CGE model documentation
[6] Devarajan, S. & Robinson, S., 2013. Contribution of computable general equilibrium modeling to policy formulation in developing countries

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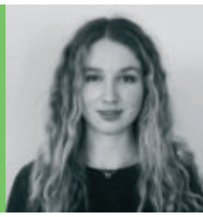
Anna Gorbatcheva 1st Year PhD Student at UCL Energy Institute
Supervisors Prof David Shipworth, Dr Francis Li



@AnnaGorbatcheva

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Analysis and Design of a Peer-to-Peer Energy Trading System to support local Electricity Grid Balance

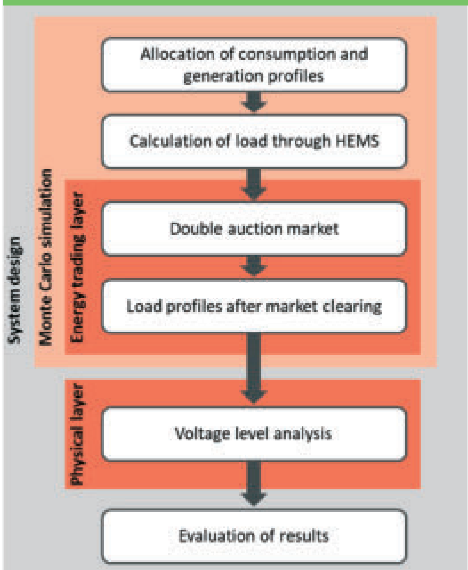
WHAT IS P2P ENERGY TRADING?

Peer-to-peer (P2P) energy trading allows prosumers (small-scale energy consumers and producers) to directly trade their electrical energy with other participants on a market without the need for a large central party.

BACKGROUND

- The integration of small-scale renewable energy systems into the distribution grid level is rapidly transforming the operation of the electricity grid
- Through photovoltaic (PV) rooftop installations energy end-consumers turn into energy producers requiring a consumer-centric approach to distribution grid management
- New market mechanisms such as peer-to-peer energy (P2P) trading can allow prosumers to participate in the competitive energy market
- P2P energy trading can be used to reduce operational challenges for Distribution Network Operators (DNO) caused by high penetration of small-scale renewable energy systems

SYSTEM DESIGN & METHODOLOGY



A simulation environment was developed to understand the **impact of P2P energy trading on the distribution network** using different energy agents:

- IEEE 906 bus test feeder with 55 residential energy loads
- All houses are equipped with a Home Energy Management System (HEMS) a battery storage system for Demand Side Response (DSR)
- Market platform based on double-auction market with one Market Clearing Price (MCP)

Four scenarios considered:

ZI-traders	I-traders	
I	II	**50% PV penetration***
III	IV	**100% PV penetration***

ZI-traders: Zero-intelligence traders randomly submitting bids to the market
I-traders: intelligent agents submit bids to market based on the success of past decisions

*No of households in LV distribution grid with solar panel

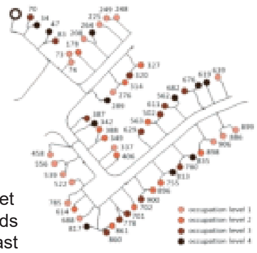


Fig 1: IEEE PES European test feeder

Figure 2 and 3 highlight the impact of PV on the voltage level of the feeder before and after PV integration:

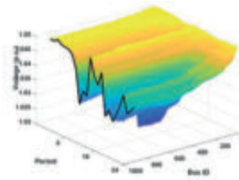


Fig 2: Voltage profile phase A without PV penetration over 24h

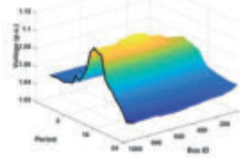


Fig 3: Voltage profile phase A with 100% PV penetration over 24h

RESULTS

Scenario I and II - 50% PV penetration

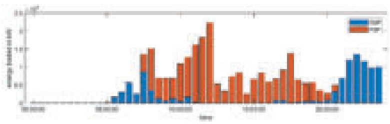


Fig 4: Scenario I - energy traded between market participants (P2P) and energy bought from the grid with ZI-traders (G2P)

- No significant difference in the amount of energy traded between ZI-traders and I-traders
- MCP of I-traders is 19% higher than of ZI-traders
- No buses with overvoltage

Scenario III and IV - 100% PV penetration

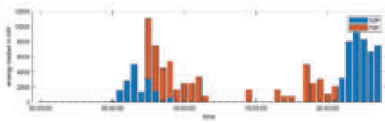


Fig 5: Scenario III - energy traded between market participants (P2P) and energy bought from the grid with ZI-traders (G2P)

- No significant difference in the amount of energy traded between ZI-traders and I-traders
- MCP of I-traders is 4% higher than of ZI-traders
- 178 busses with overvoltage

Summary

- P2P energy trading offers financial benefits to its participants
- Average MCP higher in Scenario I&II than in Scenario III&IV
- I-traders are able to perform more competitive bidding decisions
- The impact of P2P energy trading on load distribution is dependent on the balance between demand and supply
- Additional market mechanisms are required for better DSR

CONCLUSION

- The overall performance of a P2P energy trading platform is highly depended on its specific configuration
- Forecasting data and generation and consumption uncertainty should be included in the model for more accurate results
- Some impacting factors which should be considered in more detail are: number of market participants, size and location of energy load and generation, DSR service provider, design of HEMS, role of DNOs, market platform mechanism

PhD RESEARCH PROJECT

Following the results of the MRes dissertation, the research during the PhD will be focusing on the challenges that P2P energy trading platforms are facing when growing in size over time at the different stages of efficiency under varying configuration conditions.

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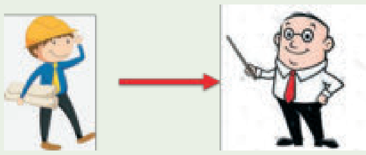
An investigation of feedback and feedforward energy efficiency mechanisms from a UK school crowdsourced building stock model.

PhD Researcher: **Duncan Grassie**
Supervisory Team: **Prof Dejan Mumovic, Dr. Ivan Korolija, Prof. Paul Ruyssevelt**

Context

- Non-domestic energy demand (18% of UK total) crucial to reach 2050 climate targets
- Schools – relevant due to standardisation in design, services, refurbishment programmes
- Stock models – individual physics-based detail across stock, lack fabric/building service data
- Although design engineers motivated and technically adept…
  school users may be more directly aware of in situ usage



Research Structure

Question:

Can a national occupant dataset be constructed? → Stock model of 22,000 schools in England /Wales → Can it feedforward progress on regional & national CO_2 targets? / Can it feedback performance improvement to individual schools?

Methods:

	Scoping	Variable development		Testing	
Deliverable	Design required for individual schools / policy makers to engage	Availability of data	Criticality of variables	Robustness of base modelling with generic data	Data provided by Crowdsourcing
Method(s)	Semi-structured interviews / workshops	Gap-analysis	Local sensitivity analysis	Stockmodelling then POE	Develop platform then POE

What feedback will stakeholders engage with?

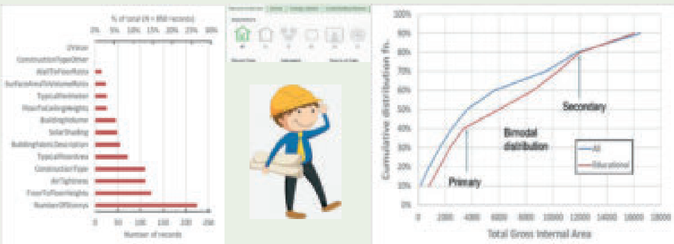
Semi-structured sessions:
- Workshops - policymakers – DfE, BEIS, CIBSE
- Interviews - 5 individual school managers/heads

Type	School occupants - feedback	National policymakers – feedforward
Drivers	Budget – maximise pupil premium - Maximise curriculum spend Environment – LA / diocese level	Current – replacing run-down stock Future – "pseudo-businesses" keen on aesthetics limited interest in energy
Questions	Identifying wastage Overheating – passive / reactive Billing 3rd parties	Specific questions on Refurbish/rebuild: Edwardian – learning environment? Post-war – overheating? Modern – control complexity?
Analysis	Aware of DEC rating Unaware of methodology Tracking improvements over time of interest	Responsible body comparison Correlation - run down, energy performance, attainment

Availability of building data?

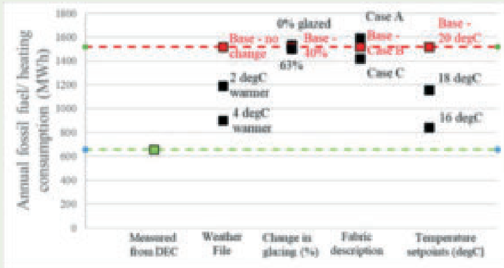
Gap analysis – data entered by engineers

1) Completeness: 2) Form design: 3) Distribution of data:



Criticality of variables to modelling?

Local sensitivity analysis:
Expansion of below study - include 15-20 IEA Annex 66 variables



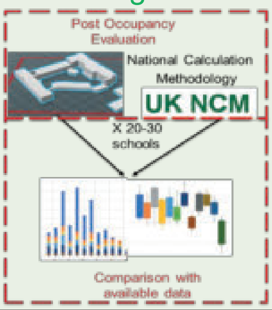
Robustness of base modelling

Comparison of EnergyPlus inputs
- NCM -> Building service usage
- DfE dataset -> Fabric

Post Occupancy Evaluation

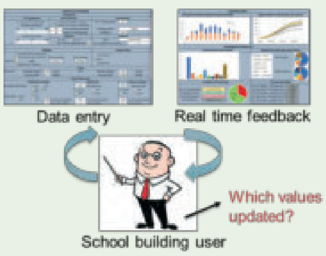
Comparison of outputs:
End-use output of models

Literature values



Crowdsourcing method

Feedback to school user in return for fabric/service usage data



Quantitative:
- Test in ~30 London schools to determine values updated

Qualitative:
- Interviews in 2-5 schools to determine understanding of participants and data quality

Conclusions:

Stakeholders: Schools to identify wastage to max curriculum spend, policymakers to correlate building condition with performance
Data availability: Geometrical data least onorous to supply, though fabric neglected. Accumulated data can be compared to national

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Occupant Behaviour: A Data Driven Modelling Approach for Occupancy Presence in Residential Buildings

•**Benjamin Halls** MRes Student, Supervisor: Dr Steven Firth

Introduction

Context

- It can be difficult to predict the activity and presence of occupants in a building. This can have a significant influence on energy demand predictions, as presence of occupants is a requirement for interactions with building systems
- A better understanding of occupancy presence in buildings can improve energy demand predictions. This can aid in the design of efficient buildings

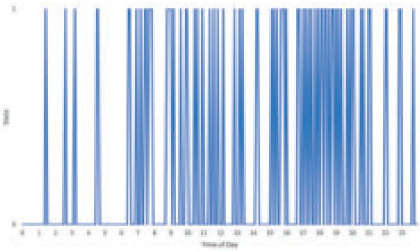
Aims of the Study

- Investigate occupancy presence in residential buildings with monitored data
- Identify typical occupancy patterns
- Develop an occupancy presence model
- Determine if proven modelling techniques can be applied to historical data from residential buildings

Method

- Monitored motion data from 20 homes in Loughborough
- Occupancy profiles generated for each home
- Markov model predicts occupancy presence
- Monte-Carlo technique produces occupancy predictions
- Each run of the model will produce different outcomes

Occupancy State	
0	Absent
1	Present



$$P_t^{ij} = p(x_{t+1} = S_j | x_t = S_i)$$

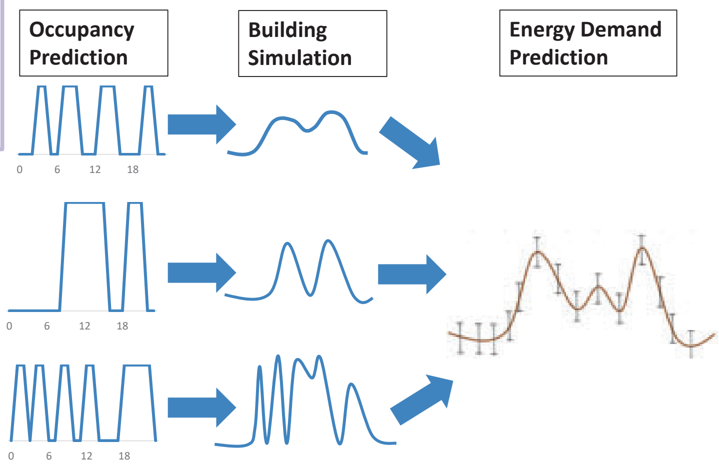
$$T = \tau_{ij} = \begin{pmatrix} \tau_{00} & \tau_{01} \\ \tau_{10} & \tau_{11} \end{pmatrix}$$

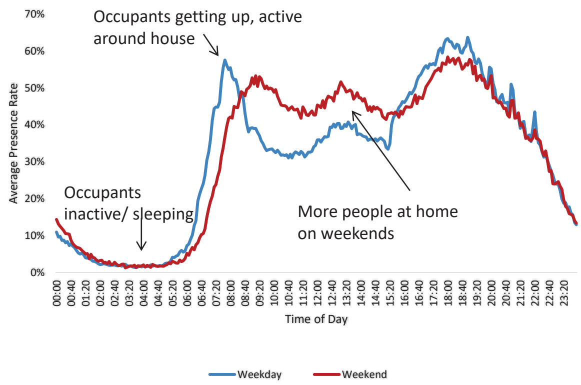
Occupancy Transition Matrix		Present State (00:05am)	
		0	1
Previous State (00:00am)	0	97.20%	2.80%
	1	43.30%	56.70%

Key Results

- Diverse occupancy patterns observed in individual households. Peaks in activity seen early morning/ early evening
- Occupancy patterns vary by; weekday/weekend, number of occupants and age
- Markov model performs well at replicating occupancy profiles,
- Occupancy predictions are appropriate to integrate into building simulation tools

- Each run of occupancy model will produce a different result
- Averaging multiple runs of building simulation will predict energy demand with uncertainty range





Future work

- Integrate occupancy presence model into building simulation tools to consider the benefit in energy demand predictions
- Performance of various modelling techniques can be compared to identify the most suitable model to predict occupancy presence

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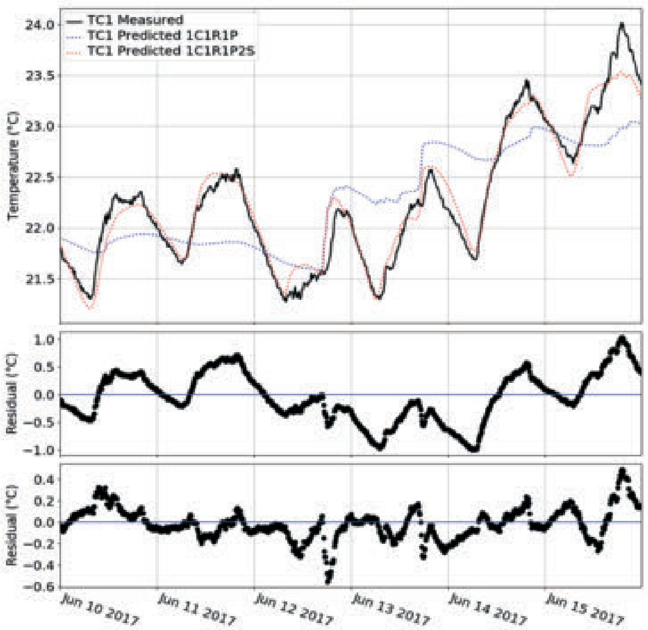
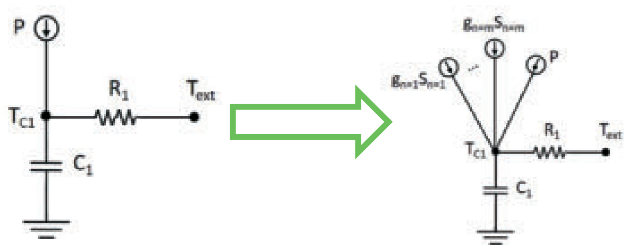
Developing a dynamic method of assessing whole house thermal performance: exploring the inclusion of 4 effects

Frances Hollick

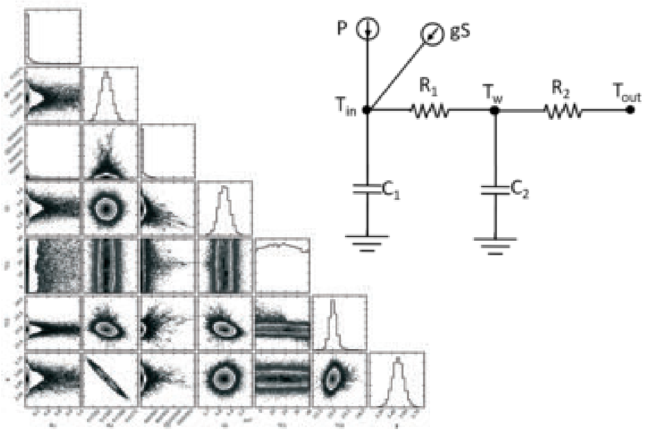
Final year PhD Student (UCL)

Solar gains per facade

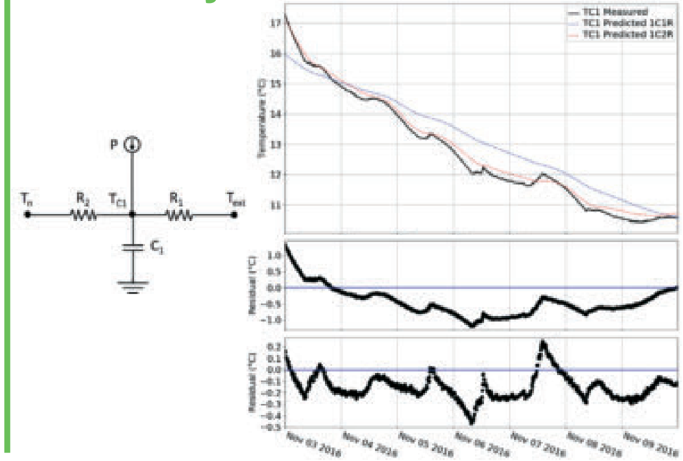




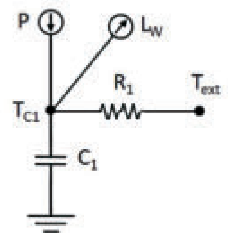
An unnecessary second node



Party wall heat transfer



'Down-the-drain' water heat loss

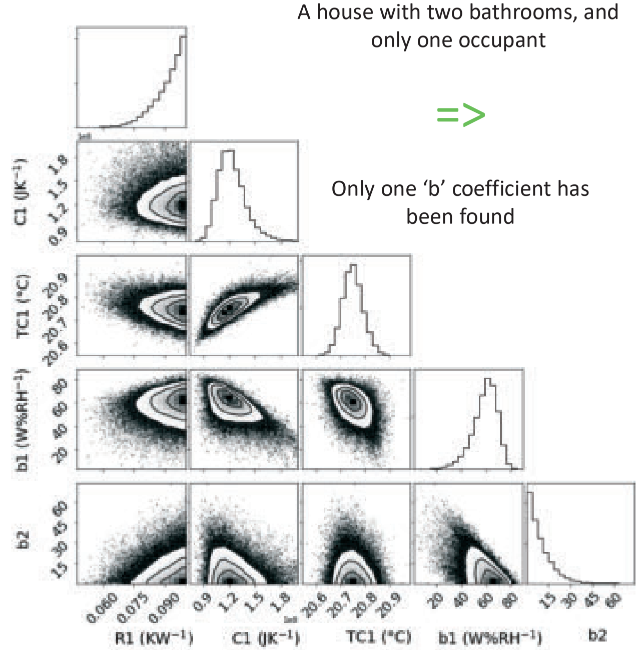


$$L_W(t) = b(\mathrm{RH}_{bath}(t) - \mathrm{RH}_{norm}(t))$$

A house with two bathrooms, and only one occupant

=>

Only one 'b' coefficient has been found



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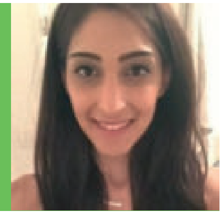
Evaluating the in-situ thermal performance of loft insulation in cold-pitched domestic roofs: determination of R-/U-values and opportunities for minimising heat loss.



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Suneina Jangra suneina.jangra.16@ucl.ac.uk

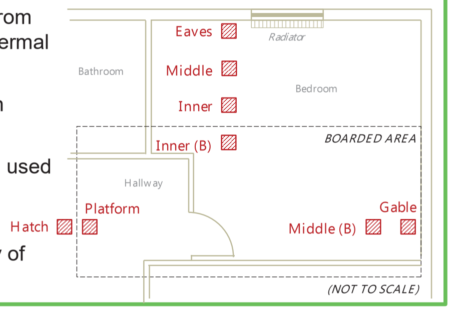
UCL Energy Institute (Supervisors: Dr Cliff Elwell & Prof Bob Lowe

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.

RESEARCH METHOD & DATA ANALYSIS

- Measured heat flux and temperature data from four case studies is used to estimate the thermal performance of the ceiling and loft cavity.
- In-situ performance is calculated using both static and dynamic analysis methods.
- Infrared thermography and site surveys are used to contextualise the quantitative results.
- Design U-value estimates are based on assumptions about the thermal conductivity of the building materials identified.

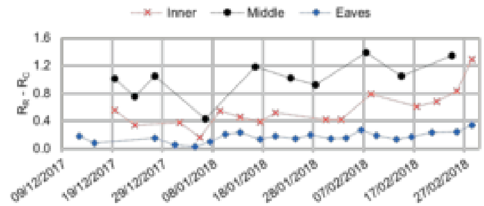


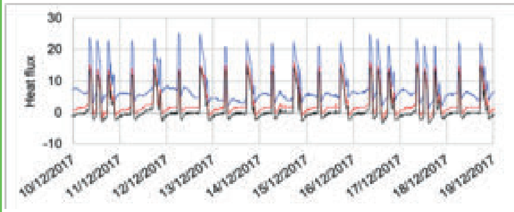
ONGOING WORK

- Testing 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.

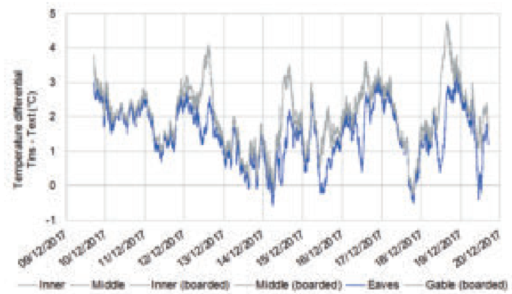
[1] S.H. Hong, T. Oreszczyn, I. Ridley (2006) The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings. Energy and Buildings 38 (10).
[2] C.A. Elwell et al. (2017) The thermal characteristics of roofs: policy, installation and performance. Science Direct 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.

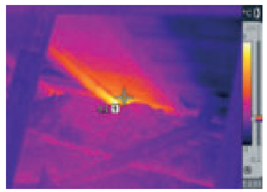
PRELIMINARY RESULTS

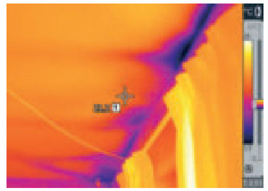




The resistance of the loft cavity is consistently lowest at the eaves and recorded heat flux is higher. The monitored temperature difference at the eaves is consistently lower compared with other locations.

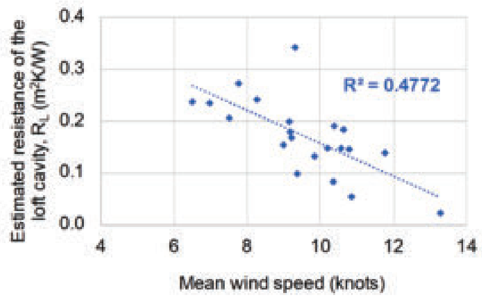




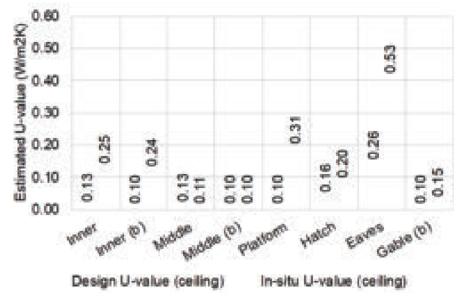


Infrared thermography suggests that there may be **unexpected air gaps** around the insulation at the eaves junction allowing cold air to penetrate the loft cavity and driving **convective heat losses**.

At the eaves, there is a moderate relationship whereby **when the wind speed is higher, the implied resistance of the loft cavity is lower**.



U-values estimated using both static and dynamic methods are higher than design U-values, suggesting that the in-situ performance is **worse than expected** in this case study. This observed 'performance gap' is greatest at the eaves location for both ceiling and whole roof U-values.



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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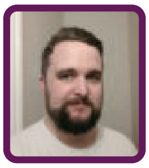
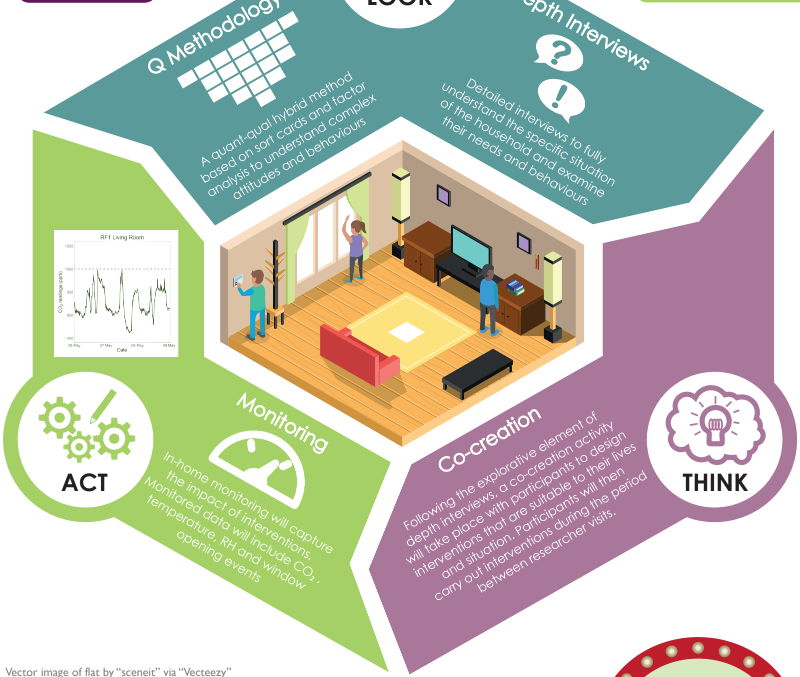
ANNUAL COLLOQUIUM 2019

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



Seb Junemann

3rd Year PhD candidate



Vector image of flat by "sceneit" via "Vecteezy"
Vector characters by "freepik.com"

Efforts to understand the interactions between people and the spaces they inhabit have, in recent years, been dominated by studies focused on energy consumption and heat. However, ventilation and indoor air quality are areas 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, better understand the impacts that behaviours have on indoor air quality.

What?

This project is concerned with building an understanding of **the interactions between people and ventilation systems in the home** with an overall aim of understanding what impact occupant behaviours have on indoor air quality and whether changing behaviour produces any impact.

The project builds on a previous MRes case study that found that people often behaved in **unexpected and unpredictable** ways in terms of ventilation, which presented challenges to understanding impacts on their internal environments.

Why?

As the UK housing stock moves towards greater levels of airtightness, we can no longer rely on cracks in the floorboards and leaky windows to keep our homes supplied with fresh air. Adequate ventilation must therefore be achieved through means such as windows, mechanical ventilation and other passive vents. However, there is **limited empirical evidence to show how people use these measures and how they impact their internal environments.** Should ventilation systems be used differently to design expectations, there is a risk of inadequate ventilation, leading to **potential comfort/health issues**.

How?

This project takes a **mixed-method, case study approach using participatory action research (PAR).** PAR is a cyclical method, involving three key stages applied, in this project, as follows:

1) LOOK - Gather information about how participants ventilate their homes. This will include interviews, monitoring, physical surveys and Q Methodology.

2) THINK - Analyse the data and co-create behavioural interventions with the participants to change their ventilation behaviours.

3) ACT - Participants carry out the interventions while data loggers and journals record any changes.

COME AND TRY Q FOR YOURSELF

Instructions

1. Sort each card into three piles: agree, disagree and neutral
2. Place each card into a box on the grid opposite
3. Each box must have a card on it - no doubles, no splits!

Q Methodology is a "quantitative-qualitative" research method, based on an inversion of the classic "R Methodology" factor technique.

In (the more commonplace) R factor analysis, the aim is to identify correlations **between variables** (e.g. between student results in maths tests and physics tests). In Q, however, correlations **between people** are the key interest.

To achieve this, participants are provided with a set of statements (The Q-Set) on a topic and asked to sort them onto a distribution (e.g. to the left!). The Q-Sorts are then analysed to identify similarities between individuals but they also provide rich insights into individual **subjectivity** within each sort.

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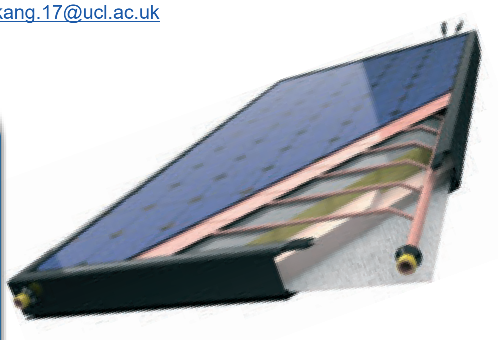
ANNUAL COLLOQUIUM 2019

Opportunities for Communal PVT Heating?

Anneka Kang 2nd Year PhD Student. Email: a.kang.17@ucl.ac.uk



Motivation

- Global efforts are required to reduce greenhouse gas emissions and ultimately limit global temperature rise.
- 70% of the world's population are projected to live in urban areas by 2060; therefore reducing urban area domestic emissions is key.
- Photovoltaic-thermal (PVT) is a promising high energy density technology; simultaneously producing electricity and heat whilst increasing the PVT efficiency with cooling.
- A literature review has identified a gap in communal solar PVT systems with thermal and electrical storage.

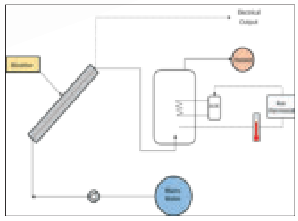


Fig 1: PVT system setup

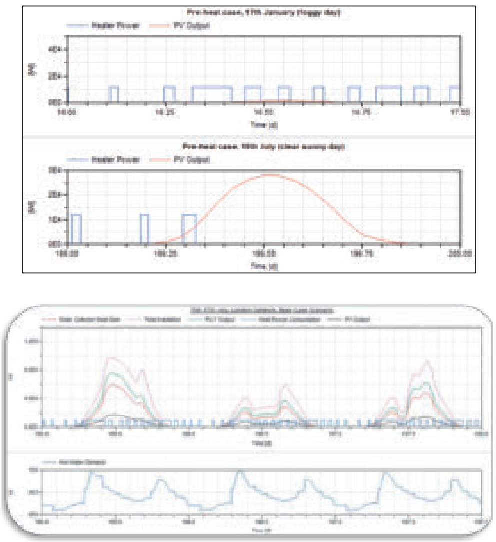


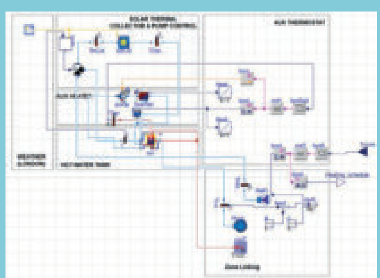
Fig 2: Output examples

Method

Aim: Investigate the reduction of heating emissions brought about by 1 PVT system with thermal and electrical storage used to heat urban areas.

- The PVT and storage system is modelled in Dymola/Modelica (dynamic system modelling), a simple system representation is shown in figure 1.
- The buildings fabric and construction are developed and modelled in EnergyPlus.
- Co-simulation using the functional mock-up interface (FMI) standard is then being used to determine the percentage of space heating/hot water/electricity covered by the PVT system (figure 2).

Method Overview



Heating Schedule

Zone Temperature

ANNUAL COLLOQUIUM 2019

David Kenington

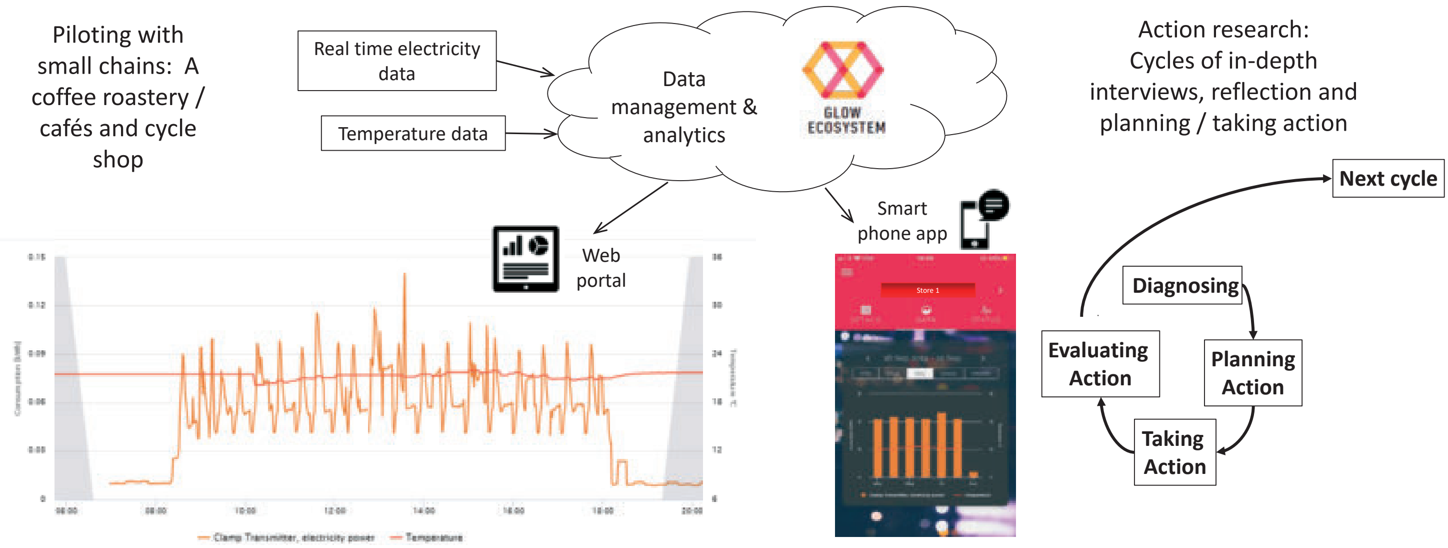
Can energy management be improved within retail and hospitality organisations using opportunities provided by smart meters?

London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

It is estimated that smart meters will help reduce small business energy demand by encouraging energy efficient behaviour. However it is unclear whether and how this will be achieved and small business energy efficiency interventions have previously had unpredictable and different outcomes from those intended.

This **action research** project is working with a technology innovator Hildebrand Technology Ltd to design and pilot a new energy management eco-system using real-time data and investigate how it influences energy management behaviour amongst retail and hospitality small businesses.



"This may be useful to manage sites as you can tell as you can tell whether we opened on time, and whether the coffee machines had enough time to warm up before the morning rush"

Cafe / Roastery

"Our shop is south facing so we installed a large HVAC system to keep it cool for customers in summer. However, it can be over-used, and so I'd like to be able to see what temperature it is and the energy use of the system to help manage the internal environment"

Cycle-shop

By using action research cycles the project, aims to build innovations which are attractive to customers, improve energy efficiency and deliver other benefits.

Within this, undertaking phased in-depth interviews with pilot sites has helped to understand small business needs, and how smart meter data can benefit businesses.

To date, two areas of benefits have been identified:

1) Operational – for example, using real-time data to support operational management. Examples have included knowing if there is a power cut, also whether a particular site has opened on-time, or whether energy using equipment is used correctly and at the right time.
2) Improved energy management, including accurate billing and helping to identify opportunities, for example eliminating unnecessary out of hours energy use.

hildebrand UCL Loughborough University EPSRC

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ANNUAL COLLOQUIUM 2019

How hot will it get? Predicting the summer indoor temperatures of English homes

Giorgos Petrou – UCL Doctoral Researcher (giorgos.petrou.16@ucl.ac.uk), **Dr. Anna Mavrogianni and Dr. Phil Symonds** – Academic Supervisors
Anastasia Mylona – CIBSE, **Gurdane Virk** – Atkins, **Dr. Rokia Raslan and Prof. Michael Davies** – UCL IEDE Academic Contributors

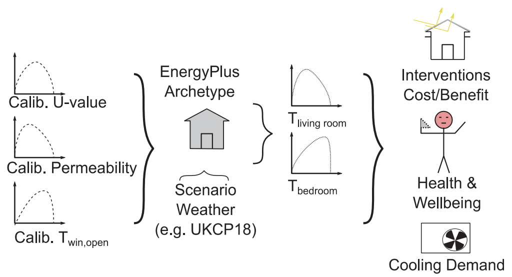
Introduction

- A **record-breaking** temperature of 38.7℃ was recorded in England during the summer of 2019 [1].
- Epidemiological studies identified an almost **linear increase in London mortality** when the external temperature exceeds 25.5℃ [2].
- High summer temperatures can also result in **thermal discomfort, lower productivity and potentially increased cooling demand.**

Aim

Use the 2011 Energy Follow-Up Survey dataset to calibrate the UCL English housing stock model through Bayesian Inference

Why is this useful?

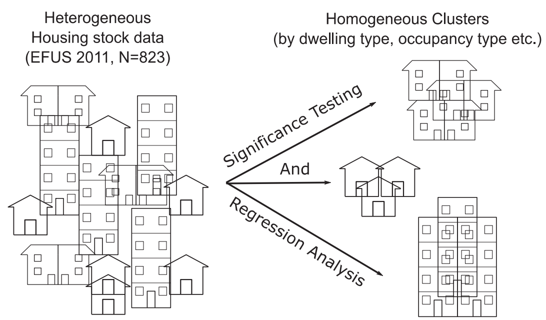


How?

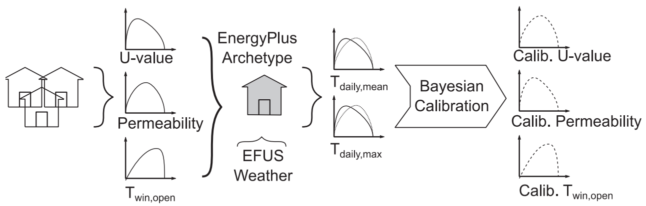
Two-stage process

1. Cluster dwellings from the 2011 Energy Follow-Up Survey (EFUS) based on common and influential characteristics using significance testing and regression analysis.
2. Improve the archetype-based model assumptions through Bayesian Calibration.

Stage 1: Clustering & Statistical Analysis



Stage 2: Bayesian Calibration



Results

- The association of 9 household and 11 dwelling characteristics with summer indoor summer temperatures was explored (fig. 1) [3].
- Main heating system, tenure and occupant vulnerability all had a statistically significant correlation with summer indoor temperatures.
- Indoor temperatures were highest for dwellings with SAP rating > 70.
- Explanatory variable correlation was explored (fig. 2).

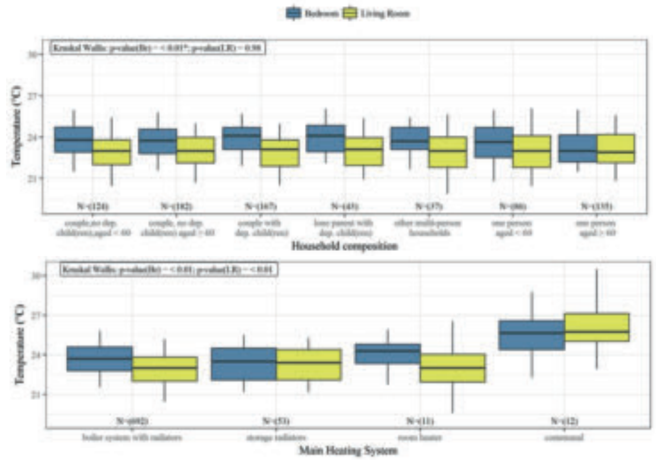


Figure 1: Box plots of standardized indoor temperatures [3].

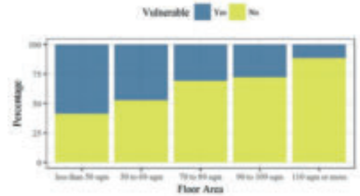


***Figure 2**: Bar plots of floor area and household vulnerability (defined in EFUS as dwellings on means tested or certain disability benefits [3].*

Limitations

- The summer of 2011 was not particularly warm – EFUS 2018?
- Granularity of data.

Conclusions

- Isolating dwelling characteristics does not capture the full picture.
- Actions required to prevent energy efficient homes from overheating.

References

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2. Armstrong BG, Chalabi Z, Fenn B, et al. Association of mortality with high temperatures in a temperate climate: England and Wales. Journal of Epidemiology and Community Health. Epub ahead of print 2010. DOI: 10.1136/jech.2009.093161.
3. Petrou G, Symonds P, Mavrogianni A, et al. The summer indoor temperatures of the English housing stock: Exploring the influence of dwelling and household characteristics. Building Services Engineering Research and Technology 2019; 40: 492–511.

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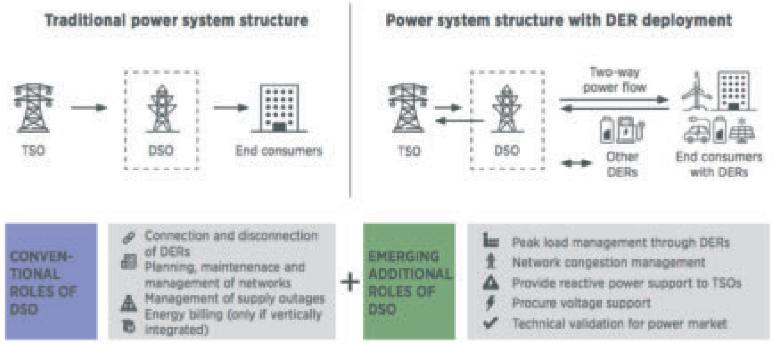
ANNUAL COLLOQUIUM 2019

Governing electricity distribution networks for the low-carbon energy transition in Great Britain

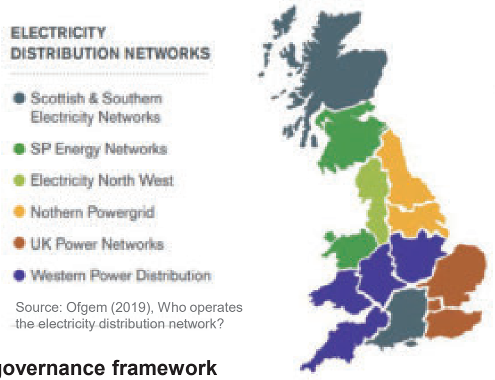
Giulia Ragosa, 1st year MPhil/PhD, Supervisors: Dr Lai Fong Chiu, Prof Michael Grubb

Background

In order to enable a cost-effective integration of low-carbon technologies in the low-voltage network and fulfill the Government's vision for a decentralised and digitalised energy system laid out in the *Smart Systems and Flexibility Plan*, distribution network operators (DNOs) need to undergo profound changes in coming years. Not only they have to become more active managers of their infrastructures, but also act as neutral market facilitators to unlock the value of distributed energy resources (DERs). **This study investigated the institutions and governing processes underpinning the evolution of the sector, and the strategies employed by state and non-state actors to fulfill their visions for the distribution grid of the future.**



Source: IRENA (2019), Innovation landscape brief: Future role of distribution system operators, Abu Dhabi.



Source: Ofgem (2019), Who operates the electricity distribution network?

A governance framework

This study drew on *Governance Theory* to analyse decision-making in the context of Great Britain's electricity distribution grid. This scholarly tradition focuses on institutions and actors within and beyond government, emphasises the blurring boundaries and power interdependencies between the state, the private sector and civil society, and recognises the capacity of the government to achieve policy objectives through the use of new tools and techniques. It is particularly relevant to the study of power grid institutions in the aftermath of privatisation and liberalisation.

Research methods and data

This study relied on the qualitative thematic analysis of official policy and industry documents and interviews with the following key energy system stakeholders:

Participants	N.
Central government	3
Regulator	1
Networks interest group	3
Consumer body	1
Decentralised energy interest group	1
Community energy interest group	1
Innovator	1
Local government	2
London-based consultancy	1
Local community energy group	1
Total	15

Key findings

- Evidence was found for a shift from *government to governance.* As such, the capacity of both central and local government to steer change seem to be limited and highly contingent upon the expertise and actions of other stakeholders.
- The regulator Ofgem is the leading actor responsible for steering the behaviour of DNOs towards decarbonisation objectives, a process that is being carried out through a set of pioneering regulatory reforms. However, Ofgem operates within a constrained remit, which has led to some inconsistencies between the regulatory framework, national and local policy.
- The industry has taken a leadership role in driving change through the *Open Networks Project* led by the Energy Networks Association. This is against the background of the growing weight of international capital in the governance of strategic national infrastructure, which raises questions around legitimacy and the possibility for disruptive change, and is exemplified by calls to bring networks back into public control.
- New forms of social contract have emerged with civil society and community actors taking over the delivery of social outputs in innovation activity, often in partnership with incumbent companies.
- Evidence was found for the *strategic re-orientation of state power.* Policymakers have been employing a set of subtle strategies including priority-setting, the funding of research activity and coordination approaches both at the national and local level to encourage network companies to take leadership in driving system renewal.
- Findings point to the challenges of managing system renewal through indirect governance tools due to the dilution of power and the responsibility for decarbonisation as attempts to impose hierarchical control can often lead to unintended consequences.

To be continued...

My PhD research will focus on the political economy of electricity market design and governance, and will cast the net wider by comparing the GB experience with that of other countries with the aim of drawing relevant policy insights. In particular, it will investigate **whether and how differences in economic and political institutional settings, especially the relationship between governments, regulators and the private sector, have led to variation in the scope and nature of state intervention in electricity markets to accommodate a high share of renewables and unlock the value of flexibility resources.** Possible cases for comparison include the US State of New York, Denmark and Germany.

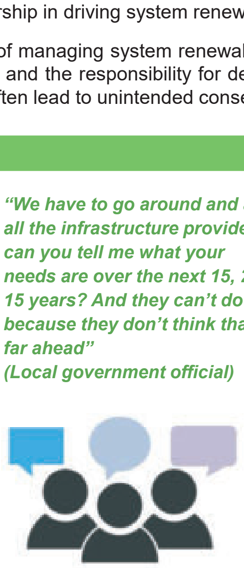
What do stakeholders say?

"Government and the incumbents, who are largely leading governance, are not able to grasp how fast change is going and how broad it is. Companies like ours, we can see that, but we do not have the experience to participate in them in a meaningful way" (Innovator)

"We have to go around and ask all the infrastructure providers: can you tell me what your needs are over the next 15, 20, 15 years? And they can't do that because they don't think that far ahead" (Local government official)

"If Ofgem is going to allow companies to bill consumers for financing the smart grid then the companies would want to do it. If they set the level of return at 3% then [...] investors all over the world will go: "3% is a lot of risk. I could just invest in US gold or something like that" (Network representative)

"I think it is a tale of evolution as opposed to revolution" (Central government official)



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ANNUAL COLLOQUIUM 2019

Closing the UK District Heating Performance Gap: A Case Study Performance Assessment using Real-Operational Data

Niki Sahabandu – 1st Year PhD Student
Dr. Cliff Elwell, Dr. Jenny Crawley, Prof. Bob Lowe – Academic Supervisors

1. Context

- District heating is proposed as a key part of UK climate strategies and its uptake is expected to grow[1]
- Currently, there are approx. 2000 district heating systems in the UK[2]
- Troublingly, investigations of UK district heating have provided evidence for underperforming systems[3]

2. Research Questions

For a real case study:
1. What is the impact of increasing subsystem and component efficiencies (from their real values to their design values) on overall district heating system (DHS) emissions?
2. How can the emissions related performance of the DHS be improved?

3. Secondary Data

- Dwelling heat meter data collected daily
- Data collection in the energy centre at approximately weekly intervals
  - Variables include gas input to CHP and both boilers, thermal output of CHP unit and individual boilers, electricity exports and imports, CHP and boiler run times

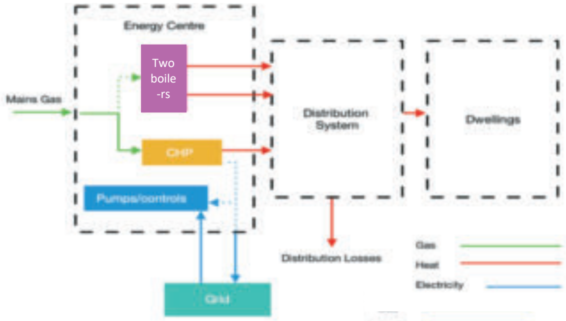

Fig. 1. Diagram of the case study DHS depicting the energy flows and the subsystems.

3. Method and Results

Method

- Analysis of seasonal average efficiencies and average thermal outputs Combined Heat and Power unit (CHP) and combined boiler unit
- Analysis of seasonal average distribution losses
- Mathematical model built to investigate impact of optimising CHP, boiler and distribution system efficiencies and other parameters on the overall emissions, as characterised by the Carbon Emissions Factor (CEF)

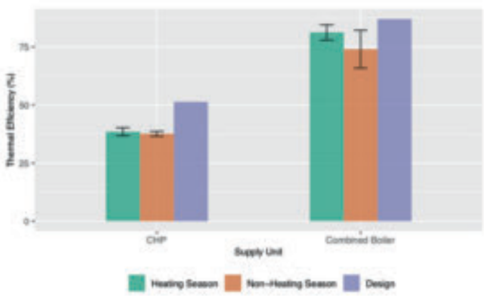

Fig. 2. Estimated real efficiencies of CHP and combined boiler unit as compared with their manufacturer stated design efficiency.

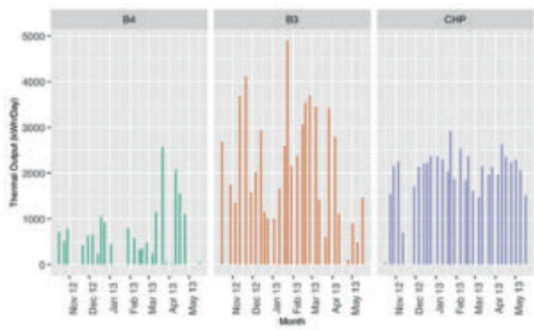

Fig. 4. Daily mean thermal output of combined heat and power and boiler (B3 and B4) units.

Results

- Distribution system was performing considerably poorly with an efficiency of 52%
- Average boiler efficiency, at 78.4%, was reasonable as compared with design efficiency
- Average CHP efficiency, at 26% less than design efficiency, stands to be improved
- Optimising efficiency and power of CHP, boilers and distribution system leads to a reduction in CEF of ~ 40%
- The data indicates sub-optimal operation and/or design (e.g. Fig. 4 shows peak boilers, intended to be used minimally, providing much of the total heat) although it was not possible to pinpoint specific causes

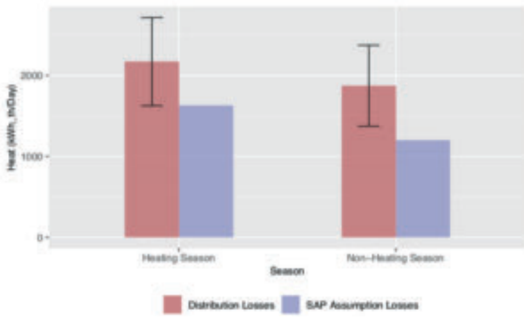

Fig. 3. Estimated real daily mean distribution losses as compared with SAP assumption distribution losses.

4. Conclusions and Future Work

- Emissions of the case study DHS was found to be significantly high
- Reasons for poor performance may be high distribution losses, poor CHP efficiency and/or poor design, however…
- Identifying specific performance solutions was not possible with the available data

Future analyses could involve data with more variables (e.g. temperature of flow and return of heat generators) measured at smaller time intervals (15min or less). This will enable events at smaller time intervals and their impact on performance to be studied and allows the operational strategy to be understood in greater detail. Operator surveys and/or interviews could contribute to the understanding of operation. This will enable performance issues to be identified and solutions to be developed more effectively.

References
1. BEIS. 2017. *The Clean Growth Strategy: Leading the way to a low carbon future*. Tech. rept.
2. DECC. 2013b. *Summary Evidence on District Heating Networks in the UK*.
3. Changeworks. 2017. *District Heating: Delivering affordable and sustainable energy*. Tech. rept. April. Joseph Rowntree Foundation.

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Vision and leadership for a sustainable built environment

ANNUAL COLLOQIUM 2019

The Integration of Heat Networks with Low-Carbon Power Generation

Salman Siddiqui 2nd/3rd 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

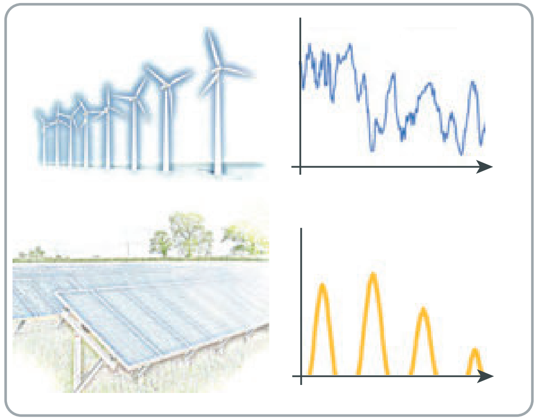
A. What renewable electricity scenarios produce generation profiles and electricity cost variance that is conducive to operate district heating with heat pumps?

B. How should district heating systems operate to minimise life time costs and carbon emissions in a low carbon energy system with heat pumps and storage?

C. 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 minimise operating costs.

D. 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?

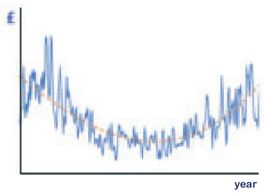
NATIONAL SCALE RENEWABLE POWER GENERATION MODEL

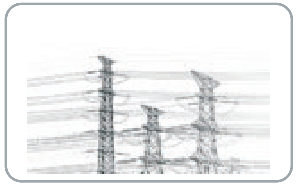


MARGINAL ELECTRICITY COSTS

+

MEAN ELECTRICITY GENERATION COSTS FOUND TO HAVE HIGH SHORT TERM AND SEASONAL VARIANCE IN HIGH WIND RENEWABLE ENERGY SCENARIOS. THIS ENABLES POSSIBLE COST SAVINGS BY OPERATING HEAT PUMPS IN TANDEM WITH LARGE SCALE STORAGE.



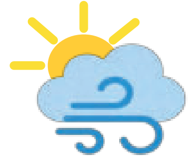


CHP POWER

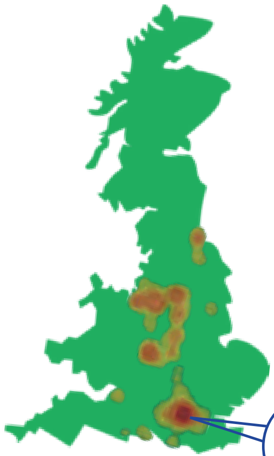
POWER FOR HEAT

£ 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 HEATING NETWORK MAPPING

DISTRICT HEATING POWER PLANT OPERATION

HEAT PUMPS
COMBINED HEAT POWER
THERMAL ENERGY STORAGE

OPTIMISATION

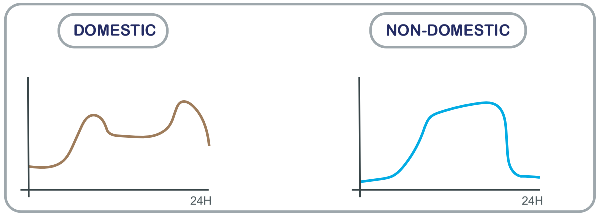
DISTRICT SCALE HEATING LOADS MODELLED

BUILDING ARCHETYPES

BUILDING THERMAL MODEL
SPECIFIC HEAT LOSS AND THERMAL MASS

+

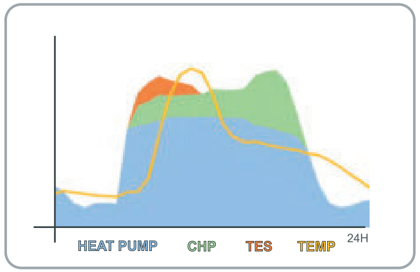
HOURLY ACTIVITY LOAD PROFILES



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

HEAT DEMAND

HEAT SUPPLY



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ANNUAL COLLOQUIUM 2019

Multi-Criteria Optimization of Building Design for Natural Ventilation

Benjamin Simpson (2nd Year PhD Loughborough University) B.Simpson@lboro.ac.uk
Supervisors: Prof. Malcolm Cook & Prof. Jonathan Wright

Overview

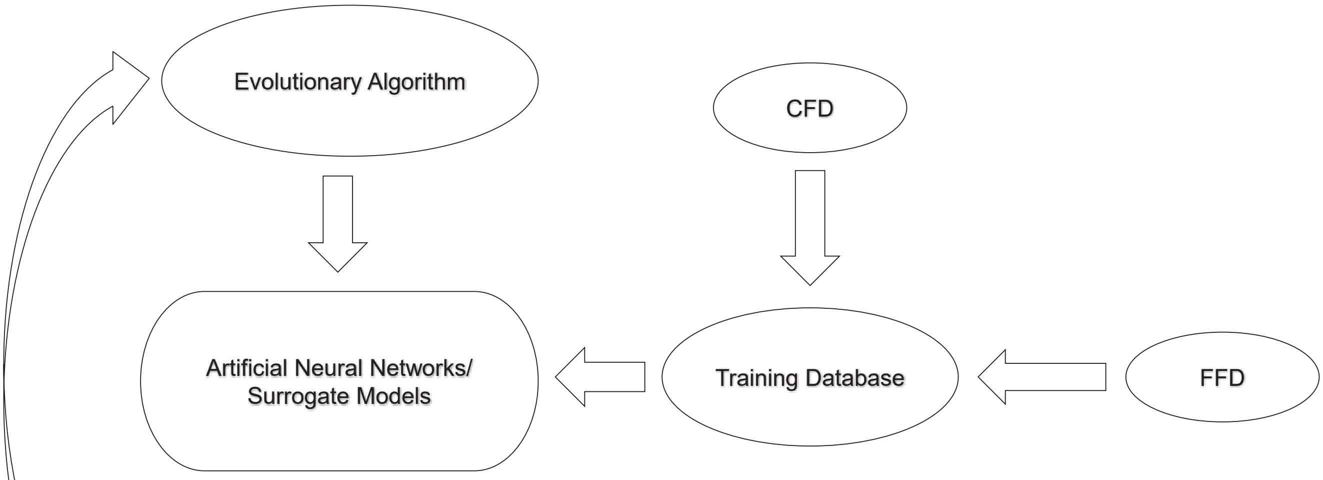
The aim of the project is to identify novel design solutions for naturally ventilated buildings. The successful building designs will endeavour to maximise the natural ventilation potential while trying to minimise external noise pollution. The assessment criteria being studied will incorporate a range of IEQ components such as IAQ, thermal comfort and acoustic comfort. To identify the design solutions, a modelling framework will be developed utilising Evolutionary Algorithms (EA), Artificial Neural Networks (ANN), Computational Fluid Dynamics (CFD) and Fast Fluid Dynamics (FFD).

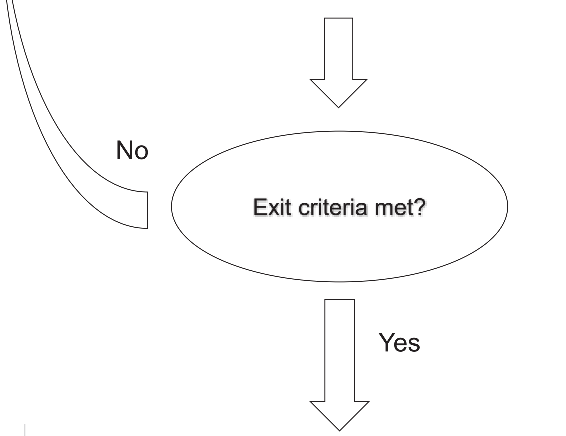
Assessment Criteria

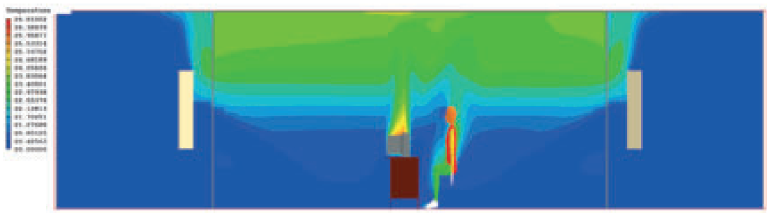
- Indoor Air Quality - Ventilation Effectiveness (E_Z)
- Thermal Comfort – PMV, PPD, Draft
- Acoustic Comfort - dB

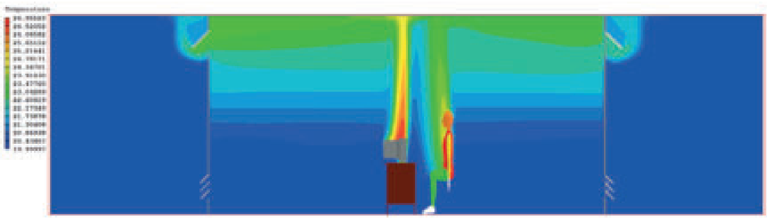
Design Variables

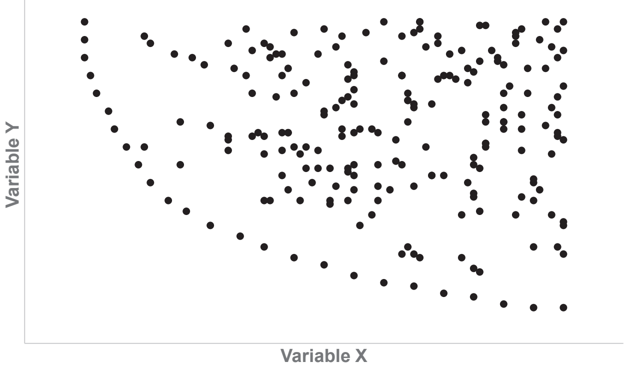
- Orientation
- Geometry
- Building Material
- Façade Design (number of openings, size, location)











Contributions to Knowledge

- Design solutions incorporating IAQ, Thermal Comfort and Acoustics
- Understanding the capabilities of FFD for modelling natural ventilation and IEQ parameters
- Determining the advantages and disadvantages of using ROMs for building design optimization

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Ventilation practices in UK homes in relation to indoor air quality, noise and overheating.

Cairan Alexander Van Rooyen (cairan.rooyen.18@ucl.ac.uk)

Supervisors: Dr Cliff Elwell (UCL), Prof Mike Davies (UCL), Dr Sani Dimitroulopoulou (PHE), Dr Benjamin Fenech (PHE), Dr Clive Shrubsole (PHE) and Dr Ross Thompson (PHE).

1. Aim

Investigate the relationship between occupant ventilation practices and indoor environmental quality (IEQ) factors, including: overheating, indoor air quality and noise and relate this to health and well-being thresholds and guidance.

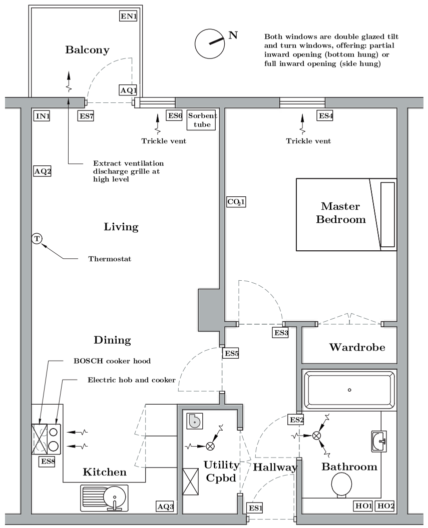

Figure 1 - Floorplan of participants dwelling.

Figure 2 - Overheating, IAQ and noise dynamic variables affecting IEQ (Zero Carbon Hub, 2015)

2. Method

A pilot case study with physical monitoring of occupant behavior and environmental parameters including the following:

- Temperature, humidity, PM_1, $PM_{2.5}$, PM_{10}, CO, CO_2, NO_2, TVOC and noise.
- Measure when any door or window is opened or closed and when mechanical ventilation systems are operated.
- Capture VOCs using sorbent tube and identify the top 10 VOCs.

3. Results

The following were observed in a pilot flat on the 6th floor of a residential building in London:

- Ventilated using trickle vents most of occupied time (73%), natural (24.5%), mechanical ventilation (1.6%) and mixed mode ventilation (0.7%).
- Bedroom and kitchen found to overheat, using static (CIBSE 2006) and adaptive (TM59) overheating metrics. Living room didnt overheat.
- IAQ remained below health related thresholds.
- No toxic VOC's measured.
- Noise above WHO thresholds day and night time.

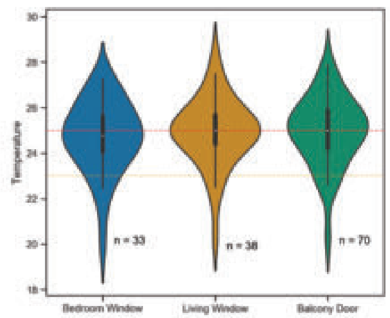

Figure 3 - Temperatures at the time when windows and door are opened.

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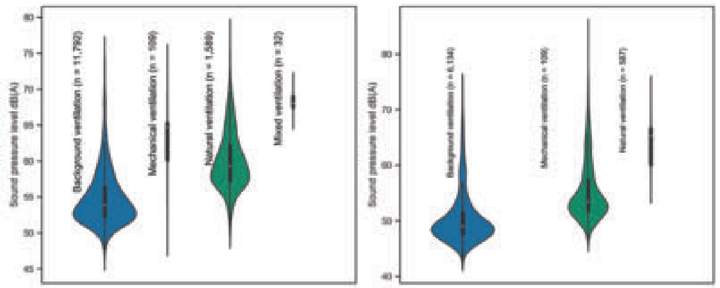
4. Conclusions

- **Ventilation practices with potential for higher ventilation flow rates (Background ➔ natural ➔ mechanical ➔ mixed mode):**
  - **= Lower air pollutants & better IAQ.**
  - **= Higher internal noise.**
  - **= Higher internal temperatures (windows opened when hot outside).**

- Evidence shows overheating & high internal noise, supports policy change to address overheating and reduce noise inside and outside dwellings.
- Results can inform modelling.



4a - Day time
4b - Night time

Internal noise levels are significantly higher when windows opened, mechanical ventilation in operation and during mixed mode ventilation, during both the day and night times.

5. Future Work

- Socio-technical study.
- Structured interviews: key ventilation behaviour, occupant satisfaction (IEQ), ventilation interaction and percieved constraints.
- Larger, more representative sample.
- Quantify ventilation rates.

References:

Zero Carbon Hub (2015): Overheating in homes. The big picture - Executive Summary.

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Cognitive Biases and Consumer Engagement with Local Energy in a Multiple Supplier Model: Survey experiments in Britain

Nicole Watson, Prof. David Shipworth, Dr. Gesche Huebner & Dr. Mike Fell

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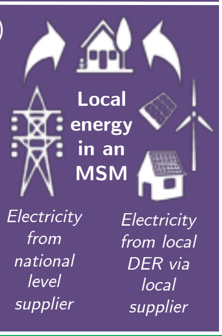
Multiple supplier models are likely to be socially acceptable for driving the growth of local energy

Multiple supplier models

- Multiple-supplier models (MSMs) would allow consumers to have more than one energy supplier.
- This could support new models, such as local energy suppliers, P2P energy trading, and others.
- It is important to understand how alternative supplier models might affect consumer engagement in an increasingly complex market.



Consumer behaviour

Many consumers do not engage with the energy market and stay with default suppliers and tariffs. **Behavioural economics** proposes 3 reasons why:

Cognitive effort

The mental effort required to process alternatives

Implication: additional complexity of MSM could hinder engagement

Implied endorsement

Consumers perceive defaults as recommended to them

Implication: active endorsement of local energy could encourage engagement

Loss aversion

Consumers emphasise losses more than gains when making decisions

Implication: option to add on a supplier in an MSM could mitigate loss aversion and drive engagement

Aim

To understand cognitive biases that might prevent consumers from switching to local energy suppliers, under both the current supplier hub model and in an MSM alternative

Method: two nationally representative online survey experiments

Experiment 1 (N=1200)

Aim: untangle cognitive biases and assess willingness to 'add on' a local supplier in an MSM

Hypothetical letter from participants' **current energy supplier** offering a chance to 'add on' a local energy company's services to their current tariff (effectively an MSM). **Random assignment:**

- N=450 — **Single-supplier default:** MSM new option – must take action to switch to MSM
- N=300 — **Active choice:** Must choose a model
- N=450 — **Combined-supplier default:** Automatic enrolment on to MSM – must take action to switch back

Experiment 2 (N=800)

Aim: understand if consumers would be more likely to switch to a local supplier under MSM or current single supplier model

Hypothetical letter from **a new local supplier** advertising their services. **Random assignment:**

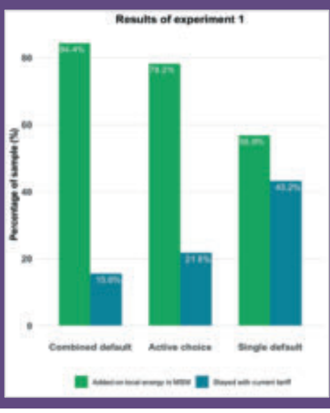
- N=400 — **Multiple-supplier:** Option to add local supplier on to current tariff in MSM
- N=400 — **Single-supplier:** Option to switch entirely to new local supplier

In both experiments, 'defaults' were conveyed through a pre-ticked box. Participants also answered an 11 item survey including measures of cognitive biases. All hypotheses and analyses were pre-registered as a **pre-analysis plan.**

Summary of results

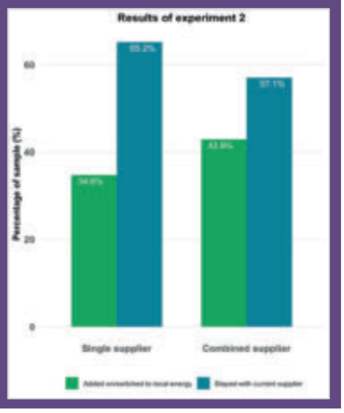
Experiment 1

- **Majority of participants chose MSM** in all conditions.
- **Results strongly suggest MSM would be socially acceptable.**
- Strongest evidence for **implied endorsement** associated with choosing the **MSM**.
- Some evidence **of loss aversion** associated with choosing the single **supplier model.**



Experiment 2

- Participants were significantly **more likely to add on local energy in MSM than switch to local supplier in single supplier model.**
- When comparing the two experiments, participants were **more likely** to add on a local supplier in an MSM in ex. 1, where they were **approached by their current supplier**, than in ex. 2, where they were approached by a new local supplier.



Policy impact

- ✓ Presented findings to Ofgem Future Retail Markets team
- ✓ Produced policy brief for Ofgem

Next steps...

- Academic dissemination
- Exploratory study on consumer attitudes to design of supplier model
- Develop field trials

Scan here to download the **policy brief**

Scan here to download the **working paper**

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