London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

ANNUAL COLLOQUIUM 2016

Thursday 17 November 2016
The Building Centre, LONDON

About the Centre

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

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

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

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

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

Prof Robert Lowe (Director UCL)

Prof Kevin Lomas (Director Loughborough)

UCL Loughborough University EPSRC

Programme

13.00	*Registration – tea and coffee, light lunch available* Vincent Suite, Lower Ground Floor
14.00	**Opening address** Professor Robert Lowe, Director, LoLo CDT *(Director, UCL Energy Institute)*
14.15	**LoLo highlights from the year** Professor Kevin Lomas, Director, LoLo CDT *(Prof of Building Simulation Loughborough University)*
14.30-15.00	**Final year student presentations**
14.30	Virginia Gori, UCL Energy Institute *A novel method for the estimation of thermophysical properties of walls from short and seasonal-independent in-situ surveys*
14.40	Vicki Tink, Loughborough University *The effect of internal wall insulation in solid wall properties upon energy demand, comfort & overheating*
14.50	Argyris Oraiopoulos, Loughborough University *Mapping the current & future risk of overheating in UK homes*
15.00	*Coffee, networking*
15.30-16.00	**Final year student presentations**
15.30	Selin Yilmaz, Loughborough University *Shifting the timing of energy demand: Developing a novel modelling framework to quantify the demand response potential of domestic appliances in UK homes*
15.40	Nafsika Drosou, Loughborough University *Assessing long-term actual daylighting performance of classrooms in use*
15.50	Ozlem Duran, Loughborough University *Optimised Retrofit Strategies for Post-War Office Buildings*
16.00-17.00	**Poster Session** Refer to list of projects
17.00	**Closing Remarks** Robert Lowe
17.10	End of main conference
17.30	**Keynote (**Ground Floor, Main Gallery)
18.30-19.30	**Drinks reception**

Keynote session

Claire Curtis-Thomas, Chief Executive, British Board of Agrément

Policy & perverse behaviours – understanding the landscape for large insulation retrofit projects in the UK

An obligation by successive UK governments to deliver global climate change agreements has led to the establishment of a billion pound property retrofit program designed to produce the agreed annual carbon savings.

Policy makers are reluctant to dictate contractual terms and conditions for carbon reduction measures and consequently industry has introduced a raft of approaches which are designed to maximise profits, an understandable objective, which we can demonstrate has been achieved at the expense of the householder and the British tax payer.

Biography

Claire Curtis-Thomas graduated in Mechanical Engineering from University College, Cardiff, and went on to obtain an MBA at Aston University. She also has an honorary PhD in Technology.

Her industry experience was gained with Shell UK. This was followed with roles at Executive of Birmingham City Council Laboratories. Claire then returned to university life as Dean of the Engineering and Business Department of the University of Wales, Newport, before moving into politics when she was elected as MP for Crosby.

During her time in parliament, Claire championed a number of issues on behalf of the construction industry and sat on three select committees: Trade & Industry, Home Affairs and Science & Technology. She also chaired All-Party Parliamentary Committees on Construction and Utility related subjects and founded the Construction & Development Partnership, a charity dedicated to bringing schools and education to the children of Sierra Leone.

Claire left politics in 2010 and before joining the BBA in 2013, she was Chief Executive of the Institution of Gas Engineers and Managers (IGEM), a Chartered Institution providing services, training, and standards to the gas.

Poster session

Charalampos Angelopoulos	Natural Ventilation in Schools: window design and performance
Radhiah Ariffin	Experienced personal light level in a building
Francesco Babich	Thermal comfort in non-uniform environments: real-time coupled CFD and human thermal-regulation modelling and validation
Kostas Chasapis	‘Smart’, remote monitoring of house fabric thermal performance: is it feasible?
Pamela Fennell	The impacts of project scale, scope and risk allocation on financial returns for clients and contractors in Energy Performance Contracts – a stochastic modelling analysis
Matej Gustin	High surface temperatures on artificial sport pitches: Potential for design improvement
Clare Hanmer	How household thermal routines shape patterns of heating demand
Frances Hollick	Developing a simple model to estimate whole dwelling heat loss which requires minimal input measurements: A pilot study
Lisa Iszatt	Investigating heat and moisture transfer through solid brick walls and the impacts of internal wall insulation
Harry Kennard	Power temperature gradients as a fuel poverty indicator
Anthony Marsh	Improving the performance of student accommodation developments through post-occupancy evaluations
Moira Nicolson	What about demand-side response? Using behavioural economics to boost consumer switching rates to time-of-use electricity tariffs – evidence from field experiments
George Papachristou	Reducing the Operation Performance Gap – improving building simulation tools through data-driven and real-time approaches
Ben Roberts	Ventilation and thermal comfort in UK homes: can we maintain indoor air quality and reduce the threat of future air-conditioning of UK homes?
Zack Wang	Trade-offs in Levelised Cost of Heat among different heating technologies
Stephen Watson	Aggregated load profiles of domestic buildings: the implications of an all-electric future
Catherine Willan	Exploring multiplicity in energy targets in a construction company’s processes and communications

PhD students

Joynal Abedin
PhD, Loughborough University
j.abedin@lboro.ac.uk

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

Charalampos Angelopoulos
PhD, Loughborough University
C.Angelopoulos@lboro.ac.uk

I hold a BSc in Mechanical Engineering from the Technological and Educational Institute of Piraeus, Athens, Greece in 2013, graduated with distinction. During this time, I undertook several internships in industry including a 6-month placement in Hellenic Telecommunications Organization SA as a mechanical engineer.

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 specialization in thermal energy. My MSc dissertation examined diverse energy storage technologies with a novel system of thermo-electric energy storage system.

Afterwards, I continued my studies at LoLo CDT in Loughborough University where I obtained my MRes in Energy Demand. My research dissertation focused on the thermal performance of single-sided naturally ventilated classrooms. For the purpose of this analysis I performed CFD simulations and the results were assessed against the updated draft version of BB101

“***Mixed mode ventilation systems in low energy buildings”***

I am currently in the 1st year of my PhD research. The aims of this project are to develop a control algorithm for mixed-mode buildings in hot climates. The sophisticated algorithm will optimally select between natural and mechanical ventilation in order to constantly maintain thermally comfortable internal environments as well as to minimise the energy consumption of the building. For the purpose of this research CFD simulations will be performed alongside with dynamic thermal modelling of the buildings.

Radhiah Arrifin
PhD, Loughborough University
r.ariffin@lboro.ac.uk

Radhiah completed her undergraduate degree in Biochemical and Biotechnology Engineering in her home country, Malaysia. She went on to purse an MSc. at Newcastle University in Environmental Engineering and graduated with a distinction. Radhiah joined LoLo CDT in September 2014, and is currently doing a PhD that is looking into the actual amount of light that people are experiencing in a building, and how it is related to their well-being.

The measurement of personal light exposure profile experienced in a work environment

The effects of light exposure have been associated with visual and non-visual effects such as physical and mental health, productivity of building occupants, and circadian rhythm. This research will explore illuminance level of occupants' in a building with two types of cohorts (moving and fixed). The aim of this study is to determine the key building design, operational and human factors that affect an occupant's light exposure in a work environment and its impact (if any) on general well-being. The study will be carried out in two seasons with varying light exposure (summer and winter) where quantitative measures will be used to examine personal light exposure by use of a wearable light data logger and a set of questionnaires to assess wellbeing of participants. Qualitative measures will also be employed, based on questionnaires and interviews that will be conducted to obtain more information and insight into participant activities and its relation to the quantitative data.

Francesco Babich
PhD, Loughborough University
f.babich@lboro.ac.uk

Francesco is a LoLo PhD Researcher and University Teacher at Loughborough University. His field of interested is numerical modelling, including CFD, human thermal regulation and dynamic thermal modelling, and measurement techniques that are used to validated the models. Alongside his research activity, Francesco organized the second LoLo student-led conference, which had over 100 registered participants mainly from UK universities, is working as a University Teacher mainly in Investment Appraisal.

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

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

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

Kostas Chasapis
PhD, Loughborough University
K.Chasapis@lboro.ac.uk

Kostas is Electrical Engineer and holds an MSc degree from the CREST of Loughborough University. His MSc dissertation was about the modelling of a house using renewable energy sources and hydrogen as means of energy storage. Kostas has working experience in the Energy sector and particularly in Renewable Energy projects and Electricity trading. Through his career he got involved with the design and installation of wind farms and PV projects both on-grid and off-grid. 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.

Modelling of community energy system

The current PhD will attempt to provide additional knowledge on the CES by modelling and simulating the operation of such a system. The aim is to create a reliable and functional model that can emulate the performance of a CES and study its operation and the technical and/or scientific problems that occur from the implementation of the CES to the local and national networks. The outcomes of the study will help to enrich the understanding of these systems that has been built up so far by the research community.

George Bennett
PhD, UCL
George.bennett.14@ucl.ac.uk

As a Mechanical Engineer I have had a relatively wide experience in industry since finishing my undergraduate studies a ‘few’ years ago. Including working as a development engineer on a wide range of Products, from stirling cycle cryocoolers to hydraulic control systems for aircraft.

For the last 10 years I have been working at Bosch Thermotechnology primarily working on the lifetime and robustness of gas boilers. If it can go wrong with a boiler or heating system, I have probably seen it! This has allowed me to live and work across Europe, through Germany, the Netherlands and to Turkey.

How are the dynamic behaviours of building heating systems represented in the National Calculation methods for EPCs and does this representation lead to inconsistent calculation of space heating and temperatures? or “Everything you always wanted to know about SAP*” *but were afraid to ask

Ranking the heating systems of today and tomorrow is a difficult task undertaken by many stakeholders. One tool, which influences both this comparison across Europe, is the Energy Performance Certificate. It gives the current environmental and financial impact of the energy system of the building and also guidance as to improvements to both building fabric and heating system. Behind the EPC lie calculation methods, which vary across Europe and have evolved from various beginnings. In the UK this is SAP and in Germany DIN 18599.

This research will use Bosch dynamic simulations in the MATLAB Simulink environment to analyse the assumptions of the standard calculation methods such as SAP to discover if they provide a level playing field for the heating technologies of today and the future. Simulation work will be supported and grounded with the help of Bosch field data from µCHP appliance field trial in Germany and a large data acquisition project in the UK.

Nafsika Drosou
PhD, Loughborough University
N.C.Drosou@lboro.ac.uk

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

Assessing actual daylighting performance of classrooms in use

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

Özlem Duran
PhD, Loughborough University
o.duran@lboro.ac.uk

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

Optimised retrofit strategies for post-war office buildings

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

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

Pamela Fennell
PhD, UCL
pamela.fennell.13@ucl.ac.uk

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

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

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

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

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

Virginia Gori
PhD, UCL
virginia.gori.12@ucl.ac.uk

Virginia is a doctoral candidate at the UCL Energy Institute. Her research focuses on the characterisation of the dynamic thermophysical behaviour of as-built building elements. Virginia is contributing to the development of a statistical-based dynamic method for the estimation of thermophysical properties of building elements by using in-situ measurements. This research attempts at overcoming some of the limitations (e.g., lengthy and seasonal monitoring periods) of current methods used for the analysis of in-situ measurements. Virginia holds an MRes in Energy Demand Studies from UCL’s Energy Institute and a Bachelor in Building Engineering from University of Florence (Italy).

***A* novel method for the estimation of thermophysical properties of walls from short and seasonal-independent in-situ surveys**

This thesis proposes a novel statistical-based dynamic method for the estimation of thermophysical properties of building elements from short and seasonal-independent monitorings. Although in-situ measurements allow the characterisation of buildings in their actual conditions, its wide adoption is currently limited by time and expertise required to undertake high-quality data collection and analysis.

A family of physically informed models was devised to describe potential heat transfer mechanisms across an element.

Four long-term-monitored differently-oriented in-situ walls and one housed in a thermal chamber were analysed to test the method. A two-thermal-mass model, strongly supported by model comparison, consistently showed a good characterisation of the thermal structure of the walls over seasons while shortening the monitoring period, showing good agreement with average method estimates and literature values, and keeping the systematic error within an acceptable range. This method supports a greater understanding of the energy performance of buildings helping closing the performance gap and informing tailored solutions.

Matej Gustin
PhD, Loughborough University
M.Gustin@lboro.ac.uk

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. During the last year of university he worked as a part-time external collaborator in an architecture and engineering firm in Trieste. 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 UK homes is a recognised existing problem for UK 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 the project is to understand the risk of the summer overheating in different UK dwellings in different locations with different occupants both now and in the future.

Clare Hanmer
PhD, UCL
clare.hanmer.15@ucl.ac.uk

Clare worked for 10 years at the Carbon Trust, contributing to innovations support programmes and strategy development across a wide range of low carbon technologies. She managed a programme investigating the challenges and opportunities for low carbon refurbishment of non-domestic buildings and les the Carbon Trust input to a European strategy for wave and tidal energy deployment.

Clare has a degree in engineering from Cambridge University and worked initially in the industrial gases industry. She gained an MSc in Renewable Energy from the University of Reading in 2003 and an MSc in Energy and Society at the University of Durham in 2015.

Flexibility and variability in morning thermal routines before and after transition to low carbon heating

An investigation of the factors that shape the patterns of home heating demand in the UK, focusing on requirements in the early morning: the point at which preferences for cooler temperatures while sleeping changes to a requirement for warmer temperatures when getting up currently causes a morning peak in gas demand. Thermal routines in homes both with conventional gas central heating and with low carbon heating systems (heat pumps and district heating) will be investigated using a combination of interviews, surveys and analysis of temperature data. The flexibility of user requirements will be assessed by testing the reactions of volunteer households to changes in timing and temperature setpoint for their heating.

Frances Hollick
PhD, UCL
frances.hollick.15@ucl.ac.uk

I studied Physics for BSc and MPhys qualifications at the University of Warwick, where I decided I wanted to work to help combat climate change. Rather than looking into climatology, the field of energy demand and buildings seemed a way to really help solve the issues contributing to climate change which to me seemed a more valuable and exciting prospect.

Developing a dynamic model to estimate whole building heat loss which requires minimal input measurements

This research aims to produce a series of dynamic models of whole dwelling heat loss which require varying numbers of measurements as inputs. The model will be based upon a combination of physical laws and data collected (both by the researcher and from secondary sources) from several domestic buildings, including an end-of terrace, recently retrofitted house and two flats in a large block. It is envisaged that this model will provide estimates for several thermophysical properties of the dwellings it is applied to, and that the effects on the accuracy of the varying numbers of input measurements will be known.

Lisa Iszatt
PhD, UCL
l.iszatt@ucl.ac.uk

Lisa started her career in low energy Architecture practices, including Architype. She completed an MSc in Environmental and Energy studies then worked in various energy focussed roles in both commercial and public sectors, including London Borough of Merton. Her work at Parity Projects furthered an interest in the responsible retrofit of existing buildings and specifically the use of internal wall insulation on solid brick walls. Lisa also works part time with Cocreate Consulting on Passivhaus certifications and moisture monitoring of low energy retrofit projects.

Hygrothermal characterisation of brick walls in the UK, and the impacts of internal wall insulation

Applying internal wall insulation to solid brick walls may contribute significantly to stock wide carbon savings. However, unintended consequences include increased moisture in the existing structure, which may lead to structural failure and risks to human health from mould.

This research will include a detailed analysis of heat and moisture in a small number of similar brick walls for at least one year before and after insulation using high resolution surface and in-wall monitoring. Planned insulation works to the three walls are staggered, so comparisons between insulated and uninsulated walls in similar environmental conditions is also possible.

Heat and moisture processes in brick walls have so far mainly been explored through hygrothermal modelling, using laboratory derived material property data. High resolution in-situ monitoring of solid walls offers a unique opportunity to assess the outputs of these models, and potentially enables hygrothermal parameter estimation, using simplified models and inverse analysis.

Harry Kennard
PhD, UCL
harry.kennard.15@ucl.ac.uk

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

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

Empirical measures of fuel poverty

The exact project focus is still being determined but it will likely seek to understand various empirical measures which occupants experience in domestic buildings, such as temperature, relative humidity and ventilation and determine how these compare between households experiencing fuel poverty and those with higher incomes. These measures will be related to government estimates of fuel poverty levels in order to determine both the prevalence of fuel poverty and aspects of domestic buildings which are associated with negative health outcomes for occupants.

Anthony Marsh
PhD, UCL
anthony.marsh.15@ucl.ac.uk

I have a first class masters degree in Energy & Environmental Engineering from the University of Leeds.

I have experience working as a technical consultant in the solar industry, and as an energy consultant - advising clients how to reduce their energy usage. I'm interested in improving multi-residential accommodation developments through post-occupancy evaluations.

Improving the performance of student accommodation developments through post-occupancy evaluations

A post-occupancy evaluation case study was carried out on a student accommodation block in the UK. The development was found to have particular problems integrating new technologies. The combined heat and power unit, the building management system and the energy display monitors were not operating as intended. The findings suggest that contractors should focus on commissioning and training processes to ensure that systems are working effectively (and are well understood by future operators) at handover. Where feasible, they should also engage in a period of after care during initial occupation to rectify any issues early on. Technical due diligence procedures for selecting and sizing low and zero carbon technologies should also receive greater focus. Additionally, facilities management staff must become better equipped to manage the growing IT aspect of their roles. Finally, recent developments should be monitored so that comparisons can be made against design stage dynamic simulation models.

Ashley Morton
PhD, Loughborough University
A.Morton@lboro.ac.uk

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

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

Heating use in UK homes

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

Thomas Neeld
PhD, UCL
tom.neeld.13@ucl.ac.uk

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

In-situ event detection in combi-boilers for end-use disaggregation

This research aims to develop a technique to detect when certain events take place within common gas fired domestic boilers. The events of interest can be broken off into three groups, with each group meeting different end user requirements. The first group includes the events: demand type; demand period; and burner firing time. The second group include: circulation pump activity; flow turbine activity; fan activity; etc. The third group regards the detection of boiler component failure modes and total system failure modes. The research involves in depth analysis of signals emanating from a range of common boiler types. Additionally, it involves the development of a sensor device which can automatically identify said events. Work is being undertaken by colleagues from UCL-Business to patent the technology.

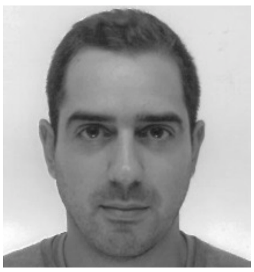
Moira Nicholson
PhD, UCL
m.nicolson.11@ucl.ac.uk

Moira Nicolson is a doctoral researcher at the UCL Energy Institute at University College London. Moira's research involves using field experiments to test whether insights from behavioural economics could be used to boost participation in demand-side response programmes and tariffs without making them mandatory or opt-out. Moira is interested in research methods and recently completed a Research Fellowship at the Behavioural Insights Team, the organisation established by the UK Government to apply behavioural science to public policy.

Encouraging domestic consumers to participate in demand-side response – evidence from field experiments

The UK Government's business case for smart meters relies on an additional 20 percent of consumers switching to a time of use tariff by 2030 (DECC, 2014). However, no studies have measured how many people will actually switch or what might boost switching rates, without harming consumers, if not enough people sign up. This PhD uses randomised control trials to test whether we can boost switching rates to these tariffs without making them mandatory or opt-out. Instead of forcing people to switch, as will take place in Ireland, so-called 'nudge' approaches could boost uptake at low-cost whilst respecting people's freedom to choose. Instead of automatically enrolling people unless they opt-out, as is being advocated in the US, this PhD will test 'nudges' that require people to make an active decision to switch, so that they do not run the risk of being signed up without their knowledge. Research in this area has been hindered because these tariffs are not yet widely commercially available. To overcome this problem without relying on opinion surveys, this research will measure demand for these tariffs (and how demand is affected by different interventions) using: (1) behavioural proxies e.g. open rates of emails that are sent providing advice on time of use tariffs and; (2) by creating a fictional energy company to measure actual switching rates to a time of use tariff designed by a startup energy supplier to be commercially viable.

Argyris Oraiopoulos
PhD, Loughborough University
a.oraiopoulos@lboro.ac.uk



With a background in Civil Engineering and an MSc in Water & Environmental Engineering (both awarded from the University of Surrey), Argyris went on to work for Costain before deciding to return back to London to study the MSc Environmental Design & Engineering at UCL, where he developed an interest on energy demand and UHI mitigation strategies. His dissertation focused on the effect of new dwellings on the urban local microclimate, using a 3D computational model.

He joined the LoLo CDT in 2012 where he completed his MRes on Energy Demand and he is currently finishing his PhD on the development of an empirical model that is able to predict overheating in UK homes, at Loughborough university, while working as a RA on a large European project (Design4Energy).

Argyris' research interests include: Overheating (criteria & predictions); Time Series Analysis & Empirical Modelling; Dynamic Thermal Simulation Modelling; Occupant Behaviour & Attitudes; Public Engagement & Education (STEM Ambassador)

Mapping the current and future risk of overheating in UK homes [contined]

Mapping the current and future risk of overheating in UK homes

Heat related mortality is likely to increase as heatwaves become more common due to climate change. Currently, overheating risk in domestic buildings is often predicted using modelling techniques based on assumptions of heat gains, heat losses and heat storage. However, a simpler method is to use empirical data to predict internal temperatures in dwellings based on external climate data. This approach can be used to identify homes which are at risk of overheating and suggest measures to reduce overheating.

The aim of this research is to take classical time series descriptive analysis that has been widely used in other fields (economics, geophysics, control engineering) and apply it in the field of building physics. This novel approach is used to understand the mechanisms behind the formation of time series room temperature data and to construct statistical models that allow the prediction of future internal temperatures based external weather data.

George Papachristou
PhD, Loughborough University

g.papachristou@lboro.ac.uk

George has a background in Civil Engineering after completing an MEng at Aristotle University of Thessaloniki. He continued his studies in the UK, where he obtained an MSc in Low Carbon Building Design and Modelling from Loughborough University with distinction. In his dissertation he used a bottom up model to explore the impact of different retrofit options on the energy use of the UK residential stock. For his performance he received the Energy Institute East Midlands MSc Student award. In his first year at the LoLo CDT, George completed the MRes in Energy Demand Studies with distinction, with his dissertation focusing on the control of natural ventilation in Central European plus energy houses.

His current research looks at modelling approaches which are most able to utilise real-time data streams for identifying suitable models of the heat dynamics of existing dwellings

Reducing the Operation 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 new approaches to modelling the thermal characteristics of buildings, based on models which can integrate and react to real-time measurements arising from in-situ sensors.

The overall goal is to develop new approaches to reducing the Operation Performance Gap. Among the expected outcomes are a set of model techniques that can include real-time performance data as part of their prediction algorithms, and which can update and calibrate in real time, to improve the thermal modelling of existing buildings.

Ben Roberts
PhD, Loughborough University
b.m.roberts@lboro.ac.uk

My interest in energy demand in the domestic sector began with an MSc. in Energy Policy at the University of Exeter where I conducted interviews and questionnaires around a policy analysis of the ill-fated Green Deal. Following this I was employed on a knowledge transfer partnership with Anglia Ruskin University and a Green Deal Provider to conduct research on consumer interaction with the early stages of the policy.

Due to the impending collapse of the Green Deal I left to begin an MRes. in Energy Demand Studies at Loughborough University in 2014 where my research focused on zonal heating controls.

I began a PhD in October 2015 investigating the effect of different window and blind opening strategies on the indoor thermal comfort during summertime.

The effect of occupant ventilation behaviour on overheating in summer

The aims of this study are to empirically evaluate and explain the thermal comfort and airflow effects of different ventilation and shading strategies in a real, typical 1930s semi-detached house in Loughborough, UK. To determine the effect of different ventilation and shading strategies and their influence on thermal comfort in other UK locations. To design the ideal strategy for providing optimum summertime thermal comfort for occupants.

Tracer gas methods will be used to quantitatively measure the air change rates under various ventilation scenarios with side-by-side comparisons of a matched pair of synthetically occupied test houses used to identify the effects on occupant thermal comfort and overheating under different window opening strategies.

The outputs of this work will recommend optimum window and blind operation to prevent summertime overheating, reducing excess summer deaths and heatwave-linked burdens on health services.

Zareen Sethna
PhD, UCL
zareen.sethna.13@ucl.ac.uk

Zareen studied Civil, Structural and Environmental Engineering at the University of Cambridge and graduated in 2008.

After graduation Zareen joined the engineering consultancy Buro Happold, she worked briefly in their London office and subsequently joined their sustainability team in Berlin.

She joined the MRes in Energy Demand Studies at UCL in 2013 and since then her interests have focused on energy consumption in homes and in particular the uptake of energy efficiency measures.

Energy efficiency in the UK private rented sector: government policy and landlords' practices

This sequential mixed methods study will analyse the impact of government policies on the uptake of energy efficiency measures in private rented dwellings in the UK in order to identify trends and barriers to uptake. The quantitative analysis will inform a second, qualitative research stage, in which private rental sector actors will be interviewed in order to gain a deeper understanding of the interactions between policy, actors' practices and the uptake of energy efficiency measures. The findings will inform an analysis of current and forthcoming policy and make recommendations for future policy.

Kate Simpson
PhD, Loughborough University
C.G.Simpson@lboro.ac.uk

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

Vicki Tink
PhD, Loughborough University
v.tink2@lboro.ac.uk

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

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

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

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

Zhikun Wang
PhD, UCL
Zhikun.wang.10@ucl.ac.uk

I am a PhD student at the UCL Energy Institute. I studied BSc Environmental Geoscience at the UCL Earth Sciences Department and graduated in 2013. After that, I had one year working experience in petrochemical industry in China. In 2015, I completed my MSc in Economics and Policy of Energy and the Environment at the UCL Energy Institute which focus 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 and storage: systematic exploration of comparative advantages of individual scale versus district level

Achieving the UK's energy and climate objectives requires not only environmental change mitigation efforts, but also investment in research and development of alternative energies and low-carbon technologies. Heating is the most important component of UK residential energy consumption and is mostly supplied through the direct burning of natural gas. Electric heat pumps together with decarbonised electricity are proposed as promising technologies that could replace gas heating and contribute to the low-carbon heat mix for the UK. However, heat pumps in heat networks are relatively new in the UK, and there are technical, social and economic challenges for their deployment. This study aims to develop scenarios, including heat pumps at individual level versus district level, in order to further explore their comparative advantages from different aspects, including technical and social impacts, carbon emission, energy efficiency, hot water storage, financial practicability and policy uncertainties.

Stephen Watson
PhD, Loughborough University
s.watson@lboro.ac.uk

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. 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 heating, especially compared to other technologies such as district heating. Stephen worked for a year in the maintenance team at an outdoor centre.

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 heating. There is a need to know more about the electricity demand of houses heated by heat pumps, in order to be able to make predictions about possible future national electricity demand with various proportions of houses using heat pumps.

Although it is possible to make predictions based on dynamic thermal modelling of the housing stock, the results of this may not be credible. Instead, a more empirical approach will be used, using high-resolution electricity demand data from real houses with heat pumps. These data will be analysed to investigate patterns of heating, the relationship to the type of house and occupants, and the degree of simultaneous usage. Based on this, estimates of future national electricity consumption of heat pumps will be produced.

Catherine Willan
PhD, UCL
catherine.willan.14@ucl.ac.uk

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

Exploring multiplicity in energy targets in a construction company's processes and communications

This research will work with a sponsoring construction company to help understand why energy expectations for the operational performance of non-domestic buildings are not always met. It hopes to uncover ways in which energy-related targets are communicated across, and practised by, the very diverse set of actors in a construction project. The PhD will use a variety of qualitative data sources, including observation, interviews and documents. Concepts from discourse analysis and the 'ontological turn' in Science and Technology Studies will be employed to explore the multiple enactments and repertoires of energy targets in construction. It will contrast findings with the experience of other core construction issues, such as health and safety. Finally, it will reflect on the implications for non-domestic building energy targets in policy and practice.

Selin Yilmaz
PhD, Loughborough University
S.Yilmaz@lboro.ac.uk

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

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

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

MRes students

Dounia Amraoui
MRes Energy Demand Studies, Loughborough University
D.Amraoui-15@student.lboro.ac.uk

Dounia completed her undergraduate degree in chemical engineering and pursued an MSc in Efficient Fossil Energy Technologies at the University of Birmingham. She has a keen interest in sustainable energy and has undertaken internships within bioenergy research, hydrogen fuel cells and catalysis.

In 2016 she joined LoLo to undertake further research within the energy demand field.

Jessica Few
MRes Energy Demand Studies, UCL
Jessica.few.16@ucl.ac.uk

Jess graduated from Durham University in 2013 with a Physics degree. She then worked for three years as a research scientist in environmental monitoring, focusing on identification and quantification of atmospheric emissions from industrial processes. She joined the LoLo MRes programme in September this year.

Jess is interested in how physical models of energy use can accommodate people's behaviour and real world data from field trials.

Duncan Grassie
MRes Energy Demand Studies, UCL
Duncan.grassie.16@ucl.ac.uk

Although I come from a Chemical physics background, having graduated from Edinburgh University with my MSc in 2006, I have spent the last 10 years working in the oil industry as a petroleum engineer. My work mainly involved building development scenario models for oil fields, designing well completions and artificial lift systems and developing bespoke software tools to extend the existing engineering capabilities of available software. I was fortunate to be able to work on new and mature fields in many locations including UK, Romania, UAE, China, Denmark, Norway and Indonesia and still maintain an interest in the industry.

For some time I have been aware of the decline in fossil fuel resources first hand and have been interested in determining whether our expectations of "what comes next" is realistic in a world of more than 10 billion people. For me this is the single most important question that needs to be answered in the world today. I hope to use my MRes to find out more about the feasibility of technology being able to keep up with this ever increasing demand and then using my PhD research to develop models within the Lolo CDT coupling human behaviour with future technological and environmental challenges.

Suneina Jangra
MRes Energy Demand Studies, UCL
suneina.jangra.16@ucl.ac.uk

Suneina graduated with an MEng in Civil Engineering from the University of Bristol in 2012.

After completing her undergraduate degree, Suneina worked in the consulting and risk assessment industry for three years before undertaking an MSc by Research at Coventry University where she developed a strength-grading methodology for structural bamboo.

Suneina joined LoLo in 2016 in order to further pursue a research career.

Sebastian Junemann
MRes Energy Demand Studies, UCL
sebastian.junemann.16@ucl.ac.uk

Seb is an energy researcher with an interest in socio-technical research in domestic buildings. Prior to joining UCL Seb worked as a freelance research consultant carrying out social research in the energy sector exploring topics including public attitudes towards fracking, energy efficiency funding and future technology innovations.

He previously worked for NatCen as Research Director of the Energy and Environment team, delivering work including the government's evaluation of the Renewable Heat Incentive. Seb has also collaborated with UCL on research projects for the Energy Technologies Institute, including the Consumer Response and Behaviour project (part of the Smart Systems and Heat programme) and Optimising Thermal Efficiency of Existing Homes.

Through his work, Seb has specialised in integrating and synthesising work from different disciplines, including qualitative and quantitative social research, technical monitoring and energy systems modelling. He has also worked to apply the findings from primary research including field trials of smart heating controls into the design of future smart technologies.

In his early career, Seb worked for seven years in social housing working on driving sustainability projects for tenants and staff including retrofit programmes, fuel poverty advice and staff training. Seb holds a BSc (Hons) in Physics and MSc in Environmental Technology, both from Imperial College.

David Kenington
MRes Energy Demand Studies, UCL
david.kenington.16@ucl.ac.uk

I graduated from Imperial College London with an MSc in Environmental Technology in 2003. Since then I have had a varied background in policy, social research and evaluation on a broad range of issues, but with a focus on energy and resource efficiency.

I worked at the Energy Saving Trust for 8 years (2003-2011) in a range of roles including programme management of energy efficiency and transport programmes, and more latterly research and evaluation.

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

I was keen to further progress my research interests in an academic context, which is why I

Matthew Li

MRes Energy Demand Studies, Loughborough University

m.g.j.li-16@student.lboro.ac.uk

Following completion of an MMath Master's degree in mathematics in 2008, Matthew spent five years (2010-2015) teaching mathematics at Seoul Global High School, South Korea.

A long-held personal interest in responsible use of energy resources motivated Matthew to join the LoLo CDT in 2016.

Murat Mustafa

MRes Energy Demand Studies, Loughborough University

m.mustafa-15@student.lboro.ac.uk

I had my first degree in electrical and electronics engineering in Eastern Mediterranean University in Cyprus. I had been working in the construction industry for 10 years as electrical building services design engineer. I worked from small to very big international contractor and consultancy companies. I studied MSc in low energy building services engineering in Loughborough University between 2015-2016. My research was about predicting electrical demand of high residential building by using high definition bottom-up modelling tool and post processing the data by using Monte-Carlo analysis to increase confident of modelled data. In 2016 I joined to LoLo as MRes student with aim to continue PhD. I am looking forward to conduct research in natural and mixed-mode ventilation in non-domestic buildings.

Giorgos Petrou

MRes Energy Demand Studies, UCL

giorgos.petrou.16@ucl.ac.uk

Giorgos is currently undertaking his MRes in Energy Demand Studies and plans to focus on the topic of overheating.

He has recently graduated from the University of Warwick with a 1st Class (Honours) in Physics, receiving the top mark of his class. His studies have allowed for strong foundations in energy flow, generation and distribution. His final year project was a computational simulation that pursued to optimise 3D PV trees (supervised by Dr. Ramachers)

His aim has been to contribute to the field of energy from the start of his studies. He approached this field from different angles, by first completing an internship in the Renewable Energy group of Kassinis International Consulting LTD. He also competed at Npower's Energy Challenge where his team's innovative idea placed second nationwide. Following this, he undertook a summer research project with Warwick's group of Surface, Interface and Thin films with his successful research having potential future applications in the Energy Industry (supervised by Dr. C. Burrows, Dr. N. Neofytou and Dr. G. Bell).

Salman Siddiqui

MRes Energy Demand Studies, UCL

salman.siddiqui.16@ucl.ac.uk

Salman graduated in 2010 with a MEng in Mechanical Engineering from Imperial College. He then went to Saudi Arabia as a member of the founding classes of KAUST under scholarship to pursue an MSc in Earth Science.

After spending four years in various engineering roles 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 moving away from a fossil fuel based supply.

Daniel Wright

MRes Energy Demand Studies, Loughborough University

d.wright-16@student.lboro.ac.uk

My academic background is in psychology and sustainability, and I worked on projects for an international conservation charity for three years before starting my studies with the LoLo Centre.

My research background is in exploring interactions with metering technologies and influence on reported environmental behaviours and I am very interested in investigating this further, as well as the role that innovation and automation can play within energy demand reduction.

I am interested in investigating methods of supporting behavior change through information technologies. I am also keen to explore behaviour impacts of automating on energy controls as well as the role of innovation uptake.

Alumni

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

alexandros.adam.11@ucl.ac.uk

Alexandros received his undergraduate diploma in Mechanical Engineering from the National Technical University of Athens. He then came to London and obtained an MSc in Building Services Engineering with Sustainable Energy from Brunel University. He worked as a building services engineer for a consultancy in London.

In 2010 he joined the London – Loughborough EPSRC Centre for Doctoral Training in Energy Demand from which he obtained his MRes in Energy Demand Studies. In 2011 he joined the UCL Chemical Engineering department for a PhD degree in collaboration with the UCL Energy Institute. In 2015 Alexandros passed his PhD viva on the topic: "System Modelling and Optimisation Studies of Fuel Cell based micro-CHP for Residential Energy Demand Reduction". Alexandros is now working as an Energy Analyst at the National Technical University of Athens.

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

carrie.b@usefulsimple.co.uk

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

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

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

a.beizaee@lboro.ac.uk

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

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

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

michael.fell.11@ucl.ac.uk

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

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

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

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

Louis Fifield (PhD, Loughborough University)

L.Fifield@lboro.ac.uk

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

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

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

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

s.gauthier@soton.ac.uk

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

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

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

Sven Hallin (PhD, Loughborough University)

s.hallin@lboro.ac.uk

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

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

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

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

Richard.Jack@willmottdixon.co.uk

I completed my PhD in 2015, having had a (mostly) fun and enlightening time in Lolo. Completing a PhD is necessarily an introspective process at times, but being a part of the Lolo really helped me to keep an outward-looking perspective which helped to make my work more relevant to others and generally made life more interesting.

After completing my PhD I worked as a research associate at Loughborough University for a year, and then moved to Willmott Dixon Energy Services as an energy solutions engineer in March 2015. I specialise in performance measurement and assessment of buildings and building systems, and continue to apply the research that I completed during my time in Lolo.

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

pmorgenstern@bam.co.uk

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

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

Jenny Love (PhD, UCL)
Research Associate, Energy & Buildings, UCL Energy Institute
jenny.love@ucl.ac.uk

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

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

Sofie Pelsmakers (PhD, UCL)
Lecturer, University of Sheffield
s.pelsmakers@sheffield.ac.uk

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

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

Daniel.Quiggin@Investecmail.com

My PhD covered supply-demand modelling of future energy scenarios and the quantification of household demand adaptations via demand side management. Energy demand research is difficult because its the interplay between economics, people, technology, social norms and buildings.

LoLo students benefit from the diverse research interests of the teach staff and PhD students alike.

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

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

Ella Quigley (PhD, Loughborough University)

E.S.Quigley@lboro.ac.uk

I have a background in mechanical engineering but I have long been interested in building energy use and sustainability. This led me to join the LoLo CDT at Loughborough University, where I undertook an MSc in Low Carbon Building Design and Modelling, followed by a PhD concerning the energy and thermal performance of steel modular residential buildings in the UK.

I completed my PhD in August 2016; I am currently writing research papers about energy use and overheating in my case study buildings, and beginning to look for an interesting career in building performance and sustainability.

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

ed.sharp@ucl.ac.uk

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

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

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

samuel.stamp@ucl.ac.uk

Sam completed a four-year MSci in Physics at the University of Bristol in 2009, including a thesis exploring the potential for small-scale tidal stream technologies.

This work on small-scale energy generation led to a position at LIRE, the Lao Institute for Renewable Energy, in Southeast Asia. Work here focused on delivering a demonstration project to provide off-grid electricity, through pico-hydro generators, to remote villages in Laos.

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

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

faye.wade.10@ucl.ac.uk

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

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

Peter.Warren@beis.gov.uk

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

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

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

Appendix: Posters

London-Loughborough EPSRC CDT
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ANNUAL COLLOQUIUM 2016

Natural Ventilation in UK Schools during the heating season: window design and performance using CFD

Charalampos Angelopoulos[1] 1st year PhD student, Loughborough University [C.Angelopoulos@lboro.ac.uk]
Poster based on MRes dissertation supervised by Prof. M. J. Cook[1], Dr. C.Iddon[2] and Dr. S. Porritt[1].
1 Loughborough University, School of Civil and Building Engineering, LE11 3TU, UK.
2SE Controls, Hood Innovation Centre, Wellington Crescent, Lichfield,WS13 8RZ, UK.

Introduction

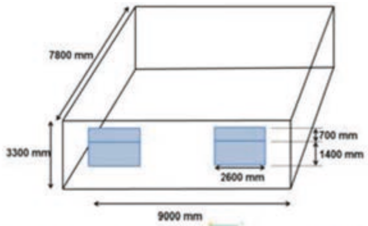
- Natural ventilation could maintain thermally comfortable internal environments[1].
- Low ventilation rates and indoor air pollutants could cause health issues[2].
- Poorly ventilated classrooms have negative impact on cognitive function[3].
- Poor indoor air quality for UK schools[4,5].
- Draft BB101 sets specific criteria for internal air temperature and velocity to avoid wintertime discomfort[6].

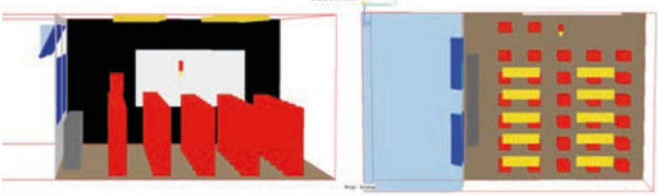
Aim

How natural ventilation systems, sized for delivering summertime cooling, should be controlled to avoid wintertime discomfort.

Methodology

Geometry





Ventilation Scenarios

Buoyancy Driven Ventilation Scenarios			Wind Driven Ventilation Scenarios
Top hung-out high level openings	**Bottom hung-in high level openings**	**Top hung-out high and low level openings**	**Top hung-out high level openings**
0°C outside		15°C outside	3.5m/s wind speed
5°C outside	5°C outside	20°C outside	5m/s wind speed
8°C outside	8°C outside		7m/s wind speed
10°C outside	10°C outside		10m/s wind speed
13°C outside	13°C outside		15m/s wind speed
15°C outside			

Evaluation criteria

Draught air speed [m/s]	0.3
$\Delta T_{\text{(Min maintained operative temp - plume local air temp)}}$ [K]	4
$\Delta T_{\text{(head to ankle)}}$ [K]	3

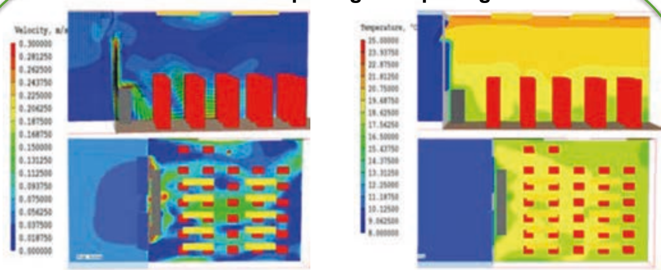
Draught Rating

$$DR = (34 - t_{\alpha})(u - 0.05)^{0.062}(0.37uT_u + 3.14)$$

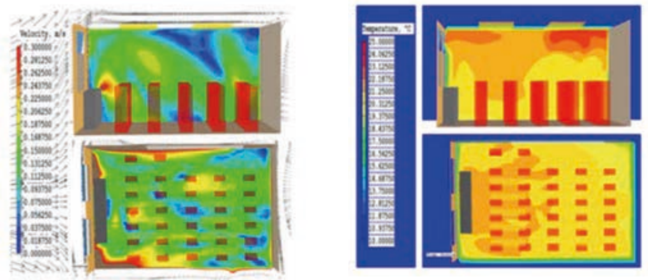
Adapted by ISO 7730 [7].

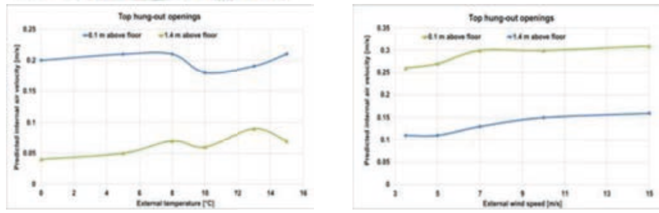
Results

T=8°C / Top hung-out openings



v_{wind}=10 m/s





- Temperature gradient divided into three zones; velocity gradient into two.
- Window configuration slightly affect the internal conditions.
- Positive correlation between wind speed & internal air velocities.
- Negative correlation between ventilation rate and wind speeds.

Conclusions

- **Single-sided natural ventilation suitable for:**
  - **Outside air temperature above 8°C.**
  - **Wind speeds below 10m/s.**
  - **78% of the occupied hours within the proposed weather conditions[8].**
  - **The placement of furniture was essential to eliminate cold draughts.**
- **80 % floor area likely to yield thermally comfortable conditions.**

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Acknowledgements

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ANNUAL COLLOQUIUM 2016

The measurement of personal light exposure profile experienced in a work environment

Radhiah Ariffin

Introduction

- The effects of light exposure have been associated with visual and non-visual effects such as physical and mental health, productivity of building occupants, and circadian rhythm.
- Architectural design and building function plays a role in determining indoor light exposure, which in turn has implications to wellbeing of occupants.

Research Questions:
1. Is there an association between personal light exposure and general well-being?
2. How is it best to measure personal light exposure in a work environment?

Aim: To determine the key building design, operational and human factors that affect an occupant's light exposure in a work environment and its impact (if any) on general well-being.

Methodology

Loughborough Design School (LDS)

HOBO light logger worn as a pendant

Attachment for HOBO using 3D printer

Quantitative:

- The study will be conducted at LDS to obtain personal light exposures of participants in selected workspaces who will be wearing a modified Hobo data logger as a pendant for 2 consecutive weeks in winter and summer.
- Participants will be asked to fill in questionnaires to assess wellbeing of participants.
- Quantification of the luminous environment of the selected workspace/rooms using HDR imaging.
- Identification of the design properties of the selected workspace/rooms and their modelled daylight performance using simulation.

Qualitative:

Questionnaires and interviews will be conducted to obtain more information and insight into participant activities and it's relation to the quantitative data.

Potential significant contribution

- A better understanding of the relationships between building designs, human & occupational factor with the actual amount of light that users are exposed to in a work environment.
- Assess personal light exposures profiles inside a building designed with plenty of internal and external glazing for the same individuals in two seasons (summer and winter), and how it is affecting their general well-being.
- Develop a method to access personal light exposure using easily accessible and affordable light logger.

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ANNUAL COLLOQUIUM 2016

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

1 WHY THIS RESEARCH

- Mechanical systems such as built-in air conditioning consume a lot of energy because they cool down quite evenly the entire space
- Due to the warming climate and the growing disposable income in several densely populated developing countries such as India, energy demand for space cooling is dramatically increasing
- Personalised air movement in warm environment improves occupants thermal comfort, but generates transient and asymmetrical environments
- Traditional thermal comfort models (PMV-PPD and Adaptive) are not suitable for asymmetric situations
- More advanced model are required, and there is only one existing fully coupled model: IESD - Fiala model and ANSYS CFX
- Linked to wider research that involves Loughborough University (UK), University of California Berkeley (USA), CEPT University Ahmedabad (India) and De Montfort University (UK)

2 AIM & OBJECTIVES

AIM

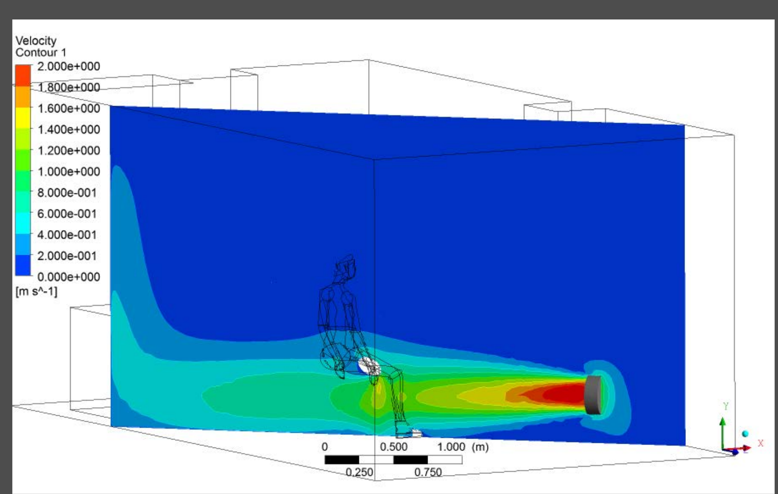
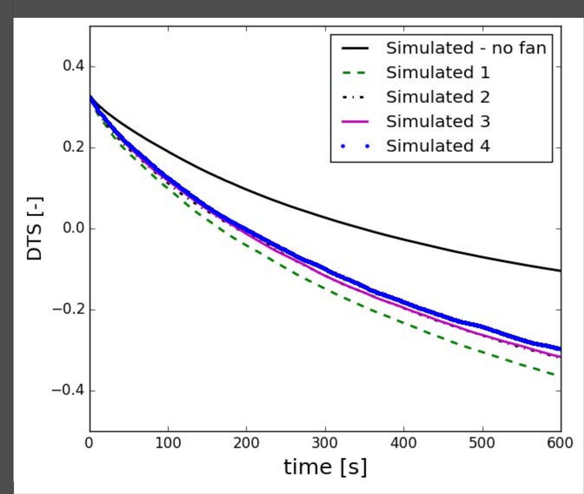
To develop a better understanding of human thermal comfort in domestic buildings and to improve the capability of prediction of human thermal comfort in domestic buildings by using computational fluid dynamics and human thermal regulation models.

OBJECTIVES

1. Coupled model development
2. Coupled model validation using data from environmental chamber
3. Identification of real residential scenarios in the UK and in India
4. CFD model of a typical Indian ceiling fan
5. Application of the coupled system to real residential scenarios
6. Estimate of the likely energy savings

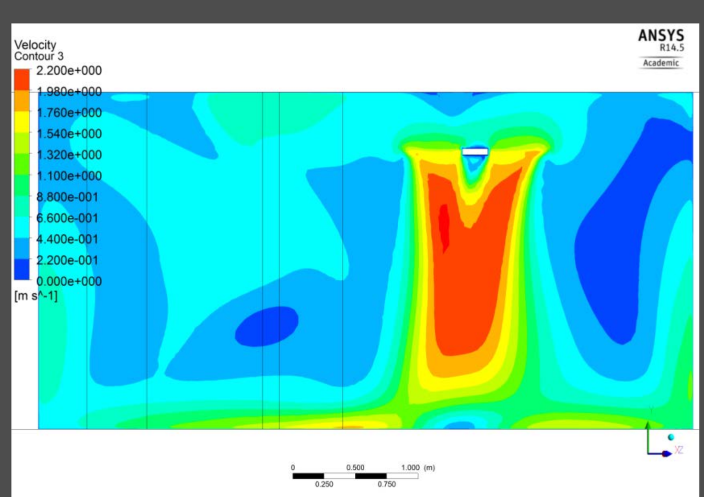
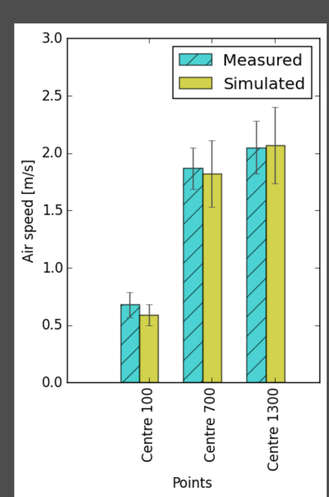
3 RESULTS

MODEL DEVELOPMENT AND VALIDATION

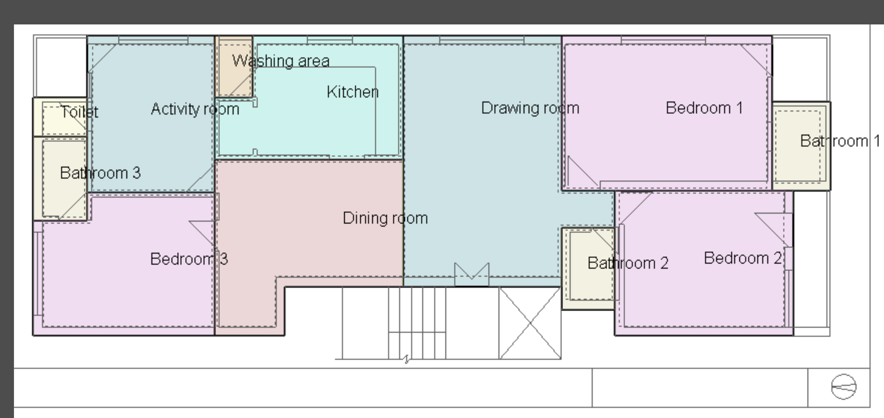
Dynamic Thermal Sensation (DTS) is superior to the traditional PMV calculation as both temporal and spatial variations and non-uniform conditions can be taken into account

REAL RESIDENTIAL SCENARIO IDENTIFICATION AND CEILING FAN MODELLING

- This implicit model of the ceiling fan is able to replicate the main characteristics of the air flow generated by the actual fan such as the meandering plume and the local fine free shear layers
- Measured and simulated values are in excellent agreement, with over 80 per cent of the simulated values (36 points of comparison) being within the error bars of the respective measured value

ESTIMATE OF ENERGY SAVINGS FOR A TYPICAL INDIANT FLAT



Cooling set-point is defined monthly based on ASHRAE 55-2013 adaptive model because:
- Closer to a real life scenario than PMV based methods
- Simpler to implement in EnergyPlus than Indian Model of Adaptive Comfort (IMAC):
  a) Calculate only a set point temperature per month (IMAC changes daily)
  b) Define in total 4 sets of monthly set points: no fan, 0.6 m/s, 0.9 m/s, 1.2 m/s
  c) Implement each of these 4 sets in Energy+/DesignBuilder using EMS
  d) Run 4 simulations. The first one, with no fan, is the base line

Simulation	Cooling hours [h]	Energy for cooling [kWh]	Energy for cooling [kWh/m^2]	Savings without considering the fan energy consumption [kWh]	Savings without considering the fan energy consumption [%]	Hours in which the fan is ON [h]	Fan power [W]	Fan energy consumption [kWh]	Savings considering the fan energy consumption [kWh]	**Savings considering the fan energy consumption [%]**	Only fan hours [h]
no fan	2527	2827	19.49	0	0	0	0	0	0	**0**	0
with Fan - 0.6 m/s	1843	1655	11.41	1172	41	2527	80	202	970	**34**	684
with Fan - 0.9 m/s	1524	1235	8.52	1592	56	2527	80	202	1390	**49**	1003
with Fan - 1.2 m/s	1327	1011	6.98	1815	64	2527	80	202	1613	**57**	1200

RESEARCH TEAM

Francesco Babich
3rd year PhD student

Professor Malcolm Cook
1st supervisor

Professor Dennis Loveday
2nd supervisor

CONTACT DETAILS

f.babich@lboro.ac.uk

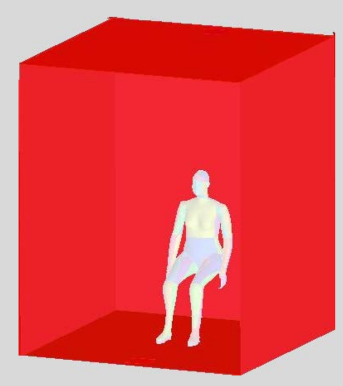
FAQ

What does "PMV-PPD" mean?
PMV means Predicted Mean Vote and it predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale. PPD stands for Percentage People Dissatisfied and it is a quantitative measure of the thermal comfort of a group of people at a particular thermal environment.
They are indices used in international standards such as ISO7730 and ASHRAE 55.

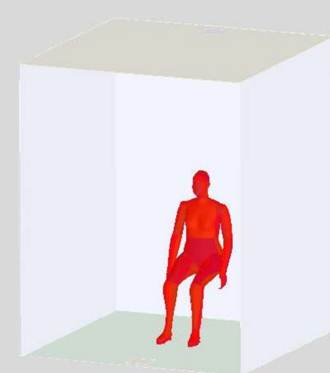
What is "computational fluid dynamics (CFD)"?
It is a technique based on numerical analysis and procedures used to solve and analyse problems that involve fluid flows such as air within a room.

What is a "human thermal regulation model"?
It is a model, such as the IESD-Fiala one, that predicts passive and active reactions of a human body to certain environmental conditions.

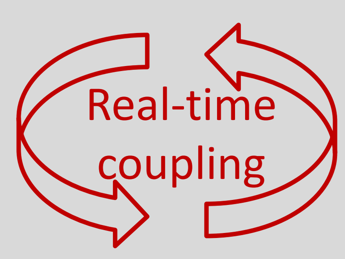
How does the "coupled model" work?
"Coupled" means that there is a real-time fully automated exchange of information between the two models while using them to solve a certain thermal comfort problem.

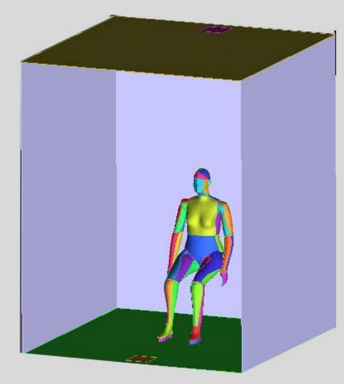


CFD: environment around person



IESD-Fiala: thermal response of the person





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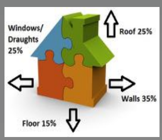
ANNUAL COLLOQUIUM 2016

‘Smart’, remote monitoring of house fabric thermal performance: is it feasible?

Kostas Chasapis (1st year PhD)
Supervisors: Prof. Dennis Loveday, Dr. David Allinson

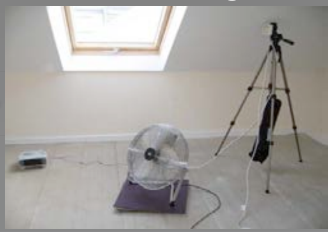
1



HEAT LOSS COEFFICIENT (HLC) = The rate at which heat is lost from the house (W/K).

Measured with the Co-Heating Test →

The Co-Heating Test



Main Drawbacks of Co-Heating Test:

1) Vacate house for 1-3 weeks.
2) Install electric heaters and fans.

2

Loughborough In-Use Heat Balance - LIUHB –

→ New approach for HLC calculation researched by Richard Jack, Loughborough University (Jack,2015).

→ Same concept with the Co-Heating Test but significantly advanced.

Main advantages of LIUHB:

1) Occupants don’t vacate their home.
2) The house’s normal heating system is implemented to the test.
3) Designed to be utilised in combination with emerging data streams (e.g. smart meters) .

Knowledge Gap →

Investigate the extent to which the LIUHB might be further developed to a completely remote technique for estimating the operational HLC.

3

Aim & Objectives

Aim:
Investigate whether the LIUHB can be applied remotely through smart meters for regular HLC calculation.

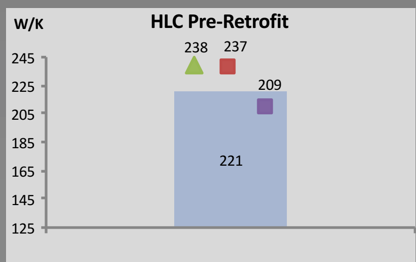
Objectives:
- O1: Develop and apply the ‘remote version’ of LIUHB and assess the process and the outcomes.
- O2: Investigate if the ‘remote version’ of LIUHB can be used to track changes in the HLC caused by interventions to the house’s fabric.

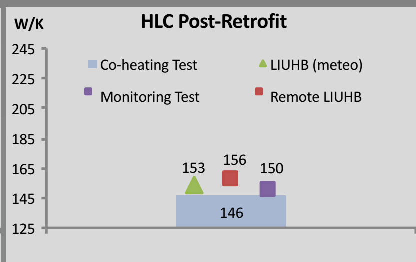
Methodology

Using data gathered from experimental test houses, HLC values obtained from ‘remote’ and ‘partially-remote’ versions of the LIUHB are compared with those from co-heating tests.

4

Findings & Observations





Implications to be addressed

- How to distantly identify the house’s location and orientation.
- How to distantly estimate the total glazed area?
- How many sensors for internal temperature?

5

Conclusion

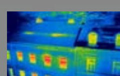
Results have so far been encouraging, though further validation is required before such an approach could be adopted at scale.

Potential Applications of LIUHB

- Post occupancy evaluation.
- Management of housing stock.
- Better targeting for subsidy schemes.
- Energy pricing.

Potential Advances of LIUHB

- Drones.
- Photogrammetry.
- 3D Terrestrial Laser Scanning.



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ANNUAL COLLOQUIUM 2016

Energy Performance Contracting
Is it time to check the small print?

Pamela Fennell, 3rd year PhD UCL Energy Institute
pamela.fennell.13@ucl.ac.uk

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

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

This study uses a stochastic modelling approach to investigate the effect of risk allocation on financial returns for clients and contractors.

- EnPCs can only trigger investment **if** building owners are confident they can rely on the guarantee.
- The guarantee is effectively defined by what can be measured since it is necessary to be able to prove energy savings were not achieved to invoke the guarantee.
- An international protocol exists which sets out approved measurement options but since the measurement boundaries are different in each case, the scope of the guarantee also varies significantly as seen in figure 1 below:

Figure 1: alternative measurement boundaries for a classroom lighting upgrade based on the International Performance Measurement and Verification Protocol

Case study: A school lighting upgrade

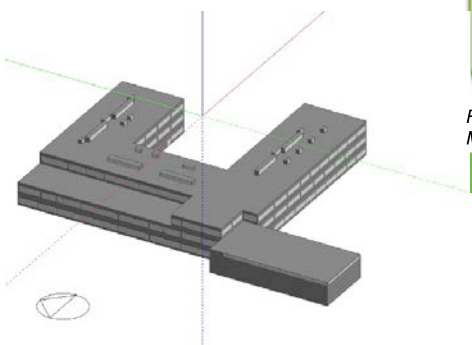

Figure 2: Secondary school model in EnergyPlus

- An energy model for a typical secondary school was created in Energyplus.
- Global sensitivity analysis was used to identify influential parameters.
- Influential parameters were varied randomly and a series of model runs used to create a profile of energy consumption reflecting the significant uncertainties in the baseline context for the upgrade.
- Upgrade was modelled as a decrease in lighting power and a reduction in lighting hours.
- Model runs were stratified by the total no. lighting hours and the stratification was preserved in the retrofit model to reflect underlying patterns driving lighting usage.
- Energy savings were calculated using 3 methods:
  - Engineering calculation based on deemed hours of use and rated power reduction – Option A.
  - Change in lighting power consumption – Option B.
  - Whole building change in energy consumption – Option C.

Results

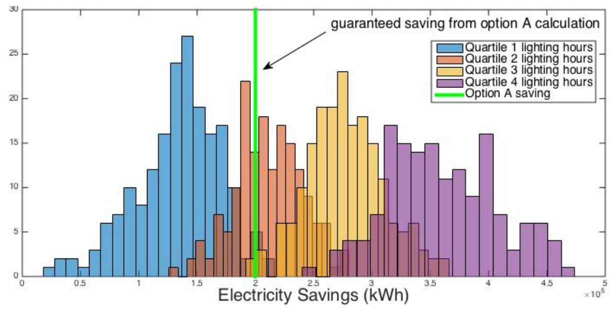

Figure 3a: Distribution of electricity savings grouped by hours of lighting use

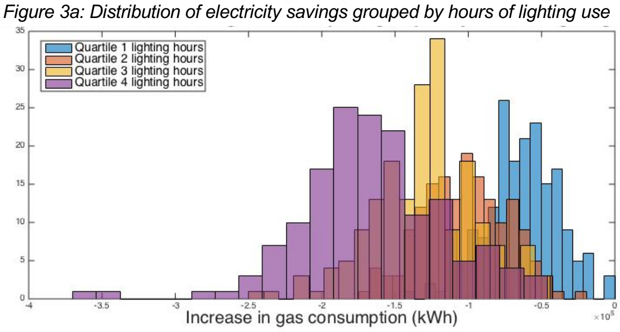

Figure 3b: Distribution of increases in gas consumption grouped by hours of lighting use

- Lower lighting users shown in blue in figure 3a (opposite) are likely to see electricity savings well below the ’guaranteed level’. If option A is used to measure savings, these users will have no protection from the guarantee.
- Higher lighting users (purple and yellow in figure 3a) are likely to achieve electricity savings in excess of the guarantee.
- All lighting users see an increase in gas consumption (shown as a negative saving in figure 3b). The mean effect is 50% of the total electricity saving but the impact is greater for higher lighting users.

Conclusions

- The choice of measurement strategy has a significant effect on the level of protection offered by the guarantee but the implications depend on the behaviour of building users.
- The guarantee may offer little protection meaning that loss of confidence is a real concern, particularly since performance contracting is an expensive form of procurement.
- The problem is exacerbated by a lack of good data on actual lighting usage in schools.
- Transparency is needed about the implications different measurement options.

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ANNUAL COLLOQUIUM 2016

High surface temperatures on artificial sport pitches: potential for design improvement

Matej Gustin - 1st year doctoral researcher, Loughborough University, Email: M.Gustin@lboro.ac.uk
Poster based on the MRes dissertation supervised by Dr. Paul Fleming and Dr. David Allinson

Background

THIRD GENERATION (3G) ARTIFICIAL SPORT PITCHES, DEVELOPED IN LATE 1990s AND LARGELY USED FOR FOOTBALL, RUGBY AND AMERICAN FOOTBALL; THE PLAYING PERFORMARCE IS COMPARABLE TO THE NATURAL TURF.

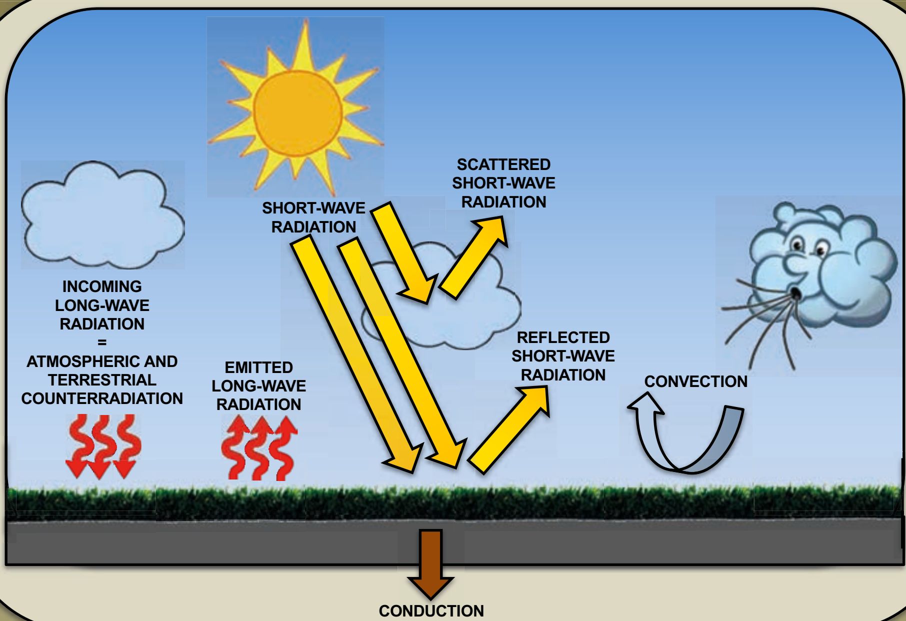
RESEARCH MAINLY FOCUSED ON COST, INJURY RISK, PLAYER AND BALL PERFORMANCE. THERE IS ONLY LIMITED RESEARCH ON THE OVERHEATING ISSUES WITH NO EFFECTIVE SOLUTIONS TO THE PROBLEM.

THE SURFACE TEMPERATURES ARE RISING UP TO 95°C; IT IS A PROBLEM ESPECIALLY IN HOT CLIMATES.

HEAT RELATED RISKS: DEHYDRTATION, BLISTERS, HIGHER PERCEPTION OF THE PLAYERS' EFFORT AND HEAT STROKES.

BLACK CRUMB RUBBER IS THE MOST COMMON INFILL, IS PRODUCED FROM SHREDDED TYRES AND HAS A HIGH HEAT ABSORPTION; IT IS ARGUED THAT IT CAN CAUSE CANCER.

Energy balance



Aim

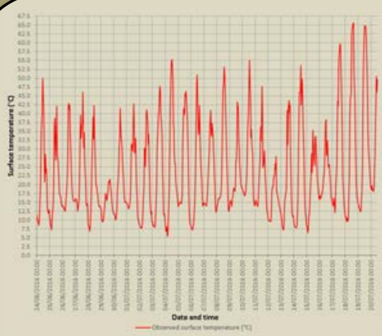
- TO INVESTIGATE THE MAIN FACTORS CONTRIBUTING TO THE OVERHEATING.
- TO EVALUATE THE POTENTIAL FOR IMPROVING THE DESIGN OF ARTIFICIAL SPORT PITCHES IN ORDER TO REDUCE THE SURFACE TEMPERATURES TO AN ACCEPTABLE LEVEL..

Methods

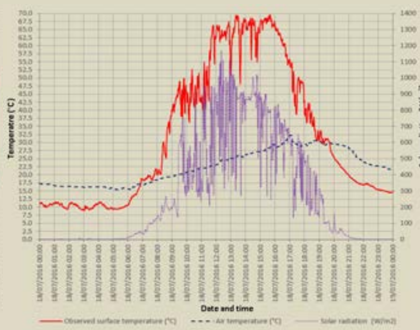
- SURFACE TEMPERATURE MEASUREMENTS.

- MODELS TO PREDICT SURFACE TEMPERATURES.
- VALIDATION OF THE MODELS.
- SENSITIVITY ANALYSES AND PARAMETRIC TESTS.

Findings



- SOLAR RADIATION EXPLAINS 84% OF THE VARIANCE IN SURFACE TEMPERATURES.



- SOLAR RADIATION AND AIR TEMPERATURE EXPLAIN 92% OF VARIANCE IN SOLAR RADIATION.

- INCREASING THE REFLECTIVITY (ALBEDO) OF THE SURFACE AND THERMAL CONDUCTIVITY OF THE INFILL ARE THE ONLY FACTORS THAT ARE ABLE TO LOWER THE SURFACE TEMPERATURES.

Conclusions

- SANDY CLAY AND HIGHLY CONDUCTIVE TPE ARE ABLE TO REDUCE THE SURFACE TEMPERATURES BY 18-23%.
- THERE IS ONLY A LIMITED POTENTIAL TO REDUCE SURFACE TEMPERATURES ON ARTIFICIAL SPORT PITCHES.
- SURFACE TEMPERATURES NEED TO BE BELOW 50-55°C TO PREVENT HEALTH RISKS.
- FUTURE RESEARCH SHOULD BE FOCUSED ON HYBRID GRASS SYSTEMS, WHICH MIGHT BE ABLE TO SOLVE THE OVERHEATING PROBLEMS.

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ANNUAL COLLOQUIUM 2016

How household thermal routines shape patterns of heating demand

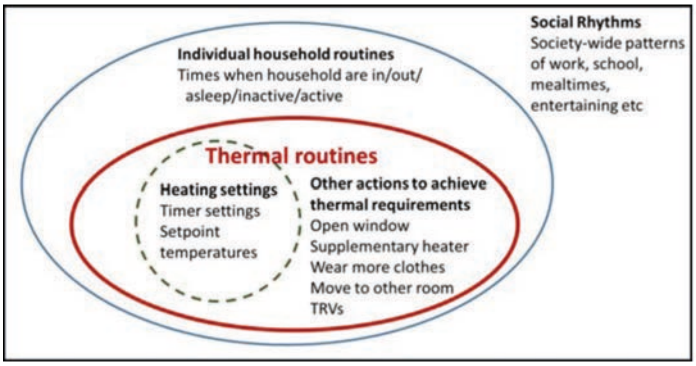
Clare Hanmer MRes Energy Demand 2015-16 clare.hanmer.15@ucl.ac.uk
Supervisor: Prof David Shipworth **Industrial Partner:** PassivSystems Ltd

Background

Understanding patterns of heating demand is important:

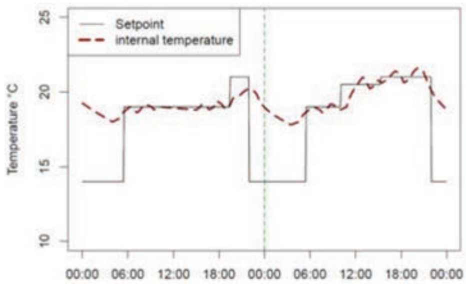
- What will the additional peak load on the electricity network be if electric heating (heat pumps) replaces gas boilers?
- Will low carbon heating be acceptable to users if operating patterns have to change (e.g. heat pumps run at night time)?
- How flexible is heating demand,? Can it be used for Demand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

Research question: How are daily patterns of heating demand for a group of homes related to individual household thermal routines?
Thermal routines are defined as regular patterns in time of heating use and other actions taken to achieve thermal requirements.



Methods and data

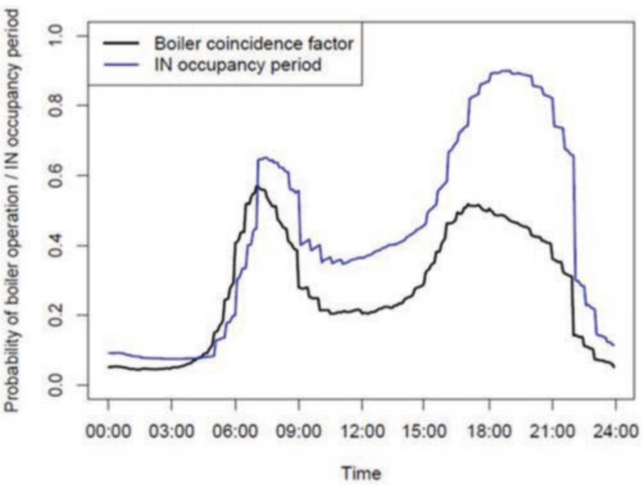
- Mixed methods:
  - Quantitative: statistics for temperature setpoints
  - Qualitative: telephone interviews with householders
  - Interviews give extra insights and check interpretation
- Investigation of actions (changes in controller settings)
- Unique data from PassivSystems controllers in 337 homes, 4 January to 28 February 2016
  - Temperature setpoint,
  - Internal temperature,
  - Call for heat
- Interviews with seven PassivSystems customers



Data from home with frequent setpoint change
(2 days in January 2016)

Key Findings

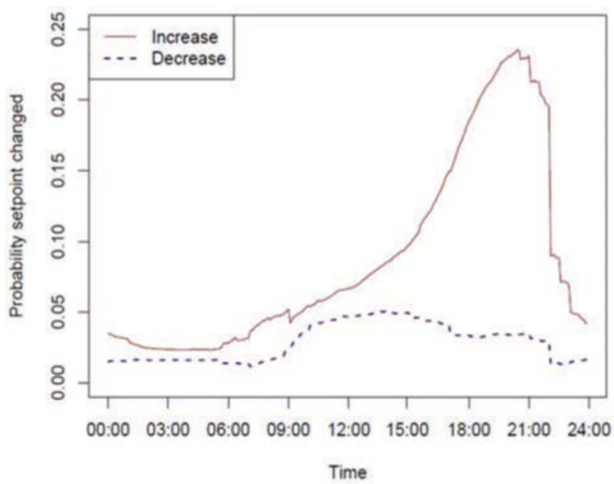
Importance of morning thermal routines



Probability boiler running at different points in the day
(337 homes, 40 weekdays in Jan/Feb 2016)

- The morning peak in proportion of boilers running is higher than the one in the evening even though more people have their heating at "IN" operating setpoint in the evening
- This difference is linked to more synchronous heating start times in the morning than afternoon/evening

Changes in temperature requirements in evening



Increases in setpoint compared to setting when heating starts in morning (337 homes, 40 weekdays in Jan/Feb 2016)

- Clear trend of more increases to temperature setpoint in evening.
- This is likely to be linked to change in activity level
- Households are not all satisfied with a consistent temperature whenever they are present in the home.

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ANNUAL COLLOQUIUM 2016

Developing a simple model to estimate whole dwelling heat loss which requires minimal input measurements

Frances Hollick UCL MPhil/PhD Student

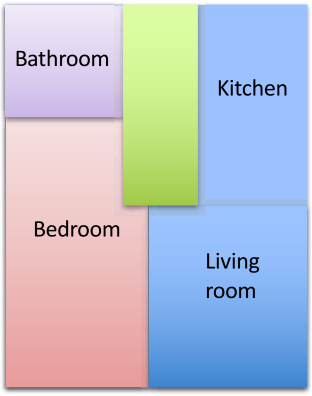
Supervisors: Cliff Elwell & Bob Lowe

Sponsor: Willmott Dixon

Aims

- Produce a simple, static model of the thermal performance of dwellings
- Use Bayesian regression techniques to estimate parameters describing the thermal performance of two flats

Case Study



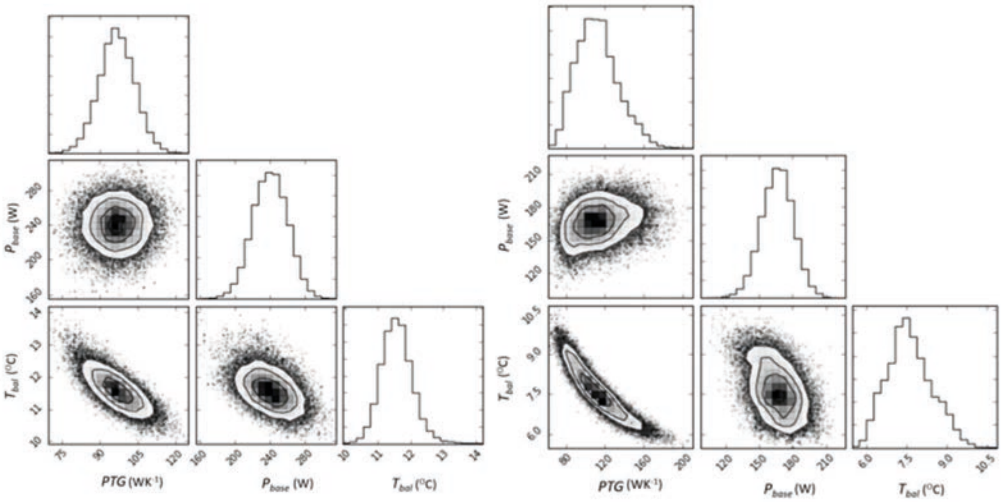
- Two flats, identical floor area and layout
- One 1st floor, two exposed external walls
- Other 6th floor, one exposed external wall

Model

$$P = \begin{cases} PTG(T_{bal} - T_{ext}) + P_{base} & for\ T_{ext} < T_{bal} \\ P_{base} & for\ T_{ext} \geq T_{bal} \end{cases}$$

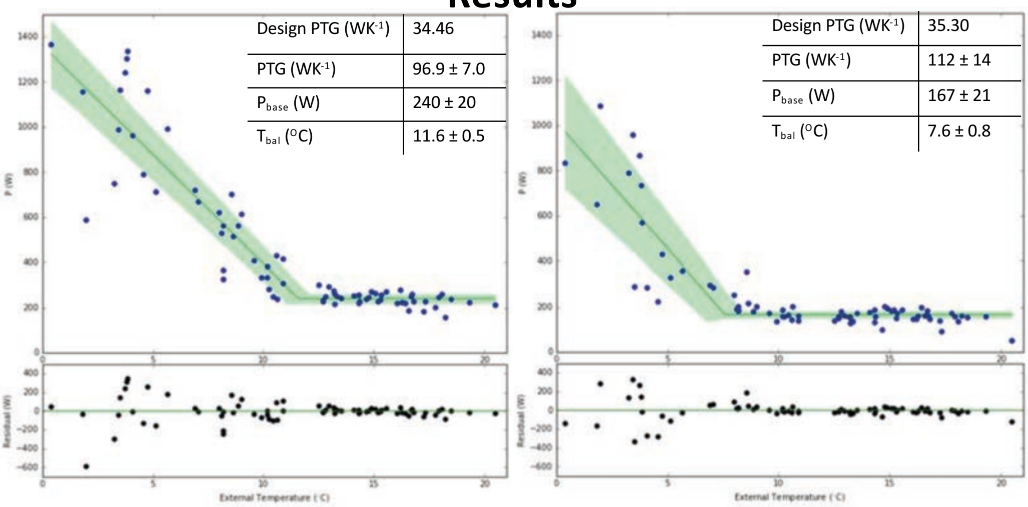
P = total power consumption; PTG = power temperature gradient; T_{bal} = balance temperature; T_{ext} = external temperature; P_{base} = non-space-heating power consumption

Parameter posterior probability distributions



T_{bal} affects the PTG and P_{base}, but the latter are independent of each other. Secondary maxima – sampling artefact or real?

Results



Design PTG (WK^{-1})	34.46
PTG (WK^{-1})	96.9 ± 7.0
P_{base} (W)	240 ± 20
T_{bal} (°C)	11.6 ± 0.5

Design PTG (WK^{-1})	35.30
PTG (WK^{-1})	112 ± 14
P_{base} (W)	167 ± 21
T_{bal} (°C)	7.6 ± 0.8

These median (of the posterior distributions) results show that one flat has a higher power consumption but a lower PTG, perhaps indicating the presence of another heat source

Conclusions

- Results seem in line with others in the stock
- Exclusion of other heat sources (e.g. solar) introduces significant uncertainty

Going forward…

- Develop a dynamic, yet still simple model
- Explore the effects on the accuracy the model predictions of the inclusion and exclusion of different parameters

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ANNUAL COLLOQUIUM 2016

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

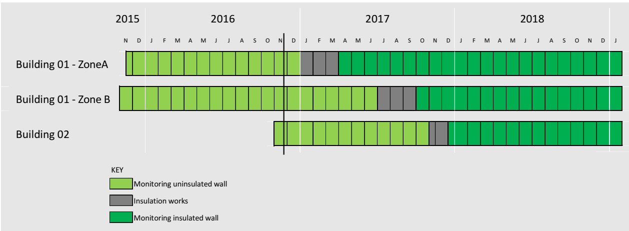
Lisa Iszatt 2nd Year PhD student (part time) **Supervisory team:** Cliff Elwell, Mike Davies, Neil May

Background

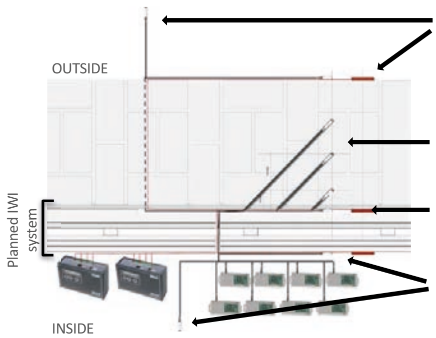
- Existing buildings account for approximately 40% of UK energy demand
- Internal wall insulation (IWI) may contribute significantly to reducing this demand
- IWI changes temperature and moisture profiles of walls → potential unintended consequences: structural damage & health risks due to mould
- High resolution in-situ monitoring of solid walls before and after IWI is rare, and there are opportunities for developing measurement and analysis techniques

Monitoring Campaigns

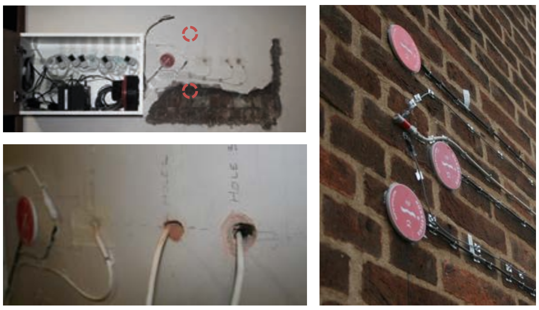
PROGRAMME OF MONITORING AND IWI INSTALLATION, 3 WALLS



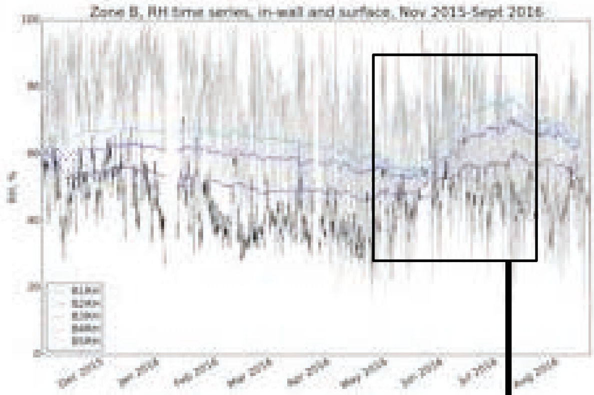
PLAN DIAGRAM

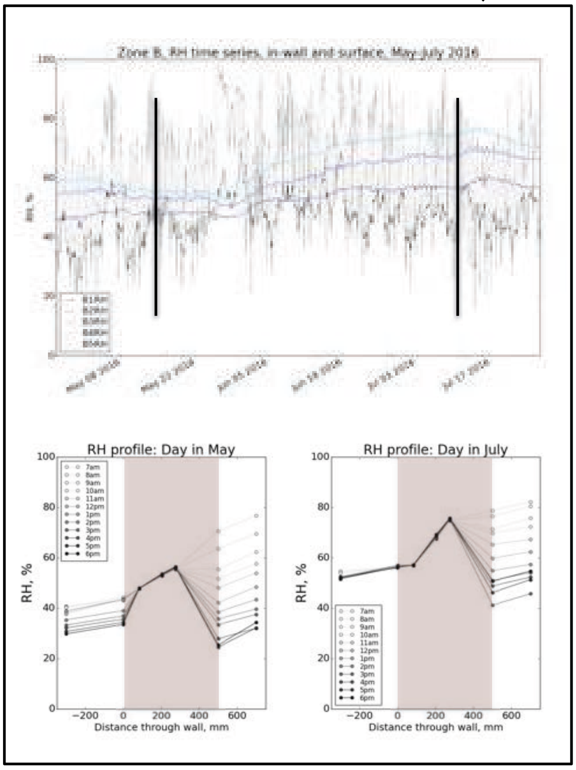


PHOTOS OF SET UP



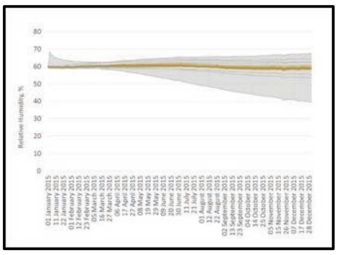
Initial results



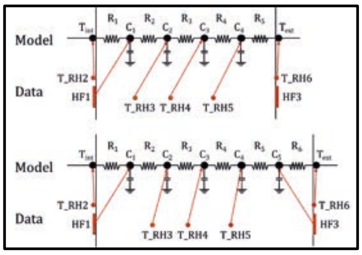


Future work

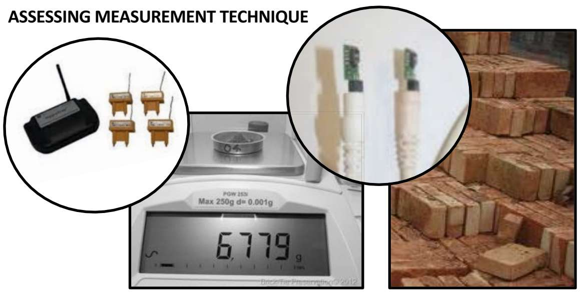
HYGROTHERMAL MODELLING PACKAGE



LUMPED CAPACITANCE MODELLING



ASSESSING MEASUREMENT TECHNIQUE



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ANNUAL COLLOQUIUM 2016

Power temperature gradients as a fuel poverty indicator

Harry Kennard 1st Year PhD UCL
Supervisors: Prof. David Shipworth, Dr. Cliff Elwell

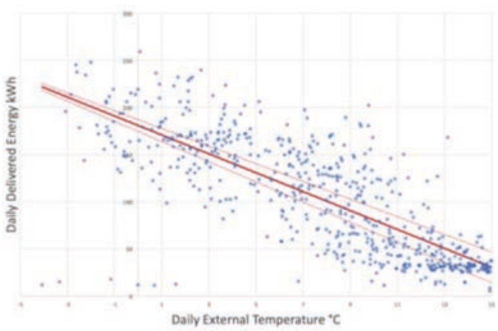
Fuel poverty in England

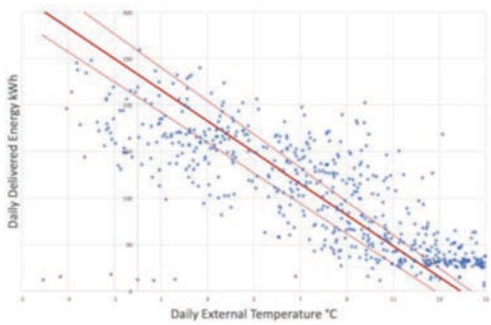
Under the current government "low income- high cost" definition a household is categorised as fuel poor if:

- To achieve a comfortable temperature, it has energy requirements above the national median
- AND meeting this requirement would leave the household with an income, after housing costs, below 60% of the median income.

However, the current implementation of this definition is likely inaccurate due to the mismatch between measured and modelled domestic energy use. This MRes project sought to understand whether the 'power temperature gradient' (PTG) (Summerfield et al. 2015) of a household might be useful for identifying fuel poor households. The PTG is constructed by plotting total metered energy against external temperature. This study analysed the PTGs of 5 low-income households from Leicester, using data collected through the Energy Demand Research Project.

Burnmoor street in Leicester, in an area of high prevalence of fuel poverty. It is unlikely that the above houses were included in this study, but data anonymity makes this impossible to determine.





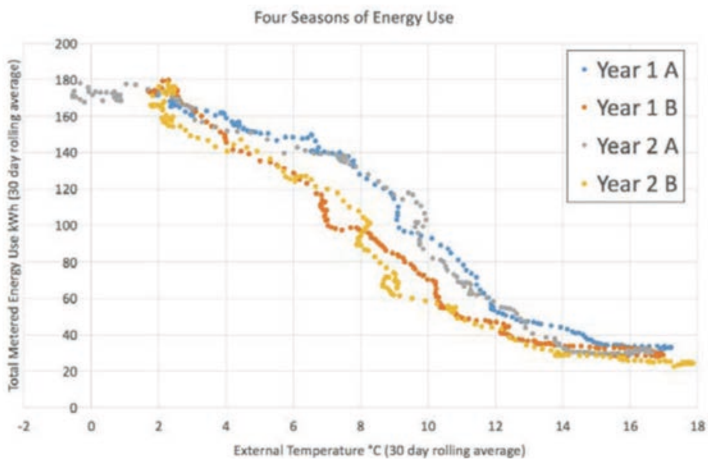
Power temperature gradient of low income households

The analysis showed that the R^2 correlation of the PTGs for all households was low (< 0.6). Moreover, the value of the PTG gradient could change between years of study. This suggested that the PTG alone may not be an adequate basis for the development of a means to identify those in fuel poverty.

Furthermore, since the independent variable (external temperature) is measured with error (±1°C) the standard assumptions of least-squares do not hold. Instead, an errors-in-variables model called Deming regression is appropriate. This suggested that the PTG may be systematically underestimated in other studies, particularly in households where the R^2 value is low. However, the effect depends on the specific way in which errors are distributed between both dependent and independent variables.

The figure to the left shows the potential extent to which the gradient (with 95% confidence intervals) may be underestimated, if, in the *worst* case, all the error falls on the independent variable and none of the dependent variable. Such a case is relevant when trying to understand the relationship between energy cost and external temperature.

Finally, the effect of a rolling average of the data was examined. The figure to the right shows the data from the above dwelling with a 30-day rolling average applied. In this instance there was some indication that energy use exhibited hysteresis. The effect may be explained by the difference in background gains, i.e. sunlight levels, at the same average external temperature.



Future work

Understand how different income levels contribute to differences in measured values of domestic comfort factors, such as temperature, and how this relates to negative health outcomes associated with fuel poverty.

References: Summerfield et al. (2015). Empirical variation in 24-h profiles of delivered power for a sample of UK dwellings: Implications for evaluating energy savings. *Energy and Buildings*, *88*, 193–202.

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ANNUAL COLLOQUIUM 2016

Improving the performance of student accommodation developments through post-occupancy evaluations

Anthony Marsh - 1st Year MPhil/PhD student, UCL Energy Institute,
Supervisors – Prof. Paul Ruyssevelt & Dr Ivan Korolija

Background

In the UK, purpose built student accommodation has received significant investment over the past couple of decades. This trend looks likely to continue. Future design decisions should be informed by the real-life performance of existing residences so that good practice can be replicated, and repeat mistakes avoided.

Research Questions

A recently constructed student accommodation development was used as a case study to answer the following questions…

1. Is the building meeting its energy performance design expectations?
2. How can these findings be used to improve future multi-residential developments?

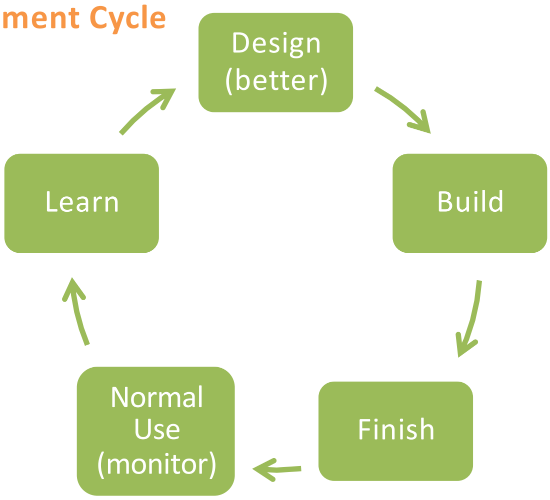
Observations

- CHP does not operate due to insufficient electrical demand (unit is oversized), plus facility has only limited year round thermal demand.
- Building energy management system (BEMS) cannot log and store energy data, hence it was not being used to manage energy within facility.
- Buildings have a propensity to overheat.
- Energy display monitors in apartments don't operate as intended (required software update).
- Heating controls in townhouses caused confusion due to overriding thermostat in common area.

Recommendations

- Clients should focus on BREEAM ***in-use*** to ensure the facilities' rating reflects operational realities, rather than design intentions.
- Commissioning, testing and handover should receive greater focus, and be given adequate time and attention accordingly.
- Original dynamic simulation models should be retained to compare with in-use performance
- Facilities management staff should receive more training on the growing IT aspects of their roles

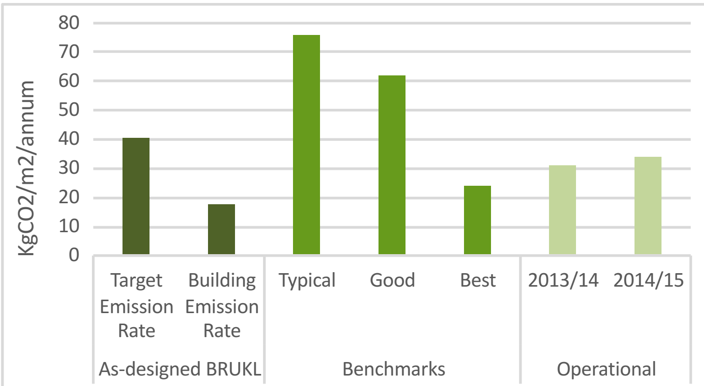
Improvement Cycle



The Case Study

General Details
Opened September 2013
648 bedrooms
BREEAM 'Excellent'
EPC 'A'

Carbon Emissions Comparison



PhD/MPhil

Compare dynamic simulation model (DSM) predictions of indoor environmental quality (IEQ) with in-use monitoring in multi-residential accommodation facilities (focus on summer time temperatures in single-aspect rooms).

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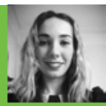


Would you like a time of use tariff with that electric vehicle? Engaging EV owners with DSR.

Moira Nicolson Third year PhD student

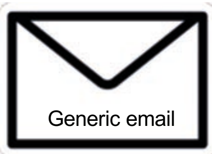
Motivation

Off-peak charging of electric vehicles (EVs) could save the UK £2.2 billion[1] in avoided low voltage electricity network reinforcement costs – but only if EV owners agree to participate in off-peak charging.

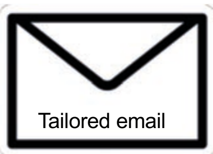
This trial provides the first compelling evidence that EV owners could be prompted to sign up to time of use tariffs or automated charging schemes by sending them an email to ask them to switch.

Method

Email sent to 7,000 private purchase recipients of the UK Government electric vehicle grant (~10% of all UK EV owners). To test what message would work best, they were assigned at random to see one of two emails.



"switch to save £300 on your energy bill – visit our top tips to find out how"



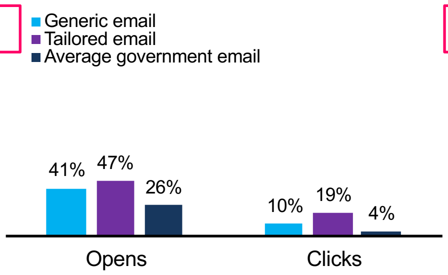
"switch to save the equivalent of 11,000 free electric miles – visit our top tips to find out how"

We worked with the Energy Saving Trust to create advice on the EST website about how electric vehicle owners could find the cheapest tariff for them – including advice on how to work out whether an Economy 7 tariff (which gives a cheaper rate for overnight electricity use) would be right for them. Although Economy 7 tariffs are likely to become redundant once smart meters are fully installed, the principle of paying a different rate for electricity depending on the time of day is the same.

Results

Email is a viable mechanism by which the UK Government could prompt EV owners to switch tariff, particularly if the email is tailored to EV owners (Fig. 1) and sent within 3 months of purchasing the vehicle (Fig. 2). Government tariff switching campaigns should also be tailored to EV owners. However, EV owners themselves are unlikely to save money on a time of use tariff unless they can also shift some of their other household electricity use away from peak times (Fig. 3). Automated charging or sub-metered time of use billing is likely to be the best way of ensuring that EV owners benefit from participating in DSR.

1



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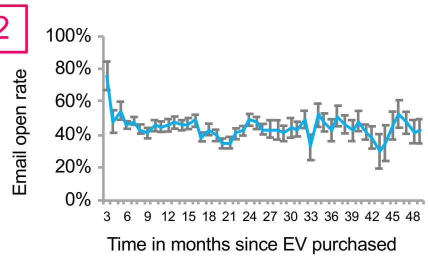

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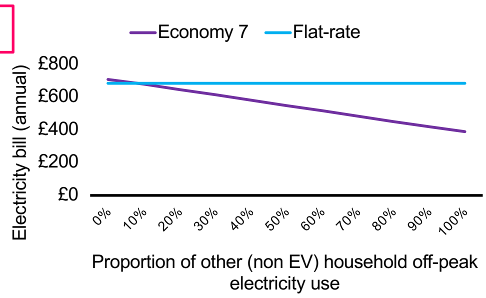

This PhD project was supervised by Dr. Gesche Huebner and Professor David Shipworth

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[1] My Electric Avenue Summary Report, 2015.

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BEN ROBERTS B.M.ROBERTS@LBORO.AC.UK
DR. DAVID ALLINSON AND PROF. KEVIN LOMAS

COLLOQUIUM 2016

OVERHEATING AND NATURAL VENTILATION

THE EFFECT OF OCCUPANT VENTILATION BEHAVIOUR ON OVERHEATING IN SUMMER

BACKGROUND

UK homes are becoming more air-tight and well insulated to reduce winter heating demand and alongside a warming climate are at increasing risk of overheating in summer. More common heatwave events could lead to an increase in excess summer deaths. A reduction in thermal comfort could encourage uptake of air-conditioning which would increase electricity demand. To improve summertime thermal comfort and prevent air-conditioning use in UK homes, a suitable ventilation and internal shading strategy needs to be devised to ensure homes stay thermally comfortable with minimum energy outlay.

Occupant behaviour directly influences internal thermal conditions during summer and more needs to be understood about precisely how and when to ventilate in terms of window opening configurations and responses to outdoor temperature.

AIMS AND OBJECTIVES

Empirically evaluate and explain the thermal and air movement effects of different ventilation behaviours in UK homes to determine and design optimum strategies for providing the most favourable summertime thermal comfort for occupants, reducing the risk of overheating and excess summer deaths.

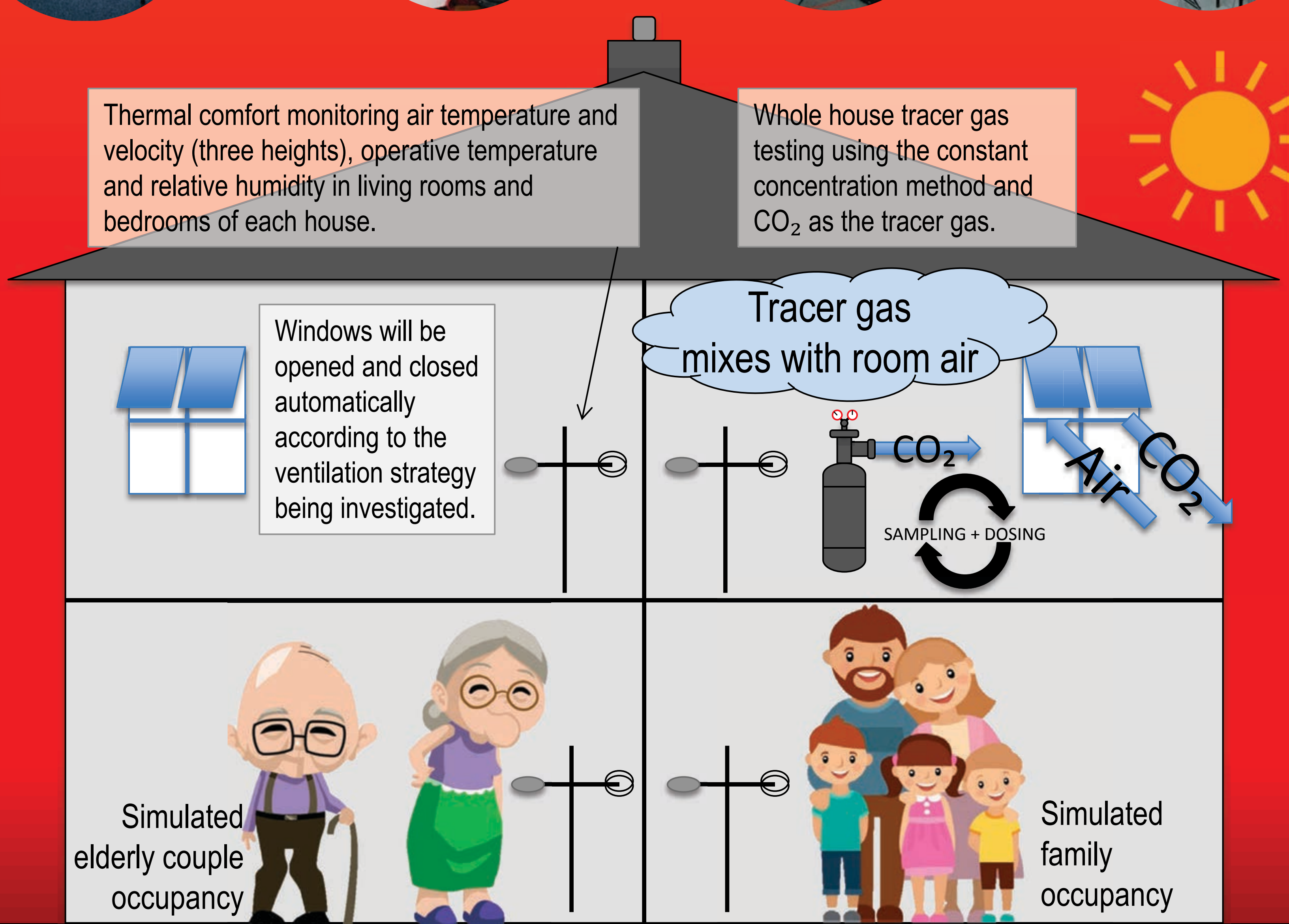
1. Develop methods to determine air change rates and critically evaluate to identify benefits and limitations.
2. Explore airflow and air changes under different window and window covering opening scenarios.
3. Explore thermal comfort under different window and curtain opening scenarios.
4. Extrapolate findings using wider UK climate data.

BENEFITS OF THIS WORK

- Identify at risk groups and tailor natural ventilation strategies to reduce overheating risk
- NHS: Lessen pressure on health services during heatwaves and reduce excess summer deaths
- Avoid wide scale adoption of air-conditioning which consume large amounts of electricity
- Develop experimental methods to detect air change rates in domestic buildings and validate models

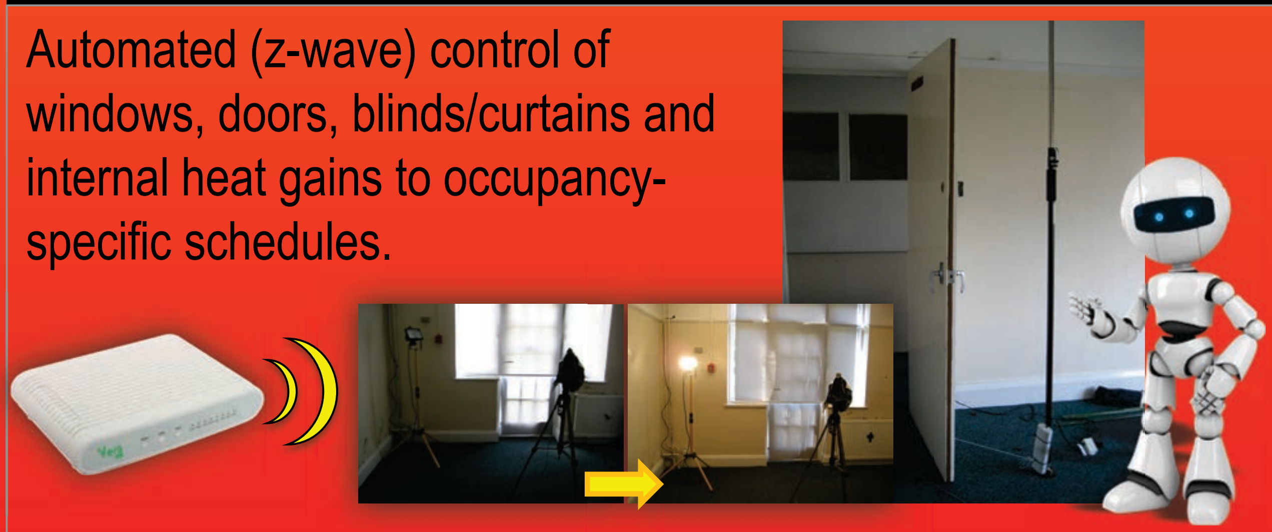
METHODOLOGY

- **Describe** – Houses with characterisation of thermal and airtightness properties.
- **Compare** – How similar are the two houses?
- **Review** – The literature on window opening behaviours.
- **Design** – Occupancy schedules to simulate behaviour based on literature.
- **Develop** – Methods to quantify air change rates.
- **Measure** – Air change rates and thermal comfort.
- **Extrapolate** – Findings to wider UK climate and projected data.
- **Recommend** – Optimum ventilation strategies to reduce overheating risk.



SYNTHETIC OCCUPANCY

Automated (z-wave) control of windows, doors, blinds/curtains and internal heat gains to occupancy-specific schedules.



LOUGHBOROUGH MATCHED PAIR TEST HOUSE FACILITY

Two 1930s mirrored adjoining semi-detached unoccupied test houses allow direct comparison of internal conditions under different synthetic occupancy behaviours whilst exposed to the same weather conditions.

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ANNUAL COLLOQUIUM 2016

Trade-offs in Levelised Cost of Heat among different domestic heating technologies

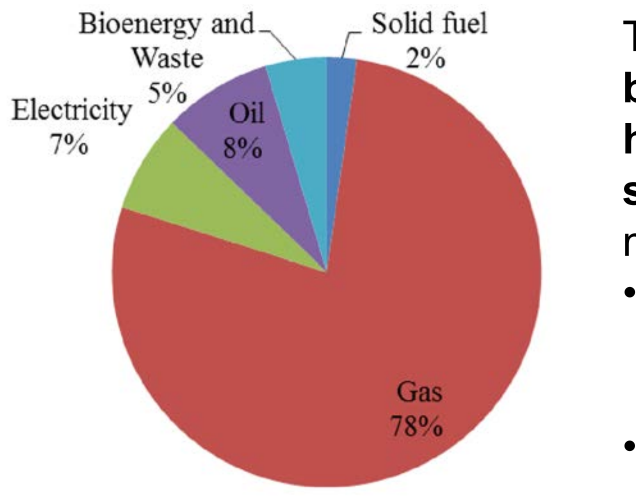
Zikun Wang 1st year PhD student
Zhikun.wang.10@ucl.ac.uk

Highlights

- A Levelised Cost of Heat model is developed to explore domestic heating options in the UK.
- Heat generated from low-carbon heat technologies may cost over twice than gas boilers.
- Compared to a gas boiler, a ground source heat pump saves 78% annual carbon emissions from heat for an individual household.

Introduction and research aims

Heating is the most important component of UK's households' energy consumption and mostly provided through the **direct burning of fossil fuel,** with over 85% of British homes have **gas boilers.** The **deployment** of low-carbon heat technologies is **low** and their **market is immature** in the UK. It is imperative to examine potential **alternative heating options** for domestic heating in the UK in order to replace conventional gas-fired systems and **reduce carbon emissions**.



Domestic space heating by fuel type in 2013.

This study aims to explore **costs elements** of **gas boilers, ground source heat pumps, air source heat pumps, biomass heating** and **solar thermal systems** through a Levelised Cost of Heat (LCOH) model.

- To investigate what determines the **costs of heat** for an individual household through different technologies.
- To estimate how low-carbon heat technologies contribute to **carbon emission reduction**.

Methodology

Levelised Cost of Energy (LCOE) is an effective method when evaluating **different** energy generation technologies, by taking into consideration **all cost factors** through their technologies **lifetimes**. It is a simple and transparent forward-looking statistical technique to **compare technologies** when the **costs and performance** of different technologies **differ due to a range of factors**, for example, their project sizes, technology efficiencies, costing structures and how they are operated.

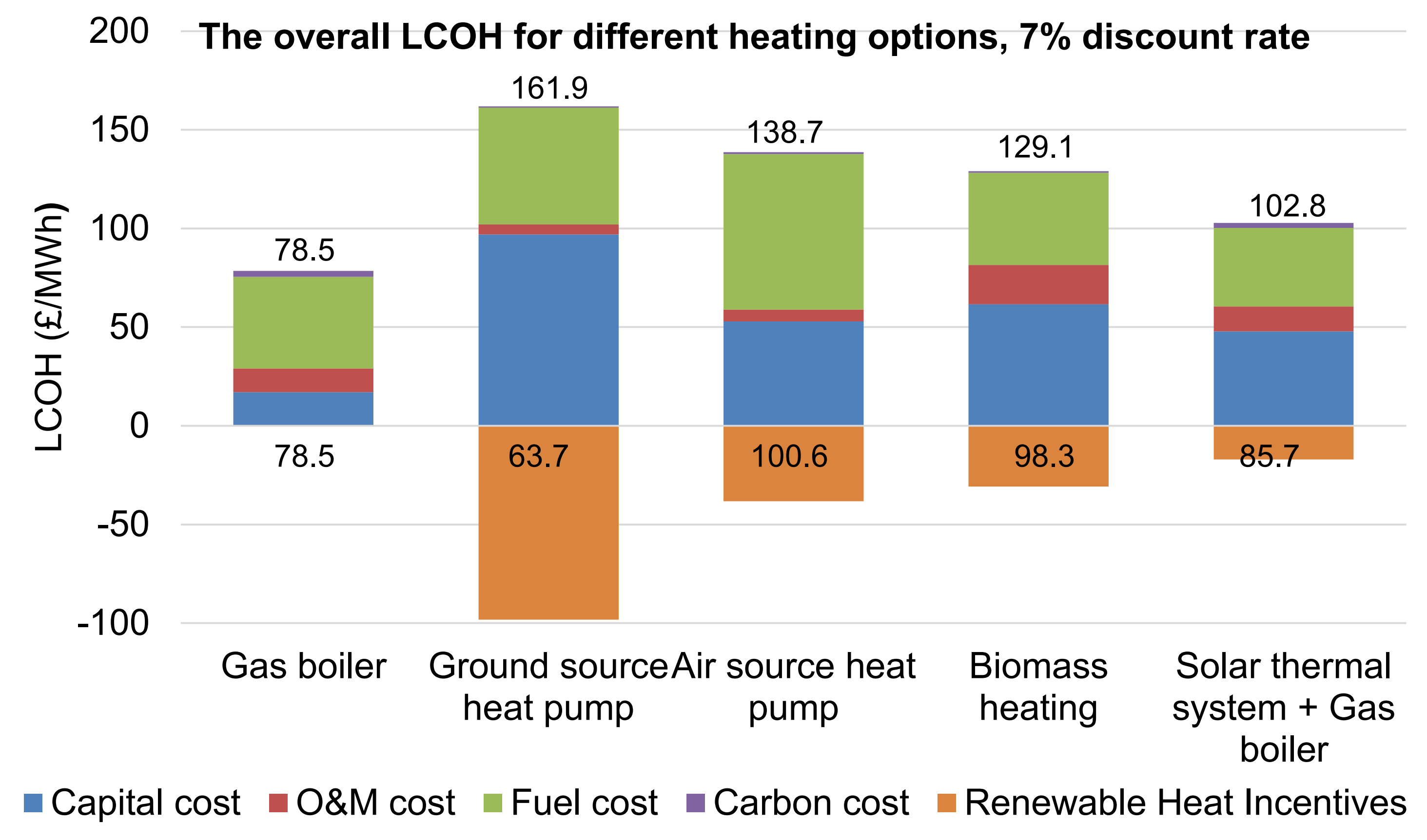
$$\mathrm{LCOH} = \frac{\text{Net Present Value (NPV) of lifetime costs}}{\text{Net Present Value (NPV) of heat produced over lifetime}}$$

$$\mathrm{LCOH} = \frac{\sum\left[\frac{\mathrm{Capital}_t + \mathrm{O\&M}_t + \mathrm{Fuel}_t + \mathrm{Carbon}_t + \mathrm{RHI}_t}{(1+\mathrm{r})^t}\right]}{\sum\left[\frac{\mathrm{MWh}_t}{(1+\mathrm{r})^t}\right]}$$

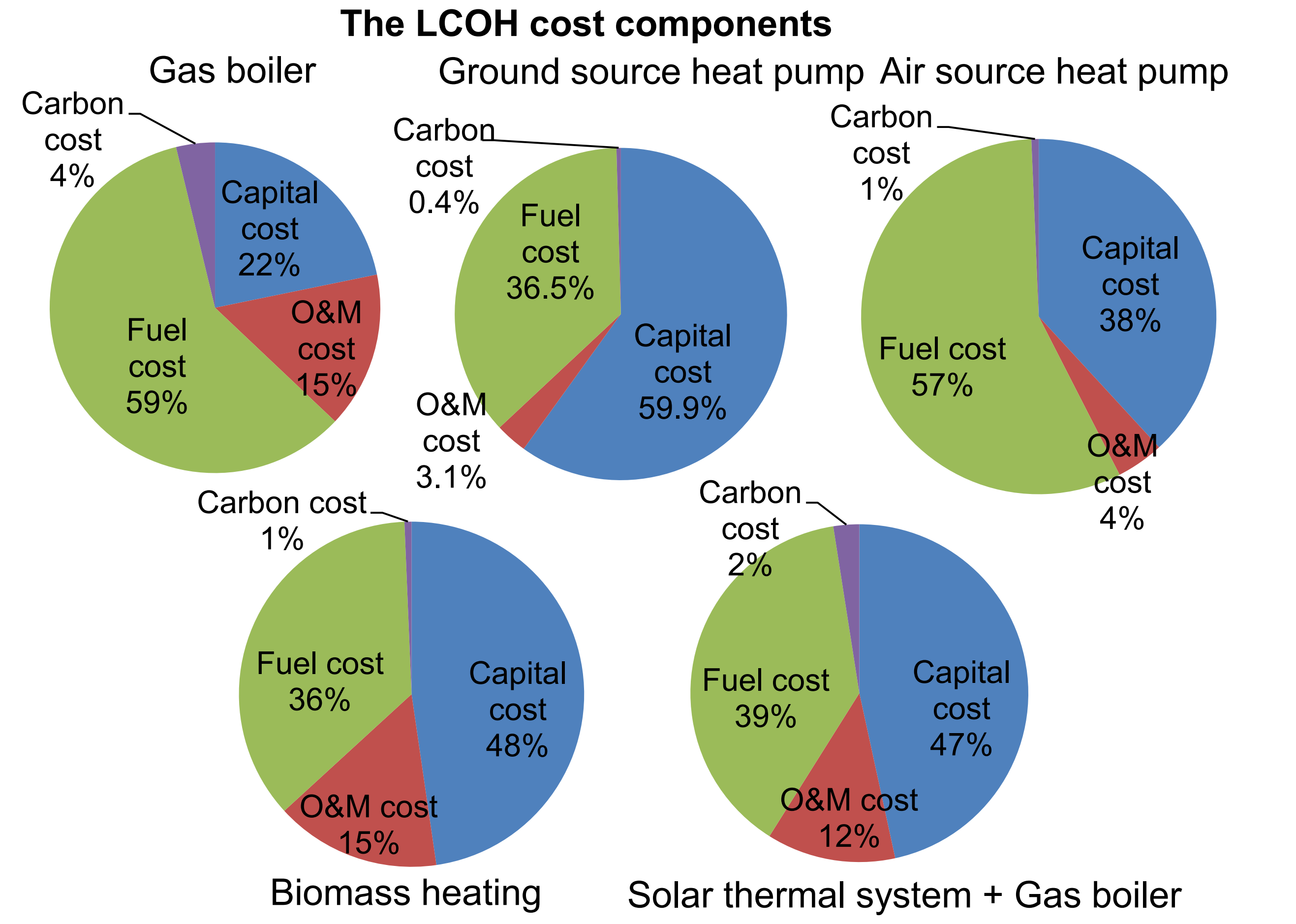
The parameters indicate:

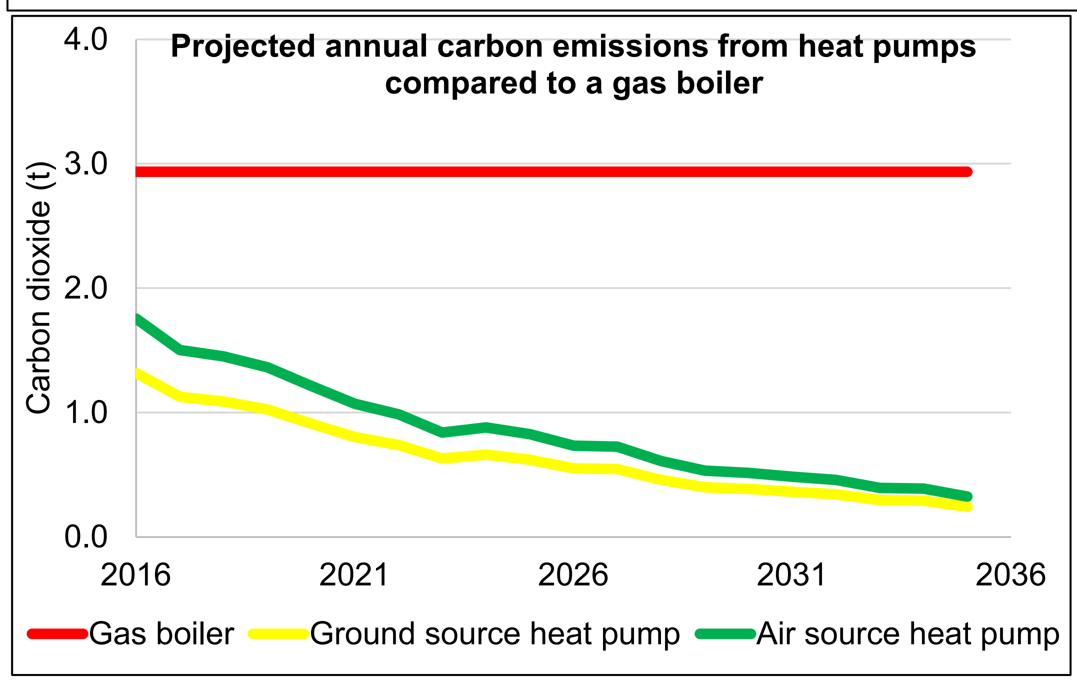
- $\mathrm{Capital}_t$: The capital expenditures in the year t.
- $\mathrm{O\&M}_t$: The operation and maintenance costs in the year t.
- Fuel_t: The fuel costs in the year t.
- Carbon_t: The carbon costs in the year t.
- RHI_t: The domestic RHI payments in the year t.
- $(1+\mathrm{r})^t$: The discount factor in the year t, with the discount rate r.
- MWh_t: The amount of heat produced in the year t.

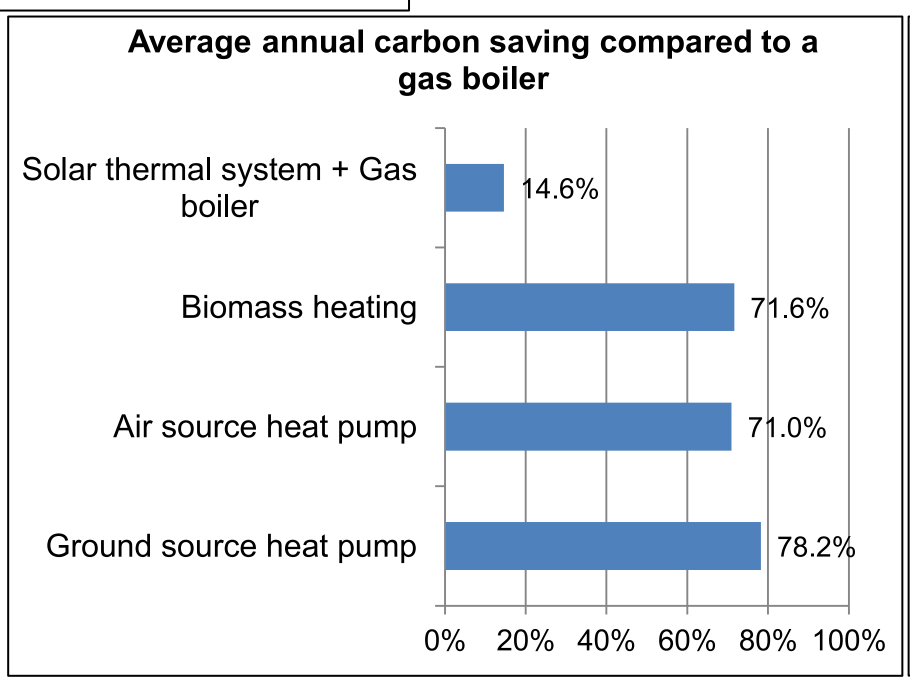
Key results

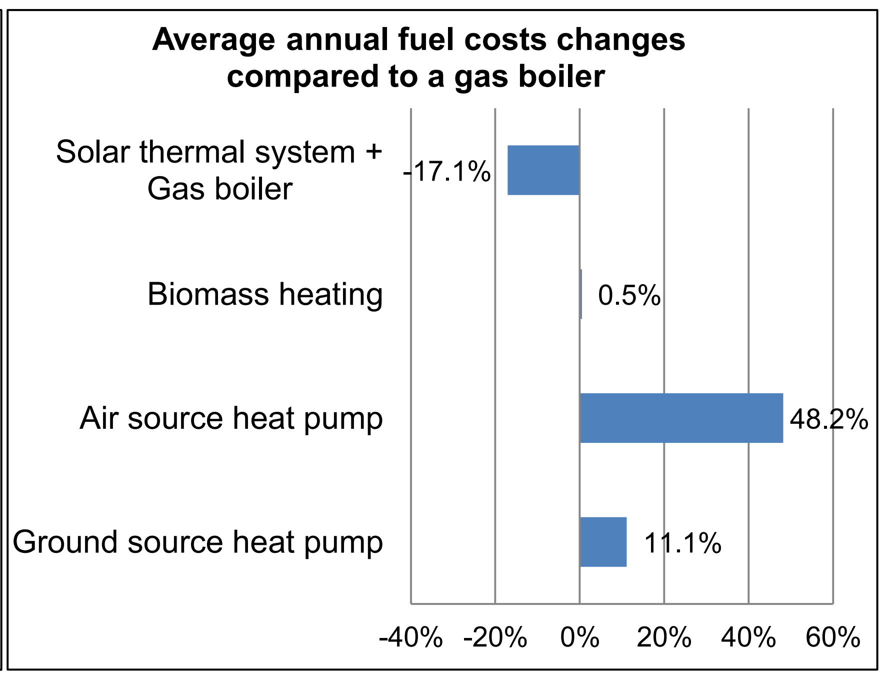


The LCOH cost components









Conclusions

- Without subsidies, the LCOH for low-carbon technologies may **surpass £160/MWh**, comparatively, the LCOH for a **gas boiler is under £80/MWh**.
- Current domestic **RHI tariffs are not high enough** for attracting households to replace gas boilers with low-carbon heat technologies.
- Low-carbon heat technologies may reduced up to **78% of annual carbon emissions** from heat compared to a gas boiler, but may also cause increases in **fuel costs**.

Future study

This poster shows my MRes research project. My PhD topic is "Management of electric heating through heat pumps and storage: systematic exploration of comparative advantages of individual scale versus district level".

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London, WC1H 0NN
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LoLo Colloquium 2016

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

Stephen Watson, supervised by Prof Kevin Lomas and Dr Richard Buswell

Aim: To characterise the influence on the demand for electricity of the widespread introduction of heat pumps in UK homes and to determine the implications for future UK energy policy.

Background:

Number of heat pumps → Additional demand for electricity
Specification of heat pump → Additional demand for electricity
Building stock → Additional demand for electricity
Behaviour of heat pump users → Additional demand for electricity

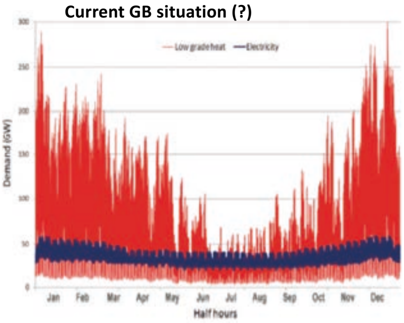

Figure 1: Synthesised national half-hourly low grade heat demand for 2010. Source: Decarbonising low-grade heat for a low carbon future, Robert Sansom, Imperial College, 2014

There is a large variation in demand for heat from day to day, and over the course of a day. Meeting this varying demand with heat pumps could be challenging.

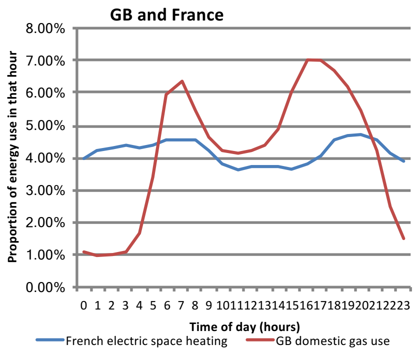

Figure 2: GB domestic gas demand and French space heating electricity demand averaged from 10th to 26th December, 2009 (GB) or 2015 (France). Source: GB data from EDRP, French data from EdF. Graph by Stephen Watson

In France, the demand for electricity for space heating is relatively flat over a day. Why is this? Could the GB profile for heat pump electricity demand be like this?

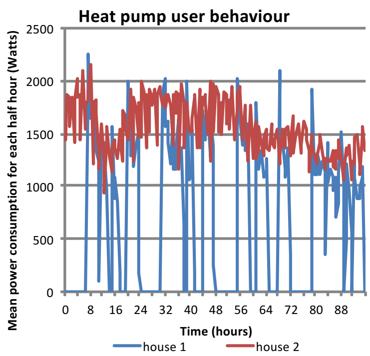

Figure 3: Mean half-hourly power consumption from two identical heat pumps, starting midnight 18/2/08. Source: Strathclyde University monitoring of heat pumps in Westfield, West Lothian. Graph by Stephen Watson.

Some heat pump users run the heat pump continuously. Others use it intermittently. The way in which heat pumps are used will affect national demand for electricity.

Method: Use measured data from houses with heat pumps to predict national electricity demand from heat pumps under various scenarios, without assuming constant profile shape.

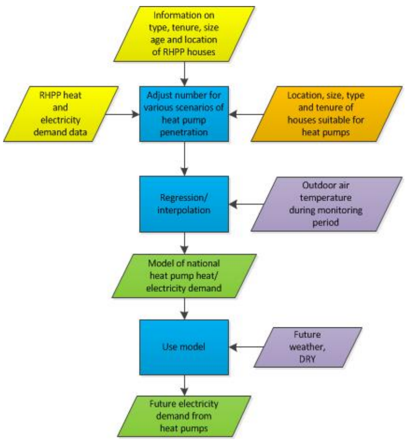

Figure 4: Proposed method using RHPP data

Further work:

- Investigate factors needed to scale up to country
- Trial various methods of regression\interpolation
- Test results against known gas measurements
- Produce estimates of additional national electricity demand from heat pumps, under various scenarios
- Draw out wider implications under different electricity generation scenarios.

Early Results:

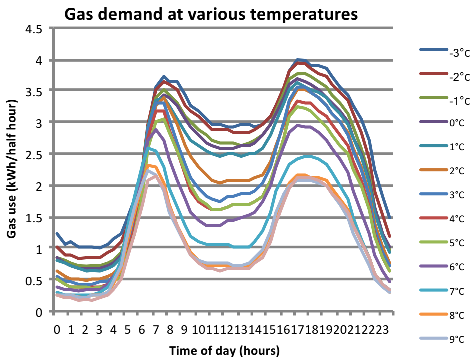

Figure 5: Mean half-hourly gas demand over a day at various temperatures. Source: data from EDRP, graph by Stephen Watson

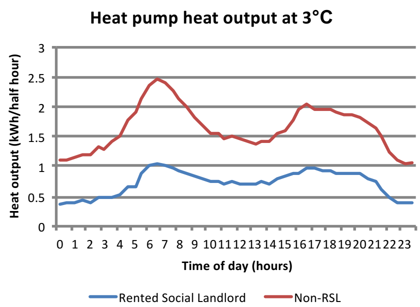

Figure 6: half-hourly heat pump heat output at 3°C from Rented Social Landlord properties and non-RSL. Data from RHPP.

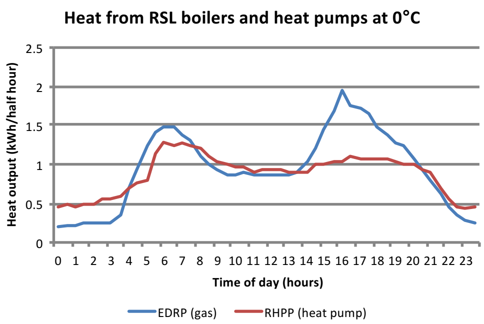

Figure 6: Heat output from gas boilers and heat pumps in Rented Social Landlord houses at 0°C outdoor temperature. Source: data from EDRP and RHPP

- Profile shape for gas demand varies with temperature – it is flatter at lower temperatures
- Heat consumption by Rented Social Landlord properties is much lower than other types, and also much flatter, for gas and for heat pumps.
- Hours of use for heat pumps are not very different to gas heating. However, heat pumps still have somewhat flatter output than equivalent gas-heated houses.
- When a separate regression between heat consumption and outdoor temperature was carried out for each half hour, an x^2 polynomial gave a good fit. The relationship between temperature and heat consumption was different at different times of day.

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ANNUAL COLLOQUIUM 2016

Exploring multiplicity of energy targets in the construction team

CATHERINE WILLAN 2nd year PhD student

Aims

The research will work in partnership with a construction company to:

- Explore the processes and communication related to energy targets in the construction of non-domestic buildings;
- Make a comparison to that of other construction issues, such as health and safety;
- Identify learnings for the company to help understand what affects the operational energy outcomes of its projects; and
- Produce qualitative case study findings to feed into the academic debate on the energy performance gap.

Data will be gathered from a variety of qualitative sources, including observation, interviews and documents. **Concepts** from discourse analysis and the 'ontological turn' in Science and Technology Studies will be employed to explore the **multiple enactments** and **repertoires** of energy targets in construction.

Looking how something is ***enacted*** can reveal not just different people's perceptions; but ***different ontologies***[1]. In complex and diverse construction teams there may actually be many different *energy realities* reflected in roles and tasks.

Using ***discourse analysis*** highlights individual differences ***(interpretative variability)*** in accounts of events. Moreover are there ***different repertoires*** being used to express energy-related targets in different contexts[2]?

Formal repertoire of engineering design statement: 'heat energy will be generated from a mixture of conventional gas fired boilers, and renewable energy technologies.'

Informal conversation: 'the renewable plant is just there to meet the design carbon target, the client will never turn it on…'

Differences may persist without challenge if practices are separated, physically or by other means, e.g.:

- If team members are in different locations;
- If team members are involved in projects at different times;
- Because recorded knowledge is incomplete;
- There is a lack of boundary object[3] to bring ontologies together;
- There is an incomplete organisational response to the presence of contractual energy targets.

If identified, differences may be navigated by means such as, hierarchy, negotiation or equivocation, e.g.:

- Practical experience is used in preference to manufacturer's performance data;
- Reconciliation of operational data to target in order to apportion differences to energy management failures, modelling flaws or occupants' 'misuse';
- Deliberate use of fudge factors (e.g. modelling in a contingency).

But what if energy targets were treated more like health and safety?

Health and safety is a critical legal risk for the construction company. Pilot findings suggests that the enaction of health and safety is highly personalised, with a range of formal-informal repertoires and practices designed to manage risk and maintain staff awareness. The organisation's health and safety approach is intended to permeate from the CEO through the layers of the organisation and on to the supply chain and beyond, and may have a greater potential to expose ontological frictions and a greater incentive to harmonise them.

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Central House
14 Upper Woburn Place
London, WC1H 0NN
www.lolo.ac.uk

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Centre for doctoral
training in energy demand

info@lolo.ac.uk
www.lolo.ac.uk
@LoLoCDT

UCL Energy Institute
Central House
14 Upper Woburn Place
London WC1H 0NN

www.ucl.ac.uk/energy
@UCL_Energy

Loughborough University
Department of Civil &
Building Engineering
Leicestershire LE11 3TU

www.lboro.ac.uk/civil
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