London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

ANNUAL COLLOQUIUM 2015

Thursday 19 November 2015
Senate House, LONDON

About the Centre

The London–Loughborough EPSRC Centre for Doctoral Research in Energy Demand is the premier centre for energy demand research in the built environment in the UK. It was set up in 2009 with EPSRC funding and received a further 5 years of funding in 2013. It has 50 PhD and MRes students working on a range of exciting projects spanning energy technology and systems, policy, economics and human behaviour.

The Centre brings together two world-class, research-intensive universities, University College London (UCL) and Loughborough University (LU). Together they have the critical mass of expertise to equip graduates with the knowledge and skills to take on senior roles in academia, industry, commerce and policy formulation. The Centre thus links two regions with vibrant and expanding activity in the energy and built environment arena.

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 course, 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 produce the next generation of energy pioneers.

Prof Robert Lowe (Director UCL)   Prof Kevin Lomas (Director Loughborough)

UCL   Loughborough University   EPSRC Engineering and Physical Sciences Research Council

Programme

9.45 **Registration** – tea and coffee available

10.15 **Welcome and Housekeeping**
Professor Robert Lowe, Director, LoLo CDT
(Director, UCL Energy Institute University College London)

10.25 **Review and Highlights from the Year**
Professor Kevin Lomas, Director, LoLo CDT
(Professor of Building Simulation Loughborough University)

10.40 **Round robin posters – participants in groups view posters**
Refer to conference booklet for full list of

11.40 **Final Year Student Presentations 1**
Refer to conference booklet for full list of presentations

12.30 **Buffet Lunch** (informal viewing of posters)

13.30 **Final Year Student Presentations 2**
Refer to conference booklet for full list of presentations

14.00 **Round robin posters – participants in groups view posters**
Refer to conference booklet for full list of presentations

Our research themes include:
Technologies and Systems
Energy Epidemiology and Economics
Urban Scale
Performance and Process
Unintended Consequences.

15.00 **Coffee, networking and panel discussion**

16.00 **Keynote by Tyler Bryant, Energy Policy Analyst – Project Manager, Energy Efficiency Unit, International Energy Agency**
The Role of Energy Efficiency in Addressing Global Energy and Carbon Challenges.

17.00 - 18.30 **Drinks Reception**

Final Year Student Presentations

Name	Presentation Title
Arash Beizaee	Measuring and modelling the energy demand reduction potential of using zonal space heating control in a UK home
Mike Fell	Public acceptability of domestic demand - side response in Great Britain
Paula Morgenstern	Understanding hospital electricity use: an end-use(r) perspective
Ashley Morton	Householders' space heating behaviour – uncovering the how, what and why.
Sofie Pelsmakers	Pre-1919 suspended timber ground floors in the UK: what do I know now that I didn't 3 years ago?

Student Presentations

Name	Title of Poster
Radhiah Arrifin	TBC
Francesco Babich	Developing a better understanding and improving the capability of prediction of human thermal comfort in domestic buildings
George Bennett	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
Ellen Coombs	Does the Standard Assessment Procedure disadvantage homes built using offsite construction?
Nafsika Drosou	Uncharted Territory: Operational Daylighting Performance In Classrooms
Ozlem Duran	Optimised refurbishment strategies for post-war office buildings
Pamela Fennell	Reducing run-time with Global Sensitivity Analysis Applying Morris' Method to Energyplus
Virginia Gori	Advanced statistical methods for the evaluation of the thermophysical performance of building elements
Lisa Iszatt	Investigating heat and moisture transfer through solid brick walls and the impacts of internal wall insulation

Student Presentations cont.

Name	Title of Poster
Tom Neeld	Boiler Whispering: In-situ boiler monitoring using passive acoustic techniques
Moira Nicholson	TBC
Argyris Oraiopoulos	Mapping the current and future risk of overheating in UK homes
George Papachristou	Reducing the Energy Performance Gap: Improving building simulation tools through data-driven and real-time approaches
Zareen Sethna	TBC
Ben Roberts	Do zonal heating controls reduce energy use during the shoulder heating season?
Vicki Tink	The effect of internal wall insulation on energy demand, thermal comfort and overheating
Stephen Watson	Energy from artificial sports pitches: Modelling surface temperatures and the effect of extracting heat
Catherine Willan	Setting energy targets in context: a case study in the construction industry
Selin Yilmaz	Modelling Framework for Household Appliance Electricity Demand (AED) for Evaluating the Demand Response Potential In UK Residential Sector

Speaker Biography

Tyler Bryant

Tyler Bryant is an energy and policy specialist with the International Energy Agency where he works on the topics of energy efficiency, energy markets and sustainable energy.

Tyler has worked as a policy analyst with the Canadian federal government at Natural Resources Canada and as the research manager at the David Suzuki Foundation's Trottier Energy Futures Project.

Tyler is currently a project manager at the IEA working on cross-organizational projects such as the Energy Efficiency Market Report and contributing to other IEA publications such as Energy Technology Perspectives.

Tyler has been the lead author of 2 publications at the IEA, 3 publications at the David Suzuki Foundation and has contributed to textbooks, articles, opinion pieces, blogs and too many tweets on climate policy.

.

PhD Students

Radhiah Arrifin

PhD, Year 1 –on interruption of studies Loughborough University

Radhiah's academic background is in Environmental Engineering in which she has an MSc with distinction from Newcastle University. She also has a B Eng. in Biochemical-Biotechnology (Hons), International Islamic University Malaysia. Radhiah's interest is in thermal comfort in built environment, natural ventilation, domestic renewable energechnologies, and energy demand reduction in space heating

R.Ariffin-14@student.lboro.ac.uk

Francesco Babich

PhD, Year 2, Loughborough University

Francesco studied at the University of Trieste (Italy), where he completed his Bachelor's Degree in Civil and Environmental Engineering and his Master Degree in Building Engineering. Having passed this Master, he was allowed to take the exam for the professional engineer license in July 2012. 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, His dissertation focused on ventilation cooling towers in plus-energy houses, and included CFD and dynamic thermal modelling.

Developing a better understanding and improving the capability of prediction of human thermal comfort in domestic buildings

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) are not suitable for these situations. Therefore, this research aims 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.

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.

F.Babich@lboro.ac.uk

Arash Beizaee

PhD, Final year Loughborough University

Arash graduated as a mechanical engineer in Iran and then continued his studies in the UK to obtain MSc in Building Services Engineering (with distinction) from Loughborough University.
He joined LoLo CDT in 2011 and completed MRes in Energy Demand Studies (with distinction) before starting his PhD in 2012. Arash is currently finalizing his PhD thesis for submission.
From October 2015, Arash is working at School of Civil and Building Engineering at Loughborough University as a Research Associate and is responsible for the technical, measurement and modelling aspects of DEFACTO project.

Measuring and modelling the energy demand reduction potential of using zonal space heating control in a UK home

Most existing houses in the UK have a single thermostat, a timer and conventional thermostatic radiator valves to control the low pressure, hot water space heating system. A number of companies are offering a solution for room-by-room temperature and time control in these older houses. These systems comprise of motorised radiator valves with inbuilt thermostats and time control. There is currently no evidence of any rigorous scientific study to support the energy saving claims of these 'zonal control' systems.

This PhD quantified the potential savings of zonal control for a typical UK home. There were three components to the research. Firstly, full-scale experiments were undertaken in a matched pair of instrumented, three bedroom, un-furbished, 1930s, test houses that included equipment to replicate the impacts of an occupant family. Secondly, a dynamic thermal model of the same houses, with the same occupancy pattern, that was calibrated against the measured results. Thirdly, the experimental and model results were extrapolated to understand how the energy savings might vary in different UK climates or in houses with different levels of insulation.

a.beizaee@lboro.ac.uk

George Bennett

PhD, Year2 UCL

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.

George.bennett.14@ucl.ac.uk

Ellen Coombs

PhD Year 1-on interruption of studies, UCL

I have recently completed the MRes in Energy Demand Studies, my academic background before this included Integrative Biosciences (MSc, Oxford University) with a particular focus on epidemiology. Before that, I studied Environmental Science (BSc, the University of York) graduating with First Class Honours. My focus at York was investigating the environmental effects of veterinary pharmaceuticals and agricultural pesticides.

I have, and am keen to undertake research that is multidisciplinary in nature. Before joining the MRes at UCL, I was working for the policy and advocacy team at a large international NGO. I focused on stakeholder management which saw me engaging with and presenting to governments and veterinary associations around the world.

Does the Standard Assessment Procedure disadvantage homes built using offsite construction? Considering construction defects and highlighting where to look for quality control.

The gap between intended and achieved dwelling energy use can be 196%-350% higher than some of their initial Standard Assessment Procedures (SAP) results predict. Studies have highlighted contributors such as constructions faults, workmanship issues and product substitution that occur during onsite construction. Offsite construction (OSC) is the manufacture and pre-assembly of components in a factory and it has been suggested that with its fewer defects, reproducibility, and fast build-speed, could help alleviate the performance gap. However, OSC is not without faults. This study considers construction defects in an OSC dwelling. Aiming to better understand build issues and assess the sensitivity of SAP (and its outputs) to fabric amendments, addressing whether SAP disadvantages an OSC dwelling.

The study concludes that assumed SAP Ψ-values overestimate heat losses in OSC, misrepresenting thermal bridging (W/m/K), but that SAP does not detrimentally disadvantage OSC. It is recommended that construction-specific Ψ-values are used to represent OSC performance

ellen.coombs.14@ucl.ac.uk

Nafsika Drosou

PhD, Year 3, Loughborough University

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

Uncharted territory: quantitative and qualitative aspects of operational daylighting performance in classrooms

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

N.C.Drosou@lboro.ac.uk

Özlem Duran

PhD, Year 3, Loughborough University

After Özlem held her undergraduate degree in architecture, she worked in various design and construction companies in Istanbul, such as Arup. In 2007, she started MSc. in Istanbul Technical University (ITU), and completed her dissertation in the Applied Sciences University of Stuttgart (HFT). Right after, she worked as a researcher in the same university. Currently, she is studying at Loughborough University as a member of LoLo CDT where she completed MRes in 2013 and started 3rd year of her PhD.

Optimized refurbishment strategies for post-war office buildings

The aim of Özlem's PhD project is to optimize the refurbishment process of post-war non-domestic modernist buildings focusing specifically on office buildings, by applying dynamic energy simulations to two typical building models that represent this defined building stock. The potential of refurbishment features for a realistic conversion of the chosen type buildings into energy efficient buildings will be analysed and supported by providing a guideline for the typical buildings of the chosen era.

Up to date, the methodology is applied to first representative model (Exemplar 1).
Further work will be revisiting cost estimations and repeating the same process with future weather data on Exemplar 1 and whole process on Exemplar 2.

o.duran@lboro.ac.uk

Mike Fell

PhD, Final Year UCL

Michael Fell researches the public acceptability of domestic demand-side response (DSR). He will be submitting his thesis in December 2015 and is looking out for opportunities to pursue after this, particularly relating to energy/DSR policy and innovation.

Prior to joining the London-Loughborough CDT he 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.

Taking Charge: Perceived control and acceptability of domestic demand-side response

Domestic demand-side response (DSR) programmes aim to influence electricity consumption patterns in people's homes, either through price (or other) signals or through direct control of electrical loads.

This project investigates how people expect their personal control to change in a variety of DSR programmes and how this is related to acceptance, how various antecedents of control (e.g. trust, choice, knowledge, usability, etc.) affect this for different people, and what can be done to design, target and communicate programmes to minimize concerns in this area.

michael.fell.11@ucl.ac.uk

Pamela Fennell

PhD, Year 2, UCL

After studying engineering at Cambridge, and a Masters in the Management of Construction Enterprises at 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.

The impacts of project scale, scope and risk allocation on financial returns for clients and contractors in Energy Performance Contracts - a stochastic modelling analysis

With a projected annual value of €1bn, the UK energy performance contracting market has the potential to unlock a large number of energy efficiency projects by reducing investment risks. However, market development has been slow and little analysis has been undertaken to understand the characteristics of successful projects. A better understanding of the impact of project scale, scope and risk allocation on outcomes for clients and ESCOs would enable investment programmes to be targeted more effectively.

This study combines stochastic approaches to both energy simulation and economic modelling to explore the range of possible outcomes for clients and ESCOs. The subject of this study is a project consisting of a typical group of UK schools. This study will explore the effects on client and ESCO financial returns of varying the number of sites in the project, the range of applied retrofit measures and the risk allocation between Client and ESCO.

pamela.fennell.13@ucl.ac.uk

Virginia Gori

PhD, Year 3, UCL

Virginia is a Doctoral Researcher 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 novel dynamic method for the estimation of thermophysical properties (e.g., thermal mass, R- and U-value) of real building elements by using in-situ measurements. This research attempts to overcome some of the limitations (e.g., long monitoring periods, seasonality) 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).

Advanced statistical methods for the evaluation of the thermophysical performance of building elements

Several studies have shown evidences of performance gap between published thermophysical properties (e.g., U-value) of building materials and those estimated from in-situ measurements, with clear consequences on the decision-making and cost-effectiveness of energy-efficient measures. A widespread use of thermophysical properties estimated from surveyed data would be preferable. However the methods generally adopted for the data analysis have several limitations (e.g., length and seasonality of the monitoring period) that may prevent their extensive use.

This research focuses on the use of advanced statistical techniques to develop a method for the estimation of thermophysical properties (e.g., thermal mass, R- and U-value) of building elements from short and seasonal-independent time series collected in-situ. The research investigates the influence that environmental conditions and building structure have on the estimation of thermophysical properties by developing several models of the potential heat transfer mechanisms across the structure. Model selection techniques are adopted to identify the most probable one.

virginia.gori.12@ucl.ac.uk

Sven Hallin

PhD, Final Year, Loughborough University

Sven 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, he then worked as an expatriate in Africa and the Far East before he returned to the UK and started his own manufacturing business specialising in the production of screen printing ink. He sold this business after eighteen years and undertook an MSc in Real Estate at Nottingham Trent University, which he completed in 2010. After completing the MRes in Energy Demand Studies, Sven is now researching his PhD project entitled "A study of the economic incentives associated with UK household energy usage".

A study of the economic incentives associated with UK household energy usage – *next page*

A study of the economic incentives associated with UK household energy usage

A key question overall is what will make people change their behaviour and reduce energy consumption and/or switch to renewable energy? There is a lack of clarity around occupant behaviour with regard to the motivations influencing domestic energy use. This research uses predictive modelling, quantitative measurements of energy use, and qualitative semi-structured interviews in case studies to gain further insight into this question. Results are compared with qualitative interviews assessing the influence of landlords, energy companies, environmental groups and government on occupant behaviour.

The research findings seek to provide greater clarity on what factors determine the threshold (financial and otherwise) beyond which people will seek to use more sustainable energy and/or improve their household energy efficiency. They also provide insight to inform policy on ways the price mechanism could be used to influence energy demand behaviour.

s.hallin@lboro.ac.uk

Lisa Iszatt

PhD, Year 2, UCL

Lisa's background was in Architecture before moving on to various Energy focused roles in both commercial and public sectors. She has a decade of experience working on environmental projects from the varied perspectives of client, consultant, designer, policy writer and more recently assisting with Passivhaus certifications. Her PhD research is on heat and moisture transfer through solid brick walls

Investigating heat and moisture transfer through solid brick walls and the impact of internal wall insulation.

Existing buildings account for approximately 40% of UK energy demand and working out effective ways to retrofit these is recognised as a key aspect of national energy and CO2 reduction targets. Solid wall insulation is predicted to contribute significantly to meeting these targets, and internal wall insulation (IWI) is often the most appropriate solution, in terms of cost, disruption and heritage considerations.

IWI changes the temperature and moisture profile of the wall, which may have unintended consequences such as structural damage and health risks due to mould. Conversely, inaction on retrofit could lead to undershooting national CO2 saving targets, so understanding the safety limits in more detail is crucial.

The physical properties of solid brick walls in the UK are currently not well characterised, and methods for determining them are not well developed. Most research to date is based on models or test walls in laboratories. This research will use in-situ monitoring campaigns to give insight into the hygrothermal behaviour of real walls in real conditions.

The proposed analysis draws on a method recently developed at UCL to derive thermophysical properties of a solid brick wall using in-situ data, a lumped thermal mass model and Bayesian statistical analysis. This technique will be extended to analyse hygrothermal properties of walls.

l.iszatt@ucl.ac.uk

Paula Morgenstern

PhD, Final Year, UCL

Paula is an engineer with a strong interest in the interface between technology and society. She holds a diploma degree in Chemical Engineering from the Technical University of Hamburg and the LoLo MRes in energy demand studies. Prior to joining UCL in 2011, Paula has worked as assistant to numerous research projects in Germany, UK and Argentina as well as for Dalkia, an energy services provider. In addition, Paula has always been passionate about communicating technology to a non-specialist audience. She has experience in working both for local and nationwide newspapers and radio stations and is a frequent attendee of festivals hosting (popular) science debates.

Understanding hospital electricity use: an end-use(r) perspective

Increasing energy costs and climate change legislation have prompted efforts to reduce energy consumption in hospitals. In addition to technological conservation strategies focussing on building and building services, staff-centred initiatives such as energy awareness campaigns are increasingly considered by NHS Trusts. But hospitals are complex buildings with unique energy requirements and it is unclear to what extent these are influenced by clinical staff and patients. This PhD research aims to improve the understanding of hospital electricity use from an end-use perspective and to determine the theoretical reduction potential from behaviour change for different hospital types and areas.

paula.morgenstern.11@ucl.ac.uk

Ashley Morton

PhD, Final year, Loughborough University

Ashley has a background in Chemistry and Energy after completing a MChem (with industrial experience) and an MSc at Heriot Watt University. During her MSc in Energy she carried out a dissertation into fuel poverty and completed modules covering energy management within buildings and renewable technologies. This led to her joining the Lo-Lo CDT in 2011.

Ashley successfully completed the MRes in energy demand studies in 2012 with her dissertation focusing on temperature variations between rooms in heated UK homes. She then joined the EPSRC funded DEFACTO: Digital Energy Feedback and Control Technology Optimisation project to undertake her PhD focusing on occupants space heating behaviour and the impact new control technologies could have.

Householders' space heating behaviour – uncovering the how, what and why.

The aim of this PhD is to identify, examine and develop household space heating behaviour categories. To do this two main investigations were carried out in order 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. The findings of which were analysed with current heating behaviour types identified in literature to develop a taxonomy of heating behaviours relating to preferential heating practices.

The second investigation being a small scale monitoring study of homes for an extended period of time which have new heating controls installed. A mixed method approach was taken to uncover what people did with their heating, how their interacted with the controls and the reasons why they did what they did. The study also allowed the evolution of heating practices through seasonal shifts regarding how occupants change their heating practices moving into winter to be studied.

A.Morton@lboro.ac.uk

Thomas Neeld

PhD, Year 1, UCL

Physics graduate with over two years' experience working as a Technology Consultant for IBM in the Energy and Utilities industry. Previous research includes: simulating novel nanofabrication methodologies in the area of computational physics and analysing the acoustic properties of domestic boilers with the use of machine learning algorithms.

In my spare time I am a keen rower and compete at international regattas such as Henley for London Rowing Club.

In-situ boiler monitoring using passive acoustic techniques

Using a non-invasive, single-point acoustic sensor to monitor events in combination boilers. In-situ monitoring of boilers provides researchers with data on boiler use patterns, consumption rates, burn intensities, burn frequencies etc. The study has thus far shown that, for the boilers investigated, the following events are detectable using an acoustic sensor: demand type (hot water or central heating); boiler ignition time; and the current pre-mix fan motor frequency (thus an accurate estimate of gas consumption).
Further research in this area provides exciting opportunities to solve issues with current and future boiler design and potentially help deal with a de-carbonising gas-network

tom.neeld.13@ucl.ac.uk

Moira Nicholson

PhD, Year 2 UCL

Moira uses randomised control trials to test whether insights from behavioural economics could be used to boost switching rates to smart electricity tariffs. Encouraging consumers to switch to time of use tariffs and other demand-side response programmes is crucial for ensuring our energy supply remains secure and affordable in the transition away from fossil fuels.

Moira has an MRes in Energy Demand Studies and an MSc in Public Policy from UCL. Prior to her PhD, she worked for the international development organisation VSO and as a project manager at a training consultancy firm..

Can we use behavioural economics to boost consumer switching rates to smart electricity tariffs? Evidence from randomised control trials

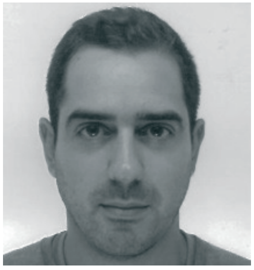
The UK Government's business case for smart meters relies on an additional 20 percent of consumers switching to a time of use tariff by 2030 (DECC, 2014). However, no studies have measured how many people will actually switch or what might boost switching rates, without harming consumers, if not enough people sign-up.

This PhD will use randomised control trials to test whether we can increase switching rates without making these tariffs mandatory (as in Ireland) or automatically switching people unless they explicitly opt-out (as in the US trials). Instead of forcing people to switch, so-called 'nudge' approaches could boost uptake at low-cost whilst respecting people's freedom to choose. Instead of opt-outs, this PhD will test 'nudges' that require people to make an active decision to switch, so that they cannot be switched without their knowledge.
To test whether these methods could boost switching rates, without relying on the responses people give in surveys, this PhD will run trials with start-up DSR providers to test whether more people switch to the first commercially available DSR programmes when they are actively nudged to switch compared to when they are not.

m.nicolson.11@ucl.ac.uk

Argyris Oraiopoulos

PhD, Year 2, Loughborough University



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.

During this course he developed an interest in energy demand. He joined the LoLo CDT in 2012 and his MRes dissertation focused on developing an empirical model predicting the daily mean internal temperature in domestic houses based on a regressive form of the external temperature and the houses' characteristics.

Argyris is currently working on his PhD at Loughborough University where he is attempting to map the current and future risk of overheating in UK homes, using a parsimonious empirical model based on time series analysis. Argyris' research interests include: Overheating (criteria & predictions); Time Series Analysis & Empirical Models; Dynamic Thermal Simulation Modelling; Occupant Behaviour & Attitudes; Public Engagement & Education.

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 and losses. 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 project is to take classical time series 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 temperatures based on past measured values..

a.oraiopoulos@lboro.ac.uk

George Papachristou

PhD, Year 2, Loughborough University

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 Energy Performance Gap - improving building simulation tools through data-driven and real-time approaches..*next page*

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

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

The aim of the project is to develop 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.

g.papachristou-12@student.lboro.ac.uk

Sofie Pelsmakers

PhD, Final year, UCL

Sofie is a chartered and environmental architect with more than a decade of hands-on experience designing, building and teaching sustainable architecture. Her PhD investigates the actual heat-loss of pre-1919 un-insulated suspended timber ground floors, heat-loss reduction potential of interventions and any unintended consequences of insulating such floors. She is author of 'The Environmental Design Pocketbook', which synthesises her practical and academic expertise to support the building industry towards a significant change in its design and building practices. It received commendation for the RIBA's 2012 Presidents Awards for Outstanding Practice Based Research and the 2nd edition is out in Dec 2014..

Pre-1919 suspended timber ground floors in the UK: measuring the in-situ thermal performance and heat-loss reduction potential of interventions

Space heating demand in UK dwellings accounts for around 13% of the UK's CO2 emissions. Reducing energy demand for space heating, in support of the UK's legislated carbon emission reduction targets, requires the effective characterisation of the UK's existing housing stock to facilitate retrofitting decision-making. Approximately 6.6 million dwellings pre-date 1919 and are predominantly of suspended timber ground floor construction, the performance of which has not been extensively investigated. This PhD thesis aims to estimate suspended timber ground floor heat loss and has undertaken high resolution floor heat loss measurements in the Salford Energy House (a reconstructed dwelling in an environmental chamber) as well as in an unoccupied house in the field. This house was also subject to insulation interventions to investigate their efficacy. Additionally, floor void conditions in 15 dwellings were monitored in order to characterise floor void conditions and assess void mould growth risk.

sofie.pelsmakers.11@ucl.ac.uk

Ben Roberts

PhD, Year 1, Loughborough University

I have a BSc. (Geography) and MSc. (Energy Policy) both from the University of Exeter. I am interested in integrating social sciences with engineering approaches to reducing energy demand.
Prior to joining LoLo, I worked on a Knowledge Transfer Partnership (KTP) jointly based at the Global Sustainability Institute in Cambridge and with an industrial partner. At the end of the KTP I was offered a job with the industrial partner and remained there for 10 months, before joining LoLo.
MRes. research investigated the impact of occupant behaviour and lower heating loads on the energy saving potential of zonal heating controls. I completed the MRes in September 2015.

Ventilation and thermal comfort in UK homes: can we maintain indoor air quality and reduce the threat of future air-conditioning of UK homes?

As we refurbish increasing numbers of UK homes for energy efficiency, we are introducing a risk of overheating in summer, particularly for the future as the climate warms.
How do people currently ventilate their homes to minimise overheating risk? What factors shape these behaviours? And what effect do different ventilation behaviours have? This work aims to gain an insight into window opening behaviours and understand the thermal effects of these strategies with more realistic models of these behaviours

b.m.roberts@lboro.ac.uk

Zareen Sethna

PhD, Year 2, UCL

Zareen studied Civil, Structural and Environmental Engineering at the University of Cambridge and graduated in 2008. During her time as an undergraduate she was involved with Engineers Without Borders UK and spent two months in Bhutan working with local engineers.

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.

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.

zareen.sethna.13@ucl.ac.uk

Vicki Tink

PhD, Year 3, Loughborough University

Vicki is a keen environmentalist, with an interest in climate change and the effect of the built environment upon the natural environment. After graduating from her undergraduate degree in Product Design and Technology she worked as a design engineer designing new products and reviewing other's ideas for suitability of manufacture.
Vicki joined the LoLo centre in 2012 where she researched into the energy consumption in thermally lightweight buildings due to intermittent occupancy for her dissertation. Her Research interests include the design, manufacture and installation of building materials for retrofit and the effect of thermal mass on energy demand and overheating.

The effect of internal wall insulation in solid wall properties upon energy demand, comfort and overheating

The purpose of this PhD is to quantify the impact of retrofitted internal wall insulation (IWI) upon energy demand, winter thermal comfort and summer overheating in UK solid wall dwellings. This is being measured within a unique facility comprised of a matched pair of solid wall semi-detached houses with synthetic occupancy. One of the solid wall houses was retrofitted with IWI, allowing a direct comparison between an uninsulated and an internally insulated house, under the same weather conditions. Air temperature, thermal comfort variables and energy consumption were measured in both houses throughout winter. In the summer, air and operative temperatures were measured to assess overheating risk and an overheating mitigation strategy to reduce high internal temperatures was tested. The data are currently being analysed and will be used to produce technical and behavioural recommendations upon the use of internal wall insulation.

v.tink2@lboro.ac.uk

Stephen Watson

PhD, Year 1, Loughborough University

Having done an MEng at Durham University in New and Renewable Energy, I became interested not only in how energy may be generated in a sustainable way, but also in how energy demand may be reduced, particularly in the built environment. My final year project at Durham was about recovery of heat from domestic greywater. My MRes project last year was about high surface temperatures on artificial sports pitches, and the possibility to cool the pitch and recover energy for a useful purpose. This gave me experience in constructing a thermal model from scratch, and in research an area where comparatively little work has already been done. A publication should be forthcoming. In my PhD project I hope to combine my interest in renewable energy with research on the nature of energy demand from the built environment.

Aggregated load profiles of domestic buildings: the implications of an all-electric future

As well as energy efficiency improvements to buildings' fabric, changes in the way homes are heated have been proposed, in order to meet emission reduction targets. This includes the idea of all-electric households in which homes are heated by electrical devices powered by de-carbonised electricity. Currently over 90% of UK homes have gas-fired space heating. Simple analyses have shown that if all these homes were heated electrically, with no shift in the time of heat demand, the electricity supply system would have to be massively reinforced and dispatchable generation massively increased. However, there are reasons to believe that the demands due to future electric heating may not be the same as those of gas heating today. Firstly, electric heat pumps respond very differently from gas-fired boilers, leading to different usage. Secondly, there are parts of the world, which have significant proportions of electric space heating.

s.watson-14@student.lboro.ac.uk

Catherine Willan

PhD, Year 1, UCL

Catherine has 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 and is a qualified chartered accountant.

How does a construction contractor take account of behavioural influences when setting energy targets for its non-domestic buildings projects?

Working in partnership with a large UK construction company, the research will explore their role in the eventual energy performance of their projects, through an examination of how the company incorporates assumptions about occupant behaviour into energy performance targets for their non-domestic building projects. The methods proposed are ethnographic observation and ethnographic interviews, which will be used to follow live construction projects through as the energy models are developed, so that the researcher can observe working practices as they occur. The aim will be to gather in-depth data from a series of projects, in order to highlight any recurring similarities, and/or differences. The research impact should be to facilitate the transfer of learnings between the construction industry and academia, which should contribute to the wider debate on the performance gap.

catherine.willan.14@ucl.ac.uk

Henry Witt

PhD, year 2-on interruption of studies, Loughborough University

Henry began his career in environmental consultancy in the energy and sustainability team for a building services engineering company. He managed and helped reduce building energy use in non-domestic buildings, including offices and schools. Henry has completed an MRes in Energy Demand Studies with Merit at Loughborough University. Previously Henry studied at Imperial College London where he completed a BSc in Geophysics with a first class honours. In his undergraduate degree Henry completed an independent environment project on the IPCC reports and the likelihood of anthropogenic climate change. Following this his MSc in Sustainable Energy Futures from the Energy Futures Lab included a dissertation on the energy efficiency of luminescent solar contractors for solar window applications As well as this, he has completed an independent environment project on the IPCC reports and the likelihood of anthropogenic climate change.

Impact of HVAC Control on Energy Use in Food Retail Buildings

Supermarket buildings use large amounts of energy for their operation and currently use rudimentary controls for HVAC systems. An Energy Management Control System (EMCS) includes a central computer that controls, monitors and has the potential to optimise and use additional controls for the energy related functions of the Heating Ventilation and Air-Conditioning (HVAC) system. It is known that more sophisticated control using different EMCS strategies of HVAC systems are a cost-effective way of significantly decreasing energy use in several commercial buildings. These control strategies have not been used in supermarkets before and could result in significant energy savings. Supermarkets are unique commercial buildings because of their large refrigeration systems. It is important to consider the energy use of both the HVAC and refrigeration systems due to their complex interaction. Sophisticated control strategies will be run in simulations validated by metered energy data and sensor measurements.

H.Witt@lboro.ac.uk

Selin Yilmaz

PhD, Year 3, Loughborough University

Selin's research aims to develop a high resolution residential electricity demand model to provide insights into the amount of flexible demand that can be available for shifting in the UK residential sector.

She has MSc on Renewable Energy Science and Technology from Ecole Polytechnique in France where she worked on organic photovoltaics. She has graduated from the Chemical Engineering Department from Middle East Technical University in Turkey..

Modelling Framework for Household Appliance Electricity Demand (AED) for Evaluating the Demand Response Potential In UK Residential Sector

This paper presents the initial development of 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. Three appliances (washing machine, tumble dryer and dishwasher) are used to explain the model development. 100 homes are simulated for a month. 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

S.yilmaz@lboro.ac.uk

MRes Students

Charalampos Angelopoulos

MRes, Loughborough University

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 am a recent graduate of the Technical University of Denmark (DTU) with a MSc 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.
Alongside with the MSc, I worked as a research assistant at the international centre for indoor environment and energy at DTU where I undertook research into thermal comfort with a focus in the temperature boundary layer around the human body under the supervision of Professor Arsen Melikov.

c.angelopoulos-15@student.lboro.ac.uk

Kostas Chasapis

MRes, Loughborough University

I am Electrical Engineer and I hold an MSc degree from the CREST of Loughborough University. My MSc dissertation was the modelling of a house using renewable energy sources and hydrogen as means of energy storage. I have working experience in the Energy sector and particularly in Renewable Energy projects and Electricity trading. Through my career I got involved with the design and installation of wind farms and PV projects both on-grid and off-grid. I got also involved with the analysis of the Electricity market and the day-ahead electricity trading. I have worked with small regional companies and international firms and have cooperated with several public authorities and organizations.

k.chasapis-15@student.lboro.ac.uk

Rebecca Corley

MRes, UCL

For my undergraduate degree I studied Mechanical Engineering with Sustainability. During my time at university I undertook industrial placements at British Sugar and then National Grid.
After graduating I took some time off to travel and then returned to National Grid. I was involved in looking into future scenarios for the gas distribution networks such as hydrogen as a fuel and district heating and also worked in a team supporting the operations of the gas transmission control room.

rebecca.corley.15@ucl.ac.uk

Matej Gustin

MRes, Loughborough University

Matej studied at the University of Trieste in Italy. He got a Bachelor's Degree in Building Engineering in 2009 and a Master's Degree with honours in Civil Engineering in 2013. 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. Building energy modelling, thermal comfort in built environment, retrofitting of buildings and design of low energy buildings.

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

Clare Hanmer

MRes, UCL

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

Clare has a degree in engineering from Cambridge University and worked initially in the industrial gases industry. In 2003 she gained an MSc in Renewable Energy from the University of Reading and in 2014-15 she pursued her interest in the social aspects of energy demand by studying for an MSc in Energy and Society at the University of Durham. Research interests: - Reduction of energy demand in buildings : interactions between people and technology -Patterns of variability in home heating energy demand

clare.hanmer.15@ucl.ac.uk

Frances Hollick

MRes, UCL

I graduated from the University of Warwick in 2015 with a BSc MPhys in Physics.

During my final year I became interested in climate change and the ways we can prevent this, which led me to the LoLo CDT.

frances.hollick.15@ucl.ac.uk

Harry Kennard

MRes, UCL

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.

harry.kennard.15@ucl.ac.uk

Anthony Marsh

MRes, UCL

In 2013 I attained a 1st class masters degree in Energy & Environmental Engineering from the University of Leeds.

My research will investigate the difference between the actual and predicted energy usage in commercial buildings - commonly referred to as the 'performance gap'.

anthony.marsh.15@ucl.ac.uk

Matthew Rees

MRes, Loughborough University

Matthew is from Swansea in South Wales. He studied Chemistry at undergraduate level at the University of Nottingham. He followed this with an MSc in Sustainable Energy and the Environment at Cardiff University. Matthew joined LoLo in 2015 in order to acquire the skills required to undertake a research career.

Matthew currently has broad research interests in the building energy demand field. He is interested in modelling and measurements of buildings and the performance gap that exists.

m.l.rees2-15@student.lboro.ac.uk

Zhikun Wang

MRes, UCL

I am a first year (MRes) student of London-Loughborough (Lo-Lo) Centre for Doctoral Training.
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 with training in geological prospecting, environmental impact assessment and Environment, Health and safety (EHS) management.
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.

Zhikun.wang.10@ucl.ac.uk

Alumni Students

Joynal Abedin

PhD, Loughborough University

Joynal is an Electronic Engineer by professional training and has substantial industrial Research & Development experience. He was awarded a prestigious industrial sponsorship by Thorn EMI Electronics Defence Group (now Thales) and studied MEng & BEng (Hons) degrees in Electronic and Electrical Engineering. He completed a two year IEE accredited post- graduate industrial training programme at Thales. Joynal has over eight years industrial R&D experience and held senior design engineer posts at Marconi Communications and Filtronic Comtek. Recently, 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.

j.abedin@lboro.ac.uk

Alexandros Adam

PhD, UCL

Alexandros received his undergraduate diploma (5 years) in Mechanical Engineering from the National Technical University of Athens. In 2007 he came to London and obtained an MSc in Building Services Engineering with Sustainable Energy from Brunel University. He then worked as a building services engineer for a consultancy in London.

In 2010 he joined the LoLo Centre from which he obtained his MRes in Energy Demand Reduction. In 2011 Alexandros started a PhD at UCL Chemical Engineering.

System integration of fuel cell micro-CHP for residential energy demand reduction

One of the most promising technologies for reducing energy consumption in residential buildings, and carbon dioxide emissions, is micro combined heat and power (micro-CHP). In this research project an investigation of ways to integrate fuel cell micro-CHP in UK houses is carried out, the aim being to improve system design, control and overall efficiency. A model has been developed that simulates the performance of fuel cell micro-CHP in residential buildings and proposes methods to optimise the design.

alexandros.adam.11@ucl.ac.uk

Carrie Behar

PhD, UCL

Carrie trained as an architect at the Bartlett School of Architecture. During this time she spent two years in practice, before returning to the Bartlett and completing her Part 2 in 2009. She then studied the MSc Environmental Design and Engineering course at the Bartlett Graduate School.

In 2010 Carrie joined the UCL Energy Institute as an MRes student, on the new Energy Demand Studies master's. Her research project comprised a post- occupancy evaluation of residential dwellings at the Grade II Listed Barbican Centre in London.

Carrie is currently in the final year of her PhD and is frantically writing her thesis!

Ventilation in low energy housing; how socio-technical constraints prevent occupants ventilating their homes as the designers anticipated'?

Carrie is a passionate believer in well designed, energy efficient and functional buildings. Her present research is concerned with the design, construction and in-use performance of new housing. Carrie's PhD employs qualitative research methods to investigate how people adapt to living with the innovative ventilation technologies that are increasingly present in new energy efficient housing. Her work borrows theoretical ideas from the fields of Sociology and Anthropology to understand the interactions between buildings, technology and people. The aim of the thesis is to explore the way our built environment informs and shapes our actions and associated consumption of energy.

carrie.behar@ucl.ac.uk

James Hedger

PhD, Loughborough University

Prior to joining the LoLo CDT James completed an undergraduate degree in Earth Sciences from Brunel University. He began full time employment following my undergraduate course as an environmental consultant. The job included a range of work from monitoring contaminated groundwater in UK landfills to supervising the construction of tailings dams on a mine in the Democratic Republic of Congo. James joined LoLo in 2010 and completed the MRes year with a dissertation that investigated the dispersion of exhaled CO_2 in school classrooms. His PhD topic stemmed from the MRes dissertation as the internal temperature which had been recorded in schools was observed to be high. This triggering his curiosity into finding out whether there was potential energy savings to be made through heating in schools. Outside of his PhD research, James' interests turn to sports including rugby 7s, skiing and athletics as well as nutrition, reading and spending time outdoors.

Back to school: To learn about heating in UK primary schools

This research project is an investigation into energy used for space heating in 3 Croydon primary schools. According to literature on energy efficiency in primary schools in the UK, they are an inefficient building stock. Guidelines recommend classroom temperatures to range between 19- 21^{o}C, thus temperature monitoring in the case study rooms was done to observe how much of the occupied time is spent above the recommended temperatures. The time spent above the recommended temperatures can be considered as excess heating and offers an opportunity to calculate potential energy savings or wastage. Therefore, this research aims to find out how much excess heating is occurring in the case study schools, what is causing the excess heating, and whether an intervention can be introduced to improve the situation.

j.hedger@lboro.ac.uk

Richard Jack

PhD, Loughborough University

I am an engineer interested in building physics and heat transfer, specializing in low-impact building performance measurement. I have a master's degree in mechanical engineering, and industrial experience as a testing engineer and in market research.

Building Diagnostics: Practical Measurement of the Fabric Thermal Performance of Houses

The thesis looks into methods of measuring the thermal performance of houses. It includes an uncertainty analysis of the co-heating test (currently the most common test for whole-building performance), resulting in a total measurement uncertainty of ±10%. The thesis moves onto looking to reduce the invasiveness of the co-heating test, which requires houses to be vacated for several days and has previously been limited to the winter months. A new method is proposed to quantify solar gains, which is demonstrated to allow accurate summertime testing in a range of houses. Finally, an in-use method is developed and demonstrated which allows accurate (±15%) measurement of house's Heat Loss Coefficients to be made while the house is occupied as usual. The demonstration is based upon comparative tests versus co-heating in vacated test houses, pre- and post-retrofit, with synthetic occupancy conditions applied and in an occupied home.

r.jack@lboro.ac.uk

Ed Sharp

PhD, UCL

After completing an undergraduate degree in Geography Ed spent several years completing the commissioning process on a range of power stations in the world's least glamorous locations. A

fter a moment of "clarity" following a day's work outside at 50oc in full PPE he returned to university. Since then he has gained and MSc in GIS, completed the MRes in Energy Demand Studies and is awaiting his PhD viva in December.

Spatiotemporal disaggregation of GB scenarios depicting increased wind capacity and electrified heat demand in dwellings

The PhD presents a method which disaggregates national annual scenarios of wind capacity and energy demand temporally to an hourly resolution and spatially to a 0.5o x 0.5o grid, which covers the GB land mass and offshore waters.
The gridded framework facilitates the development of a wind generation simulation model, SpWind, and a hybrid energy demand simulation model, SpDEAM, that are both driven by climate reanalysis data, which provides spatiotemporally homogeneous and accurate hindcasted weather data over the 25 year period of the scenarios. Wind capacity and heat pumps are assigned to the model grid, ensuring that each are exposed to realistic weather conditions in simulations.
Comprehensive evaluations of the reanalysis wind speed data, SpWind and SpDEAM, demonstrating the viability of the described approach.
The implications of the scenarios on residual demand variability, geographical diversity and extreme events are explored in detail revealing the relative impact of different factors driving demand and supply.

ed.sharp.09@ucl.ac.uk

Kate Simpson

PhD, Loughborough University

Kate has a background in Building Surveying: BSc at Leeds Metropolitan University (2010) and a year in practice (2008). Kate's MRes project was focused on the indoor air quality in schools (2011). During the final stages of PhD research she has undertaken a role within the Research & Analysis team at the Centre for Sustainable Energy. Here she has put into practice the skills gained within the LoLo Centre and further developed her knowledge of energy-efficiency, damp & mould, fuel poverty, smart meter displays and householder engagement. Kate is looking forward to gaining more expertise within the field.

Energy efficiency refurbishment to UK owner-occupied dwellings: The occupant's perspective.

The project aim is to identify whether energy-efficiency refurbishments are successful from the occupants' perspective, supported by physical measurements. Supervised by Victoria Haines and David Allinson.

Ten owner-occupied household case studies that adopted measures including wall insulation, boiler or window installations are presented. Data collection combined qualitative and quantitative methods to gain a rigorous understanding of occupants' perception of the refurbishment process and comfort changes resulting from the installations in addition to physical changes to the internal environment and energy demand. Occupant interviews were held during the winter pre and post-refurbishments and shortly after the refurbishments also. Internal air temperature and relative humidity were measured between March 2013 and May 2014. Meter readings were taken by occupants during the winter months. Fabric air-tightness was tested and each dwelling modelled pre and post using SAP09. The findings provide rich insights.

C.G.Simpson@lboro.ac.uk

Sam Stamp

PhD, UCL

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.

Assessing uncertainty in co-heating tests: Calibrating a While Building Steady State Heat Loss Measurement

Co-heating tests can provide useful feedback on actual building performance. However, to fully make use of this measurement, issues of uncertainty, reliability and comparability need to be addressed.
As little test validation has been performed to date this research project looks at various sources of uncertainty in the co-heating test method, examining the conditions required for accurate measurements as well as sources of bias.

samuel.stamp.10@ucl.ac.uk

David Veitch

PhD, Continuing Research student, UCL

David graduated from the University of Durham in 2006 with an MEng degree in Mechanical Engineering, following which he was employed as a Building Services Consultant at AECOM in London for 4 years. During this time, he gained significant design experience ranging from new build financial towers to listed building refurbishment to public sector schools/hospitals and luxury residential. In 2010, David joined the Lolo Centre and completed the MRes course, including his research project 'How can high-resolution temperature traces be used to assess building performance?' He is currently in the second year of his PhD on measuring domestic ventilation rates.

Developing improved methods for measuring ventilation rates in occupied houses

Ventilation is important in buildings for reasons of indoor air quality and thermal comfort. However, it accounts for a significant proportion of the space heating energy demand in dwellings. As airtightness of the envelope is improved to reduce energy wastage, it is of increasing importance that the dedicated ventilation systems installed operate effectively. Little empirical measurement of ventilation during occupation has been conducted, mainly due to the cost and difficulty associated with current tracer gas methods that have seen little development over the last two decades. This project looks at how tracer gas ventilation measurement approaches for occupied dwellings can be improved: using alternate methods; using advancements in sensors & electronics; whilst remaining cost effective, robust and non-intrusive.

david.veitch.10@ucl.ac.uk

Faye Wade

PhD, UCL

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 Centre for Doctoral Training, and a master's degree in chemistry at the University of York.

Exploring the installation of domestic central heating systems

My research is positioned at the severely under-investigated intersection between the installation and use of domestic central heating systems. Central heating engineers are intermediaries positioned between the heating industry and the household. The engineer has several roles in the installation process; contributing to the technology design, and acting as both a temporary user of the system and an informant to the householder. Empirically, this research has used an in-depth ethnographic approach including shadowing and interviewing those involved in heating installation, along with spending time with manufacturer sales representatives, in plumbers' merchants, and participating in manufacturer training days. This research has identified a series of different aspects shaping the heating systems installed in homes, including; the different actors involved in the installation process, the role of supply chains, and engineers' constructions of their customers.

faye.wade.10@ucl.ac.uk

Peter Warren

PhD, UCL

Peter's career interests and expertise span energy and climate policy, and business and sustainability. He recently completed his PhD in Energy and Policy at UCL, specialising in global energy efficiency policy. He has taught on UCL's MSc Economics and Policy of Energy and the Environment for the last two years on three different modules, and continues to teach on the business and sustainability module in the 2015/2016 academic year.

Peter recently undertook a four-month placement at the International Energy Agency (IEA) in Paris and has just started working at the UK Department of Energy and Climate Change (DECC).

Demand-side management policy: mechanisms for success, failure and transferability

Demand-side management (DSM) refers to activities undertaken on the demand-side of energy meters that seek to meet various energy policy objectives. A global meta-evaluation of the policy side of DSM is lacking in the literature and the research aimed to fill this gap. Furthermore, most demand-side policy research has focused on policy impacts rather than mechanisms for success and failure.

A global systematic review of DSM policy evaluations was undertaken, involving the assessment of the quality of evaluations. The final sample of 119 high-quality documents covered 690 evaluations, 30 countries, 36 sub-national states and 12 different DSM policy types.

California, China, the UK and the USA have experienced the greatest success with DSM policy, and utility obligations, performance standards and alternative utility business models have been the most successful policies overall. The thesis identified the key success and failure factors for each of the 12 DSM policy types.

peter.warren@ucl.ac.uk

.

Appendix 1: Posters

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

ANNUAL COLLOQUIUM 2015

Developing a better understanding and improving the capability of prediction of human thermal comfort in domestic buildings

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
- Personalised air movement in warm environment improves occupants thermal comfort, but generates transient and asymmetrical environments
- Traditional thermal comfort models (PMV-PPD, adaptive) are not suitable for asymmetric situations
- There is only one existing fully coupled model: IESD - Fiala model and ANSYS CFX
- There is almost no research which used data measured in actual residential buildings to evaluate CFD predictions
- 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. Literature review
2. Identification of suitable scenarios
3. Detailed measurement of these scenarios
4. Coupled model development
5. Coupled model validation
6. Energy consumption analysis
7. Wider testing of the coupled model

3 OUTLINE OF THE METODOLOGHY

FIELD STUDIES

Up to 20 houses, long term monitoring, spot detailed measurements

MODELS DEVELOPMENT

Coupled CFD-human thermoregulation model, dynamic thermal modelling

THERMAL CHAMBER STUDIES

Enhance and further validate the outputs from the coupled CFD and human thermal regulation model

WIDER APPLICATION

Test the developed model in a different context (data from other counties, other non-uniform environments)

4 PROGRESS SO FAR

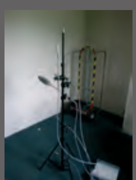
MEASUREMENTS

Long term monitoring:

- Temperature and relative humidity

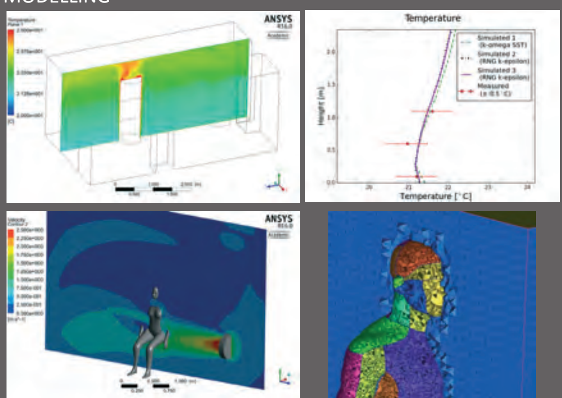
Detailed spot measurements:

- Air temperature
- Operative temperature
- Air speed
- Relative humidity



Particle image velocimetry

MODELLING



RESEARCH TEAM

Francesco Babich
2nd year PhD student
Professor Malcolm Cook
1st supervisor
Professor Dennis Loveday
2nd supervisor

CONTACT DETAILS

f.babich@lboro.ac.uk

FAQ

What is "thermal comfort"?
It is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ASHRAE 55)

What does "transient" mean?
That something is not constant over time.

What does "asymmetrical" mean?
That something is not uniform. For instance, when a person is using a fan, some parts of their body are experiencing more elevated air speed than the others.

What does "PMV-PPD" mean?
PMV means Predicted Mean Vote and it predicts the mean response of a larger 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 how a human body is affected by certain environmental conditions, but also how it affects the environment around itself.

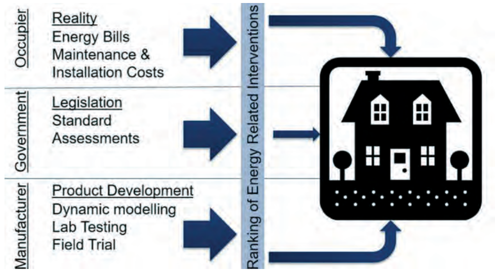
How does the "coupled model" work?
CFD is used to predict the environmental conditions around the body, while the IESD-Fiala model estimates how the body reacts to that environment. "Coupled" means that there is an exchange of information between the two models while using them to solve a certain thermal comfort problem.

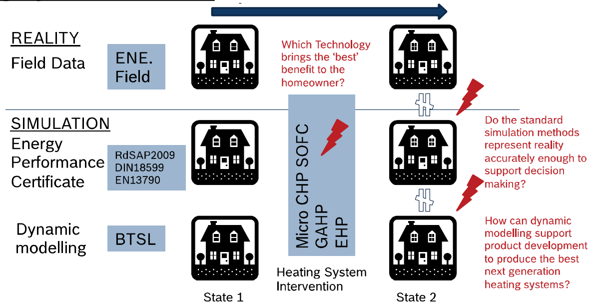
London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

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

George Bennett Industrial Sponsored PhD Year 2

Context of Ranking Heating System Solutions





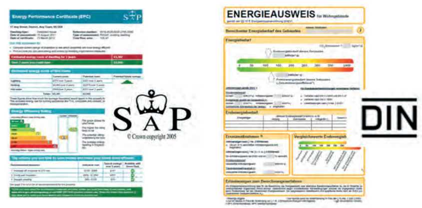
EPC EU and National Calculation Methods

European Union

EPBD: Energy Performance of Buildings Directive

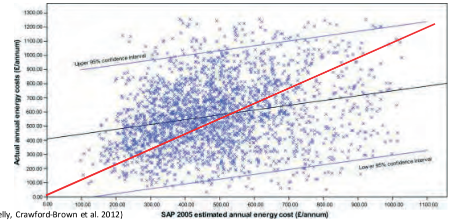
ISO 13790:2008

Member States Implementation of EPBD



DIN V 18599

EPCs poorly predict real domestic energy use

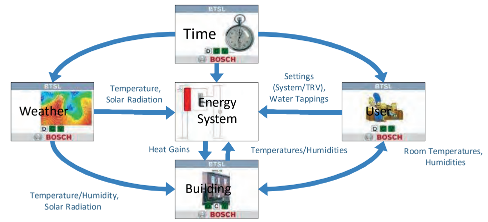


(Kelly, Crawford-Brown et al. 2012)

Cross model comparison

- Quasi-Static vs Dynamic
- SAP & DIN vs BTSL
- Quantify Space temperature and heating differences
  - Isolate Dynamic Dependencies
  - Analyse temporal variation
    - Internal Temperature
    - Mean Internal Temperature MIT
    - Space heating Input

Bosch BTSL:Building Thermal Simulation Library

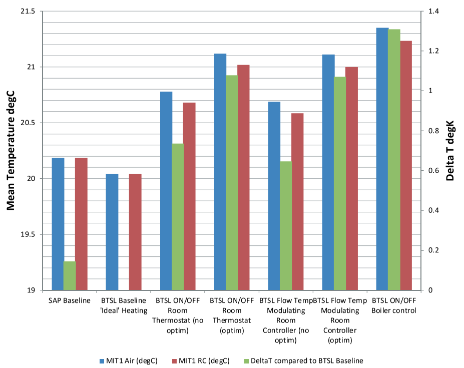


EPC Input Data: Test Case1

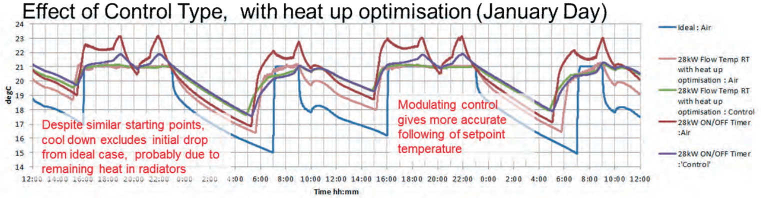
- 2 Storey Detached Building
- Gas Combi Heating
  - SEDBUK 90%
- Radiators
- Programmer
- Room Thermostat + Programmer + TRVs

Description	Value	Unit
Floor Area	100	m²
Fabric Heat loss	71.3359	W/K
Heat Loss Parameter	1.3652	W/m²K
Space Heating	4088.38	kWh/yr
Thermal Mass Parameter	283	kJ/m²K
SAP rating	C80	

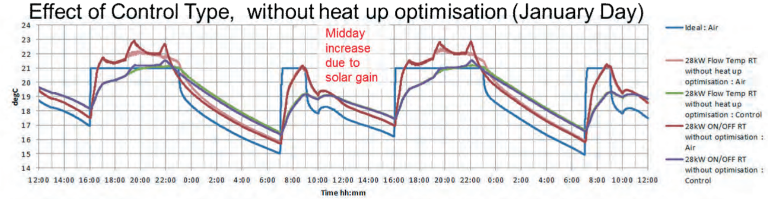
Effect of Heating Control on Mean Internal Temperature



Effect of Control Type, with heat up optimisation (January Day)



Effect of Control Type, without heat up optimisation (January Day)



UCL
Loughborough University
EPSRC Pioneering research and skills

London - Loughborough Centre for doctoral research in energy demand

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

London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

Does the Standard Assessment Procedure disadvantage homes built using offsite construction?

Ellen Coombs MPhil/PhD Candidate Year 1, UCL Energy Institute
Supervisors: Professor Paul Ruyssevelt and Dr Clifford Elwell

Introduction

Offsite construction (OSC) is the manufacture and pre-assembly of components in a factory and it has been suggested that with its fewer defects, reproducibility, and fast build-speed, it could help alleviate the performance gap. OSC is not without faults.

This study considers construction defects in an OSC dwelling, assessing the sensitivity of SAP to fabric amendments.

Aims

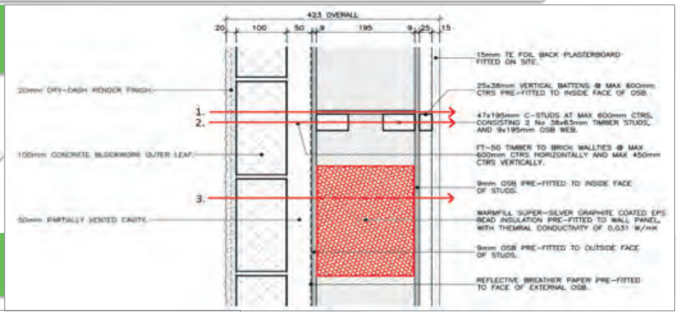
1. Does the Standard Assessment Procedure disadvantage homes built using offsite construction?

2. Do accredited Y-values and Psi (Ψ)-values in SAP 2009 reflect performance of homes built using OSC?

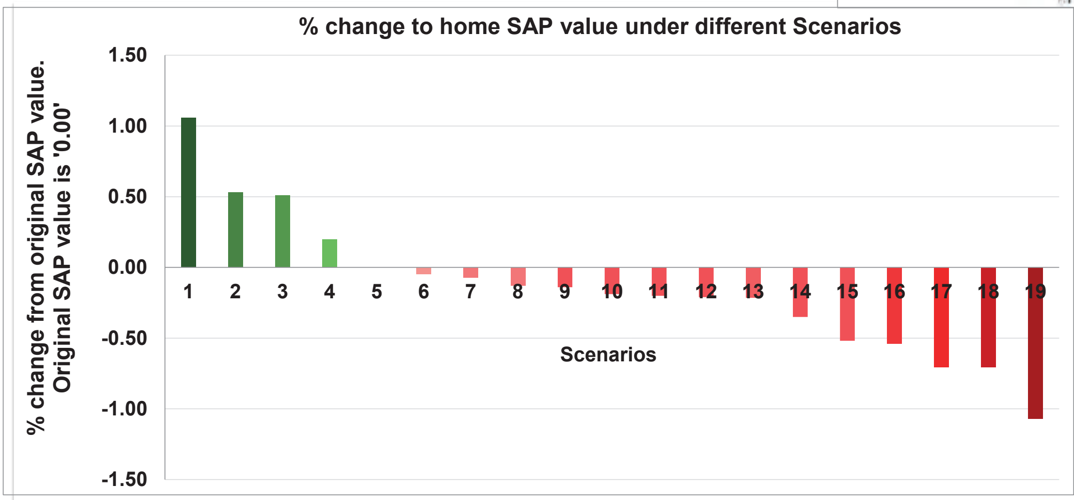
3. Are thermal-bridges accounted for in SAP 2009 of benefit or detriment to OSC homes?

Methods

Defects and fabric amendments were modelled for a Stewart Milne Sigma® II closed-panel, detached home. The effects that different scenarios (comprising of various defects of varying severity) had on the SAP value, home energy use (kWh/yr) and CO_2 emissions ($kgCO_2$/yr) were observed.



Results



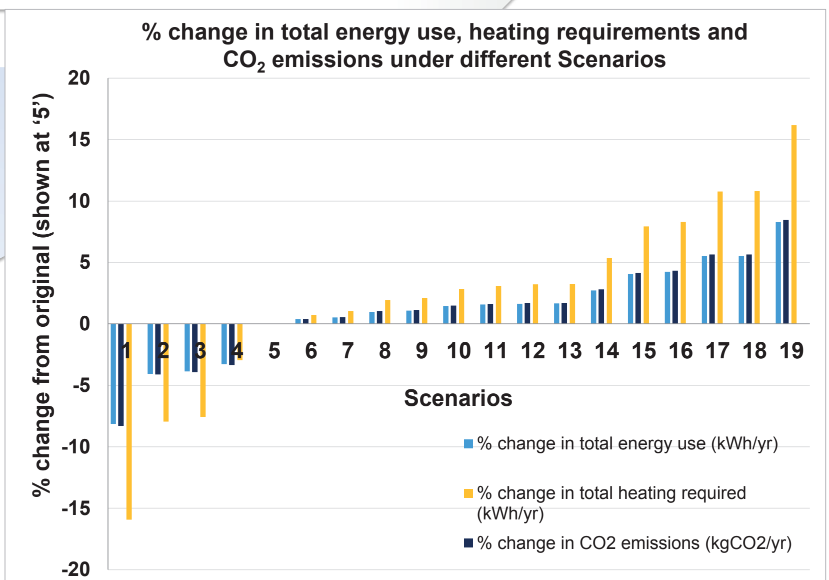
The SAP value was not as sensitive to fabric faults (e.g. missing insulation) and amendments as expected. However, altering the Y-value had a significant effect on SAP outputs.

Lowering the Y-value from that generated by SAP's assumed Ψ-values (0.06 W/m^2K) to that using accredited Ψ-values for timber-frame dwellings (0.04 W/m^2K and 0.02 W/m^2K), increased the SAP value significantly and the home energy use (kWh/yr) and CO_2 emissions ($kgCO_2$/yr) dropped.

Scenarios: 1. TB equivalent Y-value = 0.02 W/m^2K, **2.** TB equivalent Y-value = 0.04 W/m^2K, **3.** External walls missing insulation (25%) + 0.02 TB Y-value W/m^2K, **4.** External wall missing insulation (10%) + FB replaced with plain PB + Y-value 0.04 W/m^2K, **5.** Unchanged building, **6.** Ground floor missing insulation (10%), **7.** Roof missing insulation (10%), **8.** External walls missing insulation (5%) + FB replaced with plain PB + roof missing insulation (5%), **9.** TFF 25% in wall + roof, **10.** External walls missing insulation (10%), **11.** Roof missing insulation (25%), **12.** External wall missing insulation (10%) + FB replaced with plain PB, **13.** External walls missing insulation (10%) + roof missing insulation (5%), **14.** TFF 25% in wall and roof + external wall missing insulation (10%), **15.** TB equivalent Y-value = 0.08 W/m^2K, **16.** External walls missing insulation (25%), **17.** External walls missing insulation (25%) + roof missing insulation (16%) + ground floor missing insulation (10%), **18.** External wall missing insulation (5%) + roof missing insulation (16%) + Y-value 0.08 W/m^2K, **19.** External wall missing insulation (25%) + Y-value 0.08 W/m^2K

Conclusions

1. OSC is not perfect and its performance can be improved. Defects are different to onsite construction but with significant overlap. A future study would aim to consider the probability of these faults occurring in onsite and offsite.
2. Due to the more precise nature of an OSC build, the build is possibly more likely to meet design Ψ-values, reiterating the possibility that assumed SAP Ψ-values may overestimate heat losses in OSC.
3. Quality control is of particular importance at junctions and in reducing thermal-bridges to ensure OSC adheres to its low design Ψ-values, helping to inform better OSC practices.
4. Accredited Construction Details (Scottish Government, 2010) or equivalent are suggested for use when assessing OSC.



UCL Loughborough University EPSRC Pioneering research and skills

London - Loughborough Centre for doctoral research in energy demand

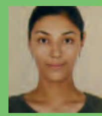
Central House
14 Upper Woburn Place
London, WC1H 0NN
www.lolo.ac.uk

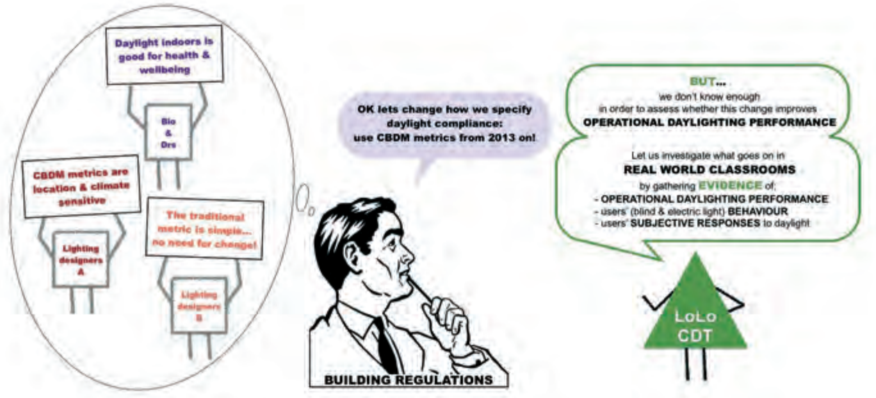
London-
Loughborough
EPSRC CDT
Centre for Doctoral Training
in Energy Demand

ANNUAL COLLOQUIUM 2015

Uncharted Territory:
Operational Daylighting Performance In Classrooms

Nafsika Christa Drosou,3rd year PhD student





METHODS

- **High Dynamic Range (HDR) imaging**
  - Measure physical parameters
  - Observe use of blinds, electric lights & Visual Display Technologies (VDT)
- **Grounded Theory Method**
  - Interviews & walkthroughs
  - Teacher survey
  - Student questionnaire
  - Focus groups
  - Industry interviews

L3

NW glazed wall with thick frames
28% effective glazing over floor area
1st floor, no view obstructions
No overhang
No shading devices

L7

Hight SE (not in use) & NE windows
24% effective glazing over floor area
1st floor, trees at NE
No overhang
NE manual vertical blinds (SE shut)

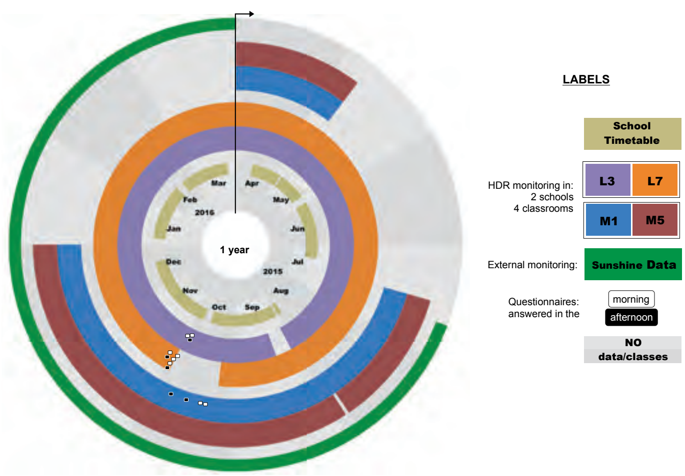
M1

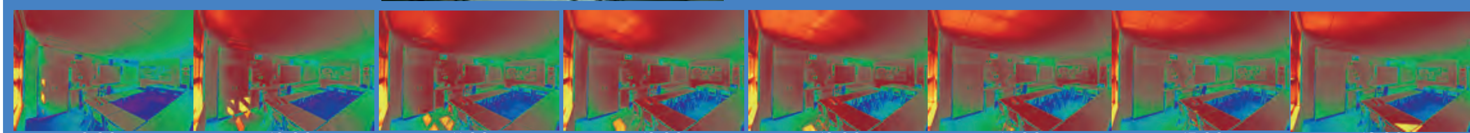
S window
6% effective glazing over floor area
Ground floor, no view obstructions
1m overhang
Manual vertical blinds

M5

N window & S at high level
11% effective glazing over floor area
1st floor, no view obstructions
0.5m roof overhang
Manual vertical blinds

TIMETABLE OF REAL WORLD DATA





9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00

CHALLENGES

- Extensive ethics requirements
- Data management and volume of HDR images (1 HDR image ~ 50MB)
- Software & equipment interoperability
- Security of high-cost equipment against theft & vandalism
- Avoidance of acoustic interference during teaching
- Creation and maintenance of good communication links with all school stakeholders
- Skill set and methodological diversity of mixed method research

EXPECTED OUTPUT

Evidence of:

- the visual demands of modern secondary classrooms
- the actions users take to meet their visual needs
- the users' perception of the luminous environment
- the implications of assessing daylight in classrooms with CBDM metrics

With Eleonora Brembilla's parallel study on CBDM applicability, quantify the discrepancy between predicted and actual daylighting performance for the 4 classrooms and estimate the potential of CBDM metrics to specify daylight design requirements that translate to well-lit classrooms.

UCL
Loughborough University
EPSRC

London -
Loughborough Centre
for doctoral research
in energy demand

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

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

ANNUAL COLLOQUIUM 2015

ÖZLEM DURAN 3rd Year PhD Researcher, Loughborough University
Supervisors: Dr. Simon Taylor, Prof Kevin Lomas

OPTIMISED REFURBISHMENT STRATEGIES FOR POST-WAR OFFICE BUILDINGS

AIM

Evaluation of the refurbishment decision making process of post-war office buildings (1945-1980) by applying dynamic energy simulations to representative building models in order to create a guidance optimising;

- Energy reduction
- Thermal comfort
- Costs

POST-WAR OFFICE BUILDINGS

EXEMPLAR 1

Corridor type plan
Natural ventilation
Daylighting

- High energy consumption
- Unregulated toxic materials
- Thermal discomfort
- Aesthetical problems

MODEL
Cellular daylit
4 storeys

EXEMPLAR 2

Open office type plan
Mechanical ventilation
Artificial lighting

- High energy consumption
- Sick building syndrome
- Thermal and visual discomfort
- Lack of natural ventilation

MODEL
Open plan 20 storeys

REFURBISHMENT PARAMETERS

Physical conditions

Model: EXEMPLAR 1 / EXEMPLAR 2
Location: Islington / Gatwick
Weather Data: Current / 2050
Gazing Ratio: 25% / 50% / 75%

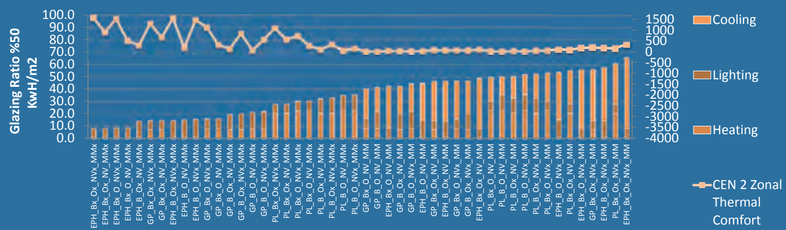
Refurbishment packages

Heating Energy Reduction: PART L / ENERPHIT
Cladding;
Keep walls as it is
Add insulation + cladding
Curtain wall;
Keep only skeleton
Add new facade

Cooling Energy Reduction:
Blinds / No
Overhangs / No
Night ventilation / No
Mixed mode ventilation + Heat recovery / No

RESULTS

After hundreds of simulations, the evaluation of the results provides series of individual information for each variation, such as;



As a summary;

- Post-war office buildings are high energy consumers
- Cause thermal discomfort in winter due to low radiant temperatures
- Commonly applied refurbishment solutions yield significant reductions in energy consumption, EnerpHit reduces heating energy close to zero
- Both Part L and EnerpHit envelopes fail to deliver the required thermal comfort in summer due to overheating except the cases with additional active cooling (mixed mode ventilation)
- The use of active cooling cause lower greenhouse gas reductions and higher costs
- Although EnerpHit provide better energy reductions, as far as the reduction of emissions is concerned, better cost value is obtained by applying Part L

FUTURE WORK

Up to date, the methodology is applied to Exemplar 1.
Further work will be revisiting cost estimations and repeating the same process with future weather data on Exemplar 1 and whole process on Exemplar 2.

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

Reducing run-time with Global Sensitivity Analysis Applying Morris' Method to Energyplus

Pamela Fennell 2nd year PhD
pamela.fennell.13@ucl.ac.uk

Introduction

Stochastic analysis of building energy models offers a more realistic picture of building performance but needs to be balanced against computing time due to the large number of variables in even simple building models.

Parameter screening allows the variables which make the greatest contribution to variation in the output to be selected and used for the stochastic analysis.

Theory

Although widely used, one-at-a-time (OAT) sensitivity analysis is not valid for complex, non-linear models. Morris' Method offers a more robust alternative as it averages the results across a number of runs. As a result the interactions with other variables are also considered

A set of k +1 sets of input values are defined in which only one variable differs between adjacent sets as illustrated in figure 1.

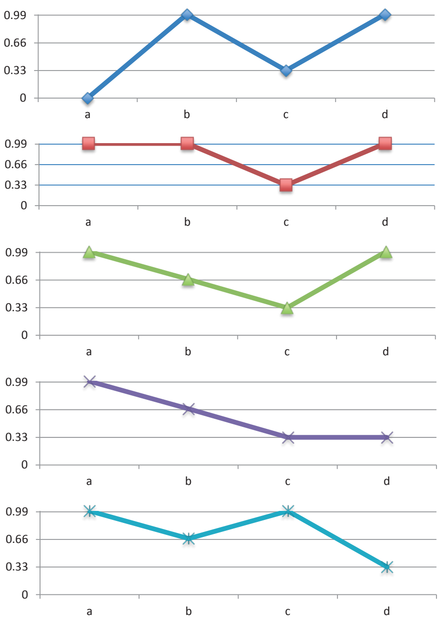


Figure 1: illustrative sets of input values

The difference in output values between sets is due to the changed variable. K+1 runs are needed to obtain 1 estimate for the sensitivity due to K variables. Repeating this process gives a series of estimates for the sensitivity of each variable, each based on a different set of input values for the other variables. The standard deviation of the magnitude of the estimates of sensitivity gives the effect of each variable on variance in the output.

Implementation

A baseline building energy model of a 420 place naturally ventilated primary school was created in DesignBuilder.

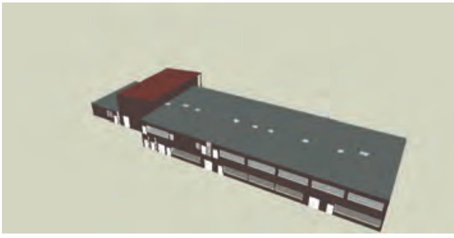


Figure 2: Rendered model of 420 primary school

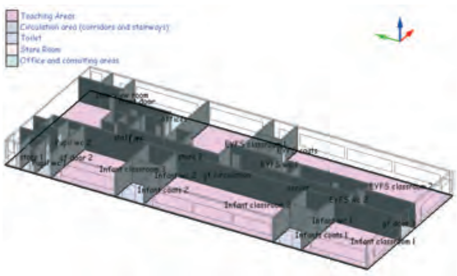


Figure 3: Ground floor layout

A literature review was used to identify 46 potentially important model parameters, each was allowed to vary by ± 20%.

Matlab was used to generate the sets of input variables and edit the base input file to produce an energy plus input file for each set of inputs.

Simulation runs were managed using JEPlus and results were analysed in Matlab, the process is summarised in figure 4.

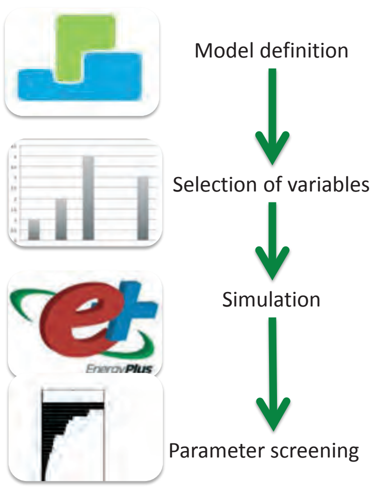


Figure 4: Sensitivity analysis workflow

Results

The original list of 46 variables was reduced to 12 which accounted for 99% of the variation in electricity consumption and 95% of the variation in gas consumption.

99%	95%
lighting gains	classroom heating set point
equipment gains - classrooms	heating system efficiency
occupancy schedule - classrooms	hall heating set point
equipment gains - kitchens	infiltration
equipment gains - offices	ventilation set point
equipment gains - toilets	DHW boiler efficiency
occupancy schedule - kitchen	classroom heating set back temp
occupancy schedule - offices	external walls u-value
equipment gains - corridors	circulation heating set point
occupancy schedule - toilets	roof u-value
equipment gains - hall	hall heating set back temp
occupancy schedule - hall	occupancy density classroom
occupancy schedule - circulation	lighting gains
classroom heating set point	DHW set point
circulation heating set point	office heating set point
hall heating set point	DHW flow rate
infiltration	circulation heating set back temp
ventilation set point	glazing u-value
DHW flow rate	occupancy gains - classrooms
classroom heating set back temp	office heating set back temp
external walls u-value	occupancy schedule - classrooms
office heating set point	external door u-value
occupancy density classroom	occupancy schedule - offices
circulation heating set back temp	occupancy density hall
roof u-value	equipment gains - classrooms
hall heating set back temp	ground floor u-value
occupancy gains - classrooms	occupancy schedule - hall
office heating set back temp	occupancy density circulation
glazing u-value	occupancy density toilets
external door u-value	Internal floor u-value
equipment gains - plant	equipment gains - kitchens
ground floor u-value	occupancy gains- hall
occupancy density circulation	equipment gains - offices
Internal floor u-value	equipment gains - toilets
occupancy density hall	occupancy density office
occupancy density toilets	occupancy gains- corridors
occupancy gains- hall	equipment gains - hall
occupancy gains- corridors	occupancy schedule - toilets
occupancy density office	occupancy gains - toilets
occupancy gains - toilets	occupancy density kitchens
occupancy density kitchens	occupancy schedule - circulation
occupancy gains - kitchens	equipment gains - corridors
occupancy gains - offices	occupancy schedule - kitchen
DHW set point	occupancy gains - kitchens
heating system efficiency	occupancy gains - offices
DHW boiler efficiency	equipment gains - plant

Conclusions

Undertaking the parameter screening exercise has resulted in a run-time reduction of 70% with the loss of only 5% of the variation in the gas output.

This reduction in run time has made it feasible to undertake a stochastic analysis of the building energy model giving a much fuller picture of the building's range of energy consumption under natural variation.

Understanding the range of possible energy consumption is particularly important in energy performance contracts where an ESCO's profits could be eroded entirely by higher than expected energy consumption post-retrofit.

UCL Loughborough University EPSRC Pioneering research and skills

London - Loughborough Centre for doctoral research in energy demand

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

London-
Loughborough Centre
for doctoral research
in energy demand

Advanced statistical methods for the evaluation of the thermophysical performance of building elements

Virginia Gori, 3rd year PhD, UCL Energy Institute Supervisory team: C.Elwell, P.Biddulph, M.Davies

Why?

- A ***commonplace use of in-situ measurements*** to evaluate the thermophysical properties (e.g., U-value and thermal mass) of buildings ***seems to be unpractical at the moment*** due to a ***number of limitations of steady-state methods*** generally adopted for data analysis.
- Thermophysical properties estimated from ***in-situ measurements*** may have an important contribution in ***closing the performance gap***[1] as:
  - do *not require any knowledge* of the *structure* and the *materials* used (unlike tabulated values assumed after visual inspection);
  - enable to ***account*** for the ***environmental conditions*** the element is exposed to, its ***conditions*** and ***conservation***.

Objectives

Use advanced statistical techniques to develop a method that:

- Allows the development of ***physically-informed models***, which may be appropriate for *different structures* and *environmental conditions*;
  - ***shortens the monitoring period*** and is ***seasonal-independent*** (overcoming current main limitations);
- Incorporates ***prior knowledge*** about the element (if available) and returns physical ***parameters*** to ***evaluate*** its ***dynamic performance*** (e.g., *thermal mass*);
- ***Objectively identifies the most representative model*** among several possible.

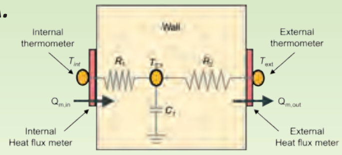
Method

*1. **Design of different models** to describe the heat transfer through the building element and **estimate** the most probable **thermophysical properties** of the element by using Bayesian-based optimisation techniques*[2]

Possible physical models of the heat transfer though the element
(predict the heat flux given the parameters and the model)

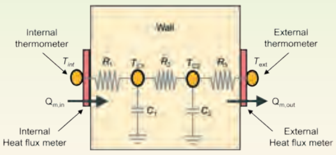
For example:

A.



Four parameters:
$w_A = [R_1, R_2, T_{C1}, C_1]$

B.



Seven parameters:
$w_B = [R_1, R_2, R_3, T_{C1}, T_{C2}, C_1, C_2]$

Bayesian-based optimisation
(estimate the parameters)

For each model, the *set of most probable parameters* (*w*) is estimated by *minimising the prediction error*.

$$\text{argmin} = \prod_{i=1}^{n} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(\Phi_{e,i}(w)-\Phi_{m,i})^2}{2\sigma^2}} \mathrm{P}(w)$$

where: $\Phi_{e,i}$, estimated heat flux by the model;
$\Phi_{m,i}$, measured heat flux;
σ, additive noise;
P(*w*), prior knowledge about the unknown parameters.

The approach allows:

- the ***estimation of uncertainties*** as output of the analysis;
- to model heat flux → it ***handles changes in heat direction*** (*e.g., in summer*).

*2. **Model selection**: identification of the physical model that better describes the data among several possible*

The *Odd's ratio* principle is used to compare the *probability of different models* describing the *observed data, accounting for the number of parameters included.*

Application on a solid wall

Figure 1: The case study

The two models described in the Method section were tested:

Figure 2: Evolution of the U-value estimation

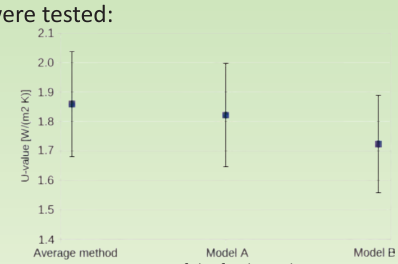


Figure 4: Estimation of the final U-value

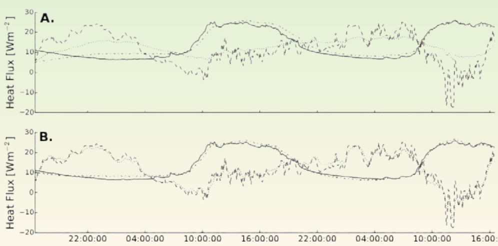


Figure 3: Prediction (dot & dash-dot line) of measured heat flux (solid & dashed line)

According to the *Odd's ratio*, ***model B*** is the best model.

References

1. Li F.G.N., …, Gori V., Oreszczyn T. 2014. Solid-wall U-values: heat flux measurements compared with standard assumptions. Building Research & Information.

2. Biddulph P., Gori V., Elwell C., Scott C., Rye C., Lowe R., Oreszczyn T. 2014. Inferring the thermal resistance and effective thermal mass of a wall using frequent temperature and heat flux measurements. Energy and Buildings.

London - Loughborough Centre for doctoral research in energy demand
Central House
14 Upper Woburn Place
London, WC1H 0NN
www.lolo.ac.uk

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

ANNUAL COLLOQUIUM 2015

Investigating heat and moisture transfer through solid brick walls and the impacts of internal wall insulation

Lisa Iszatt 2nd Year PhD student **Supervisor: Dr Cliff Elwell**

Background

Existing buildings account for approximately 40% of UK energy demand and working out effective ways to retrofit these is recognised as a key aspect of national energy and CO_2 reduction targets. Solid wall insulation is predicted to contribute significantly to meeting these targets, and internal wall insulation is often the most appropriate solution, in terms of cost, disruption and heritage considerations.

IWI changes the temperature and moisture profile of the wall, which may have unintended consequences such as structural damage and health risks due to mould. Conversely, inaction on retrofit could lead to undershooting national CO_2 saving targets, so understanding the safety limits in more detail is crucial.

Overview

The physical properties of solid brick walls in the UK are currently not well characterised, and methods for determining them are not well developed. Most research to date is based on models or test walls in laboratories. This research will use in-situ monitoring campaigns to give insight into the hygrothermal behaviour of real walls in real conditions.

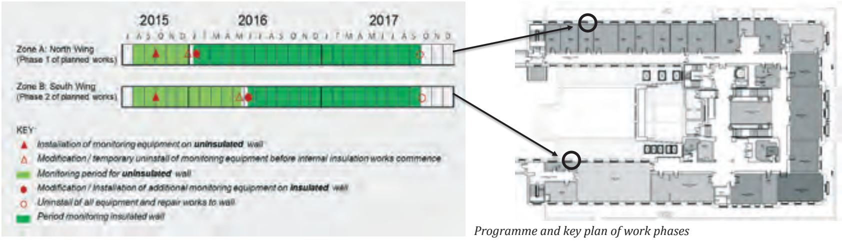
The proposed analysis draws on a method recently developed at UCL to derive thermophysical properties of a solid brick wall using in-situ data, a lumped thermal mass model and Bayesian statistical analysis*. This technique will be extended to analyse hygrothermal properties of walls.

* Biddulph, P., Gori, V., Elwell, C. a., Scott, C., Rye, C., Lowe, R., & Oreszczyn, T. (2014). Inferring the thermal resistance and effective thermal mass of a wall using frequent temperature and heat flux measurements. Energy and Buildings, 78, p10–16.

Monitoring Campaign: Long Term

Two walls in a large public building are being monitored over two years. A major retrofit is planned during this period which includes insulating the two walls in separate phases. This will allow for comparative analysis of two similar walls with and without insulation, and of each wall before and after insulation.

The diagrams and photos below show the proposed monitoring campaign currently being set up



Programme and key plan of work phases

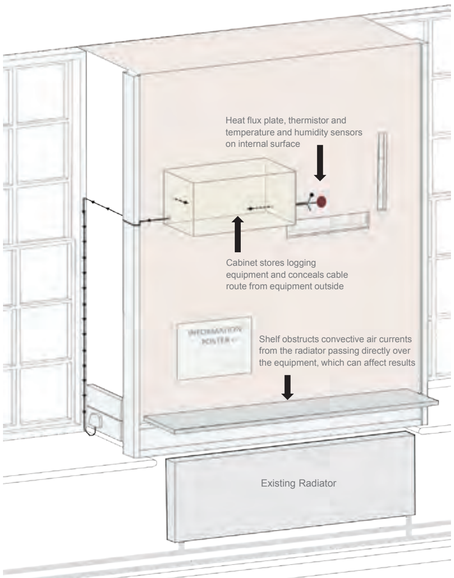
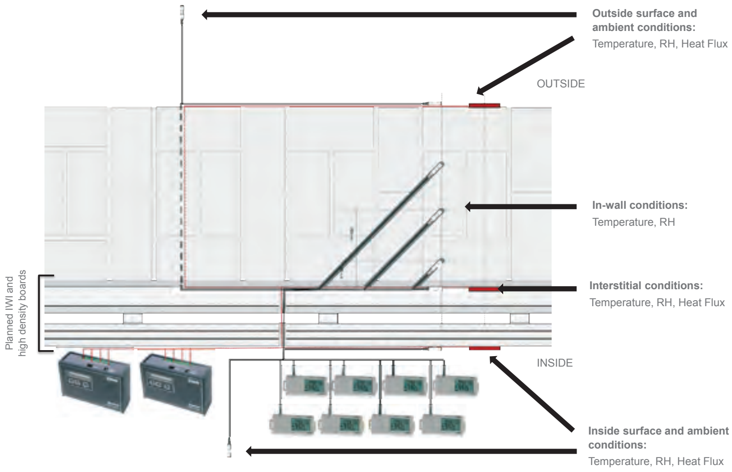
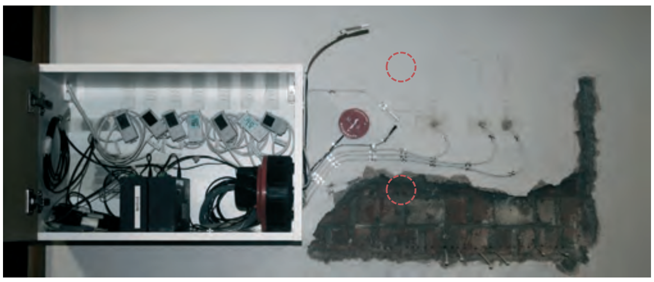


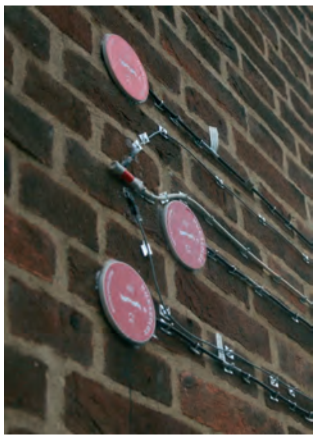
Diagram of inside face of wall

Plan detail of wall with planned internal wall insulation



Pictures of installation





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

ANNUAL COLLOQUIUM 2015

Boiler Whispering

In-situ boiler monitoring using passive acoustic techniques

Tom Neeld MPhil / PhD

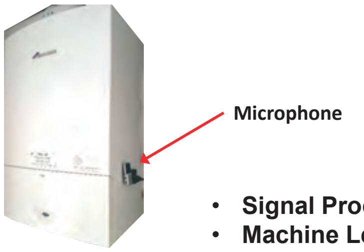
Introduction

- Residential space heating/hot water accounts for about **20% of CO_2 emissions** in UK[1]
- Over **half of heating systems are combination gas boilers**[1] (On the rise)
- No standard non-invasive monitoring technique *"…high cost associated with sophisticated fuel-use monitoring equipment…and the complexity of its installation"*[2]

➢ Can we **monitor boilers using acoustic methods**? Provide insightful data for field trials.

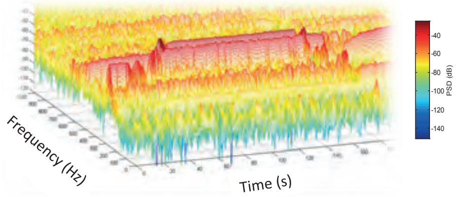
Method

Combi Boiler



Fourier Transform

$$X[k] = \sum_{n=0}^{N-1} x(n) e^{-i w_k n}$$

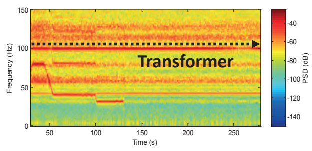


- **Signal Processing**
- **Machine Learning**
- **Spectrogram tracking**

Results

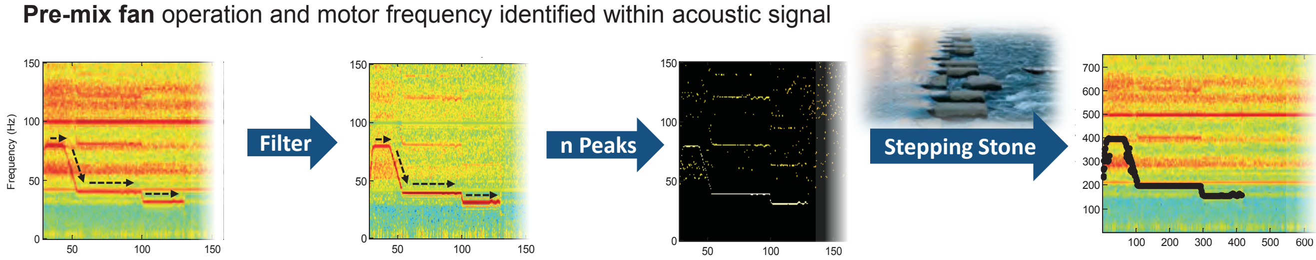
Data: Four Boilers, Three microphones – **90 Data Points**

- Boiler **start and end times** using **'magnetostriction'** noise 100 Hz



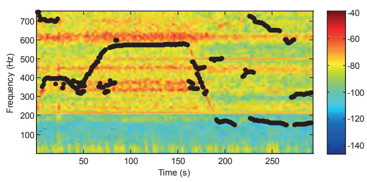
Median and mean estimates within error

- **Pre-mix fan** operation and motor frequency identified within acoustic signal



Next Steps

- Refine tracking algorithm to deal with generic boiler
- Investigate **burner** identification
- Can we monitor Lambda value in flame…
  - o *Changing calorific value in UK gas mains*[3,4]



UCL Loughborough University EPSRC Pioneering research and skills

1. DECC, 2014. United Kingdom housing energy fact file: 2013. In: DECC (ed.)
2. HONG, S. H., ORESZCZYN, T. & RIDLEY, I. 2006. The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings. *Energy and Buildings,* 38**,** 1171-1181
3. Ofgem, 2015. Ofgem Gas Quality [online]: https://www.ofgem.gov.uk/gas
4. DECC, 2015. Delivering UK energy investment: Networks. In: DECC (ed.)

London - Loughborough Centre for doctoral research in energy demand

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

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

ANNUAL COLLOQUIUM 2015

Mapping the current and future risk of overheating in UK homes

Argyris Oraiopoulos – 3rd Year PhD Researcher, Loughborough University
Supervised by Dr Steven Firth, Dr Tom Kane, Prof Kevin Lomas

Objectives

- Prediction of internal air temperature in UK homes based on empirical data.
- Develop parsimonious model able to predict internal air temperatures in homes using only past measurements of internal temperature and external weather data.
- Use current and future weather data to assess the risk of overheating in homes now and in the future.

Methodology

- *Time Series Analysis and Modelling* techniques.
- Using SPPS & EViews.
- Univariate AutoRegressive Integrated Moving Average (ARIMA) models for short term forecasting (72 hours ahead).
- Multivariate ARIMA (transfer functions) for long term forecasting (up to 60 days ahead.

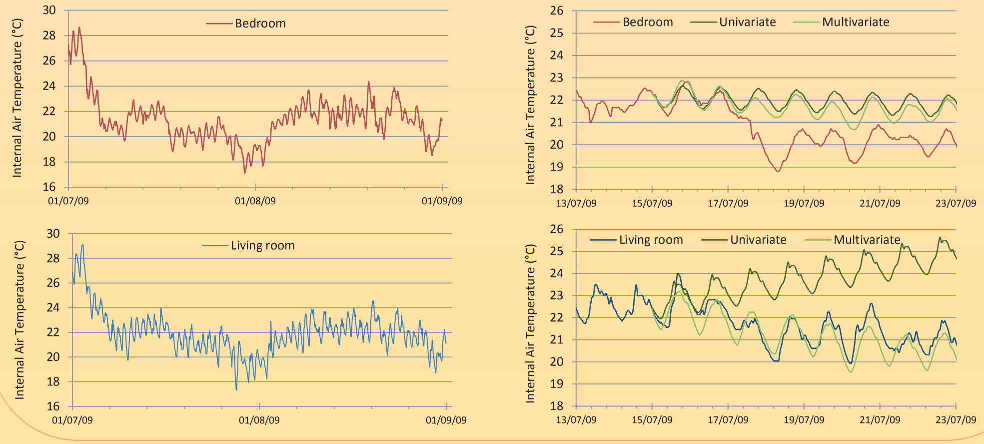
°C

2013

2014

2015

Results – Example house, Univariate model = SARIMA (2,1,2)(0,1,1)
Multivariate model = SARIMA (2,1,2)(0,1,1) + External Temperature



Future Work

- BS2015, India (December 2015)
- Apply "heavier" coefficient on the exogenous variables (external temperature)
- Categorisation of houses by impact of external on the formation of internal temperature
- Forecasts for 2030s, 2050s, 2080s
- Comparison between Empirical models and Dynamic Thermal Simulation

Dataset

- Hourly measured internal air temperatures
- 1st July - 31st August 2009
- Living rooms and main bedrooms
- 230 domestic buildings
- (417 "*free – floating*" internal spaces)
- Leicester, UK
- (Sub sample of the 4M dataset)

2016

Conclusion

- Univariate models (including only past measured values) can only produce acceptable forecasts up to 12-24 hours ahead
- Multivariate models (including exogenous variables) can increase the forecast ability up to 7-10 days.
- Main limitation are the form of the initialisation conditions and capturing pattern changes to a short term trend.

2017

t

Intended Consequences

Smart Homes

Elderly care

National Future Policies

Impact on retrofitting

UCL
Loughborough University
EPSRC Pioneering research and skills

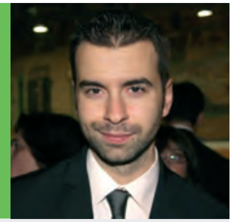
London - Loughborough Centre for doctoral research in energy demand
Central House, 14 Upper Woburn Place
London, WC1H 0NN
www.lolo.ac.uk

London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

Reducing the Energy Performance Gap

Improving building simulation tools through data-driven and real-time approaches



George Papachristou, 2nd year PhD researcher

Introduction

The current range of building performance models begin with a description of the systems and define buildings based on their physical description (forward modelling method).

The predictions of such models tend to be different from the actual energy performance of buildings even in the order of a factor of 2.5 [1].

An alternative approach that could potentially overcome the severe limitations of forward modelling is the inverse approach, where "the system under study already exists and the measured or observed system behaviour is used to aid in the model building and/or refinement" [2].

However, inverse models require a large amount of data collected over a long period of time, which are often unavailable.

Research questions

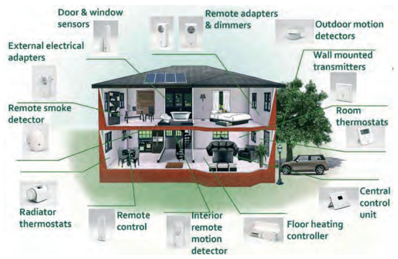
1. Which inverse modelling approaches are most able to utilise real-time data streams in order to identify suitable models of the heat dynamics of existing dwellings?
2. What measured data are required so that inverse models can provide accurate and reliable predictions for existing dwellings?

Methodology

Data

Detailed measurements in 20 homes in Loughborough, UK have been carried out for three years as part of the EPSRC-funded REFIT project.

- **Metering and monitoring equipment**: energy use, indoor thermal conditions, weather data.
- **Surveys**: building characteristics, household formation, HVAC.



Approaches

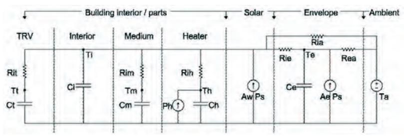
Calibration of forward models

The calibration methodology includes various techniques which can utilise high resolution data:

- **Sensitivity analysis**: assesses the influence of input parameters on model predictions.
- **Data disaggregation**: decouples multiple measured data streams.
- **Uncertainty analysis**: quantifies uncertainty in a model output.

Inverse models

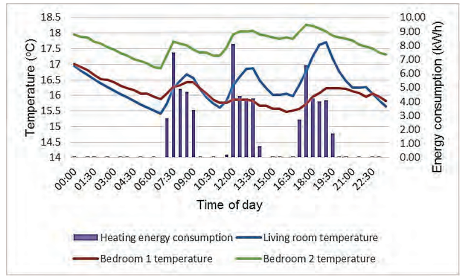
Lumped parameter models can be represented as a thermal network of resistances and capacitances.



Thermal network model of a dwelling by Dimitriou et al. [3]

Work to date

- Survey data from all REFIT houses have been collected and their respected forward models are being constructed.
- An initial analysis of monitoring data has been carried out.



Heating energy use and temperature data for a typical winter day in a dwelling occupied by an elderly couple

Anticipated outcomes

The expected outcomes include a new model and/or a set of modelling techniques that can include real-time performance data as part of their prediction algorithms, and which can update and calibrate in real time. The aim is to improve the thermal modelling of existing buildings.

References

[1] Menezes, A.C., Cripps, A., Bouchlaghem, D., and Buswell, R. (2012). Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. Applied Energy, 97, 355-364.

[2] Reddy, T.A. (2011). Applied data analysis and modeling for energy engineers and scientists. Springer.

[3] Dimitriou, V., Firth, S.K., Hassan, T., Kane, T., and Fouchal, F. (2014). Developing suitable models for domestic buildings with Smart Home controls. Proceedings of Building Simulation and Optimisation 2014, 23-24 June 2014, UCL, London.

Acknowledgments

I would like to thank my supervisors, Dr Steven Firth and Professor Kevin Lomas. Moreover, I want to thank Dr Tom Kane and the whole team of the REFIT project for providing me with data for my research. http://www.refitsmarthomes.org/

Further information

Please scan this code with your smartphone to learn more about the project.

UCL | Loughborough University | EPSRC Pioneering research and skills

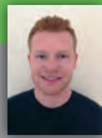
London - Loughborough Centre for doctoral research in energy demand

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

ANNUAL COLLOQUIUM 2015

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

Do zonal heating controls reduce energy use during the shoulder heating season?



Ben Roberts PhD Student (1st year) b.m.roberts@lboro.ac.uk

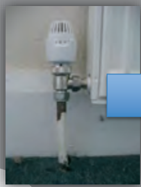
Poster based on MRes dissertation supervised by Prof. K.J. Lomas and Dr. S. Porritt.

Background

- Conventional heating controls wastefully heat the entire house for the same duration.
- Zonal controls (ZC) reduce energy demand by only heating rooms during occupancy.
- ZC reduces energy demand by 12% with no difference in internal air temperature during occupied hours compared to conventional controls in winter months (Beizaee *et al.* 2015).
- This study looked at zonal controls in shoulder heating season.

Identical uninsulated 1930s semi-detached houses

CONVENTIONAL CONTROLS

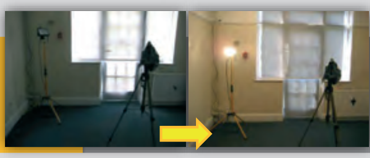


Loughborough Matched Pair Test House Facility

ZONAL CONTROLS

Methods

- Under identical weather conditions, three phases of testing occurred simultaneously in both houses.
- Standard synthetic occupancy profile mimicked heat gains and door and blind opening and closing identically simulated in both houses using Vera smart home controller and z-wave receivers during heating controls test.
- Heating controls testing ran 13th May to 7th June, collecting 24 days' worth of data.
- Energy consumption of each heating strategy and the effects on indoor temperature and thermal comfort were explored.



Co-heating test (internal door open: 11 days; doors closed: 9 days).

Heating trials recorded:
- Air and radiator surface temperature.
- Gas/elec consumption.
- Boiler heat output.

Thermal Comfort test:
- Air T and velocity at three heights.
- Operative temperature.
- Humidity.

Results

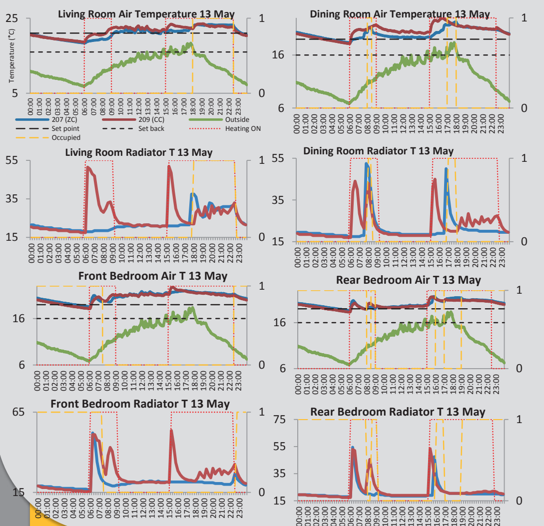
1. CO-HEATING TEST

Houses showed very similar thermal performance.

Total heat loss co-efficient (W/K)	207 Ashby Rd	209 Ashby Rd
	366	365

2. HEATING CONTROL TRIALS

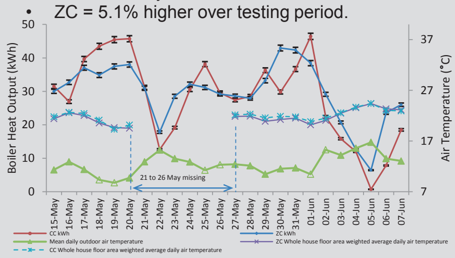
- Internal 'heating on, occupied' temperatures similar between zonal and conventional controls.
- Solar gain has greater impact than seen in the Beizaee *et al.* (2015) winter study.



Daily air and radiator surface temperature profiles 13th May, 2015.

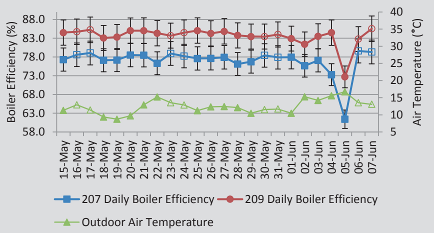
BOILER HEAT OUTPUT

- On warmer outdoor days boiler heat output is higher for the zonally controlled boiler.
- ZC = 5.1% higher over testing period.



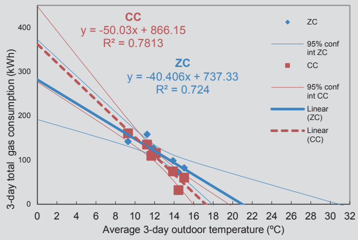
BOILER EFFICIENCY

- Efficiency is lower for the zonally controlled boiler (ZC = 76.9%, CC = 83.6% average).



GAS CONSUMPTION TO WEATHER

- Regression analysis predicts that when outdoor air temperature exceeded 10.5°C zonal controls would use more gas.



3. THERMAL COMFORT TEST

- Thermal comfort results very similar between houses.
- Slightly more favourable in the zonally controlled house.

Conclusion

Do zonal controls reduce energy demand in the shoulder heating season?

- **No**, heat output = **5.1% higher** in the zonally controlled house and combined with a **6.7pp drop in efficiency** in the ZC boiler compared to CC, the ZC house consumed **13% more gas** over the testing period.
- 'Heating on, occupied' indoor temperatures broadly similar between houses.
- Thermal comfort similar between houses (slightly more favourable in the ZC house).

Limitations

- Synthetic occupancy profile used may not reflect true occupant behaviour.
  - E.g. no window opening/ventilation.
  - E.g. internal doors always closed when room occupied.
- The heating loads were very low, particularly towards the end of testing (June) so reliable comparisons to the high-load winter months are difficult.
- Missing air temperature data 20-26 May, in future back-up Hobo sensors could be used.

References: Beizaee, A., Allinson, D., Lomas, K.J., Foda, E. and Loveday, D.L. (2015). Measuring the potential of zonal space heating controls to reduce energy use in UK homes: the case of unfurbished 1930s dwellings. *Energy and Buildings*. 92, 29-44.

UCL Loughborough University EPSRC Engineering and Physical Sciences Research Council

London - Loughborough Centre for doctoral research in energy demand

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

London-Loughborough EPSRC CDT

Centre for Doctoral Training in Energy Demand

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

Vicki Tink, 3rd year doctoral researcher

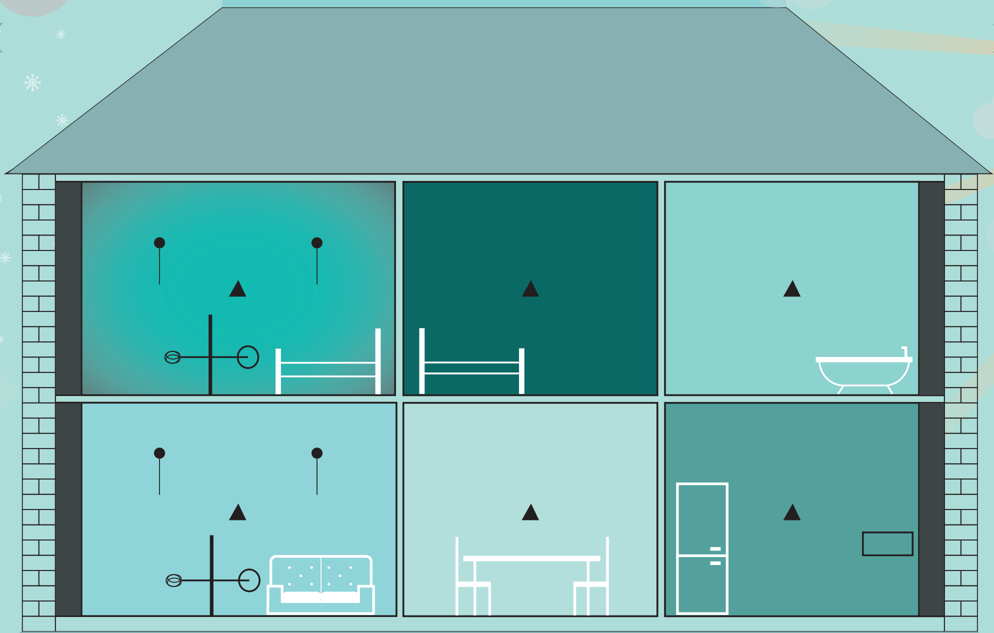
BACKGROUND

1. THE UK HAS SET LEGALLY BINDING TARGETS TO REDUCE ITS CO_2 EMISSIONS BY 2050 BY 80% COMPARED TO 1990 LEVELS.
2. HEATING HOMES ACCOUNTS FOR 1/5 OF ALL FINAL ENERGY CONSUMPTION IN THE UK.
3. BUILDINGS BUILT BEFORE 1919 USUALLY HAVE SOLID WALLS AND ARE THE MOST ENERGY INEFFICEINT TYPE OF HOUSE.
4. SOLID WALL BUILDINGS ACCOUNT FOR 30% OF THE CURRENT UK BUILDING STOCK. BY 2050 THEY WILL STILL ACCOUNT FOR 25% OF IT.
5. ONLY 4% OF SOLID WALL PROPERTIES IN THE UK HAVE CURRENTLY BEEN INSULATED.
6. SOLID WALL PROPERTIES CAN EITHER BE INSULATED INTERNALLY OR EXTERNALLY, BOTH METHODS HAVE BENEFITS AND DRAWBACKS.
7. LITTLE RESEARCH HAS BEEN DONE ABOUT THE EFFECT OF INTERNAL WALL INSULATION ON ENERGY DEMAND, COMFORT AND OVERHEATING.

WINTER COMFORT

The purpose of the experiments in the winter was to assess if an internally insulated house reduces heating energy consumption and improves thermal comfort. Thermal comfort is the "condition of mind which expresses satisfaction with the thermal environment" (ANSI/ASHRAE 2013). It is dependent upon 4 environmental variables; air temperature, humidity, mean radiant temperature and air speed. It is also dependent upon 2 personal variables, metabolic rate and clothing insulation, which were taken from CIBSE reference tables. The houses were monitored twice, once with both houses uninsulated and once with one of the houses internally insulated. This allowed for a direct comparison under any weather conditions.

The two houses were unoccupied. To produce realistic in use data, occupancy had to be synthesised. Heat sources, such as light bulbs and oil radiators were turned on and off in every room on a set schedule. The schedule in winter corresponded to a family's behaviour as this provided intermittent heating use, this was developed using the Time Use survey.



SUMMER OVERHEATING

The purpose of the experiments in the summer was to discover if an internally insulated house is more prone to overheating than an uninsulated house. Overheating is the mixture of thermal comfort variables that make a house uncomfortably hot for people. It is an issue not just for comfort, but also for sleep quality and health. It was assessed twice, first with one of the houses internally insulated, then with both houses uninsulated. After experiments on overheating, both houses were tested to see if the risk of overheating could be reduced through simple and free mitigation techniques that anyone could do in their own home. The blinds were shut throughout the day to reduce the heat from the sun entering and the windows were open at night to replace the hot air and cool the thermal mass of the building.

In the summer an occupancy profile of an elderly couple was used as heat affects the elderly worse than other age groups. The profile had two people occupying the house throughout the day, therefore providing constant internal gains and being present for the hottest part of the day.

TEST FACILITY

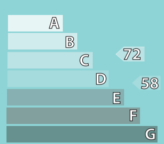
THE TEST FACILITY WAS TWO UNOCCUPIED SEMI-DETACHED SOLID WALLED HOUSES IN LEICESTERSHIRE. FORMALLY DERELICT SOCIAL HOUSING, THESE WERE BROUGHT TO MODERN STANDARDS WITH LOFT INSULATION AND DOUBLE-GLAZED WINDOWS AND DOORS. THE TWO HOUSES WERE TESTED TO ENSURE THEY BEHAVED THE SAME BOTH UNDER WINTER AND SUMMER CONDITIONS. THESE TESTS INCLUDED A WHOLE HOUSE HEAT LOSS ASSESSMENT, AN AIR INFILTRATION TEST AND A THERMAL TRANSMITTANCE ANALYSIS OF THE WALLS. ONE OF THE HOUSES THEN HAD INTERNAL WALL INSULATION APPLIED AND THESE TESTS WERE REPEATED. THE EQUIPMENT USED DURING MONITORING IS DESCRIBED HERE AND ITS PLACEMENT IS SHOWN ABOVE.

- **THERMAL COMFORT** — MEASURED USING THERMISTORS, HUMIDITY PROBES, ANEMOMETERS AND BLACK GLOBE THERMOMETERS
- **AIR TEMPERATURE** — MEASURED USING CALIBRATED THERMISTORS
- **SURFACE TEMPERATURE** — MEASURED USING THERMOCOUPLES ATTACHED TO SURFACES
- **ENERGY CONSUMPTION** — GAS AND ELECTRICITY CONSUMPTION MEASURED USING PULSE METERS

FINDINGS

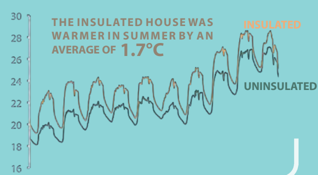
THE VICTORIAN HOUSES WITH NEW WINDOWS AND LOFT INSULATION HAVE A STANDARD ENERGY ASSESSMENT PROCEDURE RATING OF **D**

WITH INSULATION THIS IMPROVES TO A RATING **C**



THE TWO HOUSES WERE ALMOST IDENTICAL BEFORE INSULATING, WITH A DIFFERENCE IN HEAT LOSS OF 2.5%. THE HOUSE THAT WAS INSULATED HAD SLIGHTLY HIGHER HEAT LOSS IN THE BEGINNING.

THE INSULATED HOUSE WAS ON AVERAGE **1 DEGREE WARMER** IN WINTER THAN THE UNINSULATED HOUSE.



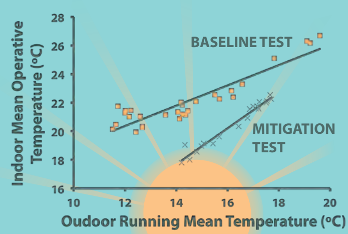
THE UNINSULATED HOUSES PERFORM 34% BETTER THAN UK STANDARD GOVERNMENT MODELS SAY THEY DO.

46% THE WHOLE HOUSE'S HEAT TRANSFER COEFFICIENT WAS REDUCED BY 46% BY INSULATING THE WALLS OF THE HOUSE.

ENERGY CONSUMPTION

DURING THE SAME PERIOD OF TIME, UNDER THE SAME WEATHER CONDITIONS, THE INSULATED HOUSE NEEDED ALMOST ¼ OF THE ENERGY OF THE UNINSULATED HOUSE TO HEAT IT **1/4**

THE OVERHEATING MITIGATION STRATEGY SIGNIFICANLY REDUCED HIGH INTERNAL TEMPERATURES IN THE INSULATED HOUSE



34%

THE INSULATED HOUSE **HEATS UP FASTER** AND **COOLS SLOWER** PROVIDING BETTER COMFORT IN WINTER

INTERNAL WALL INSULATION REDUCED HEAT TRANSMISSION THROUGH THE WALLS IN WINTER BY **89%**

THE AMOUNT OF INFILTRATION WAS MEASURED BOTH BEFORE AND AFTER INTERNAL WALL INSULATION WAS INSTALLED AND THE **AIRTIGHTNESS WAS UNCHANGED**

UCL | Loughborough University | EPSRC Pioneering research and skills

London - Loughborough Centre for doctoral research in energy demand

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

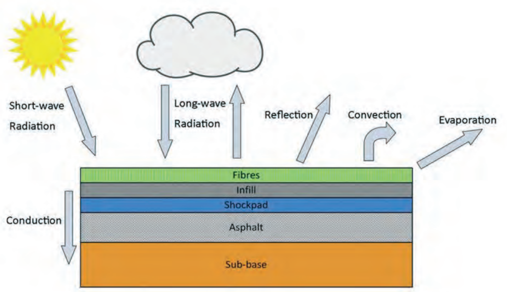
London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

ANNUAL COLLOQUIUM 2015

Energy from artificial sports pitches: Modelling surface temperatures and the effect of extracting heat

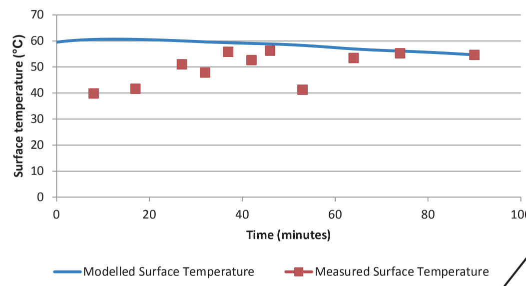
Stephen Watson

Current 1st year PhD



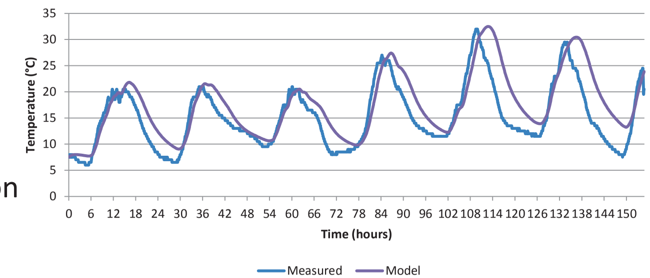
Method: Thermal model

Modelled and measured surface temperature, 14:00 to 15:30, 9/7/2015



Results: Verification

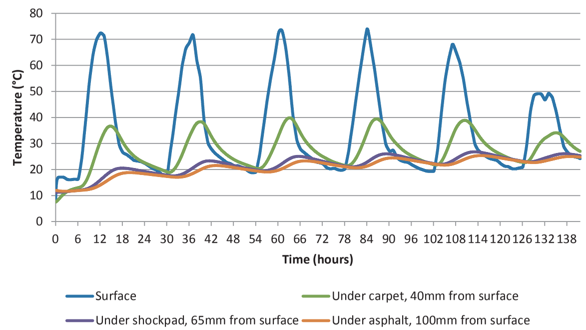
Modelled and measured temperature 35mm below surface, 7/5/2015 to 13/5/2015



Aim

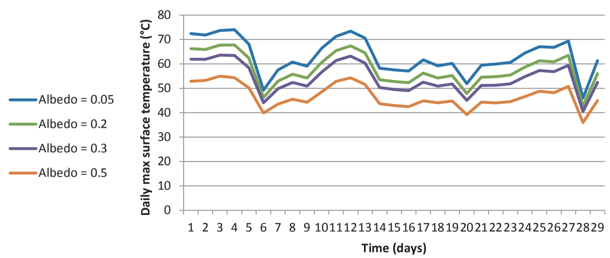
To identify the potential for removing heat from artificial sports pitches, in order to make the pitch temperature more acceptable for players and possibly use the heat energy obtained for a useful purpose.

Modelled temperature at various depths without cooling, 1st to 6th November, Abu Dhabi



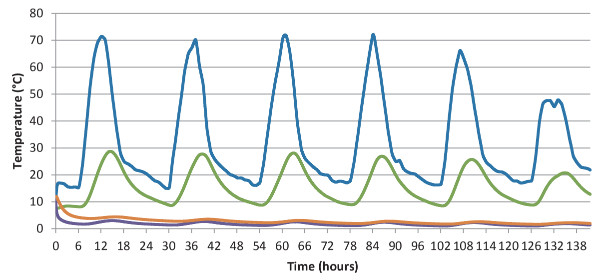
Results: Albedo

Daily maximum surface temperature with different albedos, November, Abu Dhabi



Results: Cooling system

Modelled temperature at various depths with asphalt cooling, 1st to 6th November, Abu Dhabi



Conclusions

- It was possible to construct a thermal model which predicted temperature at and below the surface with reasonable accuracy.
- With existing materials, a cooling system buried below the surface of the pitch is not able to significantly reduce surface temperatures.
- Increasing albedo is an effective way of reducing surface temperature.

UCL
Loughborough University
EPSRC Pioneering research and skills

London - Loughborough Centre for doctoral research in energy demand
Central House, 14 Upper Woburn Place
London, WC1H 0NN
www.lolo.ac.uk

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

ANNUAL COLLOQUIUM

Setting energy targets in context: a case study in the construction industry

Catherine Willan, MRes Dissertation

Research aim: to understand the role of the construction contractor in setting energy targets for a case study school, and therefore to uncover more about the causes of the energy performance gap in non-domestic building projects. In doing so, to address some of the less frequently researched areas, by:

- Examining socio-technical aspects of energy targets;
- Considering neglected "middle actors"[1], such as the construction team;
- Approaching construction industry at micro level rather than collectively[2,3];
- Assessing how targets of "good" performance are defined before construction, rather than using post-occupancy evaluation.

Feb 2015	Mar 2015	Apr 2015	May 2015	Jun 2015	Jul 2015	Aug 2015

Meetings help formulate research questions

Documents inform interview questions

Research data:

- **Meeting notes:** 2 x c.2hrs
- **Documents,** including contracts, internal reports, working papers and other items, from company and its sub-contractors: 41 items
- **Interview transcripts:** 3 x c.1hr

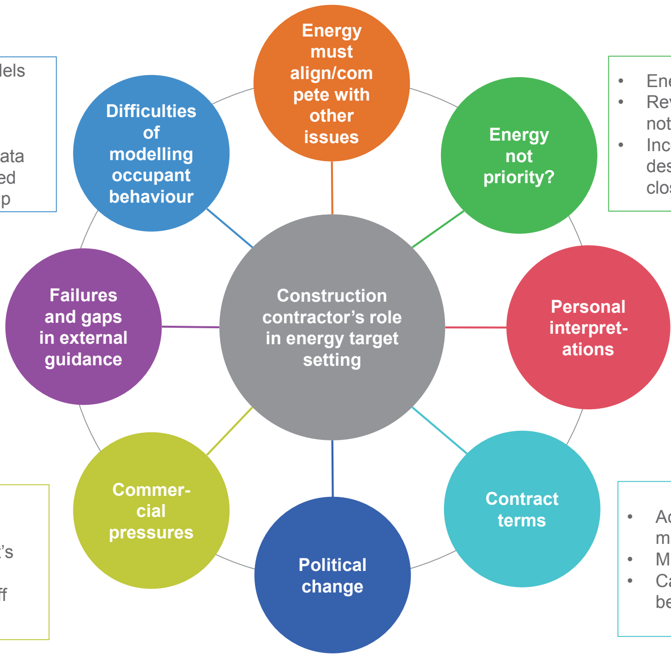
Methods:

- Qualitative case study of single school
- Sponsored by construction and facilities management contractor
- Inductive approach, drawing on theories of sociology of scientific knowledge

Potential limitations:

- Single case study
- Access via gatekeeper
- Limited number of interviews
- Retrospective analysis vs ethnographic approach
- Technical analysis not included

Results showed multiplicity of interacting socio-technical factors, underlying energy targets' formation:



Energy must align/compete with other issues: Including uncertain balance with:
- Client's priorities
- Cost
- Targets in relation to each other
- Design issues

Energy not priority?
- Energy as niche issue
- Review processes do not prioritise energy
- Incomplete services design at financial close

Personal interpretations
- Inappropriate application of feedback
- Delegation of energy responsibility changes perspectives
- Impact of personal experiences

Contract terms
- Activity split complex to manage
- Misaligned incentives
- Can foster risk-averse behaviour

Political change: Change disrupted energy target setting through:
- End of BSF programme
- Cost cuts
- Delays

Commercial pressures
- Getting modelled values to "fit" client's expectations
- Pressure to sign-off

Failures and gaps in external guidance
- Mismatch between specification and tools/standards
- Few and/or generic benchmarks
- Regulated vs unregulated energy

Difficulties of modelling occupant behaviour
- Contracts and models do little to address behavioural uncertainties
- Lack of available data
- Results in misplaced feeling of ownership

References:
[1]Parag, Y., Janda, K.B., 2014. More than filler: Middle actors and socio-technical change in the energy system from the "middle-out." Energy Research & Social Science 3, 102–112.
[2]Wingfield, J., Bell, M., Miles-Shenton, D., South, T., Lowe, R.J., 2008. Lessons from Stamford Brook: understanding the gap between designed and real performance. Leeds Metropolitan University, Leeds.
[3]Morrell, P., 2015. Collaboration for Change: The Edge Commission Report on the Future of Professionalism. The Edge, London: Calverts.
[4]Collins, H.M., 1992. Changing order : replication and induction in scientific practice. University of Chicago Press, Chicago ; London. p5

Conclusions:

- **Communication** rests on the ability of people *"to see the same things and respond to them in the same ways"*[4]: differences between the way stakeholders "see" the energy targets produces a variety and unpredictability of responses to the policy incentive
- Case study suggests energy targets are as much **socially constructed** as they are technically constructed
- Therefore **precise contractual targets are not a policymaker's panacea** for the energy performance gap, as they may conceal assumptions, uncertainties and varying interpretations and motivations which do not necessarily produce the result intended.

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

Modelling Framework for Household Appliance Electricity Demand (AED) for Evaluating the Demand Response Potential In UK Residential Sector

Selin Yilmaz 3rd year PhD student

1) Research

Aim:

To explore and quantify the potential of demand response in the UK residential sector by constructing and validating a realistic household appliance electricity demand (AED) model

Research Question: To what extent the electricity demand can be shaped with demand response in the residential sector?

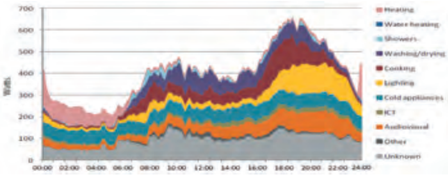


Figure 1 Average demand of domestic appliances in the UK as estimated by House Household Electricity Use Survey

2) Dataset used for developing the model

English Housing Survey (EHS 2013-2014)

- Nationally representative household sample for the household AED model
- 13,276 interviewed household

2011 Energy Follow-up Use Survey (EFUS)

- Nationally representative appliance ownership data
- 2616 households

Household Electricity Use Survey 2011 (HEUS)

- Monitored electrical power demand of 251 homes and approximately 5,860 individual appliances for a month or year
- High resolution data: 2-10 minute intervals

3) Methodology: Developing the household AED model

"Household Sample" from English Housing Survey 2013-2014

Randomly populating the "household sample" with appliances using the saturation levels

Appliance ownership from 2011 Energy Follow-up Use Survey

e.g.

ICT
Washing machine
Dishwasher
Washing machine
Fridge freezer
Oven

Household AED model from Household Electricity Use Survey 2011

Stochastic bottom-up modelling by using:

- The probabilities of the frequency of usage
- The probabilities of the switch-on times
- The probability distribution of duration of appliance usages
- The probability distribution of power demand of the appliances

Electricity demand profiles of households

4) Results: Data Analysis and Validation

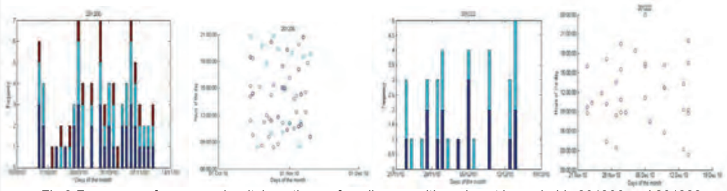


Fig 2 Frequency of usage and switch on times of appliances with cycles at households 201206 and 201222

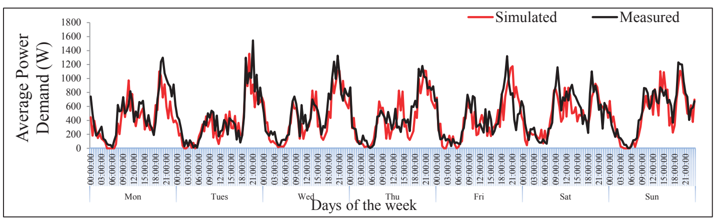


Fig 3 Comparison of the mean half hourly power demand of the dishwashers for 86 households(HEUS dataset) and 100 simulated households versus times of the day (Mean power demand for each half hour time is calculated by dividing the sum of power demand by the count the number of records of that time in the dataset)

5) Demand response case study

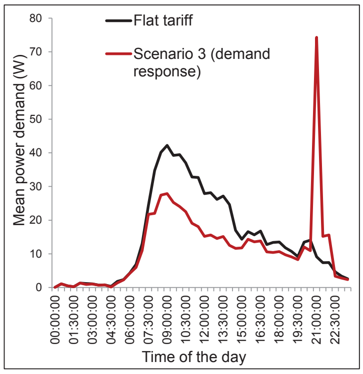


Fig 4 Comparison of average power of washing machine for the flat tariff scheme (Scenario 1) and 30% probability that households shifting the washing machine for the cheapest time slot, 9 pm. (n=100 households).

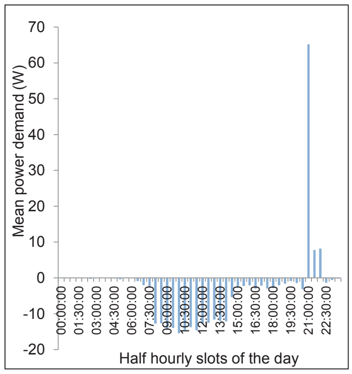


Fig 5 Hourly net power demand changes explaining the differences in the load curves between flat tariff and Scenario 3.

UCL
Loughborough University
EPSRC Pioneering research and skills

London - Loughborough Centre for doctoral research in energy demand

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

London-
Loughborough EPSRC
Centre for doctoral
research 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
@LboroCBE

EPSRC
Engineering and Physical Sciences
Research Council

UCL

Loughborough
University