RCUK Centre for Energy Epidemiology

UCL

Introduction

The RCUK Centre for Energy Epidemiology (CEE) is the UK's first dedicated energy epidemiology research centre, seeking to enact a paradigm shift in the way research is undertaken to reduce energy demand, through the development of brand new tools, methods and resources.

The UK has an urgent need to make big changes to the way we use energy in order to meet our carbon targets and address the threat of global climate change. In order to make these changes, policymakers, practitioners and academics need to have a much better understanding of the complex way that people, buildings and communities use energy than we currently have in order to develop policies and solutions that are effective, achievable and sustainable.

Launched in 2013, CEE aims to respond to the myriad challenges currently facing energy research. Through the use of research council funding we have been able to establish an expert, multidisciplinary and multisectoral team of researchers to apply the energy epidemiology approach to develop new and exciting research opportunities. Through this work, we will be able to improve our understanding of energy demand and enhance the positive impact of our research.

The Challenges

Lack of access to **high quality, high resolution data** on which to base research

Limited capacity to **analyse, organise or archive data** leading to limited impact

Lack of established **analytical methods** to handle the complex interactions between people, places, society and energy

Lack of provision of **fast, accurate and precise results** to help policymakers meet carbon targets

Lack of **multidisciplinary activity** in a complex area leading to narrow focus and incomplete understanding

Poor linkage between theory and practice to provide **tools and guidance** for practitioners and policymakers

CEE's Solutions

Undertake research and publish guidance on the use of **energy monitoring technology** to improve data collection

Build new, **high-quality data frameworks and datasets** on which to build a more robust understanding of energy demand

Develop **cutting-edge data handling and analysis techniques** to maximise their value to policymakers and industry

Develop a **new range of models** that use the energy epidemiology approach to better explain energy demand

Engage and communicate with key stakeholders to establish CEE as a lynchpin of the energy demand research community

The RCUK Centre for Energy Epidemiology

What is Energy Epidemiology?

epidemiology

"epi" - **upon;** "demos" - **the people;**
"ology" - **logic, study**

The study of what is upon the people – normally applied to the study of health.

energy epidemiology

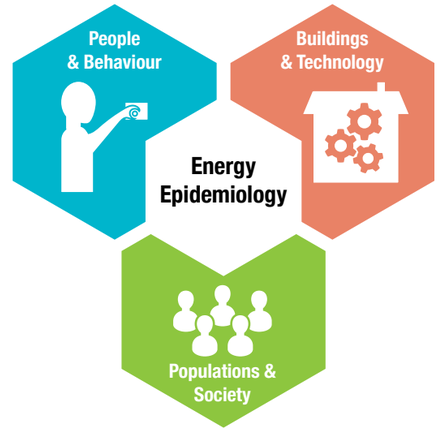
The systematic study of the distributions and patterns of energy use and their causes or influences in populations.

The study of energy demand is in its infancy compared to well established health research. Since the 1970s much of the research has focused on theoretical and laboratory-based research of energy efficiency components with little understanding of how the components interact in a complex socio-technical system (i.e. as part of a building, with complex technical features, in a specific community/environment and subject to different interactions with different people). As a result, the difference between the expected and actual situation is often drastic. As our understanding and our requirement for better answers develop, our need for a more holistic approach has become more apparent.

The word "epidemiology" is most commonly attributed to the study of outbreaks of contagious diseases in a population - "epidemics". English physician, John Snow, often credited as the father of modern epidemiology, combined an understanding of people, statistics, geography and medicine to better control outbreaks of cholera in the 1800s. Since then, a more holistic, multi-disciplinary approach to understanding the spread of disease has become commonplace in shaping policy, assessing risk and benefiting public health. We believe that such a holistic approach should now be applied to the field of energy research.

The UK has an obligation to make major changes to the way we currently use energy to achieve an 80% reduction in emissions by 2050. However, early efforts to bring about real reductions have struggled to make an impact. We believe a deeper understanding based on a holistic, multi-disciplinary approach and empirical data analysis will be key to bridging the gap between our legally binding targets and delivery.

By applying the lessons learned from over 150 years of epidemiology in health to the field of energy use, we can better equip policymakers, industry and the wider public with the information and tools they need to address our future energy challenges.



Projects

The following few pages provide brief summaries of some of the work that CEE has been carrying out recently.

For more information on any of these projects and more, visit the Centre for Energy Epidemiology website at **www.energy-epidemiology.info/**

Key to icons

The work carried out by CEE typically falls into three research themes and four broad methodologies. These are as follows:

Research Themes:

Domestic Buildings
Research involving homes and the people who own and live in them

Non-Domestic Buildings
Research involving commercial and public sector buildings and the people who own and work in them

Transport
Research involving vehicles, travel by land air or sea and those that use them

Methodologies:

Metrology
Physical measurement and data capture including environmental monitoring systems

Modelling
The development and use of computer models that simulate the real world and manipulate big data

Analysis
Interrogating big data to answer specific questions and generate outputs that yield insights

Data Interpretation
Manipulating and visualising data in order to make sense of and better communicate its messages

CEE Metrology House

CEE has its own dedicated house to test and develop new measurement techniques as well as generating data for a wide range of projects.

The CEE Metrology House is an unoccupied domestic property where CEE researchers can carry out interventions and experiments into how a real building performs without disturbing any occupants.

The house is currently instrumented to record internal and external temperatures, heat flux through the walls, wind speed, solar intensity and internal air flow.

The house is being used for a range of work including:

- Rapid analysis of the thermal properties of the walls, such as the U-Values and Thermal mass;
- Developing useful models for the complicated heat transfer through ceilings and lofts;
- Measuring variation in thermal properties due to solar radiation, wind and proximity to windows;
- Calibration of heat loss calculations and energy labelling methods.

Research Lead

Cliff Elwell
clifford.elwell@ucl.ac.uk

The RCUK Centre for Energy Epidemiology

Retrofit “Big Data” Analysis

Researchers at CEE have been studying the real impact of energy efficiency retrofits on energy demand using large datasets and detailed surveys.

The analysis has covered over 20 million dwellings by using sources such as the National Energy Efficiency Data-framework (NEED) and the Homes Energy Efficiency Database (HEED).

Using epidemiological study methods, we have studied how energy use changes following a retrofit and how household characteristics and dwelling features affect the change.

Key findings/implications:

- Popular retrofits save 5-25% of gas energy use;
- Biggest savings are from cavity wall insulation (10%) and new condensing boilers (15%);
- Households in low-income areas tend to save proportionally less than higher income areas;
- Energy efficiency programmes do save energy but require careful attention to installation.

Research Lead

Ian Hamilton
i.hamilton@ucl.ac.uk

More information

http://authors.elsevier.com/sd/article/S0378778816300718

People Don’t Use Energy, Buildings Do

Building factors are the largest contributors to how much energy we use, rather than socio-demographic or attitudinal factors.

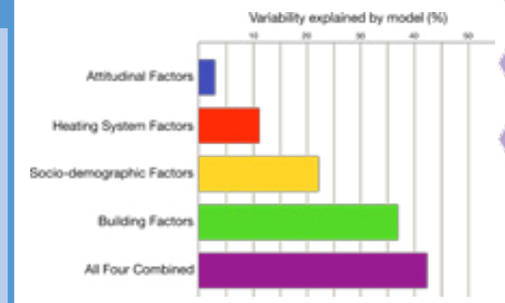
Understanding which variables link to patterns of high and low energy usage is vital in determining the most effective policy interventions; for instance, should we focus on physical improvements or behaviour-change campaigns?

This project carried out a detailed analysis on a representative sample of nearly 1,000 UK homes, aiming to quantify the relative importance of factors.

Key findings/implications:

- Building factors account for nearly 40% of variability in energy usage;
- Socio-demographics account for less than 25% whereas attitudinal factors explain even less;
- Combining models still leaves more than half of variability unexplained, requiring further research.

Comparison of modelled factors’ impact on variability of energy usage



Research Lead

Gesche Huebner
g.huebner@ucl.ac.uk

More information

http://discovery.ucl.ac.uk/1473481/

Bayesian Analysis of Condensing Boilers

Statistical analysis of data related to UK boiler use assesses the impact of government legislation, pointing to significant reductions in energy use.

In 2005, legislation was introduced to ensure all new domestic boilers were of the more efficient condensing type. CEE used Bayesian statistics and public data to build a model to evaluate the impact of this policy.

The work highlights the drop in UK gas consumption between 2005-2013 even though the number of boilers has increased.

Key findings/implications:

- Net savings from 2005-2013 equivalent to half the total gas used in a year;
- Predicted savings - 370 MTonnes of CO_2 by 2050, equivalent to 5.6 times the average UK demand;
- Model suggests that delaying introduction would have wasted 60,000 GWh/year.

Research Lead

Cliff Elwell
clifford.elwell@ucl.ac.uk

More information

http://discovery.ucl.ac.uk/1473332/

Power Temperature Gradient (PTG) and Peak Demand

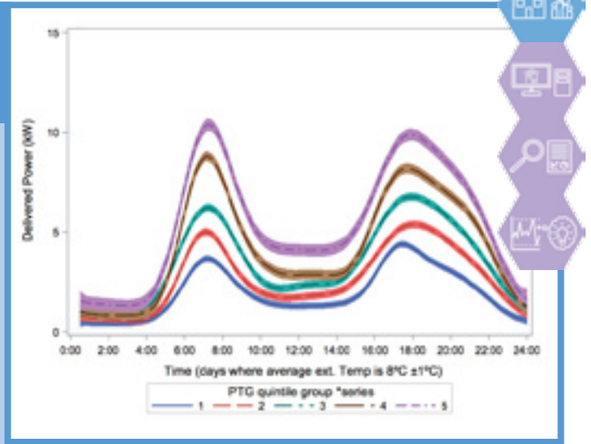
Domestic Energy Efficiency can generate 8,000 "negawatts" per dwelling during peak periods.

Energy efficiency is often talked about as the first fuel or the greenest form of energy as it avoids having to generate any energy in the first place.

For the first time in the UK, analysis of smart meter data from thousands of homes has enabled us to look at the impact of improved energy efficiency on the 24-hour demand profile of dwellings, highlighting the impact on peak demand of dwellings.

Key findings/implications:

- Smart Meter data combined with weather data can provide a proxy for building energy efficiency;
- Older buildings seem to perform more efficiently than conventional surveys and models assume;
- Energy efficient domestic retrofit can significantly reduce future peak loads and hence the number of power stations required.



Research Lead

Tadj Oreszczyn
t.oreszczyn@ucl.ac.uk

More information

http://discovery.ucl.ac.uk/1459784/

LUKES

CEE and partners have developed the groundwork for a brand new, large scale longitudinal survey of energy use on behalf of DECC.

The Longitudinal UK Energy Survey (LUKES) is a proposed panel study of up to 10,000 homes representative of the whole population.

The homes would be subject to periodic social research, physical building surveys and environmental monitoring and could be used to help answer key questions to inform UK energy and energy efficiency policy over the coming decades.

Key findings/implications:

- Has the potential to answer detailed questions about the complex interactions between people, property and energy as they change over time;
- Could reduce requirement for commissioning specific studies, saving time and money;
- CEE are currently completing further feasibility work to explore and develop proposals in more detail.

Research Lead

David Shipworth
d.shipworth@ucl.ac.uk

More information

https://www.ucl.ac.uk/steapp/research/projects/energy-lab

3DStock

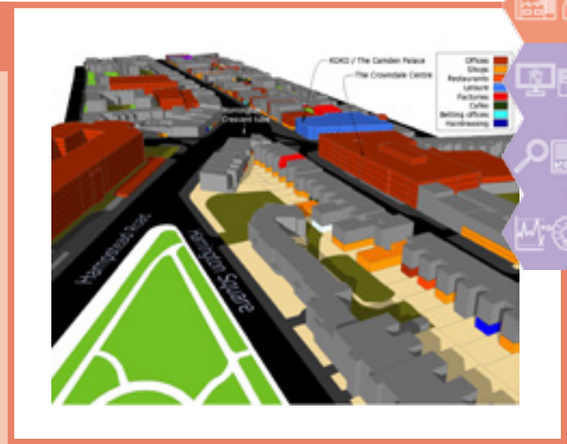
3DStock is a completely new kind of three-dimensional model of the non-domestic building stock, for use in energy analysis.

It represents the geometry and materials of individual buildings and premises in detail, and records the activities housed on each floor level and is updated automatically using public datasets and meter readings.

So far, the London Borough of Camden and the towns of Leicester, Tamworth and Swindon have been modelled. This makes possible for the first time a statistical analysis of various drivers of energy use.

Key findings/implications:

- Used to advise DECC about the national potential for renewable and low-carbon technologies including through the Building Energy Efficiency Survey (BEES) programme;
- Identifies potential for various technologies including solar thermal, heat pumps and district heating.



Research Lead

Philip Steadman
j.p.steadman@ucl.ac.uk

More information

http://iris.ucl.ac.uk/iris/publication/1058615/1

Additionality of Salix Funding

A review of energy efficiency projects in the public sector suggests that over 70% of energy efficiency improvement projects would not have happened without Salix funding.

Salix Finance provides funding to public sector bodies through two streams, “SEELS” interest-free loans and “RF” match-funding.

CEE were commissioned by Salix to answer the key questions of whether Salix funding was necessary for the projects (i.e. additionality of the funding) and what alternative funding sources were available.

Key findings/implications:

- Findings replace previous estimate of 33% additionality;
- Additionality of future SEELS projects is 69-92%;
- Additionality of past & future RF projects is 87%;
- Findings suggest that funding mechanisms for public sector energy efficiency projects are vital in order to ensure they take place.

Research Lead

Paul Ruyssevelt
p.ruyssevelt@ucl.ac.uk

SimStock

SimStock is a new approach to building stock modelling, generating stocks made of individual building models. It can be used to interpret existing communities or predict impacts of interventions at the stock level.

The model takes advantage of developments in computing power and data availability to develop an epidemiological approach to modelling complex communities of buildings. The model has been successfully trialled in the London Borough of Camden.

Key findings/implications:

- SimStock can reproduce consumption patterns at a national or local scale to better understand the factors that influence consumption;
- Stock owners could use the tool to assess the most appropriate improvements for their stock;
- Government and decision-makers could use the model to quantify potential savings of different improvement pathways at a national level.

Research Lead

Paul Ruyssevelt
p.ruyssevelt@ucl.ac.uk

The RCUK Centre for Energy Epidemiology

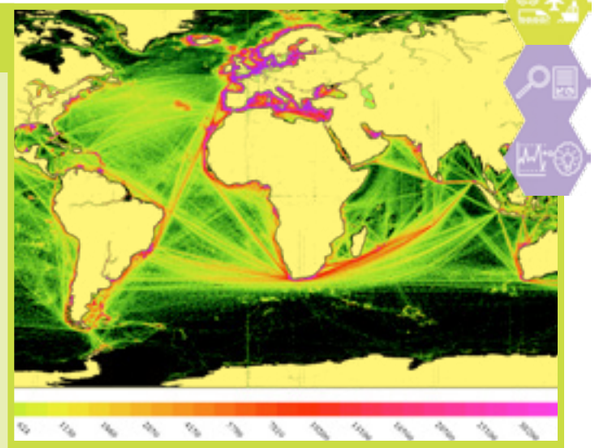
Energy Demand in Shipping

Analysis of shipping data reveals how energy demand has been impacted by the recession and highlights the urgency for energy efficiency in the face of rising demand.

By examining data from 2007-2015, this work quantifies the global shipping system’s energy demand and identifies drivers of that demand.

Key findings/implications:

- Shipping energy demand reduced during the recession, predominantly due to slow steaming;
- Some ships, however, saw increased energy intensity during this period due to running with spare capacity and through being under-utilised (i.e. reduced efficiency);
- With expectations of global demand growth outstripping the rate of energy efficiency improvement, the work has direct relevance to ongoing regulatory debates, particularly on GHG emissions.



Research Lead

Tristan Smith
tristan.smith@ucl.ac.uk

More information

http://discovery.ucl.ac.uk/1404056/

MOT Data and Inferences About Vehicle Use

Using car mileage data from MOTs, this project has explored the linkages between mileage and a range of factors to improve our understanding of car use and build a new model that can be used in future projects.

CEE’s Spatial Durbin Model (SDM) is ideally suited to regional and sub-regional analysis of vehicle usage through condensing and analysing large, complex datasets.

Key findings/implications:

- Highlights impact of public transport on car usage as a competing but also complementary factor;
- Captures the “fuel desert” effects in rural areas where access to refuelling impacts mileage;
- Suggests a link between alternative fuel car owners and lower mileage;
- Next steps are to expand the model to capture transport network effects.

Research Lead

Maria Kamargianni
m.kamargianni@ucl.ac.uk

Engagement and Impact

A key aim for CEE is to promote and facilitate engagement with the wider community, including industry, government and academia. We work with these communities in the following ways:

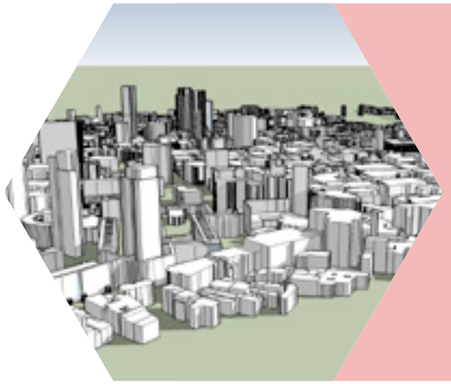
- **municipal government:** pollution analysis, transport analysis in Greater London;
- **national government:** cost-benefit calculator covering changes to public health of domestic energy-efficiency interventions;
- **industry:** analysing domestic energy demand in partnership with a major utility;
- **academia:** 64 peer-reviewed journal papers published in the first 2 years of the Centre's existence; setting up a data consortium amongst UK universities to share commercial data securely and affordably.

The following two pages detail some further, specific examples of this work.

Lancet Commission

CEE staff led a chapter on technological options to help prevent some of the catastrophic risks to human health associated with climate change for the Lancet Commission on Health and Climate Change. The commission found that action to reduce climate change could be the greatest global health opportunity of the 21st Century.

The Commission had 1.8 million downloads in the first 6 days. Plus 983 unique media coverages including BBC World, ABC, TIME and Wall Street Journal, and resulted in briefings to the White House, UK Cabinet Office and DECC.



IEA EBC Annex

CEE staff have been developing a new International Energy Agency Annex under the Energy in Buildings and Communities programme focusing on energy epidemiology.

This Annex seeks to support decision-makers and investors by focusing on developing best practice for collecting, accessing, analysing and building models with empirical data of energy demand in buildings and communities. The main products of the Annex will include a registry on national building stock surveys and models as well as best practice reports and guidance.

Residential Energy Use in Oman

Working with PassivSystems, CEE were commissioned to conduct a nine-month scoping study into domestic energy use in Oman, using cutting-edge monitoring and modelling techniques.

The study highlighted specific problem areas, such as poor typical fabric performance and the impact of property size on consumption. Through this and potential future work, Oman's Authority for Electricity Regulation can make more informed decisions on energy subsidies and design energy efficiency programmes that best benefit the Omani people.

International Engagement

CEE staff have been on a world tour, engaging the international community on energy epidemiology. This includes presentations in Australia, India, Italy and Hong Kong as well as meetings in Canada and USA.

Meanwhile, in London we have hosted two visiting academics from the University of Victoria (Michael Donn and Nigel Isaacs).

In 2016 we will be organising an Energy Epidemiology workshop, supported by the Foreign and Commonwealth Office, in New Mexico.

DAMAGE

CEE co-ordinates The Data Management and Access Group (DAMAGE) consisting of representatives from academia, government and industry.

The group works to improve the availability and quality of, research data in the sector to help promote stronger research in Energy Epidemiology research and related fields.

The group meets twice yearly.

EDF Energy Training

CEE participated in EDF's Big Home Data Workshop, which brought together staff from across EDF through a range of co-creation activities involving the large sources of EDF customer data.

Participants worked together to generate and develop a series of "proofs-of-concept" focusing on themes such as comfort, being a customer and being in control.

The innovative outputs of this workshop will be tested during EDF's R&D Big Home Data Trial project.

Building Performance Network

CEE has put together plans for a network of industry, academia and other professional bodies to support research in the field of building performance.

The Building Performance Network will work to address some of the key challenges in the field such as a lack of accessible, high quality data and a lack of skills to analyse and interpret such data.

The network will provide a forum for sharing best practice and develop a bank of knowledge and insights founded on high quality data.

Data Science

The CEE Bureau

The CEE Bureau is a service designed to help people answer questions of complicated datasets, providing access to industry leading data analysis expertise, models and wider data curated and managed by the Centre.

We can provide controlled and ethical access (see below) to sensitive datasets such as anonymised address and vehicle matched data, linking to other data sources to help better answer questions for academics, industry, consumer organisations and government in a cost effective way.

Our in-house experts can also be utilised to undertake data analysis on particular datasets to answer more detailed questions. We also run a EUED-funded Visiting Researcher scheme that allows intensive on-site collaboration with Bureau staff (statisticians and data experts).

If you'd like to find out more about what the Bureau could offer you or your organisation please contact us at **energy-epidemiology@ucl.ac.uk**

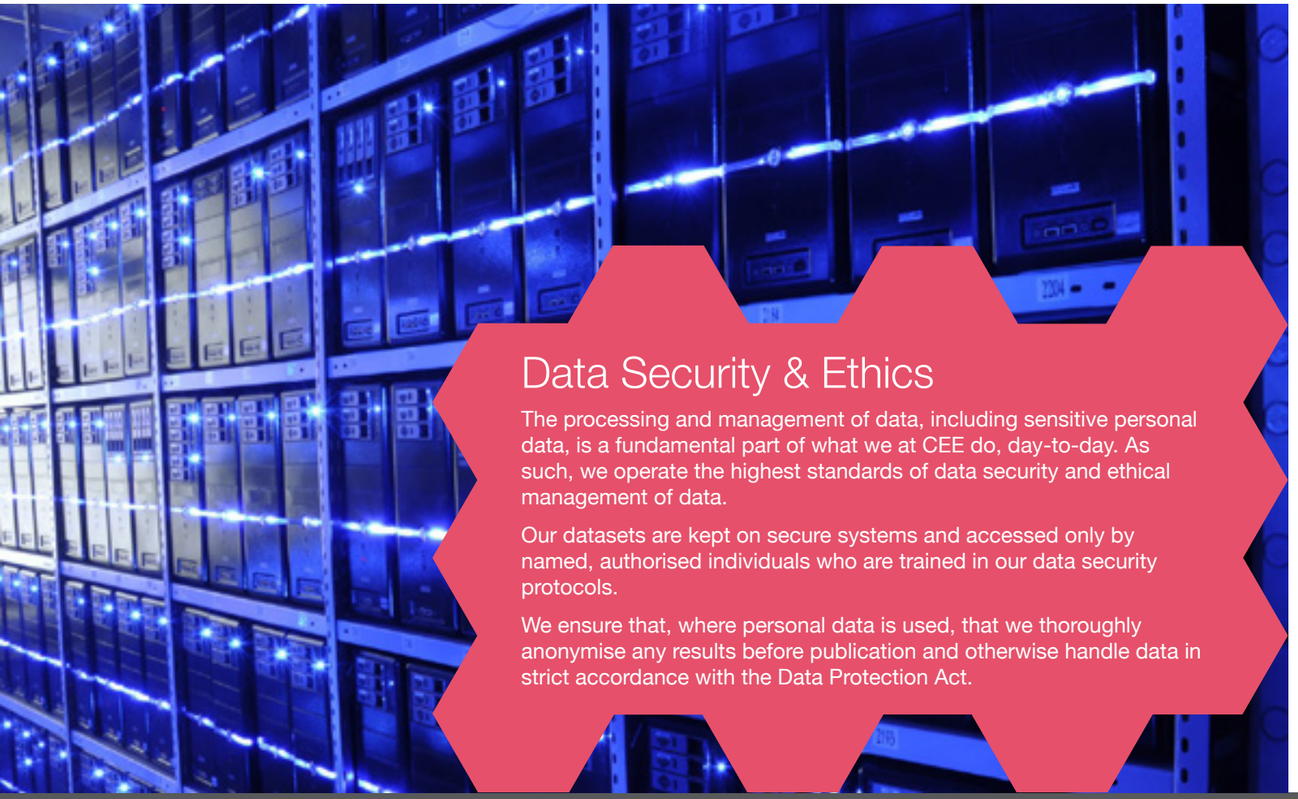
Case Study
Half-hourly Demand Shifting

(for PassivSystems)

CEE was approached by PassivSystems to investigate the potential for energy cost savings if domestic customers were able to shift their energy demand for energy intensive activities (e.g. using a washing machine or dishwasher) earlier or later, and access tariffs that reflected the half-hourly variations in the wholesale electricity market.

CEE data scientists utilised large datasets on domestic energy consumption and half-hourly energy prices and carried out a detailed analysis as part of the Bureau service.

This analysis suggested that consumers could potentially save up to £33 per year on their electricity bills if they could shift demand and have access to half-hourly tariffs.



Data Security & Ethics

The processing and management of data, including sensitive personal data, is a fundamental part of what we at CEE do, day-to-day. As such, we operate the highest standards of data security and ethical management of data.

Our datasets are kept on secure systems and accessed only by named, authorised individuals who are trained in our data security protocols.

We ensure that, where personal data is used, that we thoroughly anonymise any results before publication and otherwise handle data in strict accordance with the Data Protection Act.

Doctoral Studies

CEE's doctoral students are a key part of the process of developing and applying the Energy Epidemiology approach to new and historic problems. Below are some of the projects currently being carried out by our PhD students.

Jonathan Chambers - Power Temperature Gradient and Energy Efficiency: Dwelling energy assessments for Energy Performance Certificates are slow, intrusive and costly as well as being increasingly open to criticisms for their inaccuracy. By using smart meter data and analysis techniques that incorporate energy consumption profiles with weather data, this study aims to generate more reliable, empirical models of dwellings and their energy performance that don't rely on the EPC method.

Virginia Gori - Solid Wall Heat Flows: Understanding the thermal parameters of a solid wall (e.g. U-values) is a vital part of bridging the performance gap between predicted and observed energy demand. This study uses real measured data and modelling techniques to estimate these parameters to overcome some of the limitations of current methods used to determine these.

Badria Jaffar -Drivers of domestic energy consumption in Kuwaiti villas: Residential buildings in Kuwait account for almost 60% of the country's national electrical power generated, considerably greater than all other sectors or building types. The research aims to gain a sound understanding of the physical and social determinants that drive household energy use in Kuwaiti villas by collecting and evaluating real context-specific empirical data.

Sofie Pelsmakers - Heat Flow Through Suspended Wooden Floors: This study assesses different methods of reducing heat loss from suspended timber ground floors in older dwellings and the 'unintended consequences' of these methods. The research aims to provide solutions-based approaches to insulating floors while avoiding mould or rotting timbers.

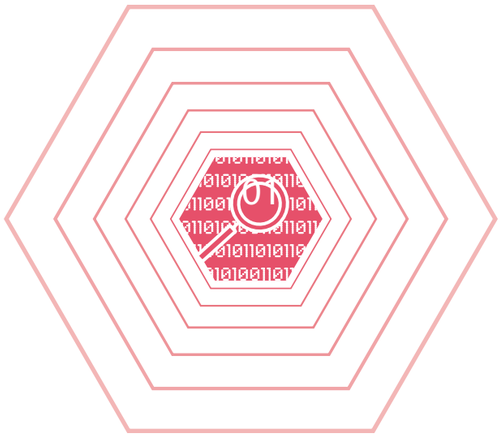
Melissa Lott - Transport, Energy and Health: The burning of fuel often releases multiple pollutants into the atmosphere and actions to reduce one may also result in the reduction of others. This study seeks to quantify and contextualise these 'co-impacts', particularly in terms of the impacts on local health by bridging the gap between energy system, air pollution and public health models.

Future Direction

Looking forward, we are set to build on the successes of the Centre's first years of operation to continue developing and applying energy epidemiology to the challenges facing the energy sector in the years and decades to come.

Some specific areas we are focusing on in the near future include:

- **Big data:** We aim to work closely with government departments (including DECC, DCLG and BIS) on connecting public and private big energy datasets, on which stronger evidence-based research and more accurate models can be built;
- **Smart meter data:** As the national roll-out of smart meters takes place, a wealth of high-resolution data on energy consumption will be collected as part of the daily operation of this new infrastructure. We aim to work with government and other relevant organizations to link this data to existing datasets to carry out novel epidemiological research to generate new insights on the way we use energy in the UK;
- **A data consortium:** We aim to work with other UK universities to build a safe place to share otherwise inaccessible data - be it commercially-sensitive or personal data - in an ethical and secure way. Doing so will allow these institutions to mutually benefit from a stronger resource of data and conduct more valuable research.



Meet the Team

From left-to-right - Back row: Michelle Shipworth, David Shipworth, Paul Ruyssevelt, Tristan Smith, Nishat Rehmatulla, Maria Kamargianni, Gael Anderson, Steve Evans; Front row: Phill Biddulph, Cliff Elwell, Bob Lowe, Andrew Smith, Tadj Oreszczyn, Lai Fong Chiu, Rob Liddiard, Phil Steadman

The team at CEE has been carefully picked to embody the wide range of skills required in our work, from our cutting-edge modelling to expert design and deployment of measurement equipment and from building physicists to behavioural scientists.

Our team also represents some of the most experienced researchers in the specific sectors where we conduct our research (domestic and non-domestic buildings and transport) ensuring that CEE has the necessary skills and experiences to tackle the multidisciplinary and complex research required for the Energy Epidemiology approach.

Tadj Oresczcyn
CEE Director

Tadj is Professor of Energy and Environment at the UCL Energy Institute, of which he was also founding director and also Director of the Bartlett School of Environment, Energy and Resources.

Tadj was a member of DECC's Climate Change Scientific Advisory Group and has advised the Energy Efficiency Deployment Office at DECC. He is a Fellow and Vice President of CIBSE and sits on the CIBSE Board.

Ian Hamilton
Domestic Buildings

Ian is a Sustainable Design Engineer with expertise in energy demand in housing, indoor environmental quality and health impacts. He has worked as a consultant to Government and private industry.

Gesche Huebner
Energy and Behaviour

Gesche is a Senior Research Associate specialising in how behaviour affects energy consumption in buildings. She has a PhD in Psychology and has previously taught on energy consumption and behaviour change.

Andreas Schaefer
Transport

Andreas is a Professor of Energy and Transport and an expert in the demand and supply characteristic of energy and transportation systems. He is also the UCL Energy Institute's Director of Research.

Partners

CEE has 32 partners across government, industry and academic institutions around the world. Support from our partners includes providing access to data; secure data storage; data analysis; dissemination to academics, local authorities, private households, industry, and building professionals; attendance at meetings and participation in the International Energy Epidemiology Network; and collaborative funding for KTPs and studentships.

UK Government

Committee on Climate Change
Department of Energy and Climate Change
Department for Communities and Local Government
Department for Transport

Industry

EDF Energy
PassivSystems
Arup
Aedas
Cambridge Architectural Research Limited (CAR)
Willmott Dixon
Intel Corporation
Johnson Controls
AECOM
The British Land Company PLC
Sustainable by Design
National Energy Foundation (NEF)
The Usable Building Trust (UBT)
National Physical Laboratory (NPL)
Transport Knowledge Transfer Network
The Chartered Institute of Building Services Engineers (CIBSE)
UK Green Building Council
The Edge
Energy Technologies Institute (ETI)
Energy Saving Trust (EST)
UK Energy Research Centre (UKERC)

Worldwide Academia

Sustainable Buildings Research Centre (SBRC), University of Wollongong
Centre for Petroleum, Energy Economics & Law (CPEEL) University of Ibadan
University of California, Berkeley
Lawrence Berkeley National Laboratory (LBNL)
Centre for Sustainability: Agriculture, Food, Energy, Environment (CSAFE), Otago University
School of Population Health, The University of Queensland
KAnE Centre for Renewable Energy Sources and Saving (CRES)
School of Energy and Environment, City University of Hong Kong

Working with CEE

As a highly collaborative centre, we are keen to work with people from across industry, academia, government and other data custodians.

If you have access to a dataset that we could build into our current and future work or have questions of your data that we could help with, get in touch.

We are also keen to hear from potential partners to collaborate on future energy research opportunities, where an energy epidemiological approach would be of benefit.

For any and all potential opportunities, we look forward to hearing from you via any of the channels listed below.

CEE is one of six End Use Energy Demand (EUED) Centres funded by the RCUK Energy Programme (with industry and government partners) the six EUED Centres research energy use in domestic, commerical, construction, food chain, industrial, retail and transport settings. They seek to better understand future energy needs and offer solutions to help meet the UK's carbon emissions targets. The six centres have

- £40m+ funding
- 200+ researchers
- 70+ projects
- 25+ institutions
- Six centres
- Five years
- One aim – to reduce the UK's energy demand

For more information visit http://www.eueduk.com/

Contact Us:

RCUK Centre for Energy Epidemiology (CEE)
UCL Energy Institute
University College London
Central House
14 Upper Woburn Place
London
WC1H 0NN

energy-epidemiology@ucl.ac.uk
www.energy-epidemiology.info

© UCL Energy Institute 2016

Image Credits:

Cover Image ©Dreamstime, 2016; p2 Header ©Adobe Stock, 2016; p4 Top Image ©Adobe Stock, 2016; p5 Top Image ©Adobe Stock, 2016; p6 Top Image ©Adobe Stock, 2016; p7 Top Image ©HOK, 2010 (via Creative Commons); p8 Bottom Image ©Highways Agency, 2007 (via Creative Commons); p9 Top Image ©Department for International Development, 2010 (via Creative Commons); p9 Middle Image Map Data ©Crown Copyright/database right, 2012, supplied by the Ordnance Survey/EDINA service; p9 Bottom Image ©Adobe Stock, 2016; p10 2nd Image from Top ©r2hox (Flickr user), 2013 (via Creative Commons); p10 Bottom Image ©StockMonkeys.com, 2012 (via Creative Commons) p11 ©BalticServers.com, 2013 (via Creative Commons); p14 Logos are copyrighted by their respective organisations

All images under Creative Commons licenses are licensed for sharing and adaptation for commercial purposes. Use of these images does not constitute an endorsement from the original author.

All other images or graphics are licensed for use by UCL or created for this publication.