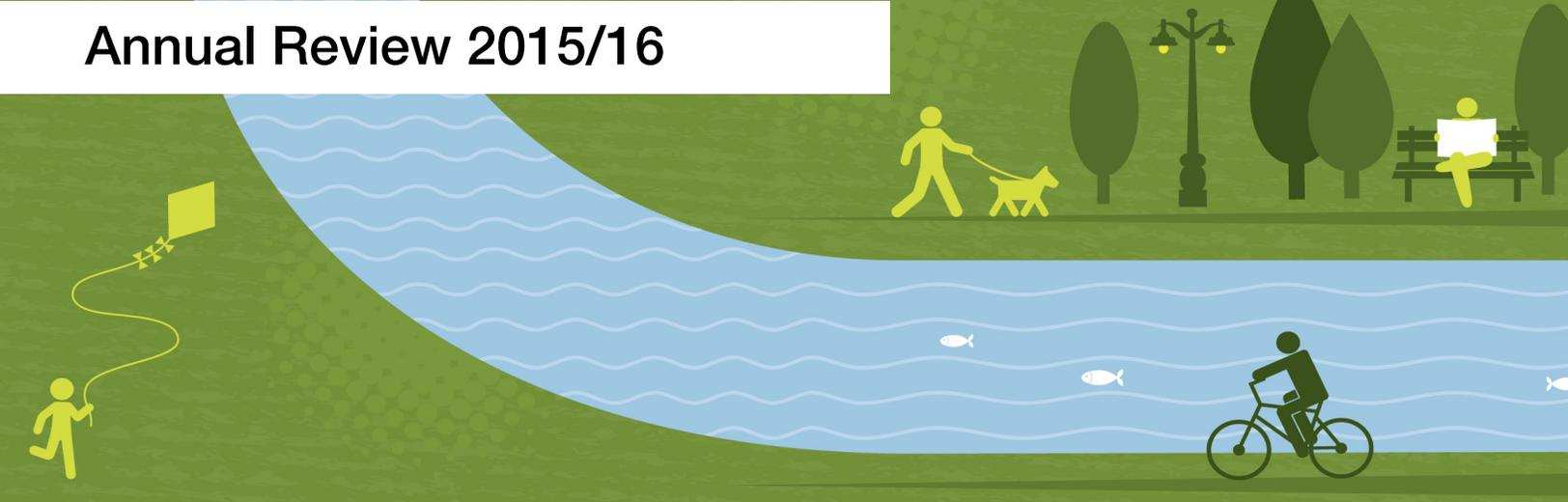


Annual Review 2015/16



Directors' Report

The transition to a secure, affordable, low carbon energy system is the challenge of the 21st Century, and one that is historically unprecedented in scale and complexity. The UCL Energy Institute seeks to be a key UK and global player in this endeavour, illuminating strategic choices from multiple disciplinary perspectives.

The historic Paris Agreement for a global architecture to limit climate change to well below 2°C, negotiated by the largest gathering in history of global leaders, was a triumph of diplomacy.

The Agreement has been echoed in the UK by the confirmation of the 5th carbon budget, committing the country to a 57% reduction in emissions by the year 2030. At the global level, grounds for optimism can also be found in the continued exponential growth in renewable energy and corresponding fall in prices. (Read more about UCL-Energy's reaction to COP21 on page 27).

But more remains to be done. In the UK, while decarbonisation of electricity supply remains more-or-less on target, there is no clarity around decarbonisation of heat, little detail on how the 2030 target will be delivered and less on the transitions from 2030 to the much more demanding 2050 target. With the abandonment of the flagship Green Deal and the zero carbon target, the buildings sector is adrift.

Given an unwillingness to regulate or to enforce regulations, to develop an energy pricing policy, to introduce sector-wide reporting systems, or to guide innovation, it is difficult to see how an effective strategy will be developed for this sector. Perhaps the merger of DECC with BIS in the new Department of Business, Energy and Industrial Strategy (BEIS) holds the key.

Highlights of our own year are set out in the rest of this Review. We have underpinned the UK government's long-term energy pathway analysis via a joint academic-government process with our UK TIMES model (pg 22). We have published a real-time map of CO₂ emissions from global shipping (pg 10). We have run landmark events, including, in partnership with the French Embassy, the

implications of the Paris Agreement for Africa. We have worked with the International Energy Agency to promote the new discipline of energy epidemiology internationally (pg 15). Lastly, we have published a series of position papers on how to transition the UK's heat and gas networks (pg 28).

We are also committed to developing the thought leaders of tomorrow, and are delighted to see 10 successful PhD completions, with our graduates taking up exciting new positions, for example in International Energy Agency (IEA), University of Oxford and KPMG (pg 18).

Finally, we must mention Brexit. With 1/3 of our students and faculty, and 1/10 of our research funding coming from the EU, this impacts us directly. We are working hard to ensure continuity in funding and stability for our most important resource – our staff and students.

Remaining positive, the wake of Brexit has also led to opportunities – e.g. through the resumption of national control over aspects of energy policy previously decided by the EU. The coming year will present great challenges and great opportunities. We intend to rise to both.



Bob Lowe
Director, UCL Energy Institute

Neil Strachan
Deputy Director, UCL Energy Institute

cover image:
(c) iStock

Image (c) UCL-Energy

UCL-Energy 2015/16 Highlights



Image (c) Dreamstime

UCL-Energy's co-authored Deep Decarbonization Pathways Project (DDPP) synthesis report details the deep emission reductions required by 2050 to put the world on course to meet the 2°C climate objective The report, published in September 2015, details the analysis by the 16 largest emitting countries, accounting for approximately 75% of global emissions. The report's lead author Steve Pye, UCL-Energy Senior Research Associate, stated: *"Analysis suggests that the incremental costs of delivering these pathways is manageable, with strong economic opportunities in low carbon technology sectors"*. Read more about UCL-Energy's DDPP public lecture on page 27.

Nationwide Building Society led a research group on Green Mortgage lending with UCL-Energy as academic partner Formed in December 2015, the group is researching how to build a stronger link between energy costs, affordability and mortgage borrowing. Supported and part-funded by Innovate UK, the research draws on the expertise of diverse groups with green credentials, including UCL-Energy, Principality Building Society, UK Green Building Council, Zero Carbon Hub, Constructing Excellence in Wales, BRE, Energy Saving Trust and Arup. Read more about UCL-Energy's partnerships on page 22.

UCL-Energy reacts to COP21, Paris 2015 In the lead up to and aftermath of the historic Paris Agreement in December 2015, UCL-Energy promoted topical work from staff and students. This included a number of blogs and media appearances by UCL-Energy researchers, as well several public facing events that focused on the lead-up and after-effects of COP21. Read more about UCL-Energy's involvement in COP21 on page 27.



Image (c) iStock

UCL-Energy named in Lloyd's List top 10 regulators of 2015 In January 2015 UCL-Energy was included in Lloyd's List's top 10 regulators of the shipping industry, alongside the European Union, the International Chamber of Shipping and the Federal Maritime Commission. Lloyd's List provides information, analysis and knowledge for business decision-makers in the global shipping community. Read more about UCL-Energy's shipping and transportation research on page 10.

UCL-Energy Deputy Director Professor Neil Strachan appointed to Catapult Energy Systems Board Professor Strachan was appointed to the board in February 2016. When asked about his appointment Prof Strachan said: *"I am really excited to be joining the Board at such an early stage in its development. I am looking forward to working across the sector to support and enhance the UK's energy networks."* Read more about UCL-Energy energy systems research on page 12.



Image (c) UCL Central Communications

UCL exhibition 'Women at UCL: Presence and Absence' featured UCL-Energy staff This exhibition, which opened in March 2016, was created to celebrate and recognise women at UCL who inspire those with which they work. The exhibition profiled women from across the UCL community and featured three UCL-Energy staff members: Dr Lai Fong Chiu, Dr Michelle Shipworth and Dr Catalina Spataru. The exhibition features were based on UCL nominations and the planning committee received over 200 submissions, which shows the real impact UCL women have on their colleagues and students. The full exhibition booklet with all UCL staff honoured in the exhibition can be viewed at bit.ly/2awqjl3. Read more about UCL-Energy's activities and outreach on page 24.

The Energy & Resource Economic Policy Group launches as a joint initiative between UCL-Energy and UCL ISR The group, launched in May 2016, promotes the integration of economic studies with disciplines related to resources and energy, involving junior and senior researchers in a prestigious research environment and network, as well as an active forum for advice, discussion and collaboration. Find more information about the group's aims and how to join the group online bit.ly/2awYG6l

UCL-Energy 2015/16 academic year saw success with 10 PhD graduates The 2015/16 academic year saw a record number of PhD students successfully pass their viva. The graduates were: Peter Warren, Faye Wade, Samuel Stamp, Ed Sharp, Carrie Behar, Tia Kansara, Sofie Pelsmakers, Mike Fell, Will Usher and Paula Morgenstern. Read a full list of all UCL-Energy PhD students and thesis titles on page 20 and on the UCL-Energy website.

wholeSEM's UK TIMES model (UKTM) used by DECC to set ambitious new fifth carbon budget with a target to reduce emissions by 57% by early 2030 UKTM is a state-of-the-art energy systems model that facilitates analysis of long-term energy pathways. Coordinated by UCL researcher Peihao Li, a multi-year collaborative venture has made UKTM a key long-term energy model for DECC. Read more about wholeSEM on page 14.

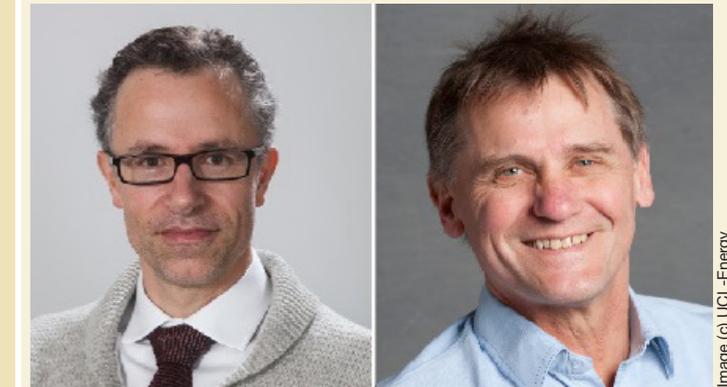


Image (c) UCL-Energy

UCL-Energy's Dr David Shipworth and Dr Mark Barrett promoted to Professor In June 2016, Dr David Shipworth and Dr Mark Barrett were promoted to the role of Professor within the Faculty of the Built Environment. Dr David Shipworth has become Professor of Energy and the Built Environment. Dr Mark Barrett has become Professor of Energy and Environmental Systems Modelling. Read more about David's building research on page 8 and Mark's Energy Space Time research on page 7.

Research at UCL-Energy

Research is the bedrock of UCL-Energy. The Institute has its own core activity but also acts as an umbrella for energy-related research at UCL, bringing together leading researchers on different topics. The multidisciplinary approach of UCL-Energy is at the heart of its success.

Most energy problems are multidisciplinary in nature; spanning science, engineering and the social sciences. Therefore different approaches are needed to understand and tackle these issues. UCL-Energy research works to develop a range of tools, models and methods that are required to address the energy challenges facing the world over the next two decades.

Most energy problems are complex, and addressing them requires a range of disciplinary perspectives and methods. UCL-Energy aims to develop a working environment in which colleagues can work across disciplinary boundaries to address such problems.

During the 2015/216 academic year, including consultancy based projects (pg 23), there were 33 active research projects at UCL-Energy across four interacting themes: Energy Space Time (pg 7); Buildings (pg 8); Transport (pg 10); and Energy Systems (pg 12).

During the 2015/16 academic year UCL-Energy submitted a further 40 research proposals, and while over 20 of these projects are still awaiting decisions, 7 were approved.

UCL-Energy also hosts two research centres, the Whole Systems Energy Modelling Consortium (wholeSEM) (pg 14) and the Research Councils UK (RCUK) Centre for Energy Epidemiology (CEE) (pg 15).

“During the 2015/216 academic year, UCL-Energy continued to combine cutting-edge techniques and interdisciplinary focus, to generate new insights into key energy challenges.”

Professor Andreas Schäfer,
Director of Research, UCL-Energy

Net Zero Research project to inform UK response to the ambition set out in the Paris Agreement

Researchers from UCL-Energy have been exploring the implications of more ambitious carbon targets for the UK, in which the energy system becomes a ‘net zero’ emitter. The research suggests important implications for the ambition of UK climate targets, both before and after 2050, and the need for specific action across a range of low-carbon technologies.

The work is informing how the UK responds to the ambition set out in the Paris Agreement, particularly in relation to achieving a net-zero system in the post-2050 period. During the past year, the work has been discussed with both DECC, the Committee on Climate Change, and with UK Parliament members.



Image (c) sxc.com

Research Theme: Energy Space Time

The Energy Space Time group at UCL-Energy researches the interplay of energy demands and supply, costs and emissions over space and time, under the influence of social, economic and meteorological factors. Activities range from theoretical investigations to implementation research, carrying out research into the design and application of sustainable energy systems, whole system integration in space and time.

The group, set up by Prof Mark Barrett and Dr Catalina Spataru in April 2015, works closely with industry, government and the third sector. In addition to the two academic staff members, the group currently consists of one research associate and nine PhD students.

Selected 2015/16 projects:

UCL-Energy’s Energy Space Time group works to support the development of secure, environmentally sound city and national energy systems.

SiCEDs Stakeholder Interactive City Energy Demand Simulator): This project funded by Innovative/TSB is a joint venture between the group and the Energy Saving Trust. The project aims to aid the development of energy and environment policy in cities and nationally using data and models. The initial focus of this project is the UK, in particular the stakeholder cities of Birmingham and Exeter.

City Energy Demand Simulation (CEDs): Funded by Innovative UK this project aims to engage with stakeholders and create scenario plans for energy projects, so that approved schemes best meet each city’s unique visions and objectives.

The vulnerability of refrigerated food to unstable power supplies for UK, Brazil, Thailand and India: This project investigate how the proliferation of refrigeration might affect the vulnerability of refrigerated food, as countries develop chilled food chains and electricity grids.

National Grid EDAM2: Electricity System Modelling at DNO/Grid Supply Level in collaboration with EST

and National Grid: Development of a scalable dynamic energy agents model (DEAM) which predicts the change in scale and shape of current demand profile and forecasts potential changes until 2050, given a mixture of efficiency and supply technologies that might be installed over the coming decades.

Energy Solutions for Ukraine and partnership solutions with EU and Russia: An international collaboration project funded by British Council in Ukraine to design and create a roadmap of solutions for reliability and energy security within Europe with a main focus on the Russia-Ukraine-EU route.

Energy Modelling and Data Analysis at Distribution Network Operators: This project is in collaboration with EST and Western Power Distribution Network part of Low Carbon Network Fund (LCNF) FALCON project.

Blackouts prevention through multi-disciplinary techniques (B-PAS): A multi-disciplinary consortium to review research methods from medicine, biology, economics and power engineering.

Common Road to 2050: Energy Networks and Policy design (ENP2050): Analyses the main barriers to planning and implementing a long-term strategy for the use of different resources, so that to achieve environmental commitments as well as energy security.

Selected 2015/16 publications:

Sharp, E., Dodds, P., Barrett, M., & Spataru, C. (2015). Evaluating the accuracy of CFSR reanalysis hourly wind speed forecasts for the UK, using in situ measurements and geographical information. *Renewable Energy*, 77, 527-538. doi:10.1016/j.renene.2014.12.025.

Catalina Spataru, Pierrick Bouffaron. Off-Grid Energy Storage. Trevor Letcher. *Storing Energy - With Special Reference to Renewable Energy Sources*, Part F: Integration - Chapter 22, pp.477-497, 2016. bit.ly/2bi2ENw

Research Theme: Buildings

The UCL-Energy's Buildings research theme covers domestic and non-domestic buildings at scales from individual components through to the national and international stock. The UCL-Energy team is one of the largest in the UK and has a global reputation in the field. It works with policy makers, research communities, industry, NGOs and the public to develop effective policy, stimulate reductions in carbon emissions and fuel poverty, and promote a wider understanding of energy and buildings research. Coordinated by Prof David Shipworth and Dr Cliff Elwell, the Buildings theme is the largest in the Institute, with eight academic staff, five visiting/honorary staff, 17 research staff and 20 PhD students.

Selected 2015/16 highlights:

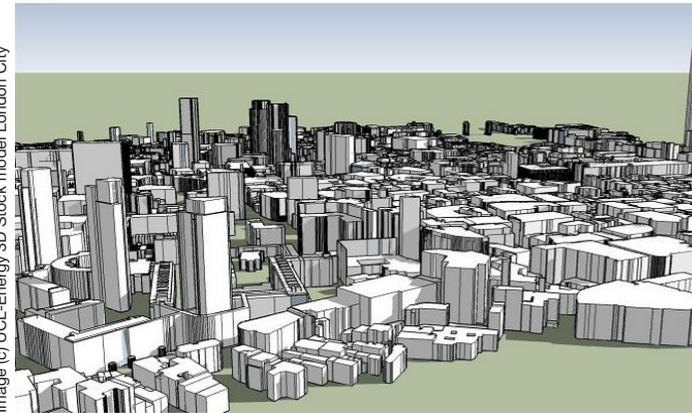


Image (c) UCL-Energy 3D Stock model London City

The year has been characterised by model and theory development for many of the research groups within the Buildings theme. There has been exciting progress in the automated construction of stock models from data through the 3D Stock and SimStock models.

3DStock: A team at UCL-Energy has been developing a new kind of 3D model of the UK non-domestic building stock. The model aims to assess energy use in buildings and study conservation options. The model has been trialled successfully in Camden London, as well as Leicester and Tamworth. The team is now working on

extending the model to large parts of England and Wales. Inclusion of the domestic stock is envisaged.

The 3D Stock model generates geometrical descriptions of self-contained units (SCUs) and their material properties, and these are passed to a specially customised version of the EnergyPlus simulation tool, called SimStock. This tool then builds energy models, covering heating and cooling uses, as well as appliances, for large numbers of SCUs testing out scenarios for future conservation options and new supply and servicing technologies. Further development is planned through the UK RCUK Centre for Energy Epidemiology and a proposal to EPSRC regarding schools. In the Building Energy Efficiency Survey (BEES) Shadow Modelling project, SimStock has been used to peer review empirically based modelling of the non-domestic building stock for DECC (read more on page 23).

Another focus of theory development as been work on the **physical characterisation of buildings**. This work currently focusses on the development of methods to assess the thermophysical and hygrothermal performance of buildings.

Through the application of Bayesian analysis combined with physically informed models, researchers are currently undertaking projects to reduce the error and required times to estimate the U-values of building components, characterise whole house heat loss, and investigate moisture transfer through walls. They have also applied these methods to assess the impact of energy policy on demand, through the analysis of national data on energy use and boiler uptake.

Theory development was also the focus of a Special Issue of Indoor and Built Environment on 'People and energy use in the indoor and built environment'. The papers in the Special Issue showed a broadening of the social science contribution to understanding energy use in the indoor and built environment. They focused on both routine actions and one-off actions to to reduce energy demand in buildings.

Selected 2015/16 projects:

Analysis of data from heat pumps installed via the Renewable Heat Premium Payment (RHPP) Scheme: This DECC funded project with PassivSystems provides the most up-to-date picture of overall performance of heat pumps in the RHPP for standard UK weather.

Energywise: Studying the impact of smart metering on the fuel poor and vulnerable: Investigates how distribution network operators (DNOs) can engage vulnerable customers to facilitate energy efficiency and Demand Side Response (DSR).

High-Rise Buildings: Energy and Density: This project assesses the comparative energy intensity of high versus low rise buildings and the implications of site size for building morphology with potential implications for planning policy.

Data-Driven Methods for a New National Household Energy Survey: Developing home monitoring and analytical methods that leverage smart-metering infrastructure to support hierarchical monitoring designs in large field-trials and surveys.

Smart Meter Data and the Public Interest: Determining how smart meter data can be harnessed to serve wider societal goals, such as reducing fuel poverty and reducing domestic carbon emissions.

Improve Honeywell's marketing of central heating controls to installers: This project, joint funded by Honeywell Control Systems and EPSRC, aims to increase uptake of smart heating controls in homes.

Business Energy Challenge: Develops energy benchmarks for offices, general retails, large food stores and hotels in London through analysis of data provided under the Mayor of London's Business Energy Challenge.

The Smarter Household Energy Data (SHED): Explores big data analytics of domestic smart meter data. With the UK Data Archive, South Africa, and UCL, this project is exploiting the UKDA's new Hadoop Big Data platform to open up new forms of analysis of energy data.

GLA Business Energy Challenge: Analysis of self-reported energy data from 1600 commercial buildings in London to develop new energy benchmarks.

The HEAT project: Establishes data agreements to link Health Surveys with Energy demand and energy retrofit data in English dwellings.

The LENDERS project: Includes Energy Performance Certificates (EPCs) in mortgage lenders calculations.

The OPTIHOUSE project: EcoCasa low-income housing energy performance and temperature analysis in Mexico with Inter-American Development Bank

The NIHR-HEE project: Links temperature and retrofits of 16 million homes with mortality and hospital admissions.

Selected 2015/16 publications:

Elwell, CA; Biddulph, P; Lowe, R; Oreszczyn, T; (2015) Determining the impact of regulatory policy on UK gas use using Bayesian analysis on publicly available data. *Energy Policy*, 86, 770-783.

Garcia Kerdan, I; Raslan, RM; Ruyssevelt, P; (2016) An exergy-based multi-objective optimisation model for energy retrofit strategies in non-domestic buildings. *Energy* 10.1016/j.energy.2016.06.041.

Hamilton, I.G., Summerfield, A.J., Shipworth, D., Steadman, J.P., Oreszczyn, T., Lowe, R.J., 2016. Energy efficiency uptake and energy savings in English houses: a cohort study. *Energy Build*, 118, 259-276.

Huebner, G. M., I. Hamilton, Z. Chalabi, D. Shipworth and T. Oreszczyn (2015). 'Explaining domestic energy consumption – The comparative contribution of building factors, socio-demographics, behaviours and attitudes.' *Applied Energy*, 159, 589-600.

Wade, F., Shipworth, M., & Hitchings, R. (2016). How installers select and explain domestic heating controls. *Building Research and Information*, 1-13.

Research Theme: Transport

Led by Prof Andreas Schäfer and Dr Tristan Smith, UCL-Energy's Transport research theme covers all major modes of transport, spanning all geographic scales, from local scale **urban transport** to global networks of **marine transportation** and **aviation**. This interdisciplinary team consists of two academic staff and seven research staff.

Selected 2015/16 highlights:



Image (c) Shippingmap.org

UCL-Energy Shipping Group launches interactive map that shows CO2 emissions for every ship for every hour
Using the methodology the group developed for the Third International Maritime Organisation Green House Gas (IMO GHG) Study 2014 and AIS data to estimate emissions from five different ship types, Shipmap.org is a new interactive map that plots 250 million data points to show the movements of the world's commercial shipping fleet over the course of a year. Read more about Shipmap.org in the media on page 30.

UCL-Energy Shipping Group and partners win new study for the on the availability of low sulphur fuels for shipping
In October 2015 the consulting arm of UCL-Energy's Shipping Group, UMAS, along with a consortium of partners led by the independent research and consultancy organisation CE Delft, won a contract to create a study to inform the IMO's decision on whether to implement a global cap on sulphur in 2020 or to postpone to 2025.



Image (c) iStock

Nature Climate Change publishes paper by UCL-Energy academics identifying the cost-effectiveness of CO₂ emission reductions from passenger aircraft

'Costs of mitigating CO₂ emissions from passenger aircraft,' published in January 2016, identifies the cost-effectiveness of CO₂ emission reductions from narrow-body aircraft, the workhorse of passenger air transportation. This paper by lead author Dr Andreas Schafer has received international attention and has been cited in numerous media outlets including PBS Newshour, the Pacific Standard, Wired Magazine and Vox.com.



Image (c) FS-MaaS Project

Rethinking mobility: the successful completion of the FS-MaaS project by the Urban Transport and Energy Group at UCL-Energy

The group received funding from the T-TRIG

scheme of the Department for Transport to explore the feasibility of a new mobility solution that could offer seamless mobility, the "Mobility-as-a-Service" (MaaS). The feasibility study was delivered successfully in June 2015.

UCL-Energy Urban Transport and Energy Group launch London Mobility Survey: Innovation in mobility and travel surveying
In June 2016 this survey invited Londoners to participate in a new survey to analyse London's travel habits and preferences for new mobility services. Through a state-of-the-art smartphone based application, respondents had the opportunity to learn about their travel and contribute to innovative research.

Selected 2015/16 projects:

Airport Capacity Consequences Leveraging Aviation Integrated Modelling (ACCLAIM): This project explores simulating local and global impacts of airport capacity expansion policies. While the tool to be developed is applicable to any airport worldwide, it will be applied initially to the London airport system, where the UK Government plans to add capacity in the near future.

CO₂ emission targets for shipping: Commissioned by the Sustainable Shipping Initiative, this study provides the SSI with an understanding of what a 2°C target would mean for shipping and what would be the implications or consequences for SSI members and the industry at large to committing to such a target.

IMO 0.5% sulphur fuel oil study: As part of a consortium led by CE Delft, the demand and supply of compliant fuel oil in 2020 is studied. The project deploys GloTraM (Global Transport Model) to model the fuel supply side, such as refineries.

Investigation into a INTERTANKO member's fleets' energy efficiency: Follow-on project to monitor performance of a member of INTERTANKO and a similarity analysis of sister ships.

ISO 19030 – Hull and propeller performance measurement: This project is the first deployment of uncertainty analysis to assist ship owners and operators in understanding trends in hull and propeller performance. The project requires extensive experience in handling measurements/data of shipping's energy demand.

Newton Fund: Working in collaboration with Universidade Federal do Rio de Janeiro to develop an international trade and shipping database and to study port and shipping efficiency.

Project work with the Centre for Energy Epidemiology: Two cross-sectional surveys of the shipping sector have been conducted focussing on the implementation of operational and technical energy efficiency measures used in shipping.

Redefining Urban Transport Mobility: This project designed the 'Mobility as a Service' concept for London and included exploring *Mode Choice Behaviour in Developing Countries: Past Habits-Today's Progress and Future Opportunities*.

Shipping in Changing Climates: Understanding supply and demand side changes and their interaction over the period 2010-2050.

Shipping GHG outreach and analysis: This project further deploys research and evidence to support IMO debates on the need and justification for a progressive target for the reduction of shipping's GHG emissions.

Substantiating shipping GHG policy debates: This project seeks to raise awareness of the implications of maritime policies and to investigate whether a sought 'best practice' has been adopted using AIS data and infographics.

Selected 2015/16 publications:

Aldous, L, Smith, T, Bucknall, R & Thompson, P 2015, 'Uncertainty analysis in ship performance monitoring', *Ocean Engineering*, vol 110, pp. 29-38.

Kamargianni, M., Matyas, M., Li, W. & Schäfer, A.W., 2015. Feasibility Study for "Mobility as a Service" concept for London. Report - UCL Energy Institute and Department for Transport.

Rehmatulla, N & Smith, T 2015, 'Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem in shipping', *Energy Policy*, vol 84, pp. 44-57.

Schäfer A.W., Evans A.D., Reynolds T.G. & Dray L., 2016. Costs of Mitigating CO₂ Emissions from Passenger Aircraft. *Nature Climate Change*, 6: 412-417.

Schäfer A., "The Prospects for Biofuels in Aviation", introductory chapter of *"Biofuels for Aviation; Feedstocks, Technology and Implementation"*, Chuck C. (editor), Elsevier, 2016.

Research Theme: Energy Systems

The Energy Systems theme at UCL-Energy, led by Professor Neil Strachan, is the UK's largest academic energy systems research group and is a globally leading centre of excellence in E4 (energy-economic-engineering-environment) modelling. The highly interdisciplinary team consists of four academics and 13 research staff members.

The team's modelling underpins the UK government's analysis on energy transition pathways and contributes to the international debate through the EU Commission, International Energy Agency and a range of international energy networks (IPCC, EERA, IAMC).

Selected 2015/16 highlights:



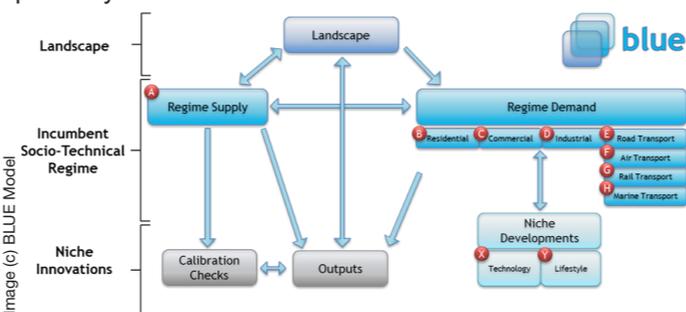
Exciting new tools have been developed, documented, published and applied by the Energy Systems team This includes a High Spatial and Temporal Resolution Electricity System Model (highRES), developed by Marianne Zeyringer and James Price which investigates the feasibility of very high shares of renewable energy in the energy systems. This requires looking at how variable renewable energy technologies (VRE) and demand vary in time and space. Transitioning to an energy future with high shares of VRE needs long-term planning and technically feasible solutions, hence the development of highRES.

HighRES complements the long running energy system model UK Times Model (UKTM) to find electricity

pathways which are cost-effective, flexible and robust to the variability of the weather. The objective of highRES is to minimise power system costs to meet hourly demand subject to a number of constraints on the operation of power plants and storage, as well as transmission constraints allowing the balancing of demand and supply across the country.

The advantage of highRES is its good representation of VRE (photovoltaic, onshore and offshore wind energy). Hourly data for 10 years with a spatial resolution of 50km x 30km is useable. This allows for the ability to capture the scope of variability of weather conditions both temporally and spatially. HighRES determines the optimal locations for VRE and the optimal capacities and location of different renewable integration options. The modelers currently include electricity network expansion, interconnection to neighbouring countries, electricity storage and flexible generation.

Another key part of energy systems research at UCL-Energy is the Behaviour, Lifestyles and Uncertainty Energy model (BLUE), by Dr Francis Li, that investigates the competing roles of different actors in energy transition pathways.



BLUE is a system dynamic model of the UK energy system that simulates technological change, energy use and emissions. A defining feature of the model is the ability to simulate the individual behaviours of multiple energy

system actors, which interact dynamically through time as changes to technologies, demands, and prices unfold.

BLUE enhances the policy relevance of energy modelling by explicitly addressing deviations from strict economic rationality found in behavioural economics literature and by enabling technological diffusion to be directly related to decisions made in specific sectors or by specific institutions. Finally, the model employs a stochastic Monte Carlo formulation that makes it particularly well-suited for exploring energy transitions under conditions of deep uncertainty.

Details of these models and others can be found at: www.ucl.ac.uk/energy-models

Nature Energy publishes paper by UCL-Energy academics: 'Reinventing the energy modelling-policy interface' This paper by senior UCL-Energy academics Neil Strachan, Birgit Fais and Hannah Daly stresses that energy modelling has a crucial underpinning role for policy making, proposing four key improvements to ensure that the modelling-policy interface delivers the insights that decision makers need.

Selected 2015/16 projects:

wholeSEM: The UK Research Council's flagship research initiative to develop, integrate and apply state-of-the-art energy models. Read more about wholeSEM on page 14.

ADVANCE: An international consortium to develop a new generation of Integrated Assessment Models (IAMs) for the analysis of climate change mitigation policies.

UKERC Phase III: The UK's largest energy policy and research consortium. The UCL team focuses on the current and future roles of different resources and energy vectors in the UK energy system.

INSIGHT_E: A Think Tank for the European Commission that provides unbiased policy advice and insights into policy options and assessing potential impact.

Realizing Transition Pathways: A novel project to undertake historically-informed, forward-looking analysis of energy system transitions, bringing together quantitative and qualitative research methods.

HYVE: The HYVE (Hydrogen's Value in the Energy System) project aims to find out how hydrogen might contribute to a transition to a low carbon economy.

Role of technologies in an energy efficient economy (REEM): A major new EU Horizon 2020 project to improve understanding of the diffusion and use at scale of technologies in an energy efficient economy.

Bio-value Energy Chains: Whole systems analysis and optimisation to understand the potential and risks of different biomass technologies and supply chains.

Energy Pathway Uncertainties: A new project for the Energy Technologies Institute to investigate and extending the uncertainty capabilities of their Energy Systems Modelling Environment (ESME) model in long terms decarbonisation pathways.

Selected 2015/16 publications:

Dodds, P. E., Keppo, I., & Strachan, N. (2015). Characterising the Evolution of Energy System Models Using Model Archaeology. *Environmental Modeling and Assessment*, 20 (2), 83-102. doi:10.1007/s10666-014-9417-3.

Fais, B., Sabio, N., & Strachan, N. (2016). The critical role of the industrial sector in reaching long-term emission reduction, energy efficiency and renewable targets. *Applied Energy*, 162, 699-712. doi:10.1016/j.apenergy.2015.10.112

Pye, S., McGlade, C., Bataille, C., Anandarajah, G., Denis-Ryan, A., and Potashnikov, V. (2016). Exploring national decarbonization pathways and global energy trade flows: a multi-scale analysis. *Climate Policy*, 16.

Trutnevyte, E., McDowall, W., Tomei, J., & Keppo, I. (2016). Energy scenario choices: Insights from a retrospective review of UK energy futures. *Renewable and Sustainable Energy Reviews*, 55, 326-337. doi:10.1016/j.rser.2015.10.067



The whole systems energy modelling consortium (wholeSEM), funded by EPSRC, is a ground-breaking multi-institution initiative to develop, integrate and apply state-of-the-art energy models.

The broad multi-disciplinary team of energy modellers from four leading UK universities, UCL, Surrey, Cambridge and Imperial are undertaking research into energy modelling with UCL-Energy Deputy Director Professor Neil Strachan as the Principal Investigator.

Highlights from wholeSEM's 2015/16 activity include:

- July 2016 - wholeSEM was delighted to stage its 3rd Annual Conference: 'Energy Modelling Insights for Iterative Decision Making'. More than 100 academics, industry experts and doctoral students from across the world came to Cambridge to attend this innovative two day conference.
- June 2016 - it was announced that the UK TIMES energy systems model, developed by UCL-Energy's wholeSEM team, was one of the principal tools used by the government in setting the fifth carbon budget.
- May 2016 - wholeSEM ran a technical workshop - 'Integrated energy system models incorporating spatial and temporal detail' - to consider the current state-of-the-art in integrated energy network models that include both spatial and temporal details.
- March 2016 - wholeSEM sponsored a UKERC residential conference: 'Energy systems challenges in a world in transition'. The conference was an important opportunity to help inform future research priorities.
- May 2016 - wholeSEM and the British Sociological Association Climate Change group hosted a two day

workshop on how everyday social practices can be re-configured to be less energy intensive.

wholeSEM's innovative **bi-directional Fellowship Programme** enables UK and international professionals in academic, policy and industrial positions to work with the wholeSEM consortium, sharing and building expertise. This programme has proven to be a great success with our fellows demonstrating huge topical and geographical diversity and creating strong links with the wholeSEM team.

wholeSEM 2015/16 fellows included:

- Chris Bataille (IDDRI, Paris – UCL, London) Chris reviewed UCL's suite of models from the perspective of behaviourally realistic bottom-up and hybrid modelling.
- Sandy Skelton (University of Cambridge - E3 Modelling, Athens, Greece) Sandy looked to develop a complete methodology for incorporating material efficiency into dynamic CGE models.
- Zenaida Sobral-Mourao (University of Cambridge - UC Berkeley, USA) Zenaida examined 'Impacts of energy system pathways on Air Quality and human health within the wider context of Integrated Earth System Models'.
- Kathrin Volkart (PSI, Switzerland – UCL, London) Kathrin researched multi-criteria optimisation in energy system modelling.
- Behnam Zakeri (Aalto University, Finland – UCL, London) Benham investigated energy transitions towards high-level integration of variable renewable energy (VRE), and flexibility of energy systems in this respect.



RCUK Centre for Energy Epidemiology

The Research Councils UK (RCUK) Centre for Energy Epidemiology (CEE) studies energy demand from transport and the built environment, and develops a new path for energy-demand research. UCL-Energy was awarded one of six Centres of Excellence in End-Use Energy Demand (www.eueduk.com) by the RCUK in 2013.

The CEE provides an evidence base for government and industry to support end-use energy reduction across buildings and transport. CEE uses an epidemiological approach derived from the study of health and disease since the 19th Century, to provide data-driven insights into the drivers of end-use energy demand, and the impacts of measures to reduce it.

Highlights from CEE's 2015/16 activity include:
Lancet Commission on Health and Climate Change: CEE staff led a chapter on technological options to help prevent some of the catastrophic risks to human health associated with climate change. The Commission found that action to reduce climate change could be the greatest

global health opportunity of the 21st Century (1.8 million downloads in the first 6 days, 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). The follow-up "Countdown to 2030" project will develop a set of targets and indicators to monitor progress against the commission's recommendations, and will be led by the UCL Institute for Global Health.

IEA EBC Annex 70 - Building Energy Epidemiology: CEE staff have developed a new International Energy Agency (IEA) Annex under the Energy in Buildings and Communities programme, focusing on energy epidemiology. Annex 70 is an international collaboration of researchers, industry and government working to improve the empirical evidence on energy demand in the building stock. A workshop was held at IEA Headquarters in Paris in May 2016 with 35 participants from 12 countries, with further presentations planned in Australia in November 2016.

London Mobility Survey: CEE researchers launched the London Mobility Survey inviting Londoners to participate in a survey to analyse their travel habits and preferences for new mobility services.

82 peer-reviewed journal papers published in CEE's first three years: These publications have included i10 index of 6 (6 papers cited at least 10 times); H index of 8 (8 papers that have been cited at least 8 times each); 61 citations in 2016; 176 citations from non-CEE papers in 160 non-CEE articles.

International Engagement: CEE staff have been engaging the international community on energy epidemiology including presentations in Australia, Chile, India, Italy, Hong Kong and Mexico as well as meetings in Canada and USA.



Image (c) CEE, IEA Annex 70 Meeting in Paris

Postgraduate Study at UCL-Energy

Graduates in energy related subjects are currently in high demand. UCL-Energy is a leading centre for research into energy demand and the built environment, a sector of increasing importance due to the challenges of climate change, energy affordability and energy security.

Students undertaking the **Master of Research in Energy Demand Studies (MRes EDS)** have the opportunity to learn from experienced and respected researchers and to undertake original research in energy demand reduction in the built environment in at a world leading institution. The aim of the MRes EDS is to provide a grounding in the required skills and knowledge to pursue a career in industry or academia.

In addition to being offered as a full time or part-time stand-alone masters course, the MRes EDS can form the first year of a four year PhD programme offered by UCL-Energy, via the London-Loughborough EPSRC Centre for Doctoral Training in Energy Demand (LoLo).

In the 2015/16 academic year 83 students were enrolled on the **Masters in Economics and Policy of Energy and the Environment (MSc in EPEE)**. Launched in September 2013, the MSc in EPEE aims to give its



Image (c) UCL-Energy MRes students attend September 2015 Loughborough block week

students the essential skills and knowledge they need to understand, analyse and manage environment-resource-economy interactions. This is now a global agenda, and one of increasing importance to business, policy makers and civil society in all countries.

The MSc in EPEE equips its graduates to become leaders and entrepreneurs in their chosen area of specialisation, whether in terms of policy making, the business management of sustainability issues, energy system modelling or their understanding and application of the innovation system.

“The MSc is an exciting and interdisciplinary course that provides students with the fundamentals necessary for careers as energy and environmental policy professionals. During the 2015/2016 academic year, the third year of the course, we built on the success of the first two years by offering a new module (Planetary Economics and the Political Economy of Energy and Climate Change, led by Professor Michael Grubb). The MSc continues to grow and go from strength to strength, and it’s hugely satisfying to see our alumni from our first years go off into careers in business, government and NGOs, with many also pursuing PhDs in the field.”

Will McDowall, Course Director MSC EPEE

“Mres EDS is a programme where students can learn the fundamentals of energy research in the built environment from an economic, scientific and social perspective. This knowledge will combine with the different analysis tools to provide the technical background required to undertake research in this challenging multidisciplinary area. Becoming a good researcher is about much more than learning techniques and facts. The transferable skills courses teach key aspects of research; the fundamentals of being a researcher and research communication.”

Catalina Spataru, Course Director, MRes EDS



Image (c) UCL-Energy MSc in EPEE Alumni panel

UCL-Energy MSc in EPEE holds its first ever alumni event in June 2016

This event was attended by MSc EPEE alumni, current students, course offer holders and industry partners from such companies as E4tech, Green Alliance and Bloomberg New Energy Finance. The evening began with a lecture on the “State of UK Environmental Policy 2016”, by Professor Paul Ekins, founder of the MSc EPEE and the UK’s foremost environmental economist, according to The Daily Telegraph.

The event continued with an MSc EPEE alumni panel where the alumni discussed their current jobs and the impact of the course and answered questions from event attendees. Some of the current companies and organisations alumni now work for include Kiwi Power, Arup, VJI Consulting, Imperial College, EFT Trading and the Carbon War Room.



Image (c) UCL-Energy

MSc in EPEE students visited Pimlico District Heating Undertaking (PDHU) in November 2015. The students took a tour of the London facility which included an overview of the district heating scheme’s history and its current energy impact in London.



Image (c) UCL-Energy

MSc in EPEE students visited South East London Combined Heat and Power (SELCHP) in February 2016. The tour of the energy recovery facility demonstrated the process by which the energy produced by burning household and business waste is contributed to the national grid.

Doctoral Research at UCL-Energy

UCL-Energy's MPhil/PhD Energy program was established in 2009 as UCL's response to the global challenges of mitigating climate change and providing energy security in the 21st century.

UCL-Energy doctoral students work alongside experienced researchers in a dynamic, multi-disciplinary environment and are core to the institute's research activities, contributing to a wide range of ongoing research and consultancy projects, including being named authors in a number of national and international papers and reports (pg 28).

During the 2015/16 academic year 60 doctoral researchers were registered with UCL-Energy and 10 students successfully passed their vivas. The London-Loughborough EPSRC Centre for Doctoral Training in Energy Demand (LoLo) experienced success with six students joining the LoLo PhD programme and eight LoLo PhDs successfully passed their vivas (pg 19).

UCL-Energy now has a rapidly expanding community of alumni from the MPhil/PhD programme with over 30 PhD students graduating since 2009 and over 20 affiliate students. UCL-Energy alumni have gone on to obtain competitive positions as lecturers and postdoctoral researchers within UCL and other academic institutions as well as entering professional positions at organisations such as the International Energy Agency in Paris, University of Oxford and KPMG. UCL-Energy is eager to keep in touch with alumni and will be launching a new UCL-Energy Alumni and Friends LinkedIn presence in early 2017.

"I very much enjoyed doing the PhD, particularly as I had great support in a truly multi-disciplinary environment, and had the freedom to design and develop my own topic. The knowledge and skills that I gained during the PhD were an important part of helping me to put theory into practice through my current position in the Department for Business, Energy & Industrial Strategy."

Peter Warren, LoLo, CDT PhD Graduate 2016

UCL-Energy PhD student led Energy Demand in Practice (EDiP) seminar series

The EDiP seminar series, launched in January 2016, is led by UCL-Energy doctoral research students, in collaboration with the LoLo management team.

The aim of the seminar series is to explore the range of career paths within the energy demand domain that are available to PhD graduates, providing students with inspiration, advice on matters such as workplace skills and networking opportunities.

During the 2015/16 academic year three successful events were held at UCL and included speakers from a range of organisations including Willmott Dixon Energy Services, Green Running, UK Power Networks, Good Homes Alliance (GHA) and a number of researchers/academic staff from UCL-Energy and other UCL institutes.



Image (c) UCL-Energy Energy Demand in Practice first event 'Is there life after a PhD?'



The London-Loughborough EPSRC Centre for Doctoral Training in Energy Demand (LoLo) is the premier UK centre for energy demand in the built environment doctoral training. Its aim is to help deliver deep reductions in CO₂ emissions by 2050 through an innovative, multi-disciplinary, high impact research and training programme.

LoLo brings together two leading energy research universities, UCL and Loughborough University. The UCL branch of LoLo is based at the UCL-Energy. The Centre's core focus is the energy performance of buildings, their technologies and multiple interactions with people and the wider energy system.

LoLo was set up as a Centre for Doctoral Training (CDT) in 2009 with funding from EPSRC for 50 studentships, with a renewal of funding in 2014 of 60 additional studentships over the next eight years.

LoLo aims to create a unique student-focussed environment. Students join active research groups supporting a wide range of projects, undertake a robust programme of skills training, engage in range of events throughout the year including our Annual Colloquium, Student Led conference and site visits and have ample opportunities to engage with leading researchers, industry and policy makers.

Since 2009, LoLo has funded a total of 60 students with a growing community of 20 alumni who have gone on to attain research positions and lectureships within UCL-Energy and other academic institutions along with technical and professional roles in external organisations such as the Department for Business, Energy & Industrial Strategy, Willmott Dixon Energy Services Limited, Useful Simple Projects and Investec Asset Management.

Vision and leadership for a sustainable built environment www.lolo.ac.uk
@LoLoCDT

LoLo actively engages with a wide network of external organisations, co-developing high impact, cutting-edge research topics with partners and establishing four-year PhD research programmes in which 70% of the costs are met by the CDT. UCL partners have included Bouygues UK, CIBSE, Crest Nicholson, EDF, Skanska, Willmott Dixon, and British Board of Agrément (BBA).

LoLo research themes:

- Technology and systems
- Energy epidemiology
- Urban scale energy demand
- Building performance and process
- Unintended consequences

These themes are investigated using a wide range of methods and disciplinary perspectives, including social sciences, economics, socio-technical studies, statistical analysis, simulation and physical measurements.



Image (c) UCL-Energy LoLo CDT Site Visit to Summit House site/Low Carbon Workplace (LCW) project hosted by Willmott Dixon (April 2016)

UCL-Energy PhD Students 2015/16

Dayang Abu Bakar: Integrated Decision Support Framework for the Assessment of Oil Palm Bioenergy for Greenhouse Gas Mitigation: Malaysia-TIMES Energy Model

Omotola Adeoye: The Development of Interconnected Electricity Networks in West Africa

Lucy Aldous: Energy mapping and optimisation on cruise vessels

Elsa Barazza: The low-carbon transition of the European electricity sector: Understanding investment costs and actors' strategic investment decisions in renewable energy generation assets through an agent-based approach

Domagoj Baresic: Barriers facing the diffusion of low carbon thinking into the mainstream of the maritime transport industry regime—A dialectic perspective

Carolyn Behar: A sociotechnical perspective of ventilation practice; Design, everyday life and change (Completed her PhD January 2016)

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”

Kim Bouwer: Building disappointment: the potential and limitations of tort liability for energy efficiency problems in domestic buildings

Pablo E. Carvajal: Assessing the impact of uncertain climate change on hydropower generation: A case study for Ecuador

Jonathan Chambers: Generating a physically based, smart meter data driven model to support efficiency decision making in individual homes

Jennifer Cronin: Integrating climate change effects in a bottom-up integrated assessment modelling (IAM) tool

Benoit Decourt: Valuing the benefits of power-to-synthetic fuel conversion

Andreas Economou: Investigating the relationship between the real oil price and its drivers across oil market regimes

Elusiyana Olufemi Eludoyin: The nature of energy access transitions: realities and possibilities for Lagos, Nigeria

Michael Fell: Taking charge: Perceived control and acceptability of domestic demand-side response (Completed his PhD January 2016)

Pamela Fennell: Energy performance contracting. Current title: Factors affecting the success of energy performance contracting projects in UK schools

Ivan Garcia Kerdan: Optimisation of building energy retrofit strategies using dynamic exergy analysis and exergoeconomics

Virginia Gori: A novel method for the estimation of thermophysical properties of walls from short, seasonal-independent in-situ surveys

Christopher Grainger: The causal relationship between climate policy and technological change: What can be learnt from machine learning and big data?

Joel Guilbaud: The economic potential of hybrid renewable power systems for the mining industry

Shih-Che Hsu: Human-oriented spatial assessment on climate change risk and policy benefit: from energy use to health status

Lisa Iszatt: Investigating heat and moisture transfer through solid brick walls and the impact of internal wall insulation

Badria Jaffar: An examination of the residential building stock in Kuwait to inform energy efficiency policy

Owain Jones: The deployment of micro-CHP in the UK and its role in a future low carbon energy system.

Sinan Kalaz: Investigation of an Integrated Ship-board Algae Harvesting System

Tia Kansara: Achieving zero carbon waste (Completed her PhD January 2016)

Maria Kikira: Energy & Life Cycle Costing of Building façade

Philip Krammer: International trade and tourism in a CO₂-constrained world

Maragatham Kumar: Future energy pathways for Malaysia: An analysis of near-optimal investment strategies and technical feasibility in the power sector

Priscila Lapa Villas Boas de Carvalho: Integrating the institutional and policy dimensions of water-energy nexus in Brazil for a sustainable future

Weibo Li: A Transport Mode Choice Study for a Developing Country: Past Habits, Today's Progress and Future Opportunities

Stephen Lochran: Implications of unconventional gas in EU energy supply systems and energy security under climate constraint

Melinda Matyas: Reinventing multimodal sustainable urban transport: Demand analysis of a 'mobility as a service' concept for London

Paula Morgenstern: Understanding hospital electricity use: an end-use(r) perspective (completed her viva June 2016)

Charlie Morris-Marsham: Visualising home energy use: can the provision of thermal images affect householders' mental models of home energy use and influence levels of consumption?

Thomas Neeld: Combustion roar as a monitoring mechanism for gas boilers

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

Ukadike Nwaobi: The economic appraisal of unconventional gas resources of the United Kingdom

Eleni Oikonomou: Summer overheating in London dwellings: A cross-cultural comparison on occupant behaviour and building interaction

Eoin O'Keefe: Modelling operations and technologies to deliver low carbon shipping

Sofie Pelsmakers: Pre-1919 suspended timber ground floors in the UK: measuring the in-situ thermal performance and heat-loss reduction potential of interventions (completed her PhD June 2016)

Vishnu Prakash: Emissions, efficiency, and shipping markets

Carlo Raucci: The potential of hydrogen to fuel international shipping

Tobias Reinauer: Technology transfer to low and middle income countries: The case of biogas in Southeast Asia

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

Ed Sharp: Spatiotemporal disaggregation of GB scenarios depicting increased wind capacity and electrified heat demand in dwellings (Completed his PhD December 2015)

Samuel Stamp: Assessing Uncertainty in Co-heating Tests: Calibrating a Whole Building Steady State Heat Loss Measurement Method (Completed his PhD December 2015)

Dina Subkhankulova: Efficient renewable energy system: A path to Energy Security

Trevor Sweetnam: Demand response: Benefits for domestic consumers

Bernard Tembo: Energy efficiency in Zambia's Copper Industry

Will Usher: The value of learning about critical energy system uncertainties (Completed his PhD May 2016)

David Veitch: Developing improved methods for measurement of ventilation rates in occupied dwellings

Faye Wade: An ethnography of installation: Exploring the role of heating engineers in shaping the energy consumed through domestic central heating systems (Completed her PhD November 2015)

Bojun Wang: Simulating impacts of airport capacity constraints on airline fares and the role of fares in airline supply decision-making under competition

Xuebing Wang: The Impacts to the International Aviation Industry by including it to the EU-ETS

Catherine Willan: How are users taken account of in the specification of thermal comfort and lighting controls in non-domestic buildings projects?

Yunyang Wu: Possibilities and Considerations for High Penetration Renewable System in the National Electricity Market (NEM)

Eleni Zafeiratou: Transforming the Greek Islands into renewable energy exporters following their interconnection with the national grid system

Senami Zamba: Promoting Modern Energy Access to Rural Communities in Developing Countries: A case study of Kogi, Nigeria

Full profiles of all UCL-Energy PhD students are available on the UCL-Energy website, in addition to supervisor lists and academic staff profiles.

UCL-Energy Partnerships

The benefits of working with UCL-Energy include access to leading academics and forthcoming research, and the chance to incorporate the Institute's research findings into strategic direction, policy, products, services and processes.

Partners are able to plug into a unique, multidisciplinary institution in which physicists, economists, social scientists, engineers, architects and data modellers work side-by-side on the same questions and challenges.

Current partnerships include:

Consultancy projects – Providing consultancy support to government and industry clients on specific questions, issues and projects, in the form of access to expertise, knowledge and data. UCL-Energy often collaborates with clients when its reputation for expertise in energy demand can be a decisive factor in project proposals (pg 23).

Support for major initiatives – Securing support from external partners for major projects, such as the RCUK Centre for Energy Epidemiology (pg 15), either as research funding or in-kind support in the form of advice, guidance, or through the provision of data.

PhD research projects – Through the LoLo CDT (pg 19), co-developing high impact, cutting-edge research topics with partners and establishing four-year PhD research programmes in which 70% of the costs are met by the CDT. Partners have included Bouygues UK, CIBSE, Crest Nicholson, EDF, Skanska, Willmott Dixon, and British Board of Agrément (BBA).

Strategic partnerships – Developing with a partner a shared research agenda that can be pursued over a number of years through various forms of engagement. Past examples include joint research projects, staff and partner involvement in teaching modules, and knowledge transfer partnerships. UCL-Energy has established

strategic partnerships with major established bodies such as EDF, the UK Department of Energy and Climate Change (DECC) and fast growing, innovative new entrants like PassivSystems.

UKTM model used as UK government's primary long-term energy model

The UK TIMES model is a state-of-the-art energy systems model that facilitates analysis of long term energy pathways. UKTM generates scenarios for the evolution of the energy system based on a set of consistent assumptions around the evolution of demands, future technology costs, measuring energy system costs and all greenhouse gases.

Coordinated by UCL researcher Dr Peihao Li, this multi-year collaborative venture has become the key long-term energy model for DECC. Most recently, in June 2016 UKTM was the underpinning model in the decision from (DECC), in agreement with the Committee on Climate Change, of the ambitious new carbon budget proposing that the fifth budgetary period covering 2028 to 2032 should be set at 1,725 MtCO₂e, broadly a 57% reduction from 1990 to early 2030.

Alec Waterhouse, Head of DECC's Central Modelling Team, said: "DECC and UCL have been co-developing the UK TIMES model for some time. We have used the model as one of three sections of analysis used in developing the HMG response to the Committee on Climate Change's recommendation on the level of the fifth carbon budget. We intend to use the model heavily this year to develop our long term strategy."

Read more about the UK TIMES model:

www.ucl.ac.uk/energy-models/models/uktm-ucl

Consultancy at UCL-Energy

UCL-Energy makes a direct, real-world impact in the advisory role it has with government and industry, bringing its knowledge and expertise in energy demand to bear on the policy and decision-making process.

The Institute contributes a focus on data quality and rigorous, robust models of energy use at regional, national and international level, taking into account factors such as economic growth, carbon emissions and climate change, and societal trends.

Over the past academic year, UCL-Energy signed 18 new consultancy contracts with a total value of over £0.5 million, including the winning of repeat business. The story for the year has been one of delivery of significant projects, with a number of major DECC projects completed.

UCL-Energy has been actively involved in several European and DECC Framework contracts for delivery of specialist advice and research in technical, economic and social-sciences areas, relevant to energy and environmental policy. UCL-Energy was also involved in two Collaborative Research projects sponsored by Innovate-UK.

Clients for the year included:

Department of Energy and Climate Change
DNV GL
EDF Energy
Energy Savings Trust (i-UK project SiCEDs)
Energy Technologies Institute

The European Commission (DG Energy, DG Environment)
Ricardo-AEA
Nationwide Building Society (i-UK project LENDERS)
Akzo-Nobel

BEES MPR: Genetic algorithm results vs number of generations

Detailed model evolution

The graph displays the convergence of five fitness metrics over 80 generations. The 'Best fitness' metric (blue line) starts at approximately 130 and drops to about 85 by generation 30, remaining stable thereafter. The 'Best RMSE thermal' (green) and 'Best RMSE elec' (red) metrics start around 60 and 40 respectively, both converging to approximately 40. The 'Best bias thermal' (cyan) and 'Best bias elec' (magenta) metrics start near 0 and remain close to 0 throughout the process.

UCL-Energy undertakes peer review of the Building Energy Efficiency Survey Hypothesis Model Methodology for DECC

The UK Department of Energy and Climate Change (DECC) undertook the Building Energy Efficiency Survey (BEES) in 2015/16 to provide an updated, disaggregated evidence base around energy end uses and abatement potential in non-domestic buildings in England & Wales. As part of the BEES project a comparison was undertaken by UCL-Energy between the building stock 'hypothesis' model employed in BEES and a tailored simulation model.

The exercise by UCL-Energy, which was conducted for health centres and offices, built confidence in the BEES hypothesis model and revealed the potential of a simulation model to represent and investigate the highly complex nature of the non-domestic building stock. The simulation model, known as SimStock, is now undergoing further development with the aim of providing a scenario analysis tool for the non-domestic building stock.

Image (c) UCL-Energy BEES MRP

Activities and Outreach

During the 2015/16 academic year, UCL-Energy continued to expand its communication and outreach activities to engage UCL staff, students, industry and the public. The academic year saw an incredibly successful public seminar series, with over 946 attendees across the events, and continued to expand its online presence.

The Institute seminar series included a fantastic programme of invited speakers from industry, academia and elsewhere, who spoke on a wide range of topics (pg 25). The series also incorporated a number of joint events with other UCL institutes, including the UCL Institute of Sustainable Resources, UCL Global Governance Institute and UCL Department of Science, Technology, Engineering and Public Policy (UCL STEaPP).

The seminar series offers both academics, students and members of the public the chance to engage critically and constructively with current research from staff members, industry speakers and visiting researchers.



Image (c) UCL-Energy 'The Paris Agreement - What does it mean for Africa?'

This series was in addition to UCL-Energy hosting the 5th Cycle for the UCL and French Embassy event collaboration under the auspices of the long-established relationship between the French Embassy's Science and Technology Department and UCL's Grand Challenges programme (pg 27).

The first two events of the three-part series focused on the lead up and the effect of the COP21 Paris agreement (pg 27). The third and final event is scheduled to take place in September 2016 and will focus on energy and climate collaboration in Europe.

The UCL-Energy YouTube channel hosts the seminar recordings, alumni videos and videos about ongoing projects. In 2015/16 academic year subscribers increased by 32% with over 30,000 video views and viewers watching from 29 different countries including India, Australia, the United States, Singapore, Brazil and the United Arab Emirates.

The UCL-Energy blog also experienced continued success during the 2015/16 academic year. There were 23 posts contributed by UCL-Energy academics, researchers and students with topics ranging from the impact of COP21, the 2016 London Mayoral Election, and International Women's Day.

UCL-Energy staff appeared in over 50 national and international publications during the year. Staff members wrote guest articles and blogs for major publications as well as being featured commentators on current events relating to energy (pg 30).

With over 3,000 subscribers to the UCL-Energy newsletter and 5,486 unique users following @UCL_Energy on twitter, UCL-Energy looks forward to continuing to expand its engagement and outreach in 2016/2017.

UCL-Energy 2015/16 Events

06 October 2015 seminar: Dr Henri Waisman, Coordinator, Deep Decarbonization Pathways Project, Institute for Sustainable Development and International Relations (IDDRI)

'The Deep Decarbonization Pathways Project (DDPP): Can country-led decarbonisation efforts help achieve a 2°C pathway?'

20 October 2015 UCL, UKERC & the French Embassy present: 'Global Energy, Global Climate'

01 December 2015 seminar: John Cunneen, founding Executive Director and Member of the Authority for Electricity Regulation, Oman
'Where are we now? Reflections on UK Energy Regulation from 1920 to 2015'

02 February 2016 seminar: Dr Laura Diaz Anadon, Visiting Senior Lecturer, UCL STEaPP
'Energy technology innovation and the role of governments: state of the art, new developments, and key questions'

01 March 2016 joint UCL-Energy, UCL Institute of Sustainable Resources and UCL Global Governance Institute Seminar: Dr Tom Pegram, Lecturer in Global Governance
'Wanted: a third generation of global governance research'

23 March 2016 UCL-Energy, UCL STEaPP, CDKN and the French Embassy present: 'The Paris Agreement - What does it mean for Africa?'

05 April 2016 seminar: Julie Hirigoyen, Chief Executive of UK-Green Building Council
'Energy efficiency in non-domestic buildings: Are we on target for 2050?'

03 May 2016 seminar: Dr Mark Barrett, lecturer UCL-Energy and Dr Ed Sharp, research associate UCL-Energy
'Developing secure, environmentally sound city and national energy systems'

24 May 2016 seminar: Dr Tristan Smith, Reader in Energy and Transport, UCL-Energy and David Balston, Director Safety & Environment, Chamber of Shipping
'International shipping GHG policy post-Paris Agreement, recent developments at IMO MEPC and their implications for the sector'

02 June 2016 joint UCL-Energy and UCL STEaPP seminar: Joe Aldy, Associate Professor of Public Policy, Harvard Kennedy School
'Evaluating the Paris Agreement's Mitigation Pledges'

09 June 2016 UCL-Energy and The Edge Expert Panel Discussion: 'EU Referendum: Environmental & climate change consequences for the built environment'

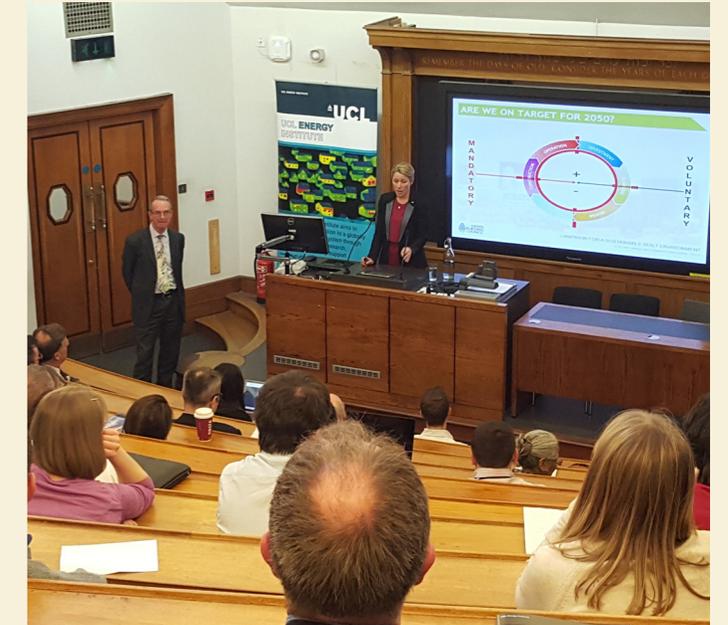


Image (c) UCL-Energy: Julie Hirigoyen, UK-Green Building Council, public lecture

UCL-Energy Global Presence

UCL-Energy's global presence continued to expand in 2015/16. With over a dozen nationalities making up UCL-Energy staff and students, the Institute cultivates an international perspective both within itself and with its global outreach, through research and online engagement.

According to Google analytics, during the past academic year the UCL-Energy website had nearly 40,000 visitors from 200 countries. Over 60% of website traffic came from international locations with the top ten countries outside the UK being the United States, India, Germany, France, Indonesia, China, Italy, Greece and Nigeria.

UCL-Energy research has a significant impact on international policy and strategy. Some of the Institute's internationally focused active grants include: Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions (SAMSET) and INSIGHT: the European Scientific multidisciplinary 'think tank'.

In June 2016, UCL-Energy's shipping group was awarded a new project to advise the Danish Shipowners Association (DSA) on CO2 strategy and targets. The DSA includes not only the world's biggest shipping company (AP M Maersk), but several world leading ship-owners including Norden, Torm, and DFDS. It is a great validation of the group's global reputation and credibility.

Throughout the academic year a number of senior UCL-Energy staff were heavily involved with work on the International Energy Agency's Energy in Buildings and Communities Programme (IEA-EBC) annexes. In December 2015 IEA-EBC approved the development of Annex 70 with RCUK Centre for Energy Epidemiology researchers based at UCL-Energy named as leads. The Annex will be developed in collaboration with government, research institutions and industry from around the globe and will comprise a major research activity on population level energy demand in buildings.

In March 2016, UCL-Energy hosted the IEA-EBC Annex 69 international meeting. This was the first meeting for the working phase of IEA Annex 69 on 'Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings'. UCL-Energy's Buildings group are playing a leading role in this Annex in the development of new thermal comfort models. The meeting was attended by working groups from all over the world, including China, the United States, Europe, Japan and Korea.



UCL-Energy director Professor Bob Lowe speaks at UK-Japan event: The Past and Future Earth

This event was hosted by the Ritsumeikan University in March 2016 at the Japanese Embassy in London. It was made possible with support by Japan Society for the Promotion of Science, Japanese Chamber of Commerce and Industry in the UK, and Japan External Trade Organisation (JETRO) London.

The aim of the event was to promote research collaboration and academic interaction between Japan and the UK. The presentations focused on climate change and the importance of creating a sustainable future "beyond borders." The event also provided a forum for researchers from the two nations to discuss current environmental issues and international goals for creating a society capable of co-existing sustainably with nature.

UCL-Energy and COP 21

In December, the 2015 Paris Climate Conference, also known as COP21, was held to address the serious issue of global warming. At the end of this conference an agreement was reached by 195 nations to drive actions and investment towards a low carbon, resilient and sustainable future and to focus efforts to limit the temperature increase to 1.5°C.

In the lead up to this conference UCL-Energy organised a series of high profile public events, focusing on issues relating to COP21 and promoting topical work from staff and students in the form of blogs, academic articles, media appearances, policy briefs and ongoing projects. A full round up of all these items and reaction pieces to the final Paris Agreement are available on the UCL-Energy website.

In October 2015, UCL-Energy hosted a seminar on The Deep Decarbonization Pathways Project (DDPP). In this seminar Dr Henri Waisman, Coordinator of the DDPP, presented key findings from the ground breaking DDPP initiative and what this meant for the COP21 process. He also reflected on the benefits and challenges of this country-led initiative, and the need for expanding Deep Decarbonization Pathways analysis internationally.

Also in October 2015, UCL-Energy made global climate the focus of its first event in the three part series organised jointly by UCL-Energy and the French Embassy, under the auspices of the long-established relationship between the French Embassy's Science and Technology Department and UCL's Grand Challenges. This event, titled 'Global Energy, Global Climate' launched the book *Global Energy*. Internationally recognised speakers from UCL-Energy, UCL Institute for Sustainable Resources, UKERC, Imperial College and CIRED discussed energy and climate solutions, in the context of the evidence laid out in the book.

In March 2016, UCL-Energy hosted the second event of

the French Embassy series focussing on the repercussions of the Paris Agreement: 'The Paris Agreement - What does it mean for Africa?'. The event addressed questions such as: Does the Paris Agreement satisfy the African negotiations position? And, how can we move from political agreement to concrete action? There was a special focus on the African Renewable Energy Initiative (AREI), nationally determined contributions and adaptation communications.

The event recordings are available at: bit.ly/1maxM4u



Shipping under scrutiny at COP21, UCL-Energy Reader Dr Tristan Smith participated in COP21 side event.

The Path for Low Carbon Shipping event considered what options are available to put shipping on a sustainable path, and how a successful COP agreement can contribute to this objective. This was the only COP21 side-event that focused on shipping.

Read about Tristan's article in The Conversation discussing the omission of shipping and aviation from the Paris Agreement on page 30.

Selected UCL-Energy Publications 2015/16

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Daly H., K. Scott, N. Strachan and J. Barrett (2015), The indirect CO2 emission implications of energy system pathways: Linking IO and TIMES models for the UK, *Environmental Science & Technology*, 49(17): 10701-10709.

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Ivan Korolija, and Richard Greenough 'Modelling the Influence of Climate on the Performance of the Organic Rankine Cycle for Industrial Waste Heat Recovery' *Energies* 9, no. 5: 335, first published on May 5, 2016 doi:10.3390/en9050335

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Lemaire X., Kerr D. (2016) Waste Management - Innovative Solutions for African Municipalities, SAMSET Policy Brief. <http://samsetproject.net/>

Li, Francis G.N., Trutnevyte, Evelina, Strachan, Neil, 2015, A review of socio-technical energy transition (STET) models, *Technological Forecasting and Social Change*, Volume 100, Pages 290-305.

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UCL-Energy in the Media 2015/16

'Estimated cost of Hinkley Point C nuclear plant rises to £37bn', The Guardian

Dr Paul Dorfman, Honorary Senior Research Associate, comments on the increase to the EDF plan for Hinkley Point C nuclear power plant and it's reflections on possible uncertainty of the project, particularly in light of Brexit. Article published on 7 July 2016.

'Ride-sharing: The solution to our transport woes?', InMotion

Maria Kamargianni, head of the UCL-Energy Urban Transport and Energy Group, discusses the availability of smartphone apps to make ride-sharing more accessible. Article published 4 July 2016.

'Non-domestic energy efficiency – policy design principles', Association for the Conservation of Energy

Peter Mallaburn, Senior Research Associate for ACE, outlines the state of knowledge on energy efficiency and identifies some key policy principles around which a new energy efficiency programme could develop. Published on 24 May 2016.

'From pirates to power plays, interactive map shows how Australia relies on ships', The Sydney Morning Herald

This article uses the interactive map created by UCL-Energy's shipping group to look at Australia's reliance on shipping for imports and exports and the political ties created through trade. Article published 26 April 2016.

Since [Shipmap.org](#) went live in April 2016, it has made over

500k twitter impressions and has been tweeted about all over the world, including a direct tweet from Bill Gates.

This interactive visualisation was picked up by a number of international media sources including The Guardian, Daily Mail, China Dialogue, Motherboard and VOX.

'New report states wind technology can yield up to 60% fuel savings for ships', Carbon War Room

UCL-Energy shipping group and the Carbon War Room published a paper reviewing the opportunities and barriers to the adoption of wind technology in the international shipping industry. This article reviewing the report was published on 19 February 2016.

'Kite Power', BBC's The One Show

Andrew Smith, UCL-Energy Research Associate, appeared on The One Show, where he discussed some of the opportunities and the challenges of kite power and how kite power may benefit other countries that don't have the same optimum off-shore environments of Britain. Aired 8 February 2016.

'How green is your skyscraper? Why the most sustainable buildings might be low-rise', City Metric

Professor Phil Steadman wrote this article published on 12 January 2016 discussing his new research project conducted in association with Create Street that will try to discover if high-rise buildings are more energy-intensive than equivalent low-rise buildings.

'Two crucial omissions that could jeopardise Paris climate hopes', The Conversation

Dr Tristan Smith, UCL-Energy Reader in Energy and Shipping, wrote an article following the November Paris COP21, discussing that the omission of shipping and aviation represents the gaps between the reality of the climate situation and the text of the Paris Agreement. Published on 15 December 2015.

'How a global solar alliance can help developing countries', The Conversation

Xavier Lemaire, UCL-Energy Senior Research Associate, wrote an article outlining the benefits of a solar alliance for emerging and developing countries and how the decarbonisation of the electricity sector may be an economic necessity. Published 4 December 2015.

'Why we need a 'space race' approach to saving the planet', The Conversation

Christopher Grainger, UCL-Energy doctoral candidate, authored an article discussing how the economic model of the historic space race remains the best way to make 'startling technical leaps forward and solve mankind's greatest challenges'. Article published 2 December 2015.

All UCL-Energy staff and student media appearances are available online: bit.ly/2b5noHw

The UCL-Energy Team 2015/16



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