THE BARTLETT
ENERGY INSTITUTE
ANNUAL REVIEW 2019

UCL

UCL Energy Institute
2019 Review

The UCL Energy Institute delivers world-leading learning, research and policy support on the challenges of climate change and energy security. We are part of The Bartlett: UCL's global faculty of the built environment.

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> @UCL_Energy

London Building Stock Model

Director's Introduction

Prof Neil Strachan reflects on the relevance of our work helping to build a globally sustainable energy system in the current climate of energy research.

Our Annual Review gives us an opportunity to look back and appreciate how far we have come.

UCL Energy Institute celebrated its 10th anniversary on 21 May 2019. In ten years we have grown from a cadre of 5 staff to over 100 faculty, staff and PhD students, plus a further large and vibrant cohort of MSc students. We continue to meet our goal to be the UK's leading research and teaching centre on energy demand and energy systems, and a leading international player in these fields.

We have now truly completed the target setting process for the energy transition. The UK's game-changing decision in June 2019 to legislate a Net Zero emissions target by 2050 (becoming the first G20 economy to do so) emphasises that every interlinked sector in the energy system must decarbonise, and that fundamental change in energy service demands is essential to meeting such deep reductions.

Now, we are in the fast-moving, high-stakes and path-dependent implementation phase of the energy transition. The UK formally left the EU on 31 January 2020, and now with a new stable government it must adapt to the risks and opportunities this creates, including balancing energy decarbonisation, security and costs while trying to help UK energy companies win the races for the new technologies, services and business models in a low carbon energy system

The role of consumers and society in the energy transition is increasingly coming to the fore, with energy and the environment becoming a top tier issue in the UK general election for the first time. The Extinction Rebellion protests remind us that many in our society are pushing hard for even more radical changes in the way we supply and consume energy, producing a very real shift in the debate and media framing. And with the UK hosting the critical COP26 conference in Glasgow, the eyes of the world will be looking for evidence based and practical action to enable a step-change in the pace and scale of energy decarbonisation.

With this exciting, challenging and sometimes unnerving backdrop in mind, our vision - to observe, analyse, interpret and influence energy use and energy systems to help to build a globally sustainable energy system - could not be more relevant and important.

This review outlines our key roles in major UK energy research collaboration centres and our presence in key EU funded research consortiums, as well as our major outputs.

Our teaching programmes also continue to go from strength to strength - our students are diffusing into key positions in industry, government and international organisations as they make it their careers to drive this decadal energy transition challenge.

Please read on to discover highlights in our research, teaching and outreach, and get in touch with us as funders, collaborators, colleagues and potential students.

Prof Neil Strachan, Director

Prof Paul Ruyssevelt, Deputy Director

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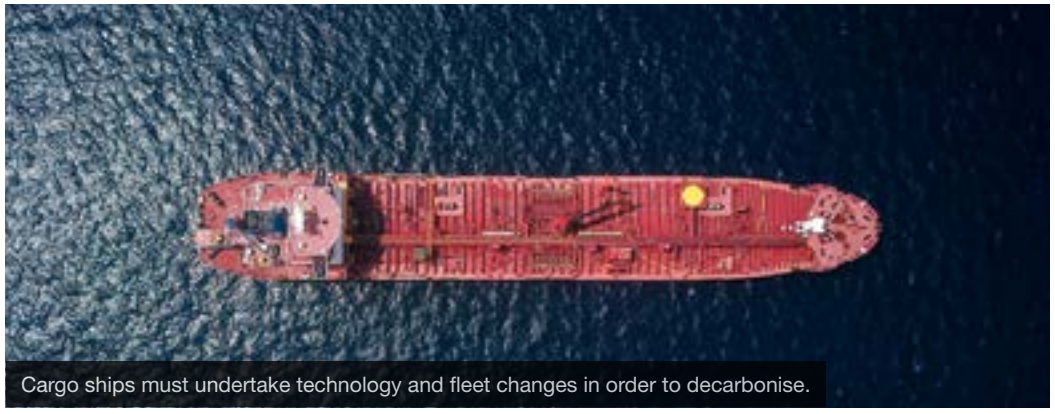
Cutting shipping emissions with responsible lending

Eleven leading international banks – including Citi, DNB and Société Générale – have promised to include climate considerations when lending to the shipping industry under Poseidon Principles.



Cargo ships must undertake technology and fleet changes in order to decarbonise.

The shipping industry accounts for up to 2.5% of global emissions. Shipping emissions were unaffected by international climate targets until 2018, when the International Maritime Organisation made a monumental agreement to halve shipping Green House Gas emissions by 2050.

To decarbonise shipping to this extent, fleets will need upgrades to shift away from dependency on fossil fuels. And with upgrades, comes cost. Enter the Poseidon Principles.

In June 2019 the Global Maritime Forum launched the Poseidon Principles to enable financial institutions to align their ship finance portfolios with responsible environmental behaviour and incentivise international shipping's decarbonisation.

The Poseidon Principles are a global framework for assessing and disclosing the climate alignment of financial institutions' shipping portfolios. They establish a common, global baseline to quantitatively assess and disclose whether financial institutions' lending portfolios are in line with climate goals, becoming an important tool to support responsible decision-making.

Dr Tristan Smith, Reader in Energy and Shipping, UCL Energy Institute, explains why the Principles are so important for the banks:

> "Shipping will undertake a rapid technology and fleet change as it shifts away from fossil fuels in order to decarbonise, exposing the banks to risk. If banks discover too late that they have invested in ships that will become undesirable or even obsolete because of this change, they could see valuation write-downs or even defaults in their portfolio.
>
> The Poseidon Principles are a tool to demonstrate that these key stakeholders are acting responsibly and allow them to compare climate risk with each other, but also a tool that will allow them to manage critical investment risks, retaining their crucial role in providing the liquidity that enables international trade."

Transactive Energy: Peer-to-peer energy trading in Columbia

UCL-Energy researchers are collaborating with researchers in Universidad EIA to set up a peer-to-peer energy trading trial in Medellin, Colombia.

Peer-to-peer energy markets face a critical challenge: How do we get people to manage and trade their own energy? Moreover, how do we handle the shift from a centralized system led by large companies to a distributed one led by the end-users?

To answer these questions, researchers from UCL and Universidad EIA are setting up a peer-to-peer pilot in Medellin, Colombia, working with Empresas Públicas de Medellin (EPM), one of the largest utilities in Latin America, and ERCO Energia, one of the most important rooftop PV installers in Colombia.

In Medellin, many energy users, especially those living in high-rise buildings, are not able to generate their own electricity. Peer-to-peer could allow these users to buy energy from other people in the city, whilst also taking into account particular energy attributes: how green it is, what the social impact is, who owns the generation infrastructure, or where it is generated within the city.

The peer-to-peer pilot will group 14 residential users with different income levels located in the city of Medellin, each one of them independently connected to EPM's distribution network. Low-income users will have solar panels installed on their rooftops and will trade energy with high-income consumers and prosumers. In addition to residential users, the pilot will include the installation of a combined solar and storage solution in a community centre. This centre is located in Comuna 13, a district of Medellin where grassroots and youth movements use hip-hop to resist violence and to create a local identity.

The project started in April 2019 and will end in October 2020.

Peer-to-peer energy trading workshop

CO_2 and cognitive performance

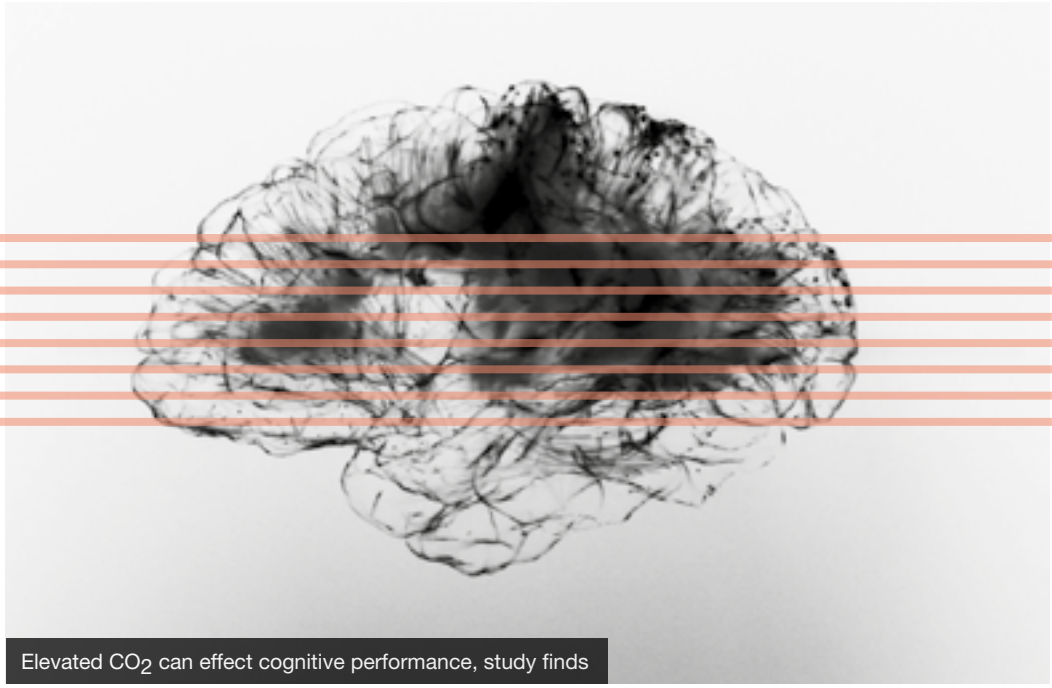
Researchers from the UCL Energy Institute win medal for their paper on how CO2 Levels effect cognitive performance.

Researchers from our Building Research theme won the Napier Shaw Bronze Medal, awarded by CIBSE (Chartered Institution of Building Services Engineers) for the best research paper published in their journal.

The paper, entitled 'Possible future impacts of elevated levels of atmospheric CO_2 on human cognitive performance and on the design and operation of ventilation systems in buildings' was published in the CIBSE journal in July 2018. Its authors were Professor Robert Lowe (lead author), Dr Gesche Huebner, and Professor Tadj Oreszczyn.

The research received widespread media attention later that year, when it was picked up by media organisations around the world. It looked at the effect of predicted higher atmospheric CO_2 concentrations on the cognitive performance of people in buildings by the end of the century. It also assessed the impact this may have on building ventilation systems and energy use, showing that a lot more work is needed to understand the problem.

The Napier Shaw Bronze Medal is awarded each year by CIBSE in recognition of the highest rated research in the building services industry published by their journal, Building Services Engineering Research and Technology.



Elevated CO_2 can effect cognitive performance, study finds

Modelling Net Zero

UCL Energy Institute undertook global analysis of how the UK can take a leadership role to limiting global temperature rise to well below 2°C for the Committee on Climate Change.

In May 2019 a much-anticipated report by the Committee on Climate Change (CCC) was published, advising government of the need to set a target of net-zero greenhouse gas (GHG) emissions from the UK by 2050 and, crucially, setting out how this can be achieved.

The analysis is clear that the Paris Agreement targets can only be achieved if all regions move to a low-carbon pathway. More rapid emissions reductions in the UK and other high-ambition countries could provide additional emissions "headroom" for developing countries, giving them some more time to ramp up their mitigation efforts. It could also drive innovation more rapidly across a range of low-carbon technologies, thereby benefitting countries that are earlier in transitioning to a net-zero emissions economy.

The research finds that pursuing the 1.5°C target is hugely challenging and can only be achieved through a stronger focus on reducing demand for energy services, such as heating and transport, undertaking large-scale afforestation, and more in-depth research on how hard-to-treat sectors such as industrial process emissions and international transport can be fully decarbonised.

The report was undertaken by a UCL Energy Institute research team that included Steve Pye, James Price, Jen Cronin, Isabella Butnar and Daniel Welsby. Commenting on the publication, Steve Pye said:

> "At a time when climate change is firmly in the public consciousness, this analysis by the CCC confirms the need for more radical action.
>
> It is imperative that the Government now takes this momentum forward, and puts in place a radical and enduring policy package that will deliver the necessary reductions now and in the future, engages society in the process, and firmly establishes a leadership role to help drive global action."

Wind turbine and photo volatics

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Students working together

Economics and Policy of Energy and the Environment MSc

We're challenging the most able students to develop robust knowledge and experience of architectural, environmental and structural design and engineering in buildings.

About the programme

Developed and conducted jointly with UCL Institute for Sustainable Resources, the Economics and Policy of Energy and the Environment (EPEE) MSc equips its graduates to grasp issues such as climate change, resource exhaustion, energy poverty and energy security, and become sustainability leaders and entrepreneurs in business, policy-making and research.


EPEE MSc students attending a lecture

This programme is taught by a world-class faculty with a breadth of industrial and academic knowledge. We provide a broad and grounded understanding of energy and climate change through:

- Research concepts and methods
- Environmental and resource economics
- Modelling, methods and scenarios
- Environmental measurement, assessment and law
- Global economics and political economy

What our students say

> "Through the EPEE course I learned to understand the relation between economic theory, legislation and policy, allowing me to explain implications of legislative changes more clearly to my clients. Additionally, I wrote my dissertation on corporate climate change risk in the CDP (Carbon Disclosure Project) and I am now advising a client on their disclosure to the CDP."
>
> **Cathy Granneman, EPEE MSc, 2019**


Dr Ilkka Keppo gives an EPEE lecture

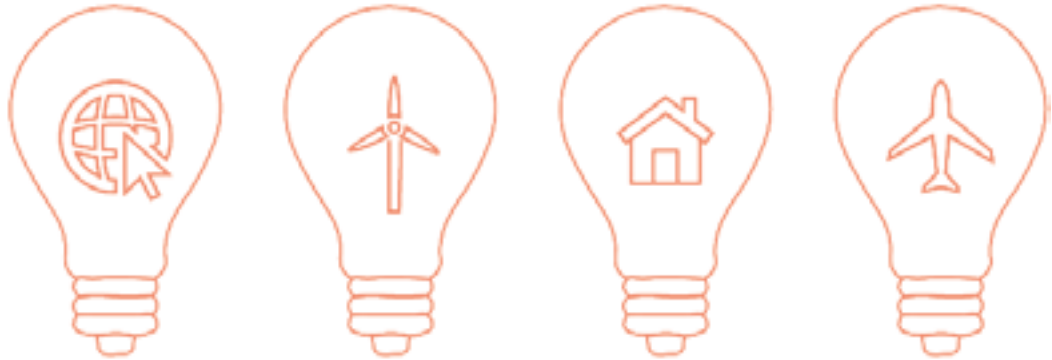
Key information

- London, Bloomsbury
- Full-time (one year), Flexible (two to five years)
- Programme lead: Dr Lorenzo Lotti

Student attending a lecture

Energy Systems and Data Analytics MSc

This MSc programme provides an academically leading and industrially relevant study of energy systems through the lens of data analytics.



About the programme

Energy Systems and Data Analytics (ESDA) MSc is the first programme of its kind in the UK, combining the study of Energy Systems with Data Science. Through this programme, we aim to equip students with a multi-sector, multi-vector understanding of Energy Systems, while developing advanced statistical and machine learning skills and getting practical experience of data analysis.

The programme is aimed at students with a quantitative background who have an interest in energy and are motivated by the use of data science to solve sustainability problems. We focus on skills sought after by the industry, enabling students to evolve as leaders and innovators in the energy sector, from established large scale utilities and data science companies to innovative start-ups.

This advanced degree programme is designed to provide a broad understanding of energy systems, statistics, programming, energy use in the built environment, energy use in the transport sector and the role of data and advanced analytics in solving relevant sustainability problems.

What our students say

> “The ESDA MSc is one of a kind. It offers the rigour of statistics to understand the promise and perils of data analytics and machine learning, while providing you a holistic view of the energy systems: transport, built environment and the electricity system.”
>
> **Simon Perez Arango, ESDA MSc, 2019**

Key information

- London, Bloomsbury
- Full-time (one year), Part-time (two years), Flexible (two to five years)
- Programme lead: Dr Aidan O’Sullivan

Student insight

We talked to Ayrton Bourn, Energy Systems and Data Analytics Alumni 2019, about what brought him to study this Master's at UCL, his experiences on the programme and what he plans to do next.

Ayrton Bourn studied the ESDA MSc from 2018-2019

What was your academic background before coming to UCL and joining the Energy Systems and Data Analytics MSc?

I studied Chemical Engineering at the University of Sheffield, focusing on the application of carbon capture in heavy industry.

What inspired you to pursue Energy Systems and Data Analytics?

As an undergraduate I carried out a research project quantifying how renewables were reducing wholesale prices for electricity, this gave me a small window into the vast but exciting field of energy systems modelling. Afterwards I was looking for a programme like ESDA but nowhere in the UK appeared to be running one, when the course was then created I knew I had to apply.

Why did you choose UCL?

My previously studies had felt very siloed, studying at The Bartlett offered the opportunity to remedy this and place my work in the context of wider changes across society and the energy sector. I was also drawn by the strong connections BSEER has with policy makers and industry, as well as the quality and volume of research the department outputs.

What have you enjoyed most about your Master's programme?

Alongside the main curriculum a series of lectures were organised around the theme 'Energy Innovators', these included talks from several heads of data science at energy companies and open-source organisations. Hearing from professionals driving change in the industry through similar techniques to what we were learning was particularly motivating.

> "ESDA MSc is one of a kind in its teaching of data analysis, statistics and energy modelling, framed within a whole systems approach for the energy sector."

What was your dissertation topic?

My dissertation topic was on applying deep learning techniques to short-term price forecasting in the UK imbalance market, which is used to ensure that the supply of electricity perfectly matches demand. This involved a combination of modelling physical aspects of the UK system such as the generation from renewable sources, as well as market based effects like firm concentration.

What top skills have you gained from the programme?

Alongside providing exposure to a very wide range of different tools that can be used for energy data science, the course also added a lot of depth in particular to statistical methods for spatial and time series analysis. There was also a strong focus on collaborative programming, which was something I hadn't done much of before but since graduating has become increasingly useful.

Would you recommend the MSc to other students?

100%. The course is one of a kind in terms of teaching the core components of data analysis, statistics and energy modelling, but more importantly this is framed within a whole systems approach for the energy sector. I'd recommend it for anyone interested in turning industry's large volumes of under-utilised data into models and insights that can help further the energy transition.

Do you have any advice for prospective students interested in joining the same programme?

I would recommend they look into the areas of the energy sector that they're particularly keen to make changes in and research how data science is being used to improve them. The programme will then give you the skills you need to answer your own questions and a great environment to work within.

What are you doing now?

At the end of my dissertation it felt as though I'd only scratched the surface of the topic so I applied for a PhD within the UCL Energy & AI research group and have been working within it since September. The MSc laid the foundation for the work I'm doing now and I wouldn't be doing it without it.

Finally, what do you plan to do after your PhD?

It feels a very long way off right now but I hope to be using data science to help find solutions for problems associated with energy production and consumption. I'm particularly interested in how energy analytics could be used to reduce uncertainty around renewable forecasting and help increase their share of supply in the UK and beyond.

Doctoral research - MPhil / PhD

We select the best students for first-class training and prepare them to launch careers as the energy pioneers of tomorrow.

About the programme

UCL Energy Institute delivers world-leading learning, research and policy support on the challenges of climate change and energy security. Our multidisciplinary research programme and strong industry links provide excellent foundation for PhD study. Our graduates are employed by the world's foremost academic, industry and governmental institutions.

Our PhD candidates work alongside experienced researchers in a dynamic, multi-disciplinary environment. They are core to the Institute's research activities, contributing to a wide range of ongoing research and consultancy projects, including being named authors on a number of national and international papers.

Our core research themes are independent but also interact, resulting in innovative approaches to energy-related problems. At the end of their PhD candidates will produce a thesis on an energy topic of their choice, demonstrating capacity to pursue original research based upon a good understanding of the research techniques and concepts appropriate to the discipline.

At the end of their studies, students are awarded a UCL Energy Institute Research Degree with a sub category: Built Environment; Economics; Engineering; Health; Human Dimensions; Policy; Resources; Transport.

Key information

> London, Bloomsbury
> Full time - Three years
> Part-time - Five years

What our students say

"Having completed a MSc in Public Policy, I decided I wanted to apply the knowledge I'd gained of behavioural public policy at PhD level. I applied and was fortunately accepted on the LoLo CDT and completed a PhD in how behavioural science could be applied to boost domestic consumer uptake of demand-side response tariffs and products.

About a year before I finished, I saw that the British Energy regulator, Ofgem, was advertising for someone with the same experience and skill set I'd been developing over my Masters and then PhD. This is the role that I now work in. I feel very confident that my PhD played a major role in making sure I was qualified for the role and hope that it will help me progress with my career in future too."

Dr Moira Nicholson,
Senior Behavioral Insights Practitioner, Ofgem

Celebrating the latest PhD graduations in August 2019 with Director Prof Neil Strachan

Omotola Adeoye

Bridging the gap between electricity demand and supply in West Africa: The role of renewable energy and interconnections

The electricity sector of West African countries is experiencing several challenges including: low electricity access rates, high usage of oil generators, frequent power outages and high electricity tariff rates.

In an effort to solve these challenges, the West African Power Pool aims to interconnect all fourteen countries in the region and develop regional power plants to benefit multiple countries.

My research evaluates the role of renewable energy sources and interconnections in providing access to affordable and reliable electricity supply.

This is achieved by first developing an electricity demand model to generate hourly demand in the year 2016 and 2030. Next, a multi-regional economic dispatch model of West Africa's interconnected electricity network is developed in PLEXOS, using the simulated 2030 hourly demand dataset.

The methodology presented in my research provides a framework that captures several unique characteristics of electricity demand consumption in developing countries.

Therefore, it can be applicable to developing countries with modelling challenges such as: scarce historical hourly demand data, electricity supply-demand gap, transition to modern technologies, and urban/rural economic divide.

Furthermore, the results from the dispatch model indicate that the majority of the planned interconnections in the region could be underutilized by 2030. Thereby providing an opportunity to integrate large scale grid-connected renewable energy sources.

Jonno Borne

Understanding the vulnerability of power-grids to cascading failures using complex-network analysis

Electrical blackouts may be exciting for 10 minutes or so. Still, they can cause real physical damage to power infrastructure and cause the economy to take a substantial hit, a 2003 blackout in New York and Eastern Canada affected 50 million people caused $5 billion of damage. Whats more blackouts can be used as a tool in conflict. During the winter of 2015, a group of hackers shut down parts of the grid around Kyiv in the Ukraine, causing a loss of power to 200 thousand people in the middle of winter.

My PhD investigates three areas:

> How targeted attacks on power networks cause cascading blackouts
> What methods we can use to understand network robustness
> How to defend against targeted attacks

These finding can be used to ensure a stable power grid for an increasingly decentralised and decarbonised future.

Energy Resilience in the Built Environment CDT

The ERBE Centre for Doctoral Training trains future leaders and innovators in the field of energy and the built environment.

The energy system is undergoing a major transition. Low carbon energy sources have an increasing role to play, accommodating them requires new flexibility in the system, and the relationship between energy supply and demand is no longer one-way.

This interaction of people, buildings and energy systems will transform the relationship between supply and demand. Our domestic and non-domestic buildings will no longer be passive consumers of heat and power; instead, our homes and businesses will participate actively in a flexible, integrated, low-carbon supply and demand system that includes buying, selling and storing heat and power. To implement this vision, we need people with a deep understanding of building physics, low-zero carbon technologies and the socio-technical context, to lead and drive change in government, industry, NGOs and academia.

The new EPSRC CDT in Energy Resilience and the Built Environment (ERBE) brings together established energy research centres at Loughborough University (LU) and University College London (UCL) with the Marine and Renewable Energy Ireland (MaREI) Centre. Loughborough and UCL will train at least 50 PhD students through a programme of energy demand research in a whole energy system context.

We build on a decade of experience of high-quality doctoral training to provide a bespoke new PhD programme, including: opportunities to work with leading researchers, projects integrated with industry and a comprehensive skills and development programme. We are centred firmly within the UK's energy research landscape and so all PhDs will have the opportunity to undertake significant, impactful research.

After a successful recruitment process, the aforementioned projects will be running during the 2019-20 academic year. For news about projects running in 2020-21 visit erbecdt.ac.uk.

Buildings

We study multiple facets of buildings and energy use including domestic and non-domestic buildings, smart energy and district-level heating.

What we do

With a new home and an increased focus on the built environment, 2019 has been a year of significant growth and change for the Buildings Theme. We have relocated wto a new home at No.10 Montague St, just off Russell Square, with new facilities for both physical and virtual collaboration.

The move comes with a renewed interest in identifying points of integration across research groups. We are currently structured into four groups:

> The Building Stock Lab
> Physical Characterisation of Buildings
> Smart Energy Research Group
> People Adaptive Comfort and smart Energy

We have major roles in several national scale consortiums programmes:

> Smart Energy Research Laboratory (SERL
> Centre for Research into Energy Demand Solutions (CREDS)
> Energy Revolution Research Consortium (EnergyREV)

Plus a number of other UKRI and related funded programmes and our flagship Energy Resilience and the Built Enviornment (ERBE) Centre for Doctoral Training.

New areas of collaboration are emerging within the Theme at the intersection of groups and projects.

One of these is urban energy systems, ranging in scale from small scale district heating and local energy trading schemes, through community scale systems, to multi-vector smart local and urban scale energy systems.

Understanding energy systems at these scales draws on the expertise of all our groups. It spans understandings of heat, electricity and gas networks and their interactions with the physics of buildings, as well as drawing on one of the Theme's core strengths in understanding socio-technical systems.

Increasingly, we are also addressing the wider impacts of energy systems choices by addressing the multiple benefits of well designed energy systems on human physical and mental health.

This work ranges from understanding the impact of internal temperatues, indoor air quality and radon exposure to occupant health, as well as understanding the impacts of rising indoor and outdoor CO2 levels on occupant cognition.

Utilising data

We now have access to unprecedented amounts of data that can provide important information for planning and evaluating the impact of carbon mitigation measures in the built environment. A number of our researchers have been working on data focussed projects and wider initiatives supporting for the use of data energy and buildings research.

The Smart Energy Research Lab was formed to provide a secure, consistent and trusted channel for researchers to access high-resolution energy data. This year they successfully recruited their first cohort of over 1000 participant households providing their smart meter data for research purposes.

Another data based project is the London Building Stock Model, created for the Greater London Authority (GLA). The model contains data on every domestic and non-domestic building in London out to the M25 motorway. Information includes the sizes of buildings, the premises and activities that they house, the materials from which they are constructed, and their servicing systems. The model is set to become the post-construction data platform for projects by the GLA.

The Energy Data Task Force run by Energy Systems Catapult provides recommendations to the Government and Ofgem on how to enable more effective data sharing and use. It recognises that transparent and accurate data use is fundamental to our economy's future, putting consumers at the heart of developing markets and allowing networks to support innovative business models and technologies. Eoghan McKenna, Paul Ruyssevelt and Michelle Shipworth from our team are involved in the Task Force.

Also working with data, Gesche Huebner edited a Special Collection for Nature Scientific Data on 'Occupant Behaviour in Buildings' - creating open-source datasets on occupant behaviour in buildings.

International engagement

We've been engaging internationally through research projects and engagement with the International Energy Agency (IEA).

The IEA is committed to shape a secure a sustainable energy future for all. Through Technology Collaboration Programmes the IEA gathers academic, governmental business and industrial partners to provide valuable input into the agency's work.

Paul Ruyssevelt Vice-Chairs the Energy in Buildings and Communities TCP, enabling building energy efficiency R&D with its 24 member countries. Led by Ian Hamilton, UCL is Operating Agent for Annex 70 on Building Energy Epidemiology and Gesche Huebner participates in Annex 79 on occupant behaviour-centric building design and operation.

The User Centred Energy Systems TCP, , chaired by David Shipworth, studies areas where people play a critical role in adopting, adapting and applying technologies for energy transition. Led by Alexandra Scheniders, UCL is the operating Agent for it's annex Global Observatory on Peer-to-Peer energy trading.

Other ongoing research projects include those with India, Oman and Colombia. The Indian collaboration saw members of CEPT University in Ahmedabad hosted at UCL for a week-long intensive training programme in urban building stock modelling. Conversely the Colombia collaboration had UCL researchers deliver training on design of peer-to-peer energy systems in Medellin.

London Building Stock Model

Aviation

The Air Transportation Systems Laboratory explores the interaction between air transportation, the economy, and the environment.

What we do

Air transportation is a vital enabler of growth in the economy and quality of life through empowering trade and tourism. At the same time, its large and still growing scale generates undesirable effects, such as air traffic delays and environmental impacts at the local, regional, and global level.

The Air Transportation Systems Laboratory explores the interaction between air transportation, the economy, and the environment. Our work is data-driven, using physical science, econometric, and operations research-based methods. The integrating mechanism is the Aviation Integrated Model (AIM), a unique tool consisting of interlinked modules simulating current and future levels of global airport-to-airport demand, flight schedules, arrival delay, technology uptake, aircraft performance, local and global emissions, aircraft noise, and the related environmental costs and economic benefits under a wide range of policy conditions.

Most recently, our work has focused on the local and global implications of airport capacity expansions.

Electric Aircraft

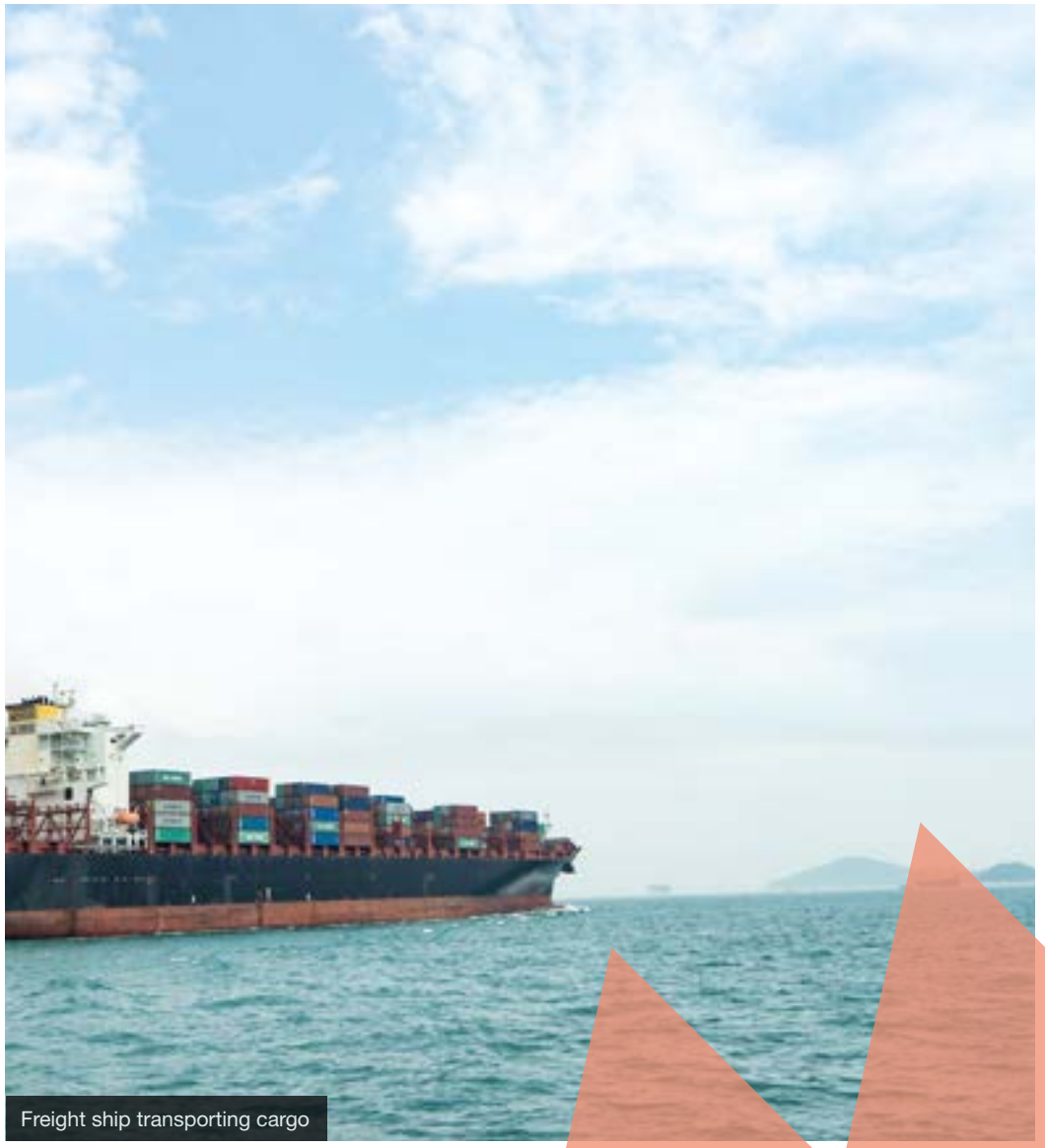
Ever since the Wright brothers' first powered flight in 1903, commercial aircraft have relied on liquid hydrocarbon fuels. However,the need for greenhouse gas emission reductions along with recent progress in battery technology for automobiles has generated strong interest in electric propulsion in aviation.

Our paper in Nature Energy provided a first-order assessment of the energy, economic and environmental implications of all-electric aircraft. We showed that batteries with significantly higher specific energy and lower cost, coupled with further reductions of costs and CO2 intensity of electricity, are necessary for exploiting the full range of economic and environmental benefits provided by all-electric aircraft. A global fleet of all-electric aircraft serving all flights up to a distance of 400–600 nautical miles (741–1,111 km) would demand an equivalent of 0.6–1.7% of worldwide electricity consumption in 2015. Although lifecycle CO2 emissions of all-electric aircraft depend on the power generation mix, all direct combustion emissions and thus direct air pollutants and direct non-CO2 warming impacts would be eliminated.

This research, carried out jointly with the MIT Laboratory of Aviation and the Environment and the University of Southampton's Institute of Sound and Vibration Research, received broad media attention, with extensive coverage in newspapers, e.g., Financial Times, and other media outlets.

Shipping

Our shipping research activity is centred on understanding patterns of energy demand and emissions in shipping and how this can be applied to help shipping transition to a low carbon future.



Freight ship transporting cargo

What we do

Our research group consists of around 15 researchers and PhD students. They work on grant-funded and consultancy projects using using models of the shipping system, shipping big data and qualitative and social science analysis of the policy and commercial structure of the shipping system.

We are world leading on two key areas; using big data to understand trends and drivers of shipping energy demand or emissions and using models to explore what-ifs for future markets and policies.

Through the consultancy vehicle, UMAS, we've delivered analysis to clients from globally in the public and private sector, including UK government

> UN International Maritime Organisation (IMO)
> European Commission
> European Bank of Reconstruction and Development (EBRD)
> Committee on Climate Change (CCC)
> Carbon War Room and Danish Shipowners Association

Reducing climate change and air pollution contibutions

In 2019 the Department for Transport released the Clean Maritime Plan, a strategy document setting a pathway to zero-emission shipping for the UK. The document drew on years of research by UMAS, our Shipping Team's consultancy vehicle, and recent UKRI funded projects led by UCL such as Low Carbon Shipping and Shipping in Changing Climates.

On the role of technologies, for example, the Clean Maritime Plan acknowledges, drawn from UMAS evidence, "that energy efficiency improvements alone will not be sufficient and that the use of alternative fuels (such as hydrogen, ammonia or methanol) will be required", and that "LNG is not estimated to be a substantial part of the fuel mix in the future" and electrification will play a smaller role compared to alternative fuels.

To find out more visit:
u-mas.co.uk/Latest/Post/413/

Zero emission vessels: transition pathways

As a follow on study, in collaboration with Lloyds Register, the study examines three key energy pathways to help identify the actions required for the shipping industry to transition to a zero-carbon future by 2050.

The study indicates that all pathways explored with the study will achieve the IMOs ambition of at least 50% reduction in GHG emissions by 2050 and go beyond to show that zero-carbon is possible, that 2020 – 2030 is the most significant decade stressing the urgency for early action. The evolution of shipping's fuel mix is closely linked to the evolution of the wider energy system, so a clear signal needs to be given to the potential fuel producers.

To find out more visit:
u-mas.co.uk/Latest/Post/407

Mobility as a Service

MaaSLab is an enthusiastic multidisciplinary research team at the forefront of the ever-changing transport sector.

Different modes of Transport in London

What we do

We focus on urban and inter-urban transport exploring new mobility services, such as shared-mobility, on-demand services, automated vehicles, drones and flying cars, and new mobility concepts, such as Mobility as a Service in developed and developing countries. Our expertise is in transport and behavioural models, survey design and innovative data collection techniques, big data handling, GIS, data visualization and new mobility service design.

MaaSLab has several research projects on the aforementioned topics, while it works closely with the industry and public authorities to make sure that the innovative solutions and methods are utilized in real-life and have an impact on society.

HARMONY

2019 saw us launch the new HARMONY project funded by the European Commission through Horizon2020.

Against the background of expanding urbanisation and evolving transport challenges, HARMONY will support public authorities and service providers in transport and spatial planning. HARMONY envisages the development of a new generation of harmonised spatial and multimodal transport planning tools which comprehensively model the dynamics of the changing transport sector and spatial organisation, enabling metropolitan area authorities to lead the transition to a low carbon new mobility era in a sustainable manner.

Islands Lab

The Islands Laboratory studies innovative solutions to tackle climate change and assess possible scenarios for disasters risk reduction and resilience

What we do

We are a unique group, providing information alonside an electronic toolbox to analyse and interpret islands data and assess sustainable solutions through innovative integrated complex systems modelling.

The lab has 13 active researchers and many collaborators. The highly interdisciplinary lab has researchers with backgrounds from mathematics, economics, power engineering, law, civil engineering and architecture, applying and combining methods across disciplines.

Research includes whole energy system modelling (ISLA model) of island nations, with a current portfolio of more than 400 case studies worldwide; resource nexus modelling (IDA3/5 model) (water-energy-land-food-materials) to inform decision makers on resource use and trade-offs.

In the last year we have analysed more than 400 case studies. We have created partnerships, including one with GLIPSA promoting action to build resilient and sustainable island communities by inspiring leadership, catalysing commitments and facilitating collaboration for all islands.

Islands Laboratory aims to provide:

> Insights and guidance about energy, sustainable use of natural resources for island nations to industry and public sector, decision makers and policies, businesses and investors

> Insights in transforming islands into sustainable circular hubs to accelerate the transition to a circular economy

> Insights and guidance for post-disaster risk management both man-made (e.g. waste) and natural disasters (e.g droughts, heatwaves, floods)

> Training for professionals and students through an interdisciplinary approach to the economics, policies and strategies of energy and sustainable resources from experts in the areas of the energy, environment, circular economy, resource efficiency, governance, disasters risk reduction and management.

Wind turbines on an island

Energy & Artificial Intelligence

We focus on the application of artificial intelligence methods to solve problems in the energy system.

What we do

Recent advances in the field of AI, combined with the greater availability of data in the energy system, have opened up a promising new research area: developing and deploying algorithms that learn through repeated simulation and experience, and have the potential to outperform human decision making, to accelerate the transition to a decarbonised energy system.

We recently established Energy & AI as a research theme, hosting 10 staff and doctoral researchers tackling projects across a range of applications in the energy system, from Artificial Intelligence agents that learn how to schedule grid scale generation assets, to collaborations with energy suppliers developing AI capable of providing individually tailored recommendations at the customer level.

We are strongly method-focused, naturally aligning with the Energy Systems and Data Analytics MSc, with the theme leader, Dr Aidan O'Sullivan, serving as programme lead and running two modules which translate the research going on in the theme to teaching. A number of dissertation projects were supervised within the theme involving collaborations with industrial partners such as Octopus Energy, assessing the impact of their new Time of Use Agile Tariff, and a large project on Industrial Energy Forecasting with Astral Tech.

This year we were awarded a large grant to work with the energy supplier Igloo Energy as part of the BEIS Smart Energy Savings project, conducting what is expected to be the largest customer trial involving smart meter and smart thermostat data, as well as a Grand Challenges Research Fund grant to explore the application of AI to support the Sustainable Development Goals.

We have been very active in the community, giving talks at the Slush tech conference, OFGEM and ENTSOE as well as the International Keynote Address at Australia Energy Week. We launched and ran the Energy Innovators talk series which invited CEOs and founders from startups in the energy space to share their experiences of launching innovative companies in the energy sector.

The theme has also provided advice to the newly established government advisory body, the Centre for Data Ethics and Innovation, while working as part of the design team on an ongoing proposal for an International Centre for AI Energy and Climate Change, which has led to a position paper and a workshop involving government and industry stakeholders.

Energy Systems and Data

Saving energy with AI

The use of AI in healthcare has been championed for some time with personalised medical recommendations tailored to the unique characteristics of individual patients the holy grail of research in the area. Within the energy supply sector, building up an understanding of customer energy consumption patterns (which vary considerably - not just from customer to customer but also from day to day of an individual customer), tailored to the myriad complexities of the individual, is a challenge which AI combined with high resolution data offers the potential to solve.

This collaboration between Igloo Energy and the Energy and AI theme under the BEIS Smart Energy Savings grant is focused on developing an AI agent that takes in disparate information about a customer through an app interface, and, combined with smart meter data and smart thermostat data, makes recommendations tailored to the individual as to how they could better manage their energy consumption.

For example, a customer with an EPC A rated home who has their heating on timer from when they wake up to when they leave the house may be recommended that due to the well-insulated nature of their home they could schedule their heating to turn off half an hour before they leave for work with no noticeable change in thermal comfort.

The AI agent will learn through experience and the effectiveness of responses which recommendations produce the most positive results. The project involves a large scale customer trial of 3000 participants.

Energy Systems

We host the largest academic centre of energy systems modelling knowledge in the UK, with a global reputation.

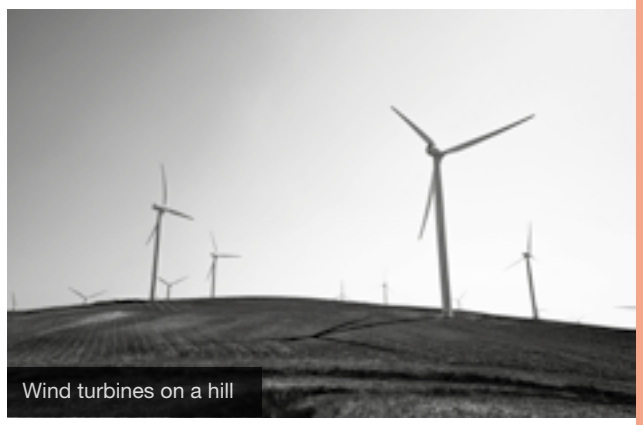
The interdisciplinary team conducts research focusing on the interactions of different energy system elements, across a wide range of geographical scales, using different tools to focus on different elements of the system, such as technology, economy, environment and climate change. Led by Dr Ilkka Keppo, the team has four academic and 15 research staff.

Several major projects concluded during the past year, including UKERC Phase III, where the team worked on the potential roles of different energy vectors in the future energy system, and the UKERC funded BECCS project focuseding on the analysis on the use of CCS with bioenergy.

Contributions to UKERC Phase IV started in May, and work on greenhouse gas removal technologies will also continue under the NERC funded GGR project. RESTLESS, an EPSRC funded project focusing on understanding how energy storage technologies can best be integrated into the UK energy system, was also finalised during the past year, while another project focusing on storage technologies, SPOT-RES, is still ongoing. A large, one year long project ICE, which studied the value of interconnection to the UK energy system, also finished during the year.

We have continued to work on a number of EU funded projects. Under INNOPATHS, activities of the Energy Systems theme have focused on building an EU wide, spatially and temporally detailed electricity system model. DEEDS, in turn, contributed heavily to the highly visible Final Report of the High-Level Panel of the European Decarbonisation Pathways Initiative, and RIPPLES continued its work in studying the energy system transformation required to implement the Paris Agreement. A new Horizon 2020 project, NAVIGATE, will kick off in September, with the aim of improving the state of the art European integrated assessment models in a range of different ways.

During recent years the work within the theme has extended to cover the modelling of socio-technical elements of energy transitions. The scope expanded this year, with several new projects starting. O-STET is a research initiative aiming to bring socio-technical energy transition ideas into use within real world decision-making. Similar tools will also be developed and used in ERRC Plus, which looks especially at local energy systems in the whole systems context. In a slightly different context, the DFID funded PATHWAYS also focuses energy system development pathways, but this time for a large developing country, namely Ethiopia.



Wind turbines on a hill

Modelling European energy transformation

The systems theme and partners recently concluded a 3.5 year long Horizon 2020 funded project REEEM that focused on trying to model in more detail specific elements affecting the transition, in addition to assessing what specific transitions might mean beyond the energy system. The assessment covered a range of aspects, including impacts of transitions on water demand and air pollution, macroeconomic consequences and lifecycle emissions related to the manufacturing of the technologies critical for the transitions.

In addition to contributing to various other tasks, systems theme led a work package focusing on consumers and how they may affect, or be affected by, the energy system transition. This work aimed to understand the preferences of individuals when making certain energy related decisions on the one hand, while assessing the distributional impacts of specific transitions on a subnational level on the other.

The findings indicated that there's heterogeneity across and within countries for these both, suggesting that the related policy measures are also likely to require carefully tailored approaches. Several journal papers are under preparation and will be submitted during the coming months.

Find out more at reeem.org

Carbon risk for fossil fuel producers

With changing investment strategies by funders, policy action by governments, and pressure from civil society, the outlook for fossil fuels is highly uncertain. We have been using different energy modelling tools to help organisations better understand the carbon risks associated with the fossil fuel sector.

Funded by the Inter-American Development Bank (IADB), one such study used the BUEGO model to explore how changing future global demand for oil and the strategies of large incumbent producers, particularly in the Middle East, could affect prospects for Latin American producers over the next 15-20 years. It found that high levels of uncertainty in a declining market could see producers with poor investment prospects, with limited domestic fiscal levers for addressing these risks. Therefore, there is a need for strategies to diversify away from over-reliance on oil revenues for government budgets.

Another research project, in collaboration with Chatham House for DFID, also focused on the carbon risks associated with the development of fossil fuel resources, focusing on new producers in Africa, specifically Tanzania and Ghana. National models were developed to explore the range of future production outlooks, and potential revenue generation, and the implications for the energy systems of these countries. These models were coupled with the global model, TIAM-UCL, which provided information on prospects for exports, and the changing prices under different scenarios. This informed broader conclusions around the need for integrated energy planning, and the recognition of carbon risks when developing energy strategies.

UCL-Energy will continue to develop this set of tools and analysis through a new research project under UKERC Phase 4.

Events

UCL Energy Institute organises events throughout the year to maximise our outreach.

Seminar Series

Each month we host a public seminar at our Bloomsbury base with speakers from across the globe alongside our in-house expertise giving insight on numerous energy challenges.

These seminars are advertised monthly through our website and mailing list, and videos of our events are posted on our YouTube channel.

For the 2018/19 academic year we hosted a number of women in energy working on innovative and inspirational energy research:

> Fuel poverty and invisible energy policy
Dr Catherine Butler, University of Exeter

> Low-carbon aviation: how far can we go?
Dr Lynette Dray, UCL Energy Institute

> Decision-making under uncertainty in the energy sector
Dr Katy Roelich, University of Leeds

Energy 10 – Celebrating 10 years of UCL Energy Institute

Officially launched in June 2009, UCL Energy Institute began as UCL's response to the global challenges of energy security in the 21st century. For the first time at UCL an energy research centre was established with a critical mass to undertake world leading research.

10 years on we have gathered over 100 researchers and postgraduate students working on an extensive research portfolio and generating global impact.

In 2019 we hosted a celebration of our achievements over the past 10 years, 'Energy 10 – The Past present and future of energy research'. Over the course of the evening, we looked back over ten years of changes in energy research and forward to the future of energy research with a series of talks and discussions. This was followed by a reception and exhibition highlighting the broad range of the Institute's work across teaching, research and partnerships.

Commenting on the celebration, our Director Professor Neil Strachan said:

> "It was a very special evening, allowing us to share with our many friends and stakeholders a look back at the journey the UCL Energy Institute has taken to become the UK's leading centre on energy demand and energy systems.
>
> With the global energy transition at a crossroads, the need for our interdisciplinary research, teaching programmes and outreach activities is clearly greater than ever."

Lady Barbara Judge CBE addresses the audience at our Energy 10 event

Partnerships

To ensure our work has real-world impact, most of our work is in partnership with industry, government and other academic bodies.

Consultancy

We deliver consultancy projects to both public and private sector clients, including reports and studies on company data sets, policy recommendations, commissioned research, bespoke design of models and many more.

This year the GLA commissioned a team from UCL Energy Institute and the Centre for Advanced Spatial Analysisto develop the London Buildings Stock Model, to be used by the GLA and London Boroughs to tackle fuel poverty and improve the energy efficiency of the capital's housing stock.

Sponsored PhD

We aim for our doctoral research to be relevant and applicable to the real world. To help address the challenges the sector faces, many of our PhD students have an industry sponsor whom they closely collaborate with on a research question that is relevant to both UCL and the partner.

Our new centre for doctoral training for Energy Resilience and the Built Environment explores the interaction of people, buildings and energy systems and new relationships between energy supply and demand. All students are co-funded by EPSRC and a likeminded external partner.

International policy development

We are leading two Annexes within the Technology Collaboration Programme of the International Energy Agency.

The Building Energy Epidemiology Annex focuses on the analysis of real building energy use at scale and the emerging field of energy epidemiology. The programme supports member countries in the development of realistic transition pathways to steep reductions in energy use and carbon emissions associated with their buildings.

The Global Observatory is a forum for international collaboration to understand the policy, regulatory, social and technological conditions necessary to support the wider deployment of peer-to-peer, community self-consumption and transactive energy models.

Knowledge transfer

To transfer knowledge between UCL and external organisations, we encourage our staff and students to take on work placements in industry and government.

This year, Research Associate Dr George Bennet is on a placement at the Department for Business, Energy and Industrial Strategy (BEIS) in the Science & Innovation for Climate and Energy (SICE) group on the topic of Low Carbon Heating. SICE is responsible for providing the knowledge and research base on which policy and modelling groups within BEIS rely.

This is a mutually beneficial way to collaborate with policy-makers working on the future of building regulations, Energy Company Obligation (ECO), Standard Assessment Procedure (SAP), and the Renewable Heat Incentive.

George distils and communicates UCL knowledge and research in an actionable way to contribute to this process whilst it is a valuable learning opportunity for him regarding daily policy-making.

Staff list

Management & Administration

Neil Strachan
Director

Paul Ruyssevelt
Deputy Director

Catherine Bridge
Institute Administrator

Velvet Young
Communications Administrator

Research & Academic

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Domagoj Baresic
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Manos Chaniotakis
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Lai Fong Chiu
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Charlotte Johnson
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Honorary Senior Research Fellow

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London Building Stock Model