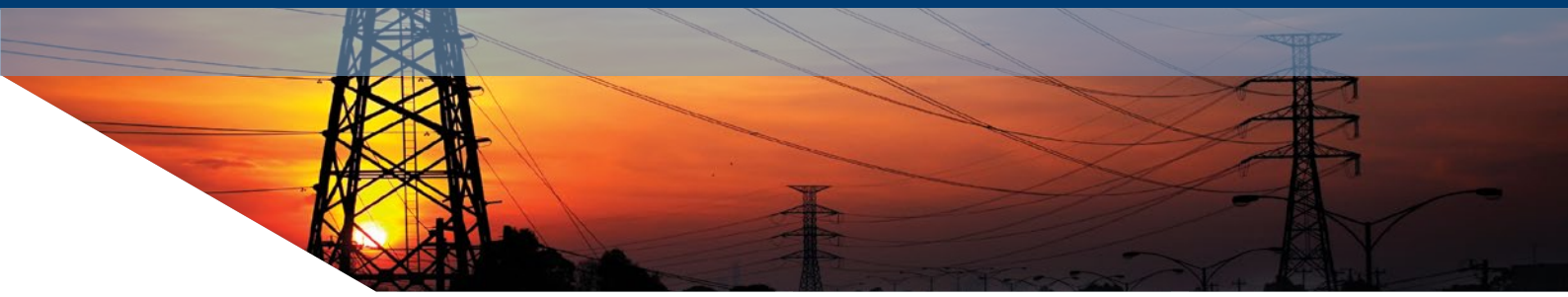
Imperial College London

Energy Futures Lab

Energy Infrastructure

Research Overview



In the pipeline

This Research Overview highlights the diverse range of approaches and technologies developed by scientists and engineers at Imperial that will be needed to rethink how organisations and people use energy. Research includes developing energy management systems that cut down on energy use at peak times, intelligent transport systems that minimise wasted energy and ways to increase the efficient use of energy and its storage, as well as work with companies to identify how they can both save energy and improve service for their customers.

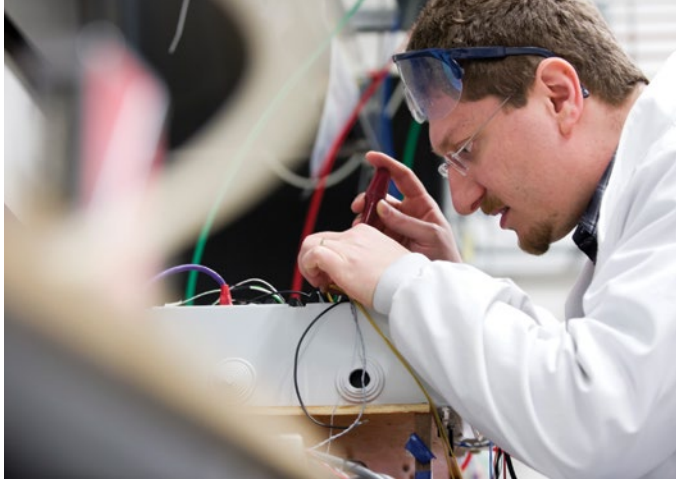
Complex flows

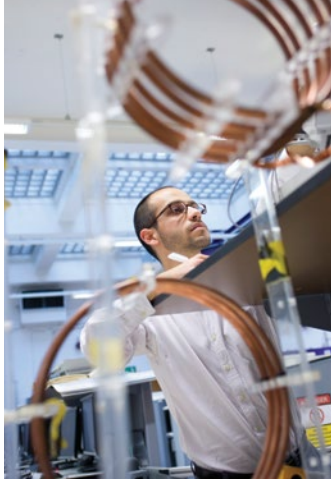
Developing an intelligent energy infrastructure is essential for the UK to minimise the consequences of climate change. Professor Tim Green, Director of the Energy Futures Lab, says, "The UK has set itself very ambitious targets to deliver an 80% cut in carbon emissions by 2050. It is quite clear that we are not going to do that without really transformational changes in how we use and how we deliver energy services. Increasingly we have to think about the system as a whole. We are going to live in a more complex, interconnected world and the energy infrastructure must go the same way."

Preventing peaking

The UK has reduced its greenhouse gas emissions by more than 25% since 1990 and met its commitment under the Kyoto Protocol. Its aim is now even more ambitious: to slash emissions of carbon dioxide by 80% between 1990 and 2050, while ensuring that its energy supply is both secure and affordable.

Improving the energy infrastructure will be crucial if this goal is to be realised. At present the UK's energy system is designed to meet peaks in demand for electricity. Coal-fired power stations, which are the nation's dirtiest form of power generation, are kept running so that they can be quickly switched to generate power should a peak in demand arise. Two-thirds of the UK's standby power comes from such high-carbon sources. If instead the energy system acted intelligently to smooth demand, by turning down non-essential services when demand for electricity rose, carbon-dioxide emissions could be cut.





(Left) Vladimir Yufit is looking at hydrogen fuel cell performance to improve their use in grid-scale energy storage.

(Mid) Professor Nilay Shah applies models to whole systems so that energy usage can be optimised.

(Right) Manuel Pinuela is investigating ways to increase the efficiency in wireless electricity transmission.

Bright lights, big city

Worldwide half the population lives in cities. In the UK some 90% of people reside in urban areas, up from 80% in 1950. Various studies show that urbanites tend to have a smaller carbon footprint than their rural cousins because they live in smaller homes and can use public transport. But cities also offer an as yet untapped potential to reap further energy savings, according to Dr James Keirstead, a Lecturer in the Department of Civil and Environmental Engineering, who conducts research on urban energy systems for the Energy Futures Lab. He is trying to identify how a systematic, integrated approach to the design and operation of urban energy systems might lead to more efficient use of energy.

Combined heat and power plants, for example, capture the waste heat generated during power production and put it to use, mostly to supply hot water for district heating. Indeed Imperial already has such a plant, which burns natural gas to generate electricity to power College buildings, lecture theatres and halls of residence, while supplying hot water and heating to the same premises.

Such systems affect the way that energy flows through cities and create links and interactions between different power supplies, says Dr Keirstead. He uses computer models to evaluate how such urban networks might change in future as cities start to become more sustainable, and has developed a toolkit called ‘SynCity’ that enables others to model urban energy systems.

Making connections

Town dwellers need to commute to work, pick up groceries and ferry children to school. Dr Keirstead and his colleagues use computer models to predict the travel needs of the population by mode, time of day, duration and location, in order not only to identify the energy needed to provide it but also to better understand how people might react to various initiatives intended to influence their behaviour. He notes that cities also provide the necessary density of demand for a service to be worthwhile, such as car-sharing schemes, where a company leaves cars in various streets that can be hired for an hour or so, as required.

One way in which road transport systems could be made more efficient would be to make them more intelligent. Professor John Polak, Professor of Transport Demand, conducts research to develop new ways to predict incidents and congestion in transport networks, which could enable managers to better cope with them. His research indicates that improved communication and co-operation between individual vehicles and the wider transport network could help cut energy use and emissions, and he is developing techniques to enable this through improved co-ordination between individual vehicles’ engine management systems, traffic signal control and vehicle navigation.

Smart communities

Professor Nilay Shah, Director of the Centre for Process Systems Engineering, makes computer models of what he calls ‘smart communities’. He examines what life would be like if a community comprising, say, a hospital, a school, offices, shops and homes, united to form a trading agreement that smoothed demand for power. He looks at the extent to which certain organisations might be able to tolerate temporary reductions in the power supplied during periods of high demand—a brick-built school, for example, might easily cope if the heating were switched off for half an hour, but a hospital might not.

Watts in store

Demand for electricity rises and falls at different times and renewable energy sources can be intermittent. To help meet the peaks of demand without building more power plants we can store energy and release it in cycles. Professor Goran Strbac, Professor of Electrical Energy Systems, studies how to integrate energy supply and storage in an affordable and efficient way. His colleagues across Imperial are developing high-capacity batteries that can be repeatedly charged and discharged and which last for decades. Alternatively energy could be stored at times when the electrical supply exceeds demand by using the excess electricity to generate hydrogen from water. The hydrogen could then be run through a fuel cell to produce electricity during peak hours or sold to run hydrogen-powered vehicles.

Intelligent use

Predictions of how the UK might reduce its emissions of carbon dioxide typically assume that energy efficiency will contribute as much as a quarter of the cuts. Changing how we use energy and using smarter technology can not only reduce carbon emissions but also cut the costs of so doing. Replacing inefficient light bulbs in homes with light-emitting diodes, a transition that has been hastened by the removal of incandescent bulbs from sale in shops, saves cash as well as carbon emissions. Other money saving interventions include improving the efficiency of residential electronics and domestic appliances, and replacing old boilers with energy efficient designs.

Dr Christos Markides, Lecturer in Clean Energy Processes in the Department of Chemical Engineering, works on identifying highly efficient and sustainable practices and technologies that can be employed in domestic, industrial and commercial processes. He says that heat, cooling and power can be used, balanced, recovered and re-used in ways that are currently not only technically but also economically viable, and that well aligned incentives can often accelerate the introduction of such technology. Dr Markides seeks to identify both innovative solutions and also solutions that can be retrofitted on existing households, settings and plants without compromising their activities. At present he is trying to develop an affordable and reliable generic waste-heat recovery and conversion system that can be implemented across a range of industrial processes for efficiency improvements and cost savings.

Pop to the shops

Energy efficiency is important to big supermarket chains that seek not only to save money but also to promote their environmental credentials. Professor Shah works with them to identify how to make their stores more energy efficient. Many supermarkets no longer have a great many open chest freezers in which to display their food but instead now have large cupboard freezers with doors. However shoppers waste energy when they open a door and dither over a purchase. Professor Shah envisages shops in which customers can chose their frozen goods using a touchscreen to select which packets of frozen peas and oven chips they desire. When they reach the checkout with their fresh produce, the frozen items will have been selected mechanically from within the freezers and be packed and ready for them to collect.

He is also interested in other interfaces between supermarkets and consumers, particularly the trend towards online grocery shopping. At present some supermarkets meet online orders by sending employees to pick up items within a store as though they were the customer. He is modelling how much money they would save if the online orders were met instead from warehouses, which would be far more energy efficient.

Smart shops

The Sainsburys store in Hythe, Kent, looks just like any other large supermarket. A steady stream of shoppers traipses through it, examining groceries, picking through the range of clothing and homeware, pausing at the fresh food counters and perhaps selecting a meal from the pizza counter where staff prepare food to order. There are few clues that their weekly shop comes from a unique store where staff at the Energy Futures Lab test their energy-saving ideas.

But behind the scenes an energy management system monitors the national grid and, at peak times, activates the store's biofuel generator, which uses waste oil and fat from food processing plants, hot food counters and out-of-date stock to power the supermarket. When the demand for power from the grid is high, the store's heating, lighting and ventilation systems also switch into power-saving mode. And when the sun shines brightly, its lights automatically dim. Not only does that lessen the need for coal-fired power stations to be kept ready to generate more power, it also enables the supermarket to function should demand outstrip supply in the future. Indeed Sainsburys has floated the idea that some of its stores could come off the electrical grid altogether.

The supermarket has separate power meters for different parts of the shop, so that the bakery counter can measure its energy efficiency against the hot food counter, for example. Professor Nilay Shah, Director of the Centre for Process Systems Engineering at Imperial, uses information from them to calibrate his computer models of how the store functions. By merely monitoring energy use, it can focus people's minds on reducing it: Sainsburys reckons that its store managers cut energy use by an average of 17% once they have been made aware of the possibility. And the technologies tested in Hythe are now being implemented in stores across the land.

Energy Futures Lab Research Overviews explore the key issues that must be addressed if we are to develop more secure and sustainable energy supplies, and explain how research at Imperial College London paves the way to meeting these challenges. Our staff and students conduct multidisciplinary energy research to cut carbon emissions. With strong links to industry, they develop an integrated view of energy supply, demand and distribution that takes into account technological, environmental, economic and security considerations.

Further articles in the Energy Futures Lab Research Overview series:

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