New Statesman

Reduce the carbon

Strategies for sustainability

Research Councils UK

Energy

For a Low Carbon Future

Key drivers

To help combat climate change the UK has a target to reduce carbon emissions by 80 per cent by 2050, an enormous task requiring changes to every sector of energy generation, supply, use and regulation. These reductions need to be delivered while creating a secure energy system for the UK, providing affordable energy, enabling continued economic growth and limiting impact on scarce natural resources and the environment.

Challenges

The key short-term challenge is to rapidly accelerate the deployment of green energy technologies that decarbonise our energy supply and increase energy efficiency in buildings, industry and transport sectors. There is also an opportunity to develop existing networks and infrastructure to support the changing energy landscape, such as through carbon capture and storage, and large-scale deployment of renewables.

Research for our future

It is only through fundamental research focused on addressing these challenges that truly transformative changes to our energy future beyond 2050 can occur. The energy programme is uniquely positioned to provide policymakers with guidance about the development of potential energy scenarios and their impact on citizens, the economy and the environment. This demands understanding of behaviour change, environmental systems analysis and technological innovation.

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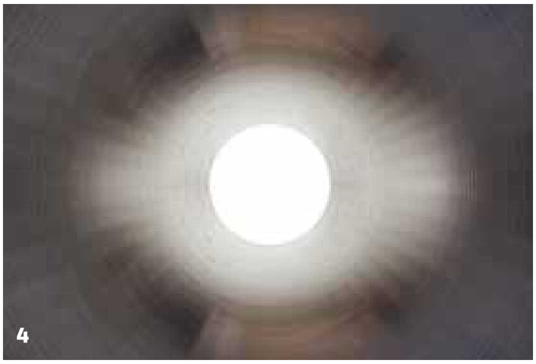
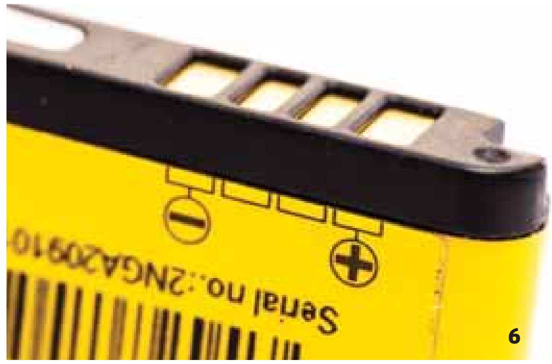


4 Future vision: carbon capture projects



6 Power pack: advances in energy storage

Steps against carbon

Worldwide there is a pressing need to cut greenhouse-gas emissions, increase clean energy production, reduce energy waste and improve our abilities to store energy.

Environmental, economic and security concerns make the case for action compelling. How to meet these challenges is not so clear cut. Political and economic forces that change the short-term conditions can skew the progress of technological developments.

In the UK, through the RCUK Energy Programme, the Research Councils are investing in universities and collaborating with industry to accelerate the application of research results. Two fields where the programme has focused its resources are energy storage, and carbon capture and storage (CCS).

The £4m Energy Storage Supergen Hub, led by the University of Oxford, draws together experts from seven universities and 14 industrial and government partners to address the technical and scientific challenges facing the wide variety of energy storage techniques. It is developing a shared vision for energy storage in the UK by drawing up the first integrated national roadmap. It is also working with industrial partners to accelerate prototyping and commercialisation.

The Engineering and Physical Sciences Research Council (EPSRC) supports research on CCS to maximise its contribution to a low-carbon energy system for the UK. A key element is the £10m invested in the UK Carbon Capture and Storage Research Centre. Led by Professor Jon Gibbins from the University of Edinburgh, the centre provides a focal point for CCS research, including more than 250 of the UK's world-class academics, as well as experts from industry, regulators and others in the sector. It co-ordinates a programme that underpins research on all aspects of CCS, in support of basic science and the UK government's efforts to meet ambitious environmental targets.

Low-carbon transport and heating/power systems employing hydrogen or fuel cells have the potential to be important technologies in our future energy system. The Hydrogen and Fuel Cells Supergen Hub, led by Imperial College London, is evaluating and demonstrating the role of this research in the UK, and looking at how to link this to the wider energy landscape internationally. It also seeks to identify, study and exploit the impact of hydrogen and fuel cells in low-carbon energy systems, and examines how they can be used to manage intermittency and support secure and affordable energy supplies.

These are just a few examples of the strategic investment the Research Councils are making in emerging technologies. This research will address not just our current energy needs, but those of future generations, while reducing our detrimental impact on the planet. ●

Professor Philip Nelson, chief executive, EPSRC

This supplement and other policy reports can be downloaded from the *NS* website at newstatesman.com/page/supplements

COVER: SHUTTERSTOCK/DESIGN BY LEON PARKS

Going underground

It's widely accepted that we're producing too much carbon, so what do we do? The answer lies in storage and porous rocks, **Guy Clapperton** finds, as he speaks to an expert

The broadcaster Danny Baker used to have a section on his radio show called "Everything You Know Is Wrong", in which he would challenge widely held misconceptions. The intention was to amuse, so he never really covered whether there is too much focus on the shortage of fossil fuels and not enough on the carbon dioxide they produce.

Nonetheless, for Jon Gibbins, director of the UK Carbon Capture and Storage Research Centre, the myth of an impending fossil fuel shortage is an important one to explode. Carbon capture and storage (CCS) is the act of taking harmful CO_2, the result of man-made processes, and storing it. The research centre is a national effort, as its name implies, including more than 250 members from about 20 academic institutions. It is administered from Edinburgh but operates UK-wide, with 27 different research projects and shared experimental facilities.

"The process means putting [carbon dioxide] somewhere it will stop long enough to avoid climate-change effects, for at least 10,000 years," Gibbins says. "Typically that's done by squeezing it into the pores of porous rock a kilometre or so underground, where there's impermeable rock above. It traps it, and we know that formations like that have held CO_2 in place – as well as other natural gases – for hundreds, thousands and millions of years."

It is likely to stay there, then – and there appear not to be any environmental drawbacks. "There are places where you get natural seeps [of CO_2], but you couldn't get it out in a hurry if you tried."

The science behind capturing CO_2 from power plants and heavy industry, such as cement manufacturing, is improving all the time, and this is what drives the consortium behind the research centre.

> "There are natural seeps. But you couldn't get gas out in a hurry if you tried"

As this supplement goes to print, the Canadian company Carbon Engineering is about to open a facility in Squamish, British Columbia, co-funded by Bill Gates, to extract CO_2 from the atmosphere. "You basically wash the air with an alkali solution that reacts with CO_2, which is slightly acidic," Gibbins explains. "Then you put the reacted CO_2 into quicklime and turn it into limestone. You heat the limestone to a high temperature with a gas and oxygen burner, and because you use oxygen you have a pretty pure source of CO_2.

"You can also use the captured CO_2, with renewable energy, to make a fuel. It's carbon-neutral," he adds, although the high cost makes this an aspiration rather than an instant commercial reality. It takes a lot of energy to turn CO_2 into something useful, so until that energy requirement can be reduced, it's not going to become mainstream. For now, you end up with a carbon-neutral way of using fossil fuels.

And producing new energy isn't the problem, Gibbins adds, getting back to the myth of shortages. The issue we face is an overabundance of fossil fuel, he believes. "Climate science is moving to the conclusion that climate change will be a function of cumulative CO_2 emissions," he says. "Which means you've got to get down to zero or else you just keep on adding."

Achieving carbon targets has potentially damaging consequences for the UK economy. The 80 per cent reduction the government wants in greenhouse gases by 2050 could cost an extra 1-2 per cent of GDP without CCS, according to the UK's Energy Technologies Institute. "The Intergovernmental Panel on Climate Change [also] looked at a lot of targets and concluded it would cost twice as much without CCS," Gibbins says.

The research centre will make this argument wherever it can, as well as seeking to recruit younger people into energy

Seeing the light: scientists want to capture CO_2 released by burning fossil fuels and pipe it offshore for storage

SHUTTERSTOCK

research. There was a dearth of recruitment in the 1990s, says Gibbins. It will link up with industry, as well as government bodies, to target its research effectively.

The UK has been working on CCS since the Gleneagles summit in 2005. Adapting proposed coal-fired gas plants to allow carbon to be collected through the flue looked promising, but that was stopped by the global financial crisis. Funds were allocated in the Energy Act 2010 but after that year's general election, with the UK in recession and gas prices having fallen, there was no money for the research.

At around the same time, Shell proposed a CCS scheme for the Peterhead power plant in north-east Scotland; a financial decision will be taken early next year. In North Yorkshire, Alstom is leading a consortium working on another CCS project; it is considering burning coal in oxygen to concentrate CO_2 and piping it offshore. The proposal is still moving towards a decision on financing, in spite of the withdrawal from the consortium last month of the UK energy company Drax.

"If we're going to do CCS then we'll have to have plants in Yorkshire," Gibbins says, pointing to the sheer concentration of power plants in the region. The coal-fired power stations may have closed but the sites are still valuable.

So why hasn't this been universally popular? A glance at ukccsrc.ac.uk, the research centre's website, confirms there was one set of objections in an area in which the CO_2 was going to be buried.

Gibbins continues: "The nature of the reaction is, fairly predictably, if you say to someone, 'I'm going to put CO_2 under your house', they say, 'Has this been done before?' and you say 'No', they say, 'Can you guarantee it's safe?' " And no matter how confident, a scientist won't give 100 per cent assurances without absolute proof. Residents then ask whether it's likely to reduce the value of their house, and the only honest answer is that it would be up to any potential buyer.

The negative logic that rejects the concept of storing carbon dioxide a kilometre under our streets is flawed, Gibbins says. For years, more dangerous gases have been pumped into homes as fuel from underground pipes, and people have been content with this. There are also man-made underground natural gas reservoirs. The difference is, we are used to it – a case of familiarity breeding content rather than the usual contempt.

In the specific case in which there were objections (in the Netherlands), these followed another unrelated issue that had hit house prices, so that sensitivities were heightened, Gibbins adds. "If you're doing something for the first time, then of course people will be nervous."

It's more straightforward for the British market: "The UK has had a policy for a long time to use offshore storage only. As the civil servants said, nobody lives offshore." Inland storage and its attendant objections are by now in the past.

The received wisdom is that we're going to run out of fossil fuel if we don't stop taking resources out of the earth. But Gibbins believes this is addressing the wrong question – we need to ask what we do with the carbon once it's released. Negotiations to secure a global agreement to reduce emissions begin in Paris on 30 November but look unlikely to conclude with any consensus; the next opportunity to negotiate will be in a decade's time. Gibbins and his fellow academics will be hoping for a better understanding of the issues among decision-makers by then. ●

Innovation will keep the power flowing

By **Nigel Brandon**, Imperial College London

Analysis at Imperial College London[1] has shown that energy storage delivers a range of benefits for many potential low-carbon electricity systems in the UK. Grid-scale storage technologies cut operating costs by improving the ability of the system to absorb renewable generation, while offsetting costly interconnection and transmission investment. Furthermore, smaller-scale distributed storage can reduce the need for reinforcement of the wider network.

However, it is in terms of investment costs in low-carbon generation that the most significant savings can be seen. Net system savings through the deployment of energy storage are predicted to increase radically between 2020 and 2050. For example, forecasts for the achievable net annual system benefits generated by storage in the UK alone range from £120m in 2020 to roughly £2bn-£5bn in 2030. From 2050, they show a further rapid increase to more than £10bn-£15bn per year.

It is clear that the UK will place increasing value on the flexibility offered by energy storage to manage its transition to a low-carbon system. No single storage technology will meet the needs of the future energy system. There will be a range of services that will require storage to be adapted accordingly, from the rapid delivery of power in a matter of seconds, through to longer-term energy storage over hours, days or weeks.

What is also clear is that we need to learn in the work we do today, to scale up and re-risk promising technologies, and at the same time support the underpinning research that will continue to drive down cost and increase the longevity of technologies in the future. We can do this by improving current storage solutions, and by developing solutions based on new

Lithium-ion batteries can be made to last longer

chemistries, materials and concepts. In the UK this is in part enabled by the Energy Storage Supergen Hub, funded by the RCUK Energy Programme.

There are exciting new storage technologies emerging for these applications. Today's lithium-ion batteries could be produced at much lower cost and with an increased lifetime (both critical requirements for grid applications) as new materials and innovations such as lithium-sulphur batteries are developed. Another significant area of research is the development of sodium-ion batteries, analogous to lithium-ion batteries, but using lower-cost and more abundant sodium.

> No single storage technology will meet the needs of the future

For high-power applications, where fast storage is needed, supercapacitors are an attractive option. Low-cost materials and fabrication technologies are being developed to meet grid storage demands.

By contrast, redox flow batteries allow energy to be stored for several hours. There has been a surge of interest in new flow battery chemistries in the past ten years, aimed at lowering cost and/or increasing energy density.

In addition to electrochemical storage, there are other options for storing large amounts of energy. These include compressed-air energy storage in salt caverns; the use of pumped heat or cryogenic energy cycles; and thermal storage.

Large amounts of energy could be stored by making hydrogen from water using electrolysis, powered by renewable energy. This hydrogen can either be reacted with captured carbon dioxide to make methane for injection into the gas grid, or used directly as a transport fuel or in the chemicals industry, displacing hydrogen produced from natural gas.

Finally, it is important that attention is paid not only to the storage technologies themselves, but also to their integration and control in the energy system.

Innovation is taking place in all aspects of energy storage. Scientists around the world are working to ensure that fit-for-purpose technologies are available to allow future generations to meet the predicted demands for storage in low-carbon energy systems. ●

[1] *"Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low-Carbon Energy Future" by Goran Strbac, Marko Aunedi, Danny Pudjianto, Predrag Djapic, Fei Teng, Alexander Sturt, Dejvises Jackravut, Robert Sansom, Vladimir Yufit, Nigel Brandon – Energy Futures Lab report for the Carbon Trust (2012). https://www.carbontrust.com/media/129310/energy-storage-systems-role-value-strategic-assessment.pdf*

Your washing machine says a lot about you

By **Nigel Goddard** and **Martin Pullinger**, University of Edinburgh

From smart metering to advanced analytics, the study of end-user demand is helping to predict, manage and – ultimately – reduce our consumption of electricity

End-user demand for energy is the amount of gas, electricity and oil that consumers in the domestic and non-domestic sectors require for the services that energy provides. These services include heating, lighting, cooking, laundry, entertainment, communication, construction and transport.

Two aspects of managing end-user demand have risen in importance in recent years. First, reducing overall demand is an important component of policies to cut greenhouse-gas emissions, increase energy security and maintain affordability – the "energy trilemma".

Second, controlling and smoothing the daily and seasonal fluctuations in demand could result in huge savings in capital-intensive infrastructure. Such controls can also reduce the growing risk of grid failures caused by decarbonising the energy system.

Traditional domestic uses of energy, such as household washing, could be timed differently to help match demand to a supply that is becoming increasingly intermittent as more generation comes from renewables. Simultaneously, new types of electricity use (for example, demand for energy for heat pumps and electric vehicles) require active management to avoid peaks overloading the grid.

Gathering better data on patterns of demand is central to efforts to respond to such challenges. One of the keys to this is the UK smart metering programme, itself part of a wider EU, and global, government and industry push. By 2020, the aim is that most UK homes, and some small and medium-sized businesses, will have smart electricity and gas meters, reporting electricity use at ten-second intervals and gas use half-hourly (and at faster rates in the future) to energy network operators and the end users themselves. The grand vision is that this will allow the people using electricity to identify technology and changes in behaviour to help reduce their demand. At the same time, it should help network operators manage the whole system more efficiently. Potentially, too, such data allows us to explore how a wide range of policy and planning affects energy demand: for instance, the links between proximity of green spaces, civic amenities and transport infrastructure, and patterns of home occupancy.

> How we use appliances could reveal as much as our credit-card use

To support more advanced data gathering and analytics, the RCUK Energy Programme funds six centres[1] and 30 research projects[2], which are developing methods to improve understanding of when and for what purpose energy is used.

We work on two of these projects, in homes and public-sector buildings such as schools and libraries. Conventional research methods are labour-intensive, involving interviews, focus groups and keeping diaries. We use low-cost, networked sensors (the so-called Internet of Things) to monitor room temperature, light and humidity, combined with whole-house electricity and gas readings, and exploit data science techniques to analyse and interpret such diverse, parallel data streams. In this work we are advancing computational methods for determining which appliances and systems (say, heating) are in use at any particular time, providing greater insight for householders wishing to reduce their energy use.

Despite the potential benefits described above, there are serious social questions raised by these technologies. If substantial savings can be achieved, will these be available to all, or only to people who are able to afford the "sensoring" of their homes? At the same time, effective controls over who has access to data are essential to safeguard privacy – patterns of energy use can be used to infer occupancy, leisure activities and even religious beliefs (for instance, changes in cooking activity related to religious observance). How we use our domestic appliances could soon inadvertently reveal as much about our lives to whoever holds the data as our credit-card records, smartphone use and social media activity do today.

Ultimately, however, enhanced end-user demand data and analytics promises to enable us to uncover, and address, a range of factors that can unlock energy savings – be it better feedback for households to make behavioural changes, or insight into which economic, social and infrastructure policies and plans encourage greater energy efficiency. ●

1 *http://www.eued.ac.uk/centres*
2 *http://teddinet.org*

Research Councils UK

Energy

For a Low Carbon Future

The Research Councils UK Energy Programme aims to position the UK to meet its energy and environmental targets and policy goals through world-class research and training. The Energy Programme is investing more than £625m in research and skills to pioneer a low-carbon future. This builds on an investment of £839m over the past eight years.

Led by the Engineering and Physical Sciences Research Council (EPSRC), the Energy Programme brings together the work of EPSRC and that of the Biotechnology and Biological Sciences Research Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC) and the Science and Technology Facilities Council (STFC). Research is the key to achieving an affordable low-carbon energy system while conserving our natural resources, the environment and our quality of life.