UNIVERSITY OF OXFORD

Oxford Energy Newsletter

Number 1, Autumn 2013

Energy Research in Oxford

This is the first edition of a newsletter which will describe developments in energy work at Oxford. Over 180 senior Oxford researchers spend a substantial part (or all) of their research time on energy, with the support of numerous post-docs and doctoral students. Descriptions of them and their work can be found by clicking on different parts of the 'Oxford Energy Wheel' (shown below) which can be found on the new website www.energy.ox.ac.uk, together with information about teaching and training, forthcoming energy events etc.

Oxford's major strength is that we are addressing all aspects—technical, economic, social and political—of most of the key issues, and are therefore well positioned to contribute to the systems approach that meeting the energy challenge requires. For example, it sometimes seems that engineers think that managing energy demand is primarily about smart meters and the grid, economists think it's about bribing people to change their behaviour with different tariffs, social scientists think it's about using other levers, and the transport experts think it's about planning. It is of course about all these things, and Oxford is able to put them all together, as we did in a seminar for policy makers that we took to London two years ago and a very powerful multidisciplinary grant application.

The Newsletter will provide all those interested in energy work in Oxford with news of recent developments and vignettes of current activities. This issue includes an article on a novel solar cooker, which could have a big impact in the developing world, and two on the very topical subject of shale gas. You are invited to send you reactions and comments to me at c.llewellyn-smith@physics.ox.ac.uk. If you are not on the distribution list, and would like to join it, send an email to philipp.grunewald@ouce.ox.ac.uk or visit energy.ox.ac.uk/join.

Professor Sir Chris Llewellyn Smith FRS
Director of Energy Research Oxford University
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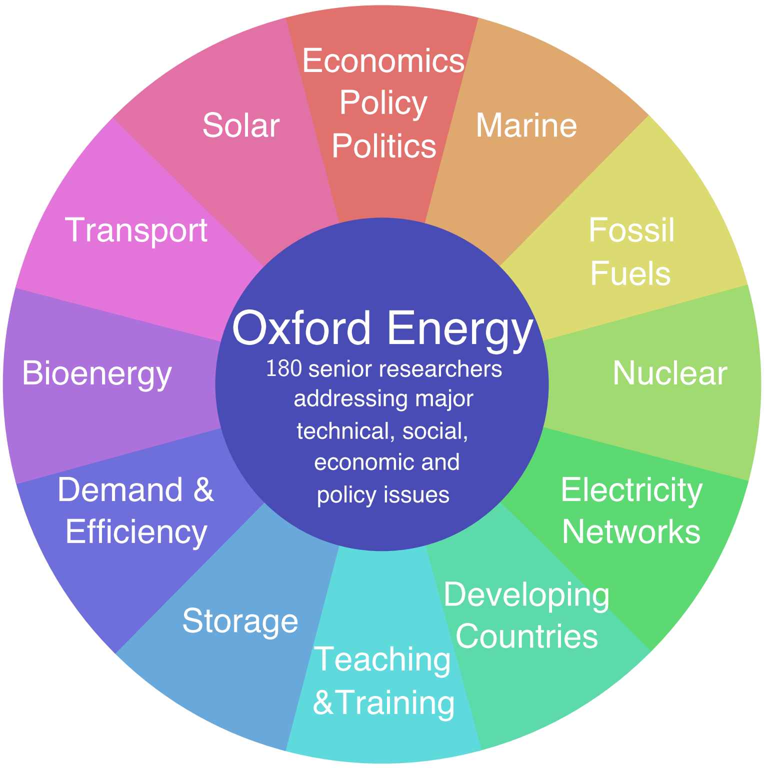


Oxford Energy Society

A lively Energy Society, which organises an excellent series of talks and events, was launched in 2012. The Society is open to members of the University from all disciplines, as well as members of other local universities and the general public. The society welcomes new members from any background and with any level of interest in energy and climate change, and aims to provide a central hub for anyone in Oxford with an interest in energy, where ideas can be explored in the company of like-minded individuals. For more information and to join go to http://energysoc.org/

Arrivals

Four distinguished senior academics who work on energy are moving to Oxford in 2013/14.

Peter Bruce FRS, FRSE, FRSC, will take up the Wolfson Chair of Materials in early 2014 when he moves from St Andrews where he currently holds the Wardlaw Chair in Chemistry. Peter is a world-renowned expert on energy materials and batteries. His research interests embrace materials chemistry and electrochemistry, including the synthesis and characterisation of new materials (extended arrays and polymers) for new generations of energy conversion and storage devices, especially lithium batteries. His recent work has focussed on nano-intercalation materials and the potentially transformational Li-air battery. Peter leads the RCUK SUPERGEN Energy Storage Consortium, a Programme Grant on Nanoionics and is a member of ALISTORE, the European Network of Excellence on Lithium Batteries. He serves on several national and international committees related to energy.

Peter Grindrod CBE joined the Mathematics Institute in September 2013. His energy interests include the smart grid (smart meters and technology insertion) and energy demand (consumer segmentation and response, and real time forecasting). More generally, his research covers aspects of human behaviour exhibited by vast data from a variety of public and private sources. He works with companies within the marketing, energy, retail, consumer goods, and mobile communication sectors. Peter has founded three start-up companies and is a former member of the Councils of both the EPSRC and the BBSRC, and a member of the MOD's Defence Scientific Advisory Committee.

Cameron Hepburn returned to Oxford (from the LSE) in September as Professor of environmental economics, based at the Smith School and the Institute for New Economic Thinking at the Oxford Martin School (he is also Professorial Research Fellow at the Grantham Research Institute at the London School of Economics). Cameron is an economist (with first degrees in law and engineering) with research interests in energy, resources and the environment. He has provided advice on energy and environmental policy to governments and international institutions around the world, and been quoted in publications such as the Economist and the Financial Times, and he has been interviewed widely in the media. He has also had an entrepreneurial career, co-founding two successful businesses and investing in several other start-ups.

Catherine Redgwell returned to Oxford in September, from a Chair at UCL, as Chichele Professor of Public International Law and Fellow of All Souls College. She is a long-standing member of the Academic Advisory Group of the Section on Energy, Environment, Natural Resources and Infrastructure Law of the International Bar Association, which has published with Oxford University Press a series of edited collections on a wide range of energy issues. Her current work includes the international regulation of unconventional energy underground (e.g. geothermal, fracking, CCS), shared responsibility for energy activities, geoengineering (she is co-director of the Oxford Geoengineering Programme and co-investigator in the ESRC/AHRC funded Climate Geoengineering Governance project) and climate justice (she is a member of the IBA Climate Change Justice & Human Rights Task Force).

A Low-Cost Solar Cooker for the Developing World

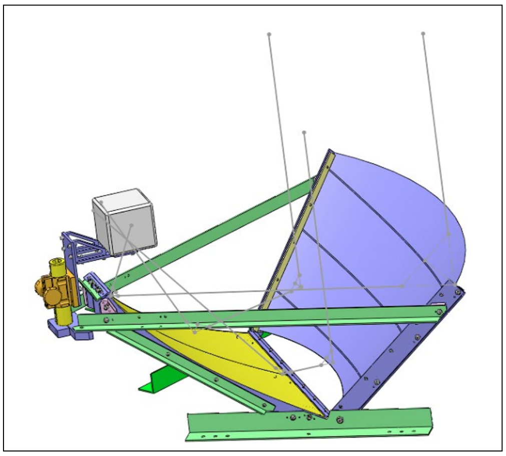
By Nick Jelley (Physics) and Richard Stone (Engineering)

About 1.5 million people in the developing world die each year from smoke inhalation due to cooking indoors using biomass and fossil fuels (WHO). An effective low-cost solar cooker would not only save lives but would enhance the quality of the lives of women and children by removing the necessity of long treks to collect ever decreasing amounts of brushwood. This would allow more time for children to study or play and for women to perform other important activities. Solar cookers can be used in large parts of Africa, in parts of India and China, and elsewhere in the world, so the potential humanitarian benefit is significant. The UN has recently laid down a challenge to industry and academia (www.solarcookers.org/index.html) to develop a better solar cooker than is currently available.

A low-cost durable solar cooker has been designed in Oxford. No other system will concentrate so much naturally available renewable energy into such a compact and usable solution. In a collaboration between Oxford and Dytecna Ltd., a design engineering company migrating its skills into the clean tech sector, prototype units are being built and field trials in Africa are planned for early in 2014.

Research funded by the Leverhulme Trust has shown that two single curvature surfaces can focus sunlight to a point and in a way well-suited for a solar cooker: Figure 1 shows how the Sun's energy can be directed off a conical mirror onto a parabolic mirror and then to the underside of a cooking platform, which can be located away from the ground and where the user can be shielded from the direct sun. The single curvature surfaces in the concentrator allow the reflective surfaces to be formed from hardwearing flat reflective sheets. This approach would reduce costs and enable the concentrator to be flat-packed - an essential requirement for disaster relief operations. It also enables a very durable design.

Figure 1: Test rig showing how parallel light from the Sun hits a 45° conical mirror (blue) and is reflected onto a parabolic mirror (yellow) that brings the light to a point focus.

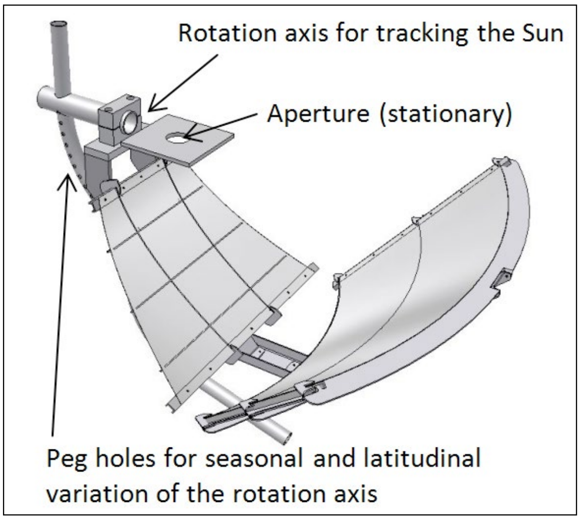


The design has been called the 'Albedo Solar Cooker' and Figure 2 shows how the mirrors are supported by ribs that are cut from sheet and slotted together.

The design will give a cooker that can be used with a saucepan on a cooking surface, with an oven, or just with a suspended pot, at a standard worktop height. It will be more comfortable to use, particularly for the elderly or infirm, and much more hygienic than with a cooker directly on the ground. To track the Sun, the mirror system merely has to be rotated about a 'horizontal' axis. With simple additions it may also be used for solar drying food and as a water sterilisation system, further enabling the use of scarce potentially contaminated water resources and helping in the prevention of sickness and disease.

The trials and their evaluation will also open up exciting areas of research: thermal stores using phase change materials to not only enable evening cooking but also possibly provide electricity using thermoelectric generators for lighting, mobiles (both web and phone), and refrigeration.

Figure 2: The layout of the conical and parabolic mirrors in the 'Albedo Solar Cooker', with the aperture that sunlight is focussed through shown uncovered, that is, without an oven or griddle in place. The mirrors are held by ribs that simply slot together.



Research Frontiers for the Shale Gas Revolution

By Joe Cartwright, Shell Professor of Earth Sciences

Amidst all the hype that has abounded in the media in the past few years about the potential for shale gas to transform economies, very little attention has been given to the uncertainties confronting this latest grand enterprise. Somehow the momentum from events unfolding over the past decade in the US has instilled a confidence in many quarters that a similar bounty awaits for any country that can take its potential resource base and exploit it effectively. Whilst it is fairly straightforward to come up with rough estimates of the shale gas resources of any nation wherever there is a reasonable amount of geological background information, the reality of converting these rough estimates into the likely exploitable reserve values[1] is riddled with uncertainty and is a major technical challenge for geoscientists and engineers.

Here in Oxford, at the Department of Earth Sciences, we are building a large new research group (largely funded by Shell) to tackle some of the fundamental earth science questions that underpin the assessment of these uncertainties and whose answers will go some way towards narrowing down the factors that are most influential in economically viable exploitation of shale gas reservoirs.

Our group is focusing on developing techniques to make the best possible physical and chemical characterisation of the diverse group of rocks that are collectively known as shale. We want to understand what controls the composition of shale, how it was deposited at the Earth's surface, what happens as it is buried, and how natural fractures develop within shaly layers. Shales are sedimentary rocks that comprise small particles with diameters less than a hundredth of the size of a human hair, and which under burial to depths of 5km or more, become heated and compacted such that the interstices between the particles (pores) become so small, that the permeability (the property of the rock that allows fluids to move through it) also becomes incredibly small. If sufficient organic carbon was buried along with the small particles, and survives the burial process, it subsequently transforms to gas (and other hydrocarbons), and this valuable resource is then locked inside the rock because the permeability is so small.

My role as the recently appointed Shell Professor of Earth Sciences is to lead the efforts in the Department in this now very topical area of research, and to act as a conduit between our group of highly talented young researchers and technical specialists inside Shell. I am particularly interested in the geological processes that lead to the development of natural fractures in shales. I have been interested in this topic since the mid 1980s, when I stumbled upon a new type of geological fault, which I termed polygonal faults. These are similar to many other types of geological fault, in that they cut through geological layers and offset them, but there is one important difference: they only occur in shales. It seems that their genesis is related to the physical and chemical changes that occur during the early burial of the clay-rich sediments that are the feedstock for shales. So my group is now analysing the shales that hold these enormous shale gas reserves in the US to see how the natural fractures inside them originally formed, and how their presence influences the 'fracking' of the layer and the ultimate gas recovery.

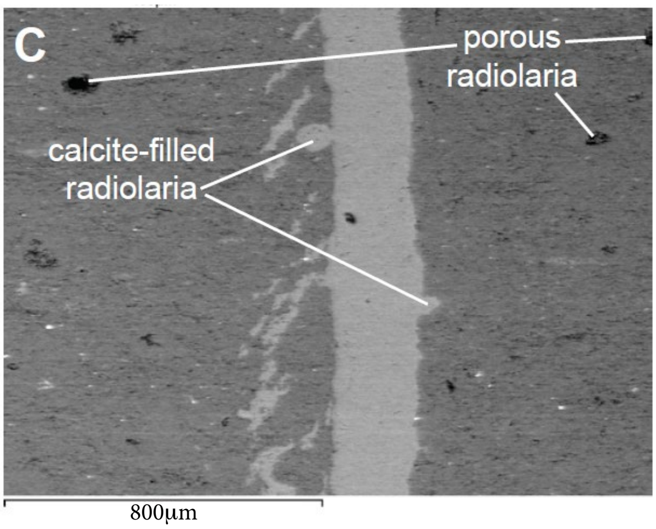


Figure 1: Photomicrograph of a shale cut by a natural fracture. The fracture is the light grey tone object in the centre of the image, and is about 0.2mm across. By analysing the minerals inside the fracture we can work out how and when it formed.

1 Exploitable reserves or technically producible reserves are the numbers that are critical for companies, governments and the general public, because these are the actual amounts of gas that can be produced to the surface and used thereafter, rather than hypothetical total amounts of gas that exist in their underground reservoirs.

UK Shale Gas – the Likely Reality

By Howard Rogers, Director of Natural Gas Research, Oxford Institute for Energy Studies

The strength of US shale gas production growth in the second half of the 2000s took the majority of gas industry participants by surprise, not least those who had invested in some 180 billion cubic metres per annum of US Liquid Natural Gas import terminals, made largely redundant in their original configuration by the prospect of US gas self-sufficiency. In 2006 shale gas accounted for 5.4% of US natural gas production; by 2012 this had risen to 34%. This surge of production ran ahead of demand, resulting in a radically lower US gas price. Although this recovered to $3.50-4.00/mmbtu by June 2013, it was still well below the corresponding UK wholesale price of around $10/mmbtu. (1 mmbtu = 1 million British Thermal Units is the standard unit for gas prices in the USA: 1 mmbtu, which is equal to 293 kW-hr, is approximetley the enrgy in 28 cubic metres of natural gas).

> The Oxford Institute for Energy Studies was rated the second best Energy and Resource Policy Think Tank in the world in a survey by the University of Pennsylvania published in January 2013.

Natural gas in 2012 accounted for 35% of the UK's primary energy consumption. Since the advent of UK North Sea gas production in the 1960s, the UK had understandably come to rely on this indigenous resource and was somewhat traumatised by the rapid (but eminently foreseeable) decline from self-sufficiency in gas as late as 2004 to today's situation of relying on imports for 50% of its requirements. It is therefore not surprising that recent assessments upgrading the UK's shale gas potential have been well received by many constituencies. In June 2013 the British Geological Society doubled its estimate of shale gas resources (in place, as distinct from recoverable) in the north of England to (a central estimate of) 1,329 Trillion Cubic Feet (Tcf). Assuming a shale gas recovery factor of 10% this implies that shale gas from this area of the UK alone would meet consumption requirements at current rates for some 50 years.

Such a conclusion is overly simplistic as it sidesteps the crucial issue of shale gas well flowrates and therefore the number of wells which would be required realise such a reserve estimate in terms of production. Oil and gas are formed when dead algae and protozoa, deposited in silt in an estuarine or inland lake-bed situation become 'cooked' by pressure and temperature as the depth of burial increases. When the resulting hydrocarbons migrate through faults and porous strata and become trapped by impermeable barriers they constitute 'conventional oil and gas'. Shale gas is essentially gas which 'never left home', i.e. it has remained in the low permeability shale strata in which it was formed. The technical challenges of shale gas extraction are firstly how to create a sufficiently large surface area to allow the gas to escape from the shale and secondly how to identify the areas of the shale 'play' where this is likely to result in commercially viable flowrates of shale gas. The first challenge has been met by the application of horizontal drilling and fracking technology which together enable networks of fractures to be promulgated around the bore of a horizontal well drilling within the shale gas stratum. The second challenge is not so easily resolved. Shale gas well flowrates depend on a number of variables such as total shale organic content, shale thickness, friability and porosity. While technology is evolving to identify those areas of a shale play which have the highest probability of yielding economically viable well production rates, there remains a significant level of uncertainty which can only be resolved by exploratory drilling. Shale gas success depends upon finding the 'sweet-spots' where well flowrates are highest and hence wells are commercially viable.

Despite this level of geological risk and uncertainty, factors which have allowed shale gas to develop so rapidly in the US and to achieve production levels there equivalent to some three times total UK gas consumption are:

- A large number of upstream players, ranging from oil and gas super-majors, through independents down to the small 'mom and pop' enterprises.
- An entrepreneurial upstream service sector which can take much of the credit for developing the technological approaches

optimising shale gas completion technology.

- A legal framework in which for most of the US geography, mineral rights reside with the land-owner thus facilitating bilateral agreements to be struck with upstream companies wishing to drill.
- A regulatory framework which has developed on the basis of at least a century of onshore (conventional) oil and gas production in the US.

It is the perhaps unique combination of these factors which has allowed so many wells to be drilled so quickly on some of the major US shale plays, e.g., on the Texas Barnett play a cumulative total of 17,000 wells since year 2000, and on the more recently developed Marcellus play in Pennsylvania approximately 2,000 wells drilled in 2011 alone. By contrast in Poland only 44 shale gas wells have been drilled to date and of these only four horizontal wells have been fracked.

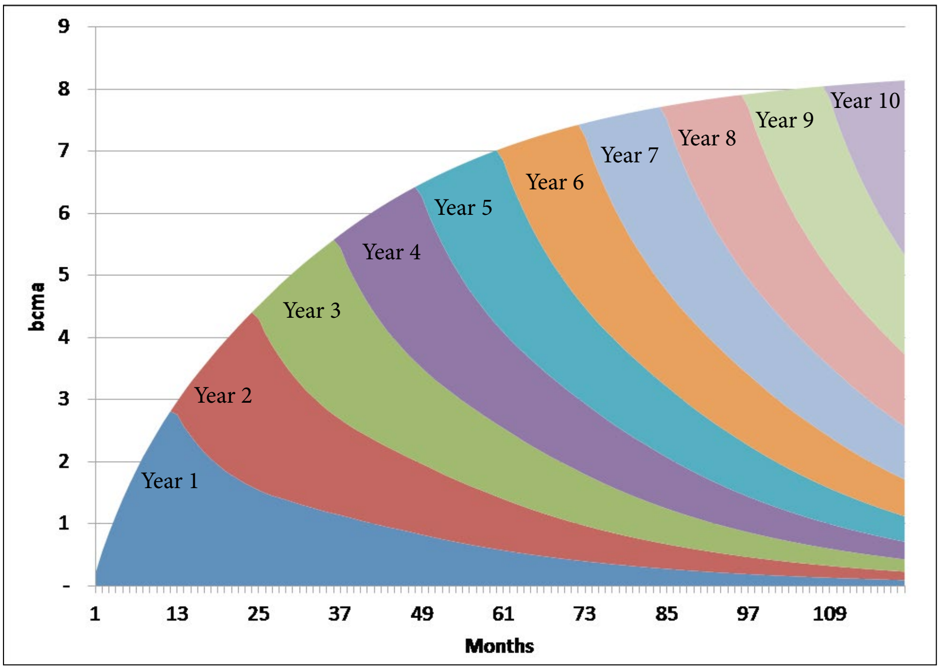
Achieving meaningful levels of shale gas production requires large scale and sustained drilling campaigns, especially as production from a single well tends to decline more rapidly than from a 'conventional gas' well. A simple calculation based on the 'mean' well production profile in the Texas Barnett shale implies that after seven years a production level of 8 billion cubic metres a year would be reached if 300 new wells were drilled every year. For context 8 billion cubic metres a year equates to just 10% of the UK's current gas consumption requirements.

Apart from the very germane question of the public acceptability of such a level of drilling intensity in a UK context, this pre-supposes that the commercial sweet-spots have been identified through a prior exploratory drilling phase. It is here that the dynamics observed in the US mark it out as possibly unique. The factors listed above allowed in the US something akin to a 'gold rush' psychology to develop on several shale plays in parallel. Upstream companies rushed in and drilled many wells quickly. The fortunate players found the 'sweet-spots' by trial and error, the unfortunate lost money. Successful areas became known through word of mouth and the industry focussed increasingly on these.

In countries other than the US, the prevalence of lengthy planning and consent procedures, slower allocation of acreage and therefore the pace of drilling will likely result in a very different dynamic. Unless upstream companies are very fortunate in locating sweet-spots in early exploratory drilling this may come to resemble more a slow motion game of 'battleships' rather than the 'gold rush' observed in the US. It remains to be seen whether such an approach will yield material results.

A much fuller discussion, with references, can be found at oxfordenergy.org/2013/07/uk-shale-gas-hype-reality-and-difficult-questions/

Figure 1: Illustrative Shale Gas Production Profile Assuming 300 additional wells per year (25 Pads) based on an Average Barnett Shale Gas Well Profile. Source: Analysis based on well data from A. Berman, Labyrinth Consulting Services, Inc



Recent Events

UK Energy Policy Day *30 May 2013*

Nearly 200 people (roughly half from inside the University, and half from outside – including some 40 alumni), participated in a one day meeting on UK Energy Policy. The presentations (excluding two lively panel sessions) may be found at www.one.ox.ac.uk/energy.html

Oxford Conference on Negative Emissions Technologies *24-26 September 2013*

This conference, which was organised by Tim Kruger of the Oxford Geoengineering Programme (part of the Oxford Martin School), brought together people with an interest in technologies that might be able to remove greenhouse gases from the atmosphere. There were over 100 participants from academic, policymaker, NGO, industry and media circles at the conference, which explored the technical, social, environmental, economic and ethical issues associated with determining whether the proposed technologies were in fact deployable. Proposed techniques included artificial trees to suck CO2 out of the air, large scale afforestation, fertilising parts of the ocean with iron compounds to promote algal blooms and means of enhancing the rate at which minerals weather.

There were delegates from the USA, Canada, China, Japan and Australia as well as from Europe, who were addressed by 38 speakers, including Sir Mark Walport, the UK's Chief Scientific Adviser who gave the Keynote Speech. The meeting concluded with an agreement to change the name of the field from "Negative Emissions Technologies" to "Greenhouse Gas Removal" and with an agreement to set up a network to help coordinate research and communication internationally and across different disciplines. A report on the meeting will be made available online in due course.

In the Next Issue...

How F1 Racing May Improve Your Car

Formula One cars currently use approximately 150kg of fuel per race. From next year there will be a 100kg fuel limit. Oxford Engineer David Limebeer, who works with Ferrari Formula One, will explain how this may be achieved without compromising performance. This dramatic reduction in fuel consumption will be passed down to mass production vehicles once the technology has been perfected and made cost effective.

Border Carbon Adjustments

Cameron Hepburn will explain how border carbon adjustments could protect energy-intensive industries in countries/regions with higher carbon prices, while also encouraging other countries/regions without carbon pricing to follow suit.

Major Advance for an Emerging Solar Cell Technology

Following a 2012 'breakthrough for perovskite cells' by Oxford physicist Henry Snaith and colleagues, Science (11/9/13) reported – under the headline above – that Henry and his team 'have delivered another surprise….the cells are just as efficient if constructed using the same method as cheap thin-film silicon cells. What's more, the simple layered cell converts more than 15% of sunlight to electricity - equal to the record for perovskite cells, set just two months ago for a nanostructured device'. Henry will describe this major breakthrough and its potential implications.

New Oxford Energy Website

Outlines of the energy research in Oxford, details of over 180 senior researchers from across the University, together with news and information about events, can be found on the new website:

energy.ox.ac.uk

Contacts

The major research themes (represented by sectors of the wheel above) have dedicated contact people, who can be found on the website. To join the Oxford Energy Network go to energy.ox.ac.uk/join or contact

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