Imperial College London

100 years of living science

100

energy futures lab

ENERGY FUTURES LAB

ANNUAL REPORT 2007

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1 Executive Director's Report

This report marks the end of the second year of operation of the Energy Futures Lab at Imperial College London. I am delighted to be able to report significant progress in developing our research agenda, with continuing success in our Urban Energy Systems Project with BP, a new strategic programme with Shell in the field of Clean Fossil Fuels, and a £4.2M programme funded by the EPSRC on new and renewable solar routes to hydrogen energy. We have been selected by E.ON UK as a partner in their low carbon research programme, which is being developed in partnership with the EPSRC, and we continue to engage with both industry and Government to support and inform decision making in the energy sector.

The EPSRC have provided direct support for our operations, and we are working closely with the Research Council's energy programme. The support of the Research Councils remains crucial to us, and we continue to play a leading role in many of the leading Research Council energy programmes, for example those in future electrical networks, fuel cells, keeping the nuclear option open, bio-energy systems and carbon capture and storage, are all led by academic teams at Imperial College.

We also continue to develop our International collaborations, and noteworthy has been our involvement with the Al Masdar programme in Abu Dhabi, where the Energy Futures Lab is working alongside industry partners to develop low carbon technologies, and to help establish a research programme in the region.

We are also grateful for a generous donation to support research scholarships in the energy sector from Alan Howard, an alumnus of the College, and two PhD students will be befitting from this support in 2007/2008.

In addition to research, I am pleased to report that the Energy Futures Lab has played its part in supporting teaching activities across Imperial College. Most significantly, we have launched our new MSc in Sustainable Energy Futures, which received its first student intake in October of this year. But we have also supported the development of a new undergraduate teaching programme through the Racing Green project, which is developing a zero emission racing car, and the Engineering Centenary Schools Challenge, where school children have been engaged in developing future energy scenarios for the UK.

Nigel Brandon

2 Overview of the Energy Futures Lab

"Imperial College embodies and delivers world class scholarship, education and research in science, engineering and medicine, with particular regard to their application in industry, commerce and healthcare. We foster interdisciplinary working internally and collaborate widely externally"

Imperial College London Mission Statement

In 2005 Imperial College London, for the first time, identified three strategic priorities to help shape its research capabilities and ensure it maintains and develops its world-class reputation. These priorities are:

- Energy
- Environment
- Healthcare

In developing these strategic goals it is apparent that the future of energy research lies at the intersection of diverse technologies and research fields. The interplay between energy resources, supply and demand, transformation technologies, and economics and policy are both complex and important, and any attempt at dealing with point solutions in the absence of treating the energy system as a whole is unlikely to succeed.

In order to maintain the leading position of Imperial College in the energy sector a new mechanism was required to draw together expertise from across the University to support the development of new research opportunities, whilst encouraging existing activities and promoting Imperial's international reputation.

Therefore, in 2005 the Energy Futures Lab was launched with a mission to:

- Develop and implement a portfolio of major cross-cutting, interdisciplinary research programmes in targeted areas of key scientific, technological or commercial interest.
- Maximise the impact of energy research performed within the College by providing co-ordination across Faculties and Departments.
- Proactively engage with industry on strategic energy themes, and develop programs for communication and discussion.
- Provide a focal point for key international relationships and collaborations.
- Develop innovative ways of working with business and industry.
- Develop highly skilled students trained at the postgraduate level in cross-cutting energy analysis and technologies.

(* Imperial College London is ranked 5th in the World overall and 2nd in Europe for Technology THES review November 2007)

3 Governance and Management

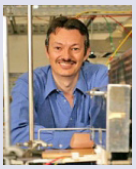
The Energy Futures Lab is led by Executive Director, Professor Nigel Brandon and supported by a Board of Directors comprising senior academics from across Imperial College. Design and management of the new MSc in Sustainable Energy Futures is spearheaded by Professor Sandro Macchietto. Each major activity has an academic lead with the core operations supported by a Programme Manager and Administrator.

The strategic focus and future direction of the Lab is supported an Advisory board chaired by Sir Roy Gardner and comprising senior figures from the energy industry.

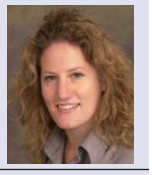
The operations of the Energy Futures Lab are supported by a three year grant from the EPSRC and strategic funds from the Faculty of Engineering. Together these funds cover the direct operating costs of the Lab (events and infrastructure), start-up costs of the new MSc and central management and administration.

3.1 Energy Futures Lab Board of Directors

Professor Nigel Brandon, Executive Director
Shell Professor of Sustainable Development in Energy
Prof Brandon is Senior Research Fellow to the Research Councils energy programme. He is management hub of the EPSRC fuel cell consortia, Principal Investigator of the Solar Routes to Hydrogen programme, and sits on the steering committee of the Shell-Imperial Grand Challenge programme.



Dr Virginia Acha
Research Fellow, Innovation Studies Centre, Tanaka Business Schools
Dr Acha specialises in addressing technology strategy in hydrocarbons and the nature of collaboration in energy R&D.



Dr Tariq Ali
Director, Energy and Environment Office
The Energy & Environment Office was created to initiate research & business development through strategic relationships with international academia, government agencies, business & other stakeholders. Dr Ali is the Director of AtlanTICC Alliance and Associate Director of Development and Policy for the Porter Institute.

Professor James Durrant
Professor of Photochemistry, Department of Chemistry
Prof Durrant is an expert in photochemistry and physical chemistry for solar energy conversion. Prof Durrant is a Co-Investigator for New and Renewable Routes to Solar Hydrogen.

Professor Robin Grimes
Professor of Materials Physics, Department of Materials
Prof Grimes is an expert in nuclear materials and is Principle Investigator of the Keeping the Nuclear Option Open (KNOO) programme.

Professor Chris Hankin
Professor of Computing Science, Department of Computing.
Prof. Hankin is Deputy Principal of the Faculty of Engineering and represents the Faculty on the Board.

Professor Sandro Macchietto
Professor of Process Systems Engineering, Department of Chemical Engineering
Prof Macchietto specialises in systems modelling, with emphasis on sustainable energy systems. He is the Director for the MSc in Sustainable Energy Futures.

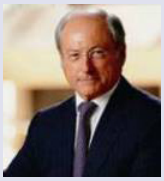
Dr Richard Murphy
Reader in Plant Science, Department of Life Sciences
Dr Murphy specialises in plant material for sustainable bioenergy and biofuels. Dr Murphy is the biofuels Theme Leader for the AtlanTICC Alliance and Theme Leader for cell walls with the Porter Institute.

Professor Peter Nixon
Professor of Biochemistry in the Department of Life Sciences
Prof Nixon is an expert in cyanobacteria and choloroplast molecular biology with particular emphasis on organic hydrogen production. Prof Nixon is a Co-Investigator for New and Renewable Routes to Solar Hydrogen.

Dr Peter Pearson
Professor of Energy and Environmental Studies
Director, Centre for Energy Policy and Technology in the Centre for Environmental Policy.
Prof Pearson specialises in long term implications of energy and environmental policy with emphasis on the transition to low carbon technology.

3.2 Energy Futures Lab Advisory Board

Sir Roy Gardner, Chairman
Chairman of Compass Group PLC
President of the Energy Institute



Dr Paul Golby
CEO, E.ON UK

Syamal Gupta
Chairman, Tata International

Professor Sir Peter Knight, FRS
Principal, Faculty of Natural Sciences, Imperial College London

Sam Laidlaw
Chief Executive, Centrica plc

Eddie O'Conner
Chief Executive Officer, Airtricity

Sir John Rose
Chief Executive, Rolls-Royce plc

Sir Neville Simms
Chairman, International Power plc

James Smith
Chairman, Shell UK

Professor John Wood, FREng, CBE
Principal, Faculty of Engineering, Imperial College London

Philip Yea
Chief Executive, 3i Group plc

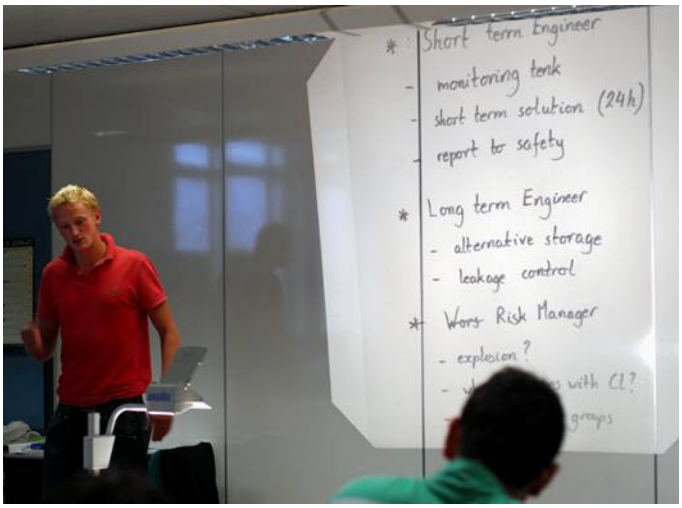
4 Research Activity

4.1 Summary of current project activities within the Energy Futures Lab

Project Title	Sponsor	Start Date	Duration
Management	EPSRC	August 2006	3 Years
Urban Energy Systems Project	BP	November 2005	5 Years
New and Renewable Routes to Solar H_2	ESPRC	October 2007	5 Years
Alan Howard Scholarships for Energy Futures	Donation	October 2007	5 Years
EON Prizes	E.ON UK	July 2007	2 Years
Maurice Hancock Energy Integration Lab supported by E.On and EDF Energy	E.ON UK	November 2006	2 Years
Amadeus Capital Partnership	DTI	April 2006	2 Years

The Energy Futures Lab also has a number of exciting projects in development.

MSc in Sustainable Energy Futures students during a Project Management Seminar



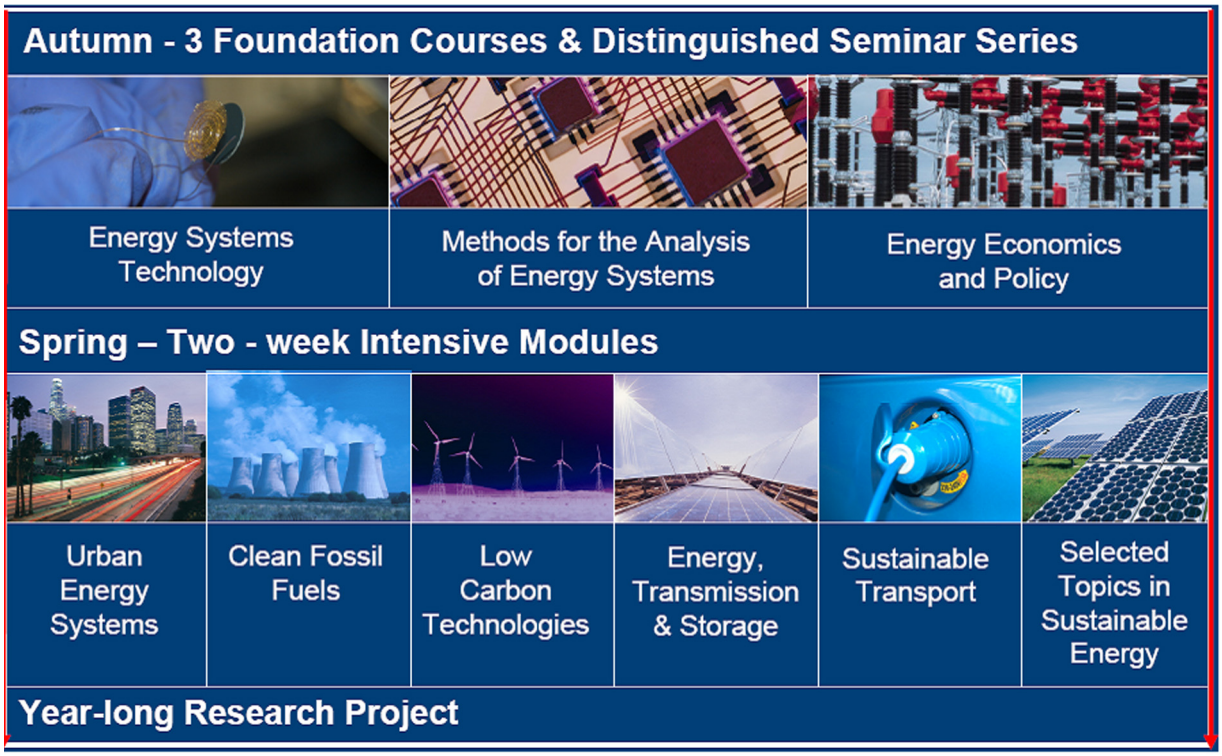
4.2 MSc in Sustainable Energy Futures

The Energy Futures Lab's MSc in Sustainable Energy Futures received its first intake of students in October 2007. This unique multidisciplinary course brings together energy expertise from across the College under the Energy Futures Lab to educate the next generation of energy industry professionals. Development of the course is supported by the Faculty of Engineering and the EPSRC. The course is led by Prof Sandro Macchietto and incorporates 11 departments from 3 faculties.

The course brings together students from diverse backgrounds, exhibited this year with students from geosciences through production engineering to those with City backgrounds. This is achieved through 3 foundation modules in the first semester to develop a common basis and language, followed by a series of two-week long intensive courses taught by specialists in the field. These two semesters are accompanied by a Distinguished Seminar Series, which is a series of one-off lectures by leaders in their area, with speakers such as Steve Koonin, Chief Scientist, BP. The students also undertake a research project which is completed in the third semester.

This course content and structure is industrially focussed and is designed to grow and develop with industry needs. This is possible through both participation within the course – through the Distinguished Seminar Series - and also through course development and research projects. The course's popularity speaks for itself; with initial student uptake estimated as 15, we have 25 enrolled for the academic year 2007-08 and are receiving enquires and applications for 2008-09 already.

The course offers an excellent opportunity for sponsorship and is already supported by E.ON UK through their E.ON Prizes for Excellence in Energy, and by Imperial College in the form of student bursaries available to UK and EU students.



MSc in Sustainable Energy Futures course structure

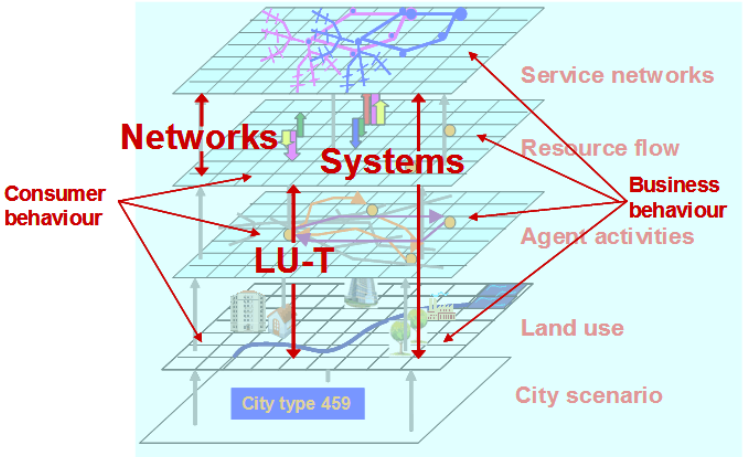
4.3 BP Urban Energy Systems Project

The BP Urban Energy Systems project explores how costs, energy and environmental impacts could be reduced in the future if cities integrate the systems that supply them with resources. It is currently completing the second year of its first 5-year term, with the current focus on modelling the demand for energy services as a driver for changes in energy supply vectors, and integrating the analysis of various networks of urban energy infrastructure. Existing models have treated these activity fields as isolated, one challenge is to capture cross-sector interactions and allow coherent aggregation across different length scales.

The programme works within six principal areas:

- Urban Systems modelling.
- Energy supply networks.
- Transport demand and land use.
- Ecological and resource use models.
- Innovation and consumption.
- Indicators and policy.

with research currently focussed on the integration of three major modelling problems, namely city layout design, land use-transport planning and the design of resource flow infrastructure networks. The methodology developed is being validated using data from 'small' scale cities in China and the USA, ahead of its application to larger 'world' cities.



Integrated city modelling

Over 25 researchers from 5 Departments and Centres at Imperial College collaborate on this project. Meetings with the programmes scientific advisory board are held biannually, with an annual report planned for release in late 2007/early 2008 (www.imperial.ac.uk/urbanenergysystems)

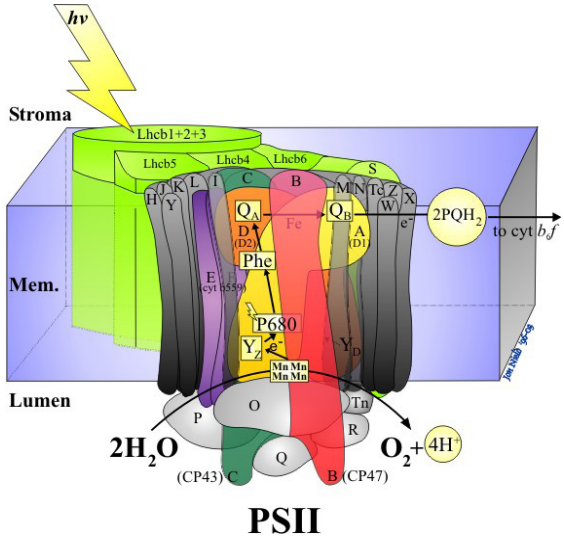
4.4 Shell – Imperial College Grand Challenge on Clean Fossil Fuels

One of the key initial themes of the Energy Futures Lab was 'The integrated clean production of fossil fuels' for which a research vision was developed by a group leading academics from across the Engineering and Natural Sciences Faculties. This vision envisages radical changes in the methods of production of coal, oil and gas over the next few decades as these energy sources continue to supply a large fraction of the world's growing energy needs. The new methods will aim to produce at surface only what is required – low or zero carbon fuels, heat and power, and chemical building blocks for materials and chemical products. Much of the downstream fossil fuel processing currently carried out on surface (eg synthesis gas production, coal or gas-to-liquids) will be relocated in the sub-surface, exploiting the high temperature-high pressure environment and transforming the subterranean well network from a passive fluids transportation conduit to an active, continuous processing plant. A large part of the carbon will remain underground, either as low-value residues or CO2 produced, captured and stored in the reservoirs without release. The energy efficiency of fossil fuel recovery will be enhanced and its environmental impact dramatically reduced.

Following the development of this broad research vision, we were delighted to be able to sign an agreement to collaborate on Clean Fossil Fuels with Shell E&P in December 2006, launched by a keynote lecture event by Shell's CTO Jan Van der Eijk in February 2007. The programme is managed by a Joint Steering Committee from both Shell and Imperial College. Strong interaction through scientific exchange and exploitation of expertise and equipment in both organisations are key components of the collaboration. The programme has two main areas of focus at present:

- Carbon dioxide lifecycle engineering in the reservoir.
- Low energy, low environmental impact processes for the recovery of non-conventional hydrocarbons

4.5 New and Renewable Routes to Solar Hydrogen



Cartoon of Photosystems II subunits
(Jon Nield 1966-2003)

In April of this year, a grant of £4.2M was awarded by the EPSRC to the Energy Futures Lab, to carry out cutting edge research on the sustainable production of hydrogen from water using solar energy under a team of senior investigators from Chemistry, Biochemistry, Chemical Engineering and Earth Science and Engineering. The project focuses on two hydrogen production strategies: the dissociation and separation of water into hydrogen and oxygen using photochemistry and the production of hydrogen from water using algae systems.

In both cases, appropriate reactor systems need to be designed, modeled and built to facilitate scale-up. The reactors will ultimately be coupled to fuel cell systems as end user a demonstration scale.

The project commenced on October 1st 2007 with significant preparatory work undertaken in the months leading up to the official start of the project. This included a half day workshop attended by leading international experts in the fields of chemical and biological hydrogen, internal knowledge sharing workshops, and the identification and recruitment of staff and students.

4.6 Alan Howard Scholarships for Energy Futures

Alan Howard, an Imperial College alumnus, generously donated funding to support research students of Israeli origin to undertake research at Imperial College London. The programme is run through the Energy Futures Lab.

The following projects have received funding to date:

- Bio mimicking, self-organisation of solar particles to enhance performance, under the guidance of Prof James Durrant and Dr Brian O'Regan of the Department of Chemistry, partnering with Bar Ilan University.

- Flameless oxidisation for power and aero-transport applications, to reduce energy consumption and lower pollutant emissions, in a high temperature context, under the guidance of Profs Alex Taylor and Fred Lockwood with Dr Yannis Hardalupas of the Department of Mechanical Engineering, partnering with the Technion.

4.7 Amadeus Capital Partners

Since July 2007, Patrick Burtis has been a Kauffman Research Associate with the Energy Futures Lab. Working with Amadeus Capital Partners, a leading UK/European venture capital firm with offices in London and Cambridge, Pat's two year Kauffman Fellowship is jointly supported by Amadeus Capital Partners and the UK Department of Trade & Industry The project aims to identify sectors of cleantech leadership at Imperial College and across the UK; to develop and execute a cleantech investment strategy for Amadeus Capital Partners; and to develop Pat's skills as a venture capitalist.

4.8 E.ON – EPSRC Strategic Partnership

Imperial College, through the Energy Futures Lab, is one of four UK universities that have worked with E.ON UK and the EPSRC to develop a new £10M research programme to look at the next generation of low carbon energy solutions. Imperial College was joined by Loughborough University, University of Nottingham and University of Birmingham in helping design the programme.

The first project from the E.ON-EPSRC strategic partnership was awarded in September 2007. The £2.1m project on transitions to a low carbon economy was awarded to a consortium including Universities of Loughborough, Strathclyde, Surrey, East Anglia, Leeds, Bath and the Policy Studies Institute, with Prof Peter Pearson of Imperial College appointed academic lead. The project will develop a set of potential transition pathways for the UK energy system to a low carbon future, and undertake integrated assessments of the technical and economic feasibility, social and environmental potential, and acceptability of these pathways.

4.9 Energy Integration Lab

The Energy Integration Lab is being developed to facilitate the teaching and research of electrical networks, with particular emphasis on renewable energy technologies. Funding has been secured from a number of sources including EON, EDF Energy, DTI and through a bequest made to the Department of Electrical and Electronic Engineering. The Lab will be built in the Department of Electrical and Electronic Engineering, and is currently in development.

4.10 Masdar Research Network

Al Masdar ('the source') is an initiative, launched in April 2006, that will see the development of world-class research, teaching and commercialisation of sustainable energy technologies in Abu Dhabi. It will build local capacity and meet regional strategic objectives for economic growth and environmental control, and the development of local human capital.

Following its launch Imperial College signed a Memorandum of Understanding with Masdar to develop the research network and to explore potential new research projects.

The Energy Futures Lab, under the guidance of Dr Velisa Vesovic, is directing a theme on Carbon Management for the Masdar Research Network, with the first projects in development. A number of Masdar funded students are undertaking our MSc in Sustainable Energy Futures as part of the development in local human capital.

Signing of the MoU in Abu Dhabi in April 2006

5 Events and Outreach

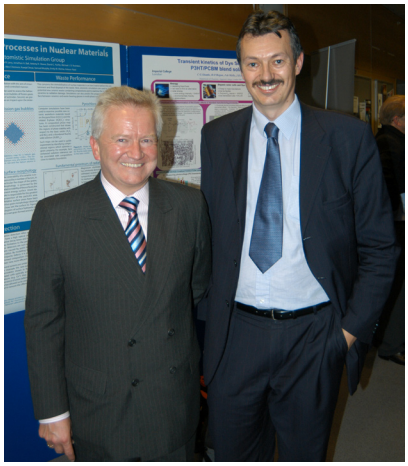
The Energy Futures Lab has developed a reputation for delivering a wide range of events, ranging from lunch time lectures to multiple day seminars. Highlights from the Energy Futures Lab events calendar include; the 2006 Annual Lecture, presented by Dr Paul Golby, E.ON UK, the 2007 Annual Lecture, presented by Sir Roy Gardner; and the half day seminar on 'Solar Fuels: Making them a reality' with presentations from international experts on biological and chemical routes to sustainable hydrogen production, and the Engineering Centenary Schools Challenge which saw 40 children from schools from London and the South East develop strategies to combat the UK's impending energy crisis.

Dr Paul Golby, CEO, E.ON UK and Prof John O'Reilly, Chief Executive, EPSRC

Students from Waldegrave School for Girls organising the energy flow diagram with their Energy Mentor Francesco Coletti

Dr Jan van der Eijk, Shell Group Chief Technology Officer presenting 'Meeting the Energy Challenge'

Students testing out the Imperial College London Racing Green Fuel cell powered racing cart at the Engineering Centenary Schools Challenge



Dr Paul Golby, CEO E.ON UK with Prof Nigel Brandon at the Energy Futures Lab Annual Lecture 2006

5.1 Events

Energy Futures Lab Launch		November 2005
Powering the Planet		February 2006
Bioethanol Conference	Chaired by Prof Sandro Macchietto	March 2006
Case for Geological Sequestration of Anthropogenic CO2		April 2006
Community Initiative in Developing a Hydrogen Economy		June 2006
AtlanTICC Alliance Special Seminar: Oak Ridge National Lab	Dr James Roberto Oak Ridge National Lab	October 2006
Annual Lecture: Changing Energy	Dr Paul Golby E.ON UK	November 2006
Economics of Climate Change: Reflections on the Stern Review	Emeritus Professor Dennis Anderson Imperial College London	December 2006
Project Launch: Meeting the Energy Challenge	Dr Jan van der Eijk Shell B.V.	February 2007
Carbon Management and Engineering	Dr Brian McPherson Energy and Geoscience Institute	March 2007
American Energy Policy	Dr Michael Webber University of Texas	April 2007
Doosan Babcock Energy Pulse Survey Launch		June 2007
Commercialising Clean Technology	Mr Pat Burtis Amadeus Capital Partners	June 2007
Solar Energy and Sustainability Lectures	Dr Nathan Lewis California Institute of Technology Prof Sir Harry Kroto University of Florida	July 2007
Solar Fuels: Making them a reality	Chaired by Prof Jim Barber; Prof James Durrant & Prof Peter Nixon	July 2007
Annual Lecture: Securing our Energy Future	Sir Roy Gardner	November 2007

5.2 Outreach

Green Week	Imperial College Union Student Initiative	February 2007
Ethical Careers Exhibition	Imperial College Student Union Initiative	February 2007
Local schools	Work Experience students	July 2007
Engineering Centenary Schools Challenge: Future Generations	40 Year 9 students from London and South East developing the UK's future energy portfolio	September 2007