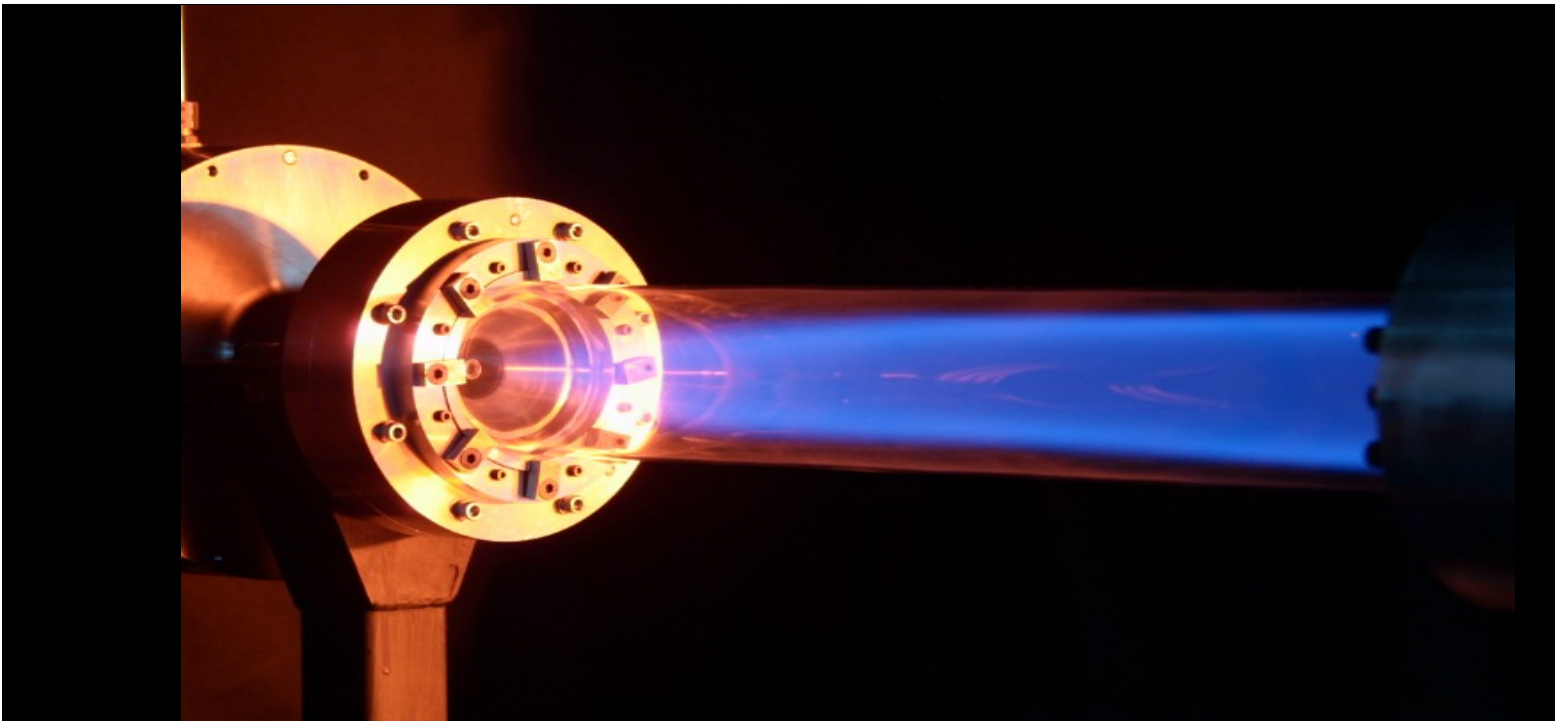


ENERGY FUTURES LAB

ANNUAL REPORT 2008



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1 Rector's Foreword

Providing clean and sustainable sources of energy is one of the most pressing challenges facing the world today.

However, in common with other global challenges, it will not be overcome through the efforts of one group of scientists alone. Increasingly we find that some of the most innovative solutions are found at the boundaries where different scientific or engineering disciplines meet.

At Imperial, we actively encourage and nurture this approach through our strong support for multidisciplinary, cross-faculty research initiatives.

The Energy Futures Lab is a successful model of this multidisciplinary approach. It joins together the capabilities of scientists and engineers from across the College to provide new solutions to energy provision - ranging from next-generation photovoltaics and fuel cells through carbon capture to the 'artificial leaf'.

Outlined in this report you will find details of some of the Energy Futures Lab's imaginative research and teaching projects. I am delighted to congratulate all those involved on the Lab's tremendous success since its establishment in 2005.

Looking forward I hope that the Energy Futures Lab will benefit from collaborative work with our other multidisciplinary initiatives including the Grantham Institute for Climate Change and the Institute for Global Health, and I hope we will witness further exciting and innovative energy technology solutions in the years to come.



Sir Roy Anderson

2 Chairman's Foreword

I am pleased to introduce the annual report for the Energy Futures Lab 2008. In the past year the Lab has continued to grow, taking on new challenges, securing new funding and working in a truly global and multidisciplinary fashion.

2008 has seen unprecedented change for the global economy. Despite these upheavals, securing a sustainable energy future has never been far from the public and private agenda. This shows that everyone is now ready for change as together we address the three key challenges of meeting demand, ensuring security of supply and mitigating environmental impact.

In rising to this formidable challenge, I am pleased to endorse the progress and contribution made by the Energy Futures Lab of Imperial College London. Ambitious targets such as the UK's commitment to reducing CO₂ emissions by 80% by 2050, will only be met by answering questions that lie at the interface of traditional academic, government and industrial boundaries. Through the Energy futures Lab, Imperial College shows that we can have a sustainable energy future provided that we can work across these historic divides, solving problems and educating the next generation of energy professionals.



Sir Roy Gardner

3 Executive Director's Report

The Energy Futures Lab at Imperial College London has just completed its third year of operation, and I am delighted to be able to introduce a summary of our activities in this report.

Energy remains a critical global challenge, which Imperial College is uniquely placed to address. Highlights during the past twelve months have been the signing of a new strategic \$70M ten year partnership with Shell, Qatar Petroleum, and the Qatar Foundation, to study the science of carbon dioxide storage in carbonate reservoirs found in the Middle East; the development with BP of a programme to support the professional development and training of BP petro-technical staff; the start of a new project with Shell and Masdar in Abu Dhabi, to analyse CO₂ and CO₂-enriched flue gas infrastructures for the UAE; the successful launch of the Racing Green undergraduate project to build and race a zero emission race car; and the graduation of the first students from our new Energy Futures Masters programme.

A review of the energy research programme across Imperial College London shows that we have an energy research income of £30M per annum, around one third of which is from industry, supporting a team of some 600 faculty, research staff and PhD students. This enables a unique combination of both depth and breadth in the energy domain at the College, with significant research themes including solar, nuclear, combustion, transport, fuel cells, hydrogen, carbon capture and storage, oil and gas, bio-energy, electrical transmission and distribution, energy systems and energy policy. The Energy Futures Lab has built on this capability by tackling a series of major 'Grand Challenges' in the energy sector, and we look forward to continuing to build on this success through the coming year.

Dissemination of our research in the energy sector remains a critical part of our mission, and we have organised a number of well attended symposia, including "Innovation and Investment Opportunities in Carbon Capture and Storage", and our Annual Lecture, which in December 2008 will be given by Ed Miliband, Secretary of State for Energy and Climate Change. Our work on science communication was recognised through the 2008 Rectors Award for Public Engagement.



Nigel Brandon

4 Strategic 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 has three strategic priorities of energy, environment and healthcare which are based upon the core strengths of the university and the demands of society.

Energy research at Imperial encompasses over 600 faculty, research staff and postgraduate students funded by £30M pa of research grants, a third of which comes from industry. It covers a wide range of disciplines including advanced petroleum engineering, nuclear, next generation renewables and transport.

In achieving the strategic goals of Imperial College it is apparent that many of the critical challenges of the 21st century lie at the interface of traditional academic boundaries and new mechanisms are needed to draw together expertise from across the University, to support new research opportunities and to maintain and develop Imperial's world class reputation. Nowhere is this more apparent than for energy with the dual challenges of meeting demand and climate change bringing about fundamental changes to the world's energy markets.

The Energy Futures Lab was launched in 2005 to meet the multidisciplinary demands of energy research and teaching at Imperial. Over the past 3 years it has grown to encompass over £45M of research programmes and has enabled further initiatives across the University. The Lab plays a key role in promoting energy research and teaching at Imperial, multidisciplinary thinking, networking and engaging with our stakeholders in all aspects of Energy. Today, we work closely with other College Institutes and headline initiatives including the Grantham Institute for Climate Change and the Porter Alliance.

The Energy Futures Lab goals are to:

- work with industry, Government and funding agencies to secure funding for research addressing major energy challenges;
- support the strategic development of energy research within the College by providing leadership and coordination;
- provide leadership for establishing and taking forward global partnerships in strategic energy themes;
- encourage and support entrepreneurship in developing energy technology;
- contribute to the skilled work-force in energy by training researchers in cross-cutting energy analysis and technologies and energy policy-makers;
- influence key decision-makers by providing the evidence to inform and shape policy;
- communicate the vision to the widest audience;
- inspire and enthuse the next generation of researchers.

5 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.

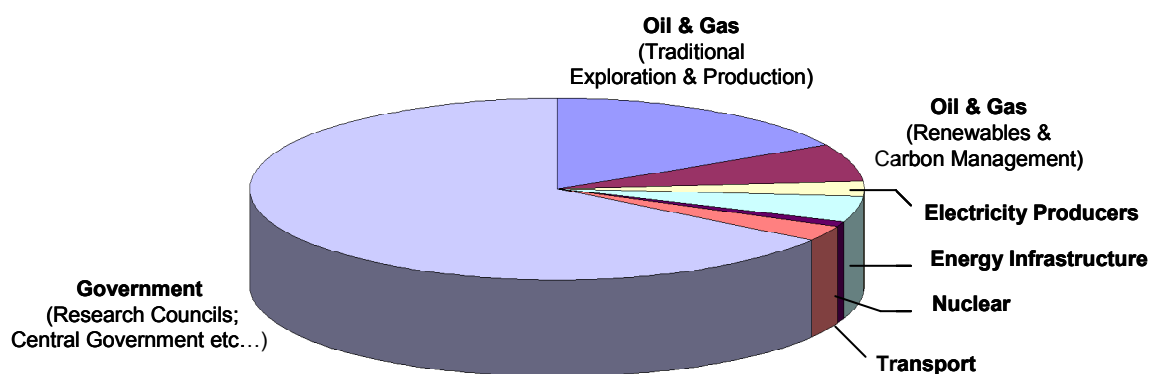
The strategic focus and future direction of the Lab is supported an Advisory board chaired by Sir Roy Gardner and comprising senior figures from the energy industry.

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.

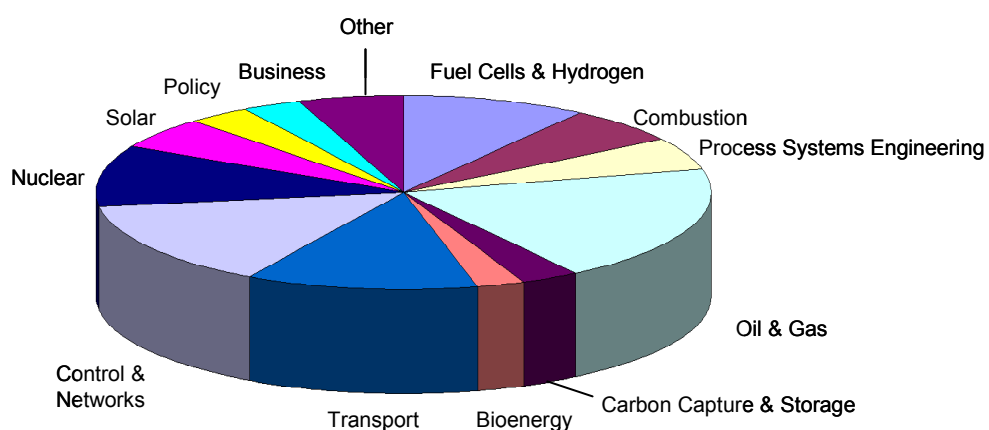
Energy Research at Imperial College 2008 - at a glance

Total number of projects	370
Government funding	£19.3M
Industry funding	£10.2M
Total funding per year	£29.5M

Distribution of funding between governmental and industrial sources



Distribution of funding within energy research at Imperial College (All sources)

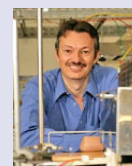


4.1 Energy Futures Lab Board of Directors

Professor Nigel Brandon FEng, Executive Director

Shell Professor of Sustainable Development in Energy

Prof Brandon is Senior Research Fellow to the Research Councils energy programme. He is the 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 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 Gerry George

Professor of Innovation and Entrepreneurship, Imperial College Business School

Prof George is the Director of the Rajiv Gandhi Centre for Innovation and Entrepreneurship.



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 B2B3 Theme Leader for the AtlanTICC Alliance. Dr Murphy is the Theme Leaders 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 chloroplast 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 the transition to low carbon technology.



4.2 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

**Dr Eddie O'Conner**

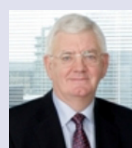
Founder and Chief Executive, Mainstream Renewable Power

**Sir John Rose**

Chief Executive, Rolls-Royce plc

**Sir Neville Simms**

Chairman, International Power plc

**James Smith**

Chairman, Shell UK

**Professor Stephen Richardson, FREng**

Principal, Faculty of Engineering, Imperial College London

**Philip Yea**

Chief Executive, 3i Group plc



6 Energy Futures Lab Research and Teaching Activities

Project Title	Sponsor	Start Date	Duration
EFL Management	EPSRC	August 2006	3 Years
Urban Energy Systems Project	BP	November 2005	5 Years
Grand Challenge on Clean Fossil Fuels	Shell	February 2007	5 Years
New and Renewable Routes to Solar H₂	ESPRC	October 2007	5 Years
Alan Howard Scholarships for Energy Futures	Donation	October 2007	5 Years
EON Prizes	E.ON UK	October 2007	2 Years
Carbon Capture, Transport and Storage Infrastructure in the UAE	Abu Dhabi Future Energy Company & Shell Abu Dhabi	October 2008	3 Years
Qatar programme	Qatar Foundation, Qatar Technology and Science Park, Shell	January 2009	10 Years
BP21CPD	BP	August 2008	10 Years
Maurice Hancock Energy Integration Lab supported by E.On and EDF Energy	E.ON UK	October 2008	Ongoing
Amadeus Capital Partnership	DTI	April 2006	2 Years



MSc in Sustainable Energy Futures students in their dedicated workroom



New MSc in Sustainable Energy Futures students arrive at Imperial College London

6.1 MSc in Sustainable Energy Futures

The first year of the new MSc in Sustainable Energy Futures was successfully completed. 24 students graduated from the course in September 2008 and an excellent new intake of 34 students, selected from 178 high quality applicants, began the programme in October.

This unique multidisciplinary course brings together energy experts from across the College under the Energy Futures Lab to educate the next generation of energy industry professionals, focusing on an overall energy systems approach. Development of the course, with all material specifically designed, was supported by the Faculty of Engineering and EPSRC. The course, led by Prof. Sandro Macchietto, involves 40 leading experts from 12 departments in the Faculties of Engineering, Natural Sciences and Business School at Imperial, together with external speakers from industry and commerce. Five UK students are supported by Imperial bursaries and several from external sponsors.

As in the first year, students joined the course from diverse backgrounds and nationalities. Some are recent graduates whilst others already had successful careers in engineering, consulting and finance. Of the new intake, 11 of the students are from the UK, 14 from the rest of Europe and 9 from the rest of the world (including China, Thailand, Pakistan, Mexico, Tanzania and Egypt), helping to give students a truly global perspective and experience.

The first cohort of graduates from the course has now moved on to new opportunities in a wide range of relevant energy fields. 82% of graduates with known destination (all but two) already had a job by the end of the course. These include positions as Energy Consultant with Camco (a large consultancy), Fuel Formulation Research Scientist with ARAMCO, Energy Strategy Analyst with EDF, Sustainable Energy Consultant with E4Tech (a smaller consultancy) and Environment and Sustainability Manager at The National Archives. One graduate is Managing Director of a start-up venture in the solar energy field. 3 of the students remained at Imperial to continue their studies towards a PhD. Their research involves a new Energy Futures Lab project with Masdar and Shell on carbon capture, the development of an algae-based hydrogen production and new electricity pricing models. The course fostered excellent bonds between the participants and we aim to remain in contact with our alumni over the years helping us track the impact of the degree in meeting the needs of academia, industry, government and commerce.

The new course has already been recognised in several ways. Prof. Macchietto was awarded the 2008 Rector's Award for Excellence in Leadership and Management. Several prizes, funded by E.ON for best overall student, best experimental research dissertation, best theoretical research dissertation and best exam result will be presented to the first cohort following the examiners meeting scheduled in November 2008. Above all, the number and quality of applicants from all over the world and the demand from industry are a good testament of the relevance and timing of this new venture.



New Msc in Sustainable Energy Futures students tour Imperial College



Professor Macchietto receiving Rectors Award for Excellence in Leadership and Management

Class of 2008: Destinations and Student Testimonial

Niels Jakeman - MSc in Sustainable Energy Futures 2007-08

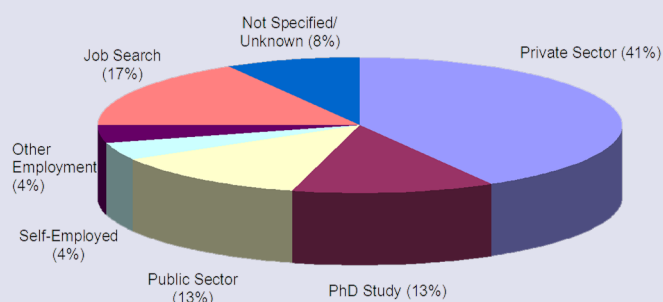
Niels graduated from the University of Durham in 2007 with a 1st in Chemistry and Physics. In the MSc in Sustainable Energy Futures at Imperial College London he has greatly enjoyed broadening his knowledge into the range of solutions available (and under development) to meet the energy challenges of the future. His interests covered the full spectrum of sustainable energy technologies, appreciating the fact that the solution to a sustainable future will inevitably depend on a broad portfolio of options. He decided to concentrate his studies on the development of carbon, capture and storage (CCS), with specific focus on encouraging investment into the technology development. Following completion of the MSc, Niels was looking to apply his knowledge gained from both degrees to a career in which he can help the energy sector meet its environmental challenges.



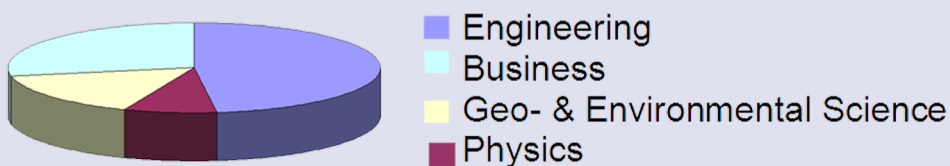
"Since completing my MSc in Sustainable Energy Futures I have joined EDF Energy as a Strategy Analyst. Within this role I am responsible for providing core analysis required to develop the long-term strategy of the firm, i.e. the targeted mix and types of energy assets needed to meet EDF Energy's needs. The MSc at Imperial provided me with an invaluable understanding of both the technological prospects and the economic trade-offs of a range of energy technologies. In combination with teaching crucial skills in modeling and optimization, as well as a strong coverage of developments in energy policy, I strongly believe this course has been the perfect bridge for a career in energy strategy."



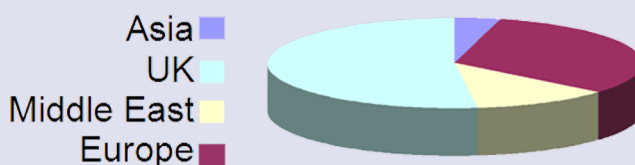
Class of 2008



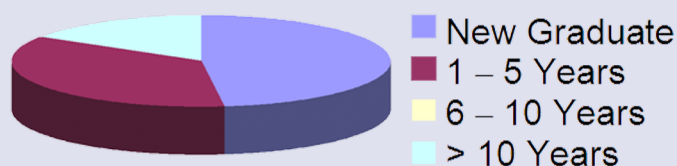
Class of 2008: Destinations



Class of 2008 : Academic Background



Class of 2008 : Home Region

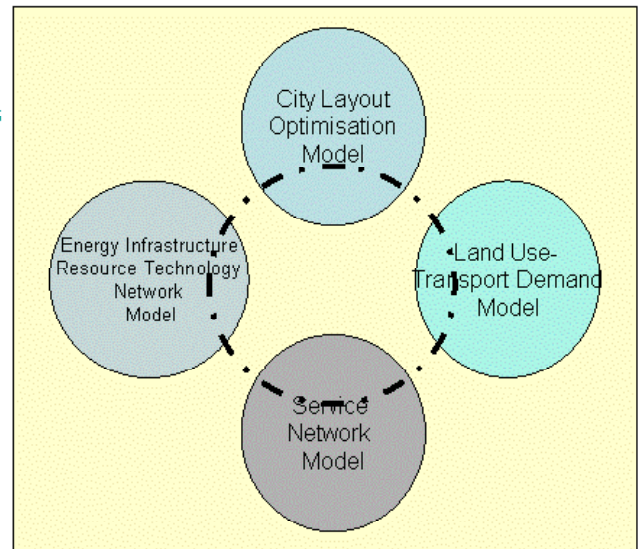
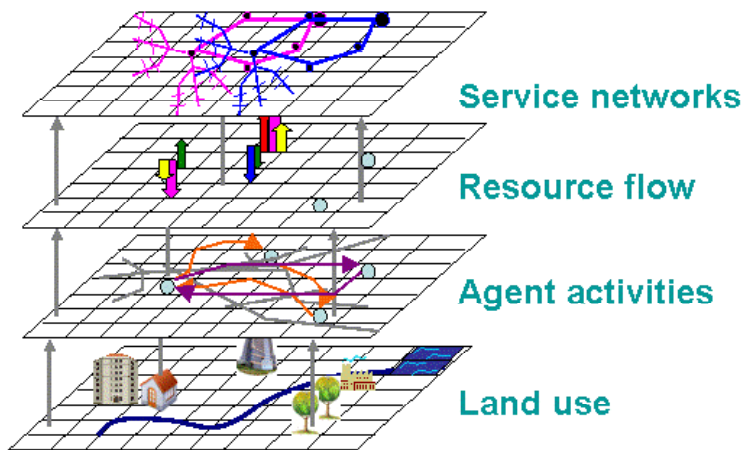


Class of 2008 : Prior Professional Experience

6.2 BP Urban Energy Systems

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 now about halfway through its 5-year term.

The major developments include a new modelling framework named SynCity; this integrates different model types and facilitates a hierarchical approach to city and energy system design.



SynCity Framework

The SynCity framework provides tools to solve four inter-related problems:

- **Layout model** - this is an optimisation-based approach to organising the city layout. It is provided with the basic information about the city, its residents and boundary conditions, desired activities and so on, and uses a combinatorial optimisation technique to develop alternative city layouts.
- **Agent-based land-use and transport model** - this model combines the important features of agent-based modelling (the use of individual agents with heterogeneous properties) and established 4-step transport demand models. It takes the city layout and identifies where the agents are at any given time and what activities they are involved in, and when they move between places their mode choices. This can then be used to infer time-dependent resource demands associated with the built environment (which can vary depending on building designs and standards) and the transport system.
- **Energy interconversion and infrastructure model** – this optimises:
 - The choice of resources to import into the city
 - The choice of resource interconversion technologies and their scale to incorporate in the city
 - The design of any networks for resource flow through the city
 - The destination of wastes (inc power, gas, heat , etc.).

Current work focuses on the application of the methodology to real-world example developments in the UK, China and the USA. Early results indicate the potential for large scale (25-50%) improvements in energy efficiency through better design and resource integration.

The BP Urban Energy Systems project is codirected by Professor David Fisk and Professor Nilay Shah with a research team of 21.

6.3 Shell Grand Challenge on Clean Fossil Fuels

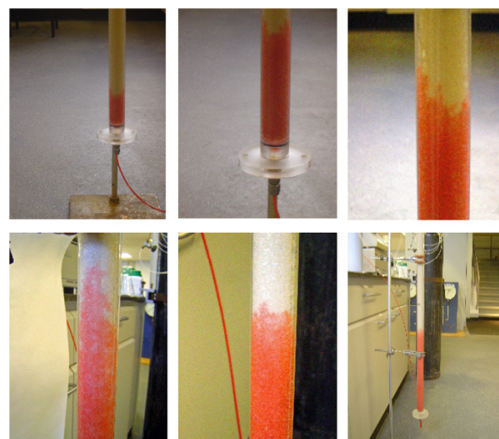
Shell has committed £3M of funding over an initial five year period to work with Imperial on research into Clean Fossil Fuels. The programme is coordinated by a Director, Professor Geoffrey Maitland, and managed by a Joint Steering Committee comprising the Director, the Shell Sponsor Dr Claus Otto, the Energy Futures Lab Executive Director Professor Nigel Brandon and Dr Rick Wentinck representing Shell Exploratory Research. Strong interaction through scientific exchange and exploitation of expertise and equipment in both organisations are key components of the collaboration. Extension beyond five years will be linked to building a highly interactive relationship as well as on technical success.

Theme A: Carbon Dioxide Lifecycle Engineering in the Reservoir

Principal Investigator: Professor Martin Blunt

The project aims to give a comprehensive understanding of the behaviour of CO_2 under reservoir conditions, its interaction with other fluids and with rocks/minerals, leading to the optimisation of its use for Enhanced Oil/Gas Recovery (EOR) and/or its Capture and Sequestration within reservoirs (CCS) and is split into five sub-projects: thermophysical properties; multiphase reservoir flow and long-term storage; thermal stimulation of coal for enhanced coal-bed methane (ECBM); CO_2 -caprock interactions; H_2 - CO_2 infrastructure.

The theme involves 10 Imperial academic staff, 4 postdoctoral researchers and 6 PhD students and as it comes to the end of the second year, promising results are emerging. New equipment is operational and novel mathematical modelling ideas have been implemented, that have led to increased engagement and interaction between the research teams at both Shell and Imperial.



CO_2 trapping experiments; sand packed column injected with non-wetting fluid (oil is dyed red)

Theme B: Low-energy, low- CO_2 release recovery of non-conventional hydrocarbons such as oil shales and tar sands

Principal Investigator: Prof Geoff Maitland

A Workshop will be held in December at which Imperial and Shell researchers will discuss industrial needs and potential engineering solutions for work in this theme to address.

Overall, the programme is now well-established and beginning to deliver new data and concepts which have been well-received by Shell. As the outputs increase, the interaction with the Shell technical community is growing all the time and we hope to improve this further over the coming year to align priorities as the projects mature.

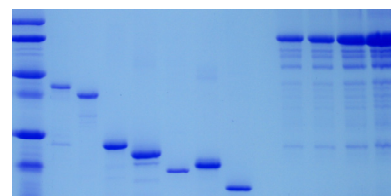
6.4 New and Renewable Routes to Solar Hydrogen

This is a £4.2M project sponsored by EPSRC. The aim is to develop materials and technologies to utilise solar radiation to convert water into hydrogen (and oxygen) gas for direct application in fuel cell systems. The project is a multi-disciplinary effort by the Departments of Biochemistry, Chemistry, Chemical Engineering and Earth Science and Engineering. Approximately 25 researchers are directly associated with the project (approx. 15 full time). The main activities this year have centred on Biology, Chemistry and Chemical Engineering.

Biology

The aim of this part of the project is to improve the yields of H_2 evolved by the green algae *Chlamydomonas reinhardtii*. To this effect the following objectives are being addressed:

- The addition of new genes into the algae to reduce the lag time before hydrogen evolution can occur (currently up to 60 hours) and enhance the conversion of starch to hydrogen metabolic pathway.
- Switching off of genes to increase the conversion efficiency of solar radiation to hydrogen
- Using a novel technology to reduce by-products such as formic acid and increase hydrogen production; waste product genes have been targeted and two test methods are employed to identify effective mutants
- Development of sensitive small scale techniques to measure hydrogen concentrations in situ.
- Trials on the long term storage of algae mutants.

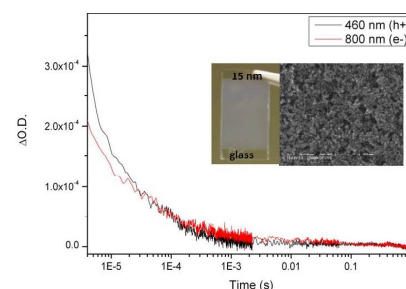


SDS-PAGE gel of protein expressed and purified for antibody production

Chemistry

The aim of this part of the project is to provide a fundamental understanding of the kinetics and lifetime of charge carriers as well as the generic interaction of photons with semiconductor interfaces, leading to the development of novel materials with high conversion efficiency. The following advances have been made to date:

- Development of novel time-resolved absorption spectroscopy (TAS) system allowing the observation of dynamic processes, facilitating the monitoring of an extended time period in a single experiment
- Development of a 4-flash system, inspired by the biological systems to prove or disprove the creation of photo-excited electrons for many photoactive materials.
- Photo-electrochemical cell for materials development, using the TAS, has been designed and constructed. Different analytical and electrochemical techniques are being incorporated for in situ analysis of dissolved gaseous species.
- Materials synthesis and characterisation such as the doping of photocatalysts to enhance light absorption in the visible spectrum and increase photo-efficiency.

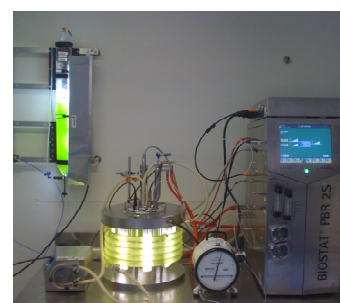


Temporal profile of the decay kinetics of the photo-generated holes and electrons in nc-TiO₂ films on a glass substrate under an argon atmosphere recorded with the new TAS spectrometer

Chemical Engineering

The aim of this part of the project is the kinetic analysis, design of devices and scale-up of both, biological hydrogen production and photo-electrochemical hydrogen production systems. The following advances have been made in both areas.

- Installation, commissioning and operation of culture reactors and a large scale multi-sensor (monitoring of temperature, oxygen concentration, pH, chlorophyll and cell density).
- Design and installation of a membrane interface to selectively extract dissolved hydrogen from the algae suspension and monitor the concentration of hydrogen for in situ determination.
- Automated photocurrent spectroscopy system to interrogate within a wide wavelength window (near IR to UV) to allow the detailed photo-electrode/electrolyte interface processes.
- The morphology of cheap photo-efficient materials is being developed in collaboration with Chemistry.



Culture Reactor and Sartorius Photobioreactor

6.5 Qatar Carbonates and Carbon Storage Research Centre

The Qatar Carbonates and Carbon Storage Research Centre (QCSSRC): a new research initiative in Clean Fossil Fuels

This is a new £35M programme that is focused on carbonate reservoirs, and is a collaboration between Shell, Qatar Petroleum, Qatar Science and Technology Park and Imperial College London building on the existing Shell Grand Challenge programme on sandstone oil and gas reservoirs and coal beds.

Carbonate reservoirs are the predominant oil and gas reservoirs in Qatar and the Middle East. Qatar has the biggest gas field in the world (the North Field) and Shell's main business there is running the Pearl Gas-to-Liquids (GTL) project which adds even more value to Qatar hydrocarbon reserves.

The overall objectives of the programme are the sustainable optimization of production and recovery from Qatar reservoirs through the development of future technical expertise and people needs of Qatar and Qatar Petroleum. This will be achieved by understanding the Qatari reservoirs, in depth, through the development of state-of-the art reservoir multiphase flow simulators and design optimum CO₂ storage and oil & gas recovery processes which will be validated with a 'Field-scale Laboratory'.



***Sir Roy Anderson,
Imperial Rector Elect, and
His Excellency Abdullah
Bin Hamad Al-Attiyah at
the signing ceremony***

The funding will provide for four new lecturers, 20 postdocs and 20 PhD students and include the involvement of many existing academic staff at Imperial College. The programme will be carried out in conjunction with Shell researchers based in the Shell Carbonate Center of Expertise, QSRTC, on the Qatar Science and Technology Park in Doha. As well as the technical outputs, it will provide trained people and expertise to help grow the new Qatar Petroleum Technology Center, QPRTC, at the same location. Many of the students and postdocs will spend time in Qatar during their research working with both the companies and Qatar Universities, and be a critical part of the knowledge transfer process into Qatar Petroleum and the broader technical/academic community.

The framework agreement for this new major research collaboration was signed on June 9th 2008 at a ceremony in London involving the Qatar Energy and Industry Minister HE Abdullah Al-Attiyah, Shell Executive Linda Cook and the Rector-elect Sir Roy Anderson. This is a joint venture between Chemical Engineering and Earth Science and Engineering, operating under the umbrella of the Energy Futures Lab, providing £35M of research funding over 10 years. The venture is coordinated by Professor Geoff Maitland FREng (Programme Director) and Professor Martin Blunt.

The detailed contracts and research plans for the five projects are currently being put in place. The aim is to start Project 1 by January 2009; adverts for Qatari students have produced several promising candidates. If suitably qualified Qataris are not available, preference will be given to students from the region who want to work in Qatar and then to high quality candidates from all countries.

6.6 Masdar

Imperial College and the Energy Futures Lab are founding partners of the Masdar Research Network. Masdar is an initiative launched by the government of Abu Dhabi. One key objective of Masdar is to position Abu Dhabi as a world-class research and development hub for new energy technologies, while ensuring that Abu Dhabi maintains a strong position in world energy markets. Masdar is seeking to help achieve this goal through partnership with leading universities. In addition to Imperial College, the Research Network's partners include: RWTH of Aachen, Germany; University of Waterloo, Canada; Tokyo Institute of Technology, Japan; Columbia University, USA and the German Aerospace Center (DLR).

In October 2008 Masdar entered into a collaborative research programme with Imperial College and Shell to develop a state-of-the-art capability to analyse CO₂ capture from flue gas in the UAE.

The objective of the three-year project is to develop a system of analysis of CO₂ capture, transport and storage technologies and the ability to use them effectively within a carbon management framework. It will provide Shell and Masdar with the opportunity to model and plan for carbon management projects in the UAE. It will also provide the capability to assess new technologies, allowing better investment decisions. Students from the UAE will be completing PhD programmes as part of the initiative, helping to develop local skills and a sustainable regional development. One of the students entered the programme after successfully completing the Energy Futures Lab MSc in Sustainable Energy Futures.

6.7 Alan Howard Scholarships

Alan Howard Scholarships for Energy Futures enables Israeli research students to study at Imperial College London in energy topics, developing inter-institutional links and the next generation of energy engineers and scientists.

We have funded two further projects and students are expected to start late 2008/ early 2009:

- Morphological characterisation of porous electrodes and membranes for fuel cells, undertaken with the supervision of Dr Rafi Blumenfeld, Department of Earth Science and Engineering (Imperial College London) and Prof Moshe Schwartz, School of Physics and Astronomy (Tel Aviv University).
- Building energy management for integration of photovoltaic energy, supervised by Prof Tim Green, Dr Paul Mitcheson (Imperial College London) and Dr Doron Shmilovitz (Tel Aviv University)

In addition to funding these PhD student projects we are also please to be able to continue our support for Yaroslav Tencer a PhD student in Mechanical Engineering.

6.8 Amadeus Capital Partners

In 2008 Patrick Burtis completed his two-year Kauffman Fellowship with the Energy Futures Lab. The Fellowship was sponsored by Amadeus Capital Partners, a leading European venture capital firm, and the UK Department of Trade and Industry. His work focused on identifying key areas of technological leadership in the 'cleantech' arena, both at Imperial College and across the UK; and on developing and executing a cleantech investment strategy for Amadeus Capital. The Fellowship culminated with one new cleantech investment for Amadeus Capital in July 2008, and a public forum in October at Imperial College, organized by Mr. Burtis and the EFL ('Innovation and Investment Opportunities in Carbon Capture & Storage'). Mr. Burtis remains an investor with Amadeus Capital and maintains close ties with the Energy Futures Lab.

6.9 Energy Integration Lab

Meeting UK targets for sustainable electricity production will place new and unprecedented demands on local and national grids to cope with the increased reliance upon intermittent and distributed generation. The Energy Integration Lab simulates the effects of intermittent power supply. The Lab is used for both teaching and research and in time, the laboratory will integrate with small-scale wind and photovoltaic systems mounted on the roof to provide real-time data.



***Construction of the
Energy Integration Lab***

Contractors are now on site refurbishing the rooms and Imperial's own technicians are installing the first items of equipment. The basic infrastructure allows each test cell to be connected to its neighbours in a very flexible way. Each cell can be programmed as a generation interface or as a load point. Together they mimic the operation of a local distribution grid. Each cell has a fully programmable DC/AC power converter (such as used for photo-voltaic or fuel-cell generation) which will allow various control strategies to be tested.

The Energy Integration Lab has only been possible because of three acts of generosity. E.ON have made a donation, principally to support the new teaching and project environment; EDF Energy have helped purchase research equipment and a bequest by the late Maurice Hancock (a former student and staff member at Imperial) has underpinned the whole project.

6.10 E.ON Donation

The donation from E.ON has been used in two ways to encourage students involved with energy teaching and research.

E.ON Prizes for Excellence in Energy recognise undergraduate and masters level student's talent in energy engineering and science.

We have awarded 8 undergraduate prizes to students in the Departments of Aeronautics, Civil Engineering Electrical Engineering and Materials and the Divisions of Molecular Biosciences and Biology and were presented on Commemoration Day.

Five master's prizes have been awarded to students from the MSc in Sustainable Energy Futures.

The donation has also been used for the Outreach activities that the Energy Futures Lab has undertaken over the past year. This includes using the E.ON Energy Experience programme to inform our educational materials.



***Racing Green fuel cell stack and IRG03 skeleton at
launch of Nissan's hydrogen powered fuel cell vehicle
at Imperial College London in July 2008.***



***The interdisciplinary Imperial Racing Green team
with IRG02 (R) and IRG03 (L)***

7 Events

'Mechanical kinetic energy recovery systems' Jon Hilton, Flybrid Systems	January 2008
Future Generations: John Cleveland College	March 2008
MSc in Sustainable Energy Futures: Industry Open Day	March 2008
Sustainable Energy UK: Energy Futures Lab presented poster	May 2008
Science Technician CPD Conference 2008 – Presented Future Generations outreach activities to conference	June 2008
"Fast, intermediate or slow pyrolysis for fuels production, power generation from various biomasses or as pre-conditioning unit for Gasifiers" Prof Andreas Hornung	June 2008
Royal Institution / NESTA: Schools Outreach	June 2008
Fuel Cell Vehicle and Hydrogen showcase	July 2008
'Tungsten Carbide, time and again' Prof Galina Tsirlina	July 2008
Innovation and Investment Opportunities in Carbon Capture and Storage: Half day conference	October 2008
London Technology Network: Renewable Energy and Energy-Efficient Technologies: Poster presented	November 2008
Energy Futures Lab Annual Lecture: Ed Miliband MP, Secretary of State for Energy and Climate Change	December 2008

8 Outreach

Following the success of the Engineering Centenary Schools Challenge Energy Futures Lab: Future Generations in 2007, the Energy Futures Lab has been able to engage more children in the energy debate by taking Energy Futures Lab: Future Generations out into the community.

A two-hour version has been developed from the day-long event, which has been presented in schools and to the Science Technician CPD conference 2008 to enable its further dissemination in schools. It has also been made available on the Energy Futures Lab website. The Energy Futures Lab also presented at a joint Royal Institution/ NESTA event to children active in sustainable energy generation projects.

In addition to the Energy Futures Lab: Future Generations, the Energy Futures Lab has hosted school aged work experience students and special needs adults to engage them with researchers and help them into the workplace.

In October 2008, the Energy Futures Lab outreach programme was recognised by the College and received the Rector's Award for Public Engagement. The Energy Future Lab outreach activities have been generously supported by Eon UK and Doosan Babcock, without their contribution and that of our students and researchers our outreach programme would not have been the success it has.