Second UK Energy Research Summit

September 2006

AKNOWLEDGMENTS

We would like to thank everyone who participated in this Second UK Energy Research Summit, and, in particular, the members of the working groups for their preparatory work before the event. We are grateful to Mike Farley, (Doosan Babcok), Duncan Botting (ABB), Tim Green (Imperial College London), Tim Jackson, (University of Surrey) and Chris Mottershead (BP) for their special contribution.

FOREWORD

On behalf of the Research Councils' Energy Programme, EPSRC is carrying out a series of UK Energy Research Summits as a novel way to engage with business, Government, other funders of energy research and the research community.

The overarching objectives of the Energy Research Summits are to:

- Engaging the sponsors of energy research in an on-going dialogue and raising awareness of common interests and priorities.

- Contribute to maximising the value of the Research Councils' investment in energy research by:
    - Increasing the ambition of research through the development of funding partnerships that are able to fund larger, coordinated research programmes and projects with more stretching objectives.
    - Increasing the synergy between funding activities.
    - Providing an opportunity for collaborations to be formed.

This process is aligned to the Government's vision for research in energy, including increased private sector energy research. We also are engaged with other initiatives such as the UK Energy Research Partnership and the Energy Technologies Institute.

The first Energy Research Summit, held in November 2005, provided a high-profile launch for the Research Councils' plans for the developing energy research and training portfolio. It also provided an opportunity for a wide ranging discussion of energy research requirements, led by business.

The second Energy Research Summit, held in September 2006, focussed on taking forward six of the business-led research priorities identified at the first summit:

- Carbon Abatement Technologies
- Networks
- Socio-Technical Issues
- Hydrogen
- Fuel cells
- Wind Energy

Building also on work of other stakeholders, this meeting provided a forum to agree business research requirements, to identify potential collaboration and to propose a collaborative research action plan.

This report contains a description of the scope and format of the second summit, the outputs that have been produced and details of next steps.

We aim to hold the third energy research summit focussed on postgraduate training requirements in Spring 2007.

EXECUTIVE SUMMARY

The second Energy Research Summit, held in September 2006 engaged research users and funders. The event focussed on taking forward six of the business-led research priority areas suggested at the first Energy Summit:

- Carbon Abatement Technologies
- Energy Networks
- Socio-Technical Issues
- Hydrogen
- Fuel cells
- Wind Energy

Building on work of other stakeholders, the objectives for the second Energy Research Summit were:

- to agree a position statement on business research requirements and potential collaboration for each theme;
- to propose a research action plan for each theme.

The meeting generated a number of outputs, including business-led research challenges and suggested action plans to be taken forward both by the private and the public sector.

We would like to encourage the owners of the proposed actions to respond to this document and we would welcome opportunities to continue to discuss a shared agenda and how best to take forward ideas in collaboration. We have considered the actions proposed to be taken forward by the Research Councils and we have identified those which we can action. We will continue to draw on the information from this summit as we develop our research and training portfolio in what is a rapidly developing environment energy innovation. Alongside taking forward specific actions, we will feed all the research challenges identified in the discussions to help develop technology priorities for the Energy Technology Institute where appropriate.

We would like to take forward of the idea of investigating underpinning science and developing novel concepts for carbon abatement technologies. We will issue a call for collaborative feasibility studies to stimulate novel ideas in underpinning science for energy research. Carbon Abatement Technologies will be within the remit of this call. Also carbon abatement technologies are a priority area for the next call for Science and Innovation Awards and we are also in the early stages of discussing a strategic partnership between EPSRC and British Coal Utilisation Research Association (BCURA).

EPSRC has recently committed a substantial investment in energy networks through the renewal of the Future Networks Supergen consortium and through a partnership with ABB, Scottish Power and EDF Energy. We are nevertheless interested in taking forward the postgraduate training agenda. We are working with the Institution of Engineering and Technology to help develop the Power Networks Research Academy that will support PhD researchers in power networks industry related projects.

We would like to take forward the idea of identifying and collaborating with business innovators to encourage the uptake of low carbon technologies. We recognise that there is only a small level of knowledge of business innovators within the Research Councils' and we would welcome advice on how we can tackle this gap.

We believe that it would be beneficial to develop a chemistry-engineering forum for hydrogen, provided that it adds value to the existing UK SHEC Supergen consortium. We will explore the idea of an online survey of current hot topics for the fuel cells industry.

We are also interested in exploring the potential for collaborative support with industry of a full scale wind turbine test facility. We value the idea of an appraisal of existing test facilities to advance research in wind energy, working also with organisations that are currently building a landscape of the UK energy research and facilities, such as the UK Energy Research Centre and the Energy Research Partnership.

The are various ways of becoming involved with EPSRC (www.epsrc.ac.uk, under Connecting with business), but we particularly wish to develop more strategic partnerships, provided that funding is available in the next spending review period.

Beside targeted activities, collaborative research proposals between business and academia can be accepted anytime through the Research Councils' responsive mode and we would like to encourage the community to take full advantage of the flexibility of this mechanism.

CONTENTS

1. INTRODUCTION

The second Energy Research Summit, held in September 2006, engaged an audience of research users and funders (Appendix I). The event focussed on taking forward six of the business-led research priority areas suggested at the first Energy Summit:

- Carbon Abatement Technologies
- Networks
- Socio-Technical Issues
- Hydrogen
- Fuel cells
- Wind Energy

These areas were selected considering the current landscape of energy research, in particular we considered:

- Gaps in the Research Councils' Energy Programme research portfolio.
- Priority areas for the Technology Programme.
- The development of related strategies in other fora.

Building on work of other stakeholders, the objectives for the second Energy Research Summit were:

- to agree a position statement on business research requirements and potential collaboration for each theme;
- to propose a research action plan for each theme.

The discussion format was tailored to the existing level of activities in each area.

Theme champions for the Carbon Abatement Technologies, energy networks and socio-technical issues areas agreed to help the Research Councils' Energy Programme by contacting relevant stakeholders and by co-ordinating the preparation of a summary describing the current landscape of research, key players and some of the key research challenges ahead. These summaries were presented by the theme champions in plenary sessions in the morning and provided the starting point for afternoon discussions, which lead to the preparation of position statements and proposed action plans.

For hydrogen, fuel cells and wind energy, it was felt that there was a need to better understand the research landscape. The discussion format was therefore in the form of facilitated sessions held in parallel during the afternoon. Wherever possible, existing material was used as starting point for discussion, including outputs from the first Summit and existing roadmaps. The outputs of these breakout sessions also consisted of position statements and proposed action plans.

This document reports the outputs achieved during the day for each theme and indicates options for progressing a shared research agenda.

2. CARBON ABATEMENT TECHNOLOGIES

This theme was championed by Mike Farley (Doosan Babcock). His presentation covered significant activities and events that involve UK industries and that are shaping the research landscape in Carbon Abatement Technologies (CAT), including EU and national technical projects, techno-economic studies and demonstrators. The presentation also illustrated the current CAT research agenda and concluded by highlighting the significant scope for underpinning research and development and "blue skies" research to support the CAT business-led research agenda to 2015. The full presentation is available in Appendix II.

Building on this session and on a discussion on research priorities, the groups agreed that the industry research requirements for CAT fall in the broad areas of advanced conversion technologies, transport, underpinning sciences, perceptions, plant optimisation (fuels, design) and capture and storage. In particular, priority was given to:

- Plant optimisation, by improving efficiency, introducing new materials, and using biomass.
- Storage, considering infrastructure needs, environmental impact, safety, basic research and breakthrough technologies.
- Carbon capture technologies in pre-combustion gas cleaning with improved reliability, applied research and development in advanced solvents for post-combustion, oxy fuel combustion.

The complete list of research priorities identified is reported in Appendix III.[1]

The action plan suggested by the participants was[2]:

Action	**By Whom?**
1. CO_2 capture workshop/Ideas Factory – research project(s) with industry	Doosan Babcock
2. Underpinning workshop/sandpit	Derek Allen (Alstom)
3. CO_2 storage and transport workshops/sandpit	BP
4. Perceptions Workshop/sandpit	Tyndall/PSI
5. Plant optimisation/efficiency workshop/sandpit	E.ON
6. Novel concepts workshop/sandpit	Academia / EPSRC

The participants were interested in stimulating a dialogue on specific priorities through fora such as workshops and we welcome these activities led by and involving the research community and stakeholders'.

[1] The research priorities listed in the appendices of this report have been transcribed from the flipcharts produced at the meeting.
[2] Some areas were discussed by two breakout groups. In those instances the action plans have been combined.

We would like to take forward of the idea of investigating underpinning science and developing novel concepts for carbon abatement technologies to stimulate speculative, high risk research and to contribute to maintaining a healthy research base. Stimulating new ideas and therefore invigorating the area would add value to the existing research landscape in carbon abatement technologies.

We are following up this idea with a call for collaborative feasibility studies to stimulate novel ideas in underpinning science for energy research. Carbon Abatement Technologies will be within the remit of this call. Carbon abatement technologies are a priority area for the next call for Science and Innovation Awards.[3]

We are also in the early stages of discussing a strategic partnership between EPSRC and British Coal Utilisation Research Association (BCURA).

Contact: Robert Heathman

3. ENERGY NETWORKS

This theme was championed by Duncan Botting (ABB), and Tim Green (Imperial College London) who delivered the presentation summarising the current position and gaps in energy networks research. The research needs were highlighted in the short (to 2010) and long term (2025-2050) and it was suggested that the Research Councils could play a key role in building the research capacity needed to tackle challenges such as security of supply and climate change. In addition to research and training challenges, the presentation summarised other issues important to the user community, including the importance of providing evidence of the research contribution to business and the need for clarity and coordination on the means by which technology is transferred to industry. The full presentation is available in Appendix IV.

Building on this session, the participants in the breakout session discussed the business driven research challenges, listed in Appendix V. Emphasis was given to the role of renewables, microgeneration and energy storage in the future generation mix and the impact of technology on the network and on infrastructures, including control and automation issues. Business needs are also driven by demand issues and the impact of the energy market on electricity generation. The discussion groups recommended that of the issues discussed, the priority challenges are:

- Control and impact of microgeneration integration (e.g. Phoenix project).
- Communication between user units and distribution networks.
- Future generation mix – that is currently well covered by Supergen.
- Testing the theory (some research currently done in Germany).

Studies on the costs of monitoring the distributed system are a potential area for collaboration.

[3] **http://www.epsrc.ac.uk/ResearchFunding/Opportunities/Capacity/SIAwards/default.htm**

The participants suggested an action plan:

Action	**By Whom?**
EPRI Telegrid Developers and academic base to discuss what the issue are Engage the Distribution Working Group Work Programme 4 (DWG 4) [4]	Distribution Working Group (DWG) 4
Distribute details of DWG 4 to community	Google - EPSRC
Identify which theories to test	Industry, Academia, Research Councils, DTI, Energy Research Partnership
Hardware test platform	ETI

EPSRC has recently committed a substantial investment in this area through the renewal of the Future Networks Supergen consortium and through a partnership with ABB, Scottish Power and EDF. We believe that the actions proposed by the participants can be taken forward through existing mechanisms and responsive mode.

We are working with the Institution of Engineering and Technology to establish a Power Networks Research Academy that will fund and support PhD researchers in power industry related projects to build a sustainable research capability for power networks.

We will feed the need for hardware test platform into the discussions to develop the priority technologies for the Energy Technology Institute.

Contact: Robert Heathman

4. SOCIO-TECHNICAL ISSUES

Chris Mottershead (BP)'s presentation covered an agenda for social science research in energy, building on Tim Jackson's summary of a Research Councils' workshop organised by ESRC and held on 6th April 2006. This summary was distributed at the event and is available on the Research Councils' Energy Programme webpages (http://www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/AdviceConsult/SummitProcess.htm).

The presentation covered the drivers for a whole-system approach to UK energy policy including economics, institutions, regulations, public acceptability, and

[4] **http://www.ensg.gov.uk:** The Electricity Networks Strategy Group (ENSG) provides advice to DTI, Ofgem, Defra, the Scottish Executive and the Welsh Assembly on issues associated with the development of the distribution and transmission electricity networks. The ENSG has a number of sub groups, the Distributed Working Group (DWG) and the Transmission Working Group (TWG). The Distributed Working Group (DWG) continues the work of the earlier Distributed Generation Coordinating Group's (DGCG) Technical Steering Group (TSG), examining the issues to enable the integration of generation onto the distribution network.

behaviour change. The full presentation is in Appendix VI. Building on this session the participants in the breakout session identified product service shift and changing behaviours and life styles as priority issues that would benefit from collaborative research. The discussion is summarised below and a full list of research priorities is in Appendix VII.

Industry Research Requirements	Potential Areas for Collaboration and key players
PRODUCT-SERVICE SHIFT -how can companies make a profit by selling less? – added value -quality not quantity -diversification – moving to other areas outside energy	-Service Providers -related services – product design and supply/household renovation -business service companies -SMEs -Regulators
CHANGING BEHAVIOUR & LIFESTYLES - interventions to achieve positive behavioural change - learning from other experiences i.e. smoking - media-understanding debates	Government – local, regional -private companies -marketing companies -stakeholders -receptive agents -opinion leaders
GOVERNANCE	Government – Departments, political parties -supranational – EU, G8, UN -regional/local government -think tanks/pressure groups -business innovators -insurance companies -financial services
SOCIO-ECONOMIC ISSUES e.g. fiscal incentives, public perception - fiscal incentives - more work on public acceptance	

The participants suggested the following action plan:

Action	By Whom?
Continue to fund/publish world class research	Research Councils
Facilitate communication of research to appropriate bodies: think tanks/Government, business etc.	Researchers
Identify business innovators for collaboration	Researchers/intermediaries
Design research – informed interventions to achieve positive behavioural change	Research Councils/Researchers Business
Securing positive economical benefit from low carbon energy innovation	Research Councils/Business /Researchers/Government

We would like to take forward the idea of collaborating with business innovators to encourage the uptake of low carbon technologies and to achieve better exploitation of research. We recognise that there is only a small level of knowledge of business innovators within the Research Councils' portfolio and we would welcome your views and to learn from your experience. To address this gap we will also build on the existing projects, such as 'Unlocking low carbon potential', supported through Carbon Vision. We will also aim to work with the Regional Development Agencies and the Research Councils' teams focussed on knowledge transfer.

We plan to include research into informed interventions to achieve positive behavioural change in future activities in energy demand reduction.

Contact: Filomena La Porta

5. HYDROGEN ECONOMY

Building on the outputs of the First Energy Summit, the discussion on research priorities identified a number of research challenges spanning from materials and components to solutions for large scale storage and transportation near the point of generation; business needs include the scaling down of technologies, environmental impact along the whole supply chain, and hydrogen production, including from biomass. Hydrogen should be easy to use, comparable with petroleum, should be integrated with devices and should have small footprint in terms of energy. The challenges discussed are listed in Appendix VIII. Following this discussion, the breakout group agreed and prioritised industry research requirements and the potential for collaborative research within the hydrogen economy. The discussion group pointed out that all that issues are closely linked and that prioritising would result in important and international issues being overlooked. However, the participants in the discussion agreed that the most urgent business research requirements are:

- Cost-effective and sustainable and socially acceptable hydrogen generation.
- Systems level approach: pathways to large-scale implantation.
- Modular approach to demonstrations (balance with rest of Europe/world).
- Sustained chemical engineering effort to develop an effective hydrogen storage material.
- Optimise hydrogen storage in a complete power/propulsion system.

Based on UK assets, the participants identified potential areas for collaboration such as:

- The direct use of biomass for hydrogen production.
- Polymer Electrolyte Membrane electrolysers.
- Polygeneration UK fossil fuels.
- A nationally coordinated strategy for hydrogen in automotive applications.

The action plan proposed by the participants in this session was:

Action	By Whom?
Systems modelling of H_2 economy – regional, national, international / issues	UKERC
H_2 production via biomass to be picked up by Supergen, UK SHEC	Supergen UK SHEC
To bridge the gap between H_2 and CAT - workshop	DTI – emerging energy technologies
Develop chemistry/engineering forum for H_2 energy	EPSRC

During the meeting, it was suggested that the challenge of hydrogen production via biomass should be addressed by the UK SHEC, the Supergen consortium in hydrogen. This consortium does include some work on hydrogen production. We plan to review our hydrogen-related research portfolio on to clarify the research gaps. In addition, research proposals are welcome through responsive mode.

It was also recommended to take forward a nationally co-ordinated strategy for hydrogen in automotive applications. We do not believe that the Research Councils' Energy Programme is best placed to co-ordinate this type of activity and we would invite colleagues from the Department for Transport to consider this action.

We believe that it would be beneficial to develop a chemistry-engineering forum for hydrogen, provided that it adds value to the existing UK SHEC Supergen consortium and to the UKERC activities. This forum would help to develop multidisciplinary research teams and strengthen the research community, both in the academic and in the private sector. Such a forum, together with the UK SHEC and UKERC, could provide a focus for the UK that could be used to maximise UK access to the EU Framework Programme.

The Research Councils have several flexible mechanisms in place to stimulate a forum of this type, for example by providing travel funding, support for administration, communication activities and workshops. However, we would like to take this action forward in collaboration with business, other funders and professional institutions and we invite you to express your interest in contributing.

Contact: Paul Rouse

6. FUEL CELLS

Building on the existing roadmap[5] and on the outputs of the First Energy Summit, the participant in this breakout sessions agreed that business is facing challenges in areas such as diagnostics, remote control issues, water transport management within the fuel cell and material performances. The participants felt that there is a need for fundamental and applied research in catalysis, membranes and simulation. The group concluded that the area would benefit from a strategy for funding and from new people that can add value to this sector. The group also recommended undertaking a

[5]UK Fuel Cell development and deployment roadmap: http://www.hfccat-demo.org/hfc_doc/docs/uk_fuel_cell_development_and_deployment_roadmap.pdf

survey of business research challenges (Appendix IX). The group agreed and proposed the following action plan for collaborative research in fuel cell technologies.

Action	**By Whom?**
Scoping/partnering workshops - materials - academia and industry	EPSRC
Mechanism for identifying new 'entrants' to field who add value	
Academic skills database in fuel cells/materials modelling	EPSRC (funded grants on the web http://gow.epsrc.ac.uk/)
Questionnaire to industry surveying current hot topics	EPSRC
Observe DTI Technology Programme for research issues arising from demonstrators	EPSRC

During the meeting it had been difficult to identify and prioritise the business-led research challenges and one of the actions suggested was to undertake a survey of current hot topics for industry. We would like to take this action forward and we are looking at the possibility of developing an online survey.

We welcome the opportunity to work in partnership and explore potential collaboration through bilateral meetings. We would encourage you to express your interest.

Contact: Neil Bateman

7. WIND ENERGY

The group in this break out session discussed research requirements and priorities ranging from turbine design, small scale wind, planning and permits, network issues (technical and economic), offshore operations and maintenance, offshore, micro-wind and perceived intermittency. The group also raised a number of issues including the removal of infrastructural barriers to new development and of barriers to high penetration levels. The introduction of predictable, faster planning procedures and public education could encourage wind to become a conventional generation technology. The UK needs to develop its knowledge base to leverage inward investment and skills and it also needs a manufacturing presence (Appendix X).

The group agreed to prioritise the following business-led research requirements and potential areas for collaboration:

Industry research requirements

- Modelling and testing of the environments, foundations and size of wind turbines.
- Step change improvements in wind turbines, through optimum design of components such as blades.
- Develop UK knowledge base for larger wind farms onshore and offshore.

Potential Areas for Collaboration

- Turbine design, involving turbine manufacturers, components manufacturers with opportunities for new entrants to the field to get involved.
- Grid integration and connection involving National Grid, manufacturers and Distribution Network Operator companies (DNOs).
- Full scale wind turbine test facility, open access for academia in collaboration with industry.

The participants suggested the following actions:

Action	**By Whom?**
Wind turbine modelling	Academia/industry
Appraisal of test bed	Component manufacturers
Intelligent wind turbine	

The availability of a full scale wind turbine test facility, with open access for academia and in collaboration with industry was the clear priority emerging from the meeting.

We will feed this priority into the discussions to develop the priority technologies for the Energy Technologies Institute. We are interested also in an appraisal of existing test facilities, working also with organisations that are currently building a landscape of the UK energy research and facilities, such as the UK Energy Research Centre and the Energy Research Partnership.

We welcome the opportunity to work in partnership and explore potential collaboration through bilateral meetings. We would encourage you to express your interest.

Contact: Paul Rouse

8. CONCLUSIONS

The discussions held during this Second Energy Summit generated actions to be taken forward both by private and public sector.

We would like to encourage the owners of the proposed actions to think about how best to take them forward and we welcome discussions about how best to work in collaboration.

We have considered the actions proposed to be taken forward by the Research Councils and we have identified those which we can action. We will continue to draw on the information from this summit as we develop our research and training portfolio in what is a rapidly developing environment energy innovation. Alongside taking forward specific actions, we will feed all the research challenges identified in the discussions to help develop technology priorities for the Energy Technology Institute where appropriate.

One of the objectives of the energy research summits is to increase the ambition of research through the development of funding partnerships that are able to support larger, coordinated research programmes and projects with more stretching objectives. We would like to continue to explore potential for collaboration with companies to stimulate the research or initiate technological innovation.

Collaborating with us can offer gearing on funding, access to an extensive knowledge of the academic base, established peer review and funding processes that have a recognised quality brand and access to our knowledge and expertise, for example in identifying key groups, organising workshops, writing and managing calls for proposals, grant processing and peer review.

The are various ways of becoming involved with EPSRC (www.epsrc.ac.uk, under Connecting with business), but we particularly wish to develop more strategic partnerships, provided that funding is available in the next spending review period.

Strategic partnerships offer flexible opportunities for collaboration through a formal arrangement between EPSRC and the collaborating organisation to co-fund or support mutually beneficial activities. Activities funded could include research proposals or collaborative training. Although our approach is flexible, we require that there is an element of openness to academic researchers and that details of the activities funded will be in the public domain. Strategic partnerships adhere to the principles of peer review and EPSRC grants are awarded to universities, not to the partner organisation. Under the conditions of a collaboration agreement between the partner organisation and the academics, it is expected that research outputs will be published and disseminated.

Alongside targeted activities, collaborative research proposals between business and academia can be accepted anytime through the Research Councils' 'responsive mode' and we would like to encourage the community to take full advantage of the flexibility of this mechanism.

For more information please contact Filomena La Porta.

APPENDIX I
DISCUSSION GROUPS

ENERGY NETWORKS

OLIMPO	ANAYA-LARA	University of Strathclyde
ANDY	BOSTON	EON Power
JACLYN	BROWN	GE Energy
JENNY	COOPER	National Grid
GARETH	EVANS	OFGEN
TIM	GREEN	Imperial College, London
BRIAN	HAYDEN	IlikaTechnologies Ltd
NICK	JENKINS	University of Manchester
BILL	LEITHEAD	University of Strathclyde
KEITH	MELTON	NaREC
PHIL	SHEPPARD	Low Carbon Technology Partnership
PETER	TAVNER	Durham University
CHRIS	WILCOX	Ceramic Fuel Cells Ltd

CARBON ABATEMENT TECHNOLOGIES

DEREK	ALLEN	ALSTOM POWER
CHRIS	BAGLEY	TWI Ltd
DAVID	DANSON	SLP Energy
TONY	ESPIE	BP Aleternative Power
JON	GIBBONS	Imperial College
ANGUS	GILLESPIE	Shell International Renewables
RICHARD	HOTCHKISS	RWE nPower
MAURA	JOLLIFFE	Ilika Technologies Ltd
ALLAN	JONES	EON Power
MARK	NAILIS	Centre for Process Innovation
KATHRYN	NEWELL	DTI
LUCY	POWELL	Scottish & Souther Energy
GRAEME	PURDY	Ilika Technolgies ltd
JONATHAN	SPENCER	OSI
SIMON	WEEKS	Rolls Royce
ADISA	AZAPAGIC	University of Manchester
FIONNUALA	COSTELLO	University of Manchester
ANDREW	CURTIS	University of Edinburgh
CHRIS	DE GOEY	ITI Energy
SUZANNE	ELLIS	Johnson Matthey
JON	GIBBONS	Imperial College, London
DAVID	IRVING	IrvingEnergy
DAVID	McCAFFREY	BCURA

STUART	MITCHELL	Mitsui Babcock Energy Ltd
BRIAN	MORRIS	DTI
JOHN	OAKLEY	Cranfield University
TONY	OLIVER	K-S Tech
PHILIP	SHARMAN	PERA
STEVE	TRENNYSON	Mast Carbon Ltd
JAN	VAN DER EIJK	Royal Dutch Shell plc
CHRIS	BAKER	NERC
MIKE	COLECHIN	E.ON Power
HUNTER	DANSKIN	SLP Energy
GARY	GRUBB	ESRC
ANTHONY	IKWUE	One North East
AURELIE	MEJEAN	UKERC
NICK	RILEY	BGS
JIM	SKEA	UKERC
GARRY	STAUNTON	Carbon Trust
KATIE	TEARNALL	BBSRC
CATHERINE	WADDAMS	ESRC Centre for Competition Policy
JEREMY	WATSON	Arup
PATRICK	GERAETS	BVG ASSOCIATES

WIND

OLIMPO	ANAYA-LARA	University of Strathclyde
ANDY	BOSTON	EON Power
JACLYN	BROWN	GE Energy
STEVE	CLARKE	
DAVID	DANSON	SLP Energy
CHRIS	DE GOY	ITI Energy
GARETH	EVANS	OFGEN
ANGUS	GILLESPIE	Shell International Renewables
TIM	GREEN	Imperial College, London
NICK	JENKINS	University of Manchester
PETER	LANG	EDF Energy
BILL	LEITHEAD	University of Strathclyde
AURELIE	MEJEAN	UKERC
KEITH	MELTON	NaREC
LUCY	POWELL	Scottish & Southern Power
ROBERT	ROWLINSON-SMITH	Garrad Hassan & Partners
JONATHAN	SHARMAN	PERA
JONATHAN	SPENCER	OSI
PETER	TAVNER	Durham University
KATIE	TEARALL	BBSRC

FUEL CELLS

PETER	BANCE	Ceres Power
ALAN	CHAPMAN	Ceramic Fuel Cells Ltd
MIKE	COLECHIN	E.ON Power
FIONNUALA	COSTELLO	University of Manchester
ROBIN	FRANCIS	Voller Energy
CELIA	GREAVES	Synnogy
BRIAN	HAYDEN	Ilika Technologioes Ltd
MARK	NAILIS	Centre for Process Innovation
KATHRYN	NEWELL	DTI
STEPHEN	PYKE	Rolls-Royce Fuel Cell Systems Ltd
JONATHAN	SHARMAN	PERA
GARY	STAUNTON	Carbon Trust
STEVE	TENNYSON	Mast Carbon Ltd
JEREMY	WATSON	Arup
CHRIS	WILCOX	Ceramic Fuel Cells Ltd

HYDROGEN

ADISA	AZAPAGIC	University of Manchester
CHRIS	BAGLEY	TWI Ltd
SUZANNE	ELLIS	Johnson Matthey
PETER	HALL	University of Strathclyde
BRIAN	HAYDEN	Ilika Technogies
DAVID	IRVING	IrvingEnergy
MAURA	JOLLIFFE	Ilika Technogies
ALLAN	JONES	Eon Power
KEVIN	KENDALL	University of Birmingham
PHILIP	SHARMAN	Pera
PHIL	SHEPPARD	Low Carbon Technology Partnership
JAN	VAN DER EIJK	Royal Dutch Shell plc
SIMON	WEEKS	Rolls-Royce

APPENDIX II

2nd Energy Summit

CATs
(Carbon Abatement Technologies for Fossil Fuels)

Development of a Research Agenda for the UK

Mike Farley
Director of Technology Policy Liaison
Mitsui Babcock

11 September 2006

MitsuiBabcock

What are CATs?

- Carbon Abatement Technologies for Power Generation and industrial processes (steel making, cement, chemical plants, etc) using Fossil Fuels (i.e. coal, gas and oil)
- Complement other low-carbon technologies
- Essential so long as use of fossil fuels continues
- Particularly important in view of the predictions for fossil fuel use in developing countries
- Essential if international targets on CO_2 emissions are to be met

MitsuiBabcock

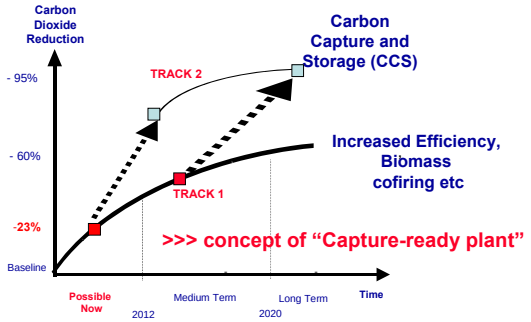
Government Strategy for CATs

- Published July 2005, covers coal and gas
- Overall Objective: "*To ensure the UK takes a leading role in the development and commercialisation of carbon abatement technologies that can make a significant and affordable reduction in CO_2 emissions for fossil fuel use*"
- Covers whole spectrum from research, development, demonstration to deployment, including requirements for regulation, incentives and public awareness
- Strategy reinforced in the Energy Review Report "The Energy Challenge" :
  - More emphasis on coal;
  - New commitments (joint project with Norway on physical infrastructure, NZEC (Near Zero Emissions Coal-fired power plant for China), regulatory framework)
  - Continuing work (Treasury) on incentives

MitsuiBabcock

What are CATS?

CO_2 Abatement from Fossil Fuels – Twin Track Approach



MitsuiBabcock

Timescales

- Research and Development: now → 2020+
- Early Demonstration projects (incl. Capture ready): now → 2012/15 and beyond
- Full commercialisation: by 2020
- Extensive implementation: 2020 – 2030

- Industry view is that the technologies that will be fully commercialised by 2020 will be based on the technologies that are known now
- BUT this does not preclude research and development!
- In fact, R&D will be essential

MitsuiBabcock

What's happening in the CATs field in UK industry?

- UK companies participating in EU and DTI Research projects on High Efficiency Boiler/Steam Turbine (AD700, including materials development for turbines, boilers and pipework)
- DTI projects on biomass cofirng
- UK companies and universities participating in EU Research projects on Capture (ENCAP, CASTOR) and Storage
- DTI Techno-Economic studies:
  - Retrofit of Gasifier to CCGT, Retrofits of Boiler/Turbines with CO_2 capture, High pressure coal gasification
- New DTI projects planned:
  - Post-combustion capture, Oxyfuel combustion, High efficiency hydrogen gas turbines
- Studies on new / retrofit power plant (capture ready or with CCS):
  - Peterhead Miller project (gas) *
  - Ferrybridge retrofit (coal, supercritical) *
  - Tilbury retrofit (coal, supercritical)
  - Hatfield , E.ON , and Teesside IGCC with CCS

(* FEED studies contracted)

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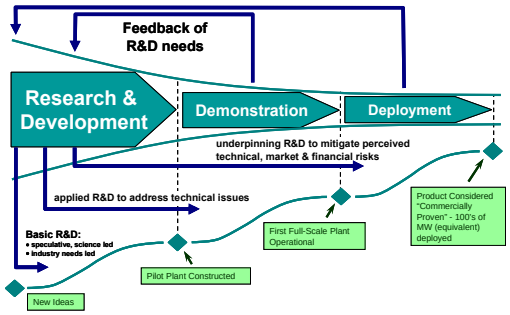
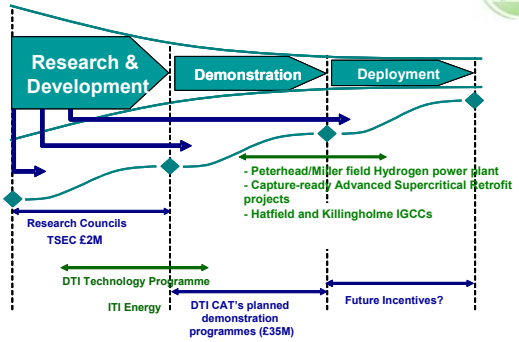
Energy Innovation Chain: where does R+D fit ?



Energy Innovation Chain Specific to Carbon Abatement Technologies for Fossil Fuels



Author: Mike Farley (Mitsui Babcock)
Contributors: Nick Otter (Alstom Power), Research Councils

Research Agenda for CATs – Industry Reference Documents

- APGTF Vision for Clean Fossil Power Generation, May 2004
- DTI CAT Strategy, July 2005
- European Power Plant Suppliers Association, R, D and D needs
- Coal Research Forum CUSG report "Coal Research Needs in the UK", 4th Edition, Sept 2005
- European Technology Platform ZEP (Zero emissions Fossil Fuel Power Plant) Strategic Research Agenda – to be published 12 September 2006. Also WG1 report on website.
- DTI CATs Roadmap – to be published
- OSI Science Review for Energy:
  - Carbon Capture and Storage – Sept 2006 Jon Gibbins
  - Clean Fossil Fuelled Power Generation – Sept 2006 - Tony Oliver

» All have in common the same research areas

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Overview of CATs Research Agenda

- Efficiency improvement for power plant
  - boilers, turbines, IGCC
- Co-use of biomass
  - cofiring, co-gasification, …
- Carbon dioxide capture
  - post-combustion, pre-combustion, oxyfuel
- Carbon dioxide transport and storage
  - Pipelines, Ships,
  - EOR, depleted gas fields, saline acquifers, unmineable coal seams

» Improved performance, economics, safety, environment and public awareness

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Efficiency improvement for Power Plant

- Materials, fabrication, inspection, monitoring and life assessment technologies for progressive increases in steam temperature and pressure to 350 bar and 750°C
  - Particular issues relating to high nickel alloys
- Utilisation of waste heat

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Co-use of Biomass

- Advanced cofiring or co-gasification (up to 20% or more by heat input), including corrosion, slagging and fouling issues
- Efficient preparation and processing of biomass energy crops (e.g. pelletisation, torrefaction)
- Other cycles using biomass (e.g. biomass feedwater heating)

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Carbon Dioxide Capture Technologies

Post-combustion (scrubbing)

- Process optimisation
- New and less energy intensive solvents (e.g. amines)
- Avoidance of solvent degradation

Pre-combustion Capture

- Gasification : process integration/optimisation, improved availability
- Gas cleaning : improved reliability
- Gas conditioning : CO_2 capture : integration and optimisation of shift conversion and CO_2 capture processes, conditioning of H_2 fuel gas stream for GT
- Gas turbine : Premix burners for hydrogen requiring
- Air separation unit : Process optimisation, improved absorbents for contamination removal, high efficiency packings for distilling fluids close to supercritical conditions

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Carbon Dioxide Capture Technologies

Oxyfuel combustion

- Process optimisation – including start-up/shut-down
- Combustion chemistry and kinetics
- Heat transfer prediction
- Materials for oxyfuel environment, corrosion issues
- Ash properties
- Flue gas cleaning to meet CO_2 specifications
- ASUs
- Flue gas cleaning and conditioning

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Carbon Dioxide Transport and Storage

Transport

- Corrosion behaviour of pipelines as a function of material, temperature, etc
- Alternative materials, joining technologies, sealing technologies
- Crack formation and growth
- Technologies for CO2 ships

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Carbon Dioxide Transport and Storage

Storage

- Gather experimental data and develop proper modelling and measuring, monitoring and verification techniques, together with knowledge and methods on trapping, rock and fluid properties, stability/integrity and CO_2 mobility
- Assess / develop cost-effective methods for managing impact of sub-surface uncertainty on performance prediction and risk.
- Develop database of equilibrium and kinetic data for use in coupled geochemical modelling of storage systems.
- Develop remote sensing techniques that give improved characterisation of stability of storage sites e.g. geomechanical properties for fault stability
- Assess potential for storage in saline aquifers e.g. develop atlas of seal and saline formation properties for North Sea
- ECBM /UCG – real absorption capacity of coal as function of depth and permeability

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Carbon Dioxide Transport and Storage

Environment

Risk of leakage,
Dispersion following leakage
Impact of leaks on eco systems
Impacts of seepage on shallow marine systems

Public perception issues

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Conclusions

- Huge scope
  - for underpinning R&D to support the Research Agenda to 2015 and
  - "blue skies" research relating to emerging technologies
- Research will not be in a vacuum; UK organisations are expected to pursue development, demonstration and deployment of CATs
- Impossible to establish *detailed* Research Agenda today

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With contribution from Allan Jones, Brian Morris, Brian Smith, Chris Mottershead, David McCaffrey, Derek Allen, Dorian Matts, Graeme Sweeney, Ian Conn, James Harrison, James Logan, Jon Gibbins, Mitchell Stuart, Nick Otter, Nick Riley, Nigel Yaxley, Olivier Dubrule, Peter Hall, Robin Irons, Tony Espie, and Tony Oliver.

Recommendations

- Series of industry / academe Workshops on each of the topics listed
  - Efficiency improvement for power plant
    - boilers, turbines, IGCC
  - Co-use of biomass
    - cofiring, co-gasification, …
  - Carbon dioxide capture
    - post-combustion, pre-combustion, oxyfuel
  - Carbon dioxide transport and storage
    - Pipelines, Ships,
    - EOR, depleted gas fields, saline acquifers, unmineable coal seams
- Each Workshop to
  - Review proposed Research Agenda
  - Identify priorities
  - Identify need for new/extensions to Supergen/Consortium topics, directed calls, open calls, etc.

Breakout Session:

Decide Workshop topics, who will lead, who to invite, objectives, agenda

APPENDIX III

Carbon abatement technologies - industry-led research priorities

Advanced Conversion Technologies

- Underground coal gasification (i.e. to complement activity on IGCC)
- Oxyfuel combustion – combustion chemistry and Kinetics
- In addition to applied R&D or gasification (e.g. IGCC cycles), some more basic research on "polygeneration" concepts (i.e. co-producing heat, electricity, H_2, chemicals etc. from a mix of feedstock)

Transport

- Transport – the most cost effective methods

Underpinning Sciences

- R&D materials and fabrication requirements for H_2 fuelled gas turbines
- Investigation and development of techniques and technologies to mitigate corrosion, fouling and other plant damage when co-using biomass
- Materials technology – cross-cuts all areas of CCS and efficiency
- Modelling – plant, storage environmental impact

Perceptions

- Local : take up
- Global: success
- EU optimum solution for Carbon Sequestration, where are optimum locations, potential for sequestration market?, EU legislation
- Public perception of CO_2 storage in underground sinks
- Stakeholder understanding of the issues and the links to electricity used in their home. Education throughout the UK population
- Important in the current culture of ability to protest and also ease of changing electricity supplier
- Skills – given the UK's circumstances of being island, how, through R&D, can we move closer to a knowledge-based economy without a subsequent 'brain-drain' to other areas of the world
- Cost – making a financially viable option
- Regulation/control

The 'Big Picture'

- Efficiency - how, through R&D, can we better match the relationship (geographically) between supply (generation) and demand (users)?
- Given comment in presentation about China, Q. How, through R&D, can we encourage take–up, internationally, of cleaner more sustainable methods of generation
- Reliable estimates of current and future CO_2 management abatement costs – to help industry optimise its activities (80% technical input – 20% economic input?)

Plant Optimisation (optimisation, fuels, design etc)

- Co-firing – slagging, fouling and corrosion issues (applied R&D)
- Efficiency of plants – increase co-firing, boilers, turbines
- Materials and fabrication technology for higher efficiency plant – R&D into the fabrication techniques required to produce higher efficiency plant using the more exotic materials (nickel alloys)
- The selection of a new power generation technology for a specific purpose will as much depend on operational performance (efficiency, availability, reliability, flexibility) as capital cost. These issues need addressing so that decision making can be done on a through – life basis
- New power plant will need to be very fuel flexible. Some work on the sensitivity to fuel type of the candidate technologies would be necessary
- Process optimisation and integration R&D – cost effectiveness – time to market
- There are significant health and safety issues associated with new power generation concepts – higher pressures and temperatures, oxyfuelling, CO_2 as an asphyxiant. There risks need to be quantified and mitigated
- Co-gasification of biomass with fossil fuels (applied R&D)

Capture

- Types and locations of aquifers/redundant reservoirs best suited to sequestration
- Assembly of published theory and calculation procedures relevant to CO_2 absorbers and regenerators (formerly known as scrubbers and strippers). At present this is scattered through many text-books published over the last 75 years and some contain mistakes which are difficult to spot.
- Capture opportunities/efficiency
- Pre-combustion gas cleaning improved reliability
- Research into novel/advanced CO_2 capture technologies (as well as more Applied R&D into more mature capture technologies)
- Carbon capture methods
- Applied R&D into advanced solvents for post-combustion CO_2 capture

Storage

- Infrastructure for CO_2 sequestration, CO_2 grid/network?, optimum pumping plants, optimum compression plants, re-use of existing infrastructure
- Environment CO_2 storage and risk of leakage
- Applied R&D into measuring , monitoring and verification for CO_2 storage
- Storage – long term (demon) – safety issues
- Feasibility of using depleted (oil & gas) fields for storage
- Breakthrough technologies in the field of post-capture storage (ie to reduce its current prohibitively expensive cost estimates)
- Carbon storage sites – characterisation, location, risks
- Storage of CO_2 – understanding trapping mechanisms (basic research)

APPENDIX IV

The Research Landscape for Energy Networks

Tim Green

Who contributed

Duncan Botting	ABB
Tim Green	Imperial
Jim McDonald	Strathclyde
Nick Jenkins	Manchester
Jenny Cooper	National Grid
John Scott	OFGEM
Lucy Powell	Scottish & Southern
Steve Wood	Scottish Power
Tony Lakin	Intelligent Power Systems
Derek Allen	Alstom Power
Peter Lang	EdF
Jonathan Hill	Econnect
Anthony Price	Swanbarton
David Russell	EA Technology
David Klauss	ASL
Phil Sheppard	Centre for Sustainable Engineering
John Collins	C-Tech Innovation
Phil Davis	Microhydro
Gareth Swales	IPA Consulting
Graeme Bathhurst	TNEI

Energy Networks

- Energy Networks research tends to concentrate on electricity networks and that field is
  - well represented with funded programmes
  - has an established research community
  - has R, D and D elements
- The gas network is less well represented
- Other energy vectors are the subject of research for future exploitation
- The central role of electricity as the most flexible energy form and the one whose loss is most immediately felt probably accounts for this concentration

Timeliness and Opportunities

- Much of the electrical network was built in the 1960s and 1970s – major asset renewal is now falling due
- Scenario analysis indicates great uncertainty over generation mix, scale, technology & location
- We need to preserve security, facilitate low-carbon energy connections and be economically efficicent
- A fortunate coincidence?
  - The assets renewal process coincides with the need to change the way we operate the networks
- Will we get it right?
  - Do we replace like-with-like?
  - Should the network be bigger or smaller?
  - How much new control is required?
- We can't build a "minimum" system in an uncertain situation but we must provide flexibility at reasonable cost

Research Topics - 1 of 2

- Connection capacity for renewables
  - Especially intermittent types, principally wind
- Active Network Management at distribution level
  - Mitigate adverse impact of distributed generation on the distribution network
  - Transmission-style control and distribution level
- Analysis and Algorithms to support active networks
  - Constraint Management
  - State Estimation
- Transmission Network Control Enhancement
  - Increased transfer capacity over existing infrastructure
  - Corrective over Preventative Control
  - Wide-Area Control and Protection
  - Real-time Decision Support Tools
- New Materials
  - Environmentally begin switch-gear insulators
  - Better cables
  - Power semiconductors (SiC etc)

Research Topics - 2 of 2

- Management of distributed generation
  - Microgrids, Aggregation and Virtual Power Plants
- Energy Storage
  - Technologies for network-scale application
  - Role and value studies
- Micro-generation
  - Control of the highly distributed power system
- Demand Side Management, Smart-Metering, etc
- Energy Efficiency and Demand Reduction
- Condition-based asset utilisation and management

- Gas Networks Modelling
  - Including gas-electricity coupling
  - Traditionally been undertaken by Adventica (BG)

Development and Deployment

- For better coordination and uptake, a matrix is required of expected outputs, their value, their carbon savings and their route to exploitation
- D&D less evident than R at present
- But this is changing - IFI (Innovation Funding Initiative) has kick-started some interesting demonstration projects
- First IFI progress reports have appeared but actual economic benefit still on its way

Do we know if research works?

- Do we know how many energy technologies funded by the RCs and expected to be commercialised have made it?
- Do we know the success and failure factors?
- Are intermediary organisations useful?
- Should we directed effort towards tangible outputs, or one big tangible output, for example,
  - The DPM's £60K house challenge
  - the DTI / Treasury Green Fuel Challenge
- Could we find examples for the network research?

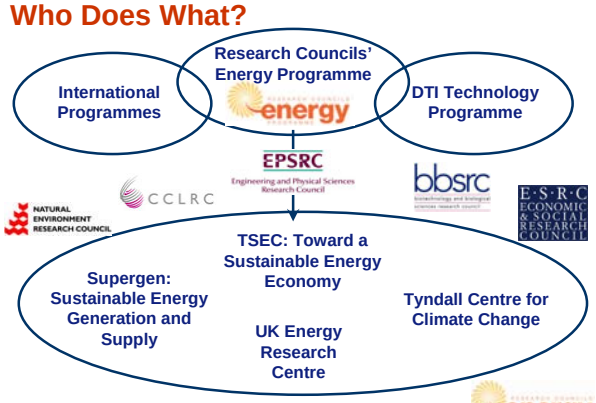
The Skills Required

- We want to make D-networks active, make T-networks corrective and replace most of the infrastructure
- We don't have the people in the industry
- We need
  - Planners and designers in the network operators
  - Researchers and designers in the equipment manufacturers
  - Educators and researchers in the universities
- The IET Power Academy is a start, but only for graduates
- But what about recruitment of
  - Post-graduates for equipment manufacturers and network operators
  - University staff
- And what about general science to begin the process
- And craft education

Industry-Academia Linkage

- A consequence of privatisation of the electricity supply industry was a reduction of research spend within the industry
- The industry-academia link is crucial for the research required
- Schemes such as ERCOS and ESR21 supported the link during the 1990s
- Supergen and Strategic Partnerships do that now but is it enough?
- Strategy and coordination is important for tackling the big issues that the sector faces
- There are reasons to be optimistic, several participants feel that the link is presently working well, but others see the need for much more work yet

Who Does What?



Who Else?

- Electrical Network Strategy Group
  - A DTI/Ofgem co-chaired organisation
  - Working groups to coordinate industry response to resolving Network related issues
- Innovation Funding Initiative (IFI) for Distribution Network Operators
  - DNO is allowed to spend up to 0.5% of its Combined Revenue
- SmartGrids
  - European Commission Technology Platform for Network research
- IntelliGrid
  - EPRI (largely USA) driven R, D & D into new Network Architectures
- Many small-scale industrially supported projects over-looked and need encouragement
- Energy Research Partnership
- OSI / Foresight Project
- RDAs
  - GLA especially active in promoting deployment projects
  - Joule Centre for Energy Research
  - NaREC New and Renewable Energy Centre

Short Term Position- 2010

- Connection solutions for Marine Energy
- Condition monitoring of aging assets
- Measures to improve or maintain quality of supply
- Measures stimulate technology transfer and particularly address technologies requiring more than 3 years to exploit
- Understand the implications for generation mix of the Energy Review and EU Green Paper
- Address skills gap with measures that begin in schools

Medium Term Position- 2010-2025

- Major issue is making the right choices on asset replacement to build in flexibility
- We are expecting to see changes in operating regime. Network improve service to generation and load customers through smarter control rather than more primary assets
- Distribution network is more active
- Transmission system uses more wide-area control concepts
- Research must cover engineering, environment, market measures and public acceptance
- The new portfolio of generation must be understood
  - inter-connectors, gas infrastructure, possible hydrogen infrastructure and electricity usage

Long Term Position – 2025-2050

- Radically different operating regimes in which security margins are very small and real-time corrective control is key to security of supply
- Potentially very different network architectures depending on how scenarios for transport, buildings etc play out and the scale/technology of renewables deployed
- High degree of coupling between energy vectors, demand response and storage leading to highly complex system requiring sophisticated analysis, control and decision support tools.

Actions

- Main drivers are security of supply and climate change, which do require fundamental rethinking of much of energy networks
- RCEP has a role in this research, in building research capacity and in providing some of the training needs
  - Increase PGT (MSc etc) courses and offer support to Home students
  - Initiate an EngD programme in Energy Networks
  - Facilitate participation in FP7: this is difficult for individual universities
  - Facilitate participation in KTP schemes (particularly with SMEs)
  - Consider how to involve SMEs in network research: increasingly difficult due to the high costs of FEC
- Ensure that there is clarity and coordination on the means by which technology is transferred to industry

APPENDIX V

Energy networks - Industry-led research priorities

- Balance of renewable and storage
- Microgeneration integration and impact of control (it is a likely challenge)
- Future generation mix
    - Flexibility for min cost
    - Infrastructure requirements
- Impacts of technologies on the network
- Ageing asset base
- Impact of climate change on network
- Control of network to max efficiency
- Testing the theory
- What level of automation is desirable
- Impact of energy market on generation
- Demand issues

APPENDIX VI

Socio-technical Issues

Chris Mottershead

why are socio-technical important?

need whole-systems approach to UK Energy Policy of:

- reducing GHG emissions
- ensuring energy security
- reducing fuel poverty
- maintaining international competitiveness

therefore need to consider:

- economics
- institutions
- regulations
- public acceptability
- behaviour change

where are we now?

Socio-technical issues are already integrated within:

- UK Energy Research Centre
- Tyndall Centre for Climate Change Research
- SUPERGEN
- Carbon Vision
- ESRC Sustainable Technologies Programme
- TSEC Managing Uncertainties

where are we now?

First Energy Summit October 2005

- socio-technical group convened to discuss priority areas for future research and possibilities for stakeholder engagement

Socio-technical workshop in April 2006

- original socio-technical group reconvened, along with additional participants
- participants represented academia and a range of stakeholder interests
- participants briefed on existing portfolio of research, and asked to identify key gaps, and research challenges to take forward
- workshop summary drafted by Tim Jackson

overarching summary?

context:

- energy technologies embedded in institutional and social systems
- change in one implies changes to others
- social sciences can aid understanding and managing systemic change to energy supply and demand

5 themes identified:

- changing behaviours and lifestyles
- product-service shift
- equity
- security of supply
- governance

changing behaviours and lifestyles

engagement and communication

- need to map people current energy perceptions
- need to develop and test innovative methods of public engagement
- need to understand the role of the media and mass communications in forming lifestyle aspirations and influencing energy consumption

lifestyle changes

- what are the key social, psychological and institutional obstacles to lifestyle change?
- what are the social-psychological drivers of frugal (energy saving) and efficient energy related behaviours?
- what lessons (successes and failures) can be learnt from previous or existing behavioural change initiatives?

Based on a report prepared by Tim Jackson

product-service shift

or *incentivising demand reductions*

- what does an energy service infrastructure look like?
- what is the utility model for demand reductions (beyond EEC)?
- what are the implications of the product-service shift for incentive structures in the supply/distribution industries?

in addition the workshop drew attention to:

- how do households and companies respond to an 'energy service' environment
- what characteristics of energy/fuel do people value and how do they express this value?

equity

- need to develop robust measures of energy inequality both for 'direct' energy consumption (energy consumed in the home) and for 'indirect' energy consumption (energy embodied in goods and services)
- need to identify the equity implications of specific policy interventions (taxes, incentives, regulation, carbon trading schemes, etc)
- need to consider equity in issues of planning and siting
- need to consider equity in climate change mitigation
- need to identify the local priorities of disadvantaged communities and integrate these into energy policy initiatives

international equity issues where thought to be particularly challenging

security of supply

- what do we mean by energy security, and what factors constitute energy security?
- what policy measures are justifiable in ensuring energy security?
- what is the role fo microgeneration and decentralised supply in maintaining energy security?
- what kind of regulatory system is most responsive to security of supply issues?
- what is the role of the market in ensuring security of supply?

governance

'incentive' or 'dictat'

- what will drive social and institutional change in the energy sector over the long-term?
- how can Government energy policy escape from the short-term horizon imposed by electoral cycles?
- what kinds of market structures promote responsible business research over the long-term?

carbon trading

- what are the links between carbon trading at different levels (personal/business/national)?
- how feasible is personal carbon trading and how effective will it be in changing people's behaviours?
- what social and political implications (obstacles, knock-on effects) are faced by carbon trading schemes?

community-based energy initiatives

- what is the role of community in achieving lifestyle changes?
- what are the conditions for success (and failure) of community-based energy iniatives?
- at what point does a household/community develop a) energy awareness and b) energy 'efficacy'?

APPENDIX VII

Socio-technical issues - industry-led research priorities

Product Service Shift

- Why is this an issue in energy rather than, say, food (service = nutrition) or housing (service = shelter)
- It is said to be inevitable that we will move from products to services and that transition underpins sustainability. This is not proved, and a wider perspective on supply-demand relation is needed
- Isn't there an inherent contradiction on 'Energy Services' in that the purchaser has no incentive to avail waste? – with heating costs included on the rent
- Immediate potential for heat as an energy vector which is not currently utilised to full potential
- How do we achieve a hydrogen economy in transport?
- Important to put energy in wider equity context e.g. not just 'fuel' poverty – equity
- City institutions – how do you value services in corporate terms
- SME's – supplying innovative energy technologies
- Energy supply cost
- Consumer groups
- Product manufacturers regulators utilities

Changing Behaviours and Life Styles

- Give an evidence base approach to society so it buys in
- Impact of increased efficiency (resulting in cost savings) on an individuals' spending power and hence overall carbon impact (may increase or at best have neutral impact)
- Give an evidence based approach to society so it buys in
- How to use peer pressure to modify energy consumption behaviour?
- Importance of incentives – very dangerous to ignore these
- How best to change people's behaviour to convince them that individual actions on energy consumption do matter and that it's in their own (and their childrens') interest to change
- In any shift from product to service need to be able to "see" possibility of higher service levels
- Need to do more than map public perceptions – need to trade them over time and understand how individuals react in different groups (e.g. households, workplace etc)
- Potential of policy measures of various kinds to shift behaviour – what can we learn from past successes or failures in other domains eg health and safety campaigns
- Better engagement with RDAs local authorities etc working to encourage behavioural change at the ground level virtuous feedback.

CHANGING BEHAVIOURS AND LIFE STYLES

Stakeholders

- Stakeholders groups – top quality editorial materials
- Socially acceptable behaviours

- Opinion formers – NGOs/media/societal “leaders”
- Utilities – product manufacturers (appliances , car)
- Local authorities
- Ryan air
- Architects

Marketing

- Market researchers – how do people decide what to buy
- Advertising/marketing and broader communication industry
- Demand side, particularly households, SMEs etc that are difficult to reach
- RDMs (eg one North East) already actively engaged in this area to have need, desire, funding
- HMT
- Environmental lobby
- DFES
- Pollsters (eg MORI)
- Newspapers
- DEFRA
- Marketing companies
- Treasury for tax and benefits
- Government – national, regional, local

Private Companies

- Private companies have lots of information on consumer responses through marketing surveys – but view these as commercially confidential – at least a dialogue would be helpful (but danger of concerted action by retailers)
- Small businesses/service sector e.g. electricians, design companies (eg in households renovation)

Security of supply

- Energy companies, FCO, think thanks, embassies
- Energy research, partnership, ETI, Original equipment Manufacturers, SMEs
- Increased emphasis on distributed supply and micro generation
- Don’t re-invent wheels - a lot of work has been done on this in different research communities
- Should this be called security of service?

Governance

NGOs/Consumer groups

- Government consumer groups
- Political opinion formers

Industry

- Government: national, regional, local
- Industry: energy supply cos., energy intensive industries, large industry (low energy intensity)
- NGOs

- "Captains" of - global companies, regional and national

Government at various levels

- Regulators
- Government needs to resolve tensions between competing policy and then have the coverage of their convictions
- Regulators government departments. EU, Local authorities, Industry (CO_2 emitters), financial services (PLAs)
- Policy formers – especially those with medium – long term interest
- National governments – through UN? EU?

Communities

- 'At risk' communities e.g. London (from flooding) to leverages influence
- The 'Governed'

Lawyers/Planners

- Governance – local interest in an industry = acceptance of that industry
- Strong policies necessary to drive local investment in jobs
- Planners – politicians – business (local and national)
- But EU law does not make this easy to do – lawyers/research on how this could be changed

Governance

- Urgent global agreement and implementation of CO_2 reduction
- Establishing 'a political' thought leadership
- Policy on local jobs and investment relating to specific technologies – eg wind
- How do you get all sectors to act in concert

APPENDIX VIII

Hydrogen Economy: output of the First Energy Summit

RESEARCH NEEDS

- Socio-economic issues – Fiscal incentives - Public perception.
- Storage at point of use: e.g. Metal hydride systems, nanotechnology, high-pressure gas storage > 750 bar.
- Medium-scale demonstration projects, research needs to be integrated towards this aim.
- Research in new and improved forms of generation/distribution technologies (e.g. high-efficiency electrolytes, coal gasification and CO_2 capture, advanced methods such as membrane separation, water dissociation).
- New and improved storage technologies at a range of sizes: e.g. hydrogen powered mobile phones.
- Satisfactory large scale implementation (including environmental impact).
- Use devices – huge research area: e.g. H_2 ICE, H_2 turbines.

Hydrogen Economy: output of the First Energy Summit

KEY OBJECTIVE AND CHALLENGE:

INFRASTRUCTURE

- Sustainable production of hydrogen
- Transport/distribution
- Storage

DRIVING FORCES	RESTRAINING FORCES
• Finite fossil fuels • No CO_2 production/emission • Air quality • Infinite available of H_2 • Economic proposition for the UK • Big potential impact • Increasing need to store energy • Low transmission losses	• Availability of large scale generation • Cost of large scale generation • Taxation risk • Status quo (companies and infrastructure) general public) • Public perception (safety/environment) • Lack of large scale storage technologies • Which comes first: hydrogen or market?

Hydrogen Economy: output of the First Energy Summit

KEY OBJECTIVE AND CHALLENGE:

USE

- All modes of Transport (e.g. Aviation)
- Stationary power Generation (e.g. distributed energy systems)
- Portable (e.g. military, lap tops, hand-held equipment).

DRIVING FORCES	RESTRAINING FORCES
• Portability • Zero-emission at point of use of pollutants	• Lack of on-board storage • Immaturity of current technologies (e.g. Fuel cells) • Cost of current technologies (e.g. fuel cells)

Hydrogen research challenges

STORAGE POINTS OF USE

Metal hydride systems
Nano technology
High pressure gas storage

- Need material with appropriate thermodynamic properties, especially for transport
- Rest of infrastructure relies on it
- Critical part to get storage density
- Carbon nanotubes could lead to breakthrough
- Technology transfer between sectors could be important

- Breakthrough advance still needed for transport application
- Progress remains slow
- Better awareness of system integration requirements needed
- Hybrid
- Tanks
- Generator at point of use (e.g. fuel station) avoiding the need for storage and infrastructure

- Technologies for distributed – integrated generation, storage/use
- Still big issues – high pressure
- Nanotubes not delivering
- MHz systems – small scale and expensive

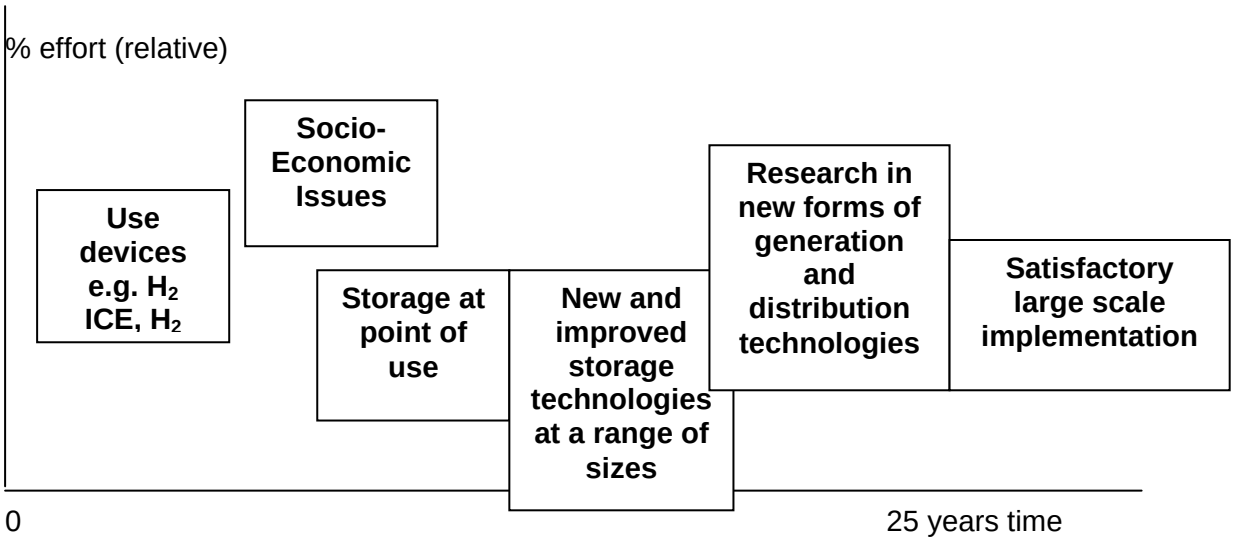
- engineering integration – research – heat and fluid management
- Odourisation of H_2 and effect on fuel cells

- Carbon nanotubes storage needs much more money to advance quicker. A good candidate for a competition or initiative akin to the human genome project
- New and improved storage technologies at a range of sizes e.g. hydrogen powered mobile phones
- chemical methods of storage (11 compounds) e.g. methanol, formaldehyde, formic acid
- focus on the applications that make a difference: Hydrogen – power, Hydrogen – transport
- Fixing hydrogen using CO_2
- Integrity of high pressure storage is still an issue.
- Chemical/metal hybrids
- H_2 infrastructure is major barrier (probably greater than 1 year ago)
- Mass fabrication of high pressure storage systems

USE DEVICES – HUGE RESEARCH AREA

- E.g. H_2 Ice, H_2 Turbines
- fuel cells
- Use drivers – still big challenges e.g. cost of fuel cells materials for H_2 turbines
- Turbo-fuel – cell generator
- Better fuel cell device – efficiency, fuel adaptive, cost and system improve
- Fuel cell hybrid systems
- Rapid, mass fabrication of fuel cells and associated equipment
- Development of new, simple scalable fuel cells – direct formic acid fuel cells, feasible at KW scale
- Integrate: H_2 storage, fuel cells, batteries
- Safe integrated systems
- Fuel cells and system integration
- H_2 turbine technology required – materials
- Pre-mixed hydrogen combustion
- Lightweight high power density fuel cells

Time line



Overarching challenge

- Ease of use
- Consumer can use at same price point and speed as other fuels
- Modularity – tank can be mass reproduced and replaced
- modularity as well as chemical solutions

- Right energy density – released in right time frame

- Safety
- Chemistry
- Has to be built in engineering

- Long life time
- Needs to have similar economic lifetime

- Integrated whole system analysis
- Fuel cell has to be used optimally material/ weight of device

Chemical and Engineering Challenge in parallel

- Storage material research has to be coordinated with international work. 'Freedom car' targets for automotive application.
- C monotube/liquid chemistry
- Explore a range of materials long term

- Engineering whole systems to deliver existing fuel technologies introduce/vehicle cell - modularity

- National aerospace strategy has head start – national/European
- Other industries need to follow example automotive key here – formative application short term – low urban vehicle
- Why are they not driving this?

- State of UK industry

Demonstration of personal transport

- Public engagement
- Car/bike producer
- DSTL?
- BOC – fuel supplier
- Shell/BP
- Island of Eth fuel dual fuel car – Norfolk
- Integrated power systems – more compact – poor electronics – low cost carbon fibre composites drive down weight.
- Medium – power electronics as big as electrical machine
    - Small SiC devices technology
    - Academe group good
- Manufacturing technologies to deliver economics at scale

Industry Requirements/Challenges Charge scale H_2 economy	**Who is (should be) doing it?**	**Small, medium or long term**	**Potential of a Collaboration**
Overlap with FP7 beyond scope of RCs - large demonstrations - need for something that will make UK stand out (complementarities)	EU funding (All have international dimension) →		EU and UK funding
Materials and components	Research in universities driven by industry needs		Uni-business
UK expertise in gas technology (making H_2 from fossil fuels)			
What comes first: market or supply? Need for 'How it will evolve' without locking it into technology	Industry in some 'niche' examples (BP)		
To scale down technologies E.g. compact reformat technologies Overlap between fuel cell technologies and compact reformat technologies – to get best out it.			
Technology demonstrations mean different things to different people (clarity needed)			
Large scale storage and transportation near point of generation (transport) (different transport options)	Mixed development some questions addressed by universities – combination		
Storage re-fuelers and generation re-fuelers			
Environmental impact along whole supply chain – link with socio-economic issues	Collaborative effort possibly led by universities		
Generation/distribution			
sources of H_2 : fossil fuels and sustainable sources Renewables - Electrolysis - Biomass - Nuclear			
H_2 production from fossil fuels - link to polygeneration (CAT)			Good science base and few companies
Renewables via electricity - too expensive - development of PEM electrolysers			Potential for collaboration
Solar/thermal (materials/componetns issue) Projects – callaboration with spain (Johnson			

Mattheys)			
Biomass (UK) (issues around land use) Open research questions			Potential for collaboration – good science base (e.g. Supergen)
Nuclear – electiricty (renewables) Generators for reactors		Long term	
Systems approach (understanding how H_2 economy will fit together with current economy – modelling etc..)			
Storage at point of use Small footprint in terms of energy Ease of use Integration with device Has to compete with 'nozzle' Ease with H_2 comparable with petroleum?			

APPENDIX IX

Fuel cells research challenges

Outputs from the First Energy Research summit

Whole System Fuel Cell Research

KEY OBJECTIVES AND CHALLENGES

1. To have one or more UK commercial fuel cell systems by 2012-15
2. Integration of fuel cells into various applications, e.g. portable, transport

Research needs:

- Whole systems research
- Larger programme for selecting materials
- Research/engineering in an application context
- Balanced of plant research should be estimated
- More public engagement

} System optimisation market economic

Outputs from the First Energy Research summit

DRIVING FORCES	RESTRAINING FORCES
• Identified applications/perceived needs • Higher efficiencies, in principle • Moving from fossil fuel • Scientific advance • Locally cleaner environment, silent • Fuel efficiency • H_2 from clean, renewable sources efficiency, low maintenance • Quality of output • Low emission/thermal signatures • Higher energy penalty than batteries • Efficiency, environmental impact, scalability • Good science base • Energy security • Climate change, prevention of energy wars, increased social freedom • Multi-functional power supplied (one cell and n-cells) • Flexibility, wide range of application	• Infrastructure (hydrogen) cost, KW& KWL durabilities? • Attempting to answer the "wrong question" system that are too complex for intended application, unrealistic hype of non delivery • Cost/commercialisation, ruggedness, logistics • Cost, durability, legislation, lack of demonstration funding, supply chain, fuel • Short lifetime is avis internal combust, high cost, sourcing catalysts, perception of H_2 as a fuel • Expense, if population control energy production – very difficult to manipulate! Social inertia • Lack of demonstration funding • Hydrogen infrastructure supply chain • Social acceptability

RESEARCH NEEDS

- Whole systems research
- Larger programme for selecting materials
- Research/engineering in an application context
- Balanced of plant research should be estimated
- More public engagement.

System optimisation market economic

Current effort:

- UKERC – Research atlas
- FCUK – Funding Finder

- Thematic working groups

- supergen beginning to make moves in this direction
- are their links the right ones?
- motor industry suffers from lack of UK owned base. Decisions made overseas

- Funding framework

- Moving research beyond 'stacks' into systems
- supergen to look to FP7
- systems level issues water/heat/flow

- Thematic working groups
- systematic review – possible action

- Industry involvement and dialogue – challenge is to maintain it

- Visibility of research to user community

High T PEM – desirable dependent on market

H_2 storage – hydrogen group

Reversible fuel cells

- Intermediate not really the challenge

- Balance of plant issues dependent on application

Some systems represent a particular challenge

- Diagnostics, remote control issues
- Water transport management within the fuel cell
- Direct methanol likely to be 1st app.
- Fuel 'cleaning' dealing with impurities
- Material performance

- Strategy for fuel cell funding
- Fundamental, basic, applied
  Catalysis
  Membranes
  Simulation
- New people that can add value to this sector
- DTI demonstration project
  - potential for lots of issues being revealed
- Survey to industry about issues

APPENDIX X

Wind Energy: user driven research challenges

- Consent for large offshore presence (R&D unknown)
- UK resource – real-scale test rig, national test rig
- Understanding environment as size and location changes
- Validate models of environment
- Solid models to predict active creep
- NIMBYism (public education)
- Understand stiffness of foundation and further interactions
- Set of models required to address large machine design
- Research on the whole life of wind turbines
- Optimising components on a volume scale
- Performance benchmarking (national scale)
- Optimum design of offshore turbines
- Reliability

Ideal

- 35% penetration
- Offshore costs equal to onshore
- Wind should become a conventional generation technology
- Removal of barriers to high penetration levels
- Sustained research program to improve existing architecture of WTG's
    - Cost reduction, reliability improvement, performance
- Storage?
- More open exchange of information between WTG manufacturing – universities/user
- Develop UK knowledge base to leverage inward investment and skills
- 'Step change' in technology research – generator, gearbox, control, blade, materials, foundations (offshore)?
- Predictable planning procedures
- Removal of infrastructural barriers to new development
- Coherent research strategy
- Manufacturing presence
- Faster planning process and public education
- Grid infrastructure capable of accepting large amounts of wind generation
- 20% wind energy by 2020 without subsidy
- Extracting value from UK IP (generation of intellectual capital)
- Quantum leap in technologies to effectively halve cost of generation
- Better and more flexible UK supply chain

CURRENT RESEARCH AND USER INVOLVEMENT

Project Economics

Current Research

- ROC's

- Cost reduction of turbines

Users involved
- Banks
- Developers (wind farm)
- Wind assoc (BWEA)

Current Research
- Existing EPSRC consortium on wind energy

Perceived Intermittency

Current Research
- Reducing the impact of intermittent resource on energy supply
- Benefits of aggregation of intermittent sources
- Transmission of bulk intermittent generation
- Over-coming this perceived issue of 'intermittency' – storages

Users involved
- Wind assoc (BWEA)
- RAEng
- Utility companies

Micro-wind

Current Research
- Testing planning consent for micro-wind

Users involved
- Supply companies
- Manufacturers of small turbines

Offshore

Current Research
- Novel foundation options for offshore (e.g. suction caissons)
- Investigation of different foundation/installation options for offshore
- Investigation of support structure options for deeper water

Users involved
- Manufacturers

Network issues (Economic)

Current Research
- Transparency of trans-national energy trading regimes (supergrid)

Users involved
- Planners

- Regulators
- Transmission companies
- Developers

Operations and Maintenance Offshore

Current Research
- Proactive O&M
- Optimal installation and maintenance of offshore fames

Users involved
- Manufacturers
- Local communities
- Safety and regulators off shore

Network Issues (Technical)

Current Research
- Grid integration
- Constraint management to provide cost efficient connections
- Large scale integration
- Innovative controls for network support
- Grid code – compliant, wind farms, fault ride through
- RC network integration work?
- Grid connections work

Users involved
- National grid – transmission operations
- 3 big manufacturers
- DNO's

Planning and Permits

Current Research
- Radar and lighting issues
- Environmental research into impacts on birds/fishing
- Environmental issues
- Centre for distribution Gen. and sustainable, Elec. energy – various R&D including wind generation issues

Users involved
- General public
- NGO's DEFRA
- Developers
- Local planning authorities

Small Scale Wind

Current Research

- Getting “supply” of wind energy closer to demand (cities) … supergrid
- Integrating wind into the management of distribution networks
- Europe – framework 6 projects

Users involved
- Local planning authorities
- DNO’s

Turbine Design

Current Research
- More reliable turbines
- Cost reduction – foundations, connection, gearbox
- Promoting breakthrough – turbine designs
- Tools for loading and performance being enhances/validated for offshore turbines and support structure
- Optimisation of turbine design (weight vs. capacity)
- New codes of practice for offshore design (GL, DKV)
- Maintenance costs – materials, access, lifetime
- Wind turbine technologies (alternatives)
- Longer life turbines
- Dynamics of blades/drive trains
- Direct drive generators (permanent magnet)
- Vibration testing of blades

Users involved
- Consultants in turbine design
- Turbine manufacturers
- New entrants
- Component suppliers