AEA

Low Carbon Energy Technologies

Annual Report 2007/08

COLLABORATIVE RESEARCH & DEVELOPMENT

LOW CARBON ENERGY TECHNOLOGIES

ANNUAL REPORT 2007/08

FOR
TECHNOLOGY STRATEGY BOARD

This report has been prepared by AEA Technology plc on behalf of the Technology Strategy Board. The Technology Strategy Board is a business-led executive non-departmental public body, established by the Government and sponsored by the Department of Innovation, Universities and Skills (DIUS). Its mission is to promote and support research into, and development and exploitation of, technology and innovation for the benefit of UK business to increase economic growth and improve the quality of life.

First published 2009

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General overview

The Technology Strategy Board, sponsored by the Department for Innovation, Universities and Skills (DIUS), was established in July 2007 to drive forward the Government's Technology Strategy. As well as investing in programmes and projects, much of its work is in spreading knowledge, understanding policy, spotting opportunities and bringing people together to solve problems or make new advances.

There is a strong focus on technologies where the UK has the capability and capacity to compete on a global stage, where the biggest benefit for UK business can be achieved and where the most difference can be made to UK capabilities. The strength of the research base and the creativity and diversity of the workforce are key assets.

The Technology Strategy Board prioritises its investment in a number of key technology areas (KTAs) and key application areas (KAAs). One of those KAAs is energy generation and supply. The Low Carbon Energy Technologies programme, described in this report, is one mechanism for supporting this area. The programme has funded projects since 2003 and was transferred to the Technology Strategy Board from the Department for Business, Enterprise and Regulatory Reform (BERR) in July 2007.

The Low Carbon Energy Technologies programme is administered on behalf of Technology Strategy Board by AEA. Responsibilities include monitoring of live projects, grant offer letters, reporting and management and communications.

Research and development overview

This Annual Report describes the projects supported by the Low Carbon Energy Technologies programme. In 2007/08 the programme had a portfolio of over 100 live research and development (R&D) projects with a total value of over £30 million.

In autumn 2007, there was a call for new project proposals in the following technology areas: carbon abatement technologies, intelligent grid management, hydrogen and fuel cells, bioenergy, and microgeneration and photovoltaics (PV).

Key results and achievements

Section 3 describes some of the highlights from projects in each of the technology areas and gives summaries of all the projects live between April 2007 and March 2008.

In the **Carbon Abatement Technologies** area:

- Doosan Babcock Energy Ltd and its partners set out to evaluate the optimal way in which the retrofit of carbon abatement technologies can be accomplished on the UK fleet of coal-fired power plants. The project has demonstrated the technical feasibility of a specific carbon capture technology (advanced supercritical retrofit capture-ready plant to power plants); although it has also established that, in most UK power plants, there is insufficient space available for the application of this equipment to all units. The project has also established the economic viability of this approach. Were carbon dioxide (CO_2) capture to become mandatory, the retrofit routes studied are likely to be the most cost-effective for existing pulverised fuel power generation plant. The project consortium members are well positioned to exploit these opportunities worldwide.

- In a second project, led by Dooson Babcock Energy Ltd, which followed on from a previous BERR-sponsored project, tests have been undertaken to extend the range of proven performance of wall-firing burners on various types of difficult coal (ie coal with high levels of moisture or relatively high ash content). A wall burner has been developed that is based on a combination of modelling and trend analysis, and its performance evaluated by full-scale testing. The relative performance of the burner in terms of NOx emissions and unburnt losses when firing each of the coals has been established. This has identified the optimum performance of the burner within its range of adjustment.

- RWE npower plc and its partners sought to assess methods for reducing slagging and fouling constraints on high levels of biomass co-firing. The project has demonstrated that 50% levels of biomass co-firing

are technically feasible. However, the commercial implementation of full-scale projects using high levels of co-firing will be dictated by factors other than combustion and boiler plant performance. This is because, on current projections, it is unlikely that sufficient quantities of indigenous or imported biomass will be available in the near future to support anything like a 50% replacement level.

In the **Intelligent Grid Management** area:

- Econnect Ventures Ltd and its partners have developed a website where users can obtain information about the electricity distribution network and the implication of adding renewable plant. The website is now up and running and offers a secure and sustainable commercial service offering an assessment tool for connection opportunities for distributed generation. The project team found that the connection assessment reports produced automatically using the website were comparable with manual assessments conducted by distribution network operators (DNO) and Econnect engineers. Most significantly, both methods agreed on the technical and financial assessment of a proposed generation site.

In the **Hydrogen and Fuel Cells** area:

- Ceres Power Ltd and its partners have been developing a prototype solid oxide fuel cell micro-CHP system for UK residential applications, operating on pipeline natural gas. They have successfully designed, produced and commissioned an integrated prototype and extended performance testing is about to commence, with further system design development to continue in parallel.

- Intelligent Energy, Prodrive, Bosch and PSA Peugeot Citroën have been collaborating on developing fuel cell engines for automotive transport. To date, Intelligent Energy has designed and constructed two laboratory-test versions of 10 kW systems. These have met with the approval of Peugeot and Bosch. Start-up from lower temperatures has been improved and the third generation of 10 kW systems has been installed for track testing in the UK and France.

- Bac2 Ltd and its partners have sought to establish the feasibility of novel, low-cost, moulded conductive polymer composite flow field plates for use in fuel cells. A key project success was the fuel cell plates produced using Bac2's ElectroPhen conductive resin, which delivered a 33% improvement in cell performance. As ElectroPhen is a low-cost material, the improved productivity at low cost should lead to the most cost competitive fuel cell plates for mass production.

In the **Bioenergy** area:

- This is the third in a series of projects to develop a unique biomass CHP concept based on hot air gas turbine cycle. The objective is to develop a commercial system at a scale of 100 kWe output with an acceptable electrical efficiency. The extended operation of the prototype has led to a decision to start manufacturing the first generation of commercial units. An electrical efficiency of 22% was achieved in a CHP installation with a potential overall efficiency of 65%.

- Green Biologics Ltd and its partners have been working to develop biobutanol as an alternative biofuel for transport. The overall aim is to develop an economic microbial fermentation process for butanol. To date, the consortium has completed a process economic model, demonstrated scale-up to 1 litre fermentation with a genetically modified strain, and constructed a new genetically modified strain.

In the **Microgeneration and Photovoltaics** area:

- Optical Products Ltd and its partners are working to develop solar concentrators and low-cost manufacturing technologies to produce building-integrated photovoltaic (PV) microgeneration units. To date, various materials and manufacturing techniques have been trialled to identify the best method for making low-cost lenses that successfully collect direct sunlight over a wide range of incident angles. The close involvement of Persimmon Homes is ensuring that the final product will comply with Building Regulations and the needs of housing developers.

- RBR Associates Ltd and its partners are aiming to develop an innovative, ridge-mounted, solar-thermal collector panel that will be built using cost-effective polymer manufacturing processes. Work to date has focused on identifying the optimum design of channels and the detailed manufacturing considerations for these large rubber injection mouldings.

In the **Wave Energy and Tidal Stream** area:

- Tidal Generation Ltd and its partners have embarked on the first of a three-part programme to design, test and install a 500 kW prototype tidal turbine. The main innovative features of the design are light, quickly installed tripod foundation and the deployment and retrieval of a floating nacelle onto or from the foundation using a single-line winch. To date, the attachment and detachment of a dummy nacelle attached to a test rig has been successfully demonstrated in a tidal estuary. The project has prepared the way for a more detailed design phase and the specifications for a novel drilling technique to secure the foundations to the sea floor.

- Peter Brotherhood Ltd and its partners sought to test a new design of air turbine driven by an oscillating water column (OWC) capable of performing bi-directionally. The project demonstrated, under test conditions, that an improved performance for the turbine could be achieved. The performance of the variable radius turbine (VRT) has highlighted its wider range of operation, thereby producing a more efficient power capture system.

In the **Offshore Wind** area:

- A project known as CORLEX, the Cost Reduction and Life Extension of Offshore Wind Farms, involves five organisations investigating various aspects of offshore wind farm design, operation and maintenance. The project met the overall objective of developing and demonstrating ways of reducing the installation and running costs of offshore wind farms. The major achievements were the design and production of a cast node system for foundations and the demonstration that the use of electron beam welding, using partial and local vacuum systems can be used to reduce fabrication costs.

- The development of stealth technology for wind turbines is designed to minimise the interference of wind farms with civil air traffic control, military defence and other radars, including weather monitoring and marine navigation aids. This project has been able to identify the major radar cross section (RCS) sources within a wind turbine that cause it to interfere with radar systems and to deliver a number of material and shaping schemes which will reduce the turbines' RCS. In addition, the project has identified and developed low-risk treatments for turbine tower and nacelle components.

1 INTRODUCTION

1.1 ROLE OF THE TECHNOLOGY STRATEGY BOARD

The Technology Strategy Board's vision and ambition is to make the UK a global leader in innovation. magnet for innovative businesses, where technology is applied rapidly, effectively and sustainably to create wealth and enhance quality of life. The task at the Technology Strategy Board is to "Connect and Catalyse1". It aims to help businesses on their journeys of discovery by:

- Providing strategic innovation leadership and investment.
- Bringing people together in partnership and working across business, Government and the research community.
- Ensuring that the UK has the necessary capability in key technologies.
- Taking a global perspective.
- Investing in networks and knowledge exchange.
- Promoting the importance of innovation and technology.
- Run collaborative R&D competitions.

Technology Strategy Board's are developing strategies in a number of broad areas representing major societal challenges or associated with the challenge of maintaining a world-leading position. Currently, they include:

- Medicines and healthcare.
- Energy generation and supply.
- Transport.
- Environmental sustainability.
- Built environment.
- Creative industries.
- High-value services.

In March 2008, the Government published a White Paper, *Innovation Nation*[2], committing it to develop a strong research base as one of the key components in its drive to place UK at the forefront of science innovation globally. The report acknowledges the important role of strategic organisations such as the Technology Strategy Board in 'driving innovation and co-ordinating Government effort'.

1.2 ADDRESSING UK ENERGY CHALLENGES

Climate change and security of supply challenges have placed energy high on national and international agendas, making it the subject of regular policy and legislative review within Government. The Government's work in this area is underpinned by two significant long-term objectives, which are set out in the 2007 Energy White Paper, *Meeting the Energy Challenge*[3]. The first of these is tackling climate change by reducing carbon dioxide (CO_2) emissions within the UK and globally. The second is to improve the security of the UK's energy supply, working towards secure, clean and affordable energy.

The Stern Review on the Economics of Climate Change not only addressed the need for an urgent response to climate change, but it also illustrated in detail the importance of Government policy in driving innovation in low carbon energy technologies. These policy drivers are creating market opportunities to deliver innovative solutions where the UK is well placed to take advantage.

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[1] http://www.innovateuk.org/_assets/pdf/Corporate-Publications/Technology Strategy Board - Connect and Catalyse.pdf

[2] http://www.dius.gov.uk/publications/scienceinnovation.pdf

[3] http://www.berr.gov.uk/files/file39564.pdf

In response, the Technology Strategy Board works to stimulate innovation throughout the **energy supply chain**, through a number of its investment mechanisms:

- Key Application Areas (KAAs):
  - Energy generation and supply.
  - Transport.
  - Environmental sustainability.
- Innovation Platforms in low-impact buildings and low-carbon vehicles, addressing respectively energy use in buildings and in transport.
- Key Technology Areas (KTAs) that address technologies that underpin the energy sector, such as advanced materials, high-value manufacturing and electronics, photonics and electrical systems.

The Technology Strategy Board provides funding for business-driven applied research & development (R&D), through to early pre-competitive demonstration. It is distinctive in its focus on wealth creation for UK business through innovation, and its ability to invest in and deliver technology programmes through complementary and flexible mechanisms, which are inclusive of micro-companies, SMEs, universities and large businesses. These include collaborative R&D, knowledge transfer networks and knowledge transfer partnerships.

1.3 WORKING IN PARTNERSHIP

The magnitude of the challenge, the broad portfolio of technologies needed and the requirements for innovative solutions in energy, are such that no single organisation can realistically take responsibility for all the elements of the innovation chain, hence co-ordination and co-operation are crucial to the effectiveness of the system.

The Technology Strategy Board works closely with key players in the UK energy innovation chain, such as: the Energy Technologies Institute (ETI); the Carbon Trust; Energy Technologies Fund (ETF) the Department for Business, Enterprise and Regulatory Reform (BERR); the Research Councils; the Regional Development Agencies; and the Devolved Administrations. Continuous dialogue allows the players to develop complementary programmes of activities, and avoid duplication and technology gaps.

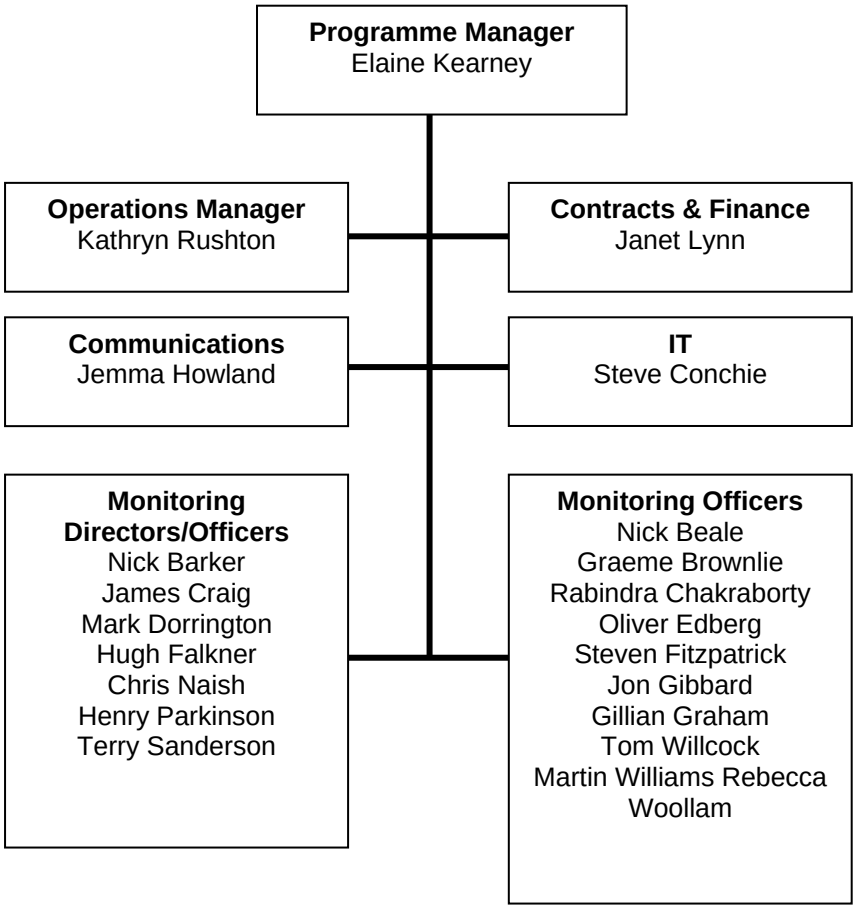
1.4 THE LOW CARBON INNOVATION COORDINATION GROUP

The Chief Executives of the Carbon Trust, ETI and the Technology Strategy Board meet regularly to identify and exploit opportunities for synergy, avoid duplication of activities and incorporate an awareness of each other's plans into decision making to achieve a coherent position and communicate it externally.

A guide to other potential sources of support in addition to that available from the Technology Strategy Board is shown in Appendix A.

1.5 DAY-TO-DAY MANAGEMENT

The Low Carbon Energy Technologies programme is administered on behalf of Technology Strategy Board by AEA, based in Harwell Oxfordshire. AEA provides a mix of energy and environment technical experts as well as marketing and project administration professionals to deliver the required services. The programme can also call upon additional resource from over 500 staff in the AEA organisation when required. During 2007/08 the delivery team consisted of:



1.5.1 SCOPE OF AEA DELIVERY

In July 2007 when the CR&D programme transferred from BERR to the Technology Strategy Board, AEA was delivering 3 main activities:

1. Monitoring of existing projects:
    - 114 projects transferred from BERR to Technology Strategy Board.
2. Production of Grant Offer Letters for Autumn 06 projects:
    - As part of the transition AEA submitted draft Offer Letters to Technology Strategy Board for approval and issue.
3. Administration of the outline assessment stage of the April 07 competition. The main activities at this time included:
    - Recruitment and contracting of assessors.
    - Allocation of applications to assessors.
    - Management of panel meetings.
    - Delivery of panel meeting reports and recommendations.
    - Feedback to applicants.
    - Support for applicant and assessor briefings.

Under the Technology Strategy Board AEA's main activities between July 2007 and March 2008 were:

1. Monitoring of Live Projects
    - At the end of the financial year AEA was managing 100 live projects.

2. Evaluation
    - AEA introduced an evaluation process for completed projects in collaboration with Hi Consulting and NEL. Seven Low Carbon Energy projects were selected to participate in the pilot evaluation process. The full programme will take place during 2008/09.
3. Support to the Review Process
    - AEA reviewed Expressions of Interest submitted to the Phase 2 Low Carbon theme of the November 07 competition.
4. Grant Offer Letters
    - Production of Autumn 06 and Spring 07 Grant Offer Letters including financial and viability checks of applicants.
5. Ad Hoc Information
    - AEA responded to a number of requests for ad hoc information during the year, including:
        - Details of marine device development projects for a BERR press release (routed through TSB);
        - Case study information to support the Low Carbon strategy document;
        - Scale of spend on Low Carbon CR&D projects since April 2007;
        - Details of low carbon energy projects funded since 2003, split by technology area;
        - Details of technologies that have received EET grant funding for projects that address different stages of their development (basic through to experimental development).
6. Reporting and Management
    - AEA produces monthly and quarterly report to the Technology Strategy Board. In addition monthly meetings are held to discuss project and delivery between AEA and the Technology Strategy Board.
7. Communications
    - Production of a quarterly e-bulletin which is received by nearly 1400 subscribers.
    - AEA developed a case study template and final report template.

2 PROGRAMME PORTFOLIO

2.1 SUMMARY OF PROJECTS

During 2007/08, the Low Carbon Energy Technologies programme included projects that addressed the following technologies:

- Carbon abatement technologies.
- Intelligent grid management Bioenergy.
- Hydrogen and fuel cells.
- Microgeneration and photovoltaics.
- Wave energy and tidal stream
- Offshore wind.

In July 2007, responsibility for live projects funded by this programme was transferred from BERR to the Technology Strategy Board. Details of the number of projects that were live between 1 July 2008 and 31 March 2008 and the average level of investment are shown below.

	Number of projects initiated	Number of projects ended or completed	Total number of projects managed	Value of portfolio (£000)	Approximate grant (£000)
Carbon abatement technologies	5	4	14	16,672	6,459
Intelligent grid management	1	5	19	17,775	8,594
Hydrogen and fuel cells	1	3	12	23,189	11,036
Bioenergy	2	3	15	12,336	5,171
Microgeneration and photovoltaics	3	1	14	9,955	5,146
Wave energy and tidal stream	6	2	21	50,735	23,881
Offshore wind	3	4	14	38,066	9,089
Totals	**21**	**22**	**109**	**168,728**	**69,376**

2.2 COMPETITIONS FOR FUNDING

On 8 November 2007, the Technology Strategy Board announced a new competition for collaborative R&D projects in the low carbon energy projects area, with a budget of about £10 million. Applications were sought in specific areas: carbon abatement technologies, bioenergy, hydrogen and fuel cells, microgeneration and photovoltaics, and intelligent grid management. Offshore wind and marine were excluded to ensure complementarity with funding provided by the ETI. The deadline for receipt of full applications was 27 March 2008.

In addition, the application and assessment processes were still underway for the autumn 2006 and spring 2007 competitions.

The numbers of applications received at each stage are as follows:

Competition	Outline applications	Full applications	Projects supported	Total value (£million)	Total grant* (£million)
Autumn 2006	62	22	8	11.3	5
Spring 2007	66	30	14	18.6	10
Autumn 2007			14	17.2	8.2

*Includes grant provided by Engineering and Physical Sciences Research Council (EPSRC)

3 Project Summaries

This section provides a more detailed description of the seven technology areas supported by the Low Carbon Energy Technologies programme and some highlights of the projects included in each area.

3.1 CARBON ABATEMENT TECHNOLOGIES

3.1.1. Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- Improving the efficiency of existing and developing technologies to support the extra demands placed upon equipment operating in increasingly aggressive environments. This includes developments in boiler technologies for efficient coal combustion, steam and gas turbine technologies to accommodate higher temperatures and pressures, and improved gasifiers for syngas production. Associated technologies that support enhanced performance and reliability such as plant asset management and condition monitoring are also included.

- Developing CO_2 capture technologies further, including pre and post- and oxyfuel firing and associated technologies to improve their efficiency and reduce capital and running costs.

- Developing CO_2 compression and handling technologies for subsequent transport and storage.

- Developing further technologies to monitor and verify geologically stored CO_2.

- Developing further technologies associated with the safe transport and storage of CO_2.

3.1.2. Project overview

Number of projects initiated	5
Number of projects completed	4
Total number of projects managed	14

The projects managed during this reporting year predominantly covered the improvement of the efficiency of existing and developing technologies, including alloy development for advanced power plant and co-firing of biomass. Oxyfuel firing processes and carbon capture and storage technologies have also been investigated.

3.1.3. Project listings

Project title	Lead	Partners	Status	Estimated duration
Coal-fired advanced supercritical boiler/turbine retrofit technology with CO_2 capture	Doosan Babcock Energy Ltd	ALSTOM Power Ltd, E.ON UK (formerly PowerGen), Air Products Ltd, Imperial College, Drax, EDF	Completed	2 years and 8 months
Towards zero emissions of NOx and mercury from coal-fired power plant	Doosan Babcock Energy Ltd	University of Nottingham, Imperial College, E.ON UK	Completed	2 years and 2 months
Alloy development for	Doosan	Corus UK Ltd,	Ongoing	3 years and

critical components on future coal-fired power Plant	Babcock Energy Ltd	Cranfield University, E.ON UK, Loughborough University, Metrode Products Ltd, NPL, TWI Ltd		6 months
Superheater and pipework component demonstration for AD 700 type coal-fired boilers in European power plant	Doosan Babcock Energy Ltd	E.ON UK, Special Metals, Wyman Gordon	Ongoing	4 years and 1 month
Development of advanced burner technology for difficult coals	Doosan Babcock Energy Ltd	Imperial College	Completed	2 years 7 months
Reducing slagging and fouling constraints on high levels of biomass co-firing	RWE npower	Imperial College	Completed	2 years and 9 months
OxyCoal-UK	Doosan Babcock Energy Ltd	Air Products plc, E.ON UK, RWE npower, University of Nottingham, Imperial College, BP	Ongoing	2 years and 3 months
Carbon dioxide amine separation and storage for capture ready pulverised fuel plant (CASS-Cap)	RWE npower	Doosan Babcock, Energy Ltd Drax Power, Scottish and Southern Energy, Visser & Smit, Hanab UK, Imperial College, ScottishPower, EDF Energy	Ongoing	2 years and 5 months
Industrial and utility scale integrated gasification single cycle coal power	Jacobs Consultancy UK Ltd	CO_2 Global AS, Siemens plc, MAN Turbo, Imperial College	Ongoing	2 years and 8 months
CO_2 aquifer storage site evaluation and monitoring (CASSEM)	ScottishPower Ltd	SSE plc, AMEC Group Ltd, Schlumberger Oil UK plc, Marathon Oil UK Ltd, Heriot-Watt University, University of Edinburgh, University of Manchester, BGS	Ongoing	2 years and 6 months
Sealing and surface engineering technologies for USB Steam Turbine Plant (700-760°C)	ALSTOM Power Ltd	Cross Manufacturing Co Ltd, NPL Management Ltd, E.ON UK, Monitor Coatings Ltd, Indestructible Paint Ltd, Cranfield University	Ongoing	3 years
Optimised Oxycoal Combustion	Doosan Babcock	Air Products plc	Ongoing	2 years and 1 month

	Energy Ltd			
Enhanced Capture with Oxygen Critical Operating Parameters Post-combustion Scrubbing	RWE npower plc	BOC Ltd, Doosan Babcock Energy Ltd, University of Leeds	Ongoing	3 years
Optimisation of Oxyfuel PF Power Plant for Transient Behaviour	Doosan Babcock Energy Ltd	Air Products plc, RWE npower plc, Imperial College	Ongoing	2 years

3.1.4. Project highlights

Coal-Fired Advanced Supercritical Boiler/Turbine Retrofit Technology with CO_2 Capture (Doosan Babcock Energy Ltd)

Retrofitting carbon abatement technology to existing pulverised fuel (pf) power plant minimises capital expenditure and maximises the use of the existing infrastructure, leading to environmental benefits being realised faster and more widely. In the short-term, efficiency improvements and biomass co-firing can deliver substantial reductions in CO_2 emissions. Longer term, as regulations and infrastructure permit, carbon capture and storage will deliver essentially zero CO_2 emissions. Based on these two approaches, this project evaluated and optimised how retrofit of carbon abatement technologies for UK fleet of coal-fired power plants.

Ratcliffe Power Station - 4 x 500 MWe Sets (courtesy E.ON UK)

Key results

- Retrofitting carbon abated clean coal technologies is a practical solution with no technical or physical barriers being identified in the term of this project.

- Advanced supercritical boiler/turbine technology is now available with the appropriate guarantees for retrofitting to coal-fired power plant to improve efficiency, reduce fuel costs and reduce CO_2 emissions.

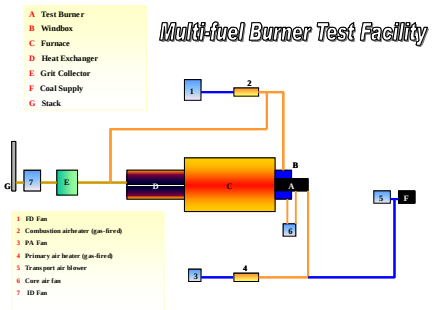
- This project has demonstrated:
  - The technical feasibility of advanced supercritical retrofit capture-ready plant to UK power plants with compliance to the large combustion plant directives (LCPD) new plant emissions standards.
  - It is technically feasible to retrofit carbon capture technologies for post combustion or oxyfuel combustion, to an existing coal-fired power plant. However, in most UK power plants there is currently insufficient space (and insufficient cooling capacity) available for the application of carbon capture equipment to all units of the power plant.
  - That advanced supercritical retrofits and advanced supercritical retrofits with CO_2 capture are economically viable in terms of the cost of electricity generated.

- When CO_2 capture and storage becomes economic or mandatory, the retrofit routes studied are likely to be among the best and most cost-effective options for existing PF power generation plant. The project consortium members are well positioned to exploit the opportunities worldwide.

Development of Advanced Burner Technology for Difficult Coals (courtesy of Doosan Babcock Energy Ltd)

This project followed on from a previous Department of Trade and Industry (DTI, now BERR) project entitled, “Combustion of Low Volatile Coal in Wall Fired Plant”. Further development work and tests have been undertaken to extend the range of proven performance of wall-firing burners on various types of difficult coal. The emission level and combustion efficiency of each coal were determined and compared with a standard reference coal to enable the performance for the difficult coals in commercial plant to be estimated. The coals studied in this project have been characterised using laboratory-based thermogravimetric analysis, rapid-heating high temperature wire mesh (HTWM) and ignition tests.

HTWM apparatus (courtesy of Imperial College)



Key results

- A wall burner capable of firing a range of difficult coals has been developed through a combination of modelling and trend analysis of previous burner experience. The performance of the burner has been evaluated by full-scale testing.

- The burner has been test fired on coals with high levels of inherent moisture (around 20%) and relatively high ash (20-25%) either singularly or in combination. Therefore, it has been proved that the burner can fire fuel with an 'as-fired' inert content up to about 50% with good flame stability and turndown capability.

- It has been proved that the burner is capable of firing high-rank coal with volatile matter content down to 8% dry mineral matter free (dmmf).

- The relative performance of the burner in terms of NOx emissions and unburnt losses when firing each of the coals has been established. This has identified the optimum performance of the burner within its range of adjustment. It is possible that further optimisation of burner performance could be achieved by modifying the burner range of adjustment to suit specific fuel types.

- A number of laboratory techniques to assist in characterising the factors related to, and controlling the ignition of, the difficult coals have been developed by Imperial College. The characteristics of specific fuels determined by these methods correlate reasonably well with the firing experience on the test burner. The techniques confirm the limit of application (in fuel terms) indicated by the burner testing.

- The laboratory characterisation of the fuels has included future oxyfuel firing conditions and has given a preliminary indication that ignition in oxygen/CO_2 mixtures is more difficult than ignition in air, particularly for high-rank coals.

Reducing Slagging and Fouling Constraints on High Levels of Biomass Co-firing (courtesy of RWE npower plc)

Biomass fuels (biofuels) vary enormously in their combustion properties and ash characteristics. This project focused on those biofuels that could be made available in substantial quantities. It aimed to provide industry with clear guidelines about those areas of the boiler that would be most at risk from increased levels of slagging and fouling as the biomass replacement was increased. This would lead to an improved understanding of the nature of the deposits and allow the development of an on-line model to predict the thermal impact of such deposition allowing the operators to optimise their soot-blowing operations. The project also provided valuable information on the use of low-cost additives to mitigate the impact of fouling deposits.

Photograph showing the dramatic effect on deposit morphology by adding a small amount of biomass RHS: Coal + 15% Olive; LHS: Coal only (courtesy of RWE npower)

Key results

- This project has demonstrated that 50% levels of biomass co-firing are technically feasible and can be achieved in terms of combustion, fouling and overall boiler performance. 50% biomass co-firing on a single 500 MWe coal-fired unit operating at a typical 50% annual load factor would require between 0.75 and 1.25 million tonnes of biomass per year depending on the type of biomass used.

- The commercial implementation of full-scale projects using high levels of co-firing will be dictated by factors other than combustion and boiler plant performance. Based on current projections, it is unlikely that sufficient quantities of indigenous or imported biomass will be available in the near future to fuel a significant number of coal-fired power stations to anything like a 50% replacement level.

3.2 INTELLIGENT GRID MANAGEMENT

3.2.1 Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- Maximising the utilisation of existing transmission and distribution assets in the face of the increasing deployment of new generating technologies.

- Facilitating the timely connection of new generation, while maintaining levels of system security and minimising the impact of constraints.

- Minimising the impact of energy losses.

- Manage the impacts of variable output caused by intermittency, etc at a system level, including applying electrical storage and demand-side measures such as “smart appliances”.

- Cost-effectively integrating onshore and offshore generation technologies, including innovation to permit Grid Code requirements to be met in the most economical way.

- Cost-effectively integrating microgeneration technologies.

- Developing low carbon network equipment, design, management, operation and control, including active management systems and methodology.

3.2.2 Project overview

Number of projects initiated	1
Number of projects completed	1
Number of projects stopped	4
Total number of projects managed	19

The 19 projects managed during the year covered, inter alia, development of electrical energy storage devices network active management systems, network connection information systems and tools, advanced metering, fault level assessment, and control and devices for the connection and control of offshore wind farms. Three projects were stopped at the request of the partners because they reached the view that they would be unable to reach their original objectives. One project was stopped because the partners could not conclude a collaboration agreement.

3.2.3 Project listings

Project title	Lead	Partners	Status	Estimated duration
Metering and monitoring of domestic embedded generation	BEAMA Power Ltd	ECS Ltd, EA Technology Ltd, EDF Energy, Powergen, npower, Good Energy	Ongoing	4 years
Fault level monitor stage two	EA Technology	Energy Networks Association, CE Electric UK, Central Networks, EDF Energy, National Grid plc, Western Power Distribution, Northern Ireland Electricity, United Utilities, ScottishPower, Scottish & Southern Energy	Stopped	2 years
Control of wind farm grids with an HVDC link	AREVA T&D UK Ltd	University of Nottingham	Ongoing	3 years
Grid compliant AC connection of offshore windfarms using a STATCOM	National Grid Transco	AREVA T&D Technology Centre	Ongoing	2 years and 6 months
Development of Redox flow battery for utility energy storage	ESD Ltd	Econnect, University of Southampton, Swanbarton Ltd, ScottishPower Power Systems Ltd	Ongoing	4 years
A combined low cost electricity and gas "Smart Meter" using	Centre for Sustainable Engineering	Polymeters Response International Ltd,	Stopped	2 years and 4 months

new solid state gas metering technology		Sentec Ltd		
Fault current calculations for distribution networks with embedded generation	TNEI Services Ltd	ScottishPower Power Systems Ltd, United Utilities, EON UK.	Ongoing	2 years and 4 months
Active management of distributed generators based on component thermal properties of power system plant	Parsons Brinckerhoff Ltd	ScottishPower Power Systems Ltd, Areva T&D UK Ltd, Imass Ltd, University of Durham.	Ongoing	3 years
Standardisation of access to electricity network information	Imass Ltd	Econnect Ltd	Completed	1 year and 9 months
Redox flow cells for intelligent grid management	C-Tech Innovation Ltd	EON UK, University of Southampton	Ongoing	3 years
Smart grid oscillation management for a changing generation mix	Psymetrix Ltd	Psymetrix Ltd, Northern Ireland Electricity, National Grid, Queen's University Belfast	Ongoing	2 years
The Plurion Red/Ox low battery	EON UK	Plurion Ltd, Central Networks	Stopped	10 months
Data acquisition system for active network management	Econnect Ventures Ltd	Fundamentals Ltd	Ongoing	2 years
Demand for wind	Econnect Ventures Ltd	Good Energy, University of Durham	Ongoing	2 years and 3 months
Managing active networks through intelligent systems (MANtIS)	Rolls Royce plc	ScottishPower Power Systems Ltd, University of Southampton, University of Strathclyde	Ongoing	3 years and 4 months
Assessment of carbon-reduction and system benefits of dynamic demand	Imperial College of Science, Technology and Medicine	Indesit UK Ltd, Bosch und Siemens Hausegeraet GmbH, Beko Plc, Invensys Controls UK Ltd, National Grid Electricity Transmission Plc, E.ON UK Ltd, Loughborough University	Stopped	2 years and 3 months
Enhanced grid connection assessment web tool	Econnect Ventures Ltd	Imass Ltd, University of Durham	Ongoing	2 years and 3 months
The zero fault level generator for active urban networks	NaREC Development Services Ltd	CRE8 Innovation Solutions Ltd, University of Nottingham, Imperial College, EDF Energy, E.ON UK, Yorkshire	Offered	2 years

		Electricity Distribution plc		
Multi-terminal DC transmission microgrid system for interfacing multiple wind turbines	Proven Energy	Scottish & Southern Energy, University of Strathclyde	Offered	3 years

3.2.4 Project highlights

Standardisation of Access to Electricity Network Information (Econnect Ventures Ltd)

A website has been developed where users can obtain information about the electricity distribution network and the implications of connecting their generation plant to that network. Web pages help the user to locate their generation site through an interactive mapping tool supported by a Geographic Information System (GIS) database, and automatically produce an initial connection assessment report for that site. The joint collaboration between specialist electrical engineering and software development company, Econnect Ventures Ltd, and leading IT company, Imass Ltd, was set up prior to this project to develop a prototype version of the website. The companies continued the partnership to deliver this follow-on project, which had the overall aim of providing secure access to information related to the electricity distribution network through a commercial Internet service covering the whole of Great Britain.

Specific objectives were to:

- Integrate geographical and electrical information published by the distribution network operators of Great Britain in one seamless database that is used to deliver interactive l maps to the user.
- Develop a network connection assessment service for distributed generation plants aimed at stakeholders in the renewable energy industry.
- Provide these services on a commercial basis and deliver them on the World Wide Web at www.gridconnection.co.uk

An example screen shot from the website is shown below

Key results

The result of the project is a secure and sustainable commercial service offering an assessment tool for connection opportunities for distributed generation.

The project has also:

- Established the principle for providing an electronic version of the long term development statement and making it available on a commercial basis.
- Completed the development of the website (www.gridconnection.co.uk) to support mapping of all the DNOs' electrical data in Great Britain.

The project team has compared the connection assessment reports produced automatically using the website with manual assessments conducted by distribution network operators and Econnect engineers.

The results were comparable, with both methods of generating connection assessments agreeing on the technical and financial assessment of a proposed generation site.

3.3 HYDROGEN AND FUEL CELLS

3.3.1 Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- Development of novel materials and systems for hydrogen storage that are capable of high volumetric and gravimetric hydrogen content, with low cost and high energy efficiency.
- R&D into novel, more durable and lower cost materials, manufacturing processes and components for hydrogen electrolysers and fuel cell systems.
- Development of innovative components and stack designs for improved efficiency and performance, and simplified system design.
- System development for advanced fuel cells focused on real-world automotive and CHP applications.
- Design, construction and evaluation of efficient, low-cost hydrogen production systems suitable for on-site vehicle refuelling.

3.3.2 Project overview

Number of projects initiated	1
Number of projects completed	3
Total number of projects managed	12

The 12 projects managed during the year covered development of novel materials for fuel cell membranes, hydrogen storage and hydrogen purification, and the evaluation of novel designs for fuel cell stacks and systems. Particular attention has been given to promoting the development of a UK supply chain.

3.3.3 Project listings

Project title	Lead	Partners	Status	Estimated duration
Monitoring proposal for the woking borough council phosphoric acid fuel cell CHP installation	Advantica Technologies Ltd		Completed	8 years and 6 months
Advanced automotive and motive power fuel cell systems and component development	Intelligent Energy	UK - formal: Prodrive Overseas - In-kind: Peugeot (France), Robert Bosch (Germany)	Ongoing	3 years and 11 months
Low-cost, high-temperature membranes for PEM fuel cells	Johnson Matthey plc	University of Reading	Completed	2 years and 8 months
Develop a durable fuel cell membrane using functionalised additives	Johnson Matthey Fuel Cells Ltd	University of Surrey, ICI Imagedata	Completed	2 years and 6 months
Integrated fuel cell system prototype demonstrator for CHP applications	Ceres Power Ltd	British Gas	Ongoing	3 years and 6 months
High throughput synthesis and screening of novel hydrogen storage materials	Ilika Technologies Ltd	CCLRC, Johnson Matthey Technology Centre, University of Oxford	Ongoing	3 years and 6 months
Low-cost moulded conductive polymer composite flow plates for use in fuel cells	Bac2 Ltd	Branwell Graphite Ltd, CMR Fuel Cells (UK) Ltd, Dynea Aycliffe Ltd, Porvair plc, University of Portsmouth	Completed	1 year and 10 months
The use of novel UV curable materials and ionic liquids in fuel cells	Ionic Polymer Solutions Ltd	C-Tech Innovations Ltd, AF ChemPharm	Ongoing	2 years and 4 months
HYPNOMEM - hydrogen permeable novel membranes	Teer Coatings Ltd	University of Birmingham	Ongoing	2 years and 4 months
Electrode design for high temperature fuel cells for stationary and industrial applications	Johnson Matthey Fuel Cells Ltd	Technical Fibre Products	Ongoing	2 years and 4 months
Innovative component development for low-cost PEM stack manufacture	Intelligent Energy	Johnson Matthey Fuel Cells Ltd, Primasil Silicones Ltd	Ongoing	3 years and 6 months
Membrane and electrode assemblies for alkaline polymer electrolyte fuel cells	Johnson Matthey PLC	DSTL, University of Reading, University of Surrey	Ongoing	2 years and 5 months

3.3.4 Project highlights

Advanced Automotive and Motive Power Fuel Cell Engines and Component Development (Intelligent Energy)

The Intelligent Energy 50-70 kW  **fuel cell system**

The Peugeot Partner vehicle that a 10 kW fuel cell system  **will incorporate**

This major project, which started in early 2005, involves work with Tier 1 suppliers and vehicle manufacturers in the fuel cell system development process. The aim is to achieve the necessary cost and performance goals that must be overcome before this technology can be released commercially for road vehicles.

Intelligent Energy is developing automotive PEM fuel cell engines with power outputs ranging from 10 kW to 50 kW that will be evaluated and incorporated into on-road and off-road vehicles by PSA Peugeot Citroën.

Prodrive will develop the fuel cell engine management systems tailored for this application and Bosch will supply automotive sensor technology. PSA Peugeot Citroën will play a leading role in setting the development targets and addressing the vehicle integration issues.

Key results

- Intelligent Energy has already designed and constructed two laboratory test versions of 10 kW systems for evaluation by Peugeot and Robert Bosch; both companies have been pleased with performance results.
- Intelligent Energy has improved start up from lower temperatures and has successfully demonstrated start up from -20ºC in less than 2 minutes.
- Intelligent Energy has now designed the third generation of 10 kW system that has been installed in a Peugeot Partner van for track testing in the UK and France. A public demonstration took place on 22 April 2008.

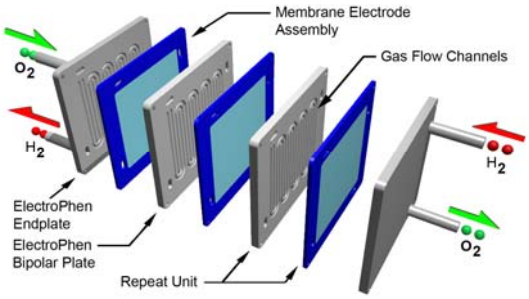
Low-cost Moulded Conductive Polymer Composite Flow Plates for use in Fuel Cells (Bac2 Ltd)

This project aims to establish the feasibility of using novel low-cost, moulded conductive polymer composite flow field plates for use in fuel cells.

Benefiting from a consortium of companies, ranging from raw material suppliers to fuel cell stack manufacturers and academic support, a key success highlighted within the project was

the fuel cell plates made from using Bac2's ElectroPhen™ conductive resin. These delivered and exceeded commercial performance properties without the need for the secondary production steps required when using non-conductive resins. As ElectroPhen is a low-cost material, this combination should lead to the most cost-competitive fuel cell plates for mass production.

Fuel cell schematic with ElectroPhen bipolar and end plates



The project also established flow-modelling techniques, to be used to optimise the design of fuel cell plate flow fields. An optimised design of the end plate for CMR Fuel Cell's Mixed Reactant Flow Through (MRFT) stack contributed to a substantial improvement in volumetric power density over the course of the project.

	Beginning of project	**End of Project**
In-plane conductivity	38 S/cm	573 S/cm
Through-plane conductivity	19 S/cm	60 S/cm
Flexural strength	11 MPa	33 MPa
Compressive strength	41 MPa	91 MPa
Largest batch produced	~1 kg	>1,000 kg
Successfully moulded plate?	No	Yes

Key results

- The partners were able to achieve or exceed the performance development targets for commercial bipolar plates that were proposed at the start of the project.
- Production of the novel ElectroPhen material for bipolar plates was successfully scaled up to batches of over 1,000 kg.
- CMR Fuel Cells successfully modelled, designed and implemented a new design of end plate for its mixed reactant fuel cell, which was then evaluated in a working cell.
- The above design of end plate was then fabricated using the novel ElectroPhen material, contributing to a 33% increase in cell performance.

Integrated Fuel Cell System Prototype Demonstrator for CHP Applications (Ceres Power Ltd)

In this project, Ceres and British Gas are working with a range of UK suppliers, to design, build and evaluate the first prototype solid oxide fuel cell micro-CHP unit for UK residential applications, operating on natural gas.

Key results

- Ceres has successfully designed, produced and commissioned an integrated prototype fuel-cell-based CHP system for residential applications.
- The project has involved a very close collaboration with British Gas involving extensive exchange of information and experience. This has helped to underpin a strong commercial alliance between the two organisations, representing the technology developer and the retail supplier.

3.4 BIOENERGY

3.4.1 Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- Development of cost-effective, advanced, biomass-conversion technologies with high electrical and overall efficiencies for CHP in process and space heating/cooling applications.
- Research to improve the understanding of how biomass fuels, and mixtures of fuels, behave in combustion and other thermal processes used for heat and electricity production, and how their physical and chemical properties impact on the reliability and performance of practical equipment.
- Development of viable, cost-effective, fuel-supply chains – including energy crops and wastes/co-products.
- Development of processing concepts that improve the overall resource use efficiency of biomass feedstocks by the integrated manufacture of renewable fuels, chemicals and energy.
- Development of innovative processes for the production of next-generation transport biofuels.

3.4.2 Project overview

Number of projects initiated	2
Number of projects completed	3
Total number of projects managed	15

The projects initiated and/or managed during the year cover a wide spectrum of areas relevant to the bioenergy area.

The remaining projects on energy-crop development and evaluation have been completed and comprehensive reports published. Work on the development of small-scale CHP technologies has continued with two further projects initiated that are targeted at the growing zero-carbon building sector.

Work continues in the transport sector. One project aims to produce butanol using genetically modified organisms and another addresses the use of diesel engines with biodiesel blends that have widely varying properties.

3.4.3 Project listings

Project title	Lead	Partners	Status	Estimated duration
Technology support for 2nd generation BIGCC plant	Siemens Industrial Turbines	Cambridge University	Ongoing	6 years
Industrial research into multi-fuel biomass boiler plant	Ashwell Engineering Services	Nottinghamshire CC	Completed	2 years
100 kWe biomass-fuelled indirect-fired microturbine	Talbotts Heating Ltd	Staffordshire University, Harper Adams University	Completed	2 years and 9 months
10 kWe biomass indirect-fired CHP system	Talbotts Heating Ltd	Staffordshire University	Ongoing	2 years
Biomass fast pyrolysis for CHP production in a 250 kWe d`ual-fuel diesel engine	Biomass Engineering Ltd	Ormrod Diesels	Ongoing	3 years
Development of a wood gasifier CHP Gas turbine plant of 75 kWe output	Rural Generation Ltd	Queen's University Belfast	Ongoing	4 years
Rapemeal valorisation: improving the economics of biodiesel manufacture	University of Wales, Bangor	North East Biofuels Central Science Laboratory Boots Dow Haltermann Clwyd Compounders Loughborough Innospec Ltd Biofuels Corporation plc D1 Oils Ltd	Ongoing	2 years
Butafuel - advanced biofuels for transportation	Green Biologics Ltd	C-Tech Innovation	Ongoing	3 years
Flex-diesel engines with sustainable biofuels for clean and efficient on and off-road vehicles	Jaguar Cars	University of Birmingham Shell Research Ltd Green Fuels Ltd Johnson Matthey PLC	Ongoing	3 years
Drying in the	Econergy Ltd		Stopped	3 years

woodfuel supply chain				
Yield models for energy coppice of poplar and willow - phase IV	Forestry Research		Completed	8 years
Integrated biomass-fuelled CHP/cooling system	Ashwell Engineering	EPS Ltd G D Strawson Gast Group Ltd University of Nottingham	Ongoing	3 years

3.4.4 Project highlights

100 kWe Biomass-fuelled Indirect-fired Microturbine

This is the third in a series of projects to develop a unique, biomass-CHP concept that is based on the hot air gas turbine cycle.

The objective is to develop a commercial system at a scale of 100 kWe output with an acceptable electrical efficiency. Previous solutions that used traditional steam engines have had a very low electrical efficiency, which has effectively prevented their use.

Key results

- Extended operation of the prototype unit at Harper Adams University has given the main company involved the confidence to start manufacture of the first generation of commercial units.
- An electrical efficiency of 22% was achieved in a CHP installation with a potential overall efficiency of 65%.

Butafuel - Advanced Biofuels for Transportation (Green Biologics Ltd)

Biobutanol is an alternative biofuel for transport. It is an attractive replacement for gasoline and could outpace ethanol, biodiesel and hydrogen. The overall aim is to develop an economic, microbial, fermentation process for butanol.

The work will focus on two aspects of the fermentation:

- Improved butanol yield and titre using specific genetic and physiological manipulation of the microbe.
- Improved butanol productivity and recovery in a novel fermentation system, based on a novel membrane reactor.

Finally, the process will be demonstrated, at laboratory scale, on a variety of industrial feedstocks. The consortium comprises a multi-disciplinary team of technology developers with expertise in molecular biology and fermentation process optimisation. The consortium has financial support and backing from feedstock suppliers and end users of bio-butanol.

Key results

- Process economic model completed.
- Demonstrated scale-up to 1 litre fermentation with a genetically modified strain.
- Constructed a new genetically modified strain.

3.5 MICROGENERATION AND PHOTOVOLTAICS

3.5.1 Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- Research that could lead to large reductions in the cost/watt of crystalline silicon PV modules, such as new techniques for growing or processing crystalline silicon.
- Process development for thin and/or large-area wafer that could lead to a lower cost/kW.
- Research into new types of PV cell that will lead to lower cost/kW and/or improved stability.
- Low-cost, high-performance transparent conducting oxide (TCO) materials for thin-film cell designs:
  - Sensitised-oxide-based and other nanostructure solar cells and modules.
  - Organically sensitised cells and modules.
  - Novel conversion concepts for super-high-efficiency and full-spectrum utilisation.
  - Novel ultra-low-cost approaches.

The Technology Strategy Board also has the wider ambition of tackling the barriers to the development of a whole-system approach to integrating microgeneration (such as heat and electrical sources) in buildings. This means that other technologies, such as microwind and solar thermal, are also included within this broad scope.

3.5.2 Project overview

Number of projects initiated	3
Number of projects completed	1
Total number of projects managed	14

Given the diverse nature of the scope of work, it is not possible to point to any major breakthroughs in the cost/kW of PV, but many projects have yielded modest advances in line with expectations.

The comparatively small number of high-quality proposals for work on core PV cell technology has been a disappointment. It is hoped that more will be received in the future. Given the international nature of the work, it is recognised that UK organisations would benefit from the ability to work with leading European organisations. The Technology Strategy Board call now includes the facility for participation in the PV ERA Net scheme specifically to address this issue, with the initial scope allowing for a wide range of work in polymer PV development.

The first PV ERA Net call (for proposals on Polymer PVs) led to three project proposals that included UK organisations. Two of these were subsequently approved by the Polymol assessment committee (a Technology Strategy Board/EPSRC assessor was part of the committee). Successful applicants have been informed, and then each member of the consortia will make efforts to gain funding from their own national funding bodies. Given the "blue skies" nature of the work, EPSRC is being kept informed of developments as it is thought the projects might be better suited to its funding programmes rather than those of the Technology Strategy Board)

No projects for microwind or the integration of microgeneration in buildings have been approved. It was felt that the projects did not sufficiently address the problems of reliability and energy capture to which small wind turbines are prone. Current Government-funded projects to research the performance of these products should provide a better steer to industry as to those aspects of design requiring further attention and, hence, assist in defining future areas of work.

3.5.3 Project listings

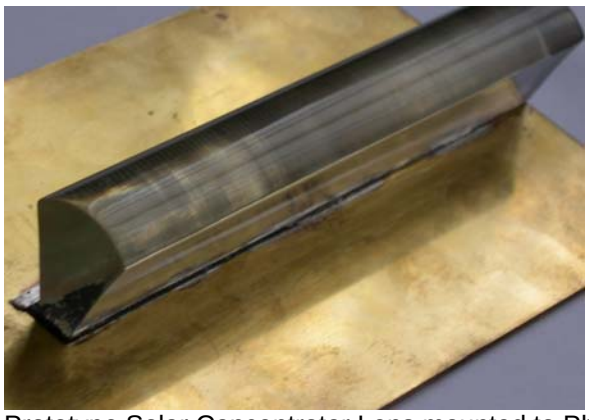
Project title	Lead	Partners	Status	Estimated duration
Power on plastic	Kodak Ltd		Ongoing	2 years
High added value modules for BIPV	NaREC	Romax, Crystalox	Ongoing	3 years
Polymer photovoltaics	Merck Chemicals Ltd	Imperial College, DuPont Teijin Films UK Ltd, BP Solar Ltd	Ongoing	3 years
Low cost 100x PV concentrator	Whitfield solar ltd		Ongoing	3 years
Low cost 100x PV concentrator	NaREC		Ongoing	3 years
Low cost 100x PV concentrator	University of Warwick		Ongoing	2 years
The development of advanced low cost indium phosphide based photovoltaic devices	The Centre for Integrated Photonics	Oxford University, Wafer Technology	Ongoing	3 years
High efficiency solar panels based on multilayer graded-bandgap CIGS	Ionotec Ltd	Pilkington Glass, Sheffield Hallam University	Ongoing	3 years
Sputtered semi-conducting silicon for large area flexible solar cells	PlasmaQuest Ltd	University of Southampton, Romag	Ongoing	3 years
Feasibility study PV coatings on steel, based on dye-sensitised titania	Corus R&D	Corus Colours, Beckers Coatings	Ongoing	1 year
Solar concentrate:	Optical products Ltd	Optical Antenna Solutions,	Ongoing	1 year

affordable building-integrated photovoltaic solar concentrator systems		Polyplas Extrusions Ltd, Persimmon Homes, Pera Innovation		
Novel inline deposition system for high performance CIGS solar cells	Scientific Vacuum Systems Ltd	University of Loughbrough	Ongoing	3 years
Hot Ridge: low-cost, roof-mounted solar-thermal panels for domestic water heating	RBR Associates Ltd	Pera Innovation Ltd, National Energy Foundation, VICIM Ltd, Murfitts Industries Ltd, Persimmon Homes	Ongoing	2 years
High efficiency silicon solar cells with PECVD dielectric rear surface passivation - HIGHPOINT	Narec	Heriot-Watt University	Ongoing	3 years
Epitaxial silicon solar cells by new generation deposition equipment - EPISODE	Narec	Echerkon	Offered	2 years

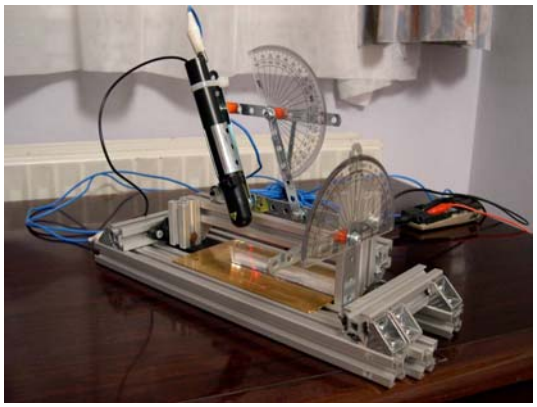
3.5.4 Project highlights

Solar Concentrate: Affordable, Building-integrated Photovoltaic Solar Concentrator Systems (Optical Products Ltd)

This project aims to develop solar concentrators and low-cost manufacturing technologies, to produce building-integrated PV microgeneration units: a wall-mounted unit and a double-glazing system that will absorb direct sunlight to generate electricity while allowing low-level ambient light through.



Prototype Solar Concentrator Lens mounted to Photovoltaic Cell.



Prototype Solar Concentrator Lens undergoing laser ray path evaluation.

(Courtesy of Pera)

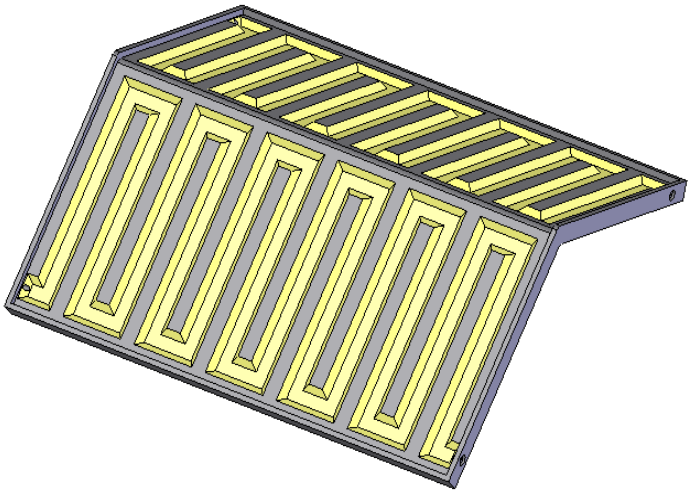
Various materials and manufacturing techniques have been trialled to identify the best method for making low-cost lenses that successfully collect direct sunlight over a wide range of incident angles. The close involvement of Persimmon homes is ensuring that the final product will comply with Building Regulations and the needs of housing developers.

Key results

- Various materials and manufacturing techniques have been trialled to identify the best method for making low cost lenses that successfully collect direct sunlight over a wide range of incident angles.
- The close involvement of Persimmon Homes is ensuring that the final product will comply with Building Regulations and the needs of housing developers.

Hot Ridge: Low-cost, Roof-mounted Solar Thermal Panels for Domestic Water Heating (RBR Associates Ltd)

This project aims to develop an innovative, ridge-mounted solar thermal collector panel to be manufactured using state-of-the-art polymer manufacturing processes that will enable the panels to be manufactured at a significantly lower cost compared to other available systems.



(Courtesy of GAH (Heating Products))

Key results

- Work to date has focused on identifying the optimum design of channels, and the detailed manufacturing considerations for the panels.
- Following extensive research work a prototype panel has been created and tests are currently in progress.

3.6 WAVE ENERGY AND TIDAL STREAM

3.6.1 Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- The development and evaluation of generic technologies, such as installation techniques, operation and maintenance techniques, and mooring or fixing techniques that are likely to contribute to cost reductions or performance enhancements of marine energy facilities.
- The reduction of cost and enhancement of the power capture of existing device concepts. This can be by the use of new materials, control systems or power-take-off mechanisms. 'Existing device concepts' means those that have already had a full scale, or near-full scale, prototype deployment at sea where the costs and performance are already established.
- R&D projects to conduct full scale, or near full scale, prototype deployment at sea of device concepts that have completed a programme of tank testing and detailed techno-economic modelling.
- R&D projects to conduct detailed laboratory-scale tank testing and detailed techno-economic modelling on device concepts that have had an initial desk-based evaluation study and that are sufficiently promising to indicate that the device concept may have long-term commercial prospects.

3.6.2 Project overview

Number of projects initiated	6
Number of projects completed	2
Total number of projects managed	21

The 21 projects were managed during the year including six new projects. Most of the R&D focused on the development of different tidal-stream concepts. Most of these are at an early developmental stage although at least one commercial prototype has recently been installed. Two other experimental devices are scheduled for deployment during 2008. In each case, the performance of the device will be monitored to determine energy conversion efficiency. One of the significant challenges facing device developers is the cost and availability of large jack-up barges to install devices. Alternative design concepts that do not rely on large monopile foundations are being developed to reduce installation costs. Some work is also continuing on the development of energy models that can be used to improve the predictability of energy capture from tidal streams.

The programme has supported three different wave energy devices. One of these has been under test in the open sea. There has also been further support to evaluate the potential for cost reduction by optimising the design and the use of different materials. Another near-shore device is scheduled for deployment during 2009. This device will use wave power to pump pressurised water to a conventional, shore-based, hydropower turbine. The third device is a floating oscillating water column that uses a novel pneumatic turbine. The key objective of wave energy and tidal stream R&D is to demonstrate the energy conversion efficiency and reliability of different devices.

3.6.3 Project listings

Project title	Lead	Partners	Status	Estimated duration
Tidal stream technology development	Lunar Energy Ltd	Cornelius Parish Ltd, Rotech Engineering Ltd, Webster Young Ltd	Ongoing	4 years and 9 months
RTT tidal Stream technology development	Lunar Energy Ltd	Cornelius Parish Ltd, Rotech Engineering Ltd, Webster Young Ltd	Ongoing	2 years and 9 months
SeaGen project-construction and operation	Sea Generation Ltd	SeaGen Ltd, Marine Current Turbines Ltd, SeaCore	Ongoing	3 years
Novel moored tidal stream generating equipment	Soil Machine Dynamics Ltd	SMD, Tidel, Tompkins	Ongoing	2 years and 9 months
Project Neptune phase 2 - experimental development	SSE Generation Ltd	Aquamarine Power Ltd (APL)	Offered	1 year and 9 months
Development, test and demonstration of high-efficiency, shallow-flow tidal device	IT Power Ltd	Pulse Generation Ltd, CIC OMEC Ltd, Econnect Ltd, BMT Renewables Ltd, IT Power	Ongoing	2 years
Performance characteristics and optimisation of marine current energy converter arrays	Garrad Hassan & Partners Ltd	University of Southampton	Ongoing	3 years
Evaluation of the cormarent tidal stream energy device to Include concept validation, economic modelling and design optimisation	Cormarent Ltd	BMT Cordah Ltd, Gurit (UK) Ltd, University of Plymouth	Ongoing	1 year and 7 months
Emerging energy technologies: hydraulic power trains for tidal turbines	Marine Current Turbines Ltd	BHR Group Ltd	Ongoing	11 months

DEEP-Gen: deep-water economic energy prototype generator - stage 1 only	Tidal Generation Ltd	SLP Engineering Ltd, Garrad Hassan Ltd and Partners, Atremis Intelligent Power Ltd	Complete	1 year and 6 months
DEEP-Gen II - completion of techno-economic validation	Tidal Generation Ltd	SLP Engineering Ltd, Garrad Hassan Ltd and Partners, Atremis Intelligent Power Ltd	Ongoing	10 months
DEEP-Gen III - prototype tidal turbine	Tidal Generation Ltd	SLP Engineering Ltd, Garrad Hassan and Partners Ltd, Atremis Intelligent Power Ltd	Ongoing	2 years and 6 months
Tidal stream technology project - stage 1 only	Swanturbines Ltd	Swanturbines Ltd, NaREC Development Services Ltd	Ongoing	1 year and 6 months
Deep-water tidal stream development project	Rolls Royce plc	Haywood Tyler Ltd, Garrad Hassan Ltd and Partners, White Ramboll Whitbybird, Corus UK Ltd	Ongoing	1 year and 4 months
Physical assessment of performance test protocol & completion of SeaGen installation	Sea Generation Ltd	MCT Ltd, Queen's University of Belfast	Ongoing	9 months
Initial research phase of momentum reversal lift turbine for tidal stream energy	IT Power Ltd	Aquascientific Ltd, University of Exeter	Ongoing	1 year
Oyster wave surge converter	Aquamarine Power Ltd	Queen's University Belfast	Ongoing	2 years and 6 months
Pelamis full-scale demonstration	Pelamis Wave Power Ltd	None (legacy project)	Ongoing	6 years

pelamis WEC cost reduction & performance enhancement programme	Pelamis Wave Power Ltd	None (legacy project)	Ongoing	3 years
Air turbine development	Peter Brotherhood Ltd	Cranfield University	Closed	1 year and 9 months
Full scale design of the MRC wave energy device and electrical generation module	Peter Brotherhood Ltd	Cranfield University, Converteam, ORECon	Ongoing	11 months

3.6.4 Project highlights

SeaGen Project - Construction and Operation (Sea Generation Ltd)

This project aimed to design, assemble and install a full-scale grid connected Seagen tidal stream turbine generator rated at over 1 MW. Seagen consists of a pair of turbine/generators that are fixed together by a cross beam and secured to the seabed using a surface-breaking monopole construction technology. The principal objective of this project is to develop and evaluate installation, maintenance and decommissioning techniques. Data from these techniques, and the performance of the device, will be used to determine the economic viability of the device. Simultaneous environmental monitoring will also be carried out.

Key results

- Successful design, fabrication and delivery of the quadropod foundation have been achieved. This will enable the device to be secured to the sea floor by four pins, thereby avoiding the use of a large monopole.
- Successful installation of the device at a test site in the narrows between Strangford Lough and the Irish Sea. After commissioning, the prototype should begin generating power in July 2008. The installation had to be installed within a very tight time window because of environmental constraints.

DEEP-Gen: Deep-water Economic Energy Prototype Generator - Stage 1 Only (Tidal Generation Ltd)

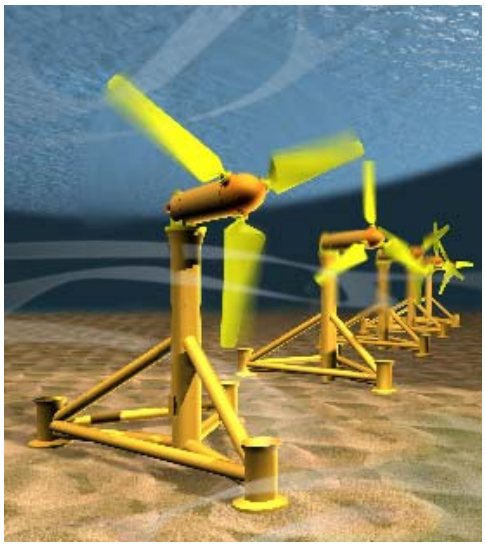
This project was the first phase to develop a turbine concept developed by Tidal Generation Ltd. The main innovative features of the concept are a light, quickly installed tripod foundation, and the deployment and retrieval of a floating nacelle onto, or from, the foundation using a single-line winch. The project work began in October 2006, and included concept and feasibility desk studies, as well as full-scale testing of the winching system.

The project, referred to as DEEP-Gen I, is the first stage of a three-part programme to design, test and install a 500 kW prototype tidal turbine. A subsequent project (DEEP-Gen II), which began in July 2007 and will be concluded early in 2008, is conducting full-scale trials of the foundation installation technique for the turbine, as well as producing detailed designs for the prototype. A third project (DEEP-Gen III) will see the prototype manufactured, installed and commissioned in 2008.

Key results

- The attachment and detachment of a dummy nacelle attached to a test rig has been successfully demonstrated in a tidal estuary.
- The project partners developed a good theoretical understanding of the way the real machine would operate.
- Project has prepared the way for a more detailed design phase (DEEP-Gen II) and the specifications for a novel drilling technique to secure the foundations to the sea floor.

DEEP Gen tidal stream turbine (Courtesy Tidal Generation Ltd)



Air Turbine Development (Peter Brotherhood Ltd now Dresser Rand)

The objective of this project was to test a new design of air turbine driven by an oscillating water column (OWC) capable of performing bi-directionally. OWC technology has been under development for several years and was originally pioneered in the UK. This new variable radius turbine (VRT) was tested under a range of conditions designed to match pressures that would be comparable with a full-scale model. The test facilities were capable of providing continuously variable wave conditions. The performance of the test rig was assessed against the computational fluid dynamics (CFD) predicted model values for the baseline turbine and the improved (VRT) All of these tests were carried out at Cranfield University by the staff allocated to the HydroAir project.

Key results

- The project demonstrated, under test conditions, that an improved performance for the turbine could be achieved. The performance of the VRT has already highlighted the wider range of operation in comparison with the Wells design and, therefore, provided a more efficient system of power capture.
- The discrepancy between experimental results and the predicted results from a CFD model was less than 2%.

3.7 OFFSHORE WIND

3.7.1 Priority R&D areas

The following R&D areas were identified for priority support in 2007/08:

- Proposals that seek to reduce the high costs of transporting and installing wind turbines in the sea, including innovative solutions to reduce the cost of expensive marine foundations.
- Proposals to reduce costs through enhancing reliability or making maintenance of offshore turbines easier, including remote control and monitoring solutions aimed at reducing operation and maintenance costs.
- Proposals that seek to reduce costs through design and materials that will lead to improvements in weight saving, speed of installation, performance and reliability.
- Proposals that seek to mitigate the interaction of wind turbines and radar (including air traffic control mitigation solutions) as this remains a key barrier to onshore and offshore development.

3.7.2 Project overview

Number of projects initiated	3
Number of projects completed	4
Total number of projects managed	14

The 14 projects managed during the year covered the key areas of focus for R&D, including approaches to cost reduction for support structures, mitigating the impact of turbines on radar and cost reduction of key offshore turbine components.

3.7.3 Project listings

Project title	**Lead**	**Status**	**Estimated duration**
Deepwater offshore wind farm demonstrator project	Talisman Energy UK Ltd	Ongoing	4 years and 7 months
Finite element modelling of offshore wind turbine support structures	Garrad Hassan & Partners Ltd	Completed	3 years
Offshore wind field sensor using lidar anemometer	QinetiQ	Completed	3 years and 1 month
Cost reduction and life extension of offshore wind farms (CORLEX)	Corus UK Ltd	Completed	2 years and 5 months
Stealth technology for wind turbines (STWT)	BAE Systems (Operations) Ltd	Completed	2 years and 1 month
Stealthy wind turbines - addressing the radar issue	QinetiQ Ltd	Ongoing	2 years and 6 months
Innovative high-power, direct-drive, superconducting generator for offshore wind	Converteam Ltd	Ongoing	3 years and 6 months
Competitive concrete towers and foundations for future offshore wind farms	Gifford and Partners Ltd	Ongoing	1 year and 6 months
A low-cost, safety-critical, radar-absorbing material for wind turbine nacelles and towers	Hitek Electronic Materials Ltd	Ongoing	2 years and 2 months
Affordable innovative rapid production of offshore wind energy rotor blades	Insenys Ltd	Ongoing	3 years and 8 months
Development of an innovative radar-absorbing composite structure for wind turbine blades	Hitek Electronic Materials Ltd	Ongoing	1 year and 10 months
Cost-effective manufacture of offshore wind turbine foundations - ManOS	TWI Ltd	Starting	2 years

In-situ wireless monitoring of offshore wind towers and blades	TWI Ltd	Starting	2 years
Prototype re-useable offshore meteorological mast using suction caisson foundation	SLP Engineering Ltd	Starting	2 years

3.7.4 Project highlights

Cost Reduction and Life Extension of Offshore Wind Farms (CORLEX) (Corus UK Ltd)

A 30% reduction in costs is thought necessary for offshore wind to be economically viable. This project, which involved five organisations, investigated various aspects of offshore wind farm design, operation and maintenance. An area where savings could be made is to reduce the costs of the support structure (tower and foundation) by:

- Cheaper and/or faster fabrication of towers and foundations (utilising electron beam welding (EBW) or any other promising method, such as narrow gap metal inert gas (NGMIG) welding, narrow gap or multi-wire gas metal arc welding (GMAW)).
- Extended structural lives through improved designs and fabrication methods.
- Light-weighting of turbines and supporting structures.

Key results

- The project met the overall objective of developing and demonstrating ways of reducing the installation and running costs of offshore wind farms. The major achievements were the design and production of a cast node system for foundations and the demonstration that the use of EBW using partial and local vacuum systems can be used to reduce fabrication costs.

- Risk-based inspection was shown to be a viable technique for minimising maintenance costs, primarily for the operating systems. The risk of a tower failure was shown to be very low and hence the cost of installing extensive strain measurements on the tower can only be justified if they are also used as an input to the turbine control methodology.

Cast steel ring node 5.5 m diameter

Stealth Technology for Wind Turbines (STWT) (BAE Systems (Operations) Ltd)

Current-generation wind turbines have very large radar signatures and the difficulty of siting wind farms offshore (and onshore) to minimise the interference with civil air traffic control, military defence and other radars (including weather monitoring and marine navigation aids) is well known. The refusal of planning applications on these grounds is a major factor in preventing the large-scale implementation of wind technology as a significant contributor to renewable energy in the UK.

The main objectives of the STWT project were:

- To identify the major radar cross section (RCS) sources within a wind turbine that cause it to interfere with radar systems and to identify where the application of radar absorbing material (RAM) treatments and/or component shaping would be of benefit.
- To develop RCS treatments for the tower, nacelle and blades through a combination of turbine modelling, shaping and absorbing or reflecting materials design.
- To demonstrate the practical implementation of commercially viable RCS reduction techniques through the manufacture and characterisation of representative turbine component sections.

Key results

- The project addressed the first two objectives very successfully. The consortium partners now have a better understanding of the major scatterers within a wind turbine, and the project has delivered a number of material and shaping schemes that will reduce the turbine's RCS.

- In addition, the programme has identified and, where necessary, developed low-risk treatments for the turbine tower and nacelle components. A low RCS blade component was partially developed. However, it was not possible to complete this activity within the current programme due to the construction of the blade, especially in areas with lightning mesh, and increased weight constraints due to blade design change during the course of the project. Therefore, further work is required in future to complete the development of a low RCS blade component.

Stealthy Blade Demonstrator Section after Trimming

4 Contact Details

For further information about the Technology Strategy Board see www.innovateuk.org. Summaries of some projects in other areas can be viewed at www.technologyprogramme.org.uk using the ‘Current Projects’ link.