Technology Strategy Board
Driving Innovation

# Energy Generation and Supply

## Key Application Area

2008-2011

The vision of the Technology Strategy Board is for the UK to be a global leader in innovation and a magnet for **innovative** businesses, where technology is applied rapidly, effectively and sustainably to create wealth and enhance quality of life.

Our three-year strategy for 2008-2011 is to drive innovation by **connecting** and **catalysing**. To achieve this we are focusing on three themes: challenge-led innovation, technology-inspired innovation and the innovation climate. For more information on the overall strategy see **www.innovateuk.org.**

We have identified a number of key application areas and key technology areas on which to focus, and for which we are developing specific area strategies.

This document presents the strategy for the key application area of **Energy Generation and Supply**.

# Foreword

The Technology Strategy Board is a new organisation with a new vision and ambition to make the UK a global leader in innovation. Our job is to ensure that the UK is at the forefront of innovation enabled by technology.

Our task at the Technology Strategy Board is to "Connect and Catalyse". As part of our challenge-led approach to innovation we treat societal and economic challenges of the future not just as threats but as opportunities for innovative solutions that enhance the quality of life and increase wealth.

In this context the secure, clean and affordable generation and supply of energy are fundamental for achieving economic, societal, political and environmental benefits for the UK. They also offer significant opportunities for innovative UK businesses both in the domestic and global marketplaces. Challenges in energy generation, supply and use have a crucial place in our strategic plans. Our Key Application Area of Energy Generation and Supply will focus on investing in innovative technologies for energy provision. In addition, energy and efficiency will be addressed by other relevant Application Areas and Innovation Platforms. Our Key Technology Areas such as Advanced Materials and Bioscience will provide underpinning support in these areas.

We fully recognise the magnitude of the challenge and the need to work with other stakeholders to support an effective energy innovation chain. We have started engaging at all levels including BERR, the RDAs and Research Councils and are working closely in partnership with the Energy Technologies Institute and the Carbon Trust to ensure our programmes are complementary to each other.

This Energy Generation and Supply strategy will provide the foundations for our work in this area in the 2008-2011 period. We are looking forward to working in partnership with the key players in energy innovation and contributing to wealth creation in the UK.

**Iain Gray**
**Chief Executive, Technology Strategy Board**

# Executive summary

## Energy Generation and Supply Key Application Area

Climate change and security of supply challenges have placed energy high on both national and international agendas, making it the subject of regular policy and legislative review within Government. The Stern Review on the Economics of Climate Change not only addressed the need for an urgent response to climate change, it also illustrated in detail the importance of Government policy in driving innovation in low carbon energy technologies. The 2007 Energy White Paper has defined the short, medium and long term challenges both on a national and global scale. UK Government and EU have developed and are still developing a range of policies and incentives to tackle these challenges, such as the UK renewables obligation, the renewable transport fuel obligation, the code for sustainable homes, and the EU renewable directives.

The policy drivers around the energy challenges are creating market opportunities to deliver innovative solutions where the UK is well placed to take advantage. A significant number of UK businesses are world leading and have a presence along the entire energy supply chain, from exploration, resource extraction and processing, to power generation (with fossil, renewable and nuclear fuel), transmission, distribution and energy service provision. In addition, supporting industries such as materials, electronics, and engineering services in the UK will benefit. To complement this business capacity, the UK has substantial academic expertise, providing the essential scientific platform for innovation.

## Our role and scope

The Technology Strategy Board aims to stimulate innovation throughout the energy supply chain, through a number of its investment mechanisms:

- Key Application Areas –
  - 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 that address technologies that underpin the energy sector, such as Advanced Materials, High Value Manufacturing and Electronics, Photonics and Electrical Systems.

The Key Application Area of Energy Generation and Supply covers oil and gas extraction, energy generation through fossil and low carbon sources, and distributed and centralised energy supply. Our aim is to promote wealth creation in the UK through investment in innovation in energy generation and supply which will also:

- Provide enhanced security of supply through maximising the recovery of UK natural fuel resources and the development of a portfolio of low-carbon energy technologies.
- Reduce environmental impact of energy technologies through the development of low carbon technologies.

The UK will need to address its energy challenges by the deployment of a portfolio of technologies, as there is no single one that will enable the achievement of UK energy policy targets. Each technology will have different needs; some are unproven at a commercial scale and involve large scale investments and infrastructures, whilst others, although proven, are not yet cost competitive with traditional technologies and/or lack a well established supply chain. These technologies potentially have substantial opportunities in markets such as electricity and heat generation and supply, transport, portable power and power plant manufacturing, with policies and regulations being key drivers for the uptake of these technologies.

### The Technology Strategy Board in the UK energy innovation chain

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 ETI, Carbon Trust, ETF, BERR, the Research Councils, regional development agencies and devolved administrations. Continuous dialogue allows the players to develop complementary programme of activities, and avoid both duplication and technology gaps.

#### The low carbon innovation coordination group

*The Carbon Trust, ETI and Technology Strategy Board Chief Executive meet regularly to identify and exploit opportunities for synergy, avoid duplication of activities and to incorporate an awareness of each others' plans into decision-making, in order to achieve a coherent position and communicate it externally.*

Within the Energy Generation and Supply Key Application Area, we have considered technologies with substantial R&D challenges, their potential to make an impact for the UK and their prioritisation and level of public funding through other agencies. Many of these are technologies which have also been identified in the Energy White Paper as potential contributors to the achievement of the UK policy goals, they include: offshore wind, marine, bioenergy, carbon abatement technologies for fossil power plants, hydrogen and fuel cells, microgeneration, intelligent grid, nuclear and technologies for the maximisation of oil and gas indigenous resources.

## Our priorities

Taking into account the current energy innovation landscape, we have prioritised areas against the Technology Strategy Board strategic criteria, and identified the need for investment in technologies for energy generation and supply and investment in knowledge flow during the period 2008-2011. Working closely with ETI, BERR, RDAs, DAs and research councils we will:

- Directly invest in R&D for carbon abatement technologies for fossil power plants, fuel cells, hydrogen and technologies for the maximisation of recovery of oil and gas indigenous resources.
- Invest through, or jointly with, other organisations in offshore wind and marine, ensuring appropriate engagement of UK business.
- Work in collaboration with other key application areas, key technology areas and Innovation Platforms to identify, invest and deliver additionality into the energy generation and supply innovation chain (for example in biofuels, microgeneration and through underpinning technologies).
- Carry out further analysis in areas where the added value of Technology Strategy Board investment is currently unclear (bioenergy, intelligent grid management and nuclear).
- Encourage flow of people and ideas to stimulate more innovative approaches to energy technologies by:
  - Leveraging on centres of expertise in energy technologies supported by the research councils in order to provide businesses with access to the expertise.
  - Invest in projects undertaken by academics to solve specific business problems, encouraging Knowledge Transfer Partnerships in the defined priority areas.
  - Explore possibilities of international and business to business or business to science Knowledge Transfer Partnerships, to stimulate flow of knowledge and people between UK leading players and international leaders in the defined priority areas.
- Building on existing structures, we will focus on the support of enhanced co-ordination of knowledge transfer activities specifically to achieve the Technology Strategy Board objectives of driving knowledge exchange in the business communities and informing government of key technology needs to help shape our future programme.

### The Technology Strategy Board has a distinctive role in the UK energy innovation chain:

- Focuses on wealth creation for UK business through technology innovation.
- Has an established reputation with business.
- Delivers innovative technology and encourages increased private sector R&D investments, through complementary and flexible mechanisms which are inclusive of micro-companies, SMEs, Universities and large businesses. Current mechanisms include:
  - Collaborative Research and Development (by Key Application or Key Technology Areas (KAA and KTA).
  - Innovation Platforms.
  - Knowledge Transfer Networks.
  - Knowledge Transfer Partnerships.
- Has a clear commitment from Research Councils and Regional Development Agencies to align a proportion of their resources with the national Technology Strategy.
- Works with the relevant Government Departments and other funding agencies to drive innovation and enable UK companies to exploit the opportunities by helping define the market opportunity and invests in innovation within it.
- Provides 40% of public sector funding (up to £20M pa) to the Energy Technologies Institute, of which it is also a board member.

Technology Strategy Board funding in this area primarily targets business-led innovation from applied R&D to early stage, pre-commercial demonstration.

# Contents

# 1. Scope

The secure, clean and affordable generation and supply of energy are fundamental for achieving economic, societal, political and environmental benefits for the UK. They also offer significant opportunities for UK businesses both in the domestic and global marketplace. For these reasons, energy has an extremely high profile, remains high on the political agenda and is the subject of regular policy and legislative review within Government.

This document identifies and prioritises where Technology Strategy Board investment is required for technologies, people and networks in the Energy Generation and Supply key technology area to achieve its aims and objectives.

The following methodology has been adopted:

- Consideration of the current energy innovation landscape, Technology Strategy Board portfolio and policy drivers (section 2).
- Illustration of the extent of market opportunities (sections 3 and 4)
- Description of those technologies that are included in the Technology Strategy Board current portfolio and identified in the Energy White Paper [1] as market failures for which intervention is necessary (section 5).
- Prioritisation against Technology Strategy Board criteria for investment (sections 5 and 6)
  - Does the UK have the capability?
  - Is there a large market opportunity?
  - Is the idea ready? (timeliness and impact)
  - Can the Technology Strategy Board make a difference? (added value)

The criteria for investment are illustrated is sections 5 and 6 in the following style:

| Fit against criteria for investment | |
|---|---|
| UK Capability | high/medium/ low? |
| Market opportunities | high/medium/ low? |
| Timeliness & Impact | high/medium/ low? |
| Added value | high/medium/ low? |

The energy supply chain covers many areas from extraction of natural resources (e.g. oil and gas) through to the use of energy in our day to day lives, both at home and in the workplace. A schematic of the major elements of the supply chain is shown in Figure 1.

This strategy document concentrates on the role of the Technology Strategy Board in the development of innovative technologies which meet the its criteria for investment and will:

(a) promote wealth creation for UK business in the UK and globally through the support of innovation,

(b) provide enhanced security of supply through maximising the recovery of UK natural fuel resources and the development of a portfolio of low-carbon energy technologies, and

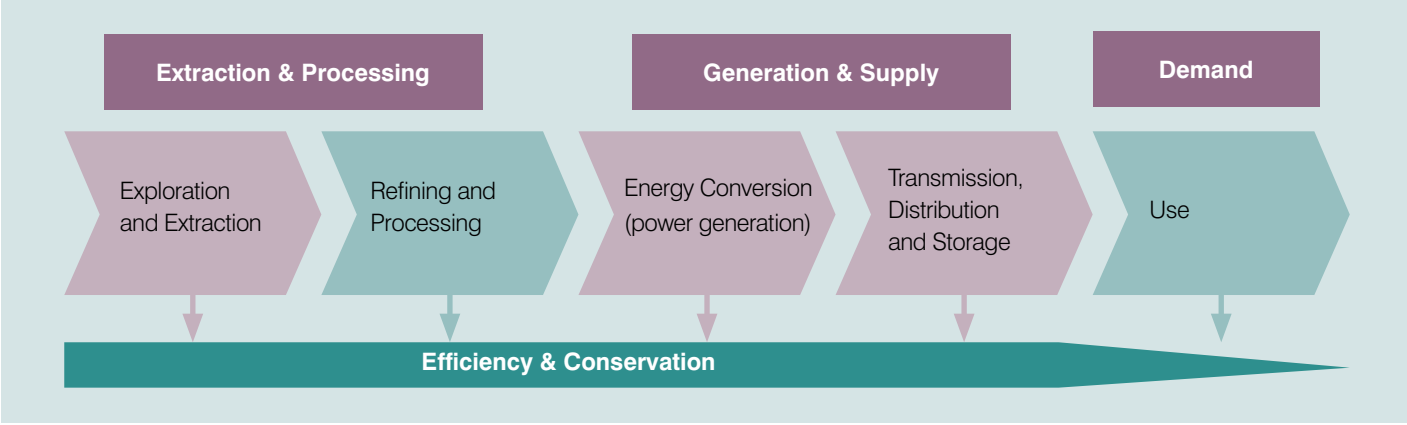
(c) reduce environmental impact of energy generation and supply technologies.

The scope of this document therefore includes the following technologies:

- Fuel extraction (oil and gas )
- Energy Generation and Supply
  - Renewables
  - Carbon abatement
  - Bioenergy
  - Hydrogen and fuel cells
  - Microgeneration
  - Intelligent grid management
  - Nuclear

It also covers the need for investment in knowledge transfer activities through people and networks.

**Figure 1: Energy supply chain (focus of strategy shown in purple arrows)**



# 2. Background and context

## 2.1. Challenges and drivers

The 2007 Energy White Paper [1] clearly defines the challenges relating to energy both on a national and global scale. These are:

- tackling climate change by reducing carbon dioxide emissions both within the UK and globally and
- ensuring secure, clean and affordable energy as we become increasingly dependent on imported fuel.

**Climate change** is now widely acknowledged and the evidence of its impact continues to mount, as does the need for immediate action to mitigate it. The Stern review [2] underlined the importance of acting now, both nationally and in partnership with other countries, to minimise both the environmental impact and cost. The report highlights innovation and technology developments as crucial in tackling climate change and the need for Government intervention to deliver such technologies in the short to medium term with an outlook to the long term.

**Security of supply** is of concern as the UK's natural reserves of oil and gas decline. While significant amounts still remain in the North Sea, production has peaked and is now falling. It is also recognised that as the economy grows, the UK will become increasingly dependent on imports. The UK must therefore optimise recovery of its existing oil and gas reserves and develop a portfolio of energy generation technologies which include renewables, fossil and nuclear, to deliver clean, secure and affordable energy.

The UK sets out to address these issues through its four energy policy goals:

- putting the UK on a path to cut the carbon dioxide emissions by some 60% by about 2050, with real progress by 2020;
- to maintain the reliability of energy supplies;
- to promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve productivity;
- to ensure that every home is adequately and affordably heated.

The recognised need for action in tackling climate change and addressing security of supply will provide significant opportunities and open up new markets for UK businesses both nationally and globally.

## 2.2. Current status

It is recognised that no single technology will enable the UK to meet its $CO_2$ reduction and security of supply targets. A 'portfolio approach' must therefore be adopted, which supports a number of low carbon energy technologies from the adoption of renewables to new nuclear power plant, addresses efficiency issues and cuts across industrial sectors (e.g. transport, housing). Figure 2 schematically illustrates how the introduction of such technologies could work to help achieve the target of 60% $CO_2$ reduction by 2050.

Historically, the DTI Emerging Energy Technologies Unit has invested in an approach to deliver a competitive, secure and reliable electricity market through a portfolio of low carbon technologies in energy generation and supply with a £20m pa ring-fenced budget since April 2004. Technologies which have been included in the portfolio are offshore wind, wave and tidal, intelligent grid management, microgeneration, carbon abatement, bio-energy and hydrogen and fuel cells.

To address the optimisation of recovery of our natural resources and hence enhance security of energy supply, oil and gas technologies have been supported through an investment of around £5m pa, managed separately from the low carbon energy technologies portfolio by the Technology Strategy Board (Figure 3).

**Figure 2: Schematic diagram illustrating how the adoption of a 'portfolio' approach to low carbon energy technologies can address the challenge of $CO_2$ reduction [3]. This representation assumes equal contribution from each technology.**

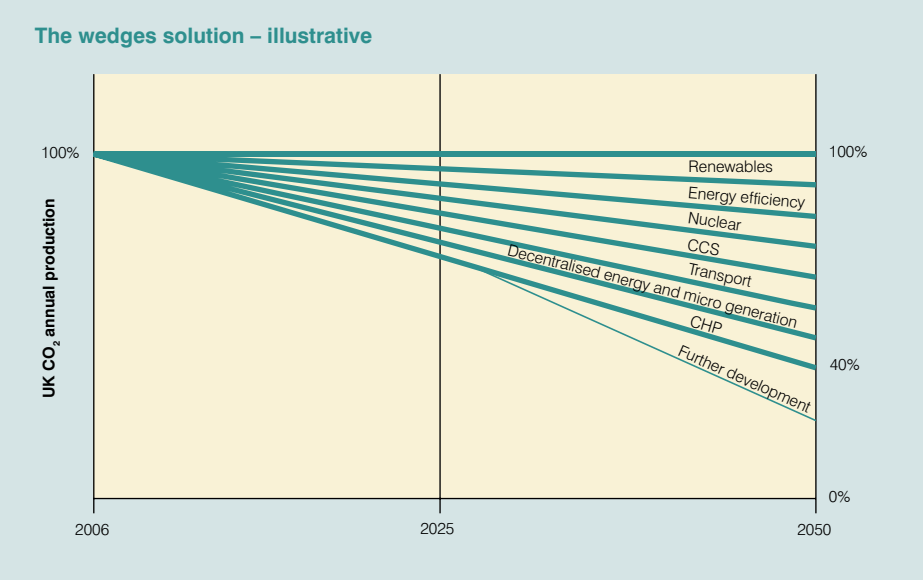
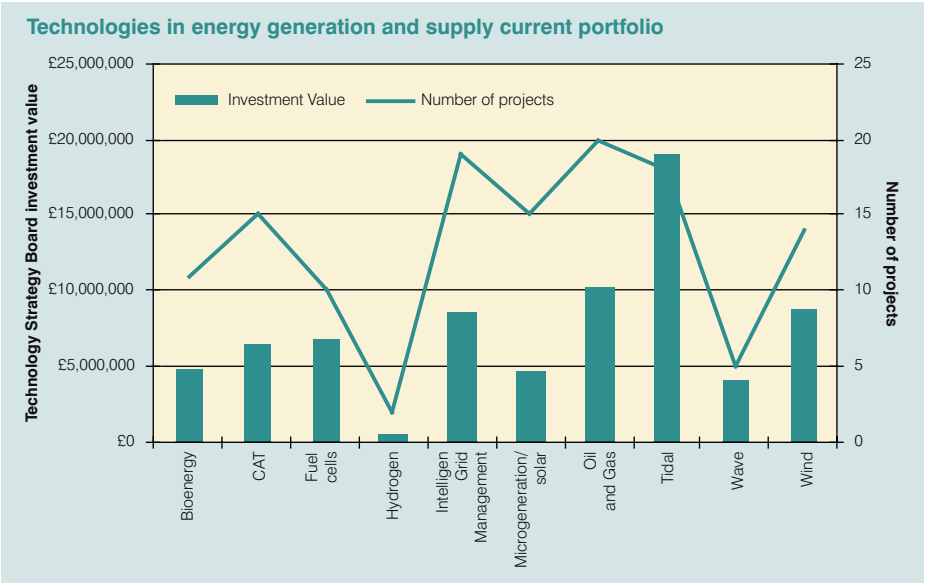


**Table 1: Coverage of energy related technologies by the Technology Strategy Board's KTA and KAA and Innovation Platforms.**

| Energy Strands | | | |
|---|---|---|---|
| **KTAs/KAAs and Innovation Platforms** | **Energy generation and supply** | **Efficiency/conservation** | **Energy and transport** |
| **Advanced Materials** | Materials for generation and supply (boilers, turbines, pipelines, pressure vessels, composite wind turbine blades, HT materials, photovoltaics (PV), superconductors, fuel cell and battery, nanostructured carbons, membranes/filters) | Self-repair and smart materials, power harvesting, insulation, packaging, lightweight materials. | Biofuels, anti-corrosion biofilms, lightweight materials |
| **Biosciences** | Biomass (next generation crops) | | Novel biofuels |
| **Medicines & Healthcare** | | Energy storage and power sources for healthcare (e.g. pacemakers, emergency services etc) | |
| **High Value Manufacturing** | Components manufacturing (turbines, PV, fuel cells etc) | Novel energy efficient industrial processes | New service delivery models through supplier-owned goods (c.f. aeroengines) |
| **Electronics, Photonics & Electrical Systems** | Sensors, power systems, components and systems for transmission and distribution, PV, control, on line/remote condition monitoring and predictive maintenance | Energy efficient lighting and displays, energy efficient power systems, control, etc. | Signage, street lighting |
| **ICT** | Control systems, integration of new generating capacity in grid, on line condition monitoring and predictive maintenance | Grid optimisation and control | Logistics optimisation, control systems, informatics, smart metering |
| **Environmental Sustainability** | Efficient use of resources, energy from waste | Energy efficiency | Efficient use of resources, sustainable fuel supplies |
| **Creative Industries** | Visualisation tools | Visualisation tools, design | Visualisation tools |
| **Transport - including aerospace and automotive** | Biofuels, hydrogen and fuel cells | Fuel efficiency | Engines and automotive design for integration with biofuels, fuel cells and hydrogen technologies |
| **Intelligent Transport Systems** | Fuelling grids (H2, electric) | | Energy efficiency |
| **Low Carbon Vehicle** | Batteries and hybrids, fuel cells | Fuel efficiency | Integration with biofuels, fuel cells and hydrogen |
| **Low Impact Buildings** | Microgeneration, integration of renewable energy in new built and existing stock. | Energy efficient buildings | Solutions to minimise transport requirements |
| **Assisted Living** | Portable power and small scale generation and storage | Smart building technology - occupant sensing and comfort profiling | |
| **Energy Generation and Supply** | CAT, hydrogen, fuel cells, microgeneration, wave/tidal. intelligent grid, oil & gas | Demand side and peak load management, smart metering, etc. | Biofuels |

**Figure 3 Technology Strategy Board investment in energy generation and supply technologies through Collaborative R&D from 2004 to 2007 (in value and number).**




By its nature, energy impacts on numerous sectors through its production, supply, demand and usage. It therefore has a number of links and interactions with other key technology areas (KTA), key application areas (KAA) and Innovation Platforms within the Technology Strategy Board. These links are shown in Table 1. This illustrates the direct investment in low carbon energy technologies and indirectly through Collaborative R&D programmes in other KTAs such as Advanced Materials, Electronics, Photonics and Electrical Systems and High Value Manufacturing. The Innovation Platforms in Low Impact Buildings and Low Carbon Vehicles are further extending the Technology Strategy Board focus on energy through investment in technologies for energy conservation and environmental impact.

## 2.3. The energy innovation chain and funding landscape

The energy research, development, demonstration and deployment landscape and the associated innovation system in the UK are diverse and continually evolving. They involve both the public and private sector.

At the top level, the Energy Unit in the Department for Business, Enterprise and Regulatory Reform (BERR) provides oversight and energy policy formulation, together with other Government departments such as the Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT).

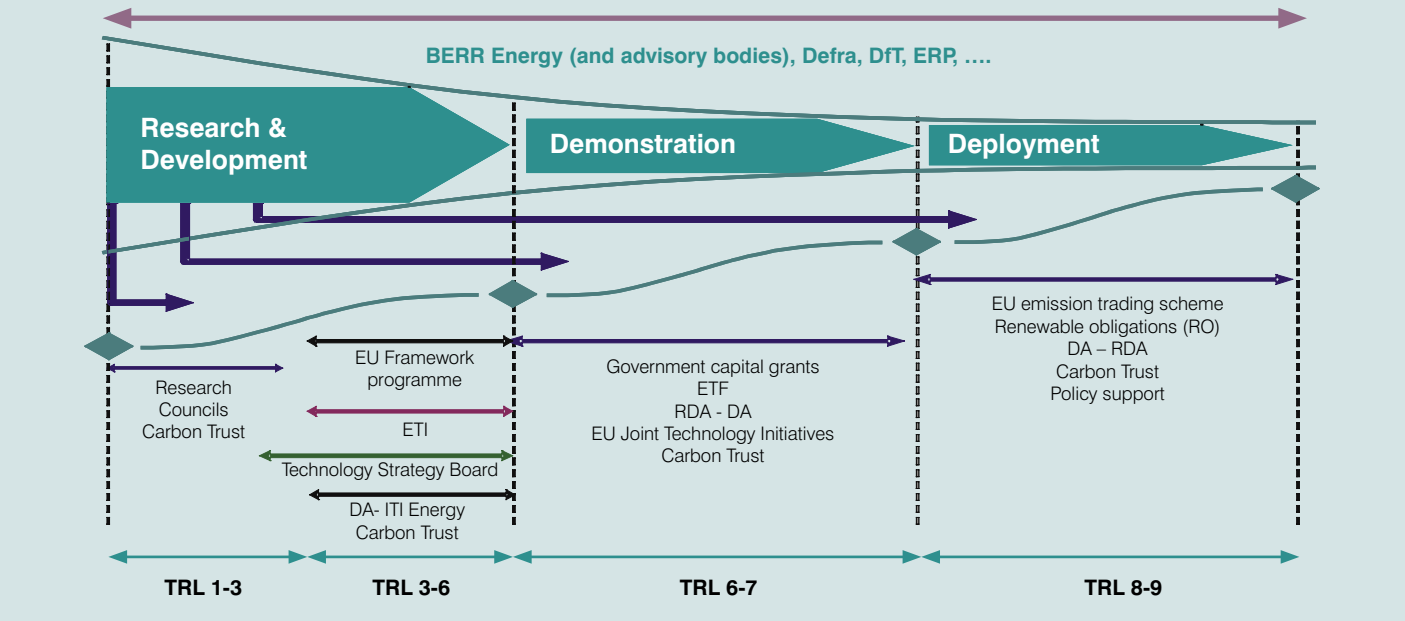
In addition the Energy Research Partnership (ERP, [4]) was established in 2005 to bring high level co-ordination between public and private sector organisations with an interest in promoting and supporting innovation in energy in the UK. The ERP produced a schematic 'map' of the energy technologies innovation chain to show the relevant position of the public/private partnerships and funding agencies along the innovation system. An adapted version is shown in Figure 4.

There are three stages which make up the energy innovation system: research and development (R&D), demonstration, and deployment. Each stage represents different Technology Readiness Levels (TRL) [5] and each of these often requires differing levels and types of public sector interventions alongside the private sector effort.

The role of each of the major public sector organisations along the innovation system is described below:

- Within the R**esearch Councils** (RC), the Energy Programme is led by EPSRC (sponsored by the Department for Innovation, Universities and Skills (DIUS)). It invests in a full spectrum of innovative, high risk research, working to develop UK research capacity in energy-related areas, including the SUPERGEN initiative and the UK Energy Research Centre (UKERC) [6]. UKERC was established by the RC in 2004. With funding of £13.8 million over 2004-09, its objective is to provide a focus for energy research (primarily academic) in the UK and for international collaboration. RC spend on energy was £77 million in 2007 - 08. The RCs only fund academic organisations and target highly speculative, pre-competitive research, typically at TRL 1-2, occasionally moving into level 3.
- The **Technology Strategy Board**, sponsored by the Department for Innovation, Universities and Skills (DIUS), provides funding for business driven applied R&D, through to early pre-competitive demonstration. The Technology Strategy Board 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

**Figure 4: Diagram illustrating the public sector support in the UK low carbon energy technologies innovation system (adapted from ERP).**




inclusive of micro-companies, SMEs, Universities and large businesses. These include Collaborative R&D, Knowledge Transfer Networks and Knowledge Transfer Partnerships. Energy related technologies are specifically supported through the Energy Generation and Supply KTA, other KTAs that provide investment in underpinning technologies and Innovation Platforms. Funding primarily targets applied R&D (TRL 2-6).

- The **Energy Technologies Institute (ETI**,[7]) announced in 2006, focuses specifically on low carbon energy and targets reduced $CO_2$, security of supply and reduced cost of electricity. It is a 50:50 public-private partnership with funding of up to £1.1 billion over 10 years. ETI will primarily cover the TRL 3-6 regime of the innovation system with a major driver to accelerate the development, demonstration and eventual commercial deployment of a focused portfolio of energy technologies. It is also expected to invest in international collaboration, to support the UK's global climate change aims. To facilitate coordination with other public funded activities and the development of a coherent energy innovation programme, the 50% public funding for ETI comes through the Technology Strategy Board and EPSRC. In addition, the Department for Transport have allocated up to £5m pa in support of the ETI transport related projects.
- The **Environmental Transformation Fund (ETF)** is a Government initiative aimed at bringing together cross-Government activity to develop low carbon economies. Led by Defra, BERR and the Department for International Development (DfID), it will be primarily aimed at getting technologies to market (e.g. capital grants for demonstration and pre-commercial deployment) which are the TRL (6+) stages of innovation. The 2007 Budget announced funding of £800 million for the international element of the ETF to support development and poverty reduction through environmental protection in developing countries, including action to tackle climate change. Defra and BERR are jointly responsible for the domestic element of ETF, which has a budget of £400m over the comprehensive spending review period, to be spent on the demonstration and deployment of low carbon energy and energy efficiency technologies.
- The **Carbon Trust** is an independent organisation funded by Government and has been supporting activities across the full spectrum of the innovation system since 2002, with an annual budget of £90-100m. Activities include: grants for R&D; strategic and business advice to start-up companies, financing and delivery of field trials to overcome market barriers. R&D activities include an open call programme for grants of up to £250,000 and the new Directed Research Initiative, which invests up to £10m in large, targeted projects. The Carbon Trust is distinctive in its ability to integrate its coverage of the complete technology innovation system with venture and seed capital finance, market development activities and policy insights to support its work in developing low-carbon technologies.

Other organisations operating in the energy funding landscape include:

- The **Regional Development Agencies (RDA)** prioritise their support for energy RDD&D on the basis of regional strengths, capacities and economic priorities. In the recent Comprehensive Spending Review they have agreed to align a proportion of their resources with the national Technology Strategy, which may include support for this KTA in some regions.
- Of the **Devolved Administrations (DA)**, by far the most proactive in energy is the DA in Scotland. ITI Energy, supported by Scottish Enterprise, identifies technologies required to address future global energy market opportunities and then funds and manages R&D programmes and the subsequent commercial exploitation of new intellectual property.
- **UK Trade and Investment (UKTI)** is the Government organisation that helps UK-based companies succeed in an increasingly global economy with a range of services tailored to the needs of individual businesses to maximise their international success. UKTI offers services to UK businesses that want to grow their business internationally and overseas businesses that want to locate in the UK. UKTI has recently published its UK Energy Excellence Marketing Strategy [8].
- The European Union funds a significant amount of R&D into low carbon energy technologies through its Energy programme within the current seventh Framework Programme (FP7) with an indicative budget of 2,350 million Euro (Jan 2007-Dec 2013) and a further 1,890million Euro investment in environmental technologies, including climate change. (All exclude nuclear which are covered in the EURATOM programme). Many of the priority R&D themes within the FP7 programme have been developed through consultation with the European Technology Platforms and their associated Strategic Research Agendas which help define future R&D priorities across Europe and in which the UK is having a significant input.

## 2.4. Policy and regulation

Energy policy and regulation, both nationally and internationally, have a significant effect on the selection of technologies in the energy sector by providing incentives or influencing the direction of investment for the market. Examples of UK and international policies are the UK renewables obligation (RO), the large combustion plant directive, the climate change levy, the renewable transport fuel obligation, zero carbon homes, the Innovation Funding Incentives (Ofgem) and the EU emissions trading scheme. At the 2007 Spring European Council, EU Heads of State and Government agreed an ambitious package of measures on energy and climate change. One of the targets agreed was that, by 2020, 20% of the EU's energy should come from renewable sources. It was also agreed that 10% of transport fuels should be from renewable sources by 2020. At the end of January 2008, the Commission published its draft directive which, when agreed by the European Council and European Parliament, will give this target legal effect. Each Member State has a proposed national target, which, for the UK is 15% [10].

These policies often seek to influence the private sector to invest in technologies that may differ from those that would be delivered to the market place in the absence of such intervention. The Stern Review on the Economics of Climate Change illustrates in detail the importance of Government policy in driving innovation in low carbon energy technologies [2].

By way of example, in the UK, the RO [11] is placed on all licensed electricity suppliers to source a proportion of all electricity supplied from eligible renewable sources. The proportion of electricity to be supplied via renewables increases each year from 6.7% in 2006-07 to 15.4% by 2015/16. Since its introduction in 2002 the RO has been successful in stimulating growth in more developed renewable electricity generation such that it has doubled since 2002. Banding of the RO is currently being introduced by Government to drive further development against its targets. This will target support on emerging technologies which are further from commercial deployment, such as wave and tidal and advanced conversion technologies. It is therefore important that any strategy being developed accounts for and is aware of developing policy and regulations.

# 3. Market and industry overview

This section presents a brief overview of the energy market and industry in energy generation and supply. This overview is primarily based on the International Energy Agency World Energy Outlook 2006 'business as usual' scenario [12]. The Technology Strategy Board recognises that alternative scenarios exist and that business as usual doesn't take into account of the driver in reducing energy demand. However, the purpose is to give an indication of the scale of opportunities that might arise, rather than comprehensively describe the sector under various scenarios.

**Figure 5: Projected increase in electricity demand to 2030 [12]**

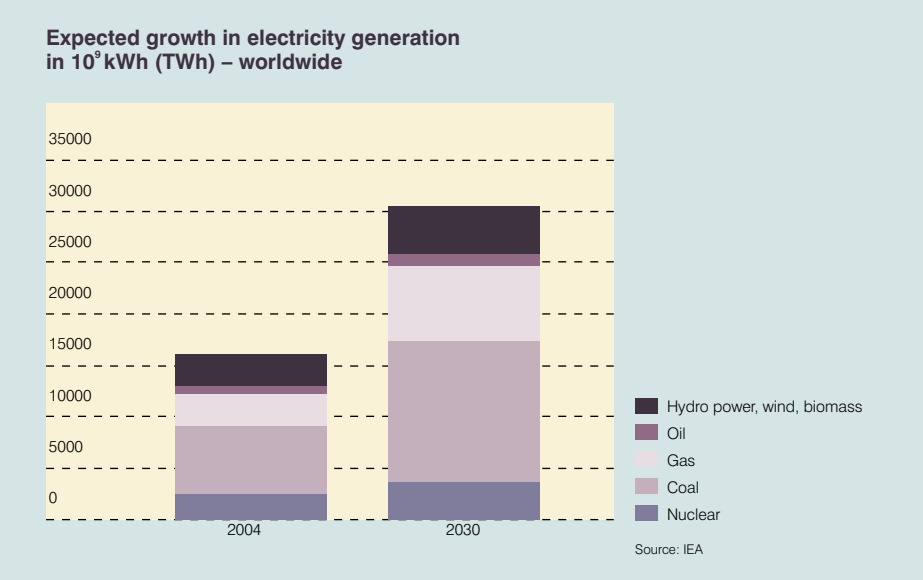



**Figure 6: Projected increase in greenhouse gas emissions to 2030 [12]**

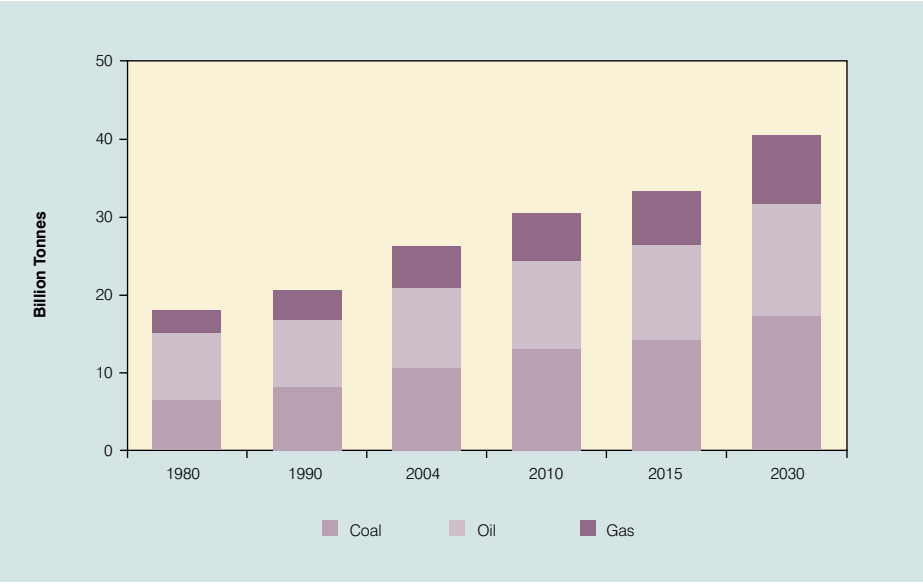


**Figure 7: Projected increase in CO2 emissions to 2030 [12]**

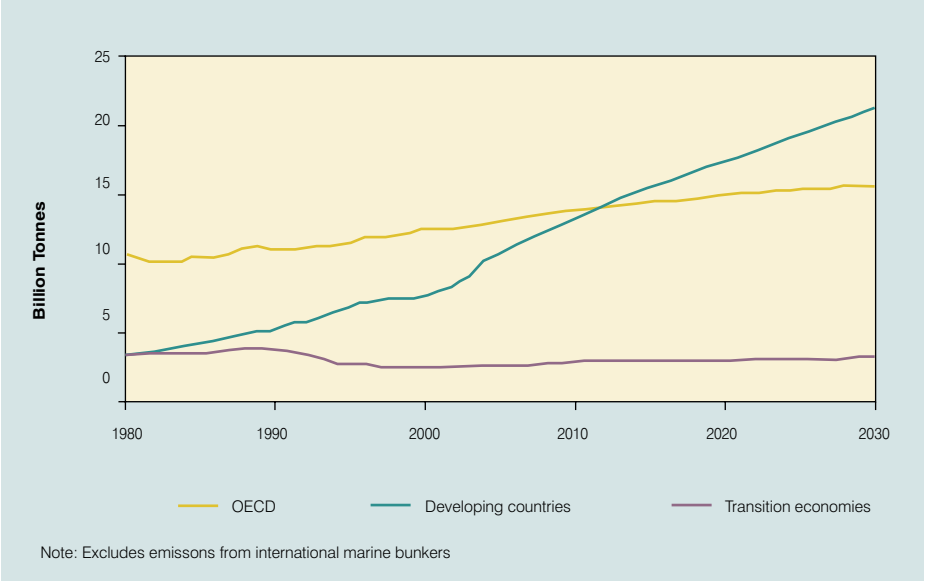
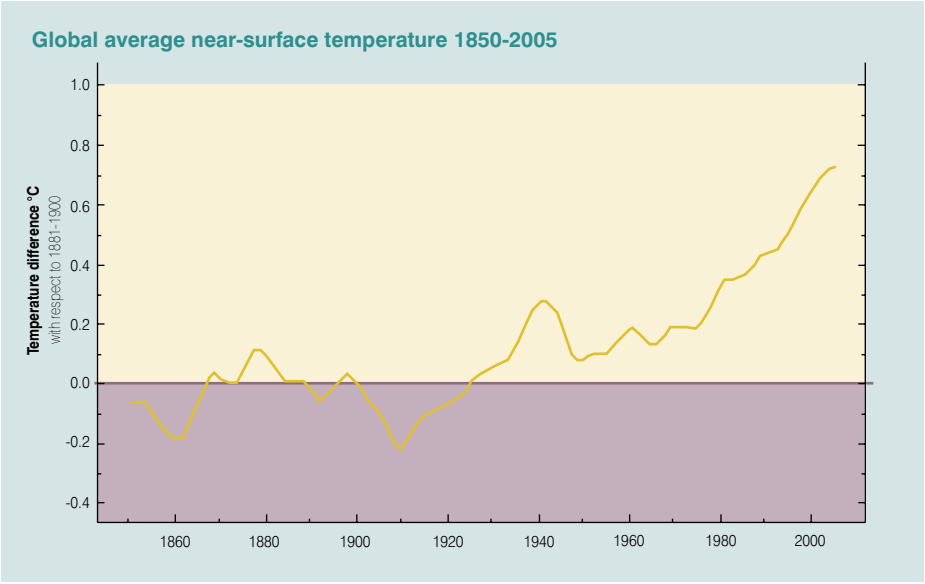



**Figure 8: Increase in global average near surface temperatures over the last two centuries [2]**




## 3.1. Facts and figures

### 3.1.1. Global demand and investment

On the basis of present policies and projections [12], global energy demand will rise by 55% and electricity demand will almost double over the next 25 years from around 15,000TWh in 2004 to 30,000 TWh in 2030 (Figure 5), with energy related greenhouse gas emissions increasing by around 55% reaching 40 Gt in 2030 (Figure 6). Much of this is due to the growth of the developing countries, which are predicted to overtake the OECD countries as major emitters of $CO_2$ by 2012 (Figure 7). For example, China has recently overtaken the United States as the world's biggest emitter of $CO_2$.
All of these trends accentuate the consuming countries vulnerability to a severe supply disruption and resulting price shock. They also amplify the magnitude of global climate change and its effect on the earth's temperature (Figure 8).

The World Energy Outlook 2006 [12] identifies under-investment in new energy supply as a real risk. To quench the world's thirst for energy, the projections call for a cumulative investment in energy-supply infrastructure of over $20 trillion in real terms over 2005-2030. Figure 9 shows this required investment by fuel type. This is substantially more than was previously estimated. Roughly half of all this projected energy investment needed worldwide is in the developing countries and as such provides major export opportunities to UK business.

In terms of the global impact, the Stern Review [2] has estimated that if no action is taken, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and into the future. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more.

### 3.1.2. UK demand and investment

The global requirements for energy are inevitably reflected in the UK and its own investment in energy technology. The consumption of electricity has grown steadily over the last three decades from around 240TWh in 1980 to 350TWh in 2006 (Figure 10). However, much of the UK fossil and nuclear plant is now coming to the end of its design life with one third due for decommissioning or replacement by 2020 (Figure 11). This will significantly impact on the ability to meet projected demand. The UK will require private sector investment in new generating capacity of an estimated 30-35GW [1] over the next 20 years, with around two thirds being required by 2020 in order to replace power station retirements and meet rising demand as the economy continues to grow. This increase in demand excludes any potential increase due to increasing electrification to reduce emissions from heat and transport via low carbon electricity.

**Figure 9: Projected required investment in the energy supply infrastructure [12]**

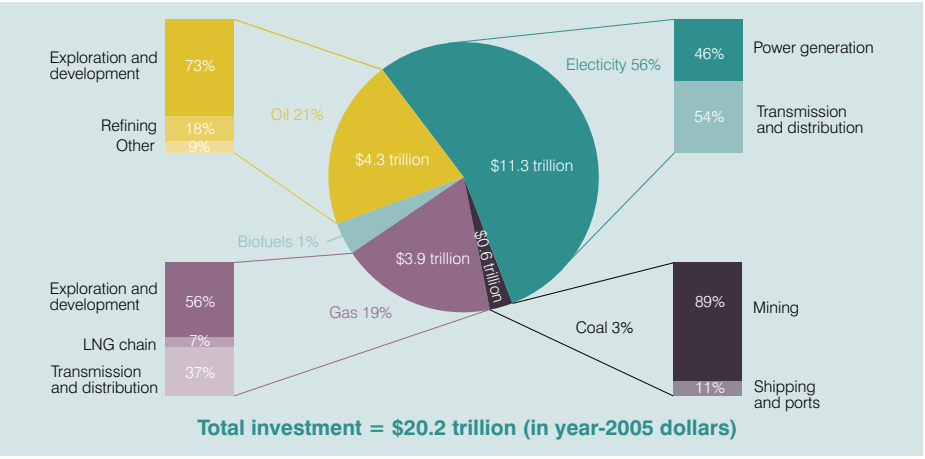



**Figure 10: Growth in UK electricity demand from 1980-2006 [14]**

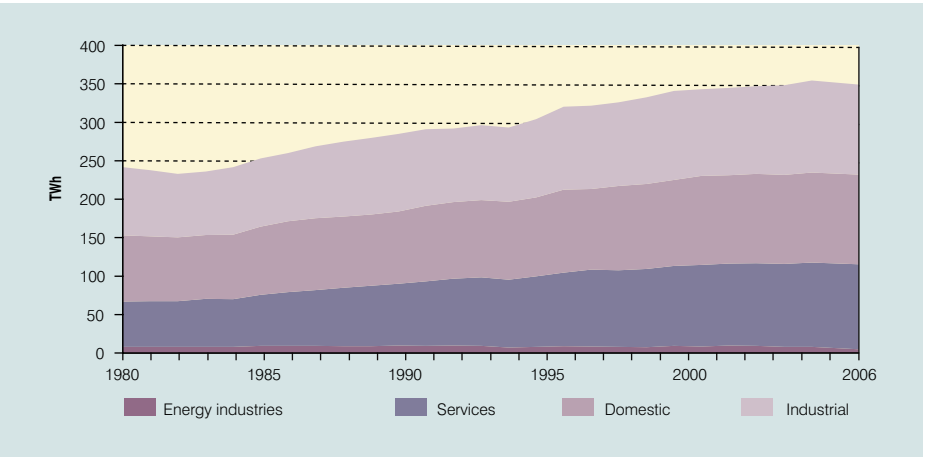



**Figure 11: Impact of scheduled power plant closures on UK electricity capacity margin**

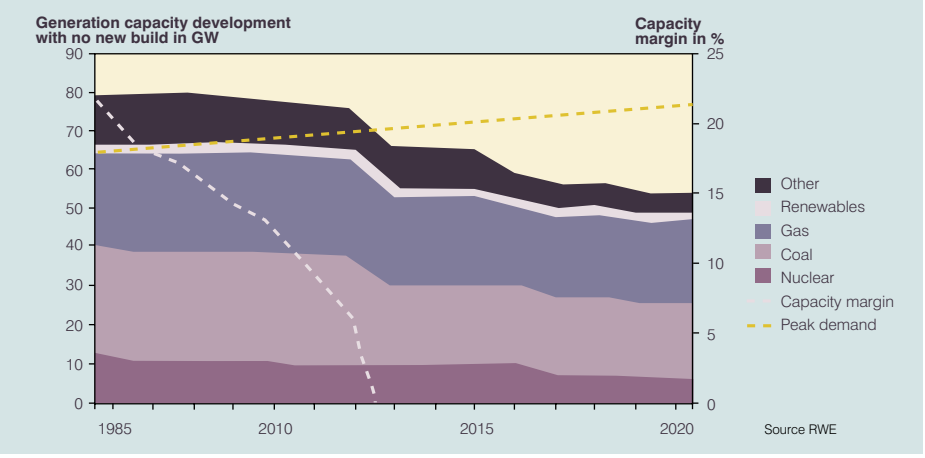


**Figure 12: UK Electricity generating mix by fuel source 2006 [14]**

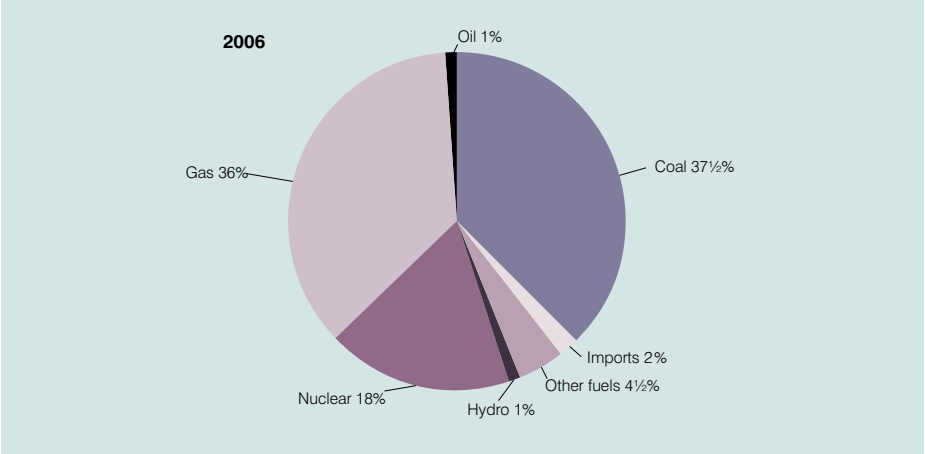



**Figure 13: Employment trends in the energy industries 1980-2006 [14]**

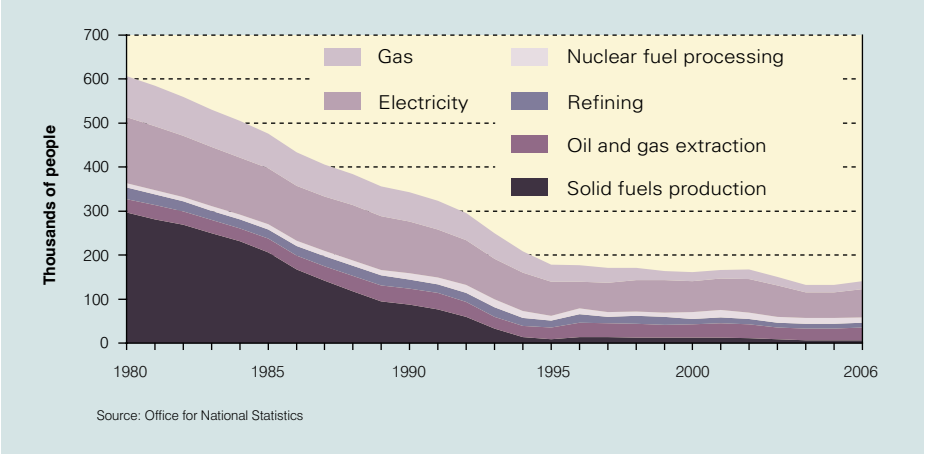
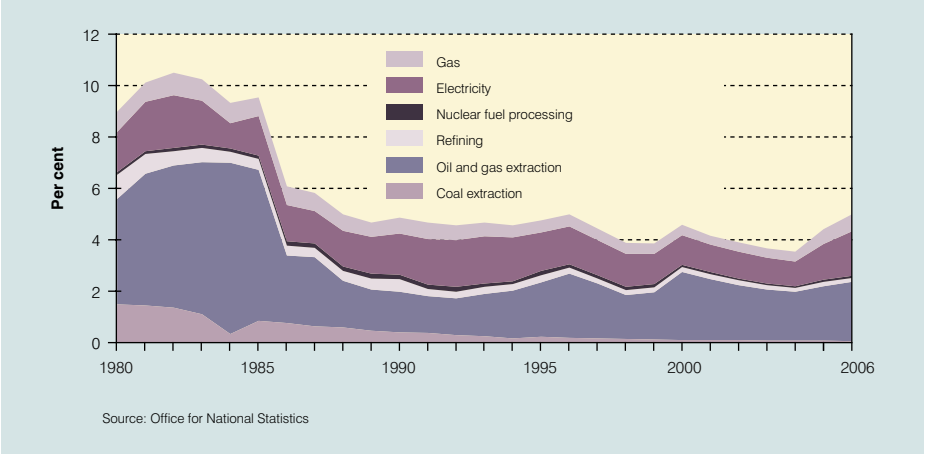



**Figure 14: Contribution to GDP of energy industries [14]**




In terms of the $CO_2$ and energy balance, the UK and the EU target a reduction in $CO_2$ emissions with specific targets on renewables as discussed in Section 2.4. To put this target into context and indicate the magnitude of the challenge, UK generation mix by fuel type at the end of 2006 comprised approximately 76% fossil fuel, 18% nuclear and 6% renewables (Figure 12).

Employment in the energy sectors in the UK has decreased dramatically over the last 20 years. Direct employment is around 142,000 people (Figure 13), with many others indirectly employed, e.g. an estimated 290,000 in support of UK Continental Shelf activities. As defined in [13], these figures refers to energy sector industries comprising of Gas, Electricity, Nuclear fuel processing, Refining, Oil and gas extraction, and Solid fuels production. This trend is now being reversed particularly when the original equipment manufacturers, service and construction businesses are considered.

As defined above, the UK energy sector represents around 5% of GDP (Figure 14), 8% of total investment and 40.6% of industrial investment in the UK. In addition, it invests 3% of industrial expenditures in R&D (in 2005).

UK industries have a presence along the entire energy supply chain, from exploration, resources extraction and processing, to power generation (with fossil, renewable and nuclear fuel) and energy service provision, transmission and distribution. Businesses include underpinning industries such as materials, control and instrumentation, consultancies and engineering services and range in size from large multinationals to Small and Medium Enterprises (SME). Whilst multinationals can be both technology users and developers, SMEs, especially in the renewable energy sector, are largely technology developers.

Investment in the UK energy industries rose by around 20% in 2006 to around £10 billion, with most of this being in electricity and oil and gas (Figure 15).

### 3.1.3 Sectors demand for energy in the UK

The entire economy relies on energy to provide power, heat and transport to individuals, communities, services and industry (Figure 16). Energy consumption, and the associated environmental impact, cuts across virtually all business sectors. In 2006, the main sources of carbon dioxide emissions (on an Intergovernmental Panel on Climate Change basis) were: power stations (32%), industry (23.5%), transport (23.5%) and the domestic sector (14.5%) with 153 million tonnes of carbon estimated to have been emitted as carbon dioxide from the UK.

The challenges, targets and market growth discussed in this section cut across numerous business sectors and provide significant opportunities for the UK to develop innovative low carbon energy solutions and hence business opportunities both nationally and on a global scale. This was supported by the Stern Review [2] which noted that policy to support innovations and the development of low carbon technologies will be significant to mitigating climate change.

**Figure 15: Investment in the energy industries 1995-2006 [14]**

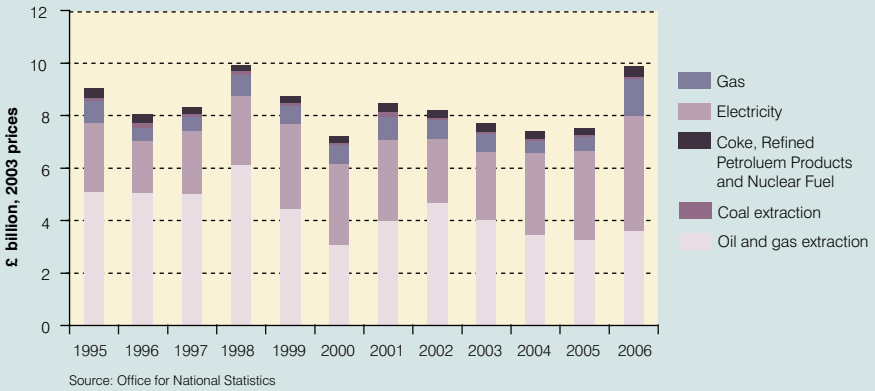
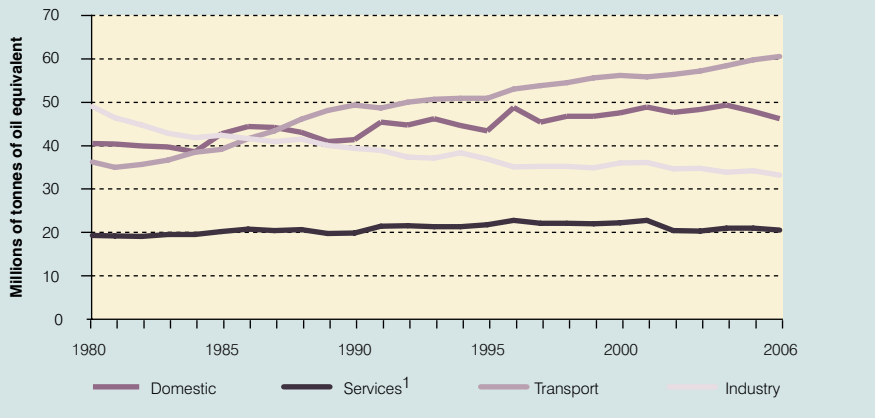



**Figure 16: Energy consumption by sector [14]**




## Summary

**Global energy market key trends between 2004 and 2030, assuming business as usual [12]:**

- Global primary energy demand will rise by 53%, leading to a 55% increase in global carbon dioxide emissions related to energy.
- Fossil fuels will remain the dominant source of energy worldwide, meeting 83% of the increase in energy demand.
- Emissions from power generation will account for 44% of global energy-related emissions by 2030, as demand for electricity rises.
- Coal will provide the largest incremental source of power generation, with the majority of this increase likely to be in China (55%).
- Over 70% of the increase in global primary energy demand will come from developing countries, reflecting rapid economic and population growth.

# 4. Market opportunities

Although there are strong needs and policy drivers to reduce demand, electricity and heat generation and supply, transport and portable power will still represent substantial market opportunities for the foreseeable future. This section presents an indication of the market opportunities that might arise, it does not attempt to describe and analyse the markets comprehensively.

To meet UK energy demand with the fuel mix illustrated in Figure 17 and to address market failures, Government has and still is developing a range of policy instruments, as outlined in Section 2.4. Therefore, the opportunities in the energy markets are heavily influenced, and in some cases entirely driven, by policy framework. The technology providers must always be aware of the potential impact that policy and regulation may have on their targeted markets.

Meeting global clean energy demand provides numerous market opportunities for UK business in generating power from a portfolio of fuels (Figure 17) and supplying electricity and heat, both centralised and distributed. In addition, power plant equipment manufacture represents a substantial market opportunity both in the UK and globally. There are also spill-over benefits and solutions for other markets such as, for example, transport and portable power.

To give an indication of the opportunities in the energy markets that UK businesses can take advantage of, a summary of some of the market trends in electricity and heat generation and supply, transport and portable power is provided here.

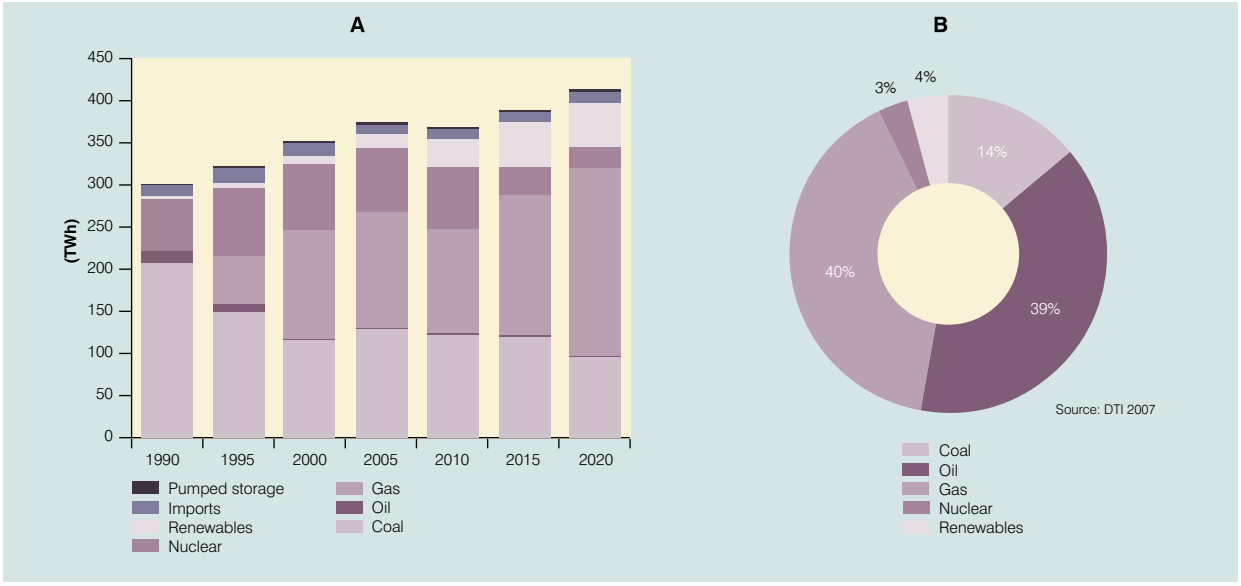
## 4.1 Electricity generation

Electricity is used in the industrial, domestic and services sector. World electricity demand is projected to double by 2030, with the share of electricity consumption rapidly rising in household appliances, followed by the service sector, but with industry remaining the largest final consumer. Projections indicate over 5000 GW of generating capacity will be built worldwide during this period. The electricity market can be segmented by fuel type: fossil, renewable and nuclear, briefly described in the following sections. Technologies such as fuel cells are also used to generate electricity. The market for stationary power provided by fuel cells could be worth US$3 bn per year. It is expected that the markets will develop first in North America and Japan and then Europe [3].

### 4.1.1 Fossil fuel

Over the next two decades, the UK will need substantial investment in new generation capacity to replace the closing fossil and nuclear power stations, and to meet expected increases in electricity demand. It is projected that around 20 to 25 GW of new generation will be required by 2020 [1] - noting that policy is indirectly driving towards reducing demand for new gas-fired power stations. Companies have already announced over 14 GW of new generation capacity [15]. UK businesses that can take advantage of this market are mostly large power generating companies also capable of providing a portfolio of energy services. In addition to the utilities, the businesses expected to benefit from the power generation supply chain in the UK would be materials/component suppliers through to the original equipment manufacturers, including project management and engineering solutions providers and the construction sector.

**Figure 17: UK fuel mix for electricity (a) and energy (b) generation by 2020 [1]**



There will be an emphasis on clean coal technologies that use carbon abatement technologies (CAT) to produce low $CO_2$ emissions, through improved efficiencies, co-firing or use of carbon capture technologies. In addition to global opportunities offered by demonstration of new technologies, the Government announcement of the competition for the UK's first carbon capture and storage (CCS) plant that, if successful, will provide opportunities for UK businesses who already have strengths in the development of CAT and have existing R&D facilities in the UK. The Stern report pointed out the importance of CCS and there will be significant opportunities for its deployment over the next 30 years, firstly in the developed countries and then in countries like India and China where the markets will be orders of magnitude greater and will run into billions of pounds. Not only will there be opportunities for higher efficiency generation plants and CCS for new built power plants but also opportunities for retrofitting these technologies to existing plants, primarily those that will be built as 'capture ready'.

### 4.1.2 Renewables

Examples of the main renewable sources used to generate electricity are wind, biomass, marine (wave and tidal), solar and hydro. Global investments in renewable and clean energy were just over US$100 billion in 2006 and this could rise to $750 bn by 2016 [16]. In the second quarter of 2007 the UK, together with India and Spain, was second in the Ernst & Young All Renewable Index (which provides scores for national renewable energy markets, renewable energy infrastructures, and their suitability for individual technologies).

- The estimated value of worldwide electricity revenues from wave energy and tidal stream could ultimately be between £60 bn/year and £190bn/year [17].
- In early December 2007 BERR announced the launch of a Strategic Environmental Assessment on a draft plan for up to 25 GW of new offshore wind development rights in UK waters. These proposals would help to bring forward offshore wind as an emerging technology and could make a major contribution to meeting the proposed UK share of the EU target of 20% renewable energy by 2020.
- Globally, the offshore renewable energy market is estimated to have been worth £8 billion in 2007 [18].
- A report commissioned by the DTI and published by the IEA [19] has estimated the global market for biomass electricity to be 5400TWh/year by 2050 if renewables intensive policies are adopted worldwide.
- In 2006, the UK generated about 1% of its electricity from hydroelectric schemes - most of which are large-scale schemes found in the Scottish Highlands. Hydroelectric is a proven and efficient technology. Opportunities to increase large-scale hydroelectric in the UK are limited as most commercially attractive and environmentally acceptable sites have been utilised. It is believed however, that full exploitation of small-scale hydroelectric power could meet just over 3% of total UK electricity needs and making a significant contribution to the Government's renewables target of 10 per cent by 2010-16 [18].
- Distributed small scale electricity generation can also be achieved through microgeneration technologies, more suitable to the built environment markets.

The UK has several world leading businesses that can take advantage of the above opportunities, from large multinationals to SMEs focussed on technology development. UK based businesses traditionally involved in the conventional fossil fuels markets are increasingly developing opportunities using renewable sources, as a consequence of the climate change and security of supply drivers.

### 4.1.3 Nuclear

In the UK, there are currently nineteen operational nuclear reactors which generated around 18% of the electricity supplied in 2006. Most of these are approaching the end of their lives and are due to be decommissioned. As a result, the contribution of nuclear power to the UK electricity supply is predicted to drop to below 5% by 2020, unless new construction is undertaken. Government announced its nuclear policy in January 2008, stating that '*it is in the country's vital long-term interest that nuclear power should play a role in providing Britain with clean, secure and affordable energy*' and energy companies have been invited to bring forward plans to build and operate new nuclear power stations [21]. It is too early to gauge the interests of the private sector in taking forward such plans.

## 4.2 Electricity supply (transmission, distribution and storage)

The IEA 2006 World Outlook figures, assuming business as usual, suggests around £3 trillion as the required expenditure on transmission and distribution. According to Ofgem, UK expenditure on transmission and distribution networks over the current five year price control period will amount to £10 bn with around £1bn pa being invested in cables. There are real opportunities for more responsive grid

control that allow greater penetration of intermittent renewable at acceptable cost.

Under conditions of average loading, estimated energy losses from transmission and distribution are around 2 and 6% respectively. This total loss of 8% equates to about 3.2GW of power or 8million tonnes of $CO_2$ entering the atmosphere from a coal fired power station. There are significant opportunities for technology developments to reduce these losses.

The UK has a number of businesses active in R&D in this area, ranging from utilities, to providers of automation and power technologies, to National Grid. In addition, there are a number of SMEs that focus on technology development such as power transformers, high temperature superconductors, etc.

## 4.3 Heat generation and supply

Heat generation accounts for around half of the UK's total energy consumption by end-use [1], with nearly three quarters used for space and water heating, primarily in the domestic sector and to a lesser extent in the commercial and public sectors. The remainder is used by industry as an input to a wide range of processes, The vast majority of heat demand in the domestic, commercial and public sectors is met by gas supplied through the gas distribution network. Current market drivers in this sector are influenced by Government policy, as heat accounts for around 47% of the UK's total carbon emissions (including emissions from electrical heating). UK Government has indicated the need to conduct further work into the policy options to reduce the carbon impact of heat, which include heat demand reduction and the use of combined heat and power (e.g. fuel cells) and renewable technologies such as microgeneration (e.g. solar thermal, heat pumps) and biomass (small scale for residential use, and larger for commercial and industrial use). These technologies currently require a distributed generation approach. The renewable heat market has been slow to develop and non competitive costs and the limited application and effectiveness of carbon pricing in this sector have been identified as market failures [1].

Renewable heat currently amounts to 0.6% of final UK heat demand. The majority of renewable heat comes from wood combustion in the domestic and industrial sectors. A number of existing renewables technologies could help to increase the amount of renewable heat in use, including biomass, heat from waste and microgeneration.

Since January 2007, the Office for Climate Change (OCC), working closely with BERR, Defra and the Department of Communities and Local Government (DCLG), has been developing a heat project with four main objectives, to:

- Provide an overview of the heat and cooling sector.
- Establish the carbon impact of heat generation (and cooling) and assess the potential for this to be reduced.
- Identify and assess alternative or additional policy mechanisms.
- Make recommendations on the optimum set of mechanisms and next steps.

More recently, the focus of work has been to develop a call for evidence on heat/ renewable heat. The call for evidence issued in late January provides an introduction to the topic of heat in the context of carbon reductions. It outlines the key relevant technologies, policy options and potential support mechanisms under consideration and seeks commentary on and input to current analysis and emerging options for action. It will be followed by further formal consultation later in 2008.

## 4.4 Power plant equipment manufacturing

Power plant equipment manufacturing, installation, operation, maintenance and decommissioning constitutes a market opportunity in itself, this is clearly linked to the predicted increased investment in electricity generation capacity, e.g. new build, retrofit, development of renewable generation capacity and asset management. The UK has a number of world leading businesses who can take advantage of this opportunity, including materials suppliers, original equipment manufacturers, off-shore industries and engineering services. The value to UK based global manufacturers will be in high value manufacturing, specialist design and Original Equipment Manufacturers (OEM) support and servicing.

## 4.5 Transport

At present oil, in various derivative forms such as gasoline, diesel and kerosene, provides the vast majority of energy for transport - both in the UK and globally. The transport sector is expected to absorb 63% of the increase in global oil demand (from 2004 to 2030). This demand is expected to grow steadily from 84mb/d in 2005 to 116 mb/d in 2030 [12]. There is an efficient worldwide infrastructure of oil exploration, production, refining and distribution that has been built up over many decades to supply this demand and the UK has a strong reputation in oil and gas activities (upstream and downstream) globally and within the UK itself (UK Continental Shelf).

Policy framework is also a strong market driver in the case of transport. Market failures and barriers to entry include the early stage of development of many relevant technologies, limited demand from consumers, a still evolving regulatory environment and the high capital costs. In response to this, Government has

developed a range of interventions including support for research, development and demonstration [22].

Climate change and security of supply drivers open up opportunities for electric-hybrid solutions and for alternative fuels, such as biofuels, technologies such as fuel cells and the use of hydrogen as an energy vector. As quoted in the King Review [23], in the medium term, as we progress towards 2030, per-kilometre emissions reductions of some 50 per cent could be achieved through a combination of battery-electric hybrids. The long-term potential for fuel cells for transport could be as much as US$8 bn per year and the global opportunity for hydrogen systems is mainly likely to follow the transport markets for fuel cells. The potential use of hydrogen in internal combustion engines for the high power segment of the car market would imply that hydrogen use would not be restricted by availability of suitable fuel cell systems or the likely market penetration for those systems [2]. However, it is uncertain whether there will be sufficient vehicles to engineer a nation-wide chain of supporting infrastructure. Transition scenarios could involve depot fuelled urban vehicles such as taxis, buses and urban delivery vehicles in places where there is a strong political commitment to the use of hydrogen (e.g. London).

UK business is in a good position to take advantage of these new opportunities: for example, BP and Shell have an interest in biofuels and are in the Top 25 companies by R&D expenditures in 2006 [24]. In the fuel cells segment, the UK has a few innovative, but world class players.

## 4.6 Portable power

The global battery market is approximately $50 billion per annum and this is expected to grow to meet increased global demand for more and more wireless products and handheld devices including:

- Products for communication (mobile phones, laptops, etc).
- Products for healthcare (equipment and instruments for emergencies and for remote locations, portable monitoring equipment, etc).
- Cordless tools for general industrial use.
- Products for Creative Industries (e.g. Film and TV).
- Products for security such as individual power sources for defence applications and emergency services.

Within this global market, approximately $4.4 bn relates to “premium portable power”, at present dominated by lithium-ion/polymer batteries with 98%share. This market is expected to grow to $6.3 bn in 2009 [25]. It is seen as one of the earliest applications for fuel cells technology and is estimated that worldwide market potential for portable fuel cells will be worth $11b by 2011 [26], although fuel cells will be in competition with market for battery technology that continue to make progress.

# 5. Technologies overview and fit to Technology Strategy Board criteria

The UK energy demands will be met by the deployment of a portfolio of technologies, as no single technology can facilitate meeting all of the UK energy policy targets. There are many technical challenges facing each technology within the proposed portfolio. Some technologies are unproven at a commercial scale and involve large scale investments with limited prospect of incremental learning through small-scale commercial units, whilst others, although proven, are not yet cost competitive with traditional technologies and/or lack well established supply chains. The Stern review on the Economics of Climate Change [2] identifies the strong role of innovation in low carbon energy technologies and identifies barriers such as higher costs compared to conventional technologies, infrastructure requirements, existing market distortions and limited competition. The review then emphasises the role that policy has in introducing these technologies in the markets [2]. The Energy White Paper identifies technologies that are market failures and that are at the research, development and early demonstration stage [1]. These technologies, with the addition of 'Oil and Gas', are suitable for Technology Strategy Board intervention if they satisfy its criteria (Section 1).

**This section presents a brief overview of each technology and a qualitative evaluation of their potential against the Technology Strategy Board criteria. This evaluation is summarised at the end of each section in the form of low, medium, high priorities. This section is not intended to provide a comprehensive technical review of energy technologies.**

## 5.1 Offshore wind

### Overview

This technology is suitable for electricity generation and provides the most potential for achieving 2010 and 2020 renewable targets. Offshore wind turbines are based on the same technology as their onshore counterparts but offer advantages in terms of higher number of suitable sites, higher wind speeds and possible use of larger turbines with lower transport costs.

Currently, there is about 1GW of installed offshore wind energy globally, with over 20% of that installed in the UK (second only to Denmark) [18].

### TRL and challenges

The technology is at the early deployment stage and further R&D is required to reduce the costs and improve reliability of the technology. The challenges include [1]:

- Optimisation of machines (e.g. through innovative design and materials which will lead to improvements in weight saving, speed of installation, performance and reliability).
- Development of lower cost components and foundation systems.
- Wind farm design.
- Efficient transportation and installation of wind turbines in the sea.
- Solutions purpose built for the marine environment ('marinisation').
- Operation and maintenance (e.g. through enhancing reliability, easier maintenance, including remote control and condition monitoring solutions).
- Interaction of wind turbines and radar.
- Testing and performance optimisation.
- Learning through industry development (e.g. best practice etc).
- Overcoming constraints of the current electricity network.
- Simulation and modelling.
- Supply chain development.

### Synergies with other Key Technology and Application Areas

- Energy generation and supply - Oil and Gas (offshore expertise)
- Advanced Materials
- Electronics, Photonics and Electrical Systems (power electronics, power conversion, control systems remote condition monitoring, etc)
- ICT (Control systems, remote condition monitoring, data management, etc)
- High Value Manufacturing

### Market opportunities

- Electricity generation
- Power plants manufacturing

### UK capacity and routes to sales

The UK has the best offshore wind resource in Europe, extensive capabilities and a proven track record in working offshore through the oil and gas sector. This offers the UK the potential to become a world leader in the transfer of wind energy technology from onshore to offshore. Whilst much of the supply chain lies outside the UK (e.g. turbine manufacture) the UK has significant expertise in the integration in the electricity grid and equipment installation, operation and maintenance. There are additional opportunities for the UK to build on the market growth in the UK through innovative product development and ownership of associated IPR to gain a market lead.

There is some strong academic expertise, although concentrated in a few centres, such as Durham, Nottingham, Strathclyde, Manchester, Loughborough and Surrey, currently collaborating in the £2.5m EPSRC funded SUPERGEN consortium 'Wind energy technologies'. The UK has also testing and development facilities, such as the New and Renewable Energy Centre (NaREC). There is also substantial industrial and academic capacity abroad, for example in Denmark and the US.

Considerable investments are already underway along all stages of the innovation chain (through the Carbon Trust, BERR, the RCs and Technology Strategy Board). In particular, a substantial programme of work on offshore wind is currently being commissioned by the ETI and Carbon Trust, aiming at accelerating the uptake and deployment of this technology.

Currently it is not felt that any additional Technology Strategy Board investment over and above current portfolio commitment, contribution to ETI and investment in underpinning technologies, such as Advanced Materials, High Value Manufacturing and Electronics Photonics and Electrical Systems, would provide additional value for this technology.

| Fit against criteria for investment | |
|---|---|
| UK Capability | Medium |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | Low |

## 5.2 Bioenergy

### Overview

This technology normally derives energy from purpose-grown energy crops or by-products of agriculture, forestry or fisheries. Examples of bioenergy resources are wood industry and forestry wastes and residues, organic waste, specifically grown energy crops such as miscanthus, willow and elephant grasses. There is also biogas and for fuels, bioethanol. Biomass can be converted into heat and electricity by, for example, burning, pyrolysis (the decomposition or transformation of a compound caused by heat), gasification (the conversion of solid biomass into a gaseous fuel), anaerobic digestion (the decomposition of an organic biodegradable material by bacterial action in the absence of air, and in warm, moist conditions) or fermentation. Biofuels applications are mostly in transport, although they also have potential for application in heat and electricity markets.

### TRL and challenges

Many proven technologies are in the deployment stage but second generation technologies and transport fuels are in early stages of development [1]. The main challenges are to:

- Improve cost effectiveness and overall efficiencies of biofuels, especially moving from the so called first generation technologies (e.g. maize) to the second generation where woody material etc. is converted.
- The development of viable, cost-effective fuel supply chains and the subsequent use of energy crops in the conversion processes.
- Ensuring the bioenergy value chains are genuinely sustainable, including a consideration of such effects as indirect changes in land use and impacts on bio-diversity.

### Synergies with other Key Technology and Application Areas

- Bioscience
- Transport
- High Value Manufacturing

### Market opportunities

- Electricity generation (large scale and distributed, CHP)
- Heat generation (including CHP)
- Transport (fuel)

### UK capacity and routes to sales

The bioenergy area is complex and UK capacity varies, for example, between biofuels conversion and crop improvement. The UK natural resources for purpose grown energy crops are limited by land availability, which is not as extensive as in other countries (e.g. Brazil, USA). Defra estimate over 1 million hectares could be made available for energy crops- although this land will be in competition for other uses and therefore is not guaranteed. In 2005, bioenergy accounted for 83% of all renewable energy used in the UK, of this, 34% was power generation from landfill. The use of biomass for electricity generation offers a solution to climate change and security of supply issues that could be more immediate than other solutions. This raises industry interest in biomass and working from a strong domestic market, UK industry could benefit from substantial overseas markets. A report commissioned by the DTI and published by the IEA has estimated the global market for biomass electricity to be 5400TWh/year by 2050, if renewable intensive policies are adopted worldwide.

There are international investments across the full spectrum of innovation and there are several UK industries involved in bioenergy. However, UK R&D activities must be considered limited and behind international leaders in this field, with some strengths in biofuels, combustion and conversion. There is clear strategic vision in Europe through the EU, and in the United States, which is being matched by considerable resource investments, not least at the biology end of the R&D spectrum, for example from the BP Energy Bioscience Institute commissioned in the USA [28].

The UK has research strength in basic bioscience and also in associated engineering technologies (Aberdeen, Aston, Forest Research and Forestry Commission in Edinburgh, Leeds, Sheffield, Lancaster, Southampton, Glamorgan, Aberystwyth (IGER), NERC and BBSRC Institutes). The UK also has some world-class R&D in thermo-chemical conversion (Aston and York). There is also much latent capability from UK chemical, combustion and fuels engineering communities. These skills to date have not been fully applied to the bioenergy industry. They could provide valuable future capability to develop new engineering control systems linked to bioprocessing, but this still represents an unknown market for the UK. High level computing and systems biology will also be necessary for the industry to develop from a strong research base [28].

BBSRC has launched, in 2007, a £20m initiative to fund a bioenergy research centre. Major capital projects to encourage the development of biomass supply chains for both power-only and CHP applications have been supported by BERR under the Bioenergy Capital Grants Scheme (BECGS) since 2003. As a direct result, 96.1MW from biomass sources has been delivered. This is 49% of the capacity since the introduction of the RO and 30% of the total UK biomass capacity.

The diversity in the technologies and related UK capacity within bioenergy means that a more focussed analysis, in collaboration with stakeholders, is required to better understand whether specific technologies would fit to Technology Strategy Board criteria.

R&D in biofuels specifically is highly relevant to the Low Carbon Vehicles Innovation Platform as there is a need to make sure that the transport sector is ready to accept those fuels by way of powertrain and infrastructure development. There is a need for a joint effort to instigate a study into the state of play in the UK and identifying where there are opportunities for UK to develop sustainable fuel stock with support from the transport sector to ensure that fuel is developed alongside vehicle and infrastructure development.

There might also be emerging opportunities if the UK biotechnology capability can be leveraged.

The Bioscience KTA has identified the following technologies as priorities:

- Second and third generation biofuels, biocatalysis, bioprocessing
- Biorefinery plant design, modelling, value chain analysis
- Sustainable processes

| Fit against criteria for investment | |
|---|---|
| UK Capability | Need confirmation |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | Need confirmation |

## 5.3 Wave and tidal

### Overview

Wave energy and tidal power devices harness the movement and energy contained in the sea and convert it into electrical power. The wave power machines are deployed either on the shoreline or in deeper waters offshore. Currently there are two commercial wave power devices in the UK with total capacity currently standing at 1.25 MW. Tidal stream technology is still in its infancy and there are no projects currently contributing to electricity supplies in the UK.

### TRL and challenges

There are numerous devices which have been put forward, but the best technical solution is still unknown. Leading wave energy and tidal stream technologies are at the demonstration stage whilst tidal barrage is a mature technology.

There are still R&D challenges to address [1] in:

- The development and evaluation of generic technologies; such as installation techniques, operation and maintenance techniques and mooring or fixing techniques.
- Reducing the cost and enhancing the power capture of existing device concepts, for example by the use of new materials, control systems, power take off mechanisms.
- Conduct full or near-full scale prototype deployment at sea of device-concepts that have completed a programme of laboratory scale testing and detailed techno-economic modelling.
- Conduct detailed laboratory-scale tank testing and detailed techno-economic modelling on sufficiently promising device concepts.
- Network constraints
- Simulation and modelling.

## Pelamis

One of the world's first floating offshore wave energy conversion systems is currently being developed by a leading UK company, Pelamis Wave Power Limited (PWP). The company have received £1,654,000 in grant aid support to develop a prototype device. This has enabled the company to take a lab based concept to a full-scale prototype.

Pelamis consists of three power conversion modules linked by hinged joints to cylindrical sections. The wave induced motion of these joints is resisted by hydraulic rams which pump high pressure oil through hydraulic motors linked to electrical generators. The device is designed to maximise power capture from waves whilst maintaining system reliability and survivability. Without government support PWP would not have been able to develop, or advance, this innovative wave energy concept to its current level.

### Synergies with other Key Technology and Application Areas

- Advanced Materials
- Electronics, Photonics and Electrical Systems (control and monitoring)
- ICT (control and monitoring, data gathering)
- High Value Manufacturing
- Energy Generation and Supply - Oil and Gas

### Market opportunities

- Electricity generation
- Power plant production

### UK capacity and routes to sales

The UK is ideally placed because of its substantial exploitable natural resources. The direction of the prevailing winds and the size of the Atlantic Ocean provide the UK with wave power levels that are among the highest in the world. Wind-generated waves on the ocean surface have a total estimated power of 90 million GW worldwide. Wave energy has the potential to provide as much renewable energy as the wind industry, but the development of wave technology is currently at the same level as the wind industry was 10 years ago. The large tidal range along the west coasts of the UK provides some of the most favourable conditions in the world for the utilisation of tidal power. If all reasonable exploitable estuaries were utilised, the annual generation of electricity from tidal power plants could achieve a potential level of 50 TW hours, equivalent to about 15 per cent of current UK electricity consumption.

Regarding UK capacity, the UK has a high concentration of SMEs and early-stage developers with successful world leaders and significant indigenous human capital applicable to the development of marine energy. For both wave energy and tidal stream the UK has more device concepts under development than any other country, and more can be found on UK capacity in the Carbon Trust Future Marine Energy report [17]. There is also growing interest from larger OEMs and utilities in these technologies. The UK also has testing and development facilities, such as the European Marine Energy Centre (EMEC) and NaREC.

Routes to sales include the development of technologies and intellectual property, the integration in the electricity grid, and equipment installation, operation and maintenance. There is some strong academic expertise, concentrated in a few centres (Edinburgh, Southampton, Swansea, Queens Belfast, Lancaster, Exeter, Robert Gordon-Aberdeen, Manchester, Newcastle, Strathclyde, Durham and Plymouth). There is wide UK academic expertise in offshore and electrical engineering, which is crucial to solve the challenges facing the technology [28].

Substantial investments are underway along all stages of the innovation system (by the Carbon Trust, BERR, the RCs and the Technology Strategy Board). A substantial programme of work on marine energy is currently being commissioned by the ETI, aimed at accelerating the uptake of this technology. The programme, in which Technology Strategy Board invests through its contribution to ETI, will consist of substantial projects undertaken by collaborative consortia. Any additional Technology Strategy Board added value is in ensuring that UK businesses are well positioned to take advantage of market opportunities and the innovation system.

| Fit against criteria for investment | |
|---|---|
| UK Capability | High |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | Medium |

## 5.4 Microgeneration

### Overview

Microgeneration is defined as any technology with a capacity below 50kW (electricity) or 45kW (heat). Most domestic installations will be below 3kW, though thermal systems could be larger. It consists of a combination of technologies including: solar (photovoltaics (PV) and water heating), microwind, micro-hydro, heat pumps, biomass, micro-CHP (Combined Heat and Power) and small scale fuel cells.

### TRL and challenges

Most technologies are proven and in the deployment phase. Micro-CHP and small-scale fuel cells are at earlier stages [1]. The challenges relate to:

- Whole systems approach to integrating microgeneration in new buildings and retrofitting existing stock.
- Facilitate how different microgeneration technologies work together.
- Energy storage and integration with electricity and grid supply infrastructure.
- New techniques, processes and approaches that could lead to large reductions in costs and improved efficiencies for PV technologies.
- Advanced PV.

### Synergies with other Key Technology and Application Areas

- Advanced Materials
- High Value Manufacturing
- ICT
- Electronics, Photonics and Electrical Systems

### Market opportunities

- Electricity and heat generation and supply (local, small scale)

### UK capacity and routes to sales

Microgeneration technologies have the potential to be strategically significant, both as an energy supply and as an industrial sector in itself. The market is likely to remain relatively small for the next few years, but expected to increase substantially through drivers such as 2016 zero carbon targets set by the Code for Sustainable Homes. Without a stable UK market it will be difficult for home grown companies to take advantage. In the UK, the industry is mostly characterized by SMEs, although a few of the large energy suppliers are now expanding into this area. The UK has a number of world leading companies in terms of integrating microgeneration solutions in building design [6]. UK companies especially in the retail, leisure, communications, construction, manufacturing and logistics sectors are becoming increasingly involved in on-site renewables, typically in the range of tens of kW to a few MW, offering a potential route to sales.

The UK has R&D strengths in organic PV, an early stage technology. However, there is little manufacturing capacity and the PV supply chain is not well developed, with only a few leading players in some element of the chain. The major route to sales will be through the opportunities in the built environment, stimulated also by the policy driver towards zero carbon homes. UK is also very strong on micro-wind R&D and deployment.

There is a strong academic base specifically related to the integration of microgeneration technologies with the built environment. Some academic centres of expertise are UCL, De Monfort, Heriot-Watt, Bath, Cardiff, Nottingham, Southampton and Strathclyde. Leading academic expertise in PV is in Cambridge, Imperial College, Loughborough, Oxford, Durham, Bath, Bangor and Southampton, mainly tackling materials challenges [28].

Investments by the Carbon Trust, BERR, Technology Strategy Board and the RCs, particularly directed in the built environment, are ongoing and planned throughout the innovation chain. The UK Government's Foresight programme is currently carrying out the Sustainable Energy Management and the Built Environment Project and ETI have just launched a call for Expressions of Interest on Distributed Energy covering the scale micro (single dwellings) to macro (communities).

Microgeneration is highly relevant to the Low Impact Buildings Innovation Platform as the main route to market and technological breakthrough lies in this sector. Addressing the challenges of integrating microgeneration and renewable energy technologies in buildings and buildings developments is within the Low Impact Buildings Innovation Platform remit.

| Fit against criteria for investment | |
|---|---|
| UK Capability | Medium |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | High (through Innovation Platform) |

## 5.5 Hydrogen and fuel cells

### Overview

Hydrogen and fuel cells are traditionally taken in consideration together (for example within the activities supported by the EU Framework Programme, Technology Strategy Board current portfolio etc.), but they can have different R&D challenges and markets.

Fuel cells produce electricity and heat by combining hydrogen and oxygen in an electrochemical process. They are similar to batteries but the fuel and oxidant are stored externally, enabling them to continue operating as long as the chemicals are supplied. In most applications the oxygen is taken directly from air, so that only the fuel has to be stored. All fuel cells run on hydrogen. This can be provided in pure form, or as part of other fuels (natural gas, petrol etc.) The hydrogen is extracted from the fuel through a reforming process, which can take place either within or external to the fuel cell, depending on its type. This means that some fuel cells systems, particularly those for stationary application, can be run on conventional fuels, as well as other fuels such as waste gases.

Hydrogen is an 'energy carrier' rather than a fuel source and, like electricity, it can only be produced using energy [18]. The term "hydrogen energy" covers all aspects of the use of hydrogen in energy systems, from the production of hydrogen from primary or secondary fuels, through the storage and distribution of hydrogen, to the end-use of hydrogen in stationary, transport, and portable applications [28].

Hydrogen can be used in:

- a fuel cell, where it produces zero emissions at the point of use,
- conventional combustion systems (e.g. in an internal combustion engine).

### TRL and challenges

Fuel cells for portable power in, e.g. laptops and mobile phones are at early deployment stage. Other technologies are at the early demonstration phase and further R&D is required to deliver major cost reductions and improved performance [1]. Priorities are:

- The widespread deployment of fuel cells, with particular emphasis on the supply chain.
- More durable and lower cost systems and manufacturing processes for fuel cell systems.
- Improved reliability, efficiency and performance and simplified system design.

In addition to the significant technological and infra-structure challenges related to low carbon hydrogen production, transport and storage, the priorities are:

- The integration of hydrogen storage with automotive fuel cell systems.
- Design, construction and evaluation of efficient, low cost hydrogen production systems suitable for on-site vehicle refuelling.

### Synergies with other Key Technology and Application Areas

- Advanced Materials
- High Value Manufacturing
- ICT
- Electronics, Photonics and Electrical Systems
- Transport

### Market opportunities

- Electricity and heat generation
- Transport
- Portable power

### UK capacity and routes to sales

The UK capacity to develop this technology is small and world class, both in industry and academia. However, there are many UK companies with fuel cell related business, including consultancies, with 50% of their sales consisting of exports. Industrial actors are mostly SMEs with a few large companies. For fuel cells technology, the largest academic centre of expertise is Imperial College. Substantial capacity is also present in St Andrews, Newcastle, Nottingham Glamorgan, Glasgow, East Anglia and Queen Mary. Other academic groups of note in the fuel cell sector are the Universities of Birmingham, Cranfield, Keele, Reading, Southampton, and Warwick, Some leading academic centres in hydrogen-related research are Birmingham, Cambridge, Cardiff, Glamorgan, Imperial College, Queen Mary, UCL, Manchester, Nottingham, Oxford and Loughborough [28]. There are substantial existing investments by the RCs and the Technology Strategy Board, and an EU Joint Technology Initiative is now close to realisation (covering both fuel cells and hydrogen). Interest in the area is increasing in the automotive industry (Honda and Suzuki). Routes to sales include IP development but also in the development of a well integrated supply chain, both for the automotive and CHP markets.

Businesses need Technology Strategy Board investment to share the risks and shorten timescales involved in the development and the eventual deployment of these technologies, in addition to enabling UK strengths to be competitive with countries such as USA, Japan and Germany.

**Hydrogen**

There are a number of UK companies tackling hydrogen-related challenges in areas such as materials, chemistry, process engineering and engineering, with only few large companies with the capability of providing hydrogen solutions. UK capabilities in materials for hydrogen storage are high. UK research in hydrogen storage materials has benefited from involvement in several international programmes funded by the EU Framework Programme and IEA.

Technology Strategy Board investment would play a major role in enabling UK capacity to maintain momentum and continue to take advantage of EU-wide opportunities, building on RCs investments and taking advantage of future demonstration programmes within the ETF.

The industry has also identified a need for a UK hydrogen roadmap from basic research to commercialisation, building on earlier studies [13] and Technology Strategy Board will seek to take this forward.

| Fit against criteria for investment | |
|---|---|
| UK Capability | High |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | High |

## The first UK vehicle project to produce a passenger car powered by a Proton Exchange Membrane (PEM) fuel cell system

Intelligent Energy Holdings plc, an international clean fuel and power systems company with its headquarters in the UK, obtained support from the **Technology Strategy Board** for the project "Advanced Automotive & Motive Power Fuel Cell Engines & Component Development".

This project aimed to engage both vehicle manufacturers and key suppliers of automotive sub-systems and components in the fuel cell system development process such that significant progress could be made towards meeting the cost and performance goals necessary for the commercialisation of the technology in road vehicles.

The funding has been used to help to develop the Intelligent Energy 7 series 10kW automotive PEM fuel cell power system. A 7 series system has been installed in a Peugeot electric car as part of its hybrid powertrain, and is currently under evaluation for potential fleet vehicle applications.

This is the first UK vehicle project to produce a passenger car powered by a PEM fuel cell system which has been developed entirely in the UK. A 50 kW power system has also been developed as a primary power source for automotive applications.

Henri Winand, Intelligent Energy's Chief Executive commented "I would like to thank the Technology Strategy Board, for its assistance in providing funds for this very important project. This work shows that a leading fuel cell power systems company like Intelligent Energy and a major automotive OEM, such as PSA Peugeot Citroën can, with in this case the very welcome support of Government, successfully partner to accelerate the development of reduced or zero emission fuel cell vehicles".

## 5.6 Carbon abatement technologies

### Overview

Fossil-fuel power plants are major contributors to $CO_2$ emissions and the challenge is to substantially reduce their impact on climate change through Carbon Abatement Technologies (CATs). Options include:

- Higher efficiency conversion process to reduce the amount of fuel consumed and the associated $CO_2$ emissions.
- Fuel switching to lower carbon alternatives - such as natural gas and co-firing with biomass.
- Carbon Capture and Storage.

### TRL and challenges [29]

Innovative technologies and system integration techniques will provide a number of challenges in CAT, including CCS. The technical challenges include:

- Improved efficiency of existing and the developing technologies needed to support the extra demands placed upon such equipment operating in increasingly aggressive environments.
- $CO_2$ capture technologies able to handle large volumes of emissions, with improved efficiency and reduced capital and running cost.
- Gasification technologies and newer technologies with the future potential for low to zero emissions.
- $CO_2$ compression and handling technologies for subsequent transport and storage.
- Technologies for the monitoring and verification of geologically stored $CO_2$.
- Technologies associated with the safe transport and storage of $CO_2$.
- Innovative solutions for cost reduction and improved reliability.

### Synergies with other Key Technology and Application Areas

- Advanced Materials
- High Value Manufacturing (equipment)
- Electronics, Photonics and Electrical Systems
- Energy Generation and Supply - oil and gas (enhanced oil recovery)

Market opportunities

- Electricity and heat generation
- Power plant manufacturing

### UK capacity and routes to sales

The UK capacity for carbon abatement technologies leverage on the world class expertise provided by the existing power generating and oil and gas companies and OEMs. These businesses have increasing R&D activities in this area, often in collaboration with the academic base. Substantial investments are ongoing and planned throughout the innovation chain by Technology Strategy Board, RCs and the EU. There is also a large intellectual resource in the oil and gas sector which can be leveraged (for example in $CO_2$ storage, enhanced oil recovery and $CO_2$ pipeline management) and utilities will benefit from a closer relationship with oil and gas companies.

Leading academic research is based at the British Geological Survey centre, Heriot-Watt, Edinburgh, Robert Gordon - Aberdeen, Imperial College, Cardiff, Cranfield and Nottingham [28].

Routes to sale include the design, build and operation of demonstrator plants, Intellectual Properties development and also operation and maintenance activities. Funding for CAT are provided by RCs, Technology Strategy Board and, for the demonstration programmes, by BERR. In the area of CCS a leadership role from ETI might be expected in the future.

The Technology Strategy Board has a clear role in investing in R&D challenges in CAT over the period covered by this strategy, encouraging collaborative approaches and alignment with the demonstration programmes. The timescales involved in R&D are often long and business might benefit from plans for support that have an element of continuity, more at programme level rather than project.

| Fit against criteria for investment | |
|---|---|
| UK Capability | High |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | High |

## 5.7 Intelligent grid integration and management

### Overview

Innovative integration technologies and techniques will be required as new renewable and other generating technologies are developed with operational characteristics quite different from conventional plant. In addition, there will be a need to manage the implications of integrating substantial amounts of variable-output and distributed generation technologies.

### TRL and challenges [3]

- Maximise the utilisation of existing transmission and distribution assets in the face of the increasing deployment of new generating technologies with diverse operating characteristics and profiles.
- Facilitate the timely connection of new generation, while maintaining levels of system security and minimising the impact of constraints.
- Energy storage.
- Minimise the impact of energy losses.
- The management of the impacts of variable output caused by intermittency etc, at a system level, including the application of electrical storage and demand side measures, including 'smart appliances'.
- The cost-effective integration of both onshore and offshore generation technologies, including innovation to permit the delivery of Grid Code requirements in the most cost-effective fashion.
- The cost effective integration of microgeneration technologies.
- Low carbon network equipment, design, management, operation and control, including the development of active management systems and methodology.

### Synergies with other Key Technology and Application Areas

- Advanced Materials
- High Value Manufacturing (equipment)
- Electronics, Photonics and Electrical Systems
- ICT

### Market opportunities

- Electricity supply

### UK capacity and routes to sales

The UK capacity is linked to the capacity in electricity generation from renewables in addition to a strong capacity in the transmission and distribution network. These businesses often collaborate with a very strong academic base. Solutions are often developed by some SMEs and consultancies, with routes to sales varying from intellectual property to licensing (for example in the case of fault control or load management software solutions). There is limited UK capacity in the private sector and not sufficient regulatory incentives to promote the development of these technologies. However, the UK has world leading academic expertise (Electrical Engineering) in universities such as Manchester, Strathclyde, Cardiff, Imperial College and Bath [28]. The market is going to need these key enabling technologies if it is going to successfully respond to the challenge of intermittent renewables, manage (and reduce) demand effectively and provide the additional capacity that will be required if electricity becomes a low carbon vector for the heat and transport markets.

Technology Strategy Board investment in this area has to date been largely policy focussed as it was funded in conjunction with the DTI Emerging Energy Technologies Unit and therefore more consultation on business needs and capacity is required.

| Fit against criteria for investment | |
|---|---|
| UK Capability | Need confirmation |
| Market opportunities | Medium |
| Timeliness & Impact | High |
| Added value | Need confirmation |

## 5.8 Oil and gas technologies

### Overview

Oil and gas will still play an important role in the UK's fuel mix in the short and medium term (Figure 17) and the challenge is to develop technologies to maximise the recovery of UK hydrocarbon reserves and improving environmental performance of Oil and Gas operations. These technologies can come from across the full range of industry operations, such as from enhancing reservoir understanding and development (e.g. 'Geomechanics') through to production enhancing technology areas such as Subsea/subsurface boosting and Subsea/subsurface water control'. The technology may be game changing or offering a significant benefit over the existing approach and innovation is essential as the UK Continental Shelf has much of its remaining reserves locked up in more technically and economically challenging reservoirs. Developing technologies are blocked by the reluctance of bigger players to accept the risk of field trials or early adoption without a track record and because of the inherent costs of trials within the UK Continental Shelf (UKCS), industry past performance for introducing new technologies into the UKCS has not had a good record. Collaboration between operators, service sector (in the oil and gas industry) and developers could overcome these barriers. This is where Technology Strategy Board can provide added value. This technology, developed for the harsh UKCS environment, where reserves are difficult to exploit, has potential route to sales into other oil and gas fields as they are increasingly exploited, and therefore the resources more difficult to access.

### TRL and challenges

The high level technology challenges span from research to field trials and are related to:

- Cost Reduction
- Drilling
- Maximising Resource Recovery, identifying additional and incremental hydrocarbon reserves
- Geophysical Imaging & Reservoirs
- Environmental Challenges
- Production efficiency, accessing reserves cost effectively and sustaining and improving existing production from mature fields

Synergies with other Key Technology and Application Areas

- Advanced Materials
- High Value Manufacturing (equipment)
- ICT (control and condition monitoring)
- Electronics, Photonics and Electrical Systems
- Energy Generation and Supply (CCS, wind, wave and tidal)

Market opportunities

- Electricity generation (gas)
- Portable power (that can be integrated in oil and gas technologies)
- Heat (gas)
- Transport (oil)

### UK capacity and routes to sales

The UK has extensive capabilities and a proven track record in the oil and gas sector, and remains one of the world's top producers of hydrocarbons [3]. As such, domestic supplies play a large part in security of supply and energy provision issues for the UK both now and for many years to come. Oil and gas remains a priority for the Devolved Administration of Scotland and some RDAs in England, and its importance was highlighted in the Energy White Paper. The sector can also take advantage of synergies with the challenges in CCS (as indicated in section 5.6).

There is also considerable strong academic expertise throughout the country with specialist centres in Aberdeen (Robert Gordon and Aberdeen Universities), Central Scotland (eg Heriot-Watt), and in England with Cambridge (along with an associated multitude of spin-out companies) Cranfield and Imperial College, London. There has been a trend over the last few years for international oil and gas companies and major service companies to move R&D centres into the UK (some of these are equivalent in size to oil and gas companies). In addition, many more companies are establishing specialist technology teams in the UK, recognising the part that technology has to play in maximising hydrocarbon recovery and hence revenues and a competitive position for the UK. It must also be recognised that the make-up of operators on the UKCS has shifted significantly from a few large multinational operators to a more diverse pool of small to medium size operators - this shift is likely to continue and increase. These smaller operators rely heavily on working collaboratively to leverage limited R&D budgets and bring new technology to the market through service companies.

As such, there is a clear role for Technology Strategy Board to promote collaborations between smaller players and multinationals to ensure that new technologies are introduced in the market in a timely manner.

Fostering UK capacity will continue to make the UK attractive to multinational businesses for their R&D investments. The Technology Strategy Board has also a role in encouraging collaboration and knowledge transfer between oil and gas companies and the other players involved in CCS.

| Fit against criteria for investment | |
|---|---|
| UK Capability | High |
| Market opportunities | High |
| Timeliness & Impact | High |
| Added value | High |

## 5.9 Nuclear

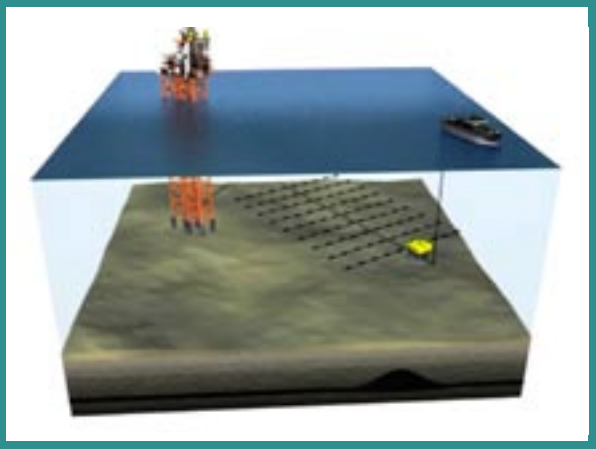
Nuclear power has the potential to make a significant low carbon contribution to the UK's electricity generation portfolio. Although there is no longer an indigenous UK reactor manufacturer, the UK still retains research expertise in many areas of the nuclear fuel cycle. This expertise exists within the industrial and academic context. The Technology Strategy Board with the North West Development Agency and other relevant stakeholders will analyse UK nuclear technologies fit to its criteria before considering investment in this area.

# Oil and gas

Listening with light, fibre optic sensors for permanent seismic reservoir monitoring

**Overview**

Today oil companies typically extract about 30% of the hydrocarbons in place in an oil & gas reservoir. Increasingly they are conducting time-lapse seismic surveys over their reservoirs. This technique, known as 4D-4C seismic, has been shown to be highly effective in the management of reservoirs throughout their working life, identifying and accessing additional and incremental hydrocarbon reserves. The uptake of 4D-4C has been hampered by the high cost, poor reliability and difficult and costly deployment of existing electrical systems. This research and development project, led by the recently established company, Stingray Geophysical Limited, in partnership with Atlas Elektronik UK, has provided important work contributing towards the development of a fibre-optic based system Fosar™. This system is expected to offer the potential of a cost effective, more reliable and easier to deploy solution, enabling a more cost effective access to reserves. Its application on producing reservoirs will improve existing production from mature fields, and will be one of the key technologies enabling total recoveries to rise from an average 30% towards 50% and ultimately 60%. The company has attracted considerable funding to support other development work required for the system, including £6.6 million of venture capital.



The Technology Stategy Board funding was instrumental in helping them leverage additional industry funding.

For Stingray, Technology Strategy Board funding has been vital. Chief Executive Officer, Martin Bett states: “The funding has enabled us to stretch our research and development budget to meet the requirements of developing such advanced technology to address the needs of oil and gas companies. Without the funding, the ability to collaborate with our manufacturing partner, Atlas Eletronik UK, would have been limited. Additionally we would not have been able to design and build the full scale system simulator which has delivered us a key competitive advantage in proving the scalability of our system. With this funding support we are able to compete effectively for what will be a multi-billion pound global market.”

Atlas Elektronik UK already has considerable expertise in fibre optic technology. Managing Director Bob Waters states: “The Technology Strategy Board funding has enabled us to collaborate effectively with Stingray which in turn has been instrumental in allowing us to enhance our capability and facility. This will help to secure our position as an internationally recognised expert in this area with resultant benefits to our workforce and business growth in Newport, South Wales. It has helped us to take a pro-active role in advancing technology, in creating a better qualified skill-base and in exploiting our business in the market as part of the Stingray team.”

# 6 Strategy to invest in energy generation and supply

The complexity of the innovation related requirements in energy are such that no single organisation can realistically take responsibility for all the elements of the innovation chain (Figure 4), and co-ordination and co-operation are crucial to the effectiveness of the system.

The Technology Strategy Board is distinctive as the fully public funded body driving innovation for wealth creation and capable of supporting challenges, specific technologies, people and networks. It can deliver programmes through complementary mechanisms which are inclusive of micro-companies, SMEs, Universities and large businesses.

Investments through collaborative mechanisms specifically encourage increased private R&D investments and can be undertaken in collaboration with other funding bodies such as RCs and RDA/DAs.

In addition to investing in the Energy Generation and Supply KAA, the Technology Strategy Board is also unique in its ability to leverage the knowledge and the networks supported in all the other technologies that underpin energy.

The Technology Strategy Board therefore has a leading role in investing in R&D for innovative energy generation and supply technologies and knowledge transfer activities through people and networks.

These technologies and activities must be prioritised according to its criteria for support, so that technology-enabled businesses sustain or attain global significance.

The Technology Strategy Board will collaborate with partners along the innovation system such as ETI, BERR, Carbon Trust, RCs, RDAs and DAs to stimulate UK innovation, ensure complementarity, and avoid both duplication and technology gaps.

This section identifies the current status, aspirations for the next three years and a strategy to realise these aspirations for investment in technology, people and networks and working strategically with ETI, RCs, Carbon Trust, RDAs, DAs and ETF.

## 6.1 Investment in challenges and technologies

Focusing on the key challenges of tackling climate change and ensuring secure, clean and affordable energy, the energy sector offers substantial market opportunities. The Technology Strategy Board aims to stimulate novel opportunities and address new challenges as identified with business in large and small scale electricity generation and supply, fuels for heat and transport and portable power markets.

The Technology Strategy Board has historically invested (in conjunction with the DTI Emerging Energy Technologies Unit) in a broad range of technologies to address these challenges, potentially diluting effective funding. The establishment of the ETI and the ETF means it is appropriate and timely to review this portfolio.

We have prioritised technologies for intervention over 2008-2011. Priorities are based on the current status, funding landscape and according to the fit with criteria for investment of the technologies discussed in Section 5

### Offshore wind

Whilst there are still a number of technology challenges in this area, mainly associated with reducing the cost and improving reliability of offshore turbines, the main driver is the need for rapid deployment on a large scale. A substantial programme of work on offshore wind is currently being commissioned jointly by the ETI and Carbon Trust, aiming at accelerating the uptake of this technology. We do not consider that additional investment over and above our contribution to ETI can provide any additional value and therefore we do not propose additional effort in this area at this stage. **Key conclusion:- We will invest in this area through ETI (working with Carbon Trust) programmes and help to ensure appropriate engagement of UK business. This technology can leverage capacity from other KTAs.**

### Bioenergy

At this stage there is insufficient evidence of a strong and innovative UK capacity across the whole area that would benefit from Technology Strategy Board investment, although there might be some opportunities in biofuels, combustion and conversion technologies. The diversity in the technologies and related UK capacity within Bioenergy means that a more focussed analysis, in collaboration with stakeholders, is required to better understand whether specific technologies would fit to the criteria for investment.

The Bioscience KTA has identified the following technologies as priorities:

- Second and third generation biofuels, biocatalysis and bioprocessing.
- Biorefinery plant design, modelling, value chain analysis.
- Sustainable processes.

Biofuels technology is highly relevant to the Low Carbon Vehicle Innovation Platform as there is a need to make sure that the transport sector is ready to accept those fuels by way of powertrain and infrastructure development. Initially we will work on a joint effort to instigate a study into the state of play in the UK and to identify where there are opportunities for the UK to develop sustainable fuel stock with support from the transport sector to ensure that fuel is developed alongside vehicle and infrastructure development. We will revisit this position in 08/09, after a consultation with UK businesses and trade associations. **Key conclusion:- Carry out more detailed review of the sector in 2008, in particular in biofuels working with the Low Carbon Vehicles Innovation Platform and the Bioscience KTA.**

## Wave and tidal

Development of this very immature technology is undertaken predominantly by world leading small and medium sized businesses. Their needs are mostly to be supported through the development of the technology to a stage at which private funding can be attracted to enable deployment and commercialisation. The SMEs' focus on intellectual property exploitation and retention to realise profits, could create a barrier to working collaboratively. A substantial programme of work on marine energy is currently being commissioned by the ETI, aimed at accelerating the uptake of this technology. We will work with ETI and other stakeholders to maximise the engagement of innovative SMEs and promote their opportunities for effective deployment and commercialisation. **Key conclusion:- We will invest in this area through the ETI programme and ensure that UK businesses are well positioned. This technology can leverage capacity from other KTAs.**

## Microgeneration

Development of this technology will have the greatest impact in the built environment, where the UK has significant strengths. Traditionally, the built environment and the microgeneration technology developers have not undertaken an integrated and co-ordinated approach, which is crucial to ensure that the Zero Carbon Homes aspiration is achieved. Policy and regulatory environment provide a unique opportunity for supporting such an integrated approach through the Innovation Platform on Low Impact Buildings and the Energy Technologies Institute's Distributed Energy Programme. **Key conclusion:- We will invest in Microgeneration technologies for buildings and building developments within the remit of the Low Impact Buildings Innovation Platform and also through the ETI.**

## Hydrogen and fuel cells

The UK has some world leading players in this area. Currently UK businesses are supported through the Technology Strategy Board, the Carbon Trust and through EU activities. Businesses need Technology Strategy Board investment to share the risks and shorten timescales involved in the development and the eventual deployment of these technologies. The Technology Strategy Board will continue its investment , working with other funding partners (such as the Carbon Trust). In addition, we aim to understand better the European and International funding landscape and explore the potential for supporting UK business in international collaboration that might enable them to maintain their leading position. We will work with relevant partners to update technology roadmaps for this area. **Key conclusion:- Continued Technology Strategy Board investment as appropriate. This technology can leverage capacity from other KTAs.**

## Carbon abatement technologies

The UK businesses involved in innovative carbon abatement technologies are mainly large organisations, involved in large scale power generation and supply markets (power generators, suppliers and original equipment manufacturers). In addition to providing clean energy, business needs are mostly driven by reducing costs and timescales to market. These industries can be technology users or providers, or in some instances, both. Often they have the capability to develop technologies in-house and successfully exploit their intellectual property, and also to work in collaborations, where the costs involved in technology development are high.

There are R&D activities in CAT supported by the RCs and Technology Strategy Board. Major national and international demonstration programmes have been announced and future R&D needs will be linked to the delivery of the demonstration work. The timescales involved in R&D are often long and business might benefit from plans for support that have an element of continuity, more at programme level rather than project, and that are clearly set out over a longer timeframe. The scale of the investment involved suggests that a consortia approach might be best suited, and in the area of Carbon Capture and Storage a leadership role from ETI might be expected in the future. However, over the period covered by this strategy, we will support this area. **Key conclusion:- Continued investment from Technology Strategy Board as appropriate, and working with the other stakeholders in the innovation system. This technology can leverage capacity from other KTAs**

## Intelligent grid integration and management

Although there are substantial technological challenges, at this stage there is no clear route to sales. Priorities in past Technology Strategy Board calls in this area (in conjunction with DTI Emerging Energy Tecnologies Unit) were largely policy focussed and more consultation on business needs is required. In addition, current policy incentives are insufficient to drive innovation. Most of the R&D incentives to business come through the Ofgem Innovation Funding Incentive (IFI). However this confines expenditure to network related assets and to research that will lead to practical demonstration for the benefit of electricity consumers. With a number of major long term projects committed, the focus is shifting towards shorter term demonstration that can produce immediate, quantifiable benefits.
**Key conclusion:- Review the whole area of transmission, distribution and grid management in 08/09, in consultation with business, BERR, regulatory bodies (Ofgem), trade associations and RCs.**

## Oil and gas

It is important that promising technologies are supported through the very high-risk field trial stage to ensure that technologies are moved quickly, with due process, from concept through to implementation and contribution in the field. Failure to do so will mean that small companies will not have the support to develop essential next generation technology and significant UK wealth generation opportunity will be lost. It must also be recognised that the make-up of operators on the UKCS has shifted significantly from a few large multinational operators to a more diverse pool of small to medium size operators) - this shift is likely to continue and increase. These smaller operators rely heavily on working collaboratively to leverage R&D budgets and share risks with the oil and gas service community in bringing new technologies to the marketplace. This must also be viewed in the context that the UKCS has much of its remaining reserves locked up in more technically and economically challenging reservoirs and 'compartments' of reservoirs. As such, there is a clear role for Technology Strategy Board to promote collaborations between smaller players and multinationals to ensure that the right technologies are developed and introduced in the market at the right time, and used on the UKCS to recover as much of the remaining reserves as possible. In addition, fostering UK capacity will continue to make the UK attractive to multinational businesses for their R&D investments. The Technology Strategy Board has also a role in encouraging collaboration and knowledge transfer between oil and gas companies and players involved in CCS. There is an opportunity here to work in collaboration with RDAs and Devolved Administration.
**Key conclusion:- Invest in this area and explore potential partnerships with RDAs and Devolved Administration.**

## Nuclear

Nuclear power has the potential to make a significant low carbon contribution to the UK's electricity generation portfolio. Although there is no longer an indigenous UK reactor manufacturer, the UK still retains research expertise in many areas of the nuclear fuel cycle. This expertise exists within the industrial and academic context. The Technology Strategy Board with the North West Development Agency and other partners will analyse UK nuclear technologies fit to its criteria before considering investment in this area.
**Key conclusion:- Assess fit of this technology to Technology Strategy Board criteria in partnership with relevant stakeholders.**

**Table 2 summarises the areas in which Technology Strategy Board is best placed to lead in the next three years, where there are opportunities for collaboration and where other partners are better placed to lead.**

| Technology solutions to Energy Generation and Supply | Fit to Technology Strategy Board criteria* | Technology Strategy Board lead | Collaborate |
|---|---|---|---|
| **Offshore wind** | 1 Medium<br>2 High<br>3 High<br>4 Low | | √ (ETI) |
| **Wave and tidal** | 1 High<br>2 High<br>3 High<br>4 Medium | Ensure that UK businesses are well positioned | √ (ETI) |
| **CAT** | 1 High<br>2 High<br>3 High<br>4 High | √ | √ (e.g. ETI for CCS) |
| **Bioenergy (in the context of energy generation and supply)** | 1 requires confirmation<br>2 High<br>3 High<br>4 requires confirmation | Through Low Carbon Vehicles IP and Bioscience KTA | |
| **Microgeneration (in the context of the built environment)** | 1 Medium<br>2 High<br>3 High<br>4 High | Through Low Impact buildings IP | √ (e.g. ETI, Carbon Trust) |
| **Intelligent grid** | 1 requires confirmation<br>2 Medium<br>3 High<br>4 requires confirmation | Requires confirmation | |
| **Oil and Gas** | 1 High<br>2 High<br>3 High<br>4 High | √ | √ (e.g. EEDA, Scottish Enterprise) |
| **Hydrogen and Fuel Cells** | 1 High<br>2 High<br>3 High<br>4 High | √ | √ (e.g. Carbon Trust) |
| **Nuclear** | Analysis of fit against Technology Strategy Board criteria required | With North West RDA and others | |

Table 2: Summary of priorities for energy generation and supply technologies.
*The areas in which Technology Strategy Board will focus must fulfil its criteria:
1 - Does the UK have the capability?
2 - Is there a large market opportunity?
3 - Is the idea ready?
4 - Can the Technology Strategy Board make a difference?

## 6.2 People

Following a period of relatively low investment and cost cutting through the 1990's, increased public and private investments in energy are driving the need for skilled people. Employers are also attempting to address the issues of fragmentation, isolated pockets of expertise, skills gaps and skills shortages. In addition, the sector faces a demographic challenge. Replacing the skills, expertise and know-how is a major challenge and, often, current levels of recruitment and training (for apprentices and graduates) are inadequate. The industry has responded by developing the National Skills Academies for Nuclear and for the Process Industries, while the oil & gas and electricity sectors are developing alternative, but comparable strategies. Working through the Sector Skills Council, the gas industry secured Ofgem's agreement to £72 million for apprentice training in the latest Price Control Review. Emerging technologies and renewables are fragmented and have no comparable strategies. Going forward, they will face competition from sectors with strong labour market buying power. The Sector Skills Council, Energy & Utility Skills, is coordinating the network's approach to renewables and new energy technologies. The large number of individuals and businesses involved, many of whom have only occasional involvement (e.g. installations in the built environment), constitutes a barrier to progress.

The RCs are providing increased investment through post-graduate training, sometimes in partnership with business or innovative mechanisms such as Science and Innovation Awards. There are some good examples of flow of people between business and academe within specific technologies (e.g. clean fossil). However, this is mostly based on individual relationships and takes place on a project by project basis rather than in any strategic way. SMEs have indicated a need for training in cutting edge, new technologies (especially renewable and sustainable technologies such as fuel cells and carbon abatement).

The Technology Strategy Board has invested in a small and fragmented number of KTPs; 7 in oil and gas and 25 in Low carbon energy technologies. This is felt to be insufficient, given the current market trends.

The ERP has undertaken an investigation into high-level skills shortages in the energy sector with the key findings that technical skills shortages are causing recruitment problems in this sector, with a shrinking pool of graduates and organisations looking abroad for skilled resource.

The energy sector is buoyant now, and there is a need to ensure that there are sufficient skills to enable the UK to take advantage of this positive outlook. There is also an opportunity to capitalise on the RCs' investments. We are in the unique position in the innovation system to be able to encourage the flow of people and ideas, to stimulate a more innovative approach to energy technologies by:

- Leveraging on centres of expertise in energy technologies supported by the RCs (e.g. SUPERGEN and TSEC consortia) in order to provide training to businesses.
- Invest in energy relevant Knowledge Transfer Partnerships and provide a focus to consolidate existing KTPs in the priority areas indicated.
- Explore possibilities for international KTPs, either business to business or science to business, with flow of knowledge and people between UK leading players and international leaders in the same priority areas.

## 6.3 Networks

The Technology Strategy Board has the unique position in the innovation system of providing support to knowledge transfer through networks. The current Technology Strategy Board investment in Knowledge Transfer Networks – which does not currently include a KTN in energy is under review. However almost every KTN currently supported has an interest in the broader energy area, including generation and supply:

In addition to the Technology Strategy Board funded networks, and a number of smaller, local university based networks focussed on specific energy technologies, there are several other national networks in the energy space. Some examples are UKERC, the Energy Institute and the ERP. UKERC has strong academic focus. This is a relatively new body, set up in 2004, and although knowledge transfer activities are within their remit, their effort has been focussed on other priorities. The Energy Institute is professional body, with major focus on education and training. The ERP is not a network as such, rather a high level forum, bringing together private and public sector stakeholders in UK.

The Technology Strategy Board objectives of driving knowledge exchange in the business communities, and informing Government of key technology needs to help shape our future programme, are not currently being addressed adequately through existing structures.

The energy innovation landscape is diverse and crowded, and introducing a Knowledge Transfer Network might just add to the complexity and not realise the benefits expected from a KTN.

Rather than introducing a new network, we propose to build on existing structures and focus on the investment in the co-ordination of knowledge transfer activities.

| KTN | Area |
|---|---|
| Resource efficiency & Environmental Services | Energy efficiency, demand management, energy from waste, bioenergy |
| Low carbon and fuel cell technologies | Fuel cells, biofuels |
| Bioprocess UK and Bioscience for business | Bioenergy, demand reduction for processes |
| Modern built environment | Energy efficiency, microgeneration |
| Electronics, Integrated Products Manufacturing, Photonics, UK display and lighting, Sensors | Energy efficiency, power systems and control, sensors |
| Materials, Micro and Nanotechnology | Materials for energy |

This might be in the form of resources for knowledge transfer co-ordinators attached to an existing network/s that should have:

- Sufficiently broad technical coverage.
- An existing high visibility and leadership, including engagement with FP7.
- An existing infrastructure (e.g. physical office, IT, including web, dissemination vehicles).
- Ability to gain clear quantifiable benefits in undertaking knowledge transfer activities.

We will scope in more detail the requirements in consultation with partners and the business community.

## 6.4 Engagement with stakeholders

We will improve our engagement with businesses in the energy generation and supply sector by developing more effective and inclusive dialogue, building on existing fora. In particular, we will seek to develop a consultation process that would enable us to engage the advice of the diverse spectrum of business involved in energy generation and supply technologies.

## 6.5 Summary

Through the Energy Generation and Supply KTA the Technology Strategy Board will:

- Directly invest in carbon abatement, fuel cells, hydrogen and oil and gas technologies working with partners.
- Invest in offshore wind and wave and tidal technologies through our contribution to the Energy Technologies Institute, ensuring that UK businesses are well positioned.
- Working with partners, undertake analysis of UK capacity and Technology Strategy Board added value in the other technologies that can contribute to achieving UK policy targets for both energy and wealth creation.
- Work in collaboration with other KTAs and Innovation Platforms to identify, invest and deliver additionality into the Energy Generation and Supply innovation chain
- Invest in knowledge transfer through people and network co-ordination activities.
- Improve engagement with partners.

# 7. References & acronyms

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## Acronyms

| | |
|---|---|
| **BBSRC** | Biotechnology and Biological Sciences Research Council |
| **BERR** | Department for Business, Enterprise and Regulatory Reform |
| **CAT** | Carbon Abatement Technologies |
| **CCS** | Carbon Capture and Storage |
| **CHP** | Combined Heat and Power |
| **CR&D** | Collaborative R&D |
| **DA** | Devolved Administration |
| **DCLG** | Department for Communities and Local Government |
| **Defra** | Department for Environment, Food and Rural Affairs |
| **DfID** | Department for International Development |
| **DfT** | Department for Transport |
| **DIUS** | Department for Innovation, Universities and Skills |
| **EMEC** | European Marine Energy Centre |
| **EPSRC** | Engineering and Physical Sciences Research Council |
| **ERP** | Energy Research Partnership |
| **EST** | Energy Saving Trust |
| **ETF** | Environmental Transformation Fund |
| **ETI** | Energy Technologies Institute |
| **IEA** | International Energy Agency |
| **IFI** | Innovation Funding Incentive |
| **ITF** | Industrial Technology Facilitator |
| **KAA** | Key Application Area |
| **KTA** | Key Technology Area |
| **KTN** | Knowledge Transfer Network |
| **KTP** | Knowledge Transfer Partnership |
| **NaREC** | New and Renewable Energy Centre |
| **OCC** | Office for Climate Change |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OEM** | Original Equipment Manufacturer |
| **PV** | Photovoltaic |
| **RC** | Research Councils |
| **RDA** | Regional Development Agency |
| **RDD&D** | Research, Development, Demonstration and Deployment |
| **RO** | Renewables Obligations |
| **SME** | Small and Medium Enterprise |
| **TRL** | Technology readiness level |
| **TSEC** | Towards a sustainable energy economy |
| **UKCS** | UK Continental Shelf |
| **UKERC** | UK Energy Research Centre |

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