



UKERC

UK ENERGY RESEARCH CENTRE

Response to the Government's Energy Review consultation

April 2006

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THE UK ENERGY RESEARCH CENTRE

The UK Energy Research Centre (UKERC) was established in 2004 following a recommendation from the 2002 review of energy initiated by Sir David King, the UK Government's Chief Scientific Advisor.

The UK Energy Research Centre's mission is to be the UK's pre-eminent centre of research, and source of authoritative information and leadership, on sustainable energy systems.

UKERC undertakes world-class research addressing the whole-systems aspects of energy supply and use while developing and maintaining the means to enable cohesive research in energy.

To achieve this we are establishing a comprehensive database of energy research, development and demonstration competences in the UK. We will also act as the portal for the UK energy research community to and from both UK stakeholders and the international energy research community.

We are funded by three research councils: the Engineering and Physical Sciences Research Council (EPSRC), the Natural Environment Research Council (NERC) and the Economic and Social Research Council (ESRC).

For more detail, go to www.ukerc.ac.uk

Introduction

The UK Energy Research Centre welcomes this opportunity to provide input to Government's Energy Review. We have addressed each of the questions posed in the consultation document calling on all UKERC members for input¹.

Key cross-cutting points:

- UKERC would urge the Government to consider energy as a whole – heat, electricity and transport – and not just electricity. Issues such as nuclear power generation, though important, should remain part of a wider discussion. Although we were repeatedly drawn towards the electricity sector in considering the questions posed, we believe this point cannot be over-stated
- The UK's energy policy goals, especially the long-term CO₂ target, are ambitious. We do not believe this target is achievable unless a more radical approach to energy policy is adopted. This would involve concerted action between a wider range of departments and bodies than currently share the Public Service Agreement target on CO₂
- Stable, long-term policy frameworks are essential in inspiring investor confidence. The long-term 60% emissions reduction target, for example, could be usefully supplemented by interim targets aligned with the investment planning timescales of energy companies. Such targets should be backed with policies which provide assurance to businesses looking to develop longer-term business plans in the understanding that targets will be met. The extension of the Renewables Obligation to 2015, for example, proved helpful in this respect
- Greater progress will be achieved by building on existing policies; constantly introducing new measures will undermine investor confidence. This does not mean that policies should be set in stone, but innovation and continuity must be balanced
- Long-term goals should be supported with a consistent level of research, development and demonstration investment directed at addressing knowledge gaps and resolving obstacles in the way of achieving energy goals. We have identified these needs where possible. We would make a general call for more research investment specifically to support large-scale development and deployment
- Innovation (see Annex A) is key to both meeting long-term goals and in helping to reconcile competing objectives. As well as RD&D, policies based on a firm understanding of innovation processes are needed to create, develop, commercialise and encourage the market to adopt low carbon technologies

¹ The document was prepared through inputs from and consultations with as wide a range of individuals associated with the Centre as possible. However, the views expressed have been arrived at through discussions with a core group of individuals charged with preparing the response. We do not expect, nor do we think it desirable, that everyone associated with UKERC would agree with every statement.

Contents

Question 1	3
Question 2	10
Question 3	12
Question 4	15
Question 5	18
Question i	20
Question ii	22
Question iii	24
Question iv	26
Annex A	29
Annex B	33

QUESTION 1: What more could the government do on the demand or supply side for energy to ensure that the UK's long-term goal of reducing carbon emissions is met?

Long-term targets will not be met without strenuous efforts on both the supply and demand side. Up to 2020 or so, reduction of energy demand will be the primary means to reductions in carbon emissions and should thus be the foundation of policy. We address energy demand in the second half of the response to this question.

In the longer term there are many opportunities on the supply side. A mix of technologies will need to be deployed. Fossil fuels will play a major role in the energy mix for decades to come and it is apparent that cleaner use of fossil fuels (clean coal, carbon capture and storage (CCS)) must make a contribution to emissions reduction. Nuclear fission, renewable energy (off-shore wind, solar PV, marine, bio-energy) and, much further ahead, nuclear fusion are all options for the future.

As nuclear fission, clean coal, CCS, and bio-energy are treated explicitly in responses to Q3, Q4, and iv respectively, this part of our response deals with the remaining issues of renewable and micro-generation technologies.

RENEWABLE ENERGY: KEY POINTS

- A mixed portfolio of renewable technologies is needed to reach long-term goals while mitigating variability and matching demand for electricity with supply
- Market stimulation, over and above the reflection of renewable's low or zero carbon properties in the market, is warranted. The detailed design of such measures, whether ROCs or feed-in tariffs, is critical
- The Renewable Obligation should be differentiated so that technologies that are further from market viability are given greater support
- There is a continuing need for research, development and demonstration activity in solar PV, marine energy and wind system monitoring and maintenance

The UK has abundant wind, wave and tidal resources available; its mild climate lends itself to bio-energy production, and solar radiation levels are sufficient to sustain a viable solar industry in the medium (2020) to longer term (2050). If renewables are to make a significant contribution to meeting long-term carbon targets, Government needs to significantly increase its efforts to speed up technology development and deployment.

Recent work by UKERC shows that the intermittent nature of renewable generation is no barrier to reliable electricity supply, as long as a sufficient capacity margin is maintained and sources are geographically dispersed. We recommend that policies aim to secure a mixed portfolio of renewable technologies in order to increase complementarity, mitigate variability and increase the match with demand for electricity.¹ The Government should set clear targets for total renewable energy supply (separately for heat and electricity) from 2020 up to 2050, and create credible and realisable delivery mechanisms that are stable and predictable by the market.

Market Stimulation

The cost of renewable technologies can be reduced through learning effects (see Annex A). This suggests that market stimulation, over and above the reflection of their low or zero carbon properties in the market, is warranted. The renewable obligation system currently provides this stimulus.

There has been debate as to whether feed-in tariffs are more effective than obligation systems, in that they provide greater certainty for investors². The detailed design of market pull measures, such as feed-in tariffs and ROCs, is critical. The renewable obligation is an un-banded mechanism which has no contractual requirements between supplier and generator, beyond the obligation itself on the supplier. This means that it is a riskier mechanism from the point of view of investment than the renewable portfolio standard (RPS) mechanisms that have been developed in the United States. These tend to have a set contract life and/or a set price to be paid for differing renewable electricity.

Since different technologies are at different states of development, we recommend that the Renewable Obligation is differentiated in some way so that technologies that are further from market viability are given greater support. The concept of "multiple ROCs" for certain technologies has been proposed and this is one option to consider. We would also recommend that the Renewables Obligation is developed to reduce the risk of investment. This would help secure a more diverse renewables portfolio and a broader range of investors.

Planning and Market Access

The rate of installation of all types of generating plant can be constrained by the planning process. Installation can be held up unnecessarily if planning officers and councillors are unfamiliar with the technology. Government and the RDAs could help by setting up appropriate training schemes. Current Planning Policy Statements should be expanded to include the new renewables, specifically biomass, wave and tidal current.

Access to the electricity network is critical. The present system of connection charging and incentives for infrastructure investment partly explains why the proportion of electricity from renewables is lower in the UK than in other European countries. Speeding up the move towards "shallow" charging would reduce uncertainties for developers. We recommend that Ofgem and the Government give further consideration to this issue, and support current measures to develop means for connection and export at low voltage levels which will encourage all domestic generation options.

¹ "Matching Renewable Electricity Generation with Demand", Scottish Executive, 2006

² The Support for Electricity from Renewable Energy Sources, COM (2005) 627, 7 December 2005

The remainder of this section addresses issues that are specific to individual technologies. A more detailed assessment of individual technologies can be found in Annex B.

Wind: Wind is a mature technology, and further RD&D to reduce costs by scaling up of the technology to 5MW and beyond, as proposed, may be expected to be initiated by the manufacturers. Engineering challenges of siting offshore turbines at increasing water depths, farther offshore, together with improved use of condition monitoring for predictive maintenance are key issues for operators. Support for continued development of technology in these areas will help meet policy aims and potentially provide an exploitable knowledge base.

Solar Photovoltaics: RD&D is needed to make PV competitive for bulk electricity generation as well as grid-remote applications. For the medium-term, the further development of thin film technologies allied to bulk manufacturing technologies could allow significant deployment on roofs/facades. By 2050, developments in the nano-engineering of materials could lead to advanced low cost PV technologies. The UK with its excellent materials science base should be more engaged with the international research community. A significant scaling up of R&D funding in the UK would be required to enable this.

Marine Energy: This remains at a pre-commercial stage with a need to improve costs, reliability and durability of equipment, so continued RD&D support in these areas is important.

Bioenergy: Bio-energy is considered in the response to question iv.

Micro-generation: Domestic CHP and building integrated renewables face considerable cost barriers at the current stage of commercial exploitation. While technology developments will potentially effect cost reduction, this is most likely to arise from increased numbers installed, so emphasis should be on market-pull measures. Micro-generation is also considered in our reply to Question i.

Other issues: Further research is needed to assess the effects of climate change on renewable energy fluxes.

ENERGY DEMAND: KEY POINTS

- Reaching the UK’s long-term targets for CO₂ emissions means making major changes to the way we use energy
- Ambitious cuts in carbon emissions are inconceivable unless patterns of individual behaviour change
- A suite of measures, framed by a bold, coherent, unified and long-term approach, is needed. These could include standards, fiscal instruments and regulation
- More radical measures, such as personal carbon allowances, need to be investigated alongside traditional approaches
- The EU Emissions Trading Scheme (ETS) and the Climate Change Levy package provide a firm basis for dealing with energy-intensive industry
- Continued progress depends on a high carbon price which in turn implies rigorous allocations of carbon allowances
- More ambitious measures (e.g. Energy Efficiency Commitments or emissions trading) are needed to supplement conventional approaches for dealing with non-energy intensive industry

Individual Energy Use

Carbon emissions associated with individuals’ energy use in houses or transport can be reduced through energy efficiency, fuel switching and changed patterns of behaviour. The figure below shows in what proportions these three factors might contribute to a 60% emissions cut.

Figure 1: Schematic diagram showing relative contribution to achieving 60% carbon savings by 2050

Personal air travel	Personal surface travel	Household energy use
Lower C fuels - ?	Lower C fuels e.g. biofuels, diesel	Lower C fuels e.g. solar water heating, PV, CHP, biofuels, large-scale renewables or nuclear for electricity
Improved energy efficiency e.g. better aircraft, higher loading, switch to rail	Improved energy efficiency e.g. smaller, more efficient cars, car sharing, switch to public transport	Improved energy efficiency e.g. home insulation, efficient heating, lighting etc., replacement of old homes with new efficient ones
Lower mobility e.g. fewer flights, less distance destinations	lower motorised mobility e.g. fewer journeys, shorter distances, switch to bike / walking	lower energy services e.g. less hot water, space heating

The clear message is that ambitious cuts in carbon emissions are inconceivable unless patterns of behaviour change. This is particularly true in the transport sector. This may include flying less and over shorter distances, having smaller homes and driving within the speed limit.

More efficient supply of those energy services is the next biggest contributor to carbon savings overall, and the largest contribution must come from housing. Tighter building regulations have an important role to play alongside implementation of the European Directive on buildings. Enforcement of building regulations has been identified as a problem that should be addressed as soon as possible. For transport, this could mean a combination of high efficiency small engined cars, hybrid cars, biofuels and a significant switch to public transport.

Tough product standards are required as well as the enforcement of existing requirements. The passive consumption of household appliances is a growing problem that needs to be addressed.

Fuel switching includes the use of micro-generation in the home (e.g. heat pumps, combined heat and power (CHP), solar thermal) and to diesel and biofuels for cars.

It is the aim of the European Commission that the EU ETS scheme will be extended to cover aviation and, perhaps, methane in 2008 or soon after. The extension of EU ETS to aviation will start to factor in the cost of carbon but it will be insufficient to curb demand. There may be no, or limited, fuel switching opportunities with aviation, so policies to affect behaviour are paramount.

Inducing behaviour change is particularly difficult and there is no single answer. A suite of measures is required. There is a need to:

- change incentives (taxes, subsidies)
- set facilitating conditions (public transport, recycling)
- set institutional context (rules and regulations)
- address the social context (strong communities)
- establish business practices (energy efficiency commitments for utilities)
- lead by example (public procurement, politicians' behaviour)
- inform and educate

Other sectors would be involved through devolving carbon targets (and additional money) to local authorities, to bring together policy on demolitions, density of new build, standards in planning permission (Merton etc), action on energy islands (Woking and GLA).

Fiscal incentives have a role, particularly in encouraging refurbishment of buildings (e.g. enhanced capital allowances for householders installing micro-generation, stamp duty rebates, green mortgages).

Reaching the Government's ambitious targets for reducing CO2 emissions requires a bold, coherent, unified and long-term approach with long-term targets – e.g. the type of combined housing and energy policy recommended in the '[40% House](#)' Report.

An ambitious step would be to introduce carbon trading for the whole of society through personal carbon allowances (PCAs) for individuals. This could be an example of the overarching framework needed to draw the public in to the challenge of reducing the climate change threat. Further investigation is needed as to whether PCAs are a more certain and equitable way than taxing fuel.

The effect of rising fuel prices may still not trigger higher income users into demand reduction, but will force low-income people (on a fixed income) into greater fuel poverty. Fuel poverty is addressed in the response to Question 5.

Business Energy Demand

There has been clear progress in reducing energy demand in the business sector, especially in energy-intensive industry. Evidence from the Energy Efficiency Innovation Review³ and a recent evaluation of the Climate Change Levy⁴ suggests that the current package of measures has been instrumental in reducing industrial energy demand.

Given the importance of giving consistent signals, we broadly support the continued use of the EU Emissions Trading Scheme (ETS) and the Climate Change Levy package as the principal mechanisms for providing incentives to energy-intensive industry. The Climate Change Agreements have been an important factor in promoting change, and we would support the continued use of the Climate Change Levy rebate for those sectors and companies taking on acceptable emission reduction targets under either the EU ETS or other agreements.

We would underline the point that the UK's goals are ambitious and will be realised only if a consistently high price of carbon is established. This can only mean setting ambitious targets under the UK's National Allocation Plan. The current policy package for energy intensive industry is complex and every opportunity should be taken to simplify the current package and, in particular, the interaction between the ETS and the Climate Change Levy. In the longer term, and in concert with EU partners, moving towards auctioning as opposed to grandfathering emission allowances could help to sharpen incentives.

Progress has been slower with non-energy intensive sectors of business. Given the diversity of businesses and lower levels of motivation, a different set of measures, more akin to those employed in the household sector are appropriate.

To accelerate progress, the package here should include: vigorous setting and implementation of the building regulations; effective implementation of the Energy Performance of Buildings Directive; and the extensive use of energy labels and products standards for office appliances.

³ Carbon Trust, UK Climate Change Programme, Potential evolution for business and the public sector, 2005
⁴ Cambridge Econometrics/PSI, Modelling the Initial Effects of the Climate Change Levy, HM Customs and Revenue, 2005

Two more ambitious measures that could secure deeper commitments should be assessed. For SMEs, an extension of the current system of Energy Efficiency Commitments for households is a possibility. For large companies, the possibility of a separate downstream emissions trading scheme linked to corporate environmental reporting could help to raise the priority attached to energy efficiency.

QUESTION 2: With the UK becoming a net energy importer and with big investments to be made over the next twenty years in generating capacity and networks, what further steps, if any, should the Government take to develop our market framework for delivering reliable energy supplies? In particular, we invite views on the implications of increased dependence on gas imports.

KEY POINTS

- Spare capacity and energy storage is necessary to avoid supply interruptions caused either by plant failure or energy supply shortages
- A review of current market arrangements for electricity and gas should be undertaken to assess whether these should be adapted to include capacity payments
- The Government should investigate the need for strategic storage capacity of gas in the UK

It is widely accepted that market arrangements are an effective way to *operate* energy supply systems. However, markets can be designed in different ways. A key issue is how market design and incentive structures can be used to deliver appropriate long-term *development* of energy supply infrastructure, particularly if price volatility and occasional supply interruptions are to be avoided.

In particular, it is unclear how effective current market arrangements are likely to be in valuing and hence delivering

- *Diversity* of energy supplies and infrastructure technologies
- Provision of *spare capacity and energy storage* that will only be called upon occasionally

The effectiveness of the current markets in gas and electrical energy supply to stimulate the development of infrastructure capacity is a well-known question. There are supporters of the present market arrangements and there is an alternative view that without specific capacity payments the markets are unlikely to provide the long-term strategic development of infrastructure that would be desirable for the UK.

However, any capacity payment system raises the challenging question of determining the type and extent of the capacity that should be purchased.

A review of current market arrangements for electricity and gas should be undertaken in order to identify whether changes are needed to ensure reliability and, specifically, whether these could be adapted to include capacity payments. This should include an

assessment of the risks of unintended consequences caused by introducing capacity payments.

The completion of major gas and electricity infrastructure projects can take up to ten years; any market arrangements that seek to stimulate such projects need clarity and stability of the market and regulatory environment

Increased dependence on gas imports raises particular examples of the potential limitations of the market in stimulating the development of a robust energy supply system. Until the recent increases in gas prices, there was a widely held view that future electricity generation would be based on Combined Cycle Gas Turbines supplied from gas. Such developments would lead to reduced diversity of both fuel supply and, depending on the plant used, generation technologies.

Given the decline in UK Continental Shelf gas supplies, the Government should investigate the need for strategic storage capacity of gas in the UK (approx 14 days supply at average winter gas demand, compared to 90 days in France) and how the present market mechanisms could be modified to reward the provision of such capacity. Any modifications should be tested extensively through simulation for unintended consequences.

QUESTION 3: The Energy White Paper left open the option of nuclear new build. Are there particular considerations that should apply to nuclear as the government re-examines the issues bearing on new build, including long-term liabilities and waste management? If so, what are these, and how should the government address them?

KEY POINTS

- The Government should assess ways of eliminating inefficiencies from planning and regulatory processes while maintaining safety standards and retaining public confidence
- Following the outcome of CoRWM's work, clear mechanisms should be developed for assigning and financing the liabilities associated with nuclear waste and decommissioned plant
- Existing incentive mechanisms, such as the Climate Change Levy, should be assessed in light of nuclear power's status as a low carbon technology
- It is likely that additional financial incentives and changes to market arrangements would be needed to encourage new build. A careful assessment of the wider market impacts of these should be undertaken before proceeding with any changes
- the Government should support R&D, nationally and internationally, to develop improved nuclear designs, e.g. Generation IV

The status of nuclear power

New nuclear build could contribute to two of the UK's energy policy goals. If it were to displace fossil fuels, it would contribute to reductions in carbon dioxide emissions and promote supply security by improving diversity and reducing import dependence.

Nuclear power is a mature technology with more than fifty years' history. The performance of the industry has improved in the last 15 years, in terms of both operation and construction. Worldwide, the availability of nuclear plants has improved, partly because plant operators have increasingly been exposed to market disciplines. Focusing on standard reactor designs, coupled with general improvements in the management of large projects has led to shorter construction times. At best (e.g. in Korea), it has taken less than five years to build a nuclear plant based on a proven design. However, any new build in the UK is likely to be based on Generation III designs which are extensions of existing technology.

New nuclear build cannot contribute to the UK electricity mix till towards 2020. This takes account of the time that might be needed to make any modifications to the policy framework, go through regulatory and planning approval and build the plant. Nuclear power cannot therefore be part of the investment programme needed to replace coal-fired plant opted out of the Large Combustion Plant Directive (8,600 MW) and retiring nuclear plant (8,100 MW by 2020).

It is clear that the current market and policy framework is not supportive of new build. No one has so far come forward with proposals.

The key questions for Government are: what changes would need to be made to planning, regulatory and market arrangements to give investors confidence in nuclear power? And, would these changes be consistent with the broader thrust of energy policy, including the commitment to promote competitive markets?

UKERC does not have a position on nuclear power as a technology *per se*. In the following text, we highlight the trade-offs that need to be addressed in arriving at a policy decision about support for nuclear power.

Market Arrangements and Incentives

A long-term capital-intensive technology such as nuclear power will thrive only under stable market conditions. Current volatility in wholesale electricity markets works against nuclear power. It has been argued that capacity payments would encourage investment and provide a better guarantee of supply security. The key issue is whether changed market arrangements based on long-term contracts would compromise benefits that have accrued from market liberalisation. Any changes to market arrangements should also ensure continued incentives to maintain, or improve, the performance of nuclear power.

Nuclear power should be rewarded for the benefits it brings in terms of carbon emissions and supply diversity along with other zero or low-carbon generation technologies. It is arguable, for example, that exemptions to the Climate Change Levy should be extended to nuclear.

The price for carbon established through the EU Emissions Trading Scheme provides weak incentives for nuclear power. However, new build is not likely to take place without stronger incentives, such as those provided by the renewables obligation. Part of the rationale for the renewables obligation is to encourage technologies at earlier stages of development. The issue is whether this type of incentive would be appropriate for a mature technology such as nuclear. Given their very different characteristics, it would not be appropriate for a single certificate scheme to cover both sets of technologies.

Planning and Regulation

The nuclear industry sees the current planning and regulatory approval systems as barriers to new build. It is right to streamline these processes to eliminate inefficiencies. The key is to ensure that modified processes do not compromise safety or undermine public confidence. Type approval for plant designs that are new to the UK is one way of moving forward and merits consideration, as long as safety is not compromised. Any changes to the planning process as applied to nuclear power should take account of the need for due process and should be consistent with the thrust of any wider changes made following the current Barker Review of Land Use Planning.

Back-end Issues

It is extremely desirable that a credible way forward for dealing with nuclear waste arisings is in sight before any decision to facilitate new build is made. The outcome of CoRWM's work is critical in this respect. It is also unlikely that new build will take place unless plant operators are able to pass on liabilities for waste disposal to other bodies. Some form of waste levy system which accumulates sufficient funds to deal with liabilities appears essential.

Long-term Issues

Any nuclear investment in the next 10-15 years would be based on current "Generation III" designs which are refined and improved versions of current plants such as Sizewell B. In the longer term, R&D could deliver markedly different designs. "Generation IV" technology could reduce costs further, increase modularity (reducing size and construction times), enhance passive safety features and reduce waste arisings. The UK should continue to include such R&D in its portfolio.

The possible deployment of advanced fission technologies could overlap with the timescales now being claimed for nuclear fusion. The respective roles of fission and fusion over the longer term should be given consideration. If fusion were to be deployed, more research would be needed into its environmental and social consequences. For example, there is some on-going research on tritium in freshwater habitats, but nothing on terrestrial and marine environments.

QUESTION 4: Are there particular considerations that should apply to carbon abatement and other low-carbon technologies?

KEY POINTS

- The UK is uniquely well-placed to exploit the potentially large global market for carbon capture and storage (CCS)
- CCS should be brought within the scope of the EU Emissions Trading Scheme
- DTI should consider enabling several full-scale demonstration projects, serving different market needs (e.g. retrofit v. new build)
- The option of a “Decarbonised Electricity Certificate” to support early deployment should be considered
- Research is needed to underpin standards applying to CO₂ storage beneath the sea bed

In this response, we focus on carbon capture and storage (CCS).

CCS offers the potential to reconcile the large-scale use of fossil fuels with the reduction of carbon emissions. It is widely expected that fossil fuels will continue to play a major role in the global energy mix for decades to come.⁵

The component technologies of CCS are feasible and well known. The barriers to deployment lie with national and international regulation, the need for robust safety assessment and, especially, the creation of a value chain for industry.

The UK holds a leading technological position with respect to CCS. The North Sea is ideally placed for demonstration projects. Full-scale proposals include the Peterhead-Miller project, retrofit of existing coal plant, and an advanced coal-fired plant in NE England, as well as a number of projects in Norway and Denmark. For a variety of reasons, the next ten years provide a unique window of opportunity to develop CCS in the UK.

Regulatory Framework

To move towards the routine deployment of CCS, early projects will need support. Suitable short and long term frameworks which include regulatory, fiscal and environmental dimensions should be developed to encourage the technology. If not, development will take place outside the UK.

⁵ IEA World Energy Outlook 2005

CCS should be brought within the scope of the EU Emissions Trading Scheme which could play a major role in providing incentives from 2012 onwards. However, because of the long-term nature of CCS projects, investors need to have confidence that carbon abatement will be rewarded as far ahead as 2030. Setting a tight EU emissions cap or guaranteeing a base-price for carbon would encourage early investors.

The Large Combustion Plant Directive will result in a make-over for dirty coal-fired generation by 2015. It provides an opportunity to encourage the retrofitting of existing power plants with carbon-capture ready facilities, or undertaking actual retrofits. With high gas prices, industrial developers believe that such conversions are among the cheapest options for electricity production. Establishing a suitable fiscal and regulatory framework is essential to realise this potential.

One option for encouraging CCS would be a "Decarbonised Electricity Certificate", analogous to Renewable Obligation Certificates. The purpose of such a mechanism would not simply be to reward low or zero carbon generation, but to provide incentives for innovation in technologies at an early stage of their development. We therefore believe that any certificate scheme for CCS should be kept distinct from one applying to renewables (or nuclear) to reflect its different characteristics.

The impacts of any certificate schemes on the operation of electricity markets need careful assessment as renewables, nuclear and CCS are all competing for base-load. However, plant fitted with CCS could in principle operate flexibly giving it an advantage in the market.

Environmental Aspects

Environmental risks associated with CCS include: pipeline fracture and CO₂ escape; leakage from subsurface storage by means of the emplacement borehole; and seepage pathways through fractured and faulted top seal rock.

CO₂ leakage onshore could affect local air quality or even cause asphyxiation in the case of a large-scale release. CO₂ leakage offshore could result in local disturbance and impacts on organisms living on the sea-bed.

The current assessment is that such leakages would have only small environmental impacts - very much less than the consequences of continuing to discharge CO₂ to the atmosphere. More research, development and demonstration, with associated monitoring, is needed to provide the evidence necessary to set standards to allow CO₂ storage beneath the sea bed, whilst the Government is simultaneously working to change international legislation.

Co-firing of biomass with coal is now well established. If CCS is linked to biomass co-firing, then a near-to-zero-emission fossil fuel power plant can be envisaged. However, there appears to be no full life cycle analysis of carbon emissions from coal-fired CCS. We recommend that such an analysis be undertaken which takes account of the implications of land use as well as importing and transporting biomass.

Global market opportunities

If the UK demonstrates CCS at an early stage, we will be in a position to influence developing countries with increasing CO₂ emissions such as China, India and Indonesia.

The global market opportunities include CCS associated with advanced coal and gas combustion technologies and retrofitting existing plant. The DTI should consider enabling several full-scale demonstrations, which serve different market needs in the UK and elsewhere. These could include: gas to hydrogen and pre-combustion capture (e.g. Peterhead); new build integrated gasification combined cycle or oxy-fuel firing (Teesside); and/or the retrofit of post combustion capture at an existing pulverized fuel coal power station.

Strong and unambiguous signals within the next few months, to enable industry decisions to go ahead, are crucial if the UK wishes to maintain its current competitive lead.

Many practitioners of offshore engineering, environment, and geo-science are reaching the end of their careers. To exploit CCS in the long-term, we need increased investment in education and research, at both the higher and further education level.

Longer-term issues

If microgeneration/CHP takes off, then significant quantities of fossil fuels may be burned in small de-centralised systems. We need to explore options for local mid-scale CO₂ storage onshore. We would also need to investigate options for small-scale CO₂ capture.

CCS linked to coal or gas as a fuel source could enable an easy transition to the use of hydrogen as an energy vector.

QUESTION 5: What further steps should be taken towards meeting the government's goals for ensuring that every home is adequately and affordably heated?

KEY POINTS

- Consideration should be given to new policies focusing on energy efficient capital stocks (housing and equipment) rather than on income
- Government should consider establishing an address-specific database, within each local authority, so that the least energy efficient homes are identified
- New, household-specific data will be obtained from the Home Improvement Packs. These could provide the basis for defined standards that landlords and owner-occupiers have to meet before the premises are re-occupied
- UKERC is in support of improved arrangements for networking and co-ordinating research into fuel poverty and equity mechanisms

The response to this question covers all energy use in the home, not just heat.

The recent substantial rise in domestic fuel prices (e.g. gas increased 70% over 2002-6) means that the problem of fuel poverty has got worse: the number of vulnerable households in fuel poverty in England has doubled. If prices continue to rise, the number of fuel poor households will increase further. The only way for a household on a fixed income to respond to a price rise is to use less.

Previous policies achieved major reductions in the fuel poor particularly through lower prices and higher incomes: only 17% of the decline between 1996-2003 came from improved energy efficiency. The houses of the fuel poor still have a low SAP (standard assessment procedure, used to measure efficiency), and are both energy inefficient and carbon intensive.

Consideration should be given to new policies focusing on energy efficient capital stocks (housing and equipment) rather than on income, otherwise the Government will have a recurring and growing expenditure. The necessary level of expenditure is substantially more than at present – how much more will depend upon expected price rises – if the legal obligation to eradicate fuel poverty is to be met by 2016/8.

The present programmes, e.g. Warm Front and EEC, undertake quite similar, low-cost interventions. As a result, they are tackling the homes that are the easiest to reach and identify. The hard-to-identify (e.g. rural) and the hard-to-heat (solid walled, not on gas) are avoided by all groups. Even so, few of those visited are lifted out of fuel poverty.

A new, more comprehensive approach is required. The addition of micro-generation technologies (heat pumps, solar thermal, combined heat and power, etc) are required for future proofing, to protect the residents from the effect of continuing price rises. These are essential with hard-to-heat properties.

Identifying the fuel poor requires information on both the people and the property: it is the combination of low incomes and inefficient homes that causes fuel poverty.

Government should consider establishing an address-specific database, within each local authority, so that the least energy efficient homes are identified. Action on these can be financed through methods appropriate to the income of the occupant.

Better individual house energy auditing is needed (beyond SAP) to cover all energy use in this home, i.e. not just space and water heating, and based on actual consumption, not modelled expectations. The data already gathered for past HECA (Home Energy Conservation Act) reports would form the starting point. The new address-specific database would provide the local authority with the detail to comply with its carbon targets as well as find the fuel poor.

New, household-specific data will be obtained from the Home Improvement Packs. These could provide the basis for defined standards that landlords and owner-occupiers have to meet before the premises are re-occupied. Investment is currently taking place to bring local authority properties up to a 'decent' standard. In energy efficiency terms, this standard is too low and should be raised significantly.

Policies need to focus on moving the poorest people out of the worst houses (and possibly then demolishing them) and on making more affordable, appropriate housing available. New construction should focus on providing more small (in terms of floor area) homes, some in sheltered accommodation, to provide a good choice for elderly people; under-occupation is a contributory cause of fuel poverty. The legacy of an old, inefficient housing stock is inextricably linked to the problem of fuel poverty.

Regulation to reduce the cost of fuel for the poorest consumers would consider the level of the standing charge, tariff tiling and the cost of prepayment meters. Currently, the poorest people pay the highest unit price.

UKERC is in support of improved arrangements for networking and co-ordinating research into fuel poverty and social equity issues in the energy domain. We acknowledge the scoping work the Economic and Social Research Council (ESRC) has commissioned into the development of a Fuel Poverty Research Centre, and look forward to this agenda being taken forward within the framework of the Research Councils Energy Programme.

QUESTION i: The long-term potential of energy efficiency measures in the transport, residential, business and public sectors, and how best to achieve that potential?

KEY POINTS

- The potential to reduce both energy demand and carbon emissions is substantial through the combined effect of energy efficiency and micro-generation
- Energy efficiency products should be promoted through a market transformation approach – a strategic interaction of policies over a 10-15 year period
- Setting tough minimum standards of energy consumption for products by specified dates provides a clear signal for manufacturers and brings forward innovative technology
- Public procurement should be used to demonstrate new technologies and kick-start new markets

The response to this question focuses primarily on household energy efficiency and micro-generation. Behaviour is covered in the response to Question 1. Technical measures alone will not be sufficient to achieve a 60% cut in carbon emissions.

The potential to reduce both energy demand and carbon emissions is substantial through the combined effect of both energy efficiency and micro-generation. This potential would be realised over different time periods, because some technologies are already available. For those technologies that are to be commercial and widely available in the longer term (e.g. beyond 2020), the planning has to start now.

The best way to promote energy efficient products is through a market transformation approach – a strategic interaction of policies over a 10-15 year period.

Setting tough minimum standards of energy consumption for products by specified dates provides a clear signal for manufacturers and brings forward innovative technology. Historically, major improvements in efficiency have been achieved at nil cost (and major benefit) to consumers through clear, relatively tough minimum standards. Many of these products will be purchased anyway as replacements - the objective is to make sure that only efficient equipment is available.

Voluntary agreements with manufacturers appear to be less effective than minimum standards and should only be used on this basis. Voluntary agreements deliver savings more slowly as they are often marginal improvements on expected trends.

Some policies (e.g. labels and standards) are the responsibility of the European Commission, whereas others (e.g. procurement and financial incentives) are up to each individual member state. Most market transformation policy is aimed at individual products.

A scheme giving manufacturers 'permission to manufacture' or requiring them to put an energy label on all equipment before it enters the retail sector, would constrain the production of energy profligate and unnecessary equipment (e.g. patio heaters, plasma TVs, fuel effect fires). This might require EU action on traded goods: there are limitations on the effectiveness of policy if the UK acts unilaterally.

Future product policy should be framed in terms of total consumption (kWh pa) not energy efficiency (kWh / litre or wash cycle). The latter approach, for instance on energy labels, has encouraged the manufacture and purchase of larger equipment, notably fridges.

Many of the technologies required are already in existence and are either on the market or are near to market. The challenge is to get them both fully commercial and widely purchased, e.g. CHP, solar thermal, photovoltaics. Some technologies, for instance light emitting diodes and vacuum insulated panels in refrigeration, need further development to make them commercial, but the technology is known.

There are a few problems, such as solid wall insulation, where new materials could be found to overcome problems with existing solutions (too thick, unsightly). These would require basic research, mainly in the materials sciences.

Most development of new technologies should involve consumer groups and practitioners to ensure users' needs are understood and incorporated. The present debate about smart meters is a clear example.

The UK Government should focus on influential technologies (e.g. micro-generation, lighting) through procurement and financial incentives. Procurement could be a powerful tool for demonstrating new technologies and kick-starting new markets. Government departments, PFI projects and all public housing should be installing the most efficient products, CHP, micro-generation, etc.

New buildings should be built to high standards of energy efficiency and lower carbon impact. This would require the standards in the Building Regulations and conditions in planning permission (e.g. the Merton example of on-site generation) to be brought together, to avoid either corrupting the other. The Government should give clear signals about future levels of Building Regulations so that industry can prepare the correct skills. The Code for Sustainable Buildings should support this process and clearly include micro-generation.

Support for CHP, both at a community level and for individual buildings, would achieve real energy and carbon savings. Present levels of installation are below existing Government and EU targets. A growth in CHP could be fuelled by waste, biomass as well as unwanted heat from power stations.

QUESTION ii: Implications in the medium and long term for the transmission and distribution networks of significant new build in gas and electricity generation infrastructure

KEY POINTS

- Exploitation of wind energy and other investments in generation in the North imply an increase in the North South Transmission capacity
- There may be some reduction in the need for transmission and distribution assets if there is widespread adoption of local generation and/or the introduction of intelligent distribution networks
- Extensive offshore energy networks would be needed to exploit offshore renewable energy resources
- It will be difficult to meet CO2 emission reduction goals following the present philosophy of meeting all loads as they appear

As well as connecting supply with demand, transmission and distribution networks provide essential capability for the operation of energy supply systems through enabling diversity of loads, delivering ancillary services in the case of electricity and storage in the case of gas systems. They are also the physical means through which the energy supply market operates.

Locating supply close to loads will reduce the need for transmission capacity while the location of energy sources remote from the loads will lead to an increase in the requirement for transmission assets. Distribution networks are likely to be needed with almost any possible anticipated new build in gas or electricity generation infrastructure.

In general there is a north-south flow of energy in the UK with electricity generation capacity concentrated in the Midlands and north of England and the major load centres in London and the south-east. There is a similar flow of gas from the terminals at St Fergus in Scotland and Teesside. With the reduction in gas supplies from the UK Continental Shelf it is likely that gas flows from the north will reduce as LNG terminals at the Isle of Grain and Milford Haven are commissioned and additional interconnector capacity brought into service nearer the load centre of the south east.

With a continuation of the existing philosophy of developing and operating the electrical power system, the implications of possible **medium term** future developments include:

- *Exploitation of the renewable energy resource in the North of the UK.* It has been recognised for some time that the exploitation of the wind energy resource in the North of the UK will require an increase in the North South Transmission capacity. Although some work is in progress, depending on the wind generation installed and the pattern of retirement of conventional generating plant, additional North South transmission capacity is likely to be needed
- *Micro-generation.* Wide spread adoption of local generation is likely to lead to a reduction in peak flows in the electricity transmission network and there may be some reduction in the requirement for transmission and distribution assets. Providing domestic MicroCHP does not require increased gas supplies; there will be no change in the requirement for gas distribution assets
- *New large power stations.* New large power stations will obviously require connection to the electricity transmission network and, if gas fired, require connection to the high pressure gas network. Location of new power stations in the North of England will increase North-South flows and hence the requirement for transmission capacity

The present philosophy of the electrical power system was developed more than 50 years ago and is unlikely to be suitable for delivering a low-carbon energy supply system that is implied by a 60% reduction in CO₂ emissions. Hence in the **longer term** future developments include:

- *Intelligent distribution networks* to increase the efficiency with which energy supplies are used and also reduce the requirement for transmission assets. Such systems are likely to be built on integrated information and energy supply networks
- *Extensive offshore energy networks* will be needed to exploit offshore renewable energy resources
- *Integration of loads and energy storage.* The present philosophy of electricity supply is to attempt to meet all loads as they appear. It is likely to be difficult to meet the CO₂ emission reduction goals if this philosophy is maintained

QUESTION iii: Opportunities for more joint working with other countries on our energy policy goals**KEY POINTS**

- The UK should collaborate with other countries, developed and developing, to share knowledge and improve practice on how to plan, prioritise and evaluate the effectiveness of energy research
- The UK should promote and participate in international demonstration projects where possible in order to share knowledge and accelerate deployment, given their high cost
- We recommend exploiting bilateral links effectively and improving the link between domestic research activity and that funded through the European Framework Programmes
- The UK should work with developing countries to assist in human capital-building through scholarship/fellowship arrangements and shorter visits for senior staff

UKERC's insight is greatest in respect of international collaboration on energy research, development and demonstration. This text reflects insights gained from the Workshop on Energy Research and Innovation hosted by UKERC as part of the UK's G8 Presidency in May 2005, coupled with insights gathered from bilateral links.

There is a range of topics on which greater international co-operation, especially between developed and developing countries would be beneficial. These include: fossil-based systems; carbon capture and storage; solar PV; electricity networks; energy storage; bio-energy; built environment; distributed generation; transport; and systems approaches to energy. In the bio-energy field, developing countries may have unique experience from which we could learn.

There is a need to raise awareness of existing international networks, their participants and their activities. An inventory of networks would facilitate better interaction. UKERC may be able to contribute to this activity, building on the "Energy Research Atlas" which it is currently developing.

There would be a benefit in sharing with other countries knowledge about decision tools (e.g., roadmaps, scenarios) for planning and prioritising energy research activities. They would also be benefit in sharing experience of assessing and evaluating the impact of energy research programmes.

Given the high cost of demonstration projects, it would be desirable to pursue international collaboration which would help to share knowledge and accelerate deployment. Acknowledging the practical challenges of siting projects, it would be helpful to develop an improved framework based on existing international partnership programmes.

Bilateral links between the UK and other countries have an important role to play. Now that the EU has 25 Member States, bilateral initiatives such as the recent UK-Italian Workshop on Clean Coal, can help to facilitate and increase the effectiveness of energy research activity within the European Research Area.

The UK should strive to have better linkages and complementarity between research funded in the UK and that supported by the European Framework Programmes. UKERC will be including information on both UK participation in the Framework Programmes and domestic research activity in its Energy Research Atlas. This information will be developed across a range of topics within the energy research domain and should start to provide an evidence base for improving linkages.

Developing human capital is a key need in the UK, but even more so in developing countries. Mechanisms for addressing this were addressed at a recent UK-South Africa energy research workshop organised by EPSRC and the British High Commission. Recognising the limited resources available in developing countries, the UK should consider facilitating collaboration through scholarship/fellowship arrangements and shorter visits for more senior staff. Self-funded collaborative projects are difficult for developing countries. The UK should think systematically about how to involve key developing country players in the European Framework Programmes.

QUESTION iv: Potential measures to help bring forward technologies to replace fossil fuels in transport and heat generation in the medium and long term

KEY POINTS

- There is considerable potential for bio-crops to replace fossil fuels. The key task for Government is to facilitate the co-ordination of different supply chains
- Fundamental bioscience and environmental research can lead to improved feedstocks and more effective conversion and deployment of biomass and liquid biofuels
- The realisation of a hydrogen economy is for the long-term future. Maintaining the option will require RD&D along the supply chain addressing production, storage and utilisation
- A reasonable target for the UK by 2020 is the cultivation of 1 million hectares for bio-crops

Bioenergy

There is considerable potential to use dedicated bioenergy crops and other biomass resources as low carbon sources of heat, power and liquid transport fuels. Up to 20 million tonnes of biomass may be available annually in the UK¹ but much of this is lost as waste. Of the resource that is used, much is used inefficiently, leading to a poor GHG balance.

Biomass for heat and power has been successfully developed elsewhere in Europe. Some parts of the UK have the potential to commercialise this resource using specialised crops for ligno-cellulose such as willow, poplar and miscanthus grass. In the UK, land resource will constrain advances in bioenergy and a portfolio of different crop types should be maintained where multipurpose uses for plants are developed, including food combined with liquid biofuels.

Competition for land between food and energy needs to be resolved; but biofuels can also be imported. Adjustment of land use incentives will be required. Specific targets for 2020 and longer term are required together with incentives calculated to deliver these. A reasonable target for the UK by 2020 is the cultivation of 1 million hectares for bio-crops. This would deliver a few percent of UK energy demand.

The key priority for Government is to facilitate the co-ordination of different supply chains. Several large-scale projects are seeking planning permission but more incentives are needed to induce the significant investment required across the whole supply chain. The

Government should also target public sector buildings for early applications of biofuel CHP alongside best practice in energy efficiency.

RDAs have a crucial role in supporting the development of this sector particularly because of the regional diversity of the bio-resource. Energy from waste cannot be overlooked as a bio-resource. The EU landfill directive is driving in the correct direction but specific guidance to Local Authorities is needed.

Mechanisms must be put in place to deliver the 2010 target of 5% of transport fuel from bio-sources; this may well involve imported biofuels in addition to those produced in the UK.

Bioenergy Research Needs

Currently, the environmental cost of liquid biofuel production is high, since processes are inefficient. Fundamental bioscience research, enabling effective conversion and deployment of liquid biofuels, is needed. This should address improved crop yield, improved degradation of ligno-cellulosic material for second generation biofuels and improved efficiency in the production of biodiesel and bioethanol. More carbon-efficient technologies need to be developed, through increased R&D to deliver the long-term promise of liquid biofuels from biomass (including waste).

Biotechnology has the potential to provide improved feedstocks. Longer term, hydrogen from renewables could be used as a chemical feedstock to upgrade biomass to more useful biofuels (liquid and gas).

Current climate change predictions suggest there will be competition for land-use in the UK beyond 2020 for food and non-food crops. Consideration should be given to the biorefinery concept, where multiple uses are made of biomass crops.

A policy position backed by a strong evidence base needs to be developed to ensure that land in different parts of the UK is used to produce either biofuels or biomass crops. It is unlikely that all land can be used for all purposes. Land owners and managers will need prescriptions for sustainable cropping and environmental regimes. Current policies and advice could be suitably amended. The farming community are interested in future crops.

The Hydrogen Economy

Hydrogen is not an energy source but a secondary fuel acting as a vector for carrying energy. Unlike bioenergy, which has potential applications in the short-medium term, hydrogen could make a significant contribution to the energy economy only in the longer-term future, most probably well beyond 2020.

In principle, the component technologies for a hydrogen system exist. Hydrogen is an industrial gas and can be transported by tanker or pipeline. It can be generated via electrolysis or industrial processes. It can be burned in turbines, internal combustion engines or used as a feedstock for fuel cells. It can be stored under pressure or in liquid form. However, there are currently both thermodynamic and cost barriers to its commercial application.

A future hydrogen economy is in no way guaranteed. However, the prize in terms of reduced carbon dioxide emissions (if generated sustainably) and reduced dependence on imported fossil fuels is considerable. To maintain the hydrogen economy as an option, research, development and demonstration is merited in a number of areas: improved electrolysis; direct production of hydrogen from nuclear fission or fusion; biological production; novel storage approaches including carbon nanotubes and light metal hydrides; improved fuel cell performance in terms of performance, cost and longevity.

Consideration would also need to be given to the development of a hydrogen infrastructure and the role of Government in facilitating this.

Annex A: Understanding Innovation

The goal of reducing the UK's CO₂ emissions by 60% by 2050 will require a radical transformation of energy and transport systems over the medium and long term. This will require innovation in technologies and supporting institutions to bring forward low carbon sources to meet end-use demands for energy and transport services, as well as measures to manage demand and increase the efficiency with which those services are provided.

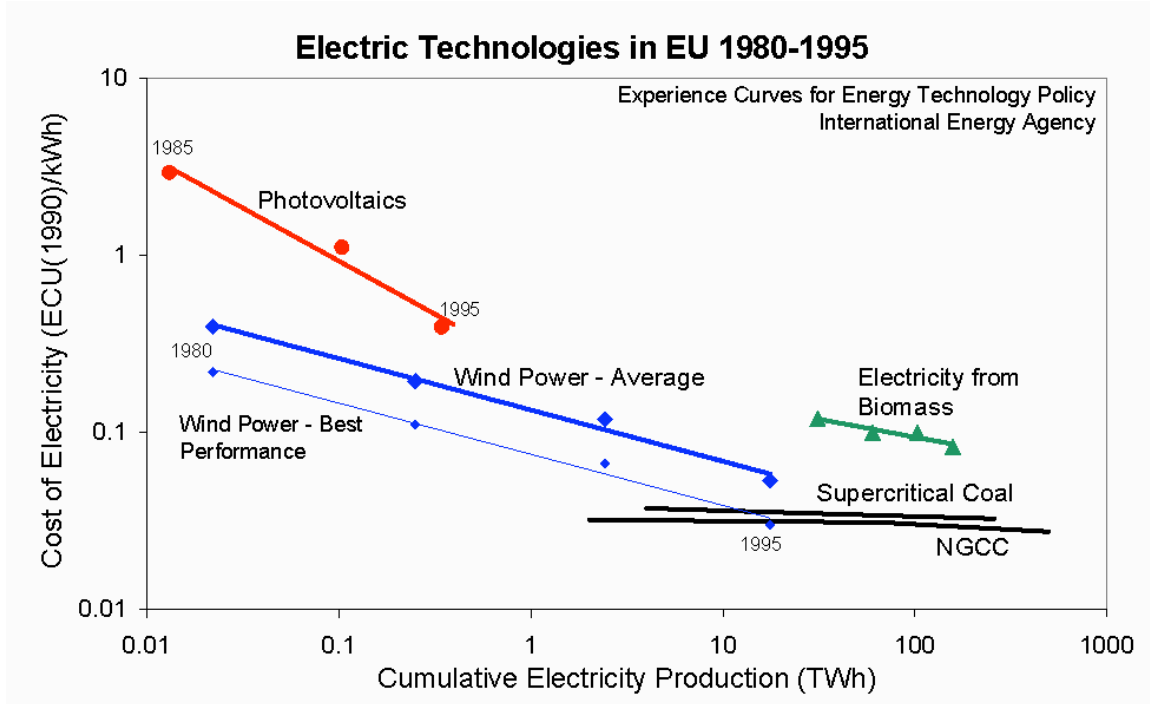
Current understanding views innovation as a complex process arising out of systemic interaction between actors and structures involved in the production, diffusion and use of new, and economically-useful, knowledge. This systems approach sees innovation as an iterative matching of technical possibilities to market opportunities, through both market and non-market interactions, feedbacks and learning processes throughout research, development and production, rather than as a one-way, linear flow from R&D to new products. This approach also emphasises the importance of the institutional framework of social rules, conventions and organisations in determining the rate and direction of technological innovation. Policy measures form a key part of this framework.

Studies of past innovations suggest that a new technology will typically first commercialise in *niche markets*, where the particular technology's advantages are strongest. These markets allow the technology to benefit from learning effects, so that costs reduce and the technology's performance can improve. If this occurs sufficiently, the new technology may then become competitive with the existing technology in the wider market. Shifts to new *technological regimes* then occur through the cumulation of niches, which gradually swell and coalesce to form a new regime. Other factors identified as key to successful innovation include the development of a skills base, and the creation of knowledge networks in the new technological system.

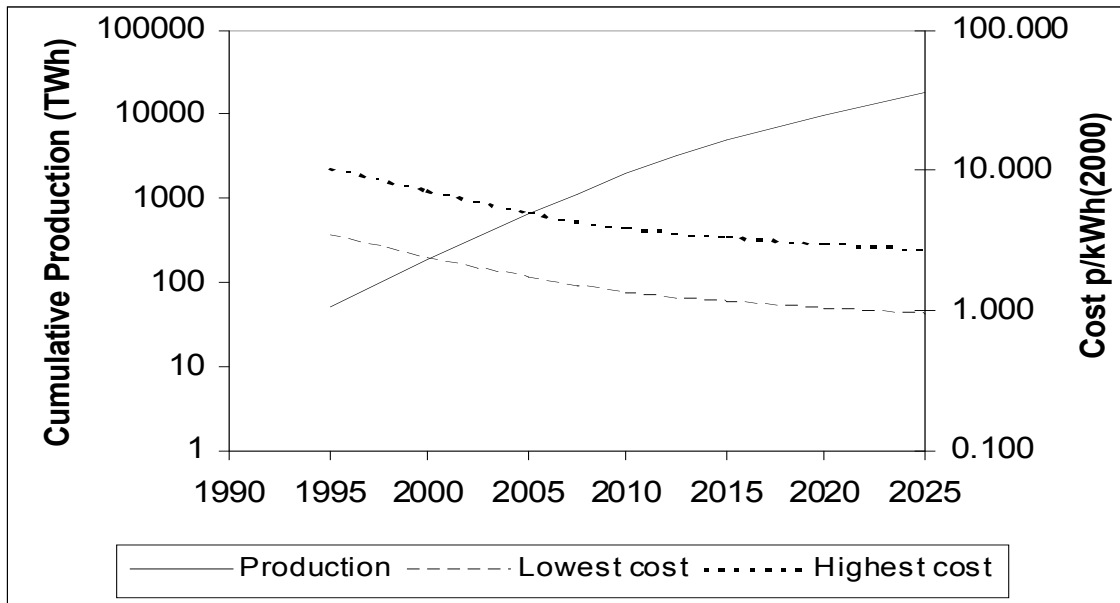
This leads to three opportunities/benefits:

- 1 Learning curves
 - suggest that unit costs of a new technology fall with the cumulative level of production
- 2 Induced technical change
 - corporate investment (R&D, learning-by-doing) in response to market and framework conditions
- 3 Increasing returns (positive feedbacks) to adoption
 - There are potentially increasing returns (positive feedbacks) to the adoption of a new technology, through scale, learning, expectation and network effects

Work by the IEA has shown how the unit costs of a range of new and renewable energy technologies have come down with cumulative installation. In common with other technology areas, these have shown learning rates of 10-20%, i.e. the unit costs reduce by 10-20% with a doubling of capacity. Hence, dramatic reductions in costs are likely for technologies which are currently at the early stages of commercialisation.

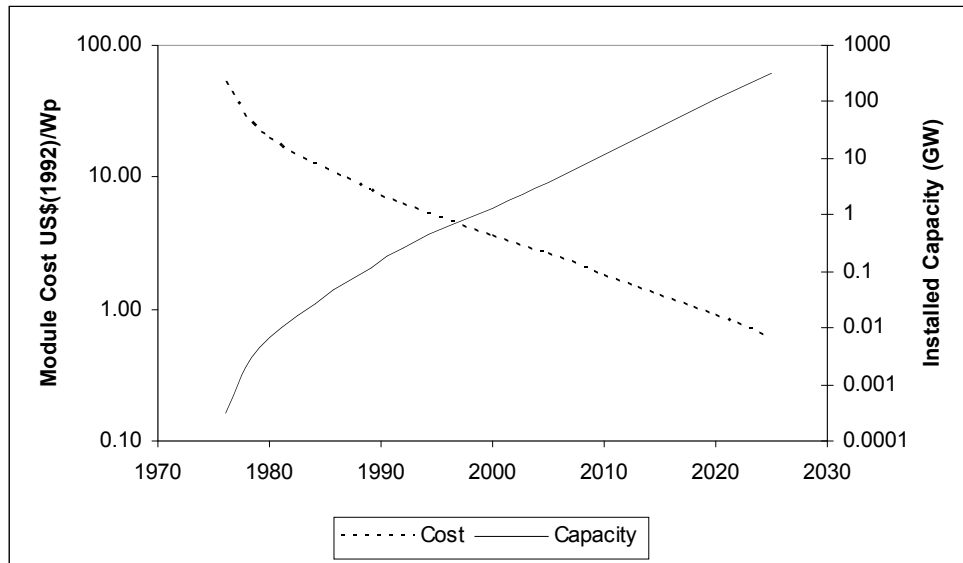


However, the use of learning curves to project future costs must be done with caution. Projections of wind energy costs based on continued growth in capacity show reduced learning as the technology matures (PIU Energy Review 2002).



Learning rates give similar cause for optimism for PV – albeit over a longer time frame for commercial viability (see Figure 3, based on PIU work below). Rather more caution is

needed for less advanced options (wave/tidal, fuel cells, offshore wind) – lack of market data makes learning assessment problematic - cf recent work from Carbon Trust.



The idea of induced technological change recognises that corporate investment (R&D, learning-by-doing) takes place in response to market conditions, within the framework of incentives and barriers provided by the wider system. Incentives for investment for innovation can seek to promote technology-push, e.g. tax credits and other incentives for R&D, market-pull, e.g. guaranteed niche markets for technologies which meet specified environmental performance standards, or the wider framing conditions, e.g. by setting out a credible long-term commitment to pursuing the potential for biofuels for transport. At present, the incentives for maintaining and developing the existing fossil-fuel-based transport systems are much stronger than the incentives for investing in the innovation of alternative fuel systems.

Innovation is characterised by uncertainty about future markets, technology potential and policy and regulatory environments, and so firms' expectations of the future have a crucial influence on their present decision-making. Expectations are often implicitly or explicitly shared between firms in the same industry, giving rise to trajectories of technological development which can resemble self-fulfilling prophecies. Hence, setting specific policy measures within a credible long-term framework with clear strategic goals and opportunities for technological and institutional learning can help to create positive expectations for the development of alternative energy and transport systems. This should not represent a return to 'picking winners' as the long-term framework and strategic goals should be based on environmental performance, not specific technologies.

However, limited levels of support for the demonstration of new technologies, such as that provided by the current Marine Energy Development Fund for wave and tidal electricity generation technologies, can provide learning opportunities to demonstrate whether these technologies have the potential to become commercially successful and feedback on choices for industry between different technology designs.

Annex B: Status of Renewable Technologies

Wind: wind energy technology is now industrially mature with proven and replicated designs up to 3MW rated. At the best onshore sites the technology is competitive with all other forms of electricity generation. Offshore, installation costs are higher, and despite a better wind resource, generation is not yet competitive without external support. There are significant economic gains anticipated, especially offshore, by scaling up of the technology to 5MW and beyond, but the engineering challenges of doing this reliably and in increasing water depths farther offshore should not be underestimated. Vigorous R&D must run alongside increased deployment and Government should be prepared to support this.

Installed capacity will be limited by network and operational constraints on the power system as a whole rather than resource and siting limitations. Here Ofgem, together with the Regulator is charged with addressing these issues; solutions need to be found that do not add large or uncertain costs to the wind developers and the move towards shallow charging should be speeded up. Up to 20% of wind capacity can be absorbed without particular difficulty and minor operational cost penalties.⁶ Beyond this, the market needs to be encouraged to evolve in the required direction through increased subsidies to offshore and deep water offshore installations so as to bring these newer technologies down the cost curve. A differentiated ROCs may be an effective way to do this for ground-breaking projects.

Note that the wind sector would not want to see ROCs abandoned in favour of a different market incentive mechanism such as a feed in law; stable market conditions are essential to growth of this sector.

Solar Photovoltaics: PV is competitive for grid-remote generation but much less so with large-scale bulk electricity generation. Further development of thin film technologies allied to bulk manufacturing technologies is projected to make systems using these technologies competitive by 2020 and roofs/facades provide ready deployment opportunities of up to 40 GWp total installed capacity in the UK. By 2050 advanced low cost PV technologies that are currently R&D concepts may well become commercial riding on expected developments in nano-engineering of materials. Germany, Japan and the USA have encouraged both local manufacture and deployment, and a vibrant commercial sector has emerged in these countries. The UK has the right skills to join these countries, but to date has lacked the appropriate state-led investments in both R&D and market programmes. Germany's generous feed in tariff for PV has encouraged very rapid market development and this should be considered for the UK.

Tidal Energy: a number of distinct conversion technologies exist; these are the barrage, lagoons, and tidal current. Of these, tidal current technology is likely to attract most commercial interest. One demonstration device has been operational for almost 3 years and a number of other developers have funding for large scale prototypes. Permission has been given for a 1 MW pre-commercial prototype for Northern Ireland that will be

⁶ PIU report

deployed later this year. This is a fast moving area with considerable support available now for R&D. Market stimulation via differentiated ROCs, or similar incentive, will be required soon to catalyse commercial deployment. Such economic stimulation must apply to the whole of the UK, for reasons of market equity. Planning permissions for tidal current projects are being scrutinised by the environmental community. More research is required to identify the impact of tidal current technology on marine life. This research needs to take place within the next 2-3 years in parallel with pre-commercial demonstrators to ensure that full commercial exploitation is not delayed by un-necessary environmental constraint. The issue of electricity network access mentioned in wind is also an issue for both tidal current and wave energy. If marine renewables are to meet 3% of UK electricity demand by 2020 (as predicted by The Carbon Trust) the needs for access to market through reinforced networks must be addressed now.

Wave Power: some variants of this technology are at the prototype demonstration stage, but there remains a plethora of different designs with potential. A standard evaluation protocol is required to help investors to appraise a technology during the early stages of development. Funding could better be targeted at the most promising technologies to accelerate their deployment and less promising technologies could be identified earlier thereby saving on the considerable investment required to get to the demonstration stage.

A standards and certification procedure needs to be developed for both tidal current and wave energy. Initially guidelines should be put in place by working with developers currently in the prototype demonstration phase. As the industry moves to full commercialisation the guidelines could be evolved into full standards and certification procedures. Government should consider funding a project now to establish such guidelines.

The challenges of designing for survival in extreme conditions are well acknowledged but cost implications for simply scaled-up technology need to be reduced based on operational experience. Evidence of long term reliable operation will provide market confidence, but developers require economic assistance to demonstrate this in the short term. This could be achieved with suitable support from enhanced ROCs or similar but these must be applied uniformly over the UK for reasons of market equity. Offshore test facilities such as EMEC in Orkney and the proposed WaveHub in the SW will be vital in gaining sustained offshore experience. With additional evidence of a few years of operational experience commercial exploitation will occur and truly competitive technology is expected to emerge between 2010 and 2020. Commercial exploitation of both wave and tidal current resources could benefit from relevant technology transfer from the offshore oil & gas industry, but work is required to investigate how this technology can be made more economically accessible. It will become a mature technology in the coming years and take its place among the diversity of commercial but sustainable generation forms. Cost-effective access to the electricity network will be critical to the exploitation of the resource, particularly in the most energetic areas. There are implications for UK infrastructure investment here that need to be addressed.

Bioenergy: the bioenergy sector is presently underdeveloped. Successful development of biomass for heat and power can be seen elsewhere in Europe and some parts of the

UK have the potential to commercialise this resource using specialised crops for lignocellulose such as willow, poplar and miscanthus grass. Several large-scale projects are seeking planning permission but more incentive and significant investment is required to support the whole supply chain. Facilitating this in such a way that the different supply chains are coordinated must be a high Government priority. In the UK, land resource will constrain advances in bioenergy and a portfolio of different crop types should be maintained where multipurpose uses for plants are developed, including food combined with liquid biofuels. Specifically: public sector buildings should be targeted for early applications of biofuel CHP alongside best practice in energy efficiency. RDAs have a crucial role in supporting the development of this sector particularly because the regional diversity of the bio-resource. Energy from waste cannot be overlooked as a bio-resource. – EU landfill directive drives in the correct direction but specific guidance to Local Authorities will be essential.

Currently, the environmental cost of liquid biofuel production is high, since processes are inefficient and this must be addressed through more fundamental bioscience research, enabling effective deployment of liquid biofuels. More carbon-efficient technologies need to be developed, through increased R&D to deliver the long term promise of liquid biofuels from biomass (including waste).

Biotechnology has the potential to provide improved feedstocks. Mechanisms must be put in place to deliver the 2010 target of 5% of transport fuel from bio-sources; this may well involve imported bio-fuels in addition to those produced in the UK. Competition for land between food and energy needs to be resolved; but biofuels can also be imported. Adjustment of land use incentives will be required. Specific targets for 2020 and longer term are required together with incentives calculated to deliver these. A reasonable target for the UK by 2020 is the cultivation of 1 million hectares for bio-crops. This would deliver a few percent of UK energy demand. Longer term hydrogen from renewables could be used as a chemical feedstock to upgrade biomass to more useful bio-fuels (liquid and gas).

Comment on micro-generation

Much is expected of micro-generation technologies of domestic PV, building integrated micro-wind turbines and micro-chp⁷ in the short to medium term. There has been a tendency to underestimate the challenges to cost effective deployment of these technologies and without very major rises in electricity costs to the customer or major subsidies, these technologies are unlikely to be deployed in large numbers.

Demand side management brings together the supply and demand issues. There are market issues that currently inhibit useful initiatives in this area.

Comment on off-shore energy industry

The UK has the best offshore renewable energy resources in the Europe, it has a market lead in the technologies and there is considerable export potential. It is vital that the UK continues to build its human capital in this field. Relevant institutions and the industrial

⁷ Not of course a renewable source

sector need to be incentivised to further invest and thereby consolidate these opportunities for energy, carbon reductions, and wealth creation.

Common Issues across the Renewables

The market signals need to be clear and stable a long way into the future. For renewables, this is especially true of the "cost" of Carbon component.

Small scale technologies such as domestic CHP or micro-wind generation might be better encouraged though through a scaling up of the new Low Carbon grants, since ROCs collection is not easily undertaken by individual householders.

Whole lifecycle carbon appraisal of technologies should be encouraged. Initially research is needed to determine exactly how such appraisals should be best undertaken.

Research should also be commissioned to determine the effects of climate change on the energy demand of the UK including changes to vehicle and generation plant efficiency; and estimate the impact on renewable energy fluxes.