

## New Lessons for Technology Policy and Climate Change

### Investment for Innovation: a briefing document for policymakers

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#### Executive Summary

There is a new understanding of the role of government policy in addressing the problem of climate change. The emphasis is now on policies for innovation and investment to initiate a transition to a low carbon global economy and society, in addition to the economic instruments of taxation and permit trading systems or regulations and standards.

This is a long-term issue – not just climate change, but also the widespread adoption of new

technologies. There are very large infrastructure assets in both the energy and transport systems. These assets will take a long time to replace, whatever the technologies chosen. The key question is how policy can direct the continuing investments that will be necessary in energy systems towards low carbon technologies, can stimulate and support innovation and investment to bring about the transition to a low carbon economy. To have the requisite impact in 2050, it is necessary to start directing investment towards low carbon technologies in the immediate and short term from now to 2010, and to persist with such low-carbon investments thereafter. The net cost of low carbon technologies will depend crucially on the extent to which policies to encourage innovation and investment are successful.

This is a significant departure from the recommendations of economic analysis based on the 'standard' or 'traditional' approach to the cost-benefit analysis of environmental problems. A new approach is emerging – the analysis of economic development as a series of disequilibria **with** endogenous/induced technical change.

Many of the technologies for a low carbon energy system are already available, but not yet fully competitive under current policies and markets. Energy efficiency improvement is central, but not sufficient, to achieve a 60% CO<sub>2</sub> reduction. Energy efficiency technologies will themselves be subject to the same considerations of innovation and investment as other energy technologies.

#### Possibilities and insights for new policies

- An international initiative focussed on encouraging innovation and the adoption of new energy technologies and practices, as the Prime Minister himself has recognised, may offer new opportunities for co-operation based on already strong national policies in many countries, and for moving 'beyond Kyoto'.
- The policy framework should reflect uncertainty - the fuel/generation mix is sensitive to the assumed technology costs, which themselves depend on assumptions about innovation and technical change.

- Policy must be durable to reduce investors' uncertainty, being appropriate for the various phases of innovation and adequate to see the new technology through to commercial competitiveness.
- Analyses suggest that the costs of achieving a low-carbon economy in this way need not be large, relative to estimates of economic growth.

### The Climate Change Levy (CCL)

- The design of the Renewables Obligation and Energy Efficiency Commitment have made them effectively invisible to consumers, in contrast to the high-profile CCL.
- Analysis of the CCL shows: there was an 'announcement effect' in the period after the announcement of the CCL in the Commerce and Public Sector which contributed a reduction in carbon emissions that was comparable to the pure price effect.
- There was an over-achievement of 2002 energy efficiency targets associated with the Climate Change Agreements (CCAs) – substantial cost-effective efficiency opportunities in industry were taken up, which might be termed the 'awareness effect' of the CCAs.

### Introduction

Recent work on energy policy has come to a new understanding of the role of government policy in addressing the problem of climate change. The emphasis is now on policies for innovation and investment to initiate a transition to a low carbon global economy and society, in addition to the economic instruments of taxation and permit trading systems or regulations and standards. The UK has been active in policy innovation for climate change and now has opportunities to develop policies to meet the goals set out in the Energy Policy White Paper (DTI, 2003a). Drawing on the results from the Tyndall Centre ETech projects (Tyndall Centre, 2004), this paper explains the analysis of long-term technological and industrial change leading to this new approach and assesses the Climate Change Levy, a major climate policy initiative. Opportunities for technology and investment policy at national and international levels to address climate change are identified. Current findings, drawing on modelling approaches incorporating the potential for technological change, which suggest that the costs of a transition to a low Carbon economy may be relatively low, are discussed. One fundamental conclusion from this research is that:

***the issue is not just how much do low carbon technologies cost, but how to direct the continuing investments that will be necessary in energy systems towards low carbon technologies, in ways that will stimulate innovation and reduce these costs?***

### **A long-term issue – not just climate change, but also the widespread adoption of new technologies**

There are very large infrastructure assets in both the energy and transport systems. These assets will take a long time to replace, whatever the technologies chosen. The systems in place in 2050 will largely depend on investments made from 2005 to 2020. Therefore, although moving to a low carbon energy and transport system is a long term policy objective, it is necessary to start directing investment towards low carbon technologies in the immediate and short term from now to 2010 and the decade thereafter. The UK government has already implicitly recognised this in the Energy Policy White Paper (DTI, 2003a) by adopting the Royal Commission on Environment and Pollution target of a 60% reduction in greenhouse gas (GHG) emissions from 1990 levels by 2050 (RCEP, 2000). However, for this target to be credible in the eyes of the investment community, it needs to be supported by policy measures and processes that promote the innovation and deployment of a range of low carbon technologies (Foxon et al., 2005a).

### **What do we know about the long term? - Things will change**

Capitalist economies have been characterised by successive 'Kondratiev waves' of new clusters of technologies (such as the current IT wave), which change the economic structures of production and consumption (Freeman and Louça, 2001). Looking at current technologies and current costs is a poor guide to the energy sector in 2050. Persistent long-term changes in society and economies can be identified in all regions of the globe: (rural to urban, agriculture to manufacturing to services, more human & product mobility). The long-run global economy seems likely to be characterized by increasingly specialised production & generalised consumption. This will increase trade leading to more currency unions, lower trade barriers, global branding and life-styles, and markets increasing in numbers, scale and specialisation with associated reduction in costs. Competitive innovation and obsolescence is another characteristic of a global economy in which information costs are falling rapidly. For the long-run global energy system, there is an increasingly unequal distribution of oil and gas resources, although coal is plentiful and transportation costs are falling.

### **Resource demands will change with economic structure.**

The most probable next 'Kondratiev waves' are the generic technologies that manipulate information, organisms and materials (currently known as information technologies (IT), biotechnologies, and nanotechnologies). These technologies will have major impacts on input structure and resource

efficiency. For example, it is forecast that, by 2100, 82% of world GDP will be in the service sector, mainly due to massive IT investment and diffusion. There is an inextricable link between technological change, industrial dynamics and environmental impact over the long term. As a result of industrial structure change, energy demand and associated CO<sub>2</sub> emissions could increase, depending on the resulting primary energy mix. Dewick, Green, Fleetwood and Miozzo (2004) highlight how, by 2050, the adoption and diffusion of biotechnologies and nanotechnologies could change industrial structure:

- Biotechnology has the potential to create many generic platforms and have a pervasive effect across a wide range of industries: pharmaceuticals, health care diagnostics, agriculture, food, materials technology, energy, and environmental monitoring. In bulk chemicals, advanced biotechnology-facilitated production processes are also likely to significantly reduce value inputs of electricity (currently 5.2% of total inputs into the EU chemicals industry).
- Nanotechnology could instigate the growth of a new 'advanced materials' industry: emulating the growth of synthetic materials since the 1950s.

The effect of the developments of these key technologies will depend, however, on the international division of labour, as driven by the operation of multinationals and the international and national regulatory systems. Evidence of consistently higher resource efficiency in the EU against the USA across different sectors, for example, raises questions about the differential diffusion of these key technologies in production and the effects on CO<sub>2</sub> emissions (Miozzo, Dewick and Green 2005).

### **60% emissions reduction is a long term goal, but action is needed now**

As explained above, the energy system cannot change instantaneously. It has a very large stocks of assets, so large scale changes will require large investment in new assets over a long period of time – both infrastructure and supply and energy use technologies. An important example is the building stock, which currently has an average life of 100 years. The same argument is true for the transport system. Therefore, policies to stimulate innovation and investment in low carbon technologies are central. This will bring further efficiency improvements, cost reductions and environmental benefits.

The contribution of innovation also raises new questions for policies at the national and international levels. The case for innovation policies has been made several times (ICEPT 2001, 2003). It has three elements:

- Creating options or bringing them forward in time, improves the flexibility of policy, which all studies agree is key both to reducing costs and to winning public acceptance.
- Reducing uncertainties about the performance of a technology before it is turned on a large scale increases the *option value* of a policy;
- Reducing costs to future investors and consumers, and enabling environmental problems to be solved sooner has appreciable positive external benefits.

This is a significant departure from the recommendations of economic analysis based on the 'standard' or 'traditional' approach to the cost-benefit analysis of environmental problems.

There is considerable controversy over the economic theory behind these arguments, though it is becoming clear that technological change must be included in any modelling of this kind DeCanio, 2003). Out of this controversy a new approach is emerging – the analysis of economic development as disequilibria **with** endogenous/induced technical change.

The most important policy question is, therefore: how can policy direct and support innovation and investment to bring about the transition to a low carbon economy?

### **Bringing new technologies to the market**

There is also a new recognition of the complex nature of the innovation process as illustrated in figure 1 (Grubb, 2002; Foxon, 2003). Successful new technologies come to the market through an innovation chain which may require policy intervention at different points to overcome institutional and market barriers to radical new technologies and products (ICEPT/E4Tech, 2003; Foxon et al., 2005b)

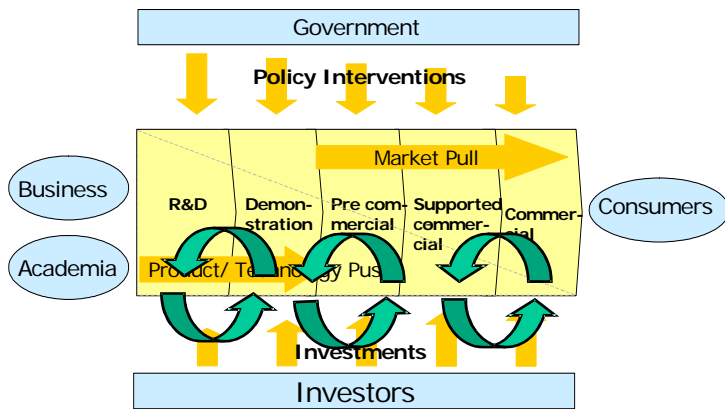
### **Many of the technologies for a low carbon energy system are already available, but not yet fully competitive under current policies and markets**

There is a diversity of technological options already available for addressing the climate change problem, most of which are capable of significant further development. The recent analysis in *Science* by Pacala and Socolow (2004), "Stabilization Wedges: solving the climate problem for the next 50 years with current technologies" provides a well-researched overview. They consider the possibilities for reducing world carbon emissions by 7 gigatons (GtC) per year by 2050, which for expository reasons they break down into seven 1 GtC 'wedges'. Nuclear power and carbon capture and storage from the use of fossil fuels (especially from coal, which would have the

advantage of providing a lower cost route to the 'hydrogen economy') are two of the options. The other five include a range of technologies

**Figure 1 The innovation process**

Source: Foxon, 2003 adapted from Grubb, 2002.



and practices for improving the efficiency of energy supply, conversion and use; the full range of renewable energy technologies, including solar, biomass from crops and wastes, onshore and offshore wind, and energy from waves and tidal streams; new technologies for transport, including fuel cell and hybrid vehicles; new, highly efficient decentralised forms of supplying combined heat and power; and novel emerging methods of storage, for hydrogen and for 'intermittent' renewable energy. The economic choice between these technologies rests on social costs, values and perceptions, not technological necessity. Most studies, including the MARKAL studies undertaken for the Energy White Paper, but also numerous studies in other countries and at the international level, point to the importance of pursuing several options and avoiding an excessive focus on one or two (Leach, Anderson et al., 2005).

### International Policy

A broad body of professional opinion has argued for incentives to support innovation directly, as a complement to carbon taxes or tradable permits (e.g. Alic et al., 2003; Rennings et al., 2003). This is now winning support throughout the OECD countries, and raises the possibility of a new international initiative.

The argument is not simply theoretical. All OECD countries now have innovation policies of one form or another, those of the US and Japan perhaps being the most notable, as does the rapidly developing regions of China, India and Brazil. At the international level, however, the role of innovation is still not fully recognised; the Kyoto process has concentrated on targets, with little emphasis on joint technological co-operation and development. This has proved to be restrictive and, as has been shown by modelling in the US, for all the faults and extreme assumptions of

such modelling, holds the danger of raising costs and inviting opposition by reducing flexibility (see e.g. Toman et al., 1999). The advantages of cap and trade policies are that such an approach covers the full set of greenhouse gas emissions sources, which stem from a huge variety of activities as indicated earlier, and governments have the freedom to select the least-cost mix of abatement opportunities with which to meet their target; also it is hard to think of other approaches which would as effectively incentivise governments to address barriers to improving energy efficiency. However, the direct incentives for innovation from cap-and-trade agreements are weak. An agreement like the Kyoto Protocol only gives *indirect* incentives to innovation, by indicating that low carbon technologies are likely to have higher value in the future if and as emission targets are strengthened through successive negotiating rounds; but this is unlikely to be sufficient to finance the degree of risky technology and innovation investments required. Governments need to adopt more active policies to stimulate innovation across the full innovation chain from R&D to large-scale commercialisation, at least at national but probably international level as well. Kyoto has only weak provisions that encourage governments to co-operate on R&D and technology standards, and to facilitate technology transfer. In this sense, the Kyoto architecture is incomplete and could be usefully complemented by more direct agreements to drive innovation in various technology areas.

An international initiative focussed on encouraging innovation and the adoption of new energy technologies and practices, as the Prime Minister himself has recognised<sup>1</sup>, may offer new opportunities for international co-operation based on already strong national policies in many countries, and for moving 'beyond Kyoto' (Leach, Anderson et al., 2005).

### Energy efficiency and uncertainty

The Tyndall Centre ETech projects have used these new approaches to analyse long term changes. They confirm the findings of other surveys that the costs of climate change mitigation may be little greater than the costs of investing in current energy technologies, depending on the extent to which innovation can reduce the costs of low-carbon technologies. Costs are further discussed below. Other policy conclusions (Anderson and Winne, 2004) are:

- Energy efficiency improvement is central, but not sufficient, to achieve a 60% CO<sub>2</sub> reduction.

<sup>1</sup> UK Prime Minister's speech on climate change, 14 September 2004, available at <http://www.number-10.gov.uk/output/page6333.asp>; see also ICEPT (2003) and earlier PCAST reports (1997, 1999).

- the transport sector has a relatively high cost of carbon reduction;
- the fuel/generation mix is sensitive to the assumed technology costs; and
- the policy framework should reflect this uncertainty;
- the importance of durability in policy, support must persist until new technologies become commercially competitive. This also reduces investors' uncertainty.

### Current UK policy and the Climate Change Levy

The Energy White Paper (DTI, 2003a) says that:

- The goal is putting the UK on track to a 60% reduction – but not committing now to how that will be achieved. But in period to 2020, the emphasis is on energy efficiency (8-12 MtC reductions); renewables (3-5 MtC); and emissions trading (2-4 MtC).
- The –60% target “is a massive challenge”.

Because of public expenditure and wider political considerations, the design of the Renewables Obligation and Energy Efficiency Commitment have made them effectively invisible to consumers, in contrast to the high-profile Climate Change Levy (CCL). Analysis of the CCL shows (Agnolucci and Ekins, 2004,):

- There was an ‘announcement effect’ in the period after the announcement of the CCL in the Commerce and Public Sector which contributed a reduction in carbon emissions that was comparable to the pure price effect (Agnolucci et al, 2004).
- There was an over-achievement of 2002 energy efficiency targets associated with the Climate Change Agreements (CCAs) – substantial cost-effective efficiency opportunities in industry were taken up, which might be termed the ‘awareness effect’ of the CCAs.
- CCA targets were not demanding (except Mineral Products in some cases) – asymmetry of information (managers achieved cost-effective reductions they had claimed did not exist).
- With tax alone a given carbon reduction is cheaper to achieve without rebates BUT
- ‘Awareness effect’ means that CCL + CCAs may have outperformed a no-rebate CCL both environmentally and (less certainly) economically (Ekins and Etheridge, 2005).

The Energy White Paper (DTI, 2003a) says that costs should be lower the more that the longer term framework is understood, i.e. as market players know

and understand the policy direction. The analysis of the CCL has shown that key issues in this respect include:

- Regulatory uncertainty & market risk cost money;
- A “theoretically” efficient instrument is not always the cheapest options to promote renewable, as can be seen by comparing costs:  
Germany (feed-in tariff): 8.7 and 5.5 Euro cent /kWh; Netherlands: 7.8 Euro cent/kWh; Denmark: 2.9 Euro cent/kWh + electricity market price < 6.5 Euro cent/kWh;  
UK (Renewables Obligation): 9.1-10.3 Euro cent/kWh (electricity market price included).
- Increasing information/attention for energy use saves money to firms.

### What are the economic impacts of GHG mitigation policies?

The first question usually asked is: how much will it cost? This paper is perhaps unusual in dealing with this question last. This is because the new analyses suggest that the costs are crucially dependent on the success of policies to direct investment and stimulate innovation. If such policies are successful, the costs need not be large, relative to estimates of economic growth. Practically all estimates, including the results of the MARKAL modelling work (DTI, 2003b), show the effects would rise from a low level today to a range of 0-2% of world GDP by 2050 (Leach, Anderson et al., 2005). In terms of GDP output lost, this represents a maximum cost of a loss of one year's growth in 2050, i.e. the modelled output in 2050 would not be reached until 2051, in a context in which GDP is likely to have risen by two to three hundred percent in most economies by this date. Recent surveys confirm these results (Grubb, Köhler & Anderson, 2002; Grübler, Nakicenovic and Victor, 1999; Tyndall Centre, 2004), depending on the success of innovation in reducing the costs of low-carbon energy options. In addition, the possibility of an economic surprise, of welfare being higher in a low-carbon economy, not lower, cannot be ruled out, depending on the ancillary benefits of the policy (such as other forms of pollution being reduced, and the achievement of more secure energy supplies) and the contribution of innovation to the reduction of costs. As Barker and Ekins (2004) point out, most modelling studies to date have not included these potential benefits. If the higher range of estimates were to be the case, 2% of GDP would of course represent a considerable loss in absolute terms; but this needs to be weighed against the very considerable potential costs of unmitigated climate change.

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