Testimony of Michael Grubb before the United States' Senate Committee on Environment and Public Works

Hearing on the Kyoto Protocol: Assessing the Status of Efforts to reduce Greenhouse gas emissions

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By

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My name is Michael Grubb.
I am Chief Economist of the UK Carbon Trust, an independent company funded by the UK government with turnover approaching US$150m/yr, established jointly between UK government and industry in 2001. The aim of the Carbon Trust is to help UK business and public sector implement CO2 emission reductions cost-effectively and to develop a competitive low carbon industry technology sector.

My post is half time, which I combine with academic research through a post at the Faculty of Economics at Cambridge University, and a Visiting Professorship at Imperial College, where I was Professor of Climate Change and Energy Policy before joining the Carbon Trust. I am also editor-in-chief of the Climate Policy journal.

In this testimony I set out some key points in relation to the UK's delivery of its emission targets and the design of the Kyoto Protocol, and append a presentation that I gave yesterday to the Columbia University School of International and Public Affairs

This submission contains the following components: key points about the emissions context for the Kyoto Protocol; implementation policies and prospects; observations about the economics of implementation of carbon management and low-carbon technology; and a concluding section that summarises my points in relation to what appear to some "common myths" about the Protocol.

1. The global emissions context

Policy on climate change is set in a context of large divergence of emissions between countries. This is illustrated in Chart 9 in the attached presentation, which shows the global distribution of CO_2 emissions in terms of three major indices: emissions per capita (height of each block); population (width of each block); and total emissions (product of population and emissions per capita = area of block).

Per capita emissions in the industrialized countries are typically as much as ten times the average in developing countries, particularly Africa and the Indian subcontinent. This is one of the reasons why industrialized countries accepted the responsibility for leading climate change efforts in the UNFCCC and subsequent Kyoto negotiations: unless they can control their own high emissions there is little prospect of controlling emissions from developing countries that start from a very much lower base.[1] There are also large

[1] Article 4.2 of the UN FCCC commits industrialised countries to adopt 'policies and measures that will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention', with the initial 'aim' of returning their

differences among the industrialized countries, with per capita emissions in the EU and Japan at about half the levels in the United States and Australia.

The main aim of the Kyoto Protocol is to contain emissions of the main greenhouse gases in ways that reflect underlying national differences in emissions, wealth and capacity, following the main principles agreed in the UN Framework Convention on Climate Change (UNFCCC). These include the need for evolutionary approaches and the principle of 'common but differentiated' responsibilities, including leadership by the richer and higher emitting industrialised countries. Following the agreed negotiating mandate,2 in Kyoto the countries that took on quantified commitments for the first period (2008-12) are the industrialised countries as listed in Annex I to the Treaty, which correspond roughly to those with per-capita emissions in 1990 of two tonnes Carbon per capita (2tC/cap) or higher - the 'Other EIT' [Economies in Transition] category and all to the left of it in the Chart.

At the same time, the currently low emissions and large population of the developing countries indicates the huge potential for global emissions growth, if and as their emissions climb towards anything like levels in the industrialized world. The Kyoto negotiations were marked by big tensions on this issue. In the final agreement, in addition to the provisions on national reporting and technology transfer, the Clean Development Mechanism is intended to provide a mechanism to start reigning in the rapid growth of developing country

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emissions of CO_2 and other greenhouse gases to 1990 levels. This became the focus of attention in the years immediately after the Convention and the failure of key industrialised countries to move in this direction was a principal reason why Kyoto moved to binding commitments focused on the industrialised countries.

[2] The COP1 meeting agreed that the UNFCCC commitments were inadequate, and consequently to 'begin a process to enable it to take appropriate action for the period beyond 2000, including the strengthening of the commitments of Annex 1 Parties, i.e. the industrialized world', to (a) 'elaborate policies and measures'; and (b) 'set quantified limitation and reduction objectives within specified time-frames, such as 2005, 2010 and 2020. It was agreed that these negotiations 'should not introduce new commitments for developing countries', but should enhance the implementation of their existing commitments under the UNFCCC. Thus were launched the intensive negotiations that finally culminated in Kyoto.

emissions without these countries themselves bearing the costs. The intent is that developing countries will engage more over time, in subsequent negotiation rounds, if and as the richer countries fulfil their commitments.

2. Current implementation policies and prospects

I shall speak in relation to policies principally in the UK, where a variety of instruments have been in place since about the year 2000 in the context of the UK Climate Change Programme (HMG, 2000), more recently complemented by the European Emissions Trading Scheme. At the core of the programme is a set of measures to encourage investment in established low carbon technologies, particularly relating to energy efficiency, combined with increased government expenditure along the 'innovation chain' of low carbon energy technologies. Already by FY 2002-3 these efforts amounted to a diverse set of instruments with a total incentive value for low carbon-related investments of around US$2bn.

The UK has generally found emissions reductions to be associated with positive economic developments. UK emissions reduced substantially during the 1990s as a result of privatisation in energy-consuming industries, that helped to boost their efficiency, and liberalisation of the UK electricity and gas systems that included a "dash for gas". It is estimated that this accounted for about half of the total observed reductions in UK CO_2 emissions. Sharply rising gas prices in the most recent years have reversed the trend towards natural gas in power production and resulted in a slight increase in CO_2 emissions.

A number of the measures indicated have continued to expand, and the government is currently conducting a major review. The Carbon Trust, for which I work half time, has steadily expanded its operations in relation to both energy efficiency and low carbon technology investments.

The Economics of Energy Efficiency

Technical assessments systematically show a potential for reducing both emissions and costs; the UK Energy White Paper estimates that the UK economy could save several billion pounds through increased energy efficiency (see appended presentation). Many barriers impede corporate take-up of this potential (Charts 13-15).

Part of the Carbon Trust's remit is to help companies deliver these efficiency improvements, and our experience confirms the potential for reducing both emissions and costs. In FY 2004-5 the Carbon Trust spent £26m (c.US$40m) on its carbon management programmes, we estimate that our clients co-invested £80m-130m (c.US$120-220m), and the value of the energy savings to these companies was £280m-£430m (c. US$400 – US$700).[Chart 16] The Carbon Trust continues to get strong and growing market interest and our budget is targeted to increase to about £110m (c. US$180m) annually over the next three years.

Companies in the Climate Change Agreements – the agreements with energy intensive sectors to deliver quantified emission reductions in return for rebates on the UK Climate Change Levy – have generally over-delivered on their targets, in part because they found more opportunities for cost-effective savings than originally anticipated.

These measures, together with other measures in the UK climate change programme and the introduction of the European Emissions Trading Scheme, mean that the UK is on track to over-achieve its Kyoto target of reducing greenhouse gas emissions to 12.5% below 1990 levels, and will profit from doing so.

Technology investment

Low carbon technology and innovation are essential to delivering long term, deep emission reductions. Most of the technologies that competitively use and supply energy today have matured in the private sector, and this is likely to be true in the future.

Based on Carbon Trust experience and developments in the empirical economics innovation, I offer four broad observations about low carbon technology from a business perspective.

First, innovation, to business, is not a dream for future decades but a continuous process of constantly evolving, improving and selling new products. From this perspective, calls for massive government R&D and technology transfer programmes are inadequate answers to an ill-defined question about delivering "low carbon technology". The idea that low carbon technologies are all things for tomorrow is a myth that does not reflect reality. There are many products and services designed for efficiency that could bear the label "low carbon" right now. There are efficient cars, appliances, buildings and even renewable energy sources growing both their sales and market share. The challenge is to accelerate their uptake in a world where consumers are aware of climate change but not ready to buy something on the basis of it. This not only reduces emissions directly, but also gives confidence to the private sector that low-carbon innovations will more quickly find markets – and hence rewards. Energy efficiency standards, trading and fiscal schemes that reward the adoption of more efficient, lower-emitting technologies, are an important part of the technology story.

Second, measures that place a price on carbon, like the EU emissions trading system for implementing Kyoto, are an essential part of a low-carbon technology strategy. Robustly implemented, cap-and-trade systems provide the beacon for deeper private sector innovation and investment, and also deter investment in carbon-intensive innovation and capital stock which could prove extremely expensive to reverse as governments respond more strongly to the mounting impacts of climate change over time.

Third, although such measures are necessary they are not sufficient. The barriers to deeper innovation are large, particularly when the price signal is so uncertain partly because of the lack of international consensus even on the fact that it is needed. Technology innovation takes a long time as good research becomes a good idea, a proven concept and finally a commercial technology. These earlier stages do not require just R&D, but a whole chain of support to help build businesses out of bright ideas, so as to help technologies bridge the 'valley of death' that has previously impeded our countries from securing the fruits of R&D. Financial support, test centres, field trials and pre-commercial markets developed through a variety of policy mechanisms all have a role to play.

Fourth, for the crucial global dimension, it is important to recognise that most innovation occurs in a handful of major industrial powers and is diffused globally through investment by multinational companies. The calls for global R&D and technology transfer programmes thus miss the point. The key is to ensure that energy innovation in those major powerhouses – national and corporate – is supported by domestic market incentives, is in a low carbon direction, and is then projected internationally by incentive systems that reward low-carbon investors in developing countries. Kyoto's Clean Development Mechanism seeks to do just that (though much must be done to make the CDM more attractive to business), and future expansion of cap-and-trade type targets and associated domestic policies over time would do the job still better.

The world will spend many trillions of dollars on energy provision over the next few decades: expenditure that will determine both the scale of climate change and the energy technology systems that will dominate the rest of the Century. At present much of that investment is flowing towards new and innovative ways of making the climate problem worse, by accessing ever more difficult sources of carbon and transforming them into useful energy. Low carbon technology offers the solution to climate change, but the question is about incentives. From a business perspective, it is wholly erroneous to suggest that the best way to deliver low carbon technologies is to avoid – or even abandon, where now adopted - the very policies that can make investing in them strategically worthwhile.

The Kyoto Protocol

The Kyoto Protocol has four main elements:

- it states that the way to solve the climate problem is for countries to negotiate quantified, binding limits on their overall greenhouse gas emissions, sequentially over time as the uncertainties reduce and they gain experience;
- these commitments are embedded in a variety of flexible market-based instruments like emissions trading, to make them as efficient as possible;
- the Treaty specifies the first round of limits, on emissions during 2008-12 for the industrialised countries that had already agreed in the original Convention to take the first specific steps;
- it has various provisions to bring in the rest of the world, including the ‘Clean Development Mechanism’ under which industrialised countries can gain emission credits for investments that reduce emissions in developing countries.

Like any agreement, it is far from perfect. But in defining commitments in terms of the outcome (emissions, on as wide a gas basis as practical, rather than trying to mandate specific technologies, policies, or measures); and in building in an unprecedented array of economics instruments with global reach, it is a Treaty probably more strongly influenced by economic reasoning than any other in history save those specifically related to trade and investment. Indeed, the Protocol's flexibility mechanisms were largely designed by US economists.

These flexibilities are crucial to understanding the compliance strategies of EU Member States. Most EU Member States do not intend to deliver all their targets domestically. The majority will fall short in domestic delivery, and will comply through use of the Protocol's flexibility mechanisms.

Most crucially, these mechanism include the Clean Development Mechanism, which generates emission reduction credits for investment in projects that help developing countries to adopt a cleaner course of development. The bigger the gap between domestic delivery and a country's Kyoto target, the more it will need to invest through the CDM and associated flexibility mechanisms in order to comply. To put it more bluntly, the Kyoto Protocol is only effective in helping developing countries to develop more cleanly to the extent that industrialised countries fall short of delivering their targets domestically; and this was built into the design of the Protocol and its first period targets. EU Member States have already set aside several billion Euros to help fund their compliance with the Kyoto Protocol in this way.

In effect, the design of the Kyoto Protocol ties countries to their targets with the elastic of international investment requirements to cover any gap. I have seen no evidence that any European country intends to defy international law by cutting this elastic.

To conclude, it appears to me that there are several misunderstandings about the nature of the Kyoto Protocol and I wish to close by setting out my perspective on these:

1. Environmental Effectiveness. The Kyoto Protocol provides the framework for a dynamic, evolving regime, with the current set of emission targets for the first commitment period being only the first step in a much longer term process of tackling climate change. The Protocol establishes a structure of rolling commitment periods, with agreement that negotiations on second period commitments (intended for 2013-2017) will start by 2005. The current first period emission targets are intended to meet the Convention requirement that industrialised countries should demonstrate that they are taking the lead by modifying their emission trends; they were never intended to provide the definitive solution to climate change. Much greater emission reductions will be needed to stabilize atmospheric concentrations of GHGs. The Protocol offers a structure through which to achieve this, by gradually "ratcheting up" the Protocol and its resulting environmental effectiveness. A similar approach was used in the ozone regime, where the Montreal Protocol's initial CFC emission target of a 50% cut was far from being environmentally effective, but was progressively tightened over time to greatly increase the treaty's environmental impact.

2. Developing country involvement. The Kyoto Protocol is very much a global agreement, and so is the Framework Convention on which it is based. All parties, including developing countries, have a general commitment to adopt climate change mitigation policies and to report on the action they are taking. The Kyoto Protocol also establishes the Clean Development Mechanism (CDM) to promote globally sustainable development, especially through partnership with the private sector. By ratifying the Convention, its 185 parties agreed that establishing quantified commitments for countries in earlier stages of development would be premature and inequitable, as well as impractical, given the huge uncertainties in their emissions data, growth trends and governance. However, there is a clear understanding that, as industrialized countries take the lead in moving their economies onto a less carbon intensive path, the developing countries will follow. This understanding is built into the Protocol, which stipulates that its overall "adequacy" must be reviewed no more than two years after it enters into force. Along with the above-mentioned requirement for negotiations on second commitment period targets, the issue of deepening developing country commitments will be on the agenda.

3. Kyoto is a flexible agreement with feasible commitments. The Kyoto targets were negotiated as a package along with the various flexibilities in the agreement, including the market-based mechanisms of joint implementation, the CDM and emissions trading, as well as carbon sinks, multiple gases and a five-year commitment period, all of which the US fought hard to get agreed in the Protocol. These flexibilities make compliance feasible even for countries that have taken little domestic action so far and are facing a large gap between domestic emissions and their Kyoto 'assigned amounts', providing they undertake appropriate investments through the mechanisms.

4. The costs of meeting the Protocol's targets are modest. I have testified to UK experience. The IPCC reported results from global modeling studies of the costs for complying with Kyoto to be in the range 0.1 to 1.1%of GDP, with full emissions trading but without other Kyoto flexibilities (multiple gases, sinks, or CDM), which would further lower costs. This equates to between 0.01 and 0.1% reduced annual GDP growth rate in the richest countries of the world, far smaller than the standard uncertainties in economic growth projections that governments routinely use as the basis for policy making. The IPCC also notes that poor climate change policies to implement the Protocol's targets could raise costs, whilst smart implementation (e.g. that harnesses cost-effective efficiency improvements, co-benefits, and 'double dividends' from shifting taxation) would lower them; some European studies even show net economic benefits.

5. Kyoto is a carefully-crafted and integrated package developed over many years of global negotiations. As with any multilateral agreement, different parties place value on different provisions. Most developing countries were already unhappy with what they saw as weak targets in the Protocol; weaken them still further and the prospects for enticing developing countries into a global regime of quantified commitments will grow ever more distant. And as noted, it is the targets themselves that drive the Protocol's international mechanisms.

Kyoto is neither perfect, nor comprehensive; what global agreement ever is? But it offers a credible structure to solve the problem. It has survived because no-one has yet come up with an overall more plausible, or more efficient, basic approach to international agreement that can effectively limit emissions and expand over time as the seriousness of the problem becomes more apparent.

The economics of greenhouse gas mitigation

Presentation to Centre for Energy, Marine Transportation and Public Policy, School of International and Public Affairs, Columbia University, 4 Oct 2005

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1.

Overview

- A few words on climate change impacts and evaluation
- A global view of the Stabilisation challenge
- The economics of energy efficiency: evidence and implications
- "Technology's the answer! (so what was the question?)":
  - The technology-push vs demand-pull debate
  - A closer look at energy-environmental innovation processes and policies
  - Strategic economics of innovation policy instruments
- Some brief observations on international strategies

2.

Evaluating climate change impacts:

Survey, stakeholder and revealed impact evidence all disagree with mainstream economic quantifications

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3.

Survey evidence …

- … consistently shows that people care more about the long-term future, and about impacts on other people, than reflected in nation-state and traditional discounting economics
- Discount rate dominates quantification: increasing acceptance in economic theory of need for logarithmic or other forms of declining discount rates for long-period problems
- The economics of transboundary impacts still in its infancy …

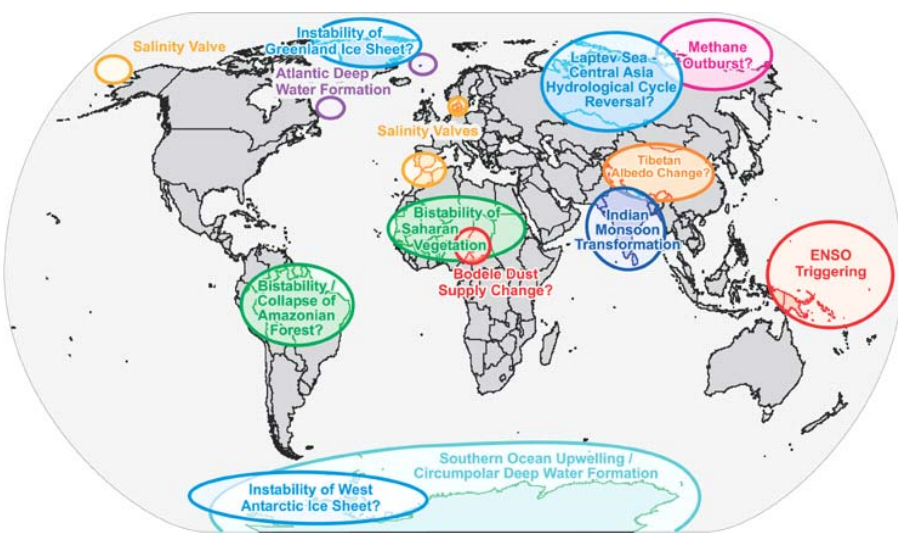
4.

Economic theory based upon ‘willingness to pay to avoid damages’ principles has never gained acceptance of the ‘victims’

- Long-standing debate between willingness-to-pay vs willingness-to-accept (compensation) remains unresolved; latter yields higher numbers but former remains the main prop of monetization studies
- Sharp illustration in the debate about ‘value of statistical life’ in international climate damages
- The debate revealed deep theoretical confusion in the context of transboundary impacts: the stakeholder evidence demonstrated that global economics cannot escape directly addressing issues of procedural and substantive ethics

5.

Meanwhile, the scientists worry far more about instabilities than about incremental change …



6.

.. Whilst revealed impact evidence suggests a model of least-cost ‘rational, optimal adaptation with foresight’ is not necessarily appropriate

- The world is *not* undertaking least-cost measures to protect those in developing countries
- The current estimates of damage associated with Hurricane Katrina exceed the total damages from climate change projected by most economists for the entire US by mid Century
- There were extensive warnings ..
- .. And the political response is not the economically optimal policy of retreat

A global view of the stabilisation challenge

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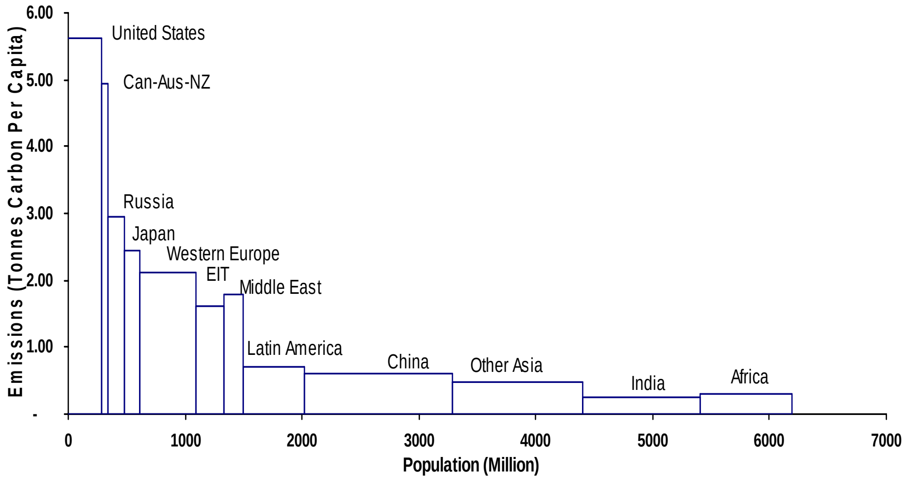
From perspective of both global inequalities and pressures for growth, the challenge is huge

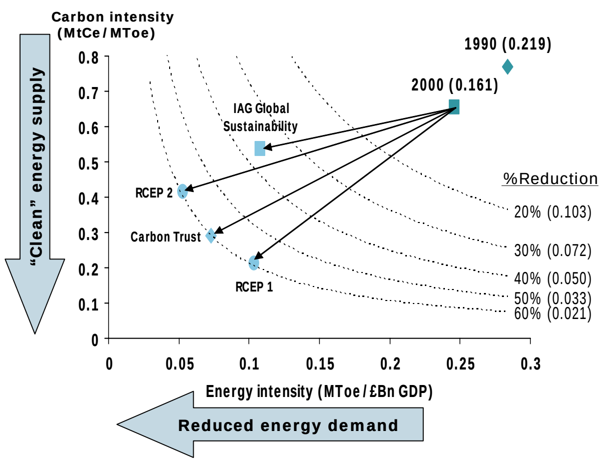
per-capita emissions vs population, 2000



9.

Global context implies need for deep emission reductions in industrialised countries

UK policy context (60% target by 2050), implies both much cleaner energy and big improvements in energy efficiency (x10 C.intensity)



The 2003 Energy White Paper set the UK on a path to reduce carbon emissions by 60% by 2050 through a combination of energy efficiency in the short term and renewables in the long term:

"[To achieve the required savings from energy efficiency] *would need roughly a doubling of the rate of energy efficiency improvement seen in the past thirty years"*

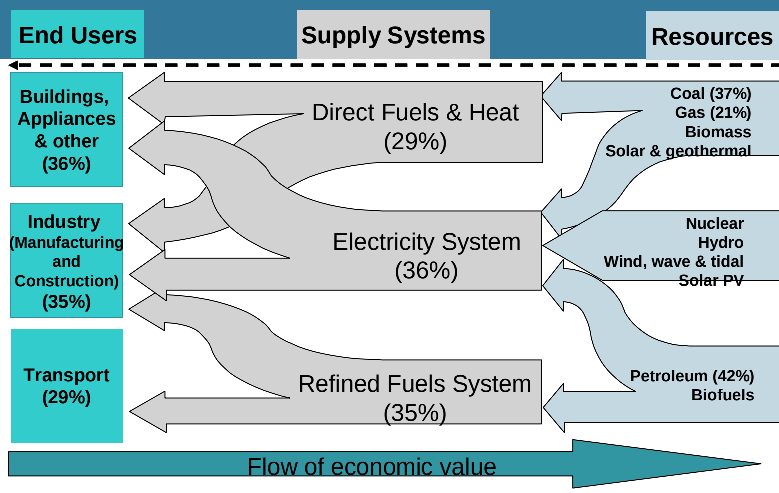
"Technology innovation will have a key part to play in underpinning all our goals and delivering a low carbon economy"

"To deliver these outcomes our aim will be to provide industry and investors with a clear and stable policy framework"

Note: Figures in brackets show UK carbon intensity (MtC/£Bn), Scenarios show 2050 projections
Source: RCEP 1998, DTI EP68 GDP growth forecasts, IAG "Long-term Reductions in GHG in the UK", Feb 2002

10.

From economic standpoint, need to address main *system components – 3 end use, 3 supply*



The data show the % of global energy-related CO2 emissions associated with the different parts of the energy system (including emissions embodied in fuels and electricity). Note that patterns vary between regions (eg. industry is lower and transport higher in developed economies), and the sectors are growing at different rates (over past 30 years, energy demand for buildings:industry:transport has grown at 2.6%:1.7%:2.5% annual average (LBNL ref)

Note: Some small flows that comprise under 1% of global energy flows (eg. electricity and natural gas contributions to transport) are not shown **End Users:** Source: IEA. 'Non-electric energy industries' (emissions from refineries, gas etc) allocated 4:1:2 to transport:industry:buildings etc.

Supply Systems: Electricity System data IEA; Refined Fuels %CO2 assumed equal to Petroleum % CO2; direct fuels and heat is the residual.

Resources: Source EIA

Economics of energy efficiency

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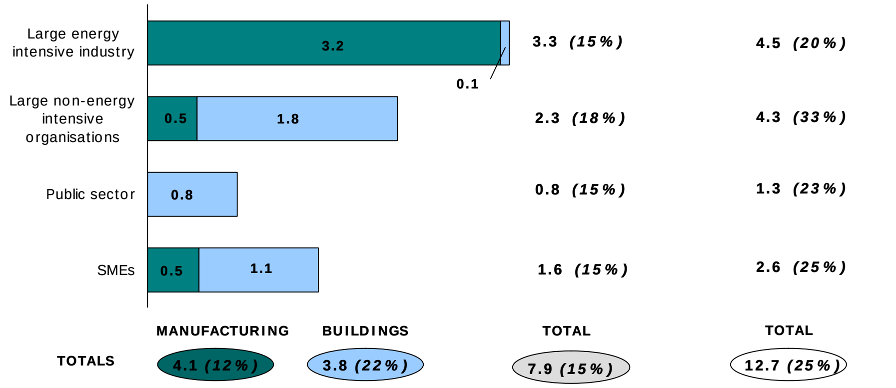
Technology and system studies all suggest significant *cost-effective* energy efficiency opportunity exists
Example of UK – CT policy review assessment @ 15% IRR

Absolute cost effective carbon abatement opportunity to 2020 | **Technical potential**

MtC *(% of total emissions in brackets)*; NPV positive at 15% discount rate

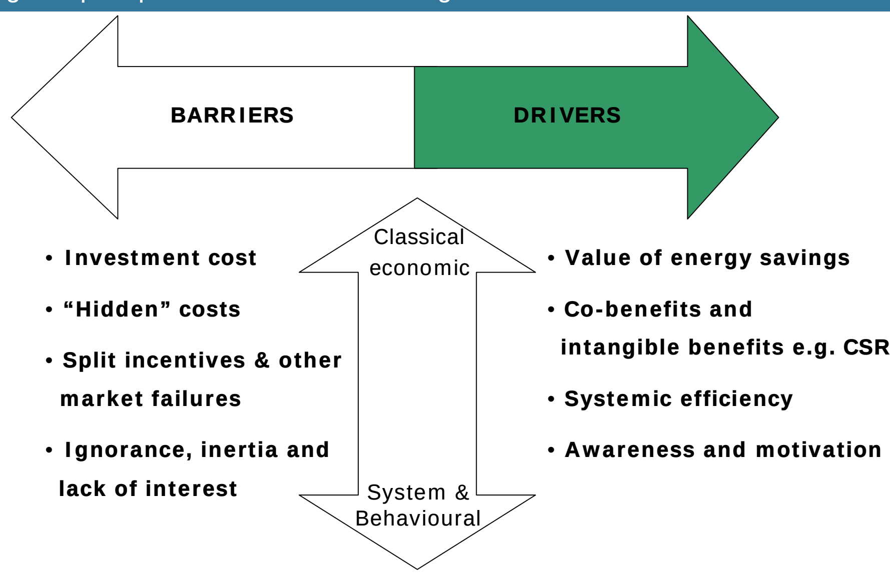


- Significant cost effective abatement opportunity outside large energy intensive industry (~60% of total), particularly within buildings
- Figures above based on existing technologies in ENUSIM and BRE abatement curves: FES analysis indicates new technologies will increase total cost effective opportunity by ~1.2 MtC by 2020

Source: Ecofys: ENUSIM abatement curves, BRE buildings measures abatement curves

13.

Delivering energy efficiency requires addressing the barriers & drivers in organisational decision-making:
- if policy can address the non-financial dimensions there is good prospect for net economic gains



14.

The 'free lunch' requires economic explanation before policy appraisal can take it seriously:

- there are numerous barriers to energy efficiency that can be most usefully classified into three main non-financial categories

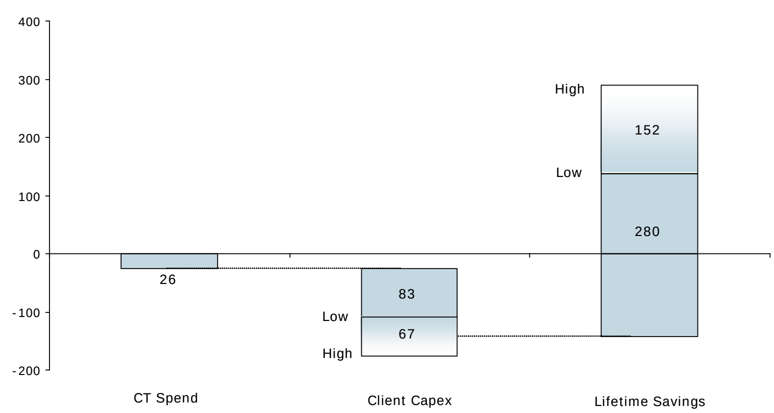
Issue	Definition	Examples	Policy options
Financial cost/benefit	Ratio of investment cost to value of energy savings	▪More expensive but more efficient equipment	▪Economic instruments that reduce equipment cost or finance cost, or increase energy prices ▪Direct legislative drivers on energy / emissions
Expanded cost/benefit (intangible, transaction and transition costs)	Cost or risk (real or perceived) of moving (or not moving) to more energy-efficient practices including managerial, information, risk and decision-making requirements, not captured under (a)	▪ **Costs & risks of change** Incompatability Performance risk Management time Other transaction costs ▪ **Exposure of not changing** Higher emissions risk Equipment obselescence Customer & employee pressure	▪Services providing information, technical support ▪Packaged energy service contracts ▪Standards requiring use of a particular technology/solution, e.g. product standards, etc. to avoid transaction costs
Market Misalignment (split incentives, system failures regulatory failures)	Market structure and constraints that prevent consistent tradeoff between specific energy efficient investment and the societal energy saving benefits	▪Landlord / tenant split ▪Regulatory failures eg. in electricity ▪First-mover costs and risks ▪Externally-imposed budget constraints	▪Contractual or market organisation solutions to split incentives between organisations ▪Standards ▪Capital market solutions (eg. Salix) ▪Socialisation of first-mover costs
Behaviour & motivation (inertia, awareness, materiality)	Internal issues of firm behaviour linked to awareness, motivation and internal organisation	▪Organisational failures (eg. internal split incentives) ▪Inertia, rules of thumb ▪Tendency to ignore small opportunities	▪Campaigns, sector learning networks ▪"Attention raising" instruments: e.g. trading; CCAs with sector targets and 'cliff' incentives (tax exemption) ▪ECA lists and low interest loans available to equipment purchasers in organisations

15.

Exploiting this potential has enabled Carbon Trust programmes to deliver major lifetime cost savings

- assessed value of energy efficiency savings from 2004-5 programmes at least twice the cost of policy and co-investment

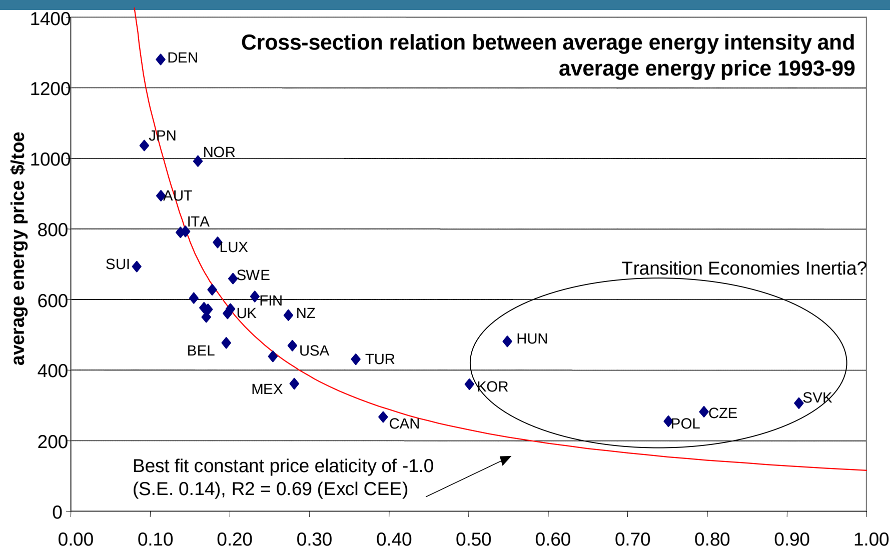
Investment costs and lifetime energy savings
2004-05 (£m)



Source: Carbon Trust Impact Assessment

16.

Cross-country comparisons suggest final national energy expenditure per unit GDP is insensitive to price in long term (elasticity c.-1) ie. price increases offset by increased efficiency



Source: Nebwery 2003

17.

Significance of the technology-push vs demand-pull debate:
evidence and implications

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18.

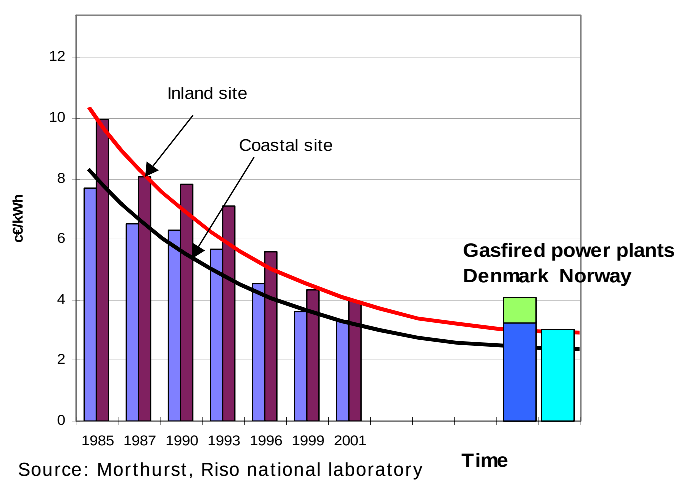
The basic issue

- Technology is the answer!
  - All studies agree that low carbon technology is central to addressing long-term climate change
  - Technologies adequate to stabilise the atmosphere are not yet commercially available
- But what was the question?
  - Is this a question of *R&D investment by governments* to develop the technologies that can solve the problem (‘technology push’ / exogenous technical change)?
  - Or a question of *market incentives* to promote private sector investment in emerging technologies and learning-by-doing (‘demand pull’ / induced technical change)
  - Or – combination reflecting a ‘systems view’ of innovation processes & markets

19.

Cost reductions - and pathways - in wind energy have been closely associated with buildup of the *industry* during the 1990s

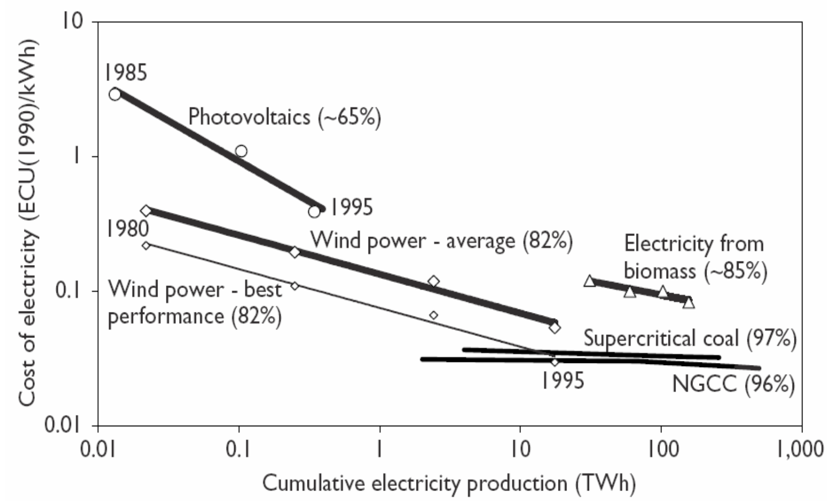
Example of wind energy costs in Denmark



Source: Morthurst, Riso national laboratory

20.

‘Experience curves’ are well-established empirically – though with complexities in understanding causes, rates, asymptotes



21.

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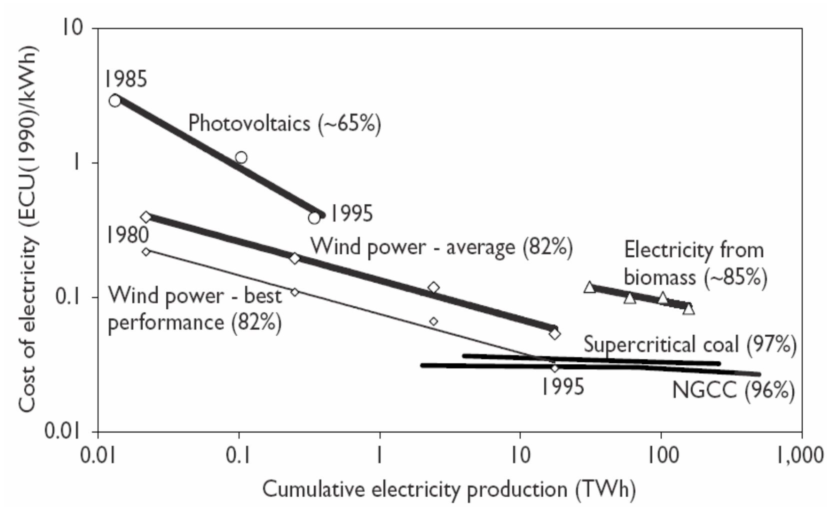


22.

If conceived as a simplistic *technology-push vs market-pull* choice, opposite conceptions of technical change can invert many policy-related conclusions

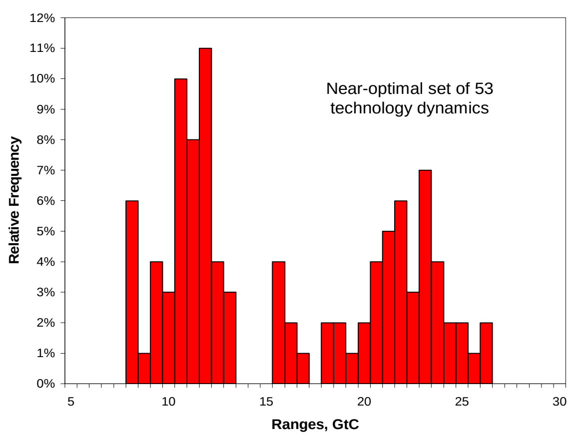
Issue	**Technology-push:** **Govt R&D-led technical change**	**Market pull:** **Demand-led technical change**
Implications for long-run economics of large-scale problems (eg. climate change)	Atmospheric stabilisation likely to be very costly unless big R&D breakthroughs	Atmospheric stabilisation may be quite cheap as incremental innovations accumulate
Policy instruments and cost distribution	Efficient instrument is government R&D, complemented if necessary by 'externality price' (eg. Pigouvian tax) phased in.	Efficient response may involve wide mix of instruments targeted to reoriented industrial R&D and spur market-based innovation in relevant sectors. Potentially with diverse marginal costs
Timing implications	Defer abatement to await technology cost reductions	Accelerate abatement to induce technology cost reductions
Carbon cost profile over time	Carbon cost starts small and rises slowly till meetings technology (Hotelling principle)	Big investment in early decades, cost declines as learning-by-doing accumulates
'First mover' economics of emissions control	Costs with little benefits	Up-front investment with potentially large benefits
Nature of international spillover / leakage effects arising from emission constraints in leading countries	Spillovers generally negative (positive leakage) due to economic substitution effects in non-participants	Positive spillovers may dominate (leakage negative over time) due to international diffusion of cleaner technologies

Source: Grubb, Koehler and Anderson, in Ann.Rev.Energy, 2002

23.

Induced technical change / learning curves can revolutionalise the long term view…
Probability density distribution of least-cost carbon emissions in 2100

- Uncertainty in key inputs
- very wide range of energy technologies and resources
- learning-by-doing
- learning spillover effects in technology clusters

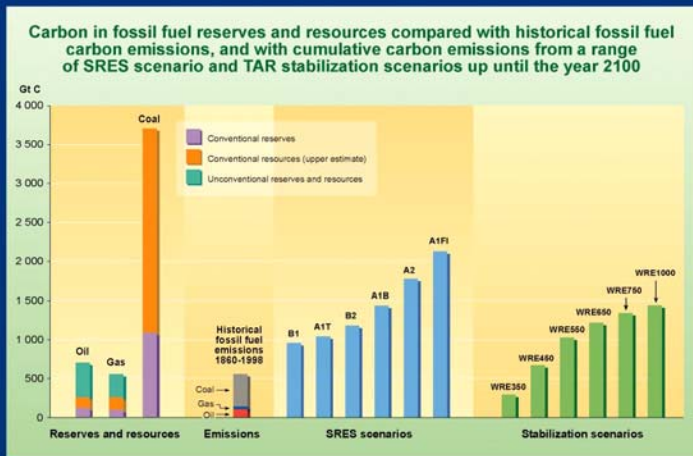


Source: Gritzevski & Nakicenovic, in *Energy Policy, 1999*

24.

The ‘double hump’ distribution of long-term CO_2 is driven by limited conventional oil reserves:

- the global energy transition could be to higher or lower carbon



SYR - FIGURE 7-5

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP

25.

A closer look at energy-environmental innovation processes and policies

CARBON TRUST

26.

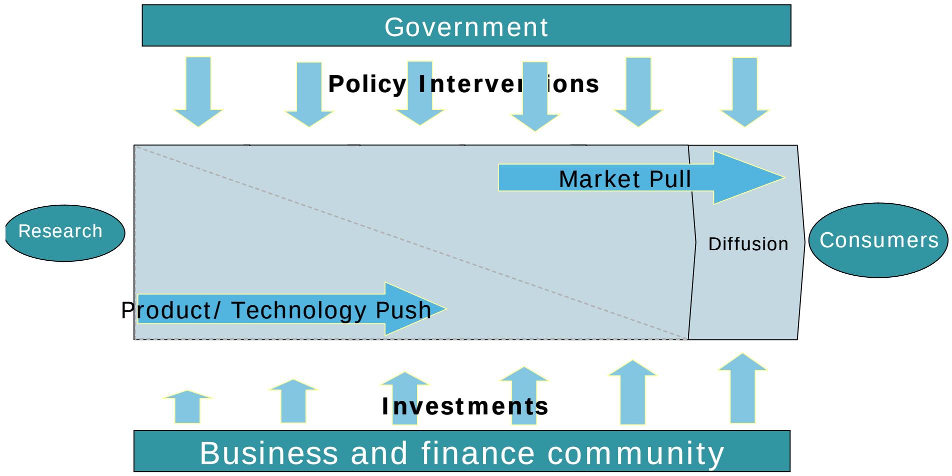
Technology-R&D push
– the track record is not encouraging..

- **The theoretical basis**
  - Classic R&D market failures
  - The impact of liberalisation
- **Some classic energy examples:**
  - Nuclear fission
  - Coal-based synthetic fuels
  - Nuclear fusion
- **Basic problems of:**
  - 'picking winners'
  - Cooperation vs competition
  - Policy displacement
- **Theoretical paradox of the 'classical' view**
  - the giant leap
  - the 'valley of death'

Demand-led induced technical change
– if only markets were so perfect ..

- **Some classic energy examples:**
  - North sea oil
  - CCGTs
  - Wind energy ...?
- **Basic problems of:**
  - Classic R&D failures
  - Policy stability for environmental innovation
  - The real world is 'second best'
- **Theoretical paradox of the 'classical' demand-led view**
  - the need for perfect R&D markets
  - The need for long term certainty
  - The need for perfect communication between government, research, and industry

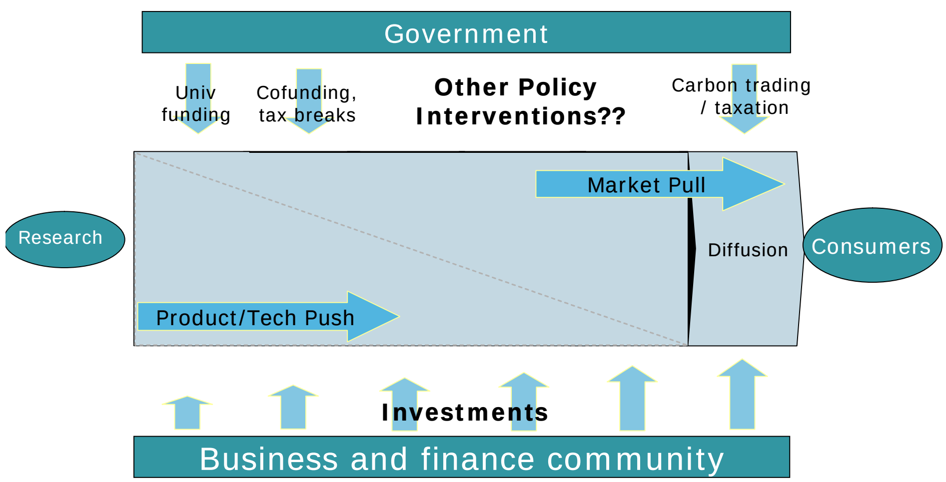
Integrated perspectives: technologies have to traverse a long, expensive and risky chain of innovation to get from idea to market



Source: Foxon (2003) adapted by the author

29.

Market theory is blind to the innovation *process* – innovation assumed to emerge out of R&D and market pull, with government no-go zone in between



30.

Consequently we lack integration across the innovation chain

- New entrants (technology and corporate)
  - require €/$ billions, and years, of development
  - Compete against established incumbants and rules
  - Rely upon regulation to embody external costs of incumbants
- political signals of future regulation are not 'bankable'
  - ('White paper reactions')
- fierce market competition and regulatory change in electricity has left:
  - Financial community extremely risk averse
  - companies without financial resources for longer term investment
  - ('CMI reactions')

Strategic economics of innovation policy

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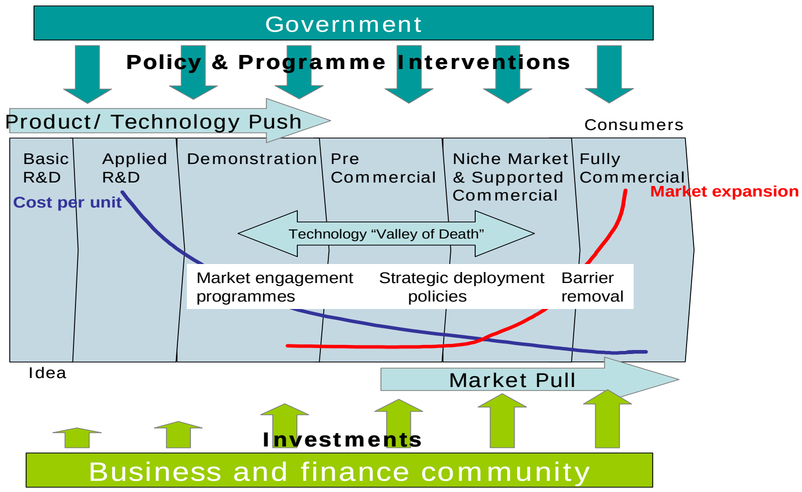
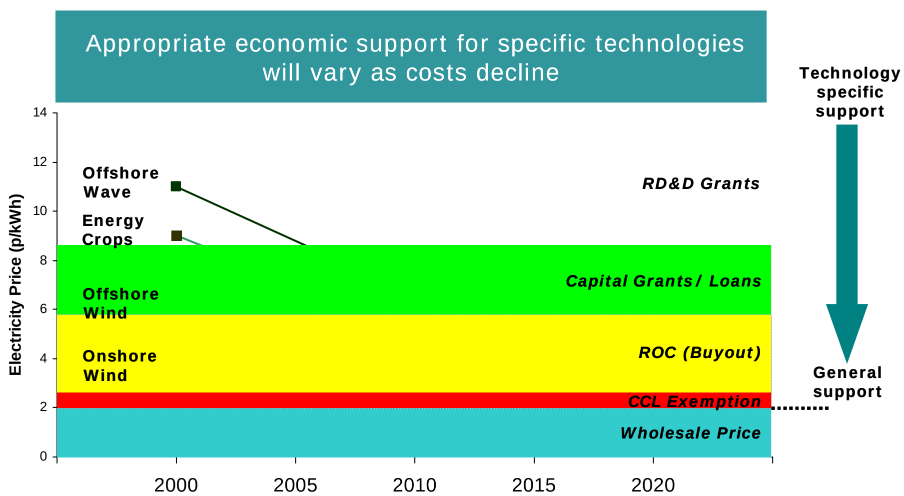
Diverse policies of market engagement and strategic deployment are needed to help technology traverse the 'innovation chain'



33.

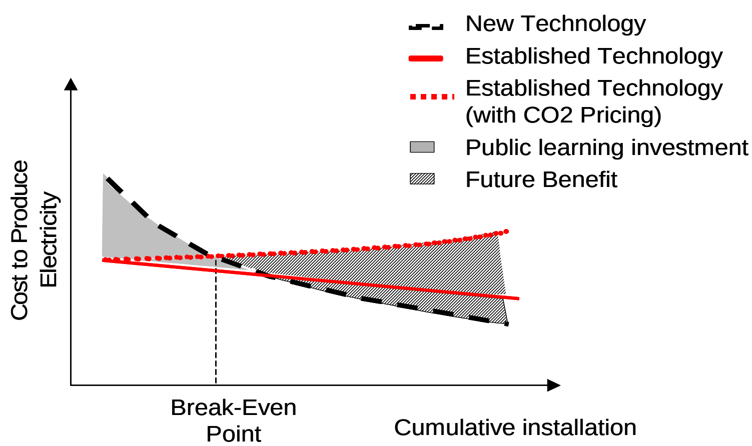
Whichever view is taken, a key will be strategy of 'convergence' through different instruments towards competitiveness under broad-based economic instruments



Note: ROC excludes recycling; Capital grant based on maximum of 40% of typical capital costs
Source: PIU Working Papers (OXERA II Base case cost decline)

34.

The cost-benefit of ‘strategic deployment’ programmes will depend on relative rates of learning, and of cost internalisation policies



Innovation policy and carbon cap & trade

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Carbon caps / prices cannot *on their own* deliver long-run solutions

- There are too many complexities and imperfections in energy demand systems (especially buildings and transport - but also industry)
- The innovation chain is too long, complex and imperfect for prices to deliver adequate innovation even if prices could be forecast
- In practice, the uncertainties are too deep (and political resistance too fierce) to establish long-run carbon prices now; but
- Industries (& finance communities) are too remote from science and governmental decision-making to act substantively on the basis of hypothetical and contested future political processes to internalise climate damage costs

37.

But caps / prices are crucial element and technology-driven international processes can only plausibly emerge as a contribution to delivering targets over time

- Carbon caps / prices are needed to:
  - deter carbon-intensive investment lock-in: $16tr projected to be invested in energy systems over next three decades
  - accelerate diffusion of available low-carbon technologies
  - influence portfolio R&D of the big multinationals and to reward innovative companies
  - incentivise and guide governments towards *effective* innovation strategies
  - provide a strategic price-based convergence goal for innovation strategies
- Innovation chain policies seek to increase the *speed, depth and efficiency* of the innovation response

38.

Some broad conclusions on mitigation economics..

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Generic conclusions on economics of climate change mitigation

- Climate change policy poses challenging problems for economic appraisal, which needs ultimately to be set in global, long term context of the problem with following considerations:
  - Pervasive nature of CO2 emissions – six major economic sectors and no single “magic bullet” solution
  - Impacts potentially severe but with considerable uncertainty about nature, timing, attribution including value-dependent (ethical) considerations
  - Technical and behavioural evidence about the “energy efficiency gap” gives potential for economic gains from mitigation
  - infrastructure development and inertia in the face of uncertainty implies need for action differentiated according to these characteristics
  - Endogenous innovation implies need to understand impact of economic policy on innovation in different areas, and balance between supply and demand side of innovation process
  - Global context implies need to differentiate upon basis of national potentials to establish comparative advantage in different areas

=> A single global carbon price, or a single instrument, is not a dynamically efficient solution. Unfortunately, real life is far more complex

Specific conclusions on business delivery and economics of UK climate policy to 2020:

Targeted policy mix could balance carbon savings with –ve resource cost (benefits to firms) and limited competitiveness/GDP impact

Negative resource cost	• **In aggregate, continuing potential for companies to respond to well-designed instruments with net resource gains**
Cost-effectiveness requires mix of instruments	• **Regulatory or awareness-raising instruments can yield economic gains where they address barriers and avoid excessive "hidden costs"** • **Cost-effectiveness of pure economic instruments depends on allocation, revenue-recycling and disaggregated subsector responsiveness**
Upstream changes can enhance savings	• **High EU ETS price ("real" c.€20/tCO2) drives coal to margin of power generation, potentially doubling near-term impact of end-use electricity savings and may deliver aggregate > 10MtC/yr by 2010**
Isolated competitiveness effects	• **Marginal (or positive) impact on newsprint and petroleum (EU ETS sectors); car manufacture and brewing (CCA sectors); and Grocery Retail and Hotels**** • **Aluminium exposed, maybe steel and cement under strong packages post 2012 without wider international participation or trade protection**
Expect limited GDP impact	• **Macroeconomic models can produce very different results depending particularly on whether and how they recycle revenues, represent awareness effects and other market imperfections, and/or endogenise technical change.**

Note: *Resource cost = NPV (Cost to Gov. + Net cost to firms)/(lifetime CO2 saved), in all packages net overall benefit to firms; ** Grocery Retail and Hotels are local markets and will be able to pass on extra cost of 100% auctioning in UK "CE ETS"; ***Based on market price of €15/tCO2 and €30/tCO2 in 2010 and 2020 and allocation cut back of 1%pa from 2005

Conclusions on international strategies

- Sequential 'target and trade' is an appropriate foundational framework
- But it is fundamental mistake to conceive of it as a 'cap-and-trade' only agreement: such agreement incentivises governments at the highest level to address:
  - the full spectrum of technologies
  - across all six key components of the energy system
  - the full chain of innovation through to deployment
  - and to tackle barriers to diffusion and cost internalisation
- And it needs to be supplemented by range of policy measures related to technology, for some of which could be good case for international cooperation directed at:
  - RD&D for expensive big-unit high-risk technologies
  - Technology roadmapping and market building (sharing costs of strategic deployment)
  - international technology transfer and diffusion at scale
  - Appropriate 'division of labour' according to technological and natural resource base