PROMOTING CLIMATE-FRIENDLY TECHNOLOGIES: INTERNATIONAL PERSPECTIVES AND ISSUES

Michael Grubb[1], *Richard Stewart*[2]

– Introduction

It is widely recognized that achieving limitations on greenhouse gas (GHG) emissions at acceptable social cost will involve far-reaching technological change in the energy and in other sectors. Indeed, at present this seems one of the few things on which there is transatlantic agreement in relation to climate change. Cooperation to promote development of low-GHG technologies thus appears as a natural issue to consider as a focus for rebuilding a constructive transatlantic dialogue. There are, however, disagreements among academics and policy analysts regarding the best way to promote appropriate technological change in the climate context. There are also practical institutional challenges in devising and successfully implementing policies, both at the domestic and international levels, that will successfully promote the needed innovations. This paper simply seeks to frame the issues presented.

– Opposing views on technology development in the climate context

Reviews of economic studies show consistently that assumptions about technology development are crucial to economic and policy conclusions (eg. Dowlatabadi 1998; Edmonds et al, 1999; World Resources Institute, 2000). The climate policy debate is often characterized by two polar views.

1. Visiting Professor, Imperial College, London and Associated Director of Policy, the Carbon Trust, London. Also Senior Research Associate, Cambridge University, UK.
2. University Professor and Director of the Center on Environmental and Land Use Law, New York University; Advisory Trustee, Environmental Defense.

The "technology push" view holds that the primary emphasis should be on development of low-GHG technologies, typically through publicly funded R&D programmes, rather than regulatory limitations on emissions. Proponents of this view argue that, given that climate risks are a function of long-term accumulation of GHG in the atmosphere, it would be preferable to concentrate in the near term on investing in technological innovation, and adopt emissions limitations later when innovation has lowered the costs of limiting GHG emissions and the existing capital stock turns over, rather than mandating costly reductions now (Wigley, Richels and Edmonds 1996) [3].

The opposing "market pull" view holds that technological change must come primarily from the business sector, and is primarily a product of economic incentives. In the climate context, this view gives priority to adoption of regulatory measures such as technology-based regulatory limitations, GHG emission caps, or charges. Profit-seeking businesses will respond by innovating to produce technologies that will reduce emissions at less cost in order to gain competitive advantage over rivals [4]. From this perspective, postponing emissions limitations would simply defer the whole process of innovation required for the private sector to produce these solutions. Proponents of this approach might acknowledge various market failures with respect to the early stages of innovation; business firms may not have adequate incentive to invest in basic research because they may be unable to appropriate (through patents, etc.) the knowledge gained, and because the commercial payoffs may be too uncertain and long-term. But "market pull" advocates tend to assume that existing general po-

3. A recent paper in *Science* by Hoffert et al. (2002) received widespread attention for its assertion that technologies to solve climate change do not yet exist, and it called for a grand technology programme encompassing new nuclear and space-based energy sources to solve the problem.
4. This perspective draws on a considerable literature on induced technical change (eg. reviewed by Weyant J.P. and T. Olavson (1999), with implications for policy considered eg. in Grubb et al. (1995); Dowlatabadi (1998); and Grubb, Koehler and Anderson (2002).
Lomborg (2001), includes an extensive (and widely cited) sceptical chapter on climate change culminated with the assertion that the problem of climate change would largely solve itself anyway because market forces would make renewable energy the preferred technology even in the absence of regulation.

licies (such as corporate tax breaks for R&D expenditure) are sufficient to overcome these failures [5].

Thus, divergent perspectives on the *process* of technology change lead to directly opposing *policy prescriptions*, in many dimensions, as summarised in Appendix I.

– Establishing a common understanding of technology innovation

This debate should be resolved by recognizing that innovation is a complex phenomenon which in reality encompasses both perspectives. Whilst engineers tend to focus upon R&D, economists since Schumpeter have tended to break innovation down into three components (invention, innovation, and diffusion) – but even this is clearly inadequate. Viewed more closely there are in fact at least six distinct stages to innovation in a market economy: basic R&D applied R&D demonstration; commercialisation; niche market accumulation; and diffusion. Each stage involves technology improvement and cost reduction, but the principal barriers and driving forces change across the different stages: 'technology push' elements dominate early stage research, whilst 'market pull' is increasingly important as technologies evolve along the chain (Figure 1).

5. There is far less need for regulation to create market incentives for innovation in technologies to facilitate adaptation to climate change, but there is need for publicly funded R&D in adaptation measures.

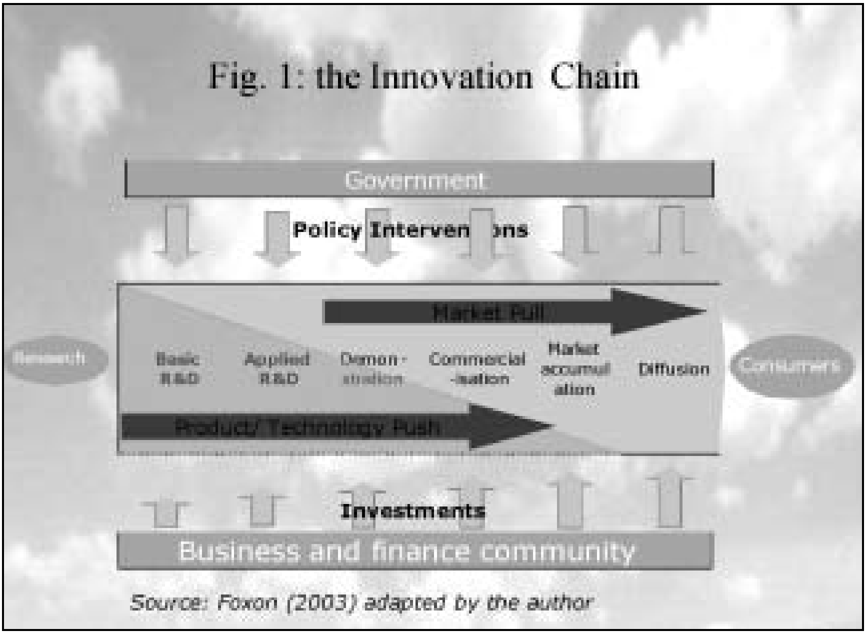

Fig. 1: the Innovation Chain

Source: Foxon (2003) adapted by the author

This framework (which to our knowledge has not been elaborated in published literature) helps to reveal the conflict between the technology push and demand pull views as a false dichotomy, and provides a framework within which a balance between the extremes can be struck. Government has a key role throughout, but its role changes radically along the innovation path. It finances basic R&D in order to lay a foundation for applied R&D and commercialization by business firms; sole reliance on demand-pull strategies will, because of market failures, not achieve the far-reaching, long-term innovations required to address climate change. Government, however, must also adopt regulations to provide market based incentives for firms to invest in innovation. Business invests at all stages, but generally more in the latter stages, driven by amount and timing of expected payoffs to the firm. It is, however, important to send credible regulatory signals to business relatively early in the process in order to create the incentives for the necessary investments. In sum, particularly for a big, long term problem like climate change, policy will be more powerful if emission constraints are combined with R&D and diverse supports to promote technology through different stages of the innovation chain.

– GHG regulatory measures and technology development

What types of regulatory measures are best calculated to stimulate technological innovations by firms by creating market demand for low-GHG technologies, products, and process and production methods and innovations in the use of sinks? The broad range of activities that generate GHG emissions and the long-term character of many of the innovations required argue powerfully for use of broadly applicable economic instruments, such as tradable GHG allowance systems or charges(Stewart and Wiener 2003). Nonetheless, command-and-control quantity limits have been able to successfully induce significant near-to-medium term innovation in particular sectors, for example with respect to automobile emissions of conventional pollutants, and may have a useful role to play with respect to some elements of GHG regulation. With respect to the timing of emissions limitations, the need for credible early regulatory signals to industry, the differing timetables for incremental and fundamental innovation, and capital stock turnover cycles argue for beginning with modest near-term limitations that are incrementally tightened within a regulatory framework that commits to appropriate emissions reduction pathways over time. (Stewart and Wiener 2003).

– Institutional challenges of public-funded technology development

Because of potential scale economies, cooperative specialization, and mutual learning, there is wide scope for beneficial international collaboration in publicly funded R&D for innovation in low-GHG emission and sequestration technologies as well as adaptation technologies. But such efforts face two basic sets of challenges.

First, any public expenditure on technology promotion is immediately faced by a flood of applications from those who believe they have the answer, if only governments would fund it sufficiently; and from companies that scent a chance of free money for something they might have done anyway. Critics – especially economists – can point to long lists of government-sponsored technology failures, some of them astonishingly expensive, due to phenomena that social scientists well recognise in terms of institutional capture. As one cynic put it, 'governments may be bad at picking winners, but losers are good at picking governments'. Good management, set against clear criteria and firm accountability mechanisms, is thus essential.

Second, some of the institutional problems in public R&D are amplified in the context of international technology programmes, where the goal of cooperation among countries is bedevilled by unavoidable issues of competitive rivalry. Every government would like its own industry / technology to receive support from international sources, especially if there is a significant prospect of it delivering commercial success, and is reluctant to spend on technologies of other countries. In addition, as technology nears commercial applicability, issues of intellectual property can become highly sensitive, leading to the reverse of cooperation as participants seek funding from the common pool whilst holding back their most commercially valuable ideas from public scrutiny. As a result, the easiest focus for international technology programmes is often technologies, such as fusion power, that no one realistically expects to be commercially viable in the foreseeable future. There are also problems of governance and accountability for international programmes, which almost inevitably acquire substantial institutional autonomy. If national programmes can be hard to terminate if the results do not fulfil the initial hopes, international ones can be even more difficult.

– Moving from generalised ideas of international technology cooperation to specific programme

In designing international programs for cooperative climate technology R&D, attention must be paid to the goals of the programme (object, scope, and time horizon along the path from basic research to commercial application); the basic R&D strategy and mechanism, extent of participation by different countries; and issues of institutional form, governance, and accountability mechanisms. In addressing these questions, one can draw on a considerable body of historical experience and ongoing programmes in the energy and international environmental fields.

In the context of the global environment, the most obvious example is the World Bank-UNDP-UNEP Global Environmental Facility, and associated World Bank and other carbon-related funds. [6] These are not explicit technology programmes, but have made a significant effort to promote technology development in certain areas (such as biomass energy development and solar PV); more specific technology funds (such as bioenergy fund) have recently been added. As another example, the International Energy Agency has now accumulated almost 30 years experience of coordinating OECD efforts on energy, including an extensive set of 'Collaborating Agreements' on specific technologies. These programmes have now extended beyond the OECD to incorporate a number of developing countries.

In the specific area of international R&D programs aimed at climate-related technology development, at least six very different concepts have been floated:

6. The World Bank Carbon Fund finances GHG-reduction projects that will generate commercially valuable emission reduction credits under the Kyoto Protocol's Clean Development Mechanism.
International trade in such credits, and of emission allowances pursuant to emissions trading systems, can provide funding for commercial development and application of new technologies to reduce greenhouse gas emissions. Thus, GHG regulatory/trading systems can both supply funds for R&D and create regulation-induced market demand for technological innovation. (Stewart and Wiener 2003).

Option	Objectives
Clean Energy R&D Fund	To provide specific R&D support to technologies whose high development cost cannot readily be borne by public funds in a single country.
Clean Energy Demonstration Fund	To provide development and demonstration support to technologies with global applications but where economic development benefits are primarily local, avoiding international IPR concerns.
Clean Energy Venture Capital Fund	To provide venture and development capital for smaller firms with climate related technological innovations
Emissions Reduction Purchase Fund	To put together a large fund for purchasing emission reductions to reward companies for developing carbon management discipline
Climate Leaders Fund	To offer an investment incentive to large companies to differentiate themselves within their sector by virtue of their ability to manage climate risk and seize solution opportunities
International Investor Initiative on Climate Risk	To mobilise mainstream institutional investors behind a programme of dialogue, education and research to assess and act upon the investment risks posed by climate change

Appendix I

The divergent policy implications of different technical change perspectives

Process:	**Technology-push: R&D - led technical change**	**Demand pull: market-led technical change**
	Technical change depends mostly on autonomous trends and government R&D	Technical change depends mostly upon corporate investment (R&D, and learning-by-doing) in response to market conditions
Economic / policy implications:		
Implications for long-rum economics of large-scale problems (eg. climate change)	Atmospheric stabilisation likely to be very costly unless big R&D breakthroughs	Atmosheric stabilisation may be quite cheap as incremental innovations accumulate
Policy instruments and cost distribution	Efficient instrument is government E&D, complemented if necessary by 'externality price' (eg. Pigouvian tax) phased in.	Efficient response may involve stronger initial action, including emission caps / pricing, plus 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
'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: adapted from Grubb, Koehler and Anderson (2002)

– References

Dowlatabadi H. (1998), "Sensitivity of climate change mitigation estimates to assumptions about technical change", *Energy Economics*, 20 (5-6), pp. 473-493

Edmonds J. et al., (1999), "Global technology strategy", Battelle Pacific NW Labs, Washington

Foxon T.J. (2003), Inducing innovation for a low carbon future: drivers, barriers and policies, Carbon Trust, London

Grubb M., M. Ha-Duong, T. Chapuis (1995), "The economics of changing course", *Energy Policy*, 23 (4), pp. 1-147

Grubb M., J. Koehler, D. Anderson (2002), "Induced Technical Change In Energy/Environmental Modelling: analytic approaches and policy implications", *Ann. Rev. En. Env.*, 27, pp. 271-308

Grubb M., C. Hope, R. Fouquet (2002) "Climatic implications of the Kyoto Protocol: the contribution of international spillover", *Climatic Change*, 54, pp. 11-28

Grubler A., N. Nakicenovic, D.G. Victor, (1999a) "Dynamics of energy technologies and global change", *Energy Policy*, 27 (5), pp. 247-280

Grubler A., N. Nakicenovic, D.G. Victor (1999b), "Modelling Technological Change: Implication for the Global Environment", *Ann. Rev. En. Env.*, 24, pp. 545-569

Hoffert M.I. et al. (2002), "Advanced technology paths to climate stability: energy for a greenhouse planet", *Science*, 298, pp. 981-987

IPCC (2001), Climate Change 2001, The IPCC Third Assessment Report, CUP, Cambridge

IPCC (1999), Special Report on Technology Transfer, IPCC/WMO, Geneve

Jaffe A., R. Stavins (1995), "Dynamic incentives of environmental regulations: The effects of alternative policy instruments on policy diffusion", *Journal of Environmental Economics and Management*, 29, pp. 43-63

Lomborg B. (2001), The Skeptical Environmentalist: Measuring the Real State of the World, CUP, Cambridge

Otto-Wene C. (2001), Use of learing curves in energy technology analysis, International Energy Agency, Paris

Stewart R., J. Weiner, (2003), Reconstructing Climate Policy: Beyond Kyoto, AEI Press, Washington DC

Weyant J.P., T. Olavson, (1999), "Issues in modeling induced technical change in energy, environmental and climate policy", *Env. Modeling and Assessment*, 4, pp. 67-85

Wigley T., R. Richels, J. Edmonds (1996), "Economics and Environmental Choises in the Stabilization of Atmospheric CO_2 Concentration", *Nature*, 379 (6562), pp. 240-243

World Resources Institute (1997), The Costs of Climate Protection: a guide for the perplexed, World Resources Institute, Washington DC