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Climate change mitigation policy: an overview of opportunities and challenges

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Abstract

This paper provides a broad overview of the opportunities and challenges facing global climate change mitigation policy ahead of the UN Climate Change Conference in Copenhagen in December 2009. It begins with a brief review of the technological options for mitigating climate change by reducing, and substituting for, the use of fossil fuels (coal, oil and gas). It then summarises the economic case for climate change mitigation, set out in the 2007 Stern Review. The paper then looks at how the implementation of climate policy measures to meet emissions reduction targets has so far had limited success, with worldwide emissions of greenhouse gases growing by 38% between 1992 and 2007. A critique is then provided of the theoretical framing of current climate policies, arguing that a more integrated, long-term approach may be needed, in order to inform the decisions of economic actors in the face of high levels of risk and uncertainty. New economic ideas are then reviewed which aim to provide a more radical re-framing of the steps needed for a transition to a low carbon economy. These include a 'green fiscal stimulus' or 'green new deal', a focus on reducing emissions upstream at the production end rather than downstream at the consumption end, and challenging the accepted economic growth paradigm. Finally, it is argued that high levels of political will, technological innovation, institutional change, business leadership and citizen engagement will be needed to put the world on a pathway to a sustainable and prosperous low-carbon future.

1. Introduction

The increasing scientific evidence of the likely severe impacts and consequences of human-induced climate change is set out in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007). However, the response by national and international policy-makers is struggling to address the global and inter-connected nature of the challenge of climate change mitigation, with (at the time of writing) hopes hanging in the balance of achieving a comprehensive and stringent agreement at the Copenhagen Climate Change Conference in December 2009. This paper sets out the main technological, economic and policy responses so far, arguing that, though progress has been made, this has been constrained by the actions of players with vested interests in maintaining current systems, and by ideological commitments to free-market based solutions. The severe challenge of setting the world on a pathway to a low carbon transition, whilst enabling economic development in developing countries, suggests that more radical approaches may be needed to overcome these difficulties.

2. Climate change mitigation options

In summary, rising atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHG) have resulted from human-induced emissions, particularly from the burning of fossil fuels (coal, oil and gas) for energy, transport and manufacturing uses, and from deforestation and other land use changes. These rising concentrations trap heat in the atmosphere and so alter the energy balance at the earth's surface, leading to rising temperatures, rising sea levels and other physical impacts. These changes lead to feedbacks affecting the energy balance, e.g. cloud cover, and the further emissions of greenhouse gases, such as methane from warming permafrost, that make exact predictions of future levels of warming difficult. Nevertheless, advanced climate systems models predict mean global temperature rises of 1.7-6.4°C by 2100, if past emissions trends continue. This is supported by evidence of a 0.7°C mean temperature rise over the last century, and discernible human influences on temperature increases, melting polar ice and glaciers, and increased frequency of extreme weather events (IPCC, 2007).

The challenge of mitigating the impacts of climate change thus focuses on efforts to reduce human emissions of GHGs from fossil fuel burning, deforestation and land use change. In this paper, we focus on reducing emissions from activities that have largely relied on fossil fuel burning. This is so challenging because these activities have contributed to the large increase in human wellbeing in industrialised countries whilst, because of increasing returns to the adoption of technologies and associated institutional rule systems, human societies are now 'locked-in' to these high carbon systems (Unruh, 2000). To avoid the worst impacts of climate change whilst maintaining and enhancing human wellbeing requires a transition to a low carbon development path.

A low carbon path will require the adoption of a range of energy efficiency improvements in delivery of energy services for households, businesses and transport, and the further development and adoption of a range of low carbon energy supply technologies. These are likely to include a number of renewable sources of electricity and heat generation, such as wind power, solar photovoltaics, solar thermal electric power, sustainably sourced biomass, wave and tidal power, as well as next generation nuclear power, and carbon capture and storage (CCS) from coal and gas-fired electricity generation plants. Rather than a single 'silver bullet' technological solution, a large number of mitigation 'wedges' from the large-scale deployment of many or all of these technologies are likely to be needed to achieve significant levels of emissions reductions by 2050 (Pacala and Socolow, 2004). The International Energy Agency has examined scenarios for reducing global CO_2 emissions by 50% to below 20 Gt CO_2 by 2050, identifying the wedges needed relative to a 'business-as-usual' emissions trajectory (IEA, 2008). They confirm that significant mitigation wedges would be needed from the power generation, transport, industry and buildings sectors, each of which would require contributions from a number of low-carbon technology options (see Figure 1). The implementation of many of these options will give rise to huge technical and political challenges, with advocates both in favour and against particular technological solutions (e.g. Romm, 2006; Mackay, 2009; Giddens, 2009).

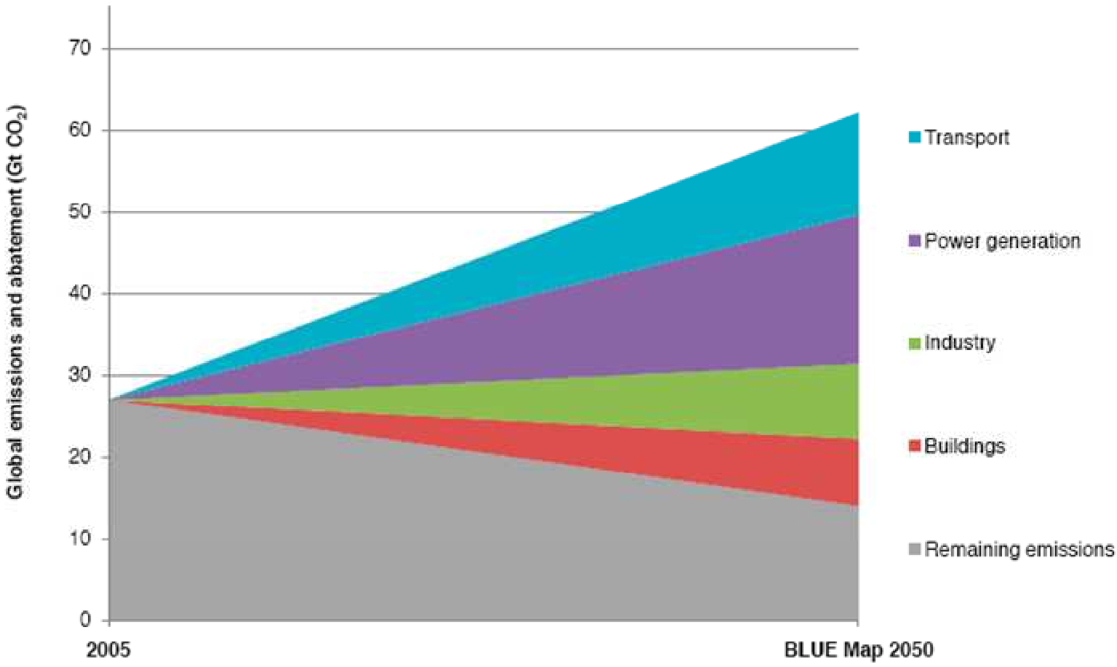

Figure 1. Mitigation wedges for IEA 'Blue Map' mitigation scenario (based on IEA, 2008)

3. Economic case for climate change mitigation

In order to inform action on climate change, in 2006, the UK Government commissioned Sir Nicholas Stern, former Chief Economist at the World Bank, to review the economics of climate change. The resulting Stern Review (Stern, 2007) laid out the economic case for government action, arguing that climate change represents the "greatest market failure the world has ever seen".

However, as Stern recognised, the economic case on its own is unlikely to stimulate action to mitigate climate change, as there are social and ethical issues that also need to be addressed. Climate change results from the *externality* associated with greenhouse gas (GHG) emissions, i.e. costs that are not paid by those who create the emissions. It has a number of features that distinguish it from other social and environmental problems:

- Mitigating climate change is a global public good (i.e. the benefits of mitigation accrue to everyone on the planet and can not be bought by any individual at the expense of others);
- Impacts are long-term and persistent;
- Uncertainties and risks are pervasive; and
- Risk of major, irreversible change with non-marginal economic effects.

Hence, questions arise of equitable sharing of the responsibility for past emissions and the costs of achieving a low-carbon transition, both between richer and poorer countries and between present and future generations. The above features also imply that some standard tools of economic analysis, such as cost-benefit analysis, are limited in their usefulness, since they assume only marginal changes. The issue of the appropriate rate for discounting future costs and benefits also proved to be controversial, with Stern and colleagues arguing that standard treatments of discounting are inappropriate for comparing potential future mitigation pathways (Dietz et al., 2007).

Whilst not undertaking a single global cost-benefit analysis to calculate the optimal level of climate change mitigation, Stern used a number of different economic tools to perform separate calculation of costs and benefits. This approach has been criticised both by neo-classical economists for a lack of rigour (Nordhaus, 2008) and by ecological economists for still retaining a number of debatable assumptions (Spash, 2008). To calculate the economic costs of climate change impacts, Stern used simple 'integrated assessment models', giving equal weight to impacts in poorer countries and on future generations. These models include impacts for which there is a 'market' value, such as agriculture and food supplies, due to changes in crop patterns, energy use, due to additional cooling requirements, and coastal zones, e.g. impacts on fisheries; 'non-market' impacts, including impacts on human health, e.g. increased prevalence of diseases and impacts on natural ecosystems; and 'system change' impacts, such as higher levels of conflict and migration. Stern argued that the likely annual social and economics costs of the impacts of climate change would be in the range 5-20% of global GDP, now and forever.

In order to calculate the economic costs of climate change mitigation, Stern used both 'bottom-up' and 'top-down' models. Bottom-up economic analyses incorporate a range of low-carbon technological options, and assume that the costs of these options fall with their implementation as a result of learning effects and economies of scale (IEA, 2000). They then calculate the costs of a low-carbon pathway, compared to the costs of a 'business-as-usual' pathway, with little or no consideration of macroeconomic factors. Bottom-up modelling by Prof. Dennis Anderson for the Stern Review calculated that, to reduce global emissions by 33% to 18 GtCO2e by 2050, the addition annual cost of following this low-carbon pathway would rise from $134bn in 2015 to $930bn in 2050. Assuming continuing high levels of economic growth over this period, this would imply that the costs of mitigation would be equal to 1% of global GDP by 2050. Top-down economic analysis uses macroeconomic models of the global economy, with a relatively small number of regions and economic sectors. These models incorporate the implications of changes in investment patterns on wider economic activity and most, but not all, models assume a 'general equilibrium' framework. They calculate that stabilisation of GHG concentrations at 450-550 ppm CO2e (carbon dioxide equivalent) implies mitigation costs of 1-2% of global GDP per year by 2050. Hence, both bottom-up technology-rich and top-down macroeconomic modelling suggest that the annual costs of climate change mitigation would be around 1-2% of global GDP by 2050. On this basis, Stern concluded that there is a strong economic case for undertaking mitigation, as the costs are likely to be much lower than the costs of the impacts of climate change. Stern argued that governments should aim to stabilise greenhouse gas (GHG) levels in the atmosphere at between 450 and 550 ppm CO_2 equivalent. A review for the Australian Government in 2007 by eminent economist Ross Garnaut came to similar conclusions (Garnaut, 2007).

Stern (2007) identified three complementary policy areas as necessary to deliver timely, effective and economically efficient climate change mitigation:

- carbon pricing, through taxes or tradable permit schemes;
- increasing support for R&D, demonstration projects and early stage commercialisation of clean technologies; and
- measures to overcome institutional and other non-market barriers to deployment of energy efficiency and low carbon measures.

Based on the scale of low carbon R&D and deployment needed, Stern recommended that deployment incentives for low-emission technologies should increase two to five times globally from current levels of $33bn to reach $65-150bn, and that global public energy R&D funding should double, to around $20bn, for the development of a diverse portfolio of technologies. This level of support is needed to bridge the gap between the current high costs of many low carbon options and the current high carbon alternatives. The deployment support would enable the low carbon options to benefit from learning, scale and adaptation effects, so reducing their unit costs. These effects are usually analysed in the form of learning or experience curves (IEA, 2000). Analysis of past cost reductions for energy technologies has typically shown empirical learning rates of 10-25%, meaning that a 10-25% reduction in unit costs results from a doubling of cumulative deployment (Macdonald and Schrattenholzer, 2001). Hence, as shown in Figure 2, early deployment support would be expected to reduce the cost of low carbon options, so that they would become cost competitive with current technologies, under the general support of a carbon price, provided by a carbon tax or trading scheme.

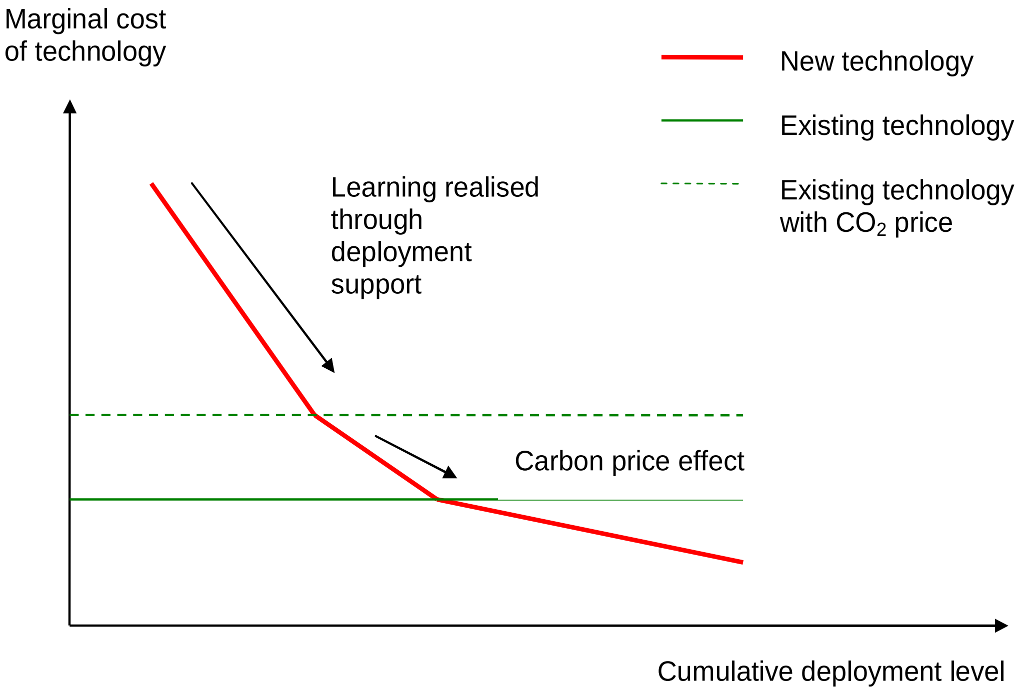

Figure 2. Interaction between carbon pricing and deployment support (based on Stern, 2007)

4. Implementation of climate policy measures

The first internationally agreed targets for climate change mitigation were those set by the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol set targets for industrialised countries only to achieve an average 5% reduction in GHG emissions by 2008-12, relative to 1990 levels. The Protocol came into force in 2005, with ratification by the Russian government, following that of all other industrialised countries, except the U.S.A. and Australia[*]. Some countries, including the UK and Germany, are on track to meet their Kyoto targets, at least partly due to the side effects of non-climate-related policies, such as the dash for gas-fired electricity generation in the UK following liberalisation of electricity markets. However, many other countries, including Canada and Spain, are highly unlikely to achieve their Kyoto targets, and, overall, worldwide GHG emissions grew by 38% between 1992 and 2007.

The Kyoto Protocol also provided for carbon emissions trading between governments and by firms, designed to stimulate the lowest-cost emissions reductions which could then be traded within overall caps. The European Emissions Trading Scheme, which began operation in 2005, followed this cap-and-trade approach in order to help the EU meet its target of 8% reduction in emissions by 2008-12 from 1990 levels. This covers emissions from power generation and energy-intensive industries totalling around 40% of total EU emissions. The Waxman-Markey Bill, which was passed by the U.S. House of Representatives in June 2009, but (at the time of writing) had yet to be agreed by the U.S. Senate, would set up a similar cap-and-trade for the U.S. to achieve emissions reductions of 17% by 2020 and 83% by 2050, relative to 2005 levels.

[*] Australia later ratified the protocol in 2007.

The policy areas identified by Stern are beginning to be reflected in policies of the European Union member states. These are seen as forming part of a “new, green industrial revolution” (Milliband, 2007; Barroso, 2007). Such calls have recently been echoed by the new US Secretary of Energy (Chu, 2009). In December 2008, the European Council of Ministers agreed on an Energy and Climate Policy package, both for domestic action and as a basis for negotiation at the Copenhagen meeting. This package aims to address environmental targets, whilst, at the same time, contributing to ensuring security of energy supply for EU countries. The main aims of this package are to achieve by 2020:

- a 20% reduction in carbon emissions, with a promise of a 30% reduction in carbon emissions by 2020, if there is an international agreement at the COP15 meeting in Copenhagen;
- 20% of final energy from renewables; and
- a 20% improvement in energy efficiency.

In July 2009, the Major Economies Forum, including China, India, Brazil and the G8 countries, recognised that, to avoid the most serious impacts, the increase in global average temperature above pre-industrial levels ought not to exceed 2°C. This is likely to require atmospheric concentrations of greenhouse gases to stabilise below 400 ppm CO_2equiv (Meinshausen, 2006; Anderson and Bows, 2008). Even for a very small chance of exceeding 4ºC rise by 2100, global emissions need to peak by 2016 and then reduce by around 3% per year to 2100 (Committee on Climate Change, 2008). This implies global GHG emissions will need to be reduced by 50% by 2050, from current 40 GtCO2e to 20-24 GtCO2e by 2050. Assuming fair allocation of these emissions amongst 9 billion people by 2050, this implies a share of 2.1 to 2.6 tCO2e per person. Hence, if these emissions are shared equitably between countries, this implies that at least 80% reductions are required by industrialised countries. Emissions reductions of these orders of magnitude will require dramatic transformation of systems of production and consumption, involving different possible transition pathways to low carbon power generation, transport and energy use systems (Foxon et al., 2009). The UK government has committed itself to a legally-binding target of reducing its GHG emissions by 80% by 2050, from 1990 levels, with a new institution, an expert-led Committee on Climate Change to recommend 5-yearly budgets to put the UK on track to achieving this target (Committee on Climate Change, 2008, 2009). Other members of the G20 group of major economies, including the U.S., are considering bringing in similar legally-binding targets.

The main policy instruments to achieve these targets being applied in European and other industrialised countries are Emissions Trading Schemes (ETS), and R&D and price-support measures for deployment of new renewable and other low-carbon energy technologies. As well as stimulating the deployment of existing low-carbon technologies and processes, these measures are intended to promote innovation and rapid take-up of low-carbon alternatives, such as wind power, solar photovoltaics, nuclear power, and carbon capture and storage (CCS), which are currently more expensive than the dominant alternatives of using coal and gas for electricity generation. Complementary measures to improve the building stock, in order to reduce the heat demand by homes and businesses, have received more attention in some countries, such as Germany, than others, such as the UK.

5. Critique of current policy approaches

Unfortunately, as described above, current policy measures have so far had relatively little success in stimulating emissions reductions. Indeed, it is notable that the 2008-09 economic recession has led to more rapid, though temporary, emissions reductions (Bowen et al., 2009b). We argue that this lack of success is at least partially the result of the theoretical framing of current climate policies, which draw on a range of theoretical approaches. This leads to potential inconsistencies and arguably forms an inadequate basis for addressing long-term environmental problems, in which actors need to make decisions in the face of high levels of risk and uncertainty, both in relation to outcomes of current actions and the potential for the development of alternatives. Table 1 outlines the main policy measures and their underlying framing.

Policy area	**Theoretical framing**	**Example policy**	**Example target**
Carbon pricing	Neo-classical economic theory	EU Emissions Trading Scheme	21% reduction in EU ETS sector emissions by 2020 (compared to 2005)
Support for R&D, demonstration projects and early commercialisation of clean technologies	(Neo-classical) innovation theory/ (evolutionary) innovation systems theory	Feed-in tariffs for renewable energy technologies in many EU countries	20% share of final energy from renewables by 2020
Overcoming institutional and non-market barriers to deployment	Institutional and behavioural economics	Fiscal, regulatory or information incentives to take-up (cost effective) energy efficiency improvements	20% reduction in energy consumption by 2020

Table 1. Framing of current climate change mitigation policies

As can be seen from the Table, these measures focus largely on the important issue of reducing emissions from energy supply and energy-intensive industries, which are within the scope of the EU Emissions Trading Scheme. There is relatively little focus on wider systems of production and consumption, to stimulate a more general greening of these systems by creating space and incentives for eco-innovators and greening of markets. Whilst markets in tradable carbon permits are likely to have an important role to play, it may be argued that the wider greening of markets and other incentives to promote wide and deep low-carbon innovation are more important to achieving a long-run transition to a low carbon economy (Andersen and Foxon, 2009).

The rationale for carbon pricing comes from environmental economics. Here, a ‘market failure’ is identified in relation to the existence of negative *environmental externalities,* i.e. environmental by-products of consuming or producing activities that affect third parties but are not reflected in market transactions and prices (Pigou, 1932). In this case, the emissions of CO_2 and other greenhouse gases from energy production and other industrial activities has historically been the unpriced externality. Arguably the simplest way to price carbon emissions would be to impose a carbon tax on activities leading to emissions. However, taxes tend to be politically highly unpopular and there are concerns about the threat to international competitiveness of industries faced with taxes, especially if there is the potential for firms to relocate production to countries without a carbon tax (so-called 'carbon leakage'). Efforts to introduce a European carbon tax in the early 1990s failed to gather enough political support to be enacted.

The alternative pricing mechanism is to impose an emissions trading scheme. Following the success of an emissions trading scheme in the U.S. to reduce emissions of sulphur dioxide from coal-fired power stations and other industrial firms, the legal basis for emissions trading was agreed in the 1997 Kyoto Protocol, which set carbon emissions reduction targets for industrialised countries. The European Union subsequently agreed a carbon Emissions Trading Scheme (ETS), which began with a first period in 2005 to 2007, to enable learning, followed by a second period covering 2008 to 2012, to coincide with the commitment period under the Kyoto Protocol. As part of the Climate Policy package agreed in December 2008, the EU agreed that the third phase of the ETS would run from 2013 to 2020. The ETS is a 'cap-and-trade' system, setting an overall emissions cap for firms included in the scheme, with permits tradable between firms that are likely to exceed their allocation and firms that have spare credits. The economic rationale is that this enables the system to find the least-cost reduction opportunities. The political and competitiveness concerns were also eased by having a high proportion of free allocation of permits to firms. However, the environmental effectiveness of the scheme is determined by the level of the overall cap. In Phase One of the EU ETS, the cap set by the sum of the national allocations was too high to require emissions reductions much beyond business-as-usual, leading to a collapse in the price of permits in early 2007. The free allocation of permits also led to 'windfall' profits for electricity companies, who were given permits for free, but received the benefits of the permit prices being included in electricity costs to consumers. For Phase Two, the European Commission required countries to impose stronger caps, though the permit price began to fall again in late 2008, as a result of reductions in energy demand due to the economic recession. In Phase Three, the allocation of permits will increasingly move from free allocation to auctioning, though one of the concessions to the East European coal industry was that it should continue to receive a proportion of free allowances. Though the new agreement for Phase Three from 2013 to 2020 gives a certain level of certainty to firms that there will be a carbon price in this period, no mechanism was agreed for setting a floor or ceiling to the carbon price. This uncertainty in the level of the carbon price means that, on its own, it is unlikely to stimulate significant levels of investment leading to innovation in low-carbon technologies and processes. Thus, a carbon price is a necessary but not sufficient driver of low-carbon innovation (since without a carbon price, the economic 'benefit' of unpriced emissions to firms would be likely to override any positive incentives for low-carbon innovation.) The plan to introduce a similar carbon trading scheme in the U.S. under the Waxman-Markey Bill looks set to reproduce many of the same advantages and drawbacks of the EU scheme.

The rationale for increasing support for R&D, demonstration projects and early stage commercialisation of clean technologies comes from innovation theory (Foxon, 2003). The economic rationale is that, since new knowledge is often easy to copy, innovators cannot always appropriate the full benefits of their investment in knowledge creation, and so private firms may lack the incentives necessary to undertake socially efficient levels of innovative activity. In addition, historical evidence shows that the costs of new technologies typically reduce along learning curves as they are introduced into the market.

The rationale for measures to overcome institutional and other non-market barriers to deployment comes mainly from institutional and behavioural economics. It is observed that firms and consumers do not act as purely rational economic agents, but their behavioural is influenced by the social and institutional context in which they act. The factors that prevent purely rational behaviour are often referred to as barriers, but they reflect these more complex drivers of behavioural change. For example, it is observed that many energy efficiency opportunities, such as installing wall or loft insulation, are not taken up, despite the fact that the initial capital costs would be quickly paid back by reduced energy bills, implying that they would be taken up by economically rational actors. In this case, the barriers could relate to the persistence of individuals' 'habits' preventing change, such as the behavioural predisposition to consider capital and running costs separately (Marechal, 2009), or to the fact that culturally embedded patterns of behaviour are slow to change (Nye et al., 2009). Similarly, firms may not invest in potentially economic low-carbon innovation opportunities, because these conflict with existing routines that firms follow based on their historical experiences (Unruh, 2000).

Thus, it is noticeable that the rationales for the different types of mitigation policy instrument come from different areas of economic theory. In particular, there is an absence of a holistic framework for understanding how these different areas could come together to achieve a transition to a low-carbon economy. Of course, it could be argued that such a piecemeal approach is the only pragmatic possibility. However, the relatively slow pace of mitigation achieved so far, and the difficulties in reaching agreement at the 2009 Copenhagen Climate Conference on anything like the emissions reduction levels that the climate science says would be necessary to limit global temperature rises to the 2°C target, suggest that a more radical re-framing of the problem may be necessary.

6. New economic thinking for climate change mitigation

Whilst most observers agree that some mechanism to price carbon emissions, either through a carbon tax or a cap-and-trade emissions scheme, is a necessary component of a climate change mitigation policy package, some have argued recently that more radical measures are likely to be needed to stimulate a global transition to a low-carbon economy. This would require global GHG emissions to peak within the next 10 years and then reduce by around 4% per annum. In order to enable economic development in developing countries, these countries would be required to decouple their rate of emissions increase from continued economic growth, so that rich and poor countries would equalise their emissions at around 2 tonnes of CO_2 equivalent per person by 2050. Debates centre on whether this can be achieved by a strengthening of the three existing types of policy instrument, or whether a more radical re-framing is necessary to achieve a more coherent policy mix. Amongst the approaches being discussed are a 'green fiscal stimulus' or 'green new deal', a focus on reducing emissions upstream at the production end rather than downstream at the consumption end, and challenging the accepted economic growth paradigm.

The 2008-09 global economic crisis has created additional difficulties in moving towards a low carbon economy, particularly in relation to whether the levels of private investment funding needed will be available. However, it has also been argued by some that this represents an opportunity for simultaneously addressing economic and environmental concerns. Most industrialised and rapidly developing countries have adopted a public fiscal stimulus package, parts of which are focussed on investment in green technologies and infrastructure. For example, South Korea is focussing around 80% of its overall fiscal stimulus on green technology and manufacturing, China is investing heavily in the installation of large wind farms and solar photovoltaics, and the U.S. is supporting the renewal of its electricity grid and moves towards a 'smart grid' that would enable more intelligent management of demand and integration of intermittent renewable energy sources. However, these and other countries are also investing in support of old, high carbon industries, such as car manufacturing, without necessarily requiring firms to move more rapidly towards developing low carbon vehicles. Nicholas Stern and colleagues proposed that a 'green fiscal stimulus' (Bowen et al., 2009a) of the order of 0.8% of global GDP, or $400 billion of extra public spending worldwide on 'green' measures over the next two years would be appropriate.

Others have suggested that a green fiscal stimulus needs to be complemented by a wider range of institutional and regulatory changes to promote a more rapid low carbon transition. This is referred to as a 'Green New Deal', after President Roosevelt's New Deal in the 1930s, which created millions of jobs and helped the U.S. to recover from the Great Depression. As part of its Green Economy Initiative, UNEP (the United Nations Environment Programme), in collaboration with a wide range of international partners and experts, is examining the conditions and requirements for a 'Global Green New Deal' (UNEP, 2009). This builds on a report that it commissioned from the respected environmental economist Edward Barbier which sets out the economic case for action (Barbier, 2009). The three broad objectives proposed in the March 2009 UNEP policy brief are:

(1) Make a major contribution to reviving the world economy, saving and creating jobs, and protecting vulnerable groups;
(2) Reduce carbon dependency and ecosystem degradation, putting economies on a path to clean and stable development; and
(3) Further sustainable and inclusive economic growth, achievement of the Millenium Development Goals, and end extreme poverty by 2015.

UNEP argues that this will require co-ordinated government action in three areas:

(a) a 'green' fiscal stimulus of the order of 1% of global GDP ($750 billion) over the next two years, or around a quarter of the total size of the fiscal stimulus packages currently proposed by the G20 countries;
(b) domestic policy reforms to enable the success of green investment within domestic economies; and
(c) reforms to international policy architecture and international co-ordination to enable and support national initiatives.

The 'green' stimulus would cover investment in energy efficiency of buildings, greener vehicles and transport infrastructure, renewable energy projects, 'smarter' electricity grids, and more sustainable agriculture and freshwater systems. A range of domestic policy interventions would aim to ensure a "level playing field" to enable the investments in green sectors to take hold and flourish as commercially viable businesses. Reforms to the international policy architecture would aim to provide the framework for a transition towards a more sustainable economic system, including action in the areas of international trade, international aid, a global carbon market, global markets for ecosystem services, development and transfer of technology, and further international co-ordination to enable the participation of both industrialised and developing countries in the global Green New Deal initiative.

In July 2008, a group of leading UK economists and environmentalists independently proposed a ‘Green New Deal’ to tackle the financial, energy and climate crises (Green New Deal Group, 2008). Their programme aims to combine stabilisation in the short term with longer-term restructuring of the financial, taxation and energy systems. They set out an even more radical programme of action, including:

- Executing a bold new vision for a low-carbon energy system making ‘every building a power station’ through a $80 billion programme of investment in energy efficiency and local renewable electricity generation;
- Creating and training a ‘carbon army’ of workers to create the human resources for a vast environmental reconstruction programme;
- Ensuring that fossil fuel prices are high enough to create the economic incentive to drive efficiency and bring alternative fuels to the market, and establishment of an Oil Legacy Fund, paid for by a windfall tax on the profits of oil and gas companies;
- Minimising corporate tax evasion by clamping down on tax havens and corporate financial reporting;
- Re-regulating the domestic financial system to ensure the creation of money at low rates of interest, combined with tighter controls on lending and the generation of credit; and
- The breaking-up of large banks and other financial institutions seen as being “too big to be allowed to fail” in the current economic crisis.

These types of reforms would obviously be opposed by those firms and institutions that perceived them as a threat to their strategic position or interests. Some observers have expressed concerns that, with the immediate financial crisis having been averted by government and central bank actions, such as higher public deficits and the creation of additional money supply through ‘quantitative easing’, the incentives for governments to undertake these types of wider institutional and regulatory reforms has weakened. The likelihood of their adoption will depend on continued public pressure and on how the state of the global and national economies evolve over the coming years.

Finally, the question has been raised of whether a sustainable, low carbon economy is compatible with current patterns of ever-increasing material consumption and the focus on achieving economic growth as the primary policy objective in industrialised countries (Victor, 2008; Jackson, 2009). The recent report of the Stiglitz Commission to the President of France, chaired by Economics Nobel Laureate Joseph Stiglitz, noted the evidence that, after basic needs have been met, further increases in consumption do not bring systematic improvement in people’s reported happiness (Stiglitz et al., 2009). The Stiglitz Commission argued that policy in industrialised countries should focus more on supporting the achievement of desired goals such as high levels of employment, reducing social inequalities and personal wellbeing through fulfilling social interactions, using a wider range of indicators than just GDP growth.

7. Towards achieving global climate change mitigation

This paper has examined the opportunities and challenges of moving to a low carbon economy to mitigate the severe threat posed by human-induced climate change. Whilst there is some agreement on the outline of the steps needed – to put a price on carbon emissions; to promote innovation and deployment of low carbon technologies; and to overcome institutional and non-market barriers to adoption of energy efficiency and low carbon measures – there is much less agreement on the technical and economic feasibility and political acceptability of these steps.

The mainstream political position has been to work in incremental steps to implement changes that will gradually reorientate economic decisions of firms and individuals in low carbon directions, whilst setting stronger long-term emissions reduction targets. Thus, the broad outlines of the proposed deal at the UN Climate Change Conference in Copenhagen in December 2009 are expected to be:

(1) Goals for reductions of GHG emissions by industrialised countries in absolute terms for 2020 and 2050;
(2) Goals for reduction in GHG emissions by developing countries relative to their expected increases in GDP, for 2020 and 2050;
(3) Funds provided by industrialised countries for transfer of low carbon technologies to developing countries;
(4) Funds provided by industrialised and rapidly developing countries for adaptation to impacts of climate change in poorer countries; and
(5) Regulatory and/or financial incentives for avoiding deforestation in developing countries.

The details, though, of the levels of emissions reduction commitments by individual countries and of the financial transfers between industrialised and developing countries to promote mitigation and adaptation are highly contentious.

Among the main instruments for achieving these targets are expected to be increases in the scope and coverage of national and international carbon markets, such as the European Emissions Trading Scheme, and further regulatory and financial incentives for the innovation and deployment of low-carbon technologies, such as renewable energy sources, electric vehicles and carbon capture and storage (CCS) of emissions from coal- and gas-fired electricity generation. However, as we have seen, the initial implementation of carbon markets in the European Union has not been without problems. Whilst some argue that these initial difficulties will be overcome as more experience with carbon markets is gained and stronger caps are imposed in future phases, others argue that this type of ‘downstream’ trading system is not likely to be the most effective mechanism for achieving high levels of emissions reductions. This is because there are a very large number of sources covered by this type of scheme. Hence an ‘upstream’ carbon trading system, based on a smaller number of sources at or closer to primary energy production, such as oil refining and electricity generation has been argued for, as part of a more streamlined policy approach (Tickell, 2008).

The scale of the transformation of systems of production and consumption to achieve a transition to low carbon economies at national and global levels has led some to argue that more radical approaches are needed. Proponents of a ‘green new deal’ have argued that both a larger green economic stimulus and significant institutional and regulatory changes are needed to address the inter-locking challenges of climate change, ecosystem degradation and economic credit crunch. Recently, the question has been raised of how compatible a sustainable, low carbon economy can be with current patterns of ever-increasing material consumption and focus on economic growth as the prime aim of policy. It is important that all these ideas are subject to public debate and scrutiny, as whether a low carbon future is possible depends on people's willingness to accept significant changes to current socio-economic systems and support for an alternative vision of a more equitable and maybe less materialistic world. In any case, it is clear that high levels of political will, technological innovation, institutional change, business leadership and citizen engagement will be needed to deliver and successfully implement the current and further global agreements to put the world on a pathway to a sustainable and prosperous low-carbon future.

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References

Anderson, K. and Bows, A. (2008), Reframing the climate change challenge in light of post-2000 emissions trends. *Phil. Trans. R. Soc. A* **366**, 3863-3882.

Andersen, M M and Foxon, T J (2009), 'The greening of innovation systems for eco-innovation – Towards an evolutionary climate mitigation policy', paper presented at DRUID Summer Conference on *'Innovation, Strategy and Knowledge'*, Copenhagen Business School, Denmark, http://www2.druid.dk/conferences/papers.php?cf=32

Barbier, E (2009), *A Global Green New Deal: Final Report*, Report prepared for UNEP, http://www.unep.org/greeneconomy/

Barroso, J M (2007), 'Europe's energy policy and the third industrial revolution', speech by President of the European Commission at Loyola de Palacio energy conference, Madrid, 1 October 2007

Bowen, A., Fankhauser, S., Stern, N. and Zenghelis, D. (2009a), *An outline of the case for a 'green' stimulus*. Policy Brief, Centre for Climate Change Economics and Policy, LSE. Available at http://www.cccep.ac.uk/pdf/AnOutlineOfTheCaseForAGreenStimulus.pdf

Bowen, A, Forster, P M, Gouldson, A, Hubacek, K, Martin, R, O'Neill, D, Rap, A and Rydge, J (2009b), 'The implications of the economic slowdown for greenhouse gas emissions and targets', *Centre for Climate Change Economics and Policy (CCCEP) Working Paper No. 11*, London School of Economics and University of Leeds.

Committee on Climate Change (2008), *Meeting Carbon Budgets – the need for a step change*, 1st Annual Report to Parliament, October 2009, http://www.theccc.org.uk/reports

Committee on Climate Change (2009), *Building a Low Carbon Economy – the UK's contribution to tackling climate change*, 1st Report, December 2008, http://www.theccc.org.uk/reports

Dietz, S, Anderson, D, Stern, N, Taylor, C and Zenghelis, D (2007), 'Right for the right reasons: A final rejoinder on the Stern Review', *World Economics* **8** (2), 229-258.

Foxon, T J (2003), *Inducing innovation for a low carbon future: drivers, barriers and policies*, The Carbon Trust, London, also available at http://www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=CT-2003-07&metaNoCache=1

Foxon, T J, Hammond, G P and Pearson, P J (2009), 'Developing transition pathways for a low carbon electricity system in the UK', *Technological Forecasting and Social Change* (to appear)

Garnaut, R (2008), *The Garnaut Climate Change Review*, Cambridge University Press.

Giddens, A (2009), *The Politics of Climate Change*, Polity Press, London.

Green New Deal Group (2008), *A Green New Deal*, New Economics Foundation, London, http://www.greennewdealgroup.org/

International Energy Agency (IEA) (2000), *Experience Curves for Energy Technology Policy*, OECD/IEA, Paris.

Jackson, T (2009), *Prosperity without Growth: Economics for a finite planet*, Earthscan, London.

Mackay, D (2009), *Sustainable Energy – without the hot air*, UIT Press, Cambridge.

Marechal, K (2009), 'An evolutionary perspective on the economics of energy consumption: The crucial role of habits', *Journal of Economic Issues*, Vol. XLIII, No. 1, pp.69-88.

Meinshausen, M. (2006), 'What does a 2C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates', in *Avoiding dangerous climate change* (eds H J Schellnhuber, W Cramer, N Nakicenovic, T Wigley & G Yohe), pp. 253–279, Cambridge University Press.

Miliband, D (2007), 'Time for a green industrial revolution', speech by Environment Secretary at University of Cambridge, 5 March 2007.

McDonald, A. and Schrattenholzer, L. (2001), Learning rates for energy technologies. *Energy Policy* **29**, 255-261.

Nordhaus, W (2008), *A Question of Balance: Weighing the Options on Global Warming Policies*, Yale University Press, New Haven, CT, 2008.

Nye, M, Whitmarsh, L and Foxon, T J (2009), 'Socio-psychological perspectives on the active roles of domestic actors in transition to a lower carbon electricity economy', *Environment and Planning A* (to appear).

Pacala, S and Socolow, R (2004), 'Stabilization wedges: solving the climate problem for the next 50 years with current technologies', *Science* Vol. 305. no. 5686, pp. 968 – 972.

Pigou, A (1932), *The Economics of Welfare* (4^{th} Edition), Macmillan, London.

Romm, J (2006), *Hell and High Water: Global Warming - the Solution and the Politics -and What We Should Do*, New York: William Morrow.

Spash, C (2007), 'The economics of climate change à la Stern: Novel and nuanced or rhetorically restricted?', *Ecological Economics* 63, 706-713.

Stern, N (2007), *The Economics of Climate Change – the Stern Review*, Cambridge University Press.

Stiglitz, J, Sen, A and Fitoussi, J-P (2009), *Report by the Commission on the Measurement of Economic Performance and Social Progress*, Report to President Sarkozy, Paris, France, http://www.stiglitz-sen-fitoussi.fr/

Tickell, O (2008), *Kyoto2*, Zed Books, London and New York

United Nations Environment Programme (UNEP), *A Global Green New Deal: Policy Brief*, http://www.unep.org/greeneconomy/

Unruh, G C (2000), 'Understanding carbon lock in', *Energy Policy* **28**, 817-830.

Victor, P (2008), *Managing without Growth – slower by design not disaster*, Edward Elgar, Cheltenham, UK and Northampton, MA, USA.