Climate Change Policy – Time for Plan B

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Policy Exchange

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Executive Summary

Introduction

The United Kingdom and its European Union partners have spent the best part of two decades attempting to put in place a global agreement to reduce greenhouse gas (GHG) emissions, with a headline aim of limiting the increase in mean global temperature to no more than 2°C relative to pre-industrial levels.

Unfortunately, as of today these efforts have met with failure, and the prospects of success appear increasingly slender. The most recent predictions from the International Energy Agency (IEA) show that even if governments follow through with the unilateral commitments they made at the 2009 Copenhagen Climate Conference, the global temperature will still rise by 3.5°C in the long-term.

Implications for EU and UK policy

The EU and UK have adopted ambitious targets for emissions reductions, including at EU level a 20% reduction by 2020 compared with 1990 levels. These targets formed part of an overall strategy aimed at achieving a comprehensive, legally binding and effective global agreement, through a combination of intensive diplomatic efforts with strong "leadership by example". At the time they were adopted there was a strong case for the EU to take a leadership role on climate change, given that no other major world player wished to take on such a role, and that the chances of success were perceived to be reasonably high.

However, major global players, including crucially the "G2" nations (China and the USA), have been largely unmoved by the EU's commitments. European policy-makers must therefore now come to terms with the reality of the failure of international negotiations, and the fact that EU leadership has proven much less effective than had been hoped. It is now time to develop a "Plan B" climate policy on the basis that:

1. "Leading by example" through the adoption of ambitious GHG reduction targets has been largely ineffective, and its future effectiveness as a means of persuading others to act should not be overestimated.
2. There will be no comprehensive, ambitious global agreement in the short or probably even medium-term.
3. Scientific evidence suggests that limiting warming to 2°C is very unlikely to happen.

This paper therefore proposes some high level changes in UK and EU policy, with the aim of developing a Plan B climate policy that would better reflect the new and potentially dangerous circumstances we find ourselves in. These Plan B changes fall into two categories: (1) continued efforts to promote mitigation, but with a focus on lowering the costs at global level; and (2) a range of measures aimed at preparation for a warmer world.

1. Plan B mitigation strategy: investing to lower global costs

Despite the poor outlook for a short- or medium-term global solution, the EU should continue to promote mitigation at the global level, retaining its own 2020 emissions reduction target, and its high level of ambition on longer-term decarbonisation.

However, there are questions about the proposal currently under discussion at EU level, and supported by the UK government, to increase the 2020 target from 20% to 30%. It has a cost currently estimated at €33bn (£27bn)[1] per year. Its impact on the global level of emissions would be minor (as of 2020 the difference would be roughly equivalent to two weeks of China's CO_2 emissions). Claims that it would

[1] All £ conversions of US$ and Euros are quoted in 2010 £ values using PPP exchange rates.

have a significant influence on other global players are wishful thinking, particularly in light of the failure of previous EU attempts to influence the actions of other global players. In reality there is no reason to think that such an increase would have a material impact on the behaviour of other major players, or give the EU added leverage in international negotiations. At best it will be viewed as an irrelevance by the nations that we most wish to convince.

The adoption of a 30% emissions reduction target for 2020 is not fundamental to achieving global climate mitigation. If the EU's 2020 package is reopened and the emissions target increased, then, as part of that, the EU 2020 renewable energy target should, for reasons laid out in this paper, be scrapped (or downgraded to an ambition), enabling greater emissions reduction at lower costs.

European policy-makers should instead focus on an alternative approach that, in the long run, is likely to prove more effective: *promoting technological advances that will promote greater emissions reduction at global level¸ by lowering the costs of the most important technologies for global mitigation.* A significant reduction in the cost of mitigation could do much to reduce opposition and induce meaningful action. Achieving such a reduction requires a much greater focus on innovation. For example, the IEA estimates that "achieving global energy and climate change ambitions ... will require a twofold to fivefold increase in public RD&D spending".

This paper identifies two essential criteria for assessing low carbon investments in low carbon technologies that could lead to such cost reductions:

1. The level of investment in each technology should reflect that technology's **long-term global potential contribution to mitigation.** Clearly the payoff to reducing costs is highest if we focus on the technologies that are likely to be most utilised in the future.
2. Investments should be designed to **maximise long-term global cost reductions.** In particular, this requires an appropriate balance between investments in RD&D and in deployment.

The paper illustrates the implications of these criteria for UK and EU policy with respect to three technologies: Carbon Capture and Storage (CCS), solar photovoltaic (PV) and offshore wind. The main findings are summarised below:

Technology	Long-term global potential	Strategy to maximise long-term global cost reductions	Implications for current policy
CCS	Critical to achieving mitigation goals because of its potential application to both power generation and industrial processes, its impact on total costs (IEA estimates total 2050 mitigation costs to be 70% higher without CCS), and the fact that key countries such as China have very large coal reserves. However, demonstration at commercial scale is still needed.	Focus on RD&D in the form of demonstration projects at commercial scale.	The UK and EU should devote greater resources and political capital to CCS. Focus on short-term emissions and most particularly renewable energy targets prevents this from happening. The IEA estimates a global shortfall of RD&D investment in CCS at between $8bn and $17bn/year.
Solar PV	Long-term potential for truly massive global application, including in Middle East and north Africa. However, it is currently very costly. Future potential depends on the ability to achieve more acceptable levels of cost.	Further RD&D, and deployment in sunny places.	EU policy, in particular the 2020 renewable energy target, leads to excessive deployment of costly solar PV in inappropriate locations. The level of subsidy to deployment in the EU should be reduced, with increased funding for RD&D. There is no case for widespread deployment in the UK.

Technology	Long-term global potential	Strategy to maximise long-term global cost reductions	Implications for current policy
Offshore wind	Much more limited global potential. Technical global potential is only 1% of solar PV's.	Currently costly, with potential for cost reductions unclear. UK policy focus on massive deployment reflects local factors (planning permission issues for onshore wind, regional politics).	UK support for offshore wind should be downsized substantially. Installing an equivalent amount of onshore wind, while politically more challenging, would save approximately £15bn by 2020.

The proposed criteria would mean significant changes in EU renewable policy. Current UK and EU policies favour renewable energy over other means of emissions reduction to an extent that is not justified by objective economic analysis. Moreover, the rigid 2020 targets lead to an excessive emphasis on rapid deployment of technologies rather than promoting long term innovation. Many of the investments in renewable energy expected between now and 2020 involve expensive subsidies to immature or otherwise inappropriate technologies, which are not justified by commensurate returns in terms of either cost-effective emissions reductions in the present, or cost reductions in the future.

This focus on deployment risks diverting attention from the high value of RD&D and demonstration projects in promoting advances in low carbon technologies. The paper highlights the current policy bias towards massive deployment and "learning-by-doing", as opposed to learning by RD&D.

Europe's Plan B climate policy should therefore abandon the 2020 renewable energy target, and shift instead towards treating all low carbon energy sources on a more equal footing, via a technology-neutral support scheme (such as the EU ETS plus a long-term carbon price floor) that provides a reliable long-term price signal that supports investment. While there is still room for targeted support for individual technologies, there should be a much greater focus on RD&D. Support should be provided based on an evidence-based assessment process, applied on a neutral basis to the whole range of low carbon solutions. Technology-specific support for deployment would be much more limited.

Such an approach would significantly reduce overall costs. For example, simply reducing solar PV expansion to 2020 by two thirds (and replacing it with other low carbon generation) could save up to £15bn/year across the EU by 2020. That money could be better put to use in a number of different ways, including making renewable and other forms of low carbon generation more economical in the future through increased RD&D, and financing greater expenditure on adaptation.

2. Preparing for a warmer world: adaptation and "backstops"

In light of the current status of international negotiations, Plan B climate policy should address the potential consequences of warming significantly in excess of 2°C, including the risk of touching one or more "tipping points", with potentially catastrophic impacts on human welfare. This has implications in two key areas: adaptation, and the development of one or more "backstop" options that may be needed in a worst case scenario of extreme and rapid warming.

Adaptation policy

The costs of adaptation would be high even in a 2°C scenario, and will be even greater in the new context. It is therefore essential to ensure a strong emphasis on the application of cost-benefit analysis. Such analyses should incorporate scenarios that recognise the probability of global temperature rises significantly greater than 2°C.

Global adaptation cost estimates currently range from $4 billion a year to well over $100 billion (approximately £3 billion – £65 billion), reflecting the poor knowledge base for policy-making. The effective application of cost-benefit analysis will require much greater knowledge and resources to assess the costs of adaptation.

Adaptation policy should also include some preparation, at least in the form of contingency planning, for worst case scenarios, including catastrophic outcomes. While society's ability to adapt to very extreme warming is likely to be limited, there may be high value to such measures even if their impact is small relative to the degree of harm.

Backstops

In light of the increasing risk of serious or even catastrophic damage from global warming, policymakers should develop options for a number of "backstop" technologies that could be deployed at relatively short notice to prevent the worst effects of warming. The most promising of these "geo-engineering" techniques in the scientific literature appears to be the release of sulphate aerosols that would provide a cooling effect by reflecting sunlight back into space (an effect that has been noted in the past following volcanic eruptions).

The use of geo-engineering is not a good substitute for mitigation efforts, and carries major risks of unintended consequences. However, in light of the policy failures discussed in this paper, the UK and EU would be irresponsible not to undertake serious planning for scenarios where rapid emergency action is required in response to the arrival of low probability but high impact scenarios, and some form of geo-engineering may be the best measure available. While there are legitimate concerns that the development of a backstop technology will undermine the political will for mitigation, these are outweighed by the risks of not having a backstop, and by the reality that at global level the degree of political will is in any case unacceptably low.

The UK government should therefore play a leading role in funding an appropriate long-term research programme into geo-engineering. Research funding and the location of research should be as international as possible, and the funding should cover a broad portfolio of approaches. It should also take a lead in undertaking the groundwork for future institutions that would govern any such interventions, including assessment of relevant aspects of international law, the development of proposals for possible governance mechanisms, future funding and operational management. Finally, it is essential to foster public engagement on this issue.

This report confronts some uncomfortable evidence. "Leadership by example" of Europe's target setting has not spurred wider action. Europe's focus on rapid deployment has undermined efforts to develop the technologies to get the rest of the world to decarbonise. The world is heading towards potentially dangerous levels of climate change. However, ignoring these will not reduce the harm climate change will cause. Plan A for climate change policy is not working. It is *Time for Plan B.*

1. Introduction

The United Kingdom and its European Union partners have spent the best part of two decades attempting to put in place a global agreement that would dramatically reduce greenhouse gas (GHG) emissions, with a headline aim of limiting the increase in mean global temperature to no more than 2°C relative to pre-industrial levels.[2] There is a broad consensus among EU policy makers that the benefits of such a policy massively outweigh its costs.

Unfortunately, as of today these efforts have failed, and the prospects of future success appear increasingly slender. The high point may have been the 1997 Kyoto Protocol, but even that involved commitments only from developed countries, and the failure of the US to ratify the agreement further limited its impact. Hopes of a significant successor agreement were dashed at the UN Climate Change Conference in Copenhagen in 2009. While the Cancun 2010 Climate Change Conference was generally viewed as a success, its main achievement was to keep in place the institutional framework for ongoing negotiations based on the individual commitments made at Copenhagen. It is increasingly clear that the outcome of those negotiations will be at most an agreement or set of commitments that is extremely limited relative to the UK/EU ambitions, and therefore has very little chance of restricting warming to 2°C even if signatories were to meet their commitments in full.[3] While both China and the US made significant commitments to invest in energy efficiency and low carbon energy sources, those commitments – even if implemented – are small in comparison to what the EU had hoped to achieve.[4] Analysis undertaken by the International Energy Agency (IEA)

[2] Unless indicated otherwise, all references to changes in mean global temperature are to be understood as changes relative to the pre-industrial level. Note also that forecasts of warming are inherently probabilistic in behaviour, reflecting the significant levels of uncertainty as to the climatic impact of increased GHG concentrations. A reference to forecast or expected warming of 2°C, for example, is shorthand for a forecast that provides an estimate of the probabilities of different levels of warming, including outcomes both below and above 2°C, with a median value of 2°C. The figure is of course also a global average: climate science suggests that there will be significant variation in warming by geographic location.

[3] In the short-term the prospects for even a limited binding agreement are poor. EU Climate Commissioner Hedegaard conceded in April this year that "no legally binding agreement deal will be done in Durban", while chief US negotiator Todd Stern stated that for the US "a legally binding agreement ... is not a necessary thing to happen right away", and "would have to include all the major players – China, India, Brazil, Russia, South Africa". BusinessGreen (2011), "Durban climate deal impossible, say US and EU envoys" on BusinessGreen (28 April 2011), http://www.businessgreen.com/bg/news/2046443/durban-climate-deal-impossible-eu-envoys.

confirms that they fall well short of the level of effort consistent with 2°C warming.[5]

Recent projections suggest that limiting warming to 2°C would require global GHG emissions to remain relatively flat until 2020, falling thereafter to reach a level in 2050 that is 40% below 1990 levels.[6] In light of the failure to reach a global agreement, however, a realistic assessment of the future path of global emissions likely involves much higher levels. The most recent predictions from the IEA show that:

- a continuation of "current" (i.e. pre-Copenhagen) policies would lead to stabilisation at a level consistent with expected warming of more than 6°C;[7] and
- even if governments follow through with new policy measures to meet the commitments they made at Copenhagen (e.g. national pledges to reduce GHG emissions), emissions will follow a trajectory consistent with expected warming of 3.5°C.[8]

Box 1: Future paths of CO_2 emissions

Figure 1 below shows:

1. The estimated future path of emissions in a business-as-usual "Current Policies Scenario" (in dark orange). It corresponds to expected warming of approximately 6°C.[9]
2. The estimated future path of emissions if all countries fulfil the pledges made at the Copenhagen conference (the "New Policies Scenario", in light orange).[10] It corresponds to global expected warming of approximately 3.5°C.[11]
3. The estimated path of future global energy-related CO_2 emissions that would be consistent with limiting expected warming to 2°C (the "450 Scenario", in grey).[12]

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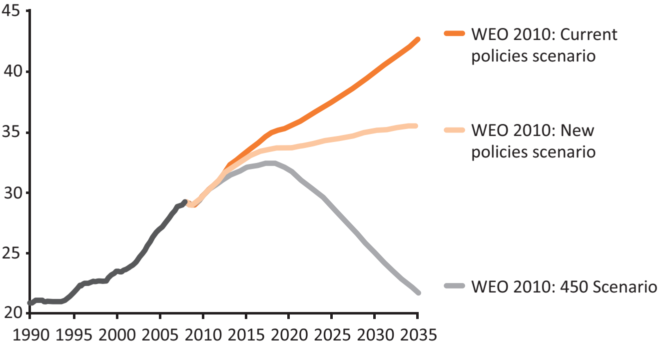
[4] China has committed itself to 40% reduction in carbon intensity compared to 2005 by 2020 (International Energy Agency (2010a), *World Energy Outlook 2010*, p. 696), and is forecast by the IEA to invest $1.4 trillion in 2009 terms (£0.9 trillion) in renewable energy from 2010-2035, greater than both the European Union ($1.2 trillion / £0.8 trillion) and the United States ($0.8 trillion / £0.5 trillion) over that period, if new government policies are implemented (IEA (2010a) p. 303). The IEA forecasts that if China's latest policy pledges are enacted, it will add 84 GW of nuclear capacity, 144 GW of hydroelectric capacity, 187 GW of wind and 75 GW of solar PV from 2008-2035 (IEA (2010a), p. 672). The United States pledged emissions reductions of around 17% by 2020, compared to a 2005 base year (See UNFCCC (2009), *Copenhagen Accord Appendix 1 – Quantified economy-wide emissions targets for 2020*, http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5264.php). The IEA forecasts that if the US enacts its latest policy pledges, it will add 24 GW of nuclear capacity, 12 GW of hydroelectric capacity, 156 GW of wind and 57 GW of solar PV from 2008-2035 (IEA (2010a), p. 632). These figures compare to the EU's total electrical generating capacity of 835 GW in 2008, and forecast additions under new policies of 31 GW of hydroelectric, 221 GW of wind and 60 GW of solar PV from 2008-2035 (IEA (2010a) p. 640).

Figure 1: World energy-related CO_2 emissions by scenario (IEA World Energy Outlook 2010)[13]



Implications for EU and UK policy

The long-term global deal that Europe hopes for would involve emissions reductions by developed countries of 80-95% by 2050.[14] Analysis by the European Commission indicates that as part of such a deal the EU itself would have to reduce its domestic emissions by at least 70% (in addition to funding further reductions outside the EU through some form of international emissions trading).[15] Current EU policy involves significant early unilateral action towards that goal, including a binding target of a 20% reduction by 2020.[16] The stated rationale for the 2020 target is that the EU will have to achieve the 2050 target once global agreement is reached, and taking action now will make compliance less costly later.[17]

The UK has set itself similarly stringent targets at national level, and put these targets on a statutory basis in the Climate Change Act (2008) which mandates emissions reductions of at least 80% by 2050. To this end, Parliament must set "carbon budgets" for each five-year period up to that point. The Committee on Climate Change

[5] See IEA (2010a), "New Policies Scenario", pp. 383-384, and the Box 1.

[6] IEA (2010a) p. 388. The IEA's scenario corresponds to stabilisation of greenhouse gases in the atmosphere at a level no higher than 450 parts per million of carbon dioxide equivalent (ppm CO_2e). The Intergovernmental Panel on Climate Change (IPCC) has estimated that stabilisation at between 445ppm and 490ppm will limit global average temperature increases to 2.0-2.4°C above pre-industrial levels (IPCC (2007), *Climate Change 2007: Synthesis Report*, p. 67, Table 5.1).

[7] See Box 1

[8] See Box 1

[9] The IEA projects that a continuation of current policies will lead to a peak in atmospheric concentrations of GHGs at above 1000 ppm CO_2e and stabilisation at around 950 ppm CO_2e, and states that this is consistent with a temperature rise in excess of 6°C (IEA (2010a), pp. 383-384) . Based on the IPCC's latest assessment, stabilisation at between 855 and 1130 ppm CO_2e will lead to warming of 4.9-6.1°C above pre-industrial levels (IPCC (2007), p. 67).

[10] The "Current Policies Scenario" developed by the IEA takes into consideration policies that had been formally adopted by mid-2010, based on IEA research into government policy development.

(CCC), tasked with advising on the level of these budgets, has recommended a legislated target of a 50% reduction by 2025,[18] and the government has accepted that recommendation.[19]

These ambitious policies are best understood in the context of the overall goal they were developed to meet: achieving a comprehensive, legally binding and effective global agreement. Policy makers believed the EU could meet that goal through a combination of intensive diplomatic efforts with strong "leadership by example", in the form of bold and aggressive measures to reduce emissions and move towards a more sustainable energy system.

That context certainly justified the ambitious GHG reduction targets adopted by the EU; the overall package of climate policies adopted in 2008, although it contains serious flaws, had a clear political logic and coherence.[20] There was a strong case for the EU to take a leadership role on climate change, given that no other major world player wished to take on such a role, and that the chances of success were perceived by many to be reasonably high.

However these hopes have not been fulfilled, and major global players, including crucially the "G2 nations" (China and the USA), appear unmoved by the EU's commitments. The EU's offer to increase its 2020 emissions reduction target from 20% to 30% contingent on global agreement has not provided us with any additional leverage, as shown by events at Copenhagen and Cancun, where the EU was not a central player.

Policymakers must therefore now come to terms with the reality of the failures of Copenhagen and Cancun, and the fact that EU leadership has proven much less effective than we had hoped. We should reassess and redesign UK and EU climate policies, developing a "Plan B" climate policy on the basis that:

1. "Leading by example" through the adoption of ambitious GHG reduction targets has been largely ineffective, and its future effectiveness as a means of persuading others to act should not be overestimated.

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[11] The IEA projects that fulfilment of new policy pledges will lead to stabilisation of atmospheric concentrations of GHGs at around 650ppm CO_2e, and links this to the IPCC's 2007 assessment. (IEA (2010a) pp. 383-384). Based on the IPCC's latest assessment, stabilisation at between 590 and 710 ppm CO_2e will lead to warming of 3.2-4.0 °C above pre-industrial levels (IPCC (2007), p. 67).

[12] In the "450 Scenario", the IEA has modelled "an energy pathway consistent with the 2°C goal through limitation of the concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2 equivalent". (IEA (2010a), p. 46).

[13] IEA (2010a), p. 384.

[14] Unless indicated otherwise, all references to changes in emissions are to be understood as changes relative to the 1990 baseline. The EU has endorsed emissions reductions of 80-95% by developed countries by 2050 (in combination with actions by developing countries to allow a global reduction in emissions of 50% by 2050) as necessary to limit warming to 2°C. European Commission (2011a), "A roadmap for moving to a low carbon economy in 2050", http://ec.europa.eu/clima/documentation/roadmap/docs/com_2011_112_en.pdf

[15] European Commission (2010), "Analysis of options to move beyond 20% greenhouse gas emission

2. There will be no comprehensive, ambitious global agreement in the short- or probably even medium-term.
3. Scientific evidence suggests that limiting warming to 2°C is very unlikely to happen.

This short paper therefore proposes some high level changes in UK and EU policy, with the aim of developing a Plan B climate policy that would better reflect the new and dangerous circumstances we find ourselves in. The Plan B changes fall into two categories: (1) continued efforts to promote mitigation, but with a focus on lowering the costs at global level; and (2) a range of measures aimed at preparation for a warmer world.

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reductions and assessing the risk of carbon leakage," 26 May 2010.

16 Prior to Copenhagen, the EU also declared its willingness to move towards a 30% by 2020 target in the context of a binding global agreement.

17 See materials relating to the 2020 targets from the European Commission at: http://ec.europa.eu/clima/documentation/package/index_en.htm.

18 Committee on Climate Change (2010), *The Fourth Carbon Budget – Reducing emissions through the 2020s,* http://www.theccc.org.uk/reports/fourth-carbon-budget.

19 Department for Energy and Climate Change (2011), UK Proposes Fourth Carbon Budget, http://www.decc.gov.uk/ en/content/cms/news/pn11_41/pn11_41.aspx

20 In January 2008 the European Commission proposed binding legislation to implement the 20-20-20 targets. This 'climate and energy package' was agreed by the European Parliament and Council in December 2008 and became law in June 2009. See also for example the discussion of the 2020 renewable energy target later in this paper, and also Moore, Simon (2011) *2020 Hindsight*, Policy Exchange.

2. Plan B Mitigation Strategy: Investing to Lower Global Costs

Despite the poor outlook for a short- or medium-term global solution, the EU should continue to promote mitigation at the global level. While a "top-down" Kyoto-style global deal is unlikely, there are still potential benefits from pursuing the "bottom-up" approach that came out of Copenhagen and was formalised at Cancun. In that context the EU should stick to its own 2020 emissions reduction target, and maintain a high level of ambition on longer-term decarbonisation, albeit that the underlying rationale for the targets is now weaker.

However, there are questions about the proposal currently under discussion at EU level, and supported by the UK government, to increase the 2020 target from 20% to 30%.[21] This increase has a cost currently estimated at €33bn per year, on top on the €48bn a year already required to meet the 20% target.[22] The additional reduction in emissions would make little difference to emissions on a global scale (as of 2020 the difference would be roughly equivalent to two weeks of China's CO_2 emissions).[23]

The most relevant question therefore concerns its strategic impact in the context of our continuing efforts to influence other global players. Proponents of an increase claim that it would represent "a real incentive for innovation and action in the international context ... stiffening the resolve of those already proposing ambitious action and encouraging more from those currently waiting in the wings".[24] However, this is pure wishful thinking. In reality there is no reason to think that such an increase would have a material impact on the behaviour of other major players, or give the EU added leverage in international negotiations – indeed prior to Copenhagen the

[21] See Huhne, Chris et al (2011), "Joint EU Climate Change", http://www.decc.gov.uk/en/content/cms/news/eu_cc_article/eu_cc_article.aspx

[22] See the European Commission's "Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage", 26 May 2010. The EC concludes that the cost of meeting the 20% target has fallen to €48bn per year, while the cost of meeting a 30% target would be €81bn per year.

[23] Total EU CO_2 emissions from energy in 2020 are forecast to be 3,348 Mt, while China's energy-related CO_2 emissions were forecast to be 9,381 Mt. Reducing the EU's forecast emissions by 10% (335 Mt) would therefore be equivalent to 3.6% of China's total emissions, or approximately 13 days worth. (IEA (2010a), pp. 640 and 672)

[24] Huhne et al (2011).

European Commission took the opposite view, arguing that an additional 10% reduction was not a valuable bargaining chip that should be made conditional on other countries' commitments. There is no evidence that the proposed unilateral 10% increase will have any impact on the behaviour of others. At best it will be viewed as an irrelevance by the nations that we most wish to convince.

The adoption of a 30% emissions reduction target for 2020 is not fundamental to achieving global climate mitigation. If the EU's 2020 package is reopened and the emissions target increased, then, as part of that, the EU 2020 renewable energy target should, for the reasons laid out in this paper, be scrapped (or downgraded to an ambition), enabling greater emissions reduction at lower costs.[25]

> “If the EU's 2020 package is reopened and the emissions target increased, then, as part of that, the EU 2020 renewable energy target should be scrapped”

European policy makers should instead face the reality that our ability to directly influence other countries' decisions on mitigation efforts is very limited. We should focus on an alternative approach that in the long run is likely to prove more effective in achieving influence, albeit less directly: *promoting technological advances that will promote greater emissions reduction at global level, by lowering the costs of the most important technologies for global mitigation*. It is clear that the cost of mitigation is the primary deterrent to action at present. A significant reduction in those costs could therefore do much to reduce opposition and induce meaningful action. It would also of course reduce the future costs we ourselves bear in decarbonisation.

What does the approach mean in practice? It involves designing a portfolio of investments in low carbon technologies, based on two fundamental principles:

1. The level of investment in each technology should reflect that technology's **long-term global potential contribution to mitigation.** Clearly, the payoff to reducing costs is highest if we focus on the technologies that are likely to be most utilised in the future.

[25] In line with the recommendations in Moore (2011).

2. Investments should be designed to **maximise long-term global cost reductions.** In particular, and as discussed below, this requires an appropriate balance between investments in RD&D and in deployment.

Below I discuss these two principles in greater detail, and illustrate their application to three specific technologies: CCS, solar power, and offshore wind. Finally I draw out their implications for current EU policy, in particular the 2020 renewable energy target.

1. Long-term global potential

The long-term potential of any given energy technology to contribute to global mitigation efforts depends on a number of factors, including its "technical potential" (i.e., maximum feasible deployment of the technology, ignoring economic, social and political constraints) and its expected long-run cost. From a technical perspective, the potential for deployment at global scale varies significantly by technology. For example, solar energy has the technical potential for truly massive global deployment. The combined global technical potential for solar photovoltaic (PV) and concentrated solar power (CSP) is estimated at close to 750,000 TWh per year,[26] about 25 times 2030 projected worldwide electricity demand of 30,300 TWh.[27] By contrast, the estimated technical potential of wave and tidal power generation is relatively limited: their combined maximum contribution, ignoring cost and other non-technical constraints, is about 1% of global energy needs.[28] In practice output would only ever be a small fraction of this. That in turn means that all else being equal, the potential returns to investment are higher for solar power than for wave or tidal generation.

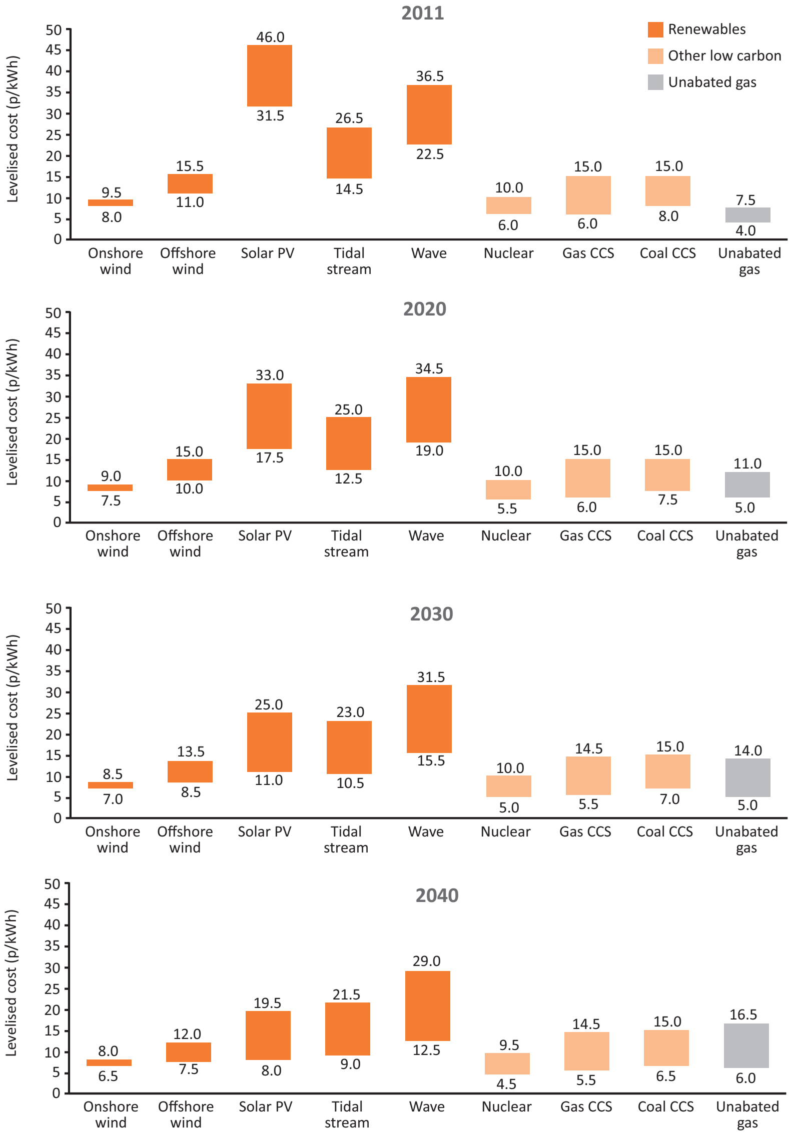
Long run cost is a second consideration. In the long run, other countries are generally unlikely to invest heavily in the deployment of extremely costly technologies. We should therefore focus our

[26] Ecofys (2008), *Global potential of renewable energy sources: a literature assessment.*

[27] IEA (2010a), p. 218.

[28] See MacKay, p. 237.

Figure 2: Estimated cost of low carbon technologies (2011, 2020, 2030, 2040)[29]



investments on technologies that we believe are likely to become relatively competitive. To illustrate the point, Figure 2 shows recent estimates produced for the UK Climate Change Committee of the costs for a range of low carbon technologies at present and at various future dates. It indicates clearly that for some technologies – most notably wave power – the potential for long-term cost reductions is limited, in the sense that they are likely to remain expensive well into the future. All else being equal, this clearly calls for less investment in wave power.

Other considerations are also relevant, depending on the specific technology. For example, issues of public acceptance and concerns about proliferation are central to nuclear power's long run potential. Careful assessment of the long run potential of each technology is therefore required. Of course there will inevitably be uncertainty around these assessments, and the uncertainty that is inherent in predicting future outcomes implies the need to invest in a portfolio of options. Within that portfolio however, it is clearly right, all else being equal, to invest more in those options with the best expected long run global potential.

2. Investing for long-term global cost reductions

UK and EU policies are heavily focused on deployment of renewable technologies so as to meet relatively short-term goals, notably the 2020 target of 20% of energy coming from renewables. By definition, a policy based on short-term targets will be heavily weighted towards deployment. In contrast, a policy aimed at maximising long-term cost reductions (with the aim of maximising long-term global penetration of low carbon technologies) requires a much greater emphasis on promoting innovation, and therefore requires a much more careful assessment of the balance between RD&D and deployment.

Both RD&D and deployment can contribute towards cost reductions. RD&D does so directly, deployment through so-called

[29] Committee on Climate Change (2011), *Renewable Energy Review,* p.70. Costs for CCS and unabated gas include a carbon price assumed to be £30/tCO_2 in 2020, rising to £70/tCO_2 in 2030 (the assumed 2040 price appears not to be specified). The CCC also notes that the estimated cost differences between renewables and other technologies are much lower if one uses a lower discount rate. However, the decisions made in other countries are more likely to reflect a discount rate similar to the one used for these estimates.

"learning-by-doing". This concept refers to the tendency for unit production costs to fall as a result of experience gained in producing increasing quantities. Learning-by-doing is widely cited as a key justification for providing greater subsidies to renewable generation deployment than to other forms of low carbon generation.[30]

Box 2: "Learning-by-doing" vs "learning-by-research"

The concept of "learning-by-doing" was first introduced by Nobel Laureate economist Kenneth Arrow.[31] Learning-by-doing effects have been identified in many contexts. However, it is often difficult to separate out the cost-reducing effect of increased production from the cost-reducing effect of RD&D, since typically both will occur over the same time period. Cambridge economists Jamasb and Koehler have used statistical methods to estimate the relative contributions of learning-by-doing and R&D ("learning-by-research") to cost reductions experienced with a range of energy technologies. Some of their analysis is summarised in Table 1 below, which shows two different estimates of the so-called "learning rate". The learning rate is defined as the reduction in unit costs associated with a doubling of the stock of output; it therefore measures the extent of learning-by-doing. The authors estimated learning rates in two ways: the first assumes that all cost reductions are due to learning-by-doing, the second attempts to take into account also the cost-impact of investments in R&D.[32] The second rate is therefore in principle a measure of the amount of cost reduction experienced during a doubling of output that is due to that doubling of output (rather than to R&D that would have lowered costs anyway). The greater the difference between the two figures, the greater the relative value of conducting R&D compared with deployment.

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[30] This justification assumes (usually implicitly) that learning-by-doing effects cannot be "appropriated" by individual firms (in contrast, a manufacture of a new consumer device might invest heavily in early stage production, because the learning-by-doing will reduce its costs but not those of its competitors, providing a significant competitive advantage). See Gillingham and Sweeney in Moselle et al (2010), *Harnessing Renewable Energy in Electric Power Systems*, p. 78.

[31] Arrow, Kenneth (1962), "The Economic Implications of Learning by Doing" in *Review of Economic Studies* 29: pp. 155–73.

[32] The first column ("estimate #1") corresponds to Jamasb and Köhler's "Learning by Doing Rate – Single-Factor Curves", and the second column ("estimate #2") to their "Learning by Doing Rate – Two-Factor Curves"., Jamasb, Tooraj and Köhler, Jonathan (2007), "Learning curves for energy technology: a critical assessment" in Grubb, Michael et al (eds.), *Delivering a Low Carbon Electricity System: Technologies, Economics and Policy.*

Table 1: Estimated learning rates for different generating technologies[33]

Technology	Learning rate (estimate 1)	Learning rate (estimate 2)
Pulverised fuel supercritical coal	4.8%	3.8%
Coal conventional technology	15.1%	13.4%
Lignite conventional technology	7.8%	5.7%
Combined cycle gas turbines (1980-89)	2.8%	2.2%
Combined cycle gas turbines (1990-98)	3.3%	0.7%
Large hydro	2.9%	2.0%
Combined heat and power	2.1%	0.2%
Small hydro	2.8%	0.5%
Waste to electricity	57.9%	41.5%
Nuclear light water reactor	53.2%	37.6%
Wind – onshore	15.7%	13.1%
Solar thermal power	22.5%	2.2%
Wind – offshore	8.3%	1.0%

The appropriate balance between RD&D and deployment will vary by technology, and that balance will shift towards deployment as the technology matures. The data shown in Table 1 suggest that for less mature generation technologies RD&D plays a more important role than deployment, exemplified by solar thermal power and offshore wind. The estimates in Table 1 must therefore be interpreted in light of the degree of maturity of each technology during the time period covered by the data set. For example, the estimates for offshore wind are based on a data set that covers the period 1994-2001, when offshore wind was at an early stage of development. It would be entirely wrong to extrapolate from these figures to estimate the likely future levels of learning-by-doing in offshore wind, at an entirely different stage in the lifecycle of the technology when the potential for learning-by-doing is undoubtedly much greater. However, it would also be wrong to ignore the potential returns to further RD&D in offshore wind.

[33] Jamasb and Köhler (2007)

The strong emphasis in current UK and EU policies on rapid large-scale deployment of renewables is therefore likely to entail an excessive focus on learning-by-doing rather than RD&D, and as a corollary, on technologies that are deployment-ready (albeit expensive) rather than on less mature ones. Such a conclusion is consistent with evidence of continued under-investment in RD&D at global level for all low carbon technologies (with the possible exception of nuclear), as per a recent IEA assessment reproduced in Table 2 below. The IEA estimates that "achieving global energy and climate change ambitions ... will require a twofold to fivefold increase in public RD&D spending".[34]

Table 2: Estimated public-sector low carbon energy technology current spending, needs and gap to achieve a 50% reduction in energy-related CO_2 emissions by by 2050 ($ millions)[35]

	Annual investment in RD&D required	**Current annual RD&D spending**	**Estimated annual RD&D spending gap**
Advanced vehicles (includes EVs, PHEVs + FCVs; energy efficiency in transport)	22,500 – 45,000	1,860	20,640 – 43,140
Bioenergy (biomass combustion and biofuels)	1,500 – 3,000	740	760 – 2,260
CCS (power generation, industry, fuel transformation)	9,000 – 18,000	540	8,460 – 17,460
Energy efficiency (industry)	5,000 – 10,000	530	4,470 – 9,470
Higher-efficiency coal (IGCC + USCSC)	1,300 – 2,600	850	450 – 1,750
Nuclear fission	1,500 – 3,000	4,030	0
Smart grids	5,600 – 11,200	530	5,070 – 10,670
Solar energy (PV + CSP + solar heating)	1,800 – 3,600	680	1,120 – 2,920
Wind energy	1,800 – 3,600	240	1,560 – 3,360
Total across technologies	**50,000 – 100,000**	**10,000**	**40,000 – 90,000**

[34] IEA (2010b), *Global Gaps in Clean Energy RD&D*: Update, 2010, p.14. In the same report the IEA notes that "[w]hile IEA member countries and other major economies have made a collective commitment to double RD&D spending for LCETs, this is insufficient to achieve global energy goals" (p.9).

[35] IEA (2010c), *Energy Technology Perspectives*, p. 480. The spending required corresponds to the IEA's BLUE Map scenario, which includes a goal of halving global energy-related CO_2 emissions by 2050 (compared to 2005 levels) and examines the least-cost means of achieving that goal.

Finally, current UK and EU policies also make no distinction between "local" and "global" cost reductions. For example, massive deployment of offshore wind turbines on the UK Continental Shelf (UKCS) would undoubtedly lead over time to some cost reductions. However, at least part of the learning-by-doing would involve learning about how to install offshore wind *on the UKCS*, for example in terms of supply chain optimisation in the UK and integration into the UK power grid. This learning would only be partially transferable to other locations, and would therefore only have limited impact on reducing costs for offshore wind outside of the UK (see also page 33).

Implications for CCS, solar power and offshore wind

The application of these two criteria would have significant practical implications for UK and EU investments in a range of low carbon technologies, as the following examples illustrate.

Example 1: Carbon Capture and Storage

The UK has announced its intention to provide public support for four CCS demonstration plants.[36] The first of these projects, to be selected via a procurement process that has been underway since 2007, will receive up to £1 billion of capital funding.[37] The Department of Energy and Climate Change's (DECC) stated aim is for that plant to be constructed by 2014/15.[38] The remaining three will be open to gas as well as coal power plants.

The UK programme fits into an overall EU support policy for CCS that is based around the promotion of up to 12 commercial scale demonstration projects, involving a projected €10.5-€16.5 billion (£7-£11 billion) of investment over the next 10 years. The EU has set aside 300 million EU ETS credits (current value of about €5 billion (£4 billion)), to be available up to 2015, to support the development of CCS and innovative renewable energy projects.[39]

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[36] Committee on Climate Change, 4th Carbon Budget. The CCC's 4th Carbon Budget, which was recently adopted by the government, envisions that four demonstration plants will be in operation by 2020.

[37] The outcome of the competition will be announced later in 2011. Funding has been awarded to E.ON and Scottish Power for Front End Engineering and Design (FEED) studies, to be completed by spring 2011. (http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/ccs/demo_prog/demo_1/demo_1.aspx)

[38] DECC, UK Carbon Capture and Storage (CCS) Commercial Scale Demonstration Programme: Delivering Projects 2-4, December 2010.

[39] EU Directive 2009/29/EC.

1. Long-term global potential

CCS technologies have the potential for massive application at global scale. CCS could be applied to mitigate emissions from coal- and gas-fired generation anywhere in the world. In addition, and of potentially great significance, CCS may also be applicable to key industrial processes such as cement production and petroleum refining that currently are themselves major sources of CO_2 emissions (representing respectively 4% and 3% of global stationary emissions).[40] Finally, CCS might also be used to combine power generation with carbon sequestration ("negative emissions generation"), through application to biomass-fired generation.

> "CCS may be applicable to key industrial processes such as cement production and petroleum refining that currently are themselves major sources of CO_2 emissions"

Moreover, CCS plays an essential role in most plausible scenarios of successful mitigation, for two reasons. The first is its impact on cost: the IEA estimates that without CCS the overall cost of reducing emissions to 2005 levels by 2050 increase by 70%.[41] The second is that, without CCS, any scenario of significant long-term global emissions reduction involves a somewhat implausible assumption that China, India, the US and others leave unexploited their hugely abundant reserves of coal and other fossil fuels. Even countries such as Norway or the UK, that in principle are strongly committed to combating climate change, remain simultaneously committed to full exploitation of their fossil fuel reserves: for example, the goals of the DECC include both combating climate change and "ensuring the recovery of all economic hydrocarbon reserves".[42] It seems unlikely therefore that countries with much less commitment will be willing to leave their reserves unexploited.

CCS is therefore clearly a critical technology technically, economically and politically. In technical terms, it provides the only route to mitigating emissions from major industrial processes (for example, there is no "renewable concrete"). In economic terms, it

[40] Intergovernmental Panel on Climate Change (2005), *Special Report on Carbon Capture and Storage (IPCC SRCCS),* Technical Summary, pp. 22-23, 2005.

[41] IEA (2009), *Technology Roadmap: Carbon capture and storage*, p.4.

[42] DECC, *Guidance on Disputes over Third Party Access to Upstream Oil and Gas Infrastructure*, April 2009, para 31: "[T]he Department's main objective in operating its petroleum legislation is to ensure the recovery of all economic hydrocarbon reserves".

could massively reduce the cost of mitigation. In political terms, it may be the only solution to the enormous economic disincentive that major owners of fossil fuel reserves currently face in reducing emissions. It is therefore not surprising that for example under the IEA BLUE Map scenario, CCS is the second largest means of emissions reductions to 2050, providing 19% of reductions, relative to the Baseline Scenario, while renewables provide just 17%.[43]

2. *Long-term global cost reductions*

At the current level of maturity it is uncontentious that the appropriate investments will be in RD&D. Moreover, the scope of those investments should reflect the wide range of potential CCS applications discussed above (both fossil and bio-fuel fired generation, other industrial processes). The IEA Technology Roadmap for CCS has identified RD&D priorities for capture, transport and storage.[44]

CCS: conclusions

The UK and other member state governments should devote greater resources and political will to the development of CCS. The size of that commitment should reflect the current shortfall in RD&D investment, which the IEA estimates at between $8 billion and $17 billion per year globally. CCS is a potentially critical technology for global mitigation efforts, and merits a correspondingly high level of attention. The focus on short-term targets for emissions reduction and renewable energy is one cause of the significant under-investment in this set of technologies.

Example 2: Solar Power

The EU is spending massively on subsidises to solar power deployment, primarily solar PV.[45] In Spain alone, solar power subsidies totalled approximately €1.9 billion (£1.5 billion) in 2009.[46] In Germany it is estimated that the net burden of subsidies to solar PV capacity installed over the last decade will be €53 billion

[43] The BLUE scenario involves halving energy-related CO_2 emissions by 2050, and is consistent with limiting warming to 2-3°C, conditional on deep cuts in other greenhouse gas emissions. IEA (2010c), p.69. The largest source of reductions is end-use fuel and electricity efficiency, at 38%. IEA (2010c), p.75.

[44] IEA (2009)

[45] The analysis here focuses on solar PV, although there is some read-over to CSP and some of the data (e.g. on technical potential) may cover both technologies. CSP is significantly cheaper than PV, with projected generating costs from 2010-2020 of £97/MWh to £204/MWh (IEA(2010a), p. 310), but remains an expensive mitigation option, with costs of approximately £134/tCO_2e to £423/tCO_2e (calculated according to the methodology described in footnote 51).

[46] See Agosti, Luis and Padilla, Jorge, "Renewable Electricity Support: The Spanish Experience", in Moselle et al (2010), p. 316.

(£42 billion), given the 20-year feed-in-tariff guarantee provided by the government.[47]

What do the two criteria laid out above imply for these very costly investments?

1. *Long-term global potential*

As noted earlier, solar power has the potential for truly massive scale, with technical potential equal to many times global energy consumption. One respectable source estimates that it would be technically and economically feasible to locate a set of very large-scale solar power facilities in coastal areas of the Middle East and North Africa with annual production almost twice that of the current EU installed power generation capacity. Locating similar facilities inland would allow for even larger output, in principle many times as high.[48]

However, solar PV is currently an extremely costly way to generate electricity, with estimated generating costs in the region of £400/MWh.[49] It is also a very costly means to reduce GHG emissions, particularly when installed in locations with relatively low levels of sunshine. The incremental costs of emissions avoided by replacing CCGT with solar PV[50] are on the order of £600/tCO_2e to £950/tCO_2e, many times higher than other available approaches such as onshore wind (approximately £98/tCO_2e) or nuclear (approximately £30/tCO_2e).[51]

The costs of solar PV have fallen dramatically since the 1970s. A number of studies estimate learning rates for solar PV in the last century at around 20%.[52] It is generally believed that further significant reductions are possible over time, through improvements in thin-film technology as well as supply chain optimisation and better grid integration.[53] The IEA projects generating costs for large-scale solar PV to fall by around 50% between 2010 and 2035 (with a projected learning rate of 17%), its largest projected reduction in costs of any renewable technology.[54] However, even at half its current cost solar PV

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[47] See Weigt, Hannes and Leuthold, Florian, “Experience with Renewable Energy Policy in Germany”, in Moselle et al (2010), p.290.

[48] The estimated coastal potential is 6,000 TWh/year, while the estimated total potential is 620,000 TWh/year (DESERTEC (www.desertec.org), cited in MacKay (2009), p. 180). EU-27 power generation was 3,072 TWh in 2009 (Eurelectric (2009), *Key Statistics,* http://www.eurelectric.org/PublicDoc.asp?ID=66005).

[49] The IEA calculated generating costs for a range of technologies across OECD countries plus Brazil, China, Russia and South Africa. The figures presented in this report are based on the median levelised costs of electricity, assuming commissioning by 2015, at a discount rate of 10%. (International Energy Agency (2010d), “Projected Costs of Generating Electricity,”.) Unless otherwise stated, all USD figures from the IEA have been converted from US$ to UK£ using a PPP exchange rate obtained from the OECD of 0.657 $/£ (http://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE4).

[50] These costs depend significantly on the location, given geographic variations in sunshine. As noted in footnote 49, these calculations are for OECD countries plus Brazil, China, Russia and South Africa.

[51] Based on replacing electricity generated by natural gas (CCGT) with electricity generated by solar energy. The

would still be one of the most expensive means of GHG abatement available, especially given that other technologies can also be expected to enjoy significant cost reductions over the same time period.

The long-term global potential for solar PV is therefore rather uncertain. Very large future cost reductions might transform it into a critical technology for power generation. If cost reductions of that order are not feasible then – despite current enthusiasm – it may remain a small part of the overall energy mix.

2. *Long-term global cost reductions*

Given the potentially important role of solar PV as a major global technology, there is a strong case for significant public support. As with other technologies, it is then necessary to identify the appropriate balance between investing in RD&D and in deployment.

Proponents of large-scale deployment of solar PV focus heavily on subsidies to deployment to create "market-pull", inducing major cost reductions through learning-by-doing as discussed above.[55] That view is reflected in UK and EU policies, built around the 2020 renewable energy target and the very large subsidies described above.

It is by no means clear however that this policy bias in favour of deployment is optimal. First, as discussed earlier, it is necessary to distinguish between cost reductions that apply at a global scale and those that are more "local". In the case of solar PV, the distinction is between reductions in the costs of manufacturing PV modules, which is a global industry, and reductions in other costs, which are largely local (e.g., the costs of installation, marketing, and grid integration).[56] By definition, cost reductions that are local in nature will not reduce the costs of installing solar PV in other parts of the world.

Second, there is evidence that factors other than learning-by-doing may be responsible for a large part of the cost reductions in solar PV that have occurred over time. One study concludes that "[o]verall, the "learning" and "experience" aspects of cumulative production do not appear to have been major factors in enabling firms to reduce

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cost per tonne of CO_2e avoided is based on the incremental cost of generation over CCGT (as per IEA(2010d)), and the IEA's emission factor for natural gas combustion of 370g/kWh (IEA (2010e), *CO_2 Emissions from Fuel Combustion, Highlights, 2010 Edition*, p. 37). As a simple calculation, if a low carbon energy source replaces CCGT, it will take approximately 2.70 MWh (1/0.37) to save one tonne of emissions. Note that this calculation does not consider manufacturing or construction emissions. The actual cost per tonne of CO_2e will vary between countries depending on actual generating costs and the type of generation displaced, but in general it is acknowledged that solar PV has a cost per unit of emissions that is an order of magnitude greater than other technologies.

[52] See van Benthem A et al (2008) "Learning-by-Doing and the Optimal Solar Policy in California", in *Energy Journal* 29: 131–51. The "learning rate" is defined as the percentage reduction in unit costs that arises with a doubling of cumulative output.

[53] Moselle et al (2010), pp. 14-15.

[54] International Energy Agency (2010a), p. 310. For CSP, costs are expected to fall by around 25%, with a projected learning rate of 10%.

[55] See for example Neuhoff, Karsten (2005), "Large Scale Deployment of Renewables for Electricity Generation" in *Oxford Review of Economic Policy,* Vol. 21, No. 1.

the cost of PV".[57] Findings of this nature suggest that, at least at the margin, the returns to investing in RD&D ("learning-by-research") could be higher than the returns to investing in massive deployment ("learning-by-doing").

There are also additional considerations that do not apply to offshore wind. First, the UK and most of the EU are not well suited to installing solar PV, because of the relatively low levels of sunshine (as illustrated in Table 3), making the investments themselves much more costly in terms of expenditure per unit of output or per unit of avoided carbon emissions.

Table 3: Solar radiation received[58]

City	Average sunshine received, per m^2
London	109
Munich	124
Paris	125
New York	147
Madrid	177
Rome	176
Athens	190
San Francisco	204
Accra	217
Rabat	217
Los Angeles	225
Nairobi	234
Cairo	237
Al Khurtum (Sudan)	263

Second, it appears that for a variety of reasons other countries are likely to invest heavily in solar PV deployment. If the latest government policy pledges are enacted, China is expected to add 75 GW of solar PV capacity and 17 GW of CSP before 2035, and the United States is expected to add 57 GW of PV and 11 GW of CSP over the same period.[59] There is therefore a real question as

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[56] These are sometimes referred to as "balance-of-system" costs. See van Benthem A et al (2008), pp. 131–51.

[57] See for example Gregory F. Nemet (2006), "Beyond the learning curve: factors influencing cost reductions in photovoltaics" in *Energy Policy* 34 (2006) pp. 3218–3232.

[58] MacKay, David, *Sustainable Energy – without the hot air,* Cambridge, 2009, p. 46.

[59] IEA (2010a) p. 632 and 672.

to the marginal impact of the "learning-by-doing" induced by EU deployment.

As noted earlier, the IEA has identified a very large gap in funding for RD&D in solar energy (PV, CSP and solar heating), of the order of $1bn-$3bn annually. RD&D priorities include improving efficiency for crystalline silicon PV technologies and automation of manufacturing.[60]

Solar power: conclusions

The case for investments to bring down the costs of solar PV is a strong one, because of the potential for large scale deployment at global level. However, current EU policy is inappropriate, involving an excessive emphasis on deployment of what remains a relatively immature technology in places to which it is not well-suited. Going forward the level of subsidy to solar PV deployment in the EU should be reduced very significantly. There is no case for solar PV deployment in the UK, except perhaps as a "hearts and minds" exercise (e.g. in the form of solar PV panels on schools) to help gain public acceptance of the costs involved in combating climate change. EU support for RD&D should increase, in line with IEA recommendations.

Example 3: Offshore Wind

The UK has massive ambitions for offshore wind. While there is not a specific offshore wind target, current policies envisage at least an additional 13 GW of offshore capacity by 2020, with significant further additions thereafter.[61] The costs of this level of deployment would be commensurately high: at current capital costs of approximately £3m/MW, 13 GW of capacity would cost £39 billion.[62] By comparison, a corresponding investment in onshore wind would cost about £24 billion, while an equivalent amount of gas-fired generation would cost about £8 billion.[63]

[60] IEA (2010f), *Global Gaps in Clean Energy RD&D: Update,* p. 29.

[61] The Renewable Energy Strategy envisages 13 GW of offshore wind capacity being added before 2020. See Committee on Climate Change (2010), *Building a low-carbon economy – The UK's innovation challenge*, p. 23.

[62] The UK Energy Research Centre (UKERC) notes that "industry consensus is that capital and energy costs are approximately £3.0m/MW and £150/MWh respectively". Greenacre, Philip et al (2010) *Great Expectations: The cost of offshore wind in UK waters*, UK Energy Research Centre, p. ix. Another recent study assessed the capital costs for offshore wind at between £2.59m/MW and £3.63m/MW, with even higher costs for Round 3 (In 2008, the Crown Estate began its Round 3 leasing programme for up to 25 GW of new offshore windfarm sites by 2020. This builds on the combined 8 GW covered by Rounds 1 and 2. Round 3 sites have characteristics, such as deeper water, that are projected to raise costs compared to previous installations.) Mott MacDonald (2010), *UK Electricity Generation Costs Update*, Tables A.8 and A.9). All costs per MW are quoted in 2009 prices unless otherwise specified.

[63] I assume that a corresponding investment would comprise 16.25 GW of onshore wind, calculated

1. Long-term global potential

The UK is particularly well-endowed with offshore wind sites, enjoying a long coastline and a significant area of seabed of suitable depth (generally thought to comprise 5m to 30m) and flatness.[64] Even for the UK however, offshore wind's potential contribution to the overall energy mix is relatively limited. The 13 GW discussed above would provide around 9% of UK electricity demand, corresponding to 2.2% of total energy consumption in 2020.[65]

Compared to the UK however, the potential for rolling out offshore wind at global scale is much more limited. Globally, the technical potential for offshore wind power is only 6% of the potential for onshore wind power, and just 1% of the potential of solar PV.[66] Viewed at global level, offshore wind appears to be a much less critical technology than either CCS or solar power.

2. Long-term global cost reductions

The potential for cost reduction in offshore wind is a matter of some controversy. In the late 1990s and early 2000s there was a general belief that costs would fall as rapidly as onshore wind costs were perceived to have fallen. However, in the past decade estimated costs increased dramatically, including a doubling of capital costs.[67] The actual prospects for cost reduction appear rather uncertain. The recent Committee on Climate Change report on renewables sees the potential for significant reduction in offshore wind costs, with capital costs falling by 16% by 2020 and 43% by 2040 in its central scenario.[68] However, the Committee also notes the high degree of uncertainty, and cautions against increasing the UK's offshore wind ambition until evidence of appropriate cost reductions is forthcoming.

Offshore wind: conclusions

Offshore wind is a relatively costly form of emissions reduction, with uncertain prospects for cost reductions. In contrast to CCS or

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based on the ratio of 2009 load factors for offshore (33.7) and onshore (26.9) wind, to achieve equivalent generation output. (DECC, Digest of United Kingdom energy statistics (DUKES), 2010, Chapter 7). The cost of wind capacity is based on capital costs of £3m/MW for offshore wind and £1.5m/MW for onshore wind (see Mott MacDonald, "UK Electricity Generation Costs Update", June 2010). The capital cost of gas CCGT is assumed to be between £0.719m and £0.864m/MWh (see Mott MacDonald, "UK Electricity Generation Costs Update", June 2010). The equivalent amount of gas required to displace offshore wind is based on a comparison of load factors (also per Mott MacDonald). Of course gas-fired generation would then entail additional ongoing fuel costs, but the difference in total costs is still large: the levelised cost (see Annex 1) of offshore wind in the UK is estimated as £146/MWh (Round 3 costs are expected to be £175/MWh), compared to £87 from onshore wind, and £65 for gas CCGT (excluding carbon costs) – (based on Mott MacDonald, Table B.1, scenario using a 10% discount rate, a 2013 project start, and projected engineering and procurement costs). Of course the CCGTs would produce significant "external costs" – owing to CO_2 emissions – that do not feature in this calculation.

64 See DTI (2002), *Future Offshore: A Strategic Framework for the Offshore Wind Industry.*

solar PV, it has much more limited potential as a major global technology.[69] Current enthusiasm for offshore wind among UK policymakers reflects in part the cost optimism of earlier years, but is probably driven above all by the difficulties experienced over the last twenty-odd years with public opposition to onshore wind deployment.[70]

As noted above, installing an equivalent amount of additional onshore wind generation could save approximately £15 billion by 2020, while still meeting the EU renewable energy target. In effect therefore, government is spending £15 billion to avoid difficulties with planning permission. Given a limited budget for GHG abatement, that money would be better spent elsewhere. UK policy should therefore involve a substantial downsizing of the current level of offshore wind subsidy.

Implications for EU Renewable Energy Policy

Defenders of the EU's renewable energy policy would argue that it is designed to meet the criteria laid out above, providing market-pull to bring down the costs of key renewable technologies through the promotion of large-scale renewable energy deployment. However, the reality is that existing policy is a blunt instrument that fails to respect those criteria in a number of key areas.

First, based on long-term global potential there is no logic for favouring renewable energy technologies per se over other low carbon technologies. The very ambitious 2020 renewables target undoubtedly biases investment in favour of renewables, to the detriment of other technologies such as CCS, whose long term global potential is higher than most if not all renewable technologies, as well as other low carbon alternatives. Forecasts of future generation costs indicate similar levels of cost reduction for a number of key nuclear, CCS and renewable technologies. For example, a 2010 study for the UK Department of Energy and Climate Change (DECC)

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65 Based on the load factors calculated by DECC (Department for Energy and Climate Change (2010), *Digest of United Kingdom Energy Statistics 2010*, pp. 179-209) and the availability and auxiliary power requirements calculated by Mott MacDonald (Mott MacDonald (2010)), 13 GW of offshore wind capacity would generate approximately 35 TWh of electricity per year, or 9.1% of the UK's projected electricity consumption in 2020 of 386 TWh and 2.2% of projected total energy consumption of 1,590 TWh. DECC (2009), *The UK Renewable Energy Strategy*, p. 37.

66 The global technical potential for offshore wind is estimated at 6 petawatthours (PWh)/y, compared to 105 PWh/y for onshore wind and 470 PWh/y for solar PV. (*Global potential of renewable energy sources: a literature assessment*, Ecofys, March 2008).

67 The UK ERC found that capital costs doubled from £1.5m/MW to £3m/MW in the five years up to 2009 (Greenacre et al (2010), p. 1.)

68 These reductions assume major scale economies, with turbines up to 20 MW by 2040, compared with around 3.5 MW today and increased total wind farm capacity (up to 250 turbines in an array, compared to 25 today).

69 Moore (2011).

70 See Pollitt, Michael, "UK Renewable Energy Policy since Privatization", in Moselle et al (2010), p. 266.

forecasted cost reductions between 2009 and 2023 of 26% for nuclear, 23% for coal IGCC with CCS, 25% for offshore wind and just 2% for onshore wind.[71]

Second, the level of support provided to individual renewable technologies is not designed to reflect their long-term global potential. Most member states provide support to a wide range of renewable technologies with little attention to the global implications of supporting one technology over another. The UK's massive offshore wind programme is one clear example, driven primarily by purely local factors (problems with planning permission and regional politics, as well the geographic fundamentals of a small crowded island which lacks broad expanses of prairie or steppe).

Third, the policy over-emphasises deployment and "learning-by-doing", contributing to the massive under-investment in RD&D identified by the IEA. While the 2020 target promotes massive deployment of costly renewable technologies, the IEA notes that "renewable energy technologies [as well as advanced vehicles and biofuels] have a particularly strong need for expanded basic science research to deliver the breakthroughs required to achieve long-term cost competitiveness goals."[72]

What of the other arguments commonly put forward to support the EU renewables target?

"Green industrial policy"

Proponents of a "green industrial policy" argue that the investments will create millions of new jobs, and it is certainly the case that there are now many people employed in renewable energy in the EU. In Germany alone, employment in the renewable energy sector was close to 280,000 in 2008.[73] However, economists generally believe that the overall level of employment in an economy reflects underlying economic fundamentals (levels of education and skills, availability and cost of childcare, minimum wage, payroll taxes and

[71] Mott MacDonald (2010). The dates 2009 and 2023 refer to project start years. Note that the 23% forecast cost reduction for coal IGCC with CCS occurs despite a forecast 26% increase for coal IGCC without CCS.

[72] IEA (2010f), p.17.

[73] O'Sullivan, Marlene et al (2009), Gross Employment from Renewable Energy in Germany in the Year 2008 – A first estimate, http://www.bmu.de/files/english/pdf/application/pdf/ee_bruttobeschaeftigung_08_en_bf.pdf.

other employment costs, etc). The likely effect of investing in deploying renewables is therefore not to change the overall level of employment, but to change the mix of jobs in the economy. There is no reason to think that this change would be a positive (or negative) one for those concerned. Moreover, the level of subsidy per job created in renewables has been very high (in Germany, one respected study estimates subsidies per worker as high as €175,000 (in 2009 terms, £125,000 in 2010 PPP terms)), and in the future it is likely that much of the large-scale employment in manufacturing renewable generation will be located outside of the EU, reflecting differential labour costs.[74] The recent shift of solar PV manufacturing from Massachusetts to China by Evergreen Solar (a company that had received $43 million (£35m) in public support) illustrates the trend.[75]

Experience of previous attempts by government to identify and invest in "cutting edge" technologies has not been positive. Government investment decisions tend to be subject to excessive influence by their beneficiaries, and governments find it hard to recognise failure and cut off support for unsuccessful projects, a problematic tendency given that a high failure rate is inherent in the process of innovation.[76]

Security of supply

It is also argued that investing in renewable energy promotes energy security of supply. While this argument is not without merit, the benefit is typically over-estimated, especially relative to a counter-factual scenario that involves greater reliance on other low carbon energy sources. For power generation, the main security of supply concern relates to the EU's growing dependence on pipeline-imported natural gas from a small number of politically unstable countries. However, the promotion of renewable power may well displace not those sources of gas, but other more secure sources, notably liquefied natural gas

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[74] Rheinisch-Westfälisches Institut für Wirtschaftsforschung (2009), Economic impacts from the promotion of renewable energies: The German experience, Final report, http://www.rwi-essen.de/media/content/pages/publikationen/rwi-projektberichte/PB_Renewable-Energy-Report.pdf.

[75] Bradsher, Keith (2011), "Solar Panel Maker Moves Work to China" in *New York Times*, January 14, 2011.

[76] Lerner, Josh (2009) *Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed – and What to Do About It,* Princeton University Press.

(LNG) imports. Moreover, the promotion of other low carbon sources of generation such as nuclear power or coal-fired generation with CCS would have an equal or greater impact on security of supply. Uranium and coal are both widely available from a diverse set of suppliers, including politically stable allies of Europe, while investments in energy efficiency would do even more to enhance energy security.[77]

The security of supply argument may be stronger for transportation, but biofuels have major problems of their own, including notably their impact on food prices: one much cited paper from the World Bank identified the production of biofuels from food grains and oilseeds as the most important factor underlying the dramatic increase in global food prices earlier this decade.[78] A better way to address reliance on imported oil may be to focus on affordable decarbonisation of the electric power system, and promote electric vehicles.

> “CCS may be applicable to key industrial processes such as cement production and petroleum refining that currently are themselves major sources of CO_2 emissions”

Conclusion

While renewable energy is an important and probably essential part of long-term climate mitigation, current UK and EU policies favour renewables over other means of emissions reduction to an extent that is not justified by objective economic analysis. Many of the investments in renewable energy expected between now and 2020 involve expensive subsidies to immature or otherwise inappropriate technologies, which are not justified by commensurate returns in terms of either cost-effective emissions reductions in the present, or cost reductions in the future. A high level of ambition is required to address climate change, but the ambition must be applied appropriately.

[77] On the security of supply issue for gas and electricity see Moselle, Boaz, “Renewable Generation and Security of Supply”, in Moselle et al (2010).

[78] Mitchell, A Note on Rising Food Prices, The World Bank Development Prospects Group, July 2008.

Europe's Plan B climate policy should therefore abandon the 2020 renewable energy target, and shift instead towards treating all low carbon energy sources on a more equal footing, via a technology-neutral support scheme (such as a carbon price floor) that provides a reliable long-term price signal that supports investment. While there is still room for targeted support for individual technologies, there should be a much greater focus on RD&D. Support should be provided on the basis of an evidence-based assessment process, applied on a neutral basis to the whole range of low carbon solutions. Technology-specific support for deployment would be much more limited.[79]

Such an approach would significantly reduce overall costs. For example, the European Commission estimates that its current policies will deliver over 80 TWh from solar generation by 2020.[80] Reducing projected additional deployment of solar PV by two-thirds and making equivalent investments in other low carbon sources of energy could produce EU-wide savings of up to £15 billion per year by 2020.[81] As noted earlier, replacing the UK's offshore wind ambitions with equivalent amounts of onshore wind, while politically challenging, would save £15 billion in capital investments.[82] That money could be put to better use in a number of different ways, including making renewable and other forms of low carbon generation more economical in the future through increased RD&D, and financing greater expenditure on adaptation.

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[79] For example, Gillingham and Sweeney in Moselle et al (2010), pp. 69-92 find that the existence of learning-by-doing effects justifies subsidies for installing residential solar PV in California, but that the optimal programme would lead to about 200,000 installations in 2018 (at which point the programme should have ended). In contrast, California public policy had set a headline target of one million installations. California has a population of 37 million people, and is of course much sunnier than the UK and most of Europe (see Table 2 above).

[80] European Commission (2011b) "Energy infrastructure priorities for 2020 and beyond – A Blueprint for an integrated European energy network". http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SPLIT_COM:2010:0677%2801%29:FIN:EN:PDF.

[81] Using the cost estimates shown in Figure 2 shows that replacing solar PV with nuclear power could save up to 27.5p/kWh, giving a saving of £14.9 billion on 54TWh.

[82] I.e. £15 billion in total, not per year.

3. Preparing for a Warmer World: Adaptation and "Backstops"

As argued in Chapter 2, the EU should continue to work towards a global agreement, but policy should no longer be predicated on an assumption that such an agreement will be reached, and policy makers should bear in mind that even the most optimistic scenario is very unlikely to achieve the reductions needed for a 2°C limit.

While the impacts of warming are inherently difficult to forecast, existing analysis suggests that adapting to rises above 2°C is a significantly different proposition from adapting to rises at or below 2°C (indeed 2°C was chosen as a target in part for that reason), as Figure 3 illustrates.[83]

The higher expected warming that follows from the failure to achieve a comprehensive global international agreement brings with it significantly higher risk of extreme outcomes. These include the possibilities of warming beyond 4°C, and of touching one or more "tipping points", with potentially catastrophic impacts on human welfare. One recent paper in the scientific literature notes that:

> *There are a range of other potential thresholds in the climate system and large ecosystems that might be crossed as the world warms from 2°C to 4°C and beyond. These include permanent absence of summer sea ice in the Arctic, loss of the large proportion of reef-building tropical corals, melting of permafrost at rates that result in positive feedbacks to greenhouse gas warming through* CH_4 *and* CO_2 *releases and die-back of the Amazon forest. While the locations of these thresholds are not precisely defined, it is clear that the risk of these transitions occurring is much larger at 4°C – and so the nature of the changes in climate we experience may well start shifting from incremental to transformative.*[84]

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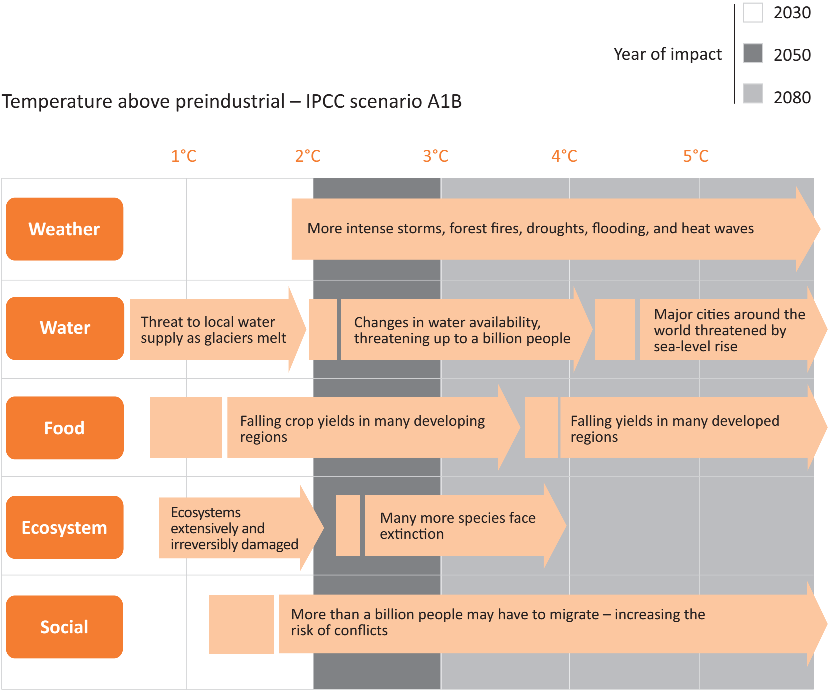
[83] Economics of Climate Adaptation Working Group (2009), *Shaping climate-resilient development: a framework for decision-making,* http://www.mckinsey.com/App_Media/Images/Page_Images/Offices/SocialSector/PDF/ECA_Shaping_Climate%20Resilent_Development.pdf. Note that more recent developments in the scientific literature suggest that the choice of a 2°C limit may be optimistic: "it is reasonable to assume, ceteris paribus, that 2°C now represents a threshold, not between acceptable and dangerous climate change, but between dangerous and 'extremely dangerous' climate change". See Anderson, Kevin and Bows, Alice (2011) "Beyond 'dangerous' climate change: emission scenarios for a new world", in *Phil*. Trans. R. Soc. A 369, pp. 20–44, and references therein.

[84] New, Mark et al (2011), "Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications", in *Phil*. Trans. R. Soc. A 369, pp. 6–19.

Figure 3: Possible impact of global warming on different sectors



Plan B climate policy should therefore address the potential consequences of warming significantly in excess of 2°C. This has implications in two key areas: adaptation, and the development of one or more "backstop" options that may be needed in a worst case scenario of extreme and rapid warming.

Some implications for adaptation policy

The costs of adaptation would be high even in a 2°C scenario, and will be even greater in the new context. It is therefore essential to ensure a strong emphasis on the application of cost-benefit analysis. While it may be difficult to obtain accurate estimates of costs and benefits, a coherent approach to cost-benefit analysis will at the least allow some kind of ranking of measures, and also facilitate possible future trade-offs between spending on adaptation versus mitigation.

In principle the UK government has endorsed this approach, adopting as one of its "key adaptation principles" that "the long term benefits of adaptation actions should outweigh the costs".[85] Whether policy over the coming years and decades will in practice reflect this principle remains to be seen. At EU level, where the UK is already perceived as a leader in developing adaptation policy, it should work with the European Commission and others to ensure that the principle is adopted and implemented by other member states as an important element of Plan B climate change policy.[86] It should also push other member states to ensure that cost-benefit analyses, and adaptation plans overall, are based on scenarios that recognise the probability of global temperature rises significantly greater than 2°C.[87]

However, the effective application of cost-benefit analysis will require much greater knowledge and better techniques to perform such analysis. The current state of play is described in a recent Grantham Institute report which notes that "Global adaptation cost estimates [the annual cost of adapting to 'median' climate change over the next 20 years] range from $4 billion a year to well over $100 billion [approximately £3bn – £65bn] ... The wide range is symptomatic of the poor state of knowledge, with most estimates indicative and incomplete, but also of the analytical difficulty of defining adaptation. There is also a dearth of independent studies using different estimation techniques."[88]

There is therefore a strong case for devoting much greater resources to developing the necessary evidence base for cost-benefit assessment of adaptation measures. A related point is the need for

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[85] See HM Government (2008), *Climate Change: Taking Action Delivering the Low Carbon Transition Plan and preparing for a changing climate,* http://www.defra.gov.uk/environment/climate/documents/taking-action.pdf.

[86] One recent study describes the UK as a "frontrunner country in many respects: a comprehensive approach, strong scientific and technical support, attention to legal framework, implementation and review." See Swart, R. et al (2009), *Europe Adapts to Climate Change: Comparing National Adaptation Strategies* p.19.

[87] At least in principle, the UK's approach already does so: analysis undertaken by the relevant government department DEFRA (the Department for Environment, Food and Rural Affairs), refers to the UK Climate Projections (UKCP09), which provide projections of future climate change under three different future GHG emissions scenarios, corresponding to three of the IPCC scenarios. The most extreme of these scenarios (scenario "A1F1") involves a best estimate temperature increase of 4°C, with a "likely range" of 2.4°C to 6.4°C. See DEFRA (2010), *Climate Change Plan 2010,* http://www.defra.gov.uk/environment/climate/documents/climate-change-plan-2010.pdf, DEFRA (2011), UK Climate Projections, http://ukclimateprojections.defra.gov.uk, and (2007), p.45.

[88] Fankhauser, Samuel in Parry, Martin et al (2009)

additional research to understand better both the probabilities associated with high impact catastrophic events, and the potential to develop "early warning" systems. Better understanding of the probability and impact of these events would feed into our understanding of the benefits of mitigation, and might in the long run affect the debate in key countries outside Europe.[89] With regards to "early warning", the long-term nature of climate change, arising from the cumulative emissions of greenhouse gases, means that the concept requires careful handling: notice of an impending catastrophic event is unlikely to be sufficiently "early" to allow for effective mitigation. However, a warning some decades ahead would allow for more effective adaptation (i.e. damage-limitation) measures, and might also make possible the application of a backstop as discussed below.[90]

Finally, Plan B climate change adaptation policy should include some preparation, at least in the form of contingency planning, for worst case scenarios, including catastrophic outcomes. While society's ability to adapt to very extreme warming is likely to be limited, there may be high value to such measures even if their impact is small relative to the degree of harm. The point is well made in a recent World Bank paper:

> *The more severe the losses, the more valuable even a modest reduction in their potential magnitude. By way of analogy, consider the pandemic flu of 1918 that killed somewhere between 20 and over 40 million people worldwide, with one estimate at 50 million (Niall et al. 2002), assuredly a catastrophe. Say that additional public health adaptation measures would have had the potential to cut deaths by "only" ten percent. That still would have been an amazing accomplishment, one worth bearing significant costs to attain.*[91]

The possibility of extreme outcomes should also be taken into account in making other risk-based decisions, for example in relation

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Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates, International Institute for Environment and Development and Grantham Institute for Climate Change, London. The lower figure represents the low end of the Stern Review's estimate and the upper figure is the UNDP's high-end estimate.

[89] Some noted economists argue that the case for extensive mitigation is largely driven by the extent to which continued warming risks catastrophic outcomes. See for example Weitzman, M.L. (2007) "A Review of The Stern Review on the Economics of Climate Change" in *Journal of Economic Literature*, 45 (3), pp. 703-724 (September 2007).

[90] The possibility of developing early warning systems has also received serious attention in the scientific literature. See for example Lenton, TImothy et al (2008), "Tipping elements in the Earth's climate system" in *Proceedings of the National Academy of Sciences*, 105, (6), pp. 1786-1793.

[91] Kousky, Carolyn et al (2009), *Responding to Threats of Climate Change Mega-Catastrophes,* Policy Research Working Paper 5127, World Bank Development Research Group, Environment and Energy Team, November 2009.

to GM technologies, where the risks associated with innovation may be balanced by the risks of inaction in a context of possible future global food shortages.

Backstops

As discussed above, the possible impacts of severe warming include the potential for one or more "tipping point" thresholds to be crossed, risking catastrophic outcomes. As a key element of planning for such outcomes, policymakers should develop options for a number of "backstop" technologies that could be deployed at relatively short notice to prevent the worst effects of warming (e.g. by keeping the climate system away from a "tipping point"). Such technologies, which involve large-scale manipulation of the global climate, are commonly referred to as "geo-engineering". Numerous proposals have been made by scientists: a recent (2009) report by the Royal Society gives a clear overview as well as a very useful discussion of the policy issues.[92]

Following the Royal Society, geo-engineering techniques can usefully be classified into two groups:

1. Those that directly remove carbon dioxide from the atmosphere, for example through increased afforestation or "ocean fertilisation" (Carbon Dioxide Removal (CDR) techniques); and
2. Those that reduce the incidence or absorption of sunlight, and thereby offset global warming without attempting to affect greenhouse gas concentrations (Solar Radiation Management (SRM) techniques – see Box 3 for details). The approach that has received most attention would involve injecting sulphate aerosols (a very fine "mist" of particles) into the atmosphere. Large volcanic eruptions observed in the past provide natural experiments that have confirmed the effectiveness of this technique in temporarily lowering global temperature.

[92] The Royal Society (2009), *Geoengineering the climate: Science, governance and uncertainty*. Much of the technical information in this section is taken from this report.

Box 3: Solar Radiation Management

SRM methods aim to make the earth more reflective to decrease the amount of "insolation", i.e. absorption of solar radiation by the Earth. The goal is to balance the increased warming caused by greenhouse gas emissions with "negative forcing" relating to reduced solar energy absorption. This can be accomplished by altering the earth's surface to make it more shiny ("increasing planetary albedo"), so that more sunlight is reflected back into space, or by otherwise diverting solar radiation from reaching the earth and being absorbed.

Specific SRM techniques include:

- **Surface albedo techniques:** making the Earth more reflective by making its surface brighter. Potential methods include increasing the reflectivity of the built environment by painting roofs, although this is unlikely to be very effective due to the small portion of the planet's surface that is settled. Other methods include covering deserts with reflective material, planting reflective crops and grasslands, and reforestation;
- **Cloud-albedo enhancement:** whitening clouds over the ocean by spraying powder (e.g. sea salt) from aircraft;
- **Stratospheric aerosols:** releasing particles into the atmosphere to reflect sunlight back into space. A wide range of particles might be suitable, including sulphate aerosols, which have given rise to global cooling in the past when released during volcanic eruptions. According to The Royal Society, this appears to be the most promising SRM technique available; and
- **Space-based techniques:** positioning sun shields in space to reflect solar radiation (e.g. placing reflectors in low-earth orbit, or at a point further out in space). The early stage of R&D and high costs mean that these methods are unlikely to be feasible in the short- and medium-term.

> The advantage of SRM techniques is that while they do nothing to reduce GHG concentrations, they could reduce global temperatures rapidly after deployment, meaning in some cases deployment could be delayed until it became evident that an emergency solution was required. However, none of the primary techniques proposed are ready for deployment and there are unresolved issues relating to potential side effects and the scale of investment and technologies required.[93]

For the purposes of developing backstop technologies, the focus should be on Solar Radiation Management techniques, because only they can be deployed at appropriate speed.[94]

Geo-engineering techniques, particularly those based on SRM, have obvious drawbacks. By definition the techniques could not be tested on a global scale until they were first applied. While SRM would reduce mean global temperatures, its effect would vary by location in ways that would not necessarily reflect the effects of climate change, and its effects on other factors such as precipitation patterns are hard to predict. It would not address the increase in ocean acidification arising from higher atmospheric CO_2 concentrations. Moreover, there are concerns about ongoing reliance on the application of advanced technology that might be disrupted for example by international conflict.

In an ideal world therefore, climate change concerns would be addressed primarily by reducing GHG emissions and implementing appropriate adaptation measures, possibly alongside some CDR techniques if justified in terms of cost and risk. However, in light of the policy failures already discussed in this paper, the UK and EU would be irresponsible not to undertake serious planning for scenarios where rapid "emergency action" is required in response to the arrival of low probability but high impact scenarios, and the

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[93] The Royal Society (2009).

[94] The CDR techniques are better considered as forms of mitigation, and developed through the common policy framework described in section 1, beginning with further support for R&D along the lines proposed by the Royal Society, while bearing in mind concerns about potential environmental harm and unintended consequences (e.g. impact on marine life of ocean fertilisation, or increased food prices if large areas of agricultural land are devoted to CDR uses).

application of SRM techniques may be the best measure available. While there are legitimate concerns that the development of a backstop technology will undermine the political will for mitigation, these are outweighed by the risks of not having a backstop, and by the reality that at global level the degree of political will is, in any case, unacceptably low.

These considerations lead to three recommendations, primarily for the UK government:

1. **Fund an appropriate long-term research programme.** The UK should aim to play a leading role, but research funding and the location of research should be as international as possible. International coordination of research and shared research funding has obvious benefits in many areas, but in this case there is an added payoff that it will complement efforts in developing governance arrangements and in improving public acceptance, as discussed below. The research programme should follow the lines proposed by the Royal Society, including with regards to regulation, monitoring and transparency. While it makes sense to focus most funding on those approaches that appear most promising, the high level of uncertainty around this area implies that it will be optimal to develop a broad portfolio of approaches.
2. **Institution building.** The UK should also look to lead in undertaking the groundwork for future institutions that would govern any such interventions. This groundwork would include assessment of the complex set of issues in international law that arise (depending on the nature of the proposed intervention), the development of proposals for possible governance mechanisms (e.g. international treaties), future funding and operational management. Funding and operational management might be carried out at least in part through existing international bodies. At this stage the goal should be to clarify options and engage the international community in dialogue.

3. **Public engagement.** At present there is a "democratic deficit" in this area, with very limited public discussion of the issues. There is a very real danger that this could lead at some future point to a very negative public reaction that inhibits rational debate and decision-making, as has been seen in other areas such as nuclear power. Government should promote open discussion, focusing on the importance of research, and the principle that any intervention would be a "last resort". We should also encourage other EU member states to take a similar approach.

These recommendations are focused on the UK government rather than the EU, in part because they play to some of the specific strengths of the UK, in relation to pure science, policy development and diplomacy. The UK can contribute best if it focuses on the comparative advantage it holds in those areas.

4. Conclusions and Recommendations

1. The UK and EU should continue to work towards a global agreement to address climate change concerns through a coordinated reduction in global GHG emissions, with the goal of limiting global warming to 2°C. However, policy should recognise that this is an unlikely outcome.
2. Future policy should recognise the EU's relatively limited ability to influence the behaviour of other major global players, and in particular that efforts to "lead by example" have not proven successful.
3. The adoption of a 30% emissions reduction target for 2020 is not fundamental to achieving global climate mitigation. If the EU's 2020 package is reopened and the emissions target increased, then, as part of that, the EU 2020 renewable energy target should be scrapped (or downgraded to an ambition), enabling greater emissions reduction at lower costs and – as laid out in this paper – the adoption of policies more likely to have real impact globally.[95]
4. The UK and EU should instead focus on measures that are more likely to encourage greater mitigation efforts by others, in particular measures that support technological innovation that will make it less costly for others to reduce emissions in the future.
5. This requires (i) a focus on supporting technologies that are or will become affordable, and that can be deployed globally at scale; (ii) investing to bring down costs, which is often best achieved through a greater focus on Research, Development and Demonstration, rather than early large-scale deployment.

[95] In line with the recommendations in Moore (2011).

6. In practice this would lead to very significant changes, particularly in relation to the current focus on large-scale deployment of renewables.
7. In particular, it would involve scrapping the current renewable energy target, as Policy Exchange has previously recommended. Instead EU policy should be based on a support scheme that treats all low carbon sources on an equal footing, and provides support on the basis of objective analysis. The nature and extent of the support will then vary according to the results of that analysis. For example,
    a) Support for CCS would increase very significantly, reflecting the critical role those technologies can play in global mitigation.
    b) Support for solar PV would focus much more on RD&D and on deployment in sunnier locations (i.e. largely outside of the EU), since it is a technology that combines global scalability with very high current costs.
    c) In contrast, support for offshore wind would be significantly reduced, since that is a very costly technology with relatively limited global application.
8. As a complement to effective mitigation policies, the UK and EU need a coherent long-term policy framework for adaptation that incorporates:
    a) Realistic assessments of the consequences of global warming, taking into account a range of likely outcomes including ones that involve levels of warming significantly higher than 2°C.
    b) Robust assessments of the costs and benefits of alternative adaptation measures.
9. Much more research is required into the costs and benefits of adaptation.
10. Adaptation policy should include some preparation for worst case scenarios, including so-called “catastrophic outcomes”.
11. In light of the increasing importance of “low probability, high impact” scenarios involving particularly grave damage from

global warming, policymakers should develop options for a number of "backstop" technologies ("geo-engineering" techniques) that could be deployed at relatively short notice to prevent the worst effects of warming. Government should therefore:

b) Aim to play a leading role in funding an appropriate long-term research programme, along the lines recently recommended by the Royal Society. Research funding and the location of research should be as international as possible. The funding should cover a broad portfolio of approaches.

c) Lead in undertaking the groundwork for future institutions that would govern any such interventions, including assessment of relevant aspects of international law, the development of proposals for possible governance mechanisms, future funding and operational management.

d) Actively foster public engagement. The UK and other EU member state governments should promote open discussion, focusing on the importance of research, and the fact that any intervention would be a "last resort".

The EU and UK have adopted ambitious targets for emissions reductions, part of an overall strategy aimed at achieving a comprehensive, legally binding and effective global agreement, through a combination of intensive diplomatic efforts with strong "leadership by example". However, major global players, including crucially China and the USA, have been largely unmoved by the EU's commitments. European policy-makers must therefore now come to terms with the reality of the failure of international negotiations, and the fact that EU leadership has proven much less effective than had been hoped. It is now time to develop a "Plan B" Climate Policy.

This paper therefore proposes high level changes in UK and EU policy, with the aim of developing a "Plan B" Climate Policy that would better reflect the new and potentially dangerous circumstances we find ourselves in. These "Plan B" changes fall into two categories: (1) continued efforts to promote mitigation, but with a focus on lowering the costs at global level; and (2) a range of measures aimed at preparation for a warmer world.

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