

## PIU Working Paper: Environmental Risks and Costs

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### **Summary**

- Energy systems and energy policies impact on a wide range of environmental issues, many of which create costs and benefits for large parts of society. These externalities provide a basic rationale for Government intervention.
- In assessing the implications for energy policy, a number of issues need to be considered. Key amongst these will be an assessment of the source and impact of each environmental impact. This will often lead to an attempt to attach monetary values to environmental impacts, which can be helpful when environmental impacts are to be weighed against other impacts. However, this does not negate the fact that – in some cases – there are environmental limits that cannot be traded-off against other objectives.
- Another important issue to take into account is the degree of risk and uncertainty associated with an environmental impact. For example, uncertainty is prevalent in impact assessment and evaluation; and there may be risks attached to different policy responses. A third issue to consider is the extent to which an environmental issue is affected by energy policy, which will vary considerably in relative and absolute scale.
- In classifying different environmental impacts against these criteria, it is clear that greenhouse gas emissions – which cause climate change – and radiological impacts are the key environmental issues related to energy systems and policy. Of these, greenhouse gas emissions are considerably more prevalent across energy systems as a whole, and are the focus of attention in this annex.
- Evaluating the external costs associated with greenhouse gas emissions is extremely difficult, and subject to considerable uncertainty. But DEFRA's current best estimate of £70/tC seems to be a sensible starting point, and should be factored in to policy-making as the central estimate in an upwardly-skewed range.
- Climate change is also subject to considerable risks and uncertainties over the short, medium and long term. Uncertainty about the future direction of international climate change policy, climate change science and actual climate change impacts all create risks in the pursuit of different energy policy options.
- Of the other environmental impacts, the most significant risks are associated with radiological impacts, where the potential costs are dominated by events with very low probability, but very serious consequences. Such events are not easily assessed.

### **Introduction and Background**

1. Environmental concerns are widely recognised to be an increasingly important driver of energy policy. Energy extraction, conversion and use are a major contributor to some important environmental problems – in some cases the dominant cause. This is one of the important ways in which 'energy is different' from some other sectors of the economy.
2. Climate change, due very largely to the emissions of carbon dioxide from fossil fuel combustion is now widely seen as the principal energy/environment problem. Given the dominant role of fossil fuels, this is a long term and serious issue for the energy sector.

3. But climate change is not the only environmental problem. Only two decades ago, air quality and the associated acidification of land and freshwater was seen as the dominant environmental problem of fossil fuels, and these problems have not disappeared. Alternatives to fossil fuels also have characteristic environmental problems, notably the radiological health hazards of nuclear power and the amenity concerns generated by some renewable energy technologies.
4. The purpose of this annex is three-fold:
  - (1) To set out the approaches and limitations to measurement and valuation of environmental impacts, and to classify environmental impacts according to the risk and uncertainty associated with them, and the relative contribution to them from energy policy;
  - (2) To focus on the costs, risks, uncertainties and impact of energy policy associated with climate change, the key environmental problem affected by energy policy as a whole;
  - (3) To summarise costs, risks, uncertainties and impact of energy policy associated with the full range of environmental impacts associated with energy systems and policy.

## ***Measurement and Classification of Environmental Impacts***

### **Measuring Environmental Impacts**

5. Most of the environmental impacts of energy use create “externalities” or “external costs”. These are costs that result from an economic activity, but that are not reflected in the prices charged for the products or services associated with that activity. In other words, the costs do not fall on customers, but on some other group in society. Pollution tends to impose costs on a wide population and there are, in general, no practical legal or contractual means by which those who suffer from pollution can individually be recompensed for these costs. This provides a basic rationale for Government intervention.
6. If the costs of environmental impacts are to be included in energy decision-making, it is necessary to evaluate their magnitude. This involves three separate but linked exercises:
  - *source assessment*, i.e. measurement of the pollution burdens (emissions and other releases) from energy system operations;
  - *impact assessment*, i.e. tracing the route that pollution follows through the environment to the point where it has an impact, and quantifying any deleterious effect on human health, or the natural or built environment;
  - *impact evaluation*, i.e. a social, political and/or economic assessment of the extent to which different impacts are costs to society.

### ***Source and Impact Assessment***

7. In general, there is reasonable data on the emissions from energy activities, certainly to the level of accuracy required given the uncertainties in impact assessment. The only exception to this is for very low probability releases, where the statistical base is insufficient to make a reasonable assessment of the actual probability (such as for non-routine emissions of radioactive materials, whether by accident or sabotage).
8. In theory a full assessment requires consideration of the burdens from all stages of the fuel chain and from the manufacture of the capital equipment that goes into that chain. This ‘full life cycle approach’ is formidably complex, but fortunately, in practice, can be simplified considerably, as the burdens emitted at one or two points in each fuel chain usually predominate.

9. In general, although considerable scientific uncertainties remain, there is broad agreement on the identity of the important impacts and the key causal relationships. Some of the issues are discussed later in this annex.

### *Impact Evaluation*

10. There is no generally accepted methodology for evaluating environmental impacts. Two broad approaches stand out, based on two different approaches to sustainable development<sup>1</sup>:
- *Monetary evaluation*, in which everything is analysed in a common metric (money) so that different impacts can be weighed against each other. This is based on an assumption of *weak sustainability*, i.e. that environmental damage can, at the margin, be traded off against other aspects of human welfare.
  - Use of *sustainability levels* to judge the scale and acceptability of aggregate pollution loads against the ability of the environment to absorb them. These draw on the assumption of *strong sustainability*, i.e. that the natural environment is not substitutable by other goods, and therefore that key aspects of it merit absolute protection.<sup>2</sup>
11. Most balanced assessments concede that neither school has a monopoly of wisdom. Seeking to protect all aspects of the environment, whatever the cost, is neither desirable, nor even feasible. On the other hand, no amount of additional economic production is likely to be an acceptable trade-off for the long-term destruction of the ozone layer or catastrophic climate change.
12. Monetary valuation has the very considerable advantage of allowing impact evaluation to be factored into cost benefit analysis. Even where impacts are uncertain and/or valuations contentious, it is generally clear that the costs of environmental damage are not zero. Energy policy should therefore generally allow for monetary valuation of environmental effects. On the other hand, economic instruments based on current marginal damage estimates may not guarantee long term environmental sustainability, especially if market discount rates for future impacts are used<sup>3</sup>. Targets for aggregate emissions reduction may therefore be needed on key issues where environmental sustainability is threatened.
13. Environmental policy in the energy sector needs to consider both cost-benefit analysis and targets for ‘sustainable’ levels of environmental damage or risk. Monetary estimates of environmental impacts should be included in the assessment of different policy instruments. But, broad long-term goals for critical environmental problems need to be set in the context of environmentally sustainable levels of pollution. In many cases, similar conclusions will be reached, and similar policy approaches appropriate.

### **Risk and Uncertainty**

14. The cost imposed by an environmental impact is not the only issue that needs to be taken into account in policy-making. Rarely, if ever, is it possible to estimate costs with certainty, or to be able to “price in” all of the risks associated with environmental impacts and associated policies. And rarely is there comprehensive knowledge of how the impacts may be dealt with and

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<sup>1</sup> These are compared in Royal Commission on Environmental Pollution (2000), “Energy- The Changing Climate”, Background Paper Number 5.

<sup>2</sup> Synergies and trade-offs between different objectives of sustainable development are discussed in more detail in the PIU report “Resource productivity: making more with less” (2001).

<sup>3</sup> See for example Pearce, D.W. (1993), “Economic values and the natural world”, Earthscan.

mitigated. The “precautionary principle” sets out the basic approach to dealing with risk and uncertainty, and requires that cost-effective action be taken to prepare for the full range of possible eventualities. This makes it important that policy-makers consider the degree of risk and uncertainty<sup>4</sup> associated with an environment issue, alongside estimates of its costs.

15. Local air quality and acidification<sup>5</sup> might provide one example where the levels of uncertainty are decreasing, and where the risks seem low. Developments such as low-sulphur coal and flue-gas desulphurisation (FGD) have meant that emissions of SO<sub>x</sub> from coal-fired power stations are now much less of an issue than has previously been the case.
16. More generally, uncertainty is pervasive in impact assessment and evaluation. Impacts in the environment are multiple, complex, inter-related and dependent on background conditions. Where pollution is widespread, there may be very small impacts on a very large number of receptors and these low dose effects may be very difficult to measure, even if the aggregate effect is large. In many case impacts are far into the future and therefore against an intrinsically uncertain base case. Impact evaluation necessarily involves the measurement of human behaviour or opinion, whether ‘lay’ or ‘expert’. Different methodological approaches generate different results and, even within a single approach, there is often significant statistical uncertainty. Effective consideration of environmental issues into decision making requires both ‘good science’ and more subjective assessments of how these are evaluated.

### **Relative Importance of Energy Systems and Policy**

17. In addition, and irrespective of the costs, risks and uncertainty associated with an environmental impact, it is important to be aware of the relative contribution of any particular policy area to an environmental problem. Government intervention does not come free of charge, and can itself be subject to “government failure”. What this means is that, where the relative contribution of any particular policy area is small in relation to the overall problem, intervention may not be a priority – especially where it would result in trade-offs with other, more directly affected objectives.
18. Clearly there are some environmental issues – e.g. inert waste – which are affected by energy systems and hence by energy policy, but for which there are much more pressing concerns. In contrast, other environmental issues – e.g. climate change – are linked extremely closely to energy systems. It will be the latter on which attention needs to focus.

### **Summary Categorisation of Environmental Issues**

19. The table overleaf summarises a qualitative categorisation of environmental issues against the twin axes of degree of risk and uncertainty, and relative importance of energy systems and policy. The table shows clearly that climate change (caused by greenhouse gas emissions) and radiological impacts are key areas for energy policy to address. Of these, greenhouse gas emissions are the more pervasive, and are the focus of the next section.
20. In assessing the degree of risk and uncertainty relating to radiological impacts, there are two distinct issues to take into account. On the one hand, it is evident that there are massive risks and uncertainties associated with major and non-routine emissions of radioactive substances. On the other hand, the probability of such a major and non-routine event is extremely small. It is for this reason that the table shows radiological impacts in both the “high risk” and “low risk” column.

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<sup>4</sup> It is important to be clear about the difference between risk and uncertainty. The former can typically be quantified, even if only in relatively inexact terms; the latter is by definition “unknown”, and cannot be quantified. In general terms, this paper notes that *uncertainties* surrounding the response to climate change will feed through into *risks* for energy policy.

<sup>5</sup> These issues are discussed in more detail later in the annex.

Classification of environmental issues in relation to energy policy		Risk		
		High	Medium	Low
Importance	High	Climate change / greenhouse gas emissions Radiological impacts – consequences of event*	-	Radiological impacts – probability of event* Local air quality / acidification
	Medium	-	-	Land use Visual amenity
	Low	-	Water abstraction	Other hazardous waste (coal fly ash) Inert waste Water quality Biodiversity <sup>6</sup>

(\* See explanation in paragraph 20 above.)

### ***Climate Change: Costs, Risks and Uncertainties***

21. Greenhouse gases (primarily carbon dioxide) are the cause of climate change. The basic mechanisms of atmospheric warming are very well understood, but there remains some uncertainty about the sensitivity of climate to greenhouse gas concentrations and the risks of major climatic disruption. Combustion of fossil fuel is the predominant cause. The effects are global and long term. Because of the key role of the climate in human activities, impacts are expected to be very wide ranging. However, the scale of impacts will depend on the rate of climate change, location and capacity to respond.
22. Because climate change is a global problem caused by global emissions of greenhouse gases, action to reduce greenhouse gas emissions will also, ultimately, have to take place on a global basis. Fundamental economic realities dictate that this must be so – costs incurred by any single country in reducing emissions will result in benefits spread across the world as a whole, making the economics of unilateral action extremely disadvantageous. This is not to say that there are no benefits from leading the international effort to reduce emissions, because the benefits for the environment and – ultimately – for the economy (for example through creation of new industries that will become global leaders) could be significant. However, paragraphs 36-37 below highlight the fact that leading is only worthwhile if others follow.
23. The international response to climate change has commenced through the United Nations Framework Convention on Climate Change (UNFCCC), and the Kyoto Protocol to the Convention, which sets targets for the world's industrialised nations. At present, there are no limits on the emissions of developing countries, but they will certainly need to play a role in the long-term. What is likely to occur is some degree of "contraction and convergence", through which per capita emissions converge to a level that will deliver the required absolute emission reductions. This is discussed further in paragraph 41.

### **Costing Climate Impacts**

24. Climate change impacts are genuinely global. However, changes to global temperature will not be uniform. Perhaps more importantly, rainfall changes are expected to be very unevenly distributed.

<sup>6</sup> Other than that caused indirectly by climate change and other impacts.

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Extreme weather events will be more frequent, with best guesses that the number and severity of both droughts and floods will increase. Sea level will rise. Other 'surprise' outcomes, such as changes to major oceanic currents and destabilisation of greenhouse gas sinks, are possible, but are currently not predicted. However, the atmosphere/ocean system is complex and highly non-linear, and therefore there can be no guarantee that existing model predictions will prove correct.

25. A wide variety of other environmental factors and human activities are dependent on climate and weather. Effects are likely to include impacts on: coastal protection; loss of land; heat and cold stress; prevalence of tropical diseases; energy demand for heating and cooling; agricultural production; water supply and demand; flood, storm and drought damage; ecosystems and biodiversity; migration; and famine. A comprehensive impact assessment would therefore need to cover all these and their interactions, over the whole Earth for a very long period of time. Needless to say, this has not been achieved.
26. Because of uncertainties in the implications of any level of climate change for particular meteorological variables in any single place, none of the impacts can be assessed very precisely. Reasonably accurate estimates can be made for some of the impacts earlier the list shown above. However, the costs of food and water supply impacts on migration and famine are 'socially contingent', i.e. they depend at least as much on how society responds to the impacts than the physical impacts themselves<sup>7</sup>. For example, in a well-organised and equitable world, a reduction in food production in one region may result only in small changes in world food prices; but in a divided and inequitable world it may result in famine, migration and even war. In general, impacts will be larger in poorer countries, because the capacity to respond effectively is less.
27. Evaluation of climate change impacts faces other issues arising from the temporal and spatial scales involved. If monetary evaluation techniques are used, the outcome is very sensitive to two issues<sup>8</sup>:
  - Estimation of values across different regions of the world, especially the controversial issue of valuation of life in different countries;
  - Estimation of values over time, where there are arguments about the issue of discounting.
28. Monetary valuation of some climate change impacts is therefore very sensitive to the methodological assumptions and cannot escape some fundamental ethical dilemmas. That said, monetary valuation remains the only technique likely to generate a mechanism for incorporating climate change impacts into individual policy instruments. A large number of estimates of climate change costs have been undertaken. Early attempts were extremely crude, for example assuming that impacts over the whole world would mirror those projected for the USA. More recent studies are based on more credible impact assessments. However, they tend to exclude the more controversial 'socially contingent' impacts, and therefore represent partial estimates.
29. DEFRA has undertaken a review of climate change costing.<sup>9</sup> This recommends a current best estimate of £70/tC based on the extensive European Commission project on environmental externalities, ExternE.<sup>10</sup> However, it is noted that the risks are strongly positively skewed, and the report recommends use of an upwardly skewed range. It seems sensible to include this in policy-

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<sup>7</sup> It should of course be recognised that adaptation to climate change does itself have a cost, which should be factored in to the calculation of costs.

<sup>8</sup> Discussed in detail in Clarkson, R. and Deyes, K. (2001), "Estimating the Social Costs of Carbon Emissions", EPE Division, DEFRA.

<sup>9</sup> Clarkson and Deyes (2001), op cit.

<sup>10</sup> ExternE - Externalities of Energy. Volume 8 - Global Warming Damages. European Commission, 1999.

making procedures, as the best possible guess in view of the data limitations. It further recommends that the value should rise at £1/tC/year to reflect the growing costs of climate change.

## **Climate Change and Energy Policy**

30. The UK is committed as part of the EU to ratification of the Kyoto Protocol, which sets binding emissions limits for greenhouse gases. The UK's target will be to reduce greenhouse gas emissions to 12.5% below 1990 levels by the period 2008-12. In addition, the UK has a domestic goal of reducing emissions of carbon dioxide, the main greenhouse gas, to 20% below 1990 levels by 2010. Looking to the longer term, the Royal Commission on Environmental Pollution (RCEP) has identified a case for 60% reductions by 2050.
31. Action to tackle climate change has major implications for energy policy. The vast majority of greenhouse gas emissions come from the combustion of fossil fuels to produce energy. Around one-third of emissions come from the energy supply industry itself; over one-fifth of emissions come from energy use in transport; and many of the emissions from the domestic and business sectors come from the direct use of gas, oil or coal to provide heat. In order to meet the challenge of climate change, action will be needed to decouple energy use from GDP growth, and to decouple emissions from energy use. The Government's Climate Change Programme<sup>11</sup> has set in place a number of measures, many of which interact directly with different parts of the energy system. There are also a plethora of EU-level initiatives set out in the European Climate Change Programme<sup>12</sup>, and the international community is proposing the use of international emissions trading and other "flexible mechanisms" in the response to the climate change challenge.
32. One other aspect of climate change could have a significant impact on energy systems over a 50 year time period, namely the impacts of climate change itself. There remains considerable uncertainty about the impact that climate change will have in the UK, but what is likely is that there will be more extreme weather events (floods, storms, etc.) and a trend towards warmer temperatures. Globally – and particularly in the developing world – the impacts could be much more severe. Many of these impacts could impose considerable burdens on energy systems.

## **Climate Change Risks and Uncertainties**

### *Emissions Reductions in the Short-Term*

33. The UK's Climate Change Programme has put the UK well on course to exceed its Kyoto target, and to move towards its domestic goal<sup>13</sup>. However, there are still three key uncertainties that could pose some risks for energy policy:
  - There is uncertainty surrounding the *split between national<sup>14</sup> policy-making and EU-level policy-making* (see chapter 8). As with any other area of policy, there are areas of Community competence that impinge upon energy policy – single market concerns, State Aids, competition policy, etc. But more pertinently, the Environment Directorate-General (DG ENV) at the European Commission has been extremely proactive in pushing forward EU-level policies and measures to tackle climate change, many of them relating to energy systems and energy policy<sup>15</sup>. These latest developments seem to be part of a long-term trend towards more and more EU-level regulation, with the proposed trading scheme

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<sup>11</sup> <http://www.defra.gov.uk/environment/climatechange/cm4913/index.htm>

<sup>12</sup> <http://www.europa.eu.int/comm/environment/climat/eccp.htm>

<sup>13</sup> <http://www.defra.gov.uk/environment/climatechange/cm4913/index.htm>

<sup>14</sup> For the purposes of this discussion taken to include devolved, regional and local.

<sup>15</sup> <http://www.europa.eu.int/comm/environment/climat/eccp.htm>

seeing this extended to economic instruments. Although it is not clear how this will develop into the future, the balance must lie with the likelihood that EU-level measures will increasingly impinge on the ability of Member States to set their own energy policy.

- The second area of uncertainty relates to *what will happen to the UK's over-achievement of its Kyoto target*. This issue has arisen because of the way in which targets have been set for European Member States. In the Kyoto Protocol, the EU as a whole, and every individual Member State, signed up to an 8% emissions reduction on 1990 levels by 2008-12. The exact contribution of each Member State was subsequently agreed through a “burden sharing” arrangement. A draft report from the “EU Monitoring Mechanism”<sup>16</sup> suggests that apart from the UK, only Germany and Luxembourg<sup>17</sup> are on track to exceed their targets, with most of the other countries currently on track to fall well short. Even when new measures are factored in<sup>18</sup>, the total EU shortfall is projected to be around 90 mtC. There must be a risk that, at least in part, the UK will be constrained in terms of how it can use over-achievement arising from further action to reduce greenhouse gas emissions over the next ten years.
- The third area of uncertainty relates to the possibility that *emissions projections could prove to be significantly inaccurate*. This would be of particular concern if emissions turned out to be under-estimated, so that actual emissions are higher than expected, and we struggle to meet our commitments under burden-sharing. The UK's Third National Communication on Climate Change<sup>19</sup>, published October 2001, undertakes a sensitivity analysis, which comes up with a range of +/- 10 mtC around the UK's central projections (which show comfortable over-achievement). On the basis of this analysis, the Third National Communication notes that, “*it seems likely that the target will be met even if the baseline with measures scenario proves optimistic and the additional measures deliver less than anticipated*”. This top-down assessment of uncertainties in emissions projections needs to be accompanied by a bottom-up assessment of the key areas. But on the basis of the top-down assessment alone, there seems to be a very low risk that the UK will unexpectedly miss its burden-sharing target.

### *Target-Setting in the Medium Term*

34. The United Nations Framework Convention on Climate Change requires that the process of agreeing the next round of greenhouse gas emission targets (post-2012) must begin by 2005. In practice, informal discussions are likely to begin before then. It is not yet clear what form the next round of targets will take. One option would be simply to follow the same sort of format as the Kyoto targets, with emissions reductions specified for the period 2013-2017 (or thereabouts).
35. However, there is increasing pressure (e.g. from the UNFCCC itself) to adopt a somewhat more coherent and forward-looking approach. The Inter-Governmental Panel on Climate Change (IPCC) has plotted out a number of different emissions profiles that would deliver different

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<sup>16</sup> The Monitoring Mechanism was established to monitor Member States emissions of greenhouse gases, in relation to their emission commitments. The first report is available at [http://europa.eu.int/comm/environment/docum/00749\\_en.htm](http://europa.eu.int/comm/environment/docum/00749_en.htm). The second report, “Report under Council Decision 1999/296/EC for a monitoring mechanism of Community greenhouse gas emissions”, is due to be published shortly.

<sup>17</sup> And total emissions in Luxembourg are so low that they are largely irrelevant to the EU as a whole.

<sup>18</sup> These results should be treated with caution, as different Member States are at different stages in announcing their policies and measures.

<sup>19</sup> Under the United Nations Framework Convention on Climate Change, all Annex I Parties are required to submit at regular intervals national communications that report on action being taken to tackle climate change. The UK's third such communication was published on 30 October 2001, and is available at <http://www.defra.gov.uk/environment/climatechange/3nc/default.htm>.

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stabilisation targets for CO<sub>2</sub> concentrations<sup>20</sup>. What each of these have in common is a very low level of emissions in the very long-term (2150 and beyond), and a roughly similar profile in the medium-term (out to 2020). This suggests that the most appropriate response might be to set a long-term goal, and to explicitly work back from that to medium-term targets. This approach might also provide a means of bringing in the developing countries, for which “emissions reductions relative to 1990 levels” are meaningless.

36. Notwithstanding these uncertainties, what is clear is that the UK will shortly be moving into a period of negotiation with respect to its next set of commitments to climate change. It will be important for the UK to continue to set a lead, and to be clear in its commitment to further emission reductions. However, the benefits of “leading” will only be felt if others follow.
37. In view of the risk that the UK will lead without being followed, considerable caution will need to be exercised in committing the UK to a programme of emissions reductions over the period beyond 2012. There is also uncertainty concerning the ability of the UK to take control of its own targets, with the European Commission pushing for a move to qualified majority voting in target-setting. This may set mean that the UK’s energy policy agenda is effectively set elsewhere.

*A Long-Term Perspective*

38. There is a strong case for some sort of global target for where emissions levels have to get to in the *very long-term*. IPCC modelling suggests that whatever the ultimate concentration at which CO<sub>2</sub> concentrations are stabilised (within a “reasonable” range of 450ppm to 1000ppm), annual global emissions will eventually have to reduce to something around a quarter of their current levels.
39. The main effect of different concentrations is to alter the time by which this must be achieved. For low concentrations (450ppm), this level of emissions will have to be achieved by around 2100; for higher concentrations (1000ppm), emissions would not have to reach this level until sometime after 2300. In each of these scenarios, the mean estimate of temperature change over the next 100 years would be around 2.5 degrees Celsius; the final mean temperature change upon reaching stabilisation is estimated at between 2.5 and 5 degrees. The UK’s Climate Change Programme suggests that emissions reductions of 95% on current levels may be needed in the developed world, perhaps before the century is out.
40. A stabilised CO<sub>2</sub> concentration of 550ppm is commonly adopted as a reasonable central case. If this is the end point, IPCC modelling suggests that annual global emissions should be around 9 GtC by 2050. This is broadly the same as current emission levels, but needs to be set in the context of a “business-as-usual” emissions projection showing emissions at around 16 GtC by 2050. This sharp growth is due in large part to the industrialisation of developing countries – a process well under way in places like China and India.
41. So at the global level, a suitable target for 2050 would be to hold emissions at something like 2000 levels. But this will need to be achieved in the face of rapid developing-country growth, as well as ongoing growth in the developed world. By 2050, emissions from the current developed world will be only about 20-30% of the global total. If the assumption is that the developed world is to shoulder the bulk of the burden (consistent with some element of contraction-and-convergence), then this will become increasingly difficult as its share of total emissions declines.
42. The implications of all this for where we will need to be in 2050 are not at all clear. What we can say with reasonable certainty is that the UK – along with the rest of the developed world – needs

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<sup>20</sup> All references to IPCC analysis taken from the “IPCC Synthesis Report to the TAR” (Third Assessment Report), published on 30 September 2001.

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to be moving towards an economy with negligible greenhouse gas emissions<sup>21</sup>. There are three possible uncertainties surrounding this long-term goal:

- That *current science may be over-stating the problem*. The current view is that this is unlikely – recent developments in the science have resulted in a more pessimistic view;
- That the use of *carbon sinks* (e.g. from the planting of new forests) or *carbon capture and sequestration* (C&S) will mean that emissions can be higher than currently thought. Carbon sinks are subject to considerable uncertainty, and it would be dangerous to assume that they will provide any sort of solution. The latest report from the Hadley Centre<sup>22</sup> suggests that planting forests could actually accelerate global warming. C&S is described in chapter 5 – there are some considerable technical uncertainties to overcome;
- That the world *chooses to adapt to climate change*, rather than to reduce emissions. Some adaptation will be necessary whatever action is taken to reduce emissions from now on. But unless the estimates of temperature change and its impacts are very wrong, then a response focused solely on adaptation is highly unlikely<sup>23</sup>. Whatever the short-term position, by far the more likely choice in the long-term will be to reduce emissions.

43. Even without these uncertainties, there is no solid justification for a firm target of 60% reductions by 2050, as has been suggested by the RCEP. This number and timescale are certainly in the right sort of range, and are a useful indication of the scale of the challenge. But there would seem to be little merit in accepting a single figure and a specific date, which may subsequently be overtaken by events. A better option would be to talk in more general terms, such as “reducing emissions by more than half” by “the middle of the century”. Sending “indicative” signals for the direction of policy in the long term is one means of providing greater long-term certainty to the private sector<sup>24</sup>, and would also maintain the UK’s world-leading role, without running the risk of the UK becoming isolated.

### *Climate Impacts*

44. The above discussion focuses on the role of energy systems as “active” contributors to climate change, and hence as a key area in which emissions will need to be reduced. But energy systems are also linked in a more “passive” way to climate change, as recipients of climate impacts.

45. In general terms, the main impacts of climate change in the UK are likely to be:

- Increased frequency of “extreme” weather events, such as floods and storms;
- Gradual increases in temperature, leading to milder winters and hotter summers;
- Pressure on water supplies in the south-east during the summer months;
- Sea level rise (up to 0.5m by 2050) threatening coastal erosion, especially in the south-east and East Anglia.

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<sup>21</sup> For example, if it is assumed that there will be no alternative to the use of fossil fuels in aviation over the next 50-100 years – and if there is to be a residual level of emissions from industrial processes – then the UK may need to move away completely from the use of fossil fuels in providing heat, power and surface transport.

<sup>22</sup> <http://www.met-office.gov.uk/corporate/pressoffice/pr20010706a.html>

<sup>23</sup> This approach might be thought of as a caricature of the US response, caused by the fact that climate impacts in the US may turn out to be beneficial in net terms. However, this is a short-sighted view. Even though parts of the developed world may indeed benefit from climate change in the short-term, further increases in temperature are likely to see all countries suffer. And developing countries are likely to suffer in the short and medium-term, exacerbating global poverty and unrest.

<sup>24</sup> An issue addressed in more detail in the PIU project “Resource productivity: making more with less”.

46. For energy demand, the key element of uncertainty surrounds the future pattern of demand for space heating versus air conditioning. This will have implications for total energy demand and for seasonal patterns. In the short term there is little doubt that the reduction in heating demand will be more significant in the UK<sup>25</sup> and this effect is already factored into Government demand projections to 2020. In the longer term, the increased use of air conditioning may be the more significant, but will depend on building design and socio-economic factors.
47. For energy supply, extreme weather events could increasingly threaten infrastructure, perhaps requiring more robust build, or a switch from overhead to underground cables. Pressure on water abstraction could limit the availability of cooling water for power generation and industry; and if water temperatures are warmer, more will be needed to deliver the same cooling effect. Finally, power stations in coastal areas could be threatened by sea level rise, storm surges and increased coastal erosion.

### ***Other Environmental Impacts: Costs, Risks and Uncertainties***

#### **Radiological Impacts**

48. Radiological impacts result from the emission of radiation and radioactive substances. They operate on a range of different temporal and spatial scales (depending on the isotopes involved), but some are very long lasting. The carcinogenic health impacts are fairly well understood, although there remains some disagreement about the impacts of very low doses.
49. Radioactive waste management involves dealing safely with the long-lived wastes from processes involving radioactivity. This waste comes from a number of sources, and ranges from mildly irradiated paper towels used in hospitals, to acid solution from irradiated nuclear fuel that is so radioactive it needs to be permanently cooled. The most significant sources of nuclear waste in the UK are, however, nuclear power stations and the Sellafield reprocessing plant. The future of nuclear power appears to be bound up with action that is taken to improve the safe disposal of nuclear waste. The Government is currently looking into how best to manage solid radioactive waste, and on 12 September 2001 launched a six-month consultation which aims to begin a nationwide debate on the issue over the next 5 years<sup>26</sup>. The UK has only one nuclear re-processing facility (at Sellafield), and there is a reluctance elsewhere to accept nuclear waste.
50. Routine emissions and their impacts are relatively well understood. Routine emissions from nuclear installations are small but not insignificant, for example the combined impact of annual UK nuclear industry emissions is expected to produce 125 fatal cancers<sup>27</sup>. Approximately half of this impact is due to reprocessing. Regulatory constraints on nuclear installations focus on the 'maximum affected individual'. As with amenity impacts (see below), it is implicitly environmental justice, rather than economic efficiency that is the driving force.
51. However, the possible consequences of non-routine releases are very large. The total inventory of radiological material in the nuclear fuel chain is many orders of magnitude larger than will ever be emitted through routine emissions, so that non-routine emissions have the potential to release far greater radioactivity. This means that the expected value of emissions may be dominated by these low probability events – accidental or malevolent. Quantification of the probability of these is inevitably highly uncertain and subjective. Four types of event can be conjectured:

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<sup>25</sup> UK Climate Change Impacts Review Group [...]

<sup>26</sup> <http://www.defra.gov.uk/environment/radioactivity/waste/index.htm>

<sup>27</sup> Based on Royal Commission on Environmental Pollution 'Energy- The Changing Climate' Background Paper number 5.

- plant or operator error in a power station or reprocessing plant,
- high level waste facility failure,
- deliberate attacks on any of these, and
- theft of fissile material for nuclear weapons manufacture.

52. Power plant failure has been studied the most extensively, and the risk in a well-designed and managed plant of a very large containment failure is certainly exceedingly low. However, in all cases, there is no credible way to determine the probability with any certainty. As the Chernobyl accident showed, the potential consequences are huge – releases of more than 10 million times annual routine releases, leading to tens of thousands of fatal cancers and massive land contamination.
53. The economic loss associated with such an event would be of the order of £100 billion. However, there is no generally accepted way to value the risks of such a low probability, high consequence event. They are outside the scope of insurance markets. It is not even agreed that the expected value (probability multiplied by consequence) is the correct input, given societal risk aversion<sup>28</sup>.
54. The maximum consequences, if they occur, would fit any definition of “unsustainable” for the affected region, but that does not provide quantitative guidance of the level of probability that society might view as acceptable. Some strict interpretations of sustainability, certainly those held by many opponents of nuclear power, would assert that any technology with these attributes is unacceptable. Others would say that provided the probability can be kept to very low levels, high consequence risks can be acceptable.

### **Land Use and Visual Amenity**

55. These are generally short term, local and subject to relatively small uncertainty. They are generally controlled through the land use planning system, where they are frequently the impacts of highest concern. All but the smallest energy supply facilities and infrastructure will need to obtain planning permission. This can act as a significant constraint on facilities. Particular concerns have been expressed in respect of nuclear plant, combustion plant and onshore wind.
56. The impact of energy infrastructure on visual amenity is a key factor in considerations of land use, and in applications through the planning system. A particular issue relates to onshore wind, where the most effective sites are often those where the visual impact is the greatest. More generally, and particularly in the longer term, patterns of development will have significant impact on the demand for energy for mobile and static purposes.
57. In principle, amenity impacts are the easiest to assess using monetary evaluation techniques. In practice, this approach is rarely used, because the land use planning system emphasises democratic process and judgement against agreed norms. Where cost benefit calculations of amenity concerns have been undertaken<sup>29</sup>, they tend to show that the economic costs of amenity loss are small in relation to other impacts and project benefits. For energy sources, such as many renewables, where amenity impacts are the major concern, external costs are small. Government interventions in energy pricing currently reflect this (through CCL exemption for renewables) and should continue to do so.

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<sup>28</sup> Krupnick, A.J., Markandya, A. and Nickell, E., “The External Costs of Nuclear Power: Ex-Ante Damages and Lay Risks”, Resources for the Future discussion paper QE93-28.

<sup>29</sup> ExternE - Externalities of Energy. Volume 6 – Wind and Hydro. European Commission, 1995.

58. Planning constraints (such as distance of noise sources from housing) generally over-internalise amenity impacts. This should not necessarily be interpreted as a judgement that planning decisions are incorrect. Externalities measure aggregate effects over the whole population, they are small for amenity impacts because few people are directly affected. However, decisions (e.g. about noise) are made on the basis of maximum acceptable levels – to protect the environment of the worst affected individual from projects with wider benefits. These are effectively judgements about sustainability levels for these impacts in a broader sense. The underlying goal of environmental justice, not economic efficiency, is a legitimate concern and the planning process is an appropriate approach to delivering it.

### **Local Air Quality / Acidification**

59. There is broad agreement that the most problematic air pollutants, other than greenhouse gases, are the regional-level acid emissions that affect air quality and lead to acid deposition. They have impacts on human health, materials, crops, forests, fisheries and other ecosystems. These are generally continental in scale and medium-term in lifetime (10-100 years). There have been major improvements in understanding in these impacts over the past 30 years and the relevant emissions are subject to constraints under European scale (UNECE and EU) agreements. Emission levels and impacts are generally falling.

60. The economic impacts of air pollution on health, materials, agriculture, fisheries and forests have been studied more extensively than any other impacts of energy use. There are considerable uncertainties, especially due to the valuation of small reductions in life expectancy. There is also some variance due to location. However, it can be concluded with reasonable confidence, throughout Europe, that the external costs of these impacts are large (of the same order of magnitude as the value of the energy output) for traditional combustion technologies with low pollution abatement. This is especially true for the impacts of particulates on human health<sup>30</sup>. For the most modern technology, costs are generally small, but where older technology remains in use, external costs are still significant.

61. The UK has adopted objectives and targets for eight different types of emission linked to local air pollution and acidification<sup>31</sup>. These have been set out in the Government's Air Quality Strategy<sup>32</sup>. More recently, Government has consulted on plans for new objectives relating to particles, benzene, carbon monoxide and polycyclic aromatic hydrocarbons<sup>33</sup>.

62. In the past, concerns about local air quality were mainly in respect of the smog caused by coal-burning in people's homes and in coal-fired power stations. These concerns have now been largely allayed, through the use of devices to remove pollutants from chimneys and exhausts and through the greatly increased use of gas in place of coal. Large combustion plants remain regulated by the Environment Agency and the Scottish Environmental Protection Agency (SEPA), under the auspices of the EU-wide Large Combustion Plant (LCP) Directive<sup>34</sup>. The Environment Agency and SEPA (and in some cases Local Authorities) also regulates industrial plant under the auspices of the Integrated Pollution Prevention and Control (IPPC) Directive<sup>35</sup>. Both Directives require investment in Best Available Technology (BAT) to deal with a range of pollutants. Where it

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<sup>30</sup> ExternE - Externalities of Energy. Volume 2 – Methodology, Volume 3 – Coal and Volume 4 – Oil and Gas. European Commission, 1995.

<sup>31</sup> The pollutants covered are benzene, 1,3-butadiene, carbon monoxide, lead, nitrogen dioxide, ozone, particles and sulphur dioxide.

<sup>32</sup> <http://www.defra.gov.uk/environment/airquality/strategy/index.htm>

<sup>33</sup> <http://www.defra.gov.uk/environment/consult/airqual01/index.htm>

<sup>34</sup> <http://www.defra.gov.uk/environment/airquality/reia/88609/index.htm>

<sup>35</sup> <http://www.defra.gov.uk/environment/ppc/index.htm>

would not be economic to introduce BAT, this can (and sometimes does) result in the early closure of plant.

63. The main concern about local air quality and acidification today is in respect of emissions from road traffic. There are three main routes by which these emissions are being addressed. The first is through increasingly tight EU-level standards for emissions from new vehicles; the second is through improvements in fuels (e.g. ultra-low sulphur fuels); and the third is through the Transport Ten Year Plan<sup>36</sup>, which seeks to reduce congestion and tackle emissions of greenhouse gases and other pollutants.

### **Water Abstraction**

64. Power stations are significant users of water, most notably for cooling purposes. The Environment Agency is responsible for policing water abstraction, using a system of licences. Reductions in electricity supply industry water use have helped to reduce total water abstraction in England and Wales by 13% from 1971 to 1997. This trend is clearly in the right direction. But increasing pressure on water supply can be expected as demand increases and – potentially – climate change causes a squeeze on supply in the south-east during the summer months. This will undoubtedly be kept under review. In the shorter term, Government has said that it will be asking the Environment Agency to develop a scheme of tradable water licenses, to facilitate competition while maintaining regulatory control<sup>37</sup>.

### **Other Impacts**

65. Other environmental impacts associated with energy systems and policies are as follows:
- A small contribution to *non-radioactive hazardous waste*, mostly through coal fly ash.
  - No major contribution to the *active waste* problem, but possibly part of the solution through the use of waste to energy technologies as an alternative to landfill.
  - A small contribution to concerns about *water quality*, most notably through emission of power station cooling water.
  - Other than the indirect impact of other environmental problems (climate change, local air pollution, water pollution, etc.), little or no impact on *biodiversity*.

### **Conclusions**

66. Energy systems and policies will have a major impact on environmental issues. In order to take account of these impacts in policy-making, it is important to assess the costs, risks and uncertainties associated with the environmental issues, and to make an assessment of the relative contribution to the issues made by energy policy. This annex has set out some methodological issues associated with these assessments, and has drawn out conclusions for each of the environmental issues impacted by energy policy. Attention has been focused on climate change and greenhouse gas emissions. The potential costs, risks and uncertainty associated with climate change are very significant, and energy policy will play the key role in tackling the problem.

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<sup>36</sup> <http://www.dtlr.gov.uk/itwp/index.htm>

<sup>37</sup> <http://www.defra.gov.uk/environment/water/consult/response/TUNING/index.htm>