6. Indexing climate change

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1. THE PROBLEM OF CLIMATE CHANGE

Changeability is an inherent component of climate on all time scales of variation. The importance of this changeability for people has largely been experienced through its influence on food production. For almost all of human history the harvesting of food has been the single most crucial determinant of well-being and socio-cultural development. It is even possible to speculate that the ecological dominance of the human species owes a great deal to its capability to survive and adapt to the swings of the climatic pendulum. The vital harvest surplus on which so much depended has always been largely determined by the vagaries of temperature and rainfall. Today, despite technological advancement – perhaps even more so because of it – humans remain highly susceptible to the jolts of a climatic system the functioning of which is only imperfectly understood. The lessons of history, however, demonstrate that climatic variability is ignored only at the cost of compromising the well-being of ourselves or our children, an unsustainable situation that runs counter to any principles of intergenerational equity.

Public sensitization to the problems of climate change has grown with the realization that, while for most of recorded history humans have been the prisoners of climate, today the converse may be true. The future course of global climate seems increasingly likely to be determined by the aggregation of individual assaults on the composition of the atmosphere by people and nation states acting in their own self-interest and armed with the technologies of the Industrial Revolution. In the most recent report of the Intergovernmental Panel on Climate Change, the considered opinion of some 2500 scientists was that 'the balance of evidence suggests a discernible human influence on global climate' (Houghton et al., 1996). Such impacts on the atmosphere necessitate a radical change in approach in terms of managing the atmospheric environment. The norms of the 30-year climate average, for so long used to build bridges, dams, sea walls and drainage systems, and to help manage the technological fabrications of modern life, are now more unsound than ever as awareness of the complex mix of natural and human-induced

climatic variability has increased. The long-term planning necessary for modern agriculture, urban settlement, coastal management, industry and a host of other endeavours has become fraught with difficulty as the future course of climate threatens a change more rapid over this century than over the ten millennia since the end of the last glaciation. This rate of change, increasing global temperature averages by 0.25°C per decade, and altering a multitude of other climatic variables in a similar fashion, may be rapid enough severely to stress natural as well as human ecosystems.

Environmental hazards, such as those associated with climate change, always most affect the margins of society. The climatic extinction of early European settlers on Greenland is a good example of this vulnerability. As the Medieval Warm Period, in which their initial colonies had been established, waned and the increased sea ice and storminess of the northern ocean beckoned the approach of the Little Ice Age, their inability to adapt and respond to climate change ultimately sealed their fate. On the margins of viable precipitation in semi-arid zones such as the Sahel, a similar hardship has been evident in more recent times. Those most vulnerable to climate change are frequently those with fewest resources and those who have been least instrumental in causing climate change. It is incumbent therefore on the scientific community to provide the best possible advice to decision-makers to enable mitigation of possible adverse effects, or indeed to capitalize on some of the new advantages climate change will confer on certain areas. In keeping with the principles of sustainable development espoused by the World Commission on Environment and Development (1987), such a 'no regrets' or 'precautionary principle' approach will ensure that the positive as well as the negative opportunities of climate change are grasped.

Climate change leads to a complex mixture of associated environmental impacts, not capable of being addressed piecemeal. The precise magnitudes of these impacts are not yet fully understood, since it is not yet possible to project confidently the regional scale of climate change from computer-based global circulation models. In addition, since climate-related systems tend to be non-linear, certain impacts may not materialize until a critical threshold is crossed, by which time recovery may be extremely difficult. However, as models tend to converge increasingly in their predictions, the assessment of impacts may be more confidently carried out. It is clear that there will be 'winners and losers' both between and within countries should climate change as suggested by most models occur. For individual countries, especially in the developing world, where dependence on the annual harvest is still of crucial economic importance, the stakes are high.

In the first instance, it may be suggested that extra warmth and extra CO_2 for photosynthesis will benefit agriculture in many areas. Yield increases of over 20 per cent can be expected in many grassland areas of north-western

Europe for example, while a poleward expansion in agricultural potential will occur. New crops will become viable beyond their present latitudinal and altitudinal limits, and additional growth periods will mean greater productivity, especially for wheat and barley in the higher mid-latitude regions. A poleward advance of 150–200 km per one degree centigrade rise in mean annual temperature is suggested by the models, with corresponding altitudinal changes of 150–200 metres. However, some new regions, such as northern Scandinavia, may be unsuitable for accepting new agriculture by virtue of their soil endowments. Upland and high-latitude regions with legacies of intensive glacial erosion are not going to be able to achieve the yield potential which their changed climate might suggest. Elsewhere, especially in the interiors of the continents, decreased soil moisture levels will similarly limit projected yield increases. Overall, reductions in the principal 'breadbaskets' of the mid-latitudes may outweigh increases elsewhere. In the developing countries of the lower latitudes, changes in the frequency and severity of such hazards as floods, droughts, storms, heatwaves, agricultural pests and diseases may make it difficult for food production to keep pace with population growth.

Similar geographical changes in productivity in ocean fisheries may occur, with cold-water species retreating polewards to be replaced by species from warmer waters, often less palatable to the consumer. Inland, salmonids may be less productive in warmer, less oxygenated, watercourses. Projected drier summers in many developed temperate regions will also create problems for the maintenance of water quality as dilution water for effluent is reduced. However, future rainfall changes are least confidently projected at present by global circulation models, mainly because of the difficulties of incorporating feedback effects due to cloud and ice-cover changes. Resolving such difficulties as they relate to precipitation holds the key to better assessment of a number of potential impacts of climate change. Certainly, new challenges will be posed for the husbanding of freshwater resources, in particular in coping with seasonal changes in water availability for hydroelectric power, irrigation, and domestic and industrial, as well as agricultural, uses.

Sea-level rise has for long been the touchstone of concern regarding climate change. As projected increases have diminished over recent years, now down to 0.5 m by the end of the twenty-first century, and as confidence in such estimates has grown, so more sober assessments of impacts have been made. Due to the slower time scale on which ocean systems respond to atmospheric changes, this sea-level change may be considered inevitable, and the areas under threat may be quite confidently delimited.

First, there is the probability of a gradual inundation of low-lying lands: deltas, marshes and coastal wetlands, estuaries and reclaimed lands in the coastal zone. In some cases these are among the most densely populated

zones in the world, and their problems may be exacerbated by local land subsidence.

Second, there is the more general problem of storm frequency and storm track changes which may accentuate wave attack on exposed coastal areas. Sea defences built in former times may need considerable strengthening to cope with higher and more frequent storm surges. Greater expanses of warmer water may also extend the ranges of tropical disturbances, posing a threat to areas further polewards of their present influence, while greater latent heat release may also increase the vigour and damage potential of mid-latitude depressions. Even under conditions of a slight sea-level rise, dramatic changes in the statistical recurrence intervals of marine incursions and coastal erosion may occur. Destabilization of dune and coastal barriers, and mobilization of coastal sediments will pose problems for the management of coastal zones.

Third, as sea level rises, coastal groundwater tables will rise, making for drainage difficulties and also increasing the risk of aquifer salinization. Public fear of coastal inundation cannot often be assuaged rationally, and 'hard' engineering schemes are frequently demanded to protect coasts. These will often not be practical outside of heavily urbanized areas. Planned retreat and precautionary planning in relation to infrastructure and settlement will be the only options available in many rural locations.

A final set of impacts relates to transformations of treasured landscapes and wildlife habitats. These are not easily quantifiable or amenable to traditional cost–benefit analysis. Peatlands, for example, can be considered as 'cultural' resources and the few raised bogs remaining intact in Europe are particularly vulnerable to drying out in 'greenhouse' summers. Sand dunes, fens, salt marshes and machair can likewise be considered environments under threat. All these ecosystems have often unique flora and faunal assemblages which society in general is loath to see disappear and which current EU policies are designed to protect.

2. THE NEED FOR CENTRAL POLITICAL INTERVENTION

The atmosphere is the last of the 'free' resources. Throughout history, ownership and utilization rights for natural resources, such as land, water, forests, minerals and so on have gradually become institutionalized and regulated as societies have recognized that freedom of access to 'common' resources leads to over-utilization and ruin. The assimilative capacity of the atmosphere for greenhouse gas emissions appears to have been exceeded, with reductions in anthropogenic emissions of over 60 per cent for carbon dioxide and 15–20 per cent for methane required to stabilize atmospheric concentrations at

present-day levels. This poses global as well as local problems since the consequences of failing to reduce such emissions may ultimately produce warmer climates beyond human experience, and accelerate and accentuate the impacts discussed above.

One appropriate analogy is that of a common area of pasture, open to all the herders of a particular village, where the positive marginal return to each individual of increasing his/her stocking level beyond its carrying capacity is achieved at the negative cost of impairment of the resource for the entire community. It will always be in the individual's and even in the nation state's interest to use the free dispersive capacity of the atmosphere as a sink for waste. It will always be economically easy to justify unilateral increases in greenhouse gas emissions either because an individual's relative contribution is small, a country is developing rapidly to catch up with its competitors, or a 'special case' applies for some reason.

Accordingly, a consensus at a global level can only be achieved by supranational bodies. Climate change is thus no different from other global environmental issues such as acid rain or ozone depletion in requiring international management. In the case of regional economic groupings, such as the European Union, international management is also necessary to standardize emission control costs between Member States in order to ensure the cost burden is equitably distributed. For an emergent problem, such as climate change, where the evidence is as yet uncertain and the natural variability of the climate system is similar to possible anthropogenic changes observed to date, a judgement must also be made on when to take action and over what time scale the burden of inconvenience should be spread. A judgement must also be made on what is technically and economically feasible, that is, a best practicable means/best available technology approach. Such management decisions require organizations with the capability of placing global priorities above national interests. Central political intervention is thus necessary in the climate change problem at a scale above that of national governments. This thinking underlies the formation of the Intergovernmental Panel on Climate Change in 1988 as a joint creation of the World Meteorological Organization and the United Nations Environment Programme.

It is the judgement of the IPCC that the time has come to set limits on emissions of the major greenhouse gases. The emission rduction commitment of the EU under the Kyoto Protocol is 8 per cent on 1990 levels, to be achieved by 2010. A primary focus on carbon dioxide, methane and nitrous oxide is apparent in seeking to achieve this objective. Annual emissions of these three gases constitute the three leading core pressure indicators identified in the EU Pressure Indicators Project. There is scientific consensus on the belief that changes in annual emissions of these three gases will provide the best criteria against which progress in slowing human-induced climate

change in the twenty-first century can be monitored. A fourth greenhouse gas family, chlorofluorocarbons, is now considered less influential as an indicator of global warming, and 'Annual CFC emissions' rank fourth in the core pressure indicators list. This is a reflection of the reductions in emissions already under way as a result of the Montreal Protocol to address the problem of stratospheric ozone depletion.

It is important to note, however, that the UN Framework Convention on Climate Change ultimately seeks to achieve stabilization of greenhouse gas *concentrations*, a much more difficult objective to realize, entailing reductions in greenhouse gas emissions in excess of 50 per cent. It is appropriate that the lead, both for short- and medium-term actions, should be taken by industrialized countries, since the bulk of emissions has emanated from such areas, and their scope for reductions without hardship is greater. Developing countries should also, within the limits of their economic circumstances, take steps to decouple energy growth from economic growth where possible. Only by a dual-track approach can political intervention forge the partnership of all nations that is necessary to provide an effective attack on the problem.

3. ACTION TO SLOW AND STABILIZE GREENHOUSE-GAS-LED CLIMATE CHANGE

There is no prospect at present of shifting the direction or magnitude of natural trends in climate. It is unclear what direction this natural trend is currently taking, either to reinforce or mitigate human forcing of climate change. Equally, because of the long atmospheric lifetime of some greenhouse gas emissions, such as carbon dioxide (100–200 years), a commitment to increasing concentrations presently exists. This means that, even if all anthropogenic emissions had been halted in 1990, about 50 per cent of the increase in atmospheric concentrations due to human activities would still be evident by 2100. These considerations, augmented by political difficulties especially between the developed and developing countries, such as those which have surfaced at recent Conferences of the Parties to the UN Framework Convention on Climate Change, suggest that a 'business-as-usual' scenario must be considered for greenhouse gas emissions for the immediate future at least.

Short-term actions to stabilize emissions should focus first on methane emissions, which have a relatively short lifetime in the atmosphere (11 years). Improvements in methane concentrations would thus be noticeable almost immediately. This explains the strong emphasis given to methane emissions per year as a core pressure indicator. A modest reduction of only 10 per cent in emissions would stabilize methane concentrations and this is readily achievable in the short term. First, action to reduce biomass burning by discouraging deforestation would considerably curtail the 40 million tonnes emitted to the atmosphere from this source each year. It would, in addition, have a beneficial effect in increasing CO_2 removal processes. Second, repair and better ongoing maintenance of natural gas pipelines should be undertaken throughout Europe and in countries such as Russia to eliminate leakages as far as possible. Although considerable improvements appear to have occurred in tackling this problem in recent years, there is still scope for improving the performance of such installations, which may contribute similar amounts of methane as biomass burning on an annual basis. Design standards for new landfill sites should also be introduced as a matter of urgency so as to enable collection or flaring of the gas. This could reduce emissions from this source by up to 90 per cent. Increased recycling would of course further reduce gas production as well as saving on fossil fuel energy expenditure. Finally, new research indicates that methane emissions from rice paddies can be greatly reduced by regulating the irrigation water more carefully. Such low-cost, low-technology solutions should be extensively implemented without delay. Ultimately, reductions in methane emissions could amount to 5 per cent of total greenhouse gas emissions.

Stabilizing carbon dioxide concentrations before the end of the twenty-first century is probably unrealistic, and therefore no stabilization of human-induced climate change can be expected. Only draconian economic measures could achieve carbon dioxide stabilization at today's concentrations and short-term measures to slow the rate of growth are, therefore, all that is practical. Foremost among these must be aggressive energy conservation measures. These should focus on improved insulation, lighting and electrical appliance efficiency standards in housing, industry and commerce. New homes and offices could be at least twice as energy-efficient as at present, while in industry the present-day capability for reducing energy consumption is in the order of 15–40 per cent. Short-term measures should also focus on developing and transferring technology relating to energy-saving devices, and energy-saving power generation technologies, to developing countries. This is particularly true for cooking and heating technologies. Improved private and public transport systems, especially in urban areas, would reduce emissions considerably, as would the immediate incorporation of presently existing vehicle energy efficiency technology. A rapid expansion in renewable energy generation is also possible with present-day technology. The fact that a 40 per cent increase in the energy efficiency of the US economy occurred between 1973 and 1990 confirms that there is scope for development and energy use to be successfully decoupled in the years ahead.

Looking further ahead, continued improvements in energy efficiency must be sought. Structural changes in settlement patterns will be required to lessen

the requirement for mobility based on the private car. Compact cities, workplaces accessible by public transport, walking or cycling, and energy technologies based on hydrogen or safe nuclear fusion hold the best prospect for success. These will all, however, entail major changes in infrastructure and lifestyle, and will need implementation on time scales which may exceed the public's patience.

4. COMMUNICATING THE PROBLEM TO THE GENERAL PUBLIC

Global warming is now perceived by the general public as an important issue facing society. This sensitization has occurred on the back of the ozone depletion problem, which stirred the public consciousness on a global environmental problem for the first time. Indeed, blurring of the two problems has become so entrenched that it is difficult to envisage climate change ever being seen by the general public for the separate and more intractable problem that it is. The fact that the seven warmest years in the global instrumental temperature record occurred in the 1990s assisted with this process of sensitization. However, society's collective memory is short and the 'post-Pinatubo' years have seen climate change slip down the political agenda. Galvanizing events, such as the spectacular satellite imagery of ozone depletion, are required to mobilize public sentiment and by its nature climate change cannot provide the catalytic instances when definite links are apparent between climatic aberrations and greenhouse-led climate change.

One way of addressing the communication difficulty is by modelling the environmental problem concerned using indices which simplify the complexity of the interacting processes. Such a procedure provides the general public, and policy-makers, with a tool whereby 'what if' questions may be answered at a rudimentary level. This is particularly important for providing initial information on the relative merits of alternative mitigation strategies. For example, the relative impact of reforestation versus energy savings from insulation might be compared, or the impact of fuel switching from coal to natural gas. Such an approach may also be integrated with other index systems currently becoming established, for example indices relating to sustainable development as part of general health indicators for the global environment.

Communicating with the public via indices is already commonplace in financial and economic matters. Such indices are in some cases the results of a complex calculation, but convey an impressionistic message which can be easily grasped. This is a desirable objective in communicating the interrelated issues of climate change to the public and to decision-makers. However, caution is required when simultaneously employing several indices. The public may get confused when an action causing a positive response in one environmental index causes a negative response in a seemingly related one. For example, a reduction in stratospheric ozone in polar regions may slow global warming. A reduction in an air pollution/acidification index may result in an opposite movement in a global warming index. Such divergences are difficult for the public to rationalize at first and it may be necessary, in the methodology of preparing an index system, to give greater consideration to presentation. Indices are essentially a new approach to bridging the gap between complex scientific interactions and complex socio-political interactions. If consistent, they are transferable between nations and perhaps ultimately between the developed and developing world. They may thus ultimately provide a 'single currency' for negotiating an accommodation between nations to limit human impact on the functioning of the atmosphere and thus assist human transition on to the path to a sustainable world.

5. CONCLUSION

Europeans have historically been both winners and losers as climate has fluctuated in past times. In the coming decades, the direction of climate will be shaped both by natural and, increasingly, by human influences, posing new threats and opportunities for inhabitants of the continent. Indeed, it is probable that, by the end of the twenty-first century, much of Europe will be warmer than at any time during the Quaternary Period. Responding to the challenges posed by this scenario of climate change will require new skills and novel management techniques; indeed, it presently necessitates an urgent marriage of scientific and political approaches. The Pressure Indicators Project represents such an innovation, a first step to ensuring that the adverse consequences do not render Europe, and indeed the world, once more a prisoner of the climate system.

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