

Understanding and managing climate change: the UK experience

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Climate change has emerged over the last 25 years not just as a physical reality, affecting global and regional climates, but also as a socio-cultural phenomenon – an icon of a globalizing world which is increasingly altering the physical fabric of our planet and at the same time demanding new forms of global governance. The UK, both through its scientific research activity and through its development of climate change policy initiatives, has been at the forefront of this emergence. This review traces some of this history from a UK perspective, with an emphasis on the last 10 years. The relationship between climate change science and policy has become increasingly reflexive, leading to new forms of research and institutional structures. The academic discipline of geography has been rather marginalized from this process.

KEY WORDS: the UK, climate change, global warming, research, policy, institutions, academic geography, post-normal science

Introduction

A 2001 UK survey of the public found climate change came eighth out of a list of 20 current local, regional and global environmental concerns (National Survey of Public Attitudes to Quality of Life; DEFRA 2002). When asked what environmental concern will be most worrying in 20 years' time, however, climate change came second only to traffic (congestion, fumes and noise). There are two interesting dimensions to this finding. First, climate change is the 'global' issue by far of most concern to the UK public and, second, people claim they are not yet fully convinced by the immediacy of this worry, preferring to project their anxiety 20 years into the future. Nevertheless, as this review article will show, climate change is now one of the major determinants of national, regional and, often, local environmental policy in the UK.

Climate change has acquired this status over a period of about 16 years, since it first emerged in the UK during the summer of 1988 from the confines of scientific research into the realms of public media commentary and political speechmaking. This

emergence is epitomized by the front page headline in *The Guardian* newspaper on 25 June 1988 (see Figure 1) and by the speech made by the then Prime Minister, Margaret Thatcher, to the Royal Society in September 1988. The strong performance of the UK Green Party in the 1989 European elections was at least partly due to this prominence. Worldwide, this 16-year period has witnessed major advances in our understanding of the planetary climate system and of our ability to perturb it substantially, and maybe irrevocably. It has also seen the emergence of new intergovernmental processes for assessing the state of climate change science and for creating global climate policy regimes. These global developments are well illustrated by the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, by the signing of the UN Framework Convention on Climate Change (UNFCCC) in June 1992, and by the creation of the Kyoto Protocol in December 1997.

Within the context of these international developments, concern in the UK about climate change has elevated it to being a major driver of public environmental policy. For example, the experience of widespread flooding in autumn 2000, boldly



Figure 1 Front page headline from *The Guardian* newspaper, 25 June 1988

Source: *The Guardian*

interpreted by the narrative of human-induced climate change, has led to a full-scale review of the way coastal and inland flooding is managed in the country. At the same time, in November 2000 the government published the first comprehensive Climate Change Programme for the UK (DETR 2000), identifying both the risks associated with climate change, and also a range of policy measures and initiatives which would contribute to its management. More recently, climate change played a major role in shaping the 2003 Energy White Paper (DTI 2003) and Aviation White Paper.

Scientific research into climate change in the UK has evolved in parallel with these developments in the policy arena, at times influencing the policy process and at other times responding to them. New research institutions have been created, science policy itself has had to adjust, and new forms of knowledge, created through interactive science-stakeholder dialogues, have emerged. In this sense, climate change is archetypical of a research paradigm where the boundaries between knowledge producers and knowledge consumers are increasingly blurred (Nowotny *et al.* 2001).

This paper reviews some of these developments in the UK, with an emphasis on the last few years. Despite the traditional home for climatology within

the academic discipline of geography, it is suggested that *geography* – as opposed sometimes to *geographers* – has played a relatively minor role in such developments. Some reasons for this are considered. What emerges from this review is not only that the relationship between climate and society is now fully reflexive, but that climate change research is in an increasingly reflexive relationship with climate policy. In this sense, at least, climate change may be seen as a fully fledged post-normal science problem (Funtowicz and Ravetz 1993).

UK climate change research: a brief institutional history

One way to reflect on the emergence of climate change research in the UK is by tracing the historical development of the institutional arrangements that have sponsored and facilitated this research, and how this research in turn has influenced the policy process. Whilst this approach may not allow a detailed analysis of the research outcomes, it allows a broader and perhaps more understandable picture to be painted of how climate change research in the UK now relates to the society that sponsors it. In the process of painting this picture, we will also see how research and policy have become increasingly

entwined, to the extent that distinctions between these two realms of activity in relation to climate change are often difficult to draw.

An emerging scientific issue: pre-1990

A notable starting point for such a history in the UK is the creation in 1971 of the Climatic Research Unit (CRU) in the School of Environmental Sciences at the University of East Anglia. Although by no means an 'institution' when created, CRU now claims the record of the longest continuous research group in Europe, and maybe the world, focused on understanding climate variability and change and its relationship with society. Founded by the late Hubert Lamb, a trained meteorologist with a historical bent, CRU began to make its mark on climate research during the 1970s and early 1980s, well before the idea of human-induced global climate change (henceforth short-handed as 'global warming') was embedded in the public mind. This was, at least initially, in opposition to the prevailing orthodoxy of the time (and espoused by the UK Met Office which Lamb had left in disillusionment) that climate change on the timescale of human lifetimes was too trivial to be of much significance for decision-making.

But under the leadership of Lamb and, after 1978, Tom Wigley, CRU made a number of seminal contributions to the worldwide understanding of the reality and processes of climate change which have established it today as a research 'institution' of world class status. Three of these contributions were the development of one of the earliest methods for the construction of climate change scenarios (Wigley *et al.* 1980), the publication of the first truly global reconstruction of surface air temperature during the instrumental period (Jones *et al.* 1986), and the creation of a simple and versatile global climate model which allowed numerous simulations of the planetary climate system to be performed, exploring its sensitivity to a range of different forcing factors (Wigley and Raper 1987).

Although hosted in a department of environmental science, CRU was nurtured during its early years by a geographer dean – Keith Clayton – and the Unit's staff has always included at least a small number of researchers trained as geographers. Nevertheless, CRU has never really been part of the mainstream academic geography establishment in the UK and the discipline has been the weaker for it. Conversely, the establishment in 1990 of the Environmental Change Unit (ECU) at the University of Oxford owed rather more to geography. Its founding Director, Martin Parry, was a geographer from the University of Birmingham who had developed a research career in the area of climate change

impacts. A corollary of the work of Lamb and CRU was that climate change *did* matter for human societies and for strategic planning, and one of the main thrusts of the ECU in the early-mid 1990s was on modelling and assessing what these future impacts might be (e.g. Carter *et al.* 1991). Strategies for adapting to climate change were also considered at that time, but in a rather mechanistic way without much consideration of the dynamics of social development and human behaviour.

The establishment of the Centre for Social and Economic Research on the Global Environment (CSERGE) in 1990, however, did create a focus for UK research on the economics of, among other things, climate change. Funded by the ESRC and housed jointly at the University of East Anglia and UCL, CSERGE began to apply formal economic analyses both to the impacts of climate change and also to the effectiveness of climate policy. Its links with established academic geography were relatively weak.

The Hadley Centre for Climate Prediction and Research was another research institution which came into existence in 1990. Housed within the UK Met Office, the Hadley Centre was very much a creation of Prime Minister Thatcher and her latter-day appreciation of the realities of global warming. A large proportion of the Hadley Centre's budget came direct from government via the then Department of Environment, as it still does today, and the Centre's mandate was to develop the UK's climate modelling and prediction capability. Over its 14-year history, this has been achieved with spectacular success and the Hadley Centre is currently regarded by many climate scientists as the leading climate modelling centre in the world. Academic geography, however, has again played a minimal role in this development – the successive cohorts of Hadley researchers having been recruited largely from the mathematical and physical sciences.

1990 also saw the first assessment report published by the IPCC, a panoramic survey by the world's leading climate scientists, steered by representatives of the world's governments, of the state of knowledge of climate change (Working Group 1), climate change impacts (Working Group 2) and climate change responses (Working Group 3). This landmark publication clearly established climate change both as an environmental reality and as an international policy issue, and it led within two years to the signing of the UNFCCC, at the Earth Summit in Rio, in June 1992.

The emergence of UK climate change policy: the 1990s

Following the IPCC's first assessment report in 1990, the UK Government, through its Department of the

Environment, published its first national assessment of the possible impacts of climate change for the UK – the so-called Climate Change Impacts Review Group (CCIRG 1991) report. Three of the 14 expert authors were working in geography departments, a recognition that a consideration of climate impacts required at least some geographical knowledge. The review considered the emerging research needs for adequately understanding and addressing climate change, but also identified issues of policy that should be addressed by government departments. A number of specific policy recommendations were made, the first steps towards a coherent government climate change policy programme that had emerged by the end of the decade.

The second CCIRG report was published in 1996 (CCIRG 1996), timed to coincide closely with the release of the second assessment report of the IPCC. This IPCC report had indicated that the 'balance of evidence' suggested a discernible human influence on global climate, a view reflected in the CCIRG. Of the 18 expert authors of the second CCIRG report, only two were working in geography departments, although a further four were academics with career origins in mainstream geography. Climate change was appropriating geography and geographers for its agenda rather than the other way round. CCIRG again made policy recommendations for government, this time with an explicit treatment of options and actions that would enhance the UK's ability to adapt to climate change. It was not the role of the CCIRG to assess or comment on the challenges of climate change mitigation.

The mid-1990s also saw NERC coordinate the largest UK scientific programme researching the natural science elements of global environmental change – the Terrestrial Initiative into Global Environmental Change (TIGER) – of which climate change was probably the single most significant component. A series of thematic sub-programmes provided funding for many UK environmental scientists, including numerous physical geographers. The programme, however, had relatively weak links to policy and the outcome of the programme as a whole made an impact that was less than the sum of its parts.

The period from the late 1980s through to the mid-1990s witnessed a series of major climatic anomalies in the UK, each of which stimulated specific research agendas and policy initiatives related to climate change. The very mild winters of 1988/89 and 1989/90, the prolonged hydrological drought of 1988–92, and the hot, dry summers of 1990 and 1995 were three of the more notable ones. Studies were compiled of the impacts of each of these anomalies in the UK (respectively, Cannell and Pitcairn 1993; Marsh *et al.* 1994; Palutikof *et al.* 1997).

Growing confidence that international scientists had detected human influence on the global climate system provided the necessary conditions for many to claim that, within the limited territory of the UK, we were also witnessing signs of human influence. The 1995 drought in particular had an important outcome for policy, water companies henceforth being statutorily required to consider climate change projections in any long-term strategic planning and investment.

Two new initiatives from the Department of the Environment followed in 1996 and 1997: the establishment of the UK Climate Impacts Programme (UKCIP) and the commissioning of a report on climate indicators in the UK. Between them, these have contributed greatly in the UK to overturning the aforementioned orthodoxy of the 1970s to a new orthodoxy for the new millennium: not only is human-induced global climate change now manifest in our national climate and environment, but the prospect of continuing, if not accelerating, climate change requires all sectors of society and the economy to adjust their environmental and business strategies to accommodate it.

UKCIP was based in the Environmental Change Institute (previously Unit) at the University of Oxford and was established in the summer of 1997. UKCIP took a different approach to assessing climate change impacts and adaptation options. Rather than creating a formal science-driven research agenda, the Programme was established to entrain organizations across society – so-called stakeholders – in jointly defining and part-sponsoring regional or sectoral studies of climate impacts (McKenzie-Hedger *et al.* 2000). UKCIP has been enormously influential in the UK in raising awareness of climate change in sections and sectors of society which would not normally be reached by conventional scientific research programmes (Figure 2). The intellectual shaping of UKCIP, however, owes more to the ideas of participatory integrated assessment (e.g. Rotmans and Dowlatabadi 1998) and the campaigning vigour of environmental organizations than it does to academic geography.

One of the first products from UKCIP was a new, comprehensive set of climate change scenarios for the UK, the so-called UKCIP98 scenarios (Hulme and Jenkins 1998; and subsequently the UKCIP02 scenarios, Hulme *et al.* 2002). Derived from climate modelling work at the Hadley Centre, these four descriptions of alternative future UK climates over the twenty-first century were widely promoted by UKCIP for use in impacts research and in adaptation planning by a large number of stakeholder organizations, ranging from water companies to nature conservation bodies and tourism agencies. As a report commissioned by government, these scenarios for the 2020s, 2050s and 2080s were scrutinized for

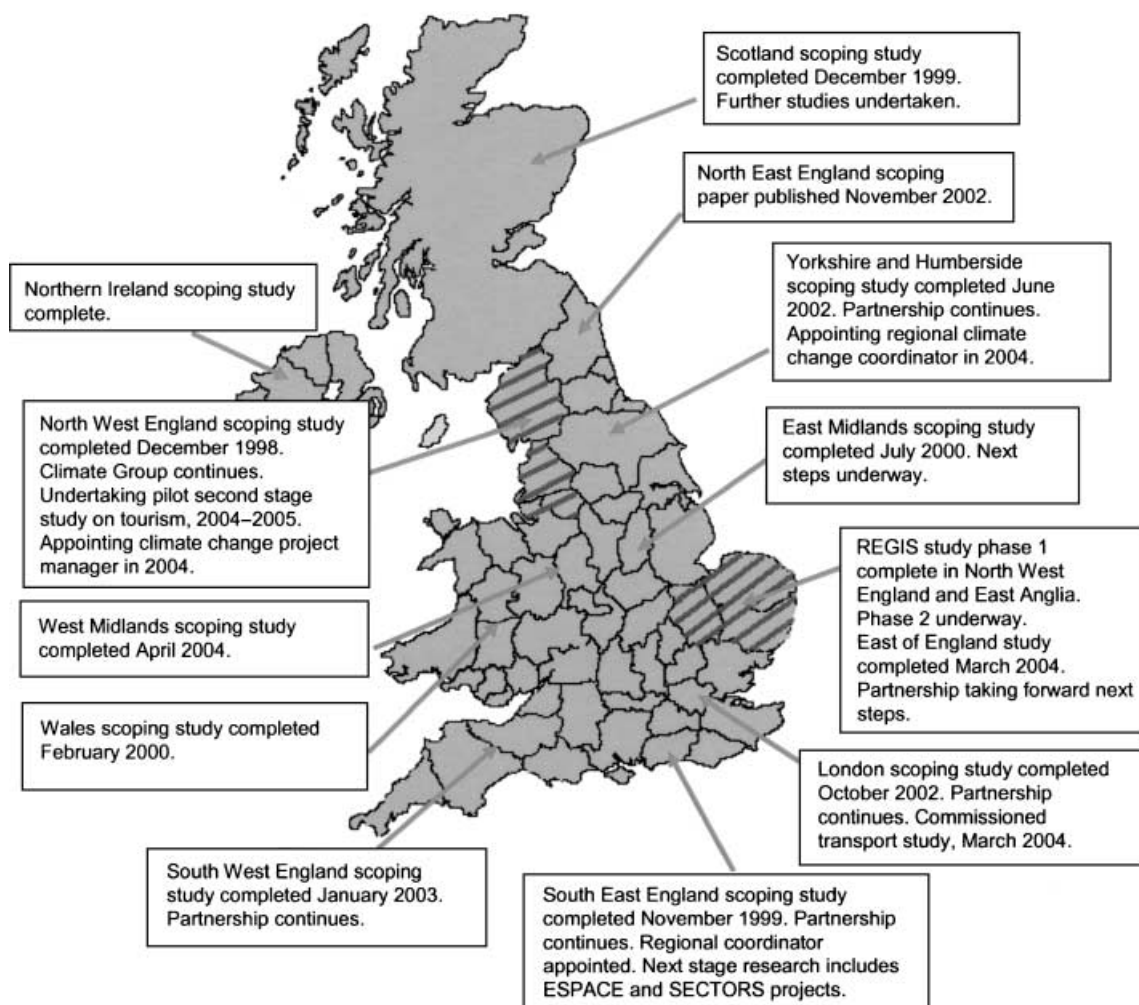


Figure 2 Sub-UK studies and partnerships developed under the umbrella of the UK Climate Impacts Programme.

Status: December 2003

Source: UKCIP

information that might inform the regulatory processes in the UK. Among others, the Environment Agency, the Building Regulations Advisory Committee and the Flood and Coastal Management Division of the Department of the Environment all began to use the scenarios in their re-evaluation of statutory regulation. For example, a sea-level rise allowance of between 4 and 6 mm/year was recommended by the Department for Environment, Transport and the Regions to be applied to any coastal management scheme in the UK (DETR 2000). Formal, regulated adaptation to prospective climate change was now becoming a conventional part of the UK policy landscape.

Following the success of the climate change scenarios, UKCIP produced further scenario tools to complement these, including a set of socio-economic scenarios (UKCIP 2001). The aim of these latter scenarios was to integrate socio-economic change with climate change in the assessment of future adaptation options.

The first report on national environmental indicators of climate change, commissioned and published by the DETR, followed shortly after (Cannell *et al.* 1999; now updated to 2003 at <http://www.nbu.ac.uk/iccuk/>) and gave further impetus to the development of climate policy. This report contained 34 quantified indicators of climate change in the UK, ranging

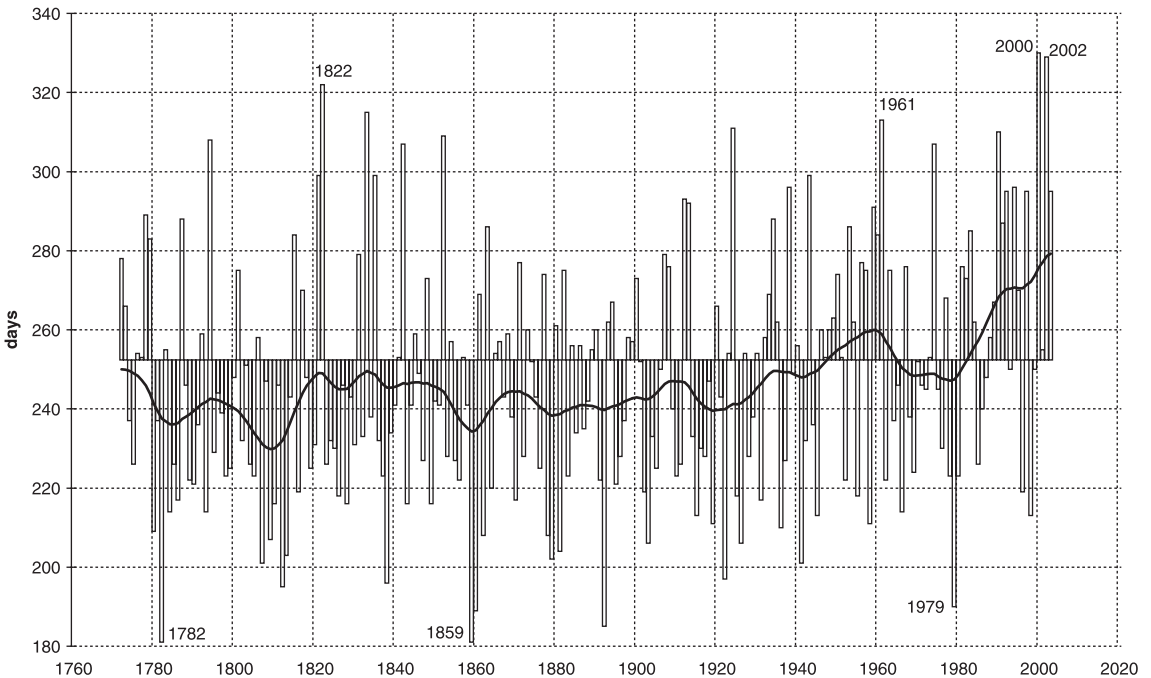


Figure 3 Thermal growing season length in the UK (1772–2003), derived from the daily Central England Temperature record
Source: Tim Mitchell, Tyndall Centre

from climatic indicators such as air temperature to ecological and economic indicators such as leaf emergence dates and property insurance claims. As the ministerial foreword stated, the report ‘... will alert us to the impact of climate change... and instill a sense of urgency in responding to it’.

By now, the late 1990s, the UNFCCC had spawned the first formal protocol for limiting emissions of greenhouse gases, at least amongst developed nations (the Kyoto Protocol signed in December 1997), and by the start of the new millennium in 2000 scientists were able to announce that, globally, the year 1998 and the decade of the 1990s had ‘probably’ been the warmest of the last thousand years (Mann *et al.* 1999). The IPCC was shortly to release its third assessment report in which it was to claim that ‘... most of the warming over the last 50 years is likely to have been due to human activities...’ (IPCC 2001, 158). In the UK there was a wealth of evidence to suggest that the parallel warming of UK climate (Figure 3) was leaving its mark on the natural world. Birds, butterflies, trees, fish and pathogens were all displaying behaviour and trends suggestive of a climatic fingerprint (e.g. Thomas *et al.* 2001; Sparks and Menzel 2002) and the autumn of 2000 was the wettest on record in the UK. The associated widespread and persistent flooding across

the country prompted a receptive political and media audience to announce the ‘wake-up call’ that global warming was happening here and now, not there and then.

The increasing confidence through the 1990s in the science of climate change detection and prediction, the experience of climate change in the UK over the previous 10 years, and its quantifiable impact on ecological and economic indicators, together with a set of national climate change scenarios laying out the prospects for the coming century, had led to the point where formal government action to try and limit climate change was acceptable, if not inevitable. The UK signed the Kyoto Protocol in the spring of 1998 (its formal ratification by the UK was to follow in 2002) and later that year the EU agreed a distribution of emissions reductions between the 15 member nations. The UK’s share was a 12.5% reduction in 1990 greenhouse gas emissions by the period 2008–12. This commitment was therefore the final piece of the jigsaw that led to the development of the UK’s first national Climate Change (policy) Programme, published in November 2000 (DETR 2000). The Climate Change Programme was predominantly setting out a range of possible and actual measures and initiatives by which the UK

Government proposed to meet its Kyoto obligations (in fact, the Programme also made play of the voluntary domestic target of a 20% reduction in carbon dioxide emissions by 2010). These included two new policy measures – a Climate Change Levy (in effect, an energy tax on business users) and a UK emissions trading scheme (Wordsworth and Grubb 2001).

The 2000 Climate Change Programme is very important for understanding subsequent developments in the UK, both new investments in scientific research and development and new policy initiatives. It provided a comprehensive statement about the UK's position on the science of climate change, the risks posed and the policy responses which would be necessary. As the previous material has shown, the government was only able to reach this position by drawing upon a considerable history of both fundamental and policy-relevant research, much of it international of course, but much of it originating within the UK itself. It was also in a position to do so given the public mood in the country at large that climate change was indeed an environmental challenge which national government, among other organizations, was expected to tackle (Lorenzoni *et al.* 2000). Research had led to policy. Could policy now lead to action?

From research and policy to action: post-1990s

From the story of research through the 1990s, it is evident that the nature of research on climate change had altered. From focusing primarily on climate change detection and attribution, the thrust had shifted towards research on what to do about a largely accepted problem. The year 2000/01 saw

the establishment of two new research institutions in the UK dealing with climate change, but both capturing the now prevailing spirit of action or solutions-oriented research – the Tyndall Centre for Climate Change Research and the Carbon Trust.

The Tyndall Centre for Climate Change Research was established in autumn 2000, the first large-scale multi-disciplinary research centre invested in by three of the UK research councils – NERC, EPSRC and ESRC. With its headquarters at the University of East Anglia, and involving a consortium of nine academic research groups across the country, its remit was to undertake integrated research to identify and evaluate sustainable responses to climate change. A number of geography departments or geographers were entrained in the developing research agenda of the Tyndall Centre. Whilst its focus was primarily the UK, the reach of its research, as the nature of the problem demanded, was global. The intellectual starting point for its research agenda was that established earlier by the IPCC and UKCIP, namely, global warming was real and accelerating and that organizations at all scales across society needed to react to the challenges of climate change mitigation and adaptation. This was a long way from the prevailing orthodoxy of the 1970s. Furthermore, its research should be shaped both by academic creativity and by the needs of those outside academia, in a creative tension between a purely science-driven agenda and a purely policy-driven agenda (Tyndall Centre 2001).

The formation of the Carbon Trust was driven by a different action-oriented objective and was a direct response to the UK Government's commitment to the Kyoto Protocol and its additional ambitious and voluntary domestic target (Figure 4).

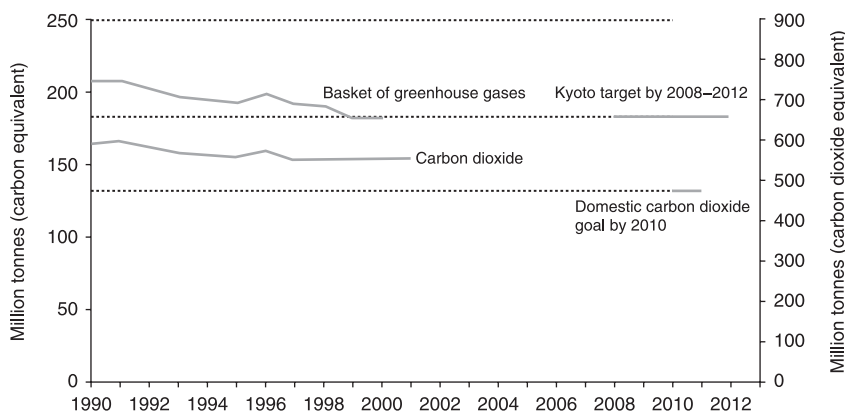


Figure 4 UK emissions of carbon dioxide and greenhouse gases, historically from 1990, and the Kyoto and domestic targets for 2010

Source: DETR (2000)

The Trust was established in spring 2001 as a joint venture between the Departments of Environment and Trade and Industry. The Trust operates as an independent not-for-profit company outside direct government control. Funded largely by the proceeds of the newly introduced Climate Change Levy, the Trust's mandate is to invest strategically in new and low carbon technologies, across the full research-to-commercialization chain. The Trust enters into funding partnerships with businesses and conventional funding bodies like the research councils, as well as investing in a variety of capacity-building and information-brokering services, all oriented towards the delivery of the low carbon economy. The publication of the Energy White Paper (DTI 2003), and its proposed aspiration for a 60% emissions reduction by 2050, provided impetus for the establishment of a further energy research related initiative, the UK's first ever national energy research centre. Funded by the same three research councils that fund the Tyndall Centre, the energy research centre will also be based within an existing university, or a consortium of universities, when it becomes operational later in 2004. The centre will have a coordinating role to make better sense of the UK's energy related research activities, but will also undertake a research programme on a range of sustainable energy issues related to the twin needs of climate change management and the security of supply.

But many new initiatives relating to the climate mitigation challenge are also emerging at regional and local scales. For example, a number of local authorities in the UK formed a new umbrella organization in the late 1990s, the Councils for Climate Protection, which in turn built on a global initiative 'Cities for Climate Protection' launched by ICLEI in 1993 (Bulkeley and Betsill 2003). The purpose was to encourage local government to work together in partnership with other organizations to reduce their greenhouse gas emissions. A different type of initiative is being pioneered by the University of East Anglia in the eastern region. CRed – the community carbon reduction initiative – is an effort to translate research and policy into action to deliver a 60% emissions reduction amongst its members by 2025, twice as rapidly as the government's aspirational target (CRed 2003). CRed is a partnership encompassing academic research, local authorities, businesses operating in the region, community groups, schools and individual citizens.

At the same time, new initiatives which aim to translate research into policy and action are emerging related to climate change adaptation. The UK Climate Impacts Programme continues its work as a stakeholder-led coordination programme to jointly

define and execute studies that benefit directly the sponsoring organizations. For example, the Greater London Authority and the London Climate Change Partnership have published a study of impacts of climate change on London and an associated portfolio of adaptation measures that could ameliorate the risks and exploit the opportunities (LCCP 2002). Similarly, a group of conservation organizations led by English Nature are supporting a study into the impacts of climate change on biodiversity in the UK and the range of management options available to these organizations to adjust conservation practise to accommodate climate change (Harrison *et al.* 2001). A third example, led this time by the Office of Science and Technology, is the OST Foresight flood and coastal defence project. Given the realities of climate change, the aim of this project, which ran from 2002 to 2004, was to produce a challenging and long-term vision for the future of flood and coastal defence that takes account of the many uncertainties, is robust, and can be used as a basis to inform policy and its delivery (OST forthcoming). These are all examples of interactive research where the agenda and questions being investigated are defined through an iterative process between stakeholders and researchers (Turnpenny *et al.* forthcoming).

Meanwhile, even within the more conventional and fundamentally oriented realms of research funding, the institutionalization of climate change research in the UK has also taken a further step forward. The new mission of the NERC, the UK's premier source of research funding for environmental science, as outlined in its five-year strategy for 2002–7, is to understand the functioning of the Earth System (NERC 2002). Within this mission, climate change – predicting and mitigating the impacts – is one of the three priority areas that will see increased support and funding. One example of NERC's commitment to this area of research is a seven-year thematic programme called RAPID, understanding better the mechanisms and time-scales over which rapid or abrupt climate change may occur in the future.

The future: climate change and post-normal science

So where does climate change research in the UK now stand and how might future research look? Is the current orthodoxy valid for a few decades or only a few years? How is the reflexivity between climate change research and climate change policy going to be manifest in the years ahead? And what is the role of academic research, whether conducted within the geographical disciplines or not?

Understanding and responding to climate change covers issues of great complexity, involving many

different organizations, many different spatial and time scales, and many different academic disciplines. It cannot be addressed by any one discipline, and certainly not by geography alone. Above all, it requires an understanding and an involvement of citizens: their motives, their behaviour and their values. In traditional Western methods of research, understanding of the world has been achieved by division into separate academic disciplines and treating each with a 'silver bullet' peopled by specialists in that narrow field. Science has been seen as largely separate from values and cultural context. When the world faces such overarching complex issues as climate change, however, it has been argued that a new sort of science is needed. So-called 'Post-Normal Science' (Funtowicz and Ravetz 1993; Ravetz 1999) is a label for the conduct of research when facts are uncertain, where values are in dispute and when the stakes are high. The concept has been applied to different fields such as ecological economics, food safety, medicine, as well as climate science (Bray and von Storch 1999; Saloranta 2001).

In all these fields, action on public policy issues depends on many value-driven decisions made in the face of uncertainty. Post-normal science moves beyond traditional research, where 'truthful output' is everything, to a method where the quality of the process of research is paramount. Complex environmental problems such as climate change will never be fully understood before action is needed to address them; a 'post-normal process' includes the enabling of these actions through joint learning and research with those who will carry out the actions, through participation in research by stakeholders as well as specialists. This ensures a 'grounding' or contextualization of research within the practical world in which the knowledge generated is applied. This review has shown that, in the UK, research on climate change has moved increasingly in this direction.

Hunt and Shackley (1999) draw a distinction between three main types of knowledge. Traditional 'academic' research is rigorous, deep and thoroughly rooted in past research, based on peer review. It is also, mostly, independent, designed and carried out by specialists and it is free to reach whatever conclusions it will. Two quite different types of research, increasingly a major part of the climate change policy process in the UK as shown by this review, are 'fiducial' and 'bureaucratic' knowledge. Fiducial knowledge is produced as a service to users, and although frequently the basis for policymaking, it is often not peer-reviewed – the status of the authors is the most important validation. The reports of the CCIRG during the 1990s might perhaps fall into this category.

Bureaucratic knowledge actually involves the user in constructing the knowledge, which is generally a synthesis for a specific group and a specific context. This synthesis or assessment is filtered – taken from approved sources, judged by 'what works' for particular political situations. Fiducial and bureaucratic knowledge are often carried out by consultancies paid by those whose policies will be affected by it; as such, the work is driven by the funder with little opportunity for researcher autonomy. Many, although not all, of the climate change studies falling under the UK Climate Impacts Programme would fall into this category. Both fiducial and bureaucratic studies are often seen (especially by academics) as 'inferior' to academic research. However, it is often these types of research which have most influence in the policy process. This tension between 'academic rigour' and 'policy relevance' is only beginning to be resolved.

Our contention is that climate change research in the UK will increasingly be governed by the requirements of post-normal science. New research institutions concerned with climate change are, implicitly or explicitly, adopting aspects of this type of scientific enterprise. As the experience and perception of climate change continues to penetrate into society in the years ahead, the increasing politicization and culturalization of climate change will require two things of the research process.

First, knowledge will need to be integrated from a very wide range of sources, both academic and lay. The values inherent in the decision-making process must be emphasized in integrated assessment research. This is well illustrated by the ongoing debate in government about the social cost of carbon (Pearce 2003). There is a need to build from traditional science and modelling, but to allow research to embrace the dimensions of context, psychology, emotion and morality that lie behind decisions.

Second, the tensions outlined above will need to be resolved. New research institutions in the UK are being created to enhance society's capacity to deal with climate change, not just to do curiosity-driven research. Such institutions must be academically rigorous and policy useful. It is not always easy to meet both requirements simultaneously, as evidenced by the criticism of the Hadley Centre made by the House of Commons Select Committee on Science and Technology report on how the UK Government receives its advice on climate change policy (House of Commons 2001). This raises significant time and resource issues, as the effort involved in continually balancing independence of research with frequent communication with outside organizations, including government, is large. There are also questions raised about the practicality of such institutions communicating effectively with the

many different audiences: government, the public, business, NGOs, children.

In the longer term, how far are researchers willing to go to change how research is done? How might these changes come about, and how long will it take? More fundamentally, is academic research and all it represents losing influence in the policy process? What counts as 'science', and what 'speculation' or 'advocacy'? Climate change researchers in the UK will have to face these and many other questions in the years ahead to continue the ground-breaking research and paths of discovery which are already an established part of the UK's approach to climate change.

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