CRISP CONSULTANCY COMMISSION 01/04 - FINAL REPORT

A REVIEW OF RECENT AND CURRENT INITIATIVES ON CLIMATE CHANGE AND ITS IMPACT ON THE BUILT ENVIRONMENT: IMPACT, EFFECTIVENESS AND RECOMMENDATIONS

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A Review of Recent and Current Initiatives on Climate Change and its Impact on the Built Environment: Impact, Effectiveness and Recommendations.

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Executive Summary

This report was commissioned by the CRISP Climate Change Task Group. The objective of the report was to:

> …identify and collate recent work on climate change and its impact on the built environment, form a view on its effectiveness and impact (or lack of impact), and the underlying reasons.

The primary focus of the work was programmes relating to the UK construction industry, but it has been necessary to consider developments in the EU. A brief review of the situation in Holland has also been undertaken. The report is based on a literature search, on-line searches and interviews carried out in July and August 2001. Due to the volume of activity in the area, the rapid rate of development and the short time available for the work, this report is indicative, rather than exhaustive.

The key findings of this report are summarised below.

Adaptation in context

One of the most important findings of this study is on the importance of ensuring that climate change adaptation strategies are developed with due consideration for other agendas for change within the construction industry and the built environment. These other agendas include:

- The general movement towards industrialisation, prefabrication and off-site construction encapsulated by Rethinking Construction (Construction Task Force 1998).
- Concern for the Health and Safety of employees in the construction industry.
- Changes in the structure of the industry through the processes of amalgamation and take-over, and in the nature of training for those working within the industry.
- The Europeanisation of the construction industry, both as a result of restructuring and as a result of the introduction of the single European Market.
- The process of economic growth which, if it continues even at 1% per annum, will lead to more than a 60% increase in economic activity by 2050 and to more than a two-fold increase by 2080 compared with the present.
- The impact of the far-reaching measures that are likely to be needed to control the emission of carbon dioxide and to control other environmental impacts from the built environment over the next 20-50 years - climate change mitigation.

While there are powerful potential synergies, for example between adaptation and the goal of mitigating climate change, such synergies are not inevitable. Lack of clear long term climate change mitigation goals or strategies - covering two to three decades beyond the 2010 Kyoto target date - and the absence of an equivalent of UKCIP charged with developing such goals and strategies, are limiting factors in this area.

Climate predictions and uncertainty
Predictions of the changes that are likely to take place in the climate in the UK over the next century are uncertain. Much of this uncertainty derives from uncertainties in the underlying climate science, but a significant proportion derives from uncertainties regarding future emissions of greenhouse gases and other human impacts on the environment. Uncertainty in climate predictions will therefore decline slowly over the coming decades.

The implication of this is that strategy will need to be based on an acceptance of the precautionary principle, on the maximisation of future flexibility, and on the expectation that perceptions of risk may change repeatedly over the next 50 years. This in turn suggests that the process of establishing and maintaining consensus for action will need to be a continuous one.

Research capacity and structures
There has been rapid change and development in the capacity for research in the area of climate change over the last three years, in particular with the development of UKCIP, the Tyndall Centre and Consortium and the Loss Prevention Council's Centre for Risk Sciences. Much of this development represents a refocusing of existing capacity, which is also taking place more widely in universities, within BRE and in industry. It is, in most cases, too early to form judgements on the likely effectiveness of these developments. What is clear is that the tasks of identifying climate impacts and researching, developing, implementing and evaluating responses demands a high level of multi- and inter-disciplinarity. It is likely that much of the expertise needed to carry out this work resides outside the centres that have been established over the last three years, a fact that places a premium on networking and openness within the whole of the research community.

There is a widespread but not unanimous view that existing funding structures are sufficiently flexible for the task ahead. It is however possible that the relatively short term goals of programmes operated by the DTI (previously DETR) Construction Directorate and the insistence upon industrial co-funding, will not be appropriate to all aspects of the work that will need to be supported in order to develop robust and integrated responses to climate change.

Priorities for action
Specific actions to develop and implement adaptations have been prioritised as follows:

low	not sufficiently large or urgent to be worth allocating significant public funding; organisations and companies that are directly affected likely to be able to establish and implement viable response strategies from internal resources; "do nothing" may be a viable response
moderate	sufficiently large or urgent to warrant explicit funding of individual research and development projects by public and private sector, incorporation of technical changes within normal product development cycles in response to emerging understanding of impact, implementation

	of sectoral responses such as voluntary codes or practice, amendments to existing regulation
high	sufficiently large or urgent to warrant funding of research and development programmes, development and implementation of new regulation and mandatory codes of practice, development and implementation of technical and other measures with potentially significant economic cost, on the precautionary principle
very high	sufficiently large or urgent to warrant the establishment of research centres to manage, coordinate and undertake R&D activities, the funding of significant demonstration programmes, coordination of training and education activities within industry and education.

Action related to particular risks have been prioritised as follows:

coastal and riverine flooding	very high
subsidence and wind and storm damage	high
warmer summers	moderate to high
UV degradation of materials	low to moderate

A significant research effort is under weigh in the areas of coastal and riverine flooding and to a lesser extent subsidence and wind and storm damage. The development of PPG 25 has begun to impact directly on the planning of settlements to minimise flood risk. The success of PPG 25 will need to be evaluated. More work is needed to develop tools to predict the interactions between development and riverine flooding. A significant proportion of inland flooding is not directly associated with rivers. Work is needed to develop and implement approaches to control run-off from large impermeable areas such as car parks. Flooding and inundation impact strongly on the economic, social and political domains. Multi- and inter-disciplinary work is needed to understand the different interests involved and to develop appropriate responses in these domains.

Significant gaps in research appear to exist in particular with respect to the impacts of warmer summers on thermal comfort in buildings. Work is needed to:

- identity the theoretical and empirical climatic limits to different passive and semi-passive approaches.
- identify those regions of the country in which each of the approaches is likely to be viable, under the range of UKCIP scenarios, to 2050 and 2080.
- identify, develop and demonstrate strategies for extending the range of viability of the most promising passive and semi-passive approaches.
- identify, develop and demonstrate retrofit strategies for extending the useful life of buildings designed for passive or semi-passive summertime operation

The development of passive methods of limiting heat gains in all classes of buildings should be a priority. Work is needed to:

- develop and demonstrate high reflectivity roof coverings and improved thermal insulation of building envelopes
- develop and demonstrate techniques for reducing internal heat gains in buildings- in particular through radical reductions in energy use by building services and IT systems

- develop improved guidance for building designers and specifiers on the performance of key envelope components such as fenestration – an obvious example would be to extend the emerging BFRC domestic window energy rating system to include information on impacts of glazing on cooling requirements of commercial buildings
- develop regulatory approaches to minimise overheating and/or cooling loads in all classes of new buildings
- develop and demonstrate aesthetic approaches to the design of new buildings that are consistent with high levels of technical and environmental performance
- examine the practical constraints imposed on natural ventilation strategies in commercial & institutional and domestic buildings by transport systems

One obvious mechanism for ensuring that the built environment can cope with climate change is to amend BSI and CEN standards. It appears, however, that there is a reluctance on the part of CEN committees to undertake such amendment, not least because of uncertainties over the magnitude of climate change. It would be useful to ensure that all relevant standards committees have formal procedures to consider the impacts of climate change. The integration of information on climate change into design tools that support standards is a step that could be taken more quickly and easily than the amendment of the standards themselves. An obvious case is BREVe, a software tool for calculating design wind speeds and loadings, which could be modified to compute, as an option for consideration by engineers, design wind speeds and loadings under one or more UKCIP scenarios. Such information would be particularly useful in connection with projects with long design lives –for example, Portcullis House.

As indicated above, integration of different agendas for change in the construction industry is an emerging area. Work is needed to explore the different and sometimes diverging interests of different stakeholders in the built environment – for example the insurance industry and housebuilders – to identify those areas where consensus exists, and, where not, to begin to develop approaches to reconciling different points of view. The survey of opinion, undertaken as part of this commission, might form a starting point for such work, through the systematic collection and analysis of opinion across industry and academia.

The construction industry's ability both to initiate and to respond to change will be a crucial factor in the development and implementation of responses to climate change. Research is needed to develop our understanding of processes and dynamics for change within the industry and to explore the impacts and requirements of education and training on the industry's capacity for change.

Relevance of Europe

The EU is likely to play and indeed has played a major role in the development of responses to climate change. The ACACIA project, based at the Jackson Environment Institute at UEA and supported by the Research Directorate General, has been under weigh since the early 90s. The EU has recently announced its Energy, Environment and Sustainable Development (EESD) research programme, of which Key Action 2 includes "Global and regional strategies to prevent, mitigate and adapt to global change". The form of words used suggests the pursuit of an integrated response to climate change.

The EU is also active in developing European targets for climate change mitigation – the Sixth Environmental Action Programme (6EAP), which until this year has lacked any specific targets, now contains a long term objective to stabilise atmospheric CO_2 concentration at 550 ppm and to derive 12% of the EU's electricity from renewables by 2010. While these are modest targets, they begin to establish a wider context for UK policy.

Information on developments in specific mainland european countries is likely to provide significant input into the development of UK response strategies, at two levels. A brief survey of developments in Holland has revealed interesting differences in priorities, with much greater emphasis being given to the long-term mitigation of climate change. Adaptation appears to be predominantly concerned with the far-reaching demands of a radical mitigation agenda, rather than with the direct impacts of climate change. The picture in Germany appears to be similar. A more thorough understanding of the situation in these countries would be a significant input into the process of formation of strategy in the UK. The approach of literature search and interviews originally planned for this commission might form a starting point.

In terms of the development of technical responses to climate change, Technology Watch projects, involving the deliberate search for techniques, products, systems and approaches in countries whose climates over the 20th Century approximate to one or other aspect of the UK climate of the 21st Century, should be undertaken – but with two provisos. The history of the last twenty years suggests that the incorporation of overseas innovations into UK construction practice is not a simple matter. It would be necessary to guard against any tendency to assume that such Technology Watch programmes obviated the need for fundamental work in the UK.

1.0 Introduction

Increasing evidence suggests climate change is inevitable and that human societies will have no choice but to adapt to it (Watson et al 1996, Hulme & Jenkins 1998, Blundell et al. 2000, IPCC 2001). Adapting the built environment will necessarily be a long-term project, because of its long physical life and slow rate of renewal. This, and the need to protect one of the nation's largest physical assets, suggests the development of adaptation strategies for the built environment is an urgent task.

One of the most basic questions for this sector, is whether adaptation will be undertaken as a series of, perhaps desperate, rearguard actions or whether it will be planned and executed over a substantial period of time, based on a solid understanding of the range of possible future impacts of climate change and of the technological responses that are, or may become available.

Industrialised countries such as the UK also have a central role to play in mitigating climate change. It is likely that climate change mitigation will require cuts in CO_2 emissions from industrialised countries of 60% or more (Blundell et al 2000, Lowe 2000). The built environment accounts directly for over 50% of carbon emissions from the UK and large reductions in emissions will not be achievable without the participation of the built environment. This is likely to require profound changes in the construction industry and to impact at all stages of the planning, construction, operation and renewal of the built environment.

The twin demands of adapting to, and mitigating climate change have the potential to become the most important drivers of change and innovation in the construction industry, over at least the next three decades. Powerful synergisms are possible between strategies for adaptation and mitigation in this sector, but synergy is not inevitable – poorly devised adaptation strategies may indeed increase sectoral emissions of greenhouse gases (Graves & Phillipson 2000, Lowe 2001a). Development and implementation of integrated policies that place these insights at their core, will need the support of a sustained, interdisciplinary and international research effort, and will be one of the most important tasks of the next decade.

Adaptation is just one of a number of agendas (both exogenous and endogenous) to which the construction industry is being asked or may be asked to respond. Others include workforce safety, equity, fuel poverty, disabled access, regional policy, the competing agendas of companies within the construction industry, the need for the industry as a whole to be profitable, globalisation, europeanisation, the desire for a reduced regulatory burden and the desire for more rigorous application of regulation. One of the insights from this study is that attention has to be paid, in developing an adaptation strategy, to ensure that, wherever possible, it harmonises rather than conflicts with other goals. Where conflict appears to be unavoidable, decision making needs to be explicit rather than by default and, if possible, by general agreement.

1.1 Objectives and limitations of the study

This study was undertaken as a short scoping study to assist the CRISP Climate Change Task Group to "identify the essential ingredients of research and other programmes that will lead to the implementation of real and effective improvements in existing and new buildings and works." The objectives of the study were to:

> …identify and collate recent work on climate change and its impact on the built environment, form a view on its effectiveness and impact (or lack of impact), and the underlying reasons. The work is particularly directed at the construction sector but examples and experiences from other industries and countries other than the UK should also be drawn in.
>
> The work identified will include publicly funded research programmes (eg. the EPSRC, UKCIP coordinated and DETR programmes) and industry initiatives.

In the event, the task has proved considerably more demanding than the author expected. The field has developed rapidly over the last two or three years, with the establishment of a number of research and research coordination centres, and a rapid increase in the number of publications dealing with the topic. This rapid expansion has made it difficult to form judgements of the success of programmes and structures based on actual performance, and it is with some difficulty that one is able to form a view on where the remaining gaps are. Reading has had to be selective - and the author apologises in advance to colleagues whose work has been overlooked. Though the author has looked briefly at both Dutch and EU programmes relating to climate change, initial plans to look at parallel developments in Germany, Denmark and Canada proved to be over-ambitious.

Areas that have not been considered in detail include the impacts of climate change on the water industry and transport, the potential impact of climate change on pests, infestations and decay mechanisms such as fungal attack in buildings, and the potential impacts of climate change and construction on biodiversity[1]. It has not been possible to examine the work of international bodies such as the CIB and CEN, or of BSI and the Agrément Board in the UK.

1.2 Method

The main method used in this study has been electronic search of databases and websites, supplemented by informal and formal telephone interviews with selected individuals in industry and academia.

[1] The two need to be considered together.

2.0 Review of programmes, initiatives and capacity

The purpose of this section is to summarise the programmes and initiatives, related to climate change, run by the main funding bodies and to look briefly at some of the main centres undertaking work related to climate change.

2.1 Public funding bodies and programmes

EPSRC

Sustainable Cities The first Sustainable Cities programme established a portfolio of 56 research grants totalling £6.00 million EPSRC (http://www.epsrc.ac.uk) funding (and £0.87 million from third party collaborators), committed from 1994-97. The broad research remit included urban waste, water, energy, transport, building re-use and renovation, urban planning, and computer modelling of sustainability indicators to provide decision support tools. The programme has given emphasis throughout to interdisciplinary research, collaboration with end users and beneficiaries, networking between groups to avoid duplication of effort and to enhance joint working and validation of sustainability models and data.

A second call for proposals was issued in 1998, focussed on the establishment and validation of appropriate models and decision support tools for urban planning research, and the generation of sustainability indicators.

Neither initiative dealt explicitly with the subject of adaptation of the built environment to climate change and none of the projects supported appears to have dealt with it.

The Tyndall Research Centre opened in November 2000, with core funding from 3 UK Research Councils (the Natural Environment Research Council, the Engineering & Physical Sciences Research Council and the Economic & Social Research Council) and with support from the Department of Trade & Industry. The Tyndall Centre is one of the more significant developments in this area, with links to centres of expertise in the built environment (UMIST Department of Building Engineering), climate science (Climate Research Unit UEA and Hadley Centre for Climate Prediction and Research) and social and political science (CSERGE, UEA).

Business Discussion Forum: Can Britain Adapt to Climate Change?
Climate experts and a panel of key industry representatives will discuss the challenges of global warming and how UK businesses can improve their ability to adapt to climate change in the 21st century. Date Issued: 28/2/2001

The Impacts of Climate Change on the Built Environment, Transport and Utilities. An invitation to submit expressions of interest in the creation of multidisciplinary research consortia. Date Issued: 28/7/2001. This call is focused squarely on the problem of adapting the built environment to a changing climate.

ESRC (http://www.esrc.ac.uk and http://www.regard.ac.uk)

Global Environmental Change (1991 to 2000) Director: Prof Jim Skea
The programme aims to develop a better understanding of the underlying social and economic drivers of environmental change, the impacts of environmental change on society and the policies and measures that address environmental problems. The centre's work is not directly relevant to the problem of adapting the built environment to a changing climate. http://www.susx.ac.uk/Units/gec/

Centre for Social and Economic Research on the Global Environment (CSERGE)
CSERGE objectives are : to undertake policy- relevant research, while not neglecting pure theoretical research; to inform policy-makers about the scale, causes and consequences of global environmental problems; and to direct policy-makers towards policy options, including changes in administrative, regulatory and pricing arrangements. The three core research foci are those of climate change, biodiversity and institutional adaptation. Additional research effort has also been directed at sustainable development and its measurement.

CSERGE objectives are not directly relevant to the problem of adapting the built environment to climate change, but provides essential background. CSERGE itself lacks expertise in the construction industry and built environment. http://www.uea.ac.uk/env/cserge:

The Tyndall Research Centre (joint initiative - see under EPSRC)

Sustainable Technologies Programme
ESRC programme investigating the development and adoption of sustainable technologies. Call for applications is planned for November 2001. First projects are expected to commence in October 2002.

NERC (http://www.nerc.ac.uk/)

The National Environment Research Council plays a significant supporting role in the development of climate change adaptation strategies, both through its fundamental research on climate and through its work with other agencies. A good example of the latter is NERC's submission to the Foresight 2000 Consultation Exercise, which stresses the importance of work on "understanding and mitigating the impacts of climate change". While framed entirely in terms of the development of renewable and low carbon energy supply systems – thus ignoring energy end-use systems such as buildings - this document emphasises the importance of developing new communities of researchers, able to cut across the boundaries of traditional scientific research.

The NERC is currently developing a new Science and Innovation Strategy to replace its existing strategy document "Looking Forward". The current draft contains a number of Key Priorities under which work of direct or indirect relevance to adaptation might be supported in the future. These include:

Environmental risks and hazards

- tools, including earth observation, for improving forecasting of extreme events and natural hazards to aid risk management
- the environmental impact of non-native and genetically modified organisms

Basic underpinning science – which includes

- to develop tools & technologies to address full life cycle planning of land use
- to develop land management strategies to mitigate climate change

Water resources

- strategies and technologies for a water stressed world , including the impacts of climate change on water resources
- impact of climate change on coastal zone management
- improved modelling of hydrological systems at a regional scale
- impacts of extreme precipitation on ecosystems and land management

Managing risk and uncertainty – which includes

- global indicators of change in large scale ecosystems
- science to provide more certainty about the scale and speed of climate change at the sub-regional level

Direct initiatives by UK Central Government Departments

Any discussion of initiatives by UK central government is complicated by the reorganisation in June 2001 of the DETR into two new departments - the Department of Environment, Food and Rural Affairs (DEFRA) and the Department of Transport, Local Government and the Regions (DTLR). The reorganisation also involves a third department, the DTI, which has taken over work previously promoted by DETR.

UK Climate Change Impacts Programme Established in 1997 by DETR to provide a stakeholder-led assessment of climate change impacts on the UK.

A crucial recent development was the publication of Climate Change Scenarios for the UK (Hulme & Jenkins 1998), and a series of regional and sectoral scoping studies. ukcip@ukcip.org.uk. Work is already under weigh to update the 1998 Climate Change Scenarios, with publication expected early in 2002.

Sustainable Development Research Network Established in April 2001 by DETR, and coordinated by the Policy Studies Institute in association with the Centre for Sustainable Development at Westminster University and the Centre for the Study of Environmental Change (CECS) at the University of Edinburgh.

Councils for Climate Change The improvement and development agency, IDeA, have been running a pilot CCP programme in which local authorities have prepared greenhouse gas emissions inventories, both of their own emissions and those of the wider community. The work of CCP is related more to mitigation than to adaptation.

Construction Research and Innovation Programme Originally set up under DETR, now operated by DTI. Main funding mechanism is Partners in Innovation (PII) previously Partners in Technology. http://www.pii.org.uk/

Key economic, social and environmental policy aims of PII are:

Economic "to develop a profitable and competitive industry — at home and abroad — which provides customer satisfaction and value" – heavily influenced by Egan Report *Rethinking Construction* (Construction Task Force 1998).
Social "An industry which respects and treats its stakeholders fairly and provides a safe and healthy built environment"
Environmental "An industry which protects and enhances the environment and minimises the impact on consumption of energy and natural resources."

PII has begun to fund work related to adaptation – examples include:
Control of overheating in well-insulated houses (PII 2000)
Sustainable Urban Drainage Systems http://www.sepa.org.uk/guidance/urban-drainage/suds.htm and http://www.epcg.co.uk/he_bmps_suds.php
Better design to help flood proof buildings.

Latest call for proposals (DTI 2001) includes a Priority Area (PA) directed at adaptation – PA 01/11 Risk assessment and mitigation of the impacts of climate change. The requirement for this PA states:

> "Two of the most obvious risks are flooding and wind damage, both of which are being addressed through significant current research initiatives. However, other risks which are not being addressed at present include, but are not limited to:
>
> - Increased internal discomfort resulting from higher average temperatures, with consequent demand for air conditioning;
> - Increased subsidence as a result of shrinkage during hot, dry summers;
> - Increased rain penetration;
> - Increased dampness with associated mould growth problems;
> - Increased frost damage resulting from wetter walls; and
> - Activation of contaminants on brownfield sites, as a result of changed ground conditions."

<u>Industrial Foresight Programme</u>

The Foresight Programme is potentially one of the more important initiatives of the last ten years. The UK Foresight programme was launched in 1994 following a major review of Government science, engineering and technology policy. The purpose of Foresight is to involve business, academia and government in the development of "visions of the future". In 1995 the first set of visions and recommendations for action were published, followed by four years of development and implementation. A second round Foresight began in 1999 and reported in December 2000.

Foresight is organised into thirteen panels. Of these, *Energy and Natural Environment* and *Built Environment and Transport* are the most directly relevant to climate change. There is a significant difference in the quality and depth of the reports of these panels. The Energy and Natural Environment Panel (Foresight 2000a) appears to have a sound grasp of the impact of sustainability in general and climate change in particular. The panel's statement that:

> "The marked decline in public sector funding through the mid 1980s-90s for energy research and the failure of this to be replaced by private sector resources are clearly of concern. There is similarly weak and fragmented support for cleaner technologies and applied environmental work. The regulatory framework is not aligned sufficiently to encourage longer term R&D. In the UK support for demonstration scheme is hard to find and there is less support than in some other countries."

while not specifically referring to work on climate change adaptation, concurs with the author's own view, and is an unpromising background against which to attempt to develop and implement a significant programme of research and development.

While the author has not been able to read the whole output of the Built Environment and Transport Panel, its contribution to the Foresight 2000 exercise (Foresight 2000b) lacks depth and focus in this area and appears unlikely to form a useful starting point for further work.

2.2 Industrial initiatives

Insurance Industry
Industrial involvement in climate change has been led by the insurance industry, both in the UK and globally. One of the most important recent developments has been the establishment in 2000 of the Loss Prevention Council's Centre for Risk Sciences as part of BRE's Centre for Fire and Risk Sciences (see http://projects.bre.co.uk/frsdiv/index.html). Individual insurance companies have been responsible for significant work on climate change impacts – eg. Halifax General Insurance committed £175,000 for a study on East Coast Settlements at Risk, based at the Cambridge University Centre for Risk in the Built Environment (CURBE).

The Association of British Insurers (ABI) has been responsible for a number of reports in the area of adaptation (see http://www.insurance.org.uk/ResearchInfo/) including:

> Impact of climate change on insurance industry to 2020,
>
> Review of the Impact of a Variable and Changing Climate on UK Wind Claims. Research Report 8.
>
> Inland Flooding Risk – Issues facing the Insurance Industry. General Insurance Research Report No 10.

The insurance industry essentially supports a futures market in risk, which complements the regulatory and code driven approaches of planning and building control and of the structural engineering profession. The insurance industry is one of the strongest proponents of an effective regulatory environment. The industry has become increasingly global over the last decade, not least as a way of spreading risk. While rendering the industry more robust with respect to risks arising solely or primarily in the UK, this also means that the industry is exposed to climatic risks in other parts of the world, including continental Europe and North America.

Also active in climate change impacts are the world's largest re-insurance companies, Munich Re http://www.munichre.com/ and Swiss Re http://www.swissre.com/.

Water industry
The water industry depends for its existence on a good understanding of climate and climate variability. Parts of the UK industry were badly hit by the effects of drought in 1995/6 and to a lesser extent in 1990, '91 and '99. While it is never possible to link individual extreme events to climate change, the possibility that such events might become more common in the future has led the industry to undertake a number of studies of the possible impacts of climate change. Significant investments have already been undertaken which will make the industry more robust with respect to future climate – in particular the development of means for long distance transport of water.

2.3 European Union

The EU through the Research DG (previously DG XII) has supported work on climate change impacts and adaptation since the early 90s. The ACACIA project (A Concerted Action Towards a Comprehensive Climate Impacts and Adaptations Assessment for the EU) is based at the Jackson Environment Institute, originally at UCL, now at UEA (Parry 2000).

The EU's main programme in this area is the Energy, environment and sustainable development (EESD) research programme, of which Key Action 2 includes "Global and regional strategies to prevent, mitigate and adapt to global change" (Environment Information Bulletin 111 pp 1-2).

The EU is also active in developing European targets for climate change mitigation – the Sixth Environmental Action Programme (6EAP), which until this year has lacked any specific targets, now contains a long term objective to stabilise atmospheric CO_2 concentration at 550 ppm and to derive 12% of the EU's electricity from renewables by 2010 .

2.4 Research capacity

The following concentrates on those centres of most direct relevance to the development of climate change adaptation strategies for the built environment. Capacity in fundamental climate science is not included here. This list is not exhaustive.

<u>BRE</u>
BRE Scotland, Loss Prevention Council Centre for Risk Sciences, Centre for Sustainable Construction

Significant work by Graves and Phillipson, Sanders. Colleagues at BRE play a crucial role in the development and maintenance of design guides and tools and on a wide range of committees in which technical standards are developed and set.

One of the most important structural developments of the late 90s was the privatisation of the BRE. One effect of this is that a large proportion of BRE funding now comes from programmes such as Partners in Innovation. As a result, the BRE probably has less freedom to develop innovative areas of work and is more dependent on the priorities of external funding programmes than hitherto. FBE management, a spin-off from BRE, has until recently, played a central part in the management of PII.

<u>CIRIA</u>
Coordinates a wide range of work in support of construction industry, most recently development of Sustainable Urban Drainage Systems.

<u>Universities</u>

Cambridge - CURBE, CAR

UEA - Tyndall Centre, CSERGE, Jackson Environment Institute

Oxford - UKCIP and Environmental Change Institute

Sussex - SPRU

UCL - the Bartlett, Centre for Transport Studies

de Montfort University

Manchester – Department of Building Engineering

University of Westminster - Centre for Sustainable Development

University of Edinburgh - Centre for the Study of Environmental Change (CECS)

Industry

The role of the Insurance and Water industries in arguing for and developing climate change response strategies has been referred to above. Industrial capacity for research in this area also exists in large engineering consultancies such as WS Atkins, Ove Arup and Oscar Faber. Significant capacity in areas related to adaptation also exists in a number of small practices exemplified by the Environmental Project Consulting Group.

2.5 Summary

This brief review of industrial and private sector initiatives illustrates a rapid change both in the priority assigned to the impacts of climate change on the built environment and in the funding available in this area. A large proportion of the initiatives and programmes listed, have begun in the last two years. It is therefore too soon to judge whether they will be successful, and difficult to assess the overall structure or identify obvious gaps.

On the research capacity side, it has been possible to identify more than a dozen centres with expertise in or related to the problem of climate change adaptation. Some are of long standing, but a large number have been established since 1999. In almost all cases, the capacity identified represents a redirection and refocusing of existing research capacity. This is to be expected, given the rapid growth of interest in the area. The interdisciplinarity of the work that needs to be done and fact that the process of identifying research needs is at an early stage means that significant research capacity exists outside those organisations identified here.

The dispersed nature of much of the existing and potential capacity is a factor that will need to be recognised by those responsible for the development of research programmes and policies. This, coupled with the relatively poorly defined nature of climate impacts and possible adaptations suggests that the construction of networks of researchers based in a possibly large number of existing institutions will play a significant part in the development of an effective research capacity.

3.0 Holland

This study included a proposal to review climate change impacts work in Holland, Denmark and Germany. It has proved impossible in the time available to explore situation in Denmark and Germany, but it has been possible to undertake a brief review of the Dutch situation.

The Nationaal Onderzoek Programma Mondiale Luchtverontreiniging en Klimaatverandering *Dutch National Research Programme on Global Air Pollution and Climate Change* (NOP) was set up in 1989 and since then has carried out two hundred research projects. The programme is financed by the Ministry of Housing, Spatial Planning and the Environment (VROM) and the Netherlands Organisation for Scientific Research (NWO). NOP is based at the Rijksinstituut voor Volksgezonheid en Milieu (RIVM). The four main themes of the programme are:

1. Behaviour of the climatic system and sub-systems
2. Vulnerability of natural and man-made systems to climatic change
3. Social causes and solutions
4. Integrity and assessment

The web site summary for theme 2 suggests that the primary focus of the programme is on mitigation rather than adaptation:

> "Vulnerability of natural and man-made systems to climate change
>
> Research into the vulnerability of natural and man-made systems must come up with the arguments for climate policy, not just at national level, but certainly at international level as well. The sharp rise in concentrations of greenhouse gases demands drastic restrictions on emissions of carbon dioxide, methane and nitrous oxide. This means that radical changes are necessary in social and economic activities and structures. Research findings which demonstrate the effects of climatic change should increase support for the necessary (painful) measures among politicians, the business community and the general public."

NOP also supports the Climate OptiOns for the Long-term (COOL) Project. The two aims of the project are:

- to investigate options for a long-term climate policy strategy in the Netherlands in an international context
- to contribute to the development of methods for participatory integrated assessment.

The web site summary reads:

> "Concern about the adverse consequences of human interference with the climate implies that discussions of climate strategies will increasingly include long-term reduction targets. This may imply that the industrialised countries need to consider how to achieve large reductions (up to 80% of current levels) in emissions of greenhouse gases by the second half of the 21st century. The COOL project was set up in the Netherlands to consider the implications of

such drastic action and to devise sensible strategies for long-term climate options. It entails stakeholders, policymakers and scientists exploring and evaluating valuable options for long-term climate policy for the Netherlands in the European and global contexts, by considering insights, opinions and ideas in a structured process.”

4.0 Climate change

The UK is well served in the area of fundamental climate science, through the Hadley Centre for Climate Prediction and Research and at the Climate Research Unit at University of East Anglia. The most authoritative exploration of the nature of potential changes in the climate of the UK is that of Hulme and Jenkins (1998). This work is part of an on-going process of refining models, predictive tools and predictions of climate. The core of this process is the work of the IPCC, represented by a series of reports over more than a decade (IPPC 1990; IPCC 1992;.IPCC 1996; IPCC 2001).

Patterns of climate change predicted by the UKCIP98 scenarios include:

higher temperatures
changing patterns of rainfall
increased periods of drought
higher peak rainfall rates
stronger winds
driven rain
higher humidity
stronger sunlight / uv
less snow
less frost
higher mean sea levels
greater storm surges around coasts

These changes can be ranked both in terms of degree of confidence, and in terms of the magnitude of the resulting impact on the construction industry and the built environment. Highest confidence is associated with mean sea level and seasonal and annual mean temperatures. Less confidence is associated with cloud cover and the factors that depend upon it including rainfall patterns, levels of solar radiation and soil moisture balance, and with wind speeds.

The main tools for predicting climate change are General Circulation Models or GCMs. Work with GCMs takes place at a small number of centres worldwide – Hadley Centre for Climate Prediction and Research, the Max Planck Institute for Meteorology at Hamburg, the Geophysical Fluid Dynamics Laboratory at Princeton and the Canadian Climate Centre at Victoria. There is a mismatch between the capabilities of climate prediction and what is needed to understand the impacts of changing climate on the built environment and the construction industry. Variables such as annual space heating depend on mean external temperatures over 6-9 months of the year, and can be predicted with reasonable confidence directly from the output of GCMs. Spatially and temporally localised variables, such as peak wind speeds, peak rainfall rates and design summer and winter temperatures, cannot be predicted directly from the output of GCMs.

Crudely, the built environment is affected both by climate and by weather. While the level of computing capacity available for climate modelling increases year on year, it is likely to be several years before the spatial and temporal resolution of GCMs (currently based on 300 – 400 km grids at monthly timesteps) approaches that needed (10 km grids) for reliable weather prediction[2].

In the meantime, the generation of climate date at the regional and local scale depends on techniques for downscaling the output from GCMs and the development of Regional Circulation Models (RCMs). UKCIP is expected to publish a revised set of climate scenarios for the UK in 2002 (UKCIP02), based on such techniques. This will provide information on daily extremes at a 50 km grid – a significant advance on UKCIP98. Nevertheless, the continued development and evaluation of techniques for downscaling must remain a priority for research over the next 5 years.

4.1 Uncertainty

The aspect of climate change that, above all, makes it difficult to devise concrete strategies for adaptation, is the large range of uncertainty in current estimates of climate change. Sources of uncertainty can be classified under 4 headings:

- uncertainties in future emissions of greenhouse gases
- uncertainties in values assigned to physical parameters in climate models
- uncertainties due to effects either not modelled at all, or modelled crudely in existing climate models

The potential range in greenhouse gas emissions is captured by a set of scenarios developed by the IPCC in 1992. UKCIP98 essentially considers two IPCC scenarios – IS92a and IS92d. These are shown in figure 4.1 below.

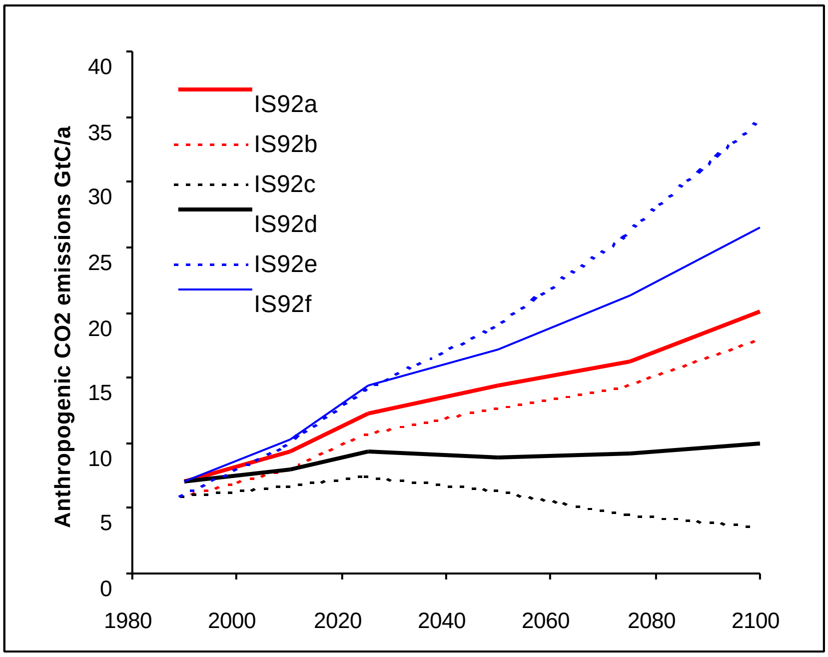

Figure 4.1 IPCC emissions scenarios (after IPCC 1992). The UKCIP98 scenarios are based primarily on IS92a and IS92d.

[2] Increasing spatial resolution from 3-400 km to a 10 km grid is likely to require more than a thousand-fold increase in computational resources.

As can be seen, emission rates in these two scenarios differ by a factor of two by the end of the century. Under IS92d, emission rates are stabilised by 2020 – with the implication that atmospheric carbon concentration rises steadily over the whole of the century. Under IS92a, atmospheric carbon concentration rises at an accelerating rate over the whole of the century. Of the IPCC scenarios, only IS92c begins to stabilise atmospheric carbon concentrations by the end of the present century. According to UKCIP98, changing from IS92d to IS92a emissions profiles increase the global temperature rise by 2100 by about 1.5 K.[3]

The effect of the choice of physical parameters in climate models is summarised in the concept of climate sensitivity – the rise in global temperature predicted for a doubling of atmospheric CO_2 concentration. The range of climate sensitivities quoted in UKCIP98 is between 1.5 and 4.5 K. This source of uncertainty is slightly more important, by 2100, than the effect of the range of emissions profiles considered in UKCIP98. The crucial difference between uncertainties in physical models and uncertainties in emission rates, is that the former can be reduced by improving the fundamental science, while the latter cannot and is likely to remain a major source of uncertainty for decades.

The final source of uncertainty is effects not captured at all, or captured very crudely in current GCMs. The most important problems involve possible positive feedback effects in which initial warming arising from anthropogenic CO_2 emissions triggers further warming mechanisms. One of the most recent developments has been the coupling of GCMs with realistic biosphere models (Cox et al 2000). This development has led to a significant upward revision of estimates of global mean temperature in the second half of the 21st Century. The biosphere is just one source of feedbacks between the primary forcing mechanism (rising greenhouse gas concentrations) and climate. Other possible feedback mechanisms are changes in the thermohaline circulation, particularly, in the context of the UK, in the North Atlantic (see for example, Hensen et al 2001), and the temperature stimulated emission of methane from land permafrost and shallow ocean deposits. Investigation of such mechanisms is at a relatively early stage of development. The current view is that such mechanisms are not likely to be significant this century, and that rapid, short-to-medium term climate change resulting from any of these feedback mechanisms may be classed as a high magnitude-low probability outcome[4]. However, the exploration of potential feedback mechanisms is a high priority task both for climate modellers and for empirical observation.

It is clear from this brief review that climate prediction is still highly uncertain, and that while some sources of uncertainty can be reduced relatively quickly, uncertainty in future greenhouse gas emissions is fundamental.

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[3] The IPCC has developed its scenario approach further with the publication of the Special Report on Emissions Scenarios (IPCC 2000).

[4] Major changes to thermohaline circulation, leading to the loss of the Gulf Stream, would result in regional cooling and significantly lower winter temperatures in the UK. It turns out that technical measures to improve the thermal performance of the UK building stock to mitigate climate change would also significantly reduce the impact of possible cooling. This is one of several examples of synergy between mitigation and adaptation measures.

5.0 Adaptation

5.1 Classifying adaptations

Climate change can impact on the built environment in a many ways:

- directly, by precipitating physical building or infrastructural failures that would not otherwise have occurred;
- directly, by changing the conditions experienced inside and outside buildings, by building users and construction industry employees;
- indirectly, through changes in the insurance market, regulatory environment and property markets which take place in response to perceptions of future risk;
- indirectly through the impact of policies to mitigate future climate change.

Adaptations to climate change can also be categorised into:

- physical changes to existing systems or components to offset the increased risk that would otherwise result from climate change;
- development or introduction of new systems or approaches to construction, partly or wholely in response to climate change;
- development of regulatory environment and design codes;
- development of planning systems to reduce future exposure to enhanced risk;
- development of social or political systems to compensate individuals who would otherwise lose out from climate change – eg. from a decision to give up land that is at risk from coastal inundation or erosion;
- developments that enhance the ability of the construction industry to initiate and/or respond to change eg. improved workforce training (Clark, in press), Rethinking Construction (Construction Task Force 1998).

It is also useful to categorise responses to climate change as:

- coping (eg. putting up with higher summer temperatures)
- default adaptations (eg. fitting air conditioning in existing and new buildings)
- early and strategic (adaptations that are planned and implemented in a timely and strategic fashion)

5.2 Understanding the context for adaptation

One of the central goals of this report is to examine the extent to which work needed to develop effective adaptation strategies for the built environment and the construction industry has been defined, to what extent it has either been done or is under weigh, to identify potential gaps in the research portfolio, and to begin to explore the question of prioritisation of research activities for the future.

It rapidly became apparent that these goals would require more than a simple listing of potential climate impacts and possible responses. The goals of prioritisation and identification of gaps require, in particular, a robust theoretical framework. The construction of such a framework has been one of the most difficult tasks confronting the author in this exercise. The reasons for this difficulty include the multi- and interdisciplinary nature of the field as a whole, the relatively early nature of much of the activity within it, and the large number of cross-cutting issues and factors that need to be considered in arriving at a balanced judgement on the relative importance of any given combination of impact and adaptations. The most important insight in this work has been that the development of climate change adaptation does not occur in a vacuum – the construction industry and the built environment are characterised by continual change, driven both by the industry's own internal structures and dynamics, and by exogenous factors. The process of change is periodically organised and given direction from within the industry by exercises such as those that led to the Latham Report and Re-thinking Construction, and from outside the industry by critiques such as "Fuel Poverty" (Boardman 1991), and the emergence of sustainability as a an issue needing to be addressed by the construction industry and by society as a whole.

5.3 Climate change mitigation

As noted in the introduction to this report, one of the most important questions raised by the need to develop climate change adaptation strategies, is whether adaptation will take place against significant programmes to mitigate climate change. Climate change mitigation is likely to require the effective decarbonisation of economies[5] within 50 to 100 years. Crucially, this goes far beyond the UK's Kyoto target, and little has been done at the national level to develop environmentally realistic strategies for the period beyond 2010. This point appears not to be widely appreciated, even within the CRISP Climate Change Task Group[6].

While a significant proportion of decarbonisation can be achieved by actions in energy supply, a complete transition to low or no-carbon energy sources will be made cheaper and quicker by measures to reduce energy demand. The author has pointed out on a number of occasions that the technology exists to reduce energy use in buildings to a small fraction of that needed in buildings typical both of existing stocks, and of new construction (Lowe 2000, Lowe 2001b). While, at a purely technical level, the achievement of reductions in carbon emissions from new buildings of up to 90% holds no mysteries, it is clear that the construction industry as a whole is currently unable to deliver such levels of performance. It appears that achieving such levels in new construction across the industry may take as much as two decades[7], while achieving it in existing stocks may take longer still.

This is not to argue that the implementation, even of radical mitigation programmes, removes the need for adaptation. Climate change is a global phenomenon with global causes. A vigorous approach to mitigation, implemented globally, would begin to make a significant impact on the rate of climate change by the end of this century, but its biggest impacts would be in the 22nd Century. Moreover the UK has no direct

[5] By the end of the century it is likely that this will apply to both industrial and developing countries. In the shorter term, it seems certain that comparatively larger reductions will be needed in industrial countries. The author lacked both the space and the time to engage in this report with the so-called contrarian view of the need to mitigate climate change as propounded for example by Lomborg (2001).
[6] One member of which observed that "We have done mitigation".
[7] This estimate is based on the author's own observations of the progress of Part L of the Building Regulations over the last ten years and opinion of the time that is likely to be needed to bring it fully into line with measures likely to be needed to achieve environmentally realistic reductions in carbon emissions from new construction.

control over the energy and environmental policies of the rest of the world. It would therefore be a major mistake to base UK adaptation strategies on an optimistic view of global mitigation. But the fact that mitigation is a global responsibility does not allow the UK to evade its share of that responsibility. It would therefore be prudent for the development of research programmes and initiatives in support of effective adaptation, to take place on the assumption that climate change mitigation will be one of the key drivers of change in the UK construction industry over the next two decades.

For any given adaptation measure, the interactions with mitigation may be positive (synergistic), negative, or neutral as indicated in figures 5.1 and 5.2 below.

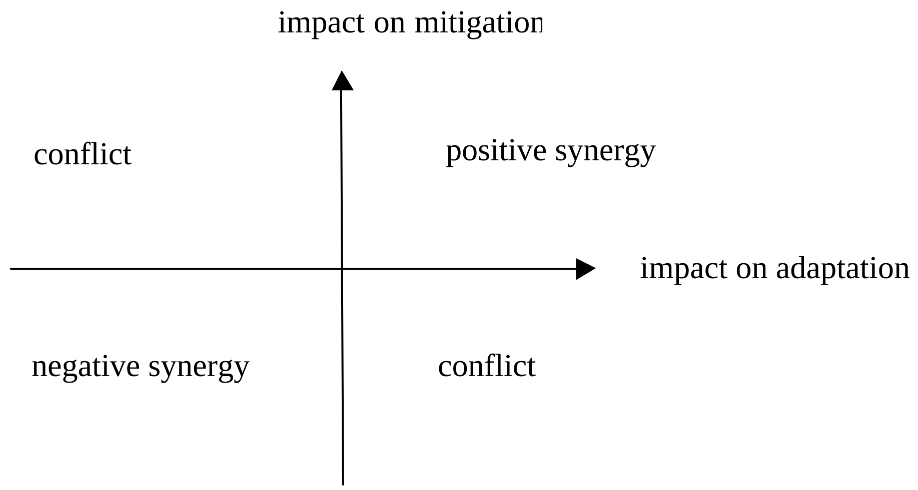

Figure 5.1 Classifying interactions between climate change mitigation and adaptation strategies.

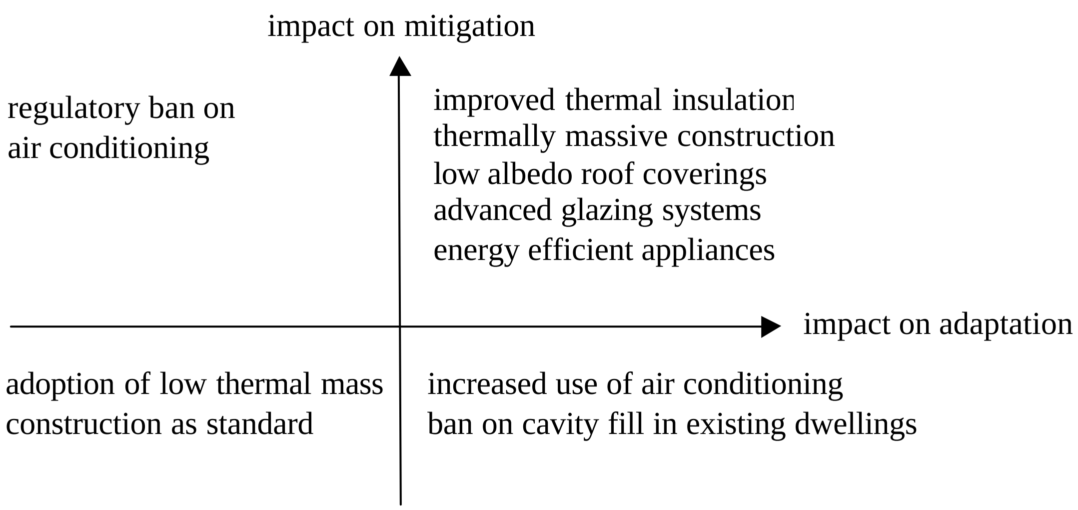

Figure 5.2 Examples of interactions between climate change mitigation and adaptation strategies.

Certain mitigation measures seem to have positive adaptive impacts against a wide range of possible climate change. One of the best examples of such measures is the adoption of highly insulated, thermally massive construction, which reduces or eliminates heating and cooling requirements, as well as providing an insurance policy against possible future climate cooling[8].

A central component of such programmes and initiatives must therefore be to identify and understand the interactions between adaptation and mitigation measures and, wherever possible, to favour measures that fall into the first quadrant of the above diagram.

5.4 Constructing and illustrating a general framework for evaluating climate impacts and adaptations

The conventional approach to organising impacts and adaptations is to construct a matrix with, for example, aspects of climate change on one axis versus specific categories of impacts on the other. The analysis presented here essentially turns this structure inside-out, taking individual climate impacts, and working systematically through a series of issues that would need to be considered in order to develop robust, research-backed, evidence-based, climate-adapted policy.

As noted above, there are a number of issues that need to be considered in developing research programmes in support of the identification, evaluation, development and ultimately deployment of individual adaptation measures, and packages of measures. These include:

- nature and timescale of expected climate impact
- nature and timescales of possible adaptations
- relationship of possible adaptations to competing drivers for change
- location of possible adaptations within the planning/design/construction/occupation/refurbishment/demolition or de-construction cycle
- location of possible adaptations along the urban design/infrastructure/building envelope/building services/building management axis
- cost of impact with no adaptation
- expected costs of early and delayed adaptation
- analysis of stakeholders
- summary of work completed or under weigh
- priority for further work

[8] Such cooling might arise from the loss of the Gulf Stream. Although this is deemed unlikely before 2100, much existing UK housing is very poorly adapted to sustained periods with temperatures below 0°C. Occupants of such housing would suffer discomfort at best and increased rates of morbidity and mortality at worst. Occupants of housing insulated to passive house standards would be largely unaffected.

To illustrate the complexities involved in exploring and developing adaptation strategies within this framework, the author has developed detailed analyses of some of the impacts of higher summer temperatures and driving rain.

5.4.1 Warmer summers and demand for air conditioning

Warmer summers and the resulting increased thermal discomfort and demand for air-conditioning are among the most obvious impacts of climate change.

Nature of Climate Change	Warmer summers
Magnitude and timescale of change	ΔT_{2080} in the range ≈1.6-3.9 K in SE (UKCIP98 low and high scenarios). ΔTs are only half as great in the north of Scotland. The lower end of this range is the rough equivalent of moving from Birmingham to London or from London to Paris, and in most of the country, will be relatively easy to adapt to. The upper end is the equivalent of moving from London to Bordeaux or Vienna, or from Newcastle to London and will pose rather larger problems.
Impacts	Climate change and resulting impacts exhibit strong regional and local variation. Temperature rises are largest in London and SE – this magnifies the overall effect because of: • concentration of population • rapidly increasing impact of each ° rise in temperature on comfort, as base temperature rises Primary impacts include: • increased thermal discomfort in poorly designed, non-air-conditioned buildings • increased energy use in air-conditioned buildings • reduced air quality in naturally ventilated buildings, due to increased periods with minimal inside-outside temperature difference needed to drive stack ventilation • expanded envelope for growth and reproduction of dust mites and other allergenic and pathogenic organisms in buildings. Secondary impacts include: • potentially large rise in demand for electricity during heat waves leading, eventually, to summer-peaking demand profile for UK – initial calculations suggest that saturation of domestic a/c could lead to as much as 30 GW rise in demand for electricity on summer days (≈50 years) • potentially large rise in loads on electricity transmission and distribution systems to and within London and other major cities (5-20 years) • slightly reduced efficiencies from thermal power stations (proportional to rise in temperature) • improved economic outlook for summer-peaking renewables eg. photovoltaics. • improved economic outlook for embedded electricity generation systems in urban centres, particularly London.

Nature and timescales of possible adaptations	Increased use of whole house air conditioning systems in new housing – already observable in London area, significant impact in rest country within 5-10 years. If temperature rise is at the upper end of the range, air conditioning is likely to become the norm in all building types. Increased use of single room a/c systems in existing housing, initially in poorly designed conservatories (many lack adequate means for stack ventilation) and in dwellings suffering from high external noise. Additional triggering factor will be saturation of a/c in cars (5-10 years) and commercial buildings, leading to generally raised expectations of summer comfort. Increased use of passive or semi-passive design – in particular highly insulated, thermally massive dwelling construction along lines of German Passivhaus model (Feist 1998) (10-15 years) and massive very low energy, mixed-mode commercial building designs along the lines of the Elizabeth Fry Building (PROBE 1998) and Wagner HQ (Schweitzer 2000) (5–10 years). Extension of Part L of Building Regulations to include explicit provisions to limit summer overheating in all buildings, primarily through measures to improve design of windows and other glazing systems. Increased use of highly reflective roof coverings to reduce heat gain through roofs in all buildings – will conflict with aesthetic expectations of planners, builders and general public. Measures to control temperatures in external environment, through construction of shade, planting of trees, use of water, colour of finishes etc. Measures to reduce external noise near dwellings, including: • lower speed limits with improved enforcement on roads in urban and sub-urban areas • reduced total road traffic • improved public transport • reduced aircraft noise Radically improved energy efficiency for domestic lights and appliances. Changes in social attitudes and patterns of behaviour – introduction of continental holiday patterns (July/August) and longer midday breaks. The default adaptation is increased use of air conditioning in all classes of building. Other adaptations compete to a greater or lesser extent with the default adaptation and, indeed, may be completely suppressed by it.

Relationships to competing drivers for change	Rise in energy use for air conditioning conflicts with climate change mitigation agenda (though offset by fall in space heating requirement in winter). Possible need to expand fuel poverty agenda to include dwellings that are hard to ventilate and cool in summer. Moves towards off-site construction using lightweight timber- and steel-framed systems may mean that new dwellings will perform significantly worse than existing. This will be particularly likely if the framework of building control fails to get to grips with the issues of thermal bridging & airtightness. Limitation of solar gain in commercial buildings is in conflict with predilection of architects and clients for very highly glazed designs. Higher thermal insulation standards (Part L) will lead to reduced fabric heat gain, particularly through roofs – but may be offset if the house building industry concludes that it is unable to deliver higher thermal insulation standards with masonry construction. Developments in Part E of building regulations may lead to increased use of massive construction to reduce sound transmission. Impact in new construction may be increased by move towards inner city sites (higher external noise levels and urban heat island effect) in response to Prescott agenda and increasingly bouyant market for new high quality, high density city centre housing. Impacts may be further increased by development of 24-hour city centres and extended licensing hours for pubs and restaurants. Strong relationship to training and education strategies for construction industry – UK housebuilding industry has very little experience of construction of massive, highly insulated dwellings, or of installation of a/c systems. Some of the necessary skills exist in other parts of the construction industry, though not at appropriate scales.

Relationship to planning/design/ construction/ occupation/ refurbishment/ demolition or de-construction cycle	planning • strong relationship through external noise, particularly related to transport systems • medium relationship through measures to control temperatures in external environment design • strong relationship to fenestration, shading and orientation • strong relationship to ventilation strategy(ies) • medium relationship to roof design and building mass construction and occupation – complex relationships refurbishment • fabric, especially glazing and roof refurbishment • refurbishment or retrofit of ventilation and a/c systems and controls demolition/de-construction – weak
location of possible adaptations along the urban design/ infrastructure/ building envelope/ building services/ building management axis	potential adaptations at all levels
cost of impact without adaptation	increased discomfort and, eventually, mortality – but note that adaptation, primarily through increased use of a/c (particularly in commercial buildings), is already taking place
costs of early and delayed adaptation	Quotes for retrofit of whole house a/c systems in Canada range from Can$5000 per dwelling upwards. This suggests that the default adaptation in the housing stock may result in a total cost of as much as £50 billion. Other adaptations delay the point at which active cooling is likely to be deemed necessary and reduce the subsequent system rating and electrical load (governed primarily by the area of unshaded glazing with orientations between Southeast and West). Costs of improved design of commercial buildings may be negative, essentially because massive opaque construction is cheaper than many glazing systems and significantly reduces a/c loads.

analysis of stakeholders	• all building owners, occupants and users • DEFRA & DTI • construction industry • up-stream suppliers • planners • transport industry • RIBA and schools of architecture • National Health Service
summary of work done	some work on passive and mixed mode systems for commercial buildings, but little replication to date little UK work on thermally massive, passive or semi-passive highly insulated dwellings, but significant bodies of work (hundreds of built examples) exist in Germany, Denmark, Switzerland and Austria
priority for further work	very high, due to pervasive nature of impacts and potentially strong synergies between adaptation and mitigation measures
nature of possible future work	improved resolution on predictions of future climate investigation of implications for electricity system of long-term development of domestic market for air conditioning development of Building Regulations to include provisions to minimise summer heat gains in dwellings identification of upgrade strategies to enable buildings of all types, designed initially for natural ventilation in summer, to adapt to warmer climate of second half of century - such flexibility will become much more important if ΔTs are in the upper end of the range given above, than if they are in the lower end.

5.4.2 Driving rain and insulation of cavity walls

Nature of Climate Change	increased driving rain in winter
Magnitude and timescale of change	20% increase by 2050, 33% increase by 2080 in SE - less in other parts of country for UKCIP98 medium-high scenario (Graves & Phillipson 2000, after UKCIP98). The change is dominated by increases in rainfall, rather than by increases in wind speed. Changes under UKCIP98 medium-low scenario are less than half of the above.
Impacts	rain penetration of existing and new cavity masonry walls
Nature and timescales of possible adaptations	tighten geographical restrictions on cavity fill in existing dwellings – 5 years tighten geographical restrictions on cavity fill in new dwellings – 5 years develop improved technical remedial measures for dwellings affected by driving rain (examples include render and rain screen systems) – 5 years develop improved detailing to allow construction of new cavity masonry walls in areas of high exposure – 5 years identify and/or develop alternatives to insulated cavity masonry walls in new construction – 5–10 years develop insurance systems (possibly no-fault) to protect individual households affected by driving rain penetration arising from cavity fill

Relationships to competing drivers for change	conflict with climate change mitigation and fuel poverty agendas, if response is to abandon cavity fill of existing dwellings in more exposed parts of country importance in new construction may be reduced by possible moves towards off-site construction, timber and steel framed dwellings with rain-screen claddings and externally insulated single-skin masonry construction impact in new construction may be reduced by higher thermal insulation standards (Part L), leading to wider and more weather-resistant wall cavities impact in new construction may be increased by move towards high-rise construction in response to Prescott agenda and increasingly bouyant market for new high quality, high density city centre housing moves toward high-rise construction may reduce exposure in existing dwellings and new low-rise dwellings in surrounding urban and sub-urban areas relationship to training and education strategies for construction industry
Relationship to planning/design/ construction/ occupation/ refurbishment/ demolition or de-construction cycle	medium strength relationship with planning strong relationship to design, through development and selection of construction details strong relationship to construction through need to ensure build quality and to cope with possible changes in construction detailing potentially strong relationship to occupation where adaptation is insufficient or badly implemented strong regional relationship to refurbishment through possible geographical restrictions on cavity fill in existing dwellings weak direct relationship to demolition/deconstruction in new and existing housing weak indirect relationship to demolition rates in existing housing

location of possible adaptations along the urban design/ infrastructure/ building envelope/ building services/ building management axis	primary adaptations at level of building envelope weak connection to urban design
cost of impact without adaptation	to be developed - should be expressed as £/m^2 of wall and cumulative £ expenditure likely to be incurred to rectify driving rain-induced failures
costs of early and delayed adaptation	relatively steep increase in costs as adaptation is delayed - minor changes in detailing compared with costs of rendering walls or fitting external rain-screens costs (in broadest sense) of adaptation strongly affected by detailed information about extent of change in climate
analysis of stakeholders	• DEFRA & DTI • fuel poor • insulation manufacturers • housebuilders • brick and block manufacturers • insurers (HBF, NHBC, ABI) • Agrément Board • National Health Service
summary of work done	existing rules for detailing cavity masonry walls (Thermal Insulation Avoiding Risks) early work by BRE (Graves and Phillipson 2000) to establish the likely changes in exposure based on UKCIP98 scenarios
priority for further work	high – costs of fundamental empirical and theoretical work in this area are likely to be low and pay-offs high

nature of possible future work	improved resolution on predictions of future climate development of codes of practice for masonry, revision of Thermal Insulation Avoiding Risks empirical and theoretical development of improved details for improvement of performance of new cavity masonry walls development of cost effective remedial methods development of broad cost-benefit analyses of cavity fill in existing dwellings, including empirically-based estimates of expected failure rates, impacts on mortality and morbidity rates

In the time available for this study, it has not been possible to conduct analyses at this depth for all other potential adaptations. Three further examples, at somewhat less depth, are presented in Appendix 2. These examples are offered as a possible model for the systematic investigation of impacts and adaptations. They illustrate the degree of multi-disciplinarity likely to be needed to develop well considered interventions in the built environment. As will become apparent in chapter 6, this has yet to be achieved in a number of areas.

5.5 Summarising and prioritising impacts and responses

Section 5.2 represents an attempt to illustrate some of the complexities involved in developing climate change adaptation strategies. This section is an attempt to prioritise the main impacts and adaptations and to present an overview in the space of a few pages.

In an attempt to convey the conclusions and the reasons for them more directly, impacts, rates of response and priorities have been graded using an adjectival system. The terms used and the meanings intended by them are listed below:

<u>impacts</u>:

low	impact not significantly greater than background noise and difficult to measure empirically
moderate	impact detectable and with measurable social, economic or technical effects; these will however be containable either as a result of measures already adopted or planned or through coping measures with acceptable costs
high	serious disruption to lives of significant number of individuals (eg. temporary loss of home), impact on businesses containable but with significant loss of sectoral profitability
very high	catastrophic impacts on the lives of significant numbers of individuals (eg. complete loss of home), significant impacts on national economic indicators, major sectoral impacts and risk of significant business failures

<u>rates of response</u>:

rapid	likely to take place within 1 year
moderate	likely to take place within 5 years
slow	likely to take place within 10 years
very slow	may take many decades

<u>priority:</u>

low	not sufficiently large or urgent to be worth allocating significant public funding; organisations and companies that are directly affected likely to be able to establish and implement viable response strategies from internal resources; "do nothing" may be a viable response
moderate	sufficiently large or urgent to warrant explicit funding of individual research and development projects by public and private sector, incorporation of technical changes within normal product development cycles in response to emerging understanding of impact, implementation of sectoral responses such as voluntary codes or practice, amendments to existing regulation
high	sufficiently large or urgent to warrant funding of research and development programmes, development and implementation of new regulation and mandatory codes of practice, development and implementation of technical and other measures with significant economic cost on precautionary principle

very high	sufficiently large or urgent to warrant the establishment of research centres to manage, coordinate and undertake R&D activities, the funding of significant demonstration programmes, coordination of training and education activities within industry and education

impact	magnitude of impact including variability and uncertainty	responses	rate of response	other agendas	priority	extent to which impact is covered within existing resources and programmes
coastal and estuarine inundation coastal erosion	high with very high impacts due to short term surges predictable year-to-year trends but wide uncertainty in long term	planning coastal defence retreat	slow or very slow[9]	regional policy and land use equity confidence of property and land markets insurance industry	very high	work under weigh – UKCIP, Jackson Environment Institute, CURBE

[9] Nevertheless, the probabilities of extreme events are highly sensitive to small changes in mean values. Chair of the Environment Agency stated recently that since it was completed in 1980, the Thames Barrier has been raised on 63 occasions, 24 of which have been in the last 12 months. The criteria for operating the barrier have not changed.

impact	magnitude of impact including variability and uncertainty	responses	rate of response	other agendas	priority	extent to which impact is covered within existing resources and programmes
riverine flooding	high to very high significant long term uncertainty and year-to-year variability	planning flood defence and river management	slow or very slow	regional policy and land use equity confidence of property and land markets insurance industry disabled access	very high	DEFRA work on flood plain management models development of planning guidance and guidance on sustainable urban drainage

impact	magnitude of impact including variability and uncertainty	responses	rate of response	other agendas	priority	extent to which impact is covered within existing resources and programmes
subsidence	high with significant long term uncertainty and year-to-year variability	improved foundation design in new construction remedial action in existing	slow or very slow	confidence of property and land markets equity insurance industry	high	significant initial work by BRE (Graves & Phillipson 2000) further work is needed to ensure that proposed measures are consistent with other goals, including long term carbon emissions goals and thermal performance in summer and winter
patterns of rainfall and water supply	moderate to high impact high inter-annual variability high long term uncertainty	increased storage improved transport reduction of losses demand management coping	slow slow moderate moderate rapid	regional policy and land use equity	moderate to high depending on region	extensive work coordinated by UKCIP and other water companies

impact	**magnitude of impact including variability and uncertainty**	**responses**	**rate of response**	**other agendas**	**priority**	**extent to which impact is covered within existing resources and programmes**
storm damage to buildings	high very high	revised codes of practice for structures closer adherence to existing guidance on roof construction	moderate to rapid	desire for reduced regulatory burden on industry	high	insurance companies and BRE have undertaken work more work needed to establish viable approaches to ensuring adherence to existing guidance and codes of practice.
impact of storms and high winds on construction process	impact of climate change is unlikely to be high due to ability of industry to adapt, decade-by-decade to demands of changing climate impact of uncertainty is low	revised codes of practice for scaffolding, wind sheeting and temporary structures	rapid – existing infrastructure is not an issue; timelags arise mainly from nature of current practice, formal training and tacit knowledge; the 21st Century will see the entire human capital of the const. industry replaced 3 or 4 times.	health and safety, Egan, need to maintain profitability and adapt to on-going technological innovation	low - due to slow rate of climate change and potentially rapid rate of adaptation in the absense of significant physical infrastructure	much of the cost, both of increased wind speeds of and adaptation, arises within individual companies - it is therefore likely that most of the responsibility for adaptation can be borne by the industry, supported by agencies such as the HSE.

impact	magnitude of impact including variability and uncertainty	responses	rate of response	other agendas	priority	extent to which impact is covered within existing resources and programmes
warmer summers and thermal comfort	moderate to high	many – coping air conditioning (default adaptation) improved building design revised building regulations retrofit of shading devices and roof insulation retrofit of high reflectance roof finishes	immediate through moderate to slow	many – equity and fuel poverty (hard-to-cool homes) climate change mitigation	moderate to high	some work undertaken, for example on passive ventilation strategies for commercial buildings. but work is needed in many areas, including further development and demonstration of passive and semi-passive strategies, development identification of likely geographical and temporal limits to such strategies under different warming scenarios, development and demonstration of retrofit techniques and strategies

impact	magnitude of impact including variability and uncertainty	responses	rate of response	other agendas	priority	extent to which impact is covered within existing resources and programmes
UV degradation of materials	low and progressive – impact proport'nl to cumulative level of UV ±4 % by 2080 depending on region (UKCIP 98)[10]	increased rated of replacement in SE improved performance of plastics and coatings	rapid (paint finishes) to moderate (windows, rainwater goods and other plastics)	large potential impact from moves to limit use of PVC in built env'nt	low to moderate	

[10] UV degradation is initiated by the impact of high energy photons on molecular bonds in materials. This explains, very simply, why impact is proportional to cumulative exposure to radiation. A reasonable upper bound to the increased maintenance cost for PVC-U windows would appear to be around £100 million per year, rather than the widely quoted £2.4 billion given in Graves and Phillipson (2000). It is possible that Graves and Phillipson confused the annual cost of increased maintenance with the net present value.

impact	magnitude of impact including variability and uncertainty	responses	rate of response	other agendas	priority	extent to which impact is covered within existing resources and programmes
driving rain and walls in dwellings	moderate	many – ranging from increased regional restrictions on cavity fill in existing through introduction of wider insulated wall cavities (150 – 200 mm) with revised details in new construction to introduction of new forms of const'n (external insulation, rainscreen cladding…) remedial options exist	rapid to moderate	many, including: equity and fuel poverty health climate change mitigation Rethinking Const'n training and skills	high	initial work undertaken by BRE. further work needed to improve understanding and extending the performance of wide, fully-filled cavity walls, to develop remedial strategies and systems (including insurance) to deal with climate induced failures

The remaining areas of the impact that have been identified, but not considered in detail in the course of this study are listed below.

Infrastructure

- water and sewerage systems
- electricity system
- gas system
- emergency services

Building process

- health and safety implications of higher wind speeds, driving rain
- implications of increased rainfall for work on foundations, sub-structures and below-ground services

Urban design

- rules for siting and design of tall buildings
- design to manage water run-off rates and to control surface water
- design for shade in outside spaces
- design of soft landscape for climate change (choice of species, design to minimise run-off and erosion)

6.0 Samples of informed opinion

Any attempt to gauge opinion from a sample of less than a dozen interviewees is needs to be treated with caution. Nevertheless, the interviews conducted as part of this study (7 formal and 2 informal) have yielded a number of useful insights.

The formal interviews were based on a semi-structured questionnaire (Appendix 2). Given the timescale and resource available for the project, the questionnaire was devised relatively quickly and was subjected only to limited internal piloting. Interviews were conducted between 18^{th} and 23^{rd} July by telephone. Formal interviews were tape recorded and handwritten notes were also made in the course of each. Interviewees were selected to cover the main groupings involved in the development of climate change adaptation strategies for the built environment – research councils, UKCIP, construction and insurance industries, BRE, DTI/DEFRA and an independent researcher with a long standing interest in and reputation for work on sustainability. In practice, availability of potential interviewees in a narrow window at the beginning of the holiday season imposed some constraint. It was unfortunately not possible to arrange formal interviews with colleagues from Germany, Holland or Denmark, though informal discussions were held with Dutch and German colleagues at the end of June.

Paul Waskett	DTI (previously DETR)
Lisa Hill	ESRC
Chris Sanders	BRE Scotland (previously Scotlab)
Ian Cooper	Eclipse Research Associates
Graham White	Axa Insurance
Neil Smith	NHBC
Tim Broyd	WS Atkins
Sebastian Macmillan	EPSRC IMI (informal)
Iain Brown	UKCIP/Tyndall Centre (informal)

Interviews were conducted on the basis that, where appropriate, views would be ascribed to named individuals – with the proviso that each interviewee would be sent a copy of the penultimate draft of the report for comment. For the sake of brevity, interviewees are identified in the rest of this section by initials.

The views expressed by interviewees do not necessarily reflect those of the organisations to which they belong.

6.1 Summary of responses

1. *What do you consider to be the 4 main drivers for change in the UK construction industry? (Egan, regulation, client demand…)*

There was considerable diversity of opinion here.

PW	Egan, sustainability, competitiveness, climate change
LH	no opinion
CS	regulation, demand, Egan (but how is the industry really doing?), fashion eg. conservatories
IC	cost and profitability, market change, internationalisation/globalisation, regulation
GW	profit
NS	cost, quality, defects reduction
TB	client driven procurement changes, skill shortage, globalisation

2. What ranking would you personally assign to these drivers? Does your view accord with the current status of programmes and initiatives in the UK in this area?

(as above)

3. *In your view, will climate change impact significantly on the built environment in the UK over the next 10 years? 50 years? by the end of the century?*

	10 years	50 years	end of century
PW	depends on definition of significant	yes, enormous; there will be a transition post 2010	
LH	probably, in terms of floods	other impacts will take a longer time; more impact if rising temperature drives [domestic] a/c	
CS	probably not, except through increased flooding	yes, things will really start to bite	much more
IC	expects a transition around 2020 – little impact before, increasing impact thereafter – but did mention potentially very large regional impact of coastal inundation in East Anglia		
GW	Yes	Yes	Yes
NS	"No with the exception of flooding and flood risk –*PPG 25* [will cause] a lot of local authorities [to review] their plans."	"Impacts will become more significant as we become more aware of the need to make buildings more climate-proof and those changes will come into the building regulations. There are still a lot of people out there who doubt the phenomenon of climate change."	
TB	No	Yes	Yes

PW noted that DTI is committed to the concept of the triple bottom line. He noted that climate change and sustainability are big factors being considered across the whole of government. Noted that of mitigation and adaptation, "adaptation is slightly on top".

IC noted that the current government is averse to regulations – the "stick" - but has no significant carrots. IC's work shows very few firms see climate change as a major driver, but this proportion may increase given an unambiguous climate signal with significant consequences for UK. Collapse of Larsen A ice shelf was unambiguous but, if anything, its lack of obvious consequences induced complacency rather than alarm.

4. My next question may appear to be asking the obvious, but the answer will nevertheless be of interest. Should research funding agencies and industry develop strategies for adapting the built environment to climate change?

Five of the seven respondents answered "yes" to this question.

IC answered "yes", but stated that mitigation would be an overwhelmingly more difficult problem to tackle.

NS "Adaptation is easier said than done. To be certain that a house is climate proof over the next two centuries, you may have to put in foundations twice as deep as required at the moment. […] Are we yet at the situation where it is reasonable to impose on every builder these additional costs - do we have the underlying research that shows that a particular area will get wetter and windier and if so what do we know about those exposure conditions? Research is needed but the industry might develop naturally with guidance."

GW stated that research would need to be multi-dimensional, based on joint strategies, and seeking to identify joint benefits.

5. What importance would you assign to the following sub-sectors of built environment:

Answers to this question are summarised below (to make the table more compact, a simple numerical coding system has been used with “very high” = 5, “high” = 4, “moderate” = 3, “low” = 2 and “very low” = 1):

	hous’g	comm’l	health/ ed’n	water & sew’age	trnspt	l’dscape & open spaces	coastal defence	river defence
PW	4.5	4	4	5	4	3.5	5	5
LH	3	3.5	3	4	4	3.5	4	4
CS	5	3	4	5	5	4	5	5
IC	3	3	3	4	4	3	5	5
GW	5	5	5	5	5	5	5	5
NS	3	2	3	4	5	2	4	4
TB	3	3	1	4	3		5	5
mean	3.8	3.4	3.3	4.4	4.3	3.5	4.7	4.7

Several respondents gave quite lengthy answers to this question, going far beyond the bald rankings presented above.

CS ranked dwellings as more important than other classes of building because their (much) longer physical life exposes them to potentially much more extreme climates. He noted the importance of not siting essential services – eg. hospitals – on flood plains or other “at risk” areas. Under “other” CS noted the importance of shipping and dock facilities, industrial buildings and leisure facilities.

IC broke the list up into:

- “impact generators” – buildings and landscape, and
- systems “at risk” – infrastructure, coastal areas and flood plains at risk from flooding

He also noted that his answer to this question would depend on whether one saw the construction industry as passive or active with respect to the issues. An active industry would have much higher rankings for impact generators.

GW rated all sub-sectors as “v. high”. He noted that there was a need for more integrated land-use planning. As an example, he would like to see more water meadows. DEFRA policy could regard farmland as “sponges” as much as food production systems. Noted that in many cases, floods of Autumn 2000 were not related to rivers – spoke of the “Tesco effect” of uncontrolled run-off from large, impermeable platforms such as carparks. He observed that there was currently too diverse an institutional infrastructure which hindered the development of integrated policies and the planning and financing of timely responses to emerging problems in this area.

TB noted that there appeared to be indications of a market for domestic air conditioning.

The overall picture is that coastal and riverine flooding have the highest ratings of "importance", followed by infrastructure and housing.

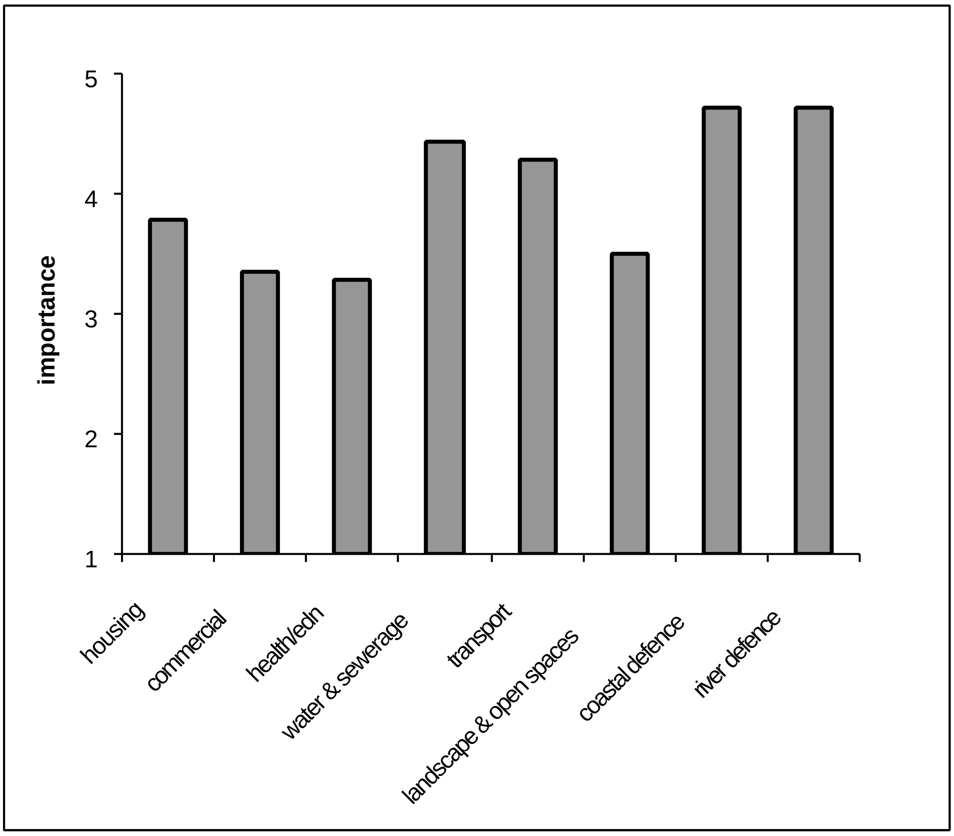

Figure 6.1 Mean ratings of relative importance of sub-sectors of built environment.

6. *What importance would you assign to the following activities? How effectively are they being covered at present?*

Answers to this question are summarised below. Once again a numerical coding system has been used in which "very high" = 5, "high" = 4, "moderate" = 3, "low" = 2 and "very low" = 1:

	climate pred'n	ident'n & quant'n of impacts	tech. dev.	regul'n	design guides & codes	studies of econ. factors	studies of social factors	public/ user info
PW	3	5	5	3	4	5	5	5
LH	4	5		4		5	5	4
CS	5	5	4	5	5	4	2	4
IC	4	4	4	5	5	5	5	4
GW	5	5	4	5	5		5	5
NS	5	4	1	3	4	4	4	4
TB	3	5	4			5	4	2
mean	4.1	4.7	3.7	4.2	4.6	4.7	4.3	4.0

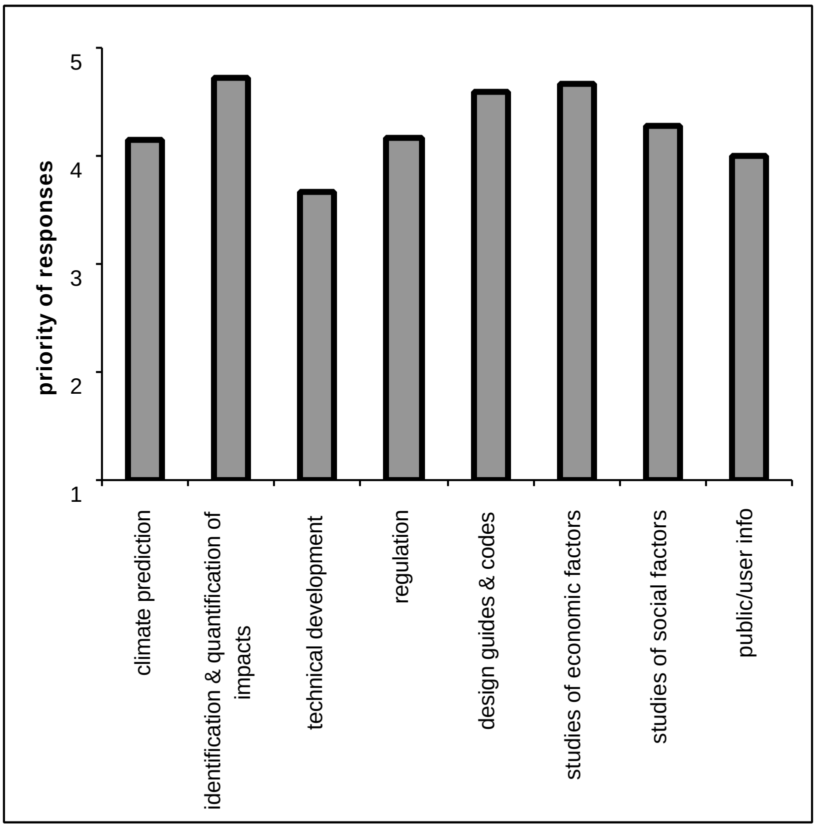

Figure 6.2 Prioritising responses - mean ratings

Mean scores are graphed above. Answers to this question were once again full.

PW stated that climate prediction was "in good hands". He was hesitant about the use of regulation. Stated that regulation…

> "…can be used, but we need to identify approaches which industry will adopt. We need to do more work…"

On communication, he stated that dissemination of research was itself a problem:

> "We fund research that we think will change the world, but it doesn't."

LH saw many uncertainties around impacts – need more work on social and economic impacts (eg. growth rates), particularly of rapid climate change – ESRC is planning a small piece of work on this and the Norwegian Government had had quite a lot of contact with NERC about impacts of rapid climate change on the natural environment. "We've only just 'opened the box' in terms of social and economics responses to climate change.

"A lot of work still concerns itself with technical fixes - not why people are not taking up the technology, why they are not taking technical risks. The way the public percieve risks is different from how the 'experts' perceive it."

LH noted that CSERGE was active in disseminating information and research results to policy makers, but that there was room for improvement with respect to public. Whether information should come from the Government or directly is unclear. There is a difference between what the Government finds out and what the public is told.

CS stated that UK work on climate prediction was "at the cutting edge". He stated that there was need to ensure that parts C,L & A of the building regulations considered the impacts of climate change. But he also stated that:

> "There is a need to ensure that current regulatory standards are enforced properly. The practice of accepting the lowest cost tenders and lack of training in the industry are problems."

On revision of design guides and codes, he stated that he was unsure about how much was going on, but was aware of no formal procedures in BSI to consider climate change. As a member of CEN TC 89, he found little acceptance of need to consider climate change.

On public/user information, he urged provision of:

- flood warning systems and advice: "…keep your gutters clear"
- advice on where to buy property and on insurability of property
- improved flood warning systems

IC stated that development of regulations maybe the key, but needs to be more wide-ranging than simply building regulations. He suggested provision of information for public along the lines of <u>Protect and Survive</u>, but hopefully with a greater chance of being used.

> "Climate change is largely a case of winning hearts and minds. The last 10,000 years have been exceptionally benign, but the future may be different. We might be among the migrants of the future. Inundation predictions for UK even for a 1 metre rise in sea level would be hard to cope with."

GW stated that he was impressed at the recent increase in effectiveness with which the issues listed in Q6 were being covered. He observed that ABI was active in mainland Europe as well as the UK and that ABI members had been affected by the French storms of 1999 and the floods on the Elbe in Autumn of 2000. The insurance industry saw a need for trans-national solutions. One of the main drivers for work on climate change in the US was flood mitigation.

On *studies of economic factors*, he stated that he needed more information, but observed that:

> "…economic development makes the whole system more sensitive."

Under *studies of social factors*, he raised the possibility of climate change impacts leading to social unrest. On *public/user information*, he referred to reports of world-wide catastrophes. GW urged the continued development of the national flood warning system.

NS stated that climate predictions at the local level were important. "The solutions are already out there but we need guidance on where to apply them. Foundations, could be made deeper or stronger quite easily, albeit at significant additional cost.

Studies of economic factors… "were a key communication issue - essential. The only reason I don't rank it 'very high' is because the whole issue of climate change does not have a very high importance at the moment."

TB stated that the climate scientists had "got their act together". The relative importance of regulation and improvements to design guides and codes of practice depends on <u>perceptions of robustness</u> of the results of climate prediction. Public information was of relatively low importance.

7. *What in your view is the relative importance of climate change for existing buildings and infrastructures and new build?*

PW	currently equal importance, but existing likely to assume more importance in future
LH	equal importance, but raise different issues
CS	existing stock more important – generally less well built – the fact that new construction adds around 1% each year to existing stocks of buildings, means that the revision of Part L or of other parts of the Building Regulations will make little difference for many years.
IC	response depends on whether we are talking about adaptation or mitigation; in terms of the latter, the existing stock is the difficult problem
GW	new build may be tactically more important and effective; existing building is nonetheless important, but tackling it in practice may be problematic
NS	new build more important, but for existing homes: “Issues of resilient reinstatement that come up. When a building is flooded, reinstate it in such a way that the next time the same damage will not be repeated - take wiring out of the floors, don't put chipboard floors down, etc.”
TB	the slow refresh rate of the stock means that changes to regulation for new build take decades to make a significant direct impact on stock as a whole; Foresight has recommended that more importance be given to refurbishment of existing stock.

8. *Would you describe the response of the UK as a whole in the area of impacts and adaptation as:*

PW	the understanding and importance of sustainability issues in government have increased steadily over the last 5 years. response of government is now strong. response of industry is weaker.
LH	strong, but more work is needed, particularly on scenarios
CS	strong
IC	almost invisible - “Government and industry commission work but don’t listen to the results. As a practice, we were well informed on sustainability by 1990 and sought business from 1992. We received our first income this year.”
GW	weak “I am not an expert in this, but unless there is regulation (eg. ‘Secure by Design’, PPG 25) nothing happens.”
NS	medium
TB	UK is strong in climate prediction, but nobody is strong in adaptation

9. Would you describe the historical and present engagement of your own organisation with this issue as:

PW	strong
LH	strong, especially since 1990
CS	strong, with Scotlab being perhaps stronger than BRE as a whole
IC	weak-to-medium
GW	medium-to-strong
NS	medium - "We've taken an interim decision to 'wait and see'. We'll watch this space for developments in regulations and codes of practice and fit in with those. We are not able to set standards that could make buildings more climate proof unilaterally. Bearing in mind the high costs that are likely to be involved, the consequence of doing so may be to discourage developers from registering their homes with NHBC - that would not serve our own, the industry's or the public's interest."
TB	weak overall but with individuals and groups achieving national international credibility for work related to water resources and impact of floods on structures… the organisation is responding to perceptions of market needs

The answers to this question appear to be consistent, and to suggest that the UK response to climate change is being led by the academic community, government, BRE and the insurance industry.

10. How important do you expect research on impacts of climate change on the built environment to be by 2005?

PW	important "Sustainability is the overriding issue."
LH	important
CS	very important
IC	of medium importance – anticipates that built environment and construction industry will be a neglected area – its role, passive or active, will be under-researched
GW	publicly, of medium-to-high importance, but behind the scenes, very important
NS	important
TB	of medium importance, but gaining in momentum – there are long timescales involved in setting things up

11. How important do you expect your own organisation's role or interest in research on impacts and adaptations to climate change in the built environment to be by 2005?

PW	very important – led by DTI/DEFRA
LH	ESRC will move out towards construction and urban environment
CS	very important
IC	of medium importance
GW	very important
NS	important
TB	of medium importance

12. To what other industries or sectors of the economy can one look for good examples of effective responses to the problems posed by climate change ?

PW	could not think of one
LH	farming, rural landscape
CS	water industry, some work in railways; comes down to individuals – mentioned an individual in Railtrack agriculture, but climate change competing with other agendas
IC	could not think of one
GW	possibly the leisure industry
NS	could not think of one
TB	water industry better than most…oil majors? wondered if the designers of long life buildings such as Portcullis House (200 year design life) had factored in the impacts of climate change?

13&14. How important, in your view, is overseas experience of the development of climate change response strategies likely to be?
If one-off or on-going studies of responses in other countries were to be undertaken, which countries do you think it would be most rewarding to focus upon?

PW	importance of watching brief and collaboration - would look to N. America especially S. California, Europe
LH	importance of watching brief (UK is taking issue more seriously, due to agendas being pushed by Blair government)
CS	
IC	depends on whether the UK adopts a “little englander” or a global perspective Netherlands, due to topography and society. “The Dutch appear to be attempting to achieve sustainability in one country.”
GW	very important – also stressed the importance of lobbying opinion in other countries Germany, Netherlands, France
NS	“Interesting, but most countries have a different climate from ours. In Germany, they have no experience of wind driven rain for example. So, yes, we can draw on overseas experience, but I don't think it will always be directly applicable.” Would perhaps look to N. America.
TB	very important France, Netherlands, NZ and Japan

15. Comment on the likely future effectiveness, in this area, of:
UK research council programmes, DTI/DLTR sponsored programmes
EU sponsored programmes, construction industry programmes
insurance industry initiatives, other industry initiatives (eg. water)
joint initiatives (DLTR/EPSRC/ESRC/industry)

PW	"…all have the potential to be effective."
LH	research council – high DTI/DLTR and joint initiatives (eg Tyndall) - very high other areas, hard to comment
CS	research council and DTI/DLTR – should be effective EU should be effective – mentioned ACACIA and Predicat (University of Reading) construction industry will become important, but is not so far insurance industry initiatives have been very effective water industry has been doing quite well – perhaps power companies? joint initiatives –as industry becomes more involved, co-funding will not be a major issue; stressed the need for interdisciplinary working; the announcement of Tyndall Consortium Associate status for the Dept. of Building Engineering at UMIST, with expertise in building and environmental science, is a significant development.
IC	noted current effectiveness of insurance industry – "…insurance is the leading edge." "Financial sector is a major driver for joint working." "There are not enough mechanisms for joint working. The DETR dispersal will make it almost impossible to get the environment into joint initiatives."
GW	emphasised need for joint working
NS	DTI/DLTR and joint initiatives should be most effective. "Industry can have a place in identifying the key areas of research and bringing reality to an otherwise purely academic study."
TB	"Do not know how I can. All could have their part." sees no cohesion – needs more talking but beware of artificial consensus "Increasingly, the public sector (Construction Directorate and EPSRC) have looked to support joint-funded projects, to ensure relevance. This has been fine for near term problems – but for climate change and the development of responses, there is a lot of searching and wondering, but no clear business case for co-funding. Government needs to fund reconnaissance and scoping."

16. In your view, can the problem of climate change be addressed effectively through existing programmes and funding mechanisms? Are there areas of activity that are not being funded or supported at present?

PW	"…as long as they are focused and targeted and aligned and managed."
LH	"There is reasonable flexibility in the present systems, especially over 2-5 year period. The construction industry represents a gap that may be addressed in the future." "There are problems in universities – cross disciplinary research is not made easier by the RAE."
CS	"The area can sustain growth."
IC	"There is unfortunately a poor relationship between policy relevance and industry relevance." "Climate change is a policy goal, but the government insists on burden sharing – co-funding – and short-to-medium term pay-offs. This will pose problems unless bits of industry can see climate change as a business opportunity. Insurance industry may end up as the co-funder of first resort."
GW	"Probably not. The insurance industry is capable of responding to the challenge and has initiated research – eg. the Halcrow work on coastal and estuary flooding – which then resulted in government funding. Would wish to work with and support government initiatives in this area."
NS	Difficult to answer without more detailed knowledge of all current programmes.
TB	quoted CERF – "Conventional thinking is inadequate in the face of today's environmental challenge." the implication is maybe not – the problem needs new people and maybe current mechanisms will not attract such people

6.2 Identifying common threads

There is broad agreement on the importance of climate change and of research on impacts and adaptations. While opinions differ on priority to be assigned to particular areas, there is general agreement on the importance of riverine and coastal and estuarine flooding.

There is a split of opinion between supporters of regulation and those who are unsure whether it has a part to play. It is interesting that the DTI interviewee falls into the latter camp, while the interviewee from the insurance industry falls very strongly into the former.

Most interviewees consider joint working to be important or essential to progress in this area. A number of interviewees comment on the difficulty of achieving this in practice. Similar perceptions were voiced by both informal interviewees. Iain Brown observed that there are many experts in the area, but few generalists. Sebastian Macmillan stated that integration "is a great gap", and observed that when Rethinking Construction was originally published, it ignored social and sustainability dimensions – though these had been filled in later. "We are all guilt of working in silos…"

There are subtle indications of a disjunction between social and political scientists and technology policy experts on the one hand, and technologists on the other, for example in Lisa Hill's comment that the construction industry represents a gap. This problem has been addressed through the inclusion of the Department of Building Engineering at UMIST in the Tyndall Consortium.

There was an interesting complementarity between the views of Paul Waskett and Ian Cooper on the effectiveness of much research in this area, with the latter stating that:

> "Government and industry commission the work but don't listen to the results."

and the former observing that dissemination of research is sometimes a problem, and that:

> "We fund research that we hope will change the world, but it doesn't always do that..."

Similarly, Paul Waskett's remark that the understanding and importance of sustainability issues in government have increased steadily over the last 5 years, and Ian Cooper's observation that his practice has only recently begun to receive commissions in this area appear to be two sides of the same coin. Both comments are indicative of the urgency and of the difficulty of communicating across organisational, disciplinary and cultural boundaries, and of the lead times required to achieve significant reorientations of priorities in government and the private sector.

There is an indication in answers to questions 15&16, that the current emphasis on co-funding and relatively short time horizons in construction research may not be appropriate in the context of climate change. Responses to climate change need to be framed on the basis of careful consideration of impacts, uncertainties and the relative weight placed on events in the future compared with the present[11]. The difficulty of doing this against a background of the current uncertainties in future climate and climate impacts is illustrated by Chris Sanders comments on the difficulties of getting standards committees to consider the impacts of climate change (echoing comments made by Graves and Phillipson (2000) and by Neil Smith's considered justification for the 'wait and see' approach being taken by the NHBC. These suggest that the task of building consensus for action will be a difficult one.

[11] In the language of economics, discount rates.

7.0 Discussion and conclusions

This report, like many others in the field, has attempted to provide a structured approach to the prioritisation of impacts and responses. Section 5.4 of demonstrates the complexity of the problem with a series of examples, while section 5.5 attempts to summarise the main categories of impact and response. The primary issues that need to be considered in developing strategies to deal with climate change include:

- the relationship between the rate of change climate and the rate of change of each part of the planning/design/construction/occupation/refurbishment/demolition or de-construction process affected, directly or indirectly, by the change in climate;
- the relative costs of the possible options for dealing with each impact, including the option of doing nothing;
- the relationship of possible adaptations to competing drivers of change and to the underlying direction of change in the industry and in society as a whole.

Consideration of these issues enables us to begin to prioritise areas for action. The most urgent problems are arguably those that revolve around systems with the longest response times. Of all the aspects of the built environment, settlement pattern is probably the most enduring. This is followed by physical infrastructure such as water supply and drainage systems, then by various physical components of building envelope and physical infrastructure, building services systems, and finally of internal finishes, furnishings and fittings, appliances (including IT) and contents. Somewhere in the latter list one can also place the soft components of the construction industry – regulatory systems, design codes, construction techniques and systems, tacit knowledge and skills – and such factors as client motivation and aspirations.

Thus, the most urgent problems posed by climate change relate to riverine flooding and coastal inundation, where the impact is catastrophic for those affected, and where risk is determined by the relationship between settlement pattern and geography. The total value of properties in inland areas at risk from flooding is put at £215 billion – approaching one third of UK annual GNP (ABI quoted in Pearson (2001b)). The risk posed by these buildings is increased by the likelihood that many buildings will be affected simultaneously by any given climate "event". Next come the impacts of storms and subsidence and soil movement. While the impact on structures is progressive, the cost is high for those buildings affected (typically £10,000 per dwelling), with annual totals currently running at between £400 and £600 million. The least urgent (of which there are many) are typified by the impact of higher levels of UV on paint finishes, where one is dealing with a small and progressive impact, short product life (re-coating intervals ranging from 3 to 7 years), non-catastrophic failure and a rapid rate of underlying improvement of products in the class over the last 20 years, which appears likely to continue into the future. This list of priorities is reflected in the literature, in the development of centres of expertise, and in the research that has begun to be undertaken.

Climate change impacts appear therefore to divide broadly into:

- a small number of major impacts for which the development of coherent and effective adaptation strategies appears to be absolutely essential;

- a larger number cases where impacts, though large, are unlikely to be catastrophic but where adaptation needs to be woven into the fabric of other agendas facing the construction industry and the built environment
- a still larger number of cases where impacts are likely to be dwarfed by other changes taking place over the next 50 to 100 years.

This sub-division is important. The very high potential impact of sea level rise clearly requires a determined and sustained response. But not all aspects of climate change are as significant as this and it is as important to guard against over-reaction as it is to guard against complacency.

One of the most important factors in developing climate change adaptation strategies is the very high degree of uncertainty that surrounds all aspects of climate change. Taking the full range of uncertainty presented in the IPCC Third Assessment Report (TAR – IPCC 2001), estimates of global sea level rise in 2001 range from under 10 cm to about 85 cm. In the most vulnerable region, East Anglia, the result could be a rise in net sea level of anything between 30 cm and over 1 metre. The implication of such uncertainty is that strategy needs to be based on an acceptance of the precautionary principle, on the maximisation of future flexibility, and on the expectation that perceptions of risk may change repeatedly over the next 50 years. This in turn suggests that the process of establishing and maintaining consensus for action will need to be a continuous one.

7.1 Areas for future work

A number of areas of work are identified in this study, but there appear to be few significant problems offering the possibility of quick wins or easy gains. One of the few that has been identified, is to liaise with relevant BS and CEN committees to discuss how standards such as BS 6399-2: 1997: Code of Practice for Wind Loads on Buildings, and associated design tools such as BREVe (Cook 2001) can be updated to include data on potential future wind environments. However, the wide range of uncertainty in predictions of future wind speeds means that it is not yet possible to determine what changes to make to the code of practice. It must also be borne in mind that much of the impact of wind on the built environment is caused by buildings that do not comply with existing codes. There appears to be little point in refining codes of practice against a background of general non-compliance. A combined strategy of improved education and training in the construction industry, improved supervision during the construction process, changes to rules governing insurance claims[12] and an enhanced role for Building Control would be likely to be more effective. The development of such a strategy would be likely to require careful balancing of different interests, including the construction industry and the insurance industry, as well as information on possible future wind regimes.

There are a number of areas in which little or no existing work has been identified. The most obvious are centred on the impacts of higher summertime temperatures.

[12] It would, for example, be possible for insurance companies to seek to introduce a policy of seeking to recover damages from construction companies in cases where buildings fail at wind speeds lower than the design wind speed.

While significant work has been undertaken in the UK over the last 15 years to develop passive summer strategies for commercial buildings, this work has been predicated on a constant climate. It has, moreover, been almost completely disregarded by the UK construction industry – Queen's Building at de Montfort University, the Elizabeth Fry Building, BRE's B16 and Portcullis House are isolated exceptions. Predictions of changes in summertime temperatures over the next century suggest that purely passive strategies will work less and less well. At the lower end of the range of warming considered in UKCIP98, Birmingham in 2080 will be as warm as London now. At the upper end of the range, London in 2080 will be as warm as Bordeaux and Vienna now.

It would appear that a range of work is needed to:

- identity the theoretical and empirical climatic limits to different passive and semi-passive approaches.
- identify those regions of the country in which each of the approaches is likely to be viable, under the range of UKCIP scenarios, to 2050 and 2080.
- identify, develop and demonstrate strategies for extending the range of viability of the most promising passive and semi-passive approaches.
- identify, develop and demonstrate retrofit strategies for extending the useful life of buildings designed for passive or semi-passive summertime operation – such projects could be built around existing, high profile, passive and semi-passive buildings – it would for example be possible to design, implement and monitor a comprehensive retrofit of the Inland Revenue Building in Nottingham, which has suffered from significant overheating problems.

One of the obvious conclusions from the above is that it would be useful to develop more distinct regional approaches to design and construction of buildings in the future. This is conclusion is, however, inconsistent with the observed tendency, throughout the built environment, to minimise or eliminate regional variation. An obvious example is the use by many housebuilders of partial cavity fill techniques for all sites, regardless of the fact that cheaper and more effective full-fill options are technically viable on the overwhelming majority of UK construction sites (Lowe 2001a)[13]. The trends towards larger construction companies, many operating internationally, and towards prefabrication and industrialisation encapsulated by *Re-thinking Construction*, all tend to militate against regionalisation of construction. The development of systems and approaches that allow and promote appropriate regionalisation despite these trends, must be a matter of priority.

The development of passive methods of limiting heat gains in all classes of buildings should be a priority. Work is needed to:

- develop and demonstrate high reflectivity roof coverings and improved thermal insulation of building envelopes

[13] The author is also reminded of a conversation with the technical adviser for a major European window manufacturer, in the run up to a meeting in Helsinki to discuss the establishment of a European window energy rating system. The individual in question stated that for any given window, such a system must deliver the same rating for the whole of the EU lest it act as a restraint on trade - this despite the wide differences in climate and therefore in technical requirements of glazing in different parts of the Union. Happily, in this particular case, the argument for regionalisation prevailed.

- develop and demonstrate techniques for reducing internal heat gains in buildings- in particular through radical reductions in energy use by building services and IT systems
- develop improved guidance for building designers and specifiers on the performance of key envelope components such as fenestration – an obvious example would be to extend the emerging BFRC domestic window energy rating system to include information on impacts of glazing on cooling requirements of commercial buildings
- develop regulatory approaches to minimise overheating and/or cooling loads in all classes of new buildings
- develop and demonstrate aesthetic approaches to the design of new buildings that are consistent with high levels of technical and environmental performance[14]
- examine the practical constraints imposed on natural ventilation strategies in commercial & institutional and domestic buildings by transport systems – note that to do this successfully would require collaboration between an unusual combination of disciplines.

In the view of the author, it is essential to ensure that all RD&D work undertaken to improve the performance of buildings with respect to possible climate warming, is consistent with the goal of achieving deep cuts in green house gas emissions by the middle of the century.

Much work is already under weigh on riverine and coastal flooding and this needs to continue as a priority. Running through all areas examined in section 5 of this report is the need to continue to refine predictions of future climate. There is a clear need to develop and gain confidence in enhanced methods for downscaling output from GCMs to provide reliable regional estimates of risks of extreme events. It must however be borne in mind that estimates of future climate will remain subject to modelling uncertainties, probably for decades, as well as being subject to uncertainties in emissions profiles (the latter particularly towards the end of the century).

Over the next decade, there will be an increasing workload from the need to monitor the impacts of adaptation initiatives. One of the first examples of this is PPG 25.

Some of the most interesting work that might be done involves the examination of potential conflicts between different agendas. It would be useful to examine issues such as the apparent progressive loss of confidence within and independence of the planning system over the last 2 decades (Pearson 2001b). There is an interesting tension between the continued goal of reducing the burden of regulation on industry and the widely perceived need for more stringent and better enforced regulation as part of a strategy both for adapting to climate change and for mitigating its extent by reducing carbon emissions attributable to the built environment. This appears to be a question that falls within the remit of the ESRC, though to tackle it successfully would require collaboration between political and social scientists and technologists.

[14] Note that to be of any use, such work would need to involve construction and full evaluation of the designs produced.

One of the most interesting areas of discussion in the course of this project has been around the factors that may affect the industry's ability both to initiate and to respond to change. The construction industry has been dominated over a period of at least two decades by a drive to reduce the need for skilled labour on the construction site. There is evidence that this, in itself, reduces the industry's capacity to cope with technological change and the introduction of new systems of construction (Clarke, forthcoming). Whether or not this is correct, there is a case for looking at the potential education and training needs of an enhanced rate of technological change, whether as a result of the need to adapt to climate change or arising from other agendas. Specific questions include whether the capacity of the construction industry to deal with change is fixed – with the implication that different agendas for change need to compete for this capacity – or whether enforced change begets an enhanced capacity for change. A recent development that may enhance the industry's general capacity to cope with change is in post-construction performance assessment (Cohen et al 2001).

An improved understanding of the processes and dynamics of technological change may begin to establish why much of the construction-related research and development work funded over the last twenty years has not been applied - the example of passive and semi-passive environmental strategies for commercial and institutional buildings has already been given.

The author has suggested a number of possible reasons for slow deployment of apparently promising technical developments (Lowe 2001b), one of which is the lack of broad consensus supporting the formulation and implementation of integrated responses to climate change. The development of such a consensus, starting from a thorough understanding of the current views both in the construction industry and in wider society, would appear to be essential to the successful development and implementation of strategy. A starting point for such a consensus might well be a much wider and more formal test of opinions and attitudes than that undertaken as part of this study[15].

It has been suggested that there is an over-reliance on industrial funding and too little public funding in the UK, and that it is difficult to obtain funding for demonstration projects (Foresight 2000a). To the extent that this applies to construction related research, it is likely to be an additional reason for slow deployment and poor uptake of research. It appears that current funding mechanisms, in particular Partners in Innovation, are too short term and place too much weight on industrial co-funding to support the long term RD&D that is likely to be needed in connection with at least some aspects of climate change adaptation described above[16]. It is likely that the implications of this conclusion will be difficult to address, given that the development of public policy over the last two decades has been in the direction of more industrial funding and less direct public investment in all areas.

[15] It is perhaps indicative of the potential value of such work that several of those who read this report in draft found the Survey of Informed Opinion in section 6 the most interesting.

[16] The problem is even more serious in the context of mitigation. For example, absence of significant publicly-funded work on very low energy buildings over a period of at least two decades has led to a steadily widening gulf between cutting edge performance of UK buildings and those in parts of continental Europe (in particular in Germany, Denmark, Sweden, Austria and Switzerland) and North America. The relative insularity of the UK construction industry and the UK construction-related research community means that there is little awareness of developments elsewhere and widespread complacency about the situation in the UK.

It is important to keep the impacts on climate change in proportion. While, at any given location, climate change will rapidly drive weather outside the range of existing variability, weather at most UK locations will remain inside range of existing variability for the whole of the UK, and weather at all UK locations will remain inside the range of existing variability for Europe and North America. Adaptation to climate change is unlikely, for a century at least, to require anything that is not done somewhere already, either in the UK or in neighbouring countries. This is not to say that innovation is of no value. Improvements to the wheel will always be of value, but the UK construction industry and research community can afford to spend significant resources ensuring that they do not re-invent it. "Technology watch" projects, involving the deliberate search for techniques, products, systems and approaches in countries whose climates over the 20th Century approximate to one or other aspect of the UK climate of the 21st Century, will pay dividends. But once again, the UK construction industry displays a highly selective ability to absorb and deploy innovations made overseas. The successful deployment of such innovations may, for example, require publicly-funded demonstration programmes that are indistinguishable from those required by domestic innovations.

7.2 Competing drivers for change

As observed in Section 4 of this report, there are many drivers of change in the built environment and its supporting industries. These include:

- The general movement towards industrialisation, prefabrication and off-site construction encapsulated by Rethinking Construction (Construction Task Force 1998).
- Concern for the Health and Safety of employees in the construction industry.
- Changes in the structure of the industry through the processes of amalgamation and take-over, and in the nature of training for those working within the industry.
- The Europeanisation of the construction industry, both as a result of restructuring and as a result of the introduction of the single European Market.
- The process of economic growth, which, if it continues indefinitely even at 1% per annum, will lead to more than a 60% increase in economic activity by 2050 and to more than a two-fold increase by 2080 compared with the present.
- The impact of the far-reaching measures that are likely to be needed to control the emission of carbon dioxide and to control other environmental impacts from the built environment over the next 20-50 years - climate change mitigation.

One of the most important conclusions from this project is that there is a widespread lack of awareness in the literature on adaptation, of the importance of competing drivers for change and, most importantly, of mitigation. This is typified by, among others, Graves & Phillipson (2000) and POST (1998) – see Lowe (2001a). Two of the few counter-examples are Henderson (1992) who stated almost a decade ago that:

> "[…] the most important effects are likely to derive from initiatives to limit global warming by improving energy efficiency, rather than from the direct effects of climate change."

and the recent scoping study for Wales (ECOTEC 2000) which observes that:

> "This study concerns how Wales might adapt. Clearly, methods of adaptation need to be consistent with techniques for mitigation, and so integrated planning strategies will need to consider the two together. If you cope with higher temperatures by turning on the air conditioning, the additional fossil fuel required adds to the greenhouse effect."

This lack of awareness was reflected in the low importance assigned to mitigation by the individuals interviewed during stage 2 of this study. The single exception was Cooper of Eclipse Research Consultancy, who stated that mitigation would ultimately be a far more demanding problem for the construction industry than adaptation.

The lack of emphasis on mitigation is reflected in the academic community. For example, UKCIP's role is to investigate impacts of climate change and to develop adaptation strategies. There appears to be no parallel body in the UK whose role is the development and coordination of mitigation strategies or integrated response strategies. The primary risk, in the absence of such coordination, is that sub-optimal adaptation strategies will make the subsequent task of mitigation more difficult.[17]

7.3 Comparison with situation in other European countries

A brief web search was undertaken for work in the Netherlands on climate change alone, and on climate change and adaptation (klimaatverandering en aanpassing). This indicates a situation that is the inverse of that in the UK. Considerable work has been and is being undertaken on mitigation of climate change (RIVM 2000), but the author was able to find a handful of studies related to impacts (Baan et al 1993; Stuurgroep Windtechnologie 1994; Middelkoop et al 2001) and nothing dealing specifically with adaptation. Even where adaptation is discussed, it is in terms of coming to terms with the changes needed to mitigate climate change – for example to achieve 80% cuts in carbon emissions by the middle of the 21st century (see eg. COOL web site).

The situation in Germany may be similar. The German Government's recently published Guideline for Sustainable Building (Bundesministerium für Verkehr, Bau und Wohnungswesen 2001) deals entirely with minimising the impact of the built environment on the natural environment and says nothing about the need for adaptation. It would be useful to confirm with colleagues in both countries whether this is indeed the case.

7.4 Volume of work and research capacity

One of the most striking conclusions from this study is the rapid expansion that has taken place over the last 4 years in the volume of published work and the number of studies under weigh in the area of adaptation. From the industrial side, work has been led by the insurance and water industries through organisations such as ABI and the Centre for Risk Sciences. From the academic side, work is being undertaken and

[17] In thinking about mitigation, one is reminded of an old electricians' joke. Electrician to apprentice: Which is the most important wire in a ring main? Apprentice: It can't be the earth, because the system works fine without it… Electrician: It is the earth, precisely because the system works fine without it.

coordinated in a number of centres including UEA (Tyndall Centre, CSERGE and Jackson Environment Institute), at Cambridge (CURBE and CAR), Oxford (UKCIP and Environmental Change Institute), at Sussex (SPRU), at UCL (the Bartlett), de Montfort, and UMIST. There are doubtless other institutions that are either undertaking work or that have the capacity to undertake work. As in many other areas, BRE has played a significant role in this area over many years and CIRIA has played an important part in key areas. While, in the main this does not represent an expansion of capacity, it does represent a real reorientation of existing capacity.

All of this activity is underpinned by fundamental work on the science of climate change being undertaken by the Hadley Centre for Climate Prediction and Research and similar centres in the US, Canada and Germany as part of an international effort coordinated by the IPCC.

Work is being funded by industry, and by the research councils, ESRC and EPSRC. The EPSRC and UKCIP have recently announced a joint call for expressions of interest in work on climate change impacts on the built environment, transport and the utilities (EPSRC & UKCIP forthcoming). The Construction Research and Innovation Programme (DETR and now DTI) has funded work in this area (eg. SUDS), and in the latest call for proposals, Risk assessment and mitigation of the impacts of climate change is one of 13 priority areas for funding[18].

It is crucial to recognise that work is also proceeding at the European level (Parry 2000; European Commission 2000), and through international bodies such as CIB (Yates 1998). The European Commission's Energy, environment and sustainable development (EESD) research programme appears take an integrated view of climate change, with Key Action 2 referring to "Global and regional strategies to prevent, mitigate and adapt to global change".

The existence of a research capacity does of itself guarantee effective research. For example, while the Tyndall Centre and CSERGE possess considerable strength in areas such as climate science, economics, social science and technology policy, they appear to have a comparatively weak grasp on the built environment. On the other hand, centres of expertise in construction and building performance have historically been relatively ineffective contributors to policy making. It is clear that disjunctions such as this will need to be overcome if the UK is to develop effective and appropriate responses to the impacts of climate change on the built environment. Furthermore, the rapid development of this field means that significant expertise resides outside existing centres. If best use is to be made of all available resources, it is essential that institutional boundaries remain fluid and that lines of communication across the whole of the research community remain open. The task of the next half decade will be to ensure that solid links are built between the construction industry, the academic communities that most directly support it, and the economic, social science and technology policy communities more traditionally associated with policy formation.

[18] The 2001 call for proposals (DTI 2001) makes it clear that this priority area focuses on adaptation rather than mitigation in the sense that it is understood in the policymaking community.

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IPCC	2001	A Report of Working Group II of the International Panel on Climate Change. Technical Summary.	Geneva: IPCC.	"Adaptation options for coastal and marine management are most effective when they are incorporated with policies in other areas, such as disaster mitigation plans and land-use plans." "Human settlements are integrators of many of the climate impacts initially felt in other sectors […] As a consequence it is difficult to make blanket statements concerning the importance of climate or climate change that will not have numerous exceptions." "Population movements caused by climate changes may affect the size and characteristics of settlement populations, which in turn changes the demand for urban services." "However, insurance, whether provided by public or private entities, also can encourage complacency and maladaptation by fostering devevlopment in at-risk areas such as US floodplains or coastal zones." "The costs of extreme weather events have exhibited a rapid upward trend in recent decades [from] US$3.9 billion yr^{-1} in the 1950s to US$40 billion yr^{-1} in the 1990s (all 1999 US$, uncorrected for purchasing power parity)." 38-41. "Human induced climate change has the potential to trigger large-scale changes in Earth systems that could have severe consequences at regional or global scales. The probabilities of triggering such events are poorly understood, but should not be ignored, given the severity of their consequences." p72
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Shackley, S., Wood, R., Hornung, M., Hulme, M., Handley, J., Darier, E. & Walsh, M.	1998	Changing by Degrees - The Impacts of Climate Change in the North West of England: Technical Overview.	University of Manchester, Manchester. 63pp.	
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Watson, R.T., Zinyowera, M.F., Moss, R.H. &. Dokken, D.J.	2001	IPCC Special Report on The Regional Impacts of Climate Change: An Assessment of Vulnerability.	Geneva: IPCC	
Wood, D.W.	2000	Eliminating Waste – Towards a Sustainable Future. Presidential Address.	London: CIBSE	

Yates, T.J.S.	1998	Climatic variability and climate change – implications for design and construction.	in Proc. Conf. World Building Congress, Gävle, Sweden. pp 507-512.	The role of CIB Task Group 13 is to "begin to evaluate the sensitivity and vulnerability of the built environment to [climate change]." "It is said that the climate of a city such as Amsterdam will change to the present climate of Paris but at present it would be difficult to indicate differences in the durability of materials on these two cities or to demonstrate that the architect is responding to the slightly different climates rather than to national tastes or the available material."

Appendix 1 Semi-structured interview protocol

CRISP CONSULTANCY COMMISSION - 01/04

A REVIEW OF RECENT AND CURRENT INITIATIVES ON CLIMATE CHANGE AND ITS IMPACT ON THE BUILT ENVIRONMENT: IMPACT, EFFECTIVENESS AND RECOMMENDATIONS

Respondent’s name:

position:

organisation:

time and date:

interviewer:

1. What do you consider to be the 4 main drivers for change in the UK construction industry? (Egan, regulation, client demand…)
    1.
    2.
    3.
    4.

2. What ranking would you personally assign to these drivers? Does your view accord with the current status of programmes and initiatives in the UK in this area?

3. In your view, will climate change impact significantly on the built environment in the UK over the next 10 years?

   What about over the next 50 years?

   And by the end of the century?

4. My next question may appear to be asking the obvious, but the answer will nevertheless be of interest. Should research funding agencies and industry develop strategies for adapting the built environment to climate change?

5. What importance would you assign to the following sub-sectors of built environment:

housing	v. high...high…medium…low...v. low
commercial building	v. high...high…medium…low...v. low
health/education	v. high...high…medium…low...v. low
water and sewerage infrastructure	v. high...high…medium…low...v. low
transport infrastructure	v. high...high…medium…low...v. low
landscaping and open spaces	v. high...high…medium…low...v. low
coastal defence	v. high...high…medium…low...v. low
river defence	v. high...high…medium…low...v. low
other (please state)	v. high...high…medium…low...v. low

6. What importance would you assign to the following activities? How effectively are they being covered at present?

   refinement of climate predictions v. high...high…medium…low...v. low

   identification & quantification of impacts
   v. high...high…medium…low...v. low

   technical development of products and systems to address impacts of climate change v. high...high…medium…low...v. low

   development/adaptation of regulatory structures to enforce climate-adapted practice v. high...high…medium…low...v. low

   development/adaptation of design guides and codes of practice to facilitate climate-adapted practice v. high...high…medium…low...v. low

   studies of economic factors relating to climate change (evaluations of future costs, cost effectiveness of possible adaptations, identification of break-even points, identification and development of economically optimal response strategies [no action, delayed action, early action], analysis of mechanisms for conveying importance of adaptation to today's decision makers, identification and investigation of possible market failures…)
   v. high...high…medium…low...v. low

   studies of social factors relating to climate change (identification of stakeholders, winners and losers, studies of innovation mechanisms, attitudes to alternative adaptation strategies…)
   v. high...high…medium…low...v. low

   Provision of public/user information on impacts and responses to climate change
   v. high...high…medium…low...v. low

7. What in your view is the relative importance of climate change for existing buildings and infrastructures and new build?
   new build more important
   equal importance
   existing stock more important

8. Would you describe the response of the UK as a whole in the area of impacts and adaptation as:
   strong…medium…weak

9. Would you describe the historical and present engagement of your own organisation with this issue as:
   strong…medium…weak

10. How important do you expect research on impacts of climate change on the built environment to be by 2005?

    v. high...high…medium…low...v. low

11. How important do you expect your own organisation's role or interest in research on impacts and adaptations to climate change in the built environment to be by 2005?

    v. high...high…medium…low...v. low

12. To what other industries or sectors of the economy can one look for good examples of effective responses to the problems posed by climate change ?

13. How important, in your view, is overseas experience of the development of climate change response strategies likely to be?

14. If one-off or on-going studies of responses in other countries were to be undertaken, which countries do you think it would be most rewarding to focus upon?

15. Comment on the likely future effectiveness, in this area, of:
    - UK research council programmes
    - DTI/DLTR sponsored programmes
    - EU sponsored programmes
    - construction industry programmes
    - insurance industry initiatives
    - other industry initiatives (eg. water)
    - joint initiatives (DLTR/EPSRC/ESRC/industry)

16. In your view, can the problem of climate change be addressed effectively through existing programmes and funding mechanisms? Are there areas of activity that are not being funded or supported at present?

Appendix 2 Further analyses of impacts and adaptations

Impacts and adaptations for coastal and estuary defence

Nature of Climate Change	Raised sea level and increased storm surges
Magnitude and timescale of change	Range for all four UKCIP98 scenarios is 22-83 cm in 2050 in East Anglia. Sea level rise under UKCIP98 medium-low and medium-high scenarios is 29-37 cm in 2050 in East Anglia. Rise is less in North of country due to isostatic adjustment. Sea level is expected to continue to rise well beyond 2100, even under emissions scenarios in which global CO_2 emissions rates fall in second half of century (IS92c, SRES B1). For IPCC scenarios roughly equivalent to UKCIP98 medium-low and medium-high scenarios, the rate of rise is likely to increase in the second half of the century. But, sea level rise is very uncertain, with large variations between different models (TAR – IPCC 2001). The range of sea level rise in 2100 for all SRES scenarios 9 (including all sources of uncertainty discussed in section 4.2) is from under 10 cm to around 85 cm.
Impacts	Coastal and estuary defence
Nature and timescales of possible adaptations	enhanced and new sea defences, design of new sea defences for future upgrade, managed retreat, improved warning systems, increased emergency service capacity, design of new buildings to cope with periodic floods, retrofit of existing buildings to cope with periodic floods primary impact depends on nature of settlement patterns and patterns of development – response time of many decades possible response times in terms of defence need to be investigated
Relationships to competing drivers for change	agricultural policy, conservation of coastal and estuarine wetlands, historical concentration of development in SE. others unclear

Relationship to planning/design/ construction/ occupation/ refurbishment/ demolition or de-construction cycle	strong relationships at all levels
location of possible adaptations along the urban design/ infrastructure/ building envelope/ building services/ building management axis	potential adaptations at all levels
cost of impact without adaptation	unclear, but possibly very high
costs of early and delayed adaptation	unclear
analysis of stakeholders	insurance companies, local authorities, building owners, land owners, general public
summary of work done	initial studies by insurance industry and UKCIP
priority for further work	high priority
nature of possible future work	to be investigated – likely to take place across a broad front

Impacts and adaptations for transport systems

Nature of Climate Change	high wind speed and increased peak rainfall
Magnitude and timescale of change	up to 7% increase in wind speed in Scotland by 2080 winter rainfall increases by 12 and 22% (medium-low and medium-high scenarios)
Impacts	airports and air traffic control: • higher wind speeds impacting on air traffic movements • potential for damage to ground installations from wind storms rail: • wind damage to overhead lines, bridges • damage to track and track bed due to land slip and erosion • flooding risk at stations • flooding and landslip risk at tunnels • debris • flooding risk to underground rail systems, particularly in London road • road surfaces (melting tarmac) • bridges • information gantries • high-sided vehicles • debris shipping - port facilities
Nature and timescales of possible adaptations	much transport infrastructure replaced or completely refurbished at 20 – 30 year intervals allowing adaptations to be incorporated as climate change unfolds
Relationships to competing drivers for change	European and UK policy for transport Transport policy likely to be strongly affected by need to incorporate mitigation strategies

Relationship to planning/design/ construction/ occupation/ refurbishment/ demolition or de-construction cycle	strong relationship to planning and design
location of possible adaptations along the urban design/ infrastructure/ building envelope/ building services/ building management axis	urban design and infrastructure
cost of impact without adaptation	to be determined
costs of early and delayed adaptation	to be determined
analysis of stakeholders	UK government, European Union, rail industry, civil aviation industry, transport unions, general public, CEN, engineering institutes
summary of work done	to be determined
priority for further work	medium?
nature of possible future work	to be determined

Impacts and adaptations for planning process

Nature of Climate Change	changes in rainfall patterns, more rainfall in winter
Magnitude and timescale of change	increase of 6-13% in SE by 2050, increase of 6-23% in SE by 2080 (UKCIP98)
Impacts	increased risk of flooding for buildings in flood plains increased risk of flooding for buildings elsewhere due to inability to control surface water
Nature and timescales of possible adaptations	more vigorous application of existing guidelines on floodplains - 5 years? measures to achieve “market transformation” of planning process through partnership with insurance industry - 10 years?
Relationships to competing drivers for change	• need for new housing • need to maintain viability of construction industry • regional policy (balance of development in SE and rest of UK) • goal of reducing burden of regulation and planning on construction industry
Relationship to planning/design/ construction/ occupation/ refurbishment/ demolition or de-construction cycle	inter-relationship between measures in new and existing buildings relationship with design of new buildings and refurbishment of existing
location of possible adaptations along the urban design/ infrastructure/ building envelope/ building services/ building management axis	main impact at the urban design level
cost of impact without adaptation	potentially very high. ABI estimates that 1.2 million inland dwellings are at risk from flooding, and 350,000 are currently earmarked for development on flood plains

costs of early and delayed adaptation	need to be explored
analysis of stakeholders	insurance industry, housebuilders, property developers, planning community, Environment Agency, central Government, emergency services, general public
summary of work done	work going back to early 90s (Parry & Parry 1991)
priority for further work	high
nature of possible future work	investigation of conflicting pressures within planning process continued development of planning policy guidance continued development of flood risk maps continued development of underlying climate science other work to be determined