SKCC Briefing Paper 2: Applying probabilistic climate information for the built environment and infrastructure – the issues and challenges

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SUMMARY

- The first SKCC workshop held in Norwich in November 2006 focused on the use of probabilistic climate information for built environment and infrastructure impacts and adaptation assessments.
- SKCC Briefing Paper 1 was produced before the workshop and provides a general background to probabilistic climate projections for non-specialists.
- SKCC Briefing Paper 2 was produced after the workshop, and provides a summary of presentations and discussions, as well as identifying key messages.
- The workshop re-iterated the benefit to users and stakeholders of moving towards a probabilistic approach.
- Nontheless, a number of communications challenges remain.
- Thus a major recommendation is to develop an integrated set of case studies of increasing complexity, that demonstrate how probabilistic climate information, such as being produced for UKCIP08, can be used in impacts and adaptation assessments.

INTRODUCTION

A series of workshops form part of the SKCC programme. The first of these - on 'The Use of Probabilistic Climate Scenarios in Impacts Assessment and Adaptation Studies' - was held at the University of East Anglia, Norwich on 10 November 2006. SKCC Briefing Paper 1 was prepared in advance of the workshop to provide a general background to the issues both for workshop participants and a wider readership, building on work undertaken as part of the Building Knowledge for a Changing Climate (BKCC) CRANIUM project.

Briefing Paper 2 was produced following the workshop. It provides a summary of key messages from the workshop, drawing together material from the presentations and the break-out group discussions. One major recommendation from the workshop was the need for demonstrative case studies. Thus two UK case study examples are presented here, focusing on the key issues to be addressed. Finally, relevant work being undertaken in the European Union funded ENSEMBLES project is outlined.

THE NORWICH SKCC WORKSHOP

Workshop objectives and participants

The first SKCC workshop attracted over 40 participants and had the following objectives:

- To bring together climate scientists, scenario end users and stakeholders with an active interest in the impacts of climate change on the built environment, infrastructure and utilities
- To examine how probabilistic climate information be used in practice for planning, design and management of the built environment and infrastructure systems
- To identify potential engineering and science research challenges arising from the use of probabilistic climate information
- To help prepare the end-user community for the arrival of probabilistic projections (such as UKCIP08), so that they can be used most effectively when they emerge
- To disseminate the new climate and socio-economic scenarios work from the BKCC BETWIXT, CRANIUM and BESEECH projects

The move towards the development and use of probabilistic climate information is still at a relatively early stage. Therefore the workshop was of primary interest to academic researchers (31 of the participants) – both climate scientists and scenario end users from SKCC and other research programmes with an active interest in the impacts of climate change on the built environment. A number of stakeholders also took part.

All the oral and poster presentations from the workshop are available on the SKCC web site – http://www.k4cc.org/events/workshops/probablistic-scenarios-workshop-review, along with rapporteur reports from the break-out group discussions. In this briefing paper, key messages from the workshop are summarised.

Workshop presentations

The workshop kicked-off with a stakeholder perspective from Jake Hacker of Arup who outlined some of the potential benefits and concerns about the move to a probabilistic approach. While concluding that probabilistic projections are a good thing and must be the way forward, he stressed the importance of communication of the physical meaning of the probabilities in ensuring their correct use by stakeholders. He also warned of the danger of 'switch off' if dissemination isn't pitched right and that the increasing complexity of impacts assessments may not necessarily be beneficial. One challenge will be to ensure take-up of probabilistic projections in areas which do not currently take a probabilistic approach to risk assessment.

Geoff Darch of Atkins Consultants spoke from the perspective of an end user and re-iterated the value and interest in probabilistic projections to end users. He also stressed the importance of communication with respect to some of the more technical aspects. In particular, it is important to be explicit about the uncertainties that are and are not incorporated in probabilistic projections, and to make users aware that projections such as UKCIP08 are conditional on the emissions scenario. He also argued for end user involvement in the development of weighting techniques (see Briefing Paper 1), giving the

example of flood forecasting and water resource assessments which may require different weighting approaches (e.g., based on rainfall-runoff model calibration).

Clare Goodess outlined climate projections for the built environment constructed as part of the BETWIXT and CRANIUM projects – see Briefing Paper 1; Goodess et al., 2007; Walsh et al., 2007; www.cru.uea.ac.uk/projects/betwixt; www.cru.uea.ac.uk/projects/cranium. Roger Salmon presented the BESEECH socio-economic scenarios for the built environment (Walsh et al., 2007). David Sexton and Geoff Jenkins outlined preparations for UKCIP08 which will incorporate probabilistic projections over land and for marine areas surrounding the UK (http://www.ukcip.org.uk/scenarios/ukcip08/).

The final three oral presentations discussed pioneering work being undertaken in the water sector, where the development and use of probabilistic projections is more advanced than other sectors.

First, Rob Wilby described the emerging use of probabilistic climate and impacts scenarios (Wilby and Harris, 2006) in the Environment Agency, focusing on work undertaken with Mark New and Ana Lopez of Oxford University on water resource assessment in the Thames Basin. This work combines output from the thousands of climate simulations undertaken in the climateprediction.net initiative with the Catchmod water balance model in order to explore different aspects of probability and uncertainty (New et al., 2007; http://www.k4cc.org/Members/Claire/Alopez.pdf). Examples were presented of risk expressed in terms of environmental standards and uncertainty expressed in timing of adaptation responses. Some of the challenges identified by Rob include the translation of new insights of uncertainty into practical guidance for decision making and the representation of uncertainty in terms of timing, together with the technical challenges of extreme events.

Second, Suraje Dessai outlined lessons learnt from working with probabilistic climate projections and Anglian Water in order to explore potential adaptation options given the decreasing surface water resources indicated by the climate scenarios (Dessai, 2005; Dessai and Hulme, 2007). It was concluded that probabilistic climate information provides more information - at least in terms of likelihood - than deterministic climate scenarios. It also fits well with current water resources planning guidelines, in particular with the concept of headroom, which is probabilistic, but there are many methodological difficulties in constructing probabilistic climate projections because of the presence of deep uncertainties. The sensitivity of decision making to the different sources of uncertainty (model, emissions, natural variability, etc.) was found to vary. In general, the adaptation options identified were found to be robust – though this was rather fortuitous - due to the focus on a rather 'dry' climate model. Finally, it was noted that this research raises the question of how much certainty is required in climate change projections to justify investment in adaptation measures.

Third, Rob Lempert from RAND, California described a series of workshops held with water managers in California to explore the response of decision makers to three different ways of representing uncertainty, i.e., conventional scenarios, probabilistic projections and scenarios derived from a robust decision-making process (http://www.rand.org/ise/projects/improvingdecisions/). 'Real-time' surveys were conducted to measure participants' understanding of concepts and willingness to adjust policy choices. It was concluded that traditional scenarios appeared to give participants much of the information they needed. However, the introduction of probabilities raised the potential of low likelihood, extremely large water shortages and quickly prompted discussion of the strengths and limitations of adaptive capacity. Finally, the robust decision-making scenarios provided some additional information on the most important drivers of change.

These plenary presentations, and a chance to view relevant posters (http://www.k4cc.org/events/workshops/probablistic-scenarios-workshop-review) over lunch, paved the way for two break-out group discussions in the afternoon. These groups focused on (1) lessons from using climate change scenarios in BKCC and other projects and (2) are we ready for probabilistic projections?

Break-out group one: Putting theory into practice – lessons from using climate change scenarios in BKCC and other projects

The original aims of this break-out group were to:

i. review how climate scenario information was handled in a number of the BKCC projects and other relevant built environment impacts and adaptation projects

ii. consider whether you could have modified your approach or would you have done things differently if the information had been probabilistic?

iii. discuss the implications for adaptation and decision-making as a result of using probabilistic-type information

iv. draw any common messages from the case studies discussed

With respect to the first aim, the discussion focused on the use of deterministic, 'story-line' scenarios based on UKCIP02 in studies of slope stability, thermal risk to buildings (http://www.ukcip.org.uk/resources/publications/pub_dets.asp?ID=69) and case studies in Manchester and Lewes undertaken as part of the ASCCUE project (http://www.k4cc.org/Members/Claire/John%20Handley_ASCCUE.doc). Some of the complexities in relation to the second aim are illustrated by two examples from work undertaken by the University of Newcastle as part of the CRANIUM project (Walsh et al., 2007; http://www.k4cc.org/Members/Claire/Lucy%20Manning_CRANIUM.ppt). A weather generator (Kilsby et al., 2007) is used to analyse spatially distributed problems, firstly for the stability analysis of a railway line (which needed joint probabilities of rainfall and potential evapotranspiration at potential failure sites) and secondly for predictions of flows in the Thames, which require predictions based on spatially-averaged information. The railway line study was done with one climate model, from UKCIP02, while the Thames study uses the PRUDENCE regional climate model set, allowing exploration of the downscaling uncertainties (see Briefing Paper 1). Joint thresholds were also required in the example of a CLIFFS case study to examine the effects of climate change on the reactivation of the landslide on Mam Tor (http://www.k4cc.org/Members/Claire/Neil%20Dixon_CLIFFS.ppt): in this case for one-month and six-month antecedent rainfall, indicating the importance of event sequences for some applications.

In practice, the third aim above was not really addressed in any detail, although there was considerable discussion of communication issues and challenges. It was suggested that communication could be condensed into two types of presentation: (a) probability distributions; or, (b) thresholds of exceedence, or non-exceedence of benchmark historical events. Whatever form of presentation is used, it is important for users and stakeholders to trust the underlying climate models. Though it was noted that users sometimes seemed to expect greater certainty in climate information than in other information about the future. Even at the present-day, large uncertainties can exist in non-climate information, e.g., in the material properties of slopes or embankments.

It was concluded that it is in theory possible to use probabilistic rather than deterministic information in the types of impacts and adaptation assessments of the built environment and

infrastructure undertaken in BKCC and other UK projects. However, there are a number of issues with respect to:

- joint probability events
- time series information
- spatial consistency of information
- provision of data at a useful resolution.

Break-out group two: Are we ready for probabilistic projections?

The second break-out group discussed four key questions (and some suggested subsidiary questions) which emerged from preliminary discussions with researchers and stakeholders during the CRANIUM project:

1. *What do users need/want to know about the representation of uncertainties and probabilistic climate projection construction methods?*

   - What uncertainties can we reasonably expect to be represented in climate projections for impacts assessments?
   - And what underlying assumptions will still have to be made?
   - What guidance can/should be provided to help users take account of uncertainty?
   - How explicit do information providers need to be about the nature of the various uncertainties and how they are (or are not represented)?

2. *How can the utility for users of probabilistic-type climate information be enhanced?*

   - How do users want to access information?
   - How can it be presented most usefully to different audiences – eg., for impacts users, for decision-makers, for less technical users?
   - Are probability or cumulative distribution functions (PDFs and CDFs) the most appropriate way of representing the uncertainties? What are the alternatives (e.g., probability bounds, two- or three-dimensional response surfaces)? What if users want maps?
   - How important is time-series data?
   - What communications/visualisation challenges and opportunities will all this bring?

3. *What are the implications for assessment and decision-making processes of using probabilistic information?*

   - Are industry approaches to climate variability sufficiently advanced to cope with new probabilistic information on climate change?
   - Can climate change impacts be described in probabilistic terms?
   - How does this information fit with current decision-making processes (and attitudes to risk) and what changes to these processes will be needed?
   - Does the use of probabilistic information impact on the decisions that can and cannot be addressed?

4. *What, based on experience so far, are the advantages and disadvantages of probabilistic, compared with non-probabilistic, information for assessment and decision-making processes?*

- Are there any examples of industry using (or preparing to use) probabilistic information on climate change?
- If so, what lessons can be learnt?
- Are there any lessons to be learned from the use of probabilistic weather forecasts to support decision making?

This session started with very brief presentations by Roger Street (Information needs of UKCIP stakeholder community), Geoff Jenkins (UKCIP08 and some answers to the key questions), Tom Dijkstra (Climate impacts forecasting for slopes), Tim Randle (Climate change impacts and probabilistic scenarios for Forest Research), Mark New (Issues in probabilistic climate data) and Alan Pearman (Are we ready for probabilistic scenarios?). The group then divided into two to discuss the above questions. Due to the lack of time and the complexity of the issues, it was not possible to address all the subsidiary questions. Nonetheless, some interesting and important points arose from the discussion, particularly with respect to the potential use of the forthcoming UKCIP08 scenarios (http://www.ukcip.org.uk/scenarios/ukcip08/) in built environment and infrastructure impacts and adaptation assessments.

It was agreed that there is strong contrast between developers of probabilistic projections, such as probability density functions (PDFs), and users of PDFs. Many users are keen on having lots of information to make decisions, but at the same time want a lot of guidance. Such users don't particularly want to know much about uncertainty and why they should consider it.

However, in complete contradiction, some people do want to see lots of transparency about the decisions made in developing the PDFs, to gauge how much these decisions affect their decision. This attitude was welcomed, since this is one of the main points and benefits of an uncertainty analysis. Uncertainty analysis could be described as a sensitivity test to all the various choices that are made along the way.

The quantification of uncertainty was seen as important both for detailed technical assessments and for persuading people who otherwise might argue that the uncertainties are too great to consider doing anything. The availability of probabilistic information will also facilitate the cost benefit analysis of adaptation options in response to specific impacts and will therefore allow full decision making based on defined risks. This is seen as a big advantage where established procedures exist for decision making, e.g., in the flood defence community.

Discussion also focused on 'how will delivery of PDFs work in practice'? It was agreed that lots of guidance is needed and that this requires a huge communication exercise. At the most basic level, this should include very simple explanations of PDFs and uncertainty and why users shouldn't just pick one deterministic scenario. It was also seen as important for guidance to evolve on the basis of users' experience. A good starting point was seen as a series of case studies which would demonstrate the benefits of a probabilistic approach and illustrate some of the practical issues and solutions. These case studies should reflect the ability of different user communities to cope with different complexities of information.

Demonstration of the advantages of a risk-based decision making approach, coupled with information about changes in relevant threshold events, is seen as very important in terms of encouraging use of probabilistic projections. Much of the climate information required is already available, or can be provided, if the developers of this information know the events and thresholds of interest to users.

The importance of different communities, such as climate scientists/end users or academia/consultancies, working together was stressed. This is seen as particularly important for industry and regulators since the climate change adaptation process may be slow without changes in relevant codes and regulations. Professional bodies were also thought to have an important role in promoting take up of climate information, particularly for sectors outside the water industry.

Finally, it was argued that climate information needs to slot into existing practices – and case studies would be a good way to illustrate this potential. This is exactly the approach being followed by the Environment Agency who are looking at existing processes, parameters, etc. and seeing how climate change information can be incorporated.

Key messages

The Norwich workshop provided clear support and evidence of the benefits of moving towards a probabilistic framework for climate change assessment and decision making. However, the communication challenges are substantial. Thus a strong recommendation from the workshop is the need for the development of an integrated set of case studies that show, in an increasingly comprehensive way, how probabilistic climate projections can be used to plan for the future. These case studies should include all relevant methodologies of acquiring, managing and manipulation of data to act as guidance that can be readily adapted by a range of potential users.

UK CASE-STUDY WORK

Following the Norwich workshop, the UEA team appealed for any SKCC researchers and/or stakeholders who would be interested in using the CRANIUM probabilistic projections (www.cru.uea.ac.uk/projects/cranium) – either quantitatively or qualitatively. Possibilities here are still being explored – please contact Clare Goodess (c.goodess@uea.ac.uk) if you would like to discuss this. In the meantime, relevant issues are being explored as part of the EPSRC funded SCORCHIO project and with respect to buildings (see below).

The UKCIP08 User Interface (http://www.ukcip.org.uk/scenarios/ukcip08/) will, at the time of launch, include a series of worked examples, intended to provide for a range of users, guidance on how the provided information can be used. A number of case studies will also be developed post-launch.

SCORCHIO

This EPSRC-funded research project (lead by The University of Manchester – Professor Geoffrey Levermore) aims to develop tools that use UKCIP08 to help planners, designers, engineers and users to adapt urban areas (demonstrated through work in Manchester and Sheffield), with particular emphasis on heat and human comfort. This research will develop a PC-based climate simulator for assessing climate change impacts and adaptation measures in urban areas; modelling typical buildings for the purpose of developing a heat and human comfort vulnerability index; estimating heat from buildings to understand adaptation options; and to develop computer map-based methods for examining adaptation options in planning and design. This is a three-year project with work having begun in April 2007.

The BKCC/SKCC UEA team is also involved in SCORCHIO, along with the CURE team from Manchester which led the ASCCUE project. Thus SCORCHIO will provide an opportunity to extend the ASCCUE work which took a deterministic scenario approach

(http://www.k4cc.org/Members/Claire/John%20Handley_ASCCUE.doc) to encompass a probabilistic approach. The new scientific challenge will be to combine probabilistic information from the UEA weather generator (which has so far only been applied to individual locations in CRANIUM) with high-resolution spatial information (see Break-out group one discussion above) across the Manchester conurbation, together with outputs from new regional climate model simulations undertaken by the Hadley Centre exploring potential future changes in the urban heat island.

Buildings research

EPSRC has issued a call for research proposals related to the use of probabilistic climate projections in adaptation decisions within the buildings sector. The expectation is that the research projects funded will focus on the practical application of probabilistic climate information in the planning, design and construction of new buildings, and retrofitting and maintenance of existing buildings. The research is expected to address the challenges and associated tensions around the capacity to accept probabilistic information and its integration into regulations, standards, best practices and policy - much of which is based on a relatively deterministic approach. The call has closed and those successful at the initial level of application participated in a network meeting in early June 2007 to facilitate the further development of the proposals and their relationships with the stakeholder community.

Proposals were requested to include a strong stakeholder involvement, including from the Chartered Institution of Building Services Engineers (CIBSE). CIBSE has recently set up a Climate Information Task Force to consider future provision of weather data for environmental design of buildings.

Successful applicants will have access to the UKCIP08 User Interface at the time of launch and may also have access where it is deemed beneficial to dummy or example outputs of UKCIP08 prior to the launch. Applicants were asked to also consider using the CRANIUM probabilistic projections. Announcements about successful applications are expected in December 2007.

EUROPEAN RESEARCH – THE ENSEMBLES PROJECT

The European Union funded ENSEMBLES project aims to develop an ensemble prediction system for climate change to produce an objective probabilistic estimate of uncertainty in future climate at seasonal to decadal and longer timescales. The exploitation of the ENSEMBLES results is maximised by linking the predictions to an extensive range of applications including agriculture, forestry, human health, water resources and energy use and demand. ENSEMBLES is co-ordinated by the Met. Office Hadley Centre and involves 66 institutions including UEA. Clare Goodess is co-ordinating work on regional scenario development within the project. The five-year project will finish in August 2009.

An ENSEMBLES regional scenarios web portal (http://www.cru.uea.ac.uk/cru/projects/ensembles/ScenariosPortal/) was launched in June 2007. It is intended to provide easy access to regional climate information and results for ENSEMBLES applications users as well as the wider user community. Much of the available material is relevant to the topics of this briefing paper and the workshop discussions.

Here, three areas of ongoing ENSEMBLES work which may be of particular interest to end users and stakeholders are outlined.

A questionnaire was circulated to ENSEMBLES partners in early 2007 seeking information from potential end users about their needs and requirements for climate scenario data and tools. In particular they were asked about the preferred formats for probabilistic regional climate projections (in a similar consultation exercise to that conducted as part of the UKCIP08 preparations). The majority of respondents were academic researchers from across Europe, including those modelling climate change impacts. The preference from most respondents was for PDFs, but at the same time most also wanted access to daily time series data. Users were also interested in having maps and information about threshold events and joint probabilities. However, very few users were able to give examples of the kind of joint probability events they are interested in. Although the responses were generally positive, it is evident that many users are not yet in a position to clearly specify their requirements with respect to probabilistic inputs. As in the UK, this demonstrates the need for good communication. The questionnaire results are currently being written up and will shortly be available from the regional portal (as document D2B.18).

One user need that was expressed at an early stage of ENSEMBLES was for statistical downscaling tools. This need has been met by a web-based statistical downscaling portal developed by the University of Cantabria in Spain - http://grupos.unican.es/ai/meteo/ensembles/index.html. This allows users to choose a method of statistical downscaling and produce high-resolution predictions either using as predictands (target data), observational datasets already mounted on the server or data uploaded by the user. In this portal, GCM forecasts (seasonal-to-decadal and climate change) can be downscaled to local stations or uniform observation grids using any of the available downscaling algorithms. This process is performed from a web browser following three steps: predictor selection, predictand selection and downscaling method. Currently, the portal allows downscaling of seasonal-to-decadal hindcasts (from the DEMETER and ENSEMBLES projects) over Europe. It will be extended to end-of-the-century climate change timescales and some non-European regions (e.g., West Africa) during later stages of the project. A key feature of the development of the downscaling portal is that this has been done in collaboration with two applications users with an interest in seasonal prediction – JRC in Italy who are interested in agricultural yield projections for Europe and EDF in France who are interested in prediction of energy demand in France. A journal paper on these two case studies will be produced in 2008.

A number of the impacts applications groups involved in ENSEMBLES are exploring methods for using probabilistic outputs directly in newer, simpler impacts models. In particular, a technique know as response surfaces (Luo et al., 2005) is being evaluated. This work is still at an exploratory stage but appears to be promising. It will eventually be reported via the ENSEMBLES Research Theme 6 web pages - http://pcwww.liv.ac.uk/avam/projects/ensembles_eu/ensembles_RT6_home.htm.

CLOSING REMARKS

This briefing paper provides a summary of the first SKCC workshop held in November 2006 which focused on the use of probabilistic climate information for buildings and infrastructure. Although the UK is leading international research in this area, the fact that this is still very much work in progress, particularly with respect to the development and dissemination of the high-resolution information which is essential for built environment impacts assessments and adaptation studies, is reflected in the extent to which it was possible to meet all the workshop objectives and address all the questions identified beforehand. Although many issues and questions remain, in part due to the rather short time available for discussion, the workshop nonetheless reached some important conclusions and made some major recommendations. In particular, the need to develop a set of case studies of varying complexity demonstrating the use of probabilistic climate information, has already been taken on board both with

respect to preparations for UKCIP08 and the EPSRC research agenda. Thus BKCC and SKCC activities continue to play a major role in making climate change science accessible to end users and stakeholders in the built environment and infrastructure, as well as complementing European research initiatives such as the ENSEMBLES project.

FURTHER READING AND RESOURCES

Dessai, S., 2005: *Robust Adaptation Decisions and Climate Change Uncertainties*, PhD Thesis, University of East Anglia, Norwich.

Dessai, S. and Hulme, M., 2007: Assessing the robustness of adaptation decisions to climate change uncertainties: A case study on water resources management in the East of England, *Global Environmental Change*, **17**,59-72.

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Kilsby, C.G., Jones, P.D., Harpham, C., Burton, A., Ford, A.C., Fowler, H.J., Smith, A. and Wilby, R.L., 2007: A daily weather generator for use in climate change studies. *Environmental Modelling and Software*, **22**, 1705-1719.

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New, M., Lopez, A., Dessai, S. and Wilby, R., 2007: Challenges in using probabilistic climate change information for impacts assessments: an example from the water sector, *Philosophical Transactions of the Royal Society A,* **365**, 2117-2131, doi:10.1098/rst.2007.2080.

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Wilby, R.L. and Harris, I., 2006: A framework for assessing uncertainties in climate change impacts: low flow scenarios for the River Thames, UK, *Water Resources Research*, **42**, W02419,doi:10.1029/2005WR004065.

Workshop presentations and reports:
http://www.k4cc.org/events/workshops/probablistic-scenarios-workshop-review

CRANIUM: http://www.ncl.ac.uk/cranium/
CRANIUM climate scenarios website: http://www.cru.uea.ac.uk/cru/projects/cranium/.

BETWIXT: http://www.cru.uea.ac.uk/cru/projects/betwixt/

ENSEMBLES regional scenarios web portal:
http://www.cru.uea.ac.uk/cru/projects/ensembles/ScenariosPortal/
ENSEMBLES statistical downscaling tool:
http://grupos.unican.es/ai/meteo/ensembles/index.html

UKCIP08: http://www.ukcip.org.uk/scenarios/ukcip08/

Climate*prediction*.net: http://www.climateprediction.net/

RAND project on Making Better Decisions When Confronted with Deep Uncertainty About the Future:
http://www.rand.org/ise/projects/improvingdecisions/

EPSRC call on The Use of Probabilistic Climate Scenarios in Adaptation Decisions within the Buildings Sector**:**
http://www.epsrc.ac.uk/CallsForProposals/Archive/AdaptationToClimateChange.htm