SKCC
Sustaining Knowledge for a Changing Climate

Linking adaptation and mitigation strategies

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Executive Summary

The United Nations Framework Convention on Climate Change (UNFCCC) identifies two options to address climate change: mitigation by reducing greenhouse gas emissions and enhancing sinks; and adaptation to the impacts of climate change. Mitigation refers to anthropogenic intervention to reduce sources or enhance the sinks of greenhouse gases. Adaptation refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate, harm or exploit beneficial opportunities (IPCC, 2001).

Both mitigation and adaptation seek to avoid the potential damages of global climate change, and they both seek to support the development of present and future generations in a sustainable manner. However, the influence and incidence of employing them as climate policy instruments are different. Despite the differences between adaptation and mitigation strategies, both are essential in reducing the risks of climate change. However, further research is needed to identify the synergies and conflicts that exist between mitigation and adaptation agendas. It may be counterproductive to force integration of the two strategies. However, many adaptation options are pathways to effective and long-term mitigation, like-wise mitigation options can facilitate planned adaptation. Adaptation and mitigation options should be considered in a framework of sustainable development and should therefore avoid conflicts with each other.

Climate change and sustainable development have been addressed in largely separate circles both in terms of research and policy; however, the need to connect the two is becoming increasingly recognised in the climate change literature. Climate change vulnerability, impacts and adaptation will influence prospects for sustainable development, and in turn, alternative development paths will not only determine greenhouse gas emission levels that affect climate change, but also influence future capacity to adapt to and mitigate climate change. A more sustained effort to consider the linkages between climate change and sustainable development has been conducted in the IPCC Fourth Assessment.

The design of integrated and effective climate policy is a significant challenge. However, climate policy is shifting from being synonymous with energy policy to sharing a large interface with sustainable development.

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) identifies two options to address climate change:

- Mitigation of climate change by reducing greenhouse gas (GHG) emissions and enhancing sinks;
- Adaptation to the impacts of climate change.

Mitigation refers to anthropogenic intervention to reduce sources or enhance the sinks of GHGs. Adaptation refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate, harm or exploit beneficial opportunities (IPCC, 2001).

The commitment by the signatories of the Kyoto Protocol and an increasing number of other countries to stabilising atmospheric greenhouse gas concentrations, will not prevent climate change in the next few decades because of the lag times in the global climate system response (see Figure 1). Adaptation is therefore necessary. Adaptation responses and decisions can be categorised as measures and strategies that contribute either to:

- *Building adaptive capacity* – creating the information (research, data collecting and monitoring, awareness raising), supportive social structures (organisational development, working in partnership, institutions) and supportive governance (regulations, legislations and guidance) that are needed as a foundation for delivering adaptation options; or
- *Delivering adaptation actions* – actions that help to reduce vulnerability to climate risks, or to exploit opportunities.

However, reliance on adaptation alone could lead to a magnitude of climate change to which effective adaptation is only possible at very high social, economic and environmental costs. Both mitigation and adaptation are therefore essential in reducing the risks of climate change. The recent Stern Review stated: '*Adaptation is the only response available for the [climate change] impacts that will occur over the next several decades before mitigation measures can have an effect*'.

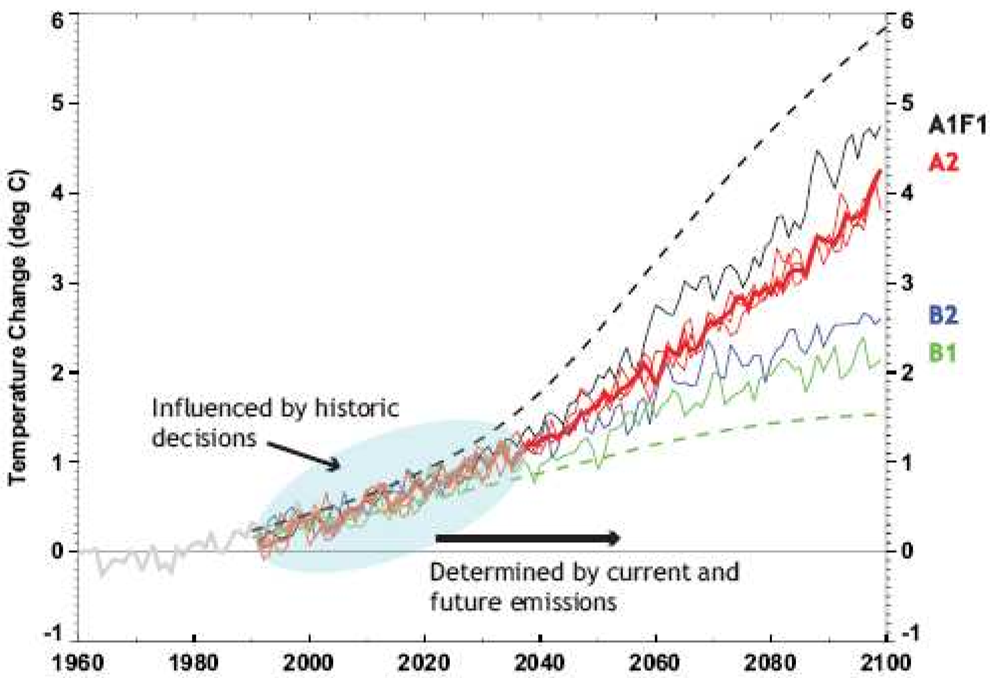

Figure 1: Projected global temperature change for four emission scenarios using UKCIP02 (Hulme *et al*., 2002).

This paper identifies the commonalities and differences between adaptation and mitigation options in terms of the temporal and spatial scales on which they are effective; the extent to which their costs and benefits can be determined and compared and the types of policies and actors required for their implementation. Combining adaptation and mitigation options is discussed in terms of the synergies and conflicts that may arise. These are illustrated using a study that identified synergies and conflicts on mitigation, environmental and economic impacts of adaptation measures to sea level rise on the islands of Fiji; and the synergies and conflicts that exist between mitigation and adaptation in the built environment. The paper then discusses the problems associated with the integrated assessment of mitigation and adaptation options. Finally, the relationship between climate change and sustainable development is addressed.

2 Commonalities and differences between mitigation and adaptation

Adaptation and mitigation offer two options to respond to climate change. They both seek to avoid the potential damages of global climate change, and they both seek to support the development of present and future generations in a sustainable manner. However, the influence and incidence of employing them as climate policy instruments are different.

2.1 Temporal scale on which they are effective

Benefits of mitigation activities carried out today will only be evidenced in several decades given the long residence time of greenhouse gases in the atmosphere, whereas many effects of adaptation measures should be apparent immediately or in the near future. Adaptation helps to respond to climate variability as well as climate change.

2.2 Spatial scales on which they are effective

Mitigation has global benefits, whilst adaptation typically takes place on the scale of an impacted system, either regionally or most likely locally. For example, mitigation investments in renewable energy sources will lower atmospheric carbon dioxide concentrations, with the gain being reduced global climate change. Whereas, adaptation investments for example improved sea defences will only benefit the settlements and ecosystems directly protected by such defences.

2.3 Extent to which their costs and benefits can be determined compared and aggregated.

Mitigation options serve to reduce greenhouse gas emissions for global benefit so where in the world mitigation takes place is irrelevant. Expressed as CO_2 equivalents, reductions in emissions can be compared with other mitigation options and if implementation costs are known, the cost-effectiveness of these options can be determined and compared (Moomaw *et al.,* 2001 in Klein *et al*., 2003). However, for a full cost benefit assessment the cost of impacts need to be understood.

Benefits of adaptation are difficult to express as a single measure. A value can be obtained by subtracting the costs of implementing the adaptation options from the benefits of adaptation (i.e. the difference between the potential impact of climate change on a system assuming no adaptation and the residual impacts assuming adaptation). However, assessing and comparing adaptation benefits is fraught with the difficulties related to the uncertainty about and differences between the impacts avoided (Klein, 2003 in Klein *et al*., 2003).

Mitigation reduces the amount of adaptation required, and thus its cost; however, adaptation does not reduce mitigation costs. However, adaptation has other benefits. Tol (2005) maintains that a society that is more robust to climate change is probably more robust to climate variability, and a society that can adapt to climate change is probably better at adapting to socio-economic change. Tol states the example of not developing a malaria vaccine because of climate change, but because malaria is a nasty, widespread disease.

2.4 Actors and types of policies involved in their implementation.

Table 1 Aggregated greenhouse gas emission trends per source category (Mt CO2 equivalent). (Source:http://www.ghgi.org.uk/documents/ES3_table_from_2005_NIR.pdf)

Source Category	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Energy	610.4	619.6	604.7	589.7	575.6	567.7	588.3	564.1	565.5	554.2	557.8	576.0	559.7	567.3
Industrial Processes	56.5	52.9	46.9	44.1	48.4	48.4	51.5	54.5	50.2	30.9	29.8	27.9	25.7	26.8
Solvents and other product use	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agriculture	53.4	52.9	51.3	50.6	51.5	51.4	51.8	52.5	51.6	51.0	49.1	46.1	46.4	45.8
Land-use Change and Forestry (emissions)	17.6	17.7	17.4	16.5	16.6	16.8	16.5	16	15.5	15.4	15.1	14.9	14.5	14.7
Land-use Change and Forestry (removals)	-14.9	-15.1	-15.3	-15.6	-15.9	-15.9	-15.9	-15.8	-15.8	-15.9	-15.8	-15.9	-16.0	-16.3
Waste	27.8	26.9	26.0	25	24.1	23.1	22.2	20.2	18.6	16.3	14.8	13.4	11.9	11.1
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (emissions only)	765.6	769.9	746.3	726.1	716.3	707.3	730.4	707.3	701.4	667.8	666.6	678.3	658.2	665.8
Total (net CO2)	750.6	754.9	731.0	710.4	700.4	691.4	714.6	691.4	685.5	651.9	650.8	662.5	642.2	649.6

Mitigation primarily involves the energy and transportation sectors in industrialised countries and to an increasing extent the energy and forestry sectors in developing countries. Table 1 summarises the trends in aggregated direct greenhouse gas emissions by sector for 1990-2003 in the UK. Compared to adaptation, the number of sectoral actors involved in mitigation is limited. They are typically well organised, closely linked to national planning and policymaking and used to taking medium to long-term investment decisions. However, energy efficiency in households and industry is also important on an individual level. In contrast, actors involved in adaptation represent a large variety of sectoral interests including agriculture, tourism and recreation, human health, water supply, coastal management, urban planning and nature conservation. Barriers to mitigation and adaptation are also likely to be different.

Table 2 provides a summary and a comparison of the main commonalities and differences between adaptation and mitigation.

Table 2 Commonalities and differences between mitigation and adaptation (Source: Dang et al., 2003).

	Mitigation	**Adaptation**
Common target	Sustainable development	Sustainable development
Distinct characters	Proactive action, long term reduction of climate change impacts	Reactive action, iterative depending on the real impacts of climate change Proactive if based on projected impacts
Temporal effect	Benefits to later generations	Benefits can be more or less appropriated by those bearing costs
Geographical effect	Global benefits, but varying across regions	Primarily local benefits
Cooperation degree required	Global	National, regional
Sectoral effect	Focus on emissions from fossil fuels	Very heterogeneous with some stress on agriculture
Relation to uncertainty	Setting of emissions targets has to be adjusted to regularly to take into account new projections	Reactive adaptation can wait until more concrete evidence of climate impacts is available. Successful proactive adaptation has difficulties to justify itself as the 'baseline' impacts are unknown
Equity	Free-riding problem, especially motivated with countries less vulnerable to climate change	Unfair, the 'victims' are not always responsible for causing climate change
Secondary benefit	Some options have high local secondary benefits (e.g. reduce air pollutants). Some options may even directly be financially viable	Some options are beneficial in the absence of climate change – "win-win" option
	Technology transfer	Technology transfer

3 Combining adaptation and mitigation options: synergies and conflicts

There are a number of areas in the built environment where strategies for adaptation to climate change might have an adverse effect on greenhouse gas emissions and hence mitigation efforts - for instance, if energy-intensive air conditioning is installed to cope with higher temperatures or desalinisation plants to enhance water resources. Many of the materials and engineering solutions for adaptation may have significant energy implications. On the other hand some mitigation measures might increase vulnerability to climate impacts, for example cavity wall insulation, which is a maladaptation to flood risk. To date, little work has been done to evaluate the impacts on mitigation of these adaptation strategies, though the FP6 project ADAM is making early progress in this field (http://www.adamproject.eu/). The aim of the European project AMICA (http://www.amica-climate.net) is developing local and regional strategies which will adopt a comprehensive approach to climate change. AMICA will highlight an optimum blend of short- and long-term preventive and reactive measures, thus reducing future planning risks.

Despite the differences between adaptation and mitigation strategies, both are essential in reducing the risk of climate change, hence opportunities are being sought to develop synergies between the two options. Synergies in climate policy are created when measures that control atmospheric greenhouse gas concentrations also reduce the effects of climate change, or vice versa. A classic example is the planting of trees in urban areas: they sequester carbon as they grow and they reduce urban heat stress in the summer (though certain species may be vulnerable to temperature increase).

The development of synergies is sought because of the intuitive appeal of implementing climate policy by carrying out mitigation and adaptation activities simultaneously. It connects mitigation and adaptation with natural resource management, biodiversity conservation and measures to combat desertification i.e. by implementing other international agreements.

However, Klein *et al*. (2003) highlight three risks involved in focussing too strongly on creating synergies between adaptation and mitigation:

- In view of the different actors involved in mitigation and adaptation, the implementation of synergetic measures will encounter greater institutional complexity, both nationally and internationally, which could limit the efficacy of the measures.
- It is doubtful that sufficient opportunities for synergies can be identified to achieve the levels of mitigation and adaptation deemed required.
- Even for those opportunities that are identified it is unclear whether they represent a wise investment in terms of the mitigation and adaptation benefits accrued i.e. the net effect of investing in synergetic measures in terms of reducing damages may be smaller than when

half the money is invested in more efficient mitigation options and the other half in more efficient adaptation options.

There is a risk that mitigation activities will be labelled adaptation activities and vice versa to make them more attractive for funding. This could diminish the effectiveness of the limited funds available for climate policy and be at the cost of vulnerable communities whose only opportunities to adapt to climate change come without mitigation benefits.

Klein *et al*. (2003) therefore argue not to focus on creating synergies between mitigation and adaptation, as this could lead to projects that are difficult to implement and administer, are cost-ineffective, and, when considered together produce insufficient mitigation and adaptation benefits. Instead it would be better to seek ancillary benefits of mitigation and adaptation outside climate policy, as long as it is recognised that these are different for the two options.

3.1 Adaptation and mitigation in tourist resorts in Fiji

There are very few examples where adaptation and mitigation options are considered in parallel. Becken (2005) provides a detailed study on tourism in Fiji in the face of climate change. The study compiles adaptation measures by tourist resorts in Fiji to climate change, the main threats being extreme events and sea level rise, as well as mitigation measures and discusses the barriers to implementing adaptation and mitigation options. Table 3 summarises the identified adaptation measures for tourism on these tropical islands and highlights the synergies and conflicts on mitigation, as well as the impacts on environmental management and economic aspects.

3.2 Climate Change Mitigation and Adaptation Implementation Plan for the draft south east plan

The overall aim of the Climate Change Mitigation and Adaptation Implementation Plan is to develop a regional plan which sets out actions required by different organisations to mitigate and adapt to the projected effects of climate change in the South East. Progress had been made by relevant organisations that had identified the benefits of mitigation and adaptation, however, most of the progress had been made in developing knowledge and in modifying regional policies, strategies and plans. Whereas these provide the framework within which mitigation and adaptation can be delivered, the Implementation Plan provides the local mechanisms and commitment to take the implementation further and to overcome perceived or actual barriers to making progress (Collingwood Environmental Planning and Land Use Consultants, 2006).

Table 3 Adaptation measures for tourism on tropical islands and their positive or negative ancillary effects (Source: Becken, 2005).

Adaptation	Impact on mitigation	Impact on environmental management	Economic aspect
Tree planting	Reduces net CO_2 emissions through carbon sink	Benefits biodiversity, water management, soils	Could be included in a carbon trading scheme
Water conservation	Reduces energy costs for supplying water	Positive in areas where water is limited	Saves costs, especially when water is shipped to islands
Renewable energy sources	Reduces CO_2 emissions	Overall, less polluting than fossil fuels	Potentially saves costs; reduces dependency on fuel imports
Using natural building materials (e.g. wood)	Smaller carbon footprint for locally produced materials	Depends on sustainability of plantations	Stimulates local forestry sector
Reducing water pollution	Possibly increased energy use for sewage treatment	Positive for coral reefs and marine life	Maintains resource basis for tourism earnings
Marine sanctuaries/coral reef protection	Neutral	Positive for marine biodiversity	Maintains resource basis for tourism earnings
Rainwater collection	Saves transport energy for supplying water	Possibly interrupts the natural water cycle	Saves costs in the long term
Guest education	Neutral	Increases awareness	Risk of deterring tourists
Setting back building structures	Neutral	Positive when structures built away from beachfront	Positive if maintenance costs are reduced
Diversifying markets	Positive if new markets are more eco-efficient ($ spent /kg CO_2)	Depends on the environmental impact of new markets	Positive if new markets are high yield
Weather-proofing tourist activities	Depends on the type of activities	Depends on the type of activities	Potential for high-yield alternative and income for local communities
Water desalinisation	High energy costs	Takes pressure off freshwater resources	Expensive
Increasing air conditioning	Increases CO_2 emissions	Air pollution in the case of diesel generation	Expensive
Beach nourishment	Energy use for mining and transportation	Disturbs ecosystems	Expensive
Reducing beach erosion with seawalls	Neutral	Disturbs natural currents and causes erosion elsewhere	Expensive, requires ongoing maintenance

4 Adaptation and mitigation in the built environment

The built environment consumes 50% of the UK's energy and nearly 50% of carbon dioxide emissions in the UK are caused by building, maintenance and occupation of buildings. Improving building design to maximize energy efficiency and minimize energy use is a win/win situation, as over the lifetime of a building its running costs are reduced and the emissions minimized (King, 2005). McEvoy *et al*. (2006) present synergies and conflicts that exist between mitigation and adaptation agendas in the built environment. In relation to the built environment, mitigation relies on two main responses: reducing the amount of energy required by end-users and reducing the carbon intensity of the energy supplied. The main climate-related hazards are stated in table 4.

Table 4 Summary of some key climate change impacts and mitigation/adaptation responses. (Source: McEvoy et al., 2006).

Possible climate impacts	Impact on the built environment	Example adaptation measures	Example links to mitigation
Drier summers with reduced soil moisture content and wetter winters	Subsidence, flooding	Reduce exposure of vulnerable places by hard and soft engineering Reduce vulnerability of building materials Avoid 'at risk' locations	Consider whole life cycle of emissions of hard and soft engineering projects, including air pollution emissions Consideration of need to travel when siting new development
Larger proportion of extremely hot and cold days	Reduced heating demand offset by increased cooling demands	Provide enhanced cooling without loss of efficiency of winter heating systems Adaptation to target vulnerable elements at risk	Heating and cooling to rely on renewable sources Consideration of negative impacts of air-conditioning
Warmer and drier summers	Greater requirement for outdoor living and access to urban open space	Reduce exposure and provide cooling through green and blue infrastructure	Consider whole lifecycle of emissions Use trees as additional carbon sinks
More extreme events	Damage to building fabric	Greater resilience of buildings and infrastructure Use of different materials	Decentralised energy infrastructure Consideration of the embodied energy of materials used
More frequent droughts	Water shortages	Storage and recycling of water	Possible implications for biofuels etc.

4.1 Examples of inter-relationships between adaptation and mitigation measures

Urban form/design

The world's population is expected to increase by 3 billion people in the next 50 years, with the majority of these additional people predicted to reside in cities and urban areas (Swart et al., 2003). The UN (2004a, 2000b) project 60% of the world's population to live in cities by 2030. The rate of growth in developing countries is faster than in industrialised countries: for example in 1978, 17.9% of China's population was living in cities, yet by 2003, 39% of its 1.3 billion population lived in urban areas (Zhao et al., 2006).

Improving energy efficiency is typically targeted at end-use residential, commercial, industrial and transport sectors. Cities are complex systems subjected to continuous processes of development and change, with energy, natural resources and resultant waste treated as flows or chains. Metabolism of the urban system and its resultant emissions is strongly influenced by the urban form i.e. spatial organisation (McEvoy et al., 2006). Innovative design of urban areas can reduce GHG emissions, while simultaneously avoiding other problems. Approaches include: improving the linkages between urban public transport and residential areas, accessibility of jobs and shops, compact urban planning, and integrated, efficient building design (Swart et al., 2003). There would also be greater viability of large-scale efficiency initiatives such as community heating systems. The greater the density of development, the less need for travel and the greater viability of large-scale efficiency initiatives such as community heating systems. Such has been increasingly translated into high-density mixed-use settlements 'compact cities' in land-use policy in England and the rest of Europe (Williams, 1999 in McEvoy *et al*., 2006). Dongtan in China is an example of an eco-city, and is the first of up to four such cities to be designed and built in China by Arup. The cities are planned to be ecologically friendly, with zero greenhouse emissions and complete self-sufficiency in water and energy.

Increasing the built mass of urban areas conflicts with the adaptation agenda in two main ways: it intensifies the urban heat island and causes problems for urban drainage. Greater consideration of ecological principles is needed, in particular the use of green and blue spaces to provide cooling, storage and enable infiltration. However, their space may be lost during development. Cities that are poorly designed for the predicted hotter summers will lead to increased use of air-conditioning, therefore enhance the effect. There may also be indirect effects such as people travelling away from the uncomfortable city conditions to more comfortable areas, thus increasing car emissions.

McEvoy et al. also highlight that adaptation measures are also needed at other spatial scales such as neighbourhood and individual building scale. Adapting to other climate-related hazards such as flooding, wind, driving rain, subsidence and soil movement requires consideration of the location and layout of development landscape architecture, building design, appropriate use of materials and provision of outdoor spaces. For example, the location and layout of a new development is particularly important in minimising flood risk, with the vulnerability of a building to flooding being partly a function of its design and materials used, along with the floor level of the structure. The location and layout of a new development can also be important in reducing the urban heat island effect. Adaptation of the built environment should simultaneously address the resilience of the building fabric to a changing climate, with the incorporation of energy-saving measures (and renewable technologies) where possible. Examples of maladaptation would be beneficial in best practice guidelines. An example of maladaptation in the built environment would be the development of floodplains, which can lead to a reduced buffering capacity for river water and thus to increased peak runoff.

Urban greening

The BKCC ASCCUE project (Adaptation Strategies for Climate Change in the Urban Environment) investigated the interactions between climate-related hazards and exposure units in urban areas. ASCCUE found that greater consideration of ecological principles are needed, in particular the use of green and blue spaces to provide cooling, storage and enable infiltration. Urban greenspace was also demonstrated to play an important role in storage and infiltration of rainwater, therefore reducing the seriousness of urban flooding given wetter winters and heightened storm drains and sewers from the increased built area. Green areas increase the CO_2 sink capacity of urban areas, this aiding mitigation of the urban heat island effect. Chiswick Park and Jubilee Park in London both show how the provision of outdoor spaces was used in commercial developments. Buildings were built around a central water feature with areas of green landscaping between them. Semi-mature trees were planted to add to the appeal of landscaping and also provide shade during summer. In addition vehicles are excluded from the parkland at the centre of the developments.

Energy supply

Traditional energy infrastructure i.e. power stations are located near water sources (for cooling purposes) and as such are at risk from sea level rise and flooding. Power lines may also be at risk from other climate change impacts such as storms and geohazards. Future loadings in terms of energy demand inevitably link not only to climate change but also to socio-economic change, are also a threat.

Conversely, promotion of renewable forms of energy favour decentralisation of energy supply and there is obvious resonance between this form of mitigation and adapting to climate change. However a distributed energy systems would require new infrastructure. Although there is a UK policy goal to increase the percentage of renewable supply, it is not yet clear how different technologies will perform under changed conditions. For example, increased storminess may have operational implications for technologies such as wind turbines. Also, biomass may not be a viable option in times of water scarcity and it is possible that planting/land-use change and emissions characteristics may have a negative impact in other areas. Crops may need transporting to point of use and the cutting of crops will impact on biodiversity. Similarly, wave power generation and wind farms may have an effect on habitats and surrounding environments. For example, ships would use more energy sailing around offshore wind farms. The operation and effectiveness of renewable options under changed climatic conditions and their possible conflicts with adaptation need further research.

Green and blue roofs

The measure ‘Green roofs’ consists of planting the roofs of existing/new buildings with grass/vegetation to improve the insulation and helps reduce the urban heat island effect. Green roofs provide a more ideal local microclimate. A reduction in the thermal stress affecting the weatherproofing of the roof and the screening out of the damaging UV radiation can increase design life of the roof. Green roofs also store and infiltrate rainfall, help combat air pollution and improve biodiversity. Green roofs reduce the temperature fluctuation. Reduction in temperature extremes on the roof will also have an ameliorating effect on the temperature of the rooms below thus reducing energy consumption. The large commercial site of Fort Dunlop just outside Birmingham has the UK’s largest green roof. The new Jubilee Campus at Nottingham University has installed green roofs to help reduce surface water runoff and aid rainwater harvesting.

‘Blue Roofs’ are water basins on top of buildings to store excess water and thus help prevent flooding. They can also be used in heat exchange for solar heating and cooling. One downside to both measures may be the potential maintenance issues.

Sustainable Urban Drainage Systems (SUDS)

SUDS systems are more sustainable than conventional drainage methods because they: reduce the impact of urbanisation on flooding by managing runoff flow rate; enhance water quality; encourage natural groundwater recharge (where appropriate); are sympathetic to environmental and local community needs and provide a habitat for wildlife in urban watercourses. Systems also have the potential to be linked to building cooling systems.

Bristol Business Park has used a number of SUDS to minimise its impact. Techniques include permeable paving in car parks which drain to swales and a wet detention pond which is able to hold additional storm water.

Building design/retro-fitting

In building design, resilience of the building fabric to a changing climate, with the incorporation of energy-saving measures (and renewable technologies) should be considered. In terms of mass of building materials if you were wanting to mitigate you would use light materials as they contain less embodied energy; on the other hand for adaptation you would choose materials with a greater mass as they contain more embodied energy and hence would require less energy intensive ventilation strategies while maintaining comfortable internal conditions. Many older buildings have higher thermal mass and embodied energy, there may be potential for re-use of these types of buildings. Using light coloured building materials help reflect solar radiation and keep buildings cool, such are common place in

Mediterranean countries. However, in cities there may prove to be maintenance issues with light coloured materials.

Incorporating renewable energy schemes into new builds and new housing developments will help reduce energy demand. A number of technologies can be employed such as ground source heat pumps, solar panels and wind turbines. However, further research is required on the efficiency of energy sources, their location and how they may affect the stability of existing buildings.

Water management

There are a number of adaptation options for water supply and management that have synergies and conflicts between adaptation and mitigation.

Major solutions to water supply deficits may include desalinisation plants. However, plants are very energy intensive. New reservoirs may have an adverse impact given the embodied energy during their construction, however, in addition to providing a water resource and storage during periods of intense rainfall, the surface water would help absorb heat and provide new habitats and recreational areas. Smaller-scale adaptation options could include water metering. Water metering would in theory reduce the amount of water consumed as people pay for what they use, there are however equity issues associated with metering. Hose pipe bans during periods of water shortages could also reduce demand. However this may then have an adverse effect on urban gardens, which are helping regulate temperature at times of higher temperatures.

There is a need to document and add to the synergies and conflicts between adaptation and mitigation options as new measures are employed. GOL’s (2006) document ‘Adapting to climate change: a developer’s guide to best practice’ presents case studies of various adaptation options for the built environment.

5 Integrated assessment of mitigation and adaptation

At present the capacity to integrate considerations of mitigation and adaptation is quite limited, although the pioneering Integrated Assessment Model (ICAM) provided an early example (Dowlatabadi and Morgan, 1993). Achieving an integrated perspective is challenging given that both the policy and research communities have traditionally treated the two categories of responses separately and more fundamentally that mitigation and adaptation are very different in what they mean and how they work, as discussed earlier. Within the mitigation research community ‘top-down’ aggregate modelling to study trade-offs inherent in mitigation dominates, with the focus being mainly on technological and economic aspects. The adaptation community focuses on local and place-based analysis. In additional, mitigation and adaptation actions may show important relationships with each other, including possible interactions and complementarities.

Willbanks (2005) argues that a lack of integrating capacity should not prevent the initiation of both mitigation and adaptation. Table 5 lists actions that make sense now in responding to climate change impacts.

Table 5 Immediate actions in responding to climate change impacts. (Source: Willbanks, 2005).

Mitigate now	Adapt now
Where an action is win-win. Where co-benefits are high, such as pollution reduction, energy cost reduction or energy security improvement. Where international agreement is attained.	Where an action is win-win. Where co-benefits are high, such as reduced vulnerability to climate variation or improved environmental sustainability. Where local agreement is achieved.

A single analytical approach is unlikely to fit all needs. For example, analysis may be aimed at different objectives (e.g. modelling for improved understanding versus modelling for decisions) and it may be focused on different targets (e.g. analyzing decision options versus analyzing decision processes). Willbanks (2005) also argues that the frame of reference should be broad. For example, be able to incorporate differences in perspectives from different geographic scales, global to local. One-time analysis is limited in value, so a capacity for sustained analytical processes rather than analytical products is needed.

A common mode of analysis is to integrate mitigation and adaptation by estimating and comparing the net present value (NPV) of various decision options. A recent example of its use was by the Oak Ridge National Laboratory (ORNL) to develop a Climate Impact Response model (CLIR). In attempting to integrate mitigation and adaptation at a local scale, the most common approach is place-based integrated assessment (a largely qualitative, deliberative process including local participation, as contrasted with “integrated assessment modelling”). In this case, the approach offers access to local data (and qualitative knowledge) not readily available elsewhere, a scale at which nature–society integration is more likely to be feasible and opportunities to facilitate stakeholder participation. Limitations may include a lack of full understanding at the local level of important larger driving forces (such as incremental technological change), a lack of available climate change projections at a the local scale, and the lack of a tradition of cross-disciplinary integrative assessment, rather than traditional disciplinary analysis (Willbanks, 2005). A recent example is an assessment by ORNL and local partners of vulnerabilities to climate change impacts and response options for the city of Cochin, India.

5.1 Top-down net present value approach

Figure 2 is a simplified depiction of the structure of the CLIR model.

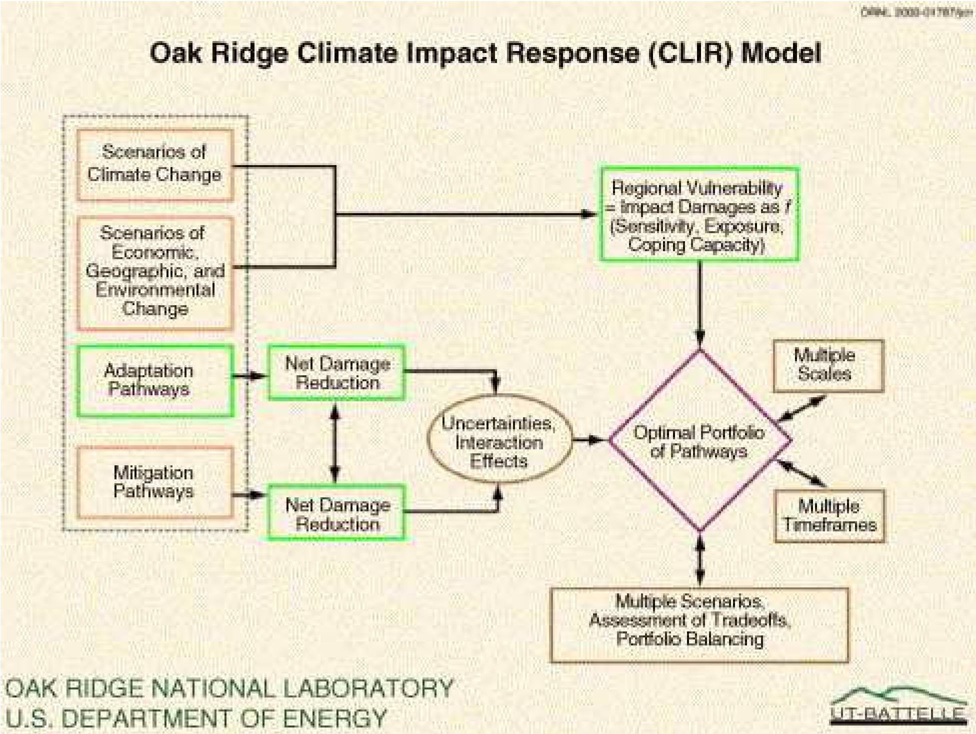

Figure 2 General structure of the Oak Ridge Climate Response Model.

ORNL:

- estimated regional impact damage as a function of regional vulnerability in 10-year time periods;
- estimated regional vulnerability as a function of sensitivity, exposure, and coping capacity with respect to projected damages from regional impacts of climate change;
- estimated effects of response pathways through time by region (mitigation pathways reducing exposure, and adaptation pathways reducing sensitivity and/or increasing coping capacity);
- determined net impact cost reductions from a pathway (benefits less costs);
- selected a set of discount rates to represent time scale dependency;
- selected an "optimal portfolio" of pathways, considering not only NPV calculations of individual pathways but also associating risks due to uncertainties about pathway performance with positive valuations of portfolio diversification.

ORNL's experience in trying to make CLIR work as a top–down tool for integrating mitigation and adaptation, using an NPV approach, supports arguments that – given adequate data and some further development of theory – this approach can be valid and useful. The fundamental problem is not with the approach in an idealized form. The problem with the approach is that it is difficult to approach that ideal with current capabilities.

5.2 Bottom-up integrated assessment approach

ORNL also attempted to integrate mitigation and adaptation through integrated assessment of vulnerabilities and response options. It used quantitative data and analytical procedures where feasible, but in fact quantitative data were severely limited. As a result, the assessment depended considerably on extensive consultations with local experts, drawing on informal local knowledge bases where quantitative data were unavailable. As one example, data were not available to support evaluations of variations in health indicators with historic temperature variation; but local health experts were able to offer qualitative observations about relationships based on their experience.

In contrast with the CLIR experience, this experiment with bottom–up integration of mitigation and adaptation seems to have been a modest success. Even without a body of data on climate change expectations and impacts that might have been considered a minimum requirement, it was able to develop robust conclusions about impact concerns and directions for response.

Based on these two integrated assessment approaches, Willbanks (2005) highlights three essential elements for a hybrid approach:

1. Multi-criteria optimization: to ground the process in quantitative analysis and enhance its value for international policymaking.
2. Scenario-based integrative assessment: to ground the process in place-based local reality and stakeholder participation.
3. Simulation/gaming strategies for analysis: to explore process relationships and incorporate competing agendas.

Achieving a valid, understandable analytical framework for integrating mitigation and adaptation is going to take some time, considerable research support, and active collaborations among experts in different aspects of the framework.

5.3 Tyndall Centre

Ongoing work at the Tyndall Centre goes someway to addressing the second of Willbank's points. The aim of the Tyndall Centre Cities Programme (see Dawson *et al*., 2006) is to develop a city-scale assessment capacity that simulates the evolution of climate impacts and emissions over the 21st century. This city-scale assessment facility will be applied for urban policy-makers, planners, engineers and other stakeholders to compare alternative adaptation and mitigation strategies and to consider *how cities grow whilst reducing emissions and vulnerability to climate change*.

Furthermore work by Turnpenny *et al*. (2005) created a set of scenarios of how the East of England region may look in 2050 under large greenhouse gas emission reductions and with adaptation to climate changes. A set of scenarios were presented to achieve a 60% greenhouse gas reduction. The scenarios highlighted the magnitude of a 60% reduction given the growth in the economy would tend to increase emissions over the reduction period. The policies and changes required in the scenarios to reach the reduction all have other social, environmental and economic consequences. They also found integrating mitigation and adaptation at the regional scale is difficult, partly due to the mismatch in spatial scales at which the two processes occur, and also because there are no ready scenarios of climate change impacts based on 60% emission reduction pathways using the latest climate models. Turnpenny et al. also conclude that scenarios at the regional level are complicated by overlapping scales of governance and ability to influence. For example, transport technology development or oil prices cannot be influenced at the regional scale; however, the region could perhaps influence demand or planning. Finally, Turnpenny *et al*. highlight the need for integrated governance structures to help deliver low-carbon sustainable futures.

6 Climate change and sustainable development

Climate change and sustainable development have been addressed in largely separate circles both in terms of research and policy; however, the need to connect the two is becoming increasingly recognised in the climate change literature. The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) suggested that sustainable development may be the most effective way to frame the mitigation question (Banuri *et al*., 2001 in Swart, *et al*., 2003) and a crucial dimension of climate change adaptation and impacts (Smit *et al*., 2001 in Swart, *et al*., 2003).

Climate change and sustainable development interact in a circular fashion. Climate change vulnerability, impacts and adaptation will influence prospects for sustainable development, and in turn, alternative development paths will not only determine greenhouse gas emission levels that affect climate change, but also influence future capacity to adapt to and mitigate climate change (see Figure 3). Impacts of climate change are exacerbated by development status, adversely affecting the poor and vulnerable socio-economic groups. However, the capacity to adapt to climate change goes beyond wealth to other pre-requisites of good development planning, including institutions, governance, economic management and technology (Downing *et al*., 2003).

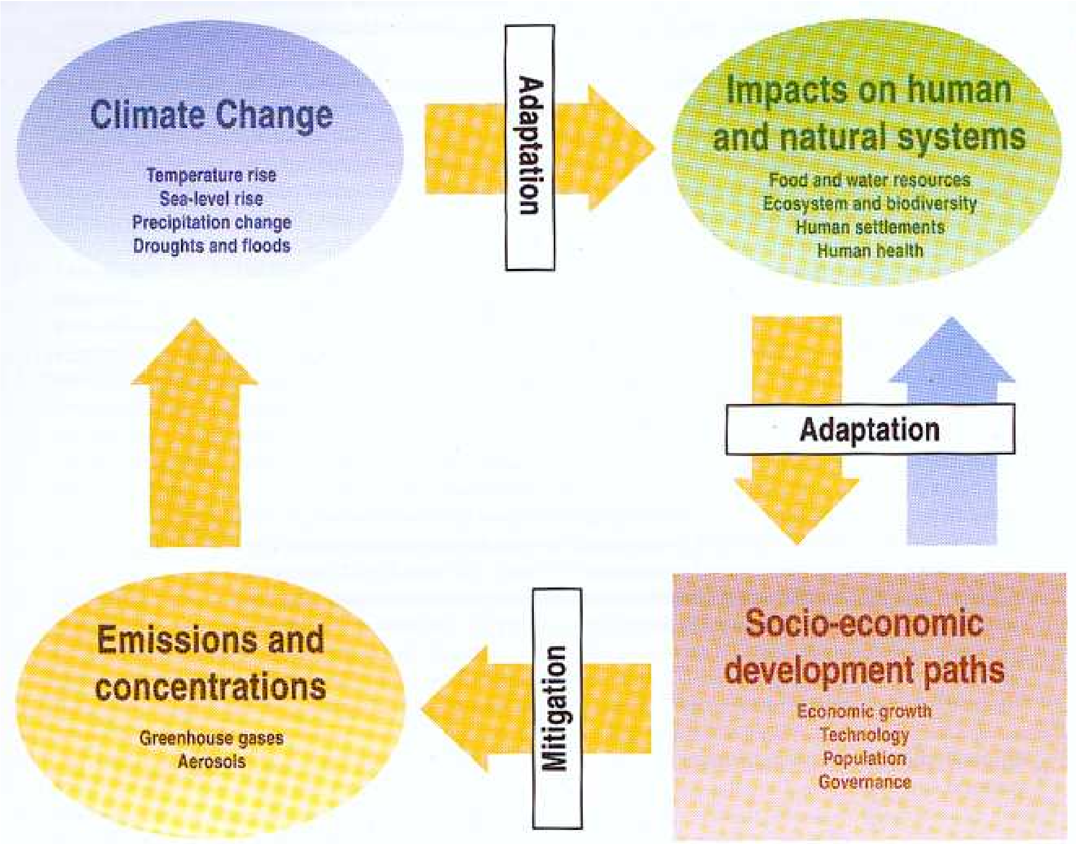

Figure 3: Climate change: an integrated framework. (Source: IPCC, 2001).

A more sustained effort to consider the linkages between climate change and sustainable development is being conducted in the IPCC Fourth Assessment (Grubb, 2003). Figure 5 shows how the range and scope of policy analysis tools used by IPCC have expanded over the assessment reports. The case for why IPCC assessments should engage sustainable development more comprehensively is usually composed of two strands: one substantive and one institutional. The substantive argument maintains that although climate policy cannot be a substitute for sustainable development policy, the goals of the two are synergistic i.e. that the realization of sustainable development can be both a framework condition and a motor for the better implementation of climate policy. The institutional argument relates to the stated intent of the UNFCCC, Kyoto Protocol, and IPCC deliberations i.e. that IPCC assessments are required to integrate sustainable development concerns (Najam *et al*., 2003).

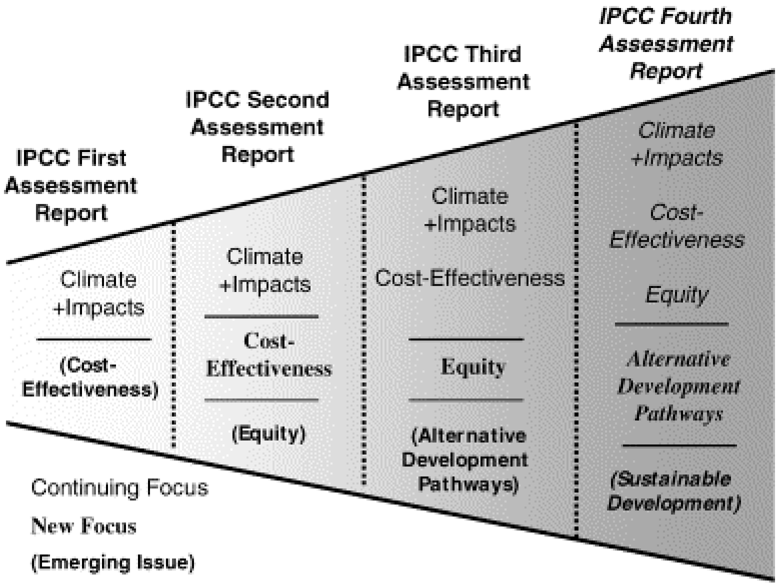

Figure 5 Evolution of the IPCC assessment process. (Source: Najam et al., 2003).

7 Conclusions

Despite the differences between adaptation and mitigation strategies, both are essential in reducing the risks of climate change. However, further research is needed to identify the synergies and conflicts that exist between mitigation and adaptation agendas. It may be counterproductive to force integration of the two strategies, however, many adaptation options are pathways to effective and long-term mitigation, like-wise mitigation options can facilitate planned adaptation. Adaptation and mitigation options should be considered in a framework of sustainable development and should therefore avoid conflicts with each other.

Many mitigation and adaptation actions offer co-benefits to facilitate their implementation now. In many cases effective integration of mitigation and adaptation to make a significant difference in cost avoidance needs better information, improved capacity for analysis and action, and further policymaking.

Large amounts of information are required for quantitative analysis of integrated strategies, for example, better high-resolution climate predictions, information about costs and benefits of mitigation and adaptation actions, better information about interactions between mitigation and adaptation actions and other sustainable development strategies, and an improved understanding of the uncertainties surrounding such issues (Willbanks and Sathaye, 2007). This also requires a capacity for sharing data and knowledge between sectors. Not only do the outcomes of strategies need to be combined but also the decision making processes.

Willbanks and Sathaye (2007) argue that effective integration of mitigation and adaptation requires improved conceptual and methodological tools and improved capacities of research communities. Developing such transcend boundaries of individual disciplines and hence require inter-disciplinary research programmes such as Sustaining Knowledge for a Changing Climate (www.k4cc.org) or the Tyndall Centre (www.tyndall.ac.uk). In addition, in reality a company or organisation may only have one person who is responsible for the ‘climate change’ remit, therefore tools and strategies that can deliver on both mitigation and adaptation are required.

Integration of mitigation and adaptation analysis is pointless without actions. Climate policy needs to include perspectives that incorporate both mitigation and adaptation alternatives and structures for policymaking that are linked with analytical support. There is a strong need for good working examples of tools and solutions e.g. Dongtan model. In the long run, integration of mitigation and adaptation to reduce risks and costs of climate change depends on effective policymaking and implementation, informed by advice about what is likely to work and reinforced by successful experiences and working models.

Within the built environment McEvoy *et al*. (2006) promote ‘place-based’ integrated assessment for exploiting the synergies that may exist, along with an effective planning system and innovative urban design for combining mitigation and adaptation measures to promote more effective climate-proofing of the urban environment. The ADAM project aims to evaluate the impacts on mitigation of a range of adaptation strategies and aims to develop a better understanding of the trade-offs and conflicts that exist between adaptation and mitigation policies. ADAM will support EU policy development in the next stage of the development of the Kyoto Protocol and will inform the emergence of new adaptation strategies for Europe.

The design of integrated and effective climate policy is a significant challenge: ‘long time frames, scientific uncertainty about impacts and about social and economic futures all conspire to test the abilities of existing decision-making processes’ (Tompkins and Adger, 2005). However, climate policy is moving in the right direction, with a shift from being synonymous with energy policy to sharing a large interface with sustainable development. Dang *et al*. (2006) argue that if climate policy could strike a rational balance between mitigation and adaptation instruments that maximise the potential synergies between them, climate policies could become socially and economically efficient and may offer greater opportunities for countries to achieve sustainable development targets.

However, Klein *et al*. (2003) present three, still pertinent, research questions that need to be addressed in order for climate policy to advance:

1. What constitutes a socially, economically and environmentally justifiable mix of mitigation, adaptation and development policy and how can it be achieved?

2. How can capacity be developed in order to seize opportunities and overcome constraints on implementing mitigation and adaptation options as part of sectoral policies?

3. How can existing financial instruments for climate policy best be used in a broader context of sectoral investments, official development assistance and other policies aimed at risk reduction and sustainable development?

8 References

Becken, S. (2005). Harmonising climate change adaptation and mitigation: the case of tourist resorts in Fiji. *Global Environmental Change* 15: 381-393.

Collingwood Environmental Planning and Land Use Consultants (2006). Climate Change Mitigation and Adaptation Implementation Plan for the Draft South East Plan. http://www.southeast-ra.gov.uk/southeastplan/plan/march_2006/implementation_plan/climate_change_implementation_plan-300306-v2.pdf

Dang, H.H., Michaelowa, A. and Tuan, D.D. (2003). Synergy of adaptation and mitigation strategies in the context of sustainable development: the case of Vietnam. *Climate Policy* 3S1: S81-S96.

Dawson, R. J., Hall, J. W., Barr, S., Batty, M., Bristow, A., Carney, S., Evans, S., Ford, A., Köhler, J., Tight, M., Walsh, C. (2006). *A blueprint for the integrated assessment of climate change in cities. Tyndall Centre Working Paper 104. http://www.tyndall.ac.uk/publications/working_papers/twp104.pdf*

Downing, T.E., Munasinghe, M. and Depledge, J. (2003). Special supplement on climate change and sustainable development, editorial. *Climate Policy 3S1: S3-S8.*

Government Office for London (2006). *Adapting to climate change: a developer's guide to best practice*. Ove Arup and Partners Ltd., London.

Grubb, M. (2003). Special supplement on climate change and sustainable development, preface. *Climate Policy 3S1: S1*.

Hulme, M., Jenkins, G. J., Lu, X., Turnpenny, J. R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R. and Hill, S. (2002). *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK

IPCC (2001). *Climate Change 2001: impacts, adaptation and vulnerability*. Cambridge University Press, Cambridge.

King, D. (2005). Climate change: the science and policy. *Journal of Applied Ecology* 42: 779-783.

Klein, R.J.T., Schipper, E.L. and Dessai, S. (2003). Integrating mitigation and adaptation into climate and development policy: three research questions. *Tyndall Centre for Climate Change Research Working Paper 40*. http://www.tyndall.ac.uk/publications/working_papers/wp40.pdf

McEvoy, D., Lindley, S. and Handley, J. (2006). Adaptation and mitigation in urban areas: synergies and conflicts. *Municipal Engineer* 159: ME4

Najam, A., Rahman, A.A., Huq, S. and Sokona, Y. (2003). Integrating sustainable development into the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Climate Policy* 3S1: S9-S17.

Swart, R., Robinson, J. and Cohen, S. (2003). Climate change and sustainable development: expanding the options. *Climate Policy* 3S1: S19-S40.

Tol, R.S.J. (2005). Adaptation and mitigation: trade-offs in substance and methods. *Environmental Science and Policy* 8: 572-578.

Tompkins, E.L. and Adger, N. (2005). Defining response capacity to enhance climate change policy. *Environmental Science and Policy* 8: 562-571.

Turnpenny, J., O'Riordan, T. and Haxeltine, A. (2005). Developing regional and local scenarios for climate change mitigation and adaptation. *Tyndall Centre for Climate Change Research Working Paper 67. http://www.tyndall.ac.uk/publications/working_papers/wp67.pdf*

UN (2004a), *State of the World's Cities 2004/2005 – Globalisation and Urban Culture*, New York, United Nations Publications.

UN (2004b), *World Urbanisation Prospects: The 2003 Revision*, New York, United Nations Publications.

Willbanks, T.J. (2005). Issues in developing a capacity for integrated analysis of mitigation and adaptation. *Environmental Science and Policy* 8: 541-547.

Zhao, S., Liangjun, D., Tang, Z., Fang, H., Song, K. and Fang, J. (2006), Ecological consequences of rapid urban expansion: Shanghai, China, *Frontiers in Ecology and the Environment*, Special Issue - China's Environmental Challenge: The Way Forward, September 2006, 4(7): 341-346.