National and sub-national decision-making is often a mixture of policy and strategic planning. The adaptation-mitigation trade-off is problematic at this scale because the effectiveness of mitigation outlays in terms of averted climate change depends on the mitigation efforts of other major greenhouse-gas emitters. However, adaptation criteria can be applied to mitigation projects or *vice versa* (Dang et al., 2003). A national policy example of synergies might be a new water law that requires metered use, enabling water companies to adjust their charges in anticipation of scarcity and conserve energy through demand-side measures. This policy would then be implemented in strategic plans by water companies and environment agencies at a sub-national level.

On the operational scale of specific projects, there may be trade-offs or synergies between adaptation and mitigation. However, the majority of projects are unlikely to have strong links, although this remains as a key uncertainty. Certainly there are many adaptive actions that have consequences for mitigation, and mitigation actions with consequences for adaptation.

The inter-relationships between adaptation and mitigation also cross scales (Rosenberg and Scott, 1995; Cash and Moser, 2000; Young, 2002). A policy framework is often seen as essential in driving strategic investment and operational projects (e.g., Grubb et al., 2002; Grubb, 2003) for technological innovation. Operational experience can be a precursor to developing sound strategies and policies (one of the motivations for early corporate experiments in carbon trading). In many cases the results of action at one scale have implications at another scale (e.g., local adaptation decisions that increase greenhouse-gas emissions, or national carbon taxes that change local resource use).

18.4 Inter-relationships between adaptation and mitigation and damages avoided

This section presents the main insights emerging from global integrated assessments implemented in different decision-analytical frameworks on trade-offs and synergies between adaptation and mitigation and on avoided damages. This is complemented by lessons from regional and sectoral studies. Principles and technical details of the methods used by the studies reported here are presented in Chapter 2.

18.4.1 Trade-offs and synergies in global-scale analysis

Analysts working on global-scale climate analyses remain apart in their formulation of the inter-relationships between adaptation and mitigation. Some consider them as substitutes and seek the optimal policy mix, while others emphasise the diversity of impacts (with little scope for adaptation in some sectors) and the asymmetry of social actors who need to mitigate versus those who need to adapt (Tol, 2005a). Yet others maintain that adaptation is the only available option for reducing climate-change impacts in the short to medium term, while the long term has a mix of adaptation and mitigation (Goklany, 2007). Note that these positions are not contradictory; they just emphasise different aspects of the same problem.

Cost-benefit analyses (CBAs) are phrased as the trade-off between mitigation costs, on the one hand, and adaptation costs and residual damages on the other. As a recent example, Nordhaus (2001) estimates the economic impact of the Kyoto-Bonn Accord with the RICE-2001 model. Without the participation of the USA, the resulting emissions path remains below the efficient reduction policy (which equates estimated marginal costs and benefits of emissions reductions) whereas the original Kyoto Protocol implied abatement that is more stringent than would be suggested by this CBA. Note that RICE-2001, like all models, has assumptions, simplifications and abstractions that affect the results. Nonetheless, this is a common finding in the cost-benefit literature, driven primarily by relatively low estimates of the marginal damage costs (Tol, 2005b). Cost-benefit models are recognised by many as sources of guidance on the magnitude and rate of optimal climate policy (for a wide range of definitions of what is 'optimal' see Azar, 1998; Brown, 1998; Tol, 2001, 2002; Chapter 2), while others criticise them for ignoring the sectoral (economic and social), spatial and temporal distances between those who need to mitigate versus those who need to adapt to climate change. CBA requires conversion of many different damages to a common metric through monetisation, for example, by polling people's values of different benefits, and the use of discount rates, which is controversial over long time-scales like those of climate change but common practice for other issues. Discounting implies that long-time-scale Earth-system transitions, such as melting of ice sheets, slowdown of the thermohaline circulation or the release of methane, have small weight in a CBA and therefore tend to attach little weight to adaptation costs (see also Chapter 17).

CBA is a special form of multi-criteria analysis. In both cases, policies are judged on multiple criteria, but in CBA all are monetised, while multi-criteria analyses use a range of mathematical methods to make trade-offs explicit and resolve them. Multi-criteria analysis has relatively few applications to climate policy (e.g., Bell et al., 2003; Borges and Villavicencio, 2004), although it is more common for adaptation (e.g., the National Adaptation Programmes of Action).

The Tolerable Windows Approach (TWA) adopts a different approach to integrating mitigation and impact/adaptation concerns and deals with adaptation indirectly in the applications. The ICLIPS (Integrated assessment of CLImate Protection Strategies) model identifies fields of long-term greenhouse-gas emissions paths that prevent rates and magnitudes of climate change leading to regional or sectoral impacts without imposing excessive mitigation costs on societies, either of which stakeholders might consider unacceptable or intolerable. This 'relaxed' cost-benefit framework can be used to explore trade-offs between climate change or impact constraints, on the one hand, and mitigation cost limits in terms of the existence and size of long-term emissions fields, on the other hand. For any given impact constraint, increasing the acceptable consumption loss due to emissions-abatement expenditures increases the emissions field and allows higher near-term emissions but involves higher mitigation rates and costs in later decades. Conversely, for any given mitigation cost limit, increasing the tolerated level of climate impact also enlarges the emissions field and allows higher near-term emissions (Toth et al., 2002, 2003a, b). This formulation allows the exploration of side-payments for enhancing adaptation in order to tolerate impacts from larger climate change. The TWA is helpful in exploring the feasibility and implications of crucial social decisions (acceptable impacts and mitigation costs) but, unlike CBA, it does not propose an optimal policy.

Cost-effectiveness analyses (CEAs) depict a rather remote relationship between adaptation and mitigation. They implicitly assume that some sort of a global climate change target can be agreed upon that would keep all climate-change impacts at the level that can be managed via adaptation or taken as 'acceptable losses'. Or, cost-effectiveness analyses consider a range of hypothetical targets, but remain silent on the appropriateness of these targets. Global CEAs have proliferated since the publication of the TAR (e.g., Edmonds et al., 2004). In addition to exploring least-cost strategies to stabilise CO_2 concentrations, CEAs are applied to analysing the stabilisation of radiative forcing (e.g., Van Vuuren et al., 2006) and global mean temperature (Richels et al., 2004). While most analyses are deterministic in the sense that they implicitly assume that we know the true state of the world, there is also a body of literature that models the 'act, then learn, then act again' nature of the decision problem, but primarily for mitigation decisions. See the WGIII AR4 Chapter 3 for details (Fisher et al., 2007).

The competition of adaptation measures, mitigation measures and non-climate policies for a finite budget has not been studied in much detail. Schelling (1995) questions whether the money that developed countries' governments plan to spend on greenhouse-gas emissions reduction, ostensibly to the benefit of the children and grandchildren of the people in developing countries, cannot be spent to greater benefit. As a partial answer to that question, Tol (2005c) concluded that development aid is a better mechanism to reduce climate-change impacts on infectious disease (e.g., malaria, the best-studied health impact) than is emissions abatement. This analysis implies that the concern about increases in these infectious diseases is not a valid argument for greenhouse-gas emissions reduction (there are of course other arguments for abatement). The same study also shows that this result does not carry over to other impacts. More broadly, Goklany (2003, 2005) shows that the contribution of climate change to hunger, malaria, coastal flooding and water stress (as measured by the population at risk for these hazards) is usually small compared with the contribution of non-climate-change-related factors. He argues that, through the 2080s at least, efforts to reduce vulnerability would be far more cost-effective in reducing these problems than would any mitigation scheme. Other studies estimate the change in vulnerability to climate change due to emissions abatement; for instance, a shift to wind and water power or biofuels would reduce carbon dioxide emissions, but increase exposure to the weather and climate (e.g., Dang et al., 2003).

Some studies estimate the change in greenhouse-gas emissions due to adaptation to the impacts of climate change (Berrittella et al., 2006, for tourism; Bosello et al., 2006, for health). They find that emissions increase in some places and some sectors (making mitigation harder), and decrease elsewhere (making mitigation easier). The disaggregated effects are small compared with the projected growth in emissions, while the net effect is negligible. Similarly, Fankhauser and Tol (2005) show that the impact of climate change on the growth of the economy and greenhouse-gas emissions is small compared with the economy as a whole and because economic adjustment processes would dampen the impact. Note that they only include those climate-change impacts that affect economic performance; they do not use monetisation techniques. Fisher et al. (2006) reach a similar conclusion for population projections, because the net increase in mortality is small. As there are so few studies, focusing on a few sectors only, these conclusions are preliminary.

Although some industries (e.g., wind farm and solar panel manufacturing) may benefit, emissions reduction is likely to slow economic growth, but this effect is probably small if smart abatement policies are used (Weyant, 2004; Barker et al., 2007; Fisher et al., 2007). However, small economic losses in the member states of the Organisation for Economic Co-operation and Development (OECD) may be amplified in poor exporters of primary products (i.e., many African countries). Tol and Dowlatabadi (2001) use this mechanism to demonstrate an interesting trade-off between adaptation and mitigation. Taking malaria as a climate-related disease, they observe that countries with an average annual income per capita of US$3,000 or more do not report significant deaths from malaria and that all world regions surpass this threshold by 2085 in most IPCC IS92 scenarios (IPCC, 1992). Progressively more ambitious emissions reductions in OECD countries gradually decrease the cumulative malaria mortality if one considers only the impact side; that is, the biophysical effects of climate-change mitigation on malaria prevalence. However, if the economic effects of mitigation efforts (i.e., the slower rate of economic growth) are also taken into account, then, according to the FUND model, the malaria-mortality improvements due to slower global warming will be gradually eliminated and eventually surpassed by the losses due to the reduced rate of income growth, unless health care expenditures are decoupled from economic growth. Note that FUND has somewhat high costs of emissions reduction (see the SAR), and also assumes a large impact of slowed growth in the OECD on the rest of the world. Barker et al. (2002), Weyant (2004), Edenhofer et al. (2006), Köhler et al. (2006) and Van Vuuren et al. (2006) show that there is a wide range of estimates of mitigation impacts on economic growth, but these studies did not explore the link between mitigation and vulnerability. In fact, the impact of mitigation on adaptive capacity has not been studied with any other model. More generally, the capacity to adapt to climate change is related to development status, although the two are not the same (Yohe and Tol, 2002; Tompkins and Adger, 2005). The earlier studies used 'adaptive capacity' and 'development' in a generic and broad sense. Tol and Yohe (2006) use more specific indicators of adaptive capacity and development without changing the general conclusion. Emissions reduction policies that hamper development would increase vulnerability and could increase impacts (Tol and Yohe, 2006). Based on this contingency, Goklany (2000b) argues that aggressive mitigation would fall foul of the precautionary principle.

The literature assessed in this sub-section indicates that initial studies tended to focus on the relationship between mitigation and damages avoided, but our knowledge of this subject is still limited and more research needs to be undertaken. More recently, the literature has begun to focus on the relationship between adaptation and damages avoided. Ultimately, better knowledge about the interaction between adaptation and mitigation actions in terms of damages avoided would be useful. However, such research is at a very rudimentary stage. Moreover, large-scale modelling of adaptation-mitigation feedbacks is needed but still lacking. A necessary first step will be improved modelling of feedbacks from impacts, which is currently immature in most long-term global integrated assessment modelling. Adaptation modelling can follow with modelling structures that permit the reallocation of production factors and budgets in response to the changing climate. The adaptation responses therefore redefine the circumstances for mitigation. However, current impact modelling capability is undeveloped and modelling of adaptation responses to climate-change impacts has only just begun. In the above assessment we do not distinguish adaptation by actors (e.g., individuals, government departments) as the conclusions generally hold for all types of adaptation.

18.4.2 Consideration of costs and damages avoided and/or benefits gained

Various approaches have been taken since the TAR to estimate the size of climate change damages that can be avoided by emissions reduction. Among the global integrated assessments reviewed in the previous sub-section, cost-effectiveness models (by far the most widely used decision analysis framework) do not include impacts, hence they cannot measure avoided damages either. In contrast, CBAs of greenhouse-gas emissions reduction (e.g., Nordhaus, 2001) necessarily estimate the avoided damages of climate change but rarely report them. Economic assessments of marginal damage costs (e.g., the incremental impact of an additional tonne of carbon emissions) provide a means of comparing damages avoided with marginal abatement costs. Such studies typically cover a range of sectors and report damage functions and estimates for scenarios of climate change, and increasingly reference scenarios of socio-economic vulnerability.

Tol (2005b) reviewed the avoided-damage literature, including 103 estimates from 28 papers published from 1991 to 2003. Some of the reviewed estimates include only a few impacts; other estimates include a wide range of impacts, including low-probability/high-impact scenarios (see Chapter 20 for further discussion). Tol (2005b) finds that most studies (72% when quality-weighted) point to a marginal damage cost of less than US$50 per tonne carbon (/tC). He also finds a systematic, upward bias in the grey literature. For instance, the 95th percentile falls from US$350/tC to US$245/tC if estimates that were not peer-reviewed are excluded. For a 5% discount rate, a value used by many governments (Evans and Sezer, 2004), the median estimate is only US$7/tC; for a 3% discount rate, it is US$33/tC.

Downing et al. (2005) updated the Tol (2005b) analysis to a 2005 base year: the very likely range of estimates runs from –US$10 to +US$350/tC; peer-reviewed estimates have a mean value of US$43/tC with a standard deviation of US$83/tC. Incorporating results from FUND (2005 version) and PAGE2002, Downing et al. (2005) find that £35/tC (at year 2000 values, or US$56/tC) is a credible lower benchmark for the social cost of carbon (as identified by the UK Government in Clarkson and Deyes, 2002). In FUND, with the Green Book discounting scheme and equity weighting, there is about a 40% chance that the social cost of carbon exceeds £35/tC. Estimates of the central tendency (whether the average or median) or upper benchmark were not agreed in that assessment, due to the limitations in our knowledge of climate impacts and the critical role of the decision perspective (see Section 18.5).

Stern (2007), including a higher level of risk of adverse impacts that are poorly represented in existing models and accepting a public policy framework that includes low discounting of the future, reports a social cost of carbon of US$304/tC (US$85/tCO_2, at pounds sterling 2005 values) from the PAGE2002 model. The range of estimates is quite large and Stern (2007) acknowledges that his central estimate is higher than most studies and is “keenly aware of the sensitivity of estimates to the assumptions that are made”.

Note that the estimates of avoided damages are highly uncertain. A survey of fourteen experts in estimating the social cost of carbon rated their estimates as low confidence, due to the many gaps in the coverage of impacts and valuation studies, uncertainties in projected climate change, choices in the decision framework and the applied discount rate (Downing et al., 2005).

The marginal damage cost only gives the value of the last unit of the damage avoided, not the total avoided damage, which is seldom estimated (see the literature review and papers in Corfee-Morlot and Agrawala, 2004). Nonetheless, as a first approximation of the avoided damages, one should multiply the tonnes of carbon emissions reduced by the marginal damage cost.

Several studies have attempted to calculate total economic damages from disparate impact studies. Warren (2006) reports a long list of ecosystem impacts at 2°C warming and below, billions of people at risk from water stress (without adaptation) and political tension in Russia. As the impact estimates are taken from different studies, with different models and different scenarios, this method introduces additional uncertainties: the difference in impact may be due to different warming scenarios, but also due to differences in models, data, economic scenarios and even subject and area of study. Furthermore, it is difficult to compare how impacts change with additional degrees of climate change, although the work does suggest that there are an increasing number of negative impacts at higher temperatures. Warren’s (2006) study is often qualitative and it is unclear whether the studies are representative of the literature (or the population of affected sectors), or whether adaptation is included. On avoidable damage, this study paints a bleak picture. At 2°C warming, which may be difficult to avoid, 97% of coral reefs and 100% of Arctic sea ice would be lost. Avoided damage is therefore less than 3% of coral reefs, and no Arctic sea ice. Hare (2006) also offers impact estimates for various warming scenarios, with the same limitations as for Warren (2006). Hitz and Smith (2004) review damage functions related to global mean temperature but do not aggregate to overall damages. Arnell et al. (2002) and Parry et al. (2004) use internally consistent models and scenarios, and report numbers for avoided damages, measured in millions of people at risk. Water resources and malaria dominate their results, but the underlying models do not account for adaptation and keep socio-economic development at 1990 levels, although populations grow.

Relatively few studies have documented damages avoided in terms of specific mitigation scenarios. Bakkenes et al. (2006) study the implications of different stabilisation scenarios on European plant diversity. Mitigation is not considered, even though biofuels and carbon plantations would substantially affect vegetation. Under the A1B scenario, plants would lose on average 29% of their current habitat by 2100, with a range between species from 10% to 53%. Stabilisation at 650 ppm would limit this to 22% (6-42%), and at 550 ppm to 18% (5-37%). With unmitigated climate change, nine plant species would disappear from Europe, but eight new ones would appear. Stabilisation would limit the number of plant disappearances from nine to eight species. In all five studies, adaptation (except in some parts of the Parry study) and the effects of mitigation on impacts are not included (see Section 18.4.1). Nicholls and Lowe (2004) estimate the avoided impact of sea-level rise due to mitigation. Because sea level responds so slowly to global warming, avoided impacts are small, at least over the 21st century. Nicholls and Lowe (2004) ignore the costs of emissions reduction; Tol (2007) shows that the bias is negligible for coastal-zone impacts. Nicholls and Lowe (2004, 2006) argue that adaptation and mitigation should be applied together for coastal zones, with mitigation to minimise the future commitment to sea-level rise and adaptation to adapt to the inevitable changes. Nicholls and Tol (2006) and Nicholls et al. (2007) also explore the economic impacts of sea-level rise.

Tol and Yohe (2006), using the integrated assessment model, Climate Framework for Uncertainty, Negotiation and Distribution (FUND), conclude that the most serious impacts of climate change can be avoided at an 850 ppm CO_2-equivalent stabilisation target for greenhouse-gas concentrations, and that incrementally avoided damages get smaller and smaller as one moves to more stringent stabilisation targets. For a 450 ppm CO_2-equivalent stabilisation target, climate-change impacts may actually increase as the reduction of sulphur emissions may lead to warming and as abatement costs slow growth and increase vulnerability. However, FUND includes a wide range but not all impacts, represents impacts in a reduced form, does not capture discontinuities or interactions between impacts, models climate change as being smooth, and does not include the ancillary benefits of reductions in sulphur. Other models also find that climate policy would reduce sulphur emissions to levels below what is required for acidification policy (e.g., Van Vuuren et al., 2006). Other integrated assessment models have yet to produce comparable analyses.

Abatement may, but need not, reduce the probability of extreme climate scenarios, such as a shut-down of the thermohaline circulation (Gregory et al., 2005) and a collapse of the West Antarctic ice sheet (Vaughan and Spouge, 2002). The few studies on the effects of drastic sea-level rise show large impacts (Schneider and Chen, 1980; Nicholls et al., 2005; Tol et al., 2006) but opinions on the impacts of a thermohaline circulation shut-down are divided (Rahmstorf, 2000; Link and Tol, 2004).

Additional assessments of damages avoided by mitigation are also provided in other chapters of this report. Chapter 20 finds that estimates of the social cost of carbon expand over at least three orders of magnitude and notes that globally aggregated figures are likely to underestimate the full costs, masking differences in impacts across sectors and regions/countries. It concludes that "it is very likely that climate change will result in net costs into the future, aggregated across the globe and discounted to today; it is very likely that these costs will grow over time". The WGIII AR4 in Chapter 3 (Fisher et al., 2007) observes that most (but not all) analyses which use monetisation suggest that social costs of carbon are positive, but the range of values is wide and is strongly dependent on modelling methodology, value judgements and assumptions. It concludes that large uncertainties persist, related to the cost of mitigation, the efficacy of adaptation, and the extent to which the negative impacts of climate change, including those related to rate of change, can be avoided. See Box 18.2 for a summary of the WGIII AR4 conclusions on damages avoided with different stabilisation scenarios.

Overall, there are only a few studies that estimate the avoided impacts of climate change by emissions reduction. Some of these studies ignore adaptation and mitigation costs. Many published studies of damages in sectors that are quantified in economic models (but mostly market-based costs and related to incremental projections of temperature) and with discount rates commonly used in economic decision-making (e.g., 3% or higher) lead to low estimates of the social cost of carbon. In general, confidence in these estimates is low. The paucity of evidence is disappointing, as avoiding impacts is presumably a major aim of climate policy. CBAs of climate change implicitly estimate avoided damages and suggest that these do not warrant very stringent emissions reduction (see Section 18.4.1). Similarly, although ecosystem impacts may be large, avoidable impacts may be much smaller. With few high-quality studies, confidence in these findings is low. This is a clear research priority. The use of the social cost of carbon in decision-making on mitigation also warrants further exploration.

18.4.3 Inter-relationships within regions and sectors

Considering the details of specific adaptation and mitigation activities at the level of regions and sectors shows that adaptation and mitigation can have a positive and negative influence on each other's effectiveness. The nature of these inter-relationships (positive or negative) often depends on local conditions. Moreover, some inter-relationships are direct, involving the same resource base (e.g., land) or stakeholders, while others are indirect (e.g., effects through public budget allocations) or remote (e.g., shifts in global trade flows and currency exchange rates). This section focuses on direct inter-relationships. Broader inter-relationships between adaptation and mitigation are discussed in other parts of this chapter and in Chapter 20 related to sustainable development.

Mitigation affecting adaptation

Land-use and land-cover changes involve diverse and complex inter-relationships between adaptation and mitigation. Deforestation and land conversion have been significant sources of greenhouse-gas emissions for decades while often resulting in unsustainable agricultural production patterns. Abating and halting this process by incentives for forest conservation and increasing forest cover would not only avoid greenhouse-gas emissions, but would also result in benefits for local climate, water resources and biodiversity.

Carbon sequestration in agricultural soils offers another positive link from mitigation to adaptation. It creates an economic commodity for farmers (sequestered carbon) and makes the land more valuable by improving soil and water conservation, thus enhancing both the economic and environmental components of adaptive capacity (Boehm et al., 2004; Butt and McCarl, 2004; Dumanski, 2004). The stability of these sinks requires further research, and effective monitoring is also a challenge.

Afforestation and reforestation have been advocated for decades as important mitigation options. Recent studies reveal a more differentiated picture. Competition for land by mitigation projects would increase land rents, and thus commodity prices, thereby improving the economic position of landowners and enhancing their adaptive capacity (Lal, 2004). However, the implications of reforestation projects for water resources depend heavily on the species composition and the geographical and climatic characteristics of the region where they are implemented. In regions with ample water resources even under a changing climate, afforestation can have many positive effects, such as soil conservation and flood control. In regions with few water resources, intense rainfalls and long spells of dry weather, forests increase average water availability. However, in arid and semi-arid regions, afforestation strongly reduces water yields (UK FRP, 2005). This has direct and wide-ranging negative implications for adaptation options in several sectors such as agriculture (irrigation), power generation (cooling towers) and ecosystem protection (minimum flow to sustain ecosystems in rivers, wetlands and on river banks).

Bioenergy crops are receiving increasing attention as a mitigation option. Most studies, however, focus on technology options, costs and competitiveness in energy markets and do not consider the implications for adaptation. For example, McDonald et al. (2006) use a global computed general equilibrium model and find that substituting switchgrass for crude oil in the USA would reduce the gross domestic product (GDP) and increase the world price of cereals, but they do not investigate how this might affect the prospects for adaptation in the USA and for world agriculture. This limitation in scope characterises virtually all bioenergy studies at the regional and sectoral scales, but substantial literature on adaptation-relevant impacts exists at the project level (e.g., Pal and Sharma, 2001; see Section 18.5 and Chapter 17).

Another possible conflict between adaptation and mitigation might arise over water resources. One obvious mitigation option is to shift to energy sources with low greenhouse-gas emissions

Box 18.2. Analysis of stabilisation scenarios

The WGIII AR4, in Chapter 3 (Section 3.5.2), looks across findings of the WGI and WGII AR4 to relate the long-term emissions scenarios literature to climate-change impact risks at different levels of global mean temperature change based on key vulnerabilities (as defined in Chapter 19). It builds on the WGI AR4 findings, which outline the probabilities of exceeding various global mean temperatures at different concentration levels (Tables 3.9 and 3.10 in Fisher et al., 2007). The relationships are based on a key finding of the WGI AR4 that there is at least an 83% probability for climate sensitivity to be at or below 4.5°C, while the best estimate is for climate sensitivity to be 3°C. The WGIII AR4 organises the stabilisation scenarios literature by the level of stringency of the scenario, setting out six groups (I-VI) that cover the full range of more to less stringent global warming objectives, in the form of concentrations (ppm) or radiative forcing (W/m^2). Table 3.9 uses the WGI AR4 findings to relate increases in global mean temperature to concentration targets, while Table 3.10 relates these outcomes to the emissions pathways associated with alternative stabilisation scenarios. (An important caveat is that these relationships do not consider possible additional CO_2 and CH_4 releases from Earth-system feedbacks and thus may underestimate required emissions reductions.)

Regarding climate-change impact risks and key vulnerabilities, this literature is organised around increase in global mean temperature. Chapter 19 shows that the following benefits would accrue from constraining temperature rise to 2°C above 1990:
- lowering the risk of widespread deglaciation of the Greenland ice sheet**;
- avoiding large-scale transformation of ecosystems and degradation of coral reefs***;
- preventing terrestrial vegetation becoming a carbon source*/**, constraining species extinction to between 10% and 40%*, and preserving many unique habitats (see Chapter 4, Table 4.1 and Figure 4.5);
- preventing flooding, drought and water-quality declines***, global net declines in food production*/•, and more intense fires**.

Other benefits of this constraint include reducing the risks of extreme weather events**, and of at least partial deglaciation of the West Antarctic ice sheet (WAIS)* (see Chapter 19, Section 19.3.7). By comparison, constraining temperature change to not more than 3°C above 1990 levels will still avoid commitment to widespread deglaciation of the WAIS* and commitment to possible shut-down of the Meridional Overturning Circulation/• but results in significantly lower avoided risks and impacts in most other areas (Chapter 19, Section 19.3.7).

(Confidence ratings are as provided by WGII Chapter 19 authors: /• = low confidence, * = medium, ** = high, and *** = very high confidence.)

such as small hydropower. In regions where hydropower potentials are still available, and also depending on the current and future water balance, this would increase the competition for water, especially if irrigation might be a feasible strategy to cope with climate-change impacts in agriculture and the demand for cooling water by the power sector is also significant. This reconfirms the importance of integrated land and water-management strategies to ensure the optimal allocation of scarce natural resources (land, water) and economic investments in climate-change adaptation and mitigation and in fostering sustainable development.

Hydropower leads to the key area of mitigation: energy sources and supply, and energy use in various economic sectors beyond land use, agriculture and forestry. Direct implications of mitigation efforts on adaptation in the energy, transport, residential/commercial and industrial sectors have been largely ignored so far. Yet, to varying degrees, energy is an important factor in producing goods and providing services in many sectors of the economy, as outlined in the discussion about the importance of energy to achieve the Millennium Development Goals in the WGIII AR4, Chapter 2 (Halsnæs et al., 2007). Reducing the availability or increasing the price of energy therefore has inevitable negative effects on economic development and thus on the economic components of adaptive capacity. The magnitude of this effect is uncertain. Peters et al. (2001) find that high-level carbon charges (US$200/tC in 2010) affect U.S. agriculture modestly if they are measured in terms of consumer and producer surpluses (reductions by less than half a percent relative to baseline values). However, the decline of net cash returns is more significant (4.1%) and the effects are rather uneven across field crops and regions. Recent studies on the implications for adaptation (capacity and options) indicate that such changes may imply larger policy shifts; for example, towards protection of the most vulnerable (Adger et al., 2006).

The most important indirect link from mitigation to adaptation is through biodiversity, an important factor influencing human well-being in general and the coping options in particular (see MEA, 2005). After assessing a large number of studies, IPCC (2002) concluded that the implications for biodiversity of mitigation activities depend on their context, design and implementation, especially site selection and management practices. Avoiding forest degradation implies in most cases both biodiversity (preservation) and climate (non-emissions) benefits. However, afforestation and reforestation may have positive, neutral or negative impacts, depending on the level of biodiversity of the ecosystems that will be replaced. By using an optimal-control model, Caparros and Jacquemont (2003) find that putting an economic value on carbon sequestered by forest management does not induce much negative influence on biodiversity, but incentives to sequester carbon by afforestation and reforestation might harm biodiversity due to the over-plantation of fast-growing alien species.

These studies demonstrate the intricate inter-relationships between adaptation and mitigation, and also the links with other environmental concerns, such as water resources and biodiversity, with profound policy implications. The land-use and forestry mitigation options in the Marrakesh Accords may provide new markets for countries with abundant land areas but may alter land allocation to the detriment of the landless poor in regions where land is scarce. They present an opportunity for soil and biodiversity protection in regions with ample water resources but may reduce water yields and distort water allocation in water-stressed regions. Accordingly, depending on the regional conditions and the ways of implementation, these implications can increase or reduce the scope for adaptation to climate change by promoting or excluding effective, but more expensive, options due to increased land rents, by supporting or precluding forms and magnitudes of irrigation due to, for example, higher water prices.

Adaptation affecting mitigation

Many adaptation options in different impact sectors are known to involve increased energy use and hence interfere with mitigation efforts if the energy is supplied from carbon-emitting sources. Two main types of adaptation-related energy use can be distinguished: one-time energy input for building large infrastructure (materials and construction), and incremental energy input needed continuously to counterbalance climate impacts in providing goods and services. Furthermore, rural renewable electrification can have both huge emissions implications (WEA, 2000) and adaptation implications (Venema and Cisse, 2004).

The largest amount of construction work to counterbalance climate-change impacts will be in water management and in coastal zones. The former involves hard measures in flood protection (dykes, dams, flood control reservoirs) and in coping with seasonal variations (storage reservoirs and inter-basin diversions), while the latter comprises coastal defence systems (embankment, dams, storm surge barriers). Even if these construction projects reach massive scales, the embodied energy, and thus the associated greenhouse-gas emissions, is likely to be merely a small proportion of the total energy use and energy-related emissions in most countries (adaptation-related construction comprises only a small part of total annual construction, and the construction industry itself represents a small part in the annual energy balances of most countries).

The magnitude and relative share of sustained adaptation-related energy input in the total energy balance depends on the impact sector. In agriculture, the input-related (CO_2 in manufacturing) and the application-related (N_2O from fields) greenhouse-gas emissions might be significant if the increased application of nitrogen fertilisers offers a convenient and profitable solution to avoid yield losses (McCarl and Schneider, 2000). Operating irrigation works and pumping irrigation water could considerably increase the direct energy input, although, where available, the utilisation of renewable energy sources on-site (wind, solar) can help avoid increasing greenhouse-gas emissions.

Adaptation to changing hydrological regimes and water availability will also require continuous additional energy input. In water-scarce regions, the increasing reuse of wastewater and the associated treatment, deep-well pumping, and especially large-scale desalination, would increase energy use in the water sector (Boutkan and Stikker, 2004). Yet again, if provided from carbon-free sources such as nuclear desalination (Misra, 2003;

Ayub and Butt, 2005), even energy-intensive adaptation measures need not run counter to mitigation efforts.

Ever since the early climate impact studies, shifts in space heating and cooling in a warming world have been prominent items on the list of adaptation options (see Smith and Tirpak, 1989). The associated energy requirements could be significant but the actual implications for greenhouse-gas emissions depend on the carbon content of the energy sources used to provide the heating and cooling services. In most cases, it is not straightforward to separate the adaptation effects from those of other drivers in regional or national energy-demand projections. For example, for the U.S. state of Maryland, Ruth and Lin (2006) find that, at least in the medium term up to 2025, climate change contributes relatively little to changes in the energy demand. Nonetheless, the climate share varies with geographical conditions (changes in heating and cooling degree days), economic (income) and resource endowments (relative costs of fossil and other energy sources), technologies, institutions and other factors. Such emissions from adaptation activities are likely to be small relative to baseline emissions in most countries and regions, but more in-depth studies are needed to estimate their magnitude over the long term.

Adaptation affects not only energy use but energy supply as well. Hydropower contributed 16.3% of the global electricity balance in 2003 (IEA, 2005) with virtually zero greenhouse-gas emissions. Climate-change impacts and adaptation efforts in various sectors might reduce the contribution of this carbon-free energy source in many regions as conflicts among different uses of water emerge. Hayhoe et al. (2004) show that emissions even in the lowest SRES (IPCC Special Report on Emissions Scenarios; Nakićenović and Swart, 2000) scenario (B1) will trigger significant shifts in the hydrological regime in the Sacramento River system (California) by the second half of this century and will create critical choices between flood protection in the high-water period and water storage for the low-flow season. Hydropower is not explicitly addressed but will probably be affected as well. Payne et al. (2004) project conflicts between hydropower and streamflow targets for the Columbia River. Several studies confirm the unavoidable clashes between water supply, flood control, hydropower and minimum streamflow (required for ecological and water quality purposes) under changing climatic and hydrological conditions (Christensen et al., 2004; VanRheenen et al., 2004).

Possibly the largest factor affecting water resources in adaptation is irrigation in agriculture. Yet studies in this domain tend to ignore the repercussions for mitigation as well. For example, Döll (2002) estimates significant increases in irrigation needs in two-thirds of the agricultural land that was equipped for irrigation in 1995, but she does not assess the implications for other water uses such as hydropower and thus for climate-change mitigation.

In general, adaptation implies that people do something in addition to or something different from what they would be doing in the absence of emerging or expected climate-change impacts. In most cases, additional activities involve additional inputs: investments (protective and other infrastructure), material (fertilisers, pesticides) or energy (irrigation pumps, air-conditioning), and thus may run counter to mitigation if the energy originates from greenhouse-gas-emitting sources. Changing practices in response to climate change offer more opportunities to account for both adaptation and mitigation needs. Besides the opportunities in land-related sectors discussed above, new design principles for commercial and residential buildings could simultaneously reduce vulnerability to extreme weather events and energy needs for heating and/or cooling. Nonetheless, there are path dependencies from past technology choices and infrastructure investments.

In summary, many effects of adaptation on greenhouse-gas emissions and their mitigation (energy use, land conversion, agronomic techniques such as an increased use of fertilisers and pesticides, water storage and diversion, coastal protection) have been known for a long time. The implications of some mitigation strategies for adaptation and other development and environment concerns have been recognised recently. As yet, however, both effects remain largely unexplored. Information on inter-relationships between adaptation and mitigation at regional and sectoral levels is rather scarce. Almost all mitigation studies stop at identifying the options and costs of direct emissions reductions. Some of them consider indirect effects of implementation and costs on other sectors or the economy at large but do not deal with the implications for adaptation options of sectors affected by climate change. Similarly, in most cases, climate impact and adaptation assessments do not go beyond taking stock of the adaptation options and estimating their costs, and thus ignore possible repercussions for emissions. One understandable reason is that adaptation and mitigation studies are already complex enough and expanding their scope would increase their complexity even further. Another reason may well be that, as indicated by the few available studies that looked at these inter-relationships, the repercussions from mitigation for adaptation and *vice versa* are between adaptation and mitigation might be significant but, in most other sectors, the adaptation implications of any mitigation project are small and, conversely, the emissions generated by most adaptation activities are only small fractions of total emissions, even if emissions will decline in the future as a result of climate-protection policies.

18.5 Inter-relationships in a climate policy portfolio

A wide range of inter-relationships between adaptation and mitigation have been identified through examples in the published literature. Taylor et al. (2006) present an inventory of published examples including full citations (available in an abbreviated form on the CD-ROM accompanying this volume as supplementary material to support the review of this chapter). The many examples have been clustered according to the type of linkage and ordered according to the entry point and scale of decision-making (Figure 18.2). Table 18.1 lists all of the types of linkages documented. The categories are illustrative; some cases occur in more than one category, or could shift over time or in different situations. For example, watershed planning is often related to managing climatic risks in using water. But if hydroelectricity is an option, then the entry point may be mitigation, and both adaptation and mitigation might be evaluated at the same time or even with explicit trade-offs.

In Figure 18.2 and Table 18.1, many of the examples are motivated by either mitigation or adaptation, with largely unintended consequences for the other (e.g., Tol and Dowlatabadi, 2001). Where adaptation leads to effects on mitigation, the linkage is labelled *A→M*. The categories of linkages include:

- individual responses to climatic hazard that increase or decrease greenhouse-gas emissions. For example, a common adaptation to heatwaves is to install air-conditioning, which increases electricity demand with consequences for mitigation when the electricity is produced from fossil fuels;
- more efficient community use of water, land, forests and other natural resources, improving access and reducing emissions (e.g., conservation of water in urban areas reduces energy used in moving and heating water);
- natural resources managed to sustain livelihoods;
- tourism use of energy and water, with outcomes for incomes and emissions (generally to increase both welfare and emissions);
- resources used in adaptation, such as in large-scale infrastructure, increases emissions.

Similarly, mitigation actions might affect the capacity to adapt or actual adaptation actions (*M→A*). These categories include:

- more efficient energy use and renewable sources that promote local development;
- CDM projects on land use or energy use that support local economies and livelihoods, perhaps by placing a value on their management of natural resources;
- urban planning, building design and recycling with benefits for both adaptation and mitigation;
- health benefits of mitigation through reduced environmental stresses;
- afforestation, leading to depleted water resources and other ecosystem effects, with consequences for livelihoods;
- mitigation actions that transfer finance to developing countries (such as per capita allocations) that stimulate investment with benefits for adaptation;
- effects of mitigation, e.g., through carbon taxes and energy prices, on resource use (generally to reduce use) that affect adaptation, for example by reducing the use of tractors in semi-subsistence farming due to higher costs of fuels.

As noted in Section 18.4.3, the effect of increased emissions due to adaptation is likely to be small in most sectors in relation to the baseline projections of energy use and greenhouse-gas emissions. Land and water management may be affected by mitigation actions, but in most sectors the effects of mitigation on adaptation are likely to be small. At least some analysts are concerned with the explicit trade-offs between adaptation and mitigation (labelled adaptation or mitigation, $\int(A,M)$). Categories include:

- public-sector funding and budgetary processes that allocate funding to both adaptation and mitigation;

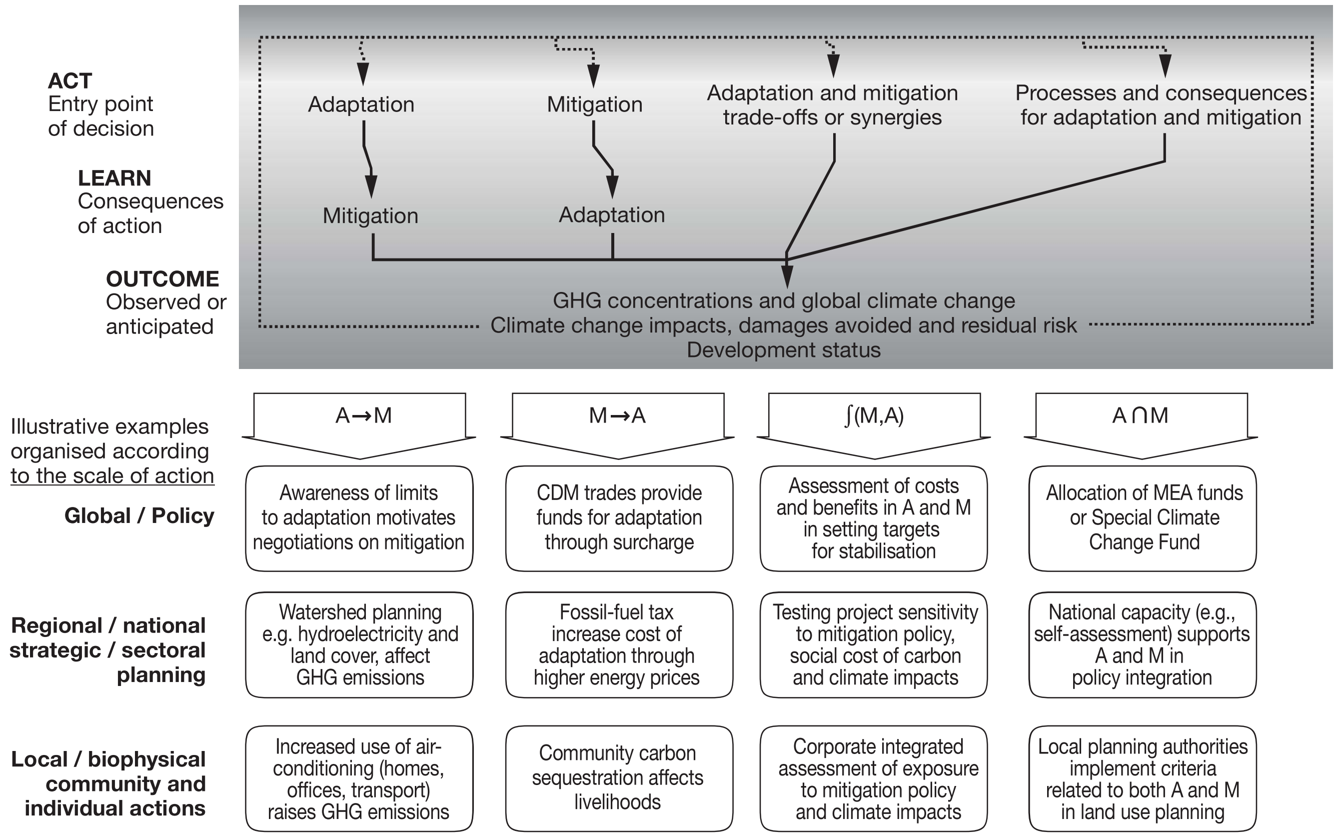

Figure 18.2. *Typology of inter-relationships between climate change adaptation and mitigation. MEA = Multilateral Environmental Agreements.*

- strategic planning related to development pathways, for example scenario and visioning exercises with urban governments that include climate responses (mainstreaming responses in sectoral and regional planning);
- allocation of funding and setting the agenda for UNFCCC negotiations and funds (e.g., the Special Climate Change Fund);
- stabilisation targets that include limits to adaptation (e.g., tolerable windows);
- analysis of global costs and benefits of mitigation to inform targets for greenhouse-gas concentrations (see Section 18.4.2);
- large-scale mitigation (e.g., geo-engineering) with effects on impacts and adaptation.

Some actions result from the simultaneous consideration of adaptation and mitigation. These concerns may be raised within the same decision framework or sequential process but without explicitly considering their trade-offs or synergies (labelled adaptation and mitigation, *A*∩*M*). Examples include:

- perception of impacts and the limits to adaptation (see Chapter 17) motivates action on mitigation, conversely the perception of limits to mitigation reinforces urgent action on adaptation;
- watershed planning where water is allocated between hydroelectricity and consumption without explicitly addressing mitigation and adaptation;
- cultural values that promote both adaptation and mitigation, such as sacred forests (e.g., Satoyama in Japan);
- management of socio-ecological systems to promote resilience;
- ecological impacts, with some human element, drive further releases of greenhouse gases,
- legal implications of liability for climate impacts motivates mitigation;
- national capacity-building increases the ability to respond to both adaptation and mitigation (such as through the National Capacity-Building Self Assessment);
- insurance spreads risk and assists with adaptation, while managing insurance funds has implications for mitigation;
- trade liberalisation may have economic benefits (increasing adaptive capacity) but also increases emissions from transport;
- monitoring systems and reporting requirements may cover indicators of both adaptation and mitigation;
- management of multilateral environmental agreements may benefit both adaptation and mitigation.

Table 18.1. *Types of inter-relationships between climate change adaptation and mitigation.*

A→M	***M→A***	***∫(A,M)***	***A∩M***
Individual responses to climatic hazards that increase or decrease greenhouse-gas emissions	More efficient energy use and renewable sources that promote local development	Public-sector funding and budgetary processes that allocate funding to both *A* and *M*	Perception of impacts (and limits to *A*) motivates *M*; perception of limits to *M* motivates *A*
More efficient community use of water, land, forests	CDM projects on land use or energy use that support local economies and livelihoods	Strategic planning related to development pathways (scenarios) to mainstream climate responses	Watershed planning: allocation of water between hydroelectricity and consumption
Natural resources managed to sustain livelihoods	Urban planning, building design and recycling with benefits for both *A* and *M*	Allocation of funding and setting the agenda for UNFCCC negotiations and funds	Cultural values that promote both *A* and *M*, such as sacred forests (e.g., Satoyama in Japan)
Tourism use of energy and water, with outcomes for incomes and emissions	Health benefits of mitigation through reduced environmental stresses	Stabilisation targets that include limits to adaptation (e.g., tolerable windows)	Management of socio-ecological systems to promote resilience
Resources used in adaptation, such as large-scale infrastructure, increase emissions	Afforestation, leading to depleted water resources and other ecosystem effects, with consequences for livelihoods	Analysis of global costs and benefits of *M* to inform targets	Ecological impacts, with some human element, drive further releases of greenhouse gases
	M schemes that transfer finance to developing countries (such as a per capita allocation) stimulate investment that may benefit *A*	Large scale *M* (e.g., geo-engineering) with effects on impacts and *A*	Legal implications of liability for climate impacts motivates *M*
	Effect of mitigation, e.g., through carbon taxes and energy prices, on resource use		National capacity-building increases ability to respond to both *A* and *M*
			Insurance spreads risk and assists with *A*; managing insurance funds has implications for *M*
			Trade liberalisation with economic benefits (*A*) increases transport costs (*M*)
			Monitoring systems and reporting requirements that cover indicators of both *A* and *M*
			Management of multilateral environmental agreements benefits both *A* and *M*

Inter-relationships between adaptation and mitigation will vary with the type of policy decisions being made, for example on different scales from local project analysis to global analysis. As discussed in Section 18.4.3, there will be clear $M \rightarrow A$ linkages in many mitigation projects, for example ensuring that adaptation is built into the project design (e.g., considering and adjusting for water availability for longer-term hydroelectric renewable or bioenergy/biofuels projects). Similarly, in the design or appraisal of adaptation projects, $A \rightarrow M$, the consideration of mitigation options can be brought in, for example in considering reduced energy use in project design. These linkages might be considered through an extension of project risk analysis as part of the appraisal process, but can also be included in cost-benefit analysis explicitly in an economic appraisal framework.

At the policy level (e.g., portfolios, funding, strategies), the same $M \rightarrow A$ and $A \rightarrow M$ issues apply, but the wider potential for cross-sectoral linkages makes simultaneous consideration of adaptation and mitigation, $A \cap M$, more important. For example, the shift up to a major (country level) energy policy towards mitigation might need to assess demand changes from adaptation across a wide range of sectors. There may be a need to consider some explicit trade-offs between adaptation and mitigation, $\int(A,M)$.

At the global level, the potential for $\int(A,M)$ becomes possible within a theoretical framework (see Section 18.4). There has been discussion of the potential for adaptation and mitigation as substitutes within narrow economic analysis (cost-benefit frameworks), and some studies have tried to assess the optimal policy balance of mitigation and adaptation using CBA based on IAMs. However, recent reviews (e.g., Watkiss et al., 2005) have shown that policy-makers are uncomfortable with the use of CBA in longer-term climate policy, because of the range of uncertainty over the relevant economic parameters of marginal mitigation costs and marginal social costs and damages avoided, but also because of the significant lack of data on the costs of adaptation. Instead, wider frameworks are considered to be more informative, using multiple aspects and risk-based approaches, for example iterative decision-making and tolerable windows (see also the risk matrix in Chapter 20). Stern (2007) explicitly adopted a risk-based framework appropriate for guiding policy from analysing the marginal costs and benefits at the project level to determination of public policy that affects future economic paths. He recognised that adaptation plays an important role, but not in an explicit trade-off against mitigation, in long-term policy.

18.6 Response capacity and development pathways

As outlined in the TAR (IPCC, 2001c, Chapter 18 and IPCC, 2001b, Chapter 1) and discussed at more length in Chapter 17 of this volume and in the WGIII AR4, Chapter 12 (Sathaye et al., 2007), the ability to implement specific adaptation and mitigation measures is dependent upon the existence and nature of adaptive and mitigative capacity, which makes such measures possible and affects their extent and effectiveness. In that sense, specific adaptation and mitigation measures are rooted in their respective capacities (Yohe, 2001; Adger et al., 2003; Adger and Vincent, 2005; Brooks et al., 2005).

Adaptive capacity has been defined in this volume (see Chapter 17) as "the ability or potential of a system to respond successfully to climate variability and change." In a parallel way, mitigative capacity has been defined as the "ability to diminish the intensity of the natural (and other) stresses to which it might be exposed" (see Rogner et al., 2007). Since this definition suggests that a group's capacity to mitigate hinges on the severity of impacts to which it is exposed, Winkler et al. (2007) have suggested that capacity be defined instead as "a country's ability to reduce anthropogenic greenhouse gases or enhance natural sinks". Clearly these two categories are closely related although, in accordance with the differences between adaptation and mitigation measures discussed in Section 18.1, capacities also differ somewhat. In particular, since adaptation measures tend to be both more geographically dispersed and smaller in scale than mitigation measures (Dang et al., 2003; Ruth, 2005), adaptive capacities refer to a slightly broader and more general set of capabilities than mitigative capacities. Despite these minor differences, however, adaptive and mitigative capacities are driven by similar sets of factors.

The term response capacity may be used to describe the ability of humans to manage both the generation of greenhouse gases and the associated consequences (Tompkins and Adger, 2005). As such, response capacity represents a broad pool of resources, many of which are related to a group or nation's level of socio-technical and economic development, which may be translated into either adaptive or mitigative capacity. Socio-cultural dimensions such as belief systems and cultural values, which are often not addressed to the same extent as economic elements (Handmer et al., 1999), can also affect response capacity (see IPCC, 2001b; Sathaye et al., 2007).

Although the concept of response capacity is new to the IPCC and has yet to be sufficiently investigated in the literature, efforts have been made to define the nature and determinants of its conceptual components: adaptive and mitigative capacity. With regard to mitigative capacity, Yohe (2001) has suggested the following list of determinants, which play out at the national level:

- range of viable technological options for reducing emissions;
- range of viable policy instruments with which the country might affect the adoption of these options;
- structure of critical institutions and the derivative allocation of decision-making authority;
- availability and distribution of resources required to underwrite the adoption of mitigation policies and the associated broadly-defined opportunity cost of devoting those resources to mitigation;
- stock of human capital, including education and personal security;
- stock of social capital, including the definition of property rights;
- a country's access to risk-spreading processes (e.g., insurance, options and futures markets);
- the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of decision-makers themselves.

In the context of developing countries, many of which possess limited institutional capacity and access to resources, mitigative and adaptive capacity could be fashioned by additional determinants. For instance, political will and the intent of decision-makers, and the ability of societies to form networks through collective action that insulates them against the impacts of climate change (Woolcock and Narayan, 2000), may be especially important in developing countries, especially in societies where policy instruments are not fully developed and where institutional capacity and access to resources are limited.

Yohe suggests a similar set of determinants for adaptive capacity, but adds the availability of resources and their distribution across the population. Recent research has sought to offer empirical evidence that demonstrates the relative influence of each of these determinants on actual adaptation (Yohe and Tol, 2002). In particular, this research indicates that the influence of each determinant of capacity is highly location-specific and path-dependent, thus revealing the importance of investigations into micro- and macro-scale determinants that influence capacity across multiple stressors (Yohe and Tol, 2002). These determinants of both adaptive and mitigative capacity expand on those identified in the TAR and agree closely with those offered by Moss et al. (2001) and Adger et al. (2004). The linkages between adaptive and mitigative capacity are demonstrated by the striking similarities between these sets of determinants, which show that both the ability to adapt and the ability to mitigate depend on a mix of social, biophysical and technological constraints (Tompkins and Adger, 2005). Recent research has pointed to the necessity of broadening these lists of determinants to include other important factors such as socio-political aspirations (Haddad, 2005), risk perception, perceived adaptive capacity (Grothmann and Patt, 2005) and political will (Winkler et al., 2007).

These discussions of determinants indicate the close connection that exists between response capacities and the underlying socio-economic and technological development paths that give rise to those capacities. In several important respects, the determinants listed above are important characteristics of such development paths. Those development paths, in turn, underpin the baseline and stabilisation emissions scenarios discussed in the WGIII AR4, Chapter 3 (Fisher et al., 2007) and used to estimate emissions, climate change and associated climate-change impacts. As a result, the determinants of response capacity can be expected to vary across the underlying emissions scenarios reviewed in this report. The climate change and climate-change impact scenarios assessed in this report will be primarily based on the SRES storylines, which define a spectrum of different development paths, each with associated socio-economic and technological conditions and driving forces (for an extended discussion of emissions pathways and climate policies, see Fisher et al., 2007). Each storyline will therefore give rise to a different set of response capacities, and thus to different likely, or even possible, levels of adaptation and mitigation.

Adaptation and mitigation measures, furthermore, are rooted in adaptive and mitigative capacities, which are in turn contained within, and strongly affected by, the nature of the development path in which they exist. The concept of development paths is discussed at more length in the WGIII AR4 in Chapters 2 (Halsnæs et al., 2007), 3 (Fisher et al., 2007) and 12 (Sathaye et al., 2007). Here, it is sufficient to think of a development path as a complex array of technological, economic, social, institutional and cultural characteristics that define an integrated trajectory of the interaction between human and natural systems over time at a particular scale. Such technological and socio-economic development pathways find their most common expression in the form of integrated scenarios (Geels and Smit, 2000; Grubb et al., 2002; Swart et al., 2003; see also WGIII AR4, Chapter 3), but are also incorporated into studies of technological diffusion (Foray and Grubler, 1996; Dupuy, 1997; Andersen, 1998; Grubler, 2000; Berkhout, 2002; Rogers, 2003), socio-technical systems (Geels, 2004) and situations in which large physical infrastructures and the requisite supportive organisational, cultural and institutional systems create conditions of quasi-irreversibility (Arthur, 1989; Sarkar, 1998; Geels, 2005; Unruh and Carrillo-Hermosilla, 2006). Technological and social pathways co-evolve through a process of learning, coercion and negotiation (Rip and Kemp, 1998), creating integrated socio-technical systems that strongly condition responses to risks such as climate change.

In the climate-change context, the TAR noted that “climate change is thus a potentially critical factor in the larger process of society’s adaptive response to changing historical conditions through its choice of developmental paths” (Banuri et al., 2001). Later in the same volume, the following typology of critical components of development paths is presented (Toth et al., 2001):

- technological patterns of natural resource use, production of goods and services and final consumption,
- structural changes in the production system,
- spatial distribution patterns of population and economic activities,
- behavioural patterns that determine the evolution of lifestyles.

The influence of economic trajectories and structures on the adaptability of a nation’s development path is important in terms of the patterns of carbon-intensive production and consumption that generate greenhouse gases (Smil, 2000; Ansuategi and Escapa, 2002), the costs of policies that drive efficiency gains through technological change (Azar and Dowlatabadi, 1999), and the occurrence of market failures which lead to unsustainable patterns of energy use and technology adoption (Jaffe and Stavins, 1994; Jaffe et al., 2005).

In addition to these components, scholars from widely varying disciplines and backgrounds have noted the importance of institutional structures and trajectories (Olsen and March, 1989; Agrawal, 2001; Pierson, 2004; Adger et al., 2005; Ruth, 2005) and cultural factors such as values (Stern and Dietz, 1994; Baron and Spranca, 1997), discourses (Adger et al., 2001) and social rules (Geels, 2004), as elements of development paths that help determine the ability of a system to respond to change.

The importance of the connection between measures, capacities and development paths is threefold. First, as pointed out in the TAR, a full analysis of the potential for adaptation or mitigation policies must also include some consideration of the capacities in which these policies are rooted. This is increasingly being reflected in the literature being assessed in both regional/sectoral and conceptual chapters of this assessment.

Second, such an analysis of response capacities should, in turn, encompass the nature and potential variability of underlying development paths that strongly affect the nature and extent of those capacities. This suggests the desirability of an integrated analysis of climate policy options that assesses the linkages between policy options, response capacities and their determinants, and underlying development pathways. Although such an integrated assessment was proposed in the Synthesis Report of the TAR (IPCC, 2001a), this type of assessment is still in its infancy.

Third, the linkages between climate policy measures and development paths described here suggest a potential disconnection between the degree of adaptation and/or mitigation that is possible and that which may be desired in a given situation. On the one hand, the development path will determine the response capacity of the scenario. On the other, the development path will strongly influence levels of greenhouse-gas emissions, associated climate change, the likely degree of climate-change impacts and thus the desired mitigation and/or adaptation in that scenario (Nakićenović and Swart, 2000; Metz et al., 2002; Swart et al., 2003).

However, there is no particular reason that the response capacity and desired levels of mitigation and/or adaptation will change in compatible ways. As a result, particular development paths might give rise to levels of desired adaptation and mitigation that are at odds with the degree of adaptive and mitigative capacity available. For example, particular development path scenarios that give rise to very high emissions might also be associated with a slower growth, or even a decline, in the determinants of response capacity. Such might be the case in scenarios with high degrees of military activity or a collapse of international co-operation. In such cases, climate-change impacts could increase, even as response capacity declines.

The linkages between climate policy, response capacities and development paths suggested above help us to understand the nature of the relationship between climate policy and sustainable development. There is a small but growing literature on the nature of this relationship (Cohen et al., 1998; Markandya and Halsnæs, 2000; Munasinghe and Swart, 2000; Schneider et al., 2000; Banuri et al., 2001; Robinson and Herbert, 2001; Smit et al., 2001; Beg et al., 2002; Metz et al., 2002; Najam et al., 2003; Swart et al., 2003; Wilbanks, 2003). Much of this literature emphasises the degree to which climate-change policies can have effects, sometimes called ancillary benefits or co-benefits, that will contribute to the sustainable development goals of the jurisdiction in question (Van Asselt et al., 2005). This amounts to viewing sustainable development through a climate-change lens. It leads to a strong focus on integrating sustainable development goals and consequences into the climate policy framework, and on assessing the scope for such ancillary benefits. For instance, reductions in greenhouse-gas emissions can reduce the incidence of death and illness due to air pollution and benefit ecosystem integrity – both of which are elements of sustainable development (Cifuentes et al., 2001). These co-benefits, furthermore, are often more immediate rather than long term in nature and can be significant. Van Harmelen et al. (2002) find that to comply with agreed upon or future policies to reduce regional air pollution in Europe, mitigation costs are significant, but these are reduced by 50-70% for SO_2 and around 50% for NO_x when combined with greenhouse-gas policies.

The challenge then becomes one of ensuring that actions taken to address environmental problems do not obstruct regional and local development (Beg et al., 2002). A variety of case studies demonstrates that regional and local development can in fact be enhanced by projects that contribute to adaptation and mitigation. Urban food-growing in two UK cities, for example, has resulted in reduced crime rates, improved biodiversity and reduced transport-based emissions (Howe and Wheeler, 1999). As such, these cities have both enhanced resilience to future climate fluctuations and have made strides towards the mitigation of climate change. Similarly, agro-ecological initiatives in Latin America have helped to preserve the natural resource base while empowering rural communities (Altieri, 1999). The concept of networking and clustering used mainly in entrepreneurial development and increasingly seen as a tool for the transfer of skills, knowledge and technology represents an interesting concept for countries that lack the necessary adaptive and mitigative capacities to combat the negative impacts of climate change.

An alternative approach is based on the findings in the TAR that it will be extremely difficult and expensive to achieve stabilisation targets below 650 ppm from baseline scenarios that embody high-emissions development paths. Low-emissions baseline scenarios, however, may go a long way towards achieving low stabilisation levels even before climate policy is included in the scenario (Morita et al., 2001). This recognition leads to an approach to the links between climate policy and sustainable development – equivalent to viewing climate change through a sustainable development lens – that emphasises the need to study how best to achieve low-emissions development paths (Metz et al., 2002; Robinson et al., 2003; Swart et al., 2003).

It has further been argued that sustainable development might decrease the vulnerability of developing countries to climate-change impacts (IPCC, 2001c), thereby having implications for the necessary amount of both adaptation and mitigation efforts. For instance, economic development and institution building in low-lying, highly-populated coastal regions may help to increase preparedness to sea-level rise and decrease vulnerability to weather variability (McLean et al., 2001). Similarly, investments in public health training programmes, sanitation systems and disease vector control would both enhance general health and decrease vulnerability to the future effects of climate change (McMichael et al., 2001). Framing the debate as a development problem rather than an environmental one helps to address the special vulnerability of developing nations to climate change while acknowledging that the driving forces for emissions are linked to the underlying development path (Metz et al., 2002). Of course it is important also to acknowledge that climate change policy cannot be considered a substitute for sustainable development policy even though it is determined by similar underlying socio-economic choices (Najam et al., 2003).

Both approaches to linking climate change to sustainable development suggest the desirability of integrating climate-policy measures with the goals and attributes of sustainable development (Robinson and Herbert, 2001; Beg et al., 2002; Adger et al., 2003; Van Asselt et al., 2005; Robinson et al., 2006). This suggests an additional reason to focus on the inter-relationships between adaptation, mitigation, response capacity and development paths. If climate policy and sustainable development are to be pursued in an integrated way, then it will become important not simply to evaluate specific policy options that might accomplish both goals, but also to explore the determinants of response capacity that underlie those options and their connections to underlying socio-economic and technological development paths (Swart et al., 2003). Such an integrated approach might be the basis for productive partnerships with the private, public, non-governmental and research sectors (Robinson et al., 2006).

There is general agreement that sustainable development involves a comprehensive and integrated approach to economic, social and environmental processes (Munasinghe, 1992; Banuri et al., 1994; Najam et al., 2003; see also Sathaye et al., 2007). However, early work tended to emphasise the environmental and economic aspects of sustainable development, overlooking the need for analysis of social, political or cultural dimensions (Barnett, 2001; Lehtonen, 2004; Robinson, 2004). More recently, the importance of social, political and cultural factors (e.g., poverty, social equity and governance) has increasingly been recognised (Lehtonen, 2004), especially by the global environmental change policy and climate change communities (Redclift and Benton, 1994; Banuri et al., 1996; Brown, 2003; Tonn, 2003; Ott et al., 2004; Oppenheimer and Petonsk, 2005) to the point that social development, which also includes both political and cultural concerns, is now given equal status as one of the 'three pillars' of sustainable development. This is evidenced by the convening of the World Summit on Social Development in 1995 and by the fact that the Millennium Summit in 2000 highlighted poverty as fundamental in bringing balance to the overemphasis on the environmental aspects of sustainability. The environment-poverty nexus is now well recognised, and the link between sustainable development and achievement of the Millennium Development Goals (MDGs) (United Nations, 2000) has been clearly articulated (Jahan and Umana, 2003). In order to achieve real progress in relation to the MDGs, different countries will settle for different solutions (Dalal-Clayton, 2003), and these development trajectories will have important implications for the mitigation of climate change.

In attempting to follow more sustainable development paths, many developing nations experience unique challenges, such as famine, war, social, health and governance issues (Koonjul, 2004). As a result, past economic gains in some regions have come at the expense of environmental stability (Kulindwa, 2002), highlighting the lack of exploitation of potential synergies between sustainable development and environmental policies. In the water sector, for instance, response capacity can be improved through co-ordinated management of scarce water resources, especially since reduction in water supply in most of the large rivers of the Sahel can affect vital sectors such as energy and agriculture, which are dependent on water availability for hydroelectric power generation and agricultural production, respectively (Ikeme, 2003). Technology, institutions, economics and socio-psychological factors, which are all elements of both response capacity and development paths, affect the ability of nations to build capacity and implement sustainable development, adaptation and mitigation measures (Nederveen et al., 2003).

18.7 Elements for effective implementation

This section considers the literature assessment of the previous sections with respect to its implications for policy and decision-making. It reviews the policy and institutional contexts within which adaptation and mitigation can be implemented and discusses inter-relationships in practice.

18.7.1 Climate policy and institutions

As explained and illustrated in the previous sections of this chapter, effective climate policy would involve a portfolio of adaptation and mitigation actions. These actions include technological, institutional and behavioural options, the introduction of economic and policy instruments to encourage the use of these options, and research and development to reduce uncertainty and to enhance the options' effectiveness and efficiency. However, the actors involved in the implementation of these actions operate on a range of different spatial and institutional scales, representing different sectoral interests. Policies and measures to promote the implementation of adaptation and mitigation actions have therefore been targeted primarily on either adaptation or mitigation; rarely have they been given similar priority and considered in conjunction (see Section 18.5 for more detail).

On the *global scale*, the UNFCCC and its Kyoto Protocol are at present the principal institutional frameworks by which climate policy is developed. The ultimate objective of the UNFCCC, as stated in Article 2, is:

> "to achieve... stabilisation of greenhouse-gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system … within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

Initially, this objective was often interpreted as having relevance only or primarily to mitigation: reducing greenhouse-gas emissions and enhancing sinks such that atmospheric concentrations are stabilised at a non-dangerous level. However, whether or not anthropogenic interference with the climate system will be dangerous does not depend only on the stabilisation level; it depends also on the degree to which adaptation can be expected to be effective in addressing the consequences of this interference. In other words, the greater the capacity of ecosystems and society to adapt to the impacts of climate change, the higher the level at which atmospheric greenhouse-gas concentrations may be stabilised before climate change becomes dangerous (see also Chapter 19). Adaptation thus complements and can, in theory and until the limits of adaptation are reached, substitute for mitigation in meeting the ultimate objective of the UNFCCC (Goklany, 2000a, 2003).

The possibility of considering adaptation and mitigation as substitutes on a global scale does not feature explicitly in the UNFCCC, the Kyoto Protocol or any decisions made by the Conference of the Parties to the UNFCCC. This is so because any global agreement on substitution would, in practice, be unable to account for the diverse, and at times conflicting, interests of all actors involved in adaptation and mitigation and for the differences in temporal and spatial scales between the two alternatives (see Section 18.3). Mitigation is primarily justified by international agreements and the ensuing national public policies, but most adaptation is motivated by private interests of affected individuals, households and firms, and by public arrangements of impacted communities and sectors. The fact that decisions on adaptation are often made at sub-national and local levels also presents a challenge to the organisation of funding for adaptation in developing countries under the UNFCCC, the Kyoto Protocol and any future international climate policy regimes (Schipper, 2006).

Yet there is one way in which adaptation and mitigation are connected at the global policy level, namely in their reliance on social and economic development to provide the capacity to adapt and mitigate. Section 18.6 introduced the concept of response capacity, which can be represented as adaptive capacity and mitigative capacity. Response capacity is often limited by a lack of resources, poor institutions and inadequate infrastructure, among other factors that are typically the focus of development assistance. People's vulnerability to climate change can therefore be reduced not only by mitigating greenhouse-gas emissions or by adapting to the impacts of climate change, but also by development aimed at improving the living conditions and access to resources of those experiencing the impacts, as this will enhance their response capacity.

The incorporation of development concerns into climate policy demonstrates that climate policy involves more than decision-making on adaptation and mitigation in isolation. Accordingly, Klein et al. (2005) identified three roles of climate policy under the UNFCCC: (i) to control the atmospheric concentrations of greenhouse gases; (ii) to prepare for and reduce the adverse impacts of climate change and take advantage of opportunities; and (iii) to address development and equity issues. Although climate change is not the primary reason for poverty and inequality in the world, addressing these issues is seen as a prerequisite for successful adaptation and mitigation in many developing countries. In a paper produced by a number of development agencies and international organisations, Sperling (2003) made the case for linking climate policy and development assistance, which would promote opportunities for mainstreaming considerations of climate change into development on the national, sub-national and local scales (Box 18.3).

With the first commitment period of the Kyoto Protocol ending in 2012, a range of proposals have been prepared that lay out a post-2012 international climate policy regime (e.g., Den Elzen et al., 2005; Michaelowa et al., 2005). The majority of current proposals focus only or predominantly on mitigation; some proposals consider adaptation and mitigation in concert. However, few proposals have been appraised in terms of, for example, their effectiveness, efficiency and equity.

On the *regional scale*, climate policies and institutions do not tend to consider inter-relationships between adaptation and mitigation. In the European Union, for example, mitigation policy is conducted separately from adaptation strategies that are being developed or studied for water management, coastal management, agriculture and public health. Most Least-Developed Countries are concerned primarily with adaptation and its links with development. The Asia-Pacific Partnership on Clean Development and Climate only refers to mitigation.

Organisations such as the World Trade Organization (WTO) and the European Union can, through specific mechanisms, integrate environmental policy into their economic rationales. In addition, there is a need to address contradictions between existing policies (e.g., policies relevant to the reduction of greenhouse-gas emissions and agricultural trade policies). Energy remains a crucial input in agro-processing, transportation and packaging, and the combined effects of increases in energy consumption in the agricultural sector and impacts of agricultural trade policies are typically not considered within the context of climate change.

Regional co-operation could create 'win-win' opportunities in both economic integration and in addressing the adverse effects of climate change (Denton et al., 2002). Initiatives such as the New Partnership for Africa's Development (NEPAD) and the African Ministerial Conference on the Environment conducted a number of consultative processes in order to prepare an Environmental Action Plan for the Implementation of the Environment Initiative of NEPAD. One of the proposed projects is to evaluate synergistic effects of adaptation and mitigation activities, including on-farm and catchment management of carbon with sustainable livelihood benefits. Organisations such as the West African Monetary Union (WAMU) are actively engaged in energy development to address the perennial problem of energy poverty in the continent. They focus on how to exploit the CDM and other mechanisms to mitigate present and future emissions, especially with the use of renewable energy. WAMU countries are vulnerable to drought and desertification and, while mitigation may not be their main concern, it does offer opportunities also to reduce the negative impacts of deforestation and land-use change. Equally, links between the UNFCCC and the UN Convention to Combat Desertification offer opportunities to exploit both adaptation and mitigation within the context of promoting sustainable livelihoods and environmental management. A number of sub-regional institutions have action plans to address desertification, such as the Arab Maghreb Union in northern Africa, the Intergovernmental Authority on Development in eastern Africa, the Southern African Development Community in the south, the Economic Community of Western African States and the Permanent Interstate Committee for Drought Control in the Sahel for the west, and the Economic Community of Central African Countries in central Africa.

Countries belonging to these and other regional groupings can identify projects that have net adaptation and mitigative benefits. Studies (e.g., Greco et al., 1994) have predicted a reduction in water supply in most of the large rivers of the Sahel, thus affecting vital sectors such as energy and agriculture, both of which are dependent on water availability for hydroelectric power generation and agricultural production. Seventeen countries in West Africa share 25 trans-boundary rivers and many countries within the region have a water-dependency ratio of around 90% (Denton et al., 2002). Water resources and watershed management in trans-boundary river basins are possible ways in which countries in West Africa can co-operate on a regional basis to build institutional capacity, strengthen regional networks and institutions to encourage co-operation, flow of information and transfer of technology. The construction of the Manantali Dam in Mali as part of the Senegal River Basin Initiative is to a large extent able to produce hydropower electricity and enable riparian communities to practice irrigation

Box 18.3. Mainstreaming

The links between greenhouse-gas emissions, mitigation of climate change and development have been the subject of intense study (for an overview see Markandya and Halsnæs, 2002). More recently the links between climate-change adaptation and development have been brought to light (Section 18.6). As these links have become apparent, the term 'mainstreaming' has emerged to describe the integration of policies and measures that address climate change into development planning and ongoing sectoral decision-making. The benefit of mainstreaming would be to ensure the long-term sustainability of investments as well as to reduce the sensitivity of development activities to both today's and tomorrow's climate (Beg et al., 2002; Klein, 2002; Huq et al., 2003; OECD, 2005).

Mainstreaming is proposed as a way of making more efficient and effective use of financial and human resources than designing, implementing and managing climate policy separately from ongoing activities. By its very nature, energy-based mitigation (e.g., fuel switching and energy conservation) can be effective only when mainstreamed into energy policy. For adaptation, however, this link has not appeared as self-evident until recently (see Chapter 17). Mainstreaming is based on the premise that human vulnerability to climate change is reduced not only when climate change is mitigated or when successful adaptation to the impacts takes place, but also when the living conditions for those experiencing the impacts are improved (Huq and Reid, 2004).

Although mainstreaming is most often discussed with reference to developing countries, it is just as relevant to industrialised countries. In both cases it requires the integration of climate policy and sectoral and development policies. The institutional means by which such linking and integration is attempted or achieved vary from location to location, from sector to sector, as well as across spatial scales. For developing countries, the UNFCCC and other international organisations could play a part in facilitating the successful integration and implementation of adaptation and mitigation in sectoral and development policies. Klein et al. (2005) see this as a possible fourth role of climate policy, in addition to the three presented earlier in this section.

In April 2006 the OECD organised a ministerial-level meeting of the OECD Development Assistance Committee (DAC) and the Environment Policy Committee (EPOC). The meeting served to launch a process to work in partnership with developing countries to integrate environmental factors efficiently into national development policies and poverty reduction strategies. The outcomes of the meeting were an agreed Framework for Common Action Around Shared Goals, as well as a Declaration on Integrating Climate Change Adaptation into Development Co-operation (OECD, 2006). These outcomes are evidence of the importance that is now being attached to mainstreaming adaptation into Official Development Assistance (ODA) activities. The OECD framework and declaration are expected to provide an impetus to all development agencies to consider climate change in their operations and thus facilitate mainstreaming.

To facilitate mainstreaming would require increasing awareness and understanding among decision-makers and managers, and creating mechanisms and incentives for mainstreaming. It would not require developing synergies between adaptation and mitigation *per se*, but rather between building adaptive and mitigative capacity, and thus with development (see Section 18.6). This fourth role of climate policy highlights the importance of involving a greater range of actors in the planning and implementation of adaptation and mitigation, including sectoral, sub-national and local actors, and the private sector (Robinson et al., 2006, see also Section 18.3).

The above may give the impression that a broad consensus has emerged that mainstreaming adaptation into ODA is the most desirable way of reducing the vulnerability of people in developing countries to climate change. There is indeed an emerging consensus among development agencies, as reflected in the OECD declaration. However, concerns about mainstreaming have been voiced within developing countries and among academics. On the one hand, there is concern that scarce funds for adaptation in developing countries could be diverted into more general development activities, which offer little opportunity to evaluate, at least quantitatively, their benefits with respect to climate change (Yamin, 2005). On the other hand, there is concern that funding for climate policy would divert money from ODA that is meant to address challenges seen as being more urgent than climate change, including water and food supply, sanitation, education and health care (Michaelowa and Michaelowa, 2005).

agriculture, especially since Senegal and Mauritania remain highly dependent on agriculture and suffer deficits in staple cereal crops. These initiatives have global sustainable development benefits since they are able to offer both adaptation and mitigative benefits as well as accelerate the economic development of countries sharing the river (namely Senegal, Mali and Mauritania) (Venema et al., 1997).

The Convention on Biological Diversity has acknowledged the potential win-win opportunities between biodiversity management, on the one hand, and adaptation and mitigation to climate change, on the other. There is particular scope for this in large-scale regional biodiversity programmes such as the Mesoamerican Biological Corridor Project, in which reforestation and avoided deforestation can help to mitigate climate change through the creation of carbon sinks, while creating livelihood benefits for local communities, thus increasing their capacity to adapt to climate change. In addition, the creation of large biological corridors will help ecological communities to migrate and adapt to changing environmental conditions (CBD, 2003).

The *national, sub-national and local scales* are where most adaptation and mitigation actions are implemented and where most inter-relationships may be expected. However, there is little academic literature that describes or analyses policy and institutions at these levels with respect to inter-relationships of adaptation and mitigation. The literature does provide a growing number of examples and case studies (see Section 18.5) but, unlike the emerging literature on global policy and institutions, it does not yet discuss the role of policies and institutions *vis-à-vis* inter-relationships between adaptation and mitigation, nor does it discuss the implications of potential inter-relationships on policy and institutions. A research field is emerging that builds on studies carried out for adaptation or for mitigation. For example, the AMICA project (Adaptation and Mitigation: an Integrated Climate Policy Approach) aims to identify synergies between adaptation and mitigation for selected cities in Europe (http://www.amica-climate.net/).

In the Niayes region of central Senegal, the government has sought to promote irrigation practices and reduce dependence on rain-fed agriculture with the planting of dense hedges to act as windbreaks. These have enhanced agricultural productivity. Windbreaks have been effective in combating soil erosion and desiccation and have also provided fuelwood for cooking, thus reducing the need for women and girls to travel long distances in a rapidly urbanising area in search of wood. The windbreaks have carbon sequestration benefits but, most of all, they have helped to intensify agricultural production, especially with commercial products, thus boosting the economic livelihoods of poor communities. Thus, what started off as an adaptation strategy has had substantial integrated development benefits by easing deforestation and reducing carbon emissions, as well as addressing gender and livelihood issues (Seck et al., 2005).

Effective implementation of climate change adaptation and mitigation is often dependent on the support from local non-governmental organisations, private sector and public government authorities. Market-based policy instruments (e.g., pollution taxes and different types of tradable permits) have been successfully implemented to provide incentives in both industrialised and developing countries. The use of tax credits and financial assistance in India has opened up the electricity market to the private sector, which has resulted in a ‘wind energy boom’ (Sawin and Flavin, 2004). Similarly, incentives for the uptake of biofuels and energy-efficiency programmes in Brazil have considerably reduced carbon emissions (Pew Center, 2002). Although these programmes have typically not been designed with the purpose of creating synergies between adaptation and mitigation, they do provide net adaptation and mitigation benefits, as well as addressing sustainable development priorities of communities. In addition, the private sector is increasingly becoming involved in environmental governance. For example, transnational corporations are being drawn into partnerships and networks to help managing the global environment.

A special role can be played by international funding agencies and climate change funds. For example, the World Bank BioCarbon Fund and Community Development Carbon Fund provide financing for reforestation projects to conserve and protect forest ecosystems, community afforestation activities, mini- and micro-hydro and biomass fuel projects. These projects are focused specifically on extending carbon finance to poorer countries and contribute not only to the mitigation of climate change but also to reducing rural poverty and improving sustainable management of local ecosystems, thereby enhancing adaptive capacity.

18.7.2 Inter-relationships in practice

In practice, adaptation and mitigation can be included in climate-change strategies, policies and measures at different levels, involving different stakeholders (see Section 18.3). For example, the European Union previously emphasised policies to focus on reducing greenhouse-gas emissions in line with Kyoto targets. However, it is increasingly acknowledging the parallel need to deal with the consequences of climate change. In 2005 the European Commission launched the second phase of the European Climate Change Programme (ECCP), which now also includes impacts and adaptation as one of its working groups. They recognise the value of win-win strategies that address climate-change impacts but also contribute to mitigation objectives (EEA, 2005).

Examples at the national level include the UK Climate Change Programme, which includes adaptation and mitigation (DETR, 2000). The UK also addresses adaptation through its Adaptation Policy Framework, the UK Climate Impacts Programme (UKCIP) and a Cross-Regional Research Programme led by the Department for Environment, Food and Rural Affairs (Defra). Malta identified in its first National Communication to the UNFCCC a range of win-win adaptation options, including efficiency in energy production, improving farming and afforestation (Ministry for Rural Affairs and the Environment Malta, 2004). The Czech Republic has agreed to give priority to win-win measures, due to financial constraints (EEA, 2005).

Relevant to the sub-national and local level in the UK is the planning policy and advice released by the Office of the Deputy Prime Minister for the benefit of regional planning bodies

(ODPM, 2005). It includes advice to planners on how to integrate climate change adaptation and mitigation into their policy planning decisions. ODPM (2004) encourages an integrated approach to ensure that adaptation initiatives do not increase energy demands and therefore conflict with greenhouse-gas mitigation measures. Adaptation measures would include decisions about the location of new settlements and not creating an unsustainable demand for water resources, by taking into account possible changes in seasonal precipitation.

Other examples of projects which incorporate 'climate proofing' include the Cities for Climate Protection Campaign, a worldwide movement of local governments working together under the umbrella of the International Council for Local Environmental Initiatives to reduce greenhouse-gas emissions, improve air quality and enhance urban sustainability. Local governments following this programme develop a baseline of their emissions, set targets and agree on an action plan to reach the targets through a sustainable development approach focusing on local quality of life, energy use and air quality (ICLEI, 2006). For example, Southampton City Council has developed a climate change strategy in conjunction with its air quality strategy and action plan, seeing close links between the two. The strategy includes measures for the council and partners to reduce net emissions of greenhouse gases and other pollutants through integrated energy systems and continued air quality monitoring. The mitigating measures are supported by improved management of the likely impacts of future climate change and the impacts on air quality through better planning and adaptation, such as coastal defence, transport infrastructure, planning and design, and flood risk mapping (Southampton City Council, 2004).

18.8 Uncertainties, unknowns and priorities for research

Many of the inter-relationships between adaptation and mitigation have been described in previous assessments of climate policy, and the literature is rapidly expanding. Nevertheless, well-documented studies at the regional and sectoral level are lacking. Adaptation and mitigation studies tend to focus only on their primary domains, and few studies analyse the secondary consequences (e.g., of mitigation on impacts and adaptation options or of adaptation actions on greenhouse-gas emissions and mitigation options). Experiences with climate change adaptation are relatively recent and large-scale, and global actions, such as insurance, adaptation protocols or issues of liability and compensation, have not been tested.

Learning from the expanding case experience of inter-relationships is a priority. Reviews, syntheses and meta-analyses should become more common in the next few years. An analytical and institutional framework for monitoring the inter-relationships and organising periodic assessments needs to be developed. At present, no organisation appears to have a leading role in this area. The experiences of stakeholders in making decisions concerning both adaptation and mitigation should be compared. The experience of the research on land-use and land-cover change would be insightful (e.g., Geist and Lambin, 2002). Effective institutional development, use of financial instruments, participatory planning and risk-management strategies are areas for learning from the emerging experience (Klein et al., 2005).

A key research need is to document which stakeholders link adaptation and mitigation. Decisions oriented towards either adaptation or mitigation might be extended to evaluate unintended consequences, to take advantage of synergies or explicitly evaluate trade-offs. Yet, the constraints of organisational mandates and administrative capacity, finance and linking across scales and sectors (e.g., Cash and Moser, 2000) may outweigh the benefits of integrated decision-making. Formulation of policies that support renewable energy in developing countries is likely to meet fiscal, market, legal, knowledge and infrastructural barriers that may limit uptake.

The effects on specific social and economic groups need to be further documented. For example, development of hydroelectricity may reduce water availability for fish farming and irrigation of home gardens, potentially adversely affecting the food security of women and children (Andah et al., 2004; Hirsch and Wyatt, 2004). Linking carbon sequestration and community development could generate new opportunities for women and marginal socio-economic groups, but this will depend on many local factors and needs to be evaluated with empirical research.

The links between a broad climate-change response capacity, specific capacities to link adaptation and mitigation, and actual actions are poorly documented. Testing and quantification of the relationship between capacities to act and actual action is needed, taking into account sectoral planning and implementation, the degree of vulnerability, the range of technological options, policy instruments and information including experience of climate change.

Analytical frameworks for evaluating the links between adaptation and mitigation are inadequate, or in some cases competing. A suite of frameworks may be necessary for particular stakeholders and levels of decision-making. Decision frameworks relating adaptation and mitigation (separately or conjointly) need to be tested against the roles and responsibilities of stakeholders at all levels of action. Global optimising models may influence some decisions, while experience at the project level is important to others. The suitability of IAMs needs to be evaluated for exploring multiple metrics, discontinuities and probabilistic forecasts (Mastrandrea and Schneider, 2001, 2004; Schneider, 2003). Global cost-benefit models should include clear analyses of uncertainty in the use of valuation schemes and discounting as well as the assumptions inherent in climate impacts models (including the role of adaptation in reducing impacts). Hybrid approaches to integrated assessments across scales (top-down and bottom-up) should be further developed (Wilbanks and Kates, 2003). Representations of risks and uncertainties need to be related to decision frameworks and processes (Dessai et al., 2004; Kasperson and Kasperson, 2005; Lorenzoni et al., 2005). Climate risk, current and future, is only one aspect of adaptation-mitigation decision-making; the relative importance and effect of other drivers needs to be understood.

The magnitude of unintended consequences is uncertain. The few existing studies (e.g., Dang et al., 2003) indicate that the repercussions from mitigation for adaptation and *vice versa* are mostly marginal at the global level, although they may be significant at the regional scale. The effects on demand or total emissions are likely to be a small fraction of the global baseline. However, in some domains, such as water and land markets, and in some locales, the inter-relationships might affect local economies. Quantitative evaluation of direct trade-offs is missing: the metrics and methods for valuation, existence of thresholds in local feedbacks, behavioural responses to opportunities, risks and adverse impacts, documentation of the baseline and project scenarios, and scaling up from isolated, local examples to systemic changes are part of the required knowledge base.

At a global or international level, defining a socially, economically and environmentally justifiable mix of mitigation, adaptation and development remains difficult and a research need. While IAMs are relatively well developed, they can only provide approximate estimates of quantitative inter-relationships at a highly aggregated scale. Fourteen experts in estimating the social cost of carbon rated their estimates as low confidence, due to the many gaps in the coverage of impacts and valuation studies, uncertainties in projected climate change, choices in the decision framework and the applied discount rate (Downing et al., 2005). Estimates of the marginal abatement cost range from –2% to +8% of GDP, while estimates of the marginal damages avoided span three orders of magnitude (see Chapter 20). The marginal cost of adaptation has not been calculated, although some estimates assume a reduction in impacts due to adaptation (see Chapter 17). Combining the marginal abatement cost, marginal damages avoided and the marginal cost of adaptation into an optimal strategy for climate response is subject to considerable uncertainty that is unlikely to be effectively reduced in the near term (see Harvey, 2006).

A systematic assessment with a formal risk framework that guides expert judgement and grounded case studies, and interprets the sample of published estimates, is required if policy-makers wish to identify the benefits of climate policy (e.g., Downing et al., 2005). Existing estimates of damages avoided are based on a sample of sectors exposed to climate change and a small range of climate stresses. Better understanding across a matrix of climate change and exposure is required (Chapter 20; Fisher et al., 2007). Socio-economic conditions and locales that are likely to experience early and significant impacts (often called 'hotspots') should be a high priority for additional studies. The extent to which targets that are set globally are consistent with national or local mixes of strategies requires a concerted effort. The distributional effects would be an important factor in evaluating tolerable windows and trade-offs between adaptation and mitigation. The lack of high-quality studies of the benefits of mitigation, and the social cost of carbon, limits confidence in setting targets for stabilisation.

The relationship between development paths and adaptation-mitigation inter-relationships requires further research. Unintended consequences, synergies and trade-offs might be unique to some development paths; equally, they might be possible in many different paths. Existing scenarios of development paths are particularly inadequate in framing some of the major determinants of vulnerability and adaptation (Downing et al., 2003). Exogenous projections of GDP are a particular obstacle for modelling the inter-relationships between adaptation and mitigation. Few global scenarios address local food security in realistic ways (Downing and Ziervogel, 2005, but see related discussion of Millennium Development Goals in Chapters 9 and 20). Scenarios of abrupt climate change, streams of extreme events, and realistic social, economic and political responses would add insight into adaptive management (the 'act, then learn, then act again' approach). Few reference scenarios explicitly frame issues related to inter-relationships between adaptation and mitigation (e.g., from the extent to which a global decision-maker makes optimising judgements to the institutional setting for local projects to exploit synergies). While the direct energy input in large infrastructure projects may be small, including a shadow price for climate change externalities may shift adaptation portfolios. An assessment of actual shifts in energy demand and ways to reduce emissions is desirable. Most integrated assessments are at the large scale of regions to world views, although local dialogues are beginning to explore synergies (Munasinghe and Swart, 2005).

The feasibility and outcome of many of the inter-relationships depend on local conditions and management options. A systematic assessment and guidance for mitigating potentially adverse effects would be helpful. The nature of links between public policy and private action at different scales, and prospects for mainstreaming integrated policy, are worth evaluating. Many of the consequences depend on environmental processes that may not be well understood; for example, the resilience of systems to increased interannual climate variability and long-term carbon sequestration in agro-forestry systems.

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