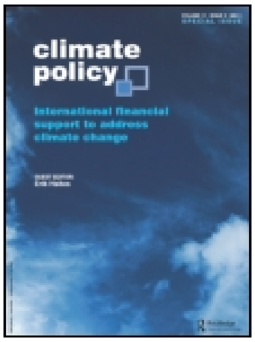

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synthesis article

Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies?

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Can an integrated approach to mitigation and adaptation offer opportunities for a more effective response to climate change than the current strategies? The nature of the linkages depends on the dimensions: economic, institutional or environmental, and on the scale. Differences are pervasive: adaptation and mitigation usually have different temporal and spatial scales and are mostly relevant for different economic sectors, so that costs and benefits are distributed differently. The article concludes that generally the global, regional and – in most countries – national potential of synergetic options to mitigate and adapt to climate change is relatively low, and both strategies should be considered as complementary. However, a few notable exceptions are identified in the land and water management and urban planning sectors, in particular in countries or locations where these sectors provide important adaptation and mitigation opportunities. What is the theoretically most efficient and least expensive mixture of adaptation and mitigation policies may not be a very urgent policy question. Instead, five pragmatic ways of broadening climate policy are suggested, while taking into account the linkages between adaptation and mitigation: (1) *avoiding trade-offs* – when designing policies for mitigation or adaptation, (2) *identifying synergies*, (3) *enhancing response capacity*, (4) *developing institutional links* between adaptation and mitigation – e.g. in national institutions and in international negotiations, and (5) *mainstreaming* adaptation and mitigation considerations into broader sustainable development policies.

Keywords: adaptive capacity; climate change; mitigative capacity; policy formation; sustainable development; synergy

Une approche intégrant mitigation et adaptation peut-elle donner lieu à des opportunités de lutte contre le changement climatique plus efficaces que les stratégies actuelles? La nature des liens dépend des dimensions économiques, institutionnelles ou environnementales et de l'échelle. Les différences sont omniprésentes : adaptation et mitigation ont habituellement lieu à différentes échelles de temps et d'espace afin de distribuer les coûts et bénéfices de manière différente. L'article conclut qu'en général, le potentiel mondial, régional et, pour la plupart des pays, national, des options agissant en synergie pour la mitigation et l'adaptation au changement climatique est relativement faible, et que les deux stratégies devraient être considérées en complément l'une de l'autre. Cependant, quelques exceptions notables sont identifiées dans les secteurs de la gestion urbaine, du sol et de l'eau, surtout dans les pays ou régions où ces secteurs offrent des possibilités importante pour les actions d'adaptation et de mitigation. Ce que serait en principe le mélange de politiques d'adaptation et de mitigation le plus efficace et le moins coûteux, n'est pas en soi une question politique de grande urgence. Nous suggérons de préférence cinq manières concrètes d'élargir la politique climatique, tout en prenant compte des liens entre adaptation et mitigation: (a) éviter les compromis *– lors de l'élaboration de politiques de mitigation et d'adaptation (b)* discerner les synergies *(c)* augmenter la capacité de réaction *(d)* développer les liens institutionnels *entre adaptation et mitigation – par exemple dans les instances nationales et les négociations internationales (e)* incorporer *adaptation et mitigation dans les politiques de développement durable plus larges.*

Mots clés: capacités adaptives; capacités de mitigation; changement climatique; développement durable; élaboration de politiques; synergie

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1. Background and objectives

Both mitigation of and adaptation to climate change have the same purpose: reducing its undesirable consequences. However, for historical reasons, the two have been separated both in science and in policy.[1] The definition of the two concepts by the Intergovernmental Panel on Climate Change (IPCC) reinforces the separation: mitigation has been defined as 'anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases' and adaptation as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC, 2001). The distinction is also reflected by the Working Group structure of the IPCC. One of the reasons that adaptation was not only treated separately but also received little attention at the beginning of the climate change negotiations was that – especially in Europe – an emphasis on adaptation was suggested in order to take away the urgency of mitigation. In the early 1990s, climate change was still considered to be merely an environmental problem that could be addressed in a fashion similar to that of acid rain and stratospheric ozone depletion, with a targets and timetable approach aiming at mitigating the impacts (Munasinghe and Swart, 2004). Also the perceived larger uncertainties involved in adaptation (where, by whom, to what?) played a role in lower levels of attention to adaptation. Finally, while the signs of climate change increased, until recently no significant changes in human or ecological systems could be definitely attributed to climate change. With some exceptions, discussed below, in the United Nations Framework Convention on Climate Change, mitigation and adaptation are generally separated. Although the ultimate objective of the UNFCCC (Article 2) on avoiding dangerous interference with the climate system implicitly involves adaptation, the emphasis on stabilization of greenhouse gas concentrations in the atmosphere also tends to focus the attention on long-term mitigation rather than reducing vulnerability to climate change or adapting to it in the shorter term. According to Pielke (2004), the UNFCCC definition of climate change leads to a bias against adaptation, since adaptation – according to the UNFCCC definition – should be limited to changes that are proven to be anthropogenic. The broader definition of climate change of the IPCC includes natural as well as anthropogenic causes and hence does not have the same bias against adaptation.

Until recently, mitigation was considered to be a problem of developed countries, which had caused the problem and not only had the responsibility but also the resources to do something about it. Adaptation was more a problem of developing countries, where per capita emissions were low and vulnerability high. Gradually, it has become clear that climate change, with its roots in the fundamental requirements of societies for energy and food, may rather be framed as a development issue rather than as an environmental problem. But even if developing countries may be more vulnerable, climate change also affects developed countries. Throughout the world many developments in society are increasing exposure and sensitivity to current climate variability, regardless of the level of climate change, such as habitation of marginal and low-lying lands, increased water and food demands, and dependence on highly technical interdependent systems. This makes adaptation increasingly relevant (Pielke, 1998).

Only in the last decade has policy attention to adaptation started to increase, because of the attribution of observed impacts to climate change and the increased recognition of vulnerability developing countries in particular. It is also significant that, following a rapid start in 1992 with an international framework convention (without binding obligations), when it came to formal commitments, international negotiations about climate change mitigation made progress only very slowly. Mitigation and adaptation both aim at reducing risks of negative climate change impacts, and are obviously closely linked in different ways. Risks from climate change can be expressed by the simple equations:

$$\text{risk} = \text{probability} * \text{climate hazard} * \text{vulnerability}$$

and

$$\text{vulnerability} = \text{exposure} * \text{sensitivity/adaptive capacity}^2$$

Mitigation aims at reducing the climate change effect, adaptation aims at reducing vulnerability to these effects. The latter can be achieved by reducing the exposure to climate change, by reducing the sensitivity, or by enhancing the capacity to adapt. According to these formulas, eventually more mitigation requires less adaptation and vice versa. This raises the question of whether an integrated approach could offer benefits over two independent, parallel strategies and, if so, how. This question is central to this article.

The literature on integrated approaches is rather sparse. In its Third Assessment Report, the IPCC included a preliminary assessment of the linkages between adaptation and mitigation (Toth et al., 2001). Toth et al. (2001) argue that the global political commitment to stabilize greenhouse gas concentrations and the physical commitment of the climate system to change because of past, current and unavoidable future greenhouse gas emissions implies that there is no choice between either mitigating or adapting, but that both have to be pursued. The question, however, is what the best share and timing of both would be, and how they can best be implemented.

This early IPCC assessment of the links between adaptation and mitigation was still rather abstract. The objective of this article is to explore in more concrete terms what the links are, and how they may be used to further climate policy development, capturing synergies between adaptation and mitigation, and avoiding trade-offs. To understand the nature of the two approaches, in the next section we first summarize the differences and then identify the links between them. In Section 3, we discuss the importance of different dimensions and scales. We then turn to more concrete examples of synergies and trade-offs in Section 4. In Section 5 we place the two options in the broader context of sustainable development, and in Section 6 we summarize our main findings and formulate five recommendations for action.

2. Differences and similarities between adaptation and mitigation

At an aggregate level, adaptation affects the costs and benefits of public mitigation policy (Kane and Shogren, 2000). At least theoretically, an optimum balance between adaptation and mitigation would be possible, and hence integrated analysis may provide useful insights. From this same economic perspective, limited to climate change response expenditures, increased spending on mitigation would be at the expense of adaptation (e.g. Michaelowa, 2001). There are indeed intrinsic differences between the two types of climate response, leading Dang et al. (2003) to conclude that 'mitigation and adaptation are currently perceived to be mutually exclusive at worst, or parallel strategies at best'. All these views ignore the fact that increases in both mitigation and adaptation efforts may make perfect sense for a society and even the economy in order to decrease climate risks and capture co-benefits. Therefore, before exploring the potential benefits of integrating adaptive and mitigative responses to climate change, it is useful to not only consider their differences, as several other authors have done (e.g. Toth et al., 2001; Tol, 2005), but also their similarities.

Table 1 summarizes the definitions of the types of responses, and the 'common wisdom' as to the different dominant focus of the two approaches. Table 1 also shows some exceptions to this 'common wisdom', and lists some similarities. Pertinent perceived differences are that spatial and temporal scales would be very different. Mitigation would be mainly aimed at addressing a global problem, while adaptation would be aimed at resolving local problems. While this is generally true, concrete mitigative as well as adaptive actions necessarily involve decisions by individuals at the local level. It

TABLE 1 Definitions, differences and similarities between mitigation and adaptation

		Mitigation		Adaptation	
Definition		Anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases		Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities	
	Issue	Dominant focus	Examples of exceptions	Dominant focus	Examples of exceptions
Differences	Causes/effect	Primarily addresses *causes*	Urban design with low energy requirements and low vulnerability	Primarily addresses *consequences*	Drought-resistant biofuels can address both vulnerability and emissions
	Spatial scale	Main objective avoiding *global* changes	Co-benefits for short-term local air pollution, energy security, jobs	Main objective *local* damage avoidance	Adaptation of temperate farmers may have global consequences
	Sectors	Mainly energy, transport, building and industry sectors	Mitigation options also available in water and land management	Mainly urban planning, water, agriculture, health, coastal zones sectors	Renewable energy sources can be vulnerable
	Time scale	*Long-term* benefit from avoided climate change	Co-benefits for short-term, local air pollution, energy security, jobs	Often main driver *short-term* benefit due to reducing vulnerability to current climate	Preparing for long-term impacts
	Beneficiaries	Mainly benefits *others* (altruistic)	Co-benefits for mitigating actors, local air pollution, energy security, jobs	Mainly benefits *those who implement it* (egoistic)	Some adaptation may have wider benefits
	Incentives	Usually *incentives needed*	No-regrets options (e.g., energy efficiency)	Often *incentives not needed*	Anticipatory actions without immediate benefits may need incentives
	Urgency	*Lower political urgency*/ legitimacy	Short-term co-benefits, local air pollution, energy security, jobs enhance urgency	*Higher political urgency*/ legitimacy	Proactive adaptation with high costs and uncertain effect can have low urgency
Similarities	Goal	Aiming at reduction of climate change risks			
	Benefits	Having ancillary benefits that may be as important as the climate-related benefits			
	Drivers	Driven by availability/penetration of new technology & societal ability to change			

can also be seen that some adaptation actions can have global consequences; for example, temperate-zone farmers are increasingly competing with tropical farmers by adapting to a warmer climate (T. Downing, 2006, personal communication), drought-resilient cultivars and improved climate predictions can have benefits far beyond the local level. From an economic perspective, the benefits from mitigation are greater at the global scale and external to a local area, while adaptation leads to greater local benefits. Hence, comparisons of mitigation and adaptation generally favour mitigation at a global scale and favour adaptation if performed at a local scale (Wilbanks et al., 2003). Thus, the dominant spatial scales of mitigation and adaptation actions are generally different, but at all geographical levels, mitigation and adaptation both play a role. In the next section we discuss some aspects of the linkages between the two responses at different levels of scale in more detail.

Thus, mitigation eventually aims at stabilizing greenhouse gas concentrations in the atmosphere, something that can only be achieved at long time scales. Adaptive actions often aim at reducing vulnerability not only to future climate change, but also to current climate variability. Again, while this is true in general, it can also be observed that many mitigative actions can also have short-term benefits, e.g. in the form of reduced air pollution,[3] or in some 'no-regrets' cases, in the form of economic benefits. Similarly, proactive adaptive actions may not have any benefit at all at any time scale, if climate changes do not materialize, or if the changes are very different from what is expected. This is mostly relevant for adaptation in the urban sector, where dealing with higher temperatures and higher precipitation can entail significant costs (T. Downing, 2006, personal communication). For adaptation in the management of land, water and resources, the risk of unnecessary adaptation is smaller, since here reduced vulnerability to current climate variability often requires smaller investments and usually does have some benefits regardless of climate change.

Another key difference is that the actors involved in adaptation and mitigation are often different. The main source of greenhouse gases is the combustion of fossil fuels, which involves mainly economic sectors such as energy, transport, industry, and the domestic sectors. With some exceptions (e.g. renewable energy sources such as biofuels, hydropower, wind energy, and solar energy are dependent on climate variables such as precipitation, wind speed and direction, and cloud cover, respectively; cooling water availability of fossil-fuel and nuclear energy), these sectors are generally less vulnerable to the impacts of climatic changes. The economic sectors most vulnerable to climate change are the agricultural, water, and coastal zone management sectors – and these are the sectors that at the global level play a lesser role in emitting greenhouse gases and hence in mitigation. However, primarily economic activities with a spatial, land component can also be relevant for mitigation, such as agriculture, forestry and urban design. In areas where hydropower or availability of cooling water plays an important role in energy supply, and also in the water sector, integration between mitigation and adaptation can be important. These issues are further discussed in Section 4.

Another set of differences has to do with responsibilities. While all may have a moral obligation to contribute to global mitigation of climate change, the direct benefits of mitigative activities usually fall on others, in other places and/or at other times. Mitigation is altruistic and can induce free-riding; incentives to join the global effort are usually required. In contrast, those implementing adaptive actions usually have a direct interest in the effects in terms of reduced vulnerability. Adaptation is egoistic and incentives may be less important. These characteristics of mitigation and adaptation have an effect on the political legitimacy and urgency of action. In both cases, however, the co-benefits may outweigh the climate benefits, but this is often not yet recognized because of the lack of a fully comprehensive evaluation of costs and benefits over time and over different scales. As to the urgency, the perception that mitigation would not be very urgent has recently changed because of increased recognition that global emissions have to peak within the next few decades in order to limit climate change to acceptable levels.

Notwithstanding these pervasive differences, mitigation and adaptation also have some aspects in common. Tompkins and Adger (2005) argue that both depend on the capability of a society to develop and diffuse new technologies and to change its behaviour, and even suggest integrating a society's adaptive and mitigative capacities into a single concept of 'response capacity', an idea also supported by Bizikova et al. (2006). However, while the determinants of adaptive and mitigative capacity are overlapping and mutually supportive, they differ in application. The same capacity may be used to respond to the impacts of climate change or to reduce greenhouse gas emissions (Winkler et al., 2007). This is further elaborated in Section 5.

As noted above, the two strategies have their main goal in common: reducing the risks associated with climate change. Jones (2006) observes that mitigation could be viewed as mainly aiming at reducing the risks of high levels of climate change in the longer term. Its benefits in terms of reduced risks are a function of the level of mitigation and the climate sensitivity. Adaptation can then be viewed as aiming at reducing the risks that remain after reducing the risks of high levels of climate change. Its benefits in terms of reduced damages occur earlier, because current climate risks are also reduced (Jones, 2006). Figure 1 not only suggests that at least theoretically an optimal mix between mitigation, adaptation and residual damage may be found (see below for a discussion on the feasibility), but it also suggests that adaptation and mitigation address two different types of climate risks. Mitigation aims primarily at reducing the risks associated with high levels of climate change and unacceptably high adaptation costs (see Jones, 2006), at mitigation costs, which are still relatively low. However, at some point mitigation costs become increasingly high. Here, adaptation further reduces residual impacts at costs much lower than those associated with unmitigated climate change, and at the same time reduces vulnerability to current climatic changes.

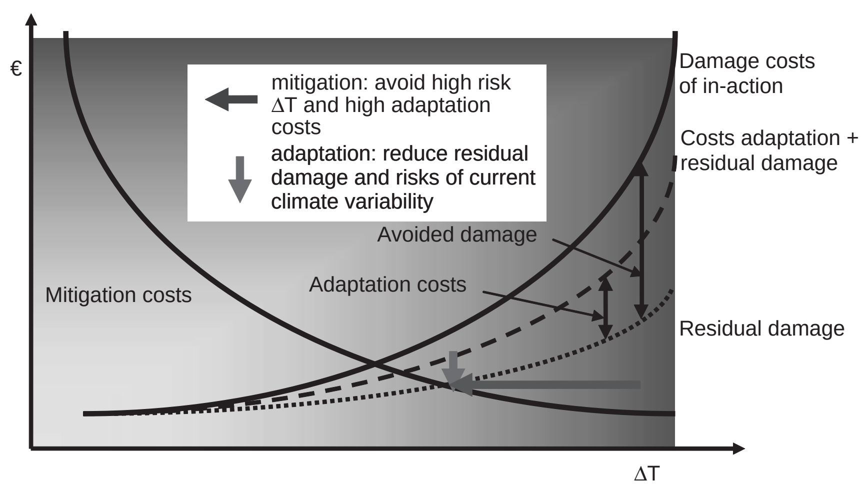

FIGURE 1 Costs of mitigation, adaptation and residual damage of climate change. Total costs of adaptation and residual damage depend on the ratio between adaptation costs and avoided damage. In the Figure it is assumed that the adaptation costs are smaller than the avoided damage. This conceptual Figure is only meaningful at the global level. The shading gets brighter from top to bottom and from right to left, indicating that the brightest, most positive situation would be the lower left corner where both mitigation and impacts/adaptation costs would be lowest; however, unfortunately there are no realistic solutions in this corner.

3. Levels of scale and dimensions of sustainable development

In its Third Assessment Report, the IPCC addressed the search for the best possible combination of adaptation and mitigation strategies, and stressed the importance of different dimensions (Toth et al., 2001). Toth et al. (2001) distinguished between economic, precautionary and institutional considerations, similar to the economic, environmental and social dimensions of sustainable development. At the same time, different processes relevant for mitigation, adaptation and sustainable development have characteristic scales; different scales tend to have different potentials and limitations for action, and existing spatial-administrative frameworks are not necessarily a good fit with the relevant scales (Wilbanks, 2007). In the matrix of Table 2 we have therefore included some examples of approaches that link adaptation and mitigation at different scales and for different dimensions, which we discuss briefly below.

3.1. Global level

In the climate change response literature, the top-left corner of the matrix on global *economic* analysis is most frequently addressed. Integrated assessment models are available that can analyse marginal costs of mitigation and marginal costs of adaptation and residual impacts (Toth et al., 2001). Although theoretically appealing, the scarcity of research results for costs and benefits of adaptation at the global level, the large uncertainties regarding costs and benefits of (avoided) impacts and mitigation, and the problem of damages that can or maybe should not be monetized make a meaningful cost–benefit analysis aiming at determining a most efficient mix of mitigation, adaptation and residual damage extremely difficult. Figure 1 should be regarded as a thought experiment to enhance the understanding of the linkages and differences between adaptation and mitigation, rather than as a basis for a quantified cost–benefit analysis. In practice, at most a comparison of mitigation costs with damage costs, with at most some exogenous simple assumptions for adaptation has been explored by a few authors (Toth et al., 2001; Tol, 2006). Also, even if an economic optimal solution could be identified, this approach generally ignores social, institutional and environmental dimensions (equity, implementation issues, natural ecosystem adaptation, e.g. see Klein et al., 2005). A very recent bold attempt at a global cost–benefit analysis that attracted much media attention was made by Stern (2006), with very rough estimates of damage costs and with conclusions which were heavily influenced by the discount rate assumptions. The IPCC, however, in its Fourth Assessment Report (IPCC, 2007), refrained from doing a cost–benefit analysis for the reasons discussed above. Finally, it should be remembered that there are limits to adaptation and mitigation. Not only will natural and human systems at some point be unable to adapt, but also adaptation or mitigation costs can exceed feasible or acceptable levels (see also Figure 1).

From an *institutional* perspective, it is interesting to note that in the UNFCCC, mitigation and adaptation are both addressed, but that they are generally not explicitly linked. The UNFCCC has several references to adaptation and mitigation together, but generally as parallel approaches. For example, it requires Parties to

> formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change (UNFCCC, 1992).

It also requires developed country Parties to assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation to those

TABLE 2 Examples of adaptation–mitigation linkages for different scales and three dimensions of sustainable development

	Global	Regional/national	Local
Economic/development dimension	Analyse theoretically optimal shares through cost–benefit analysis	Mainstream climate into development/sector policies, identify most efficient way	Avoid economic trade-offs, research most efficient solution talking into account co-benefits
Examples	*Analyse theoretically optimal shares of mitigation and adaptation action to support international negotiations*	*Include climate change mitigation and adaptation concerns in energy and water policy, spatial planning, development aid*	*Evaluate mitigation potential of renewable energy taking into account possibly increased vulnerability to climate change*
Institutional/social dimension	Negotiate balance adaptation and mitigation actions in UNFCCC context	Link local with global through national/regional SD policies (link different actors)	Enhance adaptive and mitigative capacity, involve stakeholders
Examples	*Account for justice, compensation, common but differentiated responsibility*	*Translate commitments from international agreements into framework for local actors (e.g. EU emissions trading system)*	*Inform local stakeholders (farmers, companies, citizens) about climate change risks and mitigation opportunities*
Environmental/ precautionary dimension	Determine acceptable level of climate change, limits to adaptation (Article 2)	Determine environmentally most effective national policies	Protect ecosystems, health, search synergies
Examples	*Evaluate the EU's 2°C climate goal, taking into account adaptation as well as critical vulnerable ecosystems of global importance*	*Develop ecosystem, water basin management strategies taking into account adaptation and mitigation concerns*	*Manage protected areas taking into account climate change impacts, carbon sink function, and biodiversity*

adverse effects. As a follow-up to the latter point, the Kyoto Protocol stipulates that a share of the proceeds from CDM activities is to be used to assist these vulnerable developing country Parties to meet the costs of adaptation. Another example of a link between mitigation and adaptation in the UNFCCC is the discussion on reducing the impacts of mitigation on countries whose economies are highly dependent on fossil fuels (Article 4.8). This is also part of the UNFCCC's 5-year plan for adaptation (UNFCCC, 2006). However, so far there is no direct link, e.g. countries helping other countries with adaptation actions do not get any (mitigation) credits for this, and countries that do not make any effort to mitigate GHG emissions do not yet have to pay higher side payments to vulnerable countries. In recent UNFCCC discussions on adaptation, some developed countries have suggested closer links between adaptation and mitigation but, so far, key developing countries have stressed the need not to make the issues too complicated, and mitigation remains absent from the UNFCCC's recently agreed 5-year work programme and the methodological toolkit for development and evaluation of adaptation options.

From an *environmental* perspective, the link between adaptation and mitigation at the global level is formalized in the UNFCCC's ultimate objective (Article 2) stipulating the requirement to stabilize concentrations of greenhouse gases and referring to natural adaptation of ecosystems, food security and sustainable economic development. Such links have only just begun to be explored by the scientific community. Adaptation alters the definition of tolerable change and hence would affect mitigation requirements, e.g. as analysed in the German guardrail or tolerable windows approach, which tries to operationalize the UNFCCC objective (Yohe and Toth, 2000). From a strong sustainability perspective and a strict interpretation of the precautionary principle, the most vulnerable area (high exposure, low adaptive capacity) would set the standard for global mitigation. From a weak sustainability perspective, trade-offs with social and economic dimensions have to be taken to account and a certain level of environmental impacts may have to be tolerated if this leads to less damage on the social and/or economic scores. This provides negotiation space for determining what constitutes dangerous interference with the climate system, dependent on the risk attitudes of the negotiators.

3.2. Regional and national level

Moving from the global to the regional, national and local scales, the costs and benefits of adaptation, mitigation and impacts will change, and hence the cost–benefit ratio of response options is very dependent on the scale. Equally, capturing adaptation and mitigation in one model makes little sense, because methods and tools for adaptation and for mitigation typically have different spatial and temporal scales, and relevant actors and sectors are often different and disconnected. We agree with Tol (2005) that adaptation and mitigation cannot be meaningfully compared, especially at lower levels. For example, mitigation action would still be justified if the costs of mitigation in a developed country were to be higher than the costs of inaction for that same country, because of the benefits in other regions.

At the national and regional level (e.g. the EU), governmental institutions can play a role by encouraging the integration of both mitigation and adaptation considerations into sectoral policies, not as competitors for scarce resources but as potentially equally important elements of comprehensive policy development in a broader context of sustainable development. These institutions have an intermediary role to play in ensuring proper linkages between global risks and responsibilities, and the mainly local implementation of mitigation and adaptation actions, and in providing a proper framework to arrive at the most effective solutions. In addition, national institutions play a key role in enhancing mitigative and adaptive capacity through their determinants. This is discussed further in Section 5. From the environmental perspective, national governments should ensure the environmental integrity of climate change response policies. For example, governments should ensure that biofuels are produced sustainably, or that coastal protection infrastructure does not affect ecologically valuable areas.

3.3. Local level

Many adaptation and mitigation actions are implemented at the local level. Particularly at this level, knowledge about climate change is often limited and climate change is generally one of the less urgent considerations in planning processes. Linking the global long-term problem of climate change with local priorities is a challenge (Wilbanks, 2005). Participatory approaches can play a key role here (e.g. Bizikova et al., 2006). For specific climate response actions, rather than searching for optimal combinations of adaptation and mitigation, it appears to make more sense to routinely include mitigation consequences in a comprehensive (cost–benefit) analysis of adaptation projects and to include vulnerability and adaptation consequences as one of many aspects of mitigation actions. Developing local plans and projects, economic as well as environmental aspects of mitigation and adaptation should be considered. Institutionally, at the local level, joint efforts between local governments, citizens and the private sector can enhance adaptive and mitigative capacity. In the next section, we focus more on synergies and trade-offs of concrete actions.

4. Synergies and trade-offs

In general – with some notable exceptions discussed below – most mitigation options have little direct consequence for vulnerability to climate change. We also consider indirect effects, such as increased vulnerability of populations because of mitigation expenditures, as generally being very small.[4] Similarly, most adaptation options have relatively few consequences for global climate change – even if adaptation projects may increase energy use and associated GHG emissions at the local scale. In most economic sectors, the number of concrete options that both reduce vulnerability to climate change and reduce GHG emissions (or enhance sinks) is relatively small. However, at a more detailed level, for specific sectors and locations, there are important exceptions. Table 3 summarizes some examples of synergetic options and trade-offs.[5] It comes as no surprise that most entries in Table 3 are in sectors which are important for both adaptation and mitigation; notably land (land use, urban planning, housing, agriculture and forestry) and water (water supply, hydropower, cooling water).

4.1. Synergies

Two types of synergies can be distinguished. Indirectly, mitigation can lead to reduced stresses other than climate change, reducing vulnerability to climate change. For example, reduced air pollution as a side effect of climate policies can lead to lower health impacts and consequently higher resistance to climate stresses. The same applies to ecosystem vitality. Synergetic options that more directly combine reduced greenhouse gas emissions and reduced vulnerability can mainly be found in three areas: urban and infrastructure planning, water resource management, and land-use and forestry.

Climate change adaptation and mitigation can come together in the planning of urban areas, notably in locations that are vulnerable to climate change. Urban design could pay proper attention to climate-safe siting, energy-conserving building characteristics (adapted building codes), and low transportation requirements. This would both limit energy use (and associated GHG emissions) and also reduce exposure to the possible negative consequences of climate change, e.g. in low-lying coastal areas or areas prone to flooding. At the urban level, climate change has just recently become an issue that is taken into account. Examples are initiatives in Finland (Peltonen et al., 2005), the CitiesPlus programme in Canada, which combines mitigation, adaptation and enhanced resilience (Sheltair, 2003), and METREX, a network of European metropolitan areas that has started to explore ways to respond to climate change.

Also in the land-use and forestry sectors synergies can be found. Reforestation to prevent flooding and erosion sequesters carbon. However, the types of trees best suited to preventing flooding and protecting biodiversity may not be the most effective from a carbon sequestration point of view (e.g. Dang et al., 2003). IPCC (2007) identifies synergetic options primarily for the rural poor in the least developed countries, where soil conservation (storing carbon), low water requirements, and biofuel production (reducing emissions) can go hand in hand. Also, forestry mitigation projects (e.g. forest conservation, afforestation and reforestation, biomass energy plantations, agro-forestry, urban forestry) can lower water evaporation and lower vulnerability to heat stress (IPCC, 2007).

In the water sector, the development of hydropower facilities can reduce fossil-fuel-related energy use and reduce dependency on foreign energy imports. If properly designed, the associated water storage can also limit vulnerability to precipitation variability and to climate change. However, there can also be trade-offs (see below).

The link between CDM mitigation activities and the climate adaptation fund has already been mentioned above. Using an example from Vietnam, Dang et al. (2003) suggest putting the search for synergies into practice by actively identifying opportunities for CDM projects which decrease vulnerability to climate change next to reducing GHG emissions, increasing the host country's ability to deal with climate risks, and facilitating a more active role of developing countries in the UNFCCC and Kyoto Protocol process.

TABLE 3 Examples of synergies and trade-offs between direct adaptive and mitigative responses to climate change (see also Bizikova et al., 2006). Changing social or institutional capabilities and changing development paths are not included since these are indirectly influencing greenhouse gas emissions, sinks, exposure and sensitivity

Mitigation → Adaptation ↓	Actions decreasing GHG emissions, enhancing sinks, protecting carbon stocks	Actions enhancing GHG emissions, reducing sinks, destroying carbon stocks
Actions decreasing exposure and sensitivity (vulnerability) to climate change	***Synergies (also contributing to wider sustainable development goals)*** Increase energy efficiency/reduce energy dependency Increase water use efficiency/reduce water consumption Protect soils, plant trees, develop agro-forestry (carbon storage) Improve forest fire management (early warning, fire fighting) Produce crops matching local climate and local needs Improve health through clean energy with less pollution Enhance ecosystem resilience by reduced air pollution Design urban areas with high level of protection, high density and low energy use Expand parks and other green spaces in/around cities Design appropriate building codes/standards (climate-resistant and energy-efficient, e.g. natural ventilation or renewable energy for cooling)	***Trade-offs of adaptation ('adaptive emissions')*** Use fossil-based electricity for air conditioning, cooling of buildings and water supply (e.g., desalinization), Strengthen coastal protection infrastructure (energy use) Expand fossil-fuel-energized irrigation of lands, Adapt temperate farmers competing with tropical farmers Expand crop area/number of annual crops to capture benefits of warming in relevant areas Include mitigation in development aid, research programmes at the expense of adaptation
Actions increasing exposure and sensitivity (vulnerability) to climate change	***Trade-offs of mitigation ('new vulnerabilities')*** Building low-emissions facilities (e.g. renewable/nuclear power plants) in vulnerable areas) Implement mitigation policies with costs that affect income of the vulnerable poor Increasing dependence on too narrow climate-sensitive renewable energy Establish large-scale biofuel production driving locals to vulnerable areas Include adaptation in development aid, research programmes at the expense of mitigation	***Actions contributing to unsustainable development*** Destroy forests, emitting carbon and increasing vulnerability to drought Develop urban areas in low-lying areas with little natural cooling or long travel distances, and high vulnerability to flooding

4.2. Trade-offs

The most obvious example of trade-offs of adaptation actions for mitigation is the fact that many adaptation options, such as coastal protection infrastructure, additional cooling requirements and expanded irrigation, all increase energy use, often with associated GHG emissions, and thus increase the need for mitigation ('adaptive emissions'; Bizikova et al., 2006).

An interesting example of trade-offs of adaptation options for mitigation is in the winter sports sector. To make up for the decreasing snowfall, artificial snowmaking is rapidly increasing its importance, even pushing the industry into areas that were formerly less suitable for skiing. In Austria, 40% of the ski areas are currently equipped with artificial snow facilities, and an expansion to 90% is foreseen, with large water and energy requirements (K. Radunski, 2006, personal communication). This development in one key economic sector surely does not help Austria in meeting its Kyoto target and one may wonder how sustainable this practice will be with continuing warming trends.

Trade-offs of mitigation activities for adaptation are less obvious ('new vulnerabilities'; see Bizikova et al., 2006). A higher dependency on hydropower can also increase the vulnerability to decreased precipitation because of climate change in some regions. Also, large dams can lead to methane emissions which can offset part of the GHG gains (e.g. World Commission on Dams, 2000). The magnitude and time period are, however, still fiercely debated (e.g. Fearnside, 2006; Rosa et al., 2006). Theoretically global mitigation could alter the relative valuation of different development projects such as hydropower plants because of missing benefits (Yohe et al., 2007), just as mitigation may lower the profitability of agriculture in areas that are projected to benefit from climate change. Another example of a potential trade-off is the shift of people to more vulnerable areas as a result of large-scale biofuel plantations.

5. Enhancing response capacity and mainstreaming

The IPCC Third Assessment Report (TAR) introduced the term mitigative capacity as a mirror image of adaptive capacity, a term that had already been in use for some time in impacts and vulnerability analysis. The TAR defined mitigative capacity as 'the ability to diminish the intensity of the natural and other stresses to which it might be exposed' (Banuri and Weyant, 2001), where adaptive capacity relates to the reduction of exposure or sensitivity to these stresses. Winkler et al. (2007) note that this definition suggests that only large countries or groups have a mitigative capacity in the sense of influencing global climate change, and suggest as an alternative definition 'the ability to reduce greenhouse gas emissions or enhance natural sinks'. The TAR suggests the following determinants of mitigative capacity:

- a range of viable technological options for reducing emissions
- a range of viable policy instruments with which the country might effect the adoption of these options
- a structure of critical institutions and the derivative allocation of decision-making authority
- the availability and distribution of resources required to underwrite their adoption and the associated, broadly defined opportunity costs of devoting those resources to mitigation
- a stock of human capital, including education and personal security
- a 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, etc.)
- the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves.

If we replace 'emissions' in the first item by 'vulnerability and exposure', we can see that the determinants of adaptive capacity are basically the same. Hence, as noted in the Introduction, enhancing these determinants would increase both adaptive and mitigative capacity, which brings some authors to suggest combining the two into one concept of response capacity (Tompkins and Adger, 2005; Bizikova et al., 2006).

However, it is important to note that actual capacities may be unevenly distributed between the relevant actors. Capacities have to be built both in institutions that address mitigation and in those that have to deal with adaptation, which can be very different. While the two types of capacities are very similar and are rooted in the same development basis, they can differ strongly in application (Winkler et al., 2007). When the response capacity has to be translated into action, the differences between the two types of response re-emerge. If the capacity is used to adapt, the benefit may be direct and local, and if it is used to mitigate, it would be indirect and global (if co-benefits are not taken into account). It is usually not possible or relevant for individuals, groups or companies to both adapt and mitigate at the same time. While, for farmers, water managers or coastal inhabitants, climate change adaptation may be relevant or even urgent, for most of the other citizens in both developing and industrialized countries it is not a matter of priority. For the poor in developing countries, mitigation is not very urgent or even very relevant.

In general, one may say that in most industrialized countries all or almost all the criteria for an effective adaptive and mitigative capacity are satisfied, and political determination, individual priorities and sustained efforts are likely to be important factors determining the actual level of adaptation and mitigation. However, for reasons of political economy, countries might not apply their capacity to respond (Michaelowa, 2001). In industrialized countries, the emphasis needs to be on applying the existing capacity. However, in most developing countries there is ample scope for improving on these determinants, which would be a necessary requirement for action. However, as in industrialized countries, the capacity alone would also be insufficient to actually adapt and/or mitigate and similar difficulties will arise when putting capacity into action.

Just as the adaptive and mitigative capacities are determined by the level and type of development, so the greenhouse gas emissions and the vulnerability to climate change are usually determined by the level and type of development at least as much as by specific adaptation or mitigation policies. Therefore, for an effective climate change response, it is urgent to include climate change considerations into the development of more generic development policies. At COP-8, the UNFCCC recommended integrating climate change objectives into other policy areas (UNFCCC, 2002). While to some extent this is being pursued in particular areas, such as in multilateral development collaboration (e.g. Burton and van Aalst, 2004; Agrawala, 2005) and at the local, urban level (e.g. the Cities for Climate Protection (CCP) campaign – see http://www.iclei.org/), it is in general not yet a common feature of national and sectoral policy-making. Also, mainstreaming climate change considerations into broader development policies appears to be more often suggested for developing countries (e.g. Huq et al., 2003) than for developed countries, at least until very recently. The broad, long-term strategy on sustainable development of the European Commission (EC, 2001) suggested addressing the priority problem of climate change only through a number of specific climate and energy policies rather than suggesting, in addition, integrating climate change considerations into the much broader set of European policies. The subsequent action plan *Winning the Battle against Global Climate Change* (EC, 2005) does mention links with other policy areas merely in the context of broadening the scope of the international negotiations rather than mainstreaming in Europe itself. However, in the recent communication of the European Commission on *Limiting Global Climate Change to 2 Degrees Celsius: The Way Ahead for 2020 and Beyond* (EC, 2007a) and its Green Paper on Adaptation (EC, 2007b), mainstreaming of mitigation and adaptation in other European policies is now proposed more seriously. In general, in mainstreaming activities there appears to be an emphasis on adaptation rather than on both adaptation and mitigation, e.g. GEF projects such as Mainstreaming Adaptation to Climate Change in the Caribbean (MACC, 2006).

We refer to Bizikova et al. (2007) for a more extensive discussion on the integration of climate change considerations in decision-making at the local level, creating partnerships between local authorities, citizens' groups, the private sector and scientists, and building capacity to effectively respond to climate change.

6. Discussion and recommendations

Mitigation and adaptation have been separated, to some extent artificially, in science as well as policy. The reasons for this have been discussed above. Since there is now general agreement that climate change is unavoidable and that unmitigated climate change may lead to serious impacts for natural ecosystems and human society, the question is not whether the climate has to be protected from humans or humans from climate, but how both mitigation and adaptation can be pursued in tandem. It may be tempting to now reduce the emphasis on the individual strategies and call for integrated responses that are based on optimal, least-cost solutions. Our analysis suggests that integrated approaches can indeed provide very promising options, which can primarily be identified in those sectors that can play a major role in both mitigation and adaptation, notably land-use and urban planning, agriculture and forestry, and water management. However, in some sectors, the balance of adaptation and mitigation benefits can be very uncertain. For example, in urban design, increased cooling needs and climate-friendly siting have effects which work in different directions. In the energy sector, renewable energy can reduce GHG emissions but increase vulnerability of supply. In practice, to our knowledge, few opportunities for synergistic action are yet captured, because of low awareness. However, the majority of mitigation options in key sectors such as energy, transport, buildings, industry and waste do not have any clear link with climate change adaptation, and hence the synergetic options appear to be limited in scope from a global perspective.

We have argued that the costs and benefits of climate change are too widely distributed over disparate actors and geographical and temporal scales, and uncertainties relating to costs of mitigation, adaptation and residual impacts are too large to find a meaningful answer to the question of what the most efficient and cheapest combination of adaptation and mitigation policies would be. Rather, it may be more relevant and urgent to broaden the menu of usually parallel mitigation and adaptation options and to broaden the analysis of their linkages. We propose the following five ways to develop linked adaptation and mitigation strategies:

1. *Avoid trade-offs*: when designing adaptation options, their consequences for mitigation should be routinely taken into account and vice versa, something that can be facilitated by including such considerations in the available methodological toolkits, such as design criteria and project cost–benefit analyses.
2. *Identify synergies*: for specific sectoral climate response options, notably in those sectors mentioned above, those options can be identified that contribute to both reduced greenhouse gas emissions and reduced vulnerability to climate change.
3. *Enhance and apply response capacity*: since the determinants of adaptive and mitigative capacity largely overlap, strengthening these determinants in developing countries contributes to both; in industrialized countries the emphasis should be on putting the existing capacity into action.
4. *Develop institutional links*: between adaptation and mitigation, where they are currently missing: mechanisms should be put in place to enhance communication between mitigation and adaptation policy-makers and explore innovative links, e.g. at the national level, but also in the UNFCCC negotiations, where linking adaptation and mitigation may help in bridging differences between countries.
5. *Mainstreaming*: both greenhouse gas emissions and vulnerability to climate change are as much dependent on non-climate policies as on climate policies; therefore it would be wise to integrate climate change mitigation and adaptation considerations into all general development policies. This is important for mitigation as well as adaptation, in developed as well as in developing countries.

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Notes

1. One may wonder how climate policy would have developed if the early definitional split between mitigation and adaptation had not occurred. In health care, both types of response are captured by a single term: prevention.
2. Some definitions and examples: *risk* = probability * impact; *impact*: e.g. damage in US$, loss in life years, in crop yield, in species diversity; *climate change hazard*: e.g. in ΔT, Δprecipitation; *exposure*: e.g. number of people, area of crop land or ecosystem exposed; *sensitivity*: e.g. $I/\Delta T$/cap, $I/\Delta T$/ha; *adaptive capacity*: e.g. in % potential impact reduction; *potential impacts* = exposure * sensitivity; *vulnerability* = potential impact/adaptive capacity.
3. It is worth mentioning that reducing particulate matter emissions not only reduces detrimental health effects but also lessens the aerosol cooling effect of these emissions.
4. At the national level, costs of mitigation are generally estimated to be relatively low, generally less than a few percent of GDP, which is equivalent to a small decrease in the GDP growth rate, dependent on the level and timing of emissions reductions. For specific sectors, societal groups or regions this can be different. An example of the latter would be that income growth lowered by mitigation policies may actually at some point increase the incidence of malaria morbidity and mortality (Tol and Dowlatabadi, 2001).
5. An earlier table was expanded by including ideas from a similar matrix in Bizikova et al. (2006).

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