V. AN OVERVIEW OF INVESTMENT AND FINANCIAL FLOWS NEEDED FOR ADAPTATION

5.1. INTRODUCTION

350. Raising the standard of living of the poorest peoples in the world to meet the Millennium Development Goals will be challenging, particularly as populations in the developing world continue to increase. Climate change will make this task more challenging by increasing risks to human health, inundating low-lying areas, changing extreme weather events, altering water supplies, changing crop yields and ecosystems, and through many other impacts. The investment and financial flows needed for development in the midst of population growth and climate change will be substantial. It is important to be aware of how adaptation to climate change will affect the needs for investment and financial flows.

351. This analysis does not aim to provide a precise estimate of the total cost of adaptation, but assesses the order of magnitude of additional investment and financial flows that could be required in 2030 to adapt to the impacts of climate change. Although the intimate link between economic growth, population growth, human development and adaptation is acknowledged, this analysis focuses on the additional need for adaptation over and above the investment and financial flows required to address needs related to expected economic and population growth.

352. The investment and financial flows needed for adaptation to climate change have been estimated for five sectors identified by the Working Group II contribution to the Fourth Assessment Report of the IPCC:

- Agriculture, forestry and fisheries;
- Water supply;
- Human health;
- Coastal zones;
- Infrastructure.

353. Adaptation of natural ecosystems (terrestrial and marine) was also analysed. There is, however, very limited literature on adaptation in this sector, and it was not possible to estimate the investment needs associated with adaptation to climate change. Instead, the need for investments to protect ecosystems from all current threats was analysed.

354. This report first presents the scenarios used to undertake the analysis and addresses limitations in estimating adaptation costs. For each sector included in this study, the report briefly reviews climate change impacts, the methods used for the analyses, current level of investment and financial flows in the sector, estimated future investment and financial flows needed in 2030 and a brief analysis of the adequacy of current investment and financial flows to meet the additional needs. Finally, an analysis of damages that can be avoided with mitigation measures is then presented.

5.2. SCENARIOS

355. The analysis of investment and financial flows needed for adaptation to climate change was based on emissions scenarios for which climate change impacts could be inferred and responses to the climate impacts could be projected, so that the associated investment and financial flows could be estimated. The scenarios were selected based on their suitability for the analysis, the detail they provide on estimated investment and financial flows, and how representative they are of the literature. The following scenarios have been used for different sectors:

- IPCC SRES A1B and B1 scenarios are used for the water supply and coastal zones sectors (Nakicenovic N. and Swart R. (eds). 2000);
- For the human health sector, the scenarios used were variation from the IPCC IS92a: a scenario resulting in stabilization at 750 ppmv CO_2 equivalent by 2210 (s750), and a scenario resulting in stabilization at 550 ppmv CO_2 equivalent by 2170 (s550) (Leggett et al., 1992). These scenarios were used in the context of a WHO study on the global and regional burden of disease (GBD) (McMichael AJ *et al.*, 2004);
- Projected investment in physical assets for 2030 from the OECD ENV-Linkage model were used as the basis for estimating additional investment and financial flows needed in the AFF and infrastructure sectors.[36] The projected investment in physical assets

for 2030 based on the OECD ENV-Linkage model corresponds to the projection of the IEA WEO reference scenario.

356. Higher GHG emission levels than projected under these scenarios are possible.

357. The impacts on needs for investment and financial flows for adaptation have not been modelled based on the reference and mitigation scenarios used for the mitigation analyses. Given the lack of data, this work could not be undertaken in the context of this study, so different scenarios had to be used for the adaptation analyses.

358. In 2030, the year for which needs for investment and financial flows are estimated in this study, the CO_2 concentrations and projected changes in temperature and thus the associated differences in the adverse impact of climate change between any scenarios can be expected to be quite small.[37] For some sectors, it was assumed that adaptation would only be to the realized impact of climate change in 2030 so there would be little difference across scenarios in investment and financial flows needed by then. However, in the water supply and coastal zones sectors, adaptation to climate change anticipates some change in climate for, respectively, another 20 and 50 years. In those sectors, it is assumed that those adapting have perfect information on changes in global and regional climate in 2050 and 2080. In those cases differences in greenhouse gas emissions across scenarios would be significant.

5.3. LIMITATIONS IN ESTIMATING ADAPTATION COSTS

359. There are many difficulties and limitations in estimating the costs of adapting under various scenarios as well as the ability of countries to self-finance adaptation. These include (1) differences in adaptive capacity; (2) the fact that most adaptations will not be solely for the purpose of adapting to climate change; (3) the uncertainties associated with any readily available methods to estimate adaptation costs and (4) the existence of an adaptation deficit.

5.3.1. ADAPTIVE CAPACITY

360. One of the key limitations in estimating the costs of adaptation is the uncertainty about adaptive capacity. Adaptive capacity is essentially the ability to adapt to stresses such as climate change. It does not predict what adaptations will happen, but gives an indication of the differing capacities of societies to adapt *on their own* to climate change or other stresses. Smit *et al.* (2001) identified six determinants of adaptive capacity:

- Economic resources;
- Technology;
- Information and skills;
- Infrastructure;
- Institutions;
- Equity.

361. Unfortunately, all the scenarios used in this study leave many key aspects of adaptive capacity undefined. Although, in some cases, economic resources are specified and the level of technology is defined to some extent, the other four determinants of adaptive capacity are not defined. For example, institutions, which to some extent are a proxy for governance, a key factor in adaptive capacity, are not defined. It is not clear how this and other factors might differ across the scenarios.

362. A further limitation of the scenarios is that the socio-economic variables are defined at best, only at highly aggregated scales. Development paths are not projected for individual countries. Within any scenario, it is reasonable to expect that the development paths of individual countries will differ. Some may have economic or population rates of growth that are faster or slower than the regional averages. Thus, it is not possible to determine how adaptive capacity will change at the country level based on the selected scenario.

[36] OECD. ENV-Linkages Model calibrated to the IEA WEO 2006 Reference scenario. Personal communication with Philip Bagnoli at OECD.

[37] For example, in the SRES A1B and B1 scenarios by 2050, the CO_2 concentrations are almost 540 ppmv and 490 ppmv respectively. The global mean temperature increase differs only slightly between the two scenarios, about 1.6° C for the A1B scenario and 1.4° C for the B1 scenario. By 2100, the A1B scenario results in CO_2 concentrations of more than 700 ppmv, while the B1 scenario results in concentrations of about 550 ppmv. This yields a global mean temperature increase in 2100 of 2.8° C (with a range of 1.7 to 4.4° C) for the A1B scenario and 1.8° C (with a range of 1.1 to 2.9° C) for the B1 scenario (IPCC, 2007a).

5.3.2. ADAPTATIONS ARE TYPICALLY NOT SOLELY CLIMATE CHANGE RELATED

363. A second key limitation is that most adaptations to climate change will most likely not be made solely to adapt to climate change. Most activities that need to be undertaken to adapt to climate change will have benefits even if the climate does not change. For example, improvements in the management of ecosystems to reduce stresses on them or water conservation measures can typically be justified without considering climate change. Climate change provides an additional reason for making such changes because benefits of the adaptations are larger when climate change is considered. Indeed, the need for these adaptations may not depend on specific greenhouse gas concentration levels and thus climate change associated with scenarios. It may well be justified to introduce water use efficiency or reduce harm to coral reefs no matter what scenario is assumed.

364. However, some adaptations would happen solely on account of climate change considerations. Such adaptations are typically marginal adjustments to infrastructure or land use decisions. For example, flood protection infrastructure could be enlarged to account for additional risks from sea level rise or more intense precipitation (or both). Land use decisions such as defining flood plains, regulating and guiding land use or setbacks from the coast could be adjusted to account for future risks from climate change.

5.3.3. METHODS FOR ESTIMATING ADAPTATION COSTS

365. At least four methods for estimating global and regional adaptation costs could be used; these are briefly reviewed here. The latter three have been used in this study or in other studies. A discussion of the four methods and their limitations follows.

366. The first method is a complete bottom-up approach. It involves estimating the costs of specific adaptations across the world. Currently, partial information can be obtained from national adaptation programmes of action (NAPAs) and national communications. Where costs have been estimated, they can be used; where they are not estimated in the NAPAs or national communications, they can be derived. This approach has the advantage of building on adaptations identified by countries. Moreover, it is likely that different costing methods would be applied by different countries (or even within countries). The existing information on bottom-up adaptation needs is far from being comprehensive and complete. Therefore, it is impossible to assess needs entirely from the bottom within any reasonable time and resources constraints.

367. A second method is an extrapolation of the bottom-up method. Oxfam America (Raworth, 2007) extrapolates from estimated adaptation costs in NAPAs to the rest of the developing world using three factors: population, income and land. It estimates that adaptation costs will be more than USD 50 billion per year. This method has the advantage of using official estimates of adaptation costs as the basis for the extrapolation. However, as the report notes, only 13 NAPAs have been written. It is not known if these 13 NAPAs are representative of adaptation needs across the developing world or if the identification of adaptations is comprehensive. The NAPAs target only 49 LDC Parties to the UNFCCC and may not reflect needs in more developed countries. It is also important to note that the NAPAs focus on “urgent” needs, not all adaptation needs.

368. A third method, used for the AFF, natural ecosystems, and infrastructure sectoral analyses in this study, is to use current global expenditures in the sectors and apply a rule of thumb to estimate additional costs for meeting development needs and climate change adaptation. For example, the World Bank (2006) assumed that development costs will increase by USD 10 billion to USD 40 billion per year by assuming that climate-sensitive portions of the Bank’s investment portfolio will need an additional 5 to 20 per cent in resources to adapt to climate change. This approach is akin to a sensitivity analysis and can help give an order of magnitude of adaptation costs. A key uncertainty is related to the need to use assumptions about additional costs. The assumptions could be based on experience or a wide and representative sample of studies of specific adaptations; or it could be an educated guess and may not reflect actual conditions or variance of adaptation needs. Because such assumptions may be applied to a large base (the current total level of investment), even small percentage changes can yield large differences in estimates of investment and financial needs.

369. The fourth approach is a top-down quantitative analysis and is used in the water resources, coastal resources, and human health analyses in this study. Models can be applied to estimate biophysical impacts and needs for adaptation such as infrastructure for water supply or coastal defences. Uniform cost rules (perhaps adjusted for different per capita income levels) can be applied to estimate costs. The advantage of the uniform approach is that differences across countries can reflect different conditions and needs. This approach can give a

rough estimate of total costs, but typically will not capture site-specific differences. Actual investment and financial flows needed could vary quite substantially from the uniform rules. Furthermore, top-down approaches may not be comprehensive. For example, the model used to come up with estimates of needs for the water resources sector only includes water supply, not water quality, flood protection or the systems to distribute or treat the water. Models can be very expensive and time consuming. Finally, the use of different assumptions can result in quite different estimates of magnitudes. The water supply and coastal resources analysis consider the need for investment and financial flows associated with economic and population growth, while the health analysis does not consider these two factors.

5.3.4. THE EXISTENCE OF AN ADAPTATION DEFICIT

370. Before examining how development and climate change will affect needs for investment and financial flows, it is important to note that for all of the sectors examined herein, there is a substantial deficit in investment and financial flows. In many places property and activities are insufficiently adapted to current climate, including its variability and extremes. This has been labelled as the "adaptation deficit" (Burton, 2004).

371. Evidence for the existence and size of the adaptation deficit can be seen in the mounting losses from extreme weather events such as floods, droughts, tropical cyclones, and other storms. These losses have been mounting at a very rapid rate over the last 50 years. This increase is likely to be mostly due to the expansion of human populations, socio-economic activities, real property, and infrastructure of all kinds into zones of high risk. Moreover, much of this property is built at a substandard level and does not conform even to minimal building codes and standards. This widespread failure to build enough weather resistance into existing and expanding human settlements is the main reason for the existence of an adaptation deficit. Real property and socio-economic activities are just not as climate-proof as they could and arguably should be. The evidence suggests strongly that the adaptation deficit continues to increase because losses from extreme events continue to increase. In other words, societies are becoming less well adapted to current climate. Such a process of development has been called "maladaptation".

5.4. ANALYSIS OF INVESTMENT AND FINANCIAL FLOWS TO ADDRESS ADAPTATION NEEDS

5.4.1. AGRICULTURE, FORESTRY AND FISHERIES

5.4.1.1. INTRODUCTION

POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURE, FORESTRY AND FISHERIES

372. The effects of climate change on agriculture are different across regions and over time. Yields are projected to decline in low latitudes with any increase in temperature. In high latitudes, yields can increase with up to about 3° C of warming of local temperatures,[38] then start to decrease. For the first several degrees of increase in global mean temperature over 1990, global agricultural production could increase, driven by the increased yields in mid- and high latitudes. But, this will happen while yields in low-latitude areas decrease; thus, the potential for malnutrition in developing countries can rise. Malnutrition is projected to decline as a result of development, but the declines could be partially offset by climate change. Beyond several degrees of warming, global agricultural production is projected to decline (Easterling *et al.*, 2007). That would involve widespread adverse economic impacts and greater levels of malnutrition.

373. There are many important caveats in these findings. Changes in extreme events could disrupt agricultural production with even just a few degrees of warming. Adaptative capacities will play a key role in determining vulnerability. The IPCC concluded that a 3° C regional warming would exceed the capacity of developing countries to adapt to climate change impacts on crop yields (Easterling *et al.*, 2007). The potential for technological adaptations such as crop breeding to increase tolerance for heat and drought or taking better advantage of elevated atmospheric CO_2 concentrations has not been studied. Thus uncertainties about estimated impacts of climate change on agriculture mean that actual impacts could be more negative or more benign than projected. Whatever the climate change and its impacts, global agriculture will need to adapt by changing location and types of cropping systems. For example, increased agricultural output will require changes in locations of crops and expansion of agriculture into high-latitude areas. Such adaptations will require capital investment to be realized.

[38] Note that temperature increases in mid- and high-latitude land areas will be higher than increases in global mean temperature (IPCC, 2007a).

374. Meanwhile, Easterling *et al.* (2007) projected that global forestry would be affected modestly by climate, but that regional impacts could be more substantial. Generally, production of forests would shift from low-latitude to high-latitude areas. There could be significant changes in distribution and productivity of fisheries, with fish species in many locations becoming extinct, but fish productivity increasing for some species in some locations. Higher temperatures could adversely affect aquaculture, as could increased extreme weather, presence of new diseases and other factors (Easterling *et al.*, 2007).

ADAPTATION

375. Many actors, varying from individual farmers, ranchers, herders, and fisherpeople to national governments, international research organizations and multinational corporations will be involved in adaptingto climate change and in responding to the growing need for investment and financial flows in the agriculture, forestry, and fisheries sectors. Some of the fundamental forms of adaptation are as follows:

- *Change in mix of crop, forage, and tree species/varieties.* The mix of crop, forage grasses, or trees species employed, for example, growing crops, grasses, or trees can be changed toward varieties and species that are more heat, drought, or moisture tolerant. More generally, this involves replacing some proportion of the crop, forage, and tree species with alternative species better adapted to new climate regimes;
- *Change in mix of livestock and fish species/breeds.* This involves replacing some proportion of current species or breeds with alternative species or breeds that are more suitable for the altered climatic regime. For fisheries, this may mean harvesting species that have potentially migrated into the fishing grounds. In aquaculture and domestic animal raising this involves adopting livestock and fish species from areas that have had comparable climates;
- *Change in management of crops, forests, and fisheries.* Crops can be planted or harvested earlier to adjust to altered soil warm-up rates, soil moisture conditions, earlier maturity dates, and altered water availability regimes. Livestock and fish management changes can include altering aquaculture facility characteristics, changing stocking rates, altering degree of confinement, among many other possibilities. Adaptation in wild fish management may involve using species that migrate to fishing grounds or travelling farther to catch the same species being harvested now;
- *Moisture management/irrigation.* Climate change can increase crop water needs, decrease water availability, decrease soil moisture holding capacity, and increase flooding and water logging. Adaptation may involve using irrigation, which may require investing in irrigation facilities or equipment, changing drainage management regimes, altering tillage practices to conserve water, altering time of planting/harvesting to better match water availability, changing species to more drought tolerant plants/trees;
- *Pest and disease management.* Climate change is likely to exacerbate pest, disease and weed management problems. Adaptation could involve wider use of integrated pest and pathogen management or preventative veterinary care, development and use of varieties and species resistant to pests and diseases, maintaining or improving quarantine capabilities, outbreak monitoring programmes, prescribed burning, and adjusting harvesting schedules;
- *Management of natural areas.* Some AFF production such as livestock management relies on passively managed, natural ecosystems that may require more active management under climate change to introduce new, better adapted species or to deal with climate change enhanced pest, disease, or fire risks;
- *Fire management.* Forests, grasslands, and to some extent crop lands are vulnerable to climate change induced increases in fire risk. Such risks may stimulate adaptive actions like salvaging dead timber, landscape planning to minimize fire damage, and adjusting fire management systems;
- *Land use or enterprise choice change.* Climate change may make current land uses, such as cropping unsustainable, and it may be desirable to adapt by changing the land use from crops to pasture or trees, or from trees to grazing land. For fisheries, it may be desirable to abandon aquaculture or discontinue pursuing certain fish species in some regions. In some cases, loss of productivity in agriculture, forestry, or fisheries may lead to migration of people to areas such as cities or other countries that may offer better employment opportunities.

376. Governments, international organizations and NGOs have important roles to play in adaptation. The types of adaptation actions that can be pursued are as follows:

- *Research.* Public resources can be placed into research to provide adaptation strategies that could be adopted by the AFF producers, as discussed previously. These resources will be funding domestic government research organizations, international research organizations such as the Consultative Group for International Research, universities, or research oriented NGOs;
- *Extension and training.* Traditionally, substantial funding has gone into extension services and training to disseminate information to farmers, foresters, and fisherpeople on practices and technologies. Funding would need to go into rural training and extension programmes to disseminate adaptation options, by providing information and training on practices that could be adopted by AFF producers. Extension services may need to be enhanced to cope with the demands of development and climate change;
- *Transitional assistance.* Climate change may stimulate location changes and migration. There may be scope for identifying resources for creating job opportunities, supporting incomes, developing new infrastructure/institutions, relocating industry, providing temporary food aid, improving market functions and developing insurance;
- *Trade policy.* Governments may need to revise trade policies to adapt to new climate change conditions to allow imports and exports to mitigate lost AFF production or to sell or dispose of surpluses;
- *Infrastructure development.* Public investment may be needed to adapt to climate change conditions, including development of new transport and municipal infrastructure, development of new lands, protection or improvements of existing lands, construction of irrigation and water control structures, protection of coastal resources, and incubation of new industries, among other possibilities.

METHOD USED TO ESTIMATE NEED FOR INVESTMENT AND FINANCIAL FLOWS

377. Although extensive literature exists on the impacts of climate change on agriculture production, it tends to focus on the net effects on production, not on the costs of adaptation. Indeed, many of the studies related to AFF do not specify needed adaptation measures, not to mention costing them. In the face of these realities the approach used here relies on subjective statements about the current degree to which research expenditures are directed at climate related issues and a broad assumption about how capital formation might be affected.

378. The AFF sector estimated the additional investment and financial flows needed in the primary sector (e.g. the growing of crops, the farming of animals, logging and fish farms) and the secondary sector (e.g. food, wood product and pulp and paper manufacturing industries) to cope with expected economic and population growth and the impacts of climate change.

379. In order to assess investment and financial flows needed to cope with expected economic and population growth in 2030 based on the relevant literature, it is expected that the level of resources spent on research will continue to grow at about 2 per cent per year in both developed and developing countries. Total resources spent on extension are assumed to rise by 20 per cent in developing countries due to their current and emerging food issues and the current level of resources spent on extension in developed countries are assumed to be adequate and remain constant. The projected level of investment in physical assets needed in 2030 is based on the OECD ENV-Linkage model and corresponds to the projection of the IEA WEO reference scenario.

380. In order to meet climate change adaptation needs, the following was assumed:

- Based on a study of the implications of future agricultural research needs and subjective estimates of the amount research expenditures in the Consultative Group on International Agricultural Research (CGIAR) system related to climate, it is estimated that expenditures in research and extension to cope with expected economic growth in 2030 would need to increase by 10 per cent;
- It was assumed that there will be new capital needed to, for example, irrigate areas, adopt new practices, move fish timber processing facilities, etc. However, in 2030 the need for additional investment will be

limited by the fact that most agricultural and fisheries capital tends to have a short life (10 – 20 years) and would be replaced and adapted as climate change proceeds. As a consequence, a low 2 per cent estimate was used to reflect the additional level of investment needed in new facilities for the development of new and larger land areas to cope with regionally diminished production plus expanded irrigation and other inputs, relocation of food, wood industry, and pulp and paper manufacturing facilities. Based on this, the additional investment in gross fixed capital formation between 2005 and 2030, as estimated by the OECD ENV-Linkage model, will need to increase by 2 per cent.[39]

5.4.1.2. OVERVIEW OF CURRENT INVESTMENT AND FINANCIAL FLOWS BY SOURCE OF FINANCING

381. Current expenditures on AFF are presented in TABLE V-40. Public expenditures on research are about two thirds of the total, but are more than 90 per cent of the expenditures in developing countries and less than half of the expenditures in developed countries.

382. TABLE 33-ANNEX V presents the total GFCF for the 3 AFF sub sectors (agriculture, forestry and fisheries) in 2005 and for 2030, as projected by the OECD ENV-Linkage model. About three fifths of the investment is for agriculture, one third is forestry, and the remaining 2 per cent is for fisheries. GFCF is projected to almost double in 25 years, but the shares devoted to the sub sectors are expected to remain about the same. TABLE 35.1- and 35.3-ANNEX V presents the source of funding for the investments in GFCF in the AFF sector in 2000. TABLE 35.1-ANNEX V presents the source of financing for the investment related to AFF activities in the primary sector, growing of crops, farming of animals, logging and operation of fish hatcheries and fish farms, while TABLE 35.3-ANNEX V presents the source of financing for the investment related AFF activities in the secondary sector, the food, wood product and pulp and paper manufacturing industries.[40] Domestic investment represents 97 per cent of the investment in the former sector and 84 per cent in the later, while ODA represents 1.2 per cent in the former and 0.1 per cent in the latter. In both cases, FDI is likely to play a more significant role than ODA, however FDI role is likely to be significantly greater in activities related to the manufacturing industries than in the primary sector.

383. The trend in ODA to AFF by region is displayed in TABLE 14-ANNEX V. Total ODA to AFF reached USD 6.4 billion in 2005. Total ODA in AFF rose by 8 per cent from 2000 to 2005, but expenditures in extension increased by 38 per cent and expenditures in research increased by almost 80 per cent during the same period.

5.4.1.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

384. TABLE V-41 presents estimates of additional investment and financial flows needed to address expected economic growth and population growth. TABLE V-41 also presents the additional investment and financial flows needed to adapt to climate change.

385. Overall, a substantial increase in investment and financial flows will be needed to meet the growing demand due to expected economic and population growth in 2030. It is estimated that investment and financial flows into R&D, extension activities and physical assets will need to nearly double (an increase of about USD 575 billion) between 2005 and 2030. Adaptation to the adverse impacts of climate change is estimated to add about 2 per cent to this amount or about USD 14 billion in 2030. About 75 per cent of this latter amount will be required for investment in physical assets (capital formation related investment) and 25 per cent will be required in the form of financial flows for research and extension activities. Slightly more than half of this amount will be needed in developing countries.

[39] Actual investment needs could be somewhat lower (one can imagine costs being half as much) or substantially higher (one can also imagine costs being two to three times or more higher).

[40] TABLE ANNEX V-35.3 includes all manufacturing sectors. The source of financing for the food, wood product and pulp and paper manufacturing industries might thus differ to some extent.

Table V-40. **Expenditures in agriculture, forestry and fisheries (millions of United States dollars)**

Type of expenditures	Amount
Research in developing countries[a]	15,422
Research in high income countries[a]	25,111
Extension in developing countries[a]	3,083
Extension in high income countries[a]	4,161
Capital formation in developing countries[b]	190,102
Capital formation in high income countries[b]	354,017
Total developing countries	208,608
Total high income countries	383,288
Total	**591,896**

[a] Estimated for 2000
[b] Estimated for 2005

Table V-41. **Investment and financial flows needed in 2030 for economic and population growth and for adaptation to the adverse impacts of climate change (millions of United States dollars)**

Type of expenditures	Additional investment and financial flows needed due to economic and population growth	Additional investment and financial flows needed for adaptation to the adverse impacts of climate change
Research in developing countries	13,526	1,353
Research in high income countries	20,374	2,037
Extension in developing countries	617	62
Extension in high income countries	0	0
Capital formation in developing countries	291,093	5,822
Capital formation in high income countries	248,001	4,960
Total developing countries	305,236	7,237
Total high income countries	268,375	6,997
Total	**573,611**	**14,234**

5.4.1.4. ASSESSMENT OF NEEDED CHANGES IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP IN INVESTMENT AND FINANCIAL FLOWS

386. The additional investment and financial flows needed in 2030 to cope with the adverse impacts of climate change in the AFF sector is about USD 14 billion. Slightly more than half of this amount will be needed for developing countries alone. It is estimated that approximately USD 11 billion will be needed to purchase new capital; for example to irrigate areas, adopt new practices and to move processing facilities. The additional financial flows needed in the AFF sector for research and extension activities to facilitate adaptation would be about USD 3 billion.

387. Most of the additional investment in physical assets needed in the AFF sector is for assets that are currently financed by domestic private agents. ODA currently accounts for less than one per cent of the resources channelled to this sector in non-Annex I Parties and for about 3 per cent in LDC Parties. FDI is likely to play a more significant role than ODA, however its role is likely to be significantly greater in activities related to the manufacturing industries than in the primary sector. Consequently, it can be expected that the majority of the additional investment needed would come from private sources, such as domestic AFF producers and processing firms and multinational seed companies, chemical companies and companies in the manufacturing industries. It can be expected that additional public resources will be needed to provide the private sector with the necessary information and incentives for it to make the required additional investment to better adapt to climate change. The design of adequate and coherent national policies could play a key role and targeted support will be needed for this to happen. Substantial external public resources are already channelled into agricultural and forestry policies in developing countries, in particular in Africa and Latin America. A higher fraction of these resources might need to support the integration of be needed for this, depending on the region.

388. Public sources account for two thirds of the current funding for AFF research worldwide but for as much as 90 per cent of AFF research funding in developing countries. Thus, for the additional USD 3 billion needed in investment and financial flows in 2030 for research and extension in developing countries, most of the additional funding would need to come from public sources unless adequate incentives are provided to the private sector. Assuming that public spending continues to increase by slightly more than 2 per cent per year in developing countries, an additional USD 1.4 billion would need to come from new sources of external public financing in 2030 to cope with the adverse impacts of climate change.

Box V-10. **Agriculture, Forestry and Fisheries**

Investment and financial flows needed in 2030

To address climate change impacts in this sector, an additional USD 14 billion in investment and financial flows would be needed. About half of this amount is estimated to be needed in developing countries. It is estimated that approximately USD 11 billion will be needed to purchase new capital; for example to irrigate areas, adopt new practices and to move processing facilities. The additional USD 3 billion will be needed for research and extension activities to facilitate adaptation.

Current investment and financial flows

Total current expenditure on AFF for capital formation, research and extension is estimated to be in the order of USD 591 billion. A large proportion of the investment in the AFF sector is made in privately own physical assets by AFF producers and processing firms and multinational seed companies, chemical companies and companies in the manufacturing industries. Public expenditures on research are about two-thirds of the total, but are more than 90 per cent of the expenditures in developing countries and less than half of the expenditures in developed countries. A relatively substantial level (2.9 USD billion in 2000) of external public resources are channeled into agricultural and forestry sector policies in developing countries as compared to other sectors, in particular in Africa and Latin America.

5.4.2. WATER SUPPLY

5.4.2.1. INTRODUCTION

POTENTIAL IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES

389. The IPCC reports that water resources around the world will be highly sensitive to climate change. Higher temperatures, increased melting of glaciers, salinization from rising oceans, an increased speed of the hydrological cycle and changes in precipitation patterns will affect the supply, quality and demand for water resources around the world (Kundzewicz *et al.*, 2007). One likely outcome from an increased hydrological cycle is precipitation falling in fewer but more intense events, thus increasing the likelihood of flooding in many regions and more days without precipitation, thus also increasing likelihood of drought (Tebaldi *et al.*, 2006; IPCC, 2007a). One recently finding from the literature is the likelihood of certain regional patterns of precipitation. For example, most climate models project that the Mediterranean Basin, Southern Africa, many parts of northern Brazil and southwestern North America are likely to see a reduction in precipitation (Kundzewicz *et al.*, 2007; Milly *et al.*, 2005).

ADAPTATION

390. The IPCC also notes that there are many options for adaptation related to water resources and that many water bodies in municipalities (particularly, but not exclusively, in developed countries) are already beginning to take steps to prepare for climate change. Table V-42, from Kundzewicz *et al.*, (2007), summarizes some options or adaptation. The IPCC identified reservoir construction and decommissioning, increased waste water reuse and desalinization, more efficient waste water treatment, and application of water saving technologies as other options for adaptation.

METHOD USED TO ESTIMATE NEED FOR INVESTMENT AND FINANCIAL FLOWS

391. Given the need to use readily available data for this analysis, estimates presented are only for changes in water supply and demand. The investment resources needed for water quality and flood control are not estimated. The supply costs also do not include estimates of needs for distribution systems. Consequently, the estimates in this study might be underestimating the cost of adaptation in the water resources sector.

392. Modelling was used to estimate changes in demand by each country for water supply for two scenarios: the SRES A1B and B1 scenarios. The estimates consider the needs of increasing populations and growing economies. Change in 2030 assumed planning for the next 20 years and perfect knowledge about climate change impacts in 2050. Estimates of demand for water supplies and estimates of change in supply (as affected by climate change) used by Kirshen (2007) were used. Uniform assumptions were used about how much water in basins could be used to meet off-stream uses such as domestic consumption and irrigation. Some use of desalinated water in coastal cities and some use of reclaimed water for irrigation in countries facing particular water shortages were assumed. The cost of unmet irrigation demands have not been considered in the analysis.

Table V-42. **Adaptation measures in the water resource sector**

Supply side	Demand side
Prospecting and extraction of groundwater	Improvement of water-use efficiency by recycling water
Increasing storage capacity by building reservoirs and dams	Reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted
Desalination of sea water	Reduction in water demand for irrigation by importing agricultural products, i.e., virtual water
Expansion of rain water storage	Promotion of indigenous practices for sustainable water use
Removal of invasive non-native vegetation from riparian areas	Expanded use of water markets to reallocate water to highly valued uses
Water transfer	Expanded use of economic incentives, including metering and pricing to encourage water conservation

Source: Kundzewicz *et al.*, 2007.

393. Applying uniform rules of thumb is a practical method for generating estimates of financial costs. However, it implies that country by country variance in costs and approaches cannot be considered. In the context of this study, uniform assumptions were applied for costs for extracting groundwater, building additional surface water storage capacity, installing desalinization plants, and reclaiming water. However, the cost estimates considered differences in costs in developed and developing countries. Results for regions, and particularly countries, should be treated as preliminary.

394. The cost estimates for 2030 are the total costs associated with the construction of additional infrastructure (reservoirs, wells, desalination, re-use facilities) needed to meet the projected demand for water supplies because of projected population and economic growth and expected climate change under the two scenarios.

5.4.2.2. OVERVIEW OF CURRENT INVESTMENT AND FINANCIAL FLOWS BY SOURCE OF FINANCING

395. Briscoe (1999) estimates current annual expenditures for water-related infrastructure in developing countries to be USD 15 billion for hydropower, USD 25 billion for water supply and sanitation, and USD 25 billion for irrigation and drainage, for a total of USD 65 billion. GFCF for water is estimated at USD 38.4 billion in 2005. Winpenny (2003) and Briscoe (1999) both state that the majority of present financing for all aspects of water resources use comes from public sources, with Briscoe presenting estimates that 90 per cent is from mainly public sources and 10 per cent is from external sources. TABLE 15-ANNEX V gives levels of ODA to water infrastructures in 2000 and 2005. In 2000, total ODA in the water sector infrastructure (USD 4.2 billion) accounted for about 6 per cent of the total annual expenditures estimated by Briscoe (1999).

396. As shown in TABLE 15-ANNEX V, from 2000 to 2005, real ODA directed towards water infrastructure increased by approximately 40 per cent (from USD 4.2 billion in 2000 to USD 5.9 billion in 2005). The regional distribution changed markedly, with Latin America and the Caribbean receiving in 2005 only 32 per cent of the amount it received in 2000. Contributions to Asia, Africa and the Middle East increased significantly from 2000 to 2005.

5.4.2.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

397. Much has been written about the challenges of financing Target 10 of the MDGs for halving "by 2015 the number of people without sustainable access to safe drinking water and basic sanitation" (e.g., Toubkiss, 2006, Winpenny, 2003). Eleven different estimates ranged from USD 9 billion to USD 100 billion per year. A commonly accepted estimate is that meeting the most basic domestic water and sanitation goals would require an annual expenditure of USD 10 billion through 2015 (Winpenny, 2003). It appears that none of the reports included climate change impacts on water supply or demand. This is reasonable, as domestic water demands are only a small portion of global water demands. The estimates presented below do not include the costs of meeting Target 10 of the MDGs, rather they complement it.

Table V-43. **Investment and financial flows needed in 2030 for economic and population growth and for adaptation to the adverse impacts of climate change for the SRES A1B and B1 scenarios (billions of United States dollars)**

Region	SRES A1B	SRES B1
Africa	233	223
Developing Asia	303	230
Latin America	23	23
Middle East	151	148
OECD Europe	87	25
OECD North America	41	16
OECD Pacific	3	1
Transition economies	57	54
World total	898	720
NAI Parties	720	628
Least Developed Countries	57	45

398. The estimated investment needs for the SRES A1B and B1 scenarios by region are summarized in TABLE V-43. The estimates of investment and financial flows needed represents the total flows needed for the construction of additional infrastructure required to meet the projected demand for water supply caused by population and economic growth and expected climate change by 2030.

399. The investment cost for meeting the A1B scenario, assuming climate change to 2050 is anticipated, is estimated to be USD 797 billion; the cost of meeting the B1 scenario is estimated to be USD 639 billion, some 20 per cent less. This 20 per cent reduction is mainly due to differences in socio-economic conditions between the two scenarios; there is significantly more economic growth in the A1B scenario.

400. The fraction of the change in investment needs attributable to climate change alone is estimated to be 25 per cent under both the SRES A1B and B1 scenarios. Thus climate change is estimated to increase total investment needs by 2030 by USD 225 billion under the A1B scenario and USD 180 billion under the B1 scenario.

401. Assuming that funding is provided through grants for a 20-year period, the additional investment and financial flows needed for adaptation would be about USD 9 – 11 billion in 2030. About 85 per cent of the investment (USD 8 – 9 billion) is estimated to be needed in non-Annex I Parties. Interestingly, this is of the same order of magnitude as the additional investment and financial flows needed to meet the MDG related to sustainable access to safe drinking water and basic sanitation.

5.4.2.4. ASSESSMENT OF NEEDED CHANGES IN FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP IN INVESTMENT AND FINANCIAL FLOWS

402. For adaptation alone, the additional investment and financial flows needed would be about USD 9 – 11 billion in 2030. Winpenny (2003) describes three types of obstacles to increasing the financing for water-related infrastructure and then presents many recommendations to overcome them. The major classes of obstacles include: governance; particular funding risks of the water sector such as its low rate of return, capital intensity with long payback period; and the large number of projects that cannot obtain financing from any source because of project size or the credit risk of the borrower (called the “exposed segment”). Briscoe (1999) estimates that 90 per cent of funding for all aspects of water resources use is from domestic sources and 10 per cent is from external sources. Both sources might be inadequate to meet future challenges associated with climate change. If the increase in investment needs solely related to climate change in non-Annex I Parties (USD 8 – 9 billion) is to come entirely from ODA, which is currently USD 5.9 billion per year, then ODA would need to rise by about 50 per cent to meet the additional requirements. Despite the important recent increases in ODA allocated to the water and sanitation sector, it is unlikely that this is indicative of the expected change from the present to 2030. New domestic and external public resources will be needed.

Box V-11. Water supply

Investment and financial flows needed in 2030
The total cost associated with the construction of additional infrastructure needed to meet the projected demand for water supply is estimated to increase investment needs in 2030 by USD 11 billion. About 85 per cent of the investment is estimated to be needed in non-Annex I Parties.

Current investment and financial flows
In 1999, expenditures for water-related infrastructure in developing countries were estimated at USD 65 billion. Total investment in physical assets only in this sector was estimated at USD 38.4 billion in 2005. Most of this investment is undertaken by governments. About 90 per cent of the cost for all aspects of water resource use is currently covered by domestic funding sources and 10 per cent by external funding sources. From 2000 – 2005, ODA directed towards water infrastructure increased by approximately 40 per cent (from USD 4.2 billion in 2000 to USD 5.9 billion in 2005).

5.4.3. HUMAN HEALTH

5.4.3.1. INTRODUCTION

POTENTIAL IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH

403. Climate change is likely to have widespread, diverse, and on the whole negative impacts on human health across the world. The impacts include changes in the location and incidence of infectious and diarrhoeal diseases, increases in air and water pollution in many locations, increase in risk of heat stress, increases in intensity and frequency of many extreme events, and increased risks of malnutrition and other consequences of poor food quality. In addition, disruption of natural ecosystems could enable the further spread of infectious diseases, and climate change induced human migration can be injurious to mental and physical health. On the positive side, there could be reductions in some cold-related health outcomes. On the whole, the Human Health chapter of the IPCC AR4 concluded that climate change has begun to negatively affect human health, and that projected climate change will increase the risks of climate-sensitive health outcomes (Confalonieri *et al.*, 2007).

ADAPTATION

404. The fundamental adaptation requirement for the health sector in relation to climate change is to improve the capacity of the public health system. There is tremendous disparity in health risks between the developing and developed world. The main reason is that, on average, the public health systems in the developed world function at much higher levels than do the systems in the developing world. Improving the delivery of health care in the developing world would go a long way toward helping developing countries develop and could substantially reduce vulnerability to climate change. Without substantial improvement in the public health systems, human health in developing countries will be highly vulnerable to climate change. However, even with significant improvements in health care, climate change is projected to increase the burden of climate-sensitive health determinants and outcomes.

405. Beyond this, there are many specific measures that can be taken to reduce vulnerability to climate change. These include, for example, improved monitoring systems to detect the arrival or presence of infectious diseases and heat-watch warning systems to warn urban populations about heat waves.

METHOD USED TO ESTIMATE NEED FOR INVESTMENT AND FINANCIAL FLOWS

406. The Global Burden of Disease (GBD) study conducted by the WHO (McMichael *et al.*, 2004) was used to estimate the total increase in health cases in 2030. The GBD study is the most comprehensive study of the total impacts of climate change on global human health that has been conducted to date. The study used internally consistent estimates of incidence, health state prevalence, severity and duration, and mortality for more than 130 major health outcomes, and estimated change in disability adjusted life years (DALYs) lost compared with the base period 1961 to 1990. Twenty-six risk factors were assessed, including major environmental, occupational, behavioural and lifestyle risk factors. The analysis for this adaptation study focuses on three human health outcomes: diarrhoeal disease, malnutrition and malaria. Models were used to estimate risks for each outcome. The model output is reported as a mid-range estimate. As with the study of water investment needs, the advantage of this approach is that a consistent and comprehensive framework is applied across the globe.

407. The limitations of this approach are similar to the limitations of the water assessment. What is essentially top-down modelling typically does not account for many varying local and regional factors that affect results at these scales. Such top-down approaches, however, are useful for providing a consistent and approximate estimate of impacts.

408. The GBD study uses two scenarios. The first scenario is the 750 ppmv stabilization scenario from the GBD analysis; this results in CO_2 concentrations in the atmosphere slightly higher than the SRES A1B scenario. The second scenario is the 550 ppmv stabilization scenario from the GBD analysis. This CO_2 concentration is similar to that from the SRES B1 scenario. The GBD relied on climate change estimates from one general circulation model, the HADCM2 model (Johns *et al.*, 2001).

409. A further limitation is the estimated costs for treating health outcomes. The cost estimates are low because they consider only the cost of treating one case of each health outcome, thus assuming that there is sufficient public health infrastructure to administer the treatment. The estimates do not include the costs of setting up new infrastructure (such as the ability to distribute bed nets) when a health outcome increases its geographic range. In addition, some estimated costs are low. For example, the average cost of intervention per child to combat

malnutrition is estimated to be about USD 20, whereas more recently published studies estimated costs of one order of magnitude higher.

410. Other human health impacts such as increased heat stress, exposure to air and water pollution, exposure to many other diseases such as dengue fever, and exposure to increased intensity of many extreme weather events are not examined. So the total estimated number of cases caused and the costs associated with climate change are not complete.

411. Based on Rosenzweig and Parry (1994), malnutrition is projected to increase. Despite its vintage, it is perhaps the most comprehensive study of climate change impacts on agriculture done to date. The study assumed global population growing to USD 10.8 billion by the middle of the century, whereas the SRES A1B and B1 scenarios assumed global population peaks at about 8 billion. The agriculture estimates do not account for the effect of potential increases in extreme weather on agricultural production or distribution of food. Further, the estimates are of crop yields, not food security. Micronutrient deficiencies are a major source of ill health, even in regions with sufficient crop yields. On the other hand, the study did not account for adaptations such as the development of more heat and drought-tolerant crops or crops that can take better advantage of higher atmospheric CO_2 levels. Finally, for malnutrition, stunting and wasting were analysed, but not all the health impacts. Stunting and wasting are a small percentage of the impacts of climate change, so this can represent a significant underestimate.

5.4.3.2. OVERVIEW OF CURRENT INVESTMENT AND FINANCIAL FLOWS BY SOURCE OF FINANCING

412. Health expenditures come from both the public and private sectors. In many countries, government spending is the majority of total expenditures on health, whereas in many other countries, government spending is less than half of total expenditures. External expenditures on health are typically a small share of total expenditures. However, for very poor countries, external expenditures are a large share of total expenditures and even up to 30 to 50 per cent in a few cases. Table V-44 provides regional details on the above.

Table V-44. **Selected indicators of health expenditure ratios for the year 2000**

Region	Total expenditure on health (millions of United States dollars)	Government expenditure on health as a percentage of total expenditure on health (percentage)	Private expenditure on health as a percentage of total expenditure on health (percentage)	External resources for health as of total expenditure on health (percentage)	Out-of-pocket expenditure as percentage of private expenditure on health (percentage)
Africa	34,813	43	57	5	63
Developing Asia	122,935	36	64	1	93
Latin America	119,458	50	50	1	66
Middle East	37,252	63	37	2	79
OECD Europe	862,604	75	25	0	63
OECD North America	1,572,296	45	55	0	29
OECD Pacific	477,591	78	22	0	86
Other Europe	257	70	30	0	82
Transition Economies	33,526	60	40	1	79
World Total	**3,260,733**	**58**	**42**	**0**	**45**
NAI Parties	355,384	46	54	2	81
Least developed countries	8,330	37	63	17	85

Source: WHO 2006

413. TABLE 16-ANNEX V gives details on ODA by region for the health sector in 2000 and 2005. Total real ODA rose by two thirds from 2000 to 2005, with bilateral aid doubling. Total ODA for health reached USD 5.5 billion in 2005. Africa received the largest share of aid in both years, with South Asia second. Hecht and Shah (2003) estimated development assistance for health for the Disease Control Priorities in Developing Countries project (TABLE V-45). Although aid in the health sector is still dominated by multilateral and bilateral sources, NGOs such as the Bill and Melinda Gates Foundation are becoming a relatively more important source of funding and research.

5.4.3.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

414. The increased health risks for the middle scenario from the 750 ppmv and 550 ppmv stabilization scenarios relative to 1990 are presented in TABLE V-46. Regions are based on WHO classification. The groupings are not based on income level but rather on child and adult mortality rate (see ANNEX III for details on WHO regional groupings).

415. Based on model output, under the 750 ppmv stabilization scenario, there would be about 132 million additional cases of diarrhoeal disease, 5 million additional cases of malnutrition, and 22 million additional cases of malaria for these three health outcomes alone. Although virtually all of the malnutrition and malaria cases would be in developing countries, 1–5 per cent of the diarrhoeal disease cases would be in developed countries.

Table V-45. **Development assistance for health, selected years (millions of United States dollars)**

Source	Annual average 1997 to 1999	2002
Bilateral agencies	2,560	2,875
Multilateral agencies	3,402	4,649
European Commission	304	244
Global Fund to fight AIDS, Tuberculosis, and Malaria	0	962
Bill and Melinda Gates Foundation	458	600
Total	6,724	9,330

Source: Michaud (2003) and OECD (2004)

Table V-46. **Projected excess incident cases (in thousands) in 2030 of diarrhoeal diseases, malnutrition, and malaria for the 750 ppmv and 550 ppmv stabilization scenarios (middle estimates)**

	Diarrhoeal diseases		Malnutrition		Malaria	
Region	750 ppmv scenario	550 ppmv scenario	750 ppmv scenario	550 ppmv scenario	750 ppmv scenario	550 ppmv scenario
Africa	50,343	41,952	437	328	17,703	14,170
Americas-A	0	0	0	0	0	0
Americas-B	1,465	1,465	200	86	323	258
Eastern Mediterranean	5,779	5,779	533	335	3,211	2,535
Europe	785	785	0	0	0	0
Southeast Asia-A	0	0	225	113	0	0
Southeast Asia-B	73,608	63,092	3,067	2,165	70	0
Western Pacific-A	0	0	0	0	2	1.5
Western Pacific-B	0	0	211	70	478	404
Total	131,980	113,073	4,673	3,097	21,787	17,369

416. The number of additional cases in the 550 ppmv stabilization scenario is lower than in the 750 ppmv stabilization scenario. For example, additional cases of diarrhoeal disease would drop from 132 million per year to 113 million. Incidences of malnutrition would drop from 4.7 million additional cases to 3.1 million additional cases per year.

417. The estimated total global financial flows needed to cover the cost of the additional number of cases of diseases are reported in TABLE V-47.

418. The annual financial flows needed under the two scenarios to cover the cost of these three health outcomes arising from the adverse impacts of climate change would be USD 4–5 billion. Although the additional financial flows needed could not be allocated to different region in a meaningful way, it is assumed to be all in developing countries.

419. The 550 ppmv stabilization scenario results in fewer cases and lower financial flows needed than the 750 ppmv stabilization scenario. The needs are about USD 1 billion lower, from USD 5 billion down to USD 4 billion.

420. Although an estimate of the increased financial flows needed resulting from the socio-economic changes has not being developed for this study, an estimate of current financial needs can be derived by comparing the increase in health cases from climate change with the current number of cases. This can give an indication of the magnitude of financial flows that may be needed. TABLE V-48 presents the current number of cases of the three health outcomes, the projected number of cases under the two scenarios used, and the percentage increase.

421. Assuming the cost per case remains unchanged, under the reference scenario, the total financial flow would need to increase by 3 per cent to treat diarrheal disease, by 10 per cent to treat malnutrition, and by 5 per cent to treat malaria.

422. Although this study did not estimate the costs of improving health to meet the development needs associated with the 750 ppmv and 550 ppmv stabilization scenarios, Stenberg *et al.* (2007) estimated the costs to scale up essential child health interventions to reduce child mortality by two thirds under the four MDGs aimed at children's health by 2015 in 75 countries; the countries chosen accounted for 94 per cent of death among children less than five years of age. The interventions focused on malnutrition, pneumonia, diarrhoea, malaria and key causes of death of newborns. Costs included programme-specific investment and financial flows needed at national and district levels. The authors estimated that an additional USD 52.4 billion would be required for the period 2006–2015. This averages about

Table V-47. **Estimated additional financial flows needed in 2030 to cover the cost of additional cases of diarrhoeal diseases, malnutrition, and malaria due the adverse impacts of climate change (millions of United States dollars)**

	Diarrhoeal diseases		Malnutrition		Malaria		Total	
	750 ppmv scenario	550 ppmv scenario	750 ppmv scenario	550 ppmv scenario	750 ppmv scenario	550 ppmv scenario	750 ppmv scenario	550 ppmv scenario
Financial flows needed	2,235	1,923	92 – 122	61 – 81	2,173–3,033	1,773–2,418	4,500–5,390	3,757–4,422

Table V-48. **Comparison of current diarrhoeal disease, malnutrition, and malaria cases with estimated climate change impacts in 2030 for the 750 ppmv and 550 ppmv stabilization scenarios (thousands of cases)**

Scenario		Diarrhoeal diseases	Malnutrition	Malaria
Current		4,513,981	46,352	408,227
750 ppmv scenario	Climate change impacts	131,980	4,673	21,787
	Percentage increase	3	10	5
550 ppmv scenario	Climate change impacts	131,073	3,097	17,369
	Percentage increase	2.5	7	4

USD 5 billion per year. It is interesting to note that this is of the same order of magnitude as the estimated additional level of resources needed to treat additional cases of diarrhoea, malnutrition and malaria due to climate change in 2030. Projected costs in 2015 were equivalent to increasing the average total health expenditures from all financial resources in the 75 countries by 8 per cent and raising general government health expenditure by 26 per cent over 2002.

5.4.3.4. ASSESSMENT OF NEEDED CHANGES IN FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP IN INVESTMENT AND FINANCIAL FLOWS

423. The estimated additional financial flows needed for the health sector to treat the additional number of cases of diarrhoea, malnutrition and malaria due to climate change in developing countries are about USD 4 – 5 billion, the same order of magnitude as current ODA. Based on current financing trends of health care, this amount is likely to be paid for mainly by the families of those affected, with some domestic public funds paying for the operation of health care facilities. Whether the resources available will be adequate to meet the additional needs will vary a lot from one country to another, depending on the burden the additional needs represent compared with the availability of public and private resources. In countries where private individuals cannot cope with the additional cost of treatment, new and additional public financing will be necessary. Not being able to treat these diseases will increase morbidity and mortality. Countries that are already currently highly reliant on external sources for health care, such as LDCs, may need new and additional external support to cope with climate change.

Box V-12. **Human health**

Investment and financial flows needed in 2030

The financial flows needed in 2030 to cover the cost of treating the additional number of cases of diarrhoeal disease, malnutrition and malaria due to climate change is estimated to be USD 4 – 5 billion. By assumption, all of this amount will be needed in developing countries.

Current investment and financial flows

Total expenditures on health were in the order of USD 3.3 trillion in 2000. Government expenditure on health as a percentage of total expenditures on health varies from 36 per cent in developing Asia to 75 per cent in Europe. In several countries still, the cost of treating a particular health condition is paid for mainly by the families of those affected, with some domestic public funds covering the costs of operating health care facilities. Least developed countries are particularly reliant on external funding sources for health care. Aid in the health sector is still dominated by multilateral and bilateral sources (total real ODA rose by two thirds from 2000 to 2005 and reached USD 5.5 billion in 2005), NGOs are becoming a relatively more important source of funding and research.

5.4.4. NATURAL ECOSYSTEMS (TERRESTRIAL AND MARINE)

5.4.4.1. INTRODUCTION

POTENTIAL IMPACTS OF CLIMATE CHANGE ON NATURAL ECOSYSTEMS

424. Climate change has already been linked to impacts on species across the world (e.g., Parmesan and Yohe, 2003; Root *et al.*, 2005; Cassassa *et al.*, 2007). Migration patterns, productivity, location, and other changes are being observed. In one dramatic example, the Fish and Wildlife Service of the United States of America proposed listing polar bears as a threatened species because of declining Arctic ice cover (United States Fish and Wildlife Service, 2007).

425. The future impacts of climate change on ecosystems are likely to be profound and dramatic. The IPCC notes that the resilience of many ecosystems is likely to be overcome by the combination of climate change and other socio-economic influences (in particular land-use change and overexploitation). A 1.5 – 2.5° C warming over 1990 could cause the extinction of approximately 20 per cent to 30 per cent of plant and animal species (Thomas *et al.* 2004). A 3° C warming would transform about one fifth of the world's ecosystems (Fischlin *et al.*, 2007). There also are likely to be substantial impacts on marine ecosystems with a 3° C warming.

ADAPTATION

426. The term "adaptation" needs be applied in a relative sense to natural ecosystems. In the so-called managed sectors such as coastal and water resources, agriculture and health, adaptation has the potential to substantially maintain most of the services currently provided in these sectors, particularly in the developed countries. It is not clear, however, that human intervention can substantially offset the impacts of climate change and other socio-economic drivers on natural ecosystems. At best, based on what we know now, adaptation could reduce some of the harmful impacts of climate change.

427. The IPCC concluded that human intervention to assist ecosystem adaptation should consist of actions to reduce the impacts of other threats to ecosystems, such as habitat degradation, pollution and introduction of alien species. For example, diminished or lost ecosystems could be enhanced or replaced (e.g., ecosystem re-creation, rapid dispersal by humans, pollinator reintroduction and use of pesticides for pest outbreaks). In addition, captive breeding and reintroduction and translocation or provenance trials in forestry could be used.

428. Adaptation for natural ecosystems can be put into the following categories:

- Reduce and manage stresses from other sources and activities, such as pollution; over harvesting, habitat conversion, and species invasions;
- Restore habitats;
- Increase size and/or number of reserves;
- Increase habitat heterogeneity within reserves, for example, by including gradients of latitude, altitude, and soil moisture and by including different successional states;
- Maintain ecosystem structure and function as a means to ensure healthy and genetically diverse populations able to adapt to climate change;
- Increase landscape connectivity using corridors and stepping stones to link areas of habitat or reserves;
- Increase landscape permeability through reduction of unfavourable management practices and increasing area for biodiversity;
- Translocate and reintroduce species, especially those having essential functions such as pollination;
- Conserve threatened and endangered species ex situ, for example, using seed banks or collecting germplasm and zoos, including captive breeding for release into the wild.

METHOD USED TO ESTIMATE NEEDS FOR INVESTMENT AND FINANCIAL FLOWS

429. There is very limited literature on adaptation of natural ecosystems to the adverse impacts of climate change. The existing literature emphasizes ideas about ways to reduce vulnerability of natural ecosystems to climate change. There is virtually no information on the effectiveness of these adaptations in reducing the damage to ecosystems from climate change, or on the costs of adaptation to climate change.

430. As a consequence, information on current investments and financial flows going to natural ecosystem protection and how much might be needed to protect ecosystems from current threats was used as the basis for analysis. James *et al.* (2001) estimated the additional costs needed to protect biodiversity. The results of the analysis are discussed.

431. Although the method used by James *et al.* (2001) may be the best method to estimate adaptation costs for protecting natural ecosystems, the approach is quite approximate and indirect. The James *et al.* study is an attempt to estimate the investment and financial flows needed to protect natural ecosystems from current threats. But, as is discussed below, the authors use educated

guesses as to how much additional land needs to be set aside as biodiversity protection areas. This study is not able to rely on bottom-up or top-down (e.g., modelling) estimates of natural ecosystem protection needs.

432. Furthermore, the James *et al.* study does not estimate the additional protection needs that climate change might require. Given the potential for massive disruption of habitats and ecosystems, the need for many species to migrate hundreds of kilometres and the limited options for adaptation for many species, it is possible that the additional costs for addressing adaptation to climate change would be quite substantial. There is insufficient information to hazard even an educated guess as to the magnitude of the additional resources, not to mention their effectiveness in protecting natural ecosystems and biodiversity.

5.4.4.2. OVERVIEW OF CURRENT INVESTMENT AND FINANCIAL FLOWS BY SOURCE OF FINANCING

433. Between 1991 and 2000, the GEF provided about USD 1.1 billion in grants and leveraged an additional USD 2.5 billion in co-financing for biodiversity-related projects. Most of these grants were channelled through developing-country governments and NGOs and used to support more than 1,000 protected sites covering 226 million hectares in 86 countries. OECD data show only USD 198 million in biodiversity projects from the World Bank system (including the GEF) in 2000 and USD 267 million in 2005.

434. James *et al.* report that in the mid-1990s an average of USD 6.8 billion per year was spent on global protected areas, with about 89 per cent of that amount spent in developed countries.

435. The private sector resources allocated to biodiversity protection have been relatively limited and focused in areas such as ecotourism, agroforestry and conservation of medicinal and herbal plants.

5.4.4.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

436. James *et al.* examined what they called a relatively modest goal by the World Conservation Union (IUCN) to increase protected areas by 10 per cent (but noting that some scientists call for increasing protected areas by 50 per cent). They examined two options for such an expansion, one more ambitious than the other. James *et al.* estimate that improving protection, expanding the network in line with IUCN guidelines, and meeting the opportunity costs of local communities could all be achieved with an annual increase in expenditures of USD 12–22 billion. The range is based on different options for redressing the current lack of resources going to conservation. Note that this estimate does not consider the level of resources needed to reduce other threats to natural ecosystems, such as pollution. It also does not consider any additional requirements for protecting natural ecosystems from climate change. Such requirements could include developing migration corridors for species to migrate as climate zones shift.

437. It does not appear possible to estimate how resources needed for the protection of natural ecosystems would increase as a result of the reference or mitigation scenarios. However, it is clear that the larger the magnitude of climate change, the greater the harm to natural ecosystems. Therefore, the resources needed for protecting natural ecosystems will in all likelihood be higher for the reference scenario than for the mitigation scenario.

5.4.4.4. ASSESSMENT OF NEEDED CHANGES IN FINANCIAL AND POLICY ARRANGEMENTS TO PROTECT ECOSYSTEMS FROM CURRENT THREATS

438. The James *et al.* analysis indicates that just to meet current natural ecosystem protection needs, current levels of investment and financial flows would have to increase by a factor of three to four. This would require increasing public sources of funds and leveraging private sector funding as well.

439. However, so far, attempts at leveraging private sector financing for ecosystem protection have had limited success. Demonstrating that there is a business case for ecosystem protection is a difficult endeavour. ODA for ecosystem protection is currently two orders of magnitude below the identified level of investment and financial flows needed. Clearly, a substantial increase in public domestic and external funding will be needed to address not just the current lack of resources going to ecosystem protection but also the additional needs of climate change.

Box V-13. **Natural ecosystems**

Investment and financial flows needed in 2030
Estimates in the literature indicate that improving protection, expanding the network of protected areas and compensating local communities that currently depend on resources from fragile ecosystems could be achieved for an increase in annual expenditure of USD 12 – 22 billion.

Current investment and financial flows
Current annual spending to ensure natural ecosystem protection is of the order of USD 7 billion from public domestic and external funding.

5.4.5. COASTAL ZONES

5.4.5.1. INTRODUCTION

440. The IPCC (Nicholls *et al.*, 2007) reports that hazards relating to human development of coastal areas are quite high. About 120 million people are exposed to hazards from tropical cyclones each year, and on average these events kill more than 12,000 people a year. Climate change will result in higher sea levels, increased intensity of coastal storms and the destruction of many coral reefs and coastal wetlands. The combination of this and continued expansion of human settlements in coastal areas is likely to lead to an increasing need for protection from coastal hazards.

ADAPTATION

441. Nicholls *et al.* note that, in general, the costs of adaptation to sea level rise (e.g., through protection of threatened areas) are far less than the losses associated with not protecting coastal areas. It is not clear if it is feasible to adapt to more than a few metres of sea level rise. Protection of natural ecosystems such as wetlands and coral reefs can increase their resilience to climate change. The three basic options for adaptation are:

- Protect – to reduce the risk of the event by decreasing the probability of its occurrence;
- Accommodate – to increase society's ability to cope with the effects of the event;
- Retreat – to reduce the risk of the event by limiting its potential effects.

442. Table V-49 summarizes major adaptation options for coastal resources.

443. The benefits of mitigation of GHG emissions could be quite substantial over the very long term. The IPCC found that a sustained warming of 1–4° C above 1999–2000 levels could result in the deglaciation of Greenland. This would lead to many metres of sea level rise over many centuries. Such an amount of sea level rise appears to be beyond the capacity of societies to adapt through coastal protection. Abandonment of coastal areas would be necessary in response to such an outcome. The costs of abandoning coastal development around the world would be a few orders of magnitude above protection costs for a metre or two of sea level rise and entail major implications for human migration and cultural heritage.

METHOD USED TO ESTIMATE THE NEED FOR INVESTMENT AND FINANCIAL FLOWS

444. The dynamic interactive vulnerability analysis (DIVA) tool was used for this analysis. DIVA is a very detailed model of the world's coasts. It divides the world's coasts into more than 12,000 segments and can account for the effect of different adaptation options. The study examined protection only from coastal flooding through the building of dykes or the use of beach nourishment. A benefit-cost test was applied to estimate whether the costs of coastal protection were less than the value of lost economic output should no protection measures be used. Although use of benefit-cost analysis could favour protection of wealthier coastal areas, coastal lands in many developing areas apparently had a high enough value to justify use of protection measures. The results are provided globally, for the IPCC regions, and at a finer resolution.

445. DIVA analyses a limited set of adaptations in a uniform manner. This has the advantage of applying a uniform method that can account for local and regional differences in conditions such as value of threatened areas. However, it has the disadvantage of not accounting for unique local circumstances or varying decision criteria that may be applied around the world. Such a top-down approach was also used in the water supply analysis and has similar limitations.

446. Socio-economic conditions for all scenarios were assumed to be the conditions in the SRES A1B scenario (Nakićenović and Swart, 2000). The estimated additional investment and financial flows associated with the SRES A1B and B1 scenarios presented in this analysis are exclusively to cover the cost of adaptation measures to address sea level rise itself, not socio-economic development. However, the value of protected economic output is based on the A1B scenario. The A1B scenario assumes the highest GDP growth of all of the SRES scenarios.

447. DIVA estimates investment needs without a sea level rise. This considers the costs of adapting to subsidence and flooding. The SRES scenarios incorporate sea level rise. The difference between the SRES scenarios and no sea level rise is the effect of climate change alone.

448. DIVA estimates a number of impacts from sea level rise including beach nourishment costs, land loss costs, number of people flooded, costs of building dykes, and losses from flooding. Of these, only the costs of beach nourishment and the costs of building dykes will be counted as adaptation costs. The other categories are damages. In reality, adaptation costs would likely be involved in responding to the damages.

449. Investment needs in 2030 were analysed assuming that decision makers can project future rates of sea level rise and plan for a 50- to 100-year time frame. This study assumes that decision makers plan for sea level rise out to 2080. Planning for a shorter time frame is likely to result in lower adaptation costs in 2030, whereas planning for a longer time frame (such as for expected sea level rise in 2130) would result in higher costs in 2030. Planning for 100 years rather than 50 is estimated to increase costs by about two thirds.

450. Table V-50 gives sea level rise projections to 2130. These projections were taken from the IPCC Third Assessment Report (Houghton *et al.*, 2001). There is virtually no difference between SRES emissions scenarios in 2030 A1B and B1. However, by 2080, there is a substantial difference between the two scenarios.

Table V-49. **Major physical impacts and potential adaptation responses to sea level rise**

Physical impacts		Examples of adaptation responses (P – Protection; A – Accommodation; R – Retreat)
1. Inundation, flood and storm damage	a. Surge (sea)	Dykes/surge barriers (P) Building codes/buildings (A)
	b. Backwater effect (river)	Land use planning/hazard delineation (A/R)
2. Wetland loss (and change)		Land use planning (A/R) Managed realignment/forbid hard defenses (R) Nourishment/sediment management (P)
3. Erosion (direct and indirect change)		Coast defenses (P) Nourishment (P) Building setbacks (R)
4. Saltwater Intrusion	a. Surface waters	Saltwater intrusion barriers (P) Change water abstraction (A)
	b. Groundwater	Freshwater injection (P) Change water abstraction (A)
5. Rising water tables and impeded drainage		Upgrade drainage systems (P) Polders (P) Change land use (A) Land use planning/hazard delineation (A/R)

Table V-50. **The range in sea level rise by 2030 (relative to 1990) expected for each SRES scenario (cm)**

	SRES emissions scenario	
	A1B	B1
Minimum rise	3	3
Mean rise	9	9
Maximum rise (2030)	15	15
Maximum rise (2080)	53	44
Maximum rise (2100)	69	57
Maximum rise (2130)	96	75

5.4.5.2. OVERVIEW OF CURRENT INVESTMENT AND FINANCIAL FLOWS BY SOURCE OF FINANCING

451. While there is significant interest in elaborating coastal adaptation measures and understanding their costs (e.g., Klein *et al.*, 2001; Bosello *et al.*, 2007), the level of investment in coastal adaptation is difficult to assess as there is never a single agency with published accounts in any country. However, there is some information on the level of investment and actions to protect vulnerable coastal areas in some countries and regions:

- *European Union.* The Eurosion (2004) review reported that the total annual cost of coastal adaptation for erosion and flooding across the European Union was an estimated EUR 3.2 billion (in 2001 EUR; using current exchange rates this would be about USD 4 billion). These measures mainly involved protection;
- *United Kingdom.* The Flood and Coastal Management budget increased substantially since 2000/2001 from approximately GBP 300 million to more than GBP 500 million per year in 2005/2006 (about USD 443 million to USD 910 million using current exchange rates). However, coastal investment is not directly defined and is only an element of this budget;
- *Netherlands.* This is the archetypal country threatened by sea level rise, and it invests large sums in erosion and flood management. They amount to 0.1 to 0.2 per cent of GDP at present;
- *Bangladesh.* Bangladesh has experienced the highest death toll from coastal flooding of any country on earth (Nicholls, 2006), and is a good example of a vulnerable deltaic country. Following the 1970 and 1991 cyclones, when at least 400,000 people died, an accommodation strategy was implemented via a system of flood warnings and the construction of more than 2,500 elevated storm surge shelters. Despite recent severe storms, the death toll for people (and their animals via associated raised shelters) has fallen markedly;
- *The Maldives.* These islands are a good example ofa vulnerable atoll nation where sea level rise could literally extinguish the nation over the coming century without adaptation. However, significant adaptation is occurring on the island. After a significant Southern Ocean swell event that flooded much of the capital Male in the 1980s, a large wall was built around the city with aid from Japan (Pernetta, 1991). However, the costs are not known. More recently, after the Indian Ocean tsunami of 2004, there has been interest in developing tsunami shelters, which may also have a function against climate change.

5.4.5.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

452. The estimated investment needs for the SRES A1B and B1 scenarios are displayed in TABLE V-51. Beach nourishment, land loss and flooding costs are estimated for 2030. There is no anticipation of future climate change impacts in these categories. The estimated investment required for dykes in 2030 assumes that the coastal infrastructure built in that year is sufficient to adapt to the maximum amount of sea level rise anticipated in 2080. The cost of dykes is very sensitive to the length of the planning horizon. For instance, under the A1B scenario, if the dykes were built only for the sea level observed in 2030, the costs would be USD 11.7 billion. If, however, the dykes are built to adapt to projected sea level rise 100 year hence (to 2130), the annual cost in 2030 would be USD 16.8 billion. Since the cost of dykes represents more than half of the total costs, the selection of a planning horizon is a critical assumption affecting total costs.

453. Total costs including investment costs (beach nourishment and sea dykes) and losses (inundation and flooding) are estimated to be USD 21–22 billion in 2030.

454. TABLE V-52 examines the increase in investment needed by region. About half of the required investment will be in non-Annex I Parties.

455. The estimated investment needs for the A1B and B-1 scenarios differ by USD 1 billion per year, or about 10 per cent.

Table V-51. **Investment and financial flows needed in 2030 for adaptation to sea level rise assuming anticipation to 2080 for the SRES A1B and B1 scenarios (millions of United States dollars)**

Impact category	Investment and financial flows needed with no sea level rise	A1B scenario: Investment and financial flows needed with sea level rise	A1B scenario: Difference in investment and financial flows needed with sea level rise	B1 scenario: Investment and financial flows needed with sea level rise	B1 scenario: Difference in investment and financial flows needed with sea level rise
Beach nourishment costs	573	3,042	2,469	2,888	2,316
Sea dyke costs	5,601	13,803	8,202	12,815	7,214
Total investment costs	6,174	16,845	10,681	15,703	9,529
Land loss costs	0	6	6	6	5
Sea flood costs	6,385	8,119	1,734	7,853	1,467
Total loss costs	6,385	8,125	1,740	7,859	1,472
Total cost (investment and losses)	12,559	24,971	12,422	23,562	11,002

Table V-52. **Estimated additional investment needed in coastal infrastructure for the SRES A1B and B1 scenarios in 2030 by region (millions of United States dollars)**

Region	A1B scenario: Mean 2030	A1B scenario: Maximum in 2080	B1 scenario: Mean 2030	B1 scenario: Maximum in 2080
Africa	612	1,319	528	1,197
Developing Asia	951	2,181	801	1,928
Latin America	680	1,597	573	1,414
Middle East	72	171	60	153
OECD Europe	737	1,785	624	1,587
OECD North America	1,002	2,022	882	1,838
OECD Pacific	460	1,080	388	958
Transition Economies	189	479	158	421
Total	4,702	10,634	4,014	9,496

5.4.5.4. ASSESSMENT OF NEEDED CHANGES IN FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP IN INVESTMENT AND FINANCIAL FLOWS

456. Additional investment in worldwide coastal infrastructure of about USD 10 – 11 billion will be required in 2030 for adaptation to sea level rise. Adaptation of coastal resources to climate change is highly dependent on public sources of funding. Although much coastal infrastructure may be private (e.g., buildings and homes), efforts to protect coastal areas from coastal storms and sea level rise are typically undertaken by governments. In the developed world and in parts of the developing world, the necessary financial resources are likely to be available to adapt coastal resources to climate change. However, certain settings and regions present particular challenges, as identified in the recent IPCC AR4 assessment of coastal areas (Nicholls *et al.*, in preparation). Deltaic regions, particularly the large coastal deltas in Asia and in Africa and small island states may have significant problems responding to sea level rise and climate change. In these countries, additional sources of external public financing will be needed.

457. Development and integration of coastal zone management institutions and processes, while in itself not demanding large amount of resources, could increase the efficiency of adaptation to climate change and sea level rise. GEF-funded initiatives such as the Caribbean Planning for Adaptation to Climate Change project, the Mainstreaming Adaptation to Global Change in the Caribbean project and the Pacific Islands Climate Change Assistance Programme are contributing to build the capacity in this area.

Box V-14. Coastal Zones

Investment and financial flows needed in 2030

With sea level rise, the investment needed is estimated to represent an additional USD 11 billion in 2030. This estimate assumes that decision makers take into account the expected sea level rise in 2080. About half of the required investment will be needed in non-Annex I Parties.

Current investment and financial flows

Although much of the infrastructure in coastal areas may be private (e.g. buildings and homes), efforts to protect coastal areas from coastal storms and sea level rise are typically undertaken by governments.

5.4.6. INFRASTRUCTURE

5.4.6.1. INTRODUCTION

458. Climate change is likely to have substantial consequences for the integrity, performance, lifetime and design criteria for much of the world's infrastructure. Infrastructure for water supply, sanitation, flood control, hydropower, and coastal development and defences could be substantially affected by climate change. Changes in average climate, but also changes in extreme events, will affect infrastructure. For example, sea level rise threatens to inundate coastal infrastructure. In addition, the potential for more intensive tropical cyclones would put more coastal infrastructure at risk. Changes in runoff patterns and water supplies will affect water supply, flood control, water supply and sanitation. Changes in intense precipitation, flooding and droughts will affect and most likely have major implications for construction of water supply infrastructure. Even changes in peak high and low temperatures may require adjustments to buildings and their heating and cooling systems.

ADAPTATION

459. In general, there are two types of climate change adaptation in infrastructure. The first involves making modifications to or changes in operations of infrastructure that would be directly affected by climate change. This applies to infrastructure used to manage natural resources such as water or coastal resources infrastructure. For example, coastal defences may be raised or otherwise strengthened to adapt to higher sea levels and the potential for more intense coastal storms. Infrastructure for water resource management applications such as flood protection, water supply, water quality treatment, hydropower production, and other uses may be modified to adapt to changing runoff-patterns and water quality conditions. For example, the size of reservoirs could be increased to provide more storage for water supply or flood protection. These changes will also apply to infrastructure such as heating and cooling systems directly affected by climate change.

460. The second type of adaptation affects infrastructure needed to support activities that cope with climate-affected sectors or resources. Provisions of public health services, agriculture extension, research and many other applications require supporting infrastructure. Hospitals, clinics, disease monitoring systems, buildings for extension services, laboratories, and so on may need to be built to enhance the capability to adapt to climate change.

METHOD USED TO ESTIMATE THE NEED FOR INVESTMENT AND FINANCIAL FLOWS

461. The analysis of climate change impacts on infrastructure estimates the share of infrastructure investment that is currently vulnerable to climate variability and then estimates the additional investment in infrastructure that may be necessary to adapt to climate change. It addresses only the first type of adaptation mentioned above.

462. The share of infrastructure vulnerable to the impacts of climate change is estimated based on losses due to extreme weather events.

463. Munich Re provided a data set of "Great Weather Disasters" from 1951 to 2005, from which annual regional losses were estimated. The value of overall losses for each major event from 1951 through 2005 by region and/or country is included in the database. These were summed and averaged over the 55-year record of the database to obtain average annual losses by region. Since the Munich Re data set is only for large catastrophes and does not include damage from smaller climate events, it might underestimate total losses from weather extremes. Furthermore, the analysis in this study does not consider other infrastructure costs such as damage from inundation, erosion, melting of permafrost and other causes. On the other hand, although the vast majority of the "Great Weather Disasters" are likely to be made more intense by climate change (e.g., cyclones, droughts and floods), some, but not all, cold weather events could be less severe with climate change. The Munich Re data were used to obtain an estimate of the minimum additional investment needed to adapt infrastructure to climate change. The Munich Re data were scaled up to cover all weather related losses and accounts to get an estimate of the potential upper bound on the level of additional investment needed. The adjustment used is 4.3, and corresponds to the ratio of the Association of British Insurance (ABI) data on total weather related losses for the period 2000–2006 to the Munich Re losses for the same period. The average annual loss is thus estimated at between USD 21.1 billion and USD 87.7 billion.

464. To estimate the share of infrastructure vulnerable to the impacts of climate change, the annual infrastructure investment in the middle of the period 1951–2005, that is for 1978, was used. Global GFCF data are not available for that year. The GFCF for 1980 is estimated by assuming that the growth rate projected for the period 2005–2030 by OECD (3.65 per cent per year) can be applied to period 1978–2005. That yields a global GFCF for 1978 of about USD 3,025 billion. Based on the average annual loss

estimated above, the average annual loss is estimated to be between 0.7 per cent (based on Munich Re data) and 2.9 per cent (based on ABI data) of the estimated 1978 GFCF. Note that the World Bank estimates that 2 to 10 per cent of gross domestic investment could be sensitive to climate change, although it uses a much lower figure for the annual investment.

465. To estimate the potential additional costs of adapting vulnerable infrastructure to the impacts of climate change, the World Bank estimate of a 5 to 20 per cent (as cited by Noble, 2007) increase in investment was used. The infrastructure analysis implicitly assumes that the incremental cost of 5 to 20 per cent covers the cost of adapting to all climate change impacts over the life of each facility. The upper end was not adjusted, although some studies (e.g. Kirshen *et al.*, 2006; Smith *et al.*, 2006) indicate that some infrastructure investment needs might be 30 per cent higher.

466. The projected level of investment in physical assets needed in 2030 is based on the OECD ENV-Linkage model and corresponds to the projection in the IEA WEO reference scenario.

5.4.6.2. OVERVIEW OF CURRENT INVESTMENT AND FINANCIAL FLOWS BY SOURCE OF FINANCING

467. As can be seen in TABLE 35.11-ANNEX V, total GFCF was USD 7.8 trillion in 2000. It is unclear what is the fraction of private and public infrastructure that is vulnerable to climate change. Total ODA for infrastructure is estimated at more than 15 billion in 2005; this represents a 36 per cent increase in real terms from 2000 (TABLE 17-ANNEX V). Multilateral assistance increased by almost 60 per cent in the same period. South Asia was the largest recipient on ODA in this sector in 2005 and Africa was close behind.

5.4.6.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

468. In 2030, projected total GFCF is USD 22.3 trillion. When this number is multiplied by the estimated share of infrastructure vulnerable to the impacts of climate change (0.7 and 2.9 per cent) this yields a value of between USD 153 billion and USD 650 billion of infrastructure investment vulnerable to climate change.

469. Assuming adaptation to the impacts of climate change requires a 5 to 20 per cent increase in capital costs, the adaptation costs would be USD 8–31 billion per year in 2030 based on the Munich Re data and USD 33–130 billion per year in 2030 based on the ABI data. Although the share of infrastructure vulnerable to climate change is higher in some developing country regions, total infrastructure investment is higher in developed countries, hence most of these adaptation costs are in developed countries. TABLE V-53 presents the investment needed to adapt infrastructure to the adverse impact of climate change by region in 2030. About two thirds (68 per cent) of the investment would be in OECD countries.

470. The World Bank (2006)/Stern Review (Stern *et al.*, 2006) estimated the added costs necessary to adapt investments to climate change risks at 2000 USD 40 billion, with a range of USD 10–100 billion. The range estimated in this study above is very much in line with this estimate.

471. The costs of adapting infrastructure to cope with climate change are estimated to range from about USD 8–130 billion, depending on the climate change scenario and assumption of sensitivity. As noted above, the additional investment needed to adapt infrastructure to climate change could be larger than the upper-end estimate used here. Two-thirds of the investment is expected to be in developed countries.

5.4.6.4. ASSESSMENT OF NEEDED CHANGES IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP IN INVESTMENT AND FINANCIAL FLOWS

472. The investment needed to adapt new infrastructure to climate change is estimated to be USD 8–130 billion. This corresponds to less than 0.6 per cent of total GFCF in 2030. About a third of the investment needed will be in non-Annex I Parties of which more than 80 per cent are in developing Asia. The potential sources of financing depends on the nature of the new infrastructures that are vulnerable to climate change and whether they are typically financed by the private or the public sector and whether they are financed with domestic or external resources. Although it is unclear what fraction of private and public infrastructure is vulnerable to climate change, the amount is likely to be financed by all types of sources: domestic and external, public and private. The additional investment is assumed to be on average a small fraction of the total cost of each new infrastructure vulnerable to climate change. Therefore the additional investment is likely to be financed in the same manner as the overall infrastructure: from private sources for infrastructure such as commercial buildings and industrial plants, and from public sources for infrastructure such as roads and public buildings. Public resources will also be needed

to provide adequate support and incentives for new private infrastructures that are vulnerable to climate change to be adequately adapted. The latter might be necessary in order to avoid severe damages that can have important impacts on sectoral or overall economic development. The design of adequate national policies including the integration of adaptation considerations into sectoral agencies might have an important role to play in ensuring that an optimal amount of resources both domestic and private are available to cover the cost of adaptation.

473. The World Bank/Stern Review estimated the share of ODA and concessional finance investments sensitive to climate change to be higher (20 per cent) than the global average (2 – 10 per cent). They estimated the annual cost of adapting such infrastructure to the impacts of climate change at 2000 USD 1 – 4 billion. This would be equivalent to as much as a 30 per cent increase in the ODA infrastructure spending between 2005 and 2030.

Table V-53. **Additional investment needed to adapt infrastructure to climate change risks in 2030 (millions of United States dollars)**

	Estimate based on Munich Re data		Estimate based on ABI data	
Region	5 per cent additional investment	20 per cent additional investment	5 per cent additional investment	20 per cent additional investment
Africa	22	87	92	371
Developing Asia	1,901	7,605	8,106	32,424
Latin America	405	1,620	1,726	6,906
Middle East	66	264	282	1,127
OECD Europe	1,000	3,999	4,262	17,050
OECD North America	3,736	14,943	15,925	63,702
OECD Pacific	473	1,892	2,017	8,067
Transition Economies	24	97	102	412
World Total	7,627	30,508	32,514	130,058

Box V-15. **Infrastructure**

Investment and financial flows needed in 2030

The additional investment needed to adapt new infrastructure vulnerable to climate change is estimated at 5 to 20 per cent of its cost. The additional investment needed is estimated at USD 8 – 130 billion, or less than 0.5 per cent of global investment in 2030. About one third of the additional investment would be needed in non-Annex I Parties, and more than 80 per cent of that in Asian developing countries.

Current investment and financial flows

Total investment in physical assets was estimated to be about USD 6.8 trillion in 2000. Current sources for investment in infrastructure are private sources for infrastructure such as commercial buildings and industrial plants, and from public sources for infrastructure such as roads and public buildings. Total ODA for infrastructure is estimated at more than USD 13 billion in 2005, this represents a 36 per cent increase in real terms from 2000. South Asia was the largest recipient in 2005, although Africa was close behind.

5.5. AVOIDED DAMAGES

474. Although the adaptation costs described in the previous chapters may seem significant, it is clear that the value of the climate change impacts that these expenditures would avoid could be as large or greater. This study does not estimate the total value of impacts avoided by adaptations to climate change. However, the adaptation costs can be put in perspective by looking at the cost associated with extreme events and reviewing the literature on total damages from climate change, even though it is unlikely that the adaptations discussed in this study would avoid all of these damages.

475. A major component of the total impacts from climate change is likely to be losses from extreme weather events. Climate change is projected to increase the intensity of storms, cyclones, droughts, heat waves and other events. Estimating how losses from extreme events will change as a result of climate change is challenging for a number of reasons including:

- Since there is considerable variability in year to year damages from extreme climate (e.g. Hurricane Katrina dramatically increased weather related losses in 2005), establishing a baseline for extreme weather damages can be difficult;
- Estimating the change in total infrastructure stock over time is challenging. For example, it is not clear whether infrastructure investments will grow proportionately with output or fixed capital investment or another set of data;
- It is very difficult to estimate how extreme climate events will change and how they will affect infrastructure;
- Clearly a lot of present infrastructure will be replaced over coming years. Whether climate change is factored into the replacement or redesign of infrastructure is not clear, nor is it clear how effective such adaptations would be in reducing risks from climate change.

476. In the context of this study, an attempt is made to estimate expected changes in damages due to extreme weather events. The analysis is based on different sources of data from the insurance industry on current losses. As mentioned in the infrastructure sector above, Munich Re catalogued "great natural catastrophes" which involve the loss of thousands of lives or severe economic impacts from extreme events. Such a database can substantially underestimate damages from climate because only large events are included. Taking into account differences in various insurance industry estimates of losses, estimates of current losses to climate range from about USD 160 billion to as much as USD 330 billion, and most likely between USD 200 and 300 billion. The estimates are in the order of 0.5 per cent of current gross world product.

477. The Munich Re data suggest that damages are increasing at a rate of 6 per cent per year in real terms. A paper by Risk Management Solutions (RMS) estimates that the increase in damages caused by climate change is 2 per cent per year in real terms, although it is a weak signal.[41] Accounting for the under-reporting of losses in the Munich Re "great disaster" data and extrapolating the trend at 6 per cent per year, or at 2 per cent plus economic growth results in a range of estimates of annual climate damages in 2030 of approximately USD 850 – 1,350 billion. This corresponds to approximately 1.0 – 1.5 per cent of gross world product. These estimates consider climate change and make no allowance for reduced losses following new adaptation strategies. Losses are very likely to escalate non-linearly when events become more extreme. Thus, a reduction in the increase in global mean temperature through mitigation would probably have a greater proportional effect in reducing losses from extreme events.

478. Estimating the total damages from climate change is very difficult because all potential adverse impacts need to be not only identified but also costed. This is relatively more straightforward for impacts of climate change on sectors such as agriculture and infrastructure, but is more challenging for non-market impacts such as human health and ecosystem impacts. Indeed the term "damages" includes financial impacts of climate change such as building sea walls, but also includes impacts on services such as those provided by ecosystems. These services are often not offered in markets and can be challenging to monetize.

479. In spite of these challenges, several economists have developed estimates of the total damages from climate change. The magnitude of these estimates differs quite substantially across studies. However, in spite of these differences, there are two important common findings across the studies:

- Damages increase with the magnitude of climate change. The more climate changes, with climate change typically measured as the average increase in global mean temperature, the greater the total damage. Some studies anticipate initial net benefits with up to 1 to 3° C of increase in global mean temperature, whereas others studies anticipate net damages with any increase in temperature. Even those studies estimating initial benefits find that benefits peak and become net damages at some level of climate change. Net damages keep rising with greater magnitudes of climate change;

- On average, developing countries are estimated to have larger damages as a percentage of their gross product (i.e., relative to their national incomes) than developed countries. This implies that damages and benefits are not spread evenly. In some studies, developed countries are estimated to have benefits up to some level of warming, whereas developing countries suffer damages. Note that there will probably be variation among individual countries.

480. The IPCC AR4 (Yohe *et al.*, in preparation) reported findings from numerous studies, including those from Mendelsohn *et al.* (2000), Nordhaus and Boyer (2000), and Tol (2002). It also cited in the Stern Review (Stern *et al.*, 2006). In a comparison of damage estimates from these studies,[42] the IPCC reported the following range of possible outcomes:

- A 0.5° C increase in global mean temperature could lead to negligible damages, or a possible increase in welfare equivalent to between 0.5 and 2 per cent of world GDP;
- A 2° C increase in global mean temperature could lead to negligible damages, or damage equivalent to between a 0.5 per cent and 1.5 per cent loss in world GDP;
- A 4° C increase in global mean temperature could lead to negligible damage, or damage equivalent to between a 1 per cent and 6 per cent loss in world GDP.

481. Mendelsohn *et al.* (2000) reported country-specific results according to which a 2° C global-mean warming would result in net market benefits for most OECD countries and net market damages for most non-OECD countries. The study applies response (to climate change) functions that were developed empirically for the United States of America to all countries in the world. The two types of response functions used (reduced-form and Ricardian) yield different results.

482. The more recently released Stern Review (Stern *et al.*, 2006) estimated substantial losses, particularly for large amounts of warming. Their findings suggest that the economic effects of a 5–6° C increase in global mean temperature by 2100 could reduce welfare by an amount roughly equivalent to an average reduction in GDP of 5–10 per cent.[43] Estimates in the Stern Review increase to:

- 11 per cent of GDP when non-market impacts are included (e.g., environment, human health);
- 14 per cent when evidence indicates that the climate system might be more responsive to GHG emissions than previously thought;
- 20 per cent when using weighting that reflects the expected disproportionate share of damages that will fall on poor regions of the world.

483. The Stern Review has been criticized for relying on the most pessimistic literature on climate change impacts and for using very low discount rates for estimating the present value of climate change impacts (e.g., Tol, 2006; and Yohe, 2006).

484. Although there is uncertainty about whether there will be initial net benefits or damages with a small amount of warming and about the magnitude of damage with a large amount of warming, there is agreement across the economic studies that the effects of climate change will be uneven and will on average hurt developing countries the most, and that the damages will eventually increase as warming continues.

5.6. CONCLUSION

485. The sectoral analysis demonstrates that for all sectors and regions covered, several tens of billions of dollars of additional investment and financial flows will be needed for adaptation to the adverse impacts of climate change.

486. In the sectors dependent on privately owned physical assets (such as the AFF sector and a portion of the infrastructure sector), private sources of funding may be adequate to meet adaptation needs, especially in developed countries. The additional spending likely to be required will be for climate-proofing physical assets or for shifting investment to infrastructure or productive activities that are less vulnerable to the adverse impacts of climate change. Policy changes, incentives and direct financial support will be needed to encourage a shift in investment patterns and additional spending of private resources.

[41] Even if trends in regional climate could be isolated, attributing them to anthropogenic climate change could be difficult if not impossible for many regional trends.

[42] Mendelsohn *et al.* (2000) estimate aggregate regional monetary damages (both positive and negative) without equity weighting. Nordhaus and Boyer (2000) estimates track aggregated regional monetary estimates of damages with and without population-based equity weighting; they do include a "willingness to pay (to avoid)" reflection of the costs of abrupt change. Tol (2002) estimates aggregated regional monetary estimates of damages with and without utility-based equity weighting.

[43] Based on the recently released IPCC report on the science of climate change, such a warming by 2100 is possible but unlikely (IPCC, 2007a).

487. In all sectors at least some additional external public funding will be needed. This will be particularly the case in sectors and countries that are already highly dependent on external support, such as the health sector in LDCs or for coastal infrastructure in developing countries vulnerable to sea level rise.

488. National policies may play an important role in ensuring that the use of resources, both public and private, is optimized. In particular there is a need for:

- Domestic policies that provide incentives for private investors to adapt new physical assets to the potential impacts of climate change;
- National policies that integrate climate change adaptation in key line ministries; and
- Local government adaptation policies in key sectors.

489. Bilateral donors and multilateral lenders have been directing financial resources to support the design of policies in developing countries in the sectors analyzed in this study. A particularly high amount of resources is allocated to support agricultural policies when compared with other sectors (see TABLE 13-ANNEX V). It is not possible to determine how much of these financial resources address climate change issues, let alone adaptation issues. However, the current level of support channeled explicitly for adaptation purposes is likely to be suboptimal.

490. These estimates should be treated as indicative of adaptation needs but may represent a lower bound of the amount actually required for adaptation because some activities that are likely to need additional financial and investment flows to adapt to climate change impacts have not been included. For example, the water supply sector does not address other aspects of water resource management. The estimate for the health sector does not include many diseases that are expected to become more widespread because of climate change. The estimates for coastal zones are based on the additional costs related to investment in dykes and beach nourishment. The estimate for infrastructure includes only the cost of building new infrastructure with a design that takes climate change into account.

491. There are other reasons why the estimates of costs of adapting to climate change presented in this work should be considered preliminary and be treated with caution. One of the most important reasons is that simple assumptions were used to develop all of the specific estimates. On the ground, adaptations may vary considerably in type and their costs. In addition, cost estimates may be too high, as there might be some amount of double counting. This may be the case with the estimate for infrastructure investment, which may overlap with some of the estimates for water supply and coastal zones. Also, the estimates do not take into account the potential for learning to do adaptation better. The analysis assumes a fixed cost. With a significant need for adaptation, there will probably be lessons learned on how society will adapt more efficiently. In addition, new technologies or technological applications will probably be developed which could reduce costs. The costs of adaptation by people resulting from migration, loss of employment and switching of livelihoods, have not been estimated for this study.

492. Although the additional investment and financial flows needed for adaptation described above are significant, the value of the climate change impacts that those expenditures would avoid could be larger. This study does not estimate the total value of impacts avoided by adaptation to climate change and therefore does not determine whether benefits of avoided damage exceed the adaptation costs. Existing estimates of the future damage caused by climate change vary substantially; however, available studies yield three important common findings:

- Damages increase with the magnitude of climate change;
- Investment needs for adaptation would almost certainly increase substantially in the latter decades of the twenty-first century. They will be particularly high if no mitigation measures are implemented; and
- On average, developing countries suffer more damage as a percentage of their GDP than developed countries, which implies that damages and benefits are not distributed evenly.

493. The global cost of adaptation to climate change is difficult to estimate, largely because adaptation measures to climate change will be widespread and heterogeneous. More analysis of the costs of adaptation at the sectoral and regional levels is required.