Topic 4 – Adaptation and mitigation options and responses, the inter-relationship with sustainable development, at global and regional levels (15 May 2007)

4.1 Responding to Climate Change

Society can respond to climate change by adapting and reducing vulnerability[1] or by reducing greenhouse gas emissions. It is clear that both responses are needed, adaptation to respond to the impacts of past and future climate change, and mitigation to reduce future impacts. The capacity to respond by adaptation or mitigation is dependent on socio-economic and environmental circumstances and the availability of information and technology[2]. {WGII 17.1, 17.3; WGIII 1.2}

A wide range of measures is available for both adaptation and mitigation, some of which are complementary and enhance sustainable development, while others involve tradeoffs. Adaptation measures are implemented locally and in many cases generate immediate local benefits. Mitigation measures can be implemented anywhere on the globe and can generate short-term local co-benefits and longer-term global climate benefits. Much less information is available about the costs and effectiveness of adaptation measures than about mitigation measures, but both can be enhanced by sustainable development and international cooperation. {WGII 17.2, 17.4, 18.1, 18.5. 20.8; WGIII 11.8, 11.9, 13.3}

4.2 Adaptation options

There is *high confidence* that adaptation can reduce vulnerability, especially in the short-term. {WGII 17.2, 18.1, 18.5, 20.3, 20.8}

Vulnerability to climate change can be exacerbated by non-climate stresses and factors such as rapid population growth and urbanisation, deforestation, construction and settlement in high risk areas, poor management of natural resources and the loss of traditional coping skills. Climate change can be a source of multiple stresses, and it can interact with non-climate stresses (e.g. diseases, including HIV/AIDS, land degradation, economic globalisation and market change, unsustainable consumption and production patterns, and violent conflict). In these cases, there is *very high confidence* that total vulnerability is larger than the sum of the vulnerabilities to individual impacts. {WGII 7.4, 8.3, 17.3, 20.3, 20.4, 20.7}

Societies across the world have a long record of adapting to the impacts of weather- and climate-related events such as floods, droughts and storms. Regardless of the scale of mitigation undertaken in the short- and medium-term (up to 2030), additional adaptation measures will be urgently required at regional and local levels to reduce the adverse impacts of projected climate change and variability. However, there may be no feasible or cost-effective adaptation options to deal with other effects, particularly over the long-term. {WGII 17.2, WGIII 1.2}

Some planned adaptation to climate change is already occurring on a limited basis in both developed and developing countries. Table 4.1 provides examples of planned adaptation

[1] Vulnerability to climate change is the degree to which geophysical, biological, and socio economic systems are susceptible to adverse impacts of climate change.

[2] Technology includes hardware, software and know how.

options by sector. Many adaptations have multiple drivers, such as economic development and poverty alleviation, and are embedded within broader development and sectoral planning initiatives such as water resources planning, coastal defence and disaster planning. Over time, some adaptation will occur as economies develop and as efforts to reduce poverty progress. Many of these will be embedded as part of sectoral planning initiatives such as the Bangladesh National Water Management Plan, and the coastal defence plans of The Netherlands and Norway, which incorporate specific climate change scenarios. {WGII 1.3, 11.6, 15, 5.2, 17.2}

Comprehensive estimates of the costs of adaptation at the global level are limited in number. However, the number of adaptation cost and benefit estimates at the regional and project levels for specific impacts; such as sea level rise, agriculture, energy demand for heating and cooling, water resources management and infrastructure, is growing. Based on these studies there is *high confidence* that there are viable adaptation options that can be implemented in these sectors at low cost, and/or with high benefit-cost ratios. Empirical research also suggests that higher benefit/cost ratios can be achieved by implementing many adaptation measures now compared to retrofitting long-lived infrastructure at a later date. {WGII 17.2}

Adaptive capacity is intimately connected to social and economic development, but it is not evenly distributed across and within societies. The poor, elderly, women, sick, and indigenous populations typically have less capacity. {WGII 7.1, 7.2, 7.4, 17.3}

The capacity to adapt is a dynamic process influenced by a society's productive base including: natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance structures, national income and distribution of assets, and technology. It is also affected by multiple climate and non-climate stresses. {WGII 17.3}

Recent studies reaffirm the Third Assessment Report finding that while adaptation will be vital and beneficial, financial, technological, cognitive, behavioural, political, social, and cultural constraints limit both the implementation and effectiveness of adaptation measures. Many societies have high adaptive capacity and the necessary financial resources, but have not taken effective action on adaptation to climate change, variability and extremes. For example: a heat wave in 2003 caused high levels of mortality in European cities (especially among the elderly), and Hurricane Katrina caused large human and financial costs in the U.S. {WGII 17.4}

Table 4.1. Selected examples of planned adaptation by sector.{WGII Table 17.1; 9.4; 10.4; 11.4; 12.4; 13.2; 14.5; 15.4; 16.4}

Sector	**Adaptation option/strategy** * indicates synergy with mitigation	**Underlying policy framework**	**Key constraints and opportunities to implementation (Normal font = constraints; *italics = opportunities*)**
Water	Expanded rainwater harvesting; water storage and conservation techniques; desalination	National water policies and integrated water resources management; climate forecasts; water-related hazards management	Financial, human and physical barriers; cross-border agreements; *Integrated water resources management; synergies with other sectors*
Agriculture	Adjustment of planting dates and crop variety; diversification by adding livestock; crop insurance; improved land management, e.g. erosion control and soil protection through tree planting*	R & D policies; institutional reform; land tenure and land reform; training; capacity building; financial incentives, e.g., subsidies and tax credits	Technological & financial constraints; access to new varieties; markets; *longer growing season in higher latitudes; revenues from 'new' products*
Infrastructure/ settlement (including coastal zones)	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land use policies; building codes*; insurance	Financial and technological barriers; availability of relocation space; *integrated polices; synergies with sustainable development goals*
Human health	Heat stress alerts; specially equipped medical service vehicles; distribution of bottled water; specially designated public 'cooling centres'	Public health policies that recognise climate risk; national health insurance; regional and international cooperation	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *upgraded health services; improved quality of life*
Tourism	Diversification of tourism attractions & revenues; shifting ski slopes to higher altitudes and glaciers; artificial snow-making;	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g., subsidies and tax credits	Appeal/marketing of new attractions; financial and logistical challenges; *revenues from 'new' attractions; greater involvement of non-traditional sectors and groups.*
Transport	Realignment/relocation; design standards for roads, rail, etc to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R & D for special situations, e.g., permafrost areas	Financial & technological barriers; availability of less vulnerable routes; *improved technologies and integration with key sectors (e.g. energy)*
Energy	Strengthening of overhead transmission and distribution infrastructure; underground cabling for utilities; reduced dependence on single sources of energy, e.g. large hydropower dams	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	Access to viable alternatives; financial and technological barriers; acceptance of new technologies; *stimulation of new technologies; use of local resources*

4.3 Mitigation options

There is *high agreement* and *much evidence* from both bottom-up and top-down studies that there is substantial economic potential for the mitigation of global greenhouse gas emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels. {WG III 11.3, SPM}

The global economic potentials[3] found in the top-down studies are in line with bottom-up studies (Figure 4.1). Emissions in 2000 were equal to 43 $GtCO_2$-eq, while for 2030 the projected emissions are 49 Gt CO2-eq/yr (SRES B2) and 68 Gt CO2-eq/yr (SRES A1B).[4] {WGIII 11.3}

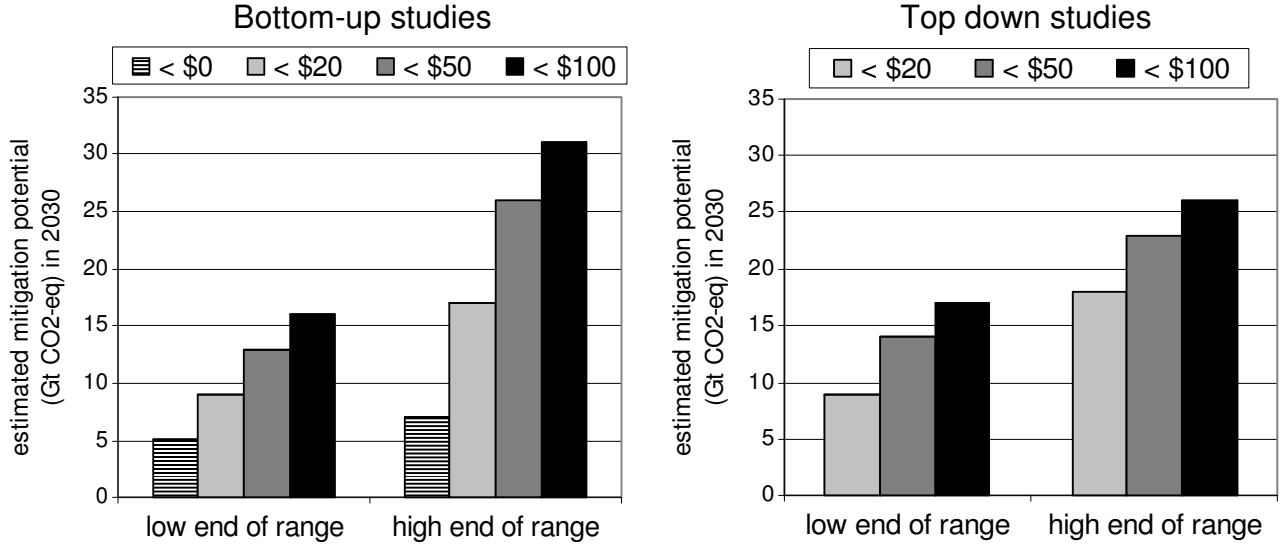

Figure 4.1. Global economic potential in 2030 estimated from bottom-up and top down studies. {WGIII Figure SPM-5}

Sectoral estimates of mitigation potential and marginal costs derived from bottom-up studies corrected for double counting are shown in Figure 4.2. While top-down and bottom-up studies agree at the global level there are considerable differences at the sectoral level. {WG III 11.3}

[3] Economic potential is defined as cost-effective greenhouse gas mitigation when non-market costs and (non-climate) benefits are included with market costs and benefits in assessing the options for particular levels of carbon prices and when using social discount rates ($\leq$ 5%) instead of private ones (typically $\geq$ 15%). It is higher than market potential, which is the actual potential with current conditions and barriers, based on private cost pricing and discount rates, including energy savings, but with barriers limiting actual uptake. {WG III 2.5}

[4] See Topic 5 for information on global macro-economic costs in 2030 and 2050

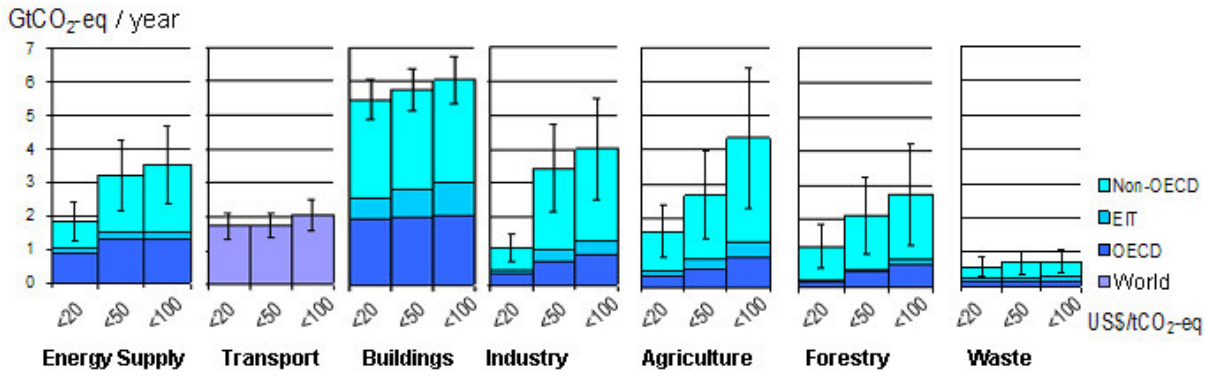

Figure 4.2. Estimated economic mitigation potential by sector and region in 2030. {WGIII SPM}
Notes:

1. *The ranges for global economic potentials as assessed in each sector are shown by vertical lines. The ranges are based on end-use allocations of emissions, meaning that emissions of electricity use are counted towards the end-use sectors and not to the energy supply sector.*
2. *The estimated potentials have been constrained by the availability of studies particularly at high carbon price levels.*
3. *Sectors used different baselines.*
4. *Only global totals for transport are shown because international aviation is included [WGIII 5.4].*
5. *Some emission categories are excluded resulting in an underestimation of the total economic potential of the order of 10-15%.*

No one technology can provide all of the mitigation potential in any sector, and the potential can only be achieved when adequate government policies are in place. Table 4.2 lists selected examples of key technologies, policies, constraints and opportunities by sector.

Future energy infrastructure investment decisions, expected to total over 20 trillion US$[5] between now and 2030, will have long term impacts on greenhouse gas emissions, because of the long life-times of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. {WGIII 4.1}

[5] 20 trillion = 20000 billion= $20*10^{12}$.

1 **Table 4.2** Selected examples of key mitigation technologies, policies and measures, constraints and opportunities. {WGIII Tables SPM-3, SPM-7}

Sector	Key mitigation technologies and practices currently commercially available. *Key mitigation technologies and practices projected to be commercialised before 2030.*	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Energy Supply {4.3, 4.4}	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS (e.g. storage of removed CO_2 from natural gas); *Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar PV.*	Reduction of fossil fuel subsidies; Taxes or carbon charges on fossil fuels	Resistance by vested interests may make them difficult to implement
		Feed-in tariffs for renewable energy technologies; Renewable energy obligations; Producer subsidies	May be appropriate to create markets for low emissions technologies
Transport {5.4}	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; *Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries*	Mandatory fuel economy, biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
		Taxes on vehicle purchase, registration, use and motor fuels, road and parking pricing	Effectiveness may drop with higher incomes
		Influence mobility needs through land use regulations, and infrastructure planning; Investment in attractive public transport facilities and non-motorised forms of transport	Particularly appropriate for countries that are building up their transportation systems
Buildings {6.5}	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation ; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases; *Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings*	Appliance standards and labelling	Periodic revision of standards needed
		Building codes and certification	Attractive for new buildings. Enforcement can be difficult
		Demand-side management programmes	Need for regulations so that utilities may profit
		Public sector leadership programmes, including procurement	Government purchasing can expand demand for energy-efficient products
		Incentives for energy service companies (ESCOs)	Success factor: Access to third party financing
Industry {7.5}	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies; *Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture*	Provision of benchmark information; Performance standards; Subsidies, tax credits	May be appropriate to stimulate technology uptake. Stability of national policy important in view of international competitiveness
		Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
		Voluntary agreements	Success factors include: clear targets, a baseline scenario, third party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry.
Agriculture {8.4}	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertiliszer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; *Improvements of crops yields*	Financial incentives and regulations for improved land management, maintaining soil carbon content, efficient use of fertiliszers and irrigation	May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation
Forestry/ forests {9.4}	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; *Tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change*	Financial incentives (national and international) to increase forest area, to reduce deforestation, and to maintain and manage forests; Land use regulation and enforcement	Constraints include lack of investment capital and land tenure issues. Can help poverty alleviation.
Waste {10.4}	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimisation; *biocovers and biofilters to optimise CH_4 oxidation*	Financial incentives for improved waste and wastewater management	May stimulate technology diffusion
		Renewable energy incentives or obligations	Local availability of low-cost fuel
		Waste management regulations	Most effectively applied at national level with enforcement strategies

Modelling studies show carbon prices rising to 20 to 80 US$/tCO$_2$-eq by 2030 and 30 to 155 US$/tCO$_2$-eq by 2050 are consistent with stabilisation at around 550 ppm CO$_2$-eq by 2100. For the same stabilisation level, studies since Third Assessment Report that take into account induced technological change lower these price ranges to 5 to 65 US$/tCO$_2$-eq in 2030 and 15 to 130 US$/tCO$_2$-eq in 2050. {WGIII 3.3, 11.4, 11.5}

There is *high agreement* and *much evidence* that many mitigation options can provide co-benefits, such as reduced air pollution, which benefits human health, agriculture and development in all regions, and can offset a substantial fraction of mitigation cost. {WGIII 11.8}

For example, energy efficiency and utilisation of renewable energy in buildings offers synergies with sustainable development in both developed and developing countries. In least developed countries energy substitution can reduce mortality and morbidity by reducing indoor air pollution, reduce the workload for women and children, and decrease the use of scarce natural resources. {WGIII 11.8}

There is also *high agreement*, but only *medium evidence* that changes in life style and behaviour patterns can contribute to climate change mitigation. {WGIII 4.1, 5.1, 6.7, 7.3, SPM}

There is *high agreement* and *much evidence* that a wide variety of national policies and instruments are available to governments to create the incentives for mitigation action. Their effectiveness depends on how well they are designed, national circumstances, an understanding of their interactions, stringency, and monitoring to improve implementation. {WGIII 7.9, 12.2, 13.2}

General findings about the performance of policies are: {WGIII SPM}

- *Integrating climate policies in broader development policies* makes implementation and overcoming barriers easier.
- *Regulations and standards* generally provide some certainty about emission levels. They may be preferable to other instruments when information or other barriers prevent producers and consumers from responding to price signals. However, they may not induce innovations and more advanced technologies.
- *Taxes and charges* can set a price for carbon, but cannot guarantee a particular level of emissions. Literature identifies taxes as an efficient way of internalising costs of greenhouse gas emissions.
- *Tradable permits* will establish a carbon price. The volume of allowed emissions determines their environmental effectiveness, while the allocation of permits has distributional consequences. Fluctuation in the price of carbon makes it difficult to estimate the total cost of complying with emission permits.
- *Financial incentives* (subsidies and tax credits) are frequently used by governments to stimulate the development and diffusion of new technologies. While economic costs are generally higher than for the instruments listed above, they are often critical to overcome barriers.
- *Voluntary agreements* between industry and governments are politically attractive, raise awareness among stakeholders, and have played a role in the evolution of many national policies. The majority of agreements has not achieved significant emissions reductions beyond business as usual. However, some recent agreements, in a few countries, have

accelerated the application of best available technology and led to measurable emission reductions.

- *Information instruments* (e.g. awareness campaigns) may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change, however, their impact on emissions has not been measured yet.
- *RD&D* can stimulate technological advances, reduce costs, and enable progress toward stabilisation.

Some corporations, local and regional authorities, NGOs and civil groups are adopting a wide variety of voluntary actions. These voluntary actions may limit greenhouse gas emissions, stimulate innovative policies, and encourage the deployment of new technologies. On their own, they generally have limited impact on national or regional level emissions. {WG III SPM}

4.4 Relationship between adaptation and mitigation options and relationship with sustainable development

There is *high confidence* that adaptation and mitigation can together reduce risks of climate change and can act as complementary response measures to climate change. {WGII 20.7; WGIII 1.2, 3.5, 3.6}

- Mitigation is required to reduce future levels of climate change, stabilise atmospheric greenhouse gas concentrations, and reduce the risk of possible future impacts. Adaptation is required to respond to the warming that is unavoidable due to past emissions, and to the further warming that is projected for the range of SRES scenarios. {WGII 20.7; WGIII 1.2}
- There is no single optimal mix. Climate change policy is not about making a choice between adapting to and mitigating climate change. There is *high confidence* that neither adaptation nor mitigation alone can avoid significant climate change impacts. However, taken together, they can reduce damages from climate change. {WGII 18.4, 18.6; WGIII 2.5}

Making development more sustainable can enhance both mitigative and adaptive capacity, and reduce emissions and vulnerability to climate change. Synergies between mitigation and adaptation can exist (see Tables 4.1 and 4.2), for example properly designed biomass production, formation of protected areas, land management, energy use in buildings and forestry. While these synergistic options may be important at the local level, they are unlikely to contribute significantly to reductions in global greenhouse gas emissions. In other situations, there may be trade-offs, such as increased greenhouse gas emissions due to increased consumption of energy related to adaptive responses. {WGIII 2.5, 3.5, 4.5, 6.9, 7.8, 8.5, 9.5, 11.9, 12.1}

Broader sustainable development decisions affect climate change and the capacity to respond in both developed and developing regions. Climate change and other sustainable development policies are often but not always synergistic. There is a growing understanding of the possibilities to choose and implement response options in several sectors to realise synergies and avoid conflicts with other dimensions of sustainable development. {WGII 20.3, 20.8; WGIII 2.5, 3.1, 11.7, 11.7, 12.2, 12.3}

Development pathways. Capacities to adapt and to mitigate are driven by similar sets of underlying factors that match well with the goals of sustainable development. Development pathways influence emissions of greenhouse gases and climate change vulnerability, and vice versa, even in the short-run. There is *very high confidence* that enhancing society's response capacity through the pursuit of sustainable development could promote both adaptation and mitigation. {WGII 20.3, 20.8.3; WGIII 2.5, 3.1, 12.2}

Integration of climate change into development decisions. There is growing evidence that decisions about macroeconomic policy, agricultural policy, multilateral development bank lending, insurance practices, electricity market reform, energy security and forest conservation, for example, which are often treated as being apart from climate policy, can significantly reduce emissions (Table 4.3). {WGIII 12.2}

Expanding climate change policy goals. Adaptation and mitigation policies that implicitly address social, environmental, economic and security issues may turn out to be important levers for creating a more sustainable world. {WGII 20.8.3; WGIII 11.7, 11.9, 12.3}

Table 4.3. Integrating climate change considerations into development policies – selected examples. {WGIII, 12.2.4.6}

Selected Sectors	Non-climate change policy instruments and actions	Impact on greenhouse gas (GHG) emissions
Macro economy	Implement non-climate taxes/subsidies and/or other fiscal and regulatory policies that promote SD	Total global GHG emissions
Forestry	Adoption of forest conservation and sustainable management practices	GHG emissions from deforestation
Electricity	Adoption of cost-effective renewables, demand-side management programs, and transmission and distribution loss reduction	Electricity sector CO_2 emissions
Petroleum imports	Diversifying imported and domestic fuel mix and reducing economy's energy intensity to improve energy security	Emissions from crude oil and product imports
Insurance for building, transport sectors	Differentiated premiums, liability insurance exclusions, improved terms for green products	Transport and building sector GHG emissions
International finance	Country and sector strategies and project lending that reduces emissions	Emissions from developing countries

4.5 International and Regional Cooperation

There is *high agreement* that notable achievements of the UNFCCC and its Kyoto protocol are the establishment of a global response to the climate change problem, stimulation of an array of national policies, the creation of an international carbon market and the establishment of new institutional mechanisms that may provide the foundation for future mitigation and adaptation efforts. {WGIII 13.3}

The impact of the protocol's first commitment period relative to global emissions is projected to be limited. Its economic impacts on participating Annex-B countries are projected to be smaller than presented in Third Assessment Report, that showed 0.2-2% lower GDP in 2012

without emissions trading, and 0.1-1.1% lower GDP with emissions trading among Annex-B countries. {WGIII 1.4, 11.4, 13.3}

There is *high agreement* that the Kyoto Protocol is currently constrained by its modest emission limits and will have a limited effect on atmospheric concentrations. It would be more effective if the first commitment period is followed up by measures to achieve deeper reductions and the implementation of policy instruments covering a higher share of global emissions. {WGIII 13.3}

There is *high agreement* and *much evidence* that there are many options for achieving reductions of global greenhouse gas emissions at the international level through cooperation. The literature suggests that successful agreements are environmentally effective, cost-effective, incorporate distributional considerations and equity, and are institutionally feasible. {WGIII SPM}

Greater cooperative efforts to reduce emissions will help to reduce global costs for achieving a given level of mitigation, or will improve environmental effectiveness. Improving, and expanding the scope of, market mechanisms (such as emission trading, Joint Implementation and CDM) could reduce overall mitigation costs. {WGIII 13.3}

Efforts to address climate change can include diverse elements such as emissions targets; sectoral, local, sub-national and regional actions; RD & D programmes; adopting common policies; implementing development oriented actions; or expanding financing instruments. These elements can be implemented in an integrated fashion, but comparing the efforts made by different countries quantitatively would be complex and resource intensive. {WGIII 13.3}

Actions that could be taken by participating countries can be differentiated both in terms of when such action is undertaken, who participates and what the action will be. Actions can be binding or non-binding, include fixed or dynamic targets, and participation can be static or vary over time. {WGIII 13.3}