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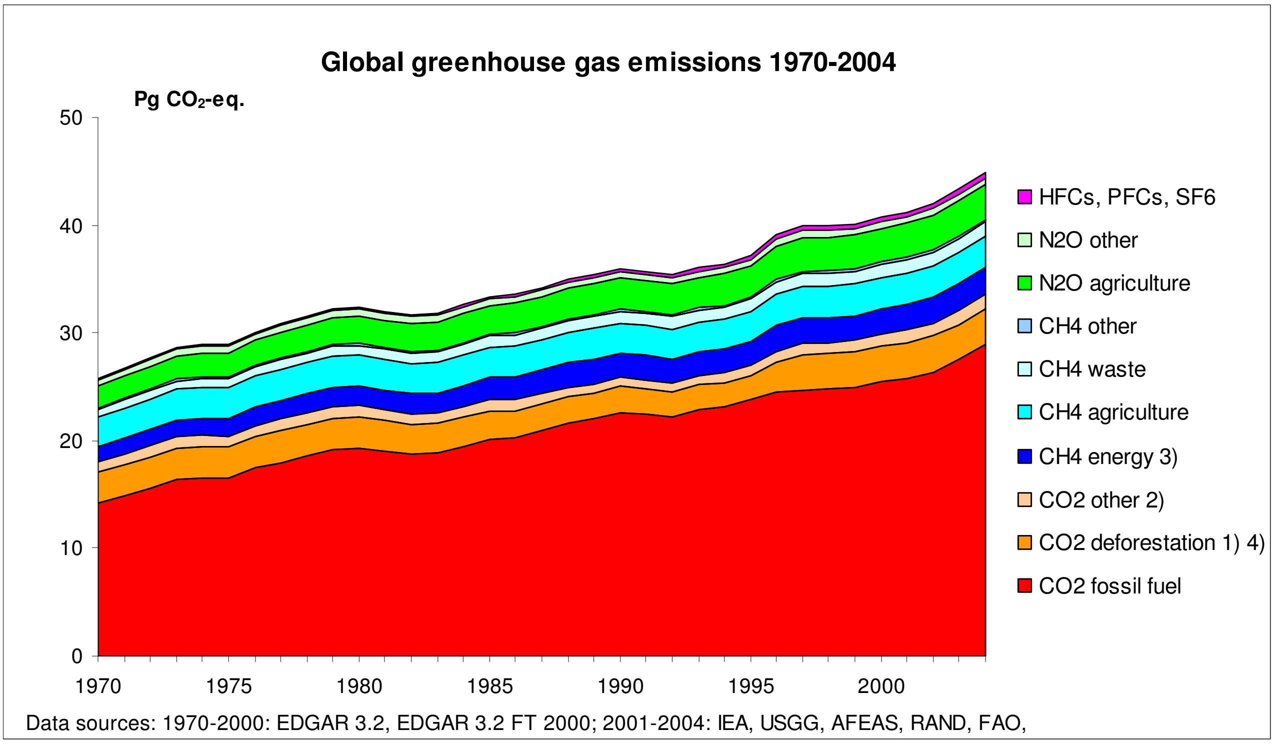
Summary for Policy Makers

A. Without additional policies global GHG emissions will continue to grow over the next few decades

1. **Since 1970 global emissions of greenhouse gases covered by the Kyoto Protocol have increased by more than 50%, with CO_2, being the largest source, having grown by about 60% *(high confidence)* (Figure SPM.1).** This has occurred because increases in population and GDP per capita have outweighed decreases in energy use per unit of GDP, while carbon intensity of energy did not change much (Figure SPM.2). Developed countries (UNFCCC Annex 1 countries) hold a 20% share in world population and account for 46 % of global GHG emissions (Figure SPM.3). Greenhouse gas emissions covered by the Montreal Protocol have declined significantly**.** [1.3]



1) Including traditional biomass combustion at 10% (assuming 90% sustainable production).
2) Including natural gas venting/flaring
3) Including from biomass
4) Including large-scale land clearing by burning biomass
Note: 100 year GWPs from IPCC 1996 (SAR) were used to convert emissions to CO_2-eq. (cf. UNFCCC reporting guidelines).1 Pg CO_2-eq = 1Gt CO_2-eq

Figure SPM.1: *Global greenhouse gas emissions trends 1970-2004. Only CO_2, CH4, N_2O, HFCs, PFCs and SF6 are included. Uncertainty in CO_2 emissions from deforestation, CH4 and N_2O from agriculture and fluorinated gases is substantially higher than that for other emissions.*

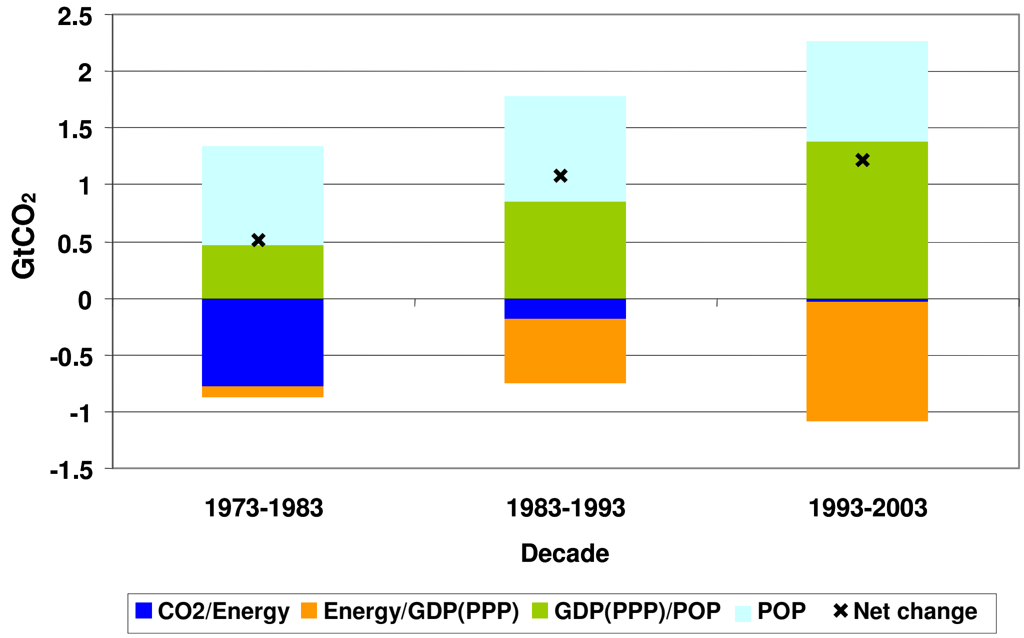
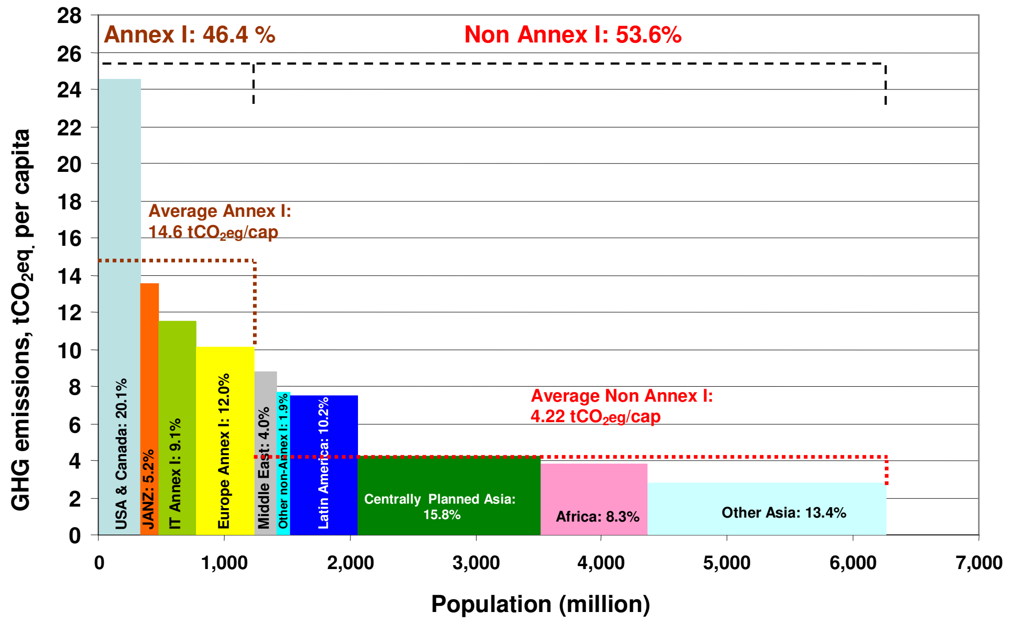


***Figure SPM.2**: Decomposition of energy related CO_2 emission growth at global scale. The figure shows that reductions in the carbon intensity of energy use (CO_2/energy) and energy intensity of the economy (energy/GDP) contributed to reductions in CO_2 emissions; the relative importance of reducing carbon intensity of energy production declined, while the importance of reducing energy intensity of the economy grew over the past 3 decades; both those relative reductions have been outweighed by a relatively steady increase in CO_2 emissions from a growing population and an increasing share of relative wealth per capita (GDP/POP). GDP(PPP) is gross domestic product at purchasing power parity conversion factors. Sources: World Bank, 2005; Marland et al, 2006 [1.3]*



Note: Height of bars gives the average annual emissions of all GHGs in tCO_2 equivalent.
Width of bars gives the population.
Percentages given indicate the fraction of 2003 global emissions attributed to each region.

***Figure SPM.3**: Distribution of regional per capita GHG emissions over different country groupings in 2003 (adapted from Bolin and Kheshgi, 2001 using IEA (2005) data. [1.3]*

2. **Assuming current policies remain unchanged, CO_2 emission are projected to increase 50-100% by 2030 relative to 2000 with two thirds of this increase originating in developing countries, though per capita emissions in developed countries will remain substantially higher *(high confidence).*** [1.3]

3. **The ranges of GHG emissions of long-term baseline scenarios (i.e. without additional climate policies) reported in the literature have not changed appreciably compared with SRES *(HM)*[1].** Some drivers for emissions, notably population projections, have been revised downwards, but for those studies incorporating these new population projections, changes in other drivers have resulted in little change in emission levels. Economic growth for Africa, Latin America and the Middle East to 2030 in post-TAR scenarios is lower than in the TAR and pre-TAR, but these regional changes have only minor effects on global economic growth and emissions. The range of projected aerosol and precursor emissions is currently lower than reported in the TAR. Most long-range scenarios reported in the literature continue to use market exchange rates to compare long-term growth in different world regions. [3.2]

4. **Policies related to climate change, energy security and supply, and sustainable development, has led to emissions lower than baseline projections in some regions, but this reduction is not large enough to significantly affect the global emissions trend *(HL)*[2].** There has been a substantial increase in formulating GHG emission reduction and sink enhancement policies (many still to be implemented), in awareness of the strong relationship between energy policy and climate change mitigation and in policy initiatives to address climate change within the broader sustainable development agenda. Decisions in these domains are strongly intertwined. [1.4, 12.2,]

[1] HM= high level of agreement; much evidence
[2] HL= high level of agreement; limited evidence.

B. Scenario studies suggest it is technically feasible to stabilise GHG concentrations in the atmosphere, even at levels as low as around 450 ppmv CO_2-eq [3]***, provided that a range of mitigation technologies is further developed and implemented. For achieving such levels policies should lead to peaking of global emissions within the next few decades. The lower the stabilisation level, the higher the costs and the uncertainty.***

5. **Global emissions need to start declining at some time in the future, and to be strongly reduced thereafter, to achieve stabilisation of GHG concentrations. Lower stabilization levels require earlier peaking of emissions. (*HM*)** (see table SPM 1) Recent studies using multi-gas reduction strategies show that peaking dates for CO_2, for a given stabilisation level, can be later than indicated in TAR. Uncertainty in the estimates of climate sensitivity leads to a range of probability estimates for temperatures at various stabilisation levels (table SPM.1). The latest insights in this uncertainty and in the carbon cycle feedbacks reported in the WG I volume imply more stringent long-term mitigation to avoid given climate change risks relative to TAR. [3.3, 3.5, WG1 AR4]

[3] See Table SPM-1; stabilization scenarios for such low levels generally assume that concentrations go above the stabilization level initially and go down afterwards, in time to keep global mean temperature below the equilibrium level for the stabilization concentration (so called overshoot scenarios); they assume very active policies to promote further development of mitigation technologies.

***Table SPM 1**: Stabilisation levels: Relationship between radiative forcing, concentration level, the probability of exceeding temperature levels, and emission reduction pathway [3.3 and 3.5]*

Class [1]	Anthropogenic addition to radiative forcing at stabilisation (W/m^2)	Multigas concentration stabilisation level (ppmv CO_2-eq)	Average of range of stabilisation levels (ppmv CO_2-eq)	Stabilisation level for CO_2 only, consistent with multi-gas level (ppmv CO_2)	Number of scenario studies	Global mean temperature increase above pre-industrial, at equilibrium, using best guess climate sensitivity[23] (°C)	Probability of staying below 2 degrees C above pre-industrial at equilibrium[45] (%)	Probability of staying below 3 degrees C above pre-industrial at equilibrium(%)	Peaking year for CO_2 emissions	Change in global emission in 2050 (% of 2000 emissions)
A	< 3.25	375 - 510	450	350 - 420	16[6]	1.3-2.6	Very likely to unlikely[7]	Very likely to likely	2000- 2040	-85 to +20
B	3.25 – 4	510 - 590	550	420 - 490	9	2.6-3.3	Unlikely to very unlikely	Likely to about as likely as not	2000- 2050	- 40 to +35
C	4 – 5	590 - 710	650	490 - 570	83	3.3-4.1	Very unlikely	About as likely as not to unlikely	2010- 2080	-5 to +75
D	5 – 6	710 - 860	785	570 - 660	6	4.1-4.9	Very unlikely	Unlikely to very unlikely	2030- 2100	+25 to + 115
E	> 6	860 - 1000	930	660 - 900	3	4.9-5.5	Very unlikely	Very unlikely	2040-2090	+65 to + 145

1. Assessed stabilization scenarios have been grouped into 5 classes, according to their stabilization level
2. Note that global mean temperature at equilibrium is different from expected global mean temperatures in 2100 due to the inertia of the climate system.
3. These equilibrium temperatures follow from the equivalent CO2 concentration value and the simplified expression for equilibrium temperatures as used in WG I, Chapter 10, section 10.7.2).
4. These probability estimates are derived for illustrative purposes by assuming WG1's estimate of the likely range of climate sensitivity, 2.0°C to 4.5 °C, as being a 80% confidence interval of a lognormal distribution. This translation of a confidence range into a lognormal probability density function (pdf) is equivalent to the applied procedure in e.g. Wigley & Raper (2001), who assumed the IPCC TAR climate sensitivity estimate of 1.5°C to 4.5°C as being a 90% confidence interval of a lognormal pdf.
5. Definition of probability terms: very likely: 90-99%; likely: 66-90%;about as likely as not:33-66%; unlikely: 10-33%; very unlikely:1-10%
6. Most of these scenarios allow for temporary overshoot of concentrations/ radiative forcing above the target level
7. Wide range due to range of stabilization levels in class A.

6. **Due to long life-times of energy and other infrastructure capital stock, widespread diffusion of low-carbon technologies may take many decades. Therefore the use of the projected investment in the expansion and renewal of energy supply till 2030 of at least US$ 16 trillion is critical for the penetration of low carbon technologies (high confidence).** Stabilisation scenario studies show that both investments in low-carbon technologies as well as technology improvements through public and private R&D are needed for achieving stabilization targets as well as cost reduction *(HM).* [2.9, 3.6, 4.3, 4.6]

According to the literature, the range of atmospheric stabilization levels assessed can be delivered by a portfolio of technologies that are either on the market or will be in coming decades, provided that the necessary incentives are in place for implementation and further development. However, implementation implies that large numbers of new low-emission installations would be needed in a relatively short period. [3.3, 3.4, 4.3, 4.4]

The contribution of different technologies to emission reductions required for stabilization varies over time, region and stabilization level. Energy efficiency is playing a key role for all regions and timescales. The lower the stabilization level, the more emphasis is put in scenarios on the use of low carbon energy sources, such as renewable energy, nuclear power, and CO_2 capture and storage (CCS), also in combination with bioenergy. For lower stabilisation levels carbon intensity improvements need to be much higher than historic levels. Including land-use and forestry mitigation options (both non-CO_2 and CO_2) provides greater flexibility and cost-effectiveness. Biomass could contribute substantially to achieving stabilization targets (for illustrative examples see figure SPM.4). [3.3, 3.4, 4.3]

A strong government role in management of long-term technology transitions is important, though approaches may differ. [2.9, 3.4, 11.5, 11.6]

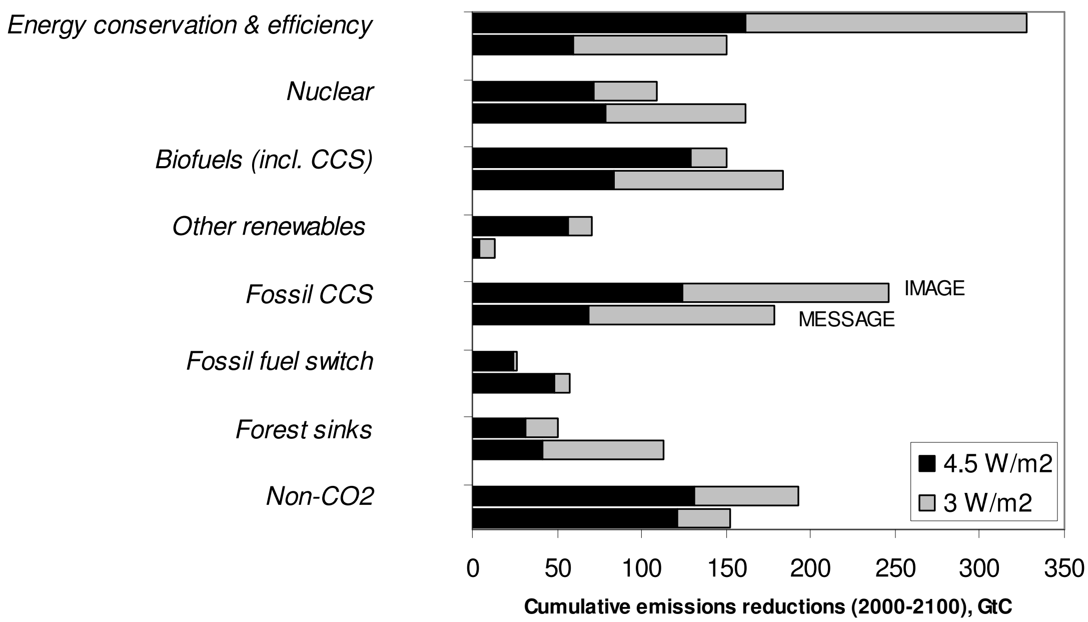


Figure SPM.4: *Cumulative emissions reductions for alternative mitigation measures (2000-2100. The figure shows scenarios from two illustrative models (IMAGE and (MESSAGE) aiming at the stabilization of radiative forcing for 3 and 4.5 W/m^2 (around 500 and 650 ppmv CO_2-eq)* *respectively. Black bars denote reductions for a target of 4.5 W/m² and grey bars the additional reductions to achieve 3 W/m². Data source: Van Vuuren et al., 2006, and Riahi et al., 2006. [3.3]*

7. **Global mitigation costs [4] rise with lower stabilisation levels, with lower levels of participation and with higher baseline emissions *(HM).*** Costs for multigas stabilisation at 650 ppmv CO_2-eq are generally below 2% loss of GDP in 2050, but a few studies give higher or negative numbers. For 550ppmv CO_2-eq these costs are 1 to 5% loss of GDP[5], again with a few studies giving higher or negative numbers; for 450 ppmv CO_2-eq there are too few studies to give reliable estimates *(HM).* (Fig SPM.5) A multi-gas approach and inclusion of carbon sinks generally reduces costs substantially compared to CO_2 emission abatement only ***(HM).*** Global average costs of stabilisation are uncertain, because assumptions on baselines and mitigation options in models vary a lot and have a major impact. For some countries, sectors, or shorter time periods costs could vary considerably from the global and long-term average. [3.3, 13.3]

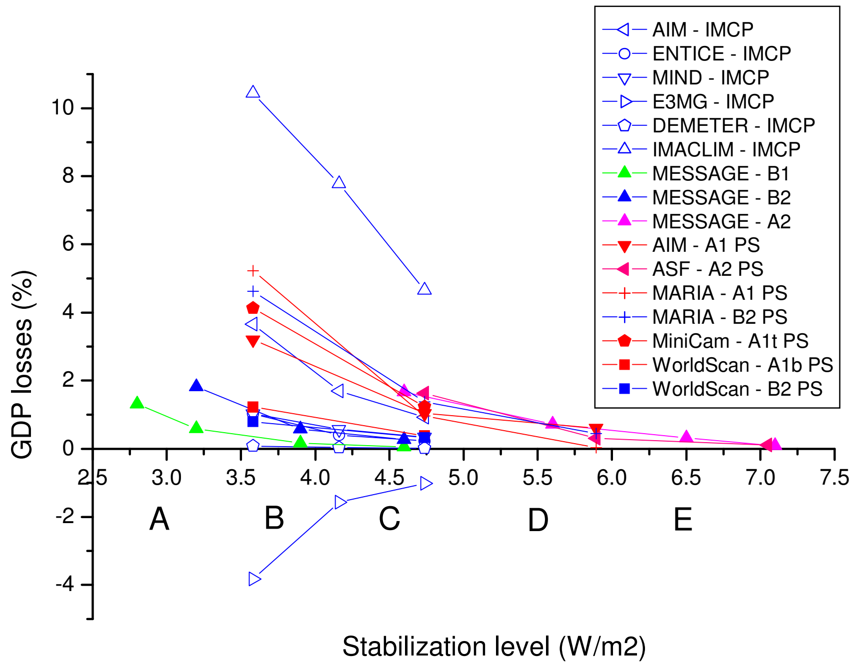


Figure SPM.5: *Studies that report GDP losses for at least three stabilization levels. For GDP, reduction in 2050 is reported. [3.3]*

8. **Comparing mitigation costs with the benefits of avoided climate change damages and other co-benefits is very complex.** This is caused by the uncertainty in regional impacts, the difficulty in estimating non-market impacts, the risks of abrupt and non-linear changes and extreme events, and the sensitivity of benefit calculations for the assumptions made, such as about the discount rate. Recent literature suggests using discount rates that decrease with time to reflect the very long term aspects involved in climate change policies. [3.3, 3.5]

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4 These results are from top-down models that assume least cost application of mitigation in all regions, but do not make assumptions on who should pay for this mitigation

5 Loss of GDP with 1-5% in 2050 is equivalent to a reduction of the average annual GDP growth rate of around 0.03 to 0.1 percentage points.

C. There is a large low-cost mitigation potential between now and 2030 in the various sectors. To be on a trajectory towards stabilisation at 450 to 550 ppmv CO_2-eq requires more costly measures, but the impact on annual GDP growth rates is limited. This potential can only be achieved with appropriate additional government policies.

All sectors

9. **The overall economic reduction potential[6] by 2030 at costs < US$ 20/tCO_2-eq is estimated at 8-12 GtCO_2-eq. At costs < US$ 100/tCO_2-eq it is estimated at 18 to 25 GtCO2eq[7], which is consistent with emission profiles for stabilisation between 450 and 550 ppmv CO_2-eq *(medium confidence)*.These potentials can only be reached when adequate government policies are in place.** (Table SPM.2). The estimates for the total potential by sector are derived from bottom-up studies, covering all sectors, but corrected for double-counting. The potentials and associated marginal costs are consistent with intermediate results of long-term top-down calculations. The potentials are in line with TAR estimates for 2020. [3.6, 11.3]

[6] Economic potential is defined as cost-effective GHG 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 instead of private ones.

[7] This estimate is taken from table SPM-2, assuming that all of the transportation measures are below US$ 100/ tCO2 eq;

***Table SPM 2:** Estimated mitigation potential at a sectoral level in 2030 compared to the SRES B2 and World Energy Outlook (2004) baseline (see notes)*

Sector (in brackets 2030 emissions WEO/SRES B2 scenario)	**Mitigation option**	**Region**	**Economic potential < 100 US$/tCO$_2$eq**		**Economic potential at different cost categories in US$/tCO$_2$eq**			
			Low	High	<0	0 - 20	20 - 50	50 - 100
			Mton CO$_2$eq					
Energy supply (n.a.)	All options in energy supply excluding electricity savings in other sectors	OECD	200	1400	100	200	290	200
		EIT	300	500	60	80	150	150
		Non OECD	1700	3100	700	700	1000	-
		Global	2200	5100	850	1000	1400	350
Transport (10.6 GtCO$_2$-CO$_2$ only)	Total	OECD	1700					
		EIT	150					
		Non OECD	1100					
		Global	3000					
Buildings (15.0 GtCO$_2$-CO$_2$ only)	Electricity savings	OECD	750		750	-	-	-
		EIT	100		100	-	-	-
		Non OECD	1200		1200	20	-	20
	Fuel savings	OECD	950	1000	750	100	150	-
		EIT	500	550	300	250	10	-
		Non OECD	150	500	250	100	-	-
	Total	OECD	1700	1700	1500	100	150	-
		EIT	600	700	400	250	10	-
		Non OECD	1400	1700	1400	100	-	20
		Global	3700	4100	3200	450	150	20
Industry (13.4 GtCO$_2$-CO$_2$ only; 1 GtCO$_2$eq non-CO$_2$ emissions in 2020)	Electricity savings	OECD	400		100		100	200
		EIT	100		30		30	50
		Non OECD	900		200		200	450
	Other savings, including non-CO$_2$ GHG	OECD	300	900	300		200	50
		EIT	150	400	80		200	20
		Non OECD	900	2900	550		1300	70
	Total	OECD	700	1300	400		300	250
		EIT	300	550	100		250	80
		Non OECD	1800	3800	750		1500	500
		Global	2800	5600	1300		2100	850
Agriculture (7.2 GtCO$_2$eq in 2020)		OECD	800			450	150	250
		EIT	150			50	50	80
		Non OECD	2300			1600	250	500
		Global	3300			2100	450	850
Forestry (n.a)		OECD	700		10	150	300	250
		EIT	150		0	40	40	60
		Non OECD	1900		150	850	550	350
		Global	2700		150	1100	900	650
Waste (1.5 GtCO$_2$eq)		Global	550	1300	700		200	
All sectors		OECD	5900	7700	1600	1300	1200	1000
		EIT	1700	2200	450	550	450	350
		Non OECD	10000	13800	2200	3900	3400	1300
		Global	18200	25000	4200	6500	5200	2700

Notes:

- Mitigation potentials for Buildings, Industry, Forestry, Agriculture and Waste compared to the SRES B2 baseline, for Energy and Transport compared to the WEO baseline.
- Mitigation options in energy supply, transport and buildings are for CO_2 only, due to limited availability of information on the other gases.

- When available the lowest and the highest range in mitigation potential is given. Potentials per cost category are based on the average of the high and low mitigation potential estimate. Mitigation options at costs >100 US$/t$CO_2$-eq are not included here, but are reported in the source chapters. Only the numbers for waste are cut off at 50 US$/t CO_2-eq. The transport mitigation potential includes an unknown amount with costs >100 US$/t$CO_2$-eq. Results in the industry cost category <20 US$/t$CO_2$-eq are included in the 0-20 US$/t$CO_2$-eq category.
- Total figures include only the categories for which data were available, causing e.g. deviations between the sum of regions and the global total. The total potentials for all sectors per cost category thus exclude transport, for which no costs specification is available.
- Without the electricity savings in buildings and industry, the energy supply sector could mitigate more than indicated here (see Chapter 4 for details). Transport mitigation potentials include light duty vehicles, biofuels and aviation only. Because the literature on mitigation in buildings for some regions did not cover high cost options, the building sector has a number of missing values. Industry is exclusive of material efficiency improvements, other than through recycling. Mitigation targeted at heating and cooling is included in the building and industry sector only; combined heat and power is not included.

Technical note: where currently only central values are given they will as far as possible be replaced by a range in the final version.

10. **Cost estimates for mitigation in the medium term (2030), consistent with emissions trajectories towards stabilisation around 650 ppmv CO_2-eq show global GDP loss below 0.5%[8]. For more stringent mitigation, consistent with trajectories towards 550 ppmv CO_2-eq, most studies show costs less than 1 % GDP loss[9], with estimates heavily dependent on assumptions and approaches (*HM*).** Cost estimates vary due to different assumptions about baseline emission growth, as well as technology development, while differences between bottom-up and top-down models have narrowed. Regional abatement costs are dependent on the allocation regime, particularly timing, but the assumed stabilisation level and baseline scenario are more important.[11.4, 13.3]

11. **Recent literature confirms the conclusions in TAR on carbon leakage[10] (in the order of 5-20%, but could be lower due to diffusion of low-emissions technology) and the spill-over effects of emission reductions in Annex-I countries on non-Annex-I countries (oil-exporting countries can expect lower oil price and GDP loss but results depend on assumptions about annex-I policies and oil exporting country responses**). There are two new findings: studies on the energy intensive industry indicate that widespread relocation is unlikely and revenues from oil exports are now much higher than assumed in earlier studies. [11.7]

12. **While studies use different methodologies, there is general agreement for all analyzed world regions that near-term health benefits from reduced air pollution following GHG reductions can be substantial and may offset a substantial fraction of mitigation costs. (*HM*)** Taking into account other co- benefits than health would further enhance cost savings**.** An integrated approach in designing air pollution abatement and climate change mitigation policies offers potentially large cost reductions. [11.8]

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8 These results are from top-down models that assume least cost application of mitigation in all regions, but do not make assumptions on who should pay for this mitigation

9 Loss of GDP of 1% in 2030 is equivalent to a reduction of the average annual GDP growth rate of around 0.05 percentage points.

10 Carbon leakage is defined as the increase in emissions in non-Annex I countries due to implementation of reductions in Annex I , expressed as a percentage of Annex_I emissions.

***Energy supply*[11]**

13. **A wide range of energy supply mitigation options is available in the short to medium time frame *(high confidence)*.** Implementation will be in the form of a portfolio of options: improved supply efficiency, renewable energy (particularly biomass), fuel switching from coal to gas, advanced nuclear power, and CO_2 capture and storage (CCS) in combination with coal or gas-fired installations. Realising these measures requires an active government policy involvement. Reduction of fossil fuel subsidies and market creation to stimulate frontrunners in specific low emission technologies through renewable energy portfolio standards, producer subsidies and, in particular, feed-in tariffs have shown to be effective. [4.3, 4.4, 4.5]

14. **New energy supply investments in developing countries, upgrades of energy infrastructure in developed countries, and security of supply policies, create opportunities to achieve GHG emission reductions, when counting co-benefits such as air pollution abatement, balance of trade improvement, energy security improvements and employment *(high confidence)***. In this context there is growing interest in new coal based power plants. A critical issue is how quickly new coal plants are going to be equipped with CCS, because retrofitting power plants with CCS later is generally economically unattractive. Hydrogen, produced from fossil fuel or biomass in combination with CCS, or from other sources, could become an important low-carbon energy carrier in the long term, but would require a challenging transition in infrastructure. [4.2, 4.3, 4.5]

Transport

15. **Transportation emissions are growing faster than emissions in any other sector. However, since the TAR, more mitigation options in the transport sector have become available.** New developments include the marketing of efficient hybrid vehicles and cleaner diesels as well as the growing use of biofuels. The development and demonstration of hydrogen powered fuel cells for vehicles has started, but deployment is likely to take a long time. Further efficiency improvements and a substantial increase of biofuels based on advanced conversion techniques are possible. [4.3, 5.3]

16. **Achieving the emissions reduction potential in the transport sector will depend on government policies.** Fuel economy and CO_2 standards are effective, provided they are stringent and cover the whole sector. Taxes on vehicle purchase, registration, use and motor fuels, as well as road and parking pricing policies have been effective, but effectiveness may drop with higher incomes. Measures to influence mobility needs through land use planning and attractive public transport facilities can make significant contributions. [5.4]

Buildings:

17. **There is a wide range of low-cost energy efficiency options for new and existing buildings that could significantly reduce CO_2 emissions at net negative cost[12] *(high confidence)*.** Energy consumption can be reduced through efficient lighting, more effective building envelopes, passive solar design methods for heating, cooling, and ventilation, as well as through

[11] Sectoral paragraphs that follow do not contain mitigation potential statements; see table SPM.2 for the respective information.

[12] Net negative costs is defined as the mitigation costs minus the saved energy costs

more efficient electric appliances and heating and cooling. By 2020, up to 60% of the GHG emissions in the buildings of developing countries and economies in transition (EIT), and up to 25% of those in developed countries, can be prevented at net negative cost (HL).Energy efficient buildings, while limiting the growth of CO_2 emissions, can contribute to lower energy costs and enhance energy security. [6.4, 6.5]

18. **A variety of government policies has been demonstrated in many countries to be successful in cutting GHG emissions in buildings *(high confidence)*.** These include appliance standards, building codes, appliance and building labelling, pricing measures and other financial incentives, and public sector energy leadership programmes, including procurement policies. To overcome the strong barriers to capturing the economic mitigation potential in the building sector, a coherent set of policies is required. [6.8]

Industry

19. **A number of sector wide, process-specific and operation related industrial mitigation measures are currently available, such as efficient use of fuels and electricity, Combined Heat and Power, fuel shifts, more efficient material use, including recycling and control of CH4, N_2O, HFC and PFC emissions *(high confidence)*.** However, their implementation requires a stable policy environment that is respecting international competitiveness and includes measures for stimulating technology uptake (information, performance standards, and economic incentives). [7.3, 7.4]

20. **Beyond 2015 there will be a substantial additional potential from energy efficiency improvement and application of CCS and non-carbon process technologies (*medium confidence*).** Examples of such new technologies that are currently only in the demonstration phase, include more energy efficient biological processes for chemicals manufacture, inert electrodes for aluminium manufacture and hydrogen for metal production.[7.3, 7.4]

Agriculture and forestry:

21. **The most prominent mitigation options in the agriculture sector are improved cropland and grazing land management and restoration of cultivated organic soils and degraded lands, leading to reduced GHG emissions and increased carbon sinks *(high confidence)*.** Lower, but still significant mitigation potential is provided by rice management, livestock and manure management. Many options are immediately deployable, do not reduce productivity and have co-benefits. The greatest synergy with sustainable development is likely to be achieved through policies that maintain soil carbon and encourage efficient use of fertilizers. [8.4]

22. **In the forestry sector a combination of aforestation and reduced deforestation is the most effective to enhance sinks and avoid emissions *(high confidence)*.** A large share (65 %) of the potential is located in the tropics (high confidence) and found mainly in above ground biomass. In estimating potential from aforestation and forest management it is so far scientifically very difficult to make a distinction between human induced and natural sequestration. Forest ecosystems may (depending on the region) be adversely impacted by climate change, reducing or eliminating their mitigation potential, but forest land can be managed to reduce this risk (medium confidence). Realisation of the mitigation potential requires an appropriate mix of regulatory and financial incentives, institutional capacity, integrated land-use planning and participation of local stakeholders. [9.6]

Properly designed and implemented forestry mitigation options are also effective in reducing vulnerability to climate change and may have substantial co-benefits in terms of employment and income generation opportunities, biodiversity and watershed conservation, provision of timber and fibre, as well as aesthetic and recreational services *(high confidence)*. [9.8]

23. **Potential fossil fuel emission offsets from dedicated bio energy crops and forest products, not covered in the agriculture and forestry mitigation potential, are of a the order of magnitude of 2.2 GtCO_2-eq/yr by 2030 at costs < US$ 50/tCO_2-eq (*LL*[13]).** This potential is based on the demand that is projected in the energy supply and transportation sector, because the literature indicates that supply from agriculture and forestry, without compromising food security at global scale, is not a limiting factor. Locally this may not always be the case. [4.3, 4.4, 5.3, 8.4, 9.4]

Waste

24. **Post-consumer waste[14] is a small contributor to global GHG emissions (<5%), but the waste sector can positively contribute to GHG mitigation. Landfill methane recovery now accounts for >15% of registered annual CERs under CDM *(high confidence)*.** A key component of sustainable development includes waste and wastewater management for improved public health and safety, pollution prevention, and GHG mitigation. The major technologies for mitigating GHG emissions from waste are mature and readily deployable, including landfill gas recovery, thermal processes such as incineration, and biological processes for waste and wastewater treatment. Moreover, recycling and waste minimization provide indirect GHG mitigation benefits via the conservation of raw materials, and energy from waste offsets fossil fuel consumption. [10.3, 10.4, 10.5]

Other

25. **Geo-engineering options, such as ocean fertilisation to remove CO_2 directly from the air, or blocking sunlight by bringing material into the upper atmosphere, remain largely speculative, uncosted and with potential for unknown side-effects**. [11.2]

D. Additional policies at the sector, national and international level can create incentives for business and consumers to implement mitigation options required to deliver the identified potentials.

26. **Carbon pricing is an essential incentive for implementing mitigation options *(high confidence)*.** All mitigation and stabilisation studies imply a positive ‘price of carbon’ to create incentives for consumers and business to significantly invest in lower carbon products, technologies and processes. Both sectoral bottom-up and top-down assessments suggest that carbon prices of US$ 20 to 25 per tCO_2-eq can begin to drive large scale shifts to zero carbon power supply and make many mitigation options in the end-use sectors attractive *(HM).* However, additional incentives related to direct government funding and regulations are also important, particularly in relation to innovation where market signals are insufficient. [3.3, 11.3]

[13] LL= Limited evidence, Low level of agreement.

[14] Industrial waste is covered in the industry sector.

27. **A wide variety of national policies and instruments are available to governments to create the incentives required. While the literature identifies advantages and disadvantages for any given instrument, four main criteria are widely used by policy makers to select and evaluate policies: *environmental effectiveness, economic efficiency, equity and political feasibility*.** General conclusion about the performance of policies are: [12.2,13.2]

- *Integrating climate policies in broader development policies* makes it easier to implement them and to overcome barriers
- *Regulatory measures and standards* generally provide environmental certainty, depending on their stringency. They may be preferable when barriers prevent business and consumers from responding to price signals.
- *Taxes and charges* are economically efficient, but cannot guarantee a particular level of emissions and may be politically difficult to implement. Their environmental effectiveness depends on stringency.
- *Tradable permits* are effective to establish a carbon price. The volume of allowed emissions determines their environmental effectiveness, while the distribution of allowances has implications for economic efficiency and competitiveness.
- *Voluntary agreements between industry and governments* and information campaigns are politically attractive, raise awareness among stakeholders, and have played a role in the evolution of many national policies. With a few exceptions, the majority has achieved little reduction beyond the baseline.
- *Financial incentives* are frequently used by governments to stimulate the diffusion of new technologies. While economic costs are generally higher, they are often critical to overcome barriers to the penetration of new technologies.

28. **Better understanding of the mechanisms of technology development and transfer highlights the need for government support of private sector technology innovation through financial contributions, taxation measures, standard setting and market creation** *(HM).* **.** Public benefits of R&D investments are much bigger than private benefits, justifying government R&D funding. However, funding for many energy research programmes, such as renewables, has been flat or declining for nearly two decades. [2.9, 3.4, 4.6, 11.5, 13.2]

29. **The most notable achievements of the Kyoto protocol are the stimulation of an array of national policies, the creation of a carbon market and the establishment of new institutional mechanisms.** The impact of its first commitment period on global emissions is likely to be limited, and economic impacts are likely to be small *(HM).* [11.4,13.3]

30. **The literature indicates that future agreements would have stronger support, if they are perceived as environmentally effective, cost-effective (flexible, economically efficient, moving toward broader participation, providing adequate investment certainty), fair/equitable, and institutionally feasible** *(HM)*. On key elements the literature allows to draw the following conclusions: [13.3]

- Long-term goals, important for investment decisions, could take the form of long-term CO_2 concentration or temperature goals, emission reduction objectives, technology deployment targets or hedging strategies.
- Methods for differentiating actions from participating countries (in terms of when and what) are available, with commitments (binding and non-binding) for different groups, depending on

mitigative capacity, contribution to climate change and opportunities for integrating climate change into sustainable development policies.

- Since climate change is a global commons problem, approaches that, respecting common but differentiated responsibilities, do not include all countries, or at a minimum the major emitters, will be more costly and less environmentally effective.
- Expanding the scope of market mechanisms (emission trading, JI and CDM) could make agreements more efficient. Transaction costs could be reduced by moving from project to sector/ national mechanisms.
- Linking climate change with arrangements for sustainable development can be cost-effective, because of the synergies between them and because of political priorities for development goals. Institutional feasibility may pose limitations (see also paragraph 31).
- Successful agreements enhance the ability to stimulate development and transfer of mitigation technologies. A combination of coordinated international R&D programmes, sectoral performance standards and adequate financial flows for investments in developing countries could be effective.
- Institutions supporting information, reporting, compliance monitoring and financial provisions are important for effective agreements
- A summary of the performance of specific approaches against the main criteria is given in table SPM.3.

Table SPM.3: *Criteria for assessing international agreements on climate change. (+) means: approach generally meets specific criterion; (?) means: uncertain if approach meets criterion; (-) means: approach generally does not meet criterion [13.3]*

Approach	**Environmental effectiveness**		**Cost effectiveness**		**Distributional / equity issues**		**Institutional feasibility**	
National emission targets and emission trading	Can be effective, depending on participation, stringency and compliance.	+	Highly efficient and cost effective; increases with broad participation and multiple gases and sectors	+	Depends on participation and initial allocation	**?**	Requires capacity to prepare robust national GHG inventories and mechanisms to ensure compliance /enforcement	+
Sectoral agreements	Not all sectors amenable to such agreements, limiting overall effectiveness. Additional risks of leaving out sector due to political difficulties	?	Lack of trading across sectors may limit overall efficiency, although may be cost-effective within individual sectors. Within-sector competitiveness concerns alleviated since sectors treated equally at global level.	0	All countries would be treated equally, which may run counter to the concept of "common but differentiated responsibility"	-	Requires many separate decisions and agreements. Within individual sectors, may require cross-country institutions to manage agreements	-
Coordinated policies and measures	Individual measures can be effective, but uncertain whether desired emission levels are met; success will be a function of stringency.	?	Risk of designing a policy package that is not efficient and does not fit all specific national circumstances. Cost- effectiveness of individual policies enhanced with coordination.	?	Coordination could allow for differentiation although if policies identical, could run counter to the concept of "common but differentiated responsibility"	-	Designing package that suitably stringent while meeting all national concerns may be difficult; high level of institutional agreement required , with multiple separate decisions	0
Technology cooperation	Can be effective, depending on rate of technology uptake and extent of new technology developed. Potential concern that technology emerges too late to achieve low stabilization levels	-	Studies are divided about the economic efficiency of postponing reductions to the future. Cost effectiveness historically low based on economic costs of R&D subsidies, and historic failure for government to pick winning technologies	?/-	Issues of intellectual property often subject to equity disputes; potential problem with large-scale transfer and diffusion of most advanced technology; does leave all countries the right to develop	-	Requires many separate decisions and agreements; often best handled by private sector - where less extensive systems exist to promote diffusion to lower income countries	-
Development oriented actions	Can be effective, but results uncertain. Some development policies may have negative effect on climate (e.g., producing electricity using local coal may increase energy security but increase climate damages)	?	Should be efficient and cost-effective, as climate change measures are supportive of economic development; should create synergies	+	Inasmuch as development is a key priority, synergies have positive feedback on social development and international equities	+	Institutional structures for development policies mostly in place, although capturing climate benefits not usually a priority for existing institutional systems	0

E. Integrating climate change into sustainable development policies can realise substantial climate benefits.

31. The two-way relationship between climate change mitigation and sustainable development can be mutually reinforcing but may not always be so. Guidelines have been proposed for mainstreaming mitigation options into development sectors. GHG emissions associated with these sectors and the opportunities to influence these through development decisions can be substantial but vary widely.

- Development pathways influence emissions of greenhouse gases and climate change vulnerability. Scenarios using different baselines show that future GHG emissions are likely to be determined by development paths as much as mitigation policies. On the other hand, climate change itself and response policies, could have significant impacts on development, positive by avoiding climate change damages and making development more sustainable, but potentially also negative, if these responses compete with meeting other vital development objectives. (Figure SPM.6)
- Decisions about fiscal policy, multilateral development bank lending, insurance practices, industrial policies, electricity market liberalization, energy security, forest conservation, for example, which may seem unrelated to climate policy, can have profound impacts upon emissions (Figure SPM.7). On the other hand, decisions about rural energy development for example will not have much influence on GHG emissions.
- National circumstances, including endowments in primary energy resources, and the strengths of institutions matter in determining how development policies ultimately impact GHG emissions. The development process is most effective when government, private sector and civil society partners participate equitably.
  [2.2, 3.3, 12.2]

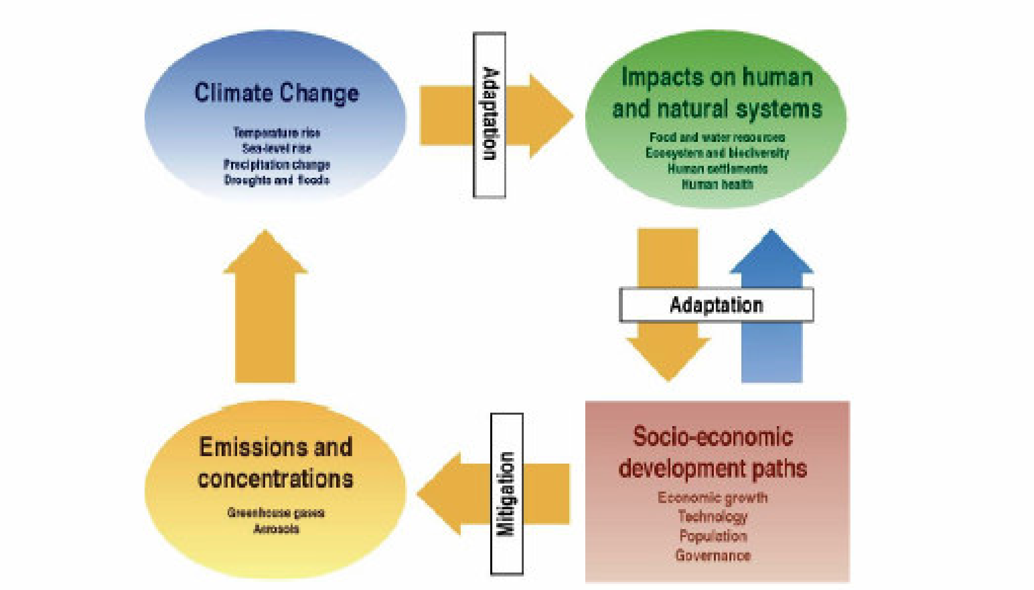
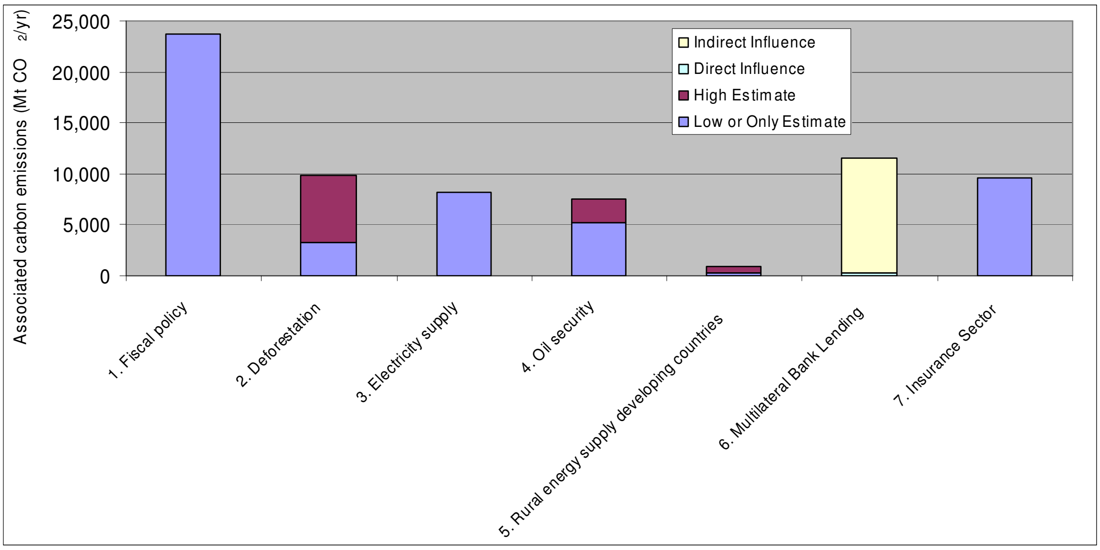


***Figure SPM.6**: Schematic representation of the two-way relationship between development and climate change. The dotted arrows indicate the potential impact of adaptation and mitigation policies on development [to be added to figure in final version]*



Explanation of policy areas and associated CO_2 emissions:

(1) Taxes and subsidies on energy and other resources that reduce fossil fuel use could affect all global energy-related CO_2 emissions

(2) Policies to reduce logging and increase use of sustainable forestry management practices could affect deforestation emissions Low and high values indicate uncertainty in emissions estimates.

(3) Liberalization of electricity markets could affect all electricity supply emissions.

(4) Energy security policies could affect the emissions associated with net oil imports for countries that import over 75% (low estimate) and 50% (high estimate) of their primary oil supply respectively.

(5) Rural energy supply policies could affect emissions associated with rural developing-country energy use. Low value shows emissions associated with estimated current fossil fuel use. High value includes emissions from LPG that could potentially replace all rural household biomass use.

(6) Multilateral development bank policies; direct influence refers to emissions associated with the World Bank energy sector lending only, and indirect value refers to all developing country emissions that MDBs could indirectly influence.

(7) Insurance industry can influence energy use and emissions associated with buildings, vehicles, aircraft, and ships worldwide. The bar shows emissions associated with the use of bunker fuels and a proportion of buildings and other transportation energy use.

Figure SPM.7: *CO_2 emissions associated with selected non-climate policy areas (2002)*

32. There is a growing understanding of the possibilities to choose mitigation options and their implementation in such a way that there will be no conflict with other dimensions of sustainable development; or, where trade-offs are inevitable, to allow rational choices to be made.

- Energy efficiency options are almost always cost effective, improve energy security and reduce local pollutant emissions. Other energy options can be designed to (1) improve energy security; (2) reduce local pollution and deleterious health impacts; (3) avoid displacement of local populations. Supply options may require more hard currency for imports of fuel and technology or higher capital investment for exploiting domestic resources.
- Reducing deforestation can have significant biodiversity, soil and water conservation benefits but may result in loss of economic welfare. Forestation and bioenergy plantations can reduce wasteland and soil degradation, manage water runoff, retain soil carbon and benefit rural economies but could compete with land for agriculture and may be negative for

biodiversity (see also paragraph 26 and 27). There are good possibilities for reinforcing sustainable development also in the waste management, transportation and buildings sectors.

[2.2, 4.5, 5.4, 6.6, 8.4, 9.7, 10.5, 12.3].