IV. AN OVERVIEW OF INVESTMENT AND FINANCIAL FLOWS NEEDED FOR MITIGATION

4.1. INTRODUCTION

85. Investment and finance are critical components of successful economic development. Generating the appropriate levels of capital is already a difficult undertaking when aiming to meet specific social and economic needs, but generating and allocating the investment and financial flows needed to meet the Millennium Development Goals (MDGs) and at the same time to finance significant climate change mitigation will make this task all that much harder.

86. This chapter presents an overview of estimates of investment and financial flows needed to return CO_2 eq emissions to current levels by 2030. The analysis is based on currently available scenarios, as explained below. The results should be considered indicative only.

87. The investment and financial flows for mitigation have been estimated for eight major GHG emission sectors identified in the Working Group III contribution to the IPCC AR4 (IPCC, 2007c). The share of anthropogenic GHG emissions in each sector in 2004 is shown in FIGURE IV-5 below.

88. For all sectors (except agriculture and forestry), the estimates presented correspond to the investment and financial flows needed to make possible a shift from the reference scenario to the mitigation scenario. For fossil fuel supply and power supply, total investments needed are estimated for each scenario. For the industry, transportation, buildings and waste sectors, only the additional investments needed for the mitigation scenario is estimated.

89. For the agriculture and forestry sectors both investment flows for agroforestry and afforestation/reforestation and financial flows for reduction of non-CO_2 emissions, reduced deforestation and forest management are estimated. Financial flows are also estimated for mitigation related technology R&D and deployment.

90. The analysis of investment and financial flows for each of the emitting sectors begins with a summary of the projected emissions in 2030 and a review of the current sources of investment. Then the investment flows needed in 2030 are estimated under the reference and mitigation scenarios. Finally, the actions needed to shift investment from the reference scenario to the mitigation scenario are discussed.

Figure IV-5. **Share of global greenhouse gas emissions by major sectors in 2004**

Source: IPCC, 2007c.

4.2. SCENARIOS

91. The reference and mitigation scenarios chosen for the analysis of different sectors are explained in detail in CHAPTER II.3.

92. For most sectors analysed (energy supply, industry, transportation and buildings), the reference scenario, unless otherwise specified, is the IEA WEO 2006 reference scenario (IEA, 2006). Two assumptions underline this scenario: that the global population will increase by approximately two billion people to approximately eight billion by 2030; and that the global average per capita income will rise from USD 9,253 in 2004 to USD 17,196 in 2030. Population and per capita income will both rise more rapidly in developing countries. The IEA estimates of cumulative investment have been converted to annual investment flows. Preliminary estimates of GDP and investment by sector corresponding to this scenario were provided by the OECD from its OECD ENV-Linkages model[13].

93. The mitigation scenario corresponds to the BAPS presented in the IEA WEO 2006. The BAPS assumes the same increase in population and per capita income as the reference scenario, but projects a significantly different pattern of energy demand and supply to return global energy-related CO_2 emissions to current levels (2004) by 2030: energy efficiency is improved significantly to provide the same services with less energy, and the mix of energy sources is changed to reduce emissions further. The IEA provides only global data for the BAPS. These data were disaggregated into the same regions as the reference scenario and the IEA estimates of cumulative investment were converted into annual investment flows.

94. The IEA has estimated in its reference scenario that without new polices and financing, about 1.4 billion people will remain without access to electricity in 2030. The BAPS does not consider this need for increased electricity access in developing countries, but focuses more on the national polices and measures related to energy security and energy-related CO_2 emissions. The additional investment needed to achieve full access to electricity by 2030 is estimated by the IEA as USD 750 billion; that is, an average of about USD 25 billion per year.

95. *For non-CO_2 emissions in the agriculture, waste and industry sectors* the reference scenario is based on projections by the US EPA (US EPA, 2006a). The mitigation scenario includes cost-effective emission reductions estimated using marginal abatement cost curves developed by the US EPA (US EPA, 2006b).

96. *For industrial process* CO_2 emissions the reference and mitigation scenarios are based on a WBCSD report on the cement industry (WBCSD, 2002).

97. *Other emissions and removals by sinks in the agriculture and forestry sectors and emissions by the forestry sector* are assumed to remain constant under the reference scenario. The mitigation scenario reflects emission reductions and removals by sinks potential estimated by the IPCC Working Group III (IPCC, 2007c).

4.3. LIMITATIONS IN ESTIMATING MITIGATION COSTS

98. Given the short time frame in which the analysis had to be undertaken, this study uses existing models and available data. The analysis of specific regions, sectors and technologies are limited by the models and data used.

99. For instance, with regard to *regional analysis*, the models available provide little detail at the country level for some regions, in particular for Africa. It is not possible to separate South Africa's share of activity and emissions from those of other African countries. However, it is acknowledged that, as for other regions, e.g. Latin America and Asia, if the largest emitters are singled out, the investment and financial flows needed for the rest of the region could differ from those of the region as a whole.

100. With regard to *sectors*, the IEA scenarios provide internally consistent projections of energy demand for industry, buildings and transportation and energy supply by fuel type. The scenarios also provide the associated CO_2 emissions and investment by sector in some detail in 2030. As discussed in CHAPTER IV.4.1 on energy supply, estimates of current investment from the IEA scenarios and other sources vary substantially and could not be reconciled.

101. The analysis on investment in transmission and distribution (T&D) is mostly based on the total amount of electricity demand. Projection in the BAPS does not consider the need for increased electricity access in developing countries.

102. Energy efficiency improvement involves actions implemented at millions of specific facilities. The regional figures presented here are derived from global analysis by IEA based on a top down approach, so they should be considered as indicative only.

103. The agriculture and forestry sectors offer both emission reductions and sink enhancement options, of which some require investment and others require ongoing financial flows. It is necessary to draw on multiple, perhaps not fully consistent, sources to estimate the scale of the emission reductions or sink enhancement and the associated investment or financial flows.

104. For agroforestry only global estimates are available.

105. Because models for estimating the mitigation scenario are not available for the forestry sector the analysis is limited to estimating the costs of the different mitigation measures. The cost data varies widely because of different assumptions and the limited information across regions.

106. For some *technologies* still under development little information is available on current practices and/or planning. For instance, knowledge of large-scale deployment of CCS is still limited, though it is assumed to play a key role in the mitigation scenario. The geographic distribution adopted is based on limited storage potential information and growth of fossil fuels fired power plants, which may not reflect the future reality.

4.4. INVESTMENT AND FINANCIAL FLOWS NEEDED FOR MITIGATION

4.4.1. ENERGY SUPPLY

4.4.1.1. INTRODUCTION

107. Combustion of fossil fuels is the largest single source of GHG emissions from human activities, accounting for about 80 per cent of anthropogenic CO_2 emissions (IPCC, 2007c). Extracting, processing, transporting, and distributing fossil fuels also releases GHGs.

108. Energy supply covers the production and transformation of fossil fuels. This includes fossil fuels such as coal, oil, gas, lignite and peat, and transformation of those fuels through petroleum refining, natural gas processing and electricity generation. It also includes nuclear energy, hydropower, wind power and solar power, biomass, including waste, tidal energy, waves and ocean thermal gradients used for electrical power generation, and geothermal energy used for electrical power and heating.

[13] For more information on OECD ENV-Linkages model, please refer to chapter II.3.

4.4.1.2. ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

RECENT TRENDS IN ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

109. The world's total primary energy supply reached 11,223 million tonnes of oil equivalent (Mtoe) in 2004 (IEA, 2006), having grown at an average annual rate of 2.2 per cent between 1994 and 2004. In 2004, oil continued to be the world's most important primary energy source, followed by coal, natural gas, nuclear energy, hydropower and advanced renewables (see FIGURE IV-6). The efficiency of conversion of primary energy to electricity varies greatly among these sources; for example, the total electricity generated from nuclear energy and hydropower is about the same, but thermal conversion processes are inherently less efficient.

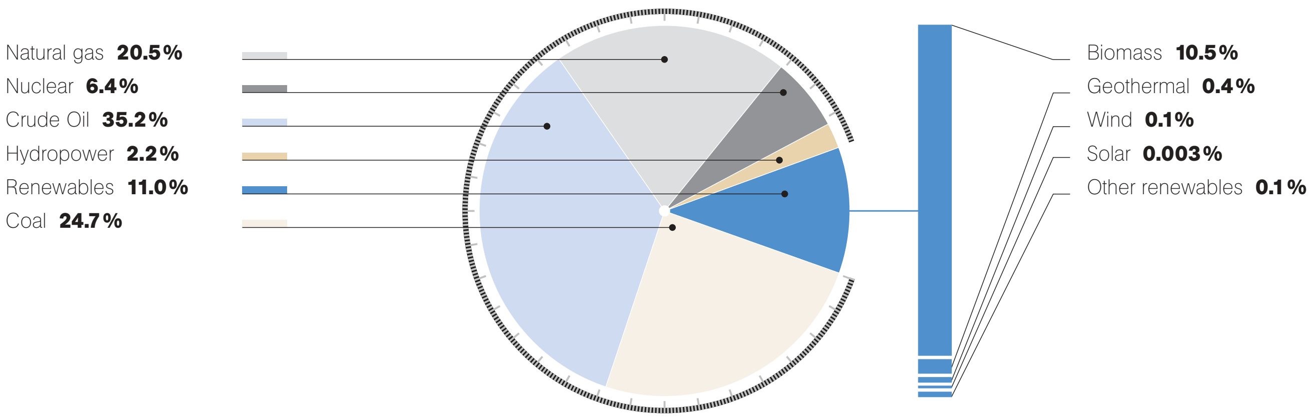
110. Energy supply and consumption are not distributed evenly worldwide. OECD countries, accounting for one sixth of the world's population, consumed around one half of the world's primary energy supply in 2004. Three countries – the United States of America, China and the Russian Federation – were the leading producers and consumers of world energy. These three countries produced 40 per cent and consumed 43 per cent of the world's energy.

111. Electric power production in 2004 was 17,450 terawatt hours (TWh). Approximately 58 per cent was produced in OECD countries, 33 per cent in developing countries and the remainder by transition economies. Power sector growth was 4 per cent per year between 1994 and 2004 but the distribution of growth is highly uneven, with particularly rapid growth recorded in China and some other developing countries. Coal produced 6,944 TWh of electricity in 2004, or 38 per cent of the world's electricity output. It is the dominant fuel for electric power production in China, India, the United States, the Russian Federation, Australia and Indonesia.

112. Global CO_2 emissions from use of petroleum, natural gas and coal and the flaring of natural gas increased from 20 Gt CO_2 in 1990 to 26 Gt CO_2 in 2004. Emissions from OECD countries account for 49 per cent of the total. The United States, China, the Russian Federation, Japan, and India were the world's five largest sources of energy-related CO_2 emissions in 2004, accounting for 54 per cent of the total, followed by Germany, Canada, the United Kingdom, the Republic of Korea and Italy, which together produced an additional 11 per cent of the global total.

113. In 2004, oil and coal made nearly identical contributions to total CO_2 emissions, around 40 per cent each. CO_2 emissions from use and flaring of natural gas accounted for the remaining 20 per cent of energy related CO_2 emissions. Power sector emissions increased from 7 Gt CO_2 in 1990 to 10.6 Gt CO_2 in 2004, faster than the rate of total emissions growth. Coal is the major source of CO_2 emissions in the power sector, accounting for 71.6 per cent of the total in 2004. Most of the increase (2.9 Gt CO_2) occurred in developing countries.

Figure IV-6. **Global primary energy mix in 2004**



Source: IEA, 2006.

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS IN 2030 UNDER THE REFERENCE SCENARIO

114. Fossil fuels are projected to remain the dominant sources of primary energy globally (see FIGURE IV-7). Their share of global primary energy mix is projected to rise slightly under the reference scenario from 80 per cent in 2004 to 81 per cent in 2030. Global primary energy demand under the reference scenario is projected to increase by 1.6 per cent per year between 2004 and 2030, reaching 17.1 billion tonne of oil equivalent (Btoe), 53 per cent (6 Btoe) more than in 2004. Over 70 per cent of the increase in global primary energy demand between 2004 and 2030 comes from the developing countries. The increase in the demand of developing countries results from their rapid economic and population growth. Industrialization and urbanization boost demand for commercial fuels.

115. Global electricity demand is projected to increase from 17,408 TWh in 2004 to 33,750 TWh in 2030 under the reference scenario, growing at 2.6 per cent per year on average. This is slower than the GDP growth rate of 3.4 per cent and faster than the total primary energy supply of 1.6 per cent. Developing Asia is the main engine of electricity demand growth. Though world electricity generation almost doubles by 2030, the generation mix remains relatively stable.

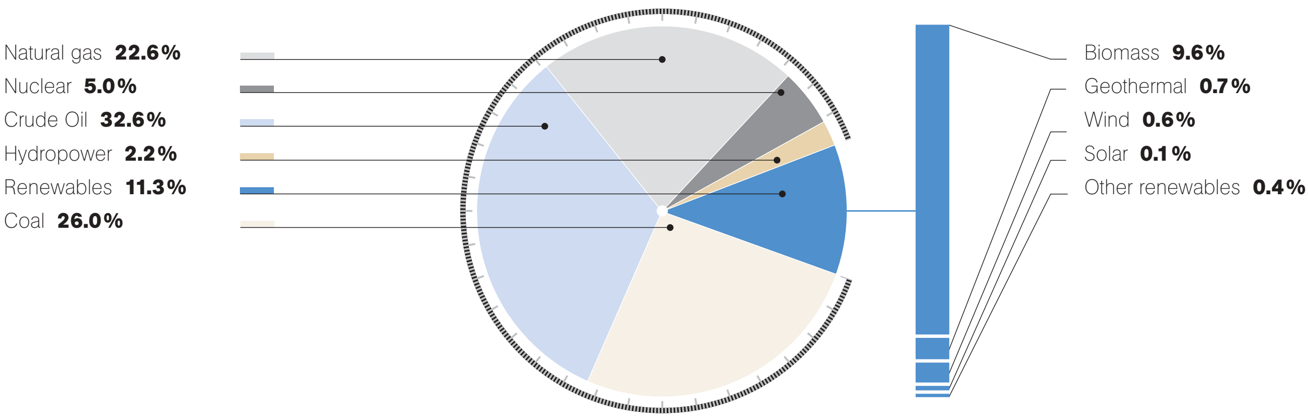
116. Global energy-related CO_2 emissions increase by 1.7 per cent per year between 2004 and 2030 under the reference scenario. They reach 40.4 Gt CO_2 in 2030, an increase of 14.3 Gt CO_2 or 55 per cent from 2004 levels. Developing countries account for over three quarters of the increase in global CO_2 emissions. This increase is greater than the growth in their energy demand, because they use more coal and less natural gas than developed countries.

117. Power generation is projected to contribute just under half the increase in global emissions between 2004 and 2030. By 2030, the power sector accounts for 44 per cent of total emissions, up from 40 per cent in 2004. Continuing improvements in the thermal efficiency of power stations are outweighed by the significant growth in demand for electricity.

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS IN 2030 UNDER THE MITIGATION SCENARIO

118. Under the mitigation scenario strong policies increase energy efficiency significantly to provide the same services with 15 per cent less energy and shift the energy supply to more climate friendly technologies. Global primary energy demand rises from 11.1 Btoe in 2004 to 14.6 Btoe in 2030, 2.5 Btoe lower than in the reference scenario. Energy demand still grows fastest in developing countries, but increased energy efficiency moderates the growth

Figure IV-7. **Global primary energy mix in 2030 under the reference scenario**



Source: IEA, 2006.

in their demand to 2.7 Btoe. Fossil fuels still play the dominant roles in primary energy supply (see FIGURE IV-8). Their share decreases to 72 per cent in 2030 from 81 per cent under the reference scenario in 2030 and 80 per cent in 2004.

119. Increased energy efficiency also limits the rate of growth of global electricity demand under the mitigation scenario to 27,983 TWh in 2030. The mitigation scenario also assumes a substantial shift in the global electricity generation mix in 2030. As shown in FIGURE IV-9, coal remains the largest source of electricity (and generation capacity increases by 95 gigawatt (GW)) but its share shrinks from 40 per cent in 2004 to 26 per cent in 2030. Gas-fired generation grows rapidly and becomes the second largest source at 21 per cent in 2030. The generation capacity of nuclear energy, hydropower and renewables expands significantly, each representing about 17 per cent of the total in 2030. The mitigation scenario assumes a significant amount of CCS for power plants and industry. By 2030 CCS is added to 70 per cent of the new coal capacity (545 GW) and 35 per cent of new gas capacity (494 GW).

120. Global energy-related CO_2 emissions peak at 30 Gt CO_2 between 2015 and 2020 and decrease to the current levels by 2030 (see FIGURE IV-10). Emissions of OECD countries remain stable from 2004 to 2015 and then decrease to 10 Gt CO_2 by 2030, 7 per cent below their 1990 emissions. Developing country emissions increase by 3.3 Gt CO_2 then start to decline by 2030. The trend for emissions in transition economies is to decrease slightly under the mitigation scenario, rather than increasing slightly under the reference scenario.

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

121. This chapter summarizes data on current investment flows related to energy supply. The information on current investment flows relates to economic sectors.

122. Components of energy supply are divided between two economic sectors. Specifically:

- Oil, gas and coal production and petroleum refining are part of the mining and quarrying sector, together with other mining activities;
- Electricity generation, T&D and gas distribution are part of electricity, gas distribution and water supply sector.

123. The electricity, gas distribution and water supply sector accounts for the largest share of energy supply investment. The sources of investment are shown in TABLE IV-6.

Table IV-6. **Investment flows for electricity, gas distribution and water supply in 2000 (percentage), by source and region**

	Total Investment	Domestic investment (private & public)	FDI flows	Debt (international borrowings)	ODA Bilateral total	ODA Multilateral total	Total	Total Investment (USD billion)
Africa	1.83	80.04	0.00	0.00	12.37	7.59	100.0	5
Developing Asia	12.28	75.59	8.57	3.61	7.51	4.72	100.0	32
Latin America	7.46	39.42	28.80	26.71	3.64	1.43	100.0	19
Middle East	1.40	93.29	0.00	0.00	5.88	0.82	100.0	4
OECD Europe	29.23	47.35	15.42	37.18	0.00	0.05	100.0	75
OECD North America	18.85	65.46	22.46	11.54	0.48	0.05	100.0	48
OECD Pacific	26.71	96.97	0.71	2.32	0.00	0.00	100.0	69
Transition Economies	2.20	92.12	2.95	0.72	3.43	0.78	100.0	6
Global Total	**100.00**	**68.81**	**12.19**	**16.44**	**1.67**	**0.88**	**100.0**	**257**
AI Parties	72.49	81.41	0.04	18.52	0.03	0.01	100.0	186
NAI Parties	26.07	77.72	12.63	5.76	0.60	3.29	100.0	67
Least Developed Countries	1.10	63.48	6.28	0.00	12.16	18.09	100.0	3

Source: Estimations by UNFCCC secretariat based on data from: UNSTAT, National Accounts Database; BIS, 2007; World Bank, 2006, World Development Indicator; OECD, CRS.
Abbreviations: AI Parties = Parties included in Annex I Parites to the Convention, FDI = Foreign Direct Investment, NAI Parties = Parties not included in the Annex I to the Convention, ODA = Official Development Assistance, OECD = Organisation for Economic Co-operation and Development.

Figure IV-8. **Global primary energy mix in 2030 under the mitigation scenario**

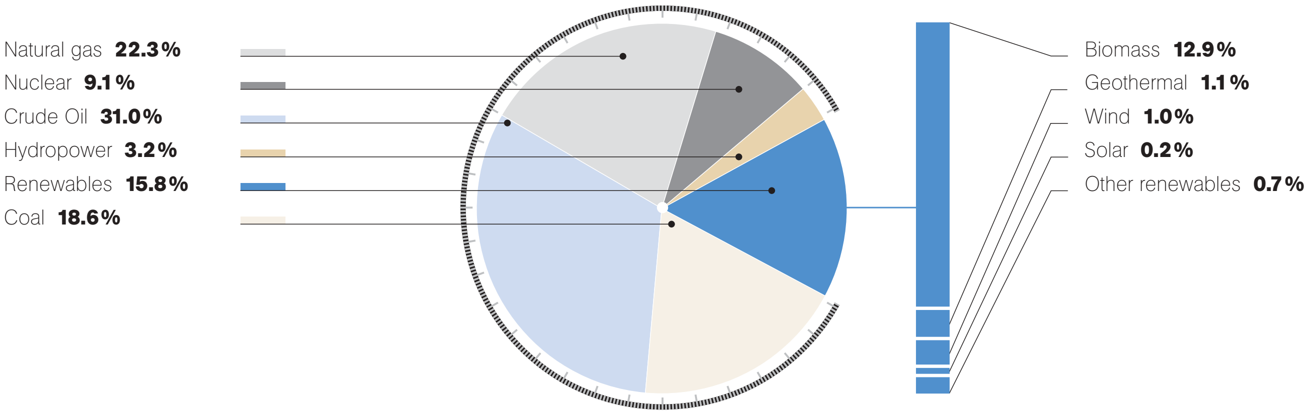
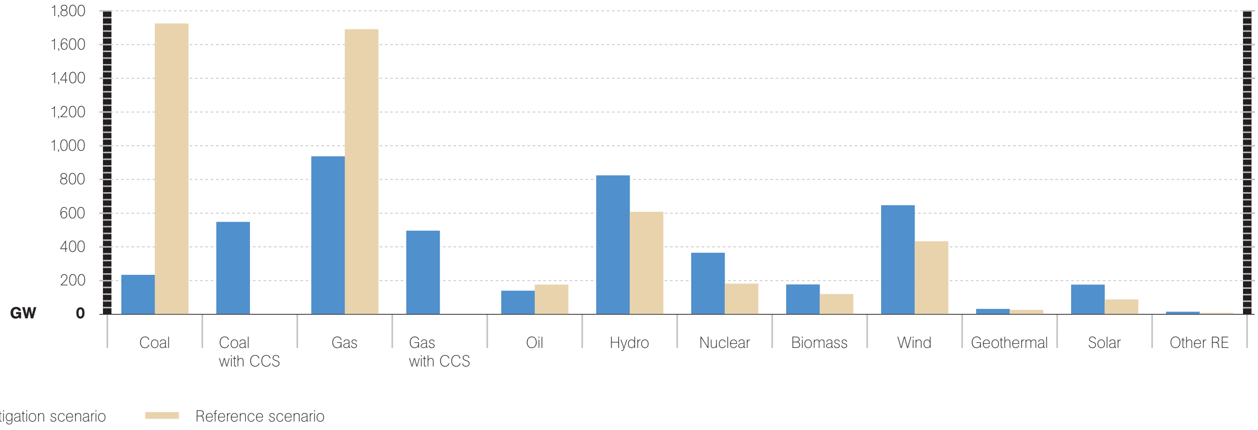
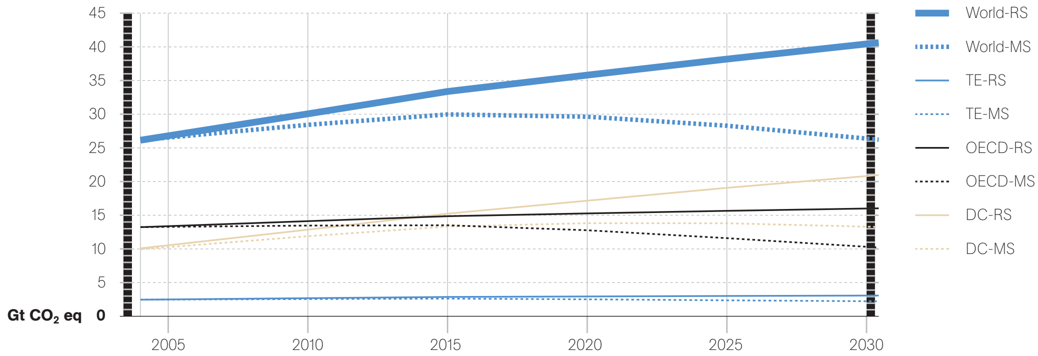


Figure IV-9. **Cumulative capacity additions in the reference and mitigation scenarios, 2004 – 2030**



Abbreviations: CCS = carbon dioxide capture and storage; RE = renewable energy.

Figure IV-10. **Energy-related carbon dioxide emissions under the reference and mitigation scenarios, 2004 – 2030**



Abbreviations: DC = developing countries; MS = mitigation scenario; OECD = Organisation for Economic Co-operation and Development; RS = reference scenario; TE = transition economies.

124. In all regions, the majority of the investment is domestic but foreign equity and debt is also important in developed countries and ODA is important in LDCs. The sources of financing vary, with mostly private financing in the United States and the United Kingdom, a mix of private and government financing in much of Europe, and government funding in transition economies and most developing countries. Much developing country financing, other than in developing Asia, comes through a combination of ODA and loans from the World Bank and regional development banks.

125. Different sources provide somewhat inconsistent estimates of annual investment for different components of energy supply. These are shown in TABLE IV-7.

126. The investment in electricity supply estimated by the IEA, USD 412 billion in 2005 (IEA, 2006) looks high relative to the estimates from the other data sources. Over half of the total IEA estimate is for investment in transmission and distribution (T&D) and that component alone is larger that the total investment estimated by other sources. Thus the explanation of the discrepancy probably lies in the estimated investment in T&D, which may not be adequately addressed in other reports, and those figures should be used with caution.

CURRENT INVESTMENT FLOWS FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY

127. TABLE IV-8 shows the sources of funding for investment in renewable energy and energy efficiency in 2005. Private investment is by far the largest source of investment, USD 28.2 billion of debt and equity out of a total of USD 29.3 billion. Private investment (as measured by New Energy Finance, 2007) is defined as investment made by financial institutions and corporations. It excludes public sector investment and R&D (whether funded by companies or governments). Since most of the investment occurs in OECD countries, it is not surprising that ODA funding for renewable energy is less than 4 per cent of the total.[14]

128. Of the USD 26.8 billion invested in renewable energy in 2005, USD 2.9 billion was provided by venture capital and private equity investors, USD 3.8 billion was raised via the public markets, and USD 20.1 billion was supplied through asset financing. As companies mature, investors can leverage their equity investment with debt. Asset financings typically involve 20–30 per cent equity and 70–80 per cent debt.

129. The range of investment activity reflects the different stages of development of renewable technologies. Wind power is the most mature technology and therefore received the highest proportion of asset finance (USD 18 billion). Solar power received a high proportion of public market investment (USD 2.2 billion) because solar companies were raising capital to expand their manufacturing capacity.

130. Private investment is – and is likely to remain – the main source of financing for renewable energy and energy efficiency. Consequently, renewable energy has flourished in countries with supportive policies such as feed-in tariffs, developed financial markets and active private investors.

131. In developing countries, financing for renewables and energy efficiency tends to come from domestic sources (public and private) and from joint ventures between local and foreign companies, reflecting the higher investment risk of these countries. Multilateral and bilateral funding is also a significant source of investment in developing countries.

132. This situation is changing, particularly in the fast growing emerging markets of China, India and Brazil, which are attracting increasing flows from foreign investors. Their rapidly expanding electricity sectors are also attracting foreign investors. LDCs, such as sub-Saharan Africa, for example, and smaller developing countries still attract limited private sector investment and continue to rely on ODA and soft loans[15] from IFIs such as the World Bank.

133. Production of renewable energy equipment and products is also growing rapidly in China, India and Brazil; photovoltaic cells for solar power in China, wind turbines in India, and ethanol in Brazil. Much of the output of photovoltaic cells and wind turbines and some of the ethanol produced is exported.

134. Developed countries continue to receive most of the private investment (93 per cent) into renewable energy and energy efficiency worldwide. In 2005, the United States attracted the largest investment flows in renewable energy (mainly for wind power) and in energy efficiency (Greenwood C *et al.*, 2007).

[14] Energy efficiency is implicit in CRS database (CRS is the source for ODA data).

[15] Loans at preferential (below market) rates which meet particular economic, social or environmental objectives.

Table IV-7. Alternative estimates of investment in energy supply in 2000 and 2005 for various components of energy supply (billions of United States dollars)

Sources							
Component of energy supply	**UNCTAD 2000**	**OECD 2005**	**IEA 2005**	**Estimates of investment in renewables and energy efficiency**			
Fossil-fired generation	–	–	107.0	–	–	–	–
Large hydro and nuclear generation	–	–	44.1	–	–	–	–
Renewables including small hydro	–	–	35.5	28.2[b]	38[c]	5.7 to 24.2[d]	Up to 2.0[e]
Transmission and distribution	–	–	225.7	–	–	–	–
Total electricity	199[a]	148	412.3	–	–	–	–
Gas distribution	17[a]	13	–	–	–	–	–
Water supply	42[a]	31	–	–	–	–	–
Electricity, gas distribution and water supply	257	191	–	–	–	–	–
Oil supply	–	–	84.5	–	–	–	–
Gas supply	–	–	134.0	–	–	–	–
Coal supply	–	–	20.0	–	–	–	–
Petroleum refining	–	–	29.5	–	–	–	–

Abbreviations: IEA = International Energy Agency, OECD = Organisation for Economic Co-operation and Development, UNCTAD = United Nations Conference on Trade and Development

[a] Based on gross fixed capital formation data by the respective sectors estimated assuming the same shares as the OECD data.
[b] New Energy Finance estimate for 2005. This includes investment from private equity/venture capital, public market and asset financing.
[c] REN21 2006, estimate for 2006 (2006 USD million). This includes only the investment observed in the capital markets. REN21 "Renewables Global Status Report 2006 Update"; Paris: REN21 Secretariat and Washington DC: Worldwatch Institute.
[d] Estimates of the investment for clean development mechanism (CDM) renewable energy and energy efficiency projects registered during 2006 and that entered the pipeline during 2006 respectively.
[e] Estimates of the investment for JI renewable energy and energy efficiency projects that entered the pipeline during 2006.

Table IV-8. Overview of funding sources in 2005 (millions of United States dollars)

	Renewable energy			Energy efficiency			
	Source	**OECD**	**Developing**	**OECD**	**Developing**	**Total**	**Per cent total**
Total investment Debt							
Private sector	NEF	9,089	656	41	6	9,791	33.4
Multilateral	CRS	–	386	–	–	386	1.3
Total debt		9,089	1,041.5	40.8	6	10,177	–
Equity							
Total equity (private sector)	NEF	14,107	2,906	1,342	96	17,451	63.0
Grants							
Multilateral (GEF)	GEF	–	42	–	30	71	0.2
Bilateral	CRS	–	601	–	–	601	2.1
Total grants		–	642	–	30	672	–
Total investment		**23,196**	**4,590**	**1,383**	**132**	**29,300**	**–**
Private investment		23,496	3,562	1,383	102	28,242	96.4
Multilateral/bilateral		–	1,028	–	30	1,058	3.6

Abbreviations: CRS = Creditor Reporting System, GEF= Global Environment Facility, NEF = New Energy Finance, OECD = Organisation for Economic Co-operation and Development.

Note: New Energy Finance assumptions on leverage (debt as per cent of whole): Venture capital investment is unleveraged (i.e. all equity and no debt). Private equity investment in companies (expansion capital) is leveraged with 30 per cent debt. Over the Counter (OTC) investments and private investments in public equities (PIPEs) are leveraged with 10 per cent debt. Public market investments are unleveraged, i.e. 100 per cent equity. Asset financing can take different forms: balance sheet finance (corporate finance) and lease/vendor finance at typically 100 per cent equity financed, bond finance is 100 per cent debt, and project finance is based on New Energy Finance standard levels of leverage (wind 74 per cent debt, solar 77 per cent debt, mini-hydro and geothermal 70 per cent debt).

CURRENT ESTIMATES OF ENERGY SUBSIDIES AND POTENTIAL REVENUE OF NON-TECHNICAL LOSSES

ENERGY SUBSIDIES

135. Subsidies are introduced for specific social, economic or environmental reasons, for example to provide affordable energy to low income groups, to stimulate R&D of energy technologies, or to reduce pollution by promoting renewable energy. Data on the cost of subsidies are not routinely collected and reported. Instead, specific studies estimate the value of subsidies, but the studies differ in terms of the subsidies included[16], geographic coverage and the methodology used.

136. Putting a monetary value on some types of subsidies can be extremely difficult. For the purposes of this analysis, given the data availability, the subsidy is estimated as the difference between the actual price (cost) and the baseline price (cost) with no subsidy. The baseline must differentiate the impact on price (production cost) of a particular government intervention that generates the subsidy from the effects of all other factors that influence the price (cost). Empirical studies of subsidies typically use market price (cost) in another jurisdiction as the baseline.

137. Globally, energy subsidies total approximately USD 250 – 300 billion per year excluding taxes (Morgan, 2007). Non-OECD countries receive the bulk of these subsidies and use most of them to lower prices for consumers. In OECD countries, most subsidies are used for production, usually in the form of direct payments to producers or support for R&D. Worldwide, fossil fuels are the most heavily subsidized energy sources; these subsidies total an estimated USD 180 – 200 billion per year. Support to the deployment of low-carbon energy sources currently amounts to an estimated USD 33 billion each year: USD 10 billion for renewables, USD 16 billion for existing nuclear power plants and USD 6 billion for biofuels.

138. The most recent global quantitative analysis of energy subsidies, carried out by the IEA in 2006, measures consumption subsidies – government measures that result in an end-user price that is below the price that would prevail in a truly competitive market – in the twenty non-OECD countries with the largest primary energy consumption. Price controls, often through state-owned companies, are the most common form of energy subsidy. As shown in TABLE 7-ANNEX V, the Russian Federation has the largest subsidies, USD 40 billion per year, most of which go to natural gas. Iran's energy subsidies, mostly for petroleum products, are about USD 37 billion per year. China, Saudi Arabia, India, Indonesia, Ukraine and Egypt have subsidies in excess of USD 10 billion per year.

139. Forty per cent of the subsidies (USD 91 billion) go to oil products with Iran (27 per cent), Indonesia (16 per cent) and Egypt (10 per cent) having the largest shares of the total. Natural gas gets 31 per cent of thesubsidies (USD 70 billion) with the Russian Federation (36 per cent), Ukraine (18 per cent) and Iran (14 per cent) accounting for most of the total. Electricity gets 24 per cent of the subsidies (USD 55 billion) with the Russian Federation (15 per cent), India (10 per cent) and China (7 per cent) having the largest shares. China accounts for most of the coal subsidies; 76 per cent of the total coal subsidies of USD 10 billion.

140. Subsidies resulting from price regulation of road transport fuels are among the easiest to observe and estimate. A recent survey of 171 countries by GTZ (2007) shows that a number of countries subsidize gasoline and diesel net of taxes (see FIGURES 1- and 2-ANNEX V). In 14 countries, gasoline prices (15 countries for diesel) are lower per litre than the international price of crude oil, implying a large subsidy. Prices are below United States retail levels – the benchmark that GTZ used for determining whether fuel is subsidized – in 24 countries for gasoline and 52 countries for diesel.

141. The value of transport fuel subsidies, based on the GTZ data and 2004 consumption data from the IEA, amounts to USD 90 billion using the international fuel price plus a distribution margin as the baseline reported by GTZ (2007). Gasoline subsidies total USD 28 billion and diesel subsidies USD 61 billion. The aggregate amount is exactly the same as the 2006 estimate of the IEA, using a similar methodology, of total oil subsidies in the world's 20 largest consuming countries in 2005.

142. The effects of energy subsidies on GHG emissions are complex. Generally lower fossil fuel prices encourage greater consumption and higher GHG emissions. But subsidizing oil products in developing countries can reduce emissions by curbing deforestation when rural households switch from firewood (von Moltke *et al.*, 2004). Nonetheless, a OECD study (OECD, 2000) estimates that trade liberalisation and elimination of global fossil-fuel subsidies in industry and the power sector would reduce energy-related CO_2 emissions by more than 6 per cent by 2010, while increasing income

by 0.1 per cent (OECD 2000). Similarly, a 1999 IEA study shows that removing consumption subsidies in eight of the largest non-OECD countries would reduce their primary energy use by 13 per cent and reduce their CO_2 emissions by 16 per cent (see TABLE 8-ANNEX V), while GDP rises by 1 per cent. This reduction corresponds to 5 per cent of global emissions.

143. A study by the Australian Bureau of Agricultural and Resource Economics (ABARE) reports a smaller reduction of world emissions; 1.1 per cent by 2010 relative to a reference case if removing fossil fuel consumption subsidies (Sanders and Schneider, 2000). These emission reductions would be largest in transition economies (8 per cent) while emissions would rise slightly in developed countries due to lower international coal prices.

144. The impacts of subsidy removal in OECD countries depend on country-specific circumstances, but an analysis shows that it would not lead to direct increases in prices and thus may not lower consumption or emissions. In Germany, subsidy removal might encourage coal imports because subsidies are paid to producers and coal consumers can choose suppliers. This could drive up international coal prices and thus push down coal demand and related CO_2 emissions.

NON-TECHNICAL LOSSES

145. The metered use of electricity by consumers is less than the electricity supplied by the generators due to T&D losses. T&D losses consist of both technical losses, such as transmission line loss, and non-technical losses, such as theft. Utilities generally try to minimize non-technical losses but some government owned utilities may tolerate non-technical losses as a socio economic policy; that is, a means of providing electricity to low-income groups.

146. Non-technical loss by region is estimated for the analysis. Using T&D losses during 2000, the 71 countries for which data are available are divided into three categories according to their total T&D loss based on a comparative analyse by Smith (Smith, 2004). A pure technical loss is assumed for the countries in each category. The difference between the total T&D loss and the pure technical loss is the estimated non-technical loss. The amount of the non-technical loss is calculated and valued using the average of the industrial and residential electricity price.[17] FIGURE 3-ANNEX V shows the estimated non-technical losses as a percentage of the total electricity supplied.

147. The estimated total revenue lost due to non-technical losses is USD 20 billion. The regional distribution of those losses as shown in FIGURE 4-ANNEX V. Revenue losses are highest in developed countries because their total electricity consumption is high. Countries with estimated non-technical losses in excess of USD 1 billion per year are India, Brazil, the Russian Federation and Mexico. Developing countries account for 57 per cent of the total losses.

[16] The International Energy Agency has defined energy subsidies as any government action that concerns primarily the energy sector that lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers (IEA, 1999).

[17] Since the non-technical losses are valued at subsidized prices, they are understated.

4.4.1.4. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE REFERENCE SCENARIO

148. Investment in energy supply infrastructure under the reference scenario is projected to be USD 762 billion in 2030 (see TABLE IV-9). The power (including generation, T&D) sector requires USD 439 billion, or 58 per cent of the total. Capital expenditure in the oil industry – oil production, pipelines and other forms of transportation, and refineries amounts to USD 154 billion, just over one-fifth of the total. Gas investment – gas production, pipelines, liquefied natural gas (LNG) and other transportation investment is USD 148 billion, or 19 per cent of the total. Investment in coal supply is about USD 20 billion, or 3 per cent of total energy investment.

149. As shown in TABLE IV-9, more than half of all the energy investment needed worldwide in 2030 is in developing countries, where demand and production increase most quickly. China alone needs to invest about USD 132 billion, 17 per cent of the global total. About USD 283 billion (37 per cent) is needed by OECD countries to replace and expand their facilities.

150. Upstream (production) investment accounts for 73 per cent of the total investment in the oil industry in 2030, 56 per cent of the total in the gas industry, and 100 per cent in the case of coal. Most of the oil industry investment occurs in the Russian Federation and the Middle East. Natural gas investment is concentrated in OECD North America, where demand increases strongly under the reference scenario and where construction costs are high. Almost half of the coal investment occurs in China and one quarter each in North America and Australia.

Table IV-9. **Investment in energy supply needed under the reference scenario in 2030 (billions of United States dollars)**

	Transmission and distribution	Power generation	Coal supply	Oil supply	Gas supply	Total
World	231.0	208.3	19.9	154.2	148.1	761.6
OECD	**71.4**	**93.9**	**6.0**	**44.2**	**67.1**	**282.5**
OECD North America	38.7	40.3	3.1	32.9	45.7	160.7
United States	29.5	34.0	–	–	–	63.5
Canada	3.2	3.7	–	–	–	6.8
Mexico	6.1	2.6	–	–	–	8.7
OECD Pacific	7.9	9.9	1.6	1.8	5.3	26.5
Japan	2.3	5.1	–	–	–	7.4
Korea	3.5	2.7	–	–	–	6.3
Australia and New Zealand	2.0	2.1	–	–	–	4.1
OECD Europe	24.8	43.7	1.3	9.5	16.0	95.3
Transition economies	**10.9**	**11.9**	**1.3**	**24.6**	**22.7**	**71.3**
Russia	4.2	6.2	0.6	18.4	16.9	46.3
Other EIT	6.7	5.6	0.7	6.2	5.7	24.9
Developing Countries	**148.7**	**102.6**	**12.7**	**85.5**	**58.3**	**407.8**
Developing Asia	108.7	72.9	11.5	25.5	17.6	236.1
China	64.5	39.6	9.2	13.5	4.8	131.5
India	26.3	18.3	1.5	1.9	2.1	50.1
Indonesia	4.7	3.7	0.5	1.9	3.3	14.1
Other Developing Asia	13.3	11.3	0.4	8.2	7.4	40.5
Latin America	17.3	13.0	0.4	14.5	10.2	55.5
Brazil	4.6	4.4	0.0	5.3	1.8	16.2
Other Latin America	12.7	8.6	0.4	9.2	8.4	39.3
Africa	13.4	9.5	0.8	18.7	15.9	58.2
Middle East	9.3	7.2	0.0	26.8	14.7	58.0

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

151. A total of 5,087 GW of generating capacity is projected to be built worldwide under the reference scenario. More than half of this capacity is located in developing countries. Total power sector investment in 2030, including generation, T&D, reaches USD 439 billion. The largest investment requirements, some USD 104 billion, arise in China. Investment needs are alsovery large in OECD North America and Europe. Investment to replace currently operating capacity accounts for over 40 per cent of total investment in the OECD and over 50 per cent in transition economies, but it is a very small share of total investment in developing countries.

152. Over half of the total investment in 2030, USD 231 billion, is for T&D networks, of which more than two-thirds goes into distribution systems. Despite the significant investment in T&D, the IEA reference scenario projects that 1.4 billion people will not have access to electricity in 2030. The IEA estimates that universal electricity access by 2030 would require an additional annual investment of USD 25 billion. Almost all of this added investment would be needed in sub-Saharan Africa and South Asia.

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE MITIGATION SCENARIO

153. Under the mitigation scenario, the large increase in energy efficiency reduces energy demand and hence projected investment in energy-supply infrastructure. Implementation of the energy efficiency measures requires investments by energy consumers in the industry, buildings and transportation sectors as discussed in CHAPTERS IV.4.2, IV.4.3 and IV.4.4.

154. Investment in energy supply infrastructure under the mitigation scenario is projected to be USD 695 billion in 2030, USD 67 billion (9 per cent) less than under the reference scenario (see TABLE IV-10). The power sector

Table IV-10. **Investment in energy supply needed under the mitigation scenario in 2030 (billions of United States dollars)**

	Transmission and distribution	Change in per cent	Power generation	Change in per cent	Coal, oil and gas supply	Change in per cent	Total	Change in per cent
World	**129.8**	**-44**	**302.4**	**45.1**	**263.2**	**-18**	**695.3**	**-9**
OECD	**23.1**	**-68**	**140.5**	**49.6**	**100.4**	**-14**	**263.9**	**-7**
OECD North America	14.0	-64	76.8	90.7	71.6	-12	162.3	1
United States	9.1	-69	69.4	104.2	0.0	–	78.5	24
Canada	0.4	-89	3.9	5.5	0.0	–	4.2	-38
Mexico	4.5	-26	3.5	33.4	0.0	–	8.0	-8
OECD Pacific	2.8	-64	16.3	63.4	6.8	-22	25.9	-2
Japan	0.0	-100	7.9	53.6	0.0	–	7.9	6
Korea	2.0	-42	3.5	29.1	0.0	–	5.6	-11
Australia and New Zealand	0.8	-62	4.8	132.6	0.0	–	5.6	37
OECD Europe	6.3	-75	47.4	8.6	22.0	-18	75.7	-21
Transition economies	**5.6**	**-48**	**17.7**	**49.6**	**38.8**	**-20**	**62.2**	**-13**
Russia	3.2	-23	10.1	61.9	29.1	-19	42.4	-8
Other EIT	2.4	-64	7.7	35.9	9.7	-23	19.8	-21
Developing Countries	**101.1**	**-32**	**144.2**	**40.6**	**124.0**	**-21**	**369.3**	**-9**
Developing Asia	74.9	-31	106.6	46.3	45.6	-16	227.1	-4
China	46.4	-28	64.8	63.8	24.1	-12	135.3	3
India	19.6	-26	24.9	36.4	4.8	-12	49.4	-1
Indonesia	3.4	-26	5.0	35.9	5.0	-13	13.4	-5
Other Developing Asia	5.4	-59	11.8	4.4	11.8	-26	29.0	-28
Latin America	10.3	-40	12.7	-2.4	17.3	-31	40.3	-27
Brazil	1.9	-59	3.4	-22.5	4.5	-37	9.8	-39
Other Latin America	8.4	-34	9.3	8.0	12.8	-29	30.5	-22
Africa	9.9	-27	14.1	49.2	27.5	-22	51.5	-12

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

requires about USD 432 billion of investment, 62 per cent of the total. Much of the increased investment in the power sector is for large-scale deployment of CCS from 2020 onwards. Capital expenditure in the oil industry – oil production, pipelines and other forms of transportation, and refineries, amounts to USD 113 billion. Investment in the gas sector – gas production, pipelines, LNG and other transportation is USD 116 billion, about the same as for oil. Investment in coal supply is about USD 12 billion, or 1.7 per cent of total energy investment.

155. The projected decline in T&D investment under the mitigation scenario relative to the reference scenario warrants further analysis. The IEA estimates T&D investment based on generation capacity with one third of the investment for transmission and two thirds for distribution. Increased energy efficiency and wider use of distributed generation[18] should reduce the need for additional T&D capacity under the mitigation scenario, but further analysis is needed to ensure that the lower investment projected is consistent with the level of energy access under the reference scenario.

CHANGES IN INVESTMENT AND FINANCIAL FLOWS BETWEEN THE REFERENCE AND MITIGATION SCENARIOS

156. FIGURE IV-11 shows the total investment in energy supply needed under the reference and mitigation scenarios.

157. The estimated investment flows for energy supply under the reference and mitigation scenarios in 2030 are shown in TABLE IV-11. The mitigation scenario requires less investment in the production of fossil fuels and associated facilities, and substantial shifts of investments within the power sector.

CHANGE IN INVESTMENT AND FINANCIAL FLOWS NEEDED IN FOSSIL FUEL SUPPLY

158. The investment in fossil fuel supply projected under the reference scenario is USD 322 billion in 2030, of which 6 per cent is for the production of coal, 48 per cent is for oil and 46 per cent for natural gas. Upstream (production) investment accounts for 73 per cent of the total in the oil industry, 56 per cent of the total in the gas industry, and 100 per cent in the case of coal.

159. Under the mitigation scenario the total investment needed is reduced by USD 59 billion in 2030, 40 per cent reduction in coal, 19 per cent in oil and 15 per cent in natural gas. Under this scenario, the consumption of oil and natural gas would be higher than present level and consumption of coal would be about the same; thus, the lower investment reflects slower growth rather than declining output. Just over half (USD 32 billion) of the reduction in investment flows would occur in non-Annex I Parties.

160. Most of the investment is made by large corporations, either government-owned or private. The mitigation scenario means they need to invest less.

CHANGE IN INVESTMENT AND FINANCIAL FLOWS NEEDED IN POWER SUPPLY

161. Under the reference scenario, investment in power supply is projected to be USD 439 billion in 2030, of which 53 per cent is T&D, 17 per cent is for coal-fired generation, 9 per cent is for renewables, 9 per cent is for gas-fired generation, 8 per cent is for hydropower and 3 per cent is for nuclear energy.

162. Under the mitigation scenario, the total investment in 2030 would be about the same as in the reference scenario (USD 432 billion), but the investment mix would be significantly different. Less investment will be needed for T&D (USD 101 billion) and fossil-fired generation (USD 55 billion, mainly coal). Additional investment will be needed for CCS in power plants (USD 63 billion), renewables (excluding hydropower) (USD 38 billion), nuclear energy (USD 25 billion) and hydropower (USD 22 billion). As noted in PARAGRAPH 155, the projected decline in T&D investment warrants further analysis.

163. Due to rapid economic growth, about 57 per cent of the power sector investment is projected to occur in non-Annex I Parties under both scenarios (USD 251 billion for the reference scenario and USD 245 billion for the mitigation scenario). The shift in mix of global investments described above occurs in non-Annex I Parties as well.

164. Most of the investment in electricity generation and T&D is made by government-owned or private, usually regulated, electric utilities. In all regions, the majority of the investment is made domestically, but foreign equity and debt are important additional sources of financing in developed countries and ODA is important in LDCs. Investment in renewables is currently concentrated in a few developed countries and a significant proportion is not financed by electric utilities, although both of these patterns are changing.

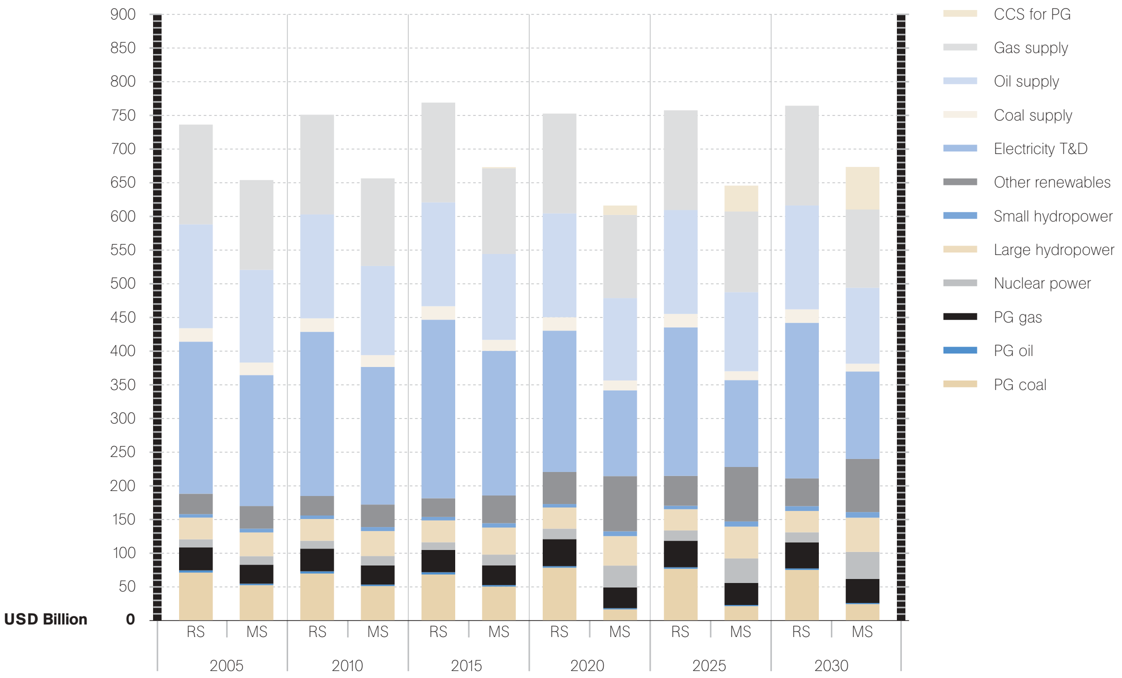
[18] Production of electricity close to where it is used.

Table IV-11. Investment flows needed for energy supply under the reference and mitigation scenarios in 2030 (billions of United States dollars)

	Global 2030			Non-Annex I Parties 2030		
Sectors	**Reference scenario**	**Mitigation scenario**	**Additional investment**	**Reference scenario**	**Mitigation scenario**	**Additional investment**
Fossil fuel supply total	322	263	-59	156	124	-32
Coal	20	12	-8	13	8	-5
Oil	154	125	-29	85	69	-16
Natural Gas	148	126	-22	58	47	-11
Power supply total	439	432	-7	251	245	-6
Coal-fired generation	75	24	-51	40	13	-27
Oil-fired plants	2	1.5	-1	1	1	0
Gas-fired plants	39	36	-3	17	13	-4
Nuclear	15	40	25	3	14	11
Hydro	37	59	22	28	46	18
Renewable	41	79	38	12	30	18
CCS Facility coal fired plants	–	40	40	0	21	21
CCS Facility gas fired plants	–	23	23	0	6	6
Transmission and distribution	231	130	-101	149	101	-48

Abbreviations: CCS = carbon dioxide capture and storage

Figure IV-11. Investment in energy supply needed under the reference and mitigation scenarios, 2005 – 2030



Abbreviations: CCS = carbon dioxide capture and storage; PG = power generation; MS = mitigation scenario; RS = reference scenario; T&D = transmission and distribution.

165. Changing the mix of technologies in the power sector as projected under the mitigation scenario poses some challenges. Specifically:

- Electric utilities will continue to add fossil-fired plants rather than switch to renewables, nuclear energy and large hydropower unless these options are less costly and their environmental, social and safety concerns are addressed;
- Electric utilities may resist adoption of CCS for fossil-fired plants because of the cost, newness of the technology, legal uncertainties and for other reasons;
- Rapid growth of renewables may be constrained by their relatively high cost, supply bottlenecks, locational constraints and grid management considerations;
- Private investors financing renewable energy projects seek supportive government policies, financial incentives, such as feed-in tariffs and renewable energy credits, and secure markets for the power generated.

166. These are challenges for Parties included in Annex I to the Convention (Annex I Parties) and non-Annex I Parties, since over a half of the projected investment is expected to occur in non-Annex I Parties. Non-Annex I Parties may need financial incentives or assistance with national policies to address these challenges.

CHANGE IN INVESTMENT AND FINANCIAL FLOWS NEEDED IN CARBON DIOXIDE CAPTURE AND STORAGE

167. CCS for power plants, and to a lesser extent for industry, is a significant contributor to the emission reductions achieved under the mitigation scenario. The investment in CCS in 2030 is over USD 75 billion, of which over 80 per cent is for power plants. There is no CCS under the reference scenario.

168. Before large-scale implementation of CCS can occur, technology development is still required, mainly related to CO_2 capture. Though no real technical barriers have yet been identified, it is envisaged that at least two generations of pilot and demonstration plants are required, which could take up to two decades. As demonstration plants often need to operate for a considerable time before large-scale deployment, this will affect the timing of full-scale commercial implementation. A detailed analysis was undertaken by Hendriks (2007).

169. Only a few quantitative estimates of CO_2 storage potential in different regions have been made. These estimates should be treated with care as methodologies for estimating storage capacity are still under development and reliable geological data are lacking, especially for aquifers and coal seams. Storage capacity is also affected by the safety considerations. As safety requirements are still under discussion, capacity estimates are uncertain.

Box IV-1. **Summary of investment and financial flows in energy supply and infrastructure**

Investment and financial flows needed in 2030

Global investment in energy supply infrastructure under the mitigation scenario is projected to be USD 695 billion in 2030, USD 67 billion (9 per cent) less than under the reference scenario. Power supply requires more than USD 432 billion of investment under the mitigation scenario, USD 7 billion (1.6 per cent) less than the reference scenario. Universal electricity access by 2030 would require an additional annual investment of USD 25 billion. Capital expenditure in fossil fuel supply would require USD 263 billion under the mitigation scenario, 59 billion (18 per cent) less than the reference scenario. More than half of all the energy investment needed worldwide is in developing countries due to their rapid economic growth.

Current investment and financial flows

In all regions, the majority of the investment is domestic, but foreign equity and debt are important in developed countries and ODA is important in LDCs. The sources of financing vary, with mostly private financing in the United States and the United Kingdom, and government funding in much of Europe, transition economies and most developing countries. Much developing country financing, other than in developing Asia, comes through a combination of ODA and loans from the World Bank and regional development banks. Most of the investment in renewable energy and energy efficiency occurs in OECD countries; ODA funding for renewable energy is less than 4 per cent of the total ODA flows. LDCs, such as in sub-Saharan Africa, and smaller developing countries, still attract limited private sector investment and continue to rely on ODA and soft loans from IFIs such as the World Bank.

170. Legal implications and public attitudes are important with respect to CCS as well. Work on resolving the associated legal and regulatory issues may not be proceeding quickly enough for large-scale implementation by 2030, and for implementation of larger-scale demonstration facilities in particular. The public is still quite unaware of CCS as an option.

171. Long-term liability issues of CCS also require resolution. The legal responsibility of entities operating CCS reservoirs must be clearly defined if they are to be able to attract the required investment. The expectation is that the CO_2 will remain in the CCS reservoir for thousands of years but the entity operating a CCS reservoir cannot be held responsible for such long periods of time, and its responsibility must be transferred to the government at some reasonable time after the reservoir is sealed.

Box IV-2. Summary of investment and financial flows in carbon dioxide capture and storage

CCS for power plants, and to a lesser extent for industry, is a significant contributor to the emission reductions achieved under the mitigation scenario. The investment in CCS in 2030 under the mitigation scenario is over USD 75 billion, of which over 80 per cent is for power plants. Technology development, legal implications, public attitudes and long-term liability of CCS are the critical factors for large-scale implementation of CCS.

4.4.1.5. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

172. The major reductions in emission achieved under the mitigation scenario rely on increased energy efficiency, shifts being made in the energy supply from fossil fuels to renewables, nuclear energy and hydropower and large-scale deployment of CCS (even though there are only a few CCS demonstration projects at the present time). Much of the shift will need to occur in developing countries where energy demand is projected to grow most rapidly.

173. Most of the investment in fossil fuel production, processing and transportation is made by large corporations, either government-owned or private. The mitigation scenario means they need to invest less.

174. Historically, nuclear power and large hydropower plants have been financed by the utilities that also build fossil-fired generation and transmission systems. These utilities would probably be expected to finance the cost of CCS at coal and gas plants under the mitigation scenario. The value of the added investment needed for nuclear energy, large hydropower and CCS is lower than the value of reduced investment in fossil-fired generation. Thus the financing challenge faced by electric utilities is less severe under the mitigation scenario than under the reference scenario, although some private utilities may be reluctant to invest in nuclear plants.

175. Renewable energy projects are presently financed largely by private investors. If this trend continues to, the scale of investment projected will require supportive government policies, financial incentives, such as feed-in tariffs and renewable energy credits, and secure markets for the power generated. It also will be necessary to ensure that the investment flows to the countries and regions that need it most. Africa probably faces the greatest challenge, needing to attract capacity investment of nearly USD 3 billion a year from a base of almost nothing.

4.4.2. INDUSTRY

4.4.2.1. INTRODUCTION

176. Globally, the industry sector[19] is responsible for nearly 27 per cent of world energy consumption, 19 per cent of energy-related CO_2 emissions and 7 per cent of non-CO_2 emissions (US EPA, 2006a). Energy and GHG intensity[20] varies greatly among the different industrial sectors and too therefore does the potential absolute emission reductions. This chapter focuses on the more intense sectors because even a small change in their energy or GHG intensity can significantly alter emissions levels (Nyboer, 2007). That is not to say other manufacturing sectors are not important; growth may be rapid and contributions to emissions significant. The following industrial sectors are covered in this chapter:

- Pulp and paper;
- Cement, lime, and other non-metallic minerals;
- Nonferrous metal smelting and iron and steel smelting;
- Metal and non-metal mining;
- Chemical products;
- Other manufacturing.

177. For energy-related CO_2 emissions, this chapter adopts the same reference and mitigation scenario as the energy supply sector – the IEA's WEO 2006 reference and the BAPS respectively. Non-CO_2 emissions are based on reference projections by the US EPA. The mitigation scenario includes cost-effective emission reductions estimated using marginal abatement cost curves developed by the US EPA. Industrial process CO_2 emissions are assumed to continue to increase under the reference scenario and to diminish under the mitigation scenario based on the WBCSD cement industry report (WBCSD, 2002).

4.4.2.2. ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

RECENT TRENDS IN ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

178. In 2000, the industry sector consumed 1,758 Mtoe energy, of which 50 per cent was consumed by OECD countries and 41 per cent by developing countries (see TABLE IV-12).

Table IV-12. **Industrial sector fuel consumption and CO_2 eq emissions in 2000**

	Fuel Consumption (Mtoe)				Emissions (Mt CO_2 eq)			
Country/region	Fossil Fuels	Electricity	Non-Fossil Fuels	Total	Combustion	Non-CO_2	Industrial process CO_2 emission	Total
World	1,139	457	161	1,757	4,366	2,446	826	7,638
OECD	538	277	67	883	1,951	1,080	266	3,296
OECD North America	242	124	45	411	822	628	66	516
OECD Pacific	100	54	5	159	413	127	70	610
OECD Europe	196	100	17	313	715	325	130	1,169.8
Transition Economies	106	41	2	149	414	497	40	951
Developing Countries	494	139	92	725	2,002	870	520	3,391
Developing Asia	332	94	36	462	1,426	527	403	2,355
Latin America	61	24	34	119	219	107	45	372
Africa	31	15	22	68	136	129	36	301
Middle East	70	6	0.2	77	221	106	36	363

Abbreviations: OECD = Organisation for Economic Co-operation and Development.

179. The OECD is responsible for 44 per cent of combustion and non-CO_2 emissions, and developing countries for 29 per cent, with the United States and China both responsible for approximately 17 per cent of global industrial emissions. Fossil fuels account for the majority of energy consumption (65 per cent) and electricity consumption makes up 26 per cent[21]. OECD countries consume 50 per cent of total fuel, slightly more than its share of emissions, while developing countries consume 26 per cent, slightly less than their share of emissions. The United States is responsible for 19 per cent of global fuel consumption, and China is the second largest consumer (15 per cent).

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS UNDER THE REFERENCE SCENARIO

180. TABLE IV-13 provides an overview of industrial energy consumption and GHGs under the reference scenario. Fuel consumption rises steadily in every region, but particularly in developing countries, where fuel consumption doubles between 2005 and 2030. This growth is driven by rising population levels and continued economic growth in China and other non-industrialized countries (WBCSD, 2006).

[19] Petroleum refining is covered in energy supply.

[20] Emissions per unit of output.

[21] Emissions associated with electricity generation are included in the energy supply sector.

Table IV-13. **Fuel consumption and GHG emissions in 2030 under the reference scenario in the industrial sector**

	Fuel Consumption (Mtoe)				Emissions (Mt CO_2 eq)			
Country/region	**Fossil Fuels**	**Electricity**	**Non-Fossil Fuels**	**Total**	**Combustion**	**Non-CO_2**	**Industrial process CO_2 emission**	**Total**
World	2,597	940	395	3,932	8,075	4,691	1871	14,637
OECD	903	351	139	1,393	2,593	1,935	248	4,777
OECD North America	410	140	70	620	1,145	1,212	62	2,419
United States	319	97	57	472	899	799	56	1,754
Canada	56	23	12	91	152	92	6	250
Mexico	35	21	1	56	94	321	–	415
OECD Pacific	189	75	20	283	588	298	49	936
Japan	100	37	8	145	320	97	32	449
Korea	67	26	6	100	208	122	14	345
Australia and New Zealand	22	12	6	39	60	79	3	142
OECD Europe	305	136	50	490	859	426	137	1,422
Transition Economies	212	72	53	337	594	695	80	1,369
Russia	104	43	41	189	280	307	–	587
Other EIT	107	29	12	148	314	388	–	702
Developing Countries	1,483	517	203	2,202	4,888	2,060	1,542	8,491
Developing Asia	1,042	393	116	1,551	3,685	1,150	1,034	5,868
China	657	282	63	1,002	2,471	710	587	3,768
India	155	46	30	231	516	226	211	953
Indonesia	53	9	3	64	155	62	0	217
Other Developing Asia	177	57	21	254	544	151	236	930
Latin America	133	67	53	253	375	279	170	825
Brazil	56	26	43	125	169	71	–	240
Other Latin America	77	41	11	128	206	208	–	415
Africa	63	33	34	130	188	294	239	721
Middle East	244	23	0	268	640	338	98	1,076

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

181. The reference scenario includes significant energy efficiency improvements and emission reduction technologies. Energy efficiency increases at 1.5 per cent annually (Vattenfall, 2007c) reducing energy intensity in developing and transition economies to close to current OECD levels by 2030 (IEA, 2006). The major emission reduction measures expected to be adopted under the reference scenario include:

- A shift of Chinese cement production to the pre-heater/precalciner technology;
- Complete switching from the basic oxygen furnace to the electric arc furnace in the steel industry by 2030;
- Commitments by the global aluminium, semiconductor, and magnesium industries o substantially reduce emissions of high global warming potential (GWP) gases.

182. As fuel consumption increases, so do combustion-related emissions. Overall emissions grow moderately in the OECD and transition economies, but grow rapidly in developing countries. Although emissions of some non-CO_2 gases decline, emissions of others grow significantly, leading to an overall increase.

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS UNDER THE MITIGATION SCENARIO

183. Table IV-14 provides an overview of industrial energy consumption and GHG emissions under the mitigation scenario. Fuel consumption rises slowly in the OECD and transition economies, but by over 60 per cent from 2005 to 2030 in developing countries. Total emissions rise continuously in each region, but global combustion emissions fall after 2020. Reductions in emissions of some non-CO_2 gases are more than offset by increases in the emissions of others. CCS facilities are used to reduce emissions by 0.5 Gt CO_2.

184. Compared with the reference scenario, fossil fuel and electricity demand under the mitigation scenario decline by 17 and 15 per cent respectively, while non-fossil fuel energy consumption rises by 5 per cent. Almost all of the growth in non-fossil fuel use comes from biomass and waste consumption, particularly in Asia, where combined heat and power projects using biomass displace some gas and coal (IEA, 2006). Significant contributors to the reduction in fossil fuel demand are a substitution of natural gas for coal in China and a decline in oil demand in developing countries due to fuel switching and improvements in process heat and boiler efficiencies.

185. Electricity consumption in OECD countries falls by 25 per cent, with motor system efficiency improvements being a prime contributor to the reduction. More than half of global industrial energy savings result from increased efficiency in the iron and steel, chemicals, and non-metallic minerals industries (IEA, 2006).

Table IV-14. **Fuel consumption and GHG emissions in 2030 under the mitigation scenario for the industrial sector**

	Fuel Consumption (Mtoe)				Emissions (Mt CO_2 eq)			
Country/region	Fossil Fuels	Electricity	Non-Fossil Fuels	Total	Combustion	Non-CO_2	Industrial process CO_2 emission	Total
World	2,167	795	415	3,377	6,076	2,931	1,656	10,663
OECD	788	299	138	1,225	2,095	1,334	221	3,651
OECD North America	354	121	66	541	940	870	49	1,858
United States	276	83	54	413	734	590	44	1,368
Canada	47	20	12	79	125	72	5	202
Mexico	31	18	1	50	81	208	–	289
OECD Pacific	167	67	23	257	458	189	47	693
Japan	89	32	9	130	242	74	31	348
Korea	60	24	6	90	171	75	12	259
Australia and New Zealand	19	11	7	36	45	39	3	87
OECD Europe	266	111	50	427	697	276	126	1,099
Transition Economies	173	62	49	284	445	438	77	961
Russia	87	39	38	164	222	197	–	419
Other EIT	86	24	10	120	224	241	–	465
Developing Countries	1,206	433	228	1,868	3,536	1,158	1,358	6,052
Developing Asia	836	328	140	1,304	2,544	537	886	3,966
China	524	234	73	831	1,646	292	509	2,447
India	122	40	33	195	366	115	177	659
Indonesia	45	8	4	57	121	36	–	157
Other Developing Asia	145	47	30	222	410	93	200	704
Latin America	110	55	50	216	300	191	162	653
Brazil	47	21	40	107	133	48	–	181
Other Latin America	63	34	11	108	167	143	–	310
Africa	54	29	38	120	149	190	220	559
Middle East	207	21	0	228	543	241	90	874

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

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

186. As TABLE IV-15 shows, most investment in the industry sector (72 per cent globally) comes from domestic sources. This is particularly so in developing and transition economies; in OECD Europe and OECD North America, only 63 per cent and 53 per cent respectively of industrial investment is domestic. FDI provides 22 per cent of the global total, but more in OECD Europe (25 per cent of total) and OECD North America (37 per cent). Debt plays a small role, and is concentrated in developed countries, while ODA barely registers as a source of industrial investment.

4.4.2.4. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE REFERENCE SCENARIO

187. As summarized in TABLE IV-16, investment in the industry sector increases under the reference scenario along with the pace of economic growth. Significant investment occurs in non-Annex I Parties, accounting for 52 per cent of the global total, 6 per cent more than OECD countries. As is currently the case, a large majority of the investment is expected to come from domestic sources.

188. The additional investment needed in 2030 for further energy efficiency improvement, CCS and destruction of non-CO_2 emissions from industrial processes to meet the mitigation scenario is shown in TABLE IV-17. Of the USD 35.7 billion total, USD 19.5 billion is needed for energy efficiency improvement. Installation of CCS infrastructure accounts for around USD 14 billion; the investment for reducing of N_2O and high GWP GHGs is only USD 0.013 billion.

Table IV-15. **Investment flows in the manufacturing sector in 2000, by source and region (percentage)**

	Total Investment	Domestic investment (private & public)	FDI flows	Debt (international borrowings)	ODA Bilateral total	ODA Multilateral total	Total	Total Investment USD billion
Africa	1.2	89.18	6.36	3.34	1.07	0.05	100	16
Developing Asia	18.66	81.35	18.02	0.56	0.07	0	100	243
Latin America	4.56	80.46	15.53	3.84	0.13	0.04	100	59
Middle East	1.07	75.24	24.75	0	0.01	0	100	14
OECD Europe	24.04	62.92	25.35	11.73	0	0	100	313
OECD North America	31.15	55.01	36.57	8.42	0	0	100	405
OECD Pacific	18	99.25	0.05	0.7	0	0	100	234
Other Europe	0.02	-175.61	0	275.61	0	0	100	0
Transition economies	1.29	85.8	14.03	0.05	0.12	0	100	17
Global Total	**100**	**71.93**	**22.09**	**5.95**	**0.03**	**0**	**100**	**1,301**
NAI Parties	34.03	84.14	15.29	0.46	0.09	0.01	100	443
Least Developed Countries	0.33	75.45	11.61	12.27	0.67	0	100	4

Source: Estimations by UNFCCC secretariat based on data from: UNSTAT, National Accounts Database; BIS, 2007; World Bank, 2006, World Development Indicator; OECD, CRS.
Abbreviations: FDI = Foreign direct investment, NAI Parties = Parties not included in Annex I to the Convention, ODA = Official Development Assistance, OECD = Organisation for Economic Co-operation and Development.

Table IV-16. **Investment flows in the industrial sector by region and time period (billions of United States dollars)**

Region	2002	2005	2010	2015	2020	2025	2030
Africa	25	20	28	36	45	56	71
Developing Asia	276	443	668	874	1,066	1,238	1,406
Latin America	88	34	44	53	61	69	79
Middle East	45	14	36	42	55	74	100
OECD Europe	313	243	291	369	417	452	431
OECD North America	323	372	426	481	543	586	628
OECD Pacific	160	251	258	342	363	387	411
Transition Economies	38	21	28	35	41	47	54
World	1,268	1,397	1,779	2,232	2,592	2,911	3,179

Source: OECD ENV-Linkage Model.
Abbreviations: OECD = Organisation for Economic Co-operation and Development.

Table IV-17. **Additional investment flows needed under the mitigation scenario in 2030 in the industrial sector (millions of United States dollars)**

Country/region	Energy-related investment	CH_4 reduction	N_2O reduction	High GWP GHG reduction	CCS	Total
World	19,500	2,028	9	4	14,125	35,665
OECD	11,500	487	5	2	2,052	14,047
OECD North America	5,115	316	2	1	626	6,059
United States	3,899	125	2	1	561	4,587
Canada	750	23	0	0	49	823
Mexico	465	168	0	0	16	649
OECD Pacific	2,340	70	0	1	798	3,209
Japan	1,194	2	0	0	550	1,747
Korea	822	8	0	0	177	1,008
Australia and New Zealand	324	59	0	0	70	453
OECD Europe	4,045	102	3	0	629	4,779
Transition economies	1,061	369	0	0	804	2,234
Russia	596	157	0	0	260	1,013
Other EIT	465	212	0	0	544	1,222
Developing Countries	6,939	1,171	3	2	11,269	19,384
Developing Asia	4,887	691	2	1	10,691	16,273
China	3,157	421	2	1	8,621	12,202
India	727	154	0	0	982	1,863
Indonesia	202	41	0	0	214	457
Other Developing Asia	802	75	0	0	875	1,751
Latin America	798	125	1	0	278	1,202
Brazil	393	21	0	0	199	614
Other Latin America	405	104	0	0	80	588
Africa	410	217	0	0	275	902
Middle East	844	139	0	0	24	1,008

Abbreviations: CCS = carbon dioxide capture and storage, EIT = Economies in transition, GHG = Greenhouse gas, GWP = Global warming potential, OECD = Organisation for Economic Co-operation and Development, CH_4 = methane, N_2O = nitrous oxide.

Box IV-3. **Summary of investment and financial flows for industry**

Investment and financial flows needed in 2030

The additional global investment needed under the mitigation scenario is approximately USD 35.7 billion, of which more than half accounts for energy efficiency improvement. Installation of CCS infrastructure accounts for around USD 14 billion. Approximately 54 per cent of the additional investment will be needed in developing countries, 39 per cent in OECD countries and the rest by transition economies.

Current investment and financial flows

Most investment mostly comes from domestic sources (more than 75 per cent). This is particularly so in developing countries and transition economies; in OECD countries, only approximately 50 – 60 per cent of industrial investment is domestic. FDI provides 22 per cent of the global total, but again is heavily weighted towards OECD countries (25 – 27 per cent). Debt plays a small role and is concentrated in developed countries, while ODA hardly registers as a source of industrial investment.

4.4.2.5. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

189. In industry, investment in energy efficiency and emission reduction measures is generally self-financed, although external financial incentives are sometimes available. The energy efficiency measures assumed have very short payback periods (less than four years).

190. Achieving the projected emission reductions in the industrial sector will require:

- Aggressive policies to increase energy efficiency and emissions reductions. Such policies could include mandatory energy efficiency standards, emissions regulations, emissions trading systems for industrial sources, and, in non-Annex I Parties, clean development mechanism (CDM) projects;
- Regulations and/or incentives to adopt CCS. The technological challenges, legal aspects, costs and other issues will also need to be addressed.

191. These are challenges for both Annex I and non-Annex I Parties, since almost half of the projected investment is expected to occur in non-Annex I Parties. Non-Annex I Parties may need to financial incentives or assistance with national policies to address these challenges.

192. The feasibility of reducing industrial emissions levels to those under the mitigation scenario is high, as emissions are easy to track, most GHG emitters are large and economically rational, abatement measures do not usually have an impact on consumers' lifestyles, and non-CO_2 gases are limited and easily identifiable (Vattenfall, 2007a). Additionally, most financing for industrial efficiency improvements is internal. However, the majority of the mitigation opportunities exist in China and other developing countries, where the initial financial investment and knowledge and availability of advanced technologies are often lacking. As a result, additional mechanisms will be needed to stimulate industrial investment to reduce emissions in these countries.

193. Internationally, the key regulatory mechanism required is to ensure that CO_2 abatement opportunities are pursued in the industrial sector is a stable financial incentive to invest in low GHG emitting technology, such as a CO_2 price. A global CO_2 price would be best, as regional differences could cause distortions. Financial incentives to reduce the capital cost of more efficient equipment and to provide incentives for small-scale CCS technologies would also be useful (Vattenfall, 2007a; IEA, 2006). To reduce non-CO_2 industrial emissions, a cap and trade system or performance standards are likely to be more efficient than technology standards, as they would spur innovation and stimulate the large number of diverse measures needed for abatement (Vattenfall, 2007a). Clear international incentives will be needed to ensure that China and non-industrialized countries achieve their abatement potential (Vattenfall, 2007a).

194. In developing countries specifically, international collaboration and technology transfer are extremely important for driving higher energy efficiency. Small-scale local industrial operations often use outdated processes and low quality fuel and feedstock, and suffer from weaknesses in transport infrastructure (IEA, 2006). As a result, there is a significant potential for energy efficiency improvement, but specific policies tailored to the industry and location are required (IEA, 2006). All of these activities should be strongly supported by IFIs, development assistance programmes and international carbon markets through the CDM (IEA, 2006).

4.4.3. TRANSPORTATION

4.4.3.1. INTRODUCTION

195. Motorization of transport and rates of automobile ownership are increasing rapidly in developing countries experiencing strong economic growth. Vehicle travel continues to grow steadily in developed and developing economies, and economic globalization is driving increases in international shipping and air transport. Investments made over the next two decades in transport equipment and infrastructure, energy efficient technologies, biofuels and R&D and demonstration will have a major influence on the level of GHG emissions from the transportation sector in 2030, and beyond.

196. Transport, as defined in this paper, includes passenger and freight movements by road vehicles, railways, aircraft, and both inland and maritime vessels. For aircraft and marine transport, both domestic and international energy use and emissions are included.

4.4.3.2. ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

RECENT TRENDS IN ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

197. In 2004, transport consumed 1,969 Mtoe of energy, a quarter of the world's final energy consumption. Petroleum dominates energy use by transport, accounting for 94 per cent of total energy consumption in the transport sector and 58 per cent of the world's oil consumption. Biofuels accounted for only 15 Mtoe (0.8 per cent), and all other energy sources (mostly electricity and natural gas) accounted for 93 Mtoe (4.7 per cent) (IEA, 2006).

198. Transport emitted about 14 per cent of global GHGs, 5.8 Gt CO_2 eq in 2004 nearly all of which was CO_2 (Vattenfall, 2007b). It accounts for one fifth of energy-related CO_2 emissions (IEA, 2006).[22] Although the IPCC AR4 WG III indicates that non-CO_2 emissions account for 4 – 12 per cent of total GHG emissions in the transport this analysis focuses on transport's energy-related CO_2 emissions.[23]

199. Road transport, including passenger and freight, is responsible for almost three quarters (73 per cent) of the sector's energy use and CO_2 emissions, followed by air transport (12 per cent), marine transport (10 per cent), rail (4 per cent) and all other modes (1 per cent) (Vattenfall, 2007b). The volume of road transport and its mode distribution varies widely across regions. In 2000, North America and Western Europe had 50 per cent higher miles per vehicle of road travel than the rest of the world combined. This situation is changing rapidly as vehicle ownership increases in developing and transitional economies. Two and three-wheel motor vehicles account for significant share of road traffic in Eastern Europe, Latin America, Japan and South and Southeast Asia. Light trucks account for a large share of road traffic in the America.

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS UNDER THE REFERENCE SCENARIO

200. Under the reference scenario total energy consumption in the transport sector is projected to be 3,111 Mtoe in 2030. Petroleum remains the dominant source of energy for transportation. Biofuel use increases from 15 to 92 Mtoe, but this still represents only 3 per cent of world transport energy use in 2030. Other energy sources, including electricity and natural gas actually decrease in relative importance. Transport CO_2 emissions increase from just over 5.5 Gt CO_2 in 2005 to 8.7 Gt CO_2 in 2030. Emissions increase in all regions but by far the greatest increases occur in the developing economies.

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS UNDER THE MITIGATION SCENARIO

201. The mitigation scenario relies on increased use of hybrid electric vehicles and bio-fuels, and further vehicle efficiency improvements. The market share for hybrid vehicles rises from 18 per cent under the reference scenario to 60 per cent under the mitigation scenario, along with a doubling of biofuel use and further improvement on efficiency of internal combustion engine. As a result, the energy consumption in transport sector drops by 447 Mtoe to 2,664 Mtoe in 2030.

202. Although petroleum remains the dominant source of energy for transportation, its share drops to 83 per cent under the mitigation scenario. Biofuel use in transport increases greatly in OECD countries from 9 Mtoe in 2005 to 169 Mtoe in 2030. In developing countries and transition economies, biofuel use grows from 6 to 125 Mtoe. While most of the growth occurs in Brazil, there are also significant increases in India, Indonesia, China, and other developing Asia countries.

[22] As might be expected with such estimates, there are some differences in the data characterizing the transportation sector. To maintain consistency throughout the full document, the IEA estimates have been adopted.

[23] Although various studies give some consideration to N_2O and F-gases from mobile air conditioning, non-CO_2 emissions from transport, especially those from aircraft, are relatively less well understood and could be of increasing concern (IPCC, 2007c, chapter 5, box 5.1).

203. Transport CO_2 emissions increase from their current level, driven by the growth of motorized transport in developing economies, but the 2030 total is 2 Gt lower than it would be under the reference scenario. Most of the reductions are achieved in developing countries, where transport is growing fastest, and in OECD North America, which has the largest stock of vehicles.

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

204. TABLE IV-18 provides an estimated total global investment in transport in 2000 to be USD 889 billion, of which 66 per cent was domestic finance, 17 per cent was FDI and 17 per cent was international debt finance. In the five largest developing countries (China, India, Mexico, South Africa and Brazil) domestic finance accounted for more than 90 per cent of transport investment, FDI for approximately 8 per cent and international debt and ODA for less than 1 per cent.

205. In 2000, most of ODA for the transport sector (USD 8.2 billion) went to developing Asia, Latin America and Africa. In Africa excluding South Africa, the ODA amounted to 10 per cent of total transport investment in 2000. Developing Asia received 65 per cent of the total transport ODA. Total transport ODA is approximately half bilateral and half multilateral. The USD 8.2 billion total represented 4 per cent of the USD 211 billion of investment made in developing economies during 2000.

206. A number of projects of the GEF have addressed energy efficiency or alternative fuels in the transport sector. In 2006, a total of 16 energy efficiency projects in the transportation sector had been funded and six more were in the pipeline, with a total funding of USD 147 million. Over the same period, six alternative fuels projects were funded or in the pipeline, with a total funding level of USD 27 million (GEF Secretariat, 2007).

4.4.3.4. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE REFERENCE SCENARIO

207. An estimate for total transport sector investment under the reference scenario was obtained from the OECD ENV-Linkages model. The global investment

Table IV-18. **Investment flows in the transportation, storage and communications sector in 2000, by source and region (percentage)**

	Total Investment	Domestic investment (private & public)	FDI flows	Debt (international borrowings)	ODA Bilateral total	ODA Multilateral total	Total	Total Investment USD billion
Africa	1.66	85.87	3.89	3.71	3.26	3.27	100.0	15
Developing Asia	15.06	90.10	2.43	3.43	2.06	1.98	100.0	134
Latin America	6.05	51.24	40.71	6.13	1.63	0.29	100.0	54
Middle East	2.57	98.59	0.50	0.57	0.18	0.16	100.0	23
OECD Europe	25.96	0.00	48.25	51.73	0.02	0.00	100.0	231
OECD North America	29.04	89.64	3.49	6.77	0.00	0.10	100.0	258
OECD Pacific	17.84	97.23	0.47	2.30	0.00	0.00	100.0	159
Other Europe	0.03	-140.42*	0.00	240.42	0.00	0.00	100.0	0
Transition economies	1.79	87.16	11.25	0.00	1.30	0.28	100.0	16
Global Total	**100.00**	**65.53**	**16.73**	**16.83**	**0.50**	**0.41**	**100.0**	**889**
AI Parties	70.94	77.53	0.26	22.20	0.01	0.01	100.0	630
NAI Parties	27.95	86.43	8.85	1.54	1.74	1.44	100.0	248
Least Developed Countries	0.54	68.21	9.10	0.00	11.90	10.80	100.0	5

Source: Estimations by UNFCCC secretariat based on data from: UNSTAT, National Accounts Database; BIS, 2007; World Bank, 2006, World Development Indicator; OECD, CRS.
Abbreviations: AI Parties = Parties included in Annex I to the Convention, FDI = Foreign direct investment, NAI Parties = Parties not included in Annex I to the Convention, ODA = Official Development Assistance, OECD = Organisation for Economic Co-operation and Development.

estimated by the OECD for 2002 (USD 1.14 trillion) shown in TABLE IV-19 is approximately 28 per cent greater than the USD 0.89 trillion for 2000 reported in TABLE IV-18. In part this can be attributed to differences in the definitions of transport, but it must be chiefly attributed to different data sources and estimation methods. The vast majority of investment is for "trade & transport", a category that includes infrastructure investments as well as all other transport equipment not considered road vehicles.

208. Under the reference scenario, global investment in motor vehicles would increase from USD 91 billion in 2005 to USD 209 billion in 2030, reflecting the expected growth in world motor vehicle supply and demand. The largest increases are expected in China, Japan, and East Asia; in Europe and North America the rates increase more slowly but the investment is still substantial. Gross investment in transport and trade grows from USD 1.5 trillion to USD 4 trillion over the same period. The greatest increases come in China and India, but there are substantial requirements for increased investment throughout the world.

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE MITIGATION SCENARIO

209. The total additional investment in transport in 2030 under the mitigation scenario is estimated USD 88 billion, of which USD 9.2 billion is for bio-fuel production and the balance mainly for more costly hybrid electric vehicles (see TABLE IV-20).

Table IV-19. **Projected transport-related investments under the reference scenario (billions of United States dollars)**

	2002	2005	2010	2020	2030
Motor vehicles	69	91	113	162	209
Petroleum and coal products	23	17	19	21	24
Trade and transport services	1,138	1,509	2,005	2,955	4,034
Total	**1,230**	**1,617**	**2,137**	**3,138**	**4,267**

Source: OECD ENV-Linkage Model.

Table IV-20. **Estimated share of additional investment in the transportation sector under the mitigation scenario in 2030, by region (billions of United States dollars)**

Country/region	Energy efficiency and vehicle	Biofuel
World	**78.7**	**9.2**
OECD	**41.9**	**5.2**
OECD North America	25.3	2.4
United States	21.1	2.3
Canada	1.8	0.1
Mexico	2.4	0.0
OECD Pacific	5.2	0.1
Japan	2.5	0.0
Korea	1.5	0.0
Australia and New Zealand	1.2	0.0
OECD Europe	11.3	2.7
Transition Economies	**5.3**	**0.0**
Russia	3.6	0.0
Other EIT	1.7	0.0
Developing Countries	**31.5**	**4.0**
Developing Asia	18.9	1.6
China	10.6	0.8
India	2.0	0.2
Indonesia	1.7	0.2
Other Developing Asia	4.7	0.4
Latin America	4.6	2.0
Brazil	2.2	2.0
Other Latin America	2.5	0.0
Africa	3.6	0.3
Middle East	4.3	0.0

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

Box IV-4. **Summary of investment and financial flows for transport**

Investment and financial flows needed in 2030
The worldwide additional investment needed under the mitigation scenario is approximately USD 88 billion, of which USD 79 billion is for hybrid vehicles and efficiency improvements in vehicles and about USD 9 billion for biofuels. Of the total additional investment needed, developing countries and OECD countries account for approximately 40 per cent and 54 per cent respectively.

Current investment and financial flows
About two thirds of the investment is financed domestically, one sixth from FDI and one sixth is financed from international debt. In China, India, Mexico, South Africa and Brazil domestic investment provided more than 90 per cent of transport investment. In 2000, most of the ODA for the transport sector went to developing Asia, Latin America and Africa.

4.4.3.5. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

210. Nearly all additional transport investment needed under the mitigation scenario is for the purchase of motor vehicles and production of transport fuels; most of this investment will be made by the private sector. There will be no significant change to large transport infrastructure investments between the reference and mitigation scenarios, such as roads, transport systems, airports, and ports, in which governments usually invest in.

211. Increased use of bio-fuels as blends with conventional fuels will need to be driven by policies. Biofuel production and consumption are likely to be co-located, as a general rule.

212. The shift to hybrid vehicles projected under the mitigation scenario will require government policies such as vehicle efficiency standards or other policies to raise the market share of hybrid vehicles. Vehicle buyers are unlikely to voluntarily pay the added cost, about USD 1,000 per vehicle. Given the rapid growth of vehicle ownership in non-Annex I Parties, they will need to adopt such policies as well. Many developing economies will not have domestic capacity for vehicle production but will record increased spending on vehicle purchases under such policies. These countries will also require investment in physical and human capital for repairing and maintaining advanced technology vehicles.

213. International funding sources such as the GEF, ODA and the CDM have thus far had minimal impact on GHG emissions in supporting mitigation in the transport sector. It does not appear likely that the CDM will provide adequate financing for transportation mitigation in developing economies (Dave *et al.*, 2005). Transport CDM projects have been slow to get started and are too few in number to have the necessary impact. These international funding sources would have to be increased by an order of magnitude or more to contribute a meaningful share of the estimated future investment needs for transport mitigation.

214. Although ODA currently constitutes a significant source of fund for transport (USD 10 billion per year), it is directed to a wide range of transportation unconnected to GHG mitigation. By continuing and expanding on efforts to bring climate change strategies into transport sector ODA, the role of ODA in meeting the mitigation scenario for the transport sector might be significant.

215. Most of the investment in transport mitigation in developed and developing economies will, however come from the private sector.

216. Investment flows for transport mitigation will have to be increased greatly if the emission reductions of the mitigation scenario are to be met. This will require appropriate policies in both developed and developing countries. In the developed countries, the investment requirements for mitigation are not large in relation to investment in the transport sector and it seems very likely that funding will be forthcoming, especially given the savings in energy expenditures that can be achieved by more energy efficient transport. In contrast, securing mitigation investment in the developing world will be difficult.

4.4.4. BUILDINGS

4.4.4.1. INTRODUCTION

217. The buildings sector includes residential floor space and all commercial or service activities of the economy. Most fuel use and emissions in the buildings sector result from the combustion of fossil fuels for space and water heating. Much of the increased energy demand in this sector has been for electricity as a result of significant increases in the number of appliances, computers and cooling (HVAC) technologies over the last few decades (the number of appliances per European household has increased tenfold over the past 30 years).

4.4.4.2. ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

RECENT TRENDS IN ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

218. Globally, 2,296 Mtoe energy was consumed by the building sectors in 2004 (see TABLE IV-21). Fossil fuel consumption is the source of direct emissions from building sector, of which OECD countries are responsible for 64 per cent and developing countries for 25 per cent. In terms of CO_2 emissions, OECD countries are again the largest emitters, at 62 per cent of emissions, with developing countries producing only 27 per cent.

Table IV-21. **Fuel consumption and GHG emissions of the buildings sector in 2000**

Country/region	Fuel Consumption (Mtoe) Fossil fuels	Electricity	Non-fossil fuels	Total	Emissions (Mt CO_2) (All combustion)
World	954	561	781	2,296	2,574
OECD	615	415	60	1,089	1,595
OECD North America	285	230	20	534	709
United States	241	202	12	455	597
Canada	34	23	2	58	86
Mexico	10	5	6	21	26
OECD Pacific	85	63	2	150	234
Japan	58	45	0	103	162
Korea	22	9	0.1	31	60
Australia and New Zealand	5	9	2	16	12
OECD Europe	245	122	38	405	652
Transition Economies	105	32	10	147	274
Russia	60	18	2	80	159
Other EIT	45	14	8	68	115
Developing Countries	234	114	712	1,060	704
Developing Asia	145	55	506	707	467
China	84	20	213	318	286
India	31	8	179	218	97
Indonesia	13	4	40	56	36
Other Developing Asia	18	23	75	116	49
Latin America	28	27	26	81	73
Brazil	8	14	7	29	21
Other Latin America	20	14	19	52	51
Africa	19	12	179	210	53
Middle East	42	20	0	62	111

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

219. The largest contributor to CO_2 emissions is space heating and ventilation (36 per cent of total), followed by lighting (16 per cent), residential appliances (15 per cent), water heating (13 per cent), commercial appliances (9 per cent), and air conditioning (8 per cent) (Vattenfall, 2007c). The commercial sector has a higher CO_2 intensity than the residential sector, due to a larger share of electricity and lower share of renewables in its fuel mix (Vattenfall, 2007c).

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSION UNDER THE REFERENCE SCENARIO

220. TABLE IV-22 shows the projected fuel consumption and GHG emission of the buildings sector per region in 2030 under the reference scenario. Fuel consumption in the buildings sector is projected to rise by 43 per cent between 2005 and 2030 under the reference scenario. Electricity use rises by 86 per cent, propelled by a 226 per cent increase in developing countries. Energy end-use technologies are assumed to become gradually more efficient (IEA, 2006), but because the lifetime of buildings is several decades or longer, some more efficient technologies are slow to penetrate the market. The residential sector is responsible for approximately three quarters of buildings sector emissions and the commercial sector is responsible for approximately one quarter of emissions, with these proportions staying constant throughout the period (Vattenfall, 2007c).

Table IV-22. **Fuel consumption and GHG emissions of the buildings sector in 2030, under the reference scenario**

	Fuel Consumption (Mtoe)				
Country/region	Fossil fuels	Electricity	Non-Fossil fuels	Total	Emissions (Mt CO_2)
World	1,500	1,322	1,146	3,968	4,089
OECD	**751**	**691**	**159**	**1,601**	**1,932**
OECD North America	337	388	37	762	847
United States	274	337	27	637	687
Canada	46	35	3	84	112
Mexico	17	15	7	40	48
OECD Pacific	109	102	17	228	297
Japan	66	59	6	132	190
Korea	33	26	3	61	82
Australia and New Zealand	10	17	8	35	25
OECD Europe	304	202	105	611	788
Transition Economies	**177**	**57**	**122**	**355**	**459**
Russia	89	28	89	206	233
Other EIT	88	29	32	149	226
Developing Countries	**573**	**574**	**865**	**2,012**	**1,697**
Developing Asia	354	379	548	1,281	1,078
China	208	197	203	607	638
India	74.0	91	196	361	234
Indonesia	28	21	50	98	81
Other Developing Asia	44	70	100	215	126
Latin America	63	62	30	156	177
Brazil	15	23	13	51	45
Other Latin America	49	38	18	105	133
Africa	54	58	284	396	164
Middle East	101	75	3	179	278

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

221. The main drivers of increased buildings sectors emissions are: floor space growth (64 per cent residential growth by 2030) (driven by population and GDP growth, a growing service sector, and the continued rise of the information economy (WBCSD, 2006); increasing demand for electric appliances; and a fuel shift to electricity (such as for water heating in developing countries) (Vattenfall, 2007c and IEA, 2006).

ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSION UNDER THE MITIGATION SCENARIO

222. Table IV-23 shows the projected fuel consumption and GHG emission of the buildings sector per region in 2030 under the mitigation scenario. Under the mitigation scenario, electricity use drops by 22 per cent compared with the reference scenario in 2030 and fuel use is reduced by 13 per cent, which cuts emissions during 2030 by 0.5 Gt CO_2 (19 per cent). OECD countries are responsible for 40 per cent of the total emission reductions, with China contributing 20 per cent. The largest proportional decline in emissions occurs in India, where CO_2 emissions fall by 34 per cent in 2030 compared with the reference scenario.

223. The largest contributing factor in the reduction in electricity use is the use of more efficient appliances, both in OECD and non-OECD countries, with improved air conditioning efficiency (primarily in non-OECD countries), better insulation, and improved lighting efficiency (primarily in OECD countries) also significant factors (IEA, 2006).

Table IV-23. Fuel consumption and greenhouse gas emissions of the buildings sector in 2030, under the mitigation scenario

	Fuel Consumption (Mtoe)				
Country/region	Fossil fuels	Electricity	Non-fossil fuels	Total	Emissions (Mt CO_2)
World	1,302	1,034	1,045	3,380	3,535
OECD	**663**	**555**	**194**	**1,412**	**1,711**
OECD North America	306	319	41	665	772
United States	247	278	30	555	624
Canada	42	29	3	74	103
Mexico	16	12	7	36	45
OECD Pacific	98	83	22	202	267
Japan	60	48	8	117	173
Korea	28	20	4	52	71
Australia and New Zealand	9	14	10	33	23
OECD Europe	259	154	132	545	672
Transition Economies	**150**	**45**	**113**	**308**	**390**
Russia	75	21	83	179	197
Other EIT	75	23	30	129	193
Developing Countries	**489**	**434**	**738**	**1,660**	**1,434**
Developing Asia	294	280	454	1,028	880
China	176	148	159	482	531
India	52	73	172	298	160
Indonesia	26	16	45	87	76
Other Developing Asia	40	42	78	160	113
Latin America	56	48	31	135	158
Brazil	14	18	12	43	41
Other Latin America	43	30	19	91	117
Africa	49	47	245	342	149
Middle East	90	59	8	157	247

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

224. Efficiency standards allow the efficiency of equipment in non-OECD countries to approach the level of efficiency currently attained in OECD countries (IEA, 2006). Stricter building codes reduce oil and gas demand for space heating in OECD countries and solar power use doubles, primarily for water heating (IEA, 2006).

225. For the residential and the commercial sectors, the largest emission mitigation measures address heating and ventilation, including improvements to the building envelop (façade, roof and floor insulation), efficiency improvement to water heating and air conditioning. Other significant measures are improving lighting efficiency in residential buildings and improving the efficiency of other appliances and reducing standby losses (Vattenfall, 2007c).

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

226. As TABLE IV-24 shows, the vast majority of commercial and residential buildings investment (97 per cent globally) are domestic, with the exception of the Middle East, where 46 per cent GFCF comes from debt. ODA to the buildings sector is virtually zero.

Table IV-24. **Investment flows in the construction sector by source and region in 2000 (percentage)**

Region	Total Investment	Domestic investment (private & public)	FDI flows	Debt (international borrowings)	ODA Bilateral total	ODA Multilateral total	Total	Total Investment USD billion
Africa	1.80	99.72	0.28	0.00	0.00	0.00	100.0	8
Developing Asia	26.01	98.46	1.54	0.00	0.00	0.00	100.0	114
Latin America	4.14	98.76	0.97	0.28	0.00	0.00	100.0	18
Middle East	0.42	49.79	3.87	46.34	0.00	0.00	100.0	2
OECD Europe	14.36	87.43	3.25	9.32	0.00	0.00	100.0	63
OECD North America	36.94	99.09	0.17	0.74	0.00	0.00	100.0	162
OECD Pacific	15.16	97.95	0.93	1.12	0.00	0.00	100.0	66
Other Europe	0.02	100.00	0.00	0.00	0.00	0.00	100.0	0
Transition Economies	1.14	97.35	2.65	0.00	0.00	0.00	100.0	5
Global Total	100.00	96.85	1.16	1.99	0.00	0.00	100.0	438
AI Parties	51.31	95.56	1.28	3.16	0.00	0.00	100.0	225
NAI Parties	47.71	98.93	0.75	0.33	0.00	0.00	100.0	209
Least Developed Countries	0.88	98.80	1.20	0.00	0.00	0.00	100.0	4

Source: Estimations by UNFCCC secretariat based on data from: UNSTAT, National Accounts Database; BIS, 2007; World Bank, 2006, World Development Indicator; OECD, CRS.
Abbreviations: AI Parties = Parties included in Annex I to the Convention, FDI = Foreign direct investment, NAI Parties = Parties not included in Annex I to the Convention, ODA = Official Development Assistance, OECD = Organisation for Economic Co-operation and Development.

4.4.4.4. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE REFERENCE SCENARIO

227. Projected investment by region during 2005 – 2030 in the residential and commercial buildings sector is shown in TABLE IV-25. Investment grows at 5 – 7 per cent per year in developing country regions, reflecting the rapid population and economic growth, urbanization and rising per capita incomes. In OECD regions, the growth rate is less than 3 per cent per year.

228. As in the current situation, almost all investment in the buildings sector is expected to come from domestic sources.

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE MITIGATION SCENARIO

229. As shown in TABLE IV-26, in 2030, USD 51 billion of additional investment will be needed worldwide in the buildings sector to meet the mitigation scenario emission levels, of which USD 14.1 billion (28 per cent) would be needed in non-Annex I Parties.

Table IV-25. **Investment flows in the residential and commercial sector by region and time period (billions of United States dollars)**

Region	2005	2010	2015	2020	2025	2030	Annual growth rate (per cent)
Africa	33	49	67	91	123	167	6.70
Developing Asia	432	770	1,069	1,422	1,861	2,383	7.10
Latin America	88	117	158	201	250	306	5.10
Middle East	42	88	144	200	266	343	8.80
OECD Europe	1,154	1,527	1,850	2,156	2,475	2,340	2.90
OECD North America	1,754	2,135	2,491	2,830	3,252	3,723	3.10
OECD Pacific	898	1,142	1,228	1,423	1,580	1,733	2.70
Transition Economies	38	66	91	121	156	197	6.80
World	4,438	5,894	7,097	8,444	9,962	11,191	3.80

Source: OECD ENV-Linkage Model.
Abbreviations: OECD = Organisation for Economic Co-operation and Development.

Table IV-26. **Additional investment needed in the buildings sector under the mitigation scenario in 2030 (billions of United States dollars)**

Country/region	Energy efficiency
World	50.8
OECD	34.2
OECD North America	16.3
United States	13.6
Canada	1.8
Mexico	0.9
OECD Pacific	4.9
Japan	2.8
Korea	1.3
Australia and New Zealand	0.8
OECD Europe	13.0
Transition Economies	2.5
Russia	1.4

Country/region	Energy efficiency
Other EIT	1.0
Developing Countries	14.1
Developing Asia	9.0
China	4.3
India	2.5
Indonesia	0.7
Other Developing Asia excluding China, India and Indonesia	1.5
Latin America	1.1
Brazil	0.4
Other Latin America	0.7
Africa	2.8
Middle East	1.3

Box IV-5. **Summary of investment and financial flows for buildings**

Investment and financial flows needed in 2030	Current investment and financial flows
The additional global investment needed under the mitigation scenario for energy efficiency improvement is about USD 51 billion of which approximately 28 per cent is needed in developing countries, 67 per cent in OECD countries and rest in transition economies.	The vast majority of commercial and residential buildings investment (97 per cent globally) are domestic, with the exception of theMiddle East, where 46 per cent of investment comes from international debt. ODA to the buildings sector is virtually zero.

230. Most emission reductions in the buildings sector result from increased efficiency of appliances, space and water heating and cooling systems, and lighting. There is also a fuel-shift away from fossil fuels and electricity, and towards biomass and waste. Within this sector, financing for CO_2 eq abatement projects generally comes from the private sector or from consumers themselves (IEA, 2006).

4.4.4.5. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

231. Most investment in commercial and residential energy efficiency comes from the building owner and is financed domestically. Most of the measures assumed have a very quick payback period (less than four years).

232. Aggressive policies, in particular stringent mandatory efficiency standards for appliances, equipment, and buildings, will be needed to overcome the recognized barriers to the adoption of cost-effective efficiency measures. These policies will be needed in non-Annex I Parties as well. Non-Annex I Parties may need access to financial incentives or assistance to develop and implement such policies.

4.4.5. WASTE

4.4.5.1. INTRODUCTION

233. The waste sector includes both landfills and wastewater. The major GHG emissions from landfills and wastewater treatment is methane (CH_4). Produced by anaerobic degradation of organic matter, the methane is often used to power sewage treatment processes or to co-generate electricity. N_2O is also emitted during wastewater processing. Energy-related emissions of waste are not considered in this sector, since most energy consumption is covered elsewhere. For example, much of the energy used to move waste material is probably recorded in the transportation sector as freight.

4.4.5.2. GREENHOUSE GAS EMISSIONS

RECENT TRENDS IN GREENHOUSE GAS EMISSIONS

234. Global emissions of CH_4 and N_2O from waste in 2000 were 1.18 Gt CO_2 eq and 95 Mt CO_2 eq respectively. Of the total CH_4 emissions, landfills were responsible for 58 per cent while wastewater contributed the remaining 42 per cent (US EPA, 2006b).

235. The vast majority of emissions in developing countries come from untreated wastewater in latrines and open sewers; over 80 per cent of domestic wastewater is uncollected and untreated in large portions of China/ centrally planned Asia, south and east Asia and Africa, with the situation worse in rural areas. Septic tanks are the largest contributor of GHG emissions from wastewater in the United States (US EPA, 2006b).

236. Developing countries contribute 53 per cent of global CH_4 emissions, with China responsible for 14 per cent and India for 10 per cent. The United States is the largest global emitter (15 per cent) of emissions. In terms of N_2O emissions, the OECD and developing countries are equal contributors, with the United States emitting 21 per cent and China 20 per cent of the global total.

GREENHOUSE GAS EMISSIONS UNDER THE REFERENCE SCENARIO

237. Emissions in the waste sector are projected to rise by 17 per cent between 2005 and 2030 under the reference scenario. They fall by 1 per cent in OECD countries, but rise by 15 per cent in transition economies and by 30 per cent in developing countries. CH_4 emissions from landfills gradually increase under the reference scenario, driven upwards by population growth and increases in personal incomes and expanding industrialization which lead to increased waste generation, particularly in developing countries.

238. Wastewater CH_4 emissions grow much faster than landfill emissions. By 2020, the share of emissions from wastewater has grown from 42 per cent of the total to 45 per cent of the total (US EPA, 2006b). Wastewater N_2O emissions are projected to decrease in several European Union (EU) countries by 2020, but rise quickly in developing countries – particularly in Africa, where they grow by 86 per cent by 2020.

GREENHOUSE GAS EMISSIONS UNDER THE MITIGATION SCENARIO

239. The major GHG abatement opportunity undertaken in the waste sector under the mitigation scenario is capture of CH_4 from landfills and wastewater, and the use of that CH_4 for fuel or electricity production. Within the landfill

Table IV-27. **Greenhouse gas emissions under the reference and mitigation scenarios and additional investment required for the waste sector in 2030**

	Reference scenario Mt CO_2 eq			Mitigation scenario Mt CO_2 eq			
Country/region	**CH_4**	**N_2O**	**Total emissions**	**CH_4**	**N_2O**	**Total emissions**	**Additional Investment USD million**
World	1,420	120	1,540	707	90	797	936
OECD	421	54	475	236	40	277	251
OECD North America	285	25	310	163.61	19	182	163
United States	176	21	197	102	16	118	102
Canada	44	2	46	31	1	32	17
Mexico	65	2	67	31	2	32	45
OECD Pacific	44	12	55	24	9	33	27
Japan	4	10	14	1	8	9	6
Korea	18	1	19	12	1	12	9
Australia and New Zealand	22	1	23	12	1	12	12
OECD Europe	92	17	110	48	13	61	61
Transition Economies	123	6	129	58	5	63	84
Russia	40	3	44	19	2	22	28
Other EIT	83	3	86	39	2	41	56
Developing Countries	876	60	936	413	45	458	600
Developing Asia	542	40	582	256	30	286	358
China	194	22	216	91	17	108	138
India	174	3	177	82	3	84	118
Indonesia	44	3	47	21	3	23	31
Other Developing Asia	130	11	142	61	9	70	71
Latin America	125	8	133	59	6	65	88
Brazil	53	5	58	25	4	29	37
Other Latin America	72	3	75	34	3	36	51
Africa	112	7	119	53	5	58	86
Middle East	97	5	14	46	4	7	67

Abbreviations: EIT = Economies in transition, OECD = Organisation for Economic Co-operation and Development.

sector, CH_4 emissions can also be reduced at the source by reducing the amount of degradable material that enters landfills through reduced initial waste production, and through recycling and composting. Wastewater emissions can be reduced by advanced treatment technologies that use aerobic rather than anaerobic digestion and by filtering out degradable waste.

240. The emission reductions estimated for the mitigation scenario are those that can be achieved at a marginal abatement cost of up to USD 30 per t CO_2 eq using cost curves from the US EPA (US EPA, 2006b). This value was selected because the marginal abatement cost curves rise sharply beyond this point. Thus this value captures virtually all of the potential emission reductions.

241. Waste sector emissions are reduced by almost 50 per cent from the reference scenario level and developing country emissions decline by 30 per cent from current levels rather than increasing at all. Most (approximately 65 per cent) of the abatement opportunities are in developing countries, coincident with the emissions.

4.4.5.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

242. Data on current investment flows for the waste sector are not available. Projected investment in this sector under the reference scenario is also not available.

243. The additional investment needed under the mitigation scenario is calculated using the capital cost from the US EPA marginal abatement cost curves used to estimate the potential emission reductions. The additional investment needed globally is almost USD 1 billion in 2030 and shown in TABLE IV-27. Most of the additional investment occurs in developing countries, coincident with the distribution of waste emissions and reduction opportunities.

Box IV-6. **Summary of investment and financial flows for waste**

The global additional investment needed to reduce CH_4 and N_2O emissions in the waste sector is approximately USD 1.0 billion in 2030. About two third of emission reductions and investment occur in developing countries, a quarter in OECD countries and the balance in transition economies.

4.4.5.4. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

244. Many developed countries are already taking measures to reduce CH_4 emissions from landfills and wastewater treatment, generally because of environmental and public health concerns other than climate change.

245. In many developed countries, actions that reduce methane emissions from landfills and wastewater treatment are likely to be undertaken for environmental and public health concerns. However, most of the abatement opportunities in developing countries still face many barriers to investment access. These include: lack of awareness of and experience in alternative technologies; poor economics at smaller dumps and landfills; limited infrastructure for natural gas use in some regions; lack of even rudimentary disposal systems at many dumps; and difficulties bringing together the many actors involved in energy generation, fertilizer supply and waste management.

246. To overcome these barriers, a combination of several measures is necessary, including institution building and technical assistance policies, voluntary agreements, regulatory measures and financial assistance. Multilateral and bilateral ODA programmes can play an important role in institution building and technical assistance. Voluntary agreements or public-private partnerships can be set up between governments and utilities to overcome information and knowledge barriers and to identify sites with high mitigation potential. Financial assistance can come from ODA, the carbon market or other sources. The carbon markets improve the economics of these projects appreciably. Over 100 projects, representing almost 10 per cent of the projected emission reductions, were in the pipeline at the end of 2006.

247. The carbon market improves the economics of landfill gas emission reduction projects appreciably. Over 100 projects representing approximately 10 per cent of the projected emission reductions were in the pipeline at the end of 2006. However, the emission reductions achieved are substantially lower than initially estimated.

4.4.6. AGRICULTURE

4.4.6.1. INTRODUCTION

248. Agricultural lands, comprising arable land, permanent crops and pasture, cover about 40 per cent of the earth's land surface (United Nations Food and Agriculture Organization, FAOSTAT, 2007), and these lands are expanding. Most of the agricultural land is under pasture (approximately 70 per cent), and only a small per cent (less than 3 per cent) are under permanent crops.

249. There are two sources of GHG emissions from agriculture:

- Non-CO_2 GHGs from management operations;
- Energy-related CO_2 emissions.

250. In addition, the agricultural sector offers significant opportunities for increased removals by sinks mainly through agroforestry and improved grassland management.

251. Agricultural products, such as biomass energy, bio-plastics and bio-fuel, can reduce GHG emissions by replacing fossil fuel based products. Those opportunities are considered in the sectors where the products are used.

4.4.6.2. GREENHOUSE GAS EMISSIONS AND REMOVALS BY SINKS

RECENT TRENDS IN GREENHOUSE GAS EMISSIONS AND REMOVALS BY SINKS

252. Current global emissions from the agriculture sector are 6.8 Gt CO_2 eq, of which 6.2 Gt CO_2 eq are non-CO_2 emissions from agriculture operations and 0.6 Gt CO_2 eq come from energy use in the agriculture sector.

GREENHOUSE GAS EMISSIONS AND REMOVALS BY SINKS UNDER THE REFERENCE SCENARIO

253. No widely accepted reference scenario of agriculture emissions is available, so the reference scenario is specified for each emission reduction and sink enhancement option analysed for the mitigation scenario. A detailed analysis is provided in CHAPTER IV.4.6.4.

GREENHOUSE GAS EMISSIONS AND REMOVALS BY SINKS UNDER THE MITIGATION SCENARIO

254. The mitigation scenario assumes that cost-effective measures to reduce non-CO_2 emissions are implemented. The emission reductions and the associated financial flows are estimated in CHAPTER IV.4.6.4. The potential for increased removals by sinks through agroforestry and the associated investment flows are also estimated in the same chapter. Options for reducing energy-related CO_2 emissions are not analysed because the level of emission reductions are low relative to the other options.

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

FINANCIAL FLOWS

255. Global government expenditures in agriculture are increasing in real terms by 2.5 per cent annually. In developed countries, government expenditures are approximately 20 per cent of agricultural GDP; they are less than 10 per cent of agricultural GDP on average in developing countries.

INVESTMENT FLOWS

256. The current sources of investment by region in AFF[24] are shown in TABLE IV-28. The vast majority of the investment comes from domestic sources, such as the farmers themselves from their own savings, funds they borrow or government assistance. In developing countries, most of the remaining investment comes from ODA. Developed countries receive some foreign investment in the form of equity or loans.

4.4.6.4. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

INVESTMENT AND FINANCIAL FLOWS NEEDED IN THE REFERENCE SCENARIO

257. TABLE IV-29 shows current and projected GFCF for the agriculture sector by region. The OECD projections for cropping agriculture show rapid and accelerating growth in Africa and the Middle East, moderate growth in most developed countries, emerging economies and transition economies, and declining investments in Japan. In the livestock sub-sector, projections are for high growth in Africa, India, South and South-East Asia, the Middle East, and Turkey. Similar to the cropping sub-sector, projections are for moderate growth in most developed countries, emerging economies and economies in transition, and declining investments in Japan.

[24] OECD ENV-Linkage model has aggregated agriculture, forest and fisheries current investment data into one category.

Table IV-28. **Investment by source for agriculture, forestry and fisheries in 2000 (percentage)**

	Total Investment	Domestic investment (private & public)	FDI flows	Debt (international borrowings)	ODA Bilateral total	ODA Multilateral total	Total	Total Investment USD billion
Africa	5.51	96.16	0.97	0.00	1.79	1.07	100.0	10
Developing Asia	17.95	96.02	2.53	0.00	0.88	0.56	100.0	31
Latin America	9.02	98.53	1.04	0.00	0.39	0.04	100.0	16
Middle East	3.49	99.95	0.00	0.00	0.05	0.00	100.0	6
OECD Europe	35.18	84.79	0.13	15.08	0.00	0.00	100.0	62
OECD North America	13.67	98.52	1.43	0.05	0.00	0.00	100.0	24
OECD Pacific	12.10	98.58	0.81	0.62	0.00	0.00	100.0	21
Other Europe	0.05	100.00	0.00	0.00	0.00	0.00	100.0	0
Transition Economies	3.02	97.60	0.85	0.00	0.23	1.32	100.0	5
Global Total	**100.00**	**93.14**	**0.97**	**5.39**	**0.30**	**0.20**	**100.0**	**175**
NAI Parties	38.65	96.88	1.72	0.19	0.76	0.45	100.0	68
AI Parties	59.64	91.05	0.04	8.91	0.00	0.00	100.0	104
Least Developed Countries	2.42	92.02	2.48	0.00	2.95	2.55	100.0	4

Source: Estimations by UNFCCC secretariat based on data from: UNSTAT, National Accounts Database; BIS, 2007; World Bank, 2006, World Development Indicator; OECD, CRS.
Note: Only aggregated estimates for agriculture, forest and fisheries are available for current investment.

Table IV-29. **Investment flows in the agriculture sector by region and time period (millions of United States dollars)**

	2005	2010	2015	2020	2025	2030
Africa	14,275	12,601	16,204	19,668	23,605	28,074
Australia/New Zealand	3,153	3,871	3,986	4498	5,009	5,483
Brazil	5,311	8,932	9,973	11,277	12,623	14,125
Canada	1,885	3,156	3,515	3,763	4,002	4,301
China	14,205	16,863	19,834	22,763	25,666	28,302
EU-15	7,548	11,672	13,044	14,215	15,137	15,733
India	9,320	11,800	14,299	16,881	19,640	22,457
Japan	4,513	7,673	7,186	7,471	7,606	7,723
Latin America/Caribbean	15,473	17,328	19,899	22,680	25,654	28,970
Mexico	461	2,352	2,120	2,689	3,010	3,219
Middle East	3,619	3,908	5,402	6,658	7,870	9,209
Russia	1,047	1,036	1,224	1,415	1,559	1,652
South & SE Asia	13,862	17,383	20,879	24,651	28,668	32,777
Republic of Korea	192	378	382	397	435	413
Turkey	1,575	2,766	2,979	3,166	3,350	3,534
United States	12,842	15,313	16,907	17,323	18,041	19,035
Global Total	**109,281**	**137,031**	**157,833**	**179,513**	**201,874**	**225,006**

Source: OECD ENV-Linkage Model.

INVESTMENT AND FINANCIAL FLOWS NEEDED IN THE MITIGATION SCENARIO

INVESTMENT AND FINANCIAL FLOWS NEEDED FOR REDUCTION OF NON-CARBON DIOXIDE GREENHOUSE GAS EMISSIONS

258. The US EPA has published two baseline (reference) scenarios for non-CO_2 emissions. The first was generated from national GHG inventories and provides disaggregated data at the country level (US EPA, 2006a). The second scenario (US EPA, 2006b) was generated from some of the same data, but used process models (daily service of century model (DAYCENT) and denitrification decomposition model (DNDC)) to improve the estimates of N_2O emissions from soils and both N_2O and CH_4 emissions from rice cultivation.

259. Both scenarios are presented in five-year increments from 1990 to 2020. The scenarios were extended to 2030 in the analysis based on a reasonable projection of the time series, usually a linear extension. The global totals for both scenarios are shown in TABLE IV-30. The regional distribution of the second scenario is provided in TABLE 9-ANNEX V.

260. The first scenario is useful for making comparisons among countries and regions because the methods are consistent from country to country. The second scenario is more appropriate for assessing the mitigation scenario and the costs associated with mitigation. It is substantially lower than the emissions reported in the national communications, so it may under estimate the potential reductions.

261. The emissions sources for non-CO_2 gases included in both baselines and their approximate share of global emissions are shown in TABLE IV-31. N_2O from soils accounts for about 45 per cent of the total and CH_4 from enteric fermentation accounts for another 30 per cent of the total.

262. A large number of mitigation options for mitigating GHG emissions from agricultural have been suggested. In many cases, production or cost trade-offs need to be understood before proper incentives for the adoption of these practices can be designed. The US EPA constructed marginal abatement curves for different regions and different sectors through 2020. Costs include capital, operation and maintenance costs. The calculation included a tax rate of 40 per cent and used a 10 per cent discount rate. Benefits include the intrinsic value of CH_4 as a natural gas or as fuel for electricity or heat generation, benefits of abatement unrelated to climate change (e.g. improved nutrient use efficiency), and the value of abating the gas given a GHG price.

263. The curves all become steep or even vertical at around USD 30 per t CO_2 eq. Thus, this analysis assumes the reduction available at USD 30 per t CO_2 eq is the maximum economic level of abatement and calculates these mitigation potentials. To construct aggregate abatement curves for agriculture, the cultivated area and number of animals can be held constant or production can be held constant. Approximately 13 per cent of total emissions could be mitigated given constant area and animal numbers. When production is held constant, approximately 16 per cent of non-CO_2 emissions could be mitigated.

264. The measures that reduce these emissions are operational measures that do not require new equipment. The annual cost of implementing the measures on the scale projected is assumed to be the marginal cost of USD 30 per t CO_2 eq. The estimated emission reductions and associated annual financial flows are presented in TABLE IV-32.

ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDS FOR INCREASED REMOVALS BY SINKS

INVESTMENT AND FINANCIAL FLOWS NEEDS FOR AGROFORESTRY

265. A rigorous analysis of the costs and mitigation potential for increased removals by sinks does not presently exist in the literature. The IPCC (2000) Special Report presented an illustration of the potential of removals by sinks to contribute to climate change mitigation. The IPCC scenario is expanded in this analysis to illustrate the potential of increased removals by sinks through agroforestry and the associated investment.

266. Activities that increase CO_2 sinks in tropical agricultural landscapes offer a cost effective means to achieve mitigation objectives. The IPCC scenario suggests that the land area available for agroforestry is 630 million ha and that 40 per cent of this area could be in agroforestry by 2040, at a rate about 19 million ha per year after the first decade. Expanding agroforestry by 19 million ha per year would require an annual investment of approximately USD 15 billion (USD 780 per ha) and operating costs of about USD 8 billion (USD 440 per ha).

Table IV-30. **Reference scenarios for non-carbon dioxide greenhouse gas emissions (Mt CO_2 eq) by source through 2030**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Global total, First scenario	5,343	5,528	5,928	6,291	6,713	7,158	7,648	8,071	8,493
Global total, second scenario	–	–	4,563	4,490	4,417	4,619	4,822	5,025	5,227

Table IV-31. **Approximate shares of non-carbon dioxide greenhouse gas from management operations**

Emissions source	Share of total emissions (percentage)
N_2O from soil	45.5
N_2O from manure management	3.5
CH_4 from enteric fermentation	30.5
CH_4 from manure management	3.5
CH_4 from rice cultivation	10.5
CH_4 from other sources (Savanna burning, burning of agricultural residues, burning from forest clearing, and agricultural soils (CH_4))	6.5

Source: Calculation based on Verchot (2007).

Table IV-32. **Potential total reductions in emissions (Mt CO_2 eq) from agriculture for selected countries and regions with carbon prices at USD 0 and USD 30 per t CO_2 eq, with constant herd size**

Regional distribution	Potential reductions (Mt CO_2 eq) from croplands		Total Cost in USD million	Potential reductions (Mt CO_2 eq) from rice cultivation		Total Cost in USD million	Potential reductions (Mt CO_2 eq) from livestock management		Total Cost in USD million
	2030			2030			2030		
Country/Region	USD 0	USD 30		USD 0	USD 30		USD 0	USD 30	
Africa	4.2	5.4	183	–	–	–	2.3	11.9	403
Brazil	1.4	3.7	125	–	–	–	9.6	16.2	549
Mexico	4.2	9.3	315	–	–	–	2.1	2.1	71
Non-OECD Annex I	35.0	39.6	1,342	–	–	–	4.1	4.1	139
OECD	69.4	89.8	3,044	1.9	10.8	366	36.1	77.7	2,634
Russia	35.0	39.6	1,342	–	–	–	2.5	2.5	85
S&SE Asia	2.5	3.3	112	73.2	115.6	3,919	11.2	19.2	651
Global total	139.6	179.7	6,092	116.2	243.3	8,248	92.4	175.2	5,939
Annex I	109.4	135.0	4,577	0.4	6.3	214	38.1	80.1	2,715
Australia/New Zealand	3.7	4.4	149	–	–	–	4.0	6.8	231
China	6.4	8.1	275	39.7	81.8	2,773	11.0	20.3	688
Eastern	5.8	8.9	302	–	–	0	1.7	1.7	58
EU-15	11.8	12.4	420	–	–	0	12.9	24.5	831
India	4.5	8.9	302	–	34.4	1,166	3.7	7.8	264
Japan	–	–	0	0.4	6.3	214	0.9	0.9	31
United States	44.9	58.6	1,987	–	–	–	10.6	33.5	1,136

Source: Table adapted from US EPA (2006b).

267. In most cases agroforestry systems are more profitable than subsistence agriculture. But resource-poor farmers cannot shift to agroforestry because of the initial costs are not recovered for three to five years. Many farmers lack knowledge about the income potential of agroforestry systems and how to grow the trees. In addition, agroforestry systems are more labour intensive than cropping systems, so labor shortages during peak seasons may inhibit their adoption.

INVESTMENT AND FINANCIAL FLOWS NEEDS FOR GRASSLAND MANAGEMENT

268. IPCC scenario suggested that the land area available for improved grassland management is 3,400 million ha and that it would be possible, with considerable international effort, to have 20 per cent of this area under improved pasture management by 2040, at a rate of about 68 million ha per year after the first decade. No estimate is available for the cost of grassland management measures to increase removals of CO_2 under the scenario.

SUMMARY OF INVESTMENT AND FINANCIAL FLOWS NEEDS

269. TABLE IV-33 summarizes the additional investment and financial flows under the mitigation scenario in 2030 for the measures analysed for the agriculture sector. The additional investment and financial flows needed for the mitigation scenario total about USD 35 billion per year. For livestock and crops 50 – 70 per cent of the additional financial flow is needed in developing countries. A regional split for agroforestry is not available.

Table IV-33. **Summary of investment flows for the reference and mitigation scenarios in 2030 (billions of United States dollars)**

Region	Non-CO_2 crops[a]	Non-CO_2 livestock[a]	Removal by sinks agroforestry[b]	Mitigation scenario
World	14.3	5.9	15	35.2
Annex I	4.8	2.7	N.A.	–
Non-Annex I	9.6	3.2	N.A.	–

Note:

[a] financial flow,
[b] investment flow.

Box IV-7. **Summary of investment and financial flows for agriculture**

Investment and financial flows needed in 2030
In the agriculture sector the global additional investment and financial flows needed under the mitigation scenario total approximately USD 35 billion of which USD 20 billion (financial flow) is non-CO_2 emissions reductions (rice cultivation, cropland practices and livestock management) and USD 15 billion (investment) is for removal by sinks through agroforestry. About 65 per cent of the financial flows for reducing non-CO_2 emissions occur in developing countries.

Current investment and financial flows
In the agriculture sector most of the investment, by far, comes from domestic sources, such as the farmers themselves from their own savings, funds they borrow or government assistance. In developing countries, most of the rest of the investment comes from ODA.

4.4.6.5. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

270. Most of the costs of farm operation are borne by the farmer but financial incentives may be needed to encourage adoption of N_2O and CH_4 emission reduction measures in developing countries.

271. Projects to reduce CH_4 emissions from livestock manure are being implemented under the CDM. Projects to collect and use agricultural waste, such as bagasse and rice husks, are also being implemented under the CDM. The CDM can contribute to reducing the non-CO_2 emissions but it cannot address the full mitigation in agriculture sector because some measures are not eligible and projects need to exceed a minimum size to be economical.

272. In principle, transition from pure agriculture to agroforestry system by planting trees is eligible as a CDM project. But that does not address the initial capital cost barrier of planting trees, or the knowledge and labour supply barriers. Since agroforestry system is more profitable than cropping system, there is a role for mechanisms that provide the initial capital and knowledge and receive a return from a share of the new crops and CDM credits.

4.4.7. FORESTRY

4.4.7.1. INTRODUCTION

273. This chapter focuses on the land in forests at each point in time. It does not include agroforestry, which is addressed in the agriculture sector, bio-energy, which is addressed in the transport and energy supply sectors, or management of wood products. Mitigation options for the forestry sector are reduction of deforestation, better management of productive forest (forest management) and afforestation and reforestation to increase the forest area.

4.4.7.2. GREENHOUSE GAS EMISSIONS AND REMOVALS BY SINKS

RECENT TRENDS IN GREENHOUSE GAS REMOVALS BY SINKS IN THE FORESTRY SECTOR

274. TABLE 10-ANNEX V compares the principal data sets for CO_2 fluxes and forest area losses. Due to differences in methods and scope, values from different data sets are not directly comparable, therefore, the table presents samples of reported results only. The main sources of information for fluxes are those reviewed by IPCC AR4 Working Group III (IPCC, 2007c)[25]. Flux estimates from the Climate Analysis Indicators Tool (CAIT) database[26] of the World Resources Institute (WRI) are also reported. Data on forest area and forest area lost between 2000 and 2005 are from the Food and Agriculture Organisation of the United Nations (FAO) Global Forest Resources Assessment (FRA) 2005 (FAO, 2006). Other estimates of forest area lost and degraded from different sources are also reported.

GREENHOUSE GAS REMOVALS BY SINKS IN THE REFERENCE SCENARIO

275. The forestry section of the IPCC WG III contribution to the Fourth Assessment Report (AR4) found there had been little new effort to develop global baseline scenarios for land-use change and the associated carbon balance against which mitigation options could be examined. Since no suitable scenario for baseline emission for the forestry sector are available, the reference scenario assumes that GHG emissions from the forestry sector in 2030 are the same as in 2004, as estimated at section 11 of the IPCC WG III contribution to the AR4 estimated at 5.8 Gt CO_2 eq. This estimate excludes peat and other bog fires (see TABLE 11-ANNEX V).

GREENHOUSE GAS REMOVALS BY SINKS IN THE MITIGATION SCENARIO

276. The potential of reducing greenhouse gas emissions or enhancing removals by sinks in the forestry sector is estimated as mitigation potential for different mitigation options. A detailed analysis is provided in CHAPTER IV.4.7.4.

[25] According to FAO (2005) equalling 4,000 Mt CO_2 year-1 FAO, 2005: Forest Finance: sources of funding to support sustainable forest management (SFM). Rome: FAO.

[26] The CAIT of the WRI in Washington uses data from: Carbon Dioxide Information Analysis Center (CDIAC), Dutch National Institute of Public Health and the Environment (RIVM), EarthTrends (WRI), Mr. Richard Houghton (Woods Hole Research Center), IPCC, IEA, The World Bank, World Health Organization (WHO).

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

277. Data on the sources of current investment in forestry are aggregated with agriculture and fisheries and are shown in TABLE IV-28 (see CHAPTER IV.4.6 on agriculture). Most of the investment comes from domestic sources. In non-Annex I Parties, most of the rest of the investment comes from ODA.

278. OECD ENV-Linkages model estimates for forestry alone put the total new investment at about USD 23 billion for 2005. Other estimates indicate that FDI into the forestry sector of developing countries has been increasing, while the share of ODA going into forestry has seen a steady decline to about USD 1.75 billion per year (Noble, 2006). Estimates vary, but all agree that FDI considerably exceeds ODA.

279. TABLE IV-34 contains information on selected funding and investment flows in the forestry sector from various sources, without claiming to be comprehensive or complete.

280. Reconciling the available data is a challenge:

- Total investment in AFF in 2000 was about USD 175 billion. OECD model estimates for forestry alone put the total new investment at about USD 23 billion for 2005. The Tomaselli (2006) estimate of USD 63 billion is three times this amount. The Tomaselli figure could include investments to purchase existing assets, such as forest land, and investments in wood products industries;
- Total ODA in 2000 for forestry was about USD 370 million, of which USD 124 million was capital investment. Some of the spending under the IFC and ITTO programmes could be included in the ODA total. The ITTO spending includes very little capital investment;
- The GEF figure of USD 1,250 million since 1997 (about USD 150 million per year) is the total spending, not just capital investment, under six operational programmes. Some contributions to GEF and some spending by implementing agencies funded by GEF could be included in the ODA total (see TABLE 12-ANNEX V).

281. Most of the current investment and financial flows into the forestry sector are not related to climate change. The vast majority of investment and financial flows into the forestry sector, including sustainable forest management (SFM) are from the private sector. According to Savcor Indufor (2006) over 90 per cent of the private sector investments are domestic and less than 25 per cent is invested in developing countries and transition economies.

282. According to PROFOR (2004), current levels of investment in the forestry sector, both domestic and foreign, fall far short of the level necessary to realize the potential of well-managed forest resources to contribute to poverty alleviation, the protection of vital environmental services, and sustainable economic growth in developing and transition countries.

Table IV-34. **Information on funding and investment flows in the forestry sector**

Funding source	Volume	Comments
Direct private investments	USD 63 billion per year, USD 15 billion per year to developing countries	USD 63 billion per year in total (all countries). USD 15 billion per year to developing countries and EITs. Mainly domestic direct investments (over 90 per cent)[a]
ODA	USD 328 million total in 2000, of which USD 110 million is capital investment	Source: Creditor Reporting System (CRS), 2006, OECD Statistics.
IFC	USD 65 to 75 million per year	Source: Program on Forests (PROFOR), 2004
ITTO	USD 11.5 million in 2006	Conservation and sustainable management, use and trade of tropical forest resources[b]
GEF	USD 1.25 billion since 1997	236 projects through six operational programmes. Leveraged co-financing USD 3.45 billion[c].
National Forest Programme (NFP) Facility, FAO	USD 17.3 million over five years (2002 to 2007), of which 12.5 is committed	The Facility has programmes in approximately 50 countries, each of which receives 300,000 USD over 3 years. Committed: USD 1.7 million in 2005, over USD 2 million in 2006. In 2006, 44 per cent of the funding went to Africa, 7.5 per cent to Central Asia, 13 per cent to Asia and the Pacific and 35 per cent to Latin America and the Caribbean[d].
PROFOR	USD 8.2 million between 2002 and 2006	34 different activities. Themes include: livelihoods, governance, financing, cross-sectoral cooperation, and knowledge management. USD 8.2 million over the period 2002 to 2006, 58 per cent was spent on global activities, 6 per cent in regions and 36 per cent in countries. It has leveraged USD 1.3 million in co-financing[e]
World Bank Global Forest Alliance	USD 1.5 – 2 million per year	It expects to raise about USD 100 million for technical and catalytic functions, about USD 300 million for piloting avoided deforestation schemes in selected pilot countries and about USD 75 million for carbon finance reforestation projects with poverty reduction objective[f]
Other funds	USD 53.8 million	Biocarbon fund[g]
New South Wales GHG Abatement Scheme		USD 6.7 million to date based on prices of AUD 11.50 per t CO_2 eq for forestation and a traded volume 0.7 M t CO_2 eq[h]

Abbreviations: IFC = International Finance Corporation; ITTO = International Tropical Timber Organization; NFP = National forest programmes; USD = United States dollar.

[a] Tomaselli 2006 cited in Savco Indufor 2006.
[b] www.itto.or.jp.
[c] GEF/C.27/14, 12 October 2005 and information directly from the GEF secretariat.
[d] 2006 Progress Report. Courtesy of NFP Facility.
[e] Savcor Indufor 2006.
[f] World Bank, 2007.
[g] www.carbonfinance.org.
[h] Modified after Savcor Indufor 2006.

4.4.7.4. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

283. The reference scenario assumes that GHG emissions from the forestry sector remain constant from 2004 through 2030 at 5.8 Gt CO_2 eq, excluding peat and other bog fires. This involves no additional investment or financial flows.

INVESTMENT AND FINANCIAL FLOWS NEEDED UNDER THE MITIGATION SCENARIO

284. The mitigation options for the forestry sector are:

- Reduced deforestation[27];
- Better management of productive forest (forest management);
- Forestation to increase the forest area (afforestation and reforestation).

285. Forestry mitigation projections are regionally unique, but linked across time and space by changes in global physical and economic forces. Boreal primary forests could be sources or sinks, depending on the net effect of enhancement of growth due to climate change versus a loss of organic matter from soil and emissions from increased fires. The temperate forests in United States, Europe, China and Oceania, will probably continue to be net carbon sinks, partly because of enhanced forest growth due to climate change. Tropical forests are expected to continue to be sinks because of human induced land-use changes. Enhanced growth of large areas of primary forests, secondary regrowth, and increasing plantation areas will also increase the sink.

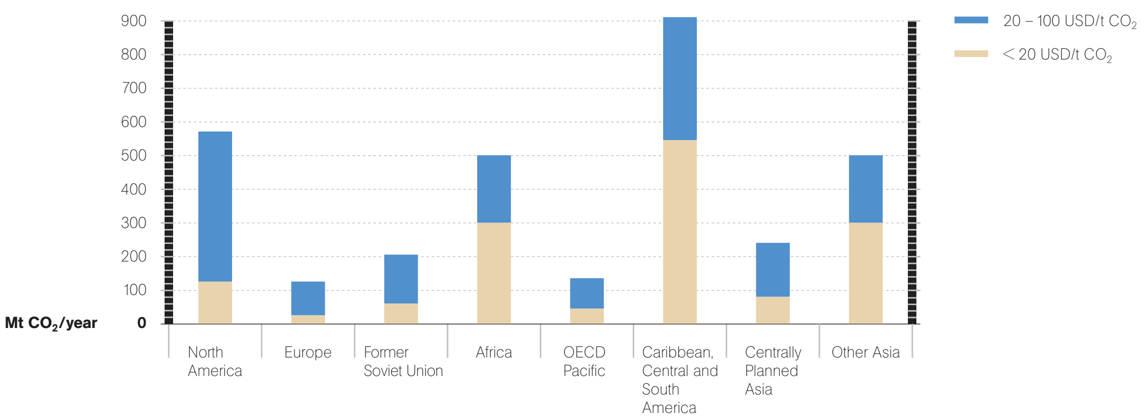
286. IPCC WGIII AR4 presents estimates of the mitigation potential for different costs per tonne for 2030, but no indication is given as to what area is required to achieve those potentials. FIGURE IV-12 shows the annual economic mitigation potential in the forestry sector by world region and cost class in 2030. The IPCC WGIII AR4 estimate that forestry mitigation options have the economic potential (at carbon prices up to USD 100 per t CO_2) to contribute between 1,270 and 4,230 Mt CO_2 in 2030 (medium confidence, medium agreement). About 50 per cent of the medium estimate can be achieved at a cost under USD 20 per t CO_2 (1,550 Mt CO_2 per year). Over two thirds of the total mitigation potential, and over 80 per cent of the low cost potential, is located in developing countries.

COSTS OF REDUCED DEFORESTATION

287. Estimates for costs of reduced deforestation include reducing emissions from both deforestation and degradation. The biggest mitigation potential in the forestry sector is to reduce deforestation and degradation in the tropics, where almost all of the emissions from deforestation and degradation originate. Available studies

[27] Reducing emission from deforestation in developing countries as defined in Subsidiary Body for Scientific and Technological Advice (SBSTA).

Figure IV-12. **Estimated economic mitigation potential in the forestry sector by region and cost class**



Source: adapted from IPCC, 2007c.
Note: The regions mentioned in the figure above are as per the Fourth Assessment Report of the IPCC.

differ widely in basic assumptions regarding carbon stocks, costs, land areas, and other major parameters. A thorough comparative analysis is therefore very difficult.

288. The financial flow needed to reduce deforestation/ degradation is estimated as the opportunity cost of converting forest to other land uses.

289. The three major direct drivers of deforestation/ degradation as follows:

- Commercial agricultur (national and international markets)
  - Commercial crops
  - Cattle ranging (large-scale)
- Subsistence farming
  - Small-scale agriculture/shifting cultivation/slash and burn agriculture
  - Fuelwood and NTFP gathering for local use, mostly family based
- Wood extraction
  - Commercial (legal and illegal) for national and international markets
  - Traded fuelwood (commercial at sub national and national level).

290. The driver for converting forest to one of these other land uses determines the opportunity cost of maintaining the forest; preventing the deforestation/forest degradation. Estimates of the opportunity costs by driver are based on ITTO (2006); Forner *et al.* (2006); Kaimowitz and Angelsen (2001); Moutinho and Schwartzman (2005); Chomitz and Kumari (1998); Chomitz, K. (2006) and Geist and Lambin (2002) and expert judgement.

291. The total net loss for countries with a negative change in forest area was 13.1 million ha per year for 1990 – 2000 and 12.9 million ha per year for the period 2000 – 2005 (FRA, 2005). Consequently, the forest loss through deforestation/degradation by main direct driver has been assumed to be 12.9 million ha per year in the absence of mitigation measures.

292. The direct drivers for deforestation/degradation differ in each country where it occurs. The share of total forest area lost to each direct driver was estimated based on the area lost by country and the direct drivers for the country.

293. Applying the opportunity cost for drivers relevant to each region to the area lost to deforestation/degradation each year in the region yields an estimated annual cost of USD 12.2 billion to reduce deforestation/forest degradation of 12.9 million ha per year as shown in TABLE IV-35. Reducing deforestation/forest degradation completely would reduce emissions by 5.8 Gt CO_2 in 2030.

Table IV-35. **Cost for reducing deforestation**

Main direct drivers	Rate of Deforestation/ Degradation (percentage)	Area of Deforestation/ Degradation (million ha per year)	Opportunity cost of forest conversion (USD per ha)	Financial flow required to compensate the opportunity costs (USD million per year)
Commercial agriculture				
Commercial crops	20	2.6	2,247	5,774.18
Cattle ranching (large-scale)	12	1.6	498	801.35
Subsistence farming				
Small scale agriculture/ shifting cultivation	42	5.5	392	2,148.13
Fuel-wood and NTFP gathering	6	0.75	263	196.95
Wood extraction				
Commercial (legal and illegal)	14	1.8	1,751	3,187.4
Fuel-wood/charcoal (traded)	5	0.7	123	85.96
Total	100	12.9	–	12,193.97

Note: Various studies have estimated cost for reducing deforestation ranging from 0.4 billion to as high as 200 billion per year. However these estimates vary greatly in assumption and opportunity cost for the deforestation drivers and the area of reduced deforestation Sathaye *et al.* (2006), IIED (2006), Stern (2006) and Trines (2007).

294. Opportunity costs vary significantly by location and over time. The underlying drivers for deforestation (e.g. structural changes in land tenure or in agricultural or forest policies) also affect the opportunity costs. The opportunity costs do not include investment or maintenance costs of alternative land-use. They also do not include administrative and transaction costs for reducing emissions from deforestation and/or forest degradation. The estimates presented above therefore must be considered as indicative only.

295. Another estimate of cost of reducing deforestation (Trines, 2007) assumes that the area of primary forest lost as reported in FRA 2005 is deforestation. The annual rate of primary forest loss between 2000 and 2005 is assumed to continue through 2030. The analysis uses primary forest loss data for 40 countries that were responsible for over 66 per cent of the CO_2 emissions in 2000 (WRI CAIT). The CO_2 emitted due to deforestation is estimated using carbon content values presented in the FRA 2005. This approach yields an estimate of approximately 148 million ha of deforestation by 2030 with total emissions of about 60,000 Mt CO_2 or annual emissions of about 2,300 Mt CO_2.

296. The highest marginal cost to completely stop deforestation – the "choke price" – is applied to the projected deforestation to estimate the cost of reduced deforestation. Choke prices estimated by Sathaye *et al.* (2006) vary between USD 11 to 77 per t CO_2, excluding transaction costs. Applying those prices to the projected emissions due to the loss of primary forest in each region yields a cost of USD 25 to 185 billion per year to stop deforestation.

297. However for this report, the mitigation potential and cost of reducing deforestation have been estimated using the opportunity costs of the direct drivers of deforestation and forest degradation.

COSTS OF FOREST MANAGEMENT

298. Forest management, in particular SFM has received ample attention over the past decade, and is promoted by the private sector, and aid agencies, but in a non-climate context. Public forests in Annex I Parties are already managed to relatively high standards, which limits possibilities for increasing removals by sinks through changed management practices (for example, by changing species mix, lengthening rotations, reducing harvest damage and or accelerating replanting rates). There may be possibilities to increase carbon storage by reducing harvest rates and/or harvest damage.

299. This analysis assumes that forest management can reduce emissions from production forests in developing countries. The production forests in each country is assumed to remain constant at the 2005 area of 602 million ha (FRA, 2005).

300. The ITTO Expert panel report estimated the costs to achieve SFM at USD 6.25 per ha for all tropical production forests in ITTO member countries (about 350 million ha) (ITTO, 1995). Adjusting for inflation and the larger area of production forest, the cost is estimated at USD 12 per ha.

301. For non-Annex I Parties in tropical and subtropical areas, the cost of achieving (sustainable) forest management on 602 million ha of production forests would be about USD 7.2 billion per year leading to increased annual removals of 5.4 Gt CO_2 (see TABLE IV-36). Non-Annex I Parties with temperate and boreal forests have the potential to increase carbon stocks through SFM at a cost of USD 20 per ha (Whiteman, 2006) for an annual cost of USD 1 billion and increased annual removals of 1.1 Gt CO_2. Thus the annual potential for increased removals through forest management in non-Annex I Parties is estimated at 6.5 Gt CO_2 at an annual cost of USD 8.2 billion in 2030.

COSTS OF FORESTATION

302. So far, afforestation and reforestation (here is referred to as 'forestation') initiatives have been driven mainly by the private sector, for 'no regret' options, such as commercial plantation forestry, or governments. Owing to the lack of liquidity of the investment, the high capital cost of establishment and long period before realizing a financial return, many plantation estates have relied upon government support, at least in the initial stages. Incentives for plantation establishment take the form of forestation grants, investment in transportation and roads, energy subsidies, tax exemptions for forestry investments, and tariffs on competing imports.

303. The drivers that influence forestation vary by region and often even within a country, and originate predominantly from outside the forestry sector. Hence, modelling the area likely to be planted as part of a forestation initiative is complicated.

304. Sathaye *et al.* (2006) present the benefits of land area planted and removals by sinks across a number of scenarios relative to a reference case to 2100. For 2050 the range of land area planted is 52 – 192 million ha whereas the carbon benefits range from 18 – 94 Mt CO_2.

305. Establishment costs for forests range from USD 654 per ha on good sites to USD 1580 per ha on difficult sites (ORNL, 1995). Using this range, the initial investment required to mitigation 18 – 94 Mt CO_2 through afforestation/reforestation on 52 – 192 million ha land is USD 34 – 303 billion.

306. The IPCC WGIII AR4 estimate of the mitigation potential of afforestation by 2030, 1,618 to 4,045 Mt CO_2 year^{-1}, is substantially lower than the estimate of Sathaye *et al.* Using a similar ratio between carbon sequestered and hectares planted, the WGIII AR4 estimates would require 4.6 – 8.2 million ha. At establish ment costs of USD 654 – 1580 per ha establishment costs that would be USD 3 – 12.9 billion or USD 0.1 – 0.5 billion per year over 25 years. Conservative estimates from IPCC have been taken for this analysis.

307. The estimated investment and financial flows for the mitigation options analysed are summarized in TABLE IV-37.

Table IV-36. **Potential removal by sinks through forest management**

Regions	Area of production forest (x 1000 ha)	Cost estimate for SFM (USD million)	Global estimate of carbon in biomass (t CO_2 per ha)	Forest managed area at a 25-years rotation basis ('000 ha) (2005 – 2030)	Additional annual growth potential through SFM (m³ per ha and year)	Increased carbon removal potential per ha through SFM (t CO_2)	Additional carbon removals potential in the year 2030 (Mt CO_2)
Total Eastern and Southern Africa	43,948	527	233.045	1.758	2.8	5.138	227.54
Total Northern Africa	46,129	554	95.42	1.845	0.5	0.9175	44.04
Total Western and Central Africa	123,912	1,487	568.85	4.956	5.8	10.643	1,317.53
Total East Asia	125,369	1,505	136.891	5.015	3.5	6.422	803.73
Total South and Southeast Asia	120,046	1,440	282.6	4.802	7	12.845	1,541.4
Total Caribbean, Central America & Mexico	46,645	560	438.198	1.866	6	11.01	513.8
Total South America	96,459	1,158	403.7	3.858	5.5	10.0925	972.55
Tropics	602,185	7,231	308.28	24.1	4.4	8.074	5,420.59

Source: FAO FRA, 2006.

Table IV-37. **Investment and financial flows needed for mitigation options in the forestry sector**

Country/Region	Afforestation/Reforestation: Emission offset potential ($Mt CO_2$) in 2030		Afforestation/Reforestation: Cost in USD billion in 2030		Forest management: Emission avoided Mt CO_2	Forest management: Cost in USD billion in 2030	Reduced deforestation: Emission reduced in 2030 Mt CO_2	Reduced deforestation: Cost in USD billion in 2030
	Lower	Higher	Lower	Higher				
Annex I	18.79	46.96	0.03	0.15	–	–	–	–
Non-Annex I	43.51	108.74	0.07	0.35	6,522	8.2	5,790	12.3
Global	**64.7**	**161.9**	**0.1**	**0.5**	**6,522**	**8.2**	**5,790**	**12.3**

Box IV-8. **Summary of investment and financial flows for forestry**

Investment and financial flows needed in 2030
In the Forestry sector the additional global investment and financial flows needed under the mitigation scenario total about USD 21 billion, of which financial flows for emission reductions through reduced deforestation account for USD 12 billion and for forest management account for USD 8 billion. Afforestation and reforestation accounts for USD 0.12 – 0.5 billion in 2030. Almost all forestry sector related investment and financial flows occur in developing countries.

Current Investment and Financial Flows
The majority of investments in forestry sector come from the private sector, mainly in plantation development and forestry concessions. Over 90 per cent of these are domestic. In non-Annex I Parties, most of the rest of investments come from ODA.

4.4.7.5. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

308. How much funding is currently being diverted to avoided deforestation, forest management or forestation is not known as financial flows are hardly ever pertinent to single activity.

FORESTATION

309. Forestation projects in developing countries can earn credits under the CDM for the carbon sequestered. The project activity extension of the CDM to forestation projects is relatively recent and not many projects have been developed yet. Thus it is too early to know whether the CDM will be able to stimulate a significant amount of forestation activity.

310. The BioCarbon Fund, which buys emission reductions, now has total capital of USD 80 million, mostly for reforestation, but also some for avoided deforestation and carbon management of the soil. More than half of BioCarbon Fund's capital is from the private sector. Forestation projects in New South Wales (NSW) and the Australian Capital Territory (ACT) can earn credits for sale in the NSW-ACT GHG Abatement Scheme.

311. Annual investment of USD 0.1 – 0.5 billion in forestation projects in 2030 could be supported by the CDM.

REDUCED DEFORESTATION

312. At COP 11, Papua New Guinea and Costa Rica, supported by several developing countries, tabled a proposal to include emissions from avoided deforestation in any kind of compensation scheme under the UNFCCC[28]. It leaves open whether that should happen under a separate forest protocol or as a part of an overall post-2012 protocol. Since then several proposals for supporting reduced deforestation have been submitted. The main features of the different proposals for voluntary approaches to reduced deforestation and degradation are presented in TABLE IV-38.

[28] Report on the second workshop on reducing emissions from deforestation in developing countries, FCCC/SBSTA/2007/3.

Table IV-38. **Proposal for policy approaches and positive incentives to reduce emissions from deforestation in developing countries**

Country (or group of countries)	Brief description of proposal
Tuvalu[29]	Proposal for a policy approach called the Forest Retention Incentive Scheme (FRIS) based on projects implemented by local communities. There are three key elements under the FRIS: the establishment of a Community Forest Retention Trust Account that retains funds for the projects; the issuance of forest retention certificates (FRCs) as a result of emissions reductions from the projects; and the establishment of an International Forest Retention Fund under the UNFCCC for the redemption of the FRCs.
India[30]	Proposal based on the concept of Compensated Conservation as a policy approach to reducing deforestation. It is based on providing compensation to countries for maintaining and increasing their forests, and consequently their carbon stocks, as a result of effective forest conservation policies and measures. Such an approach would have to be supported by a verifiable monitoring system. For the operationalisation of this approach, a new financial mechanism, linked to verifiable carbon stock increments and separate from the CDM, would have to be set up.
Congo Basin countries[31]	Establishment of a reducing emission from deforestation in developing countries (REDD) mechanism, which would provide positive incentives to support voluntary policy approaches to reducing emissions from deforestation and degradation. Establishment of a Stabilization Fund to support developing countries that have low rates of deforestation and want to maintain their existing forests. In addition, use of an Enabling Fund for developing national capacities to participate in the REDD mechanism and/or to stabilize forest stocks, as well as for pilot activities.
Brazil[32]	Provision of positive financial incentives for developing countries that voluntarily reduce their GHG emissions from deforestation. The arrangement would not generate future obligations or count towards emissions reduction commitments of Annex I Parties. Positive financial incentives would be given relative to a reference emission rate (calculated based on a pre-defined reference deforestation rate and an agreed carbon content). Parties included in Annex II to the Convention would voluntarily provide funds for this arrangement, taking into account their ODA commitments. The funds would then be divided among participating developing countries in the same ratio as the emission reductions they have achieved.
Group of Latin American countries[33]	Any mechanism to reduce emissions from deforestation should be based on a basket of incentives and any financial mechanism supporting this should include both non-market and market instruments. Call for "credit for early action" and suggested that any emission reductions generated by participating developing countries should be creditable post-2012. Setting up of an Avoided Deforestation Carbon Fund to cover specific activities that directly reduce emissions from deforestation and maintain forest cover in countries that have low rates of deforestation. Establishment of an Enabling Fund that would provide for capacity-building and pilot activities.
Coalition for Rainforest Nations[34]	Proposal based on a basket of instruments that include provision of sustainable financial resources (for which market instruments will be necessary); expanding existing efforts by building capacities and undertaking national pilot projects; and allowing credits for early action. Establishment of an REDD mechanism and two funds, the Enabling Fund and the Stabilization Fund. Under the REDD mechanism, credits generated must be fully fungible and measured against a national reference scenario.

Note: Information in the table below is based on the proposals presented by Parties at the two UNFCCC workshops on reducing emissions from deforestation in developing countries (30 August to 1 September 2006, Rome, Italy; and 7–9 March 2007, Cairns, Australia) as contained in the reports of these workshops (see documents FCCC/SBSTA/2006/10 and FCCC/SBSTA/2007/3). Additional information can be found in the latest submissions from Parties (see FCCC/SBSTA/2007/MISC.2 and Add.1). The order is the same as they appear in document

[29] See also paper no. 3 in FCCC/SBSTA/2007/MISC.2/Add.1.

[30] See also paper no. 11 in FCCC/SBSTA/2007/MISC.2.

[31] See also paper no. 9 in FCCC/SBSTA/2007/MISC.2; and FCCC/SBSTA/2006/10, paragraph 36. The countries of the Congo Basin supporting this proposal include Cameroon, the Central African Republic, the Republic of the Congo, the Democratic Republic of the Congo, Equatorial Guinea and Gabon.

[32] See also paper no. 4 in FCCC/SBSTA/2007/MISC.2; and FCCC/SBSTA/2006/10, paragraph 48.

[33] See also paper no. 7 in FCCC/SBSTA/2007/MISC.2. This submission was supported by Costa Rica, the Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, Panama, Paraguay and Peru.

[34] See also paper no. 3 in FCCC/SBSTA/2007/MISC.2. This submission was supported by Bolivia, the Central African Republic, Costa Rica, the Democratic Republic of the Congo, the Dominican Republic, Fiji, Ghana, Guatemala, Honduras, Kenya, Madagascar, Nicaragua, Panama, Papua New Guinea, Samoa, Solomon Islands and Vanuatu.

313. The World Bank has established the Global Forest Alliance, which focuses on forests and poverty reduction, forest management, and new financing mechanisms. Its targeted capital is about USD 100 million. It will build capacity and fund research rather then buy carbon.

314. The World Bank also has established the Forest Carbon Partnership Facility, as requested by the G8. This facility is designed to help reduce emissions from deforestation and degradation. The Bank envisions that this new facility will reach a funding level of USD 250 million over five years, of which one forth to one third would be for capacity building, and the rest for carbon finance transactions. Most, but not all, of the funding is expected to come from ODA sources.

315. Sustainable Forestry Management and Credit Suisse have recently announced a new facility of USD 200 million for reforestation and avoided deforestation.

316. Together the Global Forest Alliance and Forest Carbon Partnership Facility may provide annual funding of about USD 100 million for reduced deforestation. While this is significant funding for a pilot phase, it is negligible relative to the projected annual need of USD 12 billion in 2030. Implementing reduced deforestation on such a scale will require access to a market so that it can be funded privately. The alternative is to have national governments implement policies to reduce deforestation.

FOREST MANAGEMENT

317. Forest management is estimated to need annual funding of USD 8 billion in 2030. At present, only the ITTO provides funding for forest management. Currently, funding for such projects averages about USD 10 million per year. Funding USD 8 billion per year would require another source of funds.

4.5. TECHNOLOGY RESEARCH AND DEVELOPMENT

4.5.1. INTRODUCTION

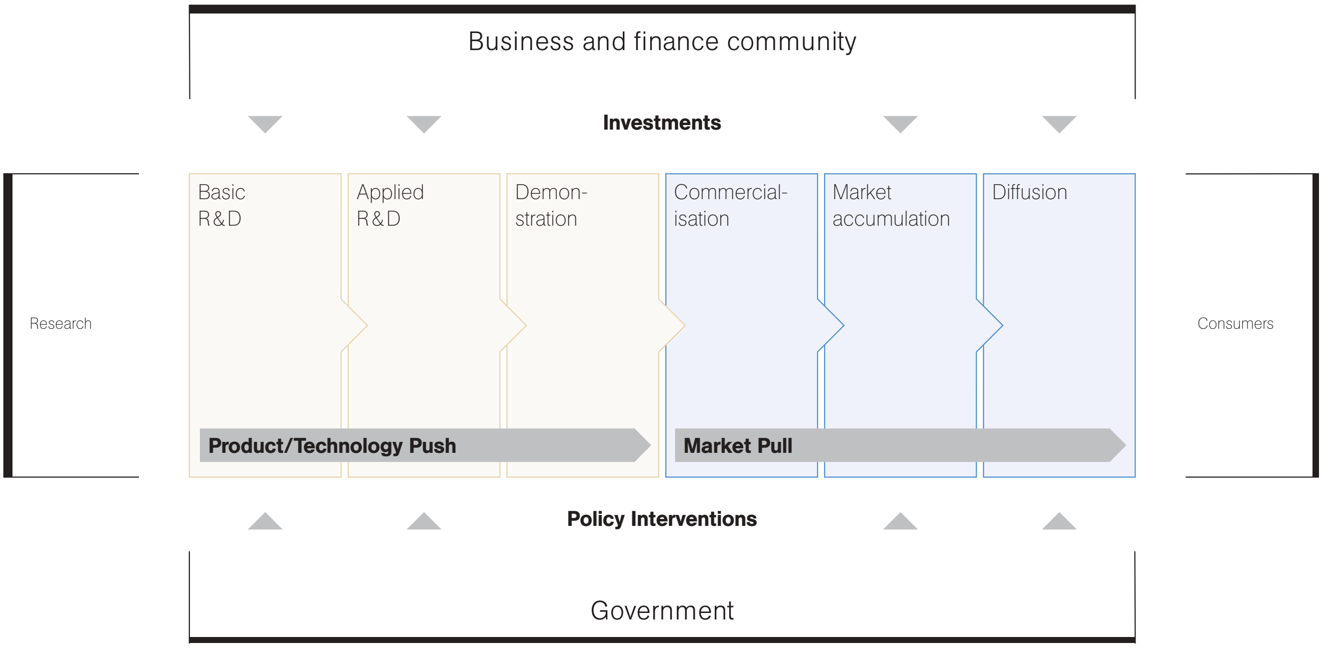
318. GHG mitigation requires mechanisms that can help both push and pull low GHG emitting technologies onto the market. This chapter discusses research and development of those technologies.

319. No single technology – say nuclear power or solar power – can deliver the emission reductions needed to stabilize atmospheric concentrations of GHG. A range of technologies is already available, but most have higher costs than existing fossil fuel based options. Others are yet to be developed. The success of efforts to move these low GHG emitting technologies through the innovation cycle will be an important determinant of whether low emission paths can be achieved.

320. Innovation is typically a cumulative process that builds on existing progress, generating competitive advantages in the process. Grubb (2004) identifies the 'stages' of innovation as shown in FIGURE IV-13. Although as with most models, this fails to capture many complexities of the innovation process, it is useful for characterizing stages of innovation. Transition between stages is not automatic (many products fail at each stage of development) and there are also linkages between them, as further progress in basic and applied R&D affects products already in the market, while subsequent learning also has an R&D impact.

321. The graph refers to both push policies – where government supports innovation through grants and ubsidies – as well as pull policies – where markets provide the incentives required to drive the innovation.

Figure IV-13. **The innovation cycle**



Source: Grubb, 2004.

4.5.2. CURRENT SITUATION ON TECHNOLOGY RESEARCH AND DEVELOPMENT

322. Worldwide, nearly USD 600 billion was expended on R&D in all sectors in 2000. Nearly 85 per cent of that amount was spent in only seven countries[35] (IPCC, 2007c). Over the last 20 years, the government share of R&D funding has generally declined while the industry share has increased in these countries. Innovation varies dramatically across sectors. The information technology and pharmaceuticals sectors have high rates of innovation with private sector financing equal to 10 – 20 per cent sector revenue (Neuhoff, 2005). In the power sector private R&D has fallen sharply with privatization to around 0.4 per cent of revenue (Margolis and Kammen, 1999).

323. Between 1970 and 1998, R&D spending for agriculture rose from USD 3.3 – 4.9 billion. Since the mid 1980s, private sector research spending has exceeded and grown faster than the public component. By 2030 total investment in agricultural research is projected to reach USD 12 billion, with 60 per cent of this amount coming from the private sector. About 75 per cent of the USD 2.5 billion annual increase in research spending between 2005 and 2030 is expected to be funded by the private sector. No information is available on the difference in research spending between the reference and mitigation scenarios in agriculture sector.

324. The significant increase in energy prices after the 1970s oil crisis led to an expansion of R&D spending as shown in FIGURE IV-14. The subsequent collapse in prices in the 1980s led to a decline of R&D initiatives and support. Recent energy price increases have so far not translated into an expansion of R&D funding.

325. Government spending on energy R&D worldwide has stagnated, while private sector spending has fallen. Total government expenditures of IEA member countries on energy R&D decreased from some USD 9.6 billion in 1992 to USD 8.6 billion in 1998, with a recovery to USD 9.5 billion in 2005. Over this period, two countries – Japan (34 per cent) and the United States (29 per cent) – accounted for more than 60 per cent of the total IEA government R&D spending. In the United States, federal funding for energy research has been falling steadily since 1980. Only Japan has maintained energy R&D spending relative to GDP. The historical trend in energy R&D spending contrasts with overall research spending in the OECD, which grew by nearly 50 per cent between 1988 and 2004 (Stern, 2006).

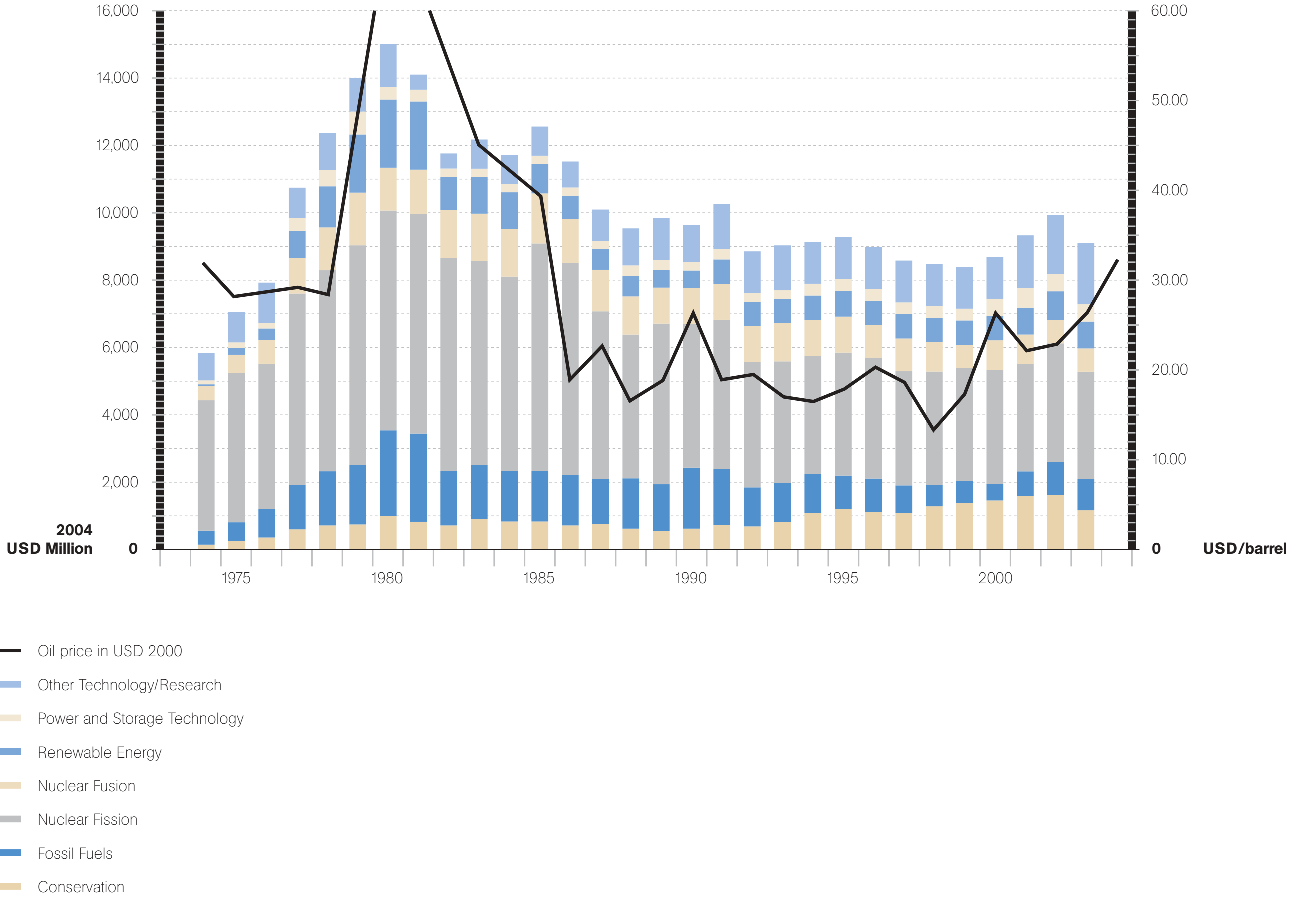
326. Spending on fossil fuels fell steadily during the second half of the 1990s, but rebounded at the start of the current decade (see FIGURE IV-14). The share of nuclear fission and fusion in total spending has dropped since the early 1990s, but still accounts for about 40 per cent of the total. Spending on energy efficiency rose significantly in the 1990s and then fell back sharply after 2002. Research on renewables and power technologies – including hydrogen – has continued to grow steadily. Energy efficiency and renewables still receive only 12 per cent of government R&D spending on energy.

327. Insufficient resources have been allocated to energy R&D to meet medium- and long-term energy policy objectives, including global climate change mitigation. IEA consultative bodies have been suggesting that member governments should find a more balanced R&D budget mix that focuses on the longer-term policy objective of sustainable development.

328. Private R&D spending for energy is discouraged by energy subsidies, since they make commercialization of new technologies more difficult. In OECD countries, where most of the energy R&D occurs, fossil fuels are subsidized to the extent of USD 20 – 30 billion per year, double or triple the total government spending on energy R&D.

[35] Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

Figure IV-14. **Government R&D expenditure in IEA countries and oil price from 1974 to 2004**



Source: OECD, 2006.

4.5.3. ESTIMATED INVESTMENT AND FINANCIAL FLOWS NEEDED

329. A portfolio of existing or well advanced low carbon technologies is assumed to be deployed under the mitigation scenario. Figure IV-15 shows the projected emission reductions under the mitigation scenario in 2030 by technology. The key technologies are end-use efficiency, CCS, renewables, nuclear energy, large hydropower and biofuels.

330. Figure IV-16 shows the annual investment by technology by region in 2030. For each of the technologies, a substantial share will be invested in developing countries. This suggests that developing country participation in R&D and deployment of these technologies could facilitate the projected investments.

331. The IEA's Energy Technology Perspectives looks at the impact of policies to increase the rate of technological development. It assumes USD 720 billion of investment in deployment support occurs over the next two to three decades, an average of USD 24 – 36 billion per year. This estimate is on top of an assumed carbon price (whether through tax, trading or implicitly in regulation) of USD 25 per t CO_2. The TECH Plus scenario is closest to the mitigation scenario. It assumes faster rates of progress for renewable and nuclear electricity generation technologies, for advanced biofuels, and for hydrogen fuel cells, leading to global energy-related CO_2 emissions about 16 per cent below current levels in 2050.

332. The Stern review estimated existing deployment support for renewables, biofuels and nuclear energy at 33 billion each year. If the IEA figure is assumed to be additional to the existing effort, it suggests an increase of deployment incentives of between 73 and 109 per cent, depending on whether this increase is spread over two or three decades. The Stern Review also suggested that global public energy R&D funding should double, to around USD 20 billion.

Box IV-9. **Summary of investment and financial flows for technology R&D**

Investment and financial flows needed in 2030
Government energy R&D budgets should double to USD 20 billion per year and government support for deployment of renewables, biofuels and nuclear energy should double to USD 60 billion per year.

Current investment and financial flows
Government spending on energy R&D has stagnated, while private sector spending has fallen. Most of the government funding comes from Japan and the United States. Japan has maintained energy R&D spending relative to GDP while federal funding for energy research has fallen steadily falling since 1980 in the United States.

Figure IV-15. **Emission reductions by technology under the mitigation scenario in 2030, in Gt CO_2 eq.**

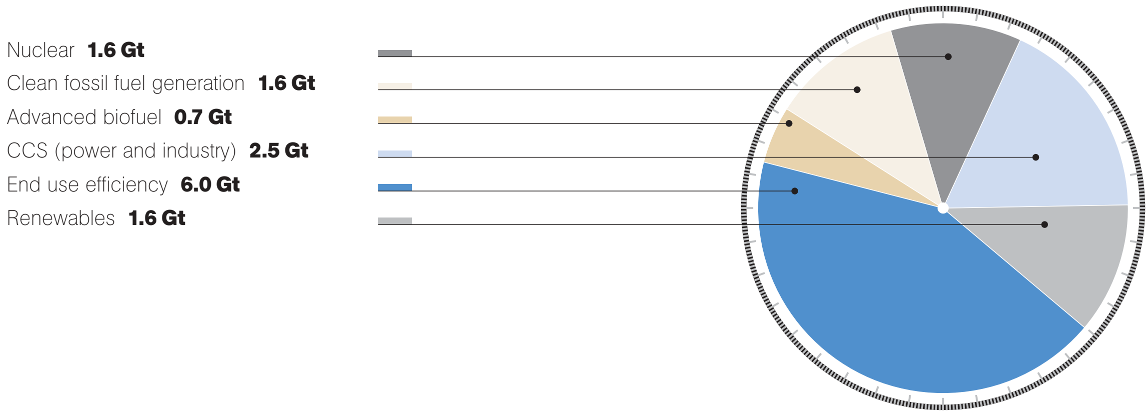
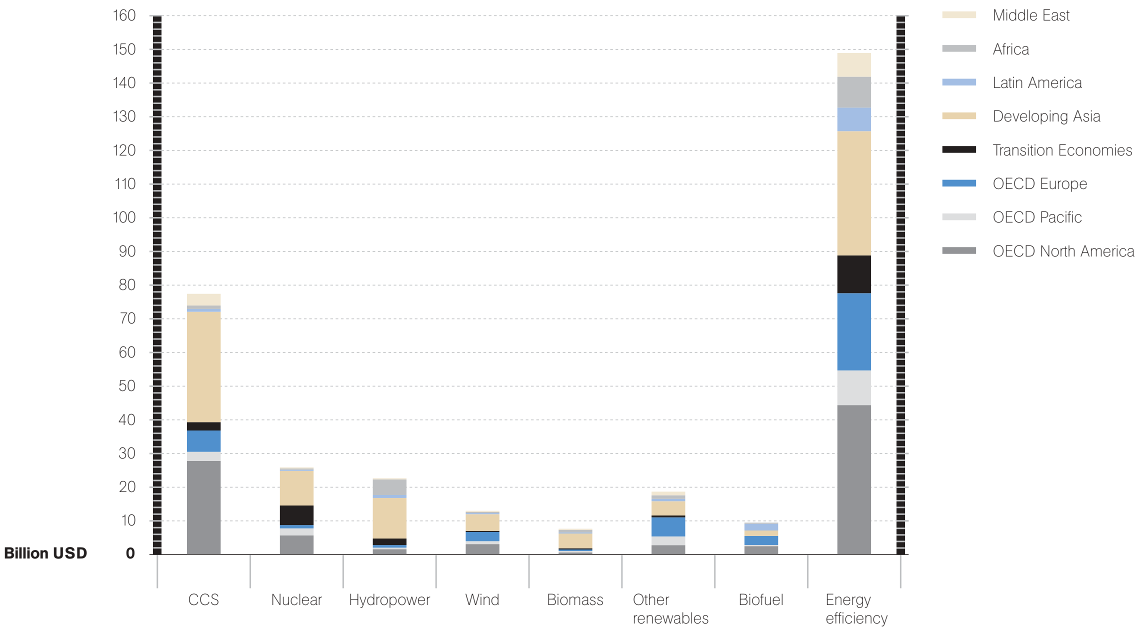


Figure IV-16. **Annual additional investment by technology and by region under the mitigation scenario in 2030**



4.5.4. ASSESSMENT OF THE CHANGES NEEDED IN INVESTMENT, FINANCIAL AND POLICY ARRANGEMENTS TO FILL THE GAP UNDER THE MITIGATION SCENARIO

333. An ambitious and sustained increase in the global energy R&D effort is required if the technologies reflected under the mitigation scenario are to be delivered within the time required. However, government funding for energy R&D has only recently recovered to the level of the early 1990s, while private funding has declined.

334. The available estimates suggest that government energy R&D budgets need to double from roughly USD 10 – 20 billion per year, and that support for deployment of renewables, biofuels and nuclear energy needs to double from roughly USD 30 – 60 billion annually.

335. Private R&D spending for energy in OECD countries is discouraged by subsidies to fossil fuels, which are double or triple the total government spending on energy R&D, since they make commercialization of new technologies more difficult.

336. The scale of some low GHG emitting technologies is too large for countries to implement individually. International cooperation is essential in accelerating efficient and cost-effective progress towards a low carbon energy future. A number of international cooperation initiatives for R&D were undertaken and showing successful results in sharing information and development costs. Further enhanced international cooperation and collaboration would be key to promote technology R&D. This would need to also include participation of emerging and developing economies countries.

4.6. CONCLUSIONS

337. The global additional investment and financial flows of USD 200 – 210 billion will be necessary in 2030 to return global GHG emissions to current levels (26 Gt CO_2), see TABLE 6-ANNEX V. In particular:

- *For energy supply,* investment and financial flows of about USD 67 billion would be reduced owing to investment in energy efficiency and biofuel of about USD 158 billion. About USD 148 billion out of USD 432 billion of projected annual investment in power sector would need to be shifted to renewables, CCS, nuclear energy and hydropower. Investment in fossil fuel supply is expected to continue to grow, but at a reduced rate;
- *For industry,* additional investment and financial flows are estimated at about USD 36 billion. More than half of the additional investment is for energy efficiency, one third for installation of CCS and the rest for reduction of non-CO_2 gases, such as N_2O and other high GWP GHGs;
- *For buildings,* additional investment and financial flows amount to about USD 51 billion. Currently commercial and residential energy efficiency investment comes from building owners and is financed domestically;
- *For transportation,* additional investment and financial flows amount to about USD 88 billion. Efficiency improvements for vehicles and increased use of biofuels are likely to require government policies, but the investment would come mostly from the private sector;
- *For waste,* additional investment and financial flows are estimated at about USD 1 billion. Capture and use of methane from landfills and wastewater treatment could reduce emissions by about 50 per cent in 2030 mainly in non-Annex I Parties;
- *For agriculture,* additional investment and financial flows are estimated at about USD 35 billion. Non-CO_2 emissions from agriculture production could be reduced by about 10 per cent at cost of USD 20 billion in 2030. With a concerted international effort and an annual investment of about USD 15 billion agroforestry could be expanded at a rate of about 19 million ha per year by 2030;
- *For forestry,* additional investment and financial flows are estimated at about USD 21 billion. An indicative estimate of the cost of reducing deforestation and forest degradation in non-Annex I Parties to zero in 2030 is USD 12 billion. The estimated investment and financial flows in 2030 to increased GHG removals by sinks through SFM is USD 8 billion and the estimated investment and financial flows needed for afforestation and reforestation is USD 020 – 0.5 billion;
- *For technology R&D and deployment,* additional investment and financial flows are estimated at about USD 35 – 45 billion. Government spending on energy R&D worldwide has stagnated, while private sector spending has fallen. Government budgets for energy R&D and support for technology deployment need to double, increased expenditures in 2030 are expected at USD 10 – 30 billion respectively.

338. In many sectors the lifetime of capital stock can be thirty years or more. The fact that total investment in new physical assets is projected to triple between 2000 and

2030 provides a window of opportunity to direct the investment and financial flows into new facilities that are more climate friendly and resilient. The investment decisions taken today will affect the world's emission profile in the future.

339. Almost half of the additional global investment and financial flows need would occur in developing countries due to rapid economic and population growth. Mitigation actions are expected to be less expensive in non-Annex I Parties. TABLE IV-39 shows that 68 per cent of the projected global emission reductions occur in non-Annex I Parties while only 46 per cent of the additional investment and financial flows are needed in non-Annex I Parties. This reflects mitigation opportunities associated with the rapid economic growth projected for large developing countries, the relatively inefficient energy use, and the prevalence of low cost mitigation opportunities in the forestry sector. The data in TABLE IV-39 should not be used to compare the cost per t CO_2 eq reduced by sector. The investment and financial flows for reducing electricity use in buildings and industry are reported in those sectors, while the emission reductions are counted in the power supply sector.

340. The estimated investment and financial flows for energy assume that the major reductions in emissions between the reference and mitigation scenarios rely on increased energy efficiency and shifts in the energy supply from fossil fuels to renewables, nuclear energy and hydropower and large-scale deployment of CCS, although there are only a few CCS demonstration projects at the present time.

Table IV-39. **Additional investment and financial flows and greenhouse gas emission reductions**

	Global		Non-Annex I Parties			
Sectors	**Emission Reduction Gt CO_2 eq**	**Investment and financial flows in 2030 USD billion**	**Emission Reduction Gt CO_2 eq**	**Investment and financial flows in 2030 USD billion**	**Per cent of global emission reduction**	**Per cent of global investment and financial flows**
Power generation[a]	9.4	148.5	5.0	73.4	53	49
Industry[b]	3.8	35.6	2.3	19.1	60	54
Transport	2.1	87.9	0.9	35.5	42	40
Building[b]	0.6	50.8	0.3	14.0	48	28
Waste	0.7	0.9	0.5	0.6	64	64
Agriculture	2.7	35.0	0.4	13.0	14	37
Forestry	12.5	20.7	12.4	20.6	100	99
Total	31.7	379.5	21.7	176.2	68	46

[a] Total investment for power supply in 2030 declines from USD 439 billion in the Reference scenario to USD 432 billion in the Mitigation scenario (see TABLE IV-11). The USD 148 billion reported in this table is the additional investment that would be needed for renewables, CCS, nuclear power and hydropower. Investment for coal-, oil- and gas-fired generation and transmission and distribution would be reduced by USD 155 billion.
[b] The emission reductions reported for the Industry and Building sectors reflect only the direct emission reductions for those sectors. The investment in electricity efficiency measures is included in the investment flows for the Industry and Building sectors, but the emission reductions due to those measures are reflected in lower emissions for the power sector.

341. Currently most of the investment in mitigation measures is domestic; however, ODA plays an important role in Africa and the LDCs. With appropriate policies and/or incentives, a substantial part of the additional investment and financial flows needed could be covered by the currently available sources. However, there will be a need for new and additional external sources of funds dedicated to mitigation.

342. Renewable energy projects are financed largely by private investors at present. The scale of projected investment will require supportive government policies, financial incentives, such as feed-in tariffs and renewable energy credits, and secure markets for the power generated. It also will be necessary to ensure that the investment flows to the countries/regions that need it most. Africa probably faces the greatest challenge, needing to attract capacity investment of nearly USD 3 billion a year from a base of almost zero.

343. Currently most of the energy sector investment is made by government-owned or private, usually regulated utilities, and is made domestically in most regions.

344. More of the capital needed for energy projects in developing countries will have to come from private and foreign sources than in the past. Financing projects in developing countries, particularly in the poorer countries, is a key challenge. The investment gaps are likely to remain in the poor developing countries, deferring the time scale for widespread access to electricity.

345. Domestic savings — the single most important source of capital for investment in infrastructure projects — exceed by a large margin all other sources in total energy-financing requirements. But in some regions, energy-capital needs are very large relative to total savings (For e.g., in Africa and LDC). And energy investment has to compete for funds which might equally well be devoted to other social development sectors.

346. The entities that make the investment decisions are different in each sector, and the policy and/or financial incentives needed will vary accordingly. For example:

- Increased energy efficiency is best achieved through appropriate policies or regulations (the investments are internal and often incremental, and have short payback periods, but adoption is hampered by recognized barriers);
- Shifting investments in efficient motor vehicles need incentives to:
  - Introduce hybrid vehicles such as vehicle purchase subsidies, regulatory standards and higher taxes on the least efficient vehicles;
  - Expand the use of biofuels with measures such as larger R&D programmes and minimum requirements for biofuels in conventional fuel blends;
- Shifting investment in the power sector to CCS and low GHG emitting generation technologies will need both policies and, financial incentives that make these technologies economically more attractive than high GHG emitting technologies. This requires large R&D programmes, incentives for large-scale demonstration plants, national or international policy frameworks, such as carbon markets, renewable portfolio standards or higher feed-in tariffs, loan guarantees to reduce the cost of capital, financial penalties on carbon emissions;
- Financial incentives will be needed to achieve significant reductions in emissions through agroforestry, agriculture waste, deforestation and forest management.

347. Policies are needed in Annex I and non-Annex I Parties. International coordination of policies by Parties in an appropriate forum will often be most effective. Areas where international coordination would be beneficial include:

- Technology R&D and deployment;
- Energy efficiency standards for internationally traded appliances, equipment.

348. Some mitigation measures, especially reduced deforestation and forest management, are likely to need significant external funding for large-scale implementation. Some countries may need assistance for the development and implementation of national policies.

349. As this paper provides only an overview of investment and financial flows based on existing data and models, it could be improved by further analytical work ensuring scenarios are more adequately developed for the purposes of estimating investment and financial flows. For example:

- *Energy efficiency* is the most promising means to reduce GHG emissions in short term. Specific analysis to promote investments for energy efficiency improvements, particularly the implication for improvements of the financial mechanism under the Convention and/or project based mechanisms under the Kyoto Protocol (CDM and JI) could be carried out at the regional and sectoral levels;

- There is need for better understanding of different national circumstances, specific analysis should focus on *different groups of countries* such as LDCs, rapid growth developing countries and economics in transition countries;
- The *removal of energy subsidies and economically efficient pricing and taxation policies* could play an important role in promoting renewable energy and energy efficiency and reducing GHG emissions. However, the role of energy subsidies and non-technical losses need further assessment in terms of their impact on GHG emissions and deterrence of investment in mitigation measures. Little data on this is currently available;
- More research is needed on the *role of different sources of funding* for specific sectors, current data cover investment flows for aggregated sectors. For example, investment data is reported for electricity, gas and water together, and it is often difficult to split the analyse for each of the sub sectors;
- The existing estimates of costs relating to mitigation options for *forestry* and for potential removals by sinks from agriculture are preliminary. There is also a lack of common understanding on assumptions to consider costs and a resulting high range of differences in estimate. More analytical and empirical work is needed;
- *CCS* is projected under the BAPS to play a key role to mitigate climate change in a medium or long term. There are, however, only a few CCS demonstration projects at the present time. Further analysis is needed on how investment from different sources such as private, public and multilateral development banks (MDBs) could collaborate to bring CCS into reality.