Endnotes

[1] This section draws largely on IPCC, 2000a; IPCC, 2001a,b; den Elzen and Meinshausen, 2005.
[2] Such an emissions reduction would achieve a 2° C target with a probability exceeding 85 percent. The reduction figure excludes emissions from land-use change and forestry. Significant climate damages may still be associated with a 2° C increase in global temperatures. See den Elzen and Meinshausen, 2005.
[3] Author calculations, based on Marland et al., 2005 and Houghton, 2003a.
[4] Author calculations, based on Marland et al., 2005 and Houghton, 2003a.
[5] Author calculations, based on BP, 2005.
[6] Author calculations, based on BP, 2005.
[7] Activities related to land-use change and forestry could also be included here (for example., land clearing). However, the data in this sector does not permit a more detailed analysis.
[8] Measured in carbon dioxide equivalent units, using 100-year global warming potentials from IPCC (1996).
[9] Official GHG inventories submitted by Parties to the UNFCCC are used only sparingly. The primary reason is that UNFCCC data has very limited geographic and temporal coverage.
[10] Most analyses of GHG emissions focus solely on CO_2 from fossil fuel combustion because it is the largest source, and because the data record is the longest, most comprehensive, and most precise. The figures here are more inclusive.
[11] Cement emissions here refer to emissions resulting from the chemical process of cement manufacture. See Chapter 13.
[12] Author calculations, based on BP, 2005. According to BP, China's total primary energy consumption increased 34 percent over the 2003 to 2004 period.
[13] Author calculations, based on BP, 2005. Global growth over the two-year period is estimated at 2.4 billion tons CO_2, with China's increase estimated at 1.3 billion tons.
[14] These figures differ from those in Figure 2.8 because of the inclusion of all gases. Coverage of six gases for the 1990 to 2002 period is not possible for most countries due to lack of data.
[15] IPCC, 2000a.
[16] IPCC, 2000a.
[17] EIA, 2003.
[18] IEA, 2004c, includes a reference case projection for world emissions in 2030 that is 62 percent above 2002 levels. Emissions are projected to grow 41 percent by 2020.
[19] EIA, 1995.
[20] *See supra*, note 2.
[21] *See e.g.*, IPCC, 2001b.
[22] For a discussion, see Kim and Baumert, 2002.
[23] *See e.g.*, Agarwal et al., 1999; Meyer, 2000.
[24] UNFCCC, 1992. Art. 3.2.
[25] Emission intensities can also be fashioned for some sectors (discussed in Part II), such as CO_2 per kilowatt hour of electricity generation or CO_2 per ton of steel produced.
[26] An analysis of GHG intensities over the 1990 to 2002 period, which would include all gases, is not possible for most countries due to lack of non-CO_2 data for the period after 2000.
[27] Author calculations, based on BP (2005) suggest increases in CO_2 emissions of 17.6 percent in 2003 and a further 14.9 percent in 2004. Reported GDP growth rates in China are in the 8 to 9 percent range.
[28] In Brazil, the rapid increase reflects at least in part the recent effort to diversify the electricity mix, moving from large hydropower to natural gas.
[29] *Greenhouse gas* intensity is the ratio of all GHG emissions per unit of gross national product. *Carbon* intensity reflects only the portion of total GHG emissions arising from fossil fuel combustion. It captures the majority of emissions in most cases and can be more accurately calculated.
[30] In reality, both hydropower (WCD, 2000) and biomass use (see Chapter 17) may entail significant emissions.
[31] Some of these shifts may be a result of data deficiencies. In some countries (e.g., India and Nepal), for instance, energy consumption may be shifting away from traditional fuel use (such as biomass) toward commercial fuel use (fossil fuels). Energy use increases may be overstated because there is a tendency for traditional fuel use to not be captured in some energy data, whereas commercial energy use is captured.
[32] Using available data, statistical correlations were estimated for (1) changes in emissions of non-CO_2 gases and changes in GDP, and (2) changes in emissions of CO_2 from fossil fuels and changes in GDP. The linear correlation measure for (1) was 0.29 (360 data points). The correlation for (2) was 0.49 (370 data points).
[33] Bouille and Girardin, 2002.
[34] Bouille and Girardin, 2002.
[35] Kim and Baumert, 2002.
[36] Updated WRI calculations, based on WRI, 2003b.
[37] WRI, 2003b.
[38] Kim and Baumert, 2002.
[39] Marland et al., 2005. CO_2 emission estimates for the period prior to 1850 are available, but for only a few countries.
[40] Methodologies for concentrations and temperature indicators follow a simple methodology that was applied in the original Brazilian Proposal and was recommended as the preliminary default by the UNFCCC expert group (UNFCCC, 2002). For more information, see WRI, 2005b.
[41] Uncertainties are found in precisely attributing temperature increases to change in concentrations, and to attributing concentration changes to changes in cumulative emissions. See Aldy et al., 2003; UNFCCC 2002; WRI, 2005b for details.
[42] Regional estimates, however, extend back to 1850. Houghton and Hackler, 2002.
[43] *See e.g.*, UNFCCC, 1997; La Rovere et al., 2002.
[44] UNFCCC, 2002a.
[45] Marland et al., 2005.
[46] GDP figures are measured in terms of purchasing power parity, in constant 2000 international dollars. World Bank, 2005.
[47] Disparities are significantly larger when income is compared using market exchange rates. Comparisons are visible in CAIT.
[48] UNDP, 2003.
[49] This figure for Ukraine, however, is from 1990 to 2000 due to lack of GDP estimates for earlier periods.
[50] IEA, 2004c. Figure pertains to 2002.
[51] UNFCCC, 1992, Art. 3.4.

[52] UNFCCC, 1992, Art. 3.1. Emphasis added.
[53] *See* Willems and Baumert, 2004.
[54] UNFCCC, 2002b: at ¶ 161 Problems reported include lack of quality data, lack of technical and institutional capacity, and problems related to methodologies.
[55] *See e.g.*, Jacobson and Brown Weiss, 1997: 100-01 (discussing as a "crucial factor" a country's "administrative capacity," which has numerous dimensions, including skill, financial support, legal authority, and access to information).
[56] For a discussion, see WRI, 2005b. For more in-depth analysis, see Neumayer (2002) and Schipper et al. (2000).
[57] The "degree-day" is a measure commonly used to evaluate demand for heating and cooling services. The measure is based on departures from an average temperature of 18 °C (65 °F), a base temperature considered to have neither heating nor cooling requirements. For underlying climatic data sources and methodologies, see WRI (2003).
[58] Some hydropower installations, it should be noted, can result in significant emissions of greenhouse gases, particularly dams in tropical countries. See WCD, 2000.
[59] BP, 2005.
[60] IEA, 2004c: 169.
[61] Author calculations, based on IEA, 2004b and BP, 2005. Australia's share of exports is about 30 percent of the world total; Japan's share of imports is about 25 percent of the world total.
[62] Bosi and Riey, 2002: 13. Coking coal represents almost 30 percent of world trade in coal, but less than 15 percent of coal production. IEA, 2004b.
[63] IEA, 2004c: 169.
[64] Author calculations, based on BP, 2005.
[65] Author calculations, based on BP, 2005.
[66] Author calculations, based on IEA, 2004b.
[67] Author calculations, based on IEA, 2004b.
[68] Author calculations, based on BP, 2005.
[69] Author calculations, based on BP, 2005.
[70] IEA, 2004c: 81.
[71] Author calculations, based on BP, 2005.
[72] Author calculations, based on BP, 2005.
[73] BP, 2005.
[74] IEA, 2004c: 129.
[75] See the U.S.-led Methane to Markets Partnership as a possible nascent example of such an initiative. Information available online at: http://www.methanetomarkets.org/.
[76] World Bank, 2005. Exports and imports each represented 12 percent shares of GDP in 1960, and 24 percent shares in 2002. The pace of trade growth relative to GDP growth has increased since 1990. See WTO (2004) regional tables pertaining to trade and GDP developments.
[77] World Bank, 2005.
[78] World Bank, 2005. Based on most recent year, 2002 or 2003.
[79] World Bank, 2005. Based on most recent year, 2002 or 2003.
[80] Ahmad, 2003: 21.
[81] BP, 2005.
[82] Bosi and Riey, 2002. Industrialized countries here refer to the IEA countries (identical to OECD, but excluding Iceland, Mexico, Poland, and Slovakia). See http://www.iea.org.
[83] Bosi and Riey, 2002: 43. This figure is for 1999.
[84] Bosi and Riey, 2002: 43. Based on data from 1999.
[85] *See* Baumert and Goldberg, 2005.
[86] On sectoral crediting mechanisms, see e.g., Samaniego and Figueres, 2002; Bosi and Ellis, 2005.
[87] *See* IPCC, 2001c: 10, 11, 542-43.
[88] *See* IPCC, 2001c: 10, 11, 542-43.
[89] For a comprehensive examination of leakage and spillover effects, see Sijm et al., 2004.
[90] Aviation measurement problems pertain less to emissions than *radiative forcing*. See Chapter 12.
[91] "Electricity & Heat," as used here, corresponds to IPCC Sector/Source category 1A1 (IPCC, 1997). Contents are described in Appendix 2.A. It includes electric power and heat plants (primarily but not exclusively public plants) and "other energy industries."
[92] "Other energy industries" includes emissions from fuel combusted in petroleum refineries and in fossil fuel extraction (IEA, 2004).
[93] Author calculations, based on IEA, 2004b.
[94] Author calculations, based on IEA, 2004b.
[95] For example, in an examination of 15 OECD countries, estimated coal-fired electricity generation efficiency ranged from 33.1 percent (United States) to 43.5 percent (Denmark) in 2000. Phylipsen et al., 2003.
[96] Author calculations, based on IEA, 2004b.
[97] Author calculations, based on IEA, 2004b.
[98] Bosi and Riey, 2002: 23-24.
[99] This was made possible by the 1992 Energy Policy Act, which liberalized international investment rules for U.S. utilities. *See* EIA, 1997.
[100] EdF, 2005.
[101] AES, 2005.
[102] Eskom, 2004.
[103] WCD, 2000. These emissions are characterized by large uncertainties and poorly developed measurement methodologies. They are usually unaccounted for in GHG emissions inventories and statistics.
[104] "Transport," as used here, pertains to IPCC Source Category 1A3, but also includes a small amount of energy-related CO_2 emissions from indirect sources (1A1), mainly electricity for rail transport. *See* Appendix 2.B.
[105] Ng and Schipper, 2005.
[106] Author calculations, based on IEA, 2004c.
[107] WTO, 2004: 101.
[108] WTO, 2004: 137.
[109] WTO, 2004: 140. The EU figure includes only extra-EU-15 exports. Including intra-EU trade, the product value is $371 billion.
[110] Author calculations, based on UNIDO, 2005. The calculations include ISIC classes 3410, 3420, and 3430.
[111] WTO, 2004: 140.
[112] Author calculations, based on UNIDO, 2005. EU countries sampled are Italy, Spain, U.K., France, and Germany.
[113] Author calculations, based on UNIDO, 2005.
[114] There are non-trivial impacts of international road traffic in Europe. This includes some gravitation toward purchasing fuels in low-priced countries, which has only a small impact in large countries, but a significant impact in some smaller countries like Luxembourg. In addition, roughly 10 percent of all trucking in continental Europe represents international transit traffic.
[115] Under IPCC Guidelines (IPCC, 1997), emissions from international aviation are not counted against national emission totals and are not classified under national emissions from transport.
[116] Author calculations, based on IEA, 2004a.
[117] IPCC, 1999: 3.
[118] IPCC, 1999: 3.
[119] IPCC, 1999: 8. This figure reflects projected growth in all other sectors as well.
[120] IPCC, 1999: 8.
[121] E-mail correspondence with Michael Metcalf, President of International Society of Transport Aircraft Trading, February 11, 2005.
[122] Airbus 2004; Embraer, 2004.
[123] Author calculations, based on UNIDO, 2005. Based on ISIC class 3530, 2001 data; includes spacecraft.
[124] Author calculations, based on UNIDO, 2005. Based on ISIC class 3530, 1999-2002 data; includes spacecraft.

[125] "Industry," as used here, covers *energy*-related CO_2 emissions from direct sources (IPCC Source Category 1 A 2) as well as *industrial process*-related GHG emissions (IPCC Source Category 2). Where possible, indirect CO_2 emissions from electricity and heat are also included in this sector definition. *See* Appendix 2.B.

[126] WTO, 2004: 101. This figure includes all manufactured goods, including automobiles, discussed in Chapter 10.

[127] Phylipsen, 2000: 43.

[128] The sector definition corresponds with ISIC Rev.3 division 24 (Manufacture of chemicals and chemical products). ISIC, see http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2&Lg=1. *See also*, ICCA, 2002.

[129] CEFIC, 2005. The two are SABIC (Saudi Arabia) and Sinopec (China).

[130] CEFIC, 2005.

[131] UNCTAD, 2004: 279.

[132] UNCTAD, 2004: 302, 303.

[133] UNCTAD, 2004: 302, 303.

[134] WTO, 2004: 127.

[135] ICCA, 2002.

[136] WTO, 2004: 127.

[137] WTO 2004: 129.

[138] WTO 2004: 129.

[139] Holcim, 2004.

[140] Hendriks et al., 2004.

[141] Price et al., 1999.

[142] Watson et al., 2005, citing U.N. Commodity Trade Statistics. Author calculations based on UNIDO (2005) suggest even smaller amounts of trade (covering ISIC classes 2694 [cement, lime and plaster] and 2695 [articles of concrete, cement and plaster]).

[143] Freedonia Group, 2004a.

[144] Xuemin, 2004; Soule et al., 2002.

[145] Xuemin, 2004; Soule et al., 2002.

[146] OECD/IEA, 2001b.

[147] OECD/IEA, 2001b, citing De Beer et al. (1999), estimated global iron and steel emissions in 1995 at 1442 $MtCO_2$, amounting to 7 percent of global CO_2. Our estimate for 2000 is less, at 1320 $MtCO_2$. One possible reason for the discrepancy is that some gas byproducts of iron and steel production (namely, coke oven gas, blast furnace gas, and oxygen steel furnace gas) are recovered and used outside the steel-making process (for example, in certain power plants). Because we account for "end use" emissions, emissions from those gas byproducts are not counted under iron and steel.

[148] OECD/IEA, 2001b.

[149] China Iron and Steel Association (CISA). Online at: http://www.chinaisa.org.cn/en/stat/stat.htm.

[150] Haoting, 2005.

[151] Mannato, 2005.

[152] Mittal company profile. Online at: http://www.ispat.com/Company/Profile.htm

[153] Author calculations, based on IISI, 2005.

[154] Inferred from IISI, 2005. Top 40 companies represent 53 percent of global production; top 80 percent represent 69 percent.

[155] IISI, 2005: 14. One quarter of this trade is within Europe.

[156] WTO, 2004: 101.

[157] IISI, 2005: 12.

[158] IISI, 2005: 12.

[159] Mannato, 2005.

[160] See Appendix 2.B for more information.

[161] Shares by application are transport (26%), construction (20%), packaging (20%), electrical (9%) and other (26%). IAI, 2002.

[162] IAI, 2005c. *See* "Environment/Aluminum's Lifecycle."

[163] Author calculations, based on IEA, 2004b and IAI, 2005c (see "Environment").

[164] IAI, 2005c. *See* "Production/Smelting/Technology Types."

[165] IAI, 2005c. *See* "Production/Recycling."

[166] IAI, 2005c. *See* "IAI."

[167] John Newman, personal communication, July 20, 2005 (citing U.N. Commodity Trade Statistics). Author calculations based on UNIDO (2005) also suggest similarly large trade flows (covering ISIC class 2720, non-ferrous metals). *See also* Watson et al., 2005.

[168] UNCTAD, 2004: 278-280.

[169] "Buildings," as used here, pertains to IPCC Source Category 1A4a (commercial/institutional) and 1A4b (residential), as well as indirect emissions from *electricity and heat* (category 1A1) consumed in buildings. See Appendix 2.B.

[170] IEA, 2004b.

[171] EIA, 2005a; IEA, 2004d.

[172] EIA, 2005a; IEA, 2004d.

[173] Brown et al., 2005.

[174] Freedonia Group, 2004b.

[175] "Agriculture," as used here, pertains to IPCC Source Category 4, but also includes *energy*-related CO_2 emissions from direct sources (category 1A4) and indirect sources (1A1). *See* Appendix 2.B.

[176] EPA, 2002: §4.1, noting that "N_2O is produced naturally in soils through the microbial process of denitrification and nitrification. A number of anthropogenic activities add nitrogen to the soils, thereby increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of N_2O emitted."

[177] WTO, 2004: 101.

[178] "Waste" pertains to IPCC Source Category 6. *See* Appendix 2.A.

[179] "Land-Use Change and Forestry" pertains to IPCC Source Category 5. *See* Appendix 2.A.

[180] These are farming systems that alternate periods of annual cropping with fallow periods, such as "slash and burn" systems, which use fire to clear fallow areas for cropping.

[181] Houghton 2003a,b. Estimates do not include the indirect or natural effects of climatic change (for example, CO_2 fertilization) or changes in carbon stocks that may result from various forms of management, such as agricultural intensification, fertilization, the trend to no-till agriculture, thinning of forests, changes in species or varieties, and other silvicultural practices.

[182] Houghton, 2003a; IPCC, 2000b: 4.

[183] Author calculations, based on Houghton, 2003a. These emissions amounted to roughly one-quarter of the annual emission levels of tropical countries in the 1990s. Earlier periods of deforestation (e.g., going back to the 16th century in Europe), for which data is not available, may have had higher emissions.

[184] IPCC, 2000b: 3.

[185] Houghton, 2003a; IPCC, 2000b.

[186] A gigaton of carbon (GtC) is equivalent to 1000 MtC, or 3,664 million tons of CO_2 equivalent.

[187] The remainder of CO_2 emissions are 6.3 GtC from fossil fuel combustion and cement manufacture. IPCC, 2000b: 5.

[188] IPCC, 2000b: 4.

[189] Houghton. 2003a.

[190] FAO, 2005: 98.

[191] *See* e.g., FAO, 2005:

[192] FAO, 2005: 42-44.

[193] FAO, 2005: 43.

[194] FAO, 2005: 46.

[195] For definitions of forest products, see http://www.fao.org/waicent/faostat/forestry/products.htm#1.

[196] FAO, 2005: 108.

[197] FAO, 2005: 108.

[198] *See* FAO, 2005: 109-111.

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