6. *Coal, Global Warming, and Health*

COAL'S CONTRIBUTION TO GLOBAL WARMING

In previous sections we have discussed the relationship between coal plant pollutants and human health. Here, we address coal's contribution to global warming, and the likely impacts of that warming on human health.

With very high carbon dioxide emissions due to combustion, and significant methane emissions from mining activities, coal is a major contributor to the buildup of greenhouse gases in the atmosphere. These gases allow solar energy to reach the planet's surface but delay that energy's escape into space, effectively trapping heat in the lower atmosphere.[1]

Atmospheric concentrations of greenhouse gases have increased markedly since 1750 as a result of human activities, especially the combustion of fossil fuels. Carbon dioxide (CO_2) is the most abundant greenhouse gas, and almost all U.S. CO_2 emissions (close to 98%) are due to fossil fuel combustion.[2] The level of atmospheric CO_2 now far exceeds pre-industrial values: Whereas the preindustrial level was 280 ppm, it is now approximately 385 ppm[3] (see Figure 6.1). China emits the most greenhouse gas of any country, but the U.S. emits the most greenhouse gas per capita.[4] Historically, the U.S. is responsible for over one-quarter of all anthropogenic greenhouse gases emitted globally.[5]

Coal-fired power plants are a major greenhouse gas source in the U.S., accounting for more than

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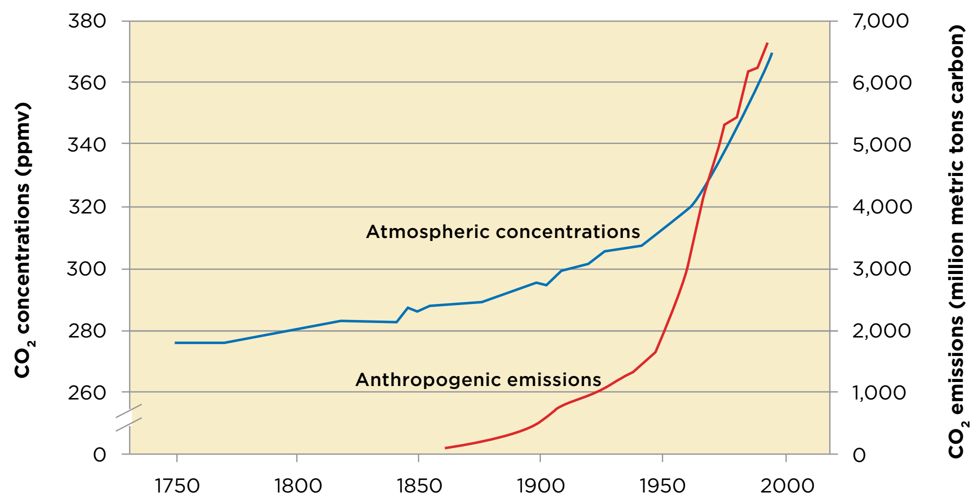
one-third of our nation's CO_2 emissions (see Figure 6.2).[6] Within the electricity sector, coal generates roughly 50% of the electricity[7] yet emits over 80% of the sector's total emissions.[8] This disproportionate carbon footprint is due to the high carbon content of coal relative to other fossil fuels such as natural gas.

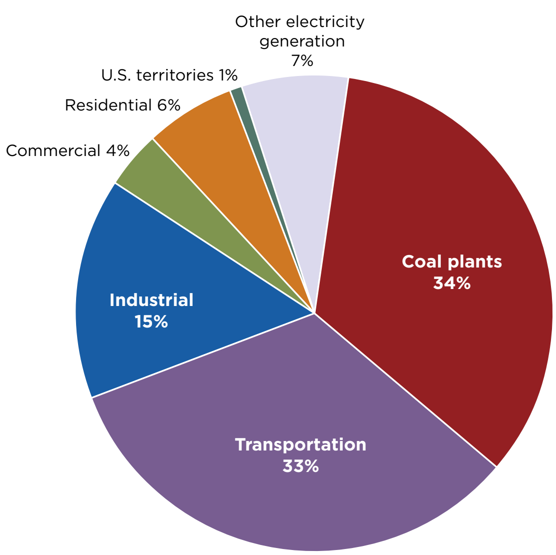
Methane emissions from coal mining are another important component of greenhouse gases.[9] Methane is produced when coal is formed and released when it is mined. Because methane is an occupational hazard in underground coal mines—it may explode or asphyxiate miners—it must be removed and ventilated into the atmosphere or burned. About 60% of methane emissions are now related to human activities,[10,11] with nearly 10% of that derived from coal mining and the remainder attributable largely to animal husbandry, waste management, and natural gas systems (see

Figure 6.1: CO_2 emissions and CO_2 concentrations (1750–2000)



Source: Oak Ridge National Laboratory. Carbon Dioxide Information Analysis Center. Available from: http://cdiac.esd.ornl.gov.

Figure 6.2: U.S. CO_2 emissions by source, 2007



Source: U.S. EPA. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2007. 2009: EPA-430/R-09-004. Available from: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

Figure 6.3).[12] Although methane has a short lifetime in the atmosphere—9 to 15 years, compared to CO_2's 100 years or more—it is approximately 23 times more effective than CO_2 in trapping heat in the atmosphere.[13,14]

GLOBAL WARMING'S IMPACT ON HUMAN HEALTH

The accumulation of greenhouse gases in the atmosphere is making itself felt on earth in the form of increases in global average land and ocean surface temperatures, increases in snow melt and receding glaciers, thawing of permafrost, increases in the mean sea level, and changes in precipitation.[15] These effects create conditions that threaten human health directly and indirectly.

The high temperatures associated with global warming have direct implications for human health. Historically, global average temperatures have been quite stable. However, since 1909 the average temperature has risen 0.74°C (1.33°F).[16] In the U.S., the number of heat waves in the eastern and western regions rose by about 20%

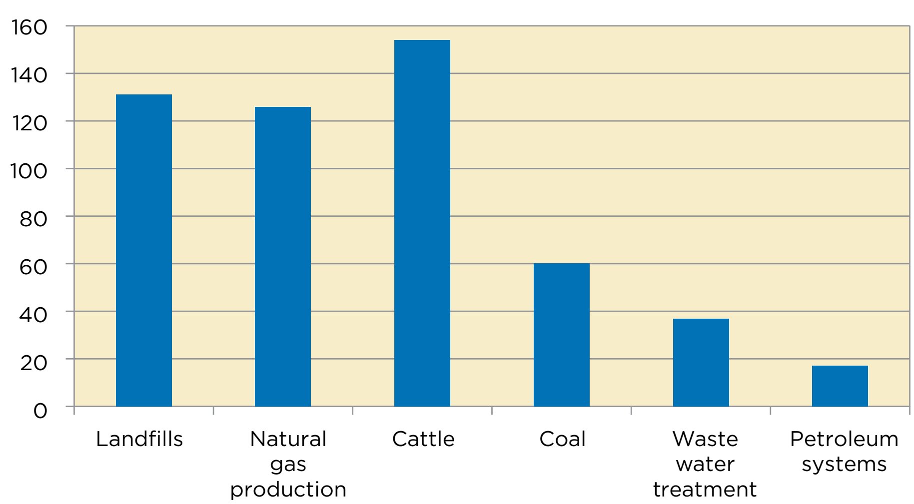
between 1949 and 1995.[17] Prolonged exposure to high temperatures can cause heat cramps, heat syncope, heat exhaustion, and heat stroke, which often leads to death. Advanced age is the most significant risk factor for heat-related deaths in the U.S., as the elderly are often less mobile, frequently home-bound and socially isolated, and may have thermoregulatory problems associated with multiple co-morbidities and medications that put them at higher risk for death during intense heat waves.[18] In addition, excessive heat exposure disproportionately affects people with certain pre-existing medical conditions, including cardiovascular disease, respiratory illnesses, and obesity.

It is difficult to quantify the number of deaths that result from heat waves, as heat-related deaths may be attributed to pre-existing conditions. However it is known that in 2003, between 22,000 and 35,000 people died as a direct result of the heat wave that swept Europe.[19,20] While it is impossible to attribute any specific heat wave to global warming, Stott, et al., concluded with a certainty of more than 90% that global warming more than doubled the probability of that heat wave occurring.[21]

In addition to the health effects directly associated with rising temperatures, global warming causes a profusion of interconnected public health problems.[22] Extreme-weather events and changing patterns of precipitation increase mortality from drowning. Flooding and infrastructure damage, along with temperature rise, increase the prevalence of insect- and water-borne diseases such as diarrhea, malaria, and dengue fever. High temperatures and continued fossil fuel consumption worsen air quality, impacting respiratory and cardiovascular health. Changing patterns of precipitation, rising temperatures, and extreme weather events cause crop damage and crop failure, affecting global food security. Competition for scarce resources such as food and water are predicted to cause mass migrations of environmental refugees, social destabilization, and war, while social destabilization and increasing global health problems are predicted to increase the risk of mental

Figure 6.3: Methane sources

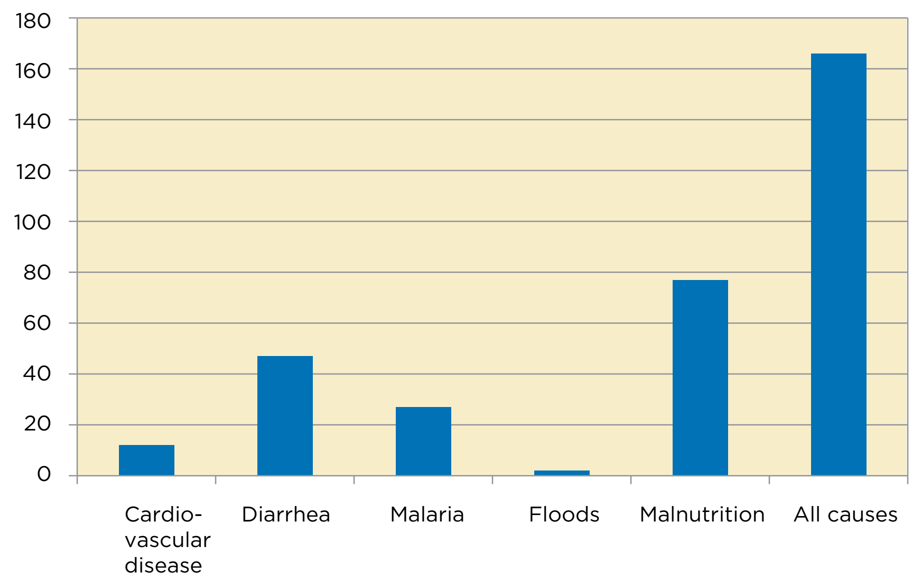
Methane emissions (Tg CO_2 equivalents). Contributions from coal include both active and abandoned mines. Contributions from cattle include emissions due to enteric fermentation and manure management.



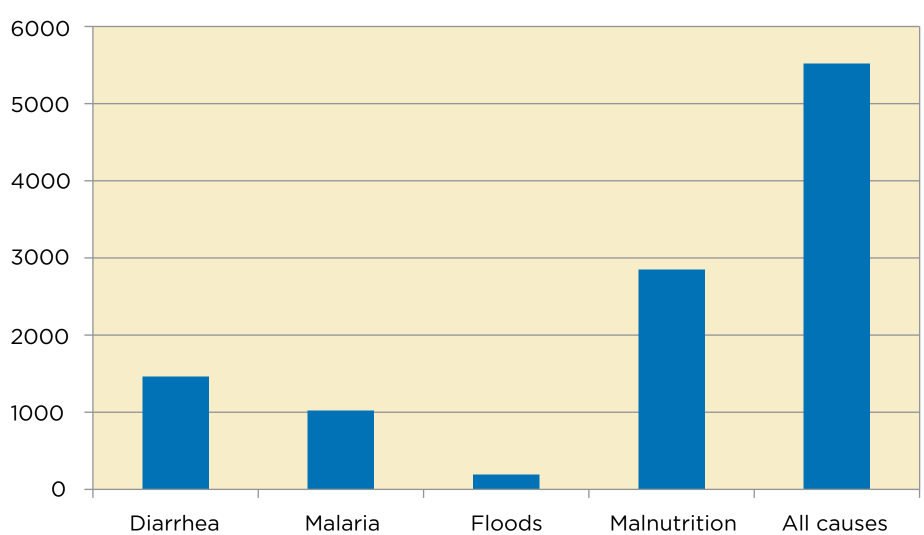
Source: U.S. EPA. Available from: http://www.epa.gov/methane/sources.html.

Figure 6.4: Morbidity and mortality due to global warming

Deaths in thousands due to global warming in 2000 compared to baseline climate recorded in 1961–1990



Morbidity, expressed in thousands of DALYs*



*DALYs = disability-adjusted life years, a measure of disease burden that combines years of life lost with years of life lived with illness or disability.

Source: 2004 World Health Organization data cited in Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature 2005 Nov 17;438:310–317.

health problems, further adding to the burden on healthcare resources.

Many of these health effects are already evident. The World Health Organization (WHO) has quantified the annual impact of global warming on some health outcomes. WHO has estimated that global warming was responsible for 166,000 deaths in the year 2000 alone, due to additional mortality from malaria, malnutrition, diarrhea, and drowning. In addition, WHO estimated that in 2000, global warming caused increases in diarrhea, malaria, cardiovascular disease, and malnutrition that led to the loss of more than five million life years to disability from illness or premature death,[23] as shown in Figure 6.4.

The health burden of global warming, already large, is predicted to increase. Table ES-2 (see page xiii) shows the predicted health effects of global warming, the mechanisms that would drive these effects, and the populations most vulnerable to their implications.

RESPONDING TO GLOBAL WARMING

Events and activities that affect climate may not make themselves visible at once; rather, their impact may manifest years later. This is especially true of gradual phenomena such as the buildup of greenhouse gases in the atmosphere. The global warming effects that we currently experience were set in motion by greenhouse gases emitted over the past 250 years. By the same token, the greenhouse gases that we emit today might not affect us noticeably at the moment; they will manifest later—and, due to their persistence in the atmosphere and the substantial amount of heat absorbed by the oceans, will continue to be felt for decades to millennia to come. This delay in the felt consequences of current actions is known as "lag" in the climate system.[24]

The rise in average global temperatures has set in motion cycles of mutually reinforcing warming events. One example is the melting of polar ice. Polar ice melt reduces the amount of light-colored surface area that reflects the sun's rays, while expanding larger areas of dark land and ocean that absorb heat. This adds to overall warming, resulting in more ice melting. Rising temperatures in northern regions also cause the permafrost to melt. Permafrost is permanently frozen soil, sediment, or rock that remains at or below 0°C for at least two years. Because it is so cold, it can tolerate the introduction of considerable heat without thawing. However, when it does thaw, it releases potentially vast amounts of methane frozen in the mud and ice. Because methane is a potent greenhouse gas, this also accelerates global warming. Thus, one warming phenomenon feeds another, creating positive feedback cycles.[25]

These and other feedback cycles push us closer to a "tipping point": a point at which the accumulation of small changes in a steady state will force a change in that state that is sudden, significant, and usually irreversible.[26] In regard to climate, the tipping point will be reached when the gradual changes set in motion by burning fossil fuels—the accumulation of greenhouse gases, rising temperatures, and positive feedback loops—overwhelm our ability to offset them. At that point, the momentum of global warming will become irreversible on a human time scale. Therefore, action must be taken now to prevent such a scenario.

Steps that would prevent further global warming include replacing coal-based generation of electricity with clean, non-fossil fuel energy sources.

There are two categories of action that must be taken in response to global warming: mitigation and adaptation. Mitigation means preventing further global warming; it encompasses steps that would slow and stop the emission of greenhouse gases.[27] Significant forms of mitigation include replacing coal-based generation of electricity with clean, non-fossil fuel energy sources such as wind and solar; substituting non-fossil fuels for the gas and diesel we burn in vehicles; and reducing the need for energy by achieving increases in energy efficiency and conservation.

Adaptation refers to steps that would reduce vulnerability to the actual or expected negative effects of climate change, such as building cities and healthcare infrastructure that can withstand extreme weather events, preparing emergency response plans, and developing drought-resistant crops.[28] With the effects of climate change already being felt, adaptation is necessary to protect vulnerable people and nations. At the same time, as a societal response adaptation is insufficient. If we continue to emit large amounts of greenhouse gases, global warming will continue and its effects will intensify. Eventually the damage wrought by floods, storms and sea level rise, drought and desertification, disease and hunger, habitat destruction and human displacement will overcome our capacity to protect ourselves. While adaptation measures are necessary, focusing our energies there to protect public health is insufficient. Adaptation does not prevent the triggering of climate tipping points such as those described above. The true protection of health and of life ultimately lies in prevention.

Lag in the climate system, especially when considered in conjunction with positive feedback

CARBON CAPTURE AND SEQUESTRATION

Carbon capture and sequestration (CCS) technology involves capturing the CO_2 from coal emissions, compressing it until it forms a liquid, and transporting the liquid CO_2 through pipelines to a geologically appropriate underground storage area where it would be stored ("sequestered") permanently.

Viewed through a public health lens, CCS poses several obstacles which would have to be resolved before it could be considered a viable option:

Concentrated CO_2 can be lethal. Concentrated CO_2 can asphyxiate people, as demonstrated in 1986 by the spontaneous release of CO_2 at Lake Nyos, Cameroon, that killed 1,700 people. Care must be taken to avoid pooling or leakage of CO_2 during both transport and storage.[29]

Permanent storage may not be possible. Storage would have to be leak-proof for geological periods of time.[30] If at any point in time stored CO_2 escaped into the atmosphere, it would contribute to global warming. If it were to leak into underground aquifers, it could dissolve and release contaminants such as arsenic, lead, mercury, and organic compounds, or could alter water acidity, affecting water quality.[31]

CCS would perpetuate coal pollution. During the time that CCS technology is being developed and safety and liability issues are being addressed, carbon emissions from coal plants would continue unabated. Even if CCS technology were successful, it would sustain the dependence on coal for the generation of electricity, perpetuating the release of other pollutants into the atmosphere, including particulates, sulfur dioxides, nitrogen oxides, and mercury, and contributing to the health-related problems associated with coal mining and the long-term storage of both pre- and post-combustion coal wastes.

CCS would divert funds from clean energy. The cost of research, development, construction, and implementation of CCS would be high.[32] The pipelines alone, reaching from every coal-powered plant in the country to appropriate storage areas, would require the construction of an extensive infrastructure system.[33] Funds spent on CCS development, construction, and deployment would be unavailable for investment in clean, safe energy from non-carbon-based sources.

Given the costs and difficulty of implementing CCS on a timeline and a scale that would effectively mitigate the health effects of global warming, the unreliability of permanent storage for geological periods of time, and the costs to health from coal's traditional pollutants, PSR has concluded that CCS is not a preferred option for developing the nation's energy future.

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loops and tipping points, has implications for our response to global warming. Even if CO_2 emissions cease today, average global temperatures will continue to rise. Therefore, current readings of CO_2 levels do not provide a full appraisal of the damage we have already inflicted on the climate system. This in turn means that we must be conservative in regard to future greenhouse gas emissions: Since the full impact of the emissions we have already released have not yet been felt, we should be cautious in assuming that we can predict the impacts of additional emissions.

The dynamics of climate change mean that we cannot take an unhurried approach to stopping global warming. We may be nearing climate tipping points; when we reach them, no human action or agency will be able to stop the climate change we will have set in motion. We must take action now, while there is still time to protect health and well-being on the planet.

NOTES

1 National Climatic Data Center. Global warming: frequently asked questions. 2008. Available from: http://www.ncdc.noaa.gov/oa/climate/globalwarming.html.

2 Energy Information Administration. Emissions of greenhouses gases report. 2008: DOE/EIA-0573(2007). Available from: http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html.

3 Pachauri RK and Reisinger A (eds). Climate Change 2007—Synthesis Report: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press; 2007.

4 Energy Information Administration. Emissions of greenhouses gases report. 2008: DOE/EIA-0573(2007). Available from: http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html.

5 Hansen J, Sato M, Ruedy R et al. Dangerous human-made interference with climate: a GISS modelE study. Atmos Chem Phys. 2007;7:2287–2312.

6 Energy Information Administration. Emissions of greenhouses gases report. 2008: DOE/EIA-0573(2007). Available from: http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html.

7 Energy Information Administration. Annual energy review 2008. Table 8.2a. Available from: http://www.eia.doe.gov/aer/envir.html.

8 Energy Information Administration. Annual energy review 2008. Table 12.7b. Available from: http://www.eia.doe.gov/aer/envir.html.

9 U.S. Climate Change Science Program. Methane as a greenhouse gas. 2006. Available from: http://www.climatescience.gov/infosheets/highlight1/CCSP-H1-methane18jan2006.pdf.

10 U.S. Geological Survey. Coalbed methane–an untapped energy resource and an environmental concern—USGS Fact Sheet FS-019-97. 1997. Available from: http://energy.usgs.gov/factsheets/Coalbed/coalmeth.html.

11 Denman KL, Brasseur G, Chidthaisong A, et al. Couplings between changes in the climate system and biogeochemistry. In: Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press; 2007.

12 EPA. Methane web page. Available from: http://www.epa.gov/methane/sources.html.

13 US Climate Change Science Program. Methane as a greenhouse gas. 2006. Available from: http://www.climatescience.gov/infosheets/highlight1/CCSP-H1-methane18jan2006.pdf

14 EPA. Methane to markets partnership: frequent questions. April 2009. Available from: http://www.epa.gov/methanetomarkets/faq.htm#3.

15 Pachauri RK and Reisinger A (eds). Climate Change 2007—Synthesis Report: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press; 2007.

16 Solomon S, Qin D, Manning M, et al (eds). Summary for Policymakers. In: Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press; 2007.

17 Gaffen DJ, Ross R. Increased summertime heat stress in the U.S. Nature 1998;396:529–30.

18 Luber G, McGeehin M. Climate change and extreme heat events. Am J Prev Med 2008 Nov;35(5):429–35.

19 Kosatsky T. The 2003 European heat waves. Euro Surveill 2005; 10: 148–149.

20 Epstein P. Climate change and human health. New Eng J Med 2005; 353: 1433–1436.

21 Stott PA, Stone DA, and Allen MR. Human contribution to the European heat wave of 2003. Nature 2004; 432: 610–614.

22 Costello A, Abbas M, Allen A, et al. Lancet and University College London Institute for Global Health Commission: managing the health effects of climate change. Lancet 2009; **373**: 1693–1733.

23 Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature 2005 Nov 17;438:310–317.

24 Solomon S, Qin D, Manning M, et al (eds). Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press; 2007.

25 U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Abrupt climate change. Reston, Virginia: U.S. Geological Survey; 2008. Available from: http://www.climatescience.gov/Library/sap/sap3-4/final-report/.

26 Epstein PR, Mills E (eds). Climate change futures: health, ecological, and economic dimensions. Center for Health and the Global Environment, Harvard Medical School 2005. Available from: http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf.

27 Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA (eds). Climate Change 2007 —Mitigation of Climate Change: Working Group III contribution to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press; 2007.

28 Schmidt CW. Beyond mitigation: planning for climate change adaptation. Environ Health Perspect 2009 Jul;117(7):A306–9.

29 International Energy Agency, Greenhouse Gas R&D Programme. Natural releases of CO_2. Undated. Available from: http://www.ieagreen.org.uk/glossies/naturalreleases.pdf.

30 Markandya A, Wilkinson P. Electricity generation and health. Lancet 2007;370:979–990.

31 Socolow R, Hotinski R, Greenblatt JB, Pacala S. Solving the climate problem: technologies available to curb CO_2 emissions. Environment 2004:46(10);8–19.

32 International Energy Agency. Technology roadmap: carbon capture and storage. 2009. Available from: http://www.iea.org/Papers/2009/CCS_Roadmap.pdf.

33 Metz B, Davidson O, de Coninck HC, Loos M, Meyer LA (eds). Carbon dioxide capture and storage: special report of Working Group III of the IPCC. Cambridge: Cambridge University Press; 2005.