

COAL's ASSAULT *on* HUMAN HEALTH

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A REPORT FROM

PHYSICIANS FOR SOCIAL

RESPONSIBILITY



EXECUTIVE SUMMARY

ACKNOWLEDGMENTS

The authors gratefully acknowledge the following experts who reviewed drafts of this report, sharing their insight and comments:

Paul Epstein, MD MPH
Howard Hu, MD MPH ScD
Philip Landrigan, MD MSc
Michael McCally, MD PhD
Cindy Parker, MD MPH
Jonathan Patz, MD MPH
Katherine Shea, MD MPH

Any remaining errors are entirely our own.

This report was made possible through the generous financial support of the Energy Foundation and the Compton Foundation.

Production was generously underwritten by PMG, a division of The Production Management Group, Ltd.

For the full report, please see www.psr.org/coalreport.

ABOUT PHYSICIANS FOR SOCIAL RESPONSIBILITY

PSR has a long and respected history of physician-led activism to protect the public's health. Founded in 1961 by a group of physicians concerned about the impact of nuclear proliferation, PSR shared the 1985 Nobel Peace Prize with International Physicians for the Prevention of Nuclear War for building public pressure to end the nuclear arms race. Today, PSR's members, staff, and state and local chapters form a nationwide network of key contacts and trained medical spokespeople who can effectively target threats to global survival. Since 1991, when PSR formally expanded its work by creating its environment and health program, PSR has addressed the issues of global warming and the toxic degradation of our environment. PSR presses for policies to curb global warming, ensure clean air, generate a sustainable energy future, prevent human exposures to toxic substances, and minimize toxic pollution of air, food, and drinking water.

NOVEMBER 2009

Coal's Assault on Human Health

Executive Summary

Coal pollutants affect all major body organ systems and contribute to four of the five leading causes of mortality in the U.S.: heart disease, cancer, stroke, and chronic lower respiratory diseases. This conclusion emerges from our reassessment of the widely recognized health threats from coal. Each step of the coal lifecycle—mining, transportation, washing, combustion, and disposing of post-combustion wastes—impacts human health. Coal combustion in particular contributes to diseases affecting large portions of the U.S. population, including asthma, lung cancer, heart disease, and stroke, compounding the major public health challenges of our time. It interferes with lung development, increases the risk of heart attacks, and compromises intellectual capacity.

Oxidative stress and inflammation are indicated as possible mechanisms in the exacerbation and development of many of the diseases under review. In addition, the report addresses another, less widely recognized health threat from coal: the contribution of coal combustion to global warming, and the current and predicted health effects of global warming.

THE LIFE CYCLE OF COAL

Electricity provides many health benefits worldwide and is a significant contributor to economic development, a higher standard of living, and an increased life expectancy.¹ But burning coal



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to generate electricity harms human health and compounds many of the major public health problems facing the industrialized world. Detrimental health effects are associated with every aspect of coal's life cycle, including mining, hauling,

preparation at the power plant, combustion, and the disposal of post-combustion wastes. In addition, the discharge of carbon dioxide into the atmosphere associated with burning coal is a major contributor to global warming and its adverse effects on health worldwide.

Coal mining leads U.S. industries in fatal injuries² and is associated with chronic health

problems among miners, such as black lung disease, which causes permanent scarring of the lung tissues.³ In addition to the miners themselves, communities near coal mines may be adversely affected by mining operations due to the effects of blasting, the collapse of abandoned mines, and the dispersal of dust from coal trucks. Surface mining also destroys forests and groundcover, leading to flood-related injury and mortality, as well

as soil erosion and the contamination of water supplies. Mountaintop removal mining involves blasting down to the level of the coal seam—often hundreds of feet below the surface—and depositing the resulting rubble in adjoining valleys. This surface mining technique, used widely across southern Appalachia, damages freshwater aquatic ecosystems and the surrounding environment by burying streams and headwaters.⁴

After removal of coal from a mine, threats to public health persist. When mines are abandoned, rainwater reacts with exposed rock to cause the oxidation of metal sulfide minerals. This reaction releases iron, aluminum, cadmium, and copper into the surrounding water system⁵ and can contaminate drinking water.⁶

Coal washing, which removes soil and rock impurities before coal is transported to power plants, uses polymer chemicals and large quantities of water and creates a liquid waste called slurry. Slurry ponds can leak or fail, leading to injury and death, and slurry injected underground into old mine shafts can release arsenic, barium, lead, and manganese into nearby wells, contaminating local

water supplies. Once coal is mined and washed, it must be transported to power plants. Railroad engines and trucks together release over 600,000 tons of nitrogen oxide and 50,000 tons of particulate matter into the air every year in the process of hauling coal, largely through diesel exhaust.⁷ Coal trains and trucks also release coal dust into the air, exposing nearby communities to dust inhalation.⁸

The storage of post-combustion wastes from coal plants also threatens human health. There are 584 coal ash dump sites in the U.S.,⁹ and toxic residues have migrated into water supplies and threatened human health at dozens of these sites.¹⁰

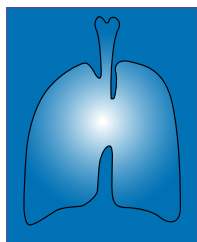
The combustion phase of coal's lifecycle exacts the greatest toll on human health. Coal combustion releases a combination of toxic chemicals into the environment and

contributes significantly to global warming. Coal combustion releases sulfur dioxide, particulate matter (PM), nitrogen oxides, mercury, and dozens of other substances known to be hazardous to human health. Coal combustion contributes to smog through the release of oxides of nitrogen, which react with volatile organic compounds in the presence of sunlight to produce ground-level ozone, the primary ingredient in smog.

Table 1 (see pages 8–9) describes the major health effects linked to coal combustion emissions. These health effects damage the respiratory, cardiovascular, and nervous systems and contribute to four of the top five leading causes of death in the U.S.: heart disease, cancer, stroke, and chronic lower respiratory diseases. Although it is difficult to ascertain the proportion of this disease burden that is attributable to coal pollutants, even very modest contributions to these major causes of death are likely to have large effects at the population level, given high incidence rates. Coal combustion is also responsible for more than 30% of total U.S. carbon dioxide pollution, contributing significantly to global warming and its associated health impacts.

Coal combustion emissions damage the respiratory, cardiovascular, and nervous systems and contribute to four of the top five leading causes of death in the U.S.

RESPIRATORY EFFECTS OF COAL POLLUTION



Pollutants produced by coal combustion act on the respiratory system to cause a variety of adverse health effects. Air pollutants—among them nitrous oxide (NO_2) and very small particles, known as $\text{PM}_{2.5}$ —adversely affect lung development, reducing

forced expiratory volume (FEV) among children.¹¹ This reduction of FEV, an indication of lung function, often precedes the subsequent development of other pulmonary diseases.

Air pollution triggers attacks of asthma, a respiratory disease affecting more than 9% of all children in the U.S. Children are particularly susceptible to the development of pollution-related asthma attacks. This may be due to their distinct breathing patterns, as well as how much time they spend outside. It may also be due to the immaturity of their enzyme and immune systems, which assist in

detoxifying pollutants, combined with incomplete pulmonary development.¹² These factors appear to act in concert to make children highly susceptible to airborne pollutants such as those emitted by coal-fired power plants.¹³

Asthma exacerbations have been linked specifically to exposure to ozone, a gas produced when NO_2 reacts with volatile organic compounds in the presence of sunlight and heat.¹⁴ The risk to children of experiencing ozone-related asthma exacerbations is greatest among those with severe asthma. That risk exists even when ambient ozone levels fall within the limits set by the EPA to protect public health.

Coal pollutants trigger asthma attacks in combination with individual genetic characteristics.¹⁵ This gene-environment interaction means that some individuals are more susceptible to the respiratory health effects of coal pollution. The genetic polymorphisms that appear to make people more susceptible include those that control inflammation and those that deal with oxidative stress, or



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OXIDATIVE STRESS

Oxygen free radicals in biological systems are a normal cellular constituent and play critical roles in the control of many cellular functions. (Free radicals are atoms or molecules that contain at least one unpaired electron in an atomic or molecular orbit and are therefore unstable and highly reactive.)

The concentration of oxygen free radicals can be increased through exposure to environmental substances such as air pollution, tobacco smoke, pesticides, and solvents. When their concentration is excessive, these highly reactive molecules damage lipids, proteins, DNA, cell membranes, and other cellular components. "Oxidative stress" is the term used to describe that physiological state.

Oxidative stress is an important contributing factor in a variety of diseases, including atherosclerosis, hypertension, rheumatoid arthritis, diabetes mellitus, and neurodegenerative disorders such as Alzheimer's disease and Parkinson's disease, as well as normal aging. It is one of several mechanisms implicated in the pathogenesis of diseases caused or made worse by coal pollutants, such as cardiovascular and pulmonary disease.

Valko M, Leibfritz D, Moncol J, Cronin MTD, Mazur M, Telser J. Free radicals and antioxidants in normal physiological functions and human disease. *Int J Biochem and Cell Biology* 2007; 39: 44–84.

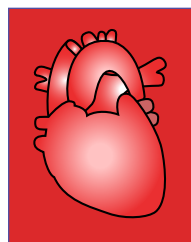
the presence of highly reactive molecules, known as free radicals, in cells. (See text box.)

Coal pollutants play a role in the development of chronic obstructive pulmonary disease (COPD), a lung disease characterized by permanent narrowing of airways. Coal pollutants may also cause COPD exacerbations, in part through an immunologic response—i.e., inflammation.^{16,17,18} PM exposure disposes the development of inflammation on the cellular level, which in turn can lead

to exacerbations of COPD. COPD is the fourth leading cause of mortality in the U.S.

Exposures to ozone and PM are also correlated with the development of¹⁹ and mortality from^{20, 21, 22} lung cancer, the leading cancer killer in both men and women.

CARDIOVASCULAR EFFECTS OF COAL POLLUTION



Pollutants produced by coal combustion damage the cardiovascular system. Coronary heart disease (CHD) is a leading cause of death in U.S., and air pollution is known to negatively impact cardiovascular health.²³ The mechanisms by which air pollution causes cardiovascular disease have not been definitively identified but are thought to be the



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same as those for respiratory disease: pulmonary inflammation and oxidative stress. Studies in both animals and humans support this theory, showing that pollutants produced by coal combustion lead to cardiovascular disease, such as arterial occlusion (artery blockages, leading to heart attacks) and infarct formation (tissue death due to oxygen deprivation, leading to permanent heart damage).

Recent research suggests that nitrogen oxides and $PM_{2.5}$, along with other pollutants, are associated with hospital admissions for potentially fatal cardiac rhythm disturbances.²⁴ The concentration of $PM_{2.5}$ in ambient air also increases the probability of hospital admission for acute myocardial infarction,²⁵ as well as admissions for ischemic heart diseases, disturbances of heart rhythm, and congestive heart failure.²⁶ Additionally, cities with high NO_2 concentrations had death rates four times higher than those with low NO_2 concentrations.²⁷ These studies show important immediate effects of coal pollutants on indicators of acute cardiovascular illness.

There are cardiovascular effects from long-term exposure as well. Exposure to chronic air pollution over many years increases cardiovascular mortality.²⁸ This relationship remains significant

even while controlling for other risk factors, such as smoking. Conversely, long-term improvements in air pollution reduce mortality rates. Reductions in $PM_{2.5}$ concentration in 51 metropolitan areas were correlated with significant increases in life expectancy,²⁹ suggesting that air quality improvements mandated by the Clean Air Act have measurably improved the health of the U.S. population. Reducing exposure to the pollutants emitted by coal combustion is therefore an important aspect of improving cardiovascular health for the population at large.

NERVOUS SYSTEM EFFECTS OF COAL POLLUTION



In addition to the respiratory and cardiovascular systems, the nervous system is also a target for coal pollution's health effects. The same mechanisms that are thought to mediate the effect of air pollutants on coronary arteries also apply to the arteries that nourish the brain. These include stimulation of the inflammatory response and oxidative stress,



Table 1: Coal's contributions to major health effects

	Disease or condition	Symptoms or result	Most-vulnerable populations	Total disease burden (coal is a suspected contributing factor in an unknown number of cases)	Coal pollutants implicated
RESPIRATORY	Asthma exacerbations	Coughing, wheezing, shortness of breath, and breathlessness with a range of severity from mild to requiring hospitalization	Children, adults	Number of visits to office-based physicians for asthma: 10.6 million in 2006. Number of hospitalizations with asthma listed first as diagnosis: 440,000. ³⁰ School days missed per year attributable to asthma: 11.8 million. ³¹	NO ₂ Ozone Particulate Matter (PM) ^{32,33,34}
	Asthma development	New cases of asthma, resulting in coughing, wheezing, shortness of breath, and breathlessness with a range of severity from mild to requiring hospitalization	Children	Children with asthma: 6.7 million (9.1%). Adults with asthma: 16.2 million (7.3%). ³⁵	Suspected but not confirmed: ^{36,37,38} NO ₂ Ozone PM _{2.5}
	Chronic Obstructive Pulmonary Disease (COPD)	Emphysema with chronic obstructive bronchitis; permanent narrowing of airways; breathlessness; chronic cough	Smokers, adults	Adults with COPD diagnosis in 2006: 12.1 million. ³⁹ Deaths in 2005: 126,000. ⁴⁰ Fourth leading cause of mortality in U.S.	NO ₂ PM ^{41,42,43}
	Stunted lung development	Reductions in lung capacity; risk factor for development of asthma and other respiratory diseases	Children	Unknown	NO ₂ PM _{2.5} ⁴⁴
	Infant mortality (relevant organ system uncertain; may be respiratory)	Death among infants age < 1 year	Infants	Deaths in 2005: 28,384. Almost 25% may have had respiratory causes: 2,234 deaths attributed to Sudden Infant Death Syndrome (SIDS), and 4,698 deaths attributed to short gestation and low birth weight. ⁴⁵	NO ₂ PM ^{46,47}
	Lung cancer	Shortness of breath, wheezing, chronic cough, coughing up blood, pain, weight loss ⁴⁸	Smokers, adults	Deaths in 2005: 159,217. Leading cause of cancer mortality in U.S. among both men and women. ⁴⁹	PM ^{50,51,52}
CARDIOVASCULAR	Cardiac arrhythmias	Abnormal rate or rhythm of the heart; palpitation or fluttering; may cause fatigue, dizziness, lightheadedness, fainting, rapid heartbeat, shortness of breath, and chest pain ⁵³	Adults, hypertensives, diabetics, those with cardiovascular disease	Unknown	NO ₂ PM _{2.5} ⁵⁴
	Acute myocardial infarction	Chest pain or discomfort; heart attack	Adults, diabetics, hypertensives	Deaths in 2006: 141,462. ⁵⁵ Cases in 2006: 7.9 million. ⁵⁶	PM _{2.5} ⁵⁷
	Congestive heart failure	Shortness of breath, fatigue, edema (swelling) due to impaired ability of heart to pump blood; can result from narrowed arteries, past heart attack, and high blood pressure; can lead to death ⁵⁸	Adults, hypertensives, diabetics, those with cardiovascular disease	Deaths in 2006: 60,337. ⁵⁹ Number of people living with heart failure: 5.7 million. New cases diagnosed each year: 670,000. ⁶⁰	PM _{2.5} ⁶¹

Table 1: Coal's contributions to major health effects, *continued*

	Disease or condition	Symptoms or result	Most-vulnerable populations	Total disease burden (coal is a suspected contributing factor in an unknown number of cases)	Coal pollutants implicated
NEUROLOGICAL	Ischemic stroke	Artery supplying blood to the brain becomes blocked due to blood clot or narrowing; ⁶² may cause sudden numbness or weakness, especially on one side of body, confusion, trouble speaking, trouble seeing, trouble walking, dizziness, severe headache; ⁶³ effects can be transitory or persistent	Elderly, hypertensives, diabetics	Deaths in 2005: 143,579. Number of strokes occurring each year: 795,000. NOTE: 87% of all strokes are ischemic; statistics are for all strokes. ⁶⁴	NO ₂ PM _{2.5} PM ₁₀ SO ₂ ^{65,66,67,68}
	Developmental delay	Reduced IQ; mental retardation; clinical impairment on neurodevelopmental scales; permanent loss of intelligence	Fetuses, infants, children	Babies born each year with cord blood concentrations of mercury >5.8 µg/L, the level above which mercury exposure has been shown to reduce IQ: 637,233 (15.7% of all babies born). ⁶⁹	Mercury ⁷⁰

which in turn can lead to stroke and other cerebral vascular disease.

Several studies have shown a correlation between coal-related air pollutants and stroke. In Medicare patients, ambient levels of PM_{2.5} have been correlated with hospital admission rates for cerebrovascular disease,⁷¹ and PM₁₀ has been correlated with hospital admission for ischemic stroke.⁷² (Eighty-seven percent of all strokes are ischemic.) PM_{2.5} has also been associated with an increase in the risk of—and death from—a cerebrovascular event among post-menopausal women.⁷³ Even though a relatively small portion of all strokes appear to be related to the ambient concentration of PM, the fact that nearly 800,000 people in the U.S. have a stroke each year makes even a small increase in risk a health impact of great importance.⁷⁴

Coal pollutants also act on the nervous system to cause loss of intellectual capacity, primarily through mercury. Coal contains trace amounts of mercury that, when burned, enter the environment. Mercury increases in concentration as it travels up the food chain, reaching high levels in large predatory fish. Humans, in turn, are exposed to coal-related mercury primarily through fish

consumption. Coal-fired power plants are responsible for approximately one-third of all mercury emissions attributable to human activity.⁷⁵

A nationwide study of blood samples in 1999–2000 showed that 15.7% of women of childbearing age have blood mercury levels that would cause them to give birth to children with mercury levels exceeding the EPA's maximum acceptable dose for mercury.⁷⁶ This dose was established to limit the number of children with mercury-related neurological and developmental impairments. Researchers have estimated that between 317,000 and 631,000 children are born in the U.S. each year with blood mercury levels high enough to impair performance on neurodevelopmental tests and cause lifelong loss of intelligence.⁷⁷

GLOBAL WARMING AND COAL POLLUTION

Coal damages the respiratory, cardiovascular, and nervous systems through pollutants acting directly on the body. But coal combustion also has indirect health effects, through its contribution to greenhouse gas emissions. Global warming is already negatively impacting public health and is predicted

to have widespread and severe health consequences in the future. Because coal-fired power plants account for more than one third of CO₂ emissions in the U.S.,⁷⁸ coal is a major contributor to the predicted health impacts of global warming.

The effects of global warming already in evidence include increases in global average land and ocean surface temperatures; increases in snow melt and receding glaciers; increases in the mean sea level; and changes in precipitation.⁷⁹ These global climate changes are already affecting human health. The World Health Organization estimated global warming to be responsible for 166,000 deaths in 2000, due to additional mortality from malaria, malnutrition, diarrhea, and drowning.⁸⁰

A continued reliance on coal combustion for electricity will contribute to the predicted health consequences of global warming.

In the future, global warming is expected to continue to harm human health. More frequent heat waves are projected to lead to a rise in heat exhaustion and heat stroke, potentially resulting in death, especially among elderly and poor urban dwellers. Declining air and water quality, an increase in infectious diseases, and a shrinking food supply are expected to contribute to disease and malnutrition, increase the migration of affected populations, and increase armed conflict and global instability. Table 2 (see page 14) describes the predicted health effects of global warming.

A continued reliance on coal combustion for electricity production will contribute to the predicted health consequences of global warming.



Table 2: Predicted health effects of global warming

Predicted human health effects	Contributing factors	Global warming mechanism	Most-vulnerable populations
Heat cramps, heat syncope, heat exhaustion, heat stroke	Heat waves	Greenhouse effect	Children, the elderly, urban dwellers, those with underlying conditions such as cardiovascular disease, obesity, and respiratory disease
Diarrhea spread by water-borne bacteria including E Coli, Shigella, and cholera	Flooding, infrastructure damage	- Increase in extreme weather events and storm surges - Sea level rise	Children most vulnerable to death from diarrheal disease
Drowning	Flooding	- Increase in extreme weather events and storm surges - Sea level rise	Children, the elderly
Exacerbations of asthma, chronic obstructive pulmonary disease, and other respiratory diseases	Worsening air quality, heat waves	- Greenhouse effect - Heat increases production of ground-level ozone - Heat increases electricity demand and resulting particulate emissions from fossil fuel combustion - Airborne allergens (such as pollen) predicted to increase with global warming	Children, the elderly, those with preexisting respiratory disease
Infectious diseases: Malaria, dengue fever, yellow fever, West Nile virus, Lyme disease, and other insect-borne infections, as well as rodent-borne infections	Increased ranges and populations of disease-carrying insects and rodents	- Warming climate expands geographic range of insect and rodent vectors - High temperatures boost reproductive rates, lengthen breeding season, and increase bite frequency of insect vectors - High temperatures boost parasite development	Children, those with impaired immune systems, the developing world
Heart disease, heart attacks, congestive heart failure and other cardiovascular diseases	Worsening air quality	- Heat increases production of ground-level ozone - Heat increases electricity demand and resulting particulate emissions from fossil fuel combustion	Adults and the elderly
Hunger, malnutrition, starvation, famine	Reduced crop yields; crop damage; crop failure; disruptions in forestry, livestock, fisheries	- Changes in the water cycle leading to drought - Heat decreases reproductive lifecycle of some major food crops - Expanded range of some insect pests - Increase in extreme weather events - Changes in ecology of plant pathogens - Loss of agricultural land due to sea level rise	Children, the poor
Mass migration; violence; war	Societal instability; infrastructure damage; reduced crop yields	All of the above	Children, the elderly, those with other underlying medical conditions
Mental health problems	All of the above	All of the above	Varied

See sources on page 16.

Carbon capture and sequestration (CCS) has been promoted as an effective way to keep CO₂ emissions out of the atmosphere, but substantial research and development are required before it can be used on the scale needed to mitigate global warming. Even then, the danger remains that CCS storage areas, whether underground or under the ocean, could leak, negating the value of CO₂ capture and storage. CCS also incurs other threats to health, including the danger of asphyxiation in the case of a large-scale CO₂ leak and the acidification of ocean waters. Moreover, the application of CCS would require continued coal mining, transportation, combustion, and waste storage, thus prolonging the emission of coal's toxic pollutants that harm human health.

Unless we address coal, the U.S. will be unable to achieve the reductions in carbon emissions necessary to stave off the worst health impacts of global warming.

POLICY RECOMMENDATIONS

The U.S. is at a crossroads for determining its future energy policy. While the U.S. relies heavily on coal for its energy needs, the health consequences of that reliance are multiple and have widespread and damaging impact. Coal combustion contributes to diseases already affecting large portions of the U.S. population, including asthma, heart disease, and stroke, thus compounding the major public health challenges of our time. Coal combustion also releases significant amounts of carbon dioxide into the atmosphere. Unless we address coal, the U.S. will be unable to achieve the reductions in carbon emissions necessary to stave off the worst health impacts of global warming. Based on that assessment, PSR finds it essential to translate our



concern for human health into recommendations for public policy.

- Emissions of carbon dioxide should be cut as deeply and as swiftly as possible, with the objective of reducing CO₂ levels to 350 parts per million, through two simultaneous strategies:
 - Strong climate and energy legislation that establishes hard caps on global warming pollution coming from coal power plants.
 - The Clean Air Act (CAA). Carbon dioxide and other greenhouse gas emissions from coal plants have been designated pollutants under the CAA. The EPA should be fully empowered to regulate carbon dioxide under the CAA so that coal's contribution to global warming can be brought to an end.
- There should be no new construction of coal-fired power plants, so as to avoid increasing health-endangering emissions of carbon dioxide, as well as criteria pollutants and hazardous air pollutants.
- The U.S. should dramatically reduce fossil fuel power plant emissions of sulfur dioxide and nitrogen oxides so that all localities are in attainment for national ambient air quality standards.
- The EPA should establish a standard, based on Maximum Achievable Control Technology, for mercury and other hazardous air pollutant emissions from electrical generation.
- The nation must develop its capacity to generate electricity from clean, safe, renewable sources so that existing coal-fired power plants may be phased out without eliminating jobs or compromising the nation's ability to meet its energy needs. In place of investment in coal (including subsidies for the extraction and combustion of



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coal and for capture of carbon and other pollutants), the U.S. should fund energy efficiency, conservation measures, and clean, safe, renewable energy sources such as wind energy, solar, and wave power.

These steps comprise a medically defensible energy policy: one that takes into account the public health impacts of coal while meeting our need for energy. When our nation establishes a health-driven energy policy, one that replaces our dependence on coal with clean, safe alternatives, we will prevent the deterioration of global public health caused by global warming while reaping the rewards in improvements to respiratory, cardiovascular, and neurological health.

ENDNOTES

- 1 Markandya A, Wilkinson P. Electricity generation and health. *Lancet* 2007;370:979–990.
- 2 Centers for Disease Control and Prevention. Available from: <http://www.cdc.gov/NIOSH/Mining/statistics/pdfs/pp3.pdf>.
- 3 Rappaport E. Coal Mine Safety. CRS Report for Congress, 2006: RS22461.
- 4 EPA Region 3. Mountaintop mining/valley fills in Appalachia final programmatic environmental impact statement. Oct 2005: EPA-9-03-R-05002. Available from: http://www.epa.gov/Region3/mtntop/pdf/mtm-vf_fpeis_full-document.pdf.
- 5 EPA Office of Solid Waste. Acid mine drainage prediction technical document. 1994: EPA530-R-94-036. Available from: <http://www.epa.gov/osw/nonhaz/industrial/special/mining/techdocs/amd.pdf>.
- 6 Lashof DA, Delano D, Devine J et al. Coal in a changing climate. 2007: Natural Resources Defense Council. Available from: <http://www.nrdc.org/globalwarming/coal/coalclimate.pdf>.
- 7 Lashof DA, Delano D, Devine J et al. Coal in a changing climate. 2007: Natural Resources Defense Council. Available from: <http://www.nrdc.org/globalwarming/coal/coalclimate.pdf>.
- 8 Aneja VP. Characterization of particulate matter (PM₁₀) in Roda, Virginia. Unpublished report to the Virginia Air Pollution Control Board. Undated. Available from: http://www.eenews.net/public/25/10670/features/documents/2009/04/23/document_pm_01.pdf.
- 9 See <http://www.earthjustice.org/library/references/09ccw-survey-summary-results.pdf>.
- 10 EPA, Human and ecological risk assessment of coal combustion wastes: draft, August 6, 2007. Available from: <http://www.earthjustice.org/library/reports/epa-coal-combustion-waste-risk-assessment.pdf>.
- 11 Gauderman WJ, Avol E, Gilliland F et al. The effect of air pollution on lung development from 10 to 18 years of age. *N Engl J Med* 2004; 351(11):1057–1067.
- 12 Bateson TF, Schwartz J. Children's response to air pollutants. *J Toxicol Environ Health Part A* 2008; 71(3):238–243.
- 13 Trasande L, Thurston GD. The role of air pollution in asthma and other pediatric morbidities. *J Allergy Clin Immunol* 2005; 115(4):689–699.
- 14 Gent JF, Triche EW, Holford TR et al. Association of low-level ozone and fine particles with respiratory symptoms in children with asthma. *JAMA* 2003; 290(14):1859–1867.
- 15 Yang IA, Fong KM, Zimmerman PV, Holgate ST, Holloway JW. Genetic susceptibility to the respiratory effects of air pollution. *Thorax* 2008; 63(6):555–563.
- 16 Halonen JI, Lanki T, Yli-Tuomi T, Kulmala M, Tiittanen P, Pekkanen J. Urban air pollution, and asthma and COPD hospital emergency room visits. *Thorax* 2008; 63(7):635–641.
- 17 Peel JL, Tolbert PE, Klein M et al. Ambient air pollution and respiratory emergency department visits. *Epidemiology* 2005; 16(2):164–174.
- 18 Dominici F, Peng RD, Bell ML et al. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA* 2006; 295(10):1127–1134.
- 19 Beeson WL, Abbey DE, Knutsen SF. Long-term concentrations of ambient air pollutants and incident lung cancer in California adults: results from the Adventist Health Study on Smog. *Environ Health Perspect* 1998; 106(12):813–823.
- 20 Beeson WL, Abbey DE, Knutsen SF. Long-term concentrations of ambient air pollutants and incident lung cancer in California adults: results from the Adventist Health Study on Smog. *Environ Health Perspect* 1998; 106(12):813–823.
- 21 Dockery DW, Pope CA, III, Xu X et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med* 1993; 329(24):1753–1759.
- 22 Pope CA, III, Burnett RT, Thun MJ et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA* 2002; 287(9):1132–1141.
- 23 Brook RD, Franklin B, Cascio W et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation* 2004; 109(21):2655–2671.
- 24 Peters A, Liu E, Verrier RL et al. Air pollution and incidence of cardiac arrhythmia. *Epidemiology* 2000; 11(1):11–17.
- 25 Peters A, Dockery DW, Muller JE, Mittleman MA. Increased particulate air pollution and the triggering of myocardial infarction. *Circulation* 2001; 103(23):2810–2815.
- 26 Dominici F, Peng RD, Bell ML et al. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA* 2006; 295(10):1127–1134.
- 27 Katsouyanni K, Touloumi G, Samoli E et al. Confounding and effect modification in the short-term effects of ambient particles on total mortality: results from 29 European cities within the APHEA2 project. *Epidemiology* 2001; 12(5):521–531.
- 28 Dockery DW, Pope CA, III, Xu X et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med* 1993; 329(24):1753–1759.
- 29 Pope CA, III, Ezzati M, Dockery DW. Fine-particulate air pollution and life expectancy in the United States. *N Engl J Med* 2009; 360(4):376–386.
- 30 Centers for Disease Control and Prevention. Available from: <http://www.cdc.gov/nchs/fastats/asthma.htm>.
- 31 National Association of School Nurses. Issue Brief: Asthma Management in the School Setting. Available from: <http://www.nasn.org/Default.aspx?tabid=264>.
- 32 Gent JF, Triche EW, Holford TR et al. Association of low-level ozone and fine particles with respiratory symptoms in children with asthma. *JAMA* 2003; 290(14):1859–1867.
- 33 Trasande L, Thurston GD. The role of air pollution in asthma and other pediatric morbidities. *J Allergy Clin Immunol* 2005; 115(4):689–699.
- 34 Peel JL, Tolbert PE, Klein M et al. Ambient air pollution and respiratory emergency department visits. *Epidemiology* 2005; 16(2):164–174.
- 35 Centers for Disease Control and Prevention. Available from: <http://www.cdc.gov/nchs/fastats/asthma.htm>.
- 36 Gilmour MI, Jaakkola MS, London SJ et al. How exposure to environmental tobacco smoke, outdoor air pollutants, and increased pollen burdens influences the incidence of asthma. *Env Health Perspect* 2006; 114(4):627–633.

- 37 Brauer M, Hoek G, van VP et al. Air pollution from traffic and the development of respiratory infections and asthmatic and allergic symptoms in children. *Am J Respir Crit Care Med* 2002; 166(8):1092–1098.
- 38 McConnell R, Berhane K, Gilliland F et al. Asthma in exercising children exposed to ozone: a cohort study. *Lancet* 2002; 359(9304):386–391.
- 39 American Lung Association. Available from: <http://www.lungusa.org/site/apps/nlnet/content3.aspx?c=dvLUK9O0E&b=4294229&ct=5296599>.
- 40 Centers for Disease Control and Prevention (CDC). Deaths from chronic obstructive pulmonary disease—United States, 2000–2005. *MMWR Morb Mortal Wkly Rep.* 2008 Nov 14;57(45):1229–32.
- 41 Halonen JI, Lanki T, Yli-Tuomi T, Kulmala M, Tiittanen P, Pekkanen J. Urban air pollution, and asthma and COPD hospital emergency room visits. *Thorax* 2008; 63(7):635–641.
- 42 Peel JL, Tolbert PE, Klein M et al. Ambient air pollution and respiratory emergency department visits. *Epidemiology* 2005; 16(2):164–174.
- 43 Dominici F, Peng RD, Bell ML et al. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA* 2006; 295(10):1127–1134.
- 44 Gauderman WJ, Avol E, Gilliland F et al. The effect of air pollution on lung development from 10 to 18 years of age. *N Engl J Med* 2004; 351(11):1057–1067.
- 45 Mathews TJ, MacDorman MF. Infant mortality statistics from the 2005 period linked birth/infant death data set. *National Vital Statistics Reports* 57(2).
- 46 Ritz B, Wilhelm M, Zhao Y. Air pollution and infant death in southern California, 1989–2000. *Pediatrics* 2006; 118(2):493–502.
- 47 Bateson TF, Schwartz J. Children's response to air pollutants. *J Toxicol Environ Health Part A* 2008; 71(3):238–243.
- 48 Centers for Disease Control and Prevention. Available from: http://www.cdc.gov/cancer/lung/basic_info/survivorship.htm.
- 49 Centers for Disease Control and Prevention. Available from: <http://www.cdc.gov/cancer/lung/statistics/index.htm>.
- 50 Beeson WL, Abbey DE, Knutsen SF. Long-term concentrations of ambient air pollutants and incident lung cancer in California adults: results from the AHSMOG study. *Environ Health Perspect* 1998; 106(12):813–823.
- 51 Dockery DW, Pope CA, III, Xu X et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med* 1993; 329(24):1753–1759.
- 52 Pope CA, III, Burnett RT, Thun MJ et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA* 2002; 287(9):1132–1141.
- 53 American Heart Association. Available from: <http://americanheart.org/presenter.jhtml?identifier=15>.
- 54 Peters A, Liu E, Verrier RL et al. Air pollution and incidence of cardiac arrhythmia. *Epidemiology* 2000; 11(1):11–17.
- 55 Heron M, Hoyert DL et al. Deaths: final data for 2006. *National Vital Statistics Reports* 57(14). Available from: http://www.cdc.gov/nchs/data/nvsr/nvsr57/nvsr57_14.pdf.
- 56 American Heart Association. Available from: <http://www.americanheart.org/presenter.jhtml?identifier=4478>.
- 57 Peters A, Dockery DW, Muller JE, Mittleman MA. Increased particulate air pollution and the triggering of myocardial infarction. *Circulation* 2001; 103(23):2810–2815.
- 58 American Heart Association. Available from: <http://www.americanheart.org/presenter.jhtml?identifier=4585>.
- 59 Heron M, Hoyert DL et al. Deaths: final data for 2006. *National Vital Statistics Reports* 57(14). Available from: http://www.cdc.gov/nchs/data/nvsr/nvsr57/nvsr57_14.pdf.
- 60 American Heart Association. Available from: <http://www.americanheart.org/presenter.jhtml?identifier=1486>.
- 61 Dominici F, Peng RD, Bell ML et al. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA* 2006; 295(10):1127–1134.
- 62 Centers for Disease Control and Prevention. Available from: http://www.cdc.gov/Stroke/about_stroke.htm.
- 63 American Heart Association. Available from: <http://www.americanheart.org/presenter.jhtml?identifier=3053#Stroke>.
- 64 American Heart Association, Heart Disease and Stroke Statistics, 2009 Update At-A-Glance. Available from: <http://www.americanheart.org/downloadable/heart/1240250946756LS-1982%20Heart%20and%20Stroke%20Update.042009.pdf>.
- 65 Wellenius GA, Schwartz J, Mittleman MA. Air pollution and hospital admissions for ischemic and hemorrhagic stroke among medicare beneficiaries. *Stroke* 2005; 36(12):2549–2553.
- 66 Miller KA, Siscovick DS, Sheppard L et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. *N Engl J Med* 2007;356(5):447–58.
- 67 Hong YC, Lee JT, Kim H et al. Effects of air pollutants on stroke mortality. *Environ Health Perspect* 2002;110(2):187–91.
- 68 Tsai SS, Goggins WB, Chiu HF, Yang CY. Evidence for an association between air pollution and daily stroke admissions in Kaohsiung, Taiwan. *Stroke* 2003;34(11):2612–6.
- 69 Trasande L, Landrigan PJ, Schechter C. Public health and economic consequences of methyl mercury toxicity to the developing brain. 2005: *Environ Health Perspect* 2005;113(5):590–596.
- 70 Committee on the toxicological effects of mercury. *Toxicological Effects of Methylmercury*. Washington, D.C.: National Research Council, National Academy Press, 2000.
- 71 Dominici F, Peng RD, Bell ML et al. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA* 2006; 295(10):1127–1134.
- 72 Wellenius GA, Schwartz J, Mittleman MA. Air pollution and hospital admissions for ischemic and hemorrhagic stroke among medicare beneficiaries. *Stroke* 2005; 36(12):2549–2553.
- 73 Miller KA, Siscovick DS, Sheppard L et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. *N Engl J Med* 2007;356(5):447–58.
- 74 American Heart Assn Statistics Committee and Stroke Statistics Subcommittee. *Heart Disease and Stroke Statistics—2009 Update*. *Circulation* 2009; 119:e21–e181.
- 75 EPA Office of Air Quality Planning & Standards and Office of Research and Development. *Mercury study report to Congress. Volume II: an inventory of anthropogenic mercury emissions in the United States; Dec 1997: EPA-452/R-97-004*.

- 76 Centers for Disease Control and Prevention. Third national report on human exposure to environmental chemicals. 2005: NCEH 05-0570.
- 77 Trasande L, Landrigan PJ, Schechter C. Public health and economic consequences of methyl mercury toxicity to the developing brain. *Environ Health Perspect* 2005; 113(5):590–596.
- 78 Energy Information Administration. Emissions of greenhouses gases report. 2008: DOE/EIA-0573(2007).
- 79 IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, RK and Reisinger, A (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
- 80 Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005 Nov 17;438:310–317.

SOURCES FOR TABLE 2

- Battisti DS, Naylor RL. Historical warnings of future food insecurity with unprecedented seasonal heat. *Science* 2009; Jan 9;323(5911):240–4.
- Bernard SM, Samet JM, Grambsch A, et al. The potential impacts of climate variability and change on air pollution-related health effects in the United States. *Environ Health Perspect* 2001; 109(Suppl 2), 199–209.
- Brownstein JS, Holford TR, Fish D. Effect of climate change on Lyme disease risk in North America. *EcoHealth* 2005;2:38–46.
- Checkley W, Epstein LD, Gilman RH, Figueroa D, Cama RI, Patz JA, Black RE. Effect of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet* 2000 Feb 5;355(9202):442–50.
- 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.
- Luber G, McGeehin M. Climate change and extreme heat events. *Am J Prev Med* 2008 Nov;35(5):429–35.
- Parker C, Shapiro SM. Climate chaos: your health at risk: what you can do to protect yourself and your family. Westport, CT: Praeger; 2008.
- Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press; 2007.
- Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005 Nov 17;438:310–317.
- Patz JA, McGeehin MA, Bernard SM, et al. The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the U.S. National Assessment. *Environ Health Perspect* 2000; 108(4), 367–376.
- Shea KM, American Academy of Pediatrics Committee on Environmental Health. Global climate change and children's health. *Pediatrics* 2007 Nov;120(5):e1359–67.
- St. Louis ME, Hess JJ. Climate change: impacts on and implications for global health. *Am J Prev Med* 2008 Nov;35(5):527–38.

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