

COAL'S ASSAULT *on* HUMAN HEALTH

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A REPORT FROM

PHYSICIANS FOR SOCIAL

RESPONSIBILITY



EXECUTIVE SUMMARY

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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.

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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

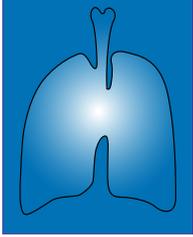
The combustion phase of coal's lifecycle exacts the greatest toll on human health. Coal combustion releases a combination of toxic chemicals into the environment and

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



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.

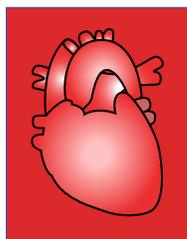
the presence of highly reactive molecules, known as free radicals, in cells. (See text box.)

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



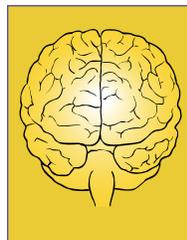
same as those for respiratory disease: pulmonary inflammation and oxidative stress. Studies in both animals and humans support this theory, showing that pollutants produced by coal combustion lead to cardiovascular disease, such as arterial occlusion (artery blockages, leading to heart attacks) and infarct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

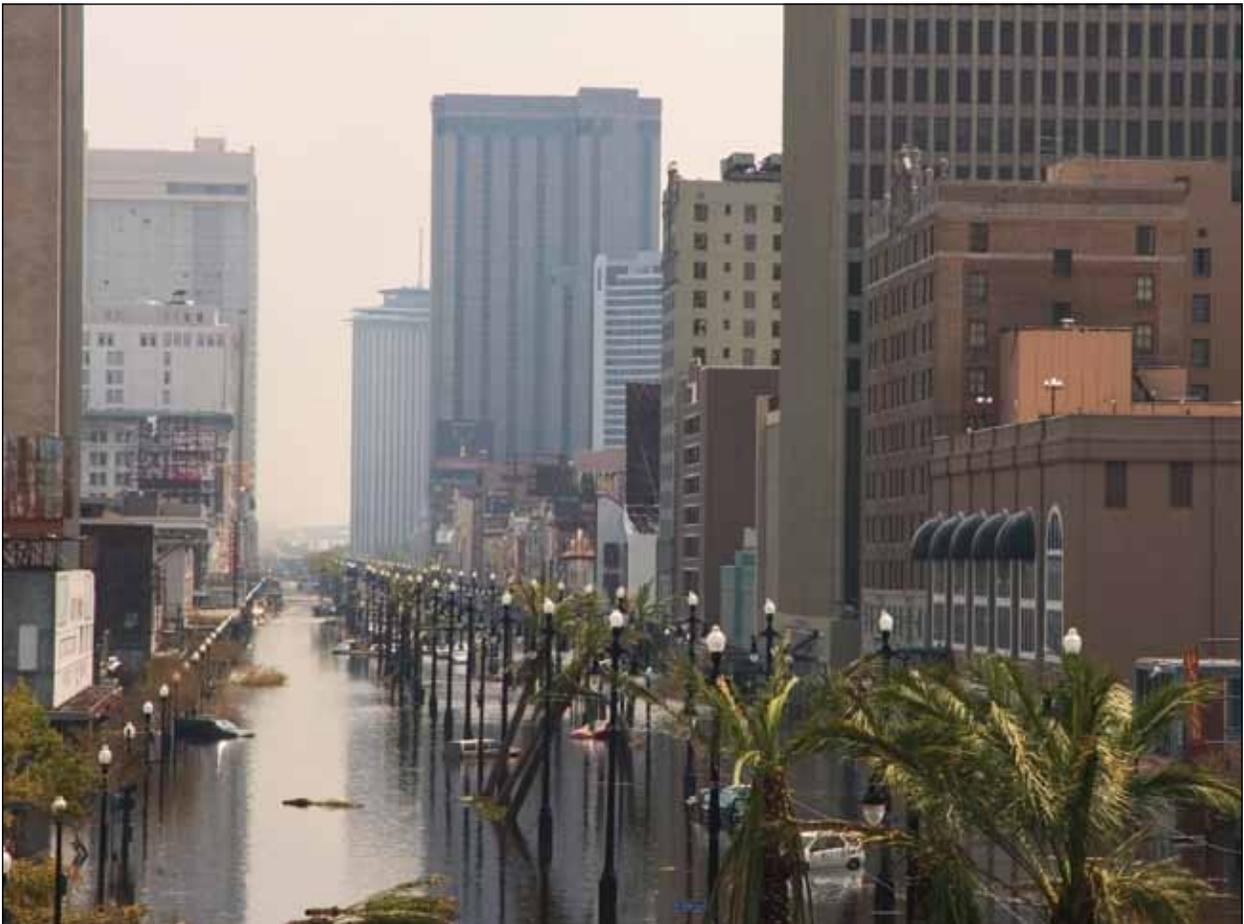


Table 2: Predicted health effects of global warming

Predicted human health effects	Contributing factors	Global warming mechanism	Most-vulnerable populations
Heat cramps, heat syncope, heat exhaustion, heat stroke	Heat waves	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Increase in extreme weather events and storm surges Sea level rise 	Children most vulnerable to death from diarrheal disease
Drowning	Flooding	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> All of the above 	Children, the elderly, those with other underlying medical conditions
Mental health problems	All of the above	<ul style="list-style-type: none"> 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.

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