A Message from the Renewable Energy Policy Project

America's air is getting cleaner, but "cleaner" may not be clean enough. Not only do tens of millions of citizens still breathe substandard air, but the best available scientific evidence suggests that *even legal levels of pollution make people sick*. In the following paper, Curtis Moore, an expert on pollution control technology, seeks to familiarize renewable energy advocates with the regulatory and health issues associated with criteria air pollutants.

Mr. Moore outlines emerging medical research indicating that the impact of air pollution on human health is worse than previously understood. Although today's powerplants, cars and factories pollute less than those built a few years ago, America's air pollution problem remains grave. The U.S. Environmental Protection Agency (EPA) estimates that in 1995, 80 million Americans lived in counties where air failed to meet Federal standards. Such exposure causes substantial discomfort, disease and even death. Particulate pollution alone is associated with over 50,000 deaths annually, as well as increased hospitalizations, missed work, and school absenteeism. Long-term exposure to even minuscule amounts of pollution may cause severe health problems, especially in the young, old and infirm. For these reasons, EPA has recently proposed new, more stringent rules for particulate and ozone pollution, including new standards for very fine particles.

Mr. Moore's paper suggests to us an important avenue for future research and advocacy within the renewable energy and environmental communities. With the exception of a brief mention in Title IV of the Clean Air Act, existing environmental policy makes little mention of renewables. Policymakers should focus more explicitly on the potential of these clean energy resources to meet environmental goals. In future research, REPP will explore the role that renewable energy can play in preventing energy-related air emissions.

We thank Mr. Moore and REPP's editor, Susan Conbere, for their work on this valuable paper.

Adam Serchuk & Alan Miller **February 28, 1997**

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DYING NEEDLESSLY: SICKNESS AND DEATH DUE TO ENERGY-RELATED AIR POLLUTION

Curtis A. Moore

Executive Summary

Clean, renewable sources of energy can alleviate the air pollution that afflicts millions of Americans, and even greater numbers of people in the developing world. Author Curtis Moore describes six major air pollutants regulated by the U.S. Environmental Protection Agency (EPA), many of which result from the combustion of fossil fuels. He then summarizes emerging medical evidence indicating that currently legal levels of pollution cause sickness and even death. Finally, Mr. Moore discusses EPA's recent proposals for more rigorous air quality standards, and the potential of renewable energy technologies to help meet these standards.

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DYING NEEDLESSLY:
Sickness and Death
Due to Energy-Related Air Pollution

Curtis A. Moore[1]

> I must tell you that we have heard much of this before in less sophisticated form. We heard it in 1970 and again in 1977. We heard it repeatedly in the 1980s. It is the same message today and it boils down to this: Impose the cost of pollution on people who breathe, so the people who pollute can avoid the cost of control. I think that is backwards. What must life be like for that asthmatic child when the very air can make her a shut-in and even threaten her life? What does it cost the rest of us to turn our backs on that child when the solution to her problem is known?
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> Former U.S. Senator Edmund S. Muskie
> November 14, 1995

In recent years, awareness of the health impacts of air pollution has increased greatly; we now know it to be far more serious than was generally understood just a few years ago. During preparation of this paper, the U.S. Environmental Protection Agency (EPA) also came to this conclusion, proposing on November 27, 1996 regulations that would significantly lower permitted levels of air pollution. If adopted, the regulations will have enormous consequences for industry, which will need to invest billions of dollars to find ways to meet the standards. Clean renewable energy technologies can help resolve our air quality problems, but have so far received inadequate attention from policymakers. This paper identifies common air pollutants, summarizes their effects on human health, and briefly identifies technological advances that could reduce and, in some cases, eliminate air pollution.

Air Pollution: A Global Health Problem

In countless cities worldwide and throughout much of the countryside, the air is so polluted that the simple act of breathing can be fatal. In some cases, the harm inflicted by air pollution on the human body is clear and direct; in others, it weakens the body, leaving it susceptible to other ailments. In the United States alone, air pollution kills over 50,000 persons a year—a death toll higher than that of traffic accidents, breast cancer, or AIDS.[2] European air pollution levels equal or exceed those of the United States. In China, India, Thailand and other industrializing nations, air pollution is literally palpable.

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[1]The author wishes to thank Lauraine Chestnut, Kurt Johnson, Alan Miller, Anne Polansky, Karl Rábago, Adam Serchuk, Rachel Shimshak, and Mike Tennis for their comments on this paper. The opinions expressed here are the author's, and do not necessarily reflect those of the reviewers, the Renewable Energy Policy Project, or its Steering Committee.

[2]See D.W. Dockery and C.A. Pope, "Acute Respiratory Effects of Particulate Air Pollution," *Annual Review of Public Health* 15 (1994), 107-32. See also a study by the Natural Resources Defense Council claiming 64,000 deaths per year in American cities due to a single pollutant: Deborah Shprentz, *Breath Taking: Premature Mortality Due to Particulate Pollution in 239 American Cities* (New York: NRDC, 1996).

AIR POLLUTION HEALTH EFFECTS: COUNTRY STUDIES

In Europe, eleven groups of researchers working at ten different centers collected data on air pollution, hospital admissions and mortality in fifteen cities during the 1970s and 1980s. The effort was part of a program called *Air Pollution Health Effects: A European Approach*. Not surprisingly, the researchers found that as levels of air pollution increased, so did deaths and hospital admissions. Some specific studies include the following:

The Netherlands: When levels of nitrogen dioxide (NO_x) rose, children suffered more upper respiratory infections. Infections of the lower respiratory tract followed local increases in black smoke, and coughing rose in step with ozone concentrations. Deaths due to particulate pollution averaged 13 per day. Among primary school children, the temporary decrease in pulmonary function due to particulate air pollution was about 5 percent, while about 700 cases of asthma were aggravated daily.

France: When levels of black smoke and sulfur dioxide rose in 1992 and 1993, so did nighttime coughing and wheezing among asthmatics. Hospital admissions for chronic obstructive pulmonary disease increased when levels of sulfur dioxide rose, while admissions for asthma rose with increases in ambient nitrogen dioxide. The researchers concluded that "relationships between air pollution and mortality and hospital admissions for respiratory causes exist even in a rather low-polluted area and even below what is usually considered as safe levels of pollutants."

Poland: Scientists collected information from more than 500,000 army-induction medical examinations conducted between 1979 and 1981 at 241 centers throughout Poland. Centers with sulfur dioxide-polluted air had four times as much asthma and three times as much bronchitis as centers without the pollution. In Krakow, researchers tracked residents for thirteen years and found that men who lived in the city's polluted areas had losses of lung function "equivalent to the effect of smoking."

Thailand: Doctors at the Bangkok Police Hospital describe how traffic officers develop a sort of "brown lung" disease, with persistent cough, sputum production, abnormal lung function tests and spots on their lungs. These officers are merely an extreme example; roughly one of every nine Bangkok residents have respiratory ailments of some sort. In Thailand's Mae Moh region, where power plants burn high-sulfur coal with no emission controls, 4,000 residents required medical treatment after weather conditions trapped sulfur dioxide pollution over the area in 1992.

The best estimates are that more than a billion people live in urban areas with unhealthful levels of air pollution.[3] (See Table 1.) Developing nations harbor some of the worst air pollution problems, due to a combination of swelling populations, economic development, and urbanization. Moreover, the trend in most developing nations is toward much dirtier air.

Although considerable progress has been made in the United States toward reducing air pollutants in recent decades, this progress is partial. In 1995, 33 million American cities failed to meet federal smog regulations.[4] In 1996, EPA estimated that 80 million Americans breathed substandard air in 1995, compared to 140 million in 1990.[5]

Regulation of Air Pollution in the United States

In the United States, the Clean Air Act (CAA) of 1970 requires EPA to review research on each of six "criteria pollutants" to account for new scientific understanding and, at least once every five years, issue a critical analysis called a "criteria document." These analyses represent an extensive scientific review process; the 1993 ozone document, for example, ran 1,628 pages and scrutinized 3,084 studies. Based on the criteria documents, EPA's Administrator must calculate the level of air pollution that is safe for human health. However, the CAA directs EPA to consider *only* "the best current scientific opinion" regarding human health impacts, and *not* economic impacts.[6]

The CAA specifies that the permissible level of each pollutant, called the "primary ambient standard," must protect "sensitive" groups—children, pregnant women, asthmatics, and so on. (See Table 2.) In addition, the standard must incorporate a "margin of safety." This acts as a safeguard not only against the unknown effects of a pollutant, but also against variable local conditions (e.g., high humidity) that can interact with air pollution to increase its potency. EPA also sets a secondary standard to safeguard public welfare by, for example, protecting soil and water quality, recreational resources and industrial interests.

After EPA determines the ambient standards, state and local governments develop state implementation plans outlining specific actions for meeting the standards. Depending on how dirty the air is, EPA directs the area to cleanse it by a deadline, called an "attainment date." In 1970, framers of the CAA anticipated that the standards would be met within a few years but in many parts of the country this proved too optimistic. The deadlines have been extended several times, most recently in 1990. For the dirtiest places, such as New York City and Los Angeles, the attainment date is well into the 21st century. Most cities, however, have attainment dates sometime in the next few years. Regulation to meet ambient standards is

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[3]World Resources Institute, *World Resources 1996-97* (New York: Oxford University Press, 1996), p. 22.
[4]U.S. Environmental Protection Agency, *Implementation Strategy for the Clean Air Act Amendments of 1990: Update* (Washington, DC, Nov. 1995), 1, EPA-410-K-95-001.
[5]Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, *National Air Quality and Emissions Trends Report 1995* (Research Triangle Park, NC: Oct. 1996).
[6]For a review of the Clean Air Act, see Murray Tabb, "Twenty-Five Years of the Clean Air Act in Perspective," *Natural Resources and Environment* 10 (Fall 1995): 13-20.

also the rule in Europe, where the European Commission is now setting its own standards for the first time. Previously, most European and other nations adopted standards set by the World Health Organization.

Six Air Pollutants Regulated by EPA

The CAA directs EPA to identify and regulate six common air pollutants, which now include ozone, particulate matter, nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead.[7] Their impact on the human body—and especially the interactions among different pollutants—are complex, but emerging epidemiological evidence points to their danger, even at relatively low levels.

Particulate Matter (PM10)

The most dangerous of the six to human health is the grab-bag of pollutants known as particulates, or soot. Particulate matter has a notorious history; to control it in the 12th century, the King of England banned the burning of coal. Violators were hanged. Today, most harmful air-borne particulates are by-products of combustion in motor vehicles, powerplants and industry. Multiple studies show that as particulate pollution rises, so, too, do sickness and death.[8] If levels of particulates in developing countries were reduced to meet World Health Organization standards, between 300,000 and 700,000 premature deaths per year could be avoided. In Mexico alone, particulate levels are estimated to cause 12,500 deaths and cost over 11

A SNAPSHOT OF SIX MAJOR POLLUTANTS

EPA regulates the following six criteria air pollutants:

Particulate matter, commonly known as soot or smoke, is linked to roughly 50,000 American deaths each year. How it does so is still poorly understood, but the large body of scientific evidence implicating particulate matter is compelling.

Sulfur dioxide, an invisible gas that poses a severe threat to asthmatics, is also the principal cause of acid rain.

Ozone, usually referred to as smog, literally burns holes through the cells of the lung, leaving children and adults alike unable to breathe normally.

Oxides of nitrogen are gases formed by car engines, smokestacks and industrial furnaces that lead to formation of both particulate matter and ozone and may themselves be linked to lung disease.

Lead, a metal used to boost the power of gasoline, destroys the intelligence of children and can increase blood pressure in adults, raising the risk of heart attack and stroke.

Carbon monoxide, an invisible gas, is a special threat to children and developing fetuses.

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[7]There are specific emissions standards for a host of other pollutants, as well. One of the most dangerous pollutants is mercury, a highly toxic by-product of fossil-fuel combustion.

[8]Such studies were conducted in Santa Clara County, CA; St. Louis, MO; Kingston, TN; Steubenville, OH; Philadelphia, PA; Provo, UT; and Birmingham, AL. The largest of these tracked the health histories of 552,138 adults in 151 American metropolitan areas from 1982 through 1989 and considered the subjects' age, weight, and use of alcohol and cigarettes, as well as other confounding factors that might produce effects similar to those of air pollution.

million workdays annually.[9] The evidence that particulate pollution kills is "absolutely complete," according to Dr. David Bates, a member of the U.S. National Academy of Sciences and former Dean of the Medical School of the University of British Columbia.[10]

Particulates vary in size and composition depending mainly on their origin. Larger particles are usually wind-blown dust or sand, lifted into the atmosphere by road travel and agriculture. Representing the large majority of air-borne particulate matter by weight, these coarse grains are trapped in the nose and throat. In contrast, particles formed by burning coal, gasoline, oil and diesel are so small that they can penetrate to the deepest recesses of the lung, where they may lodge for months or even years. Small particles are sometimes referred to as PM-10 or PM-2.5, depending on their size. (PM-10 particles are smaller than 10 microns, and PM-2.5 particles are smaller than 2.5 microns.) These "inhalable" or "fine" particles currently pose the greatest danger to human health from air pollution.

As particulate levels rise, so do runny or stuffy noses, sinusitis, sore throat, wet cough, head colds, hayfever, burning or red eyes, wheezing, dry cough, phlegm, shortness of breath, and chest discomfort or pain, as well as hospital admissions for asthma and bronchitis.[11] Cases of chronic cough, asthma, and emphysema increase, even among Seventh-Day Adventists. This fact is significant because Adventists do not smoke.[12] Bronchitis and chronic cough increase in school children, [13]as do emergency room and hospital admissions.[14] In Utah, when particulate levels rose, hospital admissions of children for respiratory illnesses tripled.[15] Some specific fractions of the particulate mix pose special risks. For example, railroad workers exposed to diesel exhaust have a 40 percent greater risk of developing lung cancer.[16]

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[9]World Resources Institute, *World Resources 1996-97* (Washington, DC: World Resources Institute/United Nations Environment Programme/United Nations Development Programme/World Bank, 1996), 22, 24.

[10]Personal communication with the author, Jun. 1995.

[11]Dockery and Pope, "Acute Respiratory Effects," 107-32.

[12]G.L. Euler, et al., "Chronic Obstructive Pulmonary Disease Symptom Effects of Long-term Cumulative Exposure to Ambient Levels of Total Suspended Particulates and Sulfur Dioxide in California Seventh-Day Adventist Residents," *Archives of Environmental Health* 42 (1987): 213-22.

[13]J. Ware, et al., "Effect of Ambient Sulfur Oxides and Suspended Particles on Respiratory Health of Preadolescent Children," *American Review of Respiratory Disease* 133 (1986): 834-42; D.W. Dockery, et al., "Effects of Inhalable Particles on Respiratory Health of Children," *American Review of Respiratory Disease* 139 (1989): 587-94.

[14]D.V. Bates and R. Sizto, "Air Pollution and Hospital Admissions in Southern Ontario: The Acid Summer Haze Effect," *Environmental Research* 43 (1987): 317-31; J.M. Samet, et al., "The Relationship Between Air Pollution and Emergency Room Visits in an Industrial Community," *Journal of the Air Pollution Control Association* 31 (1981): 236-40.

[15]J. Gross, et al., "Monitoring of Hospital Emergency Room Visits as a Method for Detecting Health Effects of Environmental Exposures," *Science of the Total Environment* 32 (1984): 289-302.

[16]F.E. Speizer, "Air Pollution and Lung Cancer," in *Epidemiology of Lung Cancer*, ed. Jonathon M. Samet (Albuquerque, NM : University of New Mexico School of Medicine and the New Mexico Tumor Registry, 1994).

Sulfur Dioxide

Sulfur dioxide (SO_2) is an invisible gas created when the sulfur contained in coal, oil or diesel fuel is burned. Roughly 70 percent of total U.S. emissions are from coal-fired powerplants, while factories account for another 13 percent.[17] Although electric utilities account for between 17 and 37 percent of exposures to "bursts," other significant sources include refineries, pulp and paper mills, copper smelters, primary lead smelters, sulfuric acid plants, and steel mills.[18] In addition, SO_2 undergoes a chemical reaction in the atmosphere to form two other pollutants, sulfates (SO_4 compounds) and sulfuric acid (H_2SO_4). Both are uniquely dangerous, although disentangling their effects is challenging.

Their devastating impacts, however, are clear. In Japan, the damage to human health from SO_2 pollution was so severe that by 1988, the government designated over 90,000 residents as official sulfur dioxide "victims." (In that year, polluters forced the curtailment of the program.) These unfortunates cough blood, wheeze, and gasp for air because of attacks due to permanent, crippling diseases. They receive government payments for disability, as well as medical and funeral expenses funded by a dedicated tax on SO_2 emissions.

Asthmatics, particularly children, are highly vulnerable to sulfur dioxide.[19] Asthma, which is the leading cause of chronic illness in children,[20] renders its victims especially sensitive to pollution. An asthmatic child or adult exposed to sulfur dioxide can be doubled over gasping for breath within minutes.[21] Between four and five percent of the American population is asthmatic, and incidence of the disease is climbing sharply, both in the United States and globally.

Physiologically, sulfur dioxide triggers a sudden swelling in airway tissue that chokes off breathing. Some SO_2 is scrubbed from the air by nasal passages, but an exercising asthmatic—one climbing as few as three flights of stairs—or one with a cold or the flu, tends to breathe through the mouth, bypassing this line of

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[17]U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends, 1900-1992* (Washington, DC, 1993), 3-15.

[18]Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Sulfur Oxides: Updated Assessment of Scientific and Technical Information, Supplement to the 1986 OAQPS Staff Paper Addendum* (Research Triangle Park, NC, Mar. 1994).

[19]M.J. Jaeger, et al., "Effect of 0.5 PPM Sulfur Dioxide on the Respiratory Function of Normal and Asthmatic Subjects," *Lung* 156 (1979): 119-27; J.Q. Koenig, et al., "Acute Effects of Inhaled SO_2 Plus NaCl Droplet Aerosol on Pulmonary Function in Asthmatic Adolescents," *Environmental Research* 22 (1980): 145-53; D. Sheppard, et al., "Lower Threshold and Greater Bronchomotor Responsiveness of Asthmatic Subjects to Sulfur Dioxide," *American Review of Respiratory Disease* 122 (1980): 873-78; D. Sheppard, et al., "Exercise Increases Sulfur Dioxide-induced Bronchoconstriction in Asthmatic Subjects," *American Review of Respiratory Disease* 123 (1981): 486-91.

[20]Mayo Foundation for Medical Education and Research, *Mayo Clinic Family Health Book* (New York: William Morrow and Company, Inc., 1990), 466.

[21]M.J. Jaeger, et al., "Effect of 0.5 PPM Sulfur Dioxide," 119-27; Michael Weisskopf, "Legal Pollution that Makes Students Sick: Sulfur Dioxide Standards Don't Protect the Particularly Sensitive," *The Washington Post*, 6 Jun. 1989, A1.

defense and increasing susceptibility to pollution-triggered attacks.[22] Attacks may be triggered in older, severe asthmatics even while resting.[23]

Ozone

Ozone is a highly toxic invisible gas. While ozone at stratospheric levels provides crucial protection from harmful ultraviolet radiation, ozone at ground level is toxic. At levels routinely encountered in most American cities, ozone, or smog, oxidizes pulmonary tissue, burning holes through the lung's cell walls, allowing cellular fluids to seep out. Over time, normal ciliated cells are destroyed by ozone and replaced by abnormally squat, thick-walled, squamous cells, causing lungs to stiffen and decreasing the ability to breathe normally.

Prolonged exposure to ozone increases susceptibility to bacterial infections, possibly because ciliated cells that normally expel foreign particles and organisms have been killed and replaced by thicker, stiffer, non-ciliated cells.[24] Scars and lesions form in the airways.[25] At ozone levels that prevail through much of the year in California and other warm-weather cities, the breathing of many healthy, non-smoking young men who exercise becomes rapid, shallow and painful.[26] As ozone levels rise, so do hospital admissions and emergency department visits.[27] In New Jersey, emergency room visits for asthma increased 28 percent at ozone concentrations half the federal standard.

Every city and metropolitan area in the United States is plagued by high levels of ozone. In 1989, the exposed population was 67 million, but in warmer years like 1988, this can more than double to 135

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[22]U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Sulfur Oxides*; W.S. Linn, et al., "Respiratory Effects of Sulfur Dioxide in Heavily Exercising Asthmatics," *American Review of Respiratory Disease* 127 (1983): 278-83; R.A. Bethel, et al., "Effects of Exercise Rate and Route of Inhalation on Sulfur Dioxide-induced Bronchoconstriction in Asthmatic Subjects," *American Review of Respiratory Disease* 128 (1983): 592-96; D. Horstman, et al., "Airway Sensitivity of Asthmatics to Sulfur Dioxide," *Toxicology and Industrial Health* 2 (1986): 289-98; M.D. Kirkpatrick, et al., "Effect of the Oronasal Breathing Route on Sulfur Dioxide-induced Bronchoconstriction in Exercising Asthmatic Subjects," *American Review of Respiratory Disease* 125 (1982): 627-31.
[23]U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Sulfur Oxides*.
[24]H.S. Van Louveren, et al., "Effect of Ozone on the Defense to a Respiratory Listeria Monocytogenes Infection in the Rat, Suppression of Macrophage Function on Cellular Immunity and Aggravation of Histopathology in Lung and Liver During Infection," *Toxicology and Applied Pharmacology* 94 (1988): 374-393; D.E. Gardner, "Use of Experimental Airborne Infections for Monitoring Altered Host Defenses," *Environmental Health Perspectives* 43 (1982): 99-107.
[25]Office of Research and Development, U.S. Environmental Protection Agency, "Executive Summary," in *Air Quality Criteria for Ozone and Related Photochemical Oxidants* (Washington, DC, Feb. 1994).
[26]W.F. McDonnell, et al., "Pulmonary Effects of Ozone Exposure During Exercise: Dose Response Characteristics," *Journal of Applied Physiology* 5 (1983): 1345-52.
[27]U.S. Environmental Protection Agency, "Executive Summary"; Kinney and Ozskaynak, "Associations of Daily Mortality and Air Pollution in Los Angeles County," *Environmental Research* 54 (1991); Kinney and Ozskaynak, "Associations Between Ozone and Daily Mortality in Los Angeles and New York City," *American Review of Respiratory Disease* 145 (1992) A95.

million.[28] Some ozone is formed naturally, but the reaction between hydrocarbons and oxides of nitrogen prevents its destruction. Ozone can be reduced by curbing emissions of oxides of nitrogen (NO_x) from powerplants, cars and trucks; and reducing hydrocarbons, principally from gasoline and industrial solvents.

Oxides of Nitrogen

The role of oxides of nitrogen (NO_X) in outdoor pollution is complicated. Not only is it a potent pollutant itself, but it plays an essential role in the formation of other dangerous pollutants.[29] When exposed to sunlight, oxides of nitrogen react with hydrocarbons to form ozone, the most pervasive urban pollutant. Oxides of nitrogen are also chemically converted in the air into fine particles, which in turn are transformed into acids. In some areas of the United States such as Los Angeles, oxides of nitrogen account for roughly one-third of fine particles.

Like ozone, oxides of nitrogen oxidize and destroy organic matter. Animals exposed to NO_x are less able to ward off bacterial infections and die sooner.[30] Their susceptibility to viral infection increases,[31] and exposure to high levels of NO_x for weeks causes emphysema-like changes in animal lungs.[32]

Many children aged twelve and younger who are exposed to NO_x have more respiratory illnesses.[33] Those exposed to high levels of NO_x outdoors have more colds that settle in their chests, chronic wheezing and cough, bronchitis, chest cough with phlegm, and episodes of respiratory illness.[34] When those exposures occur indoors—which often happens because NO_x is created by unvented gas-fired space heaters,

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[28]R.M. Friedman, *Catching Our Breath: Next Steps for Reducing Urban Ozone*, prepared for the Office of Technology Assessment, U.S. Congress (Washington, DC: U.S. Government Printing Office, 1989), OTA-0-412.

[29]The two principal oxides of nitrogen are nitric oxide (NO) and nitrogen dioxide (NO_2). Usually, NO is emitted from tailpipes or smokestacks, then transformed in the atmosphere into NO_2, which can be further converted to fine particle nitrates or gaseous nitric acids. However, in some engines (e.g., certain diesels), NO_2 is directly emitted. The nitrogen compound in which the ambient standard is expressed and for which monitors measure is NO_2.

[30]D.E. Gardner, "Oxidant-induced Enhanced Sensitivity to Infection in Animal Models and their Extrapolations to Man," *Journal of Toxicology and Environmental Health* 13 (1984): 423-39; D.E. Gardner, et al., "Influence of Exposure Mode on the Toxicity of NO_2," *Environmental Health Perspectives* 30 (1979): 23-29.

[31]R.M. Rose, et al., "The Pathophysiology of Enhanced Susceptibility to Murine Cytomegalovirus Respiratory Infection During Short-term Exposure to 5 PPM Nitrogen Dioxide," *American Review of Respiratory Disease* 137 (1988): 912-17.

[32]M.J. Evans, et al., "Renewal of the Terminal Bronchiolar Epithelium in the Rat Following Exposure to NO_2 or O_3," *Laboratory Investigation.* 35 (1976): 246-57.

[33]W. Harrington, et al., "Short-term Nitrogen Dioxide Exposure and Acute Respiratory Disease in Children.," *Journal of the Air Pollution Control Association* 35 (1985): 1061-67.

[34]V. Hasselblad, et al., "Synthesis of Environmental Evidence: Nitrogen Dioxide Epidemiology Studies," *Journal of the Air Waste Management Association* 42 (1992): 662-71.

furnaces and stoves, and kerosene and gas heaters—children can suffer from shortness of breath, chronic wheezing and cough, phlegm, and bronchitis.[35]

Animal studies indicate that high levels of the most common NO_x compound, nitrogen dioxide (NO_2), facilitates the spread of blood-borne cancer cells to the lungs. Animals exposed to the pollutant develop a significantly larger number of cancer colonies in their lungs and die sooner than animals breathing clean air. This may be because nitrogen dioxide damages blood capillaries and cells of the immune system. Since most cancer patients have circulating cancer cells, they may be at an increased risk of cancer spread merely by breathing outdoor air.[36]

NO_x is created in two ways: first, when high combustion temperatures, such as those in auto engines, powerplants or furnaces, cause the naturally occurring oxygen and nitrogen in the air to combine; and second, when fuel-bound nitrogen reacts with oxygen during combustion. NO_x can be eliminated by lowering engine temperature or installing pollution-reduction devices such as catalytic converters.

Lead

Lead is toxic in every known form. Studies indicate that children exposed to a certain level of this metal suffer measurable losses in their intelligence quotient (IQ). At blood lead levels found in large numbers of children in 1986, EPA estimated the per-child IQ reduction to be five points.[37] Even when they display no other outward symptoms, children poisoned by lead are easily distracted, unable to follow simple directions, and score lower on IQ tests.[38] Young adults who exhibited high lead levels as children have markedly higher risks of dropping out of high school and having reading disabilities. Their vocabulary, grammatical reasoning, reading and spelling skills, and hand-eye coordination are poorer; absenteeism is higher; and reaction times are slower. They have difficulty following both simple directions and sequences of directions, and they interact less well with peers.[39]

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[35]L.M. Neas, et al., "Association of Indoor Nitrogen Dioxide with Respiratory Symptoms and Pulmonary Function in Children," *American Journal of Epidemiol*ogy 135 (1991): 204-9.

[36]A. Richters and V. Richters, "Nitrogen Dioxide: Inhalation, Formation of Microthrombi in Lungs and Cancer Metastasis," *Journal of Environmental Pathology, Toxicology, and Oncology* 9 (1989): 45-51.

[37]U.S. Environmental Protection Agency, *Air Quality Criteria for Lead* (Washington, DC, 1986): vols. VII, IX, EPA-600/8-83/028.

[38]D. Bellinger, et al., "A Follow-up Study of the Academic Attainment and Classroom Behavior of Children with Elevated Dentine Lead Levels," *Biological Trace Element Research 6 (*1984): 207-23; H.L. Needleman, et al., "The Long-term Effects of Exposure to Low Doses of Lead in Childhood: An 11-Year Follow-up Report," *New England Journal of Medicine* 322 (1990): 83-88; J. Schwartz and D. Otto, "Blood Lead, Hearing Thresholds, and Neurobehavioral Development in Children and Youth," *Archives of Environmental Health* 42 (1987): 152-60; P.A. Silva, et al., "Blood Lead, Intelligence, Reading Attainment, and Behavior in Eleven Year Old Children in Dunedin, New Zealand," *Journal of Child Psychology and Psychiatry* 29 (1986): 43-52; G. Winneke, et al., "Neuropsychological Studies in Children with Elevated Tooth Lead Concentrations," *International Archives of Occupational and Environmental Health* 51 (1983): 231-52.

[39]Needleman, et al., "The Long-term Effects of Exposure," 83-88.

Lead is also associated with hypertension in middle-aged men. Studies in the United States, Great Britain, and Denmark have found that in tens of thousands of men in hundreds of cities, high blood levels of lead are associated with higher blood pressure.[40] Whether this hypertension in turn leads to heart attack, stroke or death is unclear.

Although not widely dispersed naturally, lead now has been assimilated by virtually every living organism because of its widespread use as a gasoline additive starting in the 1920s.[41] Because lead damages catalytic converters, the pollution control devices used to reduce other air pollutants in automobile tailpipe emissions, oil companies began to remove it from gasoline in the mid-1970s. Lead levels in the blood of children promptly began to fall as well, proving that gasoline was the source of widespread poisoning. However, leaded gasoline is still sold in some parts of the west and south. In other regions, the metal has become so mixed with dust that upwards of 11.7 million children continued to be exposed to lead in 1988.[42]

Carbon Monoxide

At high levels, carbon monoxide (CO) kills and cripples without warning. A gas that is not only invisible but odorless and tasteless, carbon monoxide displaces oxygen in the blood, effectively starving the heart, brain and other vital organs. Developing babies seem particularly vulnerable to carbon monoxide. Oxygen displacement in fetuses is roughly 50 percent higher than in their mothers.[43]

Carbon-rich fuels—gasoline or coal, for example—produce carbon monoxide when burned incompletely by out-of-tune or poorly designed engines or furnaces. Motor vehicles, mostly cars, account for two-thirds of carbon monoxide emissions in the U.S. Carbon monoxide levels are highest in cities, where cars are concentrated. Almost 55 million people live in areas that violate EPA's current standard for carbon monoxide.[44] Commuters, whether in cars, buses or bicycles, are heavily exposed.

Carbon monoxide can be virtually eliminated by using zero-emitting vehicles powered by batteries or fuel

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[40]D.S. Sharp, et al., "Blood Pressure and Blood Lead Concentration in Bus Drivers," *Environmental Health Perspectives* 78 (1988): 131-37; S.J. Pocock, et al., "Blood Lead Concentration, Blood Pressure, and Renal Function," *British Medical Journal* 289 (1984): 872-74; D. Krumhout, et al., "Trace Metals and Coronary Heart Disease Risk Indicators in 152 Elderly Men, *American Journal of Epidemiology* 122 (1985): 378-85.

[41]National Research Council, *Lead in the Human Environment* (Washington, DC: National Academy of Sciences, 1980).

[42]Agency for Toxic Substances and Disease Registry, *The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress* (Washington, DC: U.S. Department of Health and Human Services, 1988), VIII-2.

[43]L.D. Longo and E.P. Hill, "Carbon Monoxide Uptake and Elimination in Fetal and Maternal Sheep," *American Journal of Physiology* 232 (1977): H324-30; M.A. Bureau, et al., "Carboxyhemoglobin Concentration in Fetal Cord Blood and in Blood of Mothers Who Smoked During Labor," *Pediatrics* 69 (1982): 371-73.

[44]Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Carbon Monoxide: Assessment of Scientific and Technical Information* (Research Triangle Park, NC, Aug. 1992).

cells; or reduced by using more efficient engines, tuning them properly, or using catalytic converters or other pollution control devices.

THE PUBLIC COMMENT PERIOD ON EPA'S PROPOSED STANDARDS HAS BEEN EXTENDED TO MARCH 12, 1997. TO COMMENT:

Call: 1-888-835-5372.
Write: Office of Air and Radiation, Docket and Information Center (6102), USEPA, 401 M St., SW, Washington, D.C. 20460, Attn: Docket Number:
A-95-54 (for particulate matter, national ambient air quality standards)
A-95-58 (for ozone national ambient air quality standards)
A-96-51 (for particulate monitoring proposals)
A-95-38 (for interim implementation policy on new or revised ozone and particulate matter national ambient air quality standards)
E-mail: General comments to general.comments@epamail.epa.gov.

EPA Proposes Tighter Standards for Ozone and Particulate Matter

Based on evidence of harm to human health and the environment from ground-level ozone and particulate matter, EPA announced on November 27, 1996 its proposal for new National Ambient Air Quality Standards (NAAQS) for these pollutants. The agency estimates that adoption of the standards, combined with other planned clean air programs, would prevent 40,000 premature deaths per year and eliminate 250,000 annual cases of serious respiratory problems in children. The proposed standards also are intended to alleviate crop damage and reduced visibility.

In deciding to revise the ozone standards, EPA reviewed 186 recent studies of ozone's impact on human health. This survey demonstrated that ozone levels at the current standard are harmful, causing more than 1.5 million cases per year of significant respiratory problems in children and adults. For example, some studies found that city-dwelling asthma sufferers, children and old people missed more work and school and were hospitalized more often on days when ozone levels were high.

The current ozone standard allows an average of 0.12 parts per million (ppm) measured over one hour. Because of evidence that exposure to lower concentrations of ozone over longer periods is harmful, particularly to asthmatics, the proposed standard calls for taking average measurements over eight hours. The permissible level of ozone concentrations would be reduced from 0.12 to 0.07, 0.08 or 0.09 ppm. EPA is also soliciting opinions on retaining the current primary standard of 0.12 ppm, measured over eight hours.

EPA's current standard for particulate matter targets particles 10 microns in diameter and smaller. The regulations limit exposure to concentrations of 50 micrograms per cubic meter annually and 150 micrograms per cubic meter daily. In the newly announced proposals, EPA recommends an additional standard for particles of 2.5 microns and smaller (PM-2.5); concentrations of these smaller particles would be limited to 15 micrograms per cubic meter annually and 50 micrograms per cubic meter daily. EPA will maintain the current standards for the coarser PM-10.

After reviewing public comments, EPA will issue a final regulation in June that will be assessed by Congress. If passed, plans to meet the revised standards would be submitted by 2002 for particulates and

2000 for ozone. Full compliance would not be required for several years thereafter.[45]

Not unexpectedly, EPA's proposals have aroused considerable controversy. Public health and environmental organizations largely support the agency, while polluting industries and industries that produce polluting products reject the agency's recommendations almost unanimously. The utility industry's trade association, the Edison Electric Institute, argues that Americans have breathed increasingly cleaner air in recent decades.[46] The American Association of Automobile Manufacturers maintains that the proposals could be implemented only at "enormous cost," and that recent legislation "does not allow EPA to adopt the cost-ineffective . . . changes it has proposed."[47] A well-financed and politically connected coalition of some 500 companies, dubbed the Air Quality Standards Coalition, has questioned the science involved, arguing that the changes would "produce no significant improvement in human health."[48]

Although current standards have indeed produced cleaner air, emerging science suggests that *legal levels of pollution make people sick, and even kill.* Moreover, many areas fail to meet even current standards. Tighter standards could be expensive: EPA estimates that polluters could pay $8.5 billion annually to take steps such as installing new equipment or securing alternative energy sources.[49] However, the CAA directs EPA to protect human health on the basis of the best available science, not cost (although costs must be taken into account in developing deadlines, implementation plans, and other regulations). Equally important, it may be possible to meet more stringent health standards, at least in the electric energy sector, at reasonable cost through the use of innovative, low-emission renewable energy technologies.

New Medical Evidence Propels New Standards[50]

Current proposals to change and tighten standards for particulate air pollution reflect evolving scientific understanding, the development of more sensitive monitoring devices, and the completion of long-term, statistically valid epidemiological studies. This body of work demonstrates what many scientists long suspected: that even small amounts of particulate pollution have a dangerous effect on human health.

In the early 1970s, immediately following passage of the Clean Air Act, the EPA set air quality standards primarily on the basis of two kinds of evidence. In *clinical and toxicological studies*, researchers expose humans or animals to controlled amounts of pollutants and measure their responses. The high level of

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[45]See "EPA Issues Proposals to Modify Ozone and PM Standards in Spite of Opposition," *Car Lines* (Dec. 1996): 28-36. For further information, call (703) 241-1297.

[46]EEI Press Release, *Utilities Over Comply Under Clean Air Act, Urge EPA to Maintain Air Quality Standards* (Washington, DC: Edison Electric Institute, 25 Nov. 1996). For information, call EEI at (202) 508-5660.

[47]The Association refers to the Unfunded Mandates Reform Act. Letter from AAMA to the Office of Management and Budget, quoted in "EPA Issues Proposals," 28.

[48]Quoted in Joby Warrick, "Opponents Await Proposal to Limit Air Particulates," *The Washington Post* (27 November 1996), A1, A14.

[49]Warrick, "Opponents Await Proposal," A14. Note that some similar estimates were significantly higher than the actual costs, such as estimates of the cost to control acid rain and phase out some ozone-depleting chemicals.

[50]"New Medical Evidence Propels New Standards" was contributed by Lauraine Chestnut of Hagler Bailly Services, Inc., Boulder, CO 80306.

control that researchers maintain over the experiment permits strong correlation between cause and effect. Unfortunately, practical considerations prevent long-term clinical studies of humans; animal studies, while informative, may involve significant uncertainty regarding human health implications.

In addition to clinical studies, the EPA drew on *statistical analyses* of rare, high-pollution episodes during which epidemiologists observed elevated mortality and hospital admissions for respiratory complaints. Analysis showed the clear presence of adverse health effects among the general population during these episodes. However, it was unclear whether these effects also occurred during times of normal pollution or precisely which chemical pollutant caused the harm. While epidemiological studies published in the 1980s showed higher death rates in cities that normally suffered from high levels of air-borne particulate matter, the research was too broad to convince policymakers that pollution was indeed the sole cause of the observed morbidity and mortality.

In the late 1980s and early 1990s, researchers began to publish epidemiological studies linking short-term fluctuations in particulate matter concentrations with mortality rates, hospital admissions and work absences on a daily basis.[51] Most striking, these correlations held true even on days when PM-10 concentrations remained below EPA's legal limit. Nevertheless, skeptics continued to argue that the pollution merely hastened the death of those people already on the brink of expiring, or that it provoked the hospitalization of people substantially weakened by other causes.

More recently, researchers have begun to publish prospective mortality studies that track large groups of subjects over a ten- to fifteen-year period, recording not only incidence of death but also potentially confounding factors such as weight, smoking and occupational exposure. These studies show higher mortality in more polluted areas even after accounting for such differences in individual lifestyle. They also suggest that pollution does not merely hurry death by a few days. They conclude that fine particulates can shorten life by up to six years and that the second largest at-risk group is children, following the elderly.

The prospective studies also suggest that smaller particulates (PM 2.5) have a more severe impact on health than larger particulates.[52] This conclusion remains uncertain, however, because there are few studies using PM 2.5 and because concentrations of PM 10 and PM 2.5 correlate across locations (i.e., if one measure is higher, so is the other), although relative proportions do vary somewhat. It is also unclear whether cumulative exposure to periodic bursts of high pollution is worse than day-to-day exposure to low levels. Finally, researchers have not ruled out the possibility that a specific chemical constituent of particulate matter is the most responsible.

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[51]See, for example, D.W. Dockery, et al., "Air Pollution and Daily Mortality: Associations with Particulates and Acid Aerosols," *Environmental Research* 59 (1992), 362-373; B.D. Ostro and S. Rothschild, "Air Pollution and Acute Respiratory Morbidity: An Observational Study of Multiple Pollutants," Environmental Research 50 (1989), 238-247; J. Schwartz, "Short Term Fluctuations in Air Pollution and Hospital Admissions of the Elderly for Respiratory Disease," *Thorax* 50 (1995), 531-538.

[52]D.W. Dockery, et al., "An Association Between Air Pollution and Mortality in Six U.S. Cities," *New England Journal of Medicine* 329 (1993), 1753-9; and C.A. Pope, et al., "Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults," *American Journal of Respiratory and Critical Care Medicine* 151 (1995), 669-674.

DEREGULATION, POLLUTION AND "OLD SOURCES"

Meeting the proposed standards will require dramatic cuts in the SO_2 and NO_x emitted by the electric sector, a primary source of those pollutants. The most promising opportunity for making those cuts is in some 700 "old source" powerplants—mostly Midwestern, coal-burning plants—exempted by the 1970 Clean Air Act and the 1977 Amendments from meeting the new, stricter standards. These old source plants legally emit four to ten times the pollution of new technologies. At the time, legislators expected that utilities would retire the plants after a "natural" lifetime of twenty to thirty years. Yet, the exemptions themselves confer a competitive advantage, causing utilities to keep the old-source plants in service beyond that point. The rising cost of capital further dissuades utilities from replacing them with new, cleaner facilties.

Restructuring the electric system may exacerbate the problem. Because the Midwest has surplus generating resources, many of the "grandfathered" units operate far under their full capacity. As utility deregulation allows power producers to contract with distant customers, utilities may run these fully depreciated and cheap-to-operate facilities more intensively, thereby producing even more pollution. This prospect alarms not only environmentalists, but also politicians in states (in New England, for example) downwind of the Midwestern plants. Recent analyses suggest that, contrary to some early expectations, the dirty but fully amortized old-source plants may be quite competitive economically in a restructured electricity market. [For further information, see, for example, Bruce Biewald, "Competition and Clean Air: The Operating Economics of Electricity Generation, *The Electricity Journal* 10 (Jan./Feb. 1997), 41-45.]

A reasonable solution to this problem has two elements. First, plans to restructure the electric system should include provisions to bring old sources up to current standards. (The 1997 Massachusetts settlement included such provisions.) Second, rather than assuming a natural lifetime for existing technology, lawmakers should include specific limits for any exemptions in future legislation. In both cases, it will become even more difficult to meet acceptable clean air standards with existing technology. One promising solution to this impasse would be requiring increased use of zero-emission renewable energy technologies in exchange for exempting existing fossil-fuel powerplants.

Readers may contact Armond Cohen of the Clean Air Task Force in Boston, MA for more information on this subject at (617) 292-0234.

However, this new statistical evidence is compelling: particulate matter at current concentrations in many locations that meet EPA standards continues to menace human health. It is on this basis that EPA has proposed changes that would reduce public exposure to what scientists suspect to be the most harmful element of air-borne particulate pollution. Supporters of the proposals hope that the changes will not only lower the overall concentrations of particulates in urban air, but that the standards will motivate control efforts to focus even more on reducing emissions from the combustion of organic fuels.

Next Steps: Linking Clean Air and Renewable Energy Agendas

Wih few exceptions, scant attention has been given to integrating energy and environmental goals and strategies. U.S. energy and environmental laws are written with little sensitivity to these intersections. For example, the Clean Air Act does not provide clear guidance or means of crediting renewable energy developers with the environmental benefit of their actions. (REPP will pursue this subject in future research projects.) EPA and the Department of Energy operate largely independently of one another.

The few instances in which energy and air pollution objectives have been merged provide a starting point for more ambitious thinking. The acid rain program, adopted in the Clean Air Act Amendments of 1990, allows utilities to achieve required reductions in SO_x emissions through investments in energy efficiency and renewable energy. Reductions greater than required result in tradeable credits, which have a market value. However, most utilities have found it easiest to comply by importing low sulfur coals and other strategies that avoid the need for new technology. The Energy Policy Act of 1992 provides economic incentives for use of non-petroleum fuels, although without regard to relative differences in their environmental benefits and without eliminating tax differences which continue to favor gasoline over better alternatives.[53]

A serious approach to linking energy and environmental goals would require more radical changes in the regulatory system. For example, increased reliance on pollution taxes would reflect more accurately the environmental costs of pollution and, at the same time, create an economic incentive to avoid generating emissions. Proposals for such major changes in environmental regulation are increasingly being proposed from diverse quarters, partly in reaction to the ill-considered and unsuccessful attack on pollution control laws in the previous Congress. While much hard thinking remains, the prospect of making renewable energy an integral part of achieving our environmental goals may be near.

The potential to use renewable energy technologies much more effectively to meet air quality goals is illustrated by a 1993 report of the Center for Global Change (CGC) to the South Coast Air Quality Management District (SCAQMD).[54] The District is responsible for meeting air pollution standards in

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[53]See, generally, Office of Technology Assessment, U.S. Congress, *Saving Energy in U.S. Transportation* (Washington, DC: Government Printing Office, 1994), 26-28; Office of Technology Assessment, U.S. Congress, *Renewing Our Energy Future* (Washington, DC: Government Printing Office, 1995), 139-42.

[54] F. Muller and H. Sachs, *Renewable Energy and Pollution Prevention in Southern California, A Report for the South Coast Air Quality Management District* (College Park, MD: Center for Global Change, Jan. 1993). This report is available from REPP.

Southern California, the region that faces the most severe air quality problems in the United States. While

PHOTOVOLTAICS AND EMISSIONS REDUCTIONS

The environmental benefits of photovoltaic systems were tested in 1993 and 1994 in a cooperative project involving EPA and 11 electric utilities nationwide [Arizona Public Service, Atlantic City Electric, City of Austin Municipal Utility, New England Electric System, New York Power Authority, New York State Electric and Gas, Northeast Utilities (CT, MA, NH), Northern States Power (MI, MN, ND, SD, WI), Pacific Gas and Electric (CA), Southern California Edison, and Wisconsin Public Service]. The measured performance of sixteen PV systems was combined with emission rate and load data from the participating utilities to determine potential emission reductions. The results showed that the emissions offset varied enormously as a function of the utility fuel mix and generating equipment, by a factor of three for CO_2, four for SO_x, thirty for particulates, and more than eighty for NO_x. Variations in the solar resource proved to be much less important. Another interesting result is that a simulation of emission offsets showed a reduction of about 25% in emissions when storage systems were added to the PV systems. This is because more of the displaced power was from off-peak periods when most utilities use cleaner and more efficient powerplants.

Source: Edward Kern and Daniel Greenberg, *Demonstration of the Environmental and Demand-side Management Benefits of Grid-connected Photovoltaic Power Systems* (Cincinnati: U.S. EPA, National Risk Management Research Laboratory, Nov. 1996, EPA/600/SR-96/130). See also Edward Kern and Anne Polansky, "How Many Rooftop PV Systems Does it Take to Save the Earth?" *Solar Industry Journal* 4 (Fourth Quarter 1993), 18-27.

the region is not ideally suited for all renewables technologies, certain applications could be highly effective in reducing southern California's air emissions.

The CGC study suggested a three-pronged strategy to reduce emissions of two problem pollutants— NO_x and reactive organic gases—by 85 percent and 53 percent respectively, relative to currently projected emissions in 2010. The proposed strategy involves the following elements: (1) increasing the renewables fraction in electricity generation by utilities acquiring new renewable resources, retiring old fossil capacity, and using PVs for peak load-shaving and other high value applications; (2) replacing fossil fuel combustion and other processes through electric vehicles, heat pump water heaters, and improved industrial processes; and (3) using cost-effective solar technologies for water heating in homes and office buildings, for swimming pools, and in low temperature applications.

While far from definitive, the study illustrates how an examination of air pollution sources by region can identify numerous opportunities for using renewable energy technologies to reduce emissions. The study also found that the higher the cost of other options for meeting air quality goals, the stronger the case for renewables. Finally, the study shows that the time frame for air quality planning in many regions—up to 2010 in Southern California—is more than sufficient to allow for the transition to increasingly cost-effective renewable energy technologies.

Conclusion

Regulation has greatly improved America's air quality. These improvements translate directly into fewer deaths and more enjoyable lives. The value of a reasonable but firm clean air policy can be seen clearly by comparing air in America with that in much of the developing world, where industrialization exacts a heavy price on the environment and daily life, even as it brings economic advancement.

Yet, compelling evidence exists that air pollution—legal air pollution—still kills and sickens millions of Americans. Motor vehicles and powerplants release the vast majority of that pollution, although factories also play a major role. The common link between these sources is that all three produce energy by burning fossil fuel.

Renewable energy technologies could reduce air pollution in two major ways. First, several renewable technologies commercially available today can produce clean electricity. These include wind turbines, geothermal plants, solar thermal generators, photovoltaic panels and others. Second, that clean electricity can be stored in batteries and used to run clean vehicles. Electric cars are just reaching the market, although, of course, their environmental advantage is greatly diminished if the electricity used to charge their batteries originates at a coal-burning powerplant. In the future, electricity generated from renewable energy may be used to produce hydrogen, a clean energy carrier able to power vehicles and other devices; several analysts posit a renewable-hydrogen economy as the ideal endpoint of our search for an environmentally benign, replenishable energy system.

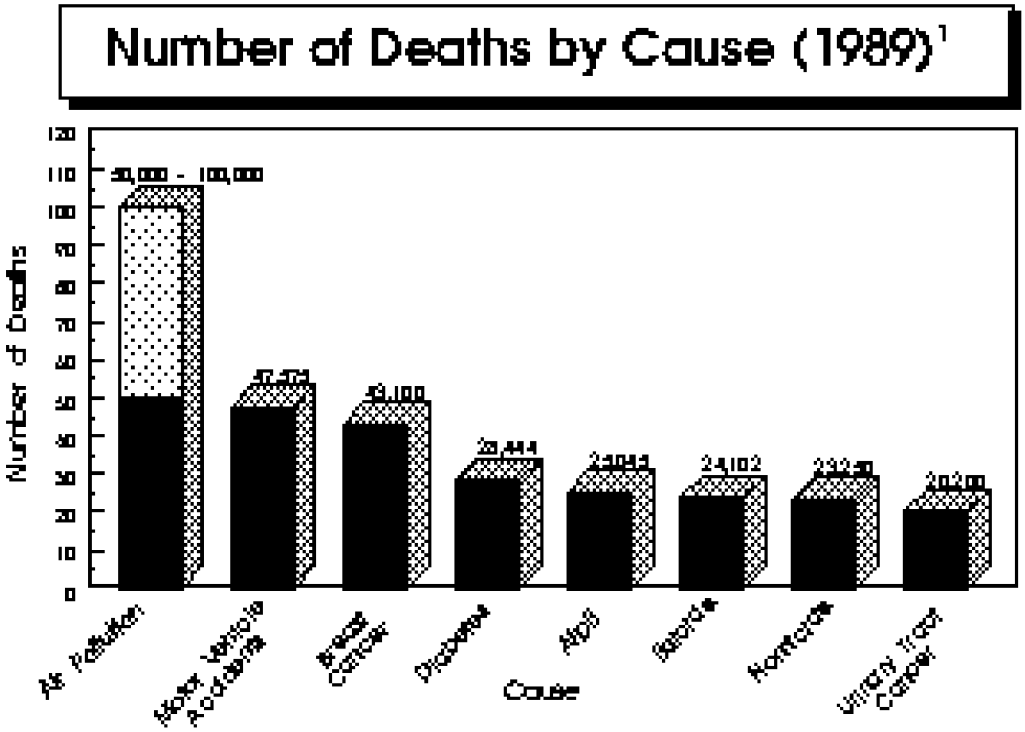
The reasons for pursuing renewable energy are grounded firmly in the value of human life. While engineering challenges remain, the primary obstacles to a renewable energy future are economic and political. As we strive for cleaner air for our children, the chief tasks before us are to face honestly the true cost of our energy decisions and to minimize those costs. It is difficult to set a value on the life of a human being but a system that sets that value at zero is clearly wrong.

TABLE 1: POLLUTION IN THE EIGHTEEN LARGEST CITIES

City	Serious Pollution Problem	Moderate Pollution Problem
Bangkok	Lead	SPM
Beijing	Ozone	SO_2, SPM
Bombay		SPM
Buenos Aires	SPM	CO
Cairo	CO	SPM, Lead
Calcutta		SPM
Jakarta	Lead, CO, Ozone	SPM
Karachi		SPM, Lead
Los Angeles	SPM, CO, NO_2	Ozone
London	CO	
Manila	Lead	SPM
Mexico City	Lead, NO_2	SO_2, SPM, Lead
Moscow	SPM, CO, NO_2	
New Delhi		SPM
New York	CO	
Rio de Janeiro	SPM, SO_2	
Sao Paulo	SPM, CO, NO_2	
Tokyo		Ozone

SPM = Suspended Particle Matter
SO_2 = Sulfur Dioxide
CO = Carbon Monoxide
NO_2 = Nitrogen Dioxide

SOURCE: World Health Organization in Molly Moore, "Mexico City Gasping in Quest of Fair Air," *Washington Post* (25 Nov. 1996), A14.


Number of Deaths by Cause (1989)[1]
Number of Deaths
50,000 - 100,000
47,575
43,100
28,444
25,045
24,102
23,250
20,200
Air Pollution
Motor Vehicle Accidents
Breast Cancer
Diabetes
Alpha
Bacteria
Nonfarcia
Urinary Tract Cancer
Cause
Source for non-air pollution mortality: Statistical Abstract of the United States 1992, pp. 84-9