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Electric Power Fuel Sources and Utility Risk Issues

How should we balance environmental impacts with our growing energy demands?

With the recent "rolling blackouts" in California and the release of the Bush-Cheney National Energy Policy in May 2001, electric power generation has become the subject of extensive discussion. Environmental issues are intertwined in this complex debate. Recent newsworthy examples of the conflict between energy and environmental policies have included the U.S. EPA's decision last year to regulate emissions of mercury from coal- and oil-fired power plants, and proposals to permit more extensive oil drilling in the Arctic National Wildlife Refuge. We are faced with the question: should we forego environmental concerns in favor of increased energy production, or should we risk future power shortages for environmental protection? This article provides a perspective on this topic by introducing some of the environmental risk issues faced by the electric power industry in its efforts to meet rising U.S. demand.

Although environmental concerns sometimes appear to favor natural gas-fired rather than coal-fired power plants, there are many other factors that complicate this choice.

The Bush-Cheney National Energy Policy recommends the construction of at least 1,300 new electric power plants by the year 2020 as a solution to future energy shortages (NEPDG, 2001). Current plans indicate that the predominant fuels will be coal and natural gas, which accounted for approximately 52% and 16% of total electricity generation, respectively, in 2000. Large future increases in energy production are unlikely to come from other energy sources. Nuclear power supplies

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I N S I D E

Letter to our Readers

September 2001

Dear Colleague,

As the public spotlight shines on the growing energy demands in our country, environmental issues associated with power plants are also drawing renewed attention. Each form of power generation is associated with some type of environmental effects. In this issue of *Trends*, we focus specifically on fossil fuel power plants, including the differences between coal and natural gas as fuels, the health effects associated with particulate matter, and electric and magnetic fields.

Contributors to this issue include Dr. Christopher Long, a Gradient environmental scientist with expertise in air emissions and solid waste generated by power plants, and Dr. Peter Valberg, Gradient Principal, inhalation toxicologist, and international expert on electric and magnetic fields. Additionally, we welcome Susan Tierney, Senior Vice President at Lexecon Inc., an economic and policy consulting firm that specializes in the energy industry. Ms. Tierney is a former Assistant Secretary for Policy at the U.S. DOE, Massachusetts Secretary of Environmental Affairs, and Commissioner of the Department of Public Utilities. She shares her thoughts regarding the California power crisis and electricity market.

In keeping with the broader scope of this newsletter beyond risk and remediation issues, we also introduce a new look and title. We hope this issue of *Trends* will provide you with new perspectives on power generation and the associated environmental management issues.

Yours truly,

Neil Shifrin, Ph.D.
President

Trends is a free publication of Gradient Corporation, a national leader in risk assessment and negotiation of risk-based remediation. If you have a colleague who would benefit from this publication, please contact Alison F. Barlow at (617) 395-5000 or email us at *trends@gradientcorp.com.*

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Electric Power Fuel Sources and Utility Risk Issues

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approximately 20% of U.S. electricity, but there are currently no plans to build additional nuclear plants. Economic and technological constraints remain a significant barrier limiting the growth of renewable energy sources (*e.g.*, wind, solar, and geothermal). Oil accounts for only approximately 3% of U.S. electricity generation, with future declines predicted by energy experts.

Natural gas is a clean fuel, with high efficiency and low air emissions. Natural gas-fired power plants can be constructed more quickly and at lower capital cost than coal-fired plants. However, whether natural gas is a viable long-term source of affordable electricity is unclear due to the potential for large price fluctuations (this year's price nearly tripled) and natural gas pipeline shortages (see related article).

A Comparison of Fuel Source Attributes

	Coal	Natural Gas
Environmental Factors		
Air Emissions	–	+
Relative Land Impacts	–	+
Other Factors		
Transport Issues	+	–
Infrastructure Demand	+	–
Power Plant Construction	–	+
U.S. Abundance	+	–
U.S. Energy Independence	+	–
Price Stability	+	–
Sustainability	+	–
Efficiency	–	+

+, more preferable; –, less preferable

Numerous factors play into the selection of fuel.

In contrast, coal is commonly considered to be a more polluting fossil fuel, based on high air emissions of particulate matter (PM), nitrous oxides (NO_x), sulfur dioxide (SO_2), mercury, and carbon dioxide (CO_2). In addition, millions of tons of coal ash are generated each year by coal-burning utilities, although a large portion of these wastes is beneficially reused in a variety of commercial products and applications including cement, wallboard, and soil amendments. However, these environmental emissions do not necessarily translate into high human health risks, as demonstrated by the EPA (1998). In a multi-pollutant, multi-pathway risk assessment employing conservative exposure assumptions, the EPA demonstrated that both non-cancer and cancer risks from 67 hazardous air pollutants (HAPs) (including mercury, radionuclides, arsenic, and dioxins) emitted as gases and particles from coal-fired utilities were minimal. In fact, the highest EPA estimate for cancer incidence due to inhalation of HAPs from all current U.S. coal-fired utilities was 1.3 cases per year in the entire U.S. population, which contrasts with a background rate of 1,200,000 per year.

Although environmental concerns sometimes appear to favor natural gas-fired rather than coal-fired power plants, there are many other factors that complicate this choice (see table). Coal's primary advantage is that it is the most abundant fuel source in the U.S., with an estimated 250 year supply. Coal prices have generally declined since the early 1980s. In addition, with the planned $2 billion federal investment, clean coal technologies offer promise for higher efficiencies and reduced environmental impacts.

Despite the advantages of coal, regulatory uncertainty is an additional factor affecting the expansion of coal-fired power plants. The EPA has pledged to issue regulations to reduce mercury emissions, and the new $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) is likely to affect power plants in areas where PM levels are close to or exceed the standard. There is also the prospect of state regulatory action, such as the recent multipollutant regulatory scheme adopted by the Massachusetts Department of Environmental Protection that regulates NO_x, SO_2, mercury, and CO_2 emissions from coal-fired utilities.

Environmental challenges can be prominent hurdles to energy production, but they are not the only constraints that can affect the choice of energy sources for electricity generation. Multiple criteria must be used to evaluate different fuel types. If electricity shortages are indeed a future reality, it is likely that difficult tradeoffs will need to be made to meet increased demands.

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National Energy Policy Development Group (NEPDG). 2001. National Energy Policy. Available at http://www.energy.gov.

U.S. EPA. 1998. "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units – Final Report to Congress." EPA-453/R-98-004a.

Impact of Power Plants on Air Quality

Divergent information from laboratory and epidemiological studies confounds our understanding of power plant air quality impacts.

Power plants are subject to stringent controls on emissions of combustion products into the air. However, the total concentrations of these products in the air we breathe are more directly relevant to health than direct emissions. For six pollutants: carbon monoxide, nitrogen dioxide, ozone, lead, particulate matter (PM), and sulfur dioxide, air quality standards have been developed to protect public health. These six are called the "criteria pollutants," and the health-protective levels are called the primary "National Ambient Air Quality Standards" (NAAQS).

The outcome of the current EPA review of PM health effects will determine whether the current NAAQS will be reaffirmed or modified…

The pie chart shows typical ambient air concentrations of the criteria pollutants, along with an estimate of the concentration of non-criteria pollutants called "hazardous air pollutants" or HAPs. Even though there has been tremendous focus on PM, its mass concentration is a small percentage among air pollutants (see figure).

The process by which the U.S. EPA sets NAAQS involves exhaustive review and evaluation of all the relevant scientific literature. The Clean Air Act and its amendments (1970, 1977, 1990) mandated the EPA to set regulations for criteria pollutants at levels that "protect human health" allowing for an "adequate margin of safety" that protects "sensitive subgroups." Because a margin of safety is incorporated, these levels should not be considered a "bright line" between safety and adverse health effects – they are more restrictive (that is, lower) than levels that would be expected to affect health.

When the EPA develops permissible levels of criteria pollutants in air, the EPA staff prepare a "Criteria Document" that details the technical criteria for a proposed standard, evaluating and analyzing relevant medical and scientific literature. This document forms the basis for the proposed health-protective standards. Conclusions are reviewed by the EPA's "Clean Air Science Advisory Committee," a group of scientists from the medical, academic, research, and regulatory communities. Often, additional outside consultants (doctors, scientists, public-health professionals, and air-quality experts) provide comments. As required by law, air quality standards are periodically reviewed as scientific knowledge improves and new information comes to light.

The NAAQS for PM is currently under review. A series of epidemiologic studies have reported correlations between increments in ambient PM and mortality and respiratory disease rates, at levels below the NAAQS (Samet *et al*., 2000). The existence of some weak associations between an area's PM and that area's mortality rates has been known for decades. But, neither laboratory experiments with PM-exposed animals nor exposure of human volunteers to PM in clinical settings is supportive of PM health effects at levels of PM below the NAAQS. It is difficult to find a toxicologic basis for postulating that PM health effects occur down to zero concentrations.

What is also not yet known, is whether the associations are causal (in part or in whole), or instead reflective of some other, causal factors that consistently correlate with PM levels (Valberg and Watson, 1998). Plausible alternative causal pathways exist by which mortality and respiratory disease rates may correlate with PM. Increased levels of PM in the air are correlated to increased societal activity, such as increased commercial activity, traffic, electricity consumption, emissions from factories, re-suspension of dust, plowing of fields, construction, and other dust-generating activity. Societal behavior patterns are themselves correlated with daily rates of death. For example, epidemiologic studies have shown that psychological stresses of various kinds, such as anger, are strongly associated with increased risk of deaths due to heart attacks. Anger may be correlated with increased commuter congestion, or increased overtime work, suggesting the possibility of non-toxicological effects in mortality rates. In fact, mortality rates correlate to day-of-week and day-of-month. Other studies show important effects of psychological

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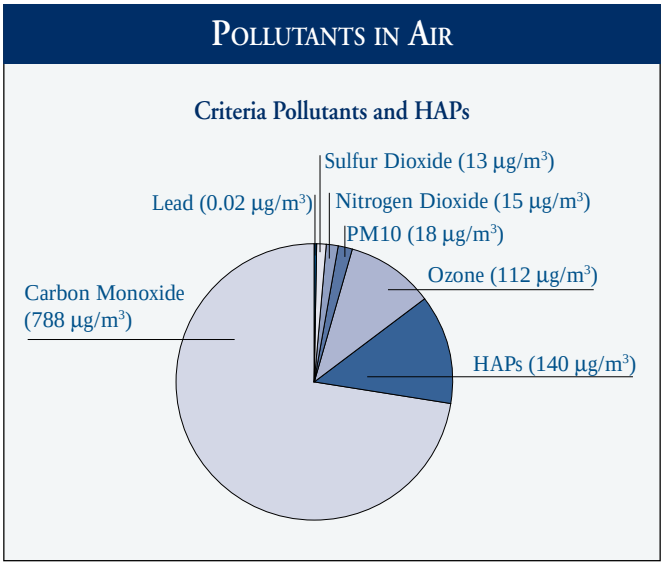

Particulate matter mass is small relative to other pollutants.

Do Power-Line Electric and Magnetic Fields (EMF) Affect Health?

Despite considerable efforts to relate EMF to health effects, a causal link has yet to be established.

Whenever the environmental impacts of electric-power generation and transmission facilities are evaluated, it is generally necessary to discuss the health effects of electric and magnetic fields, or EMF (NIEHS, 1999). EMF are produced by both natural and man-made electricity, and can be found anywhere electricity is used.

All matter contains electrically-charged particles, but most objects are electrically neutral because positive and negative charges are present in equal numbers. When this balance is altered, we experience electrical effects, such as attraction between a comb and a person's hair, or drawing sparks after walking on a synthetic rug in the wintertime. Electric charges create an electric field that exerts force on other nearby electric charges. When electric charges move, an electric current exists, which generates a magnetic field. EMF decrease in size as the distance from the source increases. In discussions about health effects, magnetic fields have received much more attention than electric fields, primarily because electric fields are easily shielded by conducting objects.

…no one has been able to identify what aspect of EMF (if any) should be avoided.

Microwave ovens, refrigerators, fluorescent lamps, electric ranges, clothes washers, toasters, vacuum cleaners, and many other appliances produce 60-Hz magnetic fields of size 40 - 100 milligauss (mG) at distances of one foot. The magnetic fields from personal-care appliances such as shavers, hair dryers, massagers, electric toothbrushes, and electric blankets can be many 100s of mG. The earth produces a steady 550 mG magnetic field. Childhood toys containing magnets and "refrigerator magnets" typically have magnetic fields of 100,000 to 500,000 mG; and, an increasingly common diagnostic procedure, magnetic resonance imaging (MRI), uses fields of 20,000,000 mG on humans. By comparison, magnetic fields of 100s of mG can be measured directly under electric-power transmission lines. Importantly, EMF are not "emissions," because power-frequency EMF do not propagate away from their source.

A 1979 epidemiologic study suggested that living near electric power distribution lines showed an association with an increased risk of childhood cancer. Since this first study, many epidemiologic studies have examined associations between disease and markers of EMF exposure. Often, studies showed that the associations disappeared when actual measured magnetic fields were substituted in place of indirect markers of EMF (*e.g.*, "wire codes").

Supporting laboratory evidence for an effect of EMF exposure on health has not been forthcoming. To date, there is neither an accepted mechanism by which power line EMF can cause disease, nor is there any animal model in which exposure to even large magnetic fields has consistently produced a disease or a pre-disease condition. This means that no one has been able to identify what aspect of EMF (if any) should be avoided. Substantial literature on the question of EMF health effects has been generated, representing the accumulation of years of laboratory work and human experience with EMF. The scientific data on EMF and health have been reviewed by many independent consensus groups of research and health scientists, including the National Academy of Sciences, the American Medical Association, the American Physical Society (the professional society for American physicists), the American Cancer Society, and others. The reports have not been able to find evidence for levels of EMF that can be deemed "harmful" or "unsafe."

Can power-line EMF affect health? To quote Dr. Charles Stevens, the chair of the 1997 National Academy of Sciences committee that reviewed EMF research: "Science can't prove that anything is safe. But so far we have failed to find a hazard."

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National Academy of Sciences. 1997. Possible Health Effects of Exposure to Residential Electric and Magnetic Fields. National Research Council, Committee on the Possible Effects of Electromagnetic Fields on Biologic Systems. NAS Press, Washington, DC.

National Institute of Environmental Health Sciences. 1999. NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields. NIH Pub. No. 99-4493.

By The Way...

On March 21, the Centers for Disease Control released the first annual National Report on Human Exposure to Environmental Chemicals. Measurements in blood and urine show declining levels of lead and cotinine (a result of second-hand smoke) in children. The studies establish baseline values of 27 chemicals and metals, and future years' measurements will document trends for an expanding list of chemicals. The report can be seen at http://www.cdc.gov/nceh/dls/report.

What's New at Gradient

Gradient Welcomes Catherine Petito Boyce

Catherine Petito Boyce has joined Gradient as a Principal Scientist in our Seattle office. She is a toxicologist who specializes in evaluating health effects, analyzing chemical fate and exposure, and assessing risks associated with toxic chemicals in the environment. She earned her S.M. in environmental health management from the Harvard School of Public Health and her B.S. in biology from Yale University.

Peter Valberg Joins the National Academy of Sciences Committee

Dr. Valberg has been nominated to serve as a member of the National Academy of Science Committee: "Estimating the Health-Risk-Reduction Benefits of Proposed Air Regulations."

Recent and Upcoming Presentations

Cambridge, MA. October 3, 2001. Lorenz R. Rhomberg. "Cancer Dose Response and the Implications of Mechanistic Research," lecture for the Harvard Center for Risk Analysis Continuing Education Course, Analyzing Risk.

Amherst, MA. October 23, 2001. Teresa S. Bowers. "Arsenic Background and Cleanup Levels in Soil: Should They be Related?" presentation at the 17th Annual International Conference on Contaminated Soils, Sediments, and Water. University of Massachusetts.

Amherst, MA. October 25, 2001. A. Dallas Wait. Moderator for "Risk and Risk-Based Decision Making," session at the 17th Annual International Conference on Contaminated Soils, Sediments, and Water. University of Massachusetts.

New Orleans, LA. October 30, 2001. Lorenz R. Rhomberg. "Principals of Toxicology," lecture at the American Chemical Society (ACS).

Boston, MA. November 5-8, 2001. Teresa S. Bowers. "Implications of Natural Levels of Metals in Soils to CDC's Exposure Report Card Results," presentation at the Geological Society of America Annual Meeting.

Recent Articles

Long, C.M., H.H. Suh, P.J. Catalano, and P. Koutrakis. 2001. Using time- and size-resolved particulate data to quantify indoor penetration and deposition behavior. *Environmental Science and Technology* 35(10):2089-2099.

Gustafsson, O., **C.M. Long**, J. MacFarlane, and P.M. Gschewend. 2001. Fate of linear alkylbenzenes released to the coastal environment near Boston Harbor. *Environmental Science and Technology* 35(10):2040-1048.

McCunney, R., H. Muranko, and **P.A. Valberg**. 2001. Carbon black. In *Patty's Toxicology, 5th Edition* (Eds: E.D. Bingham), Chapter 111 in Volume 8.

Wait, A.D. 2001. Environmental forensic chemistry and sound science in courtroom. *Fordham Environmental Law Journal* 12:293-325.

Watson, A. and **P.A. Valberg**. 2001. Carbon black and soot: Two different substances. *American Industrial Hygiene Association Journal* (62):218-228.

Borgert, C.J., B. Price, **C.S. Wells**, and G.S. Simon. 2001. Evaluating chemical interaction studies for mixture risk assessment. *Human Ecological Risk Assessment* 7:259-306.

Impact of Power Plants on Air Quality

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stress on the symptoms and severity of asthma and other respiratory diseases.

The outcome of the current EPA review of PM health effects will determine whether the current NAAQS will be reaffirmed or modified, with subsequent repercussions in the power plant industry. Hopefully, the review process will be able to reconcile the seemingly divergent lines of evidence from laboratory toxicology *versus* correlative analysis of population data.

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Samet, J.M., F. Dominici, F.C. Curriero, I. Coursac, and S.L. Zeger. 2000. Fine particulate air pollution and mortality in 20 U.S. cities, 1987-1994. *N. Engl. J. Med.* 343:1742-9.

Valberg, P.A. and A.Y. Watson. 1998. Alternative hypotheses for PM associations with daily mortality and morbidity. *Inhalation Toxicology* 10:641-662.

Guest Editorial: Power Generation Investments

Changes in competitive structures and fuel costs are causing shifts in the way power gets generated and distributed.

For the first time in decades, energy has hit the front pages. Californians have seen their prices hit the roof and faced unprecedented blackouts. At the same time, all of us are becoming more dependent upon reliable electric power, since we use electricity for virtually all of our daily activities.

Recent polls indicate that 90% of Americans believe that we're facing a current or impending energy crisis, and 38% believe that high energy prices are the Nation's worst economic problem. At the same time, almost two-thirds of Americans believe that environmental protection is so important that requirements and standards cannot be too high and must be continually improved.

While California's energy crisis has led many other states to take a cautious look at whether and how to proceed with allowing retail markets to provide basic electric service to consumers, competition in wholesale generation markets is likely to increase. Competition may proceed more quickly given the July 2001 decision by federal regulators to adopt electric transmission policies that consolidate the lower 48 states into a few "natural" power market regions, each supported by a large "regional transmission organization."

Future interest in other power generation technologies…will be shaped by future policy choices now under discussion in Washington and the states.

What types of power-technology investments can we expect competitive market forces to produce? Recent experience suggests they would lead overwhelmingly to investment in natural gas-fired, combined-cycle power plants for baseload power. This technology has dominated in an economic climate of low gas prices, difficult siting politics, pressure to reduce air emissions, and little investor taste for projects with high capital costs and long lead times. Over the past few years, more than enough new capacity has entered development to meet growth in consumers' demand.

However, high gas prices experienced over the past year have already begun to lead investors to examine alternatives. Future interest in other power generation technologies (including repowerings, wind, nuclear life extensions, new nuclear plants, advanced coal, microturbines, fuel cells) will be shaped by future policy choices now under discussion in Washington and the states. Some of the policies that could most impact investment choices are:

- New environmental laws and regulations, including the "three-pollutant" (NO_x, SO_2, mercury) or "four-pollutant" (NO_x, SO_2, mercury, CO_2) bills affecting power plants, the resolution of policy surrounding "new source review," and climate change policies;
- Adoption of transmission policies that either encourage – or discourage – new investment in transmission and new markets for small scale "distributed generation;"
- Heightened local opposition to siting certain types of plants in various parts of the country;
- Adoption by state or federal government of requirements that power sold into certain markets include a certain percentage of renewable resources;
- Increased support for research and development for different power generation technologies that are not yet commercially viable;
- State policies to oversee electric utilities' power plant investment choices.

What will be the ultimate impact of these policies in the months ahead? Stay tuned...

Susan F. Tierney
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Cambridge, Massachusetts

In the next issue:

Evolution of Pesticide Science

Risks vs. Benefits of Pesticide Use

Examining Multiple Chemical Sensitivity

Guest Editorial: Responsible Chemicals Management

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