observed in scientific studies of power-frequency electromagnetic fields, it is not clear that these effects are detrimental to human health.

The EMF associated with electric power has two components, **electric field** and **magnetic field**. An electric field is created by the attraction between opposite electric charges and exerts a force on all other charges within the field. When many opposite charges accumulate on either side of a barrier, such as in electric storms, the medium between the charges breaks down, and an electric arc forms as the charges flow together. However, electric charges flow relatively easily through some materials known as conductors. Conductors are not destroyed by the flow of charges as long as the heat they generate is carried away from the conductor immediately. The flow of electric charges in a conductor is called current. Current creates a magnetic field that exerts a force on all electric charges in the field.

The electric and magnetic fields associated with transmitting electricity are the basis for many applications of electric power. For instance, current and the magnetic field it produces are the basis for the design of electric motors. In addition, when a conductor is forced through a magnetic field, electric charges move through the conductor creating an electrical potential (voltage) between the two ends of the conductor; this is the basis for the electric generator. The properties that make electric power easy to transmit and use are the same properties creating concern for human health and the environment.

The strengths of power-frequency electric and magnetic fields are controlled by different factors. Electric field strength depends on the voltage of the source of the field. High-voltage transmission lines produce stronger electric fields than lower voltage distribution lines and most household appliances. Electric field strength diminishes with increasing distance from the source. An electric field is impeded by intervening objects; therefore, trees and buildings can provide considerable shielding from an electric field around utility equipment. Grounded objects provide the most effective shielding from electric field. Magnetic field strength depends on the amount of current in the source. For example, a hair dryer operating at "high" draws more current and produces a stronger magnetic field than one operating at "low" (but the voltage, hence the electric field strength, is the same). Magnetic field strength also diminishes with distance from the source; however, power-frequency magnetic field is propagated through most objects, including the human body, without being diminished.

Understanding the relationships between voltage and current can help to dispel some misconceptions about utility operations. The amount of electric power a utility can deliver over a transmission line is the product of the voltage and the current in the line. As discussed earlier, current produces heat, which results in loss of some energy; therefore, utility companies would like to use higher-voltage (lower-current) transmission lines to deliver power more efficiently. Because the amount of current determines the strength of the magnetic field around a line, using more efficient, higher-voltage lines would reduce the magnetic field. Although electric field strength would be greater at the higher voltage, the electric field can be shielded; therefore, high-voltage transmission lines may be desirable if further research demonstrates real human health risks from power-frequency EMF.

EMF Research: Inconsistent and Inconclusive Results

Much of the concern over human health risks of EMF has arisen from **epidemiological** studies that have looked for statistical associations between exposure to 60 Hz fields and cancer. Epidemiological research compares the death rate from a particular disease or the incidence of a disease in a population exposed to a specific environmental factor with the death rate from or incidence of the same disease in a "control" population that was not exposed to the environmental factor. This type of research can only identify statistical **correlations**, not define causes, and all epidemiological studies involve some level of statistical uncertainty.

The strongest correlations between EMF and cancer have been found in occupational exposure studies of cancer among people in "electrically related" jobs (e.g., electronics workers, power linemen and plant operators, and telephone linemen). Several of these epidemiological studies have found an increased incidence of brain tumors and male breast cancer among such workers. Generally, the studies suggest an increased risk of all types of cancer among electrical workers of 2 to 3 times over that expected in the general population. A common criticism of occupational exposure studies is that most have not measured EMF exposure directly, but rather have inferred exposure levels from job titles. Many of the occupational studies have not controlled for exposure to other known and potential carcinogens common in the environments of electrical workers, such as PCBs, lead soldering fumes, and organic solvents.

The results of epidemiological studies of EMF exposure of people living near transmission lines have been less consistent than occupational studies in suggesting increased risk of cancer, and the studies have received similar criticisms. The best known residential studies have suggested a 2- to 3-fold increased risk of leukemia among children living near electrical substations, transformers, or heavy distribution lines in Denver, Colorado. Similar studies in other areas (such as Rhode Island and Yorkshire, England) have found no increased risk. As in occupational exposure research, these epidemiological studies did not measure exposure directly, but rather inferred exposure levels based on the proximity of homes to sources of EMF such as electrical substations, transformers, or heavy distribution lines. A recent residential study in which EMF exposures were measured directly found no significant correlation between measured exposure and childhood leukemia; however, the researchers did discover some association between the distance of the homes to the EMF source. This study supports one hypothesis among EMF researchers that classifying homes by distance to EMF sources to infer the level of EMF exposure must be inadvertently including some other factor in the environment that may be associated with childhood leukemia.

Scientists characterize human health risk, in part, on the basis of **dose and exposure**; however, there is no clear picture yet of what might constitute a significant dose of EMF or what sources of exposure are most important. A dose is typically defined as the amount of a substance (such as a carcinogenic chemical) that gets into the body. For most known potential hazards it is assumed that if some is bad, more is worse; however, this may not be true of EMF. In some experiments, biological effects have been observed only in specific narrow ranges of field intensity and frequency, known as **windows of effect**. Other researchers have observed effects only after several weeks of exposure or only for a short time after a change in exposure. Still other studies have shown effects only when fields exceed some threshold. Scientists have not been able to determine definitively whether the important aspect of EMF is the strength of fields, the changes in field strength over time, the magnitude of the induced current, the duration of exposure, or some combination of these or other variables.

Determining which of these aspects contributes to an EMF dose of concern for human health will help to identify the most significant sources of EMF exposure. For instance, comparing human EMF exposure from high-voltage transmission lines and lower-voltage distribution lines shows that transmission lines score highly for intensity of exposure. On the other hand, distribution lines score highly for duration and prevalence of exposure because more people live in the immediate vicinity of distribution lines. The magnitude of the risk associated with exposure to EMF may be considerably less significant than the magnitude of some more pervasive risks for which a causal link with a disease has been clearly demonstrated, such as the increased risk of lung cancer for smokers. More information on the questions of dose and exposure is needed to determine whether setting standards for EMF exposure is warranted and how to set human exposure limits.

PPRP's Role in EMF Research

PPRP assists the Maryland PSC in its continuing re-evaluation of EMF concerns by reviewing and analyzing the results of new EMF research. Under a 1989 PSC order, PPRP prepares an annual report summarizing recent developments in understanding the human health effects of exposure to EMF and will assist the PSC in developing justifiable guidelines for protecting public health if regulation is deemed necessary.

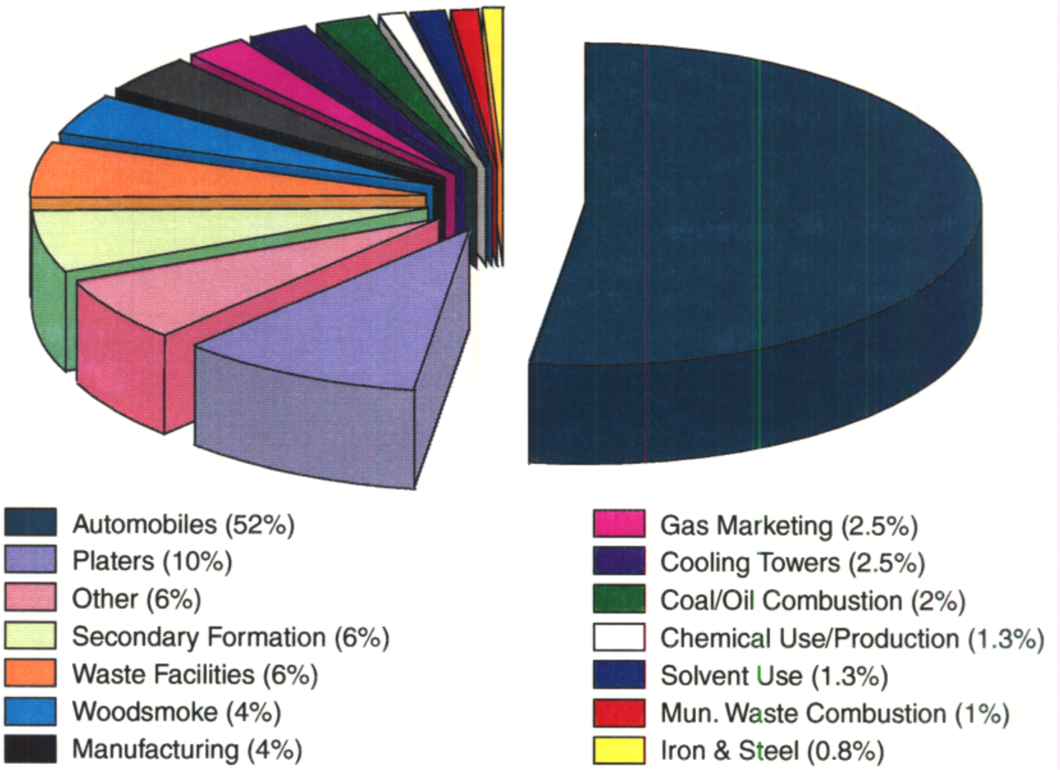
PPRP, in conjunction with BG&E, is measuring EMF exposure levels in state office buildings. PPRP staff participate in public workshops and conferences to distribute information on EMF and respond to public inquires. Through the licensing process, PPRP includes EMF effects in the overall evaluation of new transmission lines.

PPRP also supports research on the biological effects of EMF. The program is contributing funding for laboratory research to define the interaction between EMF exposure and production of a hormone called melatonin. Changes in melatonin production in rats exposed to EMF have been suggested to be related to cancer promotion. Such research may help to determine whether there is a definable relationship between EMF exposure and cancer.

Toxics

Power plants, like other industrial sources, can release **toxic** chemicals into the air, surface water, and ground water. Toxics are chemicals that if released into the environment, sometimes even in small quantities, can adversely affect the environment and human health. Research in this area is termed **fate and effects** because it looks at how toxics are released, where in the environment they end

Figure 4-2
Sources of Hazardous Air Pollutants



up, and what the consequences of the releases might be for people, plants, and animals. PPRP has sponsored a range of toxics fate and effects research.

Toxics in the Air

There is increasing public awareness and concern over the impacts of toxics released to the atmosphere, also referred to as **hazardous air pollutants (HAPs)**. The concerns relate to both routine emissions, such as from automobiles and fuel combustion, and accidental releases. They relate to carcinogens (pollutants that cause cancer) and non-carcinogens (pollutants that produce detrimental, non-cancerous health effects such as respiratory ailments). Motor vehicles are currently believed to be the major sources of routine toxic emissions in urban areas (see Figure 4-2).

People can be affected by toxics through the air they breathe — **direct pathway** — and through the food they eat — **indirect pathway**. Toxics deposited in farming areas or in watersheds that support fish can end up in food. Such indirect pathways can be complex. For example, toxics in the atmosphere can be carried to the soil by rain, then absorbed by the roots of garden fruits and vegetables, eventually contaminating the produce that reaches our dinner tables.

The federal and Maryland state governments are in the process of evaluating the effects of toxics emissions. These efforts are limited by uncertainty in the current understanding of the processes of exposure and of the potential risks. As a result, a margin of safety is usually used in formulating regulations to protect people. Worst case scenarios are often assumed. For example, air toxics regulations are frequently developed to protect a hypothetical person exposed throughout his or her lifetime, outdoors, at the location of maximum exposure from a source of toxics. This is an unrealistic situation that errs on the side of overestimating risk. As our current understanding of the processes involved increases, estimates of potential risks will continue to become more realistic.

At present, emissions of toxics from power plants are not regulated specifically either by the state or federal government. Air toxics emissions have been addressed, however, in the licensing of new power plants in Maryland. Because of the uncertainties in the health impacts of power plants, the Clean Air Act Amendments of 1990 mandate studies of the effects of air toxics emissions from utility boilers, in general, and a special study of the effects of mercury emissions. The results of these studies eventually will be used to formulate federal regulations for controlling toxic emissions from power plants.

Atmospheric Emissions of Toxics

There are many unanswered questions about the health effects of routine power plant emissions of toxics. Two of the unanswered questions are related to indirect pathways of exposure to toxics in general and to mercury emissions from coal burning in particular. Although the potential concern most frequently addressed is breathing toxics in the atmosphere, current health risk studies indicate that, in rural settings, health risks from indirect pathways of exposure (deposition of toxics by rain and incorporation into the food chain) also may be a potential concern.

Several studies of the health risks associated with utility toxics emissions are underway currently. The U.S. EPA, the Department of Energy (DOE), and the Electric Power Research Institute (EPRI) are currently focusing on assessing risks from breathing toxics and on obtaining more accurate estimates of emissions to improve estimates of human health effects.

PPRP has conducted several investigations of toxic emissions from power plants. For example, a state-of-the-art, multipathway risk assessment was performed in conjunction with the licensing of PEPCO's proposed Station H power plant in Montgomery County, Maryland. This study indicated that health effects of toxic emissions from the proposed facility would be low and would result primarily from consumption of food. Preliminary results of PPRP's investigations suggest that metals are the toxics of greatest concern for health effects, but that predicted health effects due to emissions of metals are small for the proposed plants that PPRP has investigated.

PPRP is continuing its investigations and reviewing other studies to determine the potential effects of power plant toxics emissions on the residents of Maryland. PPRP is focusing its investigations on potential toxic emissions from the types of fuels burned in Maryland power plants, the effectiveness of rain in depositing toxics in the air onto soils and ponds close to power plants, and the toxicological effects of the pollutants.

Mercury

The concentration of mercury in the global atmosphere has increased over the past 20 years. On a global basis, about one-half of the mercury released to the atmosphere through human activities can be attributed to the burning of fossil fuels — primarily coal, which contains trace amounts of the element. Atmospheric mercury enters surface waters in rainwater and possibly through dry deposition. In many lakes in the Midwest and Canada, atmospheric deposition is believed to be the primary source of contamination, because no other input has been identified. Mercury accumulates in fish and can cause toxic effects on the nervous systems of people and wildlife that eat contaminated fish.

At present, 24 states have issued health advisories limiting consumption of fish because of high levels of mercury. A survey of 12 Pennsylvania lakes indicated one lake with walleye exceeding the U.S. Food and Drug Administration (FDA) action level and several lakes with chain pickerel exceeding levels used by other states to issue advisories. As yet, no fish contamination above the FDA action levels for mercury have been observed in Maryland waters.

There are many unanswered questions about the environmental fate and effects of mercury. They include questions about how much mercury is released during combustion, the chemical and physical properties of the released mercury, the transformations that occur after it is released to the environment, and the toxicological effects on people and wildlife. In response to the growing concern, the Clean Air Act Amendments of 1990 specifically require the U.S. EPA to identify mercury emission sources, evaluate the contributions of power plants and municipal incinerators, identify control technologies, and evaluate the toxicological effects of eating mercury-contaminated fish. The Electric Power Research Institute, in coordination with the U.S. EPA, is sponsoring studies on the environmental fate and effects of mercury and is attempting to resolve difficulties in the sampling and analysis of the element. PPRP is reviewing the results of mercury research to assess the implications for power plants in Maryland.

PPRP is also initiating its own studies to determine whether mercury is a significant toxic chemical issue in Maryland. Recently, PPRP analyzed information available about the sources, fate, and possible ecological effects of mercury in Maryland. Three major sources of mercury released to the atmosphere were identified: latex paints containing mercury, municipal incinerators burning batteries and other household products containing mercury, and coal-fired power plants. At present, the importance of local atmospheric sources relative to out-of-state sources is not known. The study identified several areas where data essential for assessing risks of contamination are lacking. PPRP is currently analyzing concentrations of mercury in fish from state reservoirs that have water quality conditions favoring mercury contamination of fish. Two species — walleye and chain pickerel — were targeted because they have been shown to accumulate mercury efficiently. Results of the study will be presented in early 1993.

Accidental Releases of Toxics

There is always some possibility that hazardous substances stored and used at power plants and other industrial facilities could be released into the environment accidentally. Electric utilities must use several hazardous substances to operate their power plants, and, in most cases, there are no non-hazardous substitutes for these compounds. For example, ammonia and sulfur trioxide can be used in air pollution control systems. Chlorine is used routinely at power plants to treat cooling water prior to discharging it to surface waters. Hydrogen is used as a cooling medium for generators. Halon may be used in fire suppression systems designed to protect electrical and computer components. Although manufacture of PCBs was discontinued in the United States in 1976, there are still some transformers in use today that contain the material. Atmospheric discharge of PCBs resulting from transformer fires or explosions can present risks to an exposed population. Accidental release of natural gas and liquefied petroleum gas (LPG) poses risks of fire and explosion.

Regulations regarding accidental releases of toxic or hazardous substances into the environment have been promulgated under provisions of the Clean Air Act and Superfund. Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA), also known as the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, provides a means for informing the public of the existence, quantities, and releases of hazardous substances. This law directs states, communities, and industry to work together to plan for chemical accidents, develop inventories of hazardous substances, track toxic chemical releases, and provide public access to information on hazardous substances. SARA Title III legislation was the direct result of the release of toxic chemicals in 1984 and 1985 in Bhopal, India, and Institute, West Virginia. Utilities have to comply with the law, but are currently exempt from certain portions.

The Clean Air Act Amendments of 1990 also address accidental releases of toxics. Provisions of the 1990 Amendments required the U.S. EPA to promulgate a list of at least 100 extremely hazardous air pollutants that pose the greatest risk of death, injury, or serious adverse effects on human health or the environment during an accidental release. Under the law, sources of air toxics, including power plants that produce, process, handle, or store any listed substance in amounts exceeding the established threshold quantities, will be required to comply with regulations for preparing risk management plans. These plans detail the measures the facility will take to prevent an accidental release, as well as the response procedures in the event of such a release.

PPRP is presently evaluating the potential for accidental releases of hazardous air pollutants from Maryland power plants. This investigation will also review current and proposed state and federal regulations to ensure that utilities provide adequate and cost-effective safeguards to surrounding communities for the risks involved in power generation.

Toxics in Water

Power plants must draw in and use large quantities of river or Bay water to cool steam condenser tubing as part of the power generation process. The cooling systems frequently need to use chemical **biocides** to keep the condenser tubes free of aquatic organisms that can clog power plant systems. Chlorine is the most commonly used biocide, and trace amounts of it are released in the cooling water discharge.

In the 1970s and 1980s, concern over discharges of chlorine led the U.S. EPA and the states to regulate the concentration and duration of chlorinated discharge.

Chlorine is highly toxic to aquatic life and larval fish are particularly sensitive. Although chlorine is still the most commonly used biocide in U.S. and Maryland power plants, a number of facilities recently have conducted trials with alternative biocides, such as sodium bromide, and are exploring new techniques to minimize the amounts of chlorine used. A recent PPRP study evaluated the use of alternative biocides at U.S. power plants and tracked the results of trials conducted in Maryland.

In addition to chlorine and other components of biocides, power plants can also discharge trace amounts of metals into the environment. The sources of the metals are wastewaters from cooling operations, boiler cleaning, ash generation, and disposal. Runoff from coal piles can also release toxics into the environment. Under the 1987 Clean Water Act Amendments, the U.S. EPA developed lists of waterways that have been impacted by toxic chemicals. The U.S. EPA also developed lists of the dischargers to these waterways. Ten power plants across the U.S. were included on the Clean Water Act's list of toxic dischargers. The power plants were listed primarily because metal concentrations in their water discharges exceeded established levels. Two Maryland power plants — Brandon Shores and Vienna — were included on the list because concentrations of copper in their discharge water exceeded state standards. Control strategies are being developed to reduce these concentrations.

PPRP has recently examined the contribution that power plant discharges make to copper levels in surface waters. It has been recognized that condenser tubing in power plant systems corrodes and releases copper into the environment. Copper/nickel tubing is used at 10 of 13 of Maryland's power plants examined in the study. An alternative to copper/nickel tubing is tubing made of titanium. Titanium is much more resistant to corrosion than copper and so should not release toxic metals into the environment. The settlement of a lawsuit between the Maryland Department of the Environment (MDE) and a group of industries addresses the issue of pollutant discharges in excess of standards due to corrosion and erosion of condenser tubes. MDE's proposed regulations now provide for a one-time allowance for these discharges if the discharger commits to replacing the tubes with noncorrosive materials within five years. It is likely that new power plants will use all titanium in the future.

Toxics can also be released into the environment by being leached out of coal storage piles at power plants, or from ash landfills. PPRP has monitored potential impacts of ash storage facilities in a number of projects.

In the mid-1980s, PPRP sponsored research on the effects that arsenic and selenium released from ash landfills could have on striped bass. These metals may enter aquatic systems as airborne fly ash or in

Section 313 Toxic Release Inventory Proposed Amendments

Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA Title III), also known as the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, provides a means for ensuring that the public can be informed of the existence, quantities, and releases of hazardous substances. Under SARA Section 313, industry is required to report air, water, or ground releases of about 300 chemicals to the U.S. EPA. As of 1990, approximately 24,000 manufacturing facilities are subject to these Toxic Release Inventory (TRI) data reporting requirements. In 1990, these facilities reported the release of more than 4.8 billion pounds of TRI compounds into the environment. Under current SARA Title III provisions, electric utilities do not have to comply with the TRI reporting requirements.

In a public meeting held May 29, 1992, the U.S. EPA proposed to expand coverage under Section 313 by adding almost 500 new chemicals and requiring more types of industries to comply. Electric utilities are included in this proposal. If the rule is promulgated, utilities would be required to quantify emissions from both routine and accidental releases of listed toxic chemicals, as well as the maximum amount of listed chemicals on site during the calendar year and the amount contained in wastes transferred off site. Action on these revisions is not anticipated before 1994.

runoff from coal and ash piles. Possible effects from long-term exposure to selenium were reported at levels that could occur near discharges.

PPRP also investigated reports of declines in the numbers of yellow perch in Zekiah Swamp Run in Charles County, which is near the Faulkner Ash Storage Facility. Monitoring studies indicated that ground water collected from wells near the facility was contaminated with heavy metals, but that contamination was limited to an area within about 1,500 feet from the landfill. The chemical monitoring studies did not indicate surface water contamination of Zekiah Swamp; however, other tests conducted in Zekiah Swamp indicated that yellow perch larvae had difficulty surviving in areas of the swamp within and outside of the range of possible influence of the Faulkner facility. The study concluded that many factors are responsible for the poor larval survival and that the ash facility did not contribute to the observed mortalities.

Environmental Externalities and Power Generation

The Concept of Externality

The adverse environmental and social impacts reviewed in this report are properly viewed as part of the "social costs" which must be borne by the citizens of Maryland to obtain electric service. Several agencies in Maryland work in concert to evaluate potential environmental and social impacts from the construction of new power plants in the state. Existing, older plants are subject to a substantial range of environmental regulations under the Clean Air Act and other legislation. While the present body of regulations helps to limit and mitigate environmental impacts, it does not eliminate such effects. Power plants continue to emit pollutants, albeit at levels limited by regulation.

As public concern over environmental impacts has increased, a number of analysts and policy makers have recognized that alternative electric power resources have differing environmental impacts. For example, from an environmental standpoint, implementing conservation programs is favorable to building and operating a coal-fired plant, even though that coal plant meets all air and water emission standards and has installed all required pollution abatement controls. The standard "least-cost planning" methods do not account for the environmental attributes of alternative electric power resources, other than those costs required to meet permitting requirements.

In recognition of this problem, a number of state regulatory commissions require or are considering the incorporation of **environmental externalities** into the decision-making process. As applied to electric power, the term "externalities" refers to the costs arising from an electric power supply that do not pass through a market and therefore are unpriced. The introduction of environmental externalities into the least-cost planning process addresses an important cost item — environmental damage — that traditionally has been ignored.

Actions Taken by States

According to a recent survey, at least 28 state regulatory commissions have taken or are considering actions to incorporate environmental externalities in the utility planning process. The objective is to select electric power resources on the basis of the lowest *social* cost, not merely the lowest dollar cost (referred to as "private costs"). The recognition of externalities is intended to improve economic efficiency in resource planning and reduce the environmental damage from electricity supply.

State regulators have sought recognition of externalities in four basic ways.

- *The first and most ambitious approach is the direct "monetizing" of externalities. At least four states (Massachusetts, New York, California, and Nevada) have assigned (negative) values expressed in dollars per pound for various air pollutants. Because power plant emission rates are well known, the calculation of a penalty value on a "per kWH" basis for power plants is straightforward. The penalty factor for conservation programs would be zero.*

- *The second approach is to require quantitative recognition of externalities but only in evaluating conservation programs. Several states have included* **percentage adders** *to the utility power supply costs (i.e., "avoided costs") used to evaluate conservation programs as a substitute for the relative environmental benefits of conservation energy. For example, Vermont has required the use of a 5 percent "adder" to utility avoided costs.*

- *The third approach introduces environmental externalities into the competitive solicitation programs. A number of utilities are acquiring non-utility generation (NUG) capacity through a formal competitive process, evaluating both price and non-price aspects of the bids. Several states require that environmental attributes be included as a criterion in the project scoring. Thus, under this approach, environmental externalities are dealt with quantitatively but are not actually monetized.*

- *The fourth approach is to include environmental impacts as a qualitative factor in the resource planning process and selection process. Under this approach, the utility performs its quantitative analysis in the conventional way to identify a least-cost plan. The utility then applies several key qualitative factors to the least-cost modeling results. These might include financial feasibility, technical maturity, risk, flexibility, and diversity of the fuel mix. Some states would also include environmental attributes as an additional qualitative decision factor.*

Maryland Initiatives

To date, the Maryland PSC does not have a formal position on the appropriate role of externalities. However, some initial steps have been taken as the result of voluntary stipulations between the utilities and state agencies. DP&L's recent competitive solicitation for 150 MW of NUG capacity includes environmental attributes as an evaluation factor in the scoring of project bids. In the DSM collaborative conducted by BG&E, the environmental benefits of conservation have been given some quantitative recognition in the cost/benefit analyses used to evaluate candidate programs. At the present time, PPRP is sponsoring a comprehensive research study to determine how the inclusion of environmental externalities might affect the operations and resource planning decisions of a Maryland electric utility.

The issue that has been raised is whether the explicit inclusion of environmental externalities can improve economic efficiency while positively contributing to environmental quality. It is an emerging issue in Maryland that will be subject to considerable debate in the near future.

Need More Information on Maryland's Power Plants?

The Power Plant Research Program was established in 1971 by the Maryland legislature to ensure that Maryland meets its electricity demands at reasonable costs while protecting the state's valuable natural resources. The objectives of the Program are carried out within two divisions of the Tidewater Administration of the Maryland Department of Natural Resources:

- *The Power Plant and Environmental Review Division, and*
- *The Chesapeake Bay Research and Monitoring Division.*

PPRP conducts a range of research and monitoring projects on the topics addressed in this Cumulative Environmental Impact Report (CEIR) and many other topics as well. In fact, PPRP publishes a Bibliography every year that lists the general and site-specific power plant related reports that PPRP has produced since the early 1970s.

If you want more information on the impacts of power plants in Maryland, you can request a copy of the Bibliography, past CEIRs, and other reports from:

Maryland Department of Natural Resources
Power Plant Research Program
Tawes State Office Building
Annapolis, Maryland 21401
(410) 974-2261