UNIVERSITY OF PITTSBURGH
Institute of Politics
Environment Policy Committee

regional energy survey

Key Opportunities and Challenges in Pennsylvania's Energy Sector

by Jack Busch

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LETTER FROM THE COCHAIRS

DEAR COLLEAGUES:

In September 2009, the members of the University of Pittsburgh Institute of Politics Environment Policy Committee decided to conduct a survey of Pennsylvania's energy resources with emphasis placed on those that are particularly prominent or relevant to Southwestern Pennsylvania. The intent of the document originally was to inform the committee as it evaluated potential policy options related to the development of energy resources and the environmental impact of this development.

Because of its breadth and scope, the members of the committee now wish to share this regional energy survey with the broader community in the hope that others will find it as useful and beneficial as we found it to be in providing a baseline from which to begin policy discussions about balancing Pennsylvania's future as both an energy producer and exporter with its reputation as as a haven for nature-related tourism and green industry.

While this publication is broad and comprehensive, it purposefully contains no policy recommendations; it serves to inform rather than to advise. Speaking for the committee members and the Institute staff, we welcome your comments and suggestions as we move forward in determining how to best assist policy makers in Southwestern Pennsylvania as they make key decisions about energy that will likely have lasting impact for future generations.

Sincerely,

Caren E. Glotfelty **Charles A. Camp**

Cochairs, Environment Policy Committee

EXECUTIVE SUMMARY

Recognizing Southwestern Pennsylvania's potential as a leading energy center but also the lack of comprehensive understanding of the region's energy portfolio among policy makers, the Institute of Politics Environment Policy Committee in late 2009 commissioned a substantial survey of regional energy assets. The Committee hoped that a broad survey of economic and environmental implications for Pennsylvania's energy sources would provide a needed and appropriate baseline document for use in ongoing and future discussions of how best to manage, incentivize, and regulate energy in our state. This document is the result of that survey and it is the culmination of extensive research, interviews, and information collected on our various energy sectors. The Environment Policy Committee does not intend to pick winners and losers or to determine outcomes; rather, Committee members hope to make a substantial informational contribution to continuing policy debates on these topics.

Five key energy sectors were identified as presenting the most economic and environmental opportunities for the region: coal, natural gas, nuclear, solar, and wind. An overview of the most prevailing viewpoints, salient facts, and critical issues follows.

I. COAL

The coal industry and Pennsylvania's economy have been intrinsically linked for centuries. However, coal faces possibly the most environmental challenges of all the energy sources in Pennsylvania. The environmental scars and depressed boomtowns left behind by historical, preregulation mining techniques serve as reminders of the consequences of unsustainable mining practices. Furthermore, the combustion of coal for electricity generation has significant impacts on our region's air quality, water resources, wildlife, and public health. With the demand for the abundant and affordable electricity provided by coal unlikely to wane, there is a critical need to address the cumulative impact of coal extraction and power generation.

ENVIRONMENTAL IMPACTS AND PUBLIC HEALTH

In terms of **air emissions**, the coal industry has a promising track record of innovating cost-effective solutions that reduce emissions of regulated airborne pollutants. Untreated coal-fired emissions release a number of substances into the air that are harmful to the public health and the environment. Sulfur dioxide (SO_2) contributes heavily to acid rain, which can damage natural landscapes and buildings. Nitrogen oxide (NO_X) and carbon monoxide (CO) contribute to smog and can cause numerous short- and long-term health effects in humans and wildlife. Likewise, mercury and arsenic are harmful to humans and animals. Through federal and state regulation and technological advances, the coal industry reduced regulated emissions by 70 percent between 1970 and 2007 while increasing production by 225 percent. While an admirable and necessary step forward, improvements in coal industry emissions have not wholly eradicated the threat of air pollution, which is exacerbated by the air quality impact of the transportation sector. *The State of the Air 2010* report from the American Lung Association gave many Southwestern Pennsylvania counties F ratings for high ozone days, and the Pittsburgh/New Castle area is the third most polluted U.S. region in terms of short-term particle pollution. A PennEnvironment study estimated that our state's poor air quality contributes to thousands of premature adult deaths, respiratory hospital admissions, cases of chronic bronchitis, and asthma attacks each year.

Beyond the currently regulated pollutants, carbon dioxide (CO_2) and other greenhouse gases also have garnered recent attention due to their possible contribution to global climate change. Proposals to regulate carbon emissions are currently being debated on the federal level, and climate change has been an ongoing concern for the Pennsylvania Department of Environmental Protection (DEP). Carbon legislation could have significant impacts on the coal industry, as coal-fired electricity generation in Pennsylvania reportedly contributed 84 percent of the 135.6 million tons of CO_2 emitted by the state's electric power sector in 2008, according to U.S. Energy Information Administration data.

Historical, preregulation mining practices have left Pennsylvania with more than 250,000 acres of unreclaimed **abandoned mine lands** and more than 2 billion tons of **waste coal piles**. Symbolically, these serve as a reminder of the need for forward-looking regulatory practices across all energy sectors. Abandoned mine lands have ongoing adverse impacts on the environment. Most notable is abandoned mine drainage (AMD), which introduces sediments and pollutants into waterways and can drastically alter the pH, leading to fish kills and destruction of aquatic habitats. More than 3,000 miles of streams in Pennsylvania that have been adversely affected by AMD.

An estimated $15 billion worth of work must be done to reclaim the remaining abandoned mine lands throughout the state. A renewed demand for waste coal spurred by government incentives (e.g., waste coal is a Tier II Alternative Energy Portfolio Standards fuel source) and technological advances (e.g., fluidized bed combustion) have motivated commercial miners to reclaim more than 5,000 acres of abandoned mine lands in Pennsylvania since 1991 for an estimated value of more than $27 million. After mining operators recover or extract previously unmarketable coal from abandoned mine lands, they reclaim the land according to current regulatory standards. Sustaining demand for waste coal will continue to motivate commercial mining operators to reclaim abandoned mine lands.

Mine subsidence is not an unfamiliar issue, nor is **longwall mining** a new technique. However, more of the coal produced in Pennsylvania is extracted via longwall mining (about 80 percent, as of 2008) than ever before, and new concerns over subsidence have arisen. Rather than shoring up ceilings with pillars, longwall mining removes massive panels of coal at once and allows the mine to collapse. Afterward, subsidence typically occurs within 90 days. This is in contrast to room-and-pillar mining techniques, which carry the risk of unpredictable subsidence decades or centuries later. Because of the predictability of longwall mining subsidence, landowners are not eligible for mine insurance for damage caused by subsidence; instead, they sign pre- or post-mining agreements with operators that arrange for compensation. Typical damage caused by subsidence includes structural damage and loss of flow in waterways or diminution of water sources and springs.

Pennsylvania's Act 54 of 1994 regulates the claims process between mining companies and landowners. Act 54 also requires DEP to periodically review the effects of longwall mining subsidence on the public and the environment. The most recent report, released in February 2005, found that 3,656 structures on 3,033 properties and about 97 miles of streams were undermined during the assessment period. In many cases, lack of premining data prevented the DEP study from determining whether habitat, fish, and other wildlife had been affected by undermining.

Some environmental and advocacy groups have called for reform of Act 54, citing examples where the damage caused by longwall mining was reportedly far more significant than anticipated or compensated for by mine operators. Such disputes often lead to long, drawn out, and costly legal battles between mine operators and landowners. As a result, some groups have expressed the need for more definitive comparisons between pre- and postmining conditions for properties and habitats.

The catastrophic spill at the Tennessee Valley Authority's Kingston Fossil Plant in 2008 brought the fate of **coal combustion residuals (CCR)**, or coal ash, into the national spotlight. Emerging concerns and legislation will likely affect Pennsylvania, which produced about 9.5 million tons of CCR in 2004 and is home to numerous coal ash impoundments. CCR impoundments pose two immediate hazards: the risk of a dam failure or spill, as in Tennessee, and the impacts on drinking water supplies and surrounding habitats. Regarding dam failures, the U.S. Environmental Protection Agency (EPA) conducted a study of CCR impoundment units nationwide and found that the Bruce Mansfield Little Blue River Impoundment in Shippingport, Pa., had a ''high potential hazard rating'' based on its volume and proximity to populated areas. The distinction has no bearing on its structural integrity, however; DEP conducted an inspection of more than 42 CCR impoundments in the state and found no major structural problems.

Regarding the chemical makeup of CCR, it varies widely from plant to plant. Still, many of the typical constituents are toxic to human and animal health if consumed. Most notably, CCR is known to contain arsenic and selenium. Several studies conducted by environmental groups have found that some of Pennsylvania's CCR impoundments are improperly sited or lined and may have caused contamination of nearby water supplies.

As an alternative to disposal or impoundment, CCR also can be recycled or reused through **beneficial use**. This practice is encouraged by EPA and practiced widely in Pennsylvania, which used about 14 million tons of coal ash for reclamation and remining, 1 million tons for structural fill, and 500,000–1 million tons for concrete in 2008, leaving just 9 million tons of CCR for disposal in residual waste landfills. The beneficial use of coal ash saves the industry between $220 and $330 million each year compared to the cost of interring coal ash in a landfill. When encapsulated in concrete or used as backfill, the risk of exposure to the constituent toxins is greatly reduced.

Currently, regulation of the beneficial use, disposal, and handling of CCR is handled by the states. While often referred to as ''unregulated'' by the media, disposal of CCR in Pennsylvania is heavily monitored by DEP, which is currently working on strengthening its impoundment and disposal requirements. Certain aspects of CCR management may fall under federal purview, however, pending a rulemaking by EPA. The proposed rule may classify CCR as hazardous waste, phase out surface impoundments within five years, or both. In September 2010, EPA held public hearings in Louisville, Ky., and Pittsburgh on the proposed federal regulations regarding CCR. EPA received input from a variety of sources, including the coal industry, environmental interest groups, and private citizens. In presenting the new regulations, EPA provided two options: place the new regulations under either Subtitle C or Subtitle D within the Resource Conservation and Recovery Act. While most of the environmental groups encouraged classifying CCR under Subtitle C, the industry groups advocated for locating the new regulations in Subtitle D, to avoid the "hazardous waste" designation that accompanies materials classified under Subtitle C. Many of these speakers expressed concern that a hazardous waste designation would hurt businesses that promote beneficial uses of CCR. At the time of this publication, EPA has not yet moved forward with the adoption of the regulations.

ECONOMIC IMPACT AND INDUSTRY OVERVIEW

Coal has played a starring role in Pennsylvania's history and continues to do so today. Pennsylvania is the fourth-largest coal producer in the United States, and nearly half of the commonwealth's energy comes from coal. As an abundant, affordable, and domestic resource, coal represents one of the most strategic assets for the state as well as the entire nation. Coal is the fuel of choice for developing nations as they transition toward industrialization, a trend that contributes heavily to the projected 49 percent increase in worldwide coal consumption by 2030.

In Pennsylvania, coal-fired power plants continue to provide the most affordable source of electricity. The Pennsylvania Public Utility Commission estimates the busbar costs of electricity from coal at $75 per mWh, while Lazard, a prominent asset management and financial advisory firm, calculated the levelized cost of a new supercritical pulverized coal power plant at $74 to $135 per mWh.

The coal industry supports approximately 41,577 direct and indirect jobs each year, representing an economic output of about $7.5 billion. Southwestern Pennsylvania also is a hub for research and development within the coal industry. The CONSOL Energy Inc. research and development facility and the U.S. Department of Energy's National Energy Technology Laboratory (NETL), both of which are located in South Park, Pa., account for $500 million in coal-related research and development each year. NETL brought about 3,180 direct and indirect jobs to Pennsylvania and West Virginia and contributed about $283 million in economic output in 2006 and regularly collaborates on research projects with the University of Pittsburgh, Carnegie Mellon University, and West Virginia University via the Institute of Advanced Energy Studies.

COAL'S CONTINUED EVOLUTION

The coal industry has proven immensely adaptive and resilient in the face of changing regulatory and environmental landscapes. How the industry faces the next wave of challenges will be instrumental in ensuring that coal continues to provide jobs and economic benefits to the region. On the emissions front, many are looking toward two key technological developments: **higher efficiency coal power plants** and **carbon capture and sequestration (CCS)**.

The vast majority of existing coal power plants in Pennsylvania use pulverized coal (PC) technology, which has a thermal efficiency of about 30–35 percent. A coal-fired plant built based on the latest commercially viable PC technology—**supercritical PC**—could have efficiency levels up to 40 percent, while an ultrasupercritical PC plant could reach efficiency levels as high as 45 percent. Another technology, known as **integrated gasification combined cycle (IGCC)**, could yield an energy efficiency of 40–50 percent and, with additional processing equipment, can segregate a CO_2 stream, which would make the capture phase of CCS easier.

CCS would allow power plants to capture a certain portion of the CO_2 emissions and then inject it permanently into the earth, thereby preventing it from entering the atmosphere. CCS is still in need of technological validation. Several pilot projects are already under way, but none are located in Pennsylvania, which may be a good candidate for a CCS project. In addition to Pennsylvania's established coal industry and wealth of research and development facilities, the Department of Conservation and Natural Resources identified ''huge geologic sequestration'' opportunities, with enough space beneath Pennsylvania's surface to store captured carbon from all sources for the next 300 years. However, ensuring that the proper regulatory and legal framework is laid will be critical to sustainably developing wide-scale CCS in the state.

The Good Spring IGCC power plant, a proposed near-zero emissions coal plant in Schuylkill County, Pennsylvania, may be both the first CCS and the first IGCC power plant in Pennsylvania. The plant would provide commercial validation of both technologies and highlight Pennsylvania as a clean coal epicenter.

While CCS and high-efficiency coal power plants move toward commercial viability, there are a number of nearer term solutions that can benefit the industry and reduce its environmental impact. Cofiring with natural gas or biomass can help to cut emissions, while coal-to-liquid technology and electric cars may provide avenues for the coal industry to serve the transportation sector.

II. NATURAL GAS

Two key technologies—hydraulic fracturing and horizontal drilling—have given natural gas developers access to previously untapped resources of natural gas beneath Pennsylvania's surface. Currently, exploration and development of the Marcellus Shale formation, which underlies virtually all of Southwestern Pennsylvania, is under way. Early surveys estimated up to 489 trillion cubic feet of natural gas in the formation, amounting to about $500 billion in potential revenue. And beneath the Marcellus Shale lies the Utica Shale, which is believed to hold an equal or greater amount of recoverable gas, thanks to hydraulic fracturing. The demand for cleaner-burning domestic fuel has touched off a veritable gold rush in Pennsylvania, and heavy drilling activity is already occurring in the state, from rural areas to state forests.

While the oil and gas industry in Pennsylvania has existed for more than 100 years, the environmental and public health impacts of hydraulic fracturing are largely unknown and many regulatory gaps exist. This unprecedented level of natural gas development calls for a serious inquiry into the cumulative impacts of the industry.

ENVIRONMENTAL IMPACTS AND PUBLIC HEALTH

Potential **water impacts** from hydraulic fracturing are perhaps the greatest environmental concern to arise from the natural gas industry. A typical hydraulic fracturing job requires as much as 5 million gallons of freshwater, which, when multiplied by the hundreds of drilling operations that are under way, amounts to a substantial amount of water that is removed from the natural water cycle. Withdrawals are overseen by regional river basin commissions and DEP in order to mitigate the impacts on water supplies and aquatic environments. Nevertheless, conservation groups such as Trout Unlimited have raised concerns that stricter permitting criteria, monitoring, and analysis of water withdrawals are required to ensure sustainability.

Beyond the supply of water, environmental concerns have been raised over the chemical constituents of hydraulic fracturing fluid and fracturing wastewater and the impacts that these elements may have if they contaminate aquatic habitats and drinking water supplies. Nationally, controversy has swirled over the industry's apparent reticence in disclosing the chemicals used in hydraulic fracturing, but in Pennsylvania, DEP requires that the chemicals used at each site be documented as part of its requisite pollution prevention and contingency plan. The constituents typically present in hydraulic fracturing fluid that are known to be harmful if consumed are chloride, hydrogen sulfate, bromide, strontium, barium, and manganese. The potential for undiluted fracturing fluid to enter into public drinking water supplies is slight, according to a study conducted by the Ground Water Protection Council. Fracturing fluid is injected thousands of feet below groundwater tables, and DEP requires drillers to case and grout wells prior to drilling through deeper zones to prevent contamination.

Accidents, misconduct, leaching, and spills during transit pose greater risks of contamination than routine drilling operations. Several such incidences have occurred throughout the state, and impacts of these accidents are under investigation. EPA also is conducting a new study into the water contamination risks in connection with hydraulic fracturing that is expected to be completed in 2012.

The high level of total dissolved solids (TDS) in produced water (water that flows back as waste after a fracturing job) poses an even greater concern to the industry. Currently, treatment of produced water is not viable through municipal water treatment facilities, as the equipment is insufficient for removing TDS. Direct discharge of produced water is prohibited, as the extremely briny water would destroy aquatic habitats and damage industrial equipment in manufacturing facilities that draw water from rivers and streams. As an alternative to treatment, most wastewater is deep-well injected, which is costly. Recycling appears to be the most viable solution at this juncture, and many operators already recycle a portion of their produced water for other fracturing jobs. Methods for recycling a large amount of produced water are currently being researched and developed at regional universities and NETL.

Natural gas migration is a distinct and separate concern from hydraulic fracturing fluid chemical contamination. Water supplies can be contaminated by methane via naturally occurring fissures, but if contaminated drinking water sources are located within 1,000 feet of a drilling operation, DEP presumes the operator to be liable. Though it is unlikely that a person would drink water contaminated with methane, given its odor, consuming methane in drinking water is not particularly harmful to human health. However, natural gas migration can cause explosions or asphyxiation if methane accumulates in a home or structure.

Regarding **air impacts**, natural gas is touted as a cleaner burning alternative to petroleum and coal, as it produces about half the CO_2 emissions and virtually no particulate matter. But the equipment used for the extraction, processing, and transportation of natural gas contributes heavily to local air pollution. The trucks and heavy machinery release benzyne, xylene, and carbon disulfide into the air. The condensate tanks used for on-site storage of wastewater and other substances separated from raw natural gas emit volatile organic compounds that are harmful to nearby residents and workers. Again, the cumulative impact of hundreds to thousands of drilling projects operating in the state is difficult to measure, though undoubtedly significant. A study conducted in the Dallas/Fort Worth, Texas, area estimated that the smog-causing emissions from all oil and gas sources reached a peak of 307 tons per day in 2009 compared to the 273 tons per day emitted by vehicles in that area.

Natural gas development has notable **land impacts** as well. State regulations oversee the sustainable construction and reclamation of well pad sites, including management of surface erosion and runoff. Horizontal drilling also allows developers to drill as many as 10 laterals from a single well pad, which reduces the amount of land needed for tapping gas reserves. However, the cumulative impact of thousands of drilling operations across the state—replete with access roads, pipelines, and clearings for well pads—may have an adverse impact on wildlife migration, feeding, and breeding patterns via habitat fragmentation.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

In 2008, Pennsylvania's annual total natural gas production was just under 200,000 million cubic feet. In 2009, that figure grew to 272,574 million cubic feet. Between 2008 and 2009 natural gas consumption in Pennsylvania increased as well, from 749,884 to 804,077 million cubic feet. This indicates that a vast majority of the natural gas consumed in Pennsylvania is imported, but the untapped potential in the Marcellus Shale could easily make the state a net exporter while simultaneously providing a low-cost fuel source for domestic transportation, industrial, and energy sectors. Pennsylvania produced 8.5 percent of its electricity from natural gas in 2008, yet the state has about 10,915 mW of gas-fired installed capacity. As such, increasing natural gas' share in the state's energy mix could be done with relatively little investment in new power plant construction. The abundance of natural gas, as well as its lesser CO_2 emissions, may make it a highly affordable fuel source in the coming years. Lazard estimated the busbar cost of a new natural gas combined cycle plant at $72–$100 per mWh. An abundant source of domestic natural gas also could help to reinvigorate the industrial sector, bringing jobs and tax dollars to the region. Transitioning fleets to include more natural gas vehicles also could have economic and environmental benefits.

In the near term, increased gas development, exploration, and production promises thousands of jobs for the region. Penn State's Marcellus Shale Education & Training Center estimated that the gas industry will create between 5,000 and 13,000 direct jobs plus 6,500 indirect and 13,260 induced jobs by 2012. Using a different model, a study (see note on page 61) prepared by Penn State for the Marcellus Shale Coalition indicated that the Marcellus industry employed 29,284 workers in 2008 and would employ 174,700 by 2020 (figures include indirect and induced jobs). However, about 80 percent of these jobs are currently filled by out-of-state workers. These workers are attractive to gas developers, many of whom are based in other states themselves, because they have experience working in other shale plays in Oklahoma, Wyoming, and Texas. Cooperation between industry partnerships and regional trade schools to ensure that local graduates have the skills and training required for the job may help increase the ratio of local to out-of-state workers. Landowners also can earn money from royalties and signing bonuses through leasing agreements with gas companies.

The Marcellus Shale play is expected to have both positive and negative economic impacts on state, regional, and municipal governments. For example, the state has already leased 139,000 acres of state forest land, generating $354 million in revenue. A severance tax was discussed at the end of the 2009–10 legislative session, but ultimately no action was taken. How the proceeds of such a severance tax would be divided among state and local governments was the subject of intense debate. County- and municipal-level advocates argued that the burden of drilling activity—including maintenance of roads, processing of deeds, and mobilizing of emergency response teams—falls most heavily on local governments, while others appealed to the critical need to balance the state's budget.

COMMUNITY IMPACT

The presence of gas developers in the region likely will have a profound effect on both rural and urban communities. The influx of out-of-state workers and the unevenly distributed economic benefits of the boom may open the door to social strife, while increased population and traffic will take an expected toll on roads and other infrastructure.

One of the most pressing concerns involves the safety of nearby residents and the ability of **local emergency responders** to handle catastrophic incidents at well sites. Emergency responders may be ill trained or underequipped to respond to certain chemical spills, fires, and explosions. Given that many well sites are located in remote areas on unmarked roads, locating the site of an accident also can be a challenge. Already, there have been incidences of blowouts, fires, and explosions in Pennsylvania and West Virginia. Maintaining properly trained and prepared regional emergency response teams may alleviate this burden on local responders.

Questions have also arisen over the **primacy of the Pennsylvania Oil and Gas Act** over municipal ordinances. In two recent cases, this issue has escalated to the Pennsylvania Supreme Court. In Salem Township, the court denied the township's ordinance that sought to restrict gas developers from drilling, but in Oakmont, the court upheld the borough's right to restrict gas drilling activity through traditional zoning ordinances. It is expected that local-level attempts to regulate drilling will be approached on a case-by-case basis.

The issue of **forced pooling** or conservation pooling also is being debated. Forced pooling allows gas companies to combine leases into a single tract, simultaneously compelling unwilling landowners on adjacent properties to be included in the unit. Currently, Pennsylvania does not have a statute that allows forced pooling, though as drilling commences in more densely populated areas, such as certain neighborhoods within the city of Pittsburgh, forced pooling will need to be addressed.

III. NUCLEAR

Fears over nuclear proliferation, meltdowns, the adverse health impacts of radiation, and historical cost overruns have driven the nuclear industry into dormancy since the 1970s. However, while no new nuclear power plants have been constructed in 40 years, Pennsylvania continues to rely on nuclear energy. With five nuclear power plants with a total of nine nuclear reactors, Pennsylvania is the second-largest producer of electricity from nuclear power plants in the United States. And with the nuclear renaissance well under way in Europe and Asia and the threat of climate change perhaps looming larger on the horizon than the possibility of a nuclear meltdown, many are reconsidering nuclear power. Please note that this survey was written prior to the earthquake and subsequent effects on the nuclear industry in Japan. A brief analysis of the impact that this event could have on the future of the nuclear industry in Pennsylvania is included in the main section on nuclear energy.

ENVIRONMENTAL IMPACTS AND PUBLIC HEALTH

In terms of **air and water impacts**, nuclear power plants have a relatively negligible impact, especially when compared to other baseload power plant technologies. Nuclear power plants emit virtually no air pollution, CO_2, or particulate matter, which may make nuclear power extremely valuable if carbon emissions were to be regulated on a federal or state level. Like all thermal power stations, nuclear power plants do create heat and steam as a by-product and use water for cooling. All but one of the state's power plants uses a closed-loop cooling system, which uses less water and has a smaller impact on the environment. Large fish kills were reported at the Peach Bottom Atomic Power Station, which has an open-loop cooling system, in Delta, York County, but design measures have been taken to help mitigate entrainment and thermal pollution.

Waste treatment and storage, however, provide the most enduring challenges for nuclear power. There are two main types of radioactive waste produced at nuclear power plants: low-level waste (contaminated clothing, equipment, and water treatment residues) and high-level waste (primarily spent nuclear fuel). Pending a permanent internment location, most low- and high-level waste is stored on site. Several permanent low-level waste disposal sites exist throughout the nation—the nearest to Pennsylvania being in Barnwell, S.C.—but many have stopped accepting waste from other states. Meanwhile, on-site low-level waste storage is nearing capacity in many nuclear power plants in Pennsylvania. Regarding high-level waste, the U.S. Department of Energy has yet to deliver on its promise of providing a national nuclear disposal site, and with Yucca Mountain in Nevada removed from consideration by the current administration, a solution does not appear to be forthcoming in the near future.

Nuclear reprocessing has been posed as a partial solution, as it would allow power plants to reuse spent fuel, but the United States has willfully refrained from the practice for decades due to fears of **nuclear proliferation**. Reprocessing separates plutonium from spent fuel rods, which brings it one step closer to weapons-grade material. Also, nuclear reprocessing does not address the issue of low-level waste. Nevertheless, nuclear reprocessing is practiced widely throughout Europe and Asia by companies such as AREVA Inc., which also has a presence in Southwestern Pennsylvania.

Nuclear power also finds opponents in public health circles. The long-term impacts of exposure to **radiation** emitted from nuclear power stations during normal operations are subjects of ongoing debate. EPA states that residents living near power plants receive less than one millirem of increased annual radiation exposure, which is a negligible amount when compared to the 4 millirems of exposure from a chest X-ray and the 200 millirems of exposure from naturally occurring radon. Critics argue that there is no safe level of exposure and disagree with the notion that federal regulations can set a permissible dosage of radiation. Concerns also arise over the increased risk of stochastic effects (i.e., increased probability of health impacts from prolonged exposure) and the impacts of bioaccumulation of radioactivity, issues that are acknowledged by EPA. A 1990 study by the National Cancer Institute surveyed 62 counties surrounding nuclear power plants and reported no increased risk of cancer death, though the methodology and findings were the target of much criticism. An updated assessment by the National Academy of Sciences is currently under way.

Unsurprisingly, fears of **nuclear meltdowns** dog many Pennsylvania residents. The partial meltdown at Three Mile Island (TMI) remains the most serious nuclear accident in U.S. history. In spite of this, studies conducted by the U.S. Nuclear Regulatory Commission (NRC), the University of Pittsburgh, and DEP determined that the accident has led to no deaths or injuries to plant personnel and no notable health impacts on members of nearby communities. A study by Steven Wing of the University of North Carolina at Chapel Hill contested these findings, however, and stated that cancer rates downwind of TMI were two to 10 times higher than cancer rates upwind and reported that several hundred people experienced symptoms of high levels of radiation exposure, such as hair loss, pet death, nausea, and skin rashes.

Since the TMI incident, regulations and safety monitoring have improved immensely. After the terrorist attacks of September 11, 2001, structural and security requirements also were strengthened to ensure that power plants could deter or withstand infiltration or an aerial attack. Still, safety issues continue to be raised by some groups, particularly regarding **license renewals and uprates**. Critics claim that existing nuclear power plants, many of which were built in the 1970s, would not meet the current licensing requirements if they were constructed today and should not have their licenses renewed. In response, NRC reiterates that license renewals and uprates are granted only after rigorous inspections and substantive improvements to power plant components, equipment, and structures. A license renewal or approval of an uprate indicates that the nuclear power plant does meet today's safety standards.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

Pennsylvania's nuclear industry represents 9,305 mW of installed capacity across nine nuclear power reactors in Pennsylvania at five sites: the Beaver Valley Nuclear Generating Station near Shippingport, Beaver County; Limerick Generating Station in Limerick Township, Montgomery County; Peach Bottom Atomic Power Station in Delta, York County; Susquehanna Nuclear Power Plant in Berwick, Luzerne County; and Three Mile Island in Middletown, Dauphin County.

Nuclear energy supplied 35 percent of Pennsylvania's electricity needs in 2008. While no new construction of nuclear power plants is expected in Pennsylvania in the near future, the state can increase its nuclear power output through uprates. DEP estimates that an additional 1,050 mW of nuclear capacity can be added through uprates. The estimated busbar cost of a new nuclear power plant is between $98 and $126 per mWh, according to Lazard.

The state's nuclear power plants directly employ about 4,100 full-time workers along with thousands of contractors and temporary workers during planned maintenance and refueling. The Nuclear Energy Institute estimates that each plant creates about $430 million in annual economic output plus $40 million in total labor income. Additionally, Southwestern Pennsylvania is home to Westinghouse Electric Company LLC, which supplies the technology for nearly half of the power plants worldwide. Since 2007, Westinghouse has hired about 1,000 employees each year. Westinghouse also has licensed numerous reactors in Asia and Europe and plays an integral role in the transition to nuclear power in China, which plans to build 100 plants based on Westinghouse's AP1000 reactor design by 2020. Licensing fees from international projects help to fund research and development projects, some of which are conducted in Pennsylvania. There also are a number of Pennsylvania manufacturers that serve the nuclear supply chain and provide local jobs.

IV. SOLAR AND WIND

Solar and wind power are two of the most promising renewable energy sources, and both have seen growth in Pennsylvania in recent years. Solar and wind farms can provide a domestic source of energy without the ecological impacts of fossil fuel combustion and extraction. Plus, as state (and possibly federal) policy continues to drive demand for clean energy, Pennsylvania can serve the Pennsylvania-New Jersey-Maryland (PJM) Interconnection region by trading renewable energy credits and exporting electricity. Pennsylvania manufacturers, engineering firms, and supporting industries also can serve the growing renewable energy market. There are significant economic and environmental benefits that can be realized through investment in renewable energy within the region, but a nearly equal number of challenges exist as well.

ENVIRONMENTAL IMPACTS

The environmental benefits of alternative energy sources are best quantified in terms of offsets. Alternative energy sources, such as solar and wind, do not produce air emissions or consume significant amounts of water. The positive environmental impact of alternative energy, then, can be measured by the avoided impacts of using conventional fuels to generate an equivalent amount of energy. The American Wind Energy Association (AWEA) estimates the average U.S. fuel mix produces about 1.52 pounds of CO_2, 0.008 pounds of SO_2, and 0.0049 pounds of NO_X per KWh of generated electricity. Furthermore, alternative energy does not rely on mining, drilling, or other extractive activities that negatively impact the environment. However, the environmental benefits of solar and wind energy must be taken into consideration along with resources and energy consumed in the process of manufacturing wind turbines, solar panels, and other components. Solar panels, like computers, cell phones, and other electronics, are classified as e-waste and cause harm to the environment if disposed of improperly.

The threat that wind farms pose to birds and bats also has been highlighted as an environmental concern. In West Virginia, development of a 122-turbine wind farm was delayed after it was challenged in court by the Animal Welfare Institute on the grounds that it would harm the Indiana bat, an endangered species. The developer now must obtain a special permit from the U.S. Fish and Wildlife Service in order to proceed. In Pennsylvania, wind farm developers must coordinate with the Pennsylvania Game Commission, the Pennsylvania Fish and Boat Commission, the U.S. Fish and Wildlife Service, the Pennsylvania Department of Conservation and Natural Resources, and DEP in order to minimize the impact on habitats and wildlife. The American Wind Wildlife Institute, a national partnership between wind developers and conservancy groups, also has launched a project that will map out environmentally sensitive areas.

Environmental and economic benefits must be measured against the **capacity factor** of solar and wind power installations, which are affected by intermittency (the sun does not always shine and the wind does not always blow). Intermittency, however, is not as detrimental to the cause of alternative energy as many presume. Because wind and solar farms are not considered to be feasible as replacements for baseload power sources, a period of low production will not threaten the integrity of the energy grid, which is already designed to compensate for variability from all power sources, including coal, nuclear, and natural gas plants. True, much efficiency is lost due to improper energy infrastructure, but this applies to all energy sources, and the need for better transmission technology and a smart grid system is a separate issue.

PUBLIC HEALTH AND COMMUNITY IMPACTS

Wind farm development also has met with some local resistance, as wind turbines are often viewed as aesthetic and noise nuisances. Early model wind turbines tend to be noisier than newer turbines, particularly when installed in hilly terrain. Wind turbines also create a flickering effect as the sun sets or rises behind them, which can be unsettling to nearby residents. An independent study conducted by Nina Pierpont, a pediatrician from New York, also attributed cases of tinnitus, sleep deprivation, vertigo, heart disease, panic attacks, and migraines to infrasound and low-frequency noise emitted by wind turbines and generators. An AWEA-sponsored study into these findings found no evidence that audible or subaudible sounds have direct adverse physiological effects on human health.

ECONOMICS OF RENEWABLE ENERGY

Regulatory climate and policy initiatives are of equal or greater importance to the success of alternative energy as the amount of sun or wind a region receives. Illustrative examples include New Jersey, which has one of the most robust solar energy markets in the country, and Germany, the number one nation in solar energy thanks to government support of renewable energy. Neither New Jersey nor Germany have significantly greater solar or wind resources than Pennsylvania, indicating that the gap exists elsewhere.

In the United States, investment in renewable energy is encouraged through **tax credits**, **grants**, and **subsidies** and **Renewable Portfolio Standards** (RPS). Currently, businesses, developers, and homeowners can receive tax credits or grants of up to 30 percent of investment costs through the federal government. Pennsylvania also supports renewable energy projects through the $650 million Alternative Energy Investment Fund. In 2004, Pennsylvania established its own version of an RPS known as the **Alternative Energy Portfolio Standards** (AEPS) to reflect the inclusion of fossil fuel sources such as waste coal, IGCC, and coal-bed methane. AEPS requires that electricity distributors source a certain amount of their energy from alternative energy sources. Producers of energy from approved AEPS sources can earn Alternative Energy Credits (AECs), which can be sold to electricity distributors to meet their AEPS requirements. Alternative energy producers also can earn income through net metering, which allows them to sell excess electricity to utility companies at retail rates.

When it was first implemented, Pennsylvania's suite of alternative energy incentives was one of the most ambitious in the United States. The favorable business climate and guaranteed market for alternative energy in the state has attracted several manufacturers and developers to Pennsylvania, bringing clean energy and green jobs to the region. However, other states such as New Jersey have since launched more aggressive programs. In order to keep Pennsylvania competitive as a destination for alternative energy ventures, several solutions have been proposed and debated. Bills proposing increased AEPS requirements have been introduced in the state legislature. Experts also suggest that Pennsylvania's AEC valuation model may need reform in order to bolster investor confidence in renewable energy projects.

Germany has seen much success through its feed-in tariff, which sets a profitable price on excess generated renewable energy (as opposed to net metering at retail price, as in Pennsylvania). Some technical and legislative barriers stand in the way of imposing a feed-in tariff in the United States, however. Lastly, there is a growing need for solar and wind installers and other professionals trained and certified to work on renewable energy projects. Industry partnerships and concerted efforts—such as the Green Jobs Academy founded by Bucks County Community College and Gamesa, a Spanish company that employs about 800 and sources many of its materials from domestic suppliers, in June 2001—can help to meet this need.

SOLAR INDUSTRY OVERVIEW AND ECONOMIC IMPACTS

Solar photovoltaic (PV) technology, which converts sunlight into electricity, is the most commercially viable source of solar energy in Pennsylvania. Although solar power provides less than 1 percent of the electricity produced in Pennsylvania, the state has seen immense growth in recent years. Currently, there are approximately 9 mW of installed solar capacity in Pennsylvania. This represents a tiny fraction of the full technological potential, which has been estimated as high as 619 GW. In order to meet the goals laid out by AEPS, Pennsylvania needs 860 MW of installed solar capacity by 2021. However, with the current incentives, the American Council for an Energy Efficient Economy estimates only 680 mW of this need will be met by

2020. Lazard estimates the busbar cost of a new solar PV installation at $96–$154, but these costs are highly sensitive to government subsidies and other incentives.

There are a number of Pennsylvania-based solar manufacturers that bring jobs to the region, such as Solar Power Industries (SPI) in Belle Vernon and FLABEG Corporation in Brackenridge. These companies serve both local and international markets and would benefit from increased demand for solar energy in the United States and abroad. For example, SPI employs about 200 employees and exports most of its products to Europe and China.

WIND INDUSTRY OVERVIEW AND ECONOMIC IMPACTS

Pennsylvania has 748 mW of installed wind capacity across 17 wind farms as of 2009. Like solar energy, wind energy plays a relatively small role in Pennsylvania's overall energy mix, but there is much opportunity for growth. The National Renewable Energy Laboratory (NREL) estimates that there are approximately 660 square kilometers of land available for wind development and a potential of about 3,300 MW of installed capacity in Pennsylvania. Lazard's estimated busbar cost for wind lies between $44 and $91 per mWh.

According to AWEA, each megawatt of new wind energy creates 15–19 jobs. This includes construction workers, contractors, engineers, and factory workers for manufacturing facilities. A study by Black & Veatch Corporation, a global environmental engineering, consulting, and construction firm, indicated that AEPS requirements helped to attract more than 40 companies directly serving the wind industry to Pennsylvania, including Gamesa. Turbine manufacturers and other industries that support the wind industry would benefit from an increased demand for wind energy nationwide. In particular, the recent moves toward offshore wind projects near Delaware and New Jersey might create opportunities for Pennsylvania companies.

KEY REGIONAL OPPORTUNITIES AND CHALLENGES

The most favorable path for Pennsylvania's energy sector is apparently a transition toward sustainable alternative energy sources. The keys to clean, affordable, and abundant energy sources lie within the energy economy that is already established in the region. The next challenge is to identify which technologies and fuel sources will most prudently carry the state through the transition phase and which sustainable energy sources will serve as the backbone of the state's new energy economy in the future.

Coal, which supplies nearly half of the state's electricity and supports thousands of jobs throughout the state, has already proven itself as one of the most versatile fuel sources available. Commercial validation of higher efficiency coal power plants and carbon capture and sequestration can transform coal from one of the ''dirtiest'' fuel sources into one of the most state-of-the-art and prolific alternative energy sources.

Natural gas could serve not only as a cost-effective bridge fuel but also as a domestic alternative to petroleum-based energy sources. The vast reserves of natural gas locked within the shale beneath Pennsylvania represent a golden opportunity, but pioneering the regulatory framework that will allow sustainable development without stifling the fledgling industry before it can deliver the jobs, tax dollars, and economic development it promises will prove to be a complex challenge.

Nuclear energy already provides a vital component of Pennsylvania's baseload energy mix. Successful nuclear projects in Asia and Europe are proving that construction of new nuclear power plants is commercially viable. The environmental benefits in terms of air emissions and the avoided impacts of natural resource extraction also have given critics cause to reconsider nuclear energy. But in order for nuclear energy to flourish again in Pennsylvania, the benefits and opportunities must be reconciled with the persistent fears over national security and public health.

Pennsylvania has given renewable energy sources a strong foothold in the state, thanks to ambitious Alternative Energy Portfolio Standards and other renewable energy subsidies, incentives, and programs. Wind and solar are two of the fastest-growing renewable energy sources in the state, in the United States, and worldwide, and Pennsylvania's growing renewable manufacturing sector stands to benefit from increased demand for solar and wind components and equipment. However, further legislation may be needed in order to ensure that Pennsylvania continues to attract renewable energy developers to the region.

Regional Opportunities and Challenges in Electricity Distribution

Development of smart grid, electricity distribution, and demand-side management technologies make up the other side of the energy coin and factor into the equation for electricity produced from all sources. Southwestern Pennsylvania's energy challenges and opportunities are compounded by issues surrounding electricity distribution, all of which merit an equal amount of attention and scrutiny from regional policymakers as the energy sources discussed in this report. However, given the scope and purpose of this report, these topics will not be addressed in this document.

INTRODUCTION

''The Administrator finds that six greenhouse gases taken in combination endanger both the public health and the public welfare of current and future generations.'' This statement, made by the U.S. Environmental Protection Agency (EPA) in 2009, represents a possible transformation occurring in the United States. While the environmental threats of carbon dioxide (CO_2) and other greenhouse gases have long been scrutinized by the scientific community, carbon emissions have not been subject to federal regulation. But by officially declaring CO_2 a harmful substance, EPA has given itself an imperative to take action to regulate carbon under the Clean Air Act.

Impending carbon policy frames the environmental challenges that will substantially reshape the energy economy that sustains every facet of industry. This paradigm shift could not have come at a more critical time for the worldwide economy. The global recession has left the U.S. economy in a particularly vulnerable state, while demand for affordable energy is poised for a meteoric rise. The race for energy independence is joined by emerging markets such as Brazil, Russia, India, and China, which are fueling their rapid growth with a voracious appetite for the same international energy sources on which the United States and other developed nations rely. Now, the most available and abundant domestic natural resources—coal and other fossil fuels—are under scrutiny due to their high carbon emissions.

The nation faces an urgent set of economic and environmental challenges in the energy sector. These challenges translate directly into a unique opportunity for Pennsylvania to become a regional and national leader in the 21st-century energy economy. Southwestern Pennsylvania very well may become the next energy capital of the world.

Pennsylvania's energy economy began in the 19th century and today encompasses a diversified, integrated portfolio of assets that serve the region's energy needs. The region is synonymous with the wealth and development heralded in by coal, America's preferred source of electricity and industrial energy for centuries. But Pennsylvania also is home to the nation's first commercial oil well; first commercial nuclear reactor; and, as recently discovered, one of the world's largest untapped resources of natural gas, the Marcellus Shale formation. Furthermore, the commonwealth harbors established industries, cutting-edge research centers, and policies that support the deployment and development of renewable energy.

Pennsylvania is not only well equipped to serve the nation's energy economy, it also is strategically located. As a net exporter of electricity, Pennsylvania serves the entire northeastern market through the PJM Interconnection regional transmission organization. Pennsylvania's energy reaches farther with its bituminous coal serving markets in western states and its nuclear technology powering states across the country as well as nations in Asia and Europe.

However, the region's rich energy history is marked not only by groundbreaking economic and technological advancement but also by a legacy of environmental scars. Pennsylvania's energy booms have at times resulted in indelible impacts on the communities, natural habitats, and precious water resources that are as treasured as the natural energy resources that have transformed the region's economy. Soot-stained buildings, polluted airways, and depressed former boomtowns overlying acres of abandoned mine lands that continue to leach discharges into waterways are a few examples of the detrimental impacts that the commonwealth is addressing today.

Emerging now is a new opportunity to revisit the halcyon days of the region's leadership role as an energy epicenter. This time,

Levelized Energy Cost Comparisons

The following table shows the levelized energy costs of the different energy technologies discussed in this report, as estimated by Lazard, a prominent asset management and financial advisory firm, in June 2008. Costs reflect production tax credits and investment tax credits and are based on coal prices of $2.50 per Million Metric British Thermal Units (MMBtu) and natural gas prices of $8 per MMBtu.

PLANT TYPE	LEVELIZED ENERGY COST ($2,008/MWH)	FUEL COST ($2008/MWH)
Supercritical Pulverized Coal (SCPC)	$74–$135*	$22–$30
Integrated Gasification Combined Cycle (IGCC)	$104–$134*	$22–$26
Gas Combined Cycle	$73–$100	$54–$58
Gas Peaking	$221–$334	$81–$87
Nuclear	$98–$126	$5–$5
Solar Photovoltaic (PV)	$96–$154	N/A
Wind	$44–$91	N/A

Source: Lazard, June 2008, "Levelized Cost of Energy Analysis – Version 2.0" *Incorporates cost of 90 percent carbon capture however, the stakes are higher, the public is warier, and the world is watching more closely. This is embodied best by the Marcellus Shale play, into which Pennsylvania has already delved deeply. Two critical stewardships arise as the commonwealth takes advantage of its resources and moves toward energy independence: the economy and the environment. State and local policymakers, industry leaders, and community members must be careful not to repeat the mistakes of the past. But, at the same time, these very same leaders must not let trepidation and inaction stifle a newly reignited energy industry that offers growth for the region and the nation.

This publication aims to illuminate some of the emerging economic opportunities across the region's most vital energy sectors: coal, natural gas, nuclear, solar, and wind. These energy resources will be explored with high regard for the environment, public health, and the communities that might be positively or negatively impacted. By identifying these key areas of focus, this report also will explore the potential for the region to become a responsible yet effective national leader in the energy sector.

Federal and State Carbon Policy

Carbon dioxide has been identified as the operative agent that drives climate concerns. Legislative solutions for reducing carbon have been a topic of intense debate on the state and federal levels and introduce uncertainty for energy companies. Several options have been proposed, including a tax on carbon emissions, a cap-and-trade scheme, cap-and-dividend systems, and others. Speculation on the details and mechanisms of carbon policy is not yet prudent. However, carbon policy in any form would have one key impact on the dynamics of energy: a premium on energy sources with high carbon emissions. The nation currently relies on such energy sources, and crafting and implementing carbon policy that will curb carbon emissions without crippling the economy is a paramount concern.

The newest development related to the carbon policy debate is the introduction of legislation in the U.S. House of Representatives that would prohibit EPA from promulgating regulations relating to greenhouse gas emissions.

CHAPTER I: FOSSIL FUELS

I. COAL

Pennsylvania Coal Industry Quick Facts

- Rank among coal producers in the United States: **fourth**
- Recoverable coal reserves in Pennsylvania: **11.55 billion tons**
- 2009 coal production: **58.1 million tons**
- 2009 international mineral and ore exports from Pennsylvania: **$29 billion**
- Existing coal-fired plants in Pennsylvania: **40**
- Busbar cost for a new supercritical pulverized coal (SPCP) plant: **$74–$135 per mWh**
- 2008 electricity output: **22 million mWh (53.2 percent of state total)**
- Jobs supported: **8,724 direct, 32,853 indirect ($7.5 billion in combined economic output)**
- Total estimated cost for reclaiming abandoned mine lands: **$15 billion**
- CO_2 emissions: **208,000 pounds per billion Btu**

Section Overview

- Coal jobs are becoming more sophisticated and high tech, which poses both an opportunity and a challenge. The region's research facilities—including the CONSOL Energy Inc. research facility, the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL); and labs at the University of Pittsburgh, Carnegie Mellon University, Pennsylvania State University, and West Virginia University (WVU)—contribute millions of dollars in economic output in research and development. However, the gap between the supply of and demand for experienced, certified workers to fill positions as supervisors, engineers, and other jobs requiring significant qualifications continues to grow.
- Historical, preregulation mining practices have left a legacy of environmental challenges—including abandoned mine drainage and waste coal piles—that serve as reminders of the importance of ensuring sustainable extraction of natural resources. Government- and industry-funded efforts are steadily working toward reclaiming abandoned mine lands and rectifying environmental damage.
- Historically, the coal industry has made substantial progress toward reducing airborne emissions from coal-fired power plants. However, coal-fired electricity generation, next to vehicle emissions, is one of the largest contributors to Southwestern Pennsylvania's continuing air quality issues. Additionally, the possibility of legislation regulating CO_2 may present the next major challenge for the coal industry.
- The increased use of longwall mining techniques has changed the nature of subsidence. While Pennsylvania Act 54 of 1994 was designed to protect natural habitats and landowners, determining liability and environmental impact will be a continuing challenge.
- The 2008 coal ash spill at the Tennessee Valley Authority's Kingston Fossil Plant has galvanized EPA to bring impoundment and disposal of coal combustion residuals under federal regulation. A proposed rule has been drafted and is pending review.
- Carbon capture and sequestration (CCS) and newer, higher efficiency coal power plants may present economical solutions to environmental challenges. Pennsylvania's geology is well suited for storing captured CO_2, which makes the state an apt location for a CCS pilot project.

The numerous coal seams that traverse the land beneath Pennsylvania's homes, schools, factories, office buildings, and natural lands lend themselves to numerous symbolic analogies. They can be seen as the founding roots of Pennsylvania's culture and economy, the vital arteries carrying the lifeblood of our industry, and the latent untapped potential of our natural resources—an abundant buried treasure secured beneath domestic soil. But while the fertile legacy of coal breathes life into the regional economy and community, growing concerns over climate change, public health, and other environmental issues bloom beside it. To some, coal represents the antiquated underbelly of a society that values sustainable progress but still harbors myriad troublesome hidden costs.

Like any topic marked by heated debate, there is merit and bias on both sides of the fence. But there is undeniable consensus over one key issue: coal keeps the lights on. This is especially true in Pennsylvania, which has drawn half or more of its electricity from coal-fired power plants for decades. The importance of coal in Pennsylvania's past, present, and near future is beyond dispute. But how exactly will coal factor into our economy and environment in the coming decades?

ENVIRONMENTAL IMPACTS AND PUBLIC HEALTH

While coal is widely recognized as an abundant and affordable fuel, it also presents troubling externalities. Often referred to as the ''hidden costs of coal,'' these are the impacts of coal extraction, processing, and application that are borne not by the industry but by the environment and the communities

that surround coal mines and power plants. The debates over assumption of liability, best practices for mitigation, and the severity—or in some cases even the existence—of the issues are both historical and perpetual.

Air Quality

Coal has a reputation for being the ''dirtiest'' burning fuel, especially in terms of air emissions. The principal constituents of coal-fired emissions that have raised concerns and prompted regulation are the following:

- Sulfur dioxide (SO_2): contributes to acid rain, which damages natural landscapes and waterways as well as buildings.
- Nitrogen oxide (NO_X): contributes to smog and poses respiratory health risks
- Carbon monoxide (CO): contributes to smog and other public health issues
- Mercury: threatens the health of people, fish, and wildlife
- Arsenic: a known carcinogen that can contaminate drinking water
- Secondary particulate matter: causes various adverse effects on public health and environment

While this aspect of the coal economy has been particularly vexing, it also has been one of the areas marked by the most progress. Federal standards for emissions, outlined by the federal Clean Air Act and enforced by the Pennsylvania Department of Environmental Protection (DEP) Bureau of Air Quality, set many of the efforts toward improving air quality in motion. In order to comply with air quality standards, power plants have implemented technology—such as flue gas scrubbers and cleaner precombustion technology—that has helped to reduce regulated emissions dramatically. Accompanied by a 1990 Clean Air Act Amendments cap-and-trade system, the industry and regulatory bodies worked together to mitigate such issues as smog, acid rain, and other air quality concerns. Overall, the coal industry reduced regulated emissions by 70 percent between 1970 and 2007 while increasing production by 225 percent.

However, air quality issues remain worldwide, particularly in Pennsylvania. In its *State of the Air 2010* report, the American Lung Association listed 26 counties—including Allegheny, Beaver, and Washington—that received F ratings for high ozone days. The Pittsburgh/New Castle area was ranked the third and fifth most polluted U.S. area, according to evaluations of short-term particle pollution and year-round particle pollution, respectively. A 2006 study by PennEnvironment estimated the annual health effects of air pollution in Pennsylvania at:

- 5,000 premature adult deaths,
- 12,000 respiratory hospital admissions,
- 4,000 new cases of chronic bronchitis,
- 800,000 asthma attacks,
- 800,000 missed work days due to illness exacerbated by air pollution,
- 20 post-neonatal infant deaths, and
- 900,000 missed school days due to illness exacerbated by air pollution.

While these health effects are based on estimation and are by no means attributable solely to coal-fired electricity generation, the concern about and need for reduction in air pollution remains. As emissions from coal power plants are the largest contributor to air pollution behind vehicles, controlling those emissions provides a critical avenue for helping to curb the public health and environmental impacts of air quality.

CO_2 and Climate Change

CO_2 and greenhouse gases, which are believed to contribute to climate change, should be conspicuously separated from other air pollutants. Currently, there is no federal regulation of carbon emissions, nor is CO_2 regulated in Pennsylvania in the way that the aforementioned pollutants are. Growing awareness and concern over CO_2's role in global climate change has spurred the federal government to begin working on federal carbon policies, as discussed previously. This is highly relevant to Pennsylvania—which reportedly contributes 1 percent of all heat-trapping gases worldwide and 4 percent of the United States' share—and the commonwealth's coal industry, which contributed about 84 percent of the 135.6 million tons of CO_2 emitted by the state's electric power sector in 2008, according to U.S. Energy Information Administration (EIA) data.

Abandoned Mines, Waste Coal Piles, and Abandoned Mine Drainage

Legacy issues leftover from historical mining practices serve as important reminders of the long-term consequences of failed stewardship. But in the present term, they continue to pose ongoing environmental challenges that require immediate attention. The most familiar and enduring scars arise from unreclaimed and abandoned mine lands (AML) and waste coal piles. Across Pennsylvania, there are more than 250,000 acres of AML, which encompass open mine shafts, large water-filled pits, and other hazards. These sites impact the state's waterways and natural landscape most significantly through abandoned mine drainage (AMD). AMD occurs when improperly reclaimed underground or surface mines are flooded.

Water accumulating in these mines interacts with rock and coal to form iron and other metallic compounds that change the pH of water. When this water is discharged to the surface and enters into streams, it can kill fish and other organisms and ultimately settles on the stream bottom. Water contaminated with AMD also can be harmful to human health if consumed in large quantities. Currently, there are more than 3,000 miles of streams in Pennsylvania that have been adversely affected by AMD. The total estimated cost for reclaiming all AML in Pennsylvania is $15 billion.

Today, mining companies must adhere to strict regulations imposed by the state and the federal government to prevent AMD. No mines are permitted if they will have postmine drainage, and all mining operations must be restored to premining conditions. Meanwhile, abandoned mines are being steadily reclaimed through both government- and industry-funded efforts and remining operations. The federal Abandoned Mine Reclamation Fund is funded through a tax on each ton of mined coal. This money has been tapped by DEP for Pennsylvania's reclamation efforts. In 1997, the state put together the Comprehensive Plan for Abandoned Mine Reclamation, a collaboration among DEP, state and local government, and industry to assess the needs and rehabilitate AML.

Remining is one of the most cost-effective mechanisms for reclaiming AML and mitigating AMD. In a remining operation, coal mining companies revisit abandoned surface mines using current standards for sustainability and reclamation. Redressing of environmentally unsound conditions occurs incidentally to the extraction of previously inaccessible or untapped coal resources. Federal and state government programs have been put in place to provide incentives for remining, including bonds and financial assistance for permitting fees. Since 1991, 5,046 acres of AML in Pennsylvania have been reclaimed through 862 projects for an estimated value of more than $27 million, according to a 2008 DEP report.

In addition to abandoned mines, there are more than 2 billion tons of waste coal piles scattered across the state. During historical mining operations, coal with Btu content too low to be considered marketable was left on site. Much of this unsustainably discarded waste coal accumulated between 1900 and 1970, but the piles still remain today, causing many of the same environmental issues as AMD. Furthermore, waste coal piles can catch fire, releasing untreated emissions into the air. Current fluidized bed combustion (FBC) technology allows this lower energy grade coal to be used in electricity generation while keeping regulated emissions at acceptable levels. Due to the lower Btu content, burning waste coal yields significantly more coal ash, which can be beneficially used in mine reclamation and other applications.

Solutions for Waste Coal

The best way to sustainably and economically remove waste coal piles from Pennsylvania's landscape has been a topic of debate. Possible solutions include the followimg:

Fluidized bed combustion: FBC technology allows today's power plants to burn waste coal to produce electricity. However, burning waste coal produces more emissions and coal ash. Waste coal is currently included as a Tier II alternative energy source in Pennsylvania's Alternative Energy Portfolio Standards program.

Coal to liquids: Coal-to-liquids plants can convert waste coal into diesel, naphtha, and jet fuel. Baard Energy is planning a $6 billion coal-to-liquids plant in Ohio.

Beach grass: In 1991, a group of U.S. Department of Agriculture researchers planted beach grass in an abandoned coal refuse pile in order to reclaim the area so that it could be colonized by indigenous plant life. The study found that planting beach grass was effective to this end. Some environmentalists prefer this type of reclamation, as it keeps mercury and other pollutants locked within the waste coal rather than released via air emissions and particulate matter.

Subsidence

Like AML, subsidence is both a legacy and an ongoing issue in the region. Subsidence occurs when the ground moves or settles as a result of underground mining activities. This is most prevalent in Southwestern and central Pennsylvania, where the bulk of underground mining occurs. While subsidence has been an issue for as long as mining has existed in the state, the evolution of longwall mining techniques has been accompanied by a reintroduction of subsidence as a problem with new complexities.

Longwall mining differs from conventional mining practices, in which ''rooms'' of coal are excavated while being supported by pillars (''room and pillar''). In a longwall mine, long passageways are cut around rectangular panels of coal. The coal panels can sometimes be several miles long and are about 300–800 feet underground. A tram-mounted cutting head then works across the panel, shearing coal and moving it out of the mine on conveyor belts. As the machine progresses, the roof of the mine is allowed to collapse. Longwall mining is far more productive and requires fewer workers, making it highly cost-effective over traditional underground mining methods. Longwall mining accounted for about 80 percent of Pennsylvania's underground production in 2008.

Unlike room-and-pillar mining, which carries the risk of subsidence at some unknown point in the future, subsidence from longwall mining is not only a risk but rather an expectation. Industry representatives view the nature of subsidence caused by longwall mining in a positive light, as the subsidence typically occurs within 90 days after the area has been mined, thus eliminating the long-term potential for less predictable subsidence. This predictability allows mining companies to negotiate equitable pre- or postmining agreements with landowners in order to compensate them for damage caused by subsidence. This compensation is given in lieu of the low-cost mine insurance offered through state programs for unplanned subsidence from abandoned mines.

Pennsylvania's Act 54, which was passed in 1994 to regulate longwall mining in Pennsylvania, serves to enforce and oversee the claims process between mining companies and landowners. In order to receive compensation, landowners must first report potential damages from mining activity to DEP. DEP provides the mining company and the property owner an opportunity to reach an agreement before stepping in. If the landowner is dissatisfied with the mine operator's response, he or she must then file a claim with DEP, which will determine liability and compensation, if any, for the damage.

Act 54 also requires DEP to conduct an assessment on the impacts of all underground mining activities every five years. The most recent five-year report (released on February 4, 2005, and covering the period between 1998 and 2003), indicates that DEP received 684 reports of water supplies that were potentially damaged by mining activity, 76.3 percent of which reported diminution of water supply and about 23.3 percent of which reported contaminated water supplies. About 45.5 percent of these reports eventually led to water loss claims with DEP.

The February 2005 DEP report also shows that 3,656 structures on 3,033 properties were undermined during the assessment period. DEP received 348 reports (representing about 9.5 percent of all undermined structures) of structural problems potentially caused by mining, 141 (about 3.8 percent of all undermined structures) of which eventually became claims.

The DEP report also stated that about 97 miles of stream were undermined by longwall mine panels, which may potentially cause impairment due to diminution of flow. However, most streams with loss of water flow eventually recovered on their own without intervention. In many cases, lack of premining data prevented the DEP study from determining whether habitat, fish, and other wildlife had been affected by undermining.

Beyond the DEP findings, several environmental and advocacy groups have expressed concern over the community impacts of longwall mining. PennFuture, for example, states that the damage from subsidence has been far more significant than the ''gentle lowering of the earth'' described by the industry prior to the passage of Act 54. According to opponents of longwall mining, the practice often entails irreparable damage to homes, wells, streams, and fields. These burdens are felt alongside the ''stress and uncertainties'' that coalfield residents experience that are ''impossible to quantify or compensate.'' PennFuture has called for updates to Act 54 that would allow for greater protections of historic properties water resources, public roads, and utilities as well as additional analyses of potential impacts prior to permitting, new provisions for compensating business owners adversely affected by longwall mining, and faster timetables for payments to private property owners affected by longwall mining. In another example, two reports on the impacts of longwall mining released by the Center for Public Integrity outlined cases in which Pennsylvania landowners found themselves locked in drawn out, expensive legal disputes with coal mine owners.

The tensions that have arisen from longwall mining and subsidence issues highlight the need for solutions that will help to balance the benefits of this highly productive mining technique with the negative impacts on communities and the environment.

Coal Combustion Residuals

Until the catastrophic coal ash spill at the Tennessee Valley Authority (TVA)'s Kingston Fossil plant in 2008, relatively little attention was given to coal's most prolific by-product: coal combustion residuals (CCR). The term CCR often is used interchangeably with coal combustion waste (CCW) or simply coal ash and encompasses several materials that remain after coal combustion, including fly ash, bottom ash, boiler slag, and the residue from flue gas desulfurized scrubbers. EPA estimates that 136 million tons of CCR were produced throughout the United States in 2008. In 2004, Pennsylvania produced about 9.5 million tons of CCR, according to a report released by DOE and EPA in August 2006.

CCR can take numerous forms and are managed by plant operators in a variety of ways. CCR can be mixed with wastewater and impounded in a liquid slurry form in on-site coal ash ponds. CCR also can be landfilled. Some CCR are used as structural fill, concrete, and backfill for abandoned mines. This is known as beneficial use of coal ash.

CCR can contain elements that have been recognized as hazardous by EPA, but the physical and chemical makeup of CCR is far from uniform. Numerous parameters affect their threat level. First, it is crucial to understand which constituents of CCR may be harmful and how humans and wildlife may be exposed to such elements. Many of the typical CCR constituents are regulated by EPA under the Safe Drinking Water Act and have enforceable maximum contaminant levels (MCL). Other constituents are included in EPA's secondary MCL standards, which are nonenforceable but pertain to contaminants that may have aesthetic (odor, taste, color) or cosmetic (skin or tooth discoloration) effects. The cumulative effect of potentially harmful constituents is of the greatest concern, particularly when multiple substances have common toxicities. For example, aluminum, lead, and manganese all have neurological effects; barium, cadmium, and mercury each affects the kidneys; cobalt, thallium, and zinc can cause blood disorders; and beryllium and copper can have effects on the gastrointestinal system. The two CCR constituents that have received the most attention are arsenic, a carcinogen; and selenium, which can cause acute and chronic selenosis with symptoms such as rashes, gastrointestinal disorders, hair loss, neurological disorders, and cirrhosis.

Another concern that has been raised regarding coal ash is its radioactivity. Trace amounts of radioactive materials, such as uranium and thorium, are sometimes present in fly ash (as they are in most geologic materials). This has led to a number of news stories indicating that fly ash carries 100 times as much radiation into the environment as a nuclear power plant. The radioactivity of fly ash also has caused some to question the safety of beneficial use of coal ash. However, a 1997 study by the U.S. Geological Survey (which predates much of the media coverage of coal ash's radioactivity) indicated that dissolved concentrations of coal ash's radioactive elements are ''below levels of human health concern'' and, like nuclear power plants, coal power plants contribute less than 1 percent of the man-made radiation that humans are subjected to throughout the year.

Arsenic, selenium, and other heavy metals and toxins can come into contact with the public by leaching into the groundwater, through inhalation of stray fly ash, or through bioaccumulation (e.g., eating local fish from contaminated aquatic environments). Environmental groups have published a number of studies warning of potential and ongoing damage caused by contamination and have reported toxin levels that exceed primary and secondary MCLs in sites near coal ash disposal facilities. According to a report released by the Environmental Integrity Project (EIP) and Earthjustice, EPA has identified 71 cases of water contamination due to unregulated dumping of coal ash in unlined, poorly sited ponds. The EIP report examined an additional 31 sites, including six Pennsylvania locations, four of which were shown to have caused off-site damage due to coal ash leachate in groundwater.

In addition, the report iterates that its findings, along with EPA's, are just the ''tip of the iceberg'' and represent only 15 percent of the operating coal-fired plants in the nation. EIP opines that most of the off-site damage caused by coal ash ponds could have been prevented with ''sensible safeguards'' such as phasing out leak-prone ash ponds and requiring leachate collection systems and synthetic liners. State regulators and power plant operators, however, have questioned the methodology of such studies.

Disposal and Impoundment

The key to protecting the public from the potential adverse health effects of CCR constituents is proper disposal and monitoring. In Pennsylvania, CCR that are not beneficially used are managed by DEP as residual waste and are either interred in a surface impoundment in wet slurry form or in a dry landfill. There are three classes of residual waste landfills (I, II, and III) and two classes of surface impoundments (I and II), with Class I landfills' being designated for waste with the highest potential for adversely affecting groundwater. Coal ash is subjected to chemical, physical, and leachate analyses to determine the design standards applicable for disposal. Class I and Class II landfills and surface impoundments require a leachate detection zone as well as a synthetic liner. However, facilities constructed prior to these requirements and alternate landfill or impoundment plans approved by DEP may not have liners or groundwater monitoring systems.

Surface impoundments are the most problematic of coal ash disposal options and have received increased media attention due to the TVA Kingston Fossil Plant coal ash spill, which occurred in Tennessee in December 2008. Surface impoundments differ from landfills in that they are not covered. Coal ash in surface impoundments is interred in a wet or slurried form by mixing it with plant wastewater, scrubber sludge, and water and materials leftover from precombustion treatment of coal. Due to its liquid form, slurried coal ash is more susceptible to leaching, particularly in the absence of a synthetic liner. The overall risks of ground and surface water contamination depend on a number of factors, however, including hydrogeology, monitoring plans, and chemical makeup of the coal ash.

In response to the TVA Kingston incident, EPA conducted a survey of surface impoundments and identified 49 CCR management units with a ''high potential hazard rating,'' including the Bruce Mansfield Power Station's Little Blue Run Dam impoundment in Shippingport, Pa. EPA's reference was not a comment on the structural integrity of the facility and instead indicated that a failure would ''probably cause loss of life.'' EIP voiced concerns that a dam failure at this facility would be worse than the TVA incident, as it is larger and contains higher levels of dangerous chemicals. Little Blue Run operator FirstEnergy responded in the media by noting that that dam was intact and was inspected several times a year.

DEP also conducted a dam safety inspection of 42 coal ash, slurry, and waste impoundments around the state. In September 2009, then DEP Secretary John Hanger reported that ‘‘DEP dam safety inspectors found no major structural problems.’’ According to the DEP press release, ‘‘Hanger ordered the inspections to ensure the structures are being maintained and operated safely and in compliance with Pennsylvania's dam safety regulations,’’ which are part of ‘‘one of the most comprehensive dam safety programs in the country, with strict regulations for the construction, inspection, and maintenance of these structures, and a program of regular inspections for dams that could endanger lives and property in the event of a failure.’’

Dry landfills are considered by EPA to be less problematic than surface impoundments in terms of leachability and susceptibility for groundwater contamination. Landfills typically have more stringent requirements for liners and groundwater monitoring systems. Landfills also allow more capacity per square foot than surface impoundments and are thus more cost-effective. Because of this, the industry is trending toward more landfill disposition than surface impoundment. At least 12 coal-fired power plants in Pennsylvania have on-site landfills for coal ash disposal.

Beneficial Use

Proponents of coal ash recycling, or beneficial use of coal ash, hesitate to use the term coal combustion waste, as the by-products of coal-fired generation have a surprising number of uses. These include, but are not limited to, use as backfill for abandoned mine reclamation and remining operations, strengthening concrete for structural or road use, and even use as an antiskid material for icy roadways. In fact, the Ronald Reagan Building and International Trade Center in Washington, D.C., which houses EPA offices, was built with concrete containing fly ash.

In Pennsylvania, the vast majority of recycled coal ash is used in mining reclamation. According to DEP, about 14 million tons of coal ash were used in reclamation and remining operations in 2008 and about 20 surface mines have been reclaimed to date. About 1 million tons of coal ash were used for structural fill and an additional 500,000—1 million tons were used for concrete, leaving about 9 million tons of CCR for disposal in residual waste landfills in 2008. The beneficial use of coal ash saves the industry between $220 and $330 million each year compared to the cost of interring coal ash in a landfill.

Beneficial use of coal ash has environmental benefits as well. Most pertinent to Pennsylvania, coal ash can be used to reduce the acidity levels of water discharged from abandoned mines and vastly aids the reclamation process when used as backfill.

DEP is careful to distinguish between beneficial use and disposal and requires that all coal ash used in remining operations improve the stability and compaction of the fill, reduce water infiltration into the mine, and improve the quality of leachate.

Encapsulating coal ash in structures or in concrete also has significant benefits, as it reduces the risk of toxic exposure to CCR constituents. The increased durability and longevity of coal ash composite concrete helps to reduce the carbon footprint of cement production. Using one ton of coal ash instead of traditional concrete conserves enough energy to power a home for 19 days.

EPA draws a distinction between encapsulated (e.g., used in concrete) and unencapsulated (e.g., loose or slurry form) coal ash products and cautions that improper engineering, environmental, and siting assessments can lead to water contamination in hydrogeologically sensitive areas. For example, the Town of Pines in Indiana, which has a relatively shallow groundwater table (about 25–30 feet below the surface), used millions of tons of coal ash in landfills and road construction since 1983 and later discovered high levels of manganese, boron, and molybdenum in the area's drinking water.

Regulation of the beneficial use of coal ash in Pennsylvania falls upon DEP under 25 Pa. Code Chapter 287, which deals with residual waste management. These laws define the policies that help ensure coal ash used beneficially is used responsibly in two steps: first, by conducting a chemical, pH, and leaching analysis of the source ash and, second, by ensuring proper siting that mitigates water pollution and ensures structural stability. Reclamation projects also require a groundwater monitoring plan. In cases where groundwater contamination is detected, mine operators must notify nearby public and private water system owners and implement a DEP-approved abatement plan. Recently, DEP proposed new rule making that would incorporate the key provisions of the policies and procedures that apply to beneficial use of coal ash into more enforceable regulations. In addition to the centralizing and standardizing of the regulations, the changes would increase the parameters and frequency of ash and water monitoring; improve engineering and design requirements; and add Chapter 290 to the Pennsylvania Code, which would deal specifically with the beneficial use of coal ash. These regulations are now in final form.

Federal Coal Ash Regulation

In early May 2010, EPA released a proposed CCR rule with two options for federal regulation—regulation under Subtitle C or Subtitle D of the Resource Conservation and Recovery Act—and invited the public to comment before making a final ruling.

Currently, coal ash is exempt from regulation under the Act, as regulation is left to the states. Subtitle C, which would regulate CCR as a hazardous waste, is viewed as more stringent, although classification under either subtitle would result in significant changes to the regulatory landscape in regard to the coal industry.

In September 2010, EPA held public hearings in Louisville, Ky., and Pittsburgh on the proposed federal regulations regarding CCR. EPA received input from a variety of sources, including the coal industry, environmental interest groups, and private citizens. While most of the environmental group representatives suggested classifying CCR under Subtitle C, the industry groups advocated for locating the new regulations in Subtitle D to avoid the "hazardous waste" designation that accompanies materials classified under Subtitle C. Many of these speakers expressed concern that a hazardous waste designation would hurt businesses that promote beneficial uses of CCR. At the time of this publication, EPA has not yet moved forward with the adoption of the regulations.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

Current Production and Generation

The Pennsylvania Coal Association states that there are approximately 27 billion tons of coal in Pennsylvania. However, a number of factors, such as variability in coal thickness, geographic distribution, and various restrictions in mining, make estimating the amount of recoverable coal resources difficult. EIA data compiled by the National Mining Association (NMA) show that, as of 2008, there were 11.55 billion tons of recoverable coal (i.e., coal that is economically extractable with today's technology) in Pennsylvania.

EIA data show that Pennsylvania produced 65.4 million tons of coal in 2008, making it the fourth leading coal-producing state behind Wyoming, West Virginia, and Kentucky. In 2009, production dropped to 58.1 million tons, its lowest level in more than 100 years, due to the recession and the subsequent lower demand for electricity, according to an April 2010 EIA report. Nevertheless, coal demand is expected to resume its steady rise with the growing demand for electricity. More significant than our recent economic downturn is the enduring and growing appetite for coal in developing nations, which are expected to contribute 94 percent of the 49 percent increase in coal consumption by 2030, according to EIA's *International Energy Outlook 2009*.

Pennsylvania's geology contains the two highest-value coal types mined in the United States: bituminous and anthracite. In terms of heat value and carbon content, the types of coal are ranked (from greatest to least) anthracite, bituminous, subbituminous, and lignite.

Pennsylvania is the only state that produces anthracite in the United States. Anthracite has a higher carbon content (85–96 percent) and lower sulfur content than bituminous coal and thus produces more energy (about 15,000 Btu per pound) and burns more cleanly. According to EIA, Pennsylvania's 66 anthracite mines produced 1.7 million tons of coal in 2008. The applications and thus demand for anthracite, once widely used to heat homes and buildings, have waned significantly in recent decades. Some companies, such as Reading Anthracite (which employs about 500 workers), still market anthracite for industrial use and residential or business heating, though its combustion characteristics prohibit it from wide use in power plants.

Bituminous coal has a lower carbon content (70–80 percent) and higher sulfur content, meaning it produces less energy (about 10,500–15,500 BTu per pound) and burns less cleanly than anthracite. However, its abundance and applications are much greater than anthracite's. In 2008, according to EIA, Pennsylvania's 200 bituminous mines produced more than 63.7 million tons of coal. The vast majority of bituminous coal is used for electricity generation. Bituminous coal also can be used as a coking coal in steel mills.

Pennsylvania coal is shipped to 30 states as well as across international borders. The majority of Pennsylvania coal exports serve the eastern markets in New York, Ohio, and Maryland, but net exports reach as far west as Arizona and Texas. As of 2007, Pennsylvania was a net importer from only six states in the United States. As for international trade, Pennsylvania mineral and ore exports (the majority of which consisted of coal) amounted to $28 billion in revenue in 2009, including $9 billion from exports to Canada, $2 billion from Mexico, and about $1.5 billion from China. In 2008, total international mineral and ore exports from Pennsylvania reached as high as $34 billion.

In spite of the greater productivity of coal mining operations in the Powder River Basin (PRB) in the western United States, Pennsylvania bituminous remains competitive due to its higher energy content and proximity to eastern energy markets. For a period, federal regulations on emissions of SO_2 posed a challenge to the marketability of bituminous coal mined in Southwestern Pennsylvania. PRB coal, as well as coal mined from certain central Appalachian regions in Pennsylvania and West Virginia, has lower sulfur content than much of the bituminous coal in Pennsylvania. The introduction of sulfur-scrubbing technologies, however, has helped power plants to burn higher-sulfur bituminous coal while remaining in compliance with EPA standards. Many scrubbed units burning Pennsylvania bituminous coal emit less SO_2 than unscrubbed units burning PRB coal.

There are currently 40 coal-fired power plants in Pennsylvania, contributing 53.2 percent of the 22 million mWh of electricity generated in 2008. Pennsylvania is ranked second among the states in total electricity generation and fourth in coal-fired electricity generation as of 2009, according to EIA data. According to estimates by the Pennsylvania Public Utility Commission (PUC) in 2007, coal-fired electricity generation was the least expensive in terms of levelized energy cost at 5.7 cents per kWh (or $57 per mWh). In June 2008, Lazard estimated the levelized energy cost of an advanced super-critical pulverized coal plant at $74 per mWh (about 7.4 cents per kWh). According to the Pennsylvania Economy League study, coal set the market price for electricity in the PJM Interconnection area 78 percent of the time in 2008, which resulted in lower prices for electricity throughout the market.

Electricity from coal stands to be the most affected form of energy if carbon legislation is enacted. The added costs of compliance and investment toward development and deployment of carbon management technology would likely be passed along to ratepayers, especially given the post-deregulation utilities market in Pennsylvania. Coal can remain competitive because of its abundance and established infrastructure, but numerous unknowns regarding the stringency and mechanism of carbon legislation merit careful consideration in the coming years. Coal has many important and positive impacts on the region's economy, but the ways in which these benefits are quantified might be affected by some key public health and environmental issues.

Jobs and Economic Output

Historically, coal has provided gainful employment for thousands of Pennsylvanians and sustained hundreds of communities throughout Appalachia. While Pennsylvania has long transitioned its image and main industry away from being a coal mining state, jobs from the coal sector and the industries that support it remain a strong foundation of the region's prosperity. An April 2010 report prepared for Families Organized to Represent the Coal Economy by the Pennsylvania Economy League of Southwestern Pennsylvania found that the coal industry generated 8,724 direct jobs and $3.2 billion in economic output throughout the state of Pennsylvania in 2008. In addition, each direct job creates 3.77 indirect jobs, amounting to nearly 33,000 indirect jobs and a combined economic output of $7.5 billion.

The average annual wage of a direct coal mining job in 2007 was $64,695, up 22 percent from 2002. The average wage for a job in the supporting industries was estimated to be $50,266, up 44 percent since 2002, which is double the rate that the average wages across all industries in the private sector have increased in the same period. Pennsylvania also boasts the largest mining machinery and equipment manufacturing industry in the country, employing 3,166 workers across 24 facilities. Average annual wages for these employees was $60,154 in 2007. The National Mining Association estimates that in 2007, the coal industry generated approximately $750 million in federal, state, and local personal income and payroll tax revenues in Pennsylvania.

Coal-related jobs are becoming more sophisticated and high tech every year. Coal's classically gritty imagery belies the state-of-the-art facets of coal production and utilization that are being practiced and pioneered in the region. South Park, Pa., is home to two of the largest coal research facilities in the nation: NETL and the CONSOL Research and Development facility. Combined, these two labs account for $500 million in coal-related research and development each year. The bulk of this spending comes from NETL. In 2006, NETL released a study indicating that it had brought about 3,180 direct and indirect jobs to Pennsylvania and West Virginia and contributed about $283 million in economic output. NETL also collaborates on research projects with Pitt, Carnegie Mellon, and WVU via the Institute of Advanced Energy Studies.

Thanks to the region's wealth of intellectual and innovative capacity, Pennsylvania is home to some of the safest and most cutting-edge mining techniques in the world. The nature of the work inside a coal mine is nearly unrecognizable when compared to the mining techniques of the early 20th century. Mechanization has helped mines become safer and more productive. However, such technological advances come with challenges as well. Not only has the use of mechanized labor reduced the number of miners needed for any given mining operation, but coal miners now must have the education and qualifications required to operate sophisticated machinery and service coal mining equipment on site. Likewise, as advanced technologies are adopted by coal-fired generation plants and other supporting industries, the demand for workers with technical skills will increase in this sector.

Pennsylvania's coal mining industry also faces the same challenges shared by sectors with aging workforces. Tom Hoffman, CONSOL's former vice president of public relations, commented in a 2004 *HRWire* article that the industry's pool of experienced miners had been exhausted, a problem that would be exacerbated by 2010, when approximately 3,000–4,000 miners were expected to retire. This issue was partially muted by the recession, as many positions can now be filled by previously laid off workers while other workers delay retirement for financial reasons. Nevertheless, the demand for experienced, certified workers to fill positions as supervisors, engineers, and other jobs requiring significant qualifications is expected to rise. This is beneficial, as these jobs pay very well, but the ability of local workforces to meet this need remains in question.

COAL'S CONTINUED EVOLUTION

Improvements in coal technology have aided the industry in addressing environmental challenges in an economically viable fashion. Over the years, regulation and innovation have helped the industry to reduce emissions of NO_X, SO_2, mercury, particulate matter, and other elements while preserving coal's position as the most cost effective energy source for electricity generation. With federal legislation under consideration, CO_2 may be next. There would be two key fronts in achieving CO_2 reductions: carbon management and efficiency. Emerging technology could provide solutions for both facets of carbon reduction, and Pennsylvania is well-positioned to seize upon the economic and environmental opportunities provided by such innovations.

Carbon Capture and Sequestration (CCS)

Enthusiasm and support for CCS as a viable solution for carbon management is quickly gaining critical mass on both the state and federal levels. In February 2010, President Barack Obama announced an interagency task force to study carbon capture techniques and set a goal for 10 commercial deployments of CCS projects by 2016. On the state level, DEP has included the incorporation of CCS technology into its Climate Change Action Plan, while legislative efforts have pushed for inclusion of CCS as a Tier II Alternative Energy Portfolio Standards (AEPS) energy source. Established in 2004, AEPS sets a timetable for slowly ramping up the state's renewable energy mix by 2021.

Technologically, CCS projects are entering into the validation phase. The first U.S. CCS pilot project—American Electric Power's Mountaineer Plant—began construction in 2009 in West Virginia. This facility intends to capture and sequester 100,000 tons of CO_2 per year using a chilled ammonia process for postcombustion capture. The success of this project is an important step toward commercial deployment of CCS.

Southwestern Pennsylvania has the potential to continue the development of CCS. Pennsylvania's Department of Conservation and Natural Resources assessments identified ''huge geologic sequestration'' opportunities where CO_2 from power plants can be safely stored, particularly in Western Pennsylvania. These include deep saline formations, depleted and producing oil and gas fields, organic-rich Devonian-age shales, and unmineable coal beds. Most significant are the deep saline formations, which constitute about 85 percent of the potential CO_2 storage capacity and could accommodate Pennsylvania's total CO_2 emissions from all sources for about 300 years. A CCS project in Pennsylvania could avoid some of the complexities of private land and mineral rights leasing by taking advantage of its approximately 4.8 million acres of publicly owned land (primarily state forests and game lands). The state has ''fee simple ownership'' of about 85 percent of this land, which includes mineral rights. As home to NETL, the CONSOL Energy research facility, and several universities, Southwestern Pennsylvania also has the potential to serve as a center for ongoing technological research, development, and innovation as well as a recipient of federal funding. Furthermore, Pennsylvania's manufacturing base would benefit by helping to build the pipelines and infrastructure for transporting CO_2 as well as other components required for CCS.

In spite of the wealth of opportunities in Pennsylvania, significant obstacles remain. Most compelling is the timetable for reaching commercial viability of CCS. Estimates for deployability of utility-scale CCS projects range widely from five to 20 years while progress toward carbon policy continues to inch closer. While the coal industry is supporting provisions that will delay carbon mandates until CCS has been deployed, taking action to commercialize CCS as soon as possible remains critical.

In contrast to the need for quick and decisive action to commercialize the technology is the importance of laying the regulatory and legislative groundwork for sustainable and responsible deployment of CCS in the state. The challenges include determining policy for property and access rights; transportation; federal compliance with underground injection regulations; transportation and pipeline infrastructure; and, perhaps, most importantly, long-term liability and environmental stewardship.

Concerns over liability and environmental impacts go hand in hand with the public perception of CCS. A survey of the public perception of CCS conducted by Greenpeace showed that a number of respondents expressed concern over possible leakage and ecosystem impacts from CCS as well as the untested nature of the technology. Also, while many environmental groups support CCS as a solution to climate change, a number of groups question its long-term viability in solving an enduring host of environmental and public health challenges still posed by fossil fuel reliance. CCS can be perceived as detrimental in the following ways:

- Expenditures toward relatively unproven technology undermine investment in renewable energy sources.
- CCS may not become commercially deployed in time to meet carbon reduction goals.
- Operation of CCS technology places increased demands on already precious energy and water resources.
- Risks of failure and leakage may inhibit or negate carbon reduction efforts.

The prevailing environmental concerns over CCS are the unknown potential for and impacts of leakage. While proponents of CCS indicate that the probability of leakage is slight due the rock layers, a mile or more thick, separating injected CO_2 from groundwater and the surface, public wariness endures. Leakage of CO_2 may impact pH levels of aquatic ecosystems and soils, contaminate water supplies by mobilizing heavy metals, and perhaps threaten human health if concentrations become high enough, according to detractors of CCS.

The oldest carbon sequestration facility is located in Norway, where 1 million tons of CO_2 have been injected annually into a geological formation about 1,000 meters below the seabed since 1996. A recent environmental assessment found no incidences of leakage or tectonic activity. Still, as injected carbon is intended to be sequestered in perpetuity, the successes in Norway do not wholly eradicate lingering doubts. In addition, CO_2 injection into geologic formations has been practiced extensively in the United States and elsewhere for stimulation of petroleum production in a process known as enhanced oil recovery.

In summary, the potential for CCS development in Pennsylvania appears to be strong, but laying the necessary legislative groundwork and gaining public acceptance are significant challenges that will have to be addressed.

High-efficiency Coal Power Plants

Efficiency also is a vital factor in the carbon equation that can be pursued concurrently with CCS. By reducing the amount of coal that is burned per megawatt hour of produced electricity generated, the amount of CO_2 emitted is likewise decreased. There are a number of emerging and commercially viable technologies available today that would allow cleaner, more efficient generation of electricity from coal. However, few of them have been put to use in Pennsylvania, as many of the plants in operation today were built decades ago. It is no coincidence that Environment America's list of 100 dirtiest power plants in 2007 (a list that measured total tons of CO_2 emitted in 2007) included only a handful of plants built in the past three decades. The vast number of the plants included on the list were built prior to the 1980s, including seven Pennsylvania plants—Bruce Mansfield, Homer City, Conemaugh, Keystone, Hatfield's Ferry, Brunner Island, and Montour, which were commissioned in 1975, 1969, 1970, 1967, 1969, 1961, and 1971, respectively.

The most common type of coal-fired power plant in the United States uses pulverized coal (PC) technology. In a PC plant, coal is crushed into a fine powder and then combusted in a boiler, which creates steam to turn a turbine. PC plants are classified as subcritical, supercritical, or ultra supercritical according to

SOURCE	INSTALLED CAPACITY (MW)	CO_2 EMITTED (TONS)	CO_2 PER kWh (POUNDS)	YEAR PLANT BEGAN OPERATION
Bruce Mansfield Plant	**2,460**	**17,387,361**	**2.24**	**1975**
Homer City Generating Station	**1,884**	**13,576,987**	**2.29**	**1969**
Conemaugh Generating Station	**1,700**	**12,124,919**	**2.26**	**1970**
Keystone Generating Station	**1,711**	**11,898,614**	**2.21**	**1967**
Hatfield's Ferry Power Station	**1,710**	**10,173,499**	**1.89**	**1969**
Brunner Island	**1,483**	**9,380,958**	**2.01**	**1961**
Montour	**1,522**	**9,252,615**	**1.93**	**1971**
Statewide (All Plant Types)	**49,296**	**135,654,583**	**1.24**	**—**

Sources: *Environment America*, November 2009, "America's Biggest Polluters: Carbon Dioxide Emissions from Power Plants in 2007"; www.firstenergycorp.com; www.edison.com; www.pseg.com; www.alleghenyenergy.com; www.pplweb.com; www.epa.gov
Notes: For individual plants, CO_2 emission totals are from 2007 and a capacity factor of 72 percent (national average for coal, per EPA) was presumed. Statewide data represent CO_2 emissions from 2005, per EPA data, and include all generation technologies (most significantly, 76,289 gWh of output from nuclear plants).

the pressure level and temperature of the steam cycle. The majority of existing coal-fired plants in Pennsylvania are subcritical PC plants, which have an average thermal efficiency of about 30–35 percent. A supercritical PC (SCPC) plant built today could have an efficiency level of up to 40 percent, while an ultra supercritical plant built today could have an efficiency level of up to 45 percent. SCPC plants are already commercially viable in the United States, while development of ultra supercritical PC technology is occurring mostly in Europe and Asia.

Integrated gasification combined cycle (IGCC) is another high-efficiency coal generation technology that is reaching commercial validation worldwide. In an IGCC plant, coal is first converted into gas, which is combusted in a gas turbine to generate electricity. A second (steam) turbine, which is powered by the product heat from the gas turbine, is used to generate additional electricity. IGCC yields an energy efficiency of 40–50 percent and, with additional processing equipment, can segregate a CO_2 stream, which is easier to capture than the CO_2 in the flue gas from a typical PC plant.

In addition to the greater efficiency of a newer IGCC or SCPC plant, the costs of retrofitting an older plant with carbon capture technology are significantly greater than outfitting an IGCC or SCPC plant with a carbon capture system. The Levelized Cost of Energy Analysis presented by Lazard in June 2008 estimated that the busbar cost of a new SCPC plant would be \$74–\$135 per mWh, while the busbar cost of a new IGCC plant would be \$104–\$134. The high-end range of these estimates reflects the costs of incorporating CCS technology.

Near-zero Emissions Coal Power

The much-coveted and logical technological goal is a marriage between higher efficiency and CCS for a facility that emits drastically less carbon and very few pollutants. An advanced coal-powered plant equipped with carbon capture could capture about 90 percent of CO_2 emissions, thus emitting about 15 percent of the CO_2 of a comparable coal-fired plant without carbon capturing abilities.

The possibility of a near-zero emissions coal power plant has sparked a number of worldwide initiatives, with nations competing to be the first to create a commercially viable electricity-generating station that incorporates the latest clean coal technology. Until recently, the most promising U.S. project along these lines was FutureGen Alliance, Inc., a public-private partnership between DOE and leaders in the coal industry, including Pittsburgh's CONSOL Energy. The site of FutureGen was chosen in 2007, and construction was expected to begin in Mattoon, Ill., in 2009. However, fluctuating projected costs caused DOE to waver in its financial backing of the project, and the future of the plant remains uncertain.

The promise of a near-zero emissions coal plant combining IGCC and CCS technology has been reignited within Pennsylvania in the Good Spring IGCC plant, which is planned for construction in Schuylkill County in eastern Pennsylvania. Forged as a partnership between the Chinese Thermal Power Research Institute—the technology provider for the GreenGen plant, which was slated to come online in China in 2011—and Texas-based Future Fuels LLC, the Good Spring IGCC plant is important because it seeks to embody all of Pennsylvania's unique advantages while addressing many of the challenges faced by the coal industry worldwide. The Good Spring plant will burn the higher energy grade anthracite coal from a nearby mine (all other IGCC projects are fueled by bituminous coal) and deliver electricity to the Pennsylvania/New Jersey/Maryland market. The plant's strategic location will introduce significant cost savings which will help offset the costs of capturing the CO_2, which will be injected into nearby geologic reservoirs. The plant also will satisfy AEPS requirements, as IGCC is included as a Tier II energy source. The \$1 billion project is expected to provide 1,000 construction jobs with more than 200 permanent jobs after completion. The plant will initially provide 150 mW of electricity and capture 50 percent of its carbon emissions, and it intends to expand to 270 mW with 100 percent carbon capture by 2020. The successful deployment of the Good Spring IGCC plant would not only mark the first utility-scale CCS and IGCC plant in the country but also would demonstrate the potential of Pennsylvania as a clean coal epicenter.

Nearer Term Solutions

While big-ticket high-stakes solutions such as near-zero emissions coal plants represent an ambitious goal for the region, it's equally important to consider nearer term solutions that address carbon emissions, fuel efficiency, and energy independence. The cumulative effects of smaller steps toward cleaner coal electricity and innovative uses of coal can amount to significant environmental and economic benefits in the nearer future and be rolled into the larger picture of coal's long-term evolution.

Cofiring options are highlighted in DEP's Climate Change Action Plan as bridge solutions that will help the region meet its environmental goals while other technologies develop toward commercial viability. Biomass cofiring is deployable in many existing PC coal power plants and can immediately offset carbon emissions by 3.3 million tons with only 3 percent cofiring of the current capacity. National Renewable Energy Laboratory (NREL) studies indicate that 15 percent of biomass cofiring could lead to a reduction of 18 percent in CO_2 emissions. Cofiring also would bolster alternative biomass fuel markets. Cofiring coal with natural gas also can provide environmental benefits by reducing CO_2 as well as SO_2 and NO_X. Cofiring coal with 20 percent natural gas would reduce CO_2 emissions by up to 10 percent, or 9.5 million tons, per year. The expected abundance of natural gas due to Marcellus Shale development also would help control seasonal fuel prices. Another source of natural gas is coal bed methane, which has long been harvested by local energy companies such as CONSOL Energy's CNX subsidiary and EQT Corporation. Capturing the methane—which has 23 times the heat-trapping ability of CO_2—also has environmental benefits, as coal mining contributes about 10 percent to the nation's methane emissions.

Powering vehicles also is an area where the coal industry can benefit. Electric cars that are powered by the grid would be served directly by existing coal-fired electricity plants and would help wean the nation away from foreign petroleum-based fuels. As cleaner coal generation comes online, the environmental benefits would subsequently be passed on to the transportation sector, which looms as another leading contributor to pollution and CO_2 emissions.

Coal-to-liquids technology also has been presented by the industry as an opportunity for economic growth and increased energy independence. In Ohio, Baard Energy is moving forward with its $6 billion Ohio River Clean Fuels plant, which will produce 53,000 barrels of liquid coal fuel per day, including diesel, jet fuel, and naphtha. Opposition to the plant has been mounted by the Sierra Club and the National Resources Defense Council, which have appealed the plant's state air, water quality, and water discharge permits. The Sierra Club claims that without carbon capture technology, coal-to-liquids plants release twice as much greenhouse gases as conventional gasoline does. Baard Energy stated that the carbon from the plant would be captured and used for enhanced oil recovery or sequestered. Opponents of the plant's air emissions permit protested that the draft permit did not legally bind Baard Energy to capture its CO_2 emissions. However, the Ohio EPA ultimately approved the air permit, determining that it did not have the authority to regulate the plant's CO_2 emissions and that the expected emissions would not threaten public health.

A similar coal-to-liquids plant was proposed in Pennsylvania in Schuylkill County by Waste Management and Processors, Inc. However, this project appears to be inactive due to financing difficulties.

SUMMARY

Like coal's leading role in Pennsylvania's early and current prosperity, coal's significance in Pennsylvania's future is likely to continue. Time and time again, coal has proven itself to be both a vital and versatile asset, capable of substantially enriching the region. However, Pennsylvania also bears scars from the negative side of coal extraction history, and the state at times failed to address environmental concerns as they emerged. While the next challenge on the horizon for coal is likely to revolve around carbon emissions and climate change, it's also important to continue striving for progress on more familiar issues. In order for the region to have balanced coal development, policymakers, environmental organizations, industry leaders, state and federal regulators, and community members will have to work together to foster sustainable growth in the coal industry that will simultaneously protect the environment and strengthen the region.

II. NATURAL GAS

Natural Gas Industry Quick Facts

- Estimated recoverable gas in the Marcellus Shale formation: **489 TCf ($500 billion in potential revenue)**
- Estimated annual gas consumption for Pennsylvania and bordering states: **Nine BCf**
- Estimated jobs created by Pennsylvania's gas industry by 2020: **174,700**
- Gas drilling jobs currently filled by local workers: **about 20 percent**
- 2008 electricity output: **5.9 million mWh (8.5 percent of state total)**
- 2009 installed capacity: **10,915 mW (22 percent of state total)**
- Busbar cost for a new electricity plant: **$73–$100 (combined cycle); $221–$334 (peaking)**
- CO_2 emissions: **117,000 pounds per billion Btu (about half that of coal)**
- Operating Marcellus wells subjected to the personal income tax rate (3.07 percent) rather than the corporate net income tax rate (9.99 percent): **1,062 (70 percent)**
- State forest land under lease agreement with gas drillers: **724,000 acres (about 33 percent)**
- Water used in a typical frack job: **3–5 million gallons per well**
- Proportion of water versus chemical additives in fracturing fluid: **98–99.5 percent**
- Produced water per well: **20–80 percent of volume injected**
- Level of total dissolved solids (TDS) in produced water: **two to seven times higher than seawater**

Section Overview

- Pennsylvania overlies one of the largest unconventional natural gas reserves in the world: the Marcellus Shale formation. The advent of horizontal drilling and hydraulic fracturing allows natural gas developers to access this resource, promising ample supply and stable prices for a historically unpredictable commodity.
- Natural gas has about half the emissions of coal per Btu, giving it excellent potential as a ''bridge fuel'' toward a cleaner energy economy and greater energy independence.
- Natural gas, which can be used as an industrial feedstock, also could potentially reinvigorate the state's manufacturing sector.
- Pennsylvania is the only gas-producing state without a severance tax, although legislation to authorize such a tax was brought up in the 2009-10 session. A major point of discussion was the division of the proceeds between state and local governments, should such a tax be implemented.
- Leasing agreements and royalties can garner significant income for private landowners.
- The Barnett Shale play in Texas is a representative precursor to the Marcellus formation. In 2007, the Barnett Shale yielded $10.1 billion in statewide economic output, including $212.1 million in severance taxes and just less than 100,000 jobs.
- Fracturing flowback, or produced water, has problematically high TDS levels, which makes disposal in local water processing facilities infeasible. Currently, most produced water is deep well injected out of state. Produced water recycling and reuse—which is already in practice on many sites—poses the most viable solution.
- Increased truck traffic, drilling equipment, and condensate tanks contribute to heavy local air pollution. Permitting and regulation of aggregate emissions may help mitigate degradation of public and environmental health.
- Public concern has arisen over possible threats to drinking water supplies caused by contamination from fracturing fluids or wastewater. While previous studies have found no cases of contamination, EPA has launched a new investigation that will be completed in 2012.
- Pennsylvania does not currently have ''forced pooling'' laws, which would compel landowners without gas leases to allow gas developers to drill beneath their land. Legislation enacting a legal framework to address such practices is expected soon.
- Incidences such as well blowouts, explosions, improper disposal of wastewater, and natural gas migration highlight potential dangers posed by irresponsible drilling practices. DEP has imposed fines and penalties against offending companies.

Natural gas has potential as a bridge fuel toward a cleaner energy economy. With its wide range of uses and about half the emissions of coal per Btu, natural gas can be used as a replacement in many applications, including vehicles, heating, industrial feedstock, and electricity generation, for an immediate environmental benefit. Historically, natural gas has been subjected to wildly fluctuating prices due to unpredictable supply and demand, which placed a great strain on the industries that relied upon its use. As a solution, a number of liquefied natural gas terminals were proposed in order to allow greater importing of natural gas. The discovery of vast recoverable domestic natural gas resources have obviated this need, and now some suspect that the nation may even become a net exporter of natural gas. In essence, the greatest detriment to natural gas—its uncertainty in supply and pricing—mostly has been solved by unconventional shale plays in the United States.

THE MARCELLUS SHALE FORMATION

Beneath Pennsylvania lies one of the largest unconventional natural gas reserves in the world: the Marcellus Shale formation. This makes the region a logical source of wealth and opportunity in the context of the global shift toward natural gas. Estimates regarding the extent of recoverable reserves within the shale formation vary widely but unanimously point toward unprecedented potential. Initial assessments given by the U.S. Geological Survey in 2002 estimated that the deposit contained 1.9 trillion cubic feet of natural gas, with more recent estimates placing the potential at about 489 trillion cubic feet and about $500 billion in potential revenue. (Revenue estimates, however, are sensitive to price fluctuations in natural gas and continued exploration of the deposit.)

Although the Marcellus Shale deposit has existed for millions of years, it has been largely inaccessible. Known as an unconventional gas play, the Marcellus formation is a tightly layered, impermeable shale containing natural gas that is only recoverable if there is a fracture in the deposit. These fractures sometimes occur naturally, but hydraulic fracturing (commonly referred to as fracking or hydrofracking) allows gas drillers to break through the shale and tap into previously unrecoverable gas reserves. This technique is coupled with the practice of horizontal drilling, which allows drillers to drill multiple wells from a single well pad as well as access gas deposits nearly a mile away without disturbing the overlying geography. This is particularly advantageous in Pennsylvania, parts of which are more densely populated than typical gas field locations. The advent of horizontal fracking has opened up numerous opportunities in gas drilling but also has introduced several pressing concerns involving economic, environmental, and community impacts.

Looking Ahead to the Utica Shale

While much of the recent attention has been devoted to developments in the Marcellus Shale formation, the industry already is looking ahead toward development of the Utica Shale, which lies about 4,000 feet beneath the Marcellus formation. The Utica Shale has a similar distribution and geology as the Marcellus Shale and underlies much of Pennsylvania and New York, extending into Canada and West Virginia as well.

S. Dennis Holbrook, a spokesman for Norse Energy, stated in a June 2010 article appearing in the *Ithaca Journal* that his company expects the Utica Shale ‘‘to be every bit as significant as the Marcellus.’’ Commercial exploration of the Utica Shale is still underway. Gastem, a Canada-based company, has drilled an exploratory vertical well into the Utica Shale in Quebec and has reported that the well ‘‘largely exceeded our expectations, and we are accelerating our programs.’’ A Reuters article from July 2010 reported that Andrew Potter, an analyst with the Canadian Imperial Bank of Commerce, stated that 50 trillion cubic feet of recoverable gas was a reasonable estimate for the Quebec portion of the formation.

Meanwhile, Range Resources Corporation indicated in a Q1 2010 earnings call that it had drilled and tested a horizontal Utica well in Pennsylvania, making it the first to do so in the Appalachian Basin. Range Resources officials said they would keep the results ‘‘confidential for a while due to competitive reasons.’’

In 2008, EQT Corporation drilled a vertical well into the Utica Shale in West Virginia but has since put its Utica activities on hold while it developed other frack jobs, according to a Q3 2008 earnings call.

Development of the Utica Shale presents an additional set of opportunities and challenges. Established Marcellus Shale developers easily will be able to tap Utica Shale reserves using the same infrastructure, crew, and equipment. However, opportunities in other states and in Canada as well as differences in geology and regulatory climate may make drilling outside Pennsylvania equally or more attractive to gas developers.

ENVIRONMENTAL IMPACTS AND PUBLIC HEALTH

The economic opportunities presented by the Marcellus Shale formation go hand in hand with a new and challenging set of environmental issues. Some of the concerns regarding the potential for public health and environmental impacts have been broached before in other shale plays, while some are unique to this region and its fundamentally different geologic, regulatory, political, and social landscapes. Lessons certainly can be learned from gas plays around the nation, but solutions to Pennsylvania’s specific environmental challenges will require original thought, research, and discussion.

Regulation of Natural Gas Drilling

The primary regulator of natural gas drilling activity in Pennsylvania is DEP, which handles permitting, well site inspection, and regulation of wastewater, among other aspects of drilling. Additional regulatory duties are shared with the Pennsylvania Fish and Boat Commission as well as the U.S. Fish and Wildlife Service, the Delaware River Basin Commission, the Susquehanna River Basin Commission, and county conservation districts.

As part of the permitting process through DEP, gas drillers must report details regarding well locations, water withdrawal, erosion control measures, and plans for storing and treating wastewater. Between 1999 and 2008, the number of oil and gas well permit applications increased from 2,000 to 8,000, according to the

Pennsylvania Budget and Policy Center. DEP has increased permitting fees and has been hiring new inspectors steadily to help with the increasing regulatory demands as the industry ramps up.

Water Withdrawals

Hydraulic fracturing of each well requires approximately 5 million gallons of freshwater. The industry compares the water consumption of a drilling operation favorably to the consumption of other water uses, such as golf course irrigation and electricity generation. Even so, the cumulative water consumption of thousands of drilling sites (water which often is removed permanently from the water cycle) is far from negligible. DEP, the Susquehanna River Basin Commission, and the Delaware River Basin Commission carefully monitor water withdrawals to mitigate impacts on water supplies and aquatic environments. These agencies have the authority to order drillers to halt withdrawal or draw from a different source to prevent drought conditions.

However, conservation groups, such as Trout Unlimited, have shown continued concern for the impacts on aquatic habitats and have urged stricter permitting criteria, monitoring, and analysis of water withdrawals. Seasonal withdrawals might impact flow rates downstream, which might negatively impact the quantity and quality of water beyond the point of sustainability.

Fracturing Fluid and Produced Water

In order to aid the fracturing process, chemical additives and proppant (typically sand) are mixed into the water prior to injection. These chemicals are necessary for resisting corrosion, dissolving minerals to initiate cracks, minimizing friction, and eliminating bacteria and other biological buildups that may damage the equipment. The chemical makeup varies for each fracture job depending on the geology of the site.

Much public consternation has arisen from confusion over disclosure policies regarding the chemical constituents of hydraulic fracturing fluid. It is widely believed that the chemicals used in fracturing fluids are a closely guarded trade secret to which regulators, emergency responders, and the public are not privy. In Pennsylvania, at least, this is not true. Pursuant to the Pollution Prevention and Contingency Plan that must be submitted as part of the permitting process, drillers are required to disclose the chemicals in use at each site. A summary of hydraulic fracturing fluids used in the state is provided on the DEP Web site. This document lists product vendors, hazardous components, concentration of each listed element in the fracturing fluid, and the EPA's risk-base concentrations (if applicable). Overall, the ratio of chemicals to water is relatively small. A study from the GroundWater Protection Council (GWPC) found that hydraulic fracturing fluids used in the Fayetteville Shale were typically between 98 and 99.5 percent water by volume.

The water that returns to the surface during and after the fracturing process (called flowback or produced water) is more problematic for the industry and water management officials. At a typical site, about 20–80 percent of the injected water returns to the surface as produced water. The water picks up various minerals and salts during its time in the subsurface and has an extremely high level of TDS. When compared to saltwater, produced water from hydraulic fracturing can have between two and seven times as much TDS. There also are a number of constituents present in produced water that may pose human health risks.

Federal Hydraulic Fracturing Regulation

The Energy Policy Act of 2005 exempted the practice of hydraulic fracturing from the Safe Drinking Water Act, leaving regulation of hydraulic fracturing up to the states. But now, deployment of this technology in relatively novel applications has broached the question of whether states have the proper resources to protect the environment and public health. The Fracturing Responsibility and Awareness of Chemicals Act introduced in Congress seeks to impose federal regulations for disclosure of fracturing fluid constituents, oversight of produced water disposal, and groundwater protection. How such legislation would impact a varied and diverse industry operating in equally heterogenic geological and sociopolitical landscapes also is a key area of discussion.

Produced Water Management

Water withdrawals, truck traffic, and disposal of millions of gallons of waste carry significant costs, both in terms of dollar figures and environmental impacts. As such, it is mutually beneficial for all parties to devise an efficient and cost-effective method for sustainably reducing, treating, or reusing fracturing fluid and produced water.

There are three typical options for produced water management: treatment and discharge, disposal in Class II injection wells, and on-site recycling.

While the commonwealth's wastewater treatment facilities are capable of handling the chemical additives in fracturing fluid, they currently are not equipped to remove TDS. Water supply facilities also have very limited capacity in terms of removing TDS in the intake process. Maintaining appropriate TDS levels in rivers, streams, and other waterways is critical, then, to both water users and the environment. Dramatic TDS increases can lead to fish kills and damage aquatic habitats. Also, numerous commercial facilities draw water directly from the rivers for industrial purposes. High levels of TDS can cause corrosion and scaling in industrial equipment, causing thousands of dollars worth of damage. Such incidences—while not wholly attributable to natural gas development—led to the DEP investigation of elevated TDS in the Monongahela River in 2008. Because of these issues, treatment at a wastewater treatment plant is not seen as a viable solution at this time. However, other treatment technologies are under consideration by the gas industry.

In lieu of treatment, much of the produced water is disposed of in Class II injection wells. There are only eight Class II underground injection control disposal wells in Pennsylvania; thus, gas producers often transport produced water across state lines at a significant cost. Increased truck traffic also introduces greater strain on roadways that extends far beyond the locality of the drill site. For these reasons, continued deep well injection also is not an ideal long-term solution for handling produced water in Pennsylvania at this time.

Recycling and reuse of produced water has a number of benefits and is widely practiced by gas developers. By reusing produced water, the amount of water consumed, amount of wastewater created, and the number of truck trips made are reduced, as are the economic and environmental costs. However, current technology allows only a certain percentage of the produced water to be reused. Devising technological innovations and processes that will allow greater reuse and recycling is a critical area of research and development.

DOE is providing millions of dollars in funding through NETL for several projects seeking solutions for fracturing fluid recycling. One project, headed by Kelvin Gregory of Carnegie Mellon and Radisav Vidic and Eric Beckman of Pitt, is looking into ways to use abandoned mine drainage in conjunction with recycled produced water, while another project with WVU seeks to develop an on-site multimedia filtration system that would allow reuse of fracking fluid and reduce water use by 30–50 percent. Success in these research projects likely will benefit both regional gas development as well as future drilling operations nationwide.

Another solution to the issue of produced water is seeking an alternative to the hydraulic fracturing process. In Kentucky, EQT uses air fracturing along with horizontal drilling. However, due to the tighter formation in the Marcellus Shale, this is not currently a viable option in Pennsylvania. Draft regulations for New York's gas well issuance guidelines outline a few other possibilities:

- Liquid CO_2, which has been used for demonstration purposes in the United States but has not been deployed commercially; it also may create a market for captured carbon from coal-fired plants
- Nitrogen-based foam alternative, which previously was used in vertical shale wells in the Appalachian Basin but is currently unable to carry sufficient proppant
- Liquified petroleum gas; in limited use in Canada, it has higher viscosity and can be separated from natural gas and recycled.

Drinking Water

The combination of drilling deep below underground drinking water sources and injecting millions of gallons of fracturing fluid leads many to the logical concern for drinking water quality. There are three primary fears: possible migration or leakage of fluid during the fracturing process, leaching or spilling of on-site impoundments for fracture fluid, and discharging of produced water.

To date, EPA has not reported any cases of drinking water contamination from routine hydraulic fracturing activity. The industry, as well as a study by GWPC, rationalizes that because the fluids are injected nearly a mile below groundwater tables, the probability for contamination is extremely low. GWPC bases its finding on an earlier EPA inquiry into hydraulic fracturing used in coal bed methane extraction. As the Marcellus formation is significantly deeper than coal beds, the risk is said to be even slighter. A new study into the water contamination risks in connection with hydraulic fracturing is underway by EPA and is expected to be complete in 2012. Meanwhile, the state's well and casing regulations play an important role in protecting groundwater. In Pennsylvania, DEP requires drillers to case and grout wells through all freshwater aquifers prior to drilling through deeper zones. The casing and cement serve to protect groundwater from mixing with fluids and natural gas from inside the well as well as water and other material from the surface.

Accidents, misconduct, and unintended leaching from impoundment pits pose a greater risk of water contamination than routine operation of hydraulic fracturing. Several instances in which wastewater or fracturing fluid may have come in contact with drinking water supplies or the environment have been reported. In September 2009, three fracturing fluid spills, which polluted a stream and a wetland, were reported near Dimock Township in a single week. In October 2009, an aboveground water transfer line connection failed, spilling partially recycled flowback water into a creek. In March 2010, a hole in a pit liner caused drilling liquid to seep into groundwater near Dimock Township. The impacts of many of these incidences are still under investigation.

The direct discharge of produced water, as discussed above, currently is not permitted. The state recently approved revisions to Chapter 95, enacting more stringent requirements regarding TDS from gas drilling operations.

While the specific health risks involved with water contamination from fracturing fluid or produced water have not been fully researched, there are a few signature elements that have known health effects:

- Chloride: affects metabolism
- Hydrogen sulfate: causes diarrhea
- Bromide: causes neurological, dermatological, and gastrointestinal complications
- Strontium: impairs bone growth and causes anemia or cancer
- Barium: causes gastrointestinal disturbances, hypertension, and heart rhythm abnormalities
- Manganese: affects the nervous system

Adverse health effects for many of the above substances are manifested only when exposure is at high levels or of chronic toxicity. Nevertheless, these are important to consider when testing water supplies.

Technologically enhanced naturally occurring radioactive materials (TENORM) also can be present in produced water. This issue has been studied by EPA in connection with enhanced oil and gas recovery. EPA estimates that radiation levels can be as low as 0.1 picocurie (pCi) per liter or as high as 9,000 pCi per liter and states that, when properly diluted or disposed, produced water containing TENORM does not pose additional radiological risks. However, given the vast quantities of produced water and geological differences in the Marcellus formation, the potential for exposure risks merits further research.

Agriculture and Livestock

While the chance of fracturing fluid coming into direct contact with public drinking water systems is rare, contamination of drinking water sources for livestock poses a more immediate threat. In July 2010, the Pennsylvania Department of Agriculture quarantined 27 head of cattle at a farm in Tioga County after the animals came into contact with wastewater leaked from a natural gas well operated by East Resources. The animals reportedly had access to the wastewater—which was found to contain chloride, iron, sulfate, barium, magnesium, manganese, potassium, sodium, strontium, and calcium—for a minimum of three days. Strontium was the main element of concern, as it can be toxic to humans, especially children. Because strontium takes a long time to pass through an animal's system, it may still be present in meat produced from contaminated cattle as well as their offspring.

Given the importance of Pennsylvania's agricultural industry, an examination of the possible impacts of natural gas development on food produced in the region is highly prudent.

Air Quality

Natural gas often is cited as the cleanest burning fossil fuel, with most estimates stating that natural gas has 60 percent lower carbon emissions than coal and 30 percent lower carbon emissions than oil. EPA states that, compared to coal-fired power generation, natural gas produces half as much CO_2, less than a third as much nitrogen oxides, and only 1 percent of all sulfur oxides. Notably, EIA data show that natural gas produces a minuscule fraction of the particulate by-product of coal. As such, gas doesn't have a solid by-product equivalent in volume or environmental impact to coal ash.

In spite of these benefits, natural gas often is viewed more as a bridge fuel toward a low carbon fuel economy rather than a permanent replacement for coal and oil. While its environmental footprint is relatively smaller than other fossil fuels, its effect on the atmosphere is still significant. It should not be overlooked that natural gas—which is composed mostly of methane—is itself a greenhouse gas. According to EPA, methane is more than 20 times more effective in trapping heat in the atmosphere than CO_2 over a 100-year period. Among human-related sources of methane, natural gas systems ranks third, contributing 96.4 teragrams of CO_2 equivalent.

But whereas natural gas in a power plant setting burns more cleanly than coal, the air emissions involved in natural gas drilling and production are both significant and difficult to measure. Unlike the emissions from large, centralized facilities, air emissions from gas development come from thousands of different sources and locations, which makes permitting and monitoring aggregate emissions difficult. Compressor engines, condensate tanks, truck traffic, on-site natural gas processing equipment, and fugitive emissions all contribute heavily to air pollution.

A study conducted by the Department of Environmental and Civil Engineering at Southern Methodist University in Dallas, Texas, found emissions of smog-forming compounds from oil and gas production in the Dallas-Forth Worth area averaged 191 tons per day, peaking at 307 tons per day in the summer (by comparison, vehicle emissions in the area were estimated at 273 tons per day). Emissions of toxic air compounds—such as benzene and formaldehyde—averaged six tons per day (peaking at 17 tons per day in the summer), while greenhouse gas emissions were estimated at 33,000 equivalent tons per day.

Possible emissions solutions posited by the Southern Methodist University study included replacing compressor engines with electric motors, incorporating closed flares and vapor recovery units into condensate tanks, and replacing natural gas-actuated pneumatic valves with units actuated by compressed air.

Air quality impacts from drilling activity have been observed most clearly in Dish, Texas, a small town of about 180 with no other facilities nearby that contribute significantly to air pollution. Residents of Dish have reported acute effects of the increased air pollution, such as severe headaches, nausea, chronic eye irritation, and respiratory problems. The Texas Commission on Environmental Quality conducted air quality studies and found two sites with elevated levels of carcinogens such as benzyne, neurotoxins such as xylene and carbon disulfide, and other pollutants.

Sublette County in Wyoming, which covers 4,883 square miles and has a population of about 6,000, has experienced ground-level ozone on the magnitude typically seen in metropolitan areas. The 4,000 gas drilling sites in the area may have contributed to the uncommon levels of ozone for such a sparsely populated area. The Wyoming Department of Environmental Quality is conducting ongoing studies into the sources and public health impacts related to the expansion of natural gas drilling in the area. The most recent report indicates no increased health threat as a result of the ozone levels. However, some believe the report did not go far enough because it did not measure the compounded effects of several different pollutants; it looked at the effect of each pollutant individually. A discussion of the findings was expected to be presented by the Sublette County Commissioners at a public meeting on March 31, 2011.

Natural Gas Processing

When extracted at the wellhead, raw natural gas is mixed with a number of other hydrocarbons, principally ethane, propane, butane, and pentanes, in addition to water vapor, hydrogen sulfide, CO_2, nitrogen, helium, and other compounds. Natural gas must be processed to remove these elements so it meets the minimum quality standards required for transportation in major pipelines. Many of these elements—such as butane, propane, isobutane, and other natural gas liquids—are marketable by-products.

Processing is done both at the wellhead and at a central processing facility. Water and condensate are typically removed from raw natural gas at the wellhead, and the former is stored temporarily in on-site condensate tanks. These condensate tanks are highly flammable and may emit toxic vapors containing benzene, toluene, and xylene. Such vapors are heavier than air and can accumulate in low-lying areas, which may be particularly problematic in Pennsylvania, with its hilly topography.

The natural gas then is purified further at a processing plant, where it is ''sweetened'' by having its sulfur content removed. There are a number of gas sweetening methods, though the amine process is the most widely used. Amine gas treating produces acid waste gas, which either can be recovered and used as a feedstock in a nearby sulfur recovery or sulfuric acid plant or flared. If amine waste gas is flared, it releases SO_2, which is a contributor to acid rain. Natural gas processing plants also emit methane and hydrocarbons into the atmosphere.

Land Impacts

Horizontal drilling allows as many as 10 lateral wells to be drilled from the same well pad, significantly reducing the overall footprint and habitat disruption. Drilling operators are required to reclaim the land within nine months after the well has stopped producing. However, as noted in the testimony of Howard M. Neukrug on behalf of the Philadelphia Water Department's Office of Watersheds before the Pennsylvania House of Representatives Environmental Resources and Energy Committee in March 2009, state regulations do not require restoration of a site that was once forested back to its predrilling state. Neukrug indicated forest regrowth would be limited, as the absorbing capacity of the soil is altered and reduced as a result of soil compaction from heavy construction equipment and truck traffic.

The Pennsylvania Budget and Policy Center also highlights surface erosion as a possible barrier to restoration. Well pad development can permanently alter surface runoff patterns, which can remove fertile topsoil from agricultural lands and alter the ecosystem of streams. To address this issue, DEP requires drillers to obtain an erosion and sediment control permit for well pads affecting more than five acres at a time. This state requirement is notably more stringent than federal regulations, which exempt oil and gas drillers from National Pollutant Discharge Elimination System Stormwater Construction Permits.

Furthermore, the cumulative impact that pipelines, access roads, and drilling sites may have on habitats has been highlighted as a significant concern by environmental groups. A high density of pipelines, roads, and well sites can cause habitat fragmentation, which alters the distribution of species across the landscape and can affect migration, feeding, and breeding patterns.

Natural Gas Migration

Natural gas migration issues are distinct from contamination from hydraulic fracturing fluid and existed long before Marcellus development began. The most memorable images demonstrating the impacts of gas migration include videos of murky, foul-smelling, and flammable tap water that have been circulated by homeowners and environmental groups. Aside from the odor and aesthetic effects methane has on drinking water, consuming methane in drinking water is not particularly harmful to human health. The true danger of natural gas migration is the potential for asphyxiation or explosions if methane accumulates in a home or structure.

The Pittsburgh Geological Society is careful to point out that gas migration can be caused by a number of man-made and natural factors, such as abandoned or active mines and gas wells or naturally occurring fissures. In Pennsylvania, however, gas developers are presumed liable by DEP for any contamination of a drinking water source by gas migration within 1,000 feet of a drilling operation. If this occurs, DEP orders corrective action and requires the gas developer to provide drinking water for affected homes.

The most serious and recent case of natural gas migration occurred in Dimock Township, where Cabot Oil & Gas had been drilling. DEP investigations found a total of 14 faulty wells that had contaminated water supplies for numerous homes in the area. Cabot was fined and ordered to plug the faulty wells and install water treatment systems in the affected homes. Earlier, in 2009, a residential well exploded due to natural gas migration.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

Current Production and Generation

Natural gas is one of the most widely used and versatile domestic fuel sources in the United States, with applications for residential and commercial heating, utility-scale electric power, and industrial fuel. Nationwide, natural gas contributes about 21 percent of the electricity generation, and in Pennsylvania, natural gas provided about 8.5 percent of electricity produced in 2008. Total consumption of natural gas across all uses in the state was 749,948 MCf in 2008.

In 2008, the commonwealth produced 198,295 MCf of natural gas, which represents a tiny fraction of the untapped potential in the Marcellus Shale. There are numerous markets that can be served by Pennsylvania's abundant natural gas resources. During the 1980s and 1990s, energy companies began investing in gas-fired power plants and began outfitting existing coal-fired plants to accept natural gas as well. This trend, which originally was adopted in part as a response to EPA's Acid Rain Program, is likely to see a reemergence as energy producers seek to transition toward lower carbon-emitting fuel sources. According to the Natural Gas Supply Association, 23,475 mW of new generation capacity were planned for the nation in 2009, with about 50 percent being provided by gas firing. In the region encompassing Pennsylvania and its five bordering states, an estimated nine BCf of natural gas are consumed every day, with that number expected to rise as gas assumes a larger share of electricity generation.

Growth in the natural gas vehicle sector also is a possible opportunity. Although natural gas vehicles are an uncommon sight on most U.S. roadways (only 354 MCf of Pennsylvania's natural gas consumption went toward transportation in 2008), some public transportation fleets have been transitioning to natural gas vehicles in order to cut back on urban emissions. Several transit authorities have funded compressed natural gas (CNG) fleets with assistance from DEP's Alternative Fuels Incentive Grant Program, including, among others, the Centre Area Transportation Authority, which operates 50 CNG buses in State College; the Port Authority of Allegheny County, which operates several CNG buses and two refueling facilities; and Lower Merion School District in Montgomery County, which has more than 60 CNG buses. Further promotion of natural gas vehicles would open a market for natural gas and would further the causes of energy independence and carbon reduction. However, in order to realize these opportunities, the regional infrastructure for natural gas fleets—including fueling stations and processing and distribution facilities for CNG—must be expanded.

Jobs and Economic Output

From leasing and exploration to drilling and reclamation, Marcellus Shale development requires hundreds of workers and thus potentially creates thousands of new regional jobs. This encompasses direct jobs—such as staking, permitting, engineering, fracturing, and other occupations involved in producing and finishing a well—as well as indirect and induced jobs that support the supply chain and the industries that serve the gas industry.

There are numerous models and estimates of how many jobs will be created by the Marcellus Shale play as well as factors and unknowns that will affect job growth projections. But as we've learned from other shale plays, such as those in Texas and Wyoming, the bulk of the jobs are created during the drilling phase of the well. Penn State's Marcellus Shale Education & Training Center (MSETC) released a Marcellus Shale workforce needs assessment that estimated that about 410 individuals are needed among 150 different occupations for each new well drilled per year. This amounts to about 11.53 full-time jobs per well per year. However, about 98 percent of these jobs are needed only during the drilling phase and thus do not compound each year.

During the production phase (i.e., after the well is complete and recovery of gas begins), MSETC estimated that 0.17 direct jobs would be created per well (approximately one job for every six wells drilled). These jobs, however, are long term and do compound year to year. For example, if 10 wells were drilled each year for 10 years, 17 jobs would be created each year. These jobs would endure for as long as the well produced, which is estimated by the industry to be 30–40 years. The likelihood that production workers would be locally based also is greater.

The MSETC assessment relied on a recent study by the Pennsylvania Economy League, which found that each direct job would create an additional 1.52 indirect or induced jobs throughout the economy. Based on the above findings, this would create approximately 17.53 indirect jobs during the drilling phase and 0.26 indirect jobs during production. Overall, the MSETC assessment estimated that between 5,000 and 13,000 workers could be directly employed by the industry plus 6,500 indirect and 13,260 induced jobs by 2012. Using a different model, a study prepared by Penn State for the Marcellus Shale Coalition indicated that the Marcellus industry employed 29,284 workers in 2008 and would employ 174,700 by 2020 (figures that include indirect and induced jobs).

Marcellus jobs also are considerably high paying. According to a list of the 10 high-priority occupations compiled by the Allegheny Conference on Community Development and its Affiliates, average yearly wages range from $25,850 to $69,870. On average, gas production jobs pay about 20 percent more than the average for all private sector occupations in Pennsylvania.

Perhaps the most promising opportunity that Marcellus brings to the region is the potential to reinvigorate the manufacturing sector. During the Industrial Revolution, vast resources of metallurgical and anthracite coal helped Pennsylvania become an early worldwide leader as an industrial powerhouse. Domestic natural gas, which can serve as a readily available, low-cost, and clean-burning industrial energy source and feedstock can help Pennsylvania reclaim this leadership role in manufacturing. For example, Dow Chemical Company CEO Andrew Liveris recently penned an article for the *Houston Chronicle* describing how the company had planned to build a manufacturing plant in Texas, but, when gas prices skyrocketed, instead chose to locate it—and thousands of jobs—overseas. Liveris wrote that since 1990, the United States has lost 3 million jobs to overseas plants, partially due to uncertainty in energy prices. Pennsylvania's vast resource of natural gas can play an important role in ensuring sustained low energy costs, which will help to reclaim manufacturing jobs and attract them to the region.

Local vs. Out-of-State Workforce

The number of laborers and professionals needed to develop Marcellus Shale is undeniable and significant. But the question remains: Who will fill these jobs?

Currently, about 80 percent of Marcellus jobs are being filled by out-of-state workers. Transitioning to a higher ratio of local workers will be mutually beneficial to both gas developers and regional economies. From a regional perspective, wages, taxes, and spending will stay within communities closer to home. From an employer perspective, relying on local workforces can help to mitigate some of the drawbacks of outsourced labor, including transportation and housing costs and worker fatigue from long hours. Because of this, the industry has a vested interest in shifting toward a workforce that is 70 percent local within the next 12–24 months.

There are multiple barriers to realizing this goal. Most significant is the need for experienced workers with training and skills specific to gas drilling and production. Most of the out-of-state contractors come from regions with mature oil and gas industries, such as Oklahoma, Wyoming, and Texas, where they gained experience working in other shale plays.

Because experience and industry-specific training is key, the ability for regional trade schools and colleges to provide the education needed for natural gas jobs is somewhat limited. According to MSETC, 75 percent of the occupations needed for natural gas drilling require little formal postsecondary education and relatively few trade certifications. Ten of the high-priority occupations—including rotary drill operator, truck driver, wellhead pumper, roustabout, logger, and welder—do not require even a high school degree. However, the region's schools currently do not have training programs available for seven of these positions.

While the issue of inexperience remains, some local schools have begun working toward providing the training and education that will serve as a foundation for the skills needed to fill Marcellus development jobs. Leading this effort is the aforementioned MSETC, a collaboration between Pennsylvania College of Technology in Williamsport and Penn State Cooperative Extension. First conceived in 2008, the center leverages Penn College's extensive offering of continued training and certification courses in welding and heavy equipment operation to plan a curriculum that serves the natural gas industry. MSETC also provides courses and certifications specific to gas drilling, such as commercial driver's licenses for oil and gas truck drivers, American Petroleum Institute certifications for hand welding, and electronics for nontechnical oil field workers.

Programs like MSETC are vital to providing local workers for shale development jobs, which are expected to reach 4,500 in the next two years. Given that Pennsylvania College of Technology's entire student body is about 6,500, it is clear that more regional training efforts are needed. Statewide oil and gas industry partnerships will be instrumental in identifying employment needs and forging standardized training to help fill those gaps.

Severance Tax

In spite of numerous arguments against a severance tax, the 2010-11 state budget, which was signed in July 2010, indicated that legislation imposing a severance tax was expected to be passed by October 2010 and implemented no later than January 2011. Although this did not occur, debate over how gas extraction would be taxed and how proceeds would be distributed rages on. As the state continues to weather financial strain from the economic downturn, many see the severance tax as an excellent opportunity to increase general fund revenues. However, this notion gives rise to ample outcry from local stakeholders, who feel that an equitable distribution of funds should be sought in order to compensate those who shoulder the greatest burdens of gas development.

This debate has been waged before in other gas-producing states, such as Kentucky, which imposes a 4.5 percent tax on natural gas. Currently, up to 50 percent of severance tax revenues can be returned to counties in Kentucky, a policy that remains a focus of intense discussion. In West Virginia, 75 percent of the severance tax revenue is distributed to the gas-producing counties while the remaining 25 percent is distributed to remaining municipalities and counties. These funds are distributed annually by the state treasurer's office.

An additional issue arising from the prospect of a severance tax on natural gas is whether a similar tax should be levied on coal extraction so as not to artificially incentivize coal mining over gas drilling. In Kentucky and West Virginia, coal and natural gas both have severance taxes. However, a severance tax imposed on coal extraction in Pennsylvania would undoubtedly meet resistance from an industry that has not paid such a tax for more than a century.

Public Land Leasing

Pennsylvania has 2.1 million acres of state forest land, about one-third of which is currently under lease to gas drillers. Since 2008, about 139,000 acres of state forest have been leased, generating approximately $354 million in revenue. Concerns have arisen regarding the impact that drilling activity will have on the environment as well as the state's tourism industry, which is the second most lucrative industry in Pennsylvania.

Private Land Leasing

Leasing and royalties agreements also can be a significant source of income for private landowners. Drillers must obtain both land access rights and mineral rights. Land rights are required for the site of the well pad as well as the piping infrastructure that carries the gas. Because most wells are drilled horizontally, the holder of the land rights won't always necessarily be the holder of the mineral rights.

Leasing agreements are binding private contracts between gas developers and landowners and are not regulated by the commonwealth. Because of this, it is of the utmost importance for private landowners to be well informed and well represented by an attorney familiar with oil and gas law. There also are significant educational resources available to landowners, such as those provided by MSETC.

While the terms of each contract vary, landowners generally receive royalties as well as a one-time bonus payment for signing the lease or an annual rent payment. Currently, state law requires a minimum of 12.5 percent for gas royalties, but landowners can negotiate for more. There is no current going rate for natural gas agreements, as the value of the well will vary depending on geography and access to gas deposits. According to the Marcellus Shale Coalition, more than $200 million in lease payments are given to private landowners each year.

Economic Impacts of the Barnett Shale Play

The full economic potential of the Marcellus Shale play is just starting to be understood. But perhaps the best way to gauge the possibilities is to examine the most recent and similar shale play: the Barnett Shale in northern Texas. The economic impacts of the Barnett play were, in some ways, underestimated from the outset. In 2007, the Barnett Shale contributed $8.2 billion, or 8.1 percent of the total economic output for the region, and 83,823 jobs, or 8.9 percent of the total jobs for the area. This represents a 50 percent increase compared to the numbers reported for the year prior. Statewide, Barnett yielded $10.1 billion in economic output, including $212.1 million in severance taxes, and about 99,726 jobs. The area surrounding the Barnett Shale also has been insulated from the nationwide economic recession, thanks to multiplier effects that have rippled through virtually all of the region's industries.

Similar or greater benefits could be realized in Pennsylvania. But discussions on how to coax the most lucrative gains and how to equitably divide the expected economic boom among local and state stakeholders will continue.

COMMUNITY IMPACTS

Historically, communities have experienced significant social and economic impacts from temporary and permanent population and economic booms associated with oil and gas drilling. Resentment often arises between longtime residents and imported workers as well as among local businesses and property owners who were disparately affected by the sudden economic development.

Boomtowns impacted by resource abundance often experience higher crime rates, more traffic congestion, and other degrees of unrest that may stem from relations between communities and gas developers. Media reports have suggested that roughnecks and other workers who are required to work around the clock may abuse methamphetamine and other illegal drugs in order to stay awake during long shifts—an article in Colorado-based news magazine *High Country News*, which covers issues in the American West, in 2005 reported an increase in meth labs in the area during a recent oil and gas boom—though the industry points to regular employee drug testing in response. The social impacts of communities affected by resource booms and sudden economic growth are by no means new, especially in Pennsylvania. Lessons learned from communities nationwide and the region's own past should be heeded as gas development moves forward.

Roads and Infrastructure

The impact on infrastructure continues to be a concern, especially because many of the sites of gas development lie within rural communities where the roads are not designed or maintained to sustain heavy truck traffic. An estimated 350–1,000 truck trips are required for each well, and much of this journey is taken on public roads. Currently, local governments can require gas developers to post bonds of up to $12,000 per road mile to help pay for damage to local roads. However, as the Pennsylvania Budget and Policy Center notes, this amount has not been adjusted for 30 years and the center estimates the actual cost to replace a roadway at more than $100,000 per road mile.

Gas drilling activity also is expected to place strain on public safety services, such as fire protection, law enforcement, and emergency services. There also is an expected increase in administrative duties for county recorders and deeds offices as they handle the influx of requests regarding land ownership and subsurface rights. The Pennsylvania Budget and Policy Center warns that the additional costs associated with accommodating the needs of gas developers ultimately will be shifted to local taxpayers.

Emergency Response

Of equal concern is the preparedness of local emergency responders to handle potentially catastrophic accidents. Many of the drilling sites are currently served by volunteer fire departments that may not be equipped with the tools, personnel, or training needed to handle explosions or fire at a well pad.

In July 2010, a separator tank owned by Chesapeake Energy Corporation in Auburn Township, Susquehanna County, caught fire and burned for approximately two hours before local emergency responders, working alongside Chesapeake employees, extinguished the fire. DEP was notified within 30 minutes of the incident, and no significant environmental contamination or injuries were reported (pending investigation).

In another incident, a well blowout on a site operated by EOG Resources, Inc., sent wastewater and natural gas spewing into the air for 16 hours. According to a report from an independent consultant hired by DEP, EOG failed to incorporate proper safety barriers that would have prevented such a blowout and did not follow proper procedure of immediately alerting the state's emergency response team. According to a press release issued by DEP, the blowout ''could have been a catastrophic incident.'' If the gas had been ignited, ''the human cost would have been tragic'' and the potentially resultant explosion could have discharged wastewater for days or weeks, causing significant environmental damage. EOG was fined more than $400,000 and ordered to take nine corrective actions.

While the stiff fines imposed by DEP send a strong message to gas drillers, the sheer number of gas wells being operated within the state makes the possibility of another accident a near inevitability. In West Virginia, seven workers were injured during a gas explosion at a well site in Marshall County. In July 2010, two workers were killed when a vertical shallow gas well exploded in Indiana Township, Pennsylvania. More recently, three workers were injured at a well site in Avella, Pa., when a number of storage tanks containing natural gas caught fire.

Ensuring that state, regional, and local emergency responders and regulators are capable of mitigating and preventing a catastrophic incident remains a high priority. Assembling regional emergency response teams may be effective in meeting the challenge of responding to emergencies in remote areas and would alleviate the need for municipal responders to invest in the necessary training and equipment.

Locating and reaching well sites also might prove to be difficult. Many drilling sites are located in remote, wooded areas with unmarked or newly constructed access roads. In Lycoming County, this issue is addressed by requiring drilling companies to apply for 911 addresses when they begin to make an access road. Furthermore, the Lycoming emergency communications department has the latitude and longitude of all sites on file so they can be located by GPS in case of an emergency.

Dimock Township

While the situation in Dimock Township is far from typical, it warrants consideration as an example of how communities may be adversely affected by drilling activities and the role that DEP and the gas companies themselves have taken in redressing these issues and concerns.

In 2008, Cabot Oil & Gas, a Houston, Texas-based company, began ramping up its development in Dimock Township, a rural town with a population of less than 1,500. Since then, numerous Dimock Township residents have leased their land to Cabot, and approximately 75 gas wells were being operated as of March 2010. On January 1, 2009, a residential well exploded, spurring a DEP investigation. DEP found that Cabot's drilling activity likely was responsible for methane contamination in the fresh groundwater well due to flaws in the cement and steel casings in its gas wells. In September 2009, Cabot was fined $56,650 for three spills that introduced approximately 8,000 gallons of fracturing fluid into a nearby creek, causing a fish die-off. DEP ordered Cabot to cease its hydraulic fracturing activities until the company revised its pollution control and prevention plans. The prohibition was lifted in October 2009. DEP signed a final agreement with Cabot in November 2009 that ordered the company to pay $120,000 in civil penalties and to further improve its plan to prevent future incidences by March 31, 2010, as well as supply temporary water supplies to 13 families who had been affected. Cabot failed to meet this deadline and currently has been ordered to plug the faulty wells, and all pending permits have been suspended indefinitely. Cabot also was fined $240,000 toward the commonwealth's well-plugging account and must pay $30,000 for each month that it fails to complete its obligations under the November 2009 order.

A group of Dimock residents filed a civil suit against Cabot in November 2009 alleging that Cabot had allowed methane and metals to seep into drinking water supplies, causing neurological and gastrointestinal illnesses. The suit seeks to stop future drilling near Dimock and to establish a trust fund to cover medical treatment for those who claim they have been sickened by pollution caused by the company.

The Dimock and Cabot events represent the most egregious of violations in the state and are atypical of gas development in the region. Former DEP Secretary John Hanger described Cabot as being in ''a class in itself'' with the worst record in the industry. Nevertheless, the ongoing issues here are damaging to the public trust and illuminate a need for greater cooperation among the industry, the public, and regulators.

Pipeline Safety and Easements

Transportation of natural gas requires an intricate and expansive network of pipelines. Unlike surface and subsurface rights for drilling operation, which typically are negotiated through leases, rights of way for pipelines are secured through easements. Easements are contracts between private landowners and the pipeline operator in which the operator is granted a legal right to use a portion of the property without owning it. The holder of the easement retains use of the land in perpetuity. This means that if the property is sold, the new owner must abide by the responsibilities and restrictions delineated by the easement agreement. This may pose difficulties if formerly rural land becomes developed years later, as pipeline easements may compete for space with other infrastructure, such as water and sewer lines.

Depending on the terms of the easement or rights of way agreement, landowners may retain limited use of the land. Agricultural activities and landscaping often are allowed, but building permanent structures or planting trees that may interfere with the maintenance of, inspection of, or access to the pipeline may be prohibited. Construction, excavation, or other land use that causes damage to the pipeline may constitute an encroachment upon the easement holder's rights and can result in legal action.

Pipelines are overseen by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA). According to PHMSA, the environmental and ecological consequences are usually minimal for releases involving natural gas. A greater threat is posed by the potential for a natural gas explosion, which is relatively rare. According to PHMSA data, two public fatalities, 13 public injuries, three industry fatalities, and $111,427 worth of property damage from incidents involving on-shore natural gas transmission lines were reported nationwide between 2005 and 2009. However, in 2000, a single explosion near Carlsbad, N.M., resulted in the death of 12 campers, who were about 350 yards away from the blast.

Inspection of pipelines is handled by PHMSA, which, as of June 2010, had 88 full-time pipeline inspectors responsible for overseeing more than 2 million miles of pipelines nationwide. The closest regional office is in Trenton, N.J. Currently, the Pennsylvania PUC does not have the authority to inspect natural gas transmission lines unless the operator is registered as a public utility. As such, inspection of the approximately 40,000 miles of existing pipeline is relatively sparse.

Rural vs. Urban Development

In Pennsylvania, much of the gas development has been conducted in rural areas with relatively sparse population density. However, given that the Marcellus Shale spans the entirety of Southwestern Pennsylvania, there is a significant possibility that urban drilling may be pursued. The *Pittsburgh Post-Gazette* has reported that residents in Saxonburg and the Pittsburgh neighborhoods of Lawrenceville and Lincoln Place already have received inquiries or signed gas development leasing agreements with land agents. While permitting and other regulatory issues fall under the jurisdiction of state regulators, municipal governments and community members will face some unique challenges if drilling occurs in densely populated areas.

The impacts faced by rural communities are likely to be exacerbated in urban settings. Congestion from heavy truck traffic, dust, noise, lights, and odors would affect more homes and businesses. And unlike typical construction zones, which can be halted during rush hour or at night, gas drilling operations must proceed virtually uninterrupted once initiated. In anticipation of gas development, municipalities should devise ordinances that define noise requirements, road repair agreements, well setbacks, zoning requirements, and other aspects key to minimizing the impact on the community. Sound barriers, shielded lights, and enclosures can help to reduce nuisances associated with well sites.

Gas leasing activity in urban communities in Texas has already caused tension among neighbors, particularly in Flower Mound, where political races have revolved around the prospective candidates' action for or against urban drilling. Due to the nature of horizontal drilling, holdouts on leasing could impede development—and thus profits—for surrounding landowners who have eagerly signed leasing agreements. Conflicts such as these introduce discussions over forced pooling statutes. Forced pooling (also known as fair pooling and conservation pooling) allows gas drilling companies to combine leases into a single tract, simultaneously compelling unwilling landowners to be included in the unit. Landowners who are involuntarily included in the leasing unit are typically given the option to receive royalties or become an owner of the production and share in the costs and profits of the development. Texas, Kentucky, Oklahoma, and New York currently have forced pooling statutes. Most states with such a statute require the gas developer to hold leases for 51 percent or more of the unit before initiating a forced pool. Pennsylvania currently does not have a forced pooling statute.

Like rural gas development, urban drilling can be done in a way that is mutually beneficial to the community and the gas companies. But the social, environmental, and economic complexities of such arrangements demand greater attention to planning, community outreach, and collaboration among the industry, local governments, and state regulators.

Municipal Zoning Ordinances vs. State Oil and Gas Act

In terms of regulating gas development, the Pennsylvania Oil and Gas Act preempts local ordinances. This means that municipal governments can create ordinances regulating gas drilling activity so long as the local laws do not substantially overlap with similar regulations set forth in the Oil and Gas Act. In February 2009, the Pennsylvania Supreme Court issued concurrent decisions on two cases between municipalities and gas developers: Range Resources et al. v. Salem Township and Huntley & Huntley, Inc., v. Borough Council of the Borough of Oakmont. In the Salem case, the court prohibited the township from enforcing an ordinance that sought to regulate various aspects that already fell under the purview of the state Oil and Gas Act, including reclamation and bonding requirements. The court also opined that the township's ordinance was more stringent than the Oil and Gas Act and appeared to impose excess costs on gas developers. Meanwhile, the Supreme Court ruled that Huntley & Huntley was improperly denied a conditional use permit to drill on two residential properties in Oakmont. However, the court upheld Oakmont's right to restrict gas drilling activity through traditional zoning ordinances. These Supreme Court decisions set precedents regarding state preemption, but the validity of local ordinances will likely continue to be determined on a case-by-case basis.

SUMMARY

Natural gas from the Marcellus Shale formation represents a great opportunity for Pennsylvania, but only if the appropriate regulatory and environmental framework is established. While intense debate over key issues is already under way, countless questions in terms of how best to manage the explosive growth in gas development activity have yet to be asked. The topics outlined here should by no means be considered an exhaustive list. Local and state stakeholders will continue to explore challenges and solutions for specific issues. They will have to take a holistic approach to addressing the cumulative economic and environmental impacts of natural gas development in the region.

CHAPTER II: NUCLEAR ENERGY

NOTE FROM THE EDITORS

At the beginning of March 2011, just prior to printing of this *Regional Energy Survey*, a 9.0 magnitude earthquake and its resulting tsunami shattered the northeast section of Japan. The aftereffects of that natural disaster led to devastating consequences for the country's infrastructure, including the Fukushima Dai-ichi power plant, which was designed to withstand an 8.2 magnitude earthquake. Unfortunately, the 9.0 earthquake that devastated the plant was more than six times what the design of the plant could endure. The resulting nuclear crisis in Japan has left the world wondering how and if the nuclear power industry will move forward. As the *Regional Energy Survey* notes, prior to this disaster, a nuclear renaissance was well underway in Europe and Asia with the United States poised for a nuclear power rebirth.

While many still agree that nuclear power is clean, reliable, affordable, and a critical means of power for our future, it is most likely still too early to fully understand the implications of the disaster that has happened in Japan. Prior to this disaster, the United States was planning to increase the number of its nuclear reactors; there are currently 104. Now, many industry experts and public officials are debating whether they should proceed with that expansion, while at same time, looking at what precautions need to be taken to ensure that existing nuclear plants are properly prepared for and have taken the preventative measures to safeguard themselves from a disaster of this magnitude.

At the same time that the future of nuclear energy is being debated, China is already building a different type of reactor that some experts believe would lead to a safer nuclear alternative. Rather than using conventional fuel rod assemblies, which are packed with approximately 400 pounds of uranium, these new reactors would feature a protective layer of graphite meant to moderate the pace of nuclear reactions. This would mean that if a plant had to shut down in an emergency, the reaction would slowly stop on its own and not lead to a meltdown.

Once again, the nuclear industry finds itself in the position of having to shed a negative public image. With the limited information and analysis on the disaster at the Fukushima Dai-ichi power plant available at the time of this publication, it is difficult to predict what the next steps are for the nuclear power industry. As more information on the disaster is studied, industry experts and public officials alike will be equipped to determine more accurately the role that nuclear power will play in our energy future. Whatever the outcome is, nuclear power will still have many obstacles to overcome, burdens to bear, and considerable milestones to meet before a true nuclear rebirth is possible.

Pennsylvania Nuclear Industry Quick Facts

- Nuclear power plants in Pennsylvania: **five (nine total reactors)**
- 2009 installed capacity: **9,305 mW (20 percent of state total)**
- 2008 electricity output: **78,658 gWh (35 percent of state total)**
- Rank among nuclear electricity producing states: **second**
- Busbar cost for new plant: **$98–$125 per mWh**
- Jobs created per power plant: **400–700 ($430 million in economic output)**
- Reactors using Westinghouse Electric Company technology worldwide: **about 50 percent**
- Radiation received during chest X-ray: **four millirems**
- Radiation received from naturally occurring radon: **200 millirems a year**
- Radiation exposure from nuclear power plants: **less than one millirem a year**
- CO_2 emissions: **virtually zero**

Section Overview

- European and Asian countries increasingly are embracing nuclear power plants, while the U.S. nuclear industry remains relatively dormant. However, a nuclear renaissance might be on the nation's horizon.
- Nuclear energy is being reconsidered as a solution to concerns over CO_2 emissions and the need for baseload electricity generation using domestic fuel sources.
- The partial meltdown at Three Mile Island has spurred design and implementation of passive safety systems and improved regulation and oversight of plant operations.
- Rampant cost overruns in the past have made investors hesitant to back nuclear power plant construction projects. However, support and loan guarantees from the federal government may bolster confidence in new nuclear power plants.
- Cranberry Township-based Westinghouse developed the technology used by nearly half of the nuclear reactors in the United States as well as numerous new reactors being built overseas.
- Pennsylvania has about 9,305 mW (more with uprates) of installed nuclear energy capacity at five different sites. While construction of new nuclear power plants is not likely in the foreseeable future, those already in existence can increase output through uprates.

Reassessing the Nuclear Industry

Although nuclear energy provided about 17 percent of the electricity in the United States in 2008, the industry long has been considered dormant. This is brought into starkest relief when the nation, with its 104 nuclear power plants, is compared to the thriving nuclear power infrastructure in nations such as South Korea, Japan, and France, the last of which receives nearly 80 percent of its electricity from nuclear power. But in the United States, a multitude of drivers brought the development of the nuclear industry to a virtual halt. While the public feared nuclear proliferation, nuclear meltdowns, and incidental public health impacts from radiation, private investors and energy developers quickly became disillusioned as construction projects dragged on for decades and cost overruns became rampant. Today, it's been more than three decades since construction began on a new nuclear project in the United States. Some recent shifts in public attitudes, national policy, and the energy economy may change all of that.

The words ''nuclear renaissance'' began being uttered tentatively as far back as 2001, and the notion has been gaining steam ever since. Nuclear energy is increasingly being seen as a viable solution to the nation's climate change and energy independence challenges. As an energy source with virtually no carbon emissions, a relatively low volume of solid waste output, and little impact on habitats due to resource extraction, nuclear energy is being reconsidered by many environmental interests. From an economic standpoint, nuclear energy is competitive with coal once a plant is online, and as demand for the limited supply of fossil fuels increases, nuclear energy may become a cost-effective hedge against rising energy prices.

Considerable lessons also have been learned from nuclear energy's faltering steps in the past. The accident at Three Mile Island has spurred the design and implementation of passive safety systems and improved regulation and oversight of plant personnel. To date, no deaths caused by a nuclear accident have been recorded in the United States, comparing favorably to the number of annual injuries and deaths suffered by other energy sectors.

But perhaps the most vexing challenges for the early nuclear industry were financial. Lack of design standards, lawsuits from environmental groups, and mismanagement contributed to the industry's admittedly abysmal record for completing projects on time and within budget. This uncertainty over the costs and timetable for nuclear projects has made obtaining private and state financing extremely difficult for contemporary nuclear constructions. To solve this problem, the industry is moving toward more modular designs that will streamline the licensing and approval process and help get plants online faster. This already is happening internationally, where many nuclear power plants are completed in as few as five years.

In the United States, the revitalization of the nuclear industry is not yet underway. But the recent $8.3 billion DOE loan guarantees for two nuclear projects in Georgia show promise. Pennsylvania stands to gain from both the national and worldwide growth in nuclear power. As home to both the first commercial nuclear power plant and the oldest operating nuclear reactor in the United States, the region is well positioned to serve the reemerging industry.

ENVIRONMENTAL IMPACTS AND PUBLIC HEALTH

In spite of decades of coexistence with the industry, nuclear energy remains evocative of hazardous waste symbols and anxieties over the possible detrimental effects on the environment and public health. Imagery perpetuated through popular culture, such as shows like *The Simpsons*—which is based in a fictional town sustained by a comically imposing nuclear power plant with three-eyed fish in its ponds and a green-glowing CEO in its boardroom—did little good for nuclear energy's public reputation. Now, with climate change legislation on the table, the perceived risks of nuclear energy are being weighed in comparison to the potential environmental benefits. Just as the economic viability of nuclear energy merits reassessment, the impacts that nuclear energy has on surrounding communities and habitats deserve a second, closer look.

Air and Water

Nuclear power generation emits virtually no greenhouse gases or air pollutants. However, the fuel life cycle of nuclear power does contribute to air emissions indirectly, as the process of mining, transporting, and enriching uranium requires significant amounts of fossil fuels and electricity. But compared to coal, oil, and natural gas, nuclear power's contribution to carbon and regulated airborne pollutants is negligible. Because of this, DEP included added capacity of nuclear energy as part of its Climate Change Action Plan.

Nuclear power plants, like all thermoelectric plants, utilize a significant amount of water for cooling. In open-loop systems, about 98 percent of the water withdrawn for cooling is returned to the source. The Nuclear Energy Institute (NEI) estimates that nuclear energy consumes about 400 gallons of water per mWh with once-through cooling and 720 gallons per mWh with wet cooling towers, which is slightly more than what is consumed by a coal-fired plant. Environmental groups have expressed concern regarding the impact of large water withdrawals on aquatic wildlife. Though the industry argues that since the water is discharged back to the source, thus consuming very little water overall, changes in water temperature (thermal pollution) and other effects on the water have the potential for altering habitats. Furthermore, fish and other wildlife can be killed by being impinged upon intake screens. Smaller and early life stage wildlife also can be drawn into the station (entrainment).

Entrainment and thermal pollution are primarily associated with open-loop or once-through cooling systems, in which water is withdrawn from a source, circulated through heat exchangers, and then returned to the source body of water. In a closed-loop or recirculation cooling system, water is withdrawn from the source, circulated through heat exchangers, cooled in a pond or tower, and then recirculated without discharging. All of Pennsylvania's nuclear power plants (except Peach Bottom Atomic Power Station) have closed-loop cooling systems. Large fish kills were reported at Peach Bottom, but design solutions have been implemented in compliance with updated Clean Water Act regulations to reduce the environmental impact.

Waste Treatment and Storage

There are two main types of radioactive waste found at nuclear power plants: low-level radioactive waste, such as contaminated clothing, equipment, tools, and reactor water treatment residues, and high-level radioactive waste, which primarily consists of spent nuclear fuel. Low-level radioactive waste is typically stored on-site until the waste decays away or until there is enough waste to ship to a low-level waste disposal site. Spent nuclear fuel is either stored on-site in pools or in dry storage containers. Both methods cool the materials and contain the radiation emitted by the fuel, though dry storage containers are subjected to stricter regulations. In Pennsylvania, there are three independent spent fuel storage installations with general licenses for dry storage located in Limerick, Susquehanna, and Peach Bottom.

The issue of how and where to dispose of nuclear waste is a nationwide problem still pending a permanent solution. This pertains to both high-level and low-level waste. For example, the nearest low-level waste disposal site to Pennsylvania is in Barnwell, S.C., which has been closed to waste from most states, including Pennsylvania. Meanwhile, the on-site low-level waste storage is nearing capacity in many nuclear power plants. Exelon Corporation recently requested a permit from the U.S. Nuclear Regulatory Commission (NRC) to begin shipping its low-level waste from its Limerick plant to Peach Bottom, as the on-site storage in Limerick would be full by 2012.

Currently, nuclear power plants pay a flat disposal fee per kilowatt hour to DOE for the purposes of supporting a national repository for high-level radioactive waste produced as of 1998. However, no national nuclear waste management plan has been implemented to date. Yucca Mountain in Nevada, which was approved as the site for nuclear waste disposal in 2002, recently was removed from consideration, further distancing the industry from a national solution. Several utilities, along with NEI, have sued DOE seeking a suspension of the payments for nuclear waste disposal. Until a permanent disposal site becomes available, Pennsylvania's nuclear power plants will continue storing their high-level waste on site with oversight by NRC and DEP.

Radiation

The principal concern over any type of exposure to ionizing radiation is the potential damage to human tissue on a cellular level. Ionizing radiation damages cells by stripping away electrons, which can either be irreparable or lead to cancerous growth if the body repairs the damage improperly. EPA states that those living near a nuclear power plant receive less than one millirem of increased annual radiation exposure. By comparison, a chest X-ray exposes an individual to four millirems and the naturally occurring radon in the average home exposes residents to about 200 millirems each year.

Opinions on the degree of the health risks posed by radiation from nuclear power plants is clearly divided between supporters and opponents of nuclear energy, a debate that has produced a large amount of literature on both sides of the fence.

Parties wary of the public health impacts of routinely operated power plants often quote Karl Z. Morgan, founder of the Health Physics Society, who said, ''There is no safe level of exposure and there is no dose of radiation so low that the risk of a malignancy is zero.'' This is argued in opposition to the notion that federal regulations can set a permissible dosage of radiation. EPA acknowledges the difficulty in establishing a firm basis for a safe level of radiation and states that it makes a cautious assumption that any increase in radiation exposure is accompanied by an increased risk of stochastic effects (i.e., increased probability of health impacts from prolonged or increased exposure). Concerns also arise regarding bioaccumulation of radioactivity, increased risk for children, and a collection of studies indicating elevated levels of cancer cases and birth defects in areas in proximity to nuclear facilities.

Meanwhile, nuclear supporters attribute much of the public fear over radiation exposure to misinformation and media sensationalism. NEI reiterates the relatively low exposure doses received by those living near power plants and cites studies by the International Agency for Research on Cancer and the National Academy of Sciences and other ongoing studies that indicate that health risks remain small. Other proponents also compare the health risks of nuclear energy favorably to those posed by coal energy, which impacts public health through air and water pollution and purportedly releases 100 times as much radiation into the environment via coal ash.

Consensus on the public health impacts on communities surrounding nuclear power plants is undoubtedly unachievable. However, ongoing independent studies seek to bring contentious parties closer to common ground. In 1990, a survey of 62 counties surrounding nuclear facilities conducted by the National Cancer Institute found no increased risk of cancer death. More recently, NRC has asked the National Academy of Sciences to conduct an exhaustive study of the cancer risks posed by nuclear power generation. This study is intended to address many of the criticisms of the decades-old National Cancer Institute survey as well as to provide an updated assessment. The findings of this study, which may take several years to complete, may be key in illuminating the potential for public health risks from nuclear power.

Meltdowns

The concerns over public health impacts from a routinely operated nuclear power plant pale in significance when compared to the fears over a catastrophic event, such as a meltdown or terrorist attack. This is particularly true in Pennsylvania, where the memory of the partial meltdown at Three Mile Island still looms large after three decades. This incident remains the most serious nuclear accident in the United States to date. Studies conducted by NRC, DEP, and the University of Pittsburgh determined that the accident led to no deaths or injuries to plant personnel and no health effects for community members. These studies have been contested, however, most notably by Steven Wing of the University of North Carolina at Chapel Hill. Wing's studies showed cancer rates downwind of Three Mile Island were two to 10 times higher than cancer rates upwind. He also noted that several hundred people reported acute symptoms of high levels of radiation exposure, such as nausea, hair loss, skin rashes, vomiting, and pet death.

The Three Mile Island incident did have some positive outcomes. Since the partial meltdown, safety regulations and oversight have been tightened both on a federal level and by the industry. In addition to stricter design and engineering requirements, scrutiny of human performance at nuclear power plants has been heightened and given additional weight in the review process. NRC also requires all plants to have emergency response plans for the area in a 10-mile radius around the plant. As part of this emergency preparedness effort, during a nuclear emergency, NRC distributes potassium iodine tablets which, when taken, can help protect against thyroid cancer. Standards of safety review are being improved on the state level as well. In Pennsylvania, DEP has begun conducting at least one unannounced instance of surveillance per month at each of the nine nuclear power reactor sites in order to ensure staff vigilance.

In spite of stricter regulations and safety monitoring, some groups express concern over the notion of uprates and license renewals for aging nuclear reactors. For example, a recent article in *The Nation* characterized the nation's nuclear power plants as ''old, leaky, crumbling plants'' that were being ''pushed to the limits of their endurance.'' The article argued that if these plants were new constructions, they would not receive NRC approval by today's standards. NRC responded to these concerns by noting that the 40-year licensing term was implemented for antitrust and economic reasons rather than expectations of technical limitations. As mentioned above, NRC bases its decision to renew licenses on the ability of the facility to continue to operate safely as determined by rigorous inspections and review.

Terrorist Attacks

While Three Mile Island served as a galvanizing event for tightening safety regulations in nuclear power plants, the terrorist attacks of September 11, 2001, provided impetus for strengthening the preparedness for a terrorist attack at a reactor site. There are a few main perceived points of vulnerability at a nuclear power plant. Sabotage or infiltration from an armed force (design basis threat) is one threat that receives particular attention. NRC requires regular ''force on force'' simulations, in which a mock adversary group attempts to gain access to the protected and vital areas of the nuclear facility. Security forces are rated for their performance in deterring the attack.

There also are public fears of an air attack similar to the attack on the World Trade Center at a nuclear power plant. The threat of an air attack on a nuclear power facility was not an immediate consideration prior to 2001, when all of today's plants were designed and constructed. However, reactor containments are designed to withstand hurricanes, earthquakes, and other extreme events. NRC studies found that the relatively small, low-lying profile of the containment area makes a difficult target on a nuclear site, and thus the likelihood of a reactor core being damaged by an aircraft crash was small. (Note that the prominent cooling towers do not contain any radioactive material.) Nevertheless, NRC has been taking the ability to withstand a jetliner crash into consideration when reviewing designs for new nuclear power plants. For example, the approval of the AP1000 reactor design was delayed when NRC asked Westinghouse to modify the design to ensure that it would be protected against an air attack.

Nuclear proliferation also is a chief concern. Fears revolve most heavily around the treatment, storage, and transportation of nuclear waste and spent fuel rods. Radioactive material can be used to create a radiological dispersal device or a dirty bomb, which combines conventional explosives with radioactive material. According to NRC, most dirty bombs would not release enough radiation to kill or sicken people and would be outweighed in danger by the explosion from the paired conventional bomb.

In order to create a nuclear weapon from spent fuel rods, the waste would have to be reprocessed to separate out the plutonium. Nuclear reprocessing is used in some countries, such as France, in order to extract commercial-grade plutonium, which is distinct from weapons-grade plutonium. Still, in 1977, President Jimmy Carter banned nuclear reprocessing in the United States for fear that plutonium might be diverted from the civilian fuel cycle. This policy decision—and the United States' continued abstinence from reprocessing—also was meant to serve as an example for other nations and to discourage them from creating potential security vulnerabilities. The debate over allowing nuclear reprocessing in the United States continues, as nuclear reprocessing could serve as a partial solution to nuclear waste storage. The Reagan administration reversed the official ban on nuclear reprocessing, and in 2006, President George W. Bush proposed the Global Nuclear Energy Partnership, which would resume nuclear reprocessing in the United States. This component of the initiative was ultimately canceled by DOE. However, the discussion on nuclear reprocessing and its role in nonproliferation efforts and reducing nuclear waste is bound to continue as nuclear energy development continues in the United States.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

Current Generation and Potential

There are nine nuclear power reactors in Pennsylvania at five sites: the Beaver Valley Power Station near Shippingport, Beaver County; Limerick Generating Station in Limerick Township, Montgomery County; Peach Bottom Atomic Power Station in Delta, York County; Susquehanna Nuclear Power Plant in Berwick, Luzerne County; and Three Mile Island in Middletown, Dauphin County. The combined capacity of these plants is 9,305 mW and, in 2008, Pennsylvania nuclear plants produced 78,658 gWh, supplying about 35 percent of Pennsylvania's electricity needs. Compared to the other states with commercial nuclear power plants, Pennsylvania ranks second in output and generation behind Illinois.

Ironically, nuclear energy, which has been in use for decades, faces some of the same challenges as renewable energy. Because it has been 30 years since the successful completion of a new nuclear power plant in the United States, private investors are hesitant to back nuclear power projects. But whereas alternative energy technology benefits from adamant environmental enthusiasm, public support for nuclear energy remains equivocal. The issues surrounding the economic and environmental viability of nuclear power are exacerbated in states such as Pennsylvania, where a deregulated utilities market further discourages long-term investment in capital-intensive projects. While progress has been made on a federal level, as demonstrated by the recent DOE guarantees, significant barriers to nuclear investment remain.

PUC reported the installed cost of nuclear energy in 2007 was about $75.10 per mWh. According to the levelized energy cost analysis released by Lazard in June 2008, the busbar cost of a new nuclear power plant would be between $98 and $126 per mWh. However, quantifying the actual costs of added capacity from a new nuclear power plant is difficult, as no such undertaking has been attempted for many years. Several U.S. companies have applied for NRC licensing of new reactors, including PPL Bell Bend, which is proposing a 1,600 mW plant near the existing Susquehanna plant. The decision to move forward depends on a number of significant milestones, including approval of its NRC license, which might take three to four years; securing of DOE and private financing; and certification of its AREVA reactor technology. Because of these issues, new construction of nuclear power plants in Pennsylvania is not seen as a viable near-term opportunity.

Increasing the capacity of existing power plants is viewed as a more attainable and economically viable goal. In DEP's December 2009 update to its Climate Change Action Plan, the department estimated that Pennsylvania's existing nuclear power plants have a potential of 1,050 mW in added capacity. About 150 mW of this potential is expected to be available by 2012, with the total added capacity expected to be about 550 mW by 2020. Uprating for existing power plants is particularly pertinent now, as the 40-year NRC operating licenses for many of today's plants—which came online in the 1970s—are set to expire in the next few years. For both uprates and license renewals, NRC subjects the applicant's power plant to a rigorous technical review and safety analysis and opens the decision to public comment. In anticipation of this scrutiny, plants often will modify, replace, and upgrade major components of the plant prior to being reviewed.

About half of the existing nuclear power plants in the United States have received uprates, and substantially all of the nuclear plants are expected to apply for renewals or have already been granted renewals (typically 20-year extensions), according to EIA. NRC data indicate all of the Pennsylvania reactors have had at least one uprate application approved in the past. Most recently, NRC approved a request to increase the generating capacity for both Susquehanna units by 13 percent each in 2008.

Jobs and Economic Output

According to NEI, each nuclear plant creates about 400–700 jobs during operation and about $430 million a year in economic output plus $40 million in total labor income. Job creation by Pennsylvania's nuclear power plants reflects this estimate. The Beaver Valley Power Station and the PPL Susquehanna plant—both with two reactors on site—employ about 1,000 and 1,130 employees, respectively. Three Mile Island employs about 522 workers, not including security forces, while Peach Bottom Atomic Power Station employs about 800 and Limerick Generating Station employs about 700. Each plant also hires additional contractors and temporary workers during refueling outages. For example, the Peach Bottom plant employs about 1,000 temporary workers during refueling.

Beyond the power plants, there are several research labs and engineering firms that serve the nuclear industry in the region. Most significant is Westinghouse, which developed the nuclear reactor technology used in nearly half of the power plants worldwide, including 60 percent of the reactors in the United States. Westinghouse traces its roots back to the region and in 2007 relocated its national headquarters to Cranberry Township, where it plans to add 1,000 new jobs each year for the next five years. Much of this local growth is sustained by international business. For example, Westinghouse's AP1000 reactor is being used widely in Asia. In May 2008, Chinese officials notified Westinghouse that they planned to build 100 nuclear power plants based on Westinghouse technology by 2020. The AP1000 also is the technology of choice for about half of the reactors planned in the United States. In cases where Westinghouse does not build power plants itself—such as a $5.3 billion contract in 2007 for four reactors in China—the company receives licensing fees from the developers who use the technology in their projects. The revenue from licensing deals helps Westinghouse to fund research and development, which means many international deals translate into dollars being invested locally.

Westinghouse and other nuclear companies are served locally by manufacturing companies such as Holtec International, which recently expanded its Turtle Creek, Pa., facility that builds dry fuel storage canisters, and Curtiss-Wright Flow Control Corp., which recently built a $62 million complex in Cheswick, Pa., where it manufactures coolant pumps. NEI estimates that the recent expansions of Westinghouse, Holtec, and Curtiss-Wright added 1,600 jobs to the region.

COMMUNITY IMPACTS

Public health concerns aside, nuclear power plants have a significant effect on the communities where they are located. In Pennsylvania, this goes beyond notions of ''not in my backyard,'' as the commonwealth's nuclear power plants have been operating in these communities for decades. The principal concern is the perceived opaqueness in the decision-making and public information processes. Because nuclear energy regulation and national security fall heavily under the jurisdiction of federal agencies—such as NRC and the U.S. Department of Homeland Security—open channels of communication between officials involved with the safety and management of nuclear power plants and community members often are difficult to establish. A study conducted by a team of Carnegie Mellon University students found that 30 percent of nuclear power plant Web sites provide insufficient information regarding emergency plans, nuclear waste storage, and contact information.

This is less of an issue with Pennsylvania's power plants, however. Of the five nuclear sites in Pennsylvania, all but the Beaver Valley plant have informative Web sites that offer extensive information about the plant and its operations. (To FirstEnergy's credit, an e-mail request for information about the Beaver Valley power plant for the purpose of this report was promptly fulfilled.) The Web sites of the plants operated by Exelon are particularly forthcoming, likely in response to the incident at Three Mile Island. PPL's Web site goes as far as offering bus tours of the Susquehanna plant.

But in terms of license renewals and uprate applications, NRC has a record for being somewhat less transparent. The study by the Carnegie Mellon students found that many citizen concerns went unaddressed as they were judged to lie outside the agency's purview or to contain insufficient evidence for action. To redress this issue, the Carnegie Mellon student study recommended streamlining the formal comment process and creating a community advocate position to provide technical assistance to petitioners.

SUMMARY

Nuclear energy currently plays a vital and underappreciated role in supplying reliable energy to the nation's grid. As demand for cleaner baseload electricity rises, nuclear power appears almost as a tailor-made solution. The industry's ability to shed its negative public image and avoid the crippling financial difficulties of the past is key to revitalizing nuclear energy in the United States. Further scientific study into the possible health and environmental impacts and greater community outreach will aid public acceptance of nuclear power, while the successful completion of a new nuclear power plant on U.S. soil will serve as validation of its economic viability. Neither goal is as distant as it once seemed, but a considerable number of milestones must still be met before the nuclear renaissance becomes a reality.

CHAPTER III: ALTERNATIVE ENERGY

Section Overview

- The intermittency of solar and wind energy does not devalue their economic and environmental benefits as greatly as many presume. Renewable energy is largely considered complementary to conventional baseload power plants and thus would not affect overall reliability of the grid (and actually may alleviate the strain of peak demand load). The emissions offsets of solar and wind energy also remain important, in spite of a relatively lower capacity factor when compared to conventional power plants.
- Federal tax incentives and aggressive alternative energy portfolio standards have helped renewable energy to gain a strong foothold in the state. However, continued legislative support likely is needed in order to encourage further private investment in renewable energy.
- AEPS require that 8 percent of Pennsylvania's electricity come from Tier I alternative energy sources (with a minimum of 0.5 percent from solar photovoltaic [PV]) and 10 percent from Tier II sources by 2021.
- Producers of renewable energy can profit via net metering (selling excess generated electricity to distributors) and by selling alternative energy credits to help distributors meet AEPS requirements.
- In spite of relatively low solar resources, Pennsylvania has vast potential for generating electricity via solar PV. Germany and New Jersey, areas with similar solar resources as Pennsylvania, serve as examples of how renewable energy policy can spur growth in solar energy.
- Pennsylvania is home to several solar and wind energy manufacturers that provide hundreds of jobs.
- Habitat impacts and bird/bat kills from wind farms can largely be mitigated by proper siting and design.

Alternative and renewable energy sources are commonly viewed as distant goals, only attainable in an idealized future. The environmental threats that renewable energy addresses are clear dangers, but the seeds for such solutions are being sown now in order to meet the future demand. Alternative energy adoption may be accelerated by federal actions that modify financial incentives for reducing reliance on conventional fossil fuels. Wide commercial deployment of renewable energy is prudent as both an economic and environmental hedge. Pennsylvania has already begun establishing itself as a leader in renewable energy. Building on this success will most likely be key to the region's economic and environmental goals.

Solar, wind, and other renewable energy sources share many of the same economic and environmental impacts. As such, the benefits, challenges, and potential opportunities that are common across renewable energy sectors will be discussed in this section as unified topics.

ENVIRONMENTAL IMPACTS

The environmental benefits of alternative energy sources are best quantified in terms of offsets—that is, the avoided impacts of using conventional fuels to generate an equivalent amount of energy. This includes pollutants such as SO_2, NO_X, particulate matter, hydrocarbons, CO, mercury, CO_2, and other emissions as well as the less quantifiable disruption of habitats and property for the purpose of extracting natural resources. While industry groups give varying figures on the quantity of emissions avoided per installed mW, the logic of offsets presumes that it would be comparable to what would be produced by a conventional power plant. For example, the American Wind Energy Association (AWEA) estimates that the average U.S. fuel mix produces about 1.52 pounds of CO_2, 0.008 pounds of SO_2, and 0.0049 pounds of NO_X per kWh of generated electricity. Thus, Pennsylvania's 311 gWh of renewable electricity generation in January 2009 (per EIA) would equal annual offsets of approximately 236,360 tons of CO_2, 125 tons of SO_2, and 762 tons of NO_X.

However, when the environmental footprint of the manufacturing process for solar and wind components is factored in, the environmental benefits are somewhat muted. The time it takes to negate the footprint of any given installation's production obviously varies depending on numerous factors, but as the efficiency of both the manufacturing process and the resultant generation improve, this ''payback'' period will certainly lessen. For example, a Greentech Media report estimated that it would take four years to eliminate the carbon footprint of a typical solar panel, but by swapping out fluorine for nitrogen fluoride (a greenhouse gas) during the production phase, that timetable could be cut in half. There also are other potential ecological impacts that are unique to specific technologies.

INTERMITTENCY AND ENERGY STORAGE

Intermittency is presumed by many to be the Achilles' heel of renewable energy, as the sun does not always shine and the wind does not always blow. The fickle nature of the elements does affect the amounts of wind and solar energy on the grid, but not in the ways that many assume. To understand the value of renewable energy, it's important to consider its impact in terms of the energy goals for the region. Even the

most adamant proponents of wind and solar energy do not suggest that these technologies will replace base load power plants. Instead, renewable energy provides marginal benefits in terms of production. Every mWh of energy produced by a wind turbine or solar panel replaces a mWh that would have been produced by a conventional source. This offsets the environmental impact that would have resulted from the mWh of energy produced from a fossil fuel. It also reduces the demands on base load generation, which drives down costs during peak demand periods.

While it is true that wind and solar energy are not dispatchable—that is, they cannot be turned on quickly in order to meet a desired level of output—this has different implications from a shortcoming in reliability and availability. An idle wind or solar generator will not result in rolling blackouts, as the grid is equipped to handle fluctuations in energy demands and production from various sources. The mechanism and procedures for preventing loss of grid reliability during low production from a wind or solar generator would be the same as those that keep the lights on when a nuclear power plant goes offline for refueling or a coal-fired plant goes down for scheduled or unscheduled maintenance.

In other words, a certain amount of flexibility is not only inherent but necessary to the energy grid. Thus, the notion that renewable energy sources would benefit from or require some type of energy storage is not particularly viable—especially given the prohibitively high costs of such technology. Diversifying the sources and types of electricity being fed into the grid already serves to stabilize the variability in more valuable ways than energy storage might. A more prudent next step is investing in a smarter grid system that would more efficiently adapt to aggregate variability that is a result of all energy sources, not just renewable energy.

Intermittency does have an effect on the capacity factor (i.e., actual energy produced vs. maximum potential given that a generator was running full time at rated power) of wind and solar energy. As with all energy sources, this is taken into consideration when projecting economic and environmental benefits.

ECONOMICS OF RENEWABLE ENERGY

Federal and State Renewable Energy Standards

Encouraging development and deployment of renewable energy sources stands as a mechanism for reducing the carbon footprint of the energy economy. In 2004, Pennsylvania joined the growing number of states with renewable energy standards, a move that was instrumental in attracting green businesses to the region. Now, a federal renewable energy standard is under consideration. Some states, such as New Jersey, have updated their renewable energy standards to be even more aggressive. Should Pennsylvania also strengthen its alternative energy portfolio standards in order to remain competitive and repeat earlier successes? Or is it more important to restore a level playing field for all energy sources and let market forces shape the energy economy? These are some of the big questions posed by the prospect of renewable energy standards.

Like any technology awaiting commercial validation, renewable energy remains dependent on subsidies and policy directives. Simply put, renewable energy is expensive. Much of the technology involved in renewable energy is cutting edge and sometimes requires highly manufactured or rare and costly components. Renewable energy also lacks the economies of scale and investment track record that benefit more established energy technologies.

While tax credits, federal grants, and state programs help to ease the initial cost of installing a solar or wind power system, these initiatives are still in their infancy. Because of the high up-front costs, the decision to install alternative energy on a commercial, residential, or utility scale remains chiefly a matter of environmental conscience rather than fiscal principle. One of the keys to helping solar and wind energy gain critical mass is helping the economic motivation for alternative energy match the environmental impetus. Generating electricity through alternative energy sources at a price point that is competitive with grid electricity from conventional resources (''grid parity'') is the holy grail of the renewable energy sector. In Pennsylvania, there is still a long road ahead to achieving parity.

Solar energy, which is determined by PUC to be the ''greenest'' and most easily deployed alternative energy application, provides a good example of the high up-front costs faced by those wishing to produce renewable energy. An approximately two kW residential solar energy system that offsets 25 percent of 920 kWh of monthly electric usage (the 2008 national average, per EIA) would cost about $16,000 before incentives. The parameters vary widely depending on siting, economies of scale, and other factors, but a 25 percent offset may be ambitious for most commercial and industrial applications. For example, a 15-acre 1.9 mW solar farm serving Crayola's factory in Easton will provide about 10 percent of the facility's electricity needs.

There are a number of federal and state incentives available to renewable energy developers in Pennsylvania as well as policies that support and encourage growth in the wind and solar energy sector.

Tax Credits, Grants, and Subsidies

The bulk of alternative energy support in Pennsylvania comes from tax credits, grants, incentives, loan guarantees, and financing through the Alternative Energy Investment Act passed in 2008, which established the $650 million Alternative Energy Investment Fund. In addition, solar and wind installations can receive up to a 30 percent subsidy through the U.S. Department of the Treasury's Renewable Energy Grants or the federal business energy investment tax credit. The grant program expired in 2010 while the tax credit will apply to small (up to 100 kW) wind and solar installations installed prior to 2017. Pennsylvania also received approximately $40 million to put toward its Green Energy Development Loan and Green Energy Works programs through American Recovery and Reinvestment Act (ARRA) State Energy Program funding in 2009.

Renewable Portfolio Standards and Renewable Energy Credits

One of the most prevalent forms of renewable energy policy in the United States is the renewable portfolio standard (RPS) or renewable energy standard. RPS systems require electricity distributors to produce or purchase a certain amount of their load from approved renewable energy resources. Renewable energy is traded through renewable energy credits, or ''green tags,'' which are accrued by owners of qualified renewable energy generation facilities, including residential; commercial; and utility scale installations.

Pennsylvania's RPS, as previously discussed, is known as AEPS and sets a timetable for slowly ramping up the state's renewable energy mix by 2021. These energy sources are split into two tiers. Tier I includes solar PV and solar thermal energy, wind power, hydropower, geothermal, biogas, biomass, fuel cells, coal mine methane, and black liquor. Tier II includes waste coal, municipal solid waste, certain forms of hydropower, and IGCC as well as energy saved via demand-side management and distributed generation systems. (The inclusion of coal-based energy prompts the use of ''alternative energy'' moniker rather than ''renewable.'') The goal for 2021 is to provide 8 percent of Pennsylvania's electricity from Tier I, with a minimum of 0.5 percent consisting of solar PV energy (e.g. a solar carve out or set aside) and 10 percent from Tier II sources.

In Pennsylvania, renewable energy credits are referred to as alternative energy credits (AECs). AECs can be sold to brokers or aggregators (similar to a stock exchange) or directly to the electricity distribution companies in order to help them meet their state-mandated renewable energy requirements. Purchasing of solar AECs is incentivized in Pennsylvania by the imposition of a solar alternative compliance payment (SACP) that is set at double the average for a solar AEC for the previous energy year. In this way, electricity distributors are penalized for noncompliance and economic benefits are filtered toward generators of renewable energy.

Net Metering

Residential and commercial buildings that generate more electricity than they consume can sell this excess to the electricity distribution companies for additional income. Utilities are required by state law to offer net metering to residential customers with installations up to 50 kW in capacity and nonresidential facilities with up to three mW in installed capacity. Utilities also must offer net metering to nonresidential facilities with more than three mW but less than five mW of installed capacity, provided they make their systems available to the grid in emergencies. Net excess generation is sold to the utilities at the retail rate (a key difference compared to feed-in tariffs, discussed below) and is applied to the ratepayer's next monthly bill. Consumers also retain AECs from their generation.

The Unmet Need

Although the combination of federal and state subsidies and programs does ease the load on up-front and ongoing renewable energy costs, a significant gap remains. After applying the incentives above, the up-front cost for the two kW residential system comes down significantly to about $7,500, but this installation still has about a 17-year break-even point, according to the Solar Energy Industries Association's solar calculator.

Securing financing for commercial developers is an even greater challenge. Many large commercial buildings are already heavily leveraged with commercial mortgage-backed securities debt, making it difficult for private underwriters to identify assets for collateral. Furthermore, the income generated by solar energy systems—a diverse mix of grants, tax credits, depreciation allowances, net metering, and AEG—is equally as difficult for banks and financiers to use as collateral. This is exacerbated by the perplexing AEC market in Pennsylvania, as described by SRECTrade, an online auction platform for renewable energy credits in the northeastern and middle Atlantic regions. Currently, Pennsylvania has no schedule for SACP prices and instead sets the price six months after the end of each energy year. This lack of price certainty makes it less prudent for private institutions to enter into long-term (i.e., five or 10 years) financing based on solar AEC purchases.

The partnership among Crayola, PPL, and UGI Utilites, Inc., is a unique example, in which Crayola leased the land to the energy developers and agreed to purchase the power generated by the solar farm. Meanwhile, PPL and UGI funded the construction and will share the AECs between them. This much-publicized venture was financed in partnership with PPL Renewable Energy and UGI Energy Services along with a $1.5 million state grant funded by ARRA.

New Jersey's Solar Renewable Energy Credit (SREC)-Based Financing Program

New Jersey serves as an example for possible reform of Pennsylvania's AEC market. New Jersey has a much more aggressive solar carve out in its renewable portfolio standard, with a goal set at 2.12 percent by 2021 for a total of 1,500–2,300 mW installed solar capacity. Like Pennsylvania, New Jersey encourages renewable energy development primarily through tax rebates and incentives, offering subsidies that can amount to more than 50 percent of installation costs. According to a publication from New Jersey's Clean Energy Program, however, meeting the state's needs by 2021 with this model would eventually cost up to $9.6 billion in tax rebates and incentives.

To address this issue, New Jersey has devised a market-driven solution to solar financing challenges by implementing an SREC-based financing program. The crux of the SREC-based financing program is in devising a mechanism for introducing predictability in market value for SRECs by scheduling the SACP prices eight years in advance. This added price certainty gives private institutions more confidence to accept SRECs as part of a financing agreement. By reducing the risk for private lenders, this financing program is expected to help transition the state away from a rebate program and toward longer term financing.

While the mechanisms and nuances of AEC reform for Pennsylvania may vary, fostering price certainty for AECs appears to be a critical factor in helping solar and wind developers to secure financing.

Feed-in Tariffs

Feed-in tariffs have been highly successful in Germany, Spain, and France, where government policy guarantees grid access, long-term purchasing contracts, and a profitable price on excess generated renewable energy for all potential producers of alternative energy. Feed-in tariffs differ significantly from Pennsylvania's AEPS, AEC, and net metering systems. The key difference is that a feed-in tariff and its supporting policies guarantee not only a buyer for renewable energy but also a price point that nets a profit for the seller. Recall that net metered energy in Pennsylvania is sold to utilities at the retail price of electricity and AECs are traded on an open market.

This approach is credited as one of the main drivers of Germany's success in the wind and solar energy sectors. As of 2009, Germany produced 16.1 percent of its electricity from renewable sources, including 37,809 gWh from wind and 6,200 gWh from solar, according to German government data. Germany also is one of the leading manufacturers and exporters of solar and wind energy components. NREL research also suggests that renewable energy in countries with feed-in tariffs is less costly than governments with RPS systems driven by AEC, as the tariff system is less risky and investors more readily accept lower profits in exchange for long-term sustainability.

But in the United States, where states tend to favor RPS and subsidies, feed-in tariffs have yet to replicate the success of European models. California, Florida, Hawaii, Maine, and Vermont recently have implemented less aggressive feed-in tariffs. Gainesville Regional Utilities (GRU) rolled out a feed-in tariff in 2009 that comes the closest to replicating European examples, as it bases its tariff price on the cost of producing electricity with solar PV rather than conventional fuel sources. GRU's model is hailed as a pioneering success by proponents, but it has not been without its growing pains. As Harald Kegelmann, CEO of a Florida-based solar company, told the Apollo Alliance in September 2009, the policy attracted a glut of ''speculative projects and solar carpetbaggers'' with about 78 percent of the projects going to out-of-state developers. Still, GRU's feed-in tariff has promise, pending tweaks to the application process, implementation of annual capacity quotas, and more engagement with local investors and stakeholders, according to Kegelmann.

In general, U.S. feed-in tariffs shy away from mandating renewable energy prices above the market price for conventional generation (i.e. ''avoided cost'') partially due to uncertainty regarding the legality of such legislation under the Public Utility Regulatory Policies Act (PURPA). PURPA, passed in 1978, caps the rate at which certain energy producers can sell electricity back to utilities at avoided cost, thus presumably barring states from mandating a profit for sellers. In January 2010, however, NREL released a 68-page legal analysis of various circuitous ways that states could make a profitable feed-in tariff legal, but none has yet been attempted in Pennsylvania.

Technical barriers, such as the nation's need for a smarter grid system, stand in the way of feed-in tariffs as well. Also, as Dan Martin of the Semiconductor Equipment and Materials International PV Group observed in a recent article, feed-in tariffs may face the same political challenges as a European-modeled health care system did in the United States: It may be seen as an ''exotic policy not applicable to the U.S. market.'' Other skeptics of the European model of renewable energy policy attribute the success to the amount of subsidies, rather than the mechanism. Adam Browning was quoted on this issue by the Cleantech Group, stating that Germany had been ''handing out bags of money and calling it a feed-in tariff. People think that they want a feed-in tariff, but what they really want is those bags of money. If you want to get excited about replicating Germany's success, replicate their budget, don't worry about replicating their policy model.''

In summary, meeting the state's goals for renewable energy generation demands solutions to significant financial hurdles. Other states and nations provide examples that may help to inform the shaping of a mechanism that works within the regulatory, political, and climatic environment in Pennsylvania.

JOB CREATION AND WORKFORCE CHALLENGES

The prospect of production and development of new energy components and facilities translates into a key opportunity: jobs. Laborers, contractors, researchers, and engineers will be needed for both large-scale construction projects and residential and commercial installations. A reinvigorated manufacturing sector in Pennsylvania also would serve regional and worldwide supply chains for renewable energy markets. The commonwealth's business climate and incentives already have attracted several original equipment manufacturers to the area, such as Gamesa, Spain's market leader in wind energy, and Solar Power Industries, a global provider of photovoltaic equipment. Research centers in Pennsylvania's universities and programs—such as the Pitt Center for Energy and Carnegie Mellon's Steinbrenner Institute for Environmental Education and Research—also may be eligible to receive federal funding for future renewable energy projects.

However, uncharted technological horizons pose the same workforce challenges faced by other industries with new technical demands. Siting and deployment of wind and solar installations require industry-specific training, experience, and certification, and developers will turn to an international market for talent. It is incumbent upon the region's industry partnerships and educational facilities to produce local workers who are prepared to fill these coveted green jobs. Identifying which skills and programs are needed is one of the most significant challenges, one that can be addressed through direct collaboration with the industry. For example, Gamesa and Bucks County Community College inaugurated a Green Jobs Academy in June 2001 in order to train workers in the new skill set needed to secure family-sustaining jobs in Pennsylvania's growing green economy. The jobs are as varied as wind turbine component manufacturing, wind farm construction and turbine installation, wind turbine operations and maintenance, logistics and engineering, legal and marketing services, and much more. Gamesa will support the Green Jobs Academy both as a primary user and through company-developed wind energy training and curriculum resources.

I. SOLAR ENERGY

Pennsylvania Solar Industry Quick Facts

- Installed capacity: **Nine mW (less than 1 percent of state total)**
- Average solar resource in Pennsylvania: **1,500 kWh per square meter**
- Average solar resource in Germany (number one nation in solar): **1,000 kWh per square meter**
- AEPS target by 2021: **approximately 860 mW**
- Busbar cost: $237–$300 per mWh
- Jobs created by solar industry in 2009 (nationwide): **46,000 (indirect and direct)**
- Trained solar installers needed by 2015: **5,000**
- North American Board of Certified Energy Practitioners (NABCEP)-certified solar installers in Pennsylvania: **about 50**
- NABCEP testing facilities in Pennsylvania: **Zero**

The conventional wisdom about solar energy in Pennsylvania is that the climate is simply incompatible. After all, the National Climatic Data Center estimates Pittsburgh enjoys an average of 59 clear, sunny days each year, which ranks it squarely in the bottom tier of sunny cities (Yuma, Ariz., ranks number one with 242 cloudless sunny days). But, contrary to popular belief, it's state and federal environmental policy (or lack thereof)—not atmospheric cloudiness—that rains on solar's parade. For evidence, one need only look to the world's number one nation in solar energy: Germany. According to the Joint Research Centre for the European Commission, Germany—which gets an average of 1,000 kWh per square meter of yearly global solar radiation—is no sunnier than Pennsylvania, which has a solar resource of about 1,500 kWh per square meter, according to NREL.

ENVIRONMENTAL IMPACTS

Solar photovoltaic (PV) generation, which converts sunlight into electricity, does not consume any water or emit any pollutants. While rooftop solar installations have virtually no footprint, large utility-scale solar farms have the potential for habitat disruption due to competing land use. As with all large-scale construction projects, solar developers must obtain permits from DEP and other agencies in order to mitigate soil erosion and harm to wildlife. Such siting and conservation issues and requirements are not unique to solar farms, and thus no significant gap in policy is foreseen on this front.

Solar PV does have a substantial environmental impact during the manufacturing phase and at the end of its life cycle.

Solar PV manufacturing shares the same environmental challenges as the cell phone, computer, and other electronics industries. Highly toxic chemicals are used during the manufacturing process, including arsenic, cadmium, chromium, selenium, and others. However, measures and regulations for protecting workers and the public from the detrimental health effects of these substances have long been in place.

The fate of solar equipment at the end of its life cycle (about 25 years) looms relatively larger as a global environmental threat. Improperly disposed electronics leach harmful substances into the environment and drinking water supplies. Again, awareness of this issue is well established, and regulators will need to make sure that the same practices for safe disposal or recycling of computers and electronics (''e-cycling'') will apply to solar panels.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

Current Generation and Potential

There are two main types of solar energy that are applicable to Pennsylvania. Most significant is solar PV technology. There also is potential for harnessing solar thermal resources for use in hot water or air heating. Solar thermal energy also can be used to generate electricity in warmer climates, but this technology currently is not viable in Pennsylvania.

Compared to the nation at large, Pennsylvania has taken significantly longer strides toward supporting the solar industry. But the commonwealth's policy easily is outstripped even by our neighbors in the northeast. For example, New Jersey, which has less square mileage than and a similar solar resource to Pennsylvania, is the number two state in homes served by solar energy, outpacing states like Colorado and Nevada as of April 2009. Meanwhile, solar's contribution to Pennsylvania's renewable energy mix was too low to be included in EIA's 2007 assessment. But since the implementation of statewide solar incentives and the 2004 AEPS mandates, a total of 5.7 mW of solar generation capacity has been added between 2004 and 2009, according to a report by Black & Veatch Corporation. DEP data show that there are currently nine mW of installed solar capacity in the state. Overall, solar still makes up less than 1 percent of Pennsylvania's electricity generation, but growth is strong.

The Black & Veatch report identifies 619 gW of solar capacity in Pennsylvania, which amounts to 949,165 gWh of energy output. The bulk of this capacity would come from utility-scale solar farms, while about 22 gW would be supplied by residential and commercial rooftop solar installations. The American Council for an Energy-Efficient Economy (ACEEE) conducted a technical assessment that arrives at similar figures for Pennsylvania's solar potential at a total of 28,894 gWh and 66.4 TBtu statewide for residential and commercial solar installations (this does not include utility-scale solar generation). According to ACEEE, achieving this technical potential would offset 20 percent of all residential energy use and 39 percent of all commercial energy use.

While the technological potential of solar energy in Pennsylvania is shown to be very high, realizing the market potential of solar installations requires significant private and public investment. Helping this along most significantly is the 2004 AEPS mandate, which sets aside 0.5 percent of the Tier I goal for 2021 for solar PV generation, amounting to about 860 mW of installed solar PV capacity over the next 11 years.

Other notable advantages for solar energy/power in Pennsylvania include:

- Alternative Energy Investment Fund, which sets aside $100 million for solar incentives and another $80 million for economic development for solar manufacturers and large-scale projects (Pennsylvania Sunshine Solar Program);
- Net metering; and
- Standardized interconnection rules established in 2008 to streamline interconnection for grid-connected distributed generation.

Combined, this suite of subsidies, tax incentives, and policies creates an attractive environment for solar projects and investments. Incentives for solar investments average about 35 percent per installation. However, at the current level of program support for solar projects, the ACEEE study estimates that only 680 mW of capacity will be installed by 2020, which falls about 20 percent short of the 860 mW goal for 2021 set by AEPS. (Note again that the ACEEE study did not factor in the market or technical potential for utility-scale solar installations, which the Black & Veatch report did.) This estimate highlights the need for continued support of solar and some tailoring of state programs and policies to help overcome market barriers to solar's growth.

Solar represents the largest source of renewable energy potential by a large margin. How much of this potential can be viably tapped remains in serious question, however, as many barriers stand in the way of wide-scale adoption of solar energy, the most significant of which were discussed above.

JOBS AND ECONOMIC OUTPUT

Energy Costs

Solar power's overall costs hinge heavily upon government incentives and tax credits. Black & Veatch estimated that, in 2009, utility-scale solar PV had a levelized cost of $237 per mWh, while residential and commercial PV would cost about $300/mWh contingent upon attractive mortgage-style financing rates. This cost is expected to spike after 2016, when the investment tax credit expires, and then resume its decline to a cost of $200/mWh by 2026. Currently, this still amounts to a significant premium over conventional electricity generation as well as other renewable energy sources. But, according to Black & Veatch, if the tax credit is extended, technology continues to drive costs down, and carbon policy imposes a price on greenhouse gases, solar could reach parity with conventional electricity generation by 2029. The June 2008 Lazard levelized energy cost analysis estimated solar PV busbar cost at $96–$154. Lazard's estimate is lower because it presumes a higher capacity factor—about 20–26 percent—while the Black & Veatch estimate presumes a capacity factor between 17–19 percent.

Jobs and Workforce

There are three distinct job growth areas—research and development, manufacturing, and construction—that would benefit from an increase in solar energy in Pennsylvania.

Although solar technology still is evolving toward grid parity, there are significant opportunities involved in research and development. Research facilities associated with the region's universities and manufacturing companies also could benefit from increased federal investment in solar technology development through research grants. For example, in spring 2010, DOE funded three solar research and development programs: the Photovoltaic Manufacturing Initiative, the Web-Based Photovoltaic Database, and Photovoltaic Supply Chain and Cross-Cutting Technologies.

Pennsylvania also can benefit from the next step of the value chain: manufacturing. Providing a favorable business climate as well as a guaranteed market for solar power already has attracted to the region several manufacturing companies, which provides hundreds of jobs for factory workers, managers, and engineers. Black & Veatch reports that the region has seen a recent influx of solar companies opening their doors in Pennsylvania, including a Plextronics plant and research and development operation in Pittsburgh; a solar cell plant run by Solar Power Industries (SPI) in Belle Vernon; and other companies supporting the solar supply chain including AE Polysilicon in Morrisville, FLABEG in Brackenridge, and Conergy in Paoli. While the drivers behind this escalated interest in the region are numerous and varied, several companies have attested to the significance of state policies and incentives among the attractive components of Pennsylvania's business climate. Strengthening the incentives and growing demand for solar components can help to repeat these successes, while expanding production will lead to more jobs at existing factories.

SPI presents itself as a testament to state and federal policy and government incentives as a mechanism for job growth. SPI rose from the ashes of Ebara Solar, a short-lived flexible thin-film solar cell manufacturer founded in 2001 that faltered due to funding issues and entered state receivership in 2003. At its peak, Ebara had 100 employees. SPI saved the assets of the $7 million facility from being sold and shipped to a Chinese facility and instead began manufacturing solar cells for the power industry in Belle Vernon, where it hired 35 employees, many of whom were originally let go from Ebara. By 2009, SPI had grown its workforce to 210 employees. In July 2009, SPI announced that it was launching an expansion over the next three years that would see it employing an additional 375 workers in its newly leased 265,000-square-foot facility in the Sony Technology Center in East Huntingdon. The move originally was spurred by the promise of federal funding connected with ARRA. In the end, the $40.1 million facility will be helped along by about $14 million in state loans and assistance plus a matching grant of $937,500. Currently, SPI exports most of its products to European and Chinese markets, but it anticipates serving U.S. markets, where solar demand is expected to double by 2013.

Lastly, the need for more solar installers also can prove to be a boon to contractors, developers, and electricians. DOE estimates that its Solar America Initiative, if successful, will create a need for up to 5,000 trained solar installers in the United States by 2015. The key to seizing upon this opportunity is to prepare our workforce by establishing or raising awareness about solar training and certification programs. There are several solar education facilities nationwide—including the Florida Solar Energy Center; the Midwest Renewable Energy Association in Wisconsin; the North Carolina Solar Center; the Great Lakes Renewable Energy Association in Michigan; and Solar Energy International, which hosts online courses—but there is no such program in the Pennsylvania area. However, community and technical colleges have begun offering certificate programs for those interested in pursuing careers in the solar industry. Industry groups such as the Northeast Sustainable Energy Association, however, question whether such fragmented certification and training programs can close the gap.

Several national certification initiatives are beginning to emerge as a solution to the need for a widely recognized accreditation program for solar installers. Most notable is the model put forth by the New York State Energy Research and Development Authority (NYSERDA), which supports the development of an in-state network of training programs for prospective workers in the solar industry. NYSERDA has invested approximately $1 million into establishing seven accredited solar training centers throughout the state and has partnered with local colleges and universities and the International Brotherhood of Electrical Workers (IBEW)'s local Joint Apprenticeship and Training Committees. Another prominent national solar accreditation is offered by the North American Board of Certified Energy Practitioners (NABCEP) and is recognized as the crown jewel credential for installers. Currently, there are no NABCEP testing facilities in Pennsylvania and only about 50 NABCEP-certified solar installers currently reside in the state.

In addition to the direct employment opportunities noted above, the solar industry also opens the doors to a number of indirect or induced jobs. According to the Solar Energy Industries Association (SEIA)'s 2009 year in review report, direct solar jobs increased nationwide by 10,000 plus an additional 7,000 in induced jobs for a total of roughly 46,000 jobs directly and indirectly supporting the solar industry in the United States. SEIA predicted that this number would rise to 60,000 by the end of 2010. Given Pennsylvania's growing solar industry, it is presumed that the state also will see proportionate growth in solar induced jobs.

SUMMARY

Contrary to popular belief, Pennsylvania's solar resource is sufficient for significant added generation capacity. The low profile and deployability of solar energy allows it to be incorporated into rooftop and utility-scale installations with greater ease than more imposing facilities, such as a wind farm, but solar energy remains one of the most expensive technologies to finance.

II. WIND ENERGY

Pennsylvania Wind Industry Quick Facts

- Wind farms in Pennsylvania: **17**
- Installed capacity: **748 mW (about 2 percent of state total)**
- Total potential capacity: **3,307.2 mW**
- Busbar cost: **$44–$91 per mW**
- Jobs supported nationwide by the wind industry in 2008: **85,000 (about 15–19 per mW)**

Among renewable energy sources, wind energy has seen the strongest growth in the United States as well as in Pennsylvania. According to AWEA, more than 8,500 mW in new generating capacity from wind were added in the United States in 2008, representing a 50 percent increase over 2007 and a $17 billion investment into the national economy. Capacity grew an additional 10,000 mW in 2009 as a result of ARRA incentives; in 2010, less than 6,000 mW of new capacity was added. Pennsylvania contributed 387.5 mW of the newly installed wind energy capacity in 2009. The number of jobs supported nationwide by wind energy was estimated at 85,000 in 2008, which rivals coal-mining jobs nationwide, according to AWEA.

ENVIRONMENTAL IMPACTS

Somewhat ironically, wind installations are seen as both a solution to as well as a source of environmental threats. Endangerment to bird and bat populations has been the most enduring public concern. This issue gained the most publicity when several lawsuits were filed regarding the Altamont Pass Wind Farm, a wind farm commissioned in California in the 1980s with approximately 5,000 turbines. The Center for Biological Diversity claimed that the wind farm was built in a major migratory path for birds and raptors and was responsible for thousands of bird and raptor deaths. Mitigation options suggested by the Center for Biological Diversity included resiting and relocation, increasing the height of the wind turbines so they would be above flight paths, and managing the habitat to keep rodent prey away from turbines. In 2007, a settlement was reached, with wind developers agreeing to reduce bird mortality by 50 percent over the next two years, but controversy continues.

Closer to home, a federal judge halted development of a 122-turbine West Virginia wind farm pending a special permit from the U.S. Fish and Wildlife Service in order to mitigate harm to the Indiana bat, an endangered species. The development of the wind farm was challenged by the Animal Welfare Institute, among others, under the Endangered Species Act, making it the first case to evoke the federal policy. As such, this decision may set the tone for similar conflicts.

AWEA initially responded to concerns over avian fatalities by comparing the wind industry's impact favorably to the detrimental effects that other energy industries have on wildlife. AWEA also states that a greater number of birds are killed due to collisions with vehicles, plate glass, buildings, and other tall structures than from wind farm development. Nevertheless, AWEA has established an environmental task force in order to research and develop technology and best management practices to reduce bird, bat, and raptor kills.

In addition to bird kills from collisions with wind turbine blades, the vast amount of land that wind farms occupy also can disrupt habitats. For example, in Kansas, the Nature Conservancy has been resisting development of wind farms in the Flint Hills as they compete with the lands used for ground-nesting birds.

Solutions to bird and bat kills can be found in thorough assessments of wind farm sitings as well as design innovations. In Pennsylvania, more than 20 wind energy companies have signed a voluntary agreement with the Pennsylvania Game Commission vowing to avoid, minimize, and mitigate impacts on animal populations. A partnership between wind developers and conservancy groups has been forged in the American Wind Wildlife Institute. The institute is currently working on a nationwide mapping tool that will identify sensitive areas

in terms of potential for wildlife disruption. Access to such data may also help to mitigate the wildlife impacts of wind development. Vertical axis wind turbines have been presented as a safer alternative for birds and bats, but the technology is still under development.

PUBLIC HEALTH AND COMMUNITY IMPACTS

Although AWEA maintains that an operating modern wind farm at a distance of 750–1000 feet is ''no noisier than a kitchen refrigerator,'' there have been numerous complaints from residents regarding noise generated by nearby wind turbines. AWEA does concede that there are exceptions to quietly operating turbines, particularly with older turbines from the 1980s and newer turbines installed in hilly terrain. AWEA states that excessive wind turbine noise generally can be anticipated and avoided during the siting and development process.

Nevertheless, the complaints continue and have been gaining more publicity recently, especially in light of studies attributing certain health maladies to turbine noise. Nina Pierpont, a pediatrician from New York, recently released an independently funded study that scrutinized 36 cases of ''wind turbine syndrome'' reported by residents in both North America and Europe. Pierpont argued that conditions such as tinnitus, sleep deprivation, vertigo, heart disease, panic attacks, and migraines were caused by infrasound and low-frequency noise emitted by turbine generators.

AWEA, along with the Canadian Wind Energy Association, sponsored a study into the possible adverse effects of wind turbine noise conducted by an expert panel of audiologists, medical doctors, and acoustic professionals. The panel held there is no evidence that audible or subaudible sounds created by wind turbines have any direct adverse physiological effects. Further, the panel compared wind turbine noise to noises found in occupational settings that produced no adverse health consequences. The study also criticized Pierpont's methodology, particularly her small and self-selected sampling.

Aside from the contentions surrounding the noise generated by wind turbines, residents also have complained about the visual effects of wind mills. Concern has been expressed over shadow flicker created by the turbines during certain times of day, which is a nuisance and may carry a minimal risk of triggering epileptic seizures. In some cases, Federal Aviation Administration regulations require turbines to be illuminated, which also raises concerns of aesthetics and light pollution.

Small wind installations also may give way to debates over aesthetics and cause tension within communities. Determining whether one resident's right to reap energy from a wind installation has primacy over another resident's right to enjoy an unadulterated view may present a challenge.

The best remedy to the majority of the above-mentioned issues surrounding wind farms is proper siting. There are a number of state and federal agencies that currently play a role in the permitting process to ensure that there are minimal impacts on habitats and wildlife. For each wind farm, wildlife surveys are coordinated with and reviewed by the Pennsylvania Game Commission, Pennsylvania Fish and Boat Commission, and U.S. Fish and Wildlife Service. The Pennsylvania Department of Conservation and Natural Resources also reviews the site for potential impacts on plant life. Also, as part of the DEP permitting process, applicants must conduct a search of the Pennsylvania Natural Diversity Inventory to ensure that construction does not conflict with rare or endangered wildlife. Development of a wind farm also requires a National Pollutant Discharge Elimination System permit to protect water quality. Issues such as setbacks, noise and shadow flicker restrictions, illumination, and use of public roads are addressed in local ordinances. State and local governments collaborated with wind companies to develop a model ordinance to serve as a starting point for municipalities in crafting their own policies for wind farm construction, which can be found on the Pennsylvania Wind Working Group Web site.

ECONOMIC IMPACTS AND INDUSTRY OVERVIEW

Current Generation and Potential

The 2009 AWEA industry report indicated that Pennsylvania has 748 mW of installed wind capacity. The state more than doubled its installed capacity in 2009, when five new wind projects became operational: Locust Ridge II (102 mW) in Schuylkill County, North Allegheny (70 mW) in Blair and Cambria counties, Highland Wind Project (62.5 mW) in Cambria County, Stony Creek (52.5 mW) in Somerset County, and Armenia Mountain (100.5 mW) in Tioga and Bradford counties. According to AWEA, There are 17 total wind energy projects operating in Pennsylvania that produce enough clean energy to power approximately 162,500 homes. PennFuture estimates the commonwealth's full potential at 4,000 mW of wind energy, enough to power 1,168,000 homes.

In February 2010, NREL released an updated state-by-state assessment of wind energy potential in the United States, data that had not been revisited since 1993. In the previous studies, estimates were based on a wind tower height of 50 meters and found a potential of 5,000–8,000 gW wind capacity in the contiguous 48 states. The updated assessment is based on generation from wind towers 80 meters high in areas with a 30 percent gross capacity factor or greater and finds an estimated 10,500 gW of wind development potential in the United States. The NREL study determined that Pennsylvania had 661.4 square kilometers of available land for wind development and a potential of 3,307.2 mW of installed capacity and 9,673 gWh of annual generation. Note that this figure excludes protected lands, such as national parks and wilderness, and incompatible land use, such as urban areas, airports, wetlands, and bodies of water. These exclusions amount to about 68.9 percent of the total windy land area in Pennsylvania, or about 1,462.1 square kilometers of land that has high wind energy potential but currently is unusable.

Overall, NREL's estimate of wind potential is lower than PennFuture's assessment but still shows Pennsylvania has tapped only a fraction of its full potential for wind energy generation. According to AWEA, Pennsylvania is ranked as the state with the 15th-highest installed wind capacity and is ranked 22nd in terms of potential capacity. But in spite of the middle-level capacity ratings, Pennsylvania has a distinct advantage because it borders several states that have renewable portfolio standards but do not have sufficient land to produce wind farms. Access to the PJM Interconnection grid will make it easy for wind energy producers to markets in these states. Currently, the only northeastern state with more installed wind capacity than Pennsylvania is New Jersey.

In terms of contributing to the total generation capacity in the state, wind plays an undeniably small role, supplying just 2 percent in 2009, according to DEP. The Black & Veatch report points out, however, that wind has been the fastest-growing energy source over the last decade, with about 30 percent annual growth in worldwide capacity over the last five years. This growth has been driven in large part by the production and investment tax credit programs offered by the federal government. As mentioned above, the 2009 AWEA report showed that growth in Pennsylvania is even faster, as the state's wind industry is bolstered by AEPS and market opportunities throughout the PJM region.

Offshore wind development presents another opportunity for growth in the wind industry. Offshore wind projects would benefit from stronger and steadier winds but face greater technological challenges. Several offshore wind projects have been deployed successfully in Europe, and the Obama administration recently approved plans for a 130-turbine wind farm off the shores of Delaware and New Jersey. AWEA also recently formed the Offshore Wind Development Coalition, which is focused on advocating and promoting offshore wind developments. According to AWEA, offshore wind projects totaling more than 5,000 mW currently are in the planning or development stages in the United States, and DOE estimates that 10 times that amount likely will be needed to meet the goal of generating 20 percent of U.S. electricity from wind by 2030. U.S. Senator Sherrod Brown (D-Ohio) also has recently introduced the Program for Offshore Wind Energy Research and Development Act of 2010, which would spur development of offshore wind projects in Lake Erie. Although expanded offshore wind farms would have limited direct impact in Pennsylvania, the commonwealth's manufacturing base could support the supply chain of a growing regional industry. Portions of Lake Erie also partially composed the excluded lands in NREL's assessment of Pennsylvania's wind potential. As such, commercial viability of offshore wind development may expand Pennsylvania's generation potential.

JOBS AND ECONOMIC OUTPUT

Development of the wind energy industry introduces several job growth opportunities, primarily in the large-scale construction and manufacturing sectors. According to the Pennsylvania Wind Working Group, each megawatt of new energy creates between 15 and 19 jobs, a figure that is widely cited by international wind working groups and is not tailored narrowly to the situation and economic climate in Pennsylvania.

The Black & Veatch report cited a separate study conducted by the Political Economic Research Institute at the University of Massachusetts Amherst, which identified 10 representative occupations that could support the wind power industry and employed 127,940 Pennsylvanians as of May 2007. These occupations include environmental engineers, sheet metal workers, machinists, truck drivers, train operators, and other jobs that would support the construction of wind farms. The Black & Veatch study concluded that an expansion in the wind industry could stimulate growth in these sectors as well.

The Black & Veatch report indicated that there are more than 40 companies directly serving the wind industry in Pennsylvania, a sharp increase since 2004, when there were ''next to none.'' These companies are a significant source of jobs. For example, the report notes that Gamesa, which established a factory in Pennsylvania in 2006, had 1,000 employees before the economic downturn forced the company to lay off some of its workers. To date, Gamesa has invested more than $220 million in Pennsylvania. The company now employs 850 workers nationwide, including 800 in Pennsylvania, where the company operates its blade manufacturing plant in Ebensburg, Cambria County, and a nacelle manufacturing plant in Fairless Hills, Bucks County. More than 350 of the factory jobs are ''green collar'' positions, and employees are represented by the United Steelworkers union.

Wind farm construction also provides temporary construction jobs and permanent operation and maintenance jobs. According to AWEA, the Green Mountain Energy wind farm at Garrett—a 10.4 mW installation with six turbines—employed 12 contractors and 10 local general laborers during its five-month construction. AWEA also states that local construction contracts typically constitute about 20 percent of the cost of wind farms, meaning a 15 mW facility would generate about $3 million in business for local contractors.

The greatest opportunity for job growth related to Pennsylvania's wind industry comes from the manufacturing sector. A completed wind turbine consists of a number of highly engineered components, such as the nacelle, blades, gearbox, and towers. Pennsylvania is home to several suppliers of such wind turbine components that serve national and international wind developers. Pennsylvania's proximity to energy markets backed by RPS requirements is particularly attractive to wind manufacturers. In addition to suppliers, the wind industry also can be supported by other industries in the region. For example, Gamesa's economic impact reaches far beyond its factory walls. For each wind turbine that's manufactured, about 8,000 parts are needed for assembly. Metal components make up nearly 90 percent of the weight and more than one-third of the value of a modern wind turbine. According to Gamesa, the company's local supply goal is 75 percent. Currently, Gamesa's domestic content on its U.S.-made turbines is nearly 60 percent. The company works with 105 Pennsylvania-based subcontractors, which represent 41 percent of what is sourced in North America.

LEASING AND SMALL WIND

Private landowners, like those who sign leasing agreements with gas drillers, can realize significant income by leasing their land to wind developers. This includes royalties as well as monthly rent. The Pennsylvania Wind Working Group estimates that Pennsylvania farmers can earn between $2,000–$3,000 per turbine per year by sacrificing as little as half an acre from agricultural production for each tower. Each 100 mW of power represents about $260,000 in annual payments to landowners.

A 2001 publication from PennFuture stated that typical lease arrangements pay out 2 percent of gross revenue to the landowner on a yearly basis, with payments ranging as high as 10 percent of gross revenue depending on competing land uses. For example, a 20 mW wind facility with a 2 percent lease payment, a 25 percent capacity factor, and wind prices at $60 per mW would yield about $52,560 in payments to the landowner each year.

Homeowners and commercial building operators also can benefit from small wind installations in a similar fashion as owners of solar installations do. Net metering, electricity offsets, and AECs could provide a source of savings and income from wind installations.

SUMMARY

Wind energy is the most promising renewable energy source in Pennsylvania. Growth in the wind industry creates manufacturing and construction jobs, supports various other local industries, and provides clean energy that offsets emissions from fossil fuel-burning energy sources. Pennsylvania's favorable renewable energy policies already have attracted a number of businesses that support the wind industry within the state's borders, and as wind energy begins to play a larger role in neighboring states, Pennsylvania's established manufacturing facilities stand to benefit. The drawbacks of wind energy—namely environmental, wildlife, and community impacts—can largely be mitigated through careful siting and continued rigorous regulatory oversight.

III. OTHER ALTERNATIVE ENERGY SOURCES

While solar and wind have been receiving sustained nationwide attention, there are a number of other alternative energy sources that can be tapped in Pennsylvania. Many of these energy sources already are being used effectively in the region, but greater potential exists.

HYDROELECTRIC POWER

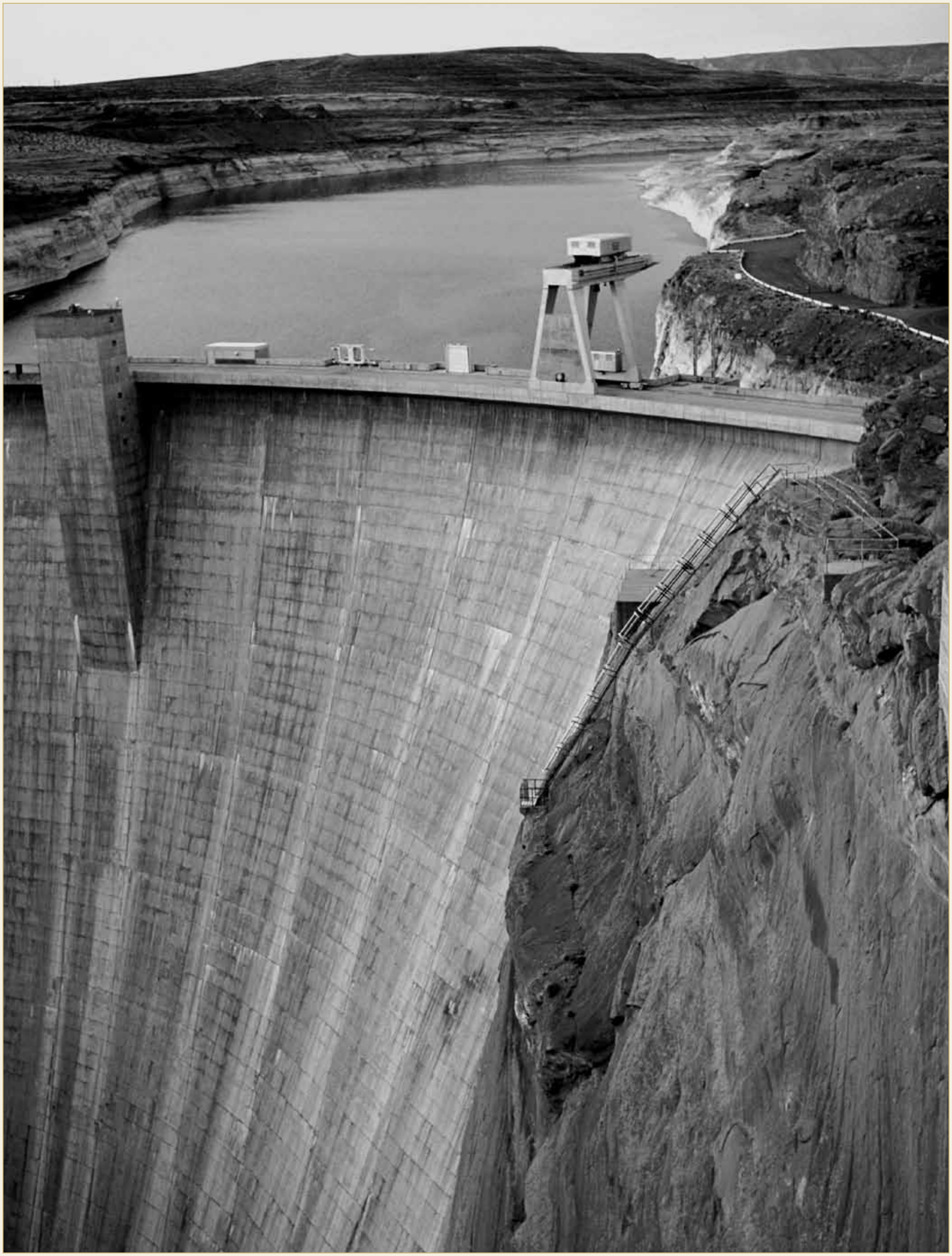
In 2007, hydroelectric power provided the largest share of electricity from renewable energy sources in Pennsylvania, contributing 1.5 percent to statewide electricity generation. Hydroelectric power from dams or stream diversion is a mature technology with little room for technological advancement. Nevertheless, the Black & Veatch report states that there are numerous sites throughout Pennsylvania with potential for new hydropower installations as well as opportunities for incremental additions to current facilities.

BIOMASS

As mentioned earlier, there is significant opportunity for cofiring biomass with coal in order to reduce carbon emissions. Biomass also can be burned in some circulating fluidized bed plants originally designed for firing waste coal.

BIOFUELS

As part of the commonwealth's Energy Independence Strategy, Pennsylvania is investing $5.3 million toward in-state biofuel production through June 2011. As production ramps up, the



state will begin mandating increasingly greater percentages of biodiesel in all diesel sold at retail. Expanded use of biofuels will help the transportation sector to cut back on emissions and will benefit farmers who grow crops that can be converted into fuels. There already are a number of biodiesel producers located in Western Pennsylvania, including United Oil Company in Pittsburgh, HERO BX in Erie, and Pennsylvania Bio Diesel in Monaca, as well as facilities in eastern Pennsylvania, including Keystone BioFuels Inc., United BioFuels, Soy Energy, Biodiesel of Pennsylvania, and Middletown BioFuels.

SUMMARY

Renewable and alternative energy sources will continue to be invaluable contributors to Pennsylvania's economy and environment. With possible carbon legislation on the horizon and the constant challenges of protecting the public health and wildlife habitats, these sources provide sustainable alternatives to a region in need of energy independence and reliable, diversified power.

CONCLUSION: KEY REGIONAL OPPORTUNITIES AND CHALLENGES

The international conversation revolving around the world's energy has identified the key needs for global economic growth and environmental stewardship. Demand for reliable, affordable, and sustainable energy cries out for answers to challenges across both traditional and alternative energy sectors. Pennsylvania is uniquely positioned to provide solutions for all of them. Serving regional, national, and worldwide energy markets and establishing the commonwealth as the energy capital of the world will bring valuable economic benefits and prestige to communities and industries within Pennsylvania's borders. Fostering this growth responsibly hinges upon the capability of Pennsylvania's commercial, legislative, regulatory, and community leaders to learn from the familiar lessons of the past as well as to take leadership roles in untraversed industry and policy frontiers.

Pennsylvania's vast coal resources have served the energy needs of the nation and enriched local communities before. But exploitation also has left the region with a legacy of environmental issues that we still are addressing today. Coal continues to play an integral role in the nation's economy, and its significance is poised for worldwide growth. Pennsylvania's established coal industry and abundant natural resources can and will be instrumental to the growing demand for energy. The coal industry has made progress in reconciling the unsustainable practices that plagued early coal extraction and coal-powered generation. But now a new environmental challenge looms in the form of climate change. As a region, we have a distinct opportunity to reap the wealth of coal without repeating the mistakes of the past. Pennsylvania has the intellectual and geological resources that are essential to becoming the first region to prove the commercial viability of emerging clean coal technology such as carbon capture and sequestration and integrated gasification combined cycle.

The concurrent breakthrough in natural gas development via the Marcellus Shale formation presents even greater opportunities for growth rooted in the region coupled with possible disruptive side effects. As one of the most exciting and essential ''bridge fuels'' toward a low carbon energy economy, natural gas is a true game changer that will bring wealth to Pennsylvania and greater energy independence to the United States. Unconventional gas plays such as the Marcellus Shale are becoming conventional, and the world is watching closely as Pennsylvania lays the regulatory groundwork that will bring about the most equitable and sustainable good to the region. Again, the commonwealth has been called upon to take a leadership role in establishing a sensible but protective framework for gas development.

Meanwhile, nuclear energy has been quietly mounting a renaissance across both the Pacific and Atlantic oceans that may be set to spill into the United States. The demand for low-carbon-emitting, reliable baseload electricity has presented the nuclear industry with a chance to redefine itself and shed its historically negative image. The same innovators who pioneered nuclear energy during the last century are active in Pennsylvania today and are ready to provide solutions to the latter-day challenges that the industry faces.

Lastly, the future of a clean energy economy is nearer than anticipated. Pennsylvania's early successes with renewable energy provide testament to the viability and promise of solar, wind, and other alternative energy technologies. Renewable energy sources will be the currency of the worldwide energy economy that is being redefined through the lens of climate change threats. The race for a robust installed capacity of alternative energy is on, and Pennsylvania has a strategic head start. But in order to maintain this advantage, further public and private investment and guidance are needed.

Note: The author of this survey, Jack Busch, would like to attach the following disclaimer regarding the use of the Penn State study, *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*, which is quoted on page 6 and at various other points throughout this report:

Recently, Responsible Drilling Alliance (RDA), a citizen advocacy group, questioned the objectivity of a Pennsylvania State University study titled *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*, written by Timothy Considine, Robert Watson, Rebecca Entler, and Jeffrey Sparks, and funded by the Marcellus Shale Coalition. William Easterling, dean of the Penn State College of Earth and Mineral Sciences, responded to RDA in a letter by noting that the criticisms were leveled at an earlier version of the report. He acknowledged that the school had found some ''flaws in the way that the report was written and presented to the public'' and indicated that the authors ''may have crossed the line between policy analysis and policy advocacy.'' These issues, among others, were rectified in an update released in May 2010. Meanwhile, the ''scientific rigor'' in both versions of the report is ''sound and does not appear to have any significant flaws,'' according to Easterling.

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ESSENTIAL TERMS AND CONCEPTS

Watts and Watt Hours: A watt (W) is a measurement of power, while a watt hour (Wh) is a measurement of energy output or consumption. For example, a 1,000 mW coal power plant would output 1,000 megawatt hours (mWh) in an hour. Running at full capacity around the clock without interruption for a year (8,760 hours), that plant would have an annual energy output of 8,760 gWh.

UNIT	POWER
Watt (W)	1 joule per second
Kilowatt (kW)	1,000 W
Megawatt (mW)	1,000 kW
Gigawatt (gW)	1,000 gW

Nominal Capacity: Sometimes referred to as nameplate capacity, nominal capacity refers to the maximum output of an energy source if the unit were to operate at full capacity without interruption.

Capacity Factor: Also called load factor or average capacity factor, the capacity factor refers to the average expected output of a generator in relation to the nominal capacity. This is typically expressed as a percentage of the nominal capacity.

For example, the Somerset, Pa., wind farm has a nominal capacity of about nine mW. Its annual maximum output would be 78,840 mWh. However, its actual annual output averages at about 25,000 mWh. Capacity factor is determined by dividing the maximum output by the actual annual output (78,840/25,000), which equals about 31.7 percent.

All power plants have a capacity factor that is lower than their nameplate capacity. Baseload power plants will have reduced capacity factors due to downtime from planned or unplanned maintenance and periods of idling due to decreased demand. Peaking power plants, by design, only operate during periods of high demand. The capacity factor of solar and wind plants, meanwhile, is affected by intermittency.

NATIONAL AVERAGE CAPACITY FACTOR BY FUEL TYPE (2008)	
ENERGY SOURCE	CAPACITY FACTOR
Nuclear	91.1%
Coal	72.2%
Natural Gas/Combined Cycle	40.7%
Other Renewables	37.3%
Hydroelectric	37.2%
Natural Gas/Other Types	10.6%
Petroleum	9.2%

Sources: U.S. Energy Information Administration, Form EIA-860, "Annual Electric Generator Report"; Form EIA-923, "Power Plant Operations Report"

Baseload Power Plants: Baseload power plants provide the backbone of the energy grid and are designed to provide continuous energy at a constant rate. Baseload power plants are high efficiency and low cost, making them the most economical to run year-round. Most baseload power plants in Pennsylvania are coal fired or nuclear.

Peaking Power Plants: Peaking power plants typically run only during periods of high demand, such as the late afternoon during summer days, when many households are running air conditioning units and cooking. Peaking power plants are less efficient and more costly to operate but typically run only a few hours a day. Gas turbine plants are the most common type of peaking power plant, but solar photovoltaic plants also can serve peak demand.

Levelized Energy Cost: Levelized energy cost, sometimes referred to as busbar cost, is a per-megawatt hour calculation that seeks to assess the break-even price for a generation project. While models vary between analyses, the calculation typically factors in initial investments; cost of capital, operations, and maintenance; and costs of fuel. When comparing renewable and conventional energy sources, the levelized energy cost also may include federal subsidies and illustrative carbon emissions costs.

Overnight Cost: This is composed of the cost for constructing a power plant without factoring in interest.

Uprate: The U.S. Nuclear Regulatory Commission grants uprates to plants that have requested permission to increase their power output and have proven that they are capable of doing so.

GLOSSARY OF ACRONYMS

ACEEE: American Council for Energy-Efficient Economy

AEC: Alternative Energy Credits

AEPS: Alternative Energy Portfolio Standards

AMD: Abandoned mine drainage

AML: Abandoned mine lands

ARRA: American Recovery and Reinvestment Act

AWEA: American Wind Energy Association

BCf: Billion cubic feet

Btu: British thermal unit

CCR: Coal combustion residuals

CCS: Carbon capture and sequestration

CCW: Coal combustion waste

CNG: Compressed natural gas

CO: Carbon monoxide

CO_2: Carbon dioxide

DEP: Pennsylvania Department of Environmental Protection

DOE: U.S. Department of Energy

EIA: U.S. Energy Information Administration

EIP: Environmental Integrity Project

EPA: U.S. Environmental Protection Agency

FBC: Fluidized bed combustion

GRU: Gainesville Regional Utilities

gWh: Gigawatt hour

GWPC: GroundWater Protection Council

IBEW: International Brotherhood of Electrical Workers

IGCC: Integrated gasification combined cycle

kWh: Kilowatt hour

MCf: Thousand cubic feet

MCL: Maximum contaminant levels

MSETC: Marcellus Shale Education & Training Center

mWh: Megawatt hour

NABCEP: North American Board of Certified Energy Practitioners

NEI: Nuclear Energy Institute

NETL: National Energy Technology Laboratory

NMA: National Mining Association

NO_x: Nitrogen oxide

NRC: U.S. Nuclear Regulatory Commission

NREL: National Renewable Energy Laboratory

NYSERDA: New York State Energy Research and Development Authority

PC: Pulverized coal

pCi: Picocurie

PHMSA: U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration

PJM: Pennsylvania-New Jersey-Maryland Interconnection

PRB: Powder River Basin

PUC: Pennsylvania Public Utility Commission

PURPA: Public Utility Regulatory Policies Act

PV: Photovoltaic (as in solar photovoltaic)

RPS: Renewable Portfolio Standards

SACP: Solar alternative compliance payment

SCPC: Supercritical pulverized coal

SEIA: Solar Energy Industries Association

SO_2: Sulfur dioxide

SPI: Solar Power Industries

TCf: Trillion cubic feet

TDS: Total dissolved solids

Tg: Teragrams

TENORM: Technologically enhanced naturally occurring radioactive materials

TVA: Tennessee Valley Authority

Wh: Watt hour

WVU: West Virginia University

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PENNSYLVANIA ENERGY SNAPSHOT

COAL

Pennsylvania Industry Quick Facts

- Rank among coal producers in United States: **fourth**
- Recoverable coal reserves in Pennsylvania: **11.55 billion tons**
- 2009 coal production: **58.1 million tons**
- 2009 international mineral and ore exports from Pennsylvania in 2009: **$29 billion**
- Existing coal-fired plants in PA: **40**
- Busbar cost for new supercritical pulverized coal (SPCP) plant: **$74–$135 per mWh**
- 2008 electricity output: **22 million mWh (53.2 percent of state total)**
- Jobs supported: **8,724 direct, 32,853 indirect ($7.5 billion combined economic output)**
- Total estimated cost for reclaiming abandoned mine lands: **$15 billion**
- CO_2 emissions: **208,000 pounds per billion Btu**

Environmental Issues

- Air Quality
- Carbon dioxide and climate change
- Abandoned mines, waste coal piles, and abandoned mine drainage
- Subsidence
- Coal combustion residuals (CCR)

Challenges and Solutions in Brief

- Historically, the coal industry has made substantial progress toward reducing airborne emissions from coal-fired power plants. However, coal-fired electricity generation, next to vehicle emissions, is one of the largest contributors to Southwestern Pennsylvania's continuing air quality issues. Additionally, the possibility of legislation regulating carbon dioxide may present the next major challenge for the coal industry.
- Preregulation mining practices have left a legacy of environmental challenges—including abandoned mine drainage and waste coal piles—that serve as reminders of the importance of ensuring sustainable extraction of natural resources. Government and industry funded efforts are steadily working toward reclaiming abandoned mine lands and rectifying environmental damage.
- The 2008 coal ash spill at the Tennessee Valley Authority's Kingston Fossil Plant in Tennessee has galvanized the U.S. Environmental Protection Agency to bring impoundment and disposal of coal combustion residuals under federal regulation. A proposed rule has been drafted and is pending review.
- Carbon capture and sequestration and newer, higher efficiency coal power plants may present economical solutions to environmental challenges. Pennsylvania's geology is well-suited for storing captured CO_2, which makes the state an apt location for a CCS pilot project.
- The increased use of longwall mining techniques has changed the nature of subsidence. While Act 54 of 1994 was designed to protect natural habitats and landowners, determining liability and environmental impact will be a continuing challenge. ■

NATURAL GAS

Pennsylvania Industry Quick Facts

- Estimated recoverable gas in Marcellus Shale formation: **489 TCf ($500 billion in potential revenue)**
- Estimated annual gas consumption for Pennsylvania and bordering states: **Nine BCf**
- Estimated jobs created by Pennsylvania's gas industry by 2020: **174,700**
- Gas drilling jobs currently filled by local workers: **about 20 percent**
- 2008 electricity output: **5.9 million mWh (8.5 percent of state total)**
- 2009 installed capacity: **10,915 mW (22 percent of state total)**
- Busbar cost for new electricity plant: **$73–$100 (combined cycle); $221 to $334 (peaking)**
- CO_2 emissions: **117,000 pounds per billion BTu (about half that of coal)**
- Operating Marcellus wells subjected to personal income tax (3.07 percent) rate rather than corporate net income tax (9.99 percent): **1,062 (70 percent)**
- State forest land under lease agreement with gas drillers: **724,000 acres (about 33 percent)**
- Water used in typical frack job: **3–5 million gallons per well**
- Proportion of water versus chemical additives in fracturing fluid: **98–99.5 percent**
- Produced water per well: **20 to 80 percent of volume injected**
- Level of total dissolved solids (TDS) in produced water: **two to seven times higher than seawater**

Environmental Issues

- Water quality
- Air quality
- Surface footprint/habitat disruption
- Natural gas migration

Challenges and Solutions in Brief

- Natural gas has about half of the emissions of coal per BTu, giving it excellent potential as bridge fuel toward a cleaner energy economy and greater energy independence.
- Fracturing flowback, or produced water, has problematically high TDS levels, which makes disposal in local water processing facilities unfeasible. Currently, most produced water is deep-well injected out of state. Produced water recycling and reuse—which already is in practice on many sites—poses the most viable solution.
- Increased truck traffic, drilling equipment, and condensate tanks contribute to heavy local air pollution. Permitting and regulation of aggregate emissions may help to mitigate degradation of public and environmental health.
- Public concern has arisen over possible threats to drinking water supplies caused by contamination from fracturing fluids or wastewater. While previous studies have found no cases of contamination, the U.S. Environmental Protection Agency (EPA) has launched a new investigation that will be completed in 2012.
- Incidences including well blowouts, explosions, improper disposal of wastewater, and natural gas migration highlight potential dangers posed by irresponsible drilling practices. The Pennsylvania Department of Environmental Protection has imposed fines and penalties against offending companies.

NUCLEAR ENERGY

Pennsylvania Industry Quick Facts

- Nuclear power plants in Pennsylvania: **Five (nine reactors total)**
- 2009 installed capacity: **9,305 mW (20 percent of state total)**
- 2008 electricity output: **78,658 gWh (35 percent of state total)**
- Rank among nuclear electricity producing states: **second**
- Busbar cost for new plant: **$98–$125 per mWh**
- Jobs created per power plant: **400–700 ($430 million in economic output)**
- Reactors using Westinghouse Electric Company technology worldwide: **about 50 percent**
- Radiation received during chest X-ray: **4 millirems a year**
- Radiation received from naturally occurring radon: **200 millirems a year**
- Radiation exposure from nuclear power plants: **less than one millirem a year**
- CO_2 emissions: **virtually zero**

Environmental Issues

- Water quality
- Waste treatment and storage
- Radiation
- Meltdowns

Challenges and Solutions in Brief

- Nuclear energy is being reconsidered as a solution to concerns over carbon dioxide emissions and the need for baseload electricity generation using domestic fuel sources.
- The partial meltdown at Three Mile Island has spurred design and implementation of passive safety systems and improved regulation and oversight of plant operations. However, the recent nuclear disaster in Japan demonstrates the serious environmental and public health impacts that a malfunctioning or leaking nuclear reactor can produce.

SOLAR ENERGY

Pennsylvania Industry Quick Facts

- Installed capacity: **nine mW (less than 1 percent of state total)**
- Average solar resource in Pennsylvania: **1,500 kWh per square meter**
- Average solar resource in Germany (number one nation in solar): **1,000 kWh per square meter**
- AEPS target by 2021: **approximately 860 mW**
- Busbar cost: **$237–$300 per mWh**
- Jobs created by solar industry in 2009 (nationwide): **46,000 (indirect and direct)**
- Trained solar installers needed by 2015: **5,000**
- North American Board of Certified Energy Practitioners (NABCEP)-certified solar installers in Pennsylvania: **about 50**
- NABCEP testing facilities in Pennsylvania: **zero**

Environmental Issues

- Surface footprint/habitat disruption (solar farms)
- Chemical release during conversion into electricity

Challenges and Solutions in Brief

- The intermittency of solar energy does not devalue its economic and environmental benefits as greatly as many presume. Renewable energy is largely considered as complementary to conventional baseload power plants and thus would not affect overall reliability of the grid (and may actually alleviate the strain of peak demand load). The emissions offsets of solar energy also remain important in spite of a relatively lower capacity factor when compared to conventional power plants.
- In spite of relatively low solar resources, Pennsylvania has vast potential for generating electricity via solar photovoltaic (PV). Germany and New Jersey, areas with similar solar resources as Pennsylvania, serve as examples of how renewable energy policy can spur growth in solar energy. ■

WIND ENERGY

Pennsylvania Industry Quick Facts

- Wind farms in PA: **17**
- Installed capacity: **748 mW (about 2 percent of state total)**
- Total potential capacity: **3,307.2 mW**
- Busbar cost: **$44–$91 per mW**
- Nationwide jobs supported by wind industry in 2008: **85,000 (about 15–19 per mW)**

Environmental Issues

- Threat to avian and bat populations
- Public health impacts/noise pollution

Challenges and Solutions in Brief

Habitat impacts and bird/bat kills from wind farms can largely be mitigated by proper siting and design. ■

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