Background

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Energy Technology in the Pittsburgh Region

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When it comes to energy technology, Westinghouse put Pittsburgh on the map. In addition to pioneering countless technologies, including the application of alternating currents, the first fully electric range, the television cameras that made it possible to watch men land on the moon and revolutionary research in batteries and materials, Westinghouse technology made our nuclear Navy possible. In fact, Westinghouse has been responsible for 40 percent of the world's nuclear technology.

After Westinghouse was broken up, many of its energy businesses have spun-off or been purchased by other companies, creating new opportunities in several technologies. At the same time, the use of clean, renewable energies has been growing.

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In just the past few years, our country's economy has faced enormous challenges, including a recession, the terrorist acts of 9/11, the ongoing war in Iraq, the devastating Gulf Coast hurricanes that impacted the nation's oil and gas production and an unprecedented global energy demand.

One of the best solutions to our current energy crisis is to increase our energy efficiency. President George W. Bush signed the National Energy Policy Act of 2005 into law on August 8, 2005. This comprehensive energy legislation provides incentives for traditional energy production and, more importantly, it places an emphasis on using science and technology to meet growing energy needs with an environmentally responsible approach. Next-generation nuclear power and hydrogen fuel cells are being developed, but the U.S. Department of Energy (DOE) also is working towards the establishment of a diverse energy portfolio, which includes renewable energy sources like solar, wind and biomass, as well as traditional fossil fuels.

In addition to creating jobs and promoting economic growth, renewable energy development can help to counteract rising fuel prices. Following the example set by the private sector, which already is putting more of its money into alternative fuels, congress plans to increase funding next year for federal research in clean energy technologies, including biofuels, solar and wind power.

In an increasingly deregulated market, the cost and supply of electricity will become progressively more of concern to all Americans, and because Pennsylvania is a major exporter of electricity, Pittsburgh is poised to take advantage of the changes taking place in the national electricity market.

Wind

A 100 megawatt wind farm, over the course of its 20-year lifetime, has the capacity to generate an amount of electricity that would require approximately 2.9 million tons of coal or over 62 billion cubic feet of natural gas to be generated by traditional U.S. grid sources.

In the past few years, the U.S. has become a wind energy leader, and with seven existing wind farms, Pennsylvania has gained prominence in the wind power industry. The U.S. wind power market currently stands at $151 billion, according to SBI, a market research company.

Meanwhile, thanks to technology advancements, the cost of wind-generated electricity has declined from 30 cents per kilowatt-hour since the early 1980s to less than five cents today.

Versatile and adaptable, wind energy is the kinetic energy of large masses of air moving over the earth. A wind turbine converts this energy into mechanical energy and then into electric energy. As the blades of the turbine rotate, the energy in the shaft can be used to operate a mechanical device or produce electricity with a generator. Offering more competitive costs in commercial power markets, wind energy is fast becoming a viable, zero-emission, utility-scale energy source.

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As manifested by the fact that some 700,000 residential energy customers of Allegheny Power now may opt in to a wind-generated power program, southwestern Pennsylvania is now home to four of the state's existing wind farms. Since 2001, the 24 megawatt Exelon-Community Energy Wind Farms at Somerset and Mill Run have been meeting the demand for clean, green electricity from leading corporations, universities and individuals in the region, including Carnegie Mellon University, which currently uses wind to supply seven percent of its energy needs. Because of an obvious dedication to exploring renewable energy options, Pittsburgh was chosen as the venue of the wind energy industry's annual four-day conference, called Windpower 2006.

The 15-megawatt Mill Run Wind Farm is located in Fayette County and has 10 turbines, the nine-megawatt Somerset Wind Farm has six turbines. The two sites are operated as a single wind power project, with all 16 turbines capable of producing an estimated 63,000 megawatt hours of power each year. This is enough energy to power approximately 8,200 average Pennsylvania homes. Owned by the nation's largest windmill owner-operator, Florida-based FPL Energy, these windmills are just the beginning. The company is actively scouting ridges and mountains throughout Pennsylvania, as they follow through on their plans to build more windmill sites.

Recently Pine Township-based US Wind Force LLC recently signed a joint venture deal with independent power producer Edison Mission Energy to develop up to 1,000 megawatts of wind power in the mid-Atlantic region. The venture primarily will operate within Pennsylvania, West Virginia and Maryland. Edison Mission will own the wind farms once in operation. US Wind Force has proposed a 15-megawatt wind farm near the operating Garrett wind farm in Somerset County. Edison Mission already oversees operation of the 1,884-megawatt, coal-fired power plant near Homer City, Indiana County.

The expansion of these wind farms are bound to increase the visibility of southwestern Pennsylvania as a laboratory for wind power and other alternative energy technologies.

But beyond the wind farms themselves, the industry's supply chain has an anchor in Pittsburgh-based PPG industries. PPG provides the fiberglass, which is a critical reinforcement that enables wind blade technology.

Although PPG's initial involvement started in Europe with the development of the market, supplies of fiberglass from U.S. facilities increased as the market grew in the America. PPG also provides coatings to protect the composite blades, as well as the towers and other metal components.

Nuclear

Home to locally based operations for Westinghouse Nuclear Power Division, the Bettis Atomic Power Laboratory and Bechtel Plant Machinery, Inc. (BPMI), Pittsburgh always has been a player

in the nuclear energy industry. The world's first commercial nuclear reactor was built not more than 30 miles outside Pittsburgh city limits at Shippingport, PA.

The Bettis Atomic Power Laboratory is a U.S. government-owned, contractor-operated research and development facility located in West Mifflin, Pennsylvania. It solely focuses on the research, design, construction, operation and maintenance of nuclear equipment for the U.S. Navy, including nuclear-powered warships.

The laboratory, founded in 1949 and consisting of approximately 207 acres, is operated for the DOE by Bechtel Bettis, Incorporated, a wholly owned subsidiary of the Bechtel Corporation. Bechtel is a global engineering and construction firm that is under contract with the U.S. Department of Defense to help develop the Navy's nuclear propulsion program (NNPP.)

Bechtel's BPMI-Pittsburgh and BPMI-Schenectady divisions initially were established in the 1950's to procure submarine components. Over the years BPMI's role as an NNPP prime contractor has continued to expand well beyond that initial procurement function. Bechtel personnel are now involved in all aspects of the design, development, procurement, and support of all submarines and surface ship (primarily carrier) construction work. Bechtel also is involved in field support activities, including refueling, defueling and overhauls.

Bechtel's reactor equipment department provides non-fuel bearing reactor components including heavy equipment and electro-mechanical equipment. The company's refueling equipment department provides equipment used to refuel and service nuclear plants, including containers for movement and shipment of new and used fuel.

Bechtel won the contract to run the Bettis laboratory in 1999; prior to that the plant was operated by Westinghouse Electric Corporation.

The laboratory developed the design of the pressurized water reactor (PWR) for naval use. It built the nuclear propulsion plants for the first U.S. nuclear submarines and surface ships including the USS Nautilus, the USS George Washington, the USS Long Beach and the USS Enterprise.

Westinghouse's nuclear division adapted the PWR design for commercial use and built the first commercial nuclear power plant in the United States, the Shippingport power plant, which was the first large-scale nuclear power plant in the world when it began operating on December 2, 1957, exactly 15 years after Enrico Fermi demonstrated the first sustained nuclear reaction.

The Duquesne Light Company of Pittsburgh constructed and operated the Shippingport plant on a site it owned on the Ohio River. The company also contributed to the cost of developing the government-owned reactor. The plant was retired in 1982. Congress assigned the decontamination

and decommissioning of this commercial reactor to the DOE. This was the first complete decontamination and decommissioning of a reactor in the United States. The reactor vessel was shipped to a low-level waste disposal facility at the Hanford Site in Richland, Washington. The reactor site was cleaned and released for unrestricted use in November 1987. Government officials proclaimed the seven-acre site is suitable for picnicking or for a children's playground.

Previously limited by environmental and safety concerns, nuclear energy is coming back into vogue as an emissions-free, economical alternative to coal.

Recent economic effects of this resurging interest in nuclear fuel include Bechtel closing most of its Schenectady, N.Y., plant and moving 260 engineering and business procurement jobs to the Pittsburgh area.

Also, in December of 2006, Westinghouse signed a $5.4 billion contract with Chinese officials to build four nuclear power plants in China, with the first coming on line in 2013. The country wants to increase its nuclear energy power to four percent by 2020, and it plans on building approximately 32 nuclear power plants.

Westinghouse won the contract thanks to its newest technology in nuclear reactors: the AP1000. This pressurized water reactor can generate more than 1,000 megawatts of electricity, which is comparable to existing nuclear plants, but the AP1000 is much safer and easier to build because of a simpler design that reduces construction time and cost. China is the first country to order the revolutionary reactor.

The China contract already has required the company to expand its research facilities in Pittsburgh, and to create or sustain 5,000 jobs. Westinghouse executives are optimistic that taking this technology forward in China also will help accelerate efforts in the United States. Currently the U.S. gets just 20 percent of its electrical power from nuclear plants, as compared to 50 percent in Ukraine, where Westinghouse was awarded a five-year contract to provide nuclear fuel supplies to three Ukrainian reactors starting in 2011. The French, also by contrast, gets 80 percent of its electrical power from nuclear sources.

Some 20 U.S. utilities and consortia already have announced plans to build about 30 nuclear power plants, most within the next 10 years. In preparing for this anticipated surge in worldwide plant construction, Westinghouse recently acquired French engineering firm, Astare, as well as South Africa-based IST Nuclear, a nuclear service systems provider.

Westinghouse also is building a $20 million nuclear power plant simulator in the Pittsburgh region that essentially will be a full-scale nuclear reactor, but without the nuclear fuel, and that will serve as a maintenance and operations training facility that is unique to the world. The training facility and lab eventually will employ 1,000.

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Other preparations for this industry's expansion are of significant importance to the Pittsburgh region, as well. Currently, only 10 percent of all U.S. engineering universities are offering nuclear engineering degrees. And with one-quarter of all U.S. nuclear engineers beginning to retire in 2012, it is paramount to train the next generation nuclear workforce. The Pennsylvania State University founded a graduate nuclear engineering program in 1959 and is among the nation's oldest. The university has seen its enrollment in then program grow in the double digits over the past several years. The University of Pittsburgh, meanwhile, also has seen increased interest in its nuclear certificate program, which certifies that a student has completed five courses in nuclear engineering.

Solar

The future of solar power lies in innovative ideas in which the sun's energy can be absorbed directly into roofing shingles or incorporated into fabrics, like tents. Traditionally, solar cells have been bulky. Cumulative solar energy production accounts for less than one-tenth of one percent of total global primary energy demand, even though the earth receives more energy from the sun in just one hour than worldwide human activity uses in a whole year.

Crystalline silicon cell technology forms about 90 percent of solar cell demand. The balance comes from thin film technologies. Historically, crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material.

The cost of solar power has lowered significantly over the years, but it continues to be more expensive than other sources of electricity. Clean Edge estimated that the U.S. market for solar energy grew 15 percent in 2008 to 9,183 MW.

One problem for the solar industry is a shortage of silicon, the material now used for most photovoltaic cells. New technologies, including the next generation p-type semiconductor technology for commercial organic solar cells currently being developed at Pittsburgh-based Plextronics, could dramatically cut the cost of solar power.

Today's silicon-based solar energy systems cost approximately five dollars per watt. Plextronics is working to provide a one-dollar-per-watt alternative using revolutionary thin film technologies designed to unlock the sun's potential. Created at Carnegie Mellon University, Plextronics' signature product is Plexcore PV, a platform polymer technology that absorbs the sun's light and generates electricity by acting like a semiconductor. Ten times cheaper to manufacture than silicon-based modules, the polymers are turned into inks that can literally be printed onto thin layers on flexible plastic substrates or even fabric. Plexcore received a $1 million grant from the Pennsylvania

Energy Development Authority and a grant in excess of $300,00 from the Pennsylvania NanoMaterials Commercialization Center to fund their efforts.

In 2005, the Pennsylvania Department of Environmental Protection awarded an $88,000 Energy Harvest grant to Carnegie Mellon University and its School of Computer Science (SCS) for the renovation of 407 S. Craig Street. The building includes a photovoltaic (PV) energy system and now houses members of SCS' Interactive Systems Lab and the Institute for Software Research International. The PV energy system contains the silicon cells and feeds directly into the building's main power supply, providing approximately 10 percent of the building's electricity needs. This solar energy system supports Carnegie Mellon's university-wide effort to reshape the way society thinks and acts about environmental issues and to improve life in the region and the world.

In 2006, Conergy AG, a German-based maker of solar-power products, located its North American headquarters of its financial subsidiary and the East Coast operations of its solar-engineering and installation subsidiary in Pennsylvania. Conergy is a world leader in the development of renewable energy systems. According to the Pennsylvania Department of Environmental Protection, Conergy's subsidiaries (called voltwerk and SunTechnics) expects to have created up to 50 engineering, financial and management jobs and originate up to $100 million in clean energy deals through 2010.

Similarly, German-owned Flaberg is building a manufacturing facility to produce glass and mirror components for panels in large-scale solar power plants, with employment expected to reach 200. In a related initiative, about $200 million of the $850 million Energy Independence Fund proposed in January 2007 for the governor's Energy Independence Strategy is committed to have some 858 megawatts of electricity generated by the sun by 2021. One megawatt powers about 800 homes.

Under the governor's plan, homes and small businesses can receive rebates of up to half the cost of a solar power system, including a rebate if the solar power panels are manufactured in Pennsylvania. That could amount to savings of up to $22,000.

In addition, system manufacturers, such as Belle Vernon-based Solar Power Industries Inc. could be eligible for a production grant for all solar panels built and deployed in the state.

Solar Power Industries, in turn, is increasing their operations to nearly 386,000 square feet, and it expects employment to jump to 585 by the end of 2009, as compared to 140 in 2007. Sales of $15 million in 2006 have at least doubled since then. Currently, 95 percent of Solar Power's business comes from overseas customers. The company is one of only five in the country that makes solar cells, and its new production line would be capable of turning out enough solar power modules to generate 100 megawatts, which can provide power to 15,000 to 25,000 homes each year.

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On average, a typical solar system today provides four kilowatts of power and ranges in price between $20,000 and $30,000, including installation; this system would handle between 80 percent and 90 percent of an average home's energy needs.

With Governor Rendell's proposed Sunshine Program rebates, along with an existing 30 percent federal tax credit, costs of a four-kilowatt system could drop to about $9,800.

Meanwhile, Community Networks LLC recently announced plans to build a solar power station that would be only the second such station in Pennsylvania and that would generate enough electricity to power 450 homes each year. Community Networks expects to purchase about 15,000 solar panels from Solar Power Industries.

And most recently, it was announced that Pittsburgh will host the first Solar Cities Conference in October of 2009, when leaders from more than 20 cities from across the Northeast will meet for two days of seminars conducted by the Department of Energy and Sandia National Laboratories with the goal of advancing the integration of solar technology. Pittsburgh's program will be used as a model.

Advances in Automotive Fuel Alternatives

In 1999, only around a half million gallons of biodiesel fuels was produced nationwide. Seven years later production amounted to about 325 million gallons. Although national sales of nearly 3160,000 hybrid and clean diesel vehicles represented only two percent of the total vehicle market in 2008, a wide variety of alternative fuel sources for the automotive industry are currently under development. But in today's market, there are few options available to the average American consumer. However, as we become more knowledgeable about options like ethanol, diesel and fuel cells and their ability to reduce our dependence on foreign oil, the demand eventually will boost production for various types transportation fuel alternatives currently being employed or explored.

Clean diesel vehicles combine diesel technology with cleaner burning fuels and emissions control systems, thereby running on 30 percent less fuel than gasoline-powered vehicles. In Europe, about half of all vehicles run on clean diesel, but the American market has been slow to catch on.

Locally, the City of Pittsburgh is advancing the use of biofuels for its 1,000-vehicle fleet. The city announced plans to turn waste vegetable oil and grease from Heinz Field's refreshment stands and restaurants into cleaner-burning biodiesel fuel for the city's 300 public service, maintenance and first responder vehicles that run on traditional diesel fuel.

In addition, Steel City Biofuels, a nonprofit organization formed in 2005 to promote the use of non-fossil fuels such as biodiesel and ethanol, has received funding from the Heinz Endowments and the Richard King Mellon Foundation to create a demonstration facility to produce biodiesel fuel in North Point Breeze.

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Recently, Pennsylvania Bio Diesel opened a $100 million manufacturing facility to produce an initial annual total of 12 million gallons of biodiesel, with a capacity for 40 to 50 million gallons each year.

Diamond Star Energy also has plans to build a biodiesel plant that initially would produce about 35 million gallons a year, but that would expand to 100 million gallons, which would represent one percent of all biodiesel made in the U.S.

Meanwhile, Thar Technologies, Inc. is developing an environmentally friendly and cost-efficient technology in high pressure processing techniques, known as supercritical fluid technology. Extracting oil from oilseeds had its drawbacks, especially since the process required the use of hexane, which the Environmental Protection Agency (EPA) classifies as a hazardous air pollutant. Thar is replacing hexane with high-pressure carbon dioxide and eliminating many of the inefficiencies of current processes. Successful development of the technology will profitably produce biodiesel directly from both edible and inedible oilseed feedstock while reducing energy consumption and eliminating environmental hazards and the need for production subsidies.

Flex fuel vehicles run on a fuel blend called E85, which is a mix of 85 percent ethanol and 15 percent gasoline. This is in stark contrast to a fuel blend that includes only 10 percent ethanol, which virtually any existing make of car can use. Besides its obvious advantage as a replacement for gasoline, ethanol burns cleaner, producing less air pollution and greenhouse gas emissions. It also lessens our dependency on foreign oil producers and supports American farmers and refiners.

Up until 2006, it had not been possible to purchase E85 in Pittsburgh, but the Sheetz convenient store chain became the first chain retailer in Pennsylvania to carry E85. This is an encouraging and exciting development in light of the fact that Pennsylvania's goal is to replace 900 million gallons of gasoline with domestically produced renewable fuels within the next decade.

Commonwealth Renewable Energy Inc. purchased the former Sony-owned American Video Glass plant in New Stanton, PA. The company, a subsidiary of the Pittsburgh-based Anderson Group of Companies, originally planned to transform the 700,000-square-foot facility into the largest ethanol plant in the country. Investment in the plant called for upwards of $100 million, but financing difficulties have stalled the project.

Production is expected to begin by late summer of 2009 creating hundreds of jobs. Company officials expect the plant to consume about 75 million bushels of corn to produce about 200 million gallons of ethanol annually.

Consensus Ethanol LLC also is in the process of establishing a $750 million ethanol processing plant, which when completed in 2012, will employ 140 people and produce 160 million gallons of ethanol annually. Construction began in early 2009.

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Energy Reclamation

The Commonwealth of Pennsylvania's Energy Independence Strategy includes an $850 million Energy Independence Fund. In concert with available funding, enactment of new laws and regulatory policies, the initiative is projected to save consumers $10 billion in energy costs over the next 10 years.

During fiscal year 2007-2008, the Pennsylvania Energy Development Authority (PEDA) invested $11.2 million in 24 clean energy projects, bringing the total authorizations since 2005 to $60 million. It is estimated that energy output from the projects will generate enough electricity to power 1,600 Pennsylvania homes and produce the equivalent of enough natural gas to supply almost 2,500 homes for a year.

There also is the potential to produce 115-million gallons of biofuel. Energy recovery from biomass and waste, including sewage sludges, wood waste, landfill gas, waste coal, municipal and production waste and even manure are becoming attractive alternatives. Pennsylvania has taken the lead with many groundbreaking projects, and it hosted the first international exhibition and conference on Energy from Biomass and Waste Expo, held in Pittsburgh in 2007.

Energy production from biomass and waste is both environmentally and economically attractive. By utilizing resources available domestically like those waste resources that can be processed into biofuel, power can be generated and vehicle fuels can be produced without harmful greenhouse gas emissions. At the same time, this creates jobs and growth opportunities for local business, instead of exporting money and employment to other countries. The EBW Expo created a marketplace and an educational forum for domestic vendors, international experts and users of the energy technology.

With respect to energy reclamation, one interesting technology invented by two University of Pittsburgh engineering professors is a new gelling agent for carbon dioxide. Eric Beckman's and Robert Enick's CO_2 gelling technique is less expensive and more environmentally attractive than previous processes, and the potential applications for this unique development include enhanced tertiary recovery of petroleum from aging oil fields.

Because of the viscosity of natural CO_2, the fluid dispersion in a reservoir is difficult to control. Increasing the viscosity of the CO_2 offers the potential to significantly improve the well stimulation, thereby enabling improved oil recovery. Also, since the CO_2 is environmentally benign, thickened CO_2 is very attractive for reducing the environmental impact of well stimulation procedures. A current focus is on the utilization of this technology for environmentally benign gas and oil well operations.

Another Pittsburgh area company in the energy reclamation space is Separation Design Group, which has invented a unique heat exchanger that uses solar thermal collectors to generate, not only

heat, but primarily mechanical energy, which in turn will be able to run electrical appliances.

The Commonwealth of Pennsylvania ranks sixth in the nation with 2,188 companies involved in alternative or renewable energy sources, like wind, solar, biomass and geothermal. The Pittsburgh region boasts a heavy selection of those types of companies.

Marcellus Shale

When Edwin Drake drilled the first successful commercial oil well in Titusville, Pennsylvania in 1859, he had no idea that the largest natural gas deposit in North America was lodged in shale 6,000 feet below the surface of upstate New York, across most of Pennsylvania and into West Virginia, eastern Ohio and parts of Kentucky.

The Marcellus shale dwarfs the Barnett shale region of Texas, and it contains an estimated 500 trillion cubic feet of natural gas with a value estimated in excess of $10 trillion. The Marcellus Shale region eventually is expected to produce enough natural gas to sustain U.S. demand for a dozen years or more.

Until recently, however, the vast shale deposit was largely ignored, because it was not economical to recover the gas contained within. But the rising value of gas and new recovery methods has attracted renewed interest

Since 2005, the commonwealth has issued about 520 drilling permits, and new filings of gas leases across the state are keeping county deed recorders very busy.

About 500 wells have been drilled to date in Pennsylvania, and approximately 30 companies from places as far afield as Texas, Louisiana and other states have set up operations in southwestern Pennsylvania, creating thousands of jobs.

Texas-based Range Resources LLC opened an office in the region, employing 130, and has drilled about 100 wells in here since 2006. It expects to double its current production.

Atlas Energy Resources LLC has doubled its local workforce to 200, in addition to its 75 employees at its headquarters near the Pittsburgh International Airport.

Other gas producers that have established operations in the Pittsburgh region include mostly Texas-based companies, like Red Oak Water Transfer, which may employ up to 150 workers, Expro, Express Energy Services, Spectra Energy Corp., Markwest Energy Partners, Laurel Mountain Midstream, Multi-Chem and Admiral Well Service. Chesapeake Energy, XTO, Dominion and CNX, a division of CONSOL, also have established drilling operations.

Coal

About half of Pennsylvania's electricity generation comes from burning coal. Pennsylvania is the fourth largest coal-producing state, and southwestern Pennsylvania and West Virginia produce nearly 20 percent of the nation's coal and nearly half of the coal mined east of the Mississippi River. Consol, headquartered here, is the largest producer of high-BTU bituminous coal in the United States with 4.3 billion tons of proven and recoverable coal reserves throughout six states. Consol also operates the largest privately owned fossil fuel research facility in the world.

Augmenting Consol's research capacity is the National Energy Technology Laboratory (NETL), which is part of the DOE's national laboratory system. With major research facilities in Pittsburgh and Morgantown, WV, the NETL is the only U.S. national laboratory devoted to fossil energy research. The NETL mission is to implement a research, development and demonstration program to resolve environmental, supply and reliability constraints of producing and using fossil resources. The NETL implements a broad spectrum of energy and environmental research and development programs that will return benefits for generations to come. These programs enable the economical use of domestic coal, natural gas and oil to power our nation's homes, industries, businesses and transportation, while protecting our environment and enhancing energy independence.

Targe Energy LLC is an Aspinwall-based energy company that operates surface coal mines, reclaims coarse waste coal, performs contract drilling services and acquires its own natural gas reserves. Targe Energy owns multiple waste coal mining operations in Northern Appalachia. Targe and Carlyle/Riverstone Global Energy and Power Fund III, L.P. (C/R) invested $100 million in Targe to fuel the company's growth strategy.

In addition to C/R's commitment, Targe also received $17.5 million from various minority investors and management. The $117.5 million in new capital has enabled Targe to advance its Appalachia-focused coiled tube drilling business, acquire additional coal reserves and roll in three existing surface and waste coal businesses that were being operated by Targe management.

Waste coal represents a major environmental hazard throughout the entire Northern Appalachian region; yet it also presents an opportunity. Historically, waste coal has been a byproduct of coal processing and cleaning that occurred at major mine facilities. It only recently has come to be viewed as a useable fuel source. Waste coal reserves represent two additional primary revenue streams: traditional and co-generation steam fuel and metallurgical coal.

Beyond reclaimed waste coal, Consol Energy and Utah-based Headwaters Inc. are jointly developing coal-based liquid fuel plants. Under the agreement, both companies are performing y engineering and environmental activities related to potential development of several Consol coal sites. This joint venture also involves the construction of one or more coal-based facilities to

produce clean liquid transportation fuels such as diesel, gasoline, liquefied petroleum gas, and jet fuel. The facilities also may produce certain petrochemical feedstocks.

Fuel Cells

While fuel cell technology was first discovered in 1839, commercialization is only now occurring. In their simplest form Fuel cells generate electricity by combining hydrogen and oxygen, producing water as a result. Hydrogen is available from a variety of fuels, including methanol, natural gas, coal gas, gasoline and other existing fuels. Because fuel cells are based on electrochemical reactions and not combustion of fossil fuels, they are extremely clean. The fuel cell also is more energy efficient than current combustion technology, and the heat generated by the electrochemical reaction also can be captured for use, boosting overall efficiency. The federal government's Departments of Energy and Defense fund considerable fuel cell R&D activity.

Fuel cells also benefit from expanded interest in distributed generation. Power generated on-site can be more reliable than grid-supplied power, virtually eliminating transmission costs and reducing demand for additional grid-based power generation and transmission improvements. In-turn, distributed power generators can sell excess capacity through the grid in a deregulated market. Before the full benefits of distributed power can be realized, however, the process of connecting distributed units to the grid must be improved, and the adoption of regulatory mechanisms allowing generators to offset costs by capturing the benefits of distributed generation also can help the adoption of distributed technologies.

Fuel cells are a market with a large number of applications, including:

- stationary, such as utilities and large facilities
- residential
- transportation
- portable devices

Several different fuel cell technologies are currently being developed. Some technologies are more appropriate for some uses than others. The various technologies are named by the composition of their electrolyte. The following are some examples:

Alkaline fuel cells have been on space missions. They operate at low temperatures and start quickly, but reactions with carbon dioxide make use impractical for commercial transportation applications. Alkaline fuel cells also are extremely sensitive to impurities in fuel. Power efficiencies of approximately 70 percent have been achieved with alkaline fuel cells.

Direct methanol fuel cells (DMFC) operate at relatively low temperatures (50 degrees to 120 degrees Celsius). They have efficiencies of 40 percent and are well suited for use with mobile devices. Still in early development, costs must be lowered by reducing the amount of platinum used in the catalyst before commercialization can occur. The DMFC has the advantage of using liquid methanol fuel directly, without prior reforming.

Molten carbonate fuel cells (MCFC) operate at high temperatures (650 degrees Celsius), and with efficiencies of 60 percent for electricity and 85 percent with cogeneration of waste heat, they are well suited to utility and large industrial applications. This type of fuel cell allows for the use of a wide variety of fuels, but its electrolyte causes corrosion of cell components. This technology competes in the same markets as solid oxide fuel cells (SOFCs).

Phosphoric acid fuel cells (PAFC) are one of the most commercially advanced technologies. They operate at low to moderate temperatures of 150 degrees to 200 degrees Celsius. They have a slight tolerance for fuel impurities and have efficiencies of 40 percent. The primary application for PAFCs is in the stationary market.

Proton exchange membrane fuel cells (PEMFC) are the most promising technology for transportation and portable device applications, as they operate at low temperatures (80 degrees Celsius) and have high power density, allowing for a smaller size. They operate at high efficiency (40 to 50 percent), start quickly and are rapidly responsive to changes in power demand.

Protonic ceramic fuel cells (PCFC) are a newly emerging technology that operates at high temperatures (700 degrees Celsius); they can use a variety of fuels, and they operate at high efficiencies. The electrolyte in the PCFC is solid and is not susceptible to leaking or drying out.

Regenerative fuel cells are a promising recent invention. Regenerative fuel cells are a closed-loop system that requires no external supply of fuel. Solar energy is used to separate the hydrogen and oxygen in the exhaust water, returning it to the fuel cell as a fuel supply. Considerable solar power research must occur before regenerative fuel cells are commercialized.

Solid oxide fuel cells (SOFC) operate at high temperatures (700 - 1,000 degrees Celsius) using a wide variety of fuels and is the fuel cell most tolerant to impurities and sulphur contamination. The solid-state ceramic electrolyte has enabled continuous unattended operation of demonstration systems for periods of two years. Solid oxide fuel cells also are highly efficient, operating at 50 percent efficiency for electric generation; 60 percent efficiency when pressurized and operated with a gas turbine and 85 percent efficiency, if the exhaust heat also is used. These fuel cells are very promising for stationary markets, such as electricity generation companies, large facilities (e.g. factories, shopping malls, hotels, hospitals, office buildings), and facilities needing a reliable, high quality off-grid power supply. These fuel cells also are projected for use in auxiliary automotive power systems.

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Zinc air fuel cells use zinc as a fuel and can be operated as a "closed loop" system, where no additional external fuel is necessary. Zinc air fuel cells are a potential low-cost, high-power alternative to existing battery technology. Prospective applications for the technology include transportation and portable devices.

Regional Fuel Cell Challenges

Other emerging fuel and energy technologies will continue to provide southwestern Pennsylvania energy companies with ongoing and fast-paced competition.

While Siemens Power Generation is a leader in solid oxide fuel cells, other companies, like Fuel Cell Energy/Marubeni, MTU, is developing molten carbonate fuel cells which may threaten the competitiveness of Siemens in the stationary fuel cell market. While the region has a pronounced strength in SOFC technology, the lack of other emerging fuel cell technologies in the region may put Pittsburgh's position at risk. Without a presence in the PEMFC technology, the region is unlikely to play a major role in emerging transportation and portable fuel cell applications.

Locally, rising energy costs are often blamed on Pennsylvania's decade-old electricity deregulation law, and the detrimental effects of rising costs (a 30 percent after deregulation) have big electricity users, including giant steelmakers Allegheny Technologies and U.S. Steel, very concerned. In fact, Allegheny Technologies says high power costs are the reason it has not committed $400 million to expand its Allegheny Ludlum subsidiary. U.S. Steel has said Pennsylvania's electricity rates are much more costly than those in other states where the company operates.

Regional Fuel Cell Strengths

Solid oxide fuel cell technology was developed in Pittsburgh by Westinghouse beginning in the 1950's, with R&D efforts continuing in the region with the acquisition of the division by Siemens. A search of patents issued clearly shows that Siemens is a prominent company in fuel cells and the industry leader in SOFC technology.

In addition to Siemens, the Pittsburgh region also has several research strengths in fuel cells. Besides comprehensive fossil fuels research, the NETL is a major source of federal funds and both conducts and manages internal and external research on other varieties of energy technologies, including stationary fuel cells. In addition to conducting cutting-edge research and technology development on site, NETL shapes, funds and manages contracted research throughout the United States and in more than 40 foreign countries. The NETL's research portfolio includes more than 1,800 projects, with a total award value of more than $9 billion and private sector cost sharing of more than $5 billion. These projects are carried out through various contracting arrangements with corporations, small businesses, universities, non-profit organizations, and other national laboratories and government agencies.

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The NETL manages the Solid State Energy Conversion Alliance (SECA), a group of corporate developers, universities, government agencies and national laboratories working to develop commercially viable SOFC technology. The SECA is the primary U.S. government stationary fuel cell program, and it is through SECA, the DOE selected Siemens Westinghouse to lead one of six industry teams charged with developing cost competitive (less than $400 per kilowatt) fuel cells for commercial markets.

Siemens Westinghouse was created in 1998 when Siemens acquired Westinghouse Power Generation (which had been working in SOFC for over thirty years, with several key pre-commercial units). Siemens Power Generation fuel cells has its manufacturing headquarters in Pittsburgh. It specializes in power plant systems, turnkey solutions and services that include the manufacture, repair, replacement and upgrade of steam-, gas- and hydroelectric generators. Siemens Westinghouse is leading the way in the development of stationary tubular SOFC technology. It has successfully operated a 100 kW cogeneration SOFC in the Netherlands, and 250kW and 1MW systems are being developed.

The Pittsburgh-based Siemens team was awarded $97 million from the DOE and will contribute $66 million in private funds. This team was charged with producing full megawatt-scale SOFC systems for future coal plants that will capture more than 90 percent of greenhouse gases with near zero production of other environmental pollutants, all with electrical efficiencies exceeding 50 percent, compared to 35 percent today, and with virtually no increase in cost to the electricity consumer. With a proximately 1,070 employees over five locations in the Pittsburgh region, Siemens' fuel cell R&D center employ about 130. Earlier projections called for Siemens to triple its size in the Pittsburgh region.

Concurrent Technologies Corporation operates the Fuel Cell Test and Evaluation Center from its Environmental Technology Facility in Johnstown, PA for the Department of Defense. The Center provides independent, unbiased testing and validation of fuel cell power plants for military and commercial applications. The primary goal of the Center is to accelerate the development and commercialization of fuel cell power plants.

University Strengths

Mechanical and chemical engineering are two disciplines closely related to fuel cells. Interdisciplinary relationships also exist between the distributed power industry, advanced materials (chiefly with regard to ceramics and advanced metals) and power electronics. Pittsburgh's universities, especially Carnegie Mellon University and the University of Pittsburgh, have worldwide reputations in all these engineering disciplines.

Carnegie Mellon's Electricity Industry Center (CEIC) is supported by core funding from The Alfred P. Sloan Foundation and the Electric Power Research Institute, with additional funding from the National Science Foundation, U.S. Environmental Protection Agency, U.S. Department of Energy, Tennessee Valley Authority, the U.S. Office of Naval Research, McDermott Technology the ABB Group, Alliant Energy, the National Rural Electrical Cooperative Association, the Pennsylvania Office of Energy and Technology Development and Customized Energy Solutions.

The CEIC's primary research areas are comprehensive and far-reaching and include distributed energy resources; advanced generation, transmission and environmental issues; reliability and security and demand estimation. Specific subjects include, but are not limited to:

- climate impacts on large-scale wind generation
- animal waste to power
- metrics for transmission line siting
- architecture of survivable power grids
- advanced protocols for grid reliability
- estimating electricity demand
- costs and benefits of thermal energy

Recently a consortium of three universities (Carnegie Mellon, the University of Pittsburgh and West Virginia University) received $26 million in funding over a two-year period ending in 2009 for fossil energy research. The NETL was the funding agency, and 75 university scientists, along with student researchers, will work with the NETL in addressing eight program areas:

- materials for energy technologies
- process and dynamic systems modeling
- catalyst and reactor development
- carbon management
- sensor systems and diagnostics
- energy conversion devices
- gas hydrates
- ultra deep and unconventional oil and gas production technology

When George Westinghouse founded his electric company in Pittsburgh in 1886, it was a catalyst for this country to tap into the alternating current electric power grid. Westinghouse also pioneered and patented the equipment needed in the measurement and distribution of natural gas. Westinghouse Electric Corporation also was responsible for putting the region on the map with respect to atomic power.

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Today with its centers of excellence in both academics and commercial ventures, and with its close geographical proximity to wind, coal and solar technology facilities, the southwestern Pennsylvania region represents a confluence of several energy technologies.

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