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**“Revitalizing the Energy Research and
Education Agenda at
West Virginia University”**

**Strategic Initiative for Energy and Environment
2006-2010**

November, 2006

Draft

“Revitalizing the Energy Research and Education Agenda at West Virginia University”

Executive Summary

In the past, reliable and affordable sources of energy such as coal, oil, natural gas, and nuclear have contributed substantially to the Nation’s prosperity. However, the 21st Century brings new challenges with respect to energy utilization and consumption some of which include terrorist threats; natural disasters; shrinking reserves of oil and natural gas; increased environmental pressures including global climate change; geopolitical unrest; the deployment of more expensive and advanced energy technologies; outdated electricity distribution networks; aging power generation and distribution infrastructure; sensitive computer-based systems requiring high quality electricity; changing global markets; and industrialization of emerging economies. These challenges are driving the need to reduce the national dependence on foreign fossil fuels.

For these reasons, the future prosperity of our Nation depends not only on reliable and affordable energy, but also on the secure delivery of fuel sources and power distribution. The U.S. energy future requires immediate action to develop advanced technologies to ensure clean, efficient and reliable sources of fuels for power generation, and the distribution of energy for the transportation, industrial, and residential sectors. WVU has established a strong record of research and education relative to energy and the environment and is poised to take on this challenge.

The “*Strategic Initiative for Energy and Environment –2006-2010*” has been developed with the overall goals to establish an enabling structure for WVU to effectively address energy and environmental problems of state, national, and global importance, and for WVU to become recognized nationally as one of the leading academic institutions for innovative energy and environmental research, education, and training. Additionally, the University wishes to broaden its role as a resource to the Nation and the State of West Virginia on energy and environmental issues. The initiative will serve as a foundation and guideline for addressing state, national, and international energy needs and priorities with a focus on fossil fuels. Recognizing that the environment for energy and related environmental issues is dynamic, this plan is intended to be flexible so that the University can respond to changing priorities and emerging opportunities.

Overall, this initiative addresses the national priority of having a diverse supply and delivery of reliable, affordable and environmentally-sound energy. This plan includes substantial initiatives on fossil sources of energy, e.g., oil, gas and coal. Examples of specific initiatives involving coal research include but are not limited to mine safety, carbon sequestration, hybrid energy systems, coal-based fuels (liquid fuels and hydrogen) and other by-products (e.g., carbon foam, fibers, etc), fuel cells, computational energy sciences, and extraction and separation technologies.

The plan also outlines a comprehensive spectrum of other strategic initiatives that includes natural gas from unconventional sources; alternative fuels; new materials; stability, robustness, and security of electric power systems; bio-fuels; and engine emissions. In addition, energy policy and economics; homeland security relating to critical infrastructure and mass migration are specific areas of interest. Environmentally sound approaches are incorporated into all of the initiatives as appropriate. Eight major initiatives include:

- *Advance environmentally friendly technologies for the safe mining, utilization, value added products, and alternative fuels from coal*
- *Advance technologies for non-coal fossil fuels*
- *Advance technologies for non-conventional transportation fuels and vehicles*
- *Advance technologies for electricity distribution, system efficiency, and reliability*
- *Advance technologies for bio-fuels and bio-products from renewable resources and reducing environmental liabilities*
- *Become a major resource for the state and nation on energy efficiency, sustainable development, economics, energy policy, and technology assistance*
- *Advance technologies and programs for West Virginia's role in enhancing homeland security in the energy and environmental areas*
- *Provide relevant educational programs and training for the next generation workforce*

The overall approach to implementing this multi-disciplinary initiative will involve strengthening established programs and forming new programs to take advantage of existing and emerging opportunities. Research clusters with faculty leaders developed around existing strengths and emerging opportunities may be formed to focus on specific cutting-edge problems. Some problems are expected to require interdisciplinary approaches. Implementation of this initiative may involve increasing the core energy/environment faculty in targeted areas, new state-of-the-art facilities and equipment, and organizational structure for administering the plan.

Additionally, the University has and will continue to engage in mutually beneficial multi-institutional partnerships that may include other academic institutions, government national labs, and the private sector on both a national and global scale.

The energy and environmental programs are expected to impact the economy through innovative technology development, technology transfer, and commercialization through licensing and new business formation. It is expected that energy/environment businesses will be attracted to West Virginia and new jobs created.

Subject to finalization of the proposed donation of property by the DOW Chemical Company in their South Charleston Technology Park, WVU plans to create the WVU Charleston Research Campus and initiate a research program focusing on energy/chemicals. A separate business plan will be developed for this campus.

This plan will be administered and assessed by the WVU Research Office, implemented through both existing and newly formed centers, and coordinated through the National Research Center for Coal and Energy. Key experts in energy and related disciplines will be invited to serve in an advisory capacity during the implementation of this plan.

Introduction

America's continued global competitiveness and quality of life depend on plentiful, affordable, secure, and reliable energy. Environmental considerations require that advanced power generation and distribution systems have reduced environmental impact, including reduced emissions from the use of fossil fuels, i.e., coal, oil and gas. In addition, world events and the scarcity of energy supplies have heightened the national need to minimize the U.S. dependence on foreign sources of fossil fuels, particularly from countries with unstable governments. Some of the drivers for this include such factors as:

- Political instability of countries having large oil and gas reserves and the growing geopolitical tensions between producer and consumer countries require more emphasis on using indigenous fuels to supply our nation's energy needs
- Accelerated demands, production constraints, and the scarcity of economic fossil fuel reserves will lead to increased prices for fossil fuels and have the potential for severely impacting our national economy
- The absence of technologies for extracting difficult-to-reach coal, gas, and oil reserves will lead to continued short supplies and higher costs for these resources
- Environmental stress due to increased energy consumption, production, and exploration will increase the cost of compliance with national standards for the environment
- Homeland security issues will require the development of a stable energy infrastructure, less dependence from international sources of supply, protection of our energy resources and delivery systems from disruption by terrorists and natural disasters, and comprehensive response and recovery capabilities for restoring disrupted services

The U.S. Congress passed the Energy Policy Act of 2005 in August, 2005. Key provisions of this act provide a national direction for energy and opens new opportunities for research, technology transfer, and economic development. Briefly, the legislation addresses production and conservation technologies, financial incentives and loan guarantees, incentives to industry and consumers for the deployment of newer technologies, the removal of regulatory uncertainties, international energy issues, and responsibilities across federal agencies as well as state and local political subdivisions.

The Homeland Security Act of 2002 and subsequent Homeland Security Presidential Directives and U.S. Department of Homeland Security policy guidance have established programmatic direction for protection of the Nation's critical infrastructure. As these programs evolve, improved protective measures and response and recovery programs will be incorporated into planning, development and operation of the Nation's energy systems. Initiatives based on this aspect of national security are a key feature of the West Virginia University strategic plan for energy and environment.

The State of West Virginia and West Virginia University are uniquely positioned to play a major role in advancing the state and national energy agendas and capitalizing on current opportunities in the international arena.

West Virginia is in the heartland of our nation's energy supply with abundant energy resources. West Virginia can capitalize on its resource base to build a sustainable economy and ensure the well-being of its citizens.

West Virginia

As the second largest producer of coal, its mining industry produces on average 150 million tons of high quality bituminous coal per year having an economic impact of greater than \$3 billion. Overall, the West Virginia coal industry and related contractors and service suppliers currently employ about 40,000 individuals, with mine workers averaging \$53,000 per year in wages.

Coal is an integral component of West Virginia's history, society, and economy and is the major energy source for electricity production in West Virginia and the nation. With polygeneration technology development, coal can be an affordable source for clean liquid transportation fuels, and it will likely be the feedstock for hydrogen which is projected to be the fuel of the future. West Virginia has nearly 53 billion tons of coal reserves in 41 counties, 19 billion tons of which are recoverable and sufficient for more than 100 years of electricity generation at the current production level in West Virginia.

Ranking 13th of 32 states in gas production, West Virginia's oil and natural gas industry employs more than 3,900 workers at an average annual wage of \$36,000, and produces 200 billion cubic feet of gas and 2 million barrels of oil per year.

West Virginia generates in excess of 93,000 GwHr of electricity annually, mostly from coal, of which approximately 60% is exported to surrounding states. Low-cost electricity and other energy products make the State's industry base more competitive in global markets.

West Virginia University

WVU has developed a new comprehensive plan, Strategic Plan 2010, covering all aspects of the University mission. This plan has been approved by the WVU Board of Governors and, in the coming months, specific areas of the plan will be further developed and implemented to provide guidance for implementation of the general plan. Examples include the Strategic Research Plan for Health Sciences, Strategic Plan for Research and Economic Development, and strategic plans are being developed by academic schools and colleges. This document describes how WVU will address state and national needs as they relate to research, education, and outreach associated with energy and related environmental issues. A broad spectrum of disciplines across the University will be engaged in the implementation of this plan.

West Virginia University has a long history of research in fields such as resource extraction, environmental remediation, energy utilization technology, and vehicle emissions; and providing assistance to the State's energy producing and energy intensive industries and collaborating with the National Energy Technology Laboratory. WVU is the home of the National Research Center for Coal and Energy (NRCCE) and other centers and programs that focus on energy and environmental research and outreach. The WVU faculty is nationally known for their contributions to improving energy systems through research, service, and technology transfer. As a land-grant institution and nationally and internationally recognized doctoral degree granting university designated as a Research University by the Carnegie Foundation, WVU can be successful in fulfilling its mission through advanced energy and environmental research and education focused on West Virginia's interests while also being responsive to national and global needs. There are additional regional and local 'energy assets and initiatives' that favor WVU expanding its leadership role in energy and environment fields. These include:

- WVU has a close working relationship with the DOE National Energy Technology Laboratory (NETL) of the Office of Fossil Energy located in Morgantown, WV and nearby Pittsburgh, PA
- WVU has strong working relationships with regional universities that have successful coal and energy research programs such as Penn State University, University of Pittsburgh, Carnegie Mellon University, Ohio State University, Michigan State University, University of Maryland, Virginia Tech, the University of Kentucky, Auburn University, Montana State University, and the University of Utah
- WVU is a partner with the University of Pittsburgh and Carnegie Mellon University in the "University Consortium" teamed with the Research and Development Solutions (RDS), LLC in managing the current R&D Site Services Contract with the NETL
- Many WVU energy and environmental programs and projects are recognized nationally and internationally
- West Virginia is an 'energy state' with a well-established mining industry and a plentiful supply of coal, natural gas, and water
- WVU has close working relationships with local coal mining and equipment and service companies; the WVU President serves on the Board of Directors of a major coal company
- West Virginia developed an "Energy Roadmap" in 2002 that outlined a comprehensive set of opportunities for West Virginia to be a vital link in the national energy economy

In addition, WVU is a voting member of the board of Texas-based Research Partnership to Secure Energy for America (RPSEA). RPSEA is a not-for-profit research organization that won the contract for them to serve as the program manager in administering funds for research on unconventional and off-shore deep-well natural gas and oil exploration authorized by the Energy Policy Act of 2005. The WVU Vice President for Research and Economic Development serves on the Executive Committee of the RPSEA Board of Directors. WVU is also a charter member of the Consortium for Fossil Fuel Science

(CFFS), along with four other nationally prominent universities in energy from coal, the USDOE-funded Consortium for Premium Carbon Products from Coal (CPCPC), C-1 Chemistry, and Stripper Well Consortium.

WVU currently has a variety of active energy and environmental research and outreach programs underway, some of which are interdisciplinary and multi-institutional. Many of these activities are aligned with programs of the NETL whose fossil fuel focus areas include: geological and environmental systems, energy systems and dynamics, computational and basic sciences, system analysis, security, and computer-based visualization technologies. Some of WVU's existing programs include:

- carbon sequestration
- advanced separation technologies for coal and minerals processing
- alternative fuel production from coal via C-1 chemistry (coal gasification/liquefaction)
- computational energy sciences for fuel cells and coal systems modeling
- environmental restoration and water-related research
- energy-related nanoscience research in materials
- stability of electric grids
- development of carbon products from coal
- fuels and engines testing
- light weight materials
- enhanced coal, oil, and natural gas extraction technologies, including coal bed methane production
- separation technologies

The NRCCE provides a key foundation to many WVU energy-related projects and has been and continues to serve in a leadership role in the University's energy and environmental research and outreach. Established in the late 1980s with funds provided by Senator Robert C. Byrd, the mission of the NRCCE is to "advance innovations for energy and the environment." This mission includes increasing the prudent utilization of our nation's fossil fuels to meet future needs for energy. NRCCE's mission is to be accomplished by conducting basic and applied research, performing technology assessment studies, and sponsoring technology transfer activities to disseminate the information developed under the programs of the NRCCE. It plays a facilitating role for sponsored programs with external partners and internal WVU research units in the colleges and centers of the University. It has more recently expanded its focus to develop secure and inexpensive energy supplies for electric power generation, transportation fuels, value-added chemicals, and to participate in international energy related projects and activities. In addition, it is the home of the WV Industries of the Future Program that facilitates cooperative projects with industry.

In view of the global nature of energy commodities and concern about the environment, and the opportunities for business development, WVU has become increasingly involved in international initiatives. The NRCCE has expanded its programs to include substantial international components to promote the exchange of technology and engage in joint

research projects. These activities include cooperative programs involving the U.S. Department of Energy, India, and China. Faculty from several colleges of the University are also engaged in international program development in energy and environmental areas such as the College of Engineering and Mineral Sciences (CEMR), Eberly College of Arts and Sciences, and the Davis College of Agriculture, Forestry, and Consumer Sciences. In addition, the West Virginia Coal and Energy Research Bureau is administered by the Department of Mining Engineering of CEMR, and the Center for Environmental Research was recently formed through the WVU Research Office.

Control of the U.S. supplies of energy is vital to national security and must include protection of critical energy infrastructure which, when disrupted, will adversely impact economic prosperity and continuity of government operations and essential services. Critical infrastructure protection (CIP) is a national homeland security priority. It is a long-term effort that requires crosscutting, multidisciplinary research and development focused on both private sector and public sector infrastructure. It also provides research-based information and technical assistance to help public and private sector leadership plan effectively for the risk tradeoffs that occur when market forces adversely impact optimum preparedness for high risk events with low probability of occurrence.

Because terrorists can take a flexible, rapid adjustment threat stance and because preparedness for a natural disaster does not affect probability of occurrence, critical infrastructure planning must be conducted in a way that recognizes interdependencies, reduces vulnerabilities, and improves ability to restore services quickly. Recognition of cross-sector interdependencies is a key to success in this process.

Reducing the U.S. dependence on foreign sources of energy and the need for environmentally friendly and energy efficient conversion of fossil fuels depend on technology advances through research, transferring technology to the private sector, and informing state and federal government officials about energy and associated environmental issues for policy considerations.

This plan outlines a spectrum of goals and strategic initiatives that will contribute to: development of advanced technologies for energy resource production; environmental protection; power generation and distribution; educating and training the next generation of energy managers, scientists, and engineers; and policy development and analysis to ensure a competitive, environmentally sustainable energy supply in the future. In addition, the plan will allow for the commercialization of technologies developed through research.

Vision Statement

West Virginia University will become nationally and internationally recognized as a leading academic institution for innovative research, education, and training in the environmentally responsible production and use of fossil energy fuels, and will be the primary resource to West Virginia, and among the leading universities nationally, on energy and related environmental issues, including policy, by the year 2010.

Mission Statement

- Generate and disseminate new and practical knowledge through advanced research on energy and environmental problems and solutions
- Educate and train the next generation of scientists, technologists and engineers for energy and environmental industries, and for relevant government agencies
- Contribute to economic development in West Virginia through education, technology transfer, commercialization of technologies, the creation of new businesses, and the attraction of established businesses in the energy and environmental sectors to West Virginia
- Provide assistance, training, education and research pertaining to energy conservation and the efficient use of energy
- Serve as a prominent resource to assist policy makers state and national levels
- Assist the State and the energy industry in deploying and implementing energy- and environment-related technologies that protect air, land and water and improve the overall quality of life for West Virginians
- Become a national leader in development of critical infrastructure protection measures and response and recovery systems for energy production and distribution systems

Initiatives

Advance environmentally friendly technologies for the safe mining, utilization, value-added products, and alternative fuels from coal

Since the 1950's, coal's share of the national energy generation market has slowly declined against natural gas and other fuels, mainly because capital-intensive equipment was required to reduce environmentally damaging emissions from coal-fired plants. However, coal still generates 51% of U.S. electricity despite having only a 35% share of the installed generation capacity. Energy experts agree that coal is expected to become even more important as a global energy source in the coming years. According to the Annual Energy Outlook (2005), U.S. coal production is projected to increase at an average rate of 1.5% per year from 2003 to 2025. According to the International Energy Agency (IEA), there is approximately one trillion tons of recoverable coal worldwide which represents 65% of all proven fossil fuel resources. The U.S. has 27% of the world supply, Russia and China (combined) 30%, and India and Australia (combined) 19%. Therefore, coal will be an integral component of energy production in the U.S. and

throughout the world for generations, and will play a critical role in meeting future national and global energy needs.

A secure energy future depends on taking action today to develop advanced, economical technologies for producing clean, efficient and reliable energy from coal. Coal use faces many challenges; key among them are the impacts of mining and burning coal on air, land, and water quality. Nevertheless, progress has been made in reducing emissions in coal-based electricity generation. From 1970 to 2003, coal-based electricity generation increased by 177%, while sulfur dioxide emissions decreased by 35%, and NOX emissions remained constant compared to the 1970 levels.

Key strategies for the responsible use of coal require marked improvements in power plant efficiency to reduce atmospheric emissions of carbon dioxide per unit of energy consumed, and the development and deployment of technologies for producing cost-efficient fuels and chemicals from coal. Liquefaction and gasification technologies demonstrated in the 1970's were not commercialized in the U.S. at the then prevailing fuel prices. However, fuel prices are at a level today to justify new efforts. Technologies under development at NETL and elsewhere could increase this efficiency substantially while producing concentrated carbon byproducts that could be directly sequestered.

West Virginia coal production peaked at 183 million tons in 1997, but has progressively declined to 140-150 million tons annually. Easy-to-get, good quality coals are being depleted rapidly. Consequently, new technologies are required to economically extract coal from thinner, deeper, dirtier, acid-producing and geologically more challenging seams.

Some are of the opinion that coal is too valuable to burn. For high quality coals selling at \$60 per ton, the cost of carbon in coal is nominally three cents per pound. However, coal refining processes which separate heteroatoms and ash from the coal matrix can produce carbon extracts which can sell for \$300 per pound. Products made from coal, such as anodes for aluminum smelting and binder pitch for graphites, can be superior to similar products currently made from petroleum coke. With petroleum resources in short supply, alternative carbon products from coal prove to be an attractive and highly profitable use of West Virginia coal.

The need for sequestration-ready clean coal technologies is becoming even more urgent to meet increased requirements for controlling the emissions of sulfur and nitrogen oxides, mercury, particulate matter, and carbon dioxide. The costs of generating electricity from non-coal sources of energy such as oil, natural gas, geothermal energy, and renewable energy sources like solar and wind power make clean coal an attractive alternative. Major national energy initiatives for coal include the Clean Coal Power Initiative for demonstrating advanced technologies at commercial scales, and FutureGen for demonstrating gasification, hydrogen production, and carbon capture and sequestration-zero emissions.

Concomitant with this push for cleaner energy production is the need for strong environmental remediation strategies for protecting the environment in the face of enhanced coal extraction and consumption. Coal extraction and energy technology present environmental challenges that can be overcome with the application of both established and new approaches to remediation and reclamation. These approaches work not only to protect and sustain the natural environment of West Virginia, but also provide opportunities of long-term economic development through energy remediation technologies.

Mined land reclamation has its roots in West Virginia; in 1939 it was the first state to pass a reclamation law. The federal Surface Mining Control and Reclamation Act passed in 1977 mirrored the West Virginia state reclamation law. During the past four decades, West Virginia University has played a key role in developing technologies for innovative reclamation approaches. WVU's leadership in environmental research of land previously mined for coal includes the analyses of coal's economic impact on communities and quality of life, carbon sequestration by reclaimed lands, watershed organization and development of clean stream programs, and involvement in state, regional, national and international reclamation and water quality committees. Much of the work in this area has been conducted through WVU's National Mine Land Reclamation Center and West Virginia Water Research Institute.

Objectives

- Develop interdisciplinary research programs that focus on the safe and environmentally responsible production of West Virginia coal while contributing to the national base for coal mining technology. Focus areas include advanced separations and mining technologies, robotics to increase production and enhance safety, advanced mining automation, and the recovery of coal fines.

Focus areas include environmental aspects of coal mine planning and development including research in geology, hydrology and water resources, soils and vegetation, reforestation, wildlife, future land use of mined areas, and impacts on communities. Other programs include ensuring the stability of mine coal slurry impoundments, reclamation of gob piles, waste minimization, and efficient use of water resources.

- Strengthen existing research programs and initiate new ones in the areas of carbon capture and sequestration, computational energy sciences, fuel cells, advanced energy materials (including nanoscience applications), coal-based fuels such as hydrogen, synthetic natural gas, liquid fuels and chemicals, utilization of combustion byproducts, and instrumentation and control of coal utilization systems. These programs will support national needs and will be conducted in cooperation with the NETL and corporations such as Allegheny Energy, American Electric Power, or other end users of the technology.
- Develop alternative uses of coal for solid products and other applications. Continue and enhance the development of technologies for producing value-added carbon products from coal feedstocks. These programs will be conducted

with manufacturers that use carbon materials in their energy-intensive processes. WVU will work with local business entrepreneurs to establish new manufacturing capabilities in the State.

- Continue West Virginia University's national leadership in environmental technology research in land and water reclamation. Focus areas include prediction and remediation of acid mine drainage, post-mining land use development, reforestation, carbon sequestration, and creation of wildlife habitat, enhancement of water and air quality, abandoned mine land reclamation, quality of life in coal communities, brownfields development, biological carbon fixation and bio-informational sciences, bioremediation for the removal of energy-related trace contaminants in soil, water, and air, and advanced technologies to reduce harmful emissions from coal-fired electric power generation.

Advance technologies for non-coal fossil fuels

Natural gas has been the fuel of choice for increasing electric power generation capacity in terms of new plant additions over the past decade. Recent assessments regarding future natural gas supplies include observations that gas production in the United States has remained constant while the number of drilling rigs has increased markedly. From a historical perspective, the larger, readily accessible gas fields were the first to be tapped and are now in decline. Newer gas fields are smaller and production technologies have improved such that the newer wells are depleted faster.

Major increases in drilling activity and the discovery of new fields are required to simply maintain the status quo for our current consumption, let alone prepare for a 50% increase in demand to 33 TCF per year. Deep gas reservoirs, referred to as unconventional sources, are considered to be, potentially, the most productive and underdeveloped source of natural gas underlying West Virginia and the Appalachian region. Development of these difficult-to-produce reservoirs enhances the opportunity for increasing West Virginia's natural gas production and exportation in meeting the rising energy demands and security of our nation.

Liquefied natural gas (LNG) offers promise for increasing our gas supply through imports, but such supplies are for the most part available only from unstable political regions, thereby reducing rather than increasing our energy independence and security. Near term, the shortage of ships to transport LNG, coupled with existing delivery contracts to other nations, and the small number of terminals will prevent LNG from making a substantial contribution to our national gas supply.

The production of coal bed methane (CBM) and coal mine methane (CMM) has grown to almost 10% of U.S. consumption and is essential to our Nation's gas supply. It is a secure energy source, and its use will continue to increase as new technology is developed. CBM from deep unminable coal seams has not been commercially produced in large quantities, although such seams hold a much greater quantity of gas than the shallow (<3,000 ft) seams. CMM gas mixed with mine ventilation air is released to the atmosphere and is a significant source of greenhouse gas emissions.

Natural-gas hydrates (NGH) are ice-like, crystalline networks of hydrogen-bonded water molecules that form cavities which encage low molecular-weight gas molecules such as methane. NGHs are typically formed when water and hydrate-forming gas molecules are both present under conditions found in sea-floor sediments and deep in the permafrost, i.e., high pressure and temperature at or below the freezing point of water. NGHs in Polar Regions and deep-water continental shelves may contain more organic carbon than all of the world's coal, oil, and non-hydrate natural gas combined. NGHs can also be a problem when they form in pipelines used for transporting gas over long distances. The Energy Policy Act extended funding for NGH R&D through 2010. The NGH research program focuses on two key energy supply goals: to ensure the safety of deep-water oil and gas operations when drilling through marine hydrate deposits, and to develop the knowledge and technology base to allow commercial production of methane from domestic hydrate deposits by 2015. As the cost of producing conventional fossil fuel reserves increases, the role of natural gas hydrates as an energy source is certain to become increasingly important. Although the technical barriers to economic production of methane from NGH are considerable, the large energy potential of this fossil reserve is substantial.

Many experts predict that the global production of oil will soon peak and then begin to decline. However, demand continues to grow, exacerbated by the increased economic development in third-world and developing countries like China and India. While much oil remains in the ground, the rate of production is limited and the harder-to-get oil supplies will be available only at increased prices unless enhanced recovery technology improvements are successful.

It has been estimated that approximately two billion barrels of crude oil remain in known, pressure-depleted reservoirs in West Virginia. Because the pressure originally contained in these reservoirs has been depleted, most of this oil must be produced by secondary or enhanced oil recovery methods. Development of methods that enable production from these reservoirs enhances the opportunity of increasing West Virginia oil production.

Objectives

- Develop technologies for the production of natural gas from unconventional resources. The focus of these programs will be to develop cost effective technologies for recovery of natural gas from conventional and unconventional gas reservoirs, NGH deposits, gas shales, tight gas formations from deeper horizons both on-shore and off-shore, increased production of coal bed methane resources, and the development of advanced equipment and measurement technologies for resource identification and characterization.
- Expand opportunities for continued production of West Virginia's oil resources. The focus of these programs will be to increase production through enhanced oil recovery as an integrated program with the carbon sequestration initiatives under the federal coal research program, mapping of our oil resources, and technologies for maximizing production from existing fields.

- Expand collaborations, service, and research programs with the West Virginia oil and natural gas producers and the regional state geological surveys to enhance the recovery of West Virginia's petroleum resources. Focal areas would include compiling comprehensive data bases and mapping of reserves (including GIS capability), technology transfer to small operators through the programs of the Petroleum Technology Transfer Council Appalachian Resource Center, workforce development, and the enhancement of academic programs in areas such as petroleum and natural gas engineering and geology to meet the demands of finding and characterizing energy resources.

Advance technologies for non-conventional transportation fuels and vehicles

The transportation sector in the United States is primarily based on fuels derived from oil. This sector is responsible for 38% of the CO₂ emissions in the United States, and is a major contributor to NOX pollution in metropolitan areas. Natural gas vehicles, hybrid electric vehicles, and hydrogen powered vehicles are being studied in shaping our national transportation system of the future. Capturing emissions from mobile sources is more difficult than stationary sources such as power plants. Therefore, the national focus is on developing more efficient, less polluting vehicles. The use of alternative fuels like hydrogen, coal-derived liquids, and advanced electric (battery driven) vehicles are seen as keys to reducing our dependence on imported petroleum products.

West Virginia University is currently a leader in engines and emissions research for heavy-duty vehicles. The objective of this goal is to expand our current programs to address a wider spectrum of issues of importance to the transportation sector.

Objectives

- Expand existing programs and initiate new programs for the development of advanced propulsion systems which have reduced environmental impacts. The focus of this program is on the development of new technologies for modifying the combustion characteristics of internal combustion engines, the development of advanced technologies for controlling emissions, and development of new technologies to replace the internal combustion engine. The program will also include the development of advanced on-board technologies such as fuel cells, hydrogen storage, and on-board reforming of hydrogen carrier fuels, hydrogen storage, and reforming of carrier fuels for transportation applications.
- Initiate new programs for the development of advanced, environmentally friendly fuels for the transportation sector. Research will address problems associated with new low sulfur and non-petroleum fuels such as Fischer-Tropsch formulations from coal. New sources of fuels will include agricultural products/wastes, biodegradable waste products, coal gasification, and hydrogen.
- Expand existing programs for the development of high strength, lightweight materials for transportation vehicles. The efficiency of the transportation sector can also be enhanced through the development and deployment of advanced materials to reduce the weight of transportation vehicles or to permit higher

- temperature operation. The focus of this program will be to design structural components which enhance safety while also reducing vehicle weight.
- Initiate new programs for the development of advanced materials for and enabling new propulsion systems and their operation. Research will focus on the operation of propulsion systems, such as hydrogen engines, at higher temperatures with capability to resist corrosion and wear in new more aggressive conditions created by the new fuels.

Advance technologies for electricity distribution, system efficiency, and reliability

The 21st Century has brought new challenges for electric power delivery. Electricity growth rates of approximately 2% per year will require additional infrastructure such as power plants and high voltage transmission lines. The general public, however, is averse to the placement of new lines, especially if their region or state does not benefit from the flow of power through the proposed line. The 20th Century electric power delivery infrastructure is aging and cannot keep pace with the Nation's growing economy and more sophisticated needs. The power transmission and distribution system requires advanced technologies which meet current demands for reliable distribution and controls in the face of deregulated markets and interconnected grid systems. Failure to maintain effective oversight of the status of the electric transmission grid and distribution systems on a national basis can result in blackouts that have a profound impact on the economy and citizen confidence. Advanced technologies are needed for the electric industry, including real-time information systems, advanced controls, new storage concepts, and distributed energy generation.

The national electric grid and the fuel supply chain are vulnerable to terrorist attacks in addition to acts of nature, such as hurricanes or intense snow falls over wide regions. Security of the Nation's energy resources and power delivery infrastructure depends on the degree to which redundant systems can be devised to protect the existing infrastructure.

Objectives

- Expand existing programs in the design, control and communication protocols for electric power distribution. WVU researchers have developed advanced concepts for the design and control of the electric grid over scales that span from regional grid systems to local distributed power systems. The WVU program also includes economic considerations for the effective dispatch of power plants in response to load. These technologies also apply to major stand-alone electric generation systems such as naval ships and large industrial sites. The focus of this program is to develop control and communication protocols which can be deployed in the electric industry sector.
- Initiate programs to ensure the stability and robustness of electric power systems. Major emphasis in modeling power systems has been placed on the transmission grid. Few models include the dynamics of the power generation system – boilers/gasifiers, turbine generators or fuel cells – and the transmission grid as a

combined system. Research will focus on the interaction of these two components of the electricity generation and transmission system to ensure system stability and robustness. Major new federal and industrial programs have been initiated under names such as SureGrid to address these issues. WVU researchers will continue projects with the NETL to study interactions between the generation and transmission components during upset conditions which may occur due to malfunctions in equipment such as pumps, faulty sensors, or fuel supply interruptions.

- Initiate programs for security of fuel supply and other infrastructure for power generation. Security of the power generation grid as part of national critical infrastructure also extends to maintaining secure and the readily deployable supplies of fuels and other critical materials for operation of power plants. The focus of this program will be to examine the flexibility of power systems, the sources of supply of fuel and other materials, and the impact of deficiencies in these areas on the stability of power systems.
- Assure critical infrastructure protection (CIP) in energy development and distribution. Initiate programs to assess the interdependencies among power systems and public and private sector enterprises to assure that planning for potential terrorist acts and natural disasters appropriately accounts for these interdependencies in policy development, legislative initiatives, and regulatory functions.

Advance technologies for bio-fuels and bio-products from renewable resources and reducing environmental liabilities

Agricultural and forestry industries are based on renewable resources. These industries generate substantial amounts of by-products with limited economic value. Value-added bio-fuels and bio-products can be obtained from these wastes using appropriate technology so as to utilize the renewable resources and reduce environmental liabilities in an efficient and sound manner. Interest in such technologies exists as suggested by the *Energy from Agriculture Conference* held in December of 2005 in St. Louis, Missouri.

A major by-product of animal agriculture is manure. In consolidated confinement farming operations, animal wastes are concentrated at each site. Wastes from animals in the United States, including broiler chickens, dairy and beef cattle as well as swine, exceeds 3.9 million tons, annually. The staggering amount of animal wastes generated in the U.S. alone overwhelms the need for organic fertilizer. Most importantly, animal wastes are now considered an environmental liability.

Bio-digestion may be a viable process but it requires multiple steps in handling and product development, and substantial energy inputs. Other than bio-digestion, few technologies have been developed for converting agricultural waste to fuels. Since agricultural waste contains a high proportion of organic compounds, it is expected to be possible to convert the waste into potential bio-fuels utilizing procedures that are more environmentally sustainable and energetically efficient. Small-scale preliminary studies involving hydro-pyrolysis have produced cost-efficient fuels suitable for blending with

conventional fuels or they are being captured as an economically viable product. It has been estimated that agricultural animal waste could annually replace a significant amount of the non-domestic fossil fuel consumption in the U.S.

Forest and lumber operations produce wood residues that are traditionally considered as wood wastes (chips, sawdust and bark) with over 39,000 tons produced per week in West Virginia alone. Logging residue adds an additional 1.2 million tons per year. These residues represent potential raw materials for use as fuel or conversion to fuel or other products.

To date, some efforts in the utilization of wood-based residue have been in the manufacture of wood pellets for energy and co-generation of electricity by burning coal with wood. However, new opportunities exist in the development and adaptation of technologies for the manufacture of bio-fuels (bioethanol, biodiesel), biochemicals (xylitol, furfural, and gas additives), and biopolymers (polylactic acid) from wood based residues.

Objectives

- Develop technologies for the production of value-added bio-fuels from non-fossil, renewable resources. The focus of these programs will be to continue current research on bio-fuels and to further develop cost-effective, environmentally sound technologies for the conversion of non-fossil renewable resources such as wood and biomass, including environmental liabilities, into fuels/energy or other chemicals. WVU researchers have developed a process for converting animal wastes to a bio-fuel that can be mixed with diesel. A demonstration production is expected to be developed in the near future for testing scale up of the process.
- Expand collaborations, service, and research programs with the state and U.S. agricultural and forestry industries. Develop focus areas in: the identification of non-traditional organic fuel resources that can be placed in sustainable production with appropriate management; lessening of environmental infringement; creating market opportunities and pilot projects; and promoting partnership development.

Become a major resource for the state and nation on energy efficiency, sustainable development, economics, energy policy, and technology assistance

The effective deployment of energy systems requires much more than the development of new or improved technology. Other factors such as cost, social acceptance, strategic considerations, financing, permitting, cost incentives, and national policies are important considerations that influence decisions to deploy new technologies. Energy savings and efficient use are important factors not only in the conservation of our scarce resources, but also in the protection of the environment and the reduction of undesirable emissions such as CO₂ and NO_x.

WVU has provided state leadership in programs such as the Industries of the Future – West Virginia [IOF-WV], the WV Energy Roadmap Workshop Series and the Energy

Forum, the WV Water Research Conference, the International Ground Control Conference, the North American Coal Bed Methane Forum, the Petroleum Technology Transfer Council Workshop Series, the National Coal Council, the Coal Utilization Research Council, and working groups such as the Strategic Initiatives for Coal and Power Group of the US DOE Office of Fossil Energy.

Objectives

- Initiate programs to serve as a resource to the State and Nation in the development of energy policy. Deployment of energy technologies must be consistent with state and national policies and regulations if a vendor wishes to recoup the long-term capital investment in energy-based systems. The focus of this objective will be to establish a Center for Energy and Environment Policy Research to include critical infrastructure protection as related to energy and environment sectors and interdependencies among energy production, distribution, and use. The Center will be a resource for the State in evaluating new industrial opportunities and will be actively involved in analyzing and proposing policy alternatives in the national and international arena.
- Expand and enhance existing programs in energy economics. Development of energy alternatives must be economically viable and socially acceptable as well as technically feasible and environmentally sustainable. The focus of this program will be on the underlying economic and social factors related to energy production and utilization. The program will serve as a resource for understanding, developing, and implementing energy alternatives that meet appropriate criteria.
- Serve as a resource to the State and Nation in the effective use of energy. A large number of businesses and industrial plants need help in managing their energy usage. The focus of this program will be to provide assistance to companies and other organizations, as well as the consumer, for efficient usage of energy and for minimizing the amount of energy that goes to waste. This will be accomplished through plant-wide assessments, in which experts from WVU evaluate the usage of energy in such systems as steam, compressed air, motors, pumps, HVAC, and lighting, and provide recommendations on how to save energy, the expected savings, associated costs, and payback periods.
- Continue and expand outreach activities to foster technology development and economic opportunities. WVU will continue and expand its outreach to the business, industrial, and technical communities through activities such as providing extension services, hosting and participating in conferences, meetings, and committees, and working with organizations which focus on economic development opportunities. Participation in national study groups will enable WVU to contribute to shaping national policy through presentation of expert testimony, drafting proposed legislative initiatives, and building coalitions to provide support for energy, environmental, and economic issues of interest to West Virginia.

Advance technologies and programs for West Virginia's role in enhancing homeland security in the energy and environmental areas

The events of September 11, 2001 have focused national attention on securing the United States homeland against terrorist attacks that may include incidents of physical violence and longer-range threats such as control of our supplies of energy and other raw materials essential for the U.S. economy and defense preparedness. Security and preparedness concepts will also apply to ensuring the safety and well-being of our citizens in the face of high consequence events such as hurricanes, electricity curtailments from transmission failures due to weather or high load demand, and major industrial disasters.

Homeland security and emergency preparedness programs address three major areas related to energy and environment: (1) providing health and safety services and other response activities to deal with emergency situations during and immediately after occurrence (e.g., helping communities restore electrical power during and after a major flood), (2) preparedness planning and training for both responding to and preventing emergencies and terrorist threats (e.g., designing redundancies or alternative routing schemes for providing electrical power in case of a blackout); and, (3) implementing alternative scenarios to reduce dependence on critical products or materials (e.g., producing alternative transportation fuels from coal to reduce imported petroleum demand). The most critical needs in an emergency scenario, after ensuring the safety of those affected, include water, food, electricity, communications and public safety. The availability of energy and energy delivery systems is central to providing these essential services.

West Virginia University's energy and environment programs can be key contributors to both the national critical infrastructure protection initiatives and the state programs of the West Virginia Division of Homeland Security and Emergency Management (DHSEM) in the Department of Military Affairs and Public Safety (MAPS). In addition to ensuring public safety and being prepared for emergencies, homeland security programs can also be stimulators of economic development through the dual aspects of using emergency systems for alternative applications under non-emergency periods, which are more the norm.

Objectives

- Develop a simulation and modeling program and complementary expertise to serve as a resource to the State in managing emergencies. WVU has considerable expertise in modeling, computer simulations, and geographic information systems which can be applied to develop energy and environment response models to guide deployment of emergency services in the event of a large scale disaster. Cooperative programs will be developed with the NETL and other state-based organizations such as the WV National Guard at Camp Dawson, West Virginia. Other objectives include developing an advanced multi-disciplinary capability for large-scale, real-time data acquisition and manipulation and simulation and modeling for energy sector critical infrastructure protection, and forming a multi-

disciplinary policy development and analysis capability for energy sector critical infrastructure protection.

- Develop emergency response scenarios for use in educating and training of first responders. Effective response to emergency incidents is conducted by well-trained and efficiently coordinated response personnel acting in accordance with local, regional, and national policy and regulations. Response preparedness involves the preparation and delivery of training materials and operational manuals to address the variety of needs related to preparing for, responding to, and recovering from an emergency situation. Training is required for local officials and the responder organizations called upon to address emergency needs. Through a coordinated approach, WVU faculty and staff teams from all relevant sectors of the University will develop and provide training and associated manuals and job aids to address state needs through MAPS and national needs through the National Infrastructure Protection Plan (NIPP). WVU expertise developed through these programs to address state preparedness needs will also be applicable to other states and national scenarios. The University will seek working relationships with external entities such as the West Virginia Energy Education Alliance.
- Develop expertise in homeland security technology areas. WVU will establish a coordinating activity among its complement of researchers and service providers to be a national resource base for homeland security and emergency preparedness in energy and environment areas. Specific activities will include: developing sector expertise to have researchers available who can address energy and environmental technology needs for needs for responding to specific kinds of emergency situations; programs addressing the cyber threat to the energy industry; developing simulation and modeling capability for a variety of energy emergency scenarios and the associated data bases needed to apply the models to specific situations; and, maintaining a working knowledge of the resources and other attributes available through the National Asset Database and similar resources. Additional emphasis will be placed on providing emergency electricity resources in support of West Virginia's role as a possible refuge for the population on the East Coast which might be displaced due to terrorism acts.

Provide relevant educational programs and training for the next generation workforce

The mining industry in West Virginia is, and will continue to be, in need of highly trained workers. The average age of workers in the mining industry in West Virginia is approaching 54 years for both labor and management categories. For example, CONSOL, a major coal mining company in West Virginia, anticipates hiring 4,000 workers over the next five years to replace retirements. The average age of workers in the oil and natural gas industry in West Virginia exceeds 50 years and this industry faces a similar situation. Newer technologies being introduced into the extraction industries require advanced training in areas such as computers, robotics, analysis, the use of sophisticated computational models, and the business, regulatory, and environmental aspects of operating an energy company which meets regulatory requirements.

As the flagship, land-grant university in the state, WVU has the opportunity and the obligation to provide the best and most relevant education and training available in new energy and environment technologies, policies, regulations, etc. to its students. WVU aspires to become the first choice of employers for trained scientists, engineers and technologists for the energy industries, including new technologies through its undergraduate, graduate, and outreach training programs.

Objectives

- Prepare the next generation of workers for the extraction and utilization industries in West Virginia. The coal industry will be replacing a high percentage of its work force at all levels from mining engineers to coal miners in the next 5-10 years. Members of the current workforce require updating and new training regarding regulations, operation of equipment, and health and safety requirements for extractive industries. New workers require more extensive training. West Virginia University will enhance its statewide network for training workers for the extractive industries through its extension programs. WVU will also establish a training center near Morgantown, WV where advanced and specialty training can be provided on a regular basis.
- Prepare technology managers and researchers for the extraction industries in West Virginia. WVU will develop enhanced interdisciplinary energy and environmental academic programs through the addition of new faculty lines and the initiation of integrated, multi-disciplinary academic energy courses and programs. These initiatives will provide nationally recognized training for bachelor degree students and expand the advanced research training available under the MS and PhD programs. The benefits of the research programs will include the development of new technologies for deployment in the industry and the preparation of advanced degree technologists to develop the next generation of mining and drilling equipment for the continued viability of West Virginia's extractive industries.
- Prepare environmental science managers and researchers for the future. WVU will develop degree programs commensurate with the energy and related environmental focus areas. These initiatives will provide nationally recognized training for bachelor degree students and expand the advanced research training available under the MS and PhD programs for the preparation of advanced degree scientists to develop the next generation of strategies for protecting the environment and to maximize West Virginia's extractive industries.
- Technology exchange programs. WVU will expand its industry outreach programs to promote more interaction between industry professionals and students to enrich the academic experience. The University will initiate personnel exchange programs with industry and the NETL.
- International training and leadership development programs. WVU will capitalize on its traditional strengths to promote improved energy utilization in rapidly developing economies. Programs with countries such as China can encourage effective, efficient utilization of the world's energy resources, thus reducing the international impacts of energy growth on the state and nation. In addition, WVU

will develop a hybrid energy collaboration through the NETL with the Basque Country of Spain.

Implementation

Key Strategies

- Align research, education, and training programs to serve long-term federal, state, and industry interests in energy and the environment
- Focus energy and environmental programs to support the strategic initiatives of the NETL with an emphasis on coal and gas technologies
- Expand the faculty base through strategic recruitment and hiring of talented and competitive faculty and research professionals who can advance WVU's position as a leader in energy and environmental research and education
- Expand existing relationships with federal agencies, with the NETL in particular, and form new ones, both alone and in partnership with other academic institutions and private entities
- Utilize the existing technology transfer infrastructure in linking technology development with commercialization; protection, licensing and forming start up companies
- Take advantage of the facilities at the WVU Charleston Research Campus for developing a research program focusing on energy, e.g., coal to chemicals
- Establish a nationally recognized advisory board to guide research priorities and facilitate technology transfer

Process

Research Cluster Formation:

The overall approach to accomplishing the ambitious goals of this strategic plan will be to build on existing programs, create new programs, and increase the capacity for energy/environment research, education, and training at WVU. Strategies may include, but not be limited to, increasing the number of faculty, improving the existing facilities and constructing new research and education facilities, upgrading equipment, and providing an enabling administrative support structure. These requirements are outlined in more detail below:

- Build a core of research faculty with expertise in research target areas. Increase the number of research track and tenure track faculty in targeted areas. A committee of faculty and administrators will conduct a gap analysis related to the capacity of WVU science and engineering faculty to undertake energy and environment research in areas targeted under this strategic plan. New faculty may be hired into tenure track positions in the colleges or into research track positions through the colleges and research centers. Key initiatives will be developed with the NETL to develop a partnership relationship whereby researchers from each

organization will work cooperatively to enhance the reputation and human resource capital in the region.

- Provide state-of-the-art facilities and equipment for advanced energy and environmental research. The NRCCE is both an administrative unit within the Research Office and a modern research facility. Opened in 1993, the facility was constructed with the capacity to add three additional floors. WVU will place a high priority on securing funds to make the maximum expansion of the building and provide equipment for advanced research.
- Develop the WVU Charleston Campus. Subject to favorable due diligence, the Dow Chemical Company will donate 58 acres and over 200,000 square feet of office and wet laboratory space in their South Charleston Technology Park to WVU. WVU will develop this donation into an economic development and educational campus focusing on the chemical and energy/environmental research and education.
- Develop an organizational structure for administering the energy and environment research activities, i.e., programs and centers, throughout the university. The purpose of this structure will be to coordinate energy and environment research activities across the University, facilitate interdisciplinary interactions, generate synergy among programs, and to seek funding for research in these areas.

Administrative Infrastructure Support

WVU Research Corporation

The West Virginia Legislature noted that the future of economic development in the state will depend in part upon research developed at the state research institutions. Enhanced research opportunities for state institutions of higher education will promote the general economic welfare of the citizens of the state. The West Virginia University Research Corporation (WVURC) was therefore created as a not-for-profit corporation in 1987 to foster and support research and economic development at West Virginia University, and to provide evaluation, development, patenting, management, and marketing services for inventions of the faculty, staff and students of the University. The Corporation also serves as the fiscal agent for sponsored programs on behalf of the University.

The WVURC entered into an affiliation agreement with the West Virginia Board of Regents, on behalf of West Virginia University, in 1989 to provide for services and activities related to the promotion, encouragement, and stimulation of research. The Corporation is governed by by-laws revised in 1998 and operational procedures amended in 1997, or as may be amended in the future. Members of the WVURC Board of Directors include senior university administrators and dean and faculty representatives.

On April 6, 2004, the WVURC Board of Directors unanimously approved the research initiatives, incentives, and infrastructure improvements described in this Strategic Plan for Research and Economic Development, and a supporting budget plan.

Administration of the Strategic Plan

The WVU Research Office has the responsibility for fostering the WVU research and economic development mission, facilitating growth of the research enterprise, and articulating research and economic development goals of the University. This office, working with the provost, deans, associate deans, chairs, directors, and faculty, and with support from the WVU Research Corporation, will provide leadership in implementing and assessing this Strategic Plan for Energy and Environment: Research, Education and Outreach.

For further information, consult the WVU Research Web page <http://www.wvu.edu/~research> or contact:

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West Virginia University is governed by the Board of Governors with Steve Goodwin as Chair, and David C. Hardesty, Jr., WVU President and Chairman of the WVU Research Corporation Board of Directors.

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