Chapter 6

Energy Research and Development

Virginia is home to a world-class university research and development (R&D) system where there is extensive energy-related activity. The state is also home to a robust technology sector, with an impressive inventory of energy capacity.

6.0 Energy Research and Development

Advancing new energy technologies is critical if the United States is ever to reach energy independence and security. Virginia is home to a world-class university research and development (R&D) system where there is extensive energy-related activity. The state is also home to a robust technology sector, with an impressive inventory of energy capacity. This chapter investigates opportunities for Virginia to be an R&D leader in energy and environmental technologies. The chapter sets out a goal to increase energy R&D by $10 million per year, with half from state resources and half from private and federal resources.

Virginia's Department of Mines, Minerals and Energy partnered with the Center for Innovative Technology to perform a study on energy-related R&D. The objectives were to:

- Identify and describe Virginia's institutional strengths in energy R&D.
- Identify Virginia energy R&D activities that are currently or could become national or international leaders.
- Assess best practices for energy R&D facilitation and coordination and how they can be applied in Virginia.
- Provide an initial analysis of the potential benefits to Virginia from coordinated energy R&D.

Numerous reports were reviewed, and the Center for Innovative Technology visited or interviewed representatives at eleven Virginia colleges and universities, several private companies, and three federal laboratories in the state. The study concentrated on institutions with the most activity and expertise. It also investigated energy R&D performed by a few large private companies and Small Business Innovation Research award recipients. Several other states were examined to establish best practices, with special attention given to those that could enhance coordination of energy R&D activities among universities, federal laboratories, and industry in Virginia. The findings of the study are incorporated in this chapter.

Energy-related research in Virginia's colleges and universities, federal laboratories, and industry focuses on several areas: long-standing interests in fossil fuels (coal and natural gas) and nuclear energy, as well as recent and increasing interest in renewable energy sources such as biomass, geothermal, solar, wind, and coastal energy. There is also research in fuel cells and hydrogen, energy efficiency and conservation, energy and the environment, energy economics, and energy policy. Several of these areas-among them nuclear energy, alternative liquid fuels, coastal energy, and carbon capture and storage-could be leveraged into positions of national leadership.

Virginia's federal research laboratories, including the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility in Newport News and NASA Langley Research Center, are engaged in energy research relevant to their core missions.

Significant energy research is being conducted by industry in Virginia, including nuclear energy stalwarts Areva NP and BWXT in Lynchburg, Siemens and Northrop Grumman Newport News on the peninsula, major electricity utilities such as Dominion Virginia Power, and a growing number of early-stage companies developing innovative energy-related technologies, often supported by federal Small Business Innovation Research and Small Business Technology Transfer Program awards.

The academic, federal, and industry sectors have overlapping research strengths in carbon sequestration, energy crops, alternative fuels, coastal/wind energy, energy efficiency and conservation, and nuclear technologies. Universities and industry have common research strengths in technologies for clean use of coal, while fuel cells are a common research area of several universities and NASA Langley.

Research leaders in Virginia's universities, federal laboratories, and industry identified lessons learned and suggested how the state could better facilitate energy-related

R&D. Six best practices were identified through investigation of the energy R&D programs of six other states and one regional collaborative. Together these suggestions provide guidance for developing a statewide program to facilitate energy R&D in Virginia. Key components of such a program include the following:

- Develop a state Energy R&D Roadmap with milestones, and track results.
- Provide a cost-sharing commitment fund to enable competitive bids for large federal projects/awards and strategic recruiting opportunities.
- Fund a state-level initiative to coordinate and build Virginia's energy research, development, demonstration, and deployment capacity and spur its economic impact.

Potential benefits of coordinated energy R&D include increases in research funding and productivity; company creation, growth, and attraction; job creation and retention; advances in technology development and deployment; and environmental improvements.

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6.1 Energy R&D at Virginia Colleges and Universities

The most comprehensive portfolio of energy-related R&D is found at Virginia Tech, which supports research activities in every energy arena identified for this Plan. The College of William and Mary, the Institute for Advanced Learning and Research, James Madison University, Norfolk State University, Old Dominion University, the University of Virginia, Virginia Commonwealth University, and Virginia State University also have research programs relating to energy resources, production, conservation, use, and in some cases, energy/environment issues and energy policy. George Mason University and Virginia Military Institute have interests in energy policy.

At least two state universities are making energy research a significant part of their strategic plans. In August 2006, Virginia Tech announced the creation of a Deans' Energy Task Force to play a key role in implementing the university's strategic initiative dealing with energy, materials, and environment. The task force, supported within Virginia Tech's Office of the Vice President for Research, has completed a detailed survey of Virginia Tech's breadth of research, education, and outreach activities related to energy.[99]

At the University of Virginia, Energy, Conservation and the Environment is a priority initiative within the office of the Vice President for Research and will be included in the university's ten-year academic plan currently in development. This initiative is being coordinated through a faculty steering committee comprising representatives from its schools of architecture, business, education, engineering, law, and arts and sciences. The university sees the three areas of energy, conservation, and the environment as equally important and is striving for a balanced program of research and education.[100]

Table 6-1 summarizes the types of energy-related R&D performed in Virginia's colleges and universities. The Center for Innovative Technology assessed the current or potential national prominence of Virginia energy research and expertise based on criteria that included founding and/or leading national-scale research consortia; winning, or placing as a finalist, in national centers; ranking among top U.S. programs by size, research funding, or distinctiveness; national-level recognition/awards to faculty or research projects; perceived critical mass of capabilities across several Virginia institutions; and geographic/resource advantage.

[99] www.research.vt.edu/energy/index.html.
[100] Phil Parrish, personal communication, September 22, 2006.

Table 6-1 Energy R&D at Virginia Universities and Colleges

	Energy Generation/Sources									Energy Use/ Impact			Energy Policy
				Alternative Fuels	Other Renewables								
Virginia College or University	Coal, Oil, Gas	Nuclear	Fuel Cells/ H2	Alternative Fuels: Waste- or Bio-derived	Geothermal	Hydroelectric	Solar/Photovoltaics	Wind	Coastal (Wind/Tidal/ Current/Wave)	Energy Storage	Efficiency/Conservation	Buildings/Environment	Energy Policy/ Economics
College of William and Mary		•					•		•				•
George Mason University													•
Institute for Advanced Learning & Research				•									
James Madison University			•	•				•	•		•		•
Norfolk State University							•		•				
Old Dominion University				•			•	•	•				
University of Virginia	•	•	•	•			•			•	•	•	•
Virginia Commonwealth University			•	•			•			•	•		
Virginia Military Institute													•
Virginia Tech	•	•	•	•	•	•	•	•	•	•	•	•	•
Virginia State University				•									

Virginia research areas with current or potential national prominence are carbon sequestration (VT), advanced separation technologies (VT), fuel cells and hydrogen (VT, UVA, VCU), alternative fuels (JMU, UVA, VSU, VT/IALR), coastal energy, including wind (CWM, JMU, NSU, ODU, VT), energy efficiency and conservation (JMU, UVA, VCU, VT) and green building design (UVA, VT). Faculty researchers in several Virginia institutions are studying nuclear power (CWM, UVA, VT), photovoltaics (CWM, NSU, ODU, UVA, VCU, VT), and energy policy (CWM, GMU, JMU, UVA, VMI, VT).

A verified figure for academic expenditures in energy-related R&D in Virginia is not available. Since "energy" is not among the National Science Foundation's (NSF's) defined list of science and engineering fields that universities and colleges use to track their R&D expenditures, there is no historical tracking of energy-related R&D. Energy-related research may therefore fall within many NSF classifications, including environmental sciences, life sciences, math and computer sciences, physical sciences, and sciences, not elsewhere classified.

Virginia universities also maintain working relationships with federal laboratories involved in energy research. The University of Virginia and Virginia Tech are among the core universities with seats on the governing board of the federal Oak Ridge National Laboratory, and they continue to be University Partners of the laboratory.[101] Several Virginia universities collaborate with the Thomas Jefferson National Accelerator Facility in Newport News, supported in part by the state through the Southeastern Universities Research Association. The association offers professorships at Virginia universities and distinguished scientist awards to assist in attracting talent and leadership to the lab.

Key energy-related research activities and expertise in Virginia colleges and universities are presented in Sections 6.1.1 through 6.1.3, organized by research category.

[101]www.ornl.gov/ornlhome/university_partners.shtml.

6.1.1 Energy Generation and Sources

Fossil Fuels (Coal, Oil, Natural Gas)

Two centers associated with Virginia Tech lead Virginia coal-related research. The Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech is an interdisciplinary research and information resource, created by Virginia's General Assembly in 1977.[102] The VCCER conducts and coordinates research for the Virginia General Assembly, state utilities, and other corporate, government, and academic sponsors. Areas of study include:

- Energy statistics and modeling.
- Socioeconomic effects of energy and coal development.
- Environmental impacts of coal and energy.
- Sustainable development of energy and mineral resources.
- Carbon management and sequestration.
- Optimization of mining systems.
- Energy-efficiency studies.
- Coalbed methane extraction and use.
- Energy infrastructure studies.

The VCCER addresses global energy development, greenhouse gas emissions, and deregulation of the electric utility industry.

The VCCER also is leading an interdisciplinary coalition comprising universities, industry, and state agencies to identify potential carbon sequestration sinks in central Appalachia, as part of the Southeast Regional Carbon Sequestration Partnership (SECARB), one of seven partnerships created by the federal Department of Energy (DOE) to determine optimum approaches for capturing and storing carbon dioxide.

Under Phase I of the carbon sequestration program, the central Appalachian coal seam research team, led by the VCCER, conducted regional characterization of the coalbeds, located favorable areas to sequester carbon dioxide, and quantified the carbon dioxide storage capacity and associated enhanced coalbed methane recovery potential in southwest Virginia. Carbon dioxide's attraction to coal is approximately twice that of methane. Carbon sequestration has the potential to increase methane production from coal seams by displacing methane that otherwise might not be produced. Theoretically, carbon dioxide molecules will be preferentially absorbed onto the coal surface, thereby releasing methane gas and boosting coalbed methane production. The cost of implementing carbon dioxide sequestration technologies could be offset by enhanced coalbed methane recovery. Carbon dioxide sequestration capacity values for coal seams have been calculated by processing and assimilating net coal thickness, coal rank, coal isotherm, and related coal-reservoir data. Factors such as historical deep mining and currently permitted deep mine areas have been taken into account in the calculations, as carbon dioxide cannot be effectively sequestered in mined locations.

The primary objectives in Phase II of this program are to continue refining the geologic characterization, expand the study area to contiguous West Virginia and Kentucky counties, and verify the sequestration capacity and performance of mature coalbed methane reservoirs through two field validation test sites. Research has identified ideal areas for sequestration in mature coalbed methane production areas in Buchanan, Dickenson, Russell, Tazewell, and Wise Counties in Virginia and in Fayette, McDowell, Raleigh, and Wyoming Counties in West Virginia (see Figure 6-1). The coal seams in the Central Appalachian Basin could store from 398 to 1,341 million tons of carbon dioxide and a corresponding enhanced coalbed methane recovery of 0.79 to 2.49 trillion cubic feet of natural gas. If these technologies prove successful, the economic development potential of enhanced coalbed methane recovery and the greenhouse gas mitigation potential of storing carbon dioxide are significant.

The Phase II sequestration testing will be conducted in actively producing coalbed methane wells in southwest Virginia's Central Appalachian Basin and in the

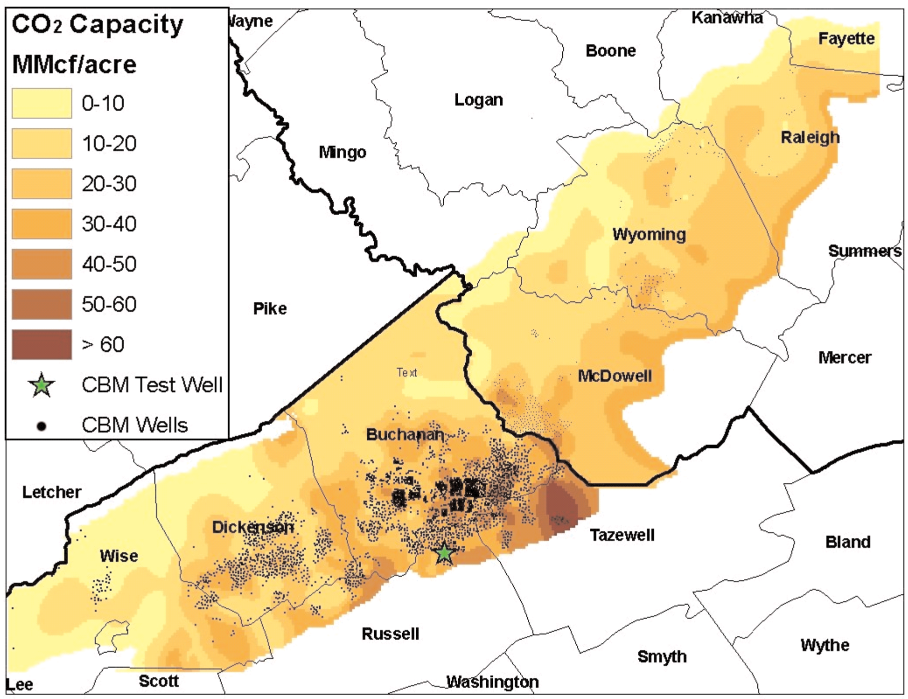
[102] www.energy.vt.edu/index.html.

Black Warrior Basin in Alabama. About 1,000 tons of carbon dioxide will be injected into donated wells in each site. Both surface and subsurface monitoring programs will measure and verify the location of the injected carbon dioxide. Throughout this program, vigorous public outreach and technology transfer activities will be conducted.

The DOE has provided $14.3 million to SECARB for Phase II of this project. The program has dedicated $3.4 million to demonstrate carbon sequestration potential in unmineable coal seams in both the Central Appalachian and Black Warrior Basins. An additional 20 percent of the total project funding is from cost sharing and contributions from the twenty industrial partners participating in the project.

Phase III of the carbon sequestration program, in which there will be large-scale sequestration testing, will be implemented during the term of this Plan. This research could be housed in a Fossil Fuel and Carbon Management Center operated by the VCCER in Abington and Dickenson County.

Figure 6-1 Carbon Capture Potential in Virginia and West Virginia



The Center for Advanced Separation Technologies (CAST) is a national consortium of seven universities formed in 2001 under the auspices of the federal DOE.[103] Its mission is to conduct fundamental and applied research to develop technologies that can be used to produce coal and mineral concentrates in an efficient and environmentally acceptable manner. The center is led by Virginia Tech's Dr. Roe-Hoan Yoon, who formerly headed Virginia Tech's Center for Coal and Minerals Processing. In March 2005, the center received a $12 million grant from the National Energy Technology Laboratory to advance separation technologies used by mining industries.

In 2004, the U.S. mining industry produced a total of $63.9 billion in raw materials (second only to China), $19.9 billion of it from coal and $44 billion from minerals. CAST is the only center in the United States devoted to separations research as applied to the mining industry.

[103]www.cast.org.vt.edu.

Virginia has significant research strength in the areas of fuel cells and hydrogen. Worldwide government spending for fuel-cell and hydrogen infra-structure approached $1.5 billion in 2004, and it is estimated that world markets for fuel cells in systems will grow more than tenfold, reaching $12.6 billion per year by 2012.[109]

"The NETL award will allow CAST to develop and transfer additional advanced separation technologies to remove impurities from coal, including mercury, sulfur dioxide, and nitrogen oxides, in an environmentally acceptable manner-and to clean up waste impoundments created in the past and acid mine water," says Dr. Yoon.

Dr. Yoon also notes that the Department of Mining Engineering at Virginia Tech is the largest such department in the nation and has one of the few mining engineering research programs.[104] With 40 percent of the mining engineers in the nation over many years having graduated from Virginia Tech, several of the leaders in this field are VT graduates. Dr. Yoon notes that coal production is down in the eastern United States, in part because of a decline in funds for mining engineering technology. To realize the full production of U.S. coal reserves from mining, methods for recovering coal from deep, thin seams must improve.

Nuclear

Virginia Tech (Eugene Brown, Mechanical Engineering, and Mark Pierson, Research Division) is working with the new Center for Advanced Engineering and Research in Lynchburg to enhance technical capabilities of the nuclear industries in Region 2000.[105] Ken Ball (Mechanical Engineering) is proposing a collaborative certificate program in nuclear and radiation engineering and science to encompass the areas of nuclear power generation, nondestructive evaluation, materials science, and nuclear medicine.[106]

The University of Virginia once had a strong nuclear engineering program, but the two nuclear reactors at the university were decommissioned (in 1988 and 1998) and the program ceased in 1999. UVA still maintains faculty expertise in nuclear containment systems based on amorphous materials resistant to corrosion (Scully, Kelly, Stoner, Materials Science).[107]

College of William and Mary researchers have interests in accelerator-based waste disposal, advanced radiation shielding, and low-level waste handling, as well as plasma-wall interactions in magnetic confinement fusion.[108]

Fuel Cells and Hydrogen

Virginia has significant research strength in the areas of fuel cells and hydrogen. Worldwide government spending for fuel-cell and hydrogen infrastructure approached $1.5 billion in 2004, and it is estimated that world markets for fuel cells in systems will grow more than tenfold, reaching $12.6 billion per year by 2012.[109] Including stationary, portable, and vehicle-based fuel cells, potential markets are estimated to exceed $45 billion by 2013.[110] Many U.S. industries are at a critical point in their need to implement fuel-cell technology in a commercially viable way. General Motors, for example, is investing $3 billion in fuel-cell technology and plans to launch a commercial fuel-cell vehicle line in 2010.[111] The federal government proposed a five-year, $1.2 billion Hydrogen Fuel Initiative, including a FY 2007 request of $289.5 million. Most of this funding is designated for the DOE's Energy and Efficiency and Renewable Energy program, with other funding designated for the Office of Science, the Fossil Energy program, the Nuclear Energy program, and a relatively small amount for the Department of Transportation.

Virginia Tech has a strong cluster of researchers focused on improving fuel-cell performance. Key researchers include James McGrath (PEMs and MEAs), Dave Dillard (fuel-cell durability/sealants), Scott Case and Jack Lesko (composite systems, durability modeling), and several others (e.g., Michael Ellis, Doug Nelson, and Michael von Spakovsky) involved in integration and performance analysis of fuel cells in systems such as buildings and automobiles. Nelson directs the Virginia Tech Center for Automotive Fuel Cell Systems, and von Spakovsky directs the Center for Energy Systems Research, both of which have received long-term funding from the federal DOE. Recent interests include development of fuel cells powered by biological processes (N. Love, M. Ellis, and I. Puri), hydrogen production

[104]Roe-Hoan Yoon, personal communication, September 26, 2006.
[105]Ken Ball, Eugene Brown, Mark Pierson, personal communication, September 26, 2006.
[106]Ibid.
[107]Phil Parrish, personal communication, September 22, 2006.
[108]Dennis Manos, personal communication, September 22, 2006.
[109]From "Why Fuel Cell Research?" provided by VT fuel cell research cluster faculty, September 2006.
[110]From chart "Potential Fuel Cell Markets," A. Scott, Chemical Week (www.chemweek.com), November 3, 2004.
[111]From "Why Fuel Cell Research?" provided by VT fuel cell research cluster faculty, September 2006.

from sugars (Percival Zhang) and from water by solar catalysis (K. Brewer), and hydrogen storage in carbon nanostructures (I. Puri).[112]

In January 2006, DOE Secretary Samuel Bodman announced that Virginia Tech was among twelve teams sharing $19 million for polymer membrane research for hydrogen fuel systems. The polymer membrane is an integral part of a hydrogen fuel-cell system that creates electricity to power a vehicle. The goal of the research is to advance membrane durability and extend its shelf life, while simultaneously bringing down the cost. Virginia Tech's James McGrath, University Distinguished Professor of Chemistry, was the recipient of a 2004 R&D 100 award for his development of novel, low-cost, high-temperature polymer membranes for hydrogen fuel cells. In 2004, McGrath and Virginia Tech's provost Mark McNamee were awarded a two-year, $600,000 NSF Partnership for Innovation grant to support a program called "Bridging the Gap Between New Materials, Fuel Cell Devices and Products." Virginia Tech's partners included Battelle, Los Alamos National Laboratory, the Center for Innovative Technology, several companies, and Virginia Commonwealth University.

The Virginia Tech fuel cell cluster is working to build its recognition to a national level. Research expenditures in the group have increased from $600,000 to more than $1 million in 2006.

The Virginia Tech fuel cell cluster is working to build its recognition to a national level. Research expenditures in the group have increased from $600,000 to more than $1 million in 2006. The VT group recently teamed with several other universities on a proposal for a five-year, $20 million NSF Engineering Research Center award. The proposal was among 9 finalists from 126 applications. Although it was not selected for one of the five awards, the team may reapply. The cluster faculty noted that a cost-sharing investment by the state would be critical for the group to receive the high-visibility NSF award and Energy Research Center designation. The group is developing a strategy to increase recognition of Virginia Tech's fuel-cell research in order to build on an NSF Research Experiences for Undergraduates award to engage top undergraduates and grow the pipeline of graduate students.[113]

Virginia Commonwealth University faculty in the departments of Mechanical Engineering (Muammer Koç) and Chemical and Life Sciences Engineering (Ken Wynne) are focused on design and manufacturability of fuel-cell systems, developing novel micromanufacturing processes to make fuel-cell components cheaper and more durable. Dr. Pura Jena (Physics) announced in July 2006 the computer-modeled design of a lithium-coated "buckyball" nanoparticle that can theoretically store hydrogen molecules at densities exceeding industry targets. Jena is currently collaborating with scientists who will conduct experiments to prove that hydrogen can be stored in the lithium buckyballs. Jena's research, supported by the DOE, is in collaboration with researchers at Richmond's Philip Morris Research Center.[114]

Several University of Virginia researchers are focused in the non-hydrogen fuel-cell arena. Steven McIntosh is working to develop high-performance anode materials for versatile high-temperature solid oxide fuel cells that can use a variety of combustible fuels, including gasoline and biodiesel, to produce both heat and electricity while minimizing carbon release. On a more fundamental level, Ian Harrison (Chemistry) and Matthew Neurock (Chemical Engineering) are working on optimizing catalytic materials for yield, selectivity, or minimized energy use. Harrison is focusing on the reactivity of methane, which with the right catalysts and conditions could potentially be harnessed at the well-head as a reliable source of easily transportable methanol for powering fuel cells.[115]

Alternative Liquid Fuels

Virginia has significant strengths in research to develop efficient methods for generating energy from renewable waste and bio-based resources. Plants, plant-derived materials, and agricultural wastes provide domestic and sustainable resources to provide power, fuel, and chemical needs. Biofuel feedstocks include animal and vegetable oil wastes.

[112]Information provided by VT fuel cell research cluster faculty, September 26, 2006.
[113]Ibid.
[114]www.news.vcu.edu/news.aspx?v=detail&nid=1466.
[115]"Research Highlights from the University of Virginia," UVA Explorations, Fall 2006.

Chapter 6

Energy Research and Development

continued

Virginia has significant strengths in research to develop efficient methods for generating energy from renewable waste and bio-based resources.

Biomass feedstocks include agricultural and forestry/mill residues, dedicated energy crops, urban wood wastes, municipal solid wastes, and landfill gas. A 2005 study found that nearly 1.4 billion dry tons of biomass could be available for large-scale bioenergy and biorefinery industries by the middle of this century while still meeting demands for forestry products, food, and fiber.[116] In June 2006 the federal DOE released an ambitious research agenda for overcoming the challenges to the large-scale production of cellulosic ethanol as part of its goal of displacing 30 percent of the 2004 U.S. transportation-fuel consumption with biofuels by 2030.[117]

Virginia Tech has extensive expertise in bioenergy and bioproducts at its main campus in Blacksburg as well as through Virginia Tech faculty affiliated with the Institute for Advanced Learning and Research in Danville. The Virginia Tech Energy Task Force lists several large categories of bioenergy/bioproducts research:[118]

- Bioenergy Adoption/Use - including feedstock and logistics issues of establishing bioenergy facilities (J. Cundiff, D. Parrish, R. Visser), economic/environmental impact assessments (G. Amacher, R. Visser, B. Smith), and orchestration with regional stakeholders such as existing energy producers and users, and local/state government entities (R. Bush, J. Waldon).
- Use in Transportation - including optimizing vehicle design for bio-based fuels (D. Nelson) and environmental and socioeconomic impacts of adopting biofuels (L. Schweitzer).
- Biomass: Sources, Creation, and Enhancement - including genetic engineering of species such as switchgrass and poplar trees for optimizing their use as bioenergy and bioproducts feedstocks (E. Beers, A. Brunner, J. Burger, J. Fike, B. Flinn [IALR], T. Fox, C. Griffey, J. Iqbal, J. Nowak, D. Parrish, J. Seiler, W. Thomason).
- Biomass Conversion, Ethanol Production - including research to optimize conversion of agricultural waste, livestock manure, and bioenergy crops into ethanol and other liquid fuels (F. Agblevor, J. S. Chen, J. Fan, C. Griffey, S. Renneckar, Y.-H. P. Zhang). One project is using animal/seafood waste for biogas production (Z. Wen).
- Products and Byproducts - including direct use of ethanol in fuel cells (M. Ellis), small-scale production of charcoal (T. Hammett and P. Radtke), fortified fuel pellets (R. Moffit [IALR], J. Nowak), and biodiesel by-product glycerol as a food source for algae rich in omega-3 polyunsaturated fatty acids (Z. Wen).

Biodiesel

The Virginia Coastal Energy Research Consortium, lead by Old Dominion University, is researching production of algae from nutrient-rich waters to serve as a feedstock for biodiesel. Led by Patrick Hatcher, the group is installing a test facility at a Hampton Roads Sanitation District waste plant that will include algae growing trays and a biodiesel reactor.

One of the four program foci of James Madison University's Center for Energy and Environmental Sustainability is alternative fuels, led by Dr. Chris Bachmann. James Madison University works closely with the City of Harrisonburg to promote the adoption of biodiesel both on campus (2% biodiesel, with a goal of 20%) and in the city's transit and school-bus fleet. This collaboration was recognized as exemplary by President Bush in summer 2005. The center is also investigating the use of engineered single-cell microalgae in a photo-bioreactor as a promising alternative feedstock for producing biodiesel. These algae, some of the fastest growing plants known, can remove waste carbon dioxide from traditional power plant emissions and can contain as much as 60 percent oil by weight. Theoretically, algae farms could produce four hundred times as much oil on a pounds-per-acre basis as soybeans, and therefore meet the nation's transportation energy demands while using less than 1 percent of the total U.S. land mass.[119]

[116] R. D. Perlack et. al., "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply," DOE/GO-102005-2135, Oak Ridge National Laboratory, Oak Ridge, TN, April 2005 (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf).

[117] U.S. DOE, "Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda," DOE/SC-0095, U.S. DOE Office of Science and Office of Energy Efficiency and Renewable Energy, June 2006 (www.doegenomestolife.org/biofuels).

[118] See www.research.vt.edu/energy/resbio.html.

[119] www.cisat.jmu.edu/biodiesel.

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At the University of Virginia, Robert Davis and Giorgio Carta (Chemical Engineering) are working on reusable, highly porous solid catalysts for converting heavy fats and oils into renewable biodiesel fuel additives (providing lubrication) as well as aqueous solution catalysts for converting the by-product glycerol into feedstock for high-value chemicals. Combinations of such catalyzed processes are necessary to enable a fully integrated biorefinery.[120]

Virginia Commonwealth University's Stephen Fong (Chemical and Life Sciences Engineering) takes a systems biology approach to rational metabolic engineering for improving bioreactors. His research includes using computational modeling with molecular genetics to predict, design, and characterize bacterial strains engineered to produce specific chemicals.[121]

Similarly, Virginia Tech's Julia Fan (Biological Systems Engineering) is developing biocatalysts through enzyme engineering and microbial strain development. These biocatalysts are used in developing and optimizing processes (e.g., pyrolysis, gasification, biodiesel production) to convert renewable resources (e.g., paper sludge, biomass, starch) to value-added products in an economically viable and environmentally sound manner.[122]

Biomass to Fuels/Products

It has been estimated that Virginia could produce 297,986 dry tons of agricultural residue biomass at $40 per ton and an additional 1.2 million dry tons of dedicated energy crops at $40 per dry ton. Urban wood waste could contribute more than 865,757 dry tons at $30 per ton.[123]

Use of agriculture and forestry-based feedstocks for energy and novel products generation/development can significantly contribute to diversification of the tobacco-based economy of Southside and southwest Virginia and open competitive opportunities for developing new industries in this region.[124] In response to this opportunity, Virginia Tech has assembled a multidisciplinary research and technology development cluster targeting small-scale (community-based) energy and novel products development, based on the sustainable cultivation of biomass in the vicinity of the processing plants. Led by Jerzy Nowak of Virginia Tech Horticulture, the team proposes establishing the Bio-Based Energy and Products Research Center with operations in Blacksburg, the Institute of Sustainable and Renewable Resources at the Institute for Advanced Learning and Research in Danville, and Windy Acres Nursery in Gretna. The center is proposed to serve as the R&D/implementation base for using short-rotation wood (hybrid poplar and loblolly pine) and herbaceous biomass (switchgrass, miscanthus, alfalfa, and clover) as feedstocks for generating bioenergy (electricity, heat, bio-oil/diesel), bio-oil extracts, and wood-based potting media, as well as high-energy wood/grass pellets integrating high-energy recyclables (in collaboration with the Institute for Advanced Learning and Research, Advanced and Applied Polymer Processing Institute). Successful research from the center would support development of a renewable resource processing center and spin-off enterprises.[125]

Percival Zhang (Biological Systems Engineering) has developed a cost-effective, low-temperature pretreatment process for efficient fractionation to separate lignin and hemicellulose from the ethanol-precursor cellulose. He also is genetically engineering enzymatic pathways for the production of hydrogen from natural sugars.[126]

The University of Virginia recently hired metabolic engineer Michael Raab, creator of GreenGenes™ technology, on which he founded the company Agrivida. Agrivida is developing an engineered seed designed for ethanol production. The technology is a biological "switch" that enables producers to activate a desired enzyme on demand to break down the biomass into basic sugars for ethanol processing. This is expected to substantially reduce the costs of ethanol production while yielding waste biomass for electricity generation. There also exists the long-term opportunity for photobiological production of hydrogen.[127]

[120]Robert Davis, UVA, presentation to statewide meeting on DOE GTL bioenergy solicitation, September 5, 2006.
[121]www.engineering.vcu.edu/fong-lab/metabolicenginee.html.
[122]www.bse.vt.edu/06/department/faculty.php#ZhiliangFan.
[123]Marie E. Walsh et al, "Biomass Feedstock Availability in the United States: 1999 State Level Analysis," DOE, April 30, 1999, updated January 2000 (http://bioenergy.ornl.gov/resourcedata/index.html).
[124]Jerzy Nowak, VT, 2006, Model Bio-Products Development System: Rural Economic Development and Environmental Benefits.
[125]Ibid.
[126]http://filebox.vt.edu/users/ypzhang/research.htm.
[127]See www.masstech.org/IS/reports/clusterreport11405.pdf.

Virginia State University's Harbans Bhardwaj focuses on improving crop species to increase yield, quality, and other traits. In the energy/environment arena, he is developing canola and white lupin as new crops in Virginia. Both crops have industrial uses: canola as a source of biodiesel, and lupin as a source of alkaloids and as a green manure crop to reduce or eliminate use of nitrogen fertilizers in a sustainable crop-production system.[128]

James Madison University's Center for Energy and Environmental Sustainability is developing an ethanol production facility that will investigate the ethanol potential of a variety of alternative-fuel feedstocks, including the giant sea kelp, *Macrocystis pyrifera*. This is one of the fastest growing plants known (it can grow more than a foot a day) and can be harvested from the ocean by large-scale commercial vessels. This seaweed is low in oil, storing much of its energy as starches and sugars. While not ideal for making biodiesel, it is well suited for ethanol production.[129]

Waste to Energy

Virginia currently has nineteen landfills producing methane for energy, and fifteen more are identified as potential sites.[130] In northern Virginia, the Alexandria/ Arlington Resource Recovery Facility processes more than 975 tons of solid waste each day, generating more than 78.4 million BTUs (23,000 kilowatt-hours) of electricity. The electricity is distributed by Dominion Power and supplies more than 300,000 residents.[131] Atlantic Waste Disposal's 373-acre landfill in Waverly now provides 15 percent of the natural gas required of Honeywell's Hopewell plant and is expected to provide as much as 50 percent in ten to fifteen years. This project has the potential to save Honeywell $50 million in energy costs while significantly reducing greenhouse gas emissions from landfill wastes.[132]

The partnership of James Madison University's Center for Energy and Environmental Sustainability with the City of Harrisonburg includes work to develop an integrated waste-to-energy facility integrating multiple systems, including use of city municipal solid waste to produce heat and electricity; use of campus, city restaurant, and school waste vegetable oils in a biodiesel refinery; and biomass processing of campus waste paper, construction and landscaping waste, and area agricultural and forestry wastes.[133]

A team of Virginia Tech researchers led by F. Agblevor (Biological Systems Engineering) is working on rapid pyrolysis reactor methods for efficient conversion of poultry litter, switchgrass, and woods into bio-oils and other products. Dr. Agblevor also invented a process to convert cotton-gin waste and recycled paper sludge into ethanol.[134]

Geothermal

Virginia Tech's Department of Geological Sciences developed the southeastern United States Geothermal Data website, hosting data on terrestrial heat flow, practical applications of low-temperature geothermal energy, and a temperature versus depth database. This site is frequently updated to include temperature data, rock thermal conductivity, and heat flow values from New Jersey to Georgia.[135]

Solar/Photovoltaics

At Norfolk State University, Sam-Shajing Sun is a recognized leader in polymer materials research for solar cell applications. Sun's research expertise includes the design, synthesis, processing, characterization, and modeling of novel organic and polymeric solid-state supra-molecular and nanostructured materials and thin films devices for electronic, photonic, magnetic, and energy conversion applications. Current research projects funded by NASA and the Air Force Research Labs include development of novel supra-molecular and nanostructured conjugated block copolymer systems for potential photo detector and solar energy conversion (solar cell) applications. In 2002, NASA awarded a Center for Research and Education in Advanced Materials, or

[128] www.vsu.edu/pages/3016.asp.
[129] www.isat.jmu.edu/AFP/fuels.html.
[130] U.S. EPA Landfill Methane Outreach Program Active Program Map, July 13, 2006 (www.epa.gov/lmop/docs/map.pdf) (quote from Southeastern SunGrant Center Virginia Biomass/Bioenergy Overview, 2006).
[131] Biomass Research and Development Initiative, 2003, Virginia Biobased Fuels, Power and Products State Fact Sheet (http://sungrant.tennessee.edu/factsheets/virginia.pdf).
[132] John Reid Blackwell, "Honeywell Finds a Solution to its Gas Needs," Greater Richmond Catalyst, November 16, 2006, at www.richmondcatalyst.com/Issue11_Honeywell2.asp (originally published April 24, 2006, in Richmond Times-Dispatch).
[133] Ron Kander, JMU, presentation to statewide meeting on DOE GTL bioenergy solicitation, September 5, 2006.
[134] www.research.vt.edu/energy/resbio.html.
[135] http://geothermal.geol.vt.edu.

CREAM, to Norfolk State University under Sun's leadership. A Norfolk State spin-off company (Sun Macromolecular Corporation) is leading an industrial partnership bid to the U.S. DOE's Solar America Initiative to commercialize the polymer solar cells.[136]

Old Dominion University has several groups researching photovoltaic materials, including Electrical and Computer Engineering faculty Hani Elsayed-Ali (thin films and physical electronics), Helmut Baumgart (atomic layer deposition for electronic thin films), and Sacharia Albin (photonics), as well as Richard Gregory in Chemistry (organic conductive polymers) and Julie Hao in Mechanical Engineering.[137]

University of Virginia's Mool Gupta at the National Institute of Aerospace in Hampton (laser applications for advanced manufacturing)[138] and Petra Reinke in Materials Science (nanoscale molecular electronics)[139] also are working on photovoltaic materials.

At Virginia Commonwealth University, James McLeskey's research interests include novel energy conversion systems, traditional power generation, nanoparticle entrainment, and engineering education. Current research revolves around optical studies of photovoltaics (solar cells) made from organic polymers and quantum dots (nanoscale particles such as carbon nanotubes or titanium dioxide).[140]

The University of Virginia and Virginia Tech have competed successfully in the federal DOE's national Solar Decathlon in Washington, D.C. (see Buildings/ Environment in Section 6.1.2, below).

Wind

Several Mid-Atlantic states have begun installing grid-connected wind energy projects in the size range of 5 to 50 megawatts, to generate electricity that can be sold as a green alternative to conventionally generated power. In Virginia, the Virginia Wind Energy Collaborative (VWEC)[141] was created as a partnership of the Virginia Tech Advanced Research Institute's Center for Energy and the Global Environment (CEAGE), James Madison University's Center for Energy and Environmental Sustainability, the Environmental Resources Trust, the George Washington University Law School, and Old Mill Power Company. Supporting agencies are the Virginia Department of Mines, Minerals and Energy and the federal Wind Powering America program. The VWEC's mission is to educate the public, inform decision makers about wind energy, and facilitate its development in the state in support of the need for reliable and affordable energy, environmental quality, and economic development. Collaborative partners provide technical support in several ways, including analysis of wind data and answering questions from developers about the feasibility of wind energy projects; support of local, state, and federal agencies in exploring potential wind energy applications on their lands; and to inform counties and cities about bulk power purchase opportunities from wind energy projects as a cost-effective means of improving air quality and complying with federal ground-level ozone standards.

Among the VWEC's activities are the technical research and analyses necessary to determine the potential for developing large, utility-scale wind systems to reclaim defunct coalfields in southwest Virginia. Virginia Tech's CEAGE, in conjunction with the Department of Mines, Minerals and Energy, is pioneering this effort.[142] CAEGE provides technical research support to wind developers and to local, state, federal, and private agencies.

A Virginia-based partnership led by James Madison University responded in November 2006 to a National Renewable Energy Laboratory Cooperative Research and Development Agreement opportunity to design, construct, and assist in operating a wind turbine test facility capable of testing blades exceeding 70 meters in length. Virginia was not successful in receiving a grant award but is investigating partnership opportunities.

[136]Adebisi Oladipupo, NSU, personal communication, October 25, 2006.
[137]Mohammad Karim, ODU, personal communication, November 6, 2006.
[138]www.seas.virginia.edu/news /gupta.php.
[139]www.virginia.edu/ms/ faculty/reinke.html#research.
[140]www.egr.vcu.edu/me/ faculty/me-faculty_mcleskey. html.
[141]http://vwec.cisat.jmu.edu/in dex.htm.
[142]Ibid.

Coastal Energy (Wind/Tidal/Current/Wave)

The 2006 General Assembly established the Virginia Coastal Energy Research Consortium (VCERC) to serve as an interdisciplinary study, research, and information resource on coastal energy issues, including wave or tidal action, currents, offshore winds, thermal differences, and methane hydrates.[143] The consortium's academic partners include Old Dominion University, the Virginia Institute of Marine Science, Virginia Tech's Advanced Research Institute, James Madison University, Norfolk State University, the University of Virginia, and Virginia Commonwealth University.[144] Science Applications International Corporation's Maritime Operations division has collaborated in developing the consortium and will serve as a lead systems integrator for marine industry support of the consortium.[145] Old Dominion University has established a working group for the consortium led by Dr. Patrick Hatcher, a geochemist focused on origin and chemical transformations of plant-derived biopolymers in natural systems. It is likely that the consortium will be able to use offshore wind and current data collected through the Center for Innovative Technology's Coastal Observation project, which is sponsored by NASA.

Offshore wind energy is the most commercially mature of several marine renewable energy sources being studied, with Denmark, Germany, and the United Kingdom particularly active in deployment. Nearly thirty offshore wind projects are under development in the United Kingdom and could supply more than 8 percent of the United Kingdom's annual electricity demand within the decade.[146] Virginia is uniquely positioned to benefit from offshore and coastal energy resources: it has 110 miles of coastline along the Atlantic Ocean, federal R&D facilities (e.g., NASA Langley Research Center and Wallops Flight Facility on the Eastern Shore), Norfolk Naval Base and Northrop Grumman Newport News Shipbuilding, repair facilities, and an integrated transportation system that includes direct ocean access. Most of Chesapeake Bay and the near-shore areas feature Class 4 winds or higher. A VWEC project led by James Madison University's Jonathan Miles studied the technical, environmental, and economic feasibility of wind turbines at NASA's Wallops Island facilities. The results provide guidance for other federal agencies in siting wind turbines.[147] Virginia Tech researchers led by George Hagerman are quantifying the potential energy and economic benefits of offshore wind energy development in Virginia, as well as identifying opportunities for the state's maritime industry and manufacturers to develop fabrication materials and methods for marine renewable energy structures.[148]

Virginia Tech's Center for Energy and the Global Environment is collaborating with the Electric Power Research Institute, utilities, and state and provincial governments to plan and develop the first North American demonstration projects for tidal current energy in San Francisco and Nova Scotia. The center is also conducting research for Verdant Power, a tidal turbine developer based in Arlington.[149]

Power generation turbine research at Virginia Commonwealth University (James McLeskey) may be relevant to these efforts (see Energy Efficiency and Conservation in Section 6.1.2, below).

6.1.2 Energy Use and Impacts

Energy Storage

Virginia Tech's Department of Electrical and Computer Engineering is engaged in the research of energy storage to, among other applications, prevent power system blackouts. The work is supported by the National Science Foundation (NSF), the Electric Power Research Institute, and the Tennessee Valley Authority.[150]

Researchers at the Virginia Tech and University of Virginia's Rotating Machinery and Controls group research modeling and control of magnetic bearing systems used in high-speed energy storage flywheels. Uninterruptible power supplies, consistent power quality, and hybrid

[143]http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+67-601.
[144]http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+67-600.
[145]Neil Rondorf, "A Virginia-Based Marine Renewable Energy Technologies," presentation to VCERC, September 19, 2006 (www.cit.org/vrtac/2006/06-09-19-VCERC-Presentation.ppt#256,1).
[146]VT CEAGE, "Marine Renewable Energy" pdf from G. Hagerman, September 28, 2006.
[147]http://vwec.cisat.jmu.edu/programs.htm.
148www.ceage.vt.edu/2DOC/IEEE_Richmond_07Sep06.pdf.
[149]VT CEAGE, "Marine Renewable Energy" pdf from G. Hagerman, September 28, 2006.
[150]Virginia Tech Research, Summer 2006 (www.research.vt.edu/resmag/2006Summer/index.html).

CPES faculty focus on improving power conversion by integrating power and load management actions. They estimate that using power management electronics available today could achieve a 3 percent savings in electricity-corresponding to 2.3 billion barrels of oil annually-by 2010 and that advancements in power electronics technology can produce 27 percent total savings in electricity and transportation energy by 2025.[152]

vehicles are among the applications.

Virginia Commonwealth University's Pura Jena is working on hydrogen storage in nanoparticles, as mentioned earlier under Fuel Cells and Hydrogen in Section 6.1.1.

Energy Efficiency and Conservation

Research in efficient energy use and resource conservation is a strength at several Virginia universities. Virginia Tech faculty, staff, and students received seven patents in 2005–including two that received R&D 100 awards from *R&D Magazine*–for technologies that use energy more efficiently and safeguard electric grid and oil resources. Five of the patents were developed at the Center for Power Electronic Systems (CPES), an NSF Engineering Research Center led by Virginia Tech that leverages more than $10 million in annual support from the NSF, industry, and university funds.[151] One is an efficient and cost-effective bidirectional DC/DC converter that reduces switch voltage stress; the technology has been adopted by Ballard Power Systems, the largest fuel-cell company in the world. The CPES has 32 faculty, 146 students, and 10 research staff, with 80 industry partners and 18 research sponsors funding more than $7 million in research annually. CPES faculty focus on improving power conversion by integrating power and load management actions. They estimate that using power management electronics available today could achieve a 3 percent savings in electricity-corresponding to 2.3 billion barrels of oil annually-by 2010 and that advancements in power electronics technology can produce 27 percent total savings in electricity and transportation energy by 2025.[152]

Other efficiency/conservation research areas in the Virginia Tech College of Engineering include novel materials for heat exchange in next-generation refrigeration systems, materials selection for reducing energy consumption, drag reduction in turbulent flows in pipelines, and screening tools for heating, ventilation, and air conditioning systems.

At Virginia Commonwealth University, James McLeskey directs the Energy Conservation Systems Laboratory. His funded projects include developing computer-modeling tools for the power generation industry-specifically, tools for calculating heat transfer and mechanical stresses in large turbo-generator rotors.[153]

In the area of conservation related to transportation energy use, the University of Virginia's Smart Travel Lab is a joint effort between the Department of Civil Engineering and the Virginia Transportation Research Council. The lab is connected to traffic management systems operated by the Virginia Department of Transportation (DOT), providing researchers with direct access to current Intelligent Transportation System (ITS) data. This allows the lab to help the DOT's Smart Travel Program reduce traffic congestion in the heavily populated areas of northern Virginia and Hampton Roads. The Smart Travel Lab is part of the University of Virginia's Center for Transportation Studies, which also is studying intermodal transportation systems.[154]

The Virginia Tech Transportation Institute (VTTI) conducts research focused on modeling, evaluation, and integration of ITS and non-ITS traffic engineering applications, including development of energy and emissions models responsive to those applications. The VTTI also operates Smart Road, a unique state-of-the-art, full-scale research facility for pavement research and evaluation of ITS concepts, technologies, and products.[155]

Buildings/Environment

As noted above, the University of Virginia's energy R&D is part of its Energy, Conservation and the Environment initiative. The university believes it is important from the outset to coordinate research on efficient use, conservation, sustainability, and environmental impacts with the development of alternate energy technologies.

The University of Virginia's architecture school is home to John Quale, a nationally recognized expert in sustainable building

[151] www.cpes.vt.edu.
[152] Charts from CPES faculty, September 26, 2006.
[153] www.engineering.vcu.edu/ecsl/index.html.
[154] cts.virginia.edu/stl_index.htm.
[155] www.vtti.vt.edu.

design, as well as experts in landscape and remediation technology (Julie Bargmann) and environmental planning and sustainable communities (Timothy Beatley). Additional expertise in conservation and sustainability resides in Civil Engineering (Teresa Culver, Michael Demetsky, Lester Hoel, Nick Garber, Brian Smith, Brian Park, Julie Zimmerman) and the Darden School of Business (Andrea Larson and Richard Brownlee). The university's Environmental Sciences Department has expertise in atmospheric chemistry (Jim Galloway), plant-atmosphere flux (José Fuentes), coastal ecology (Jay Zieman), contaminant hydrology (Todd Scanlon), organic tracers (Steve Macko), and groundwater (Janet Herman and George Hornberger).[156] Dr. Hornberger was named to the U.S. Nuclear Waste Technical Review Board by President Bush in 2004. The board provides independent scientific and technical oversight of the U.S. program for managing and disposing of spent nuclear fuel from civilian nuclear power plants.[157]

Virginia Tech has several researchers working in the "energy and built environment" arena within its College of Architecture and Urban Studies (CAUS). Energy-efficient green building design, systems and construction methods, facility energy management, and related energy policy are among the research areas of faculty in the Schools of Architecture and Design (Robert Dunay, Michael Erman, Jim Jones, Robert Schubert, Joe Wheeler), Construction (Yvan Beliveau, Annie Pearce, George Reichard), and Public and International Affairs (John Randolph).[158]

Since 2002 both the University of Virginia and Virginia Tech have competed in the federal Department of Energy's highly competitive national Solar Decathlon in Washington, D.C. In 2002, the University of Virginia's solar house placed second overall, and in 2005 Virginia Tech's entry won the Architecture and Dwelling contest.

As noted previously, since 2002 both the University of Virginia and Virginia Tech have competed in the federal Department of Energy's highly competitive national Solar Decathlon in Washington, D.C. In 2002, the University of Virginia's solar house placed second overall, and in 2005 Virginia Tech's entry won the Architecture and Dwelling contest. The university teams comprised students and faculty advisors from the University of Virginia's Architecture and Engineering schools and Virginia Tech's College of Architecture and Urban Studies and College of Engineering.

6.1.3 Energy Policy

Virginia's energy R&D includes considerable expertise in energy/environment/economic policy that can help guide successful deployment of novel energy solutions in an economically and environmentally sustainable manner.

Virginia Tech's Center for Energy and the Global Environment (CEAGE) examines issues related to energy and its role in the global environment.[159] Its mission is to promote cooperation among diverse groups interested in sustainable energy development and to act as a catalyst for developing solutions to environmental problems in many regions of the world. CEAGE is led by the Advanced Research Institute's director, Dr. Saifur Rahman. Since its creation in 1994, it has made links with industry groups and universities in more than thirty nations, making it one of the most internationally active research organizations of its kind at Virginia Tech. Among many research programs, CEAGE is working with multiple stakeholders (e.g., local, state, and federal governments, U.S. Navy, Minerals Management Service) to identify and address issues related to development of coastal energy resources.

A major CEAGE initiative is the Critical Infrastructure Modeling and Assessment Program, which provides policymakers, legislators, and researchers' with long-term perspectives and guidance on various issues affecting the planning, commissioning, and operating of critical infrastructures.

Virginia Tech has several faculty addressing law, regulation/deregulation, and policy issues related to energy and society. Research interests include energy implications for environmental quality, state incentives for use of green power, forest management, energy conservation in landscape design, housing technology, hydrogen-based energy conversion, policies promoting safe and effective distributed energy generation and storage, and nuclear energy regulation.[160]

[156] Phil Parrish and Lisa Friedersdorf, UVA, personal communication, September 22, 2006.
[157] www.virginia.edu/researchandpublicservice/expertise/honors.html.
[158] Robert Schubert, CAUS, September 26, 2006; VT Energy Portfolio-9-20-06 (from J. Lesko).
[159] www.ceage.vt.edu.
[160] VT Energy Portfolio-9-20-06 (from J. Lesko).

Chapter 6
Energy Research and Development
continued

Virginia is home to three federal research laboratories conducting energy research: the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility, NASA Langley Research Center, and the Naval Surface Warfare Center in Dahlgren.

Economist Irene Leech is studying consumer issues related to energy such as affordability, reliability, security, consumer understanding, impact on consumer of market forces versus regulation, and environmental impacts of consumer choices. She is also a member of a multidisciplinary team from several Virginia Tech departments that is completing an NSF project on energy security.[161]

James Madison University faculty are engaged in informing state energy policy in a variety of ways. Jonathan Miles and Maria Papadakis, working through the Virginia Wind Energy Collaborative, actively provide local, state, and federal policymakers with information on wind resources and options for efficiently harnessing wind energy, as well as zoning development model language, now applied in several counties statewide, which provides a special-use permitting for small wind systems.[162] Chris Bachmann and C. J. Brodrick of James Madison University are working with Virginia Tech's Lisa Schweitzer, an urban planning specialist working on environmental justice and community/bioregional energy issues, to look at the socioeconomic impacts and justice aspects of implementing alternative fuels.[163]

George Mason University's Center for Transportation Policy, Operations and Logistics is a partner with the University of Virginia and Virginia Tech in the National Center for ITS Implementation Research, one of thirty-three University Transportation Centers funded by the U.S. Department of Transportation and one of only two devoted exclusively to Intelligent Transportation Systems.[164]

The College of William and Mary's public policy program addresses questions related to adopting new energy technologies, such as structuring incentives for contractors to use photovoltaics and LEED (Leadership in Energy and Environmental Design program of the U.S. Green Building Council) standards in their buildings.[165]

Virginia Military Institute's energy policy research involves working with varied stakeholders (producers, commercial providers and users, regulatory) to determine the optimum combinations of policies and new technologies to make Virginia's energy-grid system work most efficiently as new alternative energy sources are brought on line with conventional sources. Virginia Military Institute offers itself as a "neutral ground" for Virginia stakeholders to meet and technical and policy issues, and to that end hosted the inaugural Energy Virginia Conference in October 2006.[166]

6.2 Energy R&D at Federal Labs in Virginia

Virginia is home to three federal research laboratories conducting energy research: the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility, NASA Langley Research Center, and the Naval Surface Warfare Center in Dahlgren. Table 6-2 summarizes energy R&D at these facilities.

[161]Irene Leech, VT, personal communication, September 26, 2006.
[162]Jonathan Miles, JMU, personal communication, November 7, 2006.
[163]Lisa Schweitzer, VT, personal communication, September 26, 2006.
[164]http://policy.gmu.edu/research/research_tpl.html.
[165]Dennis Manos, CWM, personal communication, September 22, 2006.
[166]Ron Erchul, VMI, personal communication, October 31, 2006.

Chapter 6

Energy Research and Development

continued

Table 6-2 Energy R&D at Federal Laboratories in Virginia

	Energy Generation/Sources									Energy Use/ Impact			Energy Policy
				Alternative Fuels	Other Renewables								
Virginia Federal Lab	Coal, Oil, Gas	Nuclear	Fuel Cells/H2	Alternative Fuels: Waste- or Bio-derived	Geothermal	Hydroelectric	Solar/Photovoltaics	Wind	Coastal (Wind/Tidal/ Current/Wave)	Energy Storage	Efficiency/Conservation	Buildings/Environment	Energy Policy/ Economics
Thomas Jefferson National Accelerator Facility (DOE)		•					•	•					
NASA Langley Research Center		•	•	•				•		•	•	•	
Naval Surface Warfare Center - Dahlgren Division											•		

6.2.1 Thomas Jefferson National Accelerator Facility (Jefferson Lab)

Jefferson Lab is a federally funded facility with a primary mission to conduct basic science research on atomic nuclei at the quark level. Applied research is a derivative mission, wherein Jefferson Lab, with industry and university partners, develops uses for the lab's free electron laser (FEL). Energy-related FEL research includes work on photovoltaics and on hardened materials for severe environments such as turbine blades. The accelerator technology at the lab could be used for transmutation of nuclear waste if Los Alamos proceeds on the technology.[167]

6.2.2 NASA Langley Research Center

NASA Langley Research Center has three main areas of expertise: systems analysis, materials and structures, and aerodynamics. It has primary systems analysis responsibility within NASA labs. For many years, NASA Langley has focused on the impact of aviation on the environment. More recently this has expanded to a systems-level approach, looking at how alternative vehicles, fuels, and transportation systems can be most efficient and reduce harmful emissions.[168] Research includes work on energy sources for aircraft, including hydrogen-fueled combustion, hydrogen fuel-cell electric propulsion, lithium-air fuel-cell electric propulsion, nuclear hybrid systems, and aluminum powder combustion. In many cases, the studies are conducted to develop "zero emissions" aircraft propulsion systems.[169]

In the area of materials and structures, NASA Langley focuses on high-temperature materials to enable more efficient combustion, lightweight design, and non-destructive evaluation methods. The lab's long experience in aerodynamics and wind tunnels is being applied not only to aircraft but also to reducing drag on trucks and even NASCAR race cars.

6.2.3 Naval Surface Warfare Center, Dahlgren Division

The Naval Surface Warfare Center, Dahlgren Division's main focus is weapons/combat systems. Its main energy-related work is on energy efficiency of weapons and electric guns.[170]

6.3 Energy R&D at Virginia Industries

6.3.1 Energy R&D at Selected Virginia Companies

Several Virginia companies were inter-viewed to determine their general energy R&D interests. Table 6-3 summarizes the findings.

[167]Fred Dylla, personal communication, September 26, 2006.
[168]Rich Antcliff, NASA Langley Research Center, personal communication, November 3, 2006.
[169]Lesa Roe, NASA Langley Research Center, communication to VRTAC Univ/Fed Lab Subcommittee, August 2006.
[170]Larry Triola, personal communication, September 18, 2006.

Chapter 6

Energy Research and Development

continued

Table 6-3 Energy R&D at Selected Virginia Companies

	Energy Generation/Sources									Energy Use/ Impact			Energy Policy
				Alternative Fuels	Other Renewables								
Virginia Company	Coal, Oil, Gas	Nuclear	Fuel Cells/H2	Alternative Fuels: Waste- or Bio-derived	Geothermal	Hydroelectric	Solar/Photovoltaics	Wind	Coastal (Wind/Tidal/ Current/Wave)	Energy Storage	Efficiency/Conservation	Buildings/Environment	Energy Policy/ Economics
Afton Chemical, Richmond											•		
Areva NP, Lynchburg		•											
BWXT, Lynchburg		•											
Consutech, Richmond				•									
Delta T, Williamsburg				•									
Dominion Power	•	•					•	•			•	•	•
GE Energy, Salem	•	•					•	•			•		
Northrop Grumman Newport News	•			•						•			
SAIC, Virginia Beach						•		•	•				•
Siemens, Newport News											•		
Verdant Power, Arlington						•			•				
SBIR/STTR Companies	•	•		•	•		•				•		

In general, the companies interviewed are currently working with, or seeking partnerships with, Virginia research universities. The companies did not provide information on their energy R&D expenditures.

In addition to companies working on the technical aspects of energy generation and use, there are numerous firms in the state and region (e.g., Science Applications International Corporation, Sentech, Cadmus) studying energy policy and economics.

Virginia's coal industry has supported the Virginia Tech Center for Advanced Separation Technologies' research to improve mining engineering and coal separations technologies.

Afton Chemical of Richmond is a global petroleum additives supplier, created from Ethyl Corporation in 2004. Afton sells lubricant and fuel additives to reduce wear in engine parts and improve fuel performance while reducing emissions. It is committed to innovative technology and world-class research, with dedicated state-of-the-art research facilities in Richmond.[171]

Areva NP has operations in Lynchburg and has expertise and active involvement in every sector of the nuclear power industry, including the nuclear fuel cycle, reactors, instrumentation, nuclear measurement systems, and engineering. Areva's three largest activities in Virginia are Nuclear Regulatory Commission certification for its EPR (European Pressurized Reactor) design, fuel design/development and manufacturing, and R&D for methods to service existing power reactors. Areva is exploring research with Virginia Tech in several areas, including non-destructive evaluation methods. Areva recently provided a list of R&D topics of interest to the new Center for Advanced Engineering and Research in Lynchburg, which is seeking to enhance the technical capabilities of the nuclear industries in the Region 2000 area. Areva is interested in engaging with research institutions, both to work on innovative solutions to problems in its industry as well as to create a pipeline of prospective employees for the company.[172]

BWXT, headquartered in Lynchburg, has more than 11,300 employees in eleven

[171]www.aftonchemical.com/Regions/North+America/Products/index.htm.

states and is a subsidiary of McDermott International, Inc., a leading worldwide energy services company. BWXT has a long history in nuclear manufacturing and operations, including unparalleled experience in nuclear safeguards and security, both with U.S. government and commercial clients and at its unique, highly secure, privately owned and operated nuclear manufacturing and laboratory facilities. BWXT has significant team member roles in nuclear operations at many national labs, including those at Argonne, Oak Ridge, Idaho, Los Alamos, and Savannah River.[173]

Consutech Systems, LLC of Richmond designs and manufactures waste combustion and air quality control equipment.[174] Its CONSUMAT waste disposal technology is also being used as the initial gasification step in an organic waste-to-fuel process developed by BRI Energy of Arkansas.[175]

Delta-T Corporation in Williamsburg is a world-class designer of high-efficiency ethanol production facilities, providing alcohol production, dehydration, and purification technology solutions to more than 115 clients worldwide in fuel, beverage, industrial, and pharmaceutical alcohol markets. Delta-T's ongoing research pipeline for "Precision Ethanol" focuses on innovation in its core technologies for high-efficiency integrated ethanol distillation/dehydration/evaporation systems as well as cellulose conversion to ethanol, flexible plants able to process multiple feedstocks for adapting to market conditions, and biorefinery options to broaden the product portfolio of ethanol makers.[176]

Dominion Power supports R&D activities directed toward improving the reliability and efficiency of its service to customers. The company was a founding member of the Electric Power Research Institute (EPRI), formed by the electric utility industry to pool assets and conduct research into technologies expected to contribute to its goals. During the 1980s and 1990s the company supported and participated in a variety of R&D projects, such as evaluation of a fuel cell installed at Old Dominion University, assessment of the potential of high-temperature superconductivity (in conjunction with the Center for Innovative Technology), and demonstration of electric vehicles and innovative recharging technology. As the structure of the electric business changed and Dominion merged with Consolidated Natural Gas and acquired an oil and gas exploration and production business, the company's R&D efforts evolved to address these broader needs. Dominion's R&D activities are now decentralized, reflecting the "unbundling" of the electric business and the company's diversification. More recent R&D activities include carbon sequestration research via the Virginia Center for Coal and Energy Research, assessment of wind power potential at selected sites, assessment of new nuclear reactor designs and clean coal technologies, and collaborative research with the EPRI to improve nuclear generation and electric transmission.[177]

General Electric's Salem facility is active in energy technology development, with expertise in control and power electronics. In addition to manufacturing capabilities, GE Salem is heavily involved in engineering new products, primarily for other GE business units. Application areas include wind energy (power converters, grid stability, control systems, and technology), coal gasification (control software and hardware development, control strategies, and optimization), oil and gas (15-megawatt electric drives for compressor motors), gas/steam turbines (new sensors/circuitry for measurements needed for performance optimization), solar energy (3-kilowatt inverter), and nuclear energy (plant simulation and performance optimization, some funded through the DOE and the Nustart Nuclear program). GE Salem is not currently funding research projects with Virginia universities, but it hires many Virginia Tech students. Although the company is interested in collaborating with local businesses and institutions, coordination with other institutions has not been a critical factor for its product-oriented environment.[178]

Northrop Grumman Newport News (NGNN)

[173]www.bwxt.com/news/news_maint.asp?news_ID=56.
[174]www.consutech.com.
[175]http://brienergy.com.
[176]deltatcorp.com/deltatcorp/index.asp?section=History.
[177]Herbert Wheary, Dominion Power, personal communication, October 2, 2006.
[178]James Maughan, GE Salem general manager, personal communication, November 17, 2006.

manages the Virginia Advanced Shipbuilding Integration Center established by the state in 1998. The center's purpose is to enhance and promote the quality and competitiveness of Virginia's shipbuilding industry and to promote the general welfare of Virginia citizens. The center, along with electronic-system and software suppliers, U.S. Navy laboratories and program representatives, and Virginia institutions of higher learning, develops and integrates new technologies for aircraft carriers and advanced shipbuilding. It also participates on the steering committee of the Virginia Hydrogen Roundtable, exploring installation of a hydrogen power park to provide both critical shipyard electric loads as well as fuel for its fleet vehicles. NGNN is also pursuing coal-to-liquid concepts and synthetic fuel technologies in order to develop a modular design for sea-based fuel production. NGNN's synthetic fuel concepts, developed with its Idaho National Laboratory partner, are being received with interest by the Department of Defense, DOE, the Defense Logistics Agency, and others.[179]

Science Applications International Corporation, as mentioned earlier under Coastal Energy in Section 6.1.1, collaborated in developing the Virginia Coastal Energy Research Consortium and will serve as lead systems integrator for marine-industry support of the consortium.[180]

Siemens Automotive in Newport News has performed research on its fuel injector systems to improve fuel economy. Much of that work is now being done in Europe, while the Virginia group currently focuses more on controlling emissions using after-exhaust treatment to remove particulates. As alternative fuel use increases in the United States, the U.S. group may refocus on optimizing injectors for use with the new fuels. Siemens collaborated with Old Dominion University and the Applied Research Center in the past on direct injection research.[181]

Verdant Power, one of three leading tidal turbine manufacturers, is headquartered in Arlington and is producing underwater turbines for deployment in a tidal stream demonstration project in New York City's East River.[182]

6.3.2 SBIR/STTR Energy Research in Virginia

The Center for Innovative Technology identified thirteen Virginia companies that have received federal energy-related Small Business Innovative Research (SBIR) or Small Technology Transfer (STTR) awards in the last five years. These companies and their research areas are:

- Advanced Resources International, Inc., Arlington - carbon dioxide sequestration.
- Airak Engineering, Manassas - power converters for distributed energy.
- AMAC International, Inc., Newport News - power couplers for high RF power applications, such as nuclear physics accelerators.
- DDL OMNI Engineering, McLean - solid-state joining processes for alloys used in first wall/blanket applications for fusion power systems.
- Defense Life Sciences, LLC, McLean - biomass/waste conversion to fuel.
- Edenspace Systems Corporation, Chantilly - transgenic crops engineered for post-harvest self-hydrolysis of biomass to cellulose for fuel production. Edenspace recently won a $1.9 million award from DOE to lead an Energy Corn Consortium to develop corn hybrids optimized for cellulosic ethanol production.[183]
- Luna Innovations, Inc., Blacksburg - sensors for high-temperature power turbines; thin-film fullerene-polymer photovoltaic materials.
- Materials Modification, Inc., Fairfax - nanostructured electrodes for solar cells; nano-catalysts for efficient carbon-dioxide-to-methanol conversion.
- NanoSonic, Inc., Christiansburg - ink-jet electrostatic self-assembly of polymer thin-film solar cells on flexible, lightweight substrates.
- New Generation Motors Corporation, Ashburn - propulsion technology.
- PhotoSonic, Inc., Blacksburg - high-temperature geothermal well logging tools.

[179]Peter Diakun, NGNN, personal communication, September 22, 2006.
[180]Neil Rondorf, "A Virginia-Based Marine Renewable Energy Technologies," presentation to VCERC, September 19, 2006 (www.cit.org/vrtac/2006/06-09-19-VCERC-Presentation.ppt#256,1).
[181]Sean Nally, Siemens Newport News, personal communication, November 2, 2006.
[182]www.verdantpower.com/initiatives/currentinit.html.
[183]www.edenspace.com/10-25-2006.html.

- Prime Research, LC, Blacksburg - photonic sensors for geothermal wells.
- Zimmerman Associates, Inc., Fairfax - carbon dioxide monitoring and verification.

Four of these companies are spin-offs from university or federal laboratory research: Luna Innovations, NanoSonic, and Prime Research near Virginia Tech in Blacksburg, and AMAC near the Thomas Jefferson National Accelerator Facility in Newport News.

6.4 State Best Practices for Facilitating Energy R&D

The Center for Innovative Technology investigated the energy R&D efforts of other states, looking for geographically distributed programs with established track records and measurable success. Specifically, the Center examined California's Public Interest Energy Research (PIER) program,[184] the Connecticut Clean Energy Fund (CCEF),[185] the Massachusetts Renewable Energy Trust (RET),[186] Minnesota's Xcel Renewable Development Fund (XERDF),[187] the New York State Energy Research and Development Authority (NYSERDA),[188] the Ohio Coal Development Office (OCDO),[189] and the Northwest Energy Technology Collaborative (NWETC),[190] a major initiative coordinated through the Washington Technology Center. An analysis of these programs suggests several best practices that Virginia may wish to adopt in a program to support its own energy R&D.

Engage a broad stakeholder base in governance. NYSERDA's board is a good example of this. It includes the heads of state government offices in Transportation, Environmental Conservation, Public Service Commission, and the N.Y. Power Authority as well as nine others, who must include an engineer/research scientist, economist, environmentalist, consumer advocate, gas utility officer, electric utility officer, and three at-large members.

Provide for a consistent and substantial funding base. California's PIER collects about $62 million annually directly from state electricity users to fund public interest energy research. NYSERDA derives its research revenues from a combination of state appropriations, a System Benefit Charge (SBC) assessment on the intrastate sales of New York State's investor-owned electric and gas utilities; funding is augmented by voluntary contributions by the N.Y. and Long Island Power Authorities. The Massachusetts RET is also funded through an SBC, which amounts to about 50 cents a month for residential customers. Minnesota's XERDF is supported by settlements paid by the Xcel Energy Corporation for storage of spent nuclear fuel.

Define a market-driven research roadmap. NYSERDA hosts regular meetings with all stakeholders to develop a roadmap for research areas that reflect state energy issues and solutions. The roadmap then directs solicitation areas and facilitates R&D cooperation.

Set funding by program topic areas and allocate among best projects proposed. Topic areas should accommodate a variety of technologies and be directed toward the roadmap-identified needs. Solicitations should allow proposals from private, public, and nonprofit institutions and should encourage research consortia (including federal research labs). Decisions should be based on recommendations of a combination of external experts and an internal program manager.

Provide maximum flexibility for financing instruments to support R&D and innovative companies. The board of directors of the Massachusetts Technology Collaborative, administrator for the state's RET, by law has the ability to expend funds to make grants, contracts, loans, equity investments, energy production credits, bill credits, or rebates, and provide financial or debt-service assistance. Connecticut's CCEF Company Investment initiative invests via equity, convertible debt, debt, and debt-like financial vehicles. Repayments should be reinvested in R&D funding programs.

[184] www.energy.ca.gov/pier/index.html.
[185] www.ctcleanenergy.com.
[186] www.mtpc.org/renewableenergy/index.htm.
[187] www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1_11824_11838-801-0_0_0-0,00.html.
[188] www.powernaturally.org.
[189] www.ohioairquality.org/ocdo/ocdo.asp.
[190] www.nwetc.com/index.php.

Require "skin-in-the-game." Nearly all competitive funding programs require projects to have significant cost sharing from private sector, universities, and/or other non-state project partners.

Facilitate "real-world" demonstration opportunities. NWETC's Test Bed demonstration engages "test bed host" utilities, industry customers, and government institutions to screen applications from energy technology ventures and provide feedback to all applicants, and place selected participants' technology in appropriate field-testing sites.[191] The Connecticut CCEF Operational Demonstration Program makes funds available to early-stage clean-energy projects making innovative use of renewable energy resources or technologies, including wind, solar, fuel cells, wave power, biomass, landfill gas, and certain types of hydropower.[192]

Showcase companies with proven novel solutions. Events like the Northwest Energy Technology Showcase [193] created by NWETC provide companies that have novel energy solutions an opportunity to present their solutions to potential customers, investors, and public-sector decision makers. The companies and technologies should be carefully chosen to be sure they offer high-quality, proven solutions.

Track effectiveness of research in developing useful products and services to demonstrate the return on investment by the state. NYSERDA states that "Since 1990, NSYERDA has successfully developed and brought into use more than 170 innovative, energy-efficient, and environmentally beneficial products, processes, and services. These contributions to the State's economic growth and environmental protection are made at a cost of about $0.70 per New York resident per year."[194]

Join ASERTTI. Virginia is not a member of the Association of State Energy Research and Technology Transfer Institutions (ASERTTI). This nonprofit organization of states, federal agencies, universities, companies, and other research institutions promotes research development and deployment of advanced energy technologies that can contribute to economic growth, environmental quality, and energy security and reliability in the United States. Though not all members are state research development and deployment organizations, ASERTTI's focus is state-level public-interest energy research, development, demonstration, and deployment (RDD&D) needs. Collaboration and the development of working relationships to serve the public interest in energy are the main focus of ASERTTI's work.[195]

Nearly all competitive funding programs require projects to have significant cost sharing from private sector, universities, and/or other non-state project partners.

Benefits of membership in ASERTTI include:[196]

- Ability to share and receive information regarding new energy programs and emerging technologies to promote energy efficiency, demand-side management, renewables, distributed generation, and other clean-energy systems.
- Development of working relationships with other states, the federal government, and other national energy research, development, and deployment institutions.
- Ease of collaborating with state and national organizations to leverage funds and other resources to conduct joint research, development, and deployment projects and to reach common goals.

The annual ASERTTI membership fee is on a sliding scale, with most organizations being at $1,000, though there is some flexibility with new members. ASERTTI's executive director noted that one of the most important benefits is the willingness of some of the better-funded members to provide both opportunities (such as solicitations, cost-shared funds for external proposals) and advice in the design and operation of programs.[197]

191www.nwetc.com/cs_testbed.php.
192www.ctinnovations.com/funding/ccef/demo_project.php.
193www.nwetc.com/nets.php.
194www.nyserda.org/About/default.asp.
195www.asertti.org.
196www.asertti.org/join.htm.
197David Terry, Executive Director, ASERTTI, personal communication.

6.5 Opportunities for Improving Virginia Coordination of Energy R&D

6.5.1 Needs

Several important themes emerged from discussions with research leaders across the state concerning how Virginia could better facilitate and coordinate energy-related R&D. Among them were the following.

Need to identify areas of core strength and strategic advantage. States that have been successful in establishing a reputation as a national leader do so through a combination of:

- Natural resources.
- Demographics and geography.
- Past success and track record.
- Research capacity.
- Partnerships.
- Agenda priority and financial commitment.

True leaders in their field have a history of focusing on what they do best, building consensus and capacity, and placing a high priority on their agenda so as to avoid resource competition.

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Need to serve key customer bases in the state. Research leaders agreed that state support for R&D should serve sectors important to Virginia's economy, such as agriculture, mining, transportation, and the military. Examples include:

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- Movement of the Southside Virginia economy away from tobacco coincides with an opportunity afforded by the need for renewable bio-based fuels.
- Poultry/agriculture wastes can be turned from regional/industry liabilities to energy resources.
- Coastal energy research and deployment can provide opportunities for collaboration with the maritime industries and the military in Hampton Roads.
- Lessons learned from implementation of efficiency/conservation criteria in government buildings can be used by policymakers to provide effective guidelines for commercial real estate construction, with much broader impact on energy demand.

Need for an integrated, system-level approach for sustainable energy generation. Another significant theme was the need to take a holistic approach to energy R&D, optimizing the balance of energy/economic/environmental issues involved in energy production. Examples include:

- Improving the economic viability of biodiesel production by R&D, leading to the ability to use the glycerol by-products in an integrated biorefinery to produce high-value chemicals.
- Coordinating research on fuel cells that can be used in homes with environmentally green building design to reduce the demand for centralized power.
- Siting offshore wind power towers to optimize the balance of power generation, access to market demand, construction and maintenance costs, and environmental impact.

Need for demonstration "reduction-to-practice" projects. Reduction-to-practice projects test promising research results in a "real-world" context, collaborating with industry and communities. James Madison University's work with the City of Harrisonburg and its own on-campus facilities management group to develop integrated waste-to-energy facilities and processes provides a systems-level model for R&D structured to serve a community's needs. James Madison University researchers work closely with the university's facilities management, using campus facilities as an initial test bed/physical lab for reducing to practice sustainable energy and conservation technologies.[198] As these capabilities are developed on campus, they are coordinated with Harrisonburg's efforts in energy conservation and waste reuse to create a real-world demonstration that fosters continued development and hastened deployment of the technologies. The proposed Bio-Based Energy and Products Development partnership among Virginia Tech, the Institute for Advanced Learning and Research, regional communities, and industry envisions a similar research-to-

[198]Ron Kander, JMU, personal communication, October 2, 2006

Virginia's ability to develop its energy R&D capacity in areas of significant interest to the state is handicapped by the geographic distribution of research strengths, and the lack of a process and staff to coordinate those activities and enable state-level responses to large federal opportunities.

demonstration and deployment transition. Providing problem-based funding to collaborative teams of localities, school systems, and businesses can engage faculty and students across disciplines to develop solutions to real-life problems of specific industry sectors (e.g., disposition of hog/poultry waste, new agriculture crop base for Southside, military need for secure, domestic sources of fuel and energy). Demonstration projects can also define specific issues for further research that have a focused market-need application, and may engage more research funding from the private sector.

Need for state cost-sharing commitments to enable competitive bids for large federal projects and awards. Several leading university research faculty and administrators, as well as industry respondents, noted that Virginia has lost opportunities to win large-scale federal R&D awards. Such awards are crucial to establishing national prominence in the sector. Although the proposals were competitive on a science/technology basis, they could not offer cost-sharing commitments from the state. For example, the Virginia Center for Coal and Energy Research's Director Michael Karmis noted that while Virginia has sites that could qualify for the $1 billion federal FutureGen initiative,[199] the state did not provide a cost-sharing commitment (approximately $5 million would have been required)[200] and lost any opportunity to host the FutureGen plant.

Likewise, as previously noted, the Virginia Tech fuel cell cluster was one of nine finalists for the National Science Foundation Engineering Research Center award ($20 million over five years). The solicitation required 30 percent cost sharing; the successful bid involved teams of industry (Westinghouse and General Electric) and universities providing cost sharing, such as shared facilities.[201]

Need increased funding of centers created by the Commonwealth. The Virginia General Assembly has recognized the importance of energy research by legislatively designating two state entities: the Virginia Center for Coal and Energy Research (VCCER) and the new Virginia Coastal Energy Research Consortium (VCERC). However, the state's low financial support has limited the effectiveness of these entities. Virginia's budgetary support of the VCCER ($141,750 and 2 FTE positions in the current biennium-more than a 50 percent reduction from 1980s' levels) is significantly less than what equivalent centers in West Virginia ($2.7 million, 33 FTE faculty/staff) and Kentucky ($5 million, 69 FTE faculty/staff) receive from their states. West Virginia's National Research Center for Coal and Energy receives significant funding from the federal DOE, reducing the need for state resources. Both West Virginia and Kentucky have committed close to an additional $5 million per year in recent years to promote programs such as carbon sequestration and coal-to-liquids.[202] The VCCER's status as a Commonwealth resource was reinforced in the 2006 legislation mandating the Virginia Energy Plan, with emphasis on its role in administering the Clean Coal Technology Research Fund. However, no monies were appropriated to the fund.

The creation of the VCERC as an "interdisciplinary study, research, and information resource for the Commonwealth on coastal energy issues" makes clear that coastal energy research (as defined in the legislation) falls under its purview. The state has designated $1.5 million in funding for the VCERC. Virginia Tech's George Hagerman pointed out that state support for graduate student and post-doctoral candidates is critically needed to allow existing research to continue while freeing senior research faculty to work with stakeholder agencies addressing issues key to offshore energy development.[203]

Need for state-level process and resources to coordinate collaboration and development of research capacity. Virginia's ability to develop its energy R&D capacity in areas of significant interest to the state is handicapped by the geographic distribution of research strengths, and the lack of a process and staff to coordinate those activities and enable state-level

[199]FutureGen is a ten-year, $1-billion public-private partnership project in concert with the international FutureGen Industrial Alliance to build the world's first zero-emissions, integrated carbon sequestration and hydrogen production research power plant. See www.fossil.energy.gov/programs/powersystems/futuregen.
[200]Michael Karmis, personal communication, September 26, 2006.
[201]Michael Karmis and Fuel Cell Cluster faculty communications, September 26, 2006.
[202]Michael Karmis, personal communication, October 20, 2006.
[203]George Hagerman, personal communication, September 28, 2006.

Funding to recruit and retain needed research and support staff, as well as support for recruitment, tuition, and stipends for graduate students and fellowships for postdoctoral researchers, is needed to attract the brightest and best to Virginia's research institutions.

responses to large federal opportunities. In some cases, funding for recruiting nationally prominent researchers is needed to make state-level responses competitive. Funding to recruit and retain needed research and support staff, as well as support for recruitment, tuition, and stipends for graduate students and fellowships for postdoctoral researchers, is also needed to attract the brightest and best to Virginia's research institutions. Such shortcomings have constrained Virginia's ability to mount a strong and competitive state-level response to, for instance, the DOE's program solicitation for two $125 million biofuels research centers.

In some cases, researchers from different institutions collaborate when their expertise is complementary and cooperation may better leverage outside funding. State university and college leaders, as well as industry representatives interviewed, generally support and encourage such mutually beneficial collaborations. Experience suggests that the best collaborations develop from the "bottom up," with complementary expertise finding a common problem of interest to solve and a source of funding to support the research. The model other states have adopted, with a state-level energy R&D initiative facilitating multidisciplinary, multi-institutional projects, should foster successful Virginia collaborations and alliances at the grassroots level.

6.5.2 Guidance for Virginia Facilitation of Energy R&D

The needs and suggestions identified above, along with the best practices from other states, provided the following guidance for developing a statewide program to facilitate energy R&D.

Develop a state Energy R&D Roadmap with milestones, and track results. One industry respondent noted that opportunities exist for collaboration with state universities but that industry requires there be a defined roadmap with milestones. Another noted that until there is consensus on the goals for energy R&D, it is difficult to design a specific, targeted strategy with measurable results that can be tracked and reported to the General Assembly.

These inputs support adopting practices of state programs such as NYSERDA that meet regularly with a broad base of stakeholders to develop a market-driven roadmap reflecting state energy issues and needed solutions. The roadmap guides solicitation areas and facilitates R&D cooperation. It should include goals that are measurable and regularly tracked.

Provide a cost-sharing commitment fund to enable competitive bids for large federal project or awards and strategic recruiting opportunities. The ability to make such cost-sharing commitments available in a timely manner is crucial to Virginia research groups being competitive for large-scale federal awards. Readily available funds also are important in responding to strategic opportunities on a smaller scale. Both types of awards serve to attract key researchers and enhance corporate partnerships, and can bolster Virginia's competitiveness in energy research. The Commonwealth Technology Research Fund is one potential vehicle to administer such funding. In both the national-level proposals as well as strategic recruiting opportunities, participating institutions would be required to demonstrate "skin-in-the-game" by providing financial commitments.

Fund a state-level initiative to coordinate and build Virginia's energy R&D capacity and spur its economic impact. The Virginia Research and Technology Advisory Council's (VRTAC's) University/Federal Lab Subcommittee has drafted a proposal for a five-year R&D initiative focused on thematic areas including "Energy, Conservation and Environment." The recommended management strategy is establishment and financial support of a consortium of universities, industry, and federal laboratories, reporting to a governor's panel. The consortium would determine core strengths and manage projects with the objectives of establishing a framework to help build research capacity in core areas at Virginia universities and providing support for collaborative research, development, and pilot-scale projects involving universities, industry, and federal labs. In order to foster job creation and economic revitalization, at least one project in the area of Energy, Conservation and Environment would be in economically deprived areas of Virginia. An example of a collaborative development project could be a biofuels program established to build research capacity which then leads to a bioreactor scale-up project in an economically deprived area, which would prove that the technology works and lead to new jobs in a short time frame.[204]

6.5.3 Benefits to Virginia from Coordinating Energy R&D

A state-level, integrated program that promotes energy R&D, addresses needs of key economic sectors, and provides staffing and cost-sharing funds to increase competitiveness for high-profile federal awards could have significant benefits for Virginia.

Data from the U.S. Bureau of Economic Analysis suggest that R&D accounted for a substantial share of the resurgence in U.S. economic growth in recent years. Using data from the National Science Foundation's annual surveys of government, academic, industry, and nonprofit R&D expenditures, the Bureau of Economic Analysis determined that R&D contributed 6.5 percent to economic growth between 1995 and 2002.[205]

A state-level, integrated program that promotes energy R&D, addresses needs of key economic sectors, and provides staffing and cost-sharing funds to increase competitiveness for high-profile federal awards could have significant benefits for Virginia. Potential outcomes include:

- Increased federal and other research funding, thus enhancing capabilities and expertise at Virginia institutions and companies.
- Attraction of high-profile researchers and premier students and post-doctoral candidates.
- New company creation, company attraction, and existing company growth.
- Job creation and retention.
- Technology development and deployment.
- Environmental benefits.

Research Funding and Productivity

Providing sufficient staffing and cost-sharing funds should give groups that are already technically competitive an added ability to win large federal projects such as a National Science Foundation Engineering Research Center. Where Virginia has provided sufficient initial funding for focused research areas, the returns have been impressive. For example, the creation of the Virginia Bioinformatics Institute in 2000, provided for by $12.3 million in initial state funds (from the Tobacco Commission), has led to a thriving, nationally recognized research center with 18 faculty and more than 200 employees managing nearly $50 million in external research support in a new 130,000-square-foot facility on the Virginia Tech campus.[206]

Attraction of Best Researchers, Students, and Postdoctoral Candidates

A state commitment to energy R&D, attracting increased federal and industrial support for research, will further the ability of institutions to attract high-profile faculty as well as the best and brightest students and postdoctoral research fellows.

Existing and New Company Growth; Company Attraction

Large company representatives interviewed noted they will support some R&D at a low level as "good citizens." However, industry is more likely to engage in university and regional research projects when state or federal funding is provided and the projects address relevant market needs. When industry is engaged in these projects, there is increased likelihood that students will gain expertise relevant to the corporate sponsors and that more students will be employed in Virginia companies. A state program facilitating energy R&D in areas where the state has recognized research strengths should also help attract companies and develop industry clusters in those areas.

A state program providing funding for energy innovation to solve market needs will also drive entrepreneurial investments in energy R&D, as is the case with

[204] Draft recommendation from VRTAC University/Federal Lab Subcommittee, December 2006.
[205] www.bea.gov/bea/newsrelarchive/2006/rdspend06.htm.
[206] www.vbi.vt.edu/about.

the federal SBIR/STTR programs supporting early-stage energy research. Other state energy programs (i.e., CCEF's Company Investment program[207] and NWETC's Energy Venture NW and Northwest Energy Angels™)[208] include investment funds supporting innovative energy companies.

Job Creation and Growth

A number of studies have looked at the economic impacts, including job creation, of deploying renewable energy. The following are examples:

- Daniel Kammen, an energy policy expert at the University of California, Berkeley, compared job creation from three scenarios with varying mixes of renewable energy sources (biomass, wind, solar) for providing 20 percent of electricity in the United States by 2020. His study predicted between 170,000 and nearly 250,000 new jobs related to energy.[209]
- A 2004 report from the Union of Concerned Scientists estimated that the 20 percent Renewable Energy Standard would create more than 355,000 new jobs in manufacturing, construction, operation, maintenance, and other industries-a net increase of nearly 157,500 jobs by 2020.[210]
- A 2004 report from the National Renewable Energy Laboratory noted that achieving the goals of the Department of Energy's Wind Powering America program during the next twenty years will create $60 billion in capital investment in rural America, provide $1.2 billion in new income for farmers and rural landowners, and create 80,000 new jobs.[211]

Technology Development, Demonstration, and Deployment

A prime metric for evaluating the success of Virginia's energy R&D facilitation program should be its ability to yield practical applications that provide for the state's energy needs in cleaner, cheaper, and/or more efficient ways. A 2005 report from California's PIER program states that from its inception in 1998 through 2003, "33 products were placed into use in their intended markets and are expected to produce ratepayer benefits between $320 million and $822 million over their lifetimes. Based on PIER program disbursements of approximately $200 million through 2003, the benefit-to-cost ratio was between 1.6 to 1 and 4.1 to 1. The range of benefits reflects uncertainties in the performance and in the sales projections for the products…the PIER benefit-to-cost ratio is quite comparable to results reported by other organizations with similar mandates, such as the Gas Research Institute, the Electric Power Research Institute, the NYSERDA, and the United States Department of Energy."[212]

Environmental Benefits

Advances in conservation and efficiency, new carbon management and sequestration technologies, and growth in alternative energy source production and use can have a significant impact on reducing energy use and air pollution. The 2005 California PIER report noted that the thirty-three products developed during the 1998-2003 period would over their lifetime save 5.6 gigawatt-hours of electricity and 8.8 billion cubic feet of natural gas, avoid 730 megawatts of capacity construction, and reduce emissions of sulfur dioxide (2,000 tons), nitrous oxides (2,700 tons), and carbon dioxide (1.8 million tons).[213]

[207] www.ctcleanenergy.com/investment/renewable_company.html.
208www.nwetc.com/nweangels.php.
[209] Daniel M. Kammen, "Business Unusual: Methods to Develop a Clean Energy Economy," presentation to NREL, September 20, 2004, Washington, D.C. (www.nrel.gov/analysis/seminar/docs/2004/ea_seminar_sept_20.ppt, Slide 30).
[210] Union of Concerned Scientists, "Renewing America's Economy: A 20 Percent National Renewable Electricity Standard Will Create Jobs and Save Consumers Money," September 2004 (www.energyfuturecoalition.org/pubs/Economic%20Growth%20Opportunities.doc).
[211] NREL, "Wind Energy for Rural Economic Development", June 2004 (www.nrel.gov/docs/fy04osti/33590.pdf).
[212] California Energy Commission, "2004 Annual Review of the PIER Program Volume 1-Commercial Successes and Benefits" (www.energy.ca.gov/2005publications/CEC-500-2005-055/CEC-500-2005-055-V1.PDF).
[213] Ibid.