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JOINT COMMISSION ON TECHNOLOGY AND SCIENCE

RENEWABLE ENERGY OPTIONS IN THE COMMONWEALTH OF VIRGINIA

Report to the Emerging Technologies Advisory Committee and the Joint Commission on Technology and Science

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I. EXECUTIVE SUMMARY

During the 2005 Interim the Emerging Technologies Advisory Committee heard presentations on various renewable and alternative energy technologies. With growing uncertainty in the international market for traditional, carbon-based energy resources and rising domestic energy prices, the Advisory Committee requested the Joint Commission on Technology and Science (JCOTS) staff to prepare a report outlining various renewable energy resources and technologies.

This report contains a brief technical explanation of each technology with greater analysis on the ability of each technology to provide energy at a cost-competitive level with existing traditional energy supplies. This report is intended to provide a basic educational overview and not a comprehensive analysis. Any comprehensive analysis would necessitate an in-depth quantitative economic study with technical staff support. During the compilation of this report, however, The Virginia Center for Coal and Energy Research (VCCER) at Virginia Polytechnic Institute and State University published a study entitled, "A Study of Increased Use of Renewable Energy Resources in Virginia." The study was prepared at the request of the Virginia Commission on Electrical Utility Restructuring and offers a more extensive review of renewable energy opportunities in the Commonwealth.

Similar to the VCCER study, this report reviewed several different types of renewable energy for use in the transportation sector and electricity market and lists the best options below. The first three technologies listed below have the potential to provide the greatest benefit at the lowest cost because they have the potential of providing a secondary market to the farming industry in Virginia. By focusing on benefits to Virginia, there is a greater chance that any investment in the following technologies would provide the greatest return.

BIODIESEL: Biodiesel holds the most promise for providing a cost-competitive alternative to regular diesel fuel while concomitantly providing a boost to Virginia's soy farmers. Biodiesel blends in low concentrations can be used in diesel vehicles without modification and without voiding factory warranties.

ETHANOL: Although the energy balance associated with producing ethanol is not as good as with biodiesel, low concentration blends of ethanol can be offered at comparable prices to gasoline. Additionally, as with biodiesel, automobiles can use low blends of ethanol without modification.

BIOMASS: Wood residues and crops grown specifically for energy generation can be used either by themselves or can be combusted with coal in traditional coal power plants. This process, known as cofiring, can produce electricity at relatively low cost without construction of a new facility. Biomass also offers farmers an alternative to cash crops such as tobacco.

WIND: Wind energy is a mature technology that can produce electricity at a cost-competitive level with traditional energy sources.

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III. INTRODUCTION

With the recent devastation in the Gulf region, growing threats from terrorist organizations and greater competition from advancing third world countries, the need for energy independence and security is growing. Renewable and alternative forms of energy hold the potential to provide for greater stability in cost, economic growth within the Commonwealth, and improvements in air and water quality.

Although many renewable energy technologies first appeared in the 1970s, no single technology has reached widespread adoption by the public. Understanding the limitations of renewable and alternative energy is essential to their successful implementation in the Commonwealth.

First, no single technology or resource will provide a 'magic bullet' capable of offsetting traditional forms of energy or electricity generation. Any approach towards implementing renewable energy should not carry unrealistic expectations related to production capacity. Renewable energy technologies are mainly a form of distributed generation. For the past one hundred years there has been a growing understanding that electricity is produced at a single large plant capable of powering hundreds of thousands of homes. With greater implementation of renewable energy generation, that paradigm will slowly change to reflect a larger number of plants, each with a smaller generating capacity.

Second, the fuels that power renewable energy vary from region to region, state to state, and even county to county. Although renewable and often inexhaustible, the quality of a renewable resource varies with location and is often non-transferable in its natural form. The same is true for wind and water resources. Only biomass resources can be shipped across far distances in their natural form. Therefore state supported or state endorsed development of renewable energy should focus on technologies that can take advantage of resources located within the Commonwealth.

Finally, although some technologies are mature, such as onshore wind turbines, many technologies have not come to maturity, resulting in unmet expectations of performance. Fuels such as hydrogen may hold promise for the future, but the focus of this report will be on those technologies that present economically viable options in today's market.

Criteria for Evaluating Efficacy

Efficacy is defined as the ability or power to produce a desired effect, which for this report is identifying cost-competitive forms of energy and electricity. Because of their unique costs and benefits, it is extremely difficult to identify the single most beneficial renewable resource for the Commonwealth. With cost as the leading factor, the criteria listed below can be used to form a more balanced analysis of different renewable energy options.

Cost: For this report, the goal is to identify the technologies that can provide cost-competitive alternatives to traditional energy sources. For the transportation sector, cost comparisons are made with gallons of gasoline and diesel fuel. For electricity, cost comparisons are made with kilowatt hours of electricity (kWh). The current average cost for electricity in Virginia is $.07 - $.09 per kWh.[1]

Environment: Although cost is a major factor, the environmental benefits of renewable forms of energy have been a major argument for their development. This report will identify the basic environmental benefits or drawbacks for each form of renewable energy.

Energy Balance: Another criterion for evaluating the various forms of alternative energy is the energy balance, especially for transportation fuels. If it takes more energy to produce a fuel than that fuel can provide, the result is a net energy loss. Although the less energy it takes to produce a fuel the better, the net energy balance is not as important if the primary goal of using an alternative fuel is to achieve energy independence. Liquid fuels are a more desirable form of energy because they can be used in the transportation sector, which is heavily dominated by petroleum.

Cross-Industry Opportunities: A final criterion evaluated in this report is the ability of a renewable resource or technology to provide a synergistic effect on the economy of the Commonwealth. By focusing on strengths already anchored in the state, there is a greater chance for success and widespread adoption of the renewable resource.

The different forms of renewable energy reviewed in this report are divided into two categories: transportation fuels and electricity and energy generation. The reason these technologies are divided is to help evaluate how implementation would benefit the citizens of the Commonwealth. Approximately 90% of the energy used in the transportation sector comes from oil. Consequently, providing incentives to develop wind energy would have no effect on gasoline or diesel prices because wind turbines generate electricity. Although this report focuses on utility scale electricity and energy generation, any discussion on how to save money on transportation fuel, electricity, and energy in general must begin with reviewing the concepts of energy efficiency and conservation, which are universally recognized as the most cost effective means of reducing a homeowner's electricity bill.

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[1] A Study of Increased Renewable Energy Resources in Virginia; The Virginia Center for Coal and Energy Research. November 11, 2005. page D-3. Hereinafter "VCCER Study".

IV. ENERGY EFFICIENCY

Energy efficiency and energy conservation are best explained by understanding the concept that it is far cheaper to save a kilowatt than generate a kilowatt of electricity. Although not technically a form of renewable energy, greater implementation of energy efficient appliances and building design can help reduce the demand on traditional forms of energy and lower costs to all consumers.

Virginia ranked 15th in the United States in total energy consumption in 1999, with consumers spending $13 billion on energy.[2] The level of energy intensity in Virginia, the amount of energy consumed per dollar of gross state product (GSP) was 9.2 BTU/$. This compares with the national average of 10.3 BTU/$ for that year.[3] As a metric of energy efficiency, Virginia is ahead of the national average in terms of leveraging energy use to generate gross state product.

Two of the largest energy efficiency resources in Virginia are commercial and residential buildings.[4] Implementing energy efficient appliances, lighting, heating, and cooling would benefit both the residential and the commercial sectors. One possible tool for encouraging greater implementation of energy efficient design and appliances would be to review the current building codes.

Appliances and office equipment account for 70% of all primary energy consumed in U.S. homes.[5] Though minimum standards of energy efficiency for appliances are set at a federal level, the Commonwealth can encourage increased efficiency of these products through incentives and other policies. Current standards have already led to dramatic reductions in energy usage among many of the products, but there are still considerable savings that can be gained.

Virginia residents could cumulatively save more than $1,236 million by the year 2020 if higher efficiency standards were adopted for a range of appliances. This would save enough electricity to equal a power plant of 57 MW or enough electricity to power 1,048 homes.[6] Virginia has millions of square feet of building space in state office buildings, hospitals, schools, and libraries. Energy savings of more than 20% are usually achievable by retrofitting these facilities with energy efficiency measures.[7]

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[2] http://www.eere.energy.gov/state_energy/efficiency.cfm?state=VA (last visited 11/14/05).
[3] Id.
[4] Id.
[5] Id.
[6] Id.
[7] http://www.eere.energy.gov/state_energy/efficiency.cfm?state=VA (last visited 11/14/05).

V. TRANSPORTATION FUELS

A. Biodiesel

Biodiesel is a clean burning alternative fuel produced from animal fats or vegetable oils, typically canola or soy. As a transportation fuel, biodiesel can be used in almost any diesel vehicle with little or no modifications. The most common blends of biodiesel marketed in the U.S. are B2, B5, B20, and B100. The number in each of the preceding figures represents the percentage of biodiesel in the fuel blends, with B100 representing a fuel containing 100% biodiesel.

Cost: The Clean Cities Program, sponsored by the Department of Energy, compiles prices for gasoline, diesel, and alternative fuels across the U.S. The table below represents the cost analysis for biodiesel in the September 2005 Clean Cities Alternative Fuel Price Report:

	B2-5	**B20**	**B100**	**Diesel**
Lower Atlantic	$2.88	$2.92	$3.53	$2.81
National Average	$2.81	$2.91	$3.40	$2.85

The prices represented in the Clean Cities report are based on voluntary submissions by participating localities of actual prices at the pump.

Environment: Biodiesel offers substantially reduced emissions in several categories of regulated and unregulated pollutants and only a small increase in the emission of nitrogen oxides (NOx).

Energy Balance: One of the most commonly cited reports on the energy balance of biodiesel is the joint study performed by the U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE). In performing a life-cycle analysis of biodiesel and petroleum-based diesel, the report concluded that every unit of energy used in making biodiesel yields 3.2 units of energy.[8] Biodiesel is recognized as having the highest energy balance of any alternative fuel.

Cross-Industry Opportunities: In addition to expanding the already existing biodiesel production facilities within the state, further support of biodiesel would provide a secondary market for the farming and agricultural industries in Virginia. Increasing production capabilities in Virginia would provide an opportunity for the state to become a net exporter of biodiesel. Given the new regulations promulgated by the EPA requiring a significant reduction in the sulfur content of diesel fuel, demand for low-sulfur biodiesel is expected to grow.

B. Ethanol

[8] *Life Cycle Inventory of Biodiesel and Petroleum Diesel for use in an Urban Bus: Final Report.* Sheehan, John, et. al. May 1998 (pg. 33).

Ethanol is similar to biodiesel in that both are biofuels derived from a biomass feedstock. Ethanol, however, is produced from fermenting and distilling crops such as corn, barley, or wheat. Ethanol is typically blended with gasoline to create E85, which contains 85% ethanol and 15% gasoline. Several automobile manufacturers offer Flexible Fuel Vehicles (FFV) that can run on E85 at the same cost to the consumer. As of 2003 it is estimated that two million FFVs have been sold in the U.S.[9] Most of the 150 public refueling stations are located in the Midwest.[10] All vehicles, regardless of designation as an FFV, can run on up to a 10% blend of ethanol without modification.

Cost: The Clean Cities Program, sponsored by the Department of Energy, compiles prices for gasoline, diesel, and alternative fuels across the U.S. The table below represents the cost analysis for E85 in the September 2005 Clean Cities Alternative Fuel Price Report:

	E85	**Gasoline**
Lower Atlantic	$2.50	$2.84
National Average	$2.41	$2.77

Environment: The benefits of ethanol are slightly different from those of biodiesel. For example, using E85 results in a significant decrease in NOx emissions and a slight decrease in carbon monoxide and carbon dioxide. Total hydrocarbon emissions, however, increase.

Energy Balance: In a 2002 update the USDA reported that the energy balance for ethanol production was 1.34.[11] Therefore every one unit of energy invested in producing ethanol from corn would yield 1.34 units of energy.

Cross-Industry Opportunities: Producing ethanol, like biodiesel, would provide a secondary market for the agricultural industry in Virginia.

[9] http://www.eere.energy.gov/afdc/afv/eth_vehicles.html (last visited on 11/16/05).
[10] Id.
[11] Shapourio, Hosein, James A. Duffield, Michael Wang, *The Energy Balance of Corn Ethanol: An Update*, USDA, pg 11 (2002). Agricultural Economic Report Number 813.

VI. ELECTRICITY AND ENERGY GENERATION

A. Wind

From transportation and mechanical needs to generating electricity, wind energy is one of the oldest forms of energy harnessed by societies. The wind industry is currently a billion dollar business in the U.S. and has been the world's fastest growing energy sector.[12] The majority of installed wind turbines in the U.S. are in Texas and California; locations with good wind resources near large population centers. Virginia has yet to build any utility scale wind turbines or wind farms, but the Highland County Board of Supervisors recently approved locating up to 20 wind turbines along a ridgeline in Highland County.[13] Developers have yet to break ground and strong opposition to this project may eventually result in a relocation or eventual termination of the project.

Wind energy can be divided into two main categories: utility-scale and small-scale units. Utility-scale turbines are typically in the range of 750 kW to 2 MW and small-scale turbines are usually less than 10 kW. Aside from the physical size and generating capacity, the main difference between the two categories is the cost of electricity produced and the payback period for a turbine. On the utility-scale level, the technology can be divided into two categories, offshore and onshore. With higher wind resources extending into state waters and the Outer Continental Shelf (OCS), there is considerable potential for offshore winds farms.[14] Although there are offshore wind farms in Europe, there are currently no offshore wind farms in the U.S. and therefore this report only reviews onshore wind energy.

Cost: Utility Onshore: The cost of electricity generated by wind turbines is currently around $.05 per kWh in an area with a good wind resource, which includes the $.015 per kWh Production Tax Credit.[15] At $.05 per kWh wind energy is cost-competitive with traditional sources of electricity, which can range between $.07 and $.09 per kWh.[16]

Environment: Environmental critics of onshore wind turbines typically focus on bird or bat kills, which studies show are far less frequent than with other man-made objects.[17] Other related environmental concerns such as noise and light flicker can be mitigated by using appropriate setback requirements. Many of the environmental issues associated with wind turbines are relatively insignificant and often brought to light by opponents more concerned with the visual impact of the turbines.

The environmental benefit of generating electricity with wind is the displacement of emissions from coal power plants. Wind turbines produce no air or water pollution over

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[12] http://www.awea.org/faq/tutorial/wwt_statistics.html (last visited on11/18/05)
[13] http://www.jmu.edu/madisonscholar/feature005.shtml (last visited on 11/18/05)
[14] VCCER Study page 19.
[15] http://www.awea.org/faq/tutorial/wwt_costs.html (last visited on 11/18/05). This credit is not adjusted for infaltion.
[16] VCCER Study page D-3.
[17]http://www.awea.org/faq/tutorial/wwt_environment.html#Bird%20and%20bat%20kills%20and%20other%20effects (last accessed on 11/18/05).

the course of their life span, often reaching 30 years. This obvious benefit of wind energy has been the main driving force of its development and deployment across the U.S.

Cross-Industry Opportunities: In the case of the Highland County Wind farm, estimated tax revenues from the project are expected to be around $250,000 per year.[18] In counties such as Highland, with little economic development outside of the farming community, generating tax revenue is a major priority.

B. Biomass

Biomass is a general reference to a resource that is grown in an agricultural manner, typically originating from a crop. The most mature and economical form of biomass energy production is the direct combustion of the biomass material. Biomass systems are typically described as either closed-loop or open-loop. Closed-loop systems use a crop that is grown specifically for combustion, whereas open-loop biomass systems typically take a byproduct or waste biomass product and combust the material to produce energy or electricity. The most promising application of closed-loop biomass systems involves a technology called cofiring. Cofiring is the process of burning a biomass material with a traditional fuel, such as coal. The VCCER Study contains an in depth discussion of this type of renewable resource and technology.

Cost: The VCCER study projects that biomass could be used as a renewable fuel at a cost of $.10 to $.15 per kWh. If cofiring processes were used in existing coal plants, electricity could be produced for as low as $.05 per kWh.[19]

Environment: Biomass as a renewable source of energy has the benefit of being carbon neutral. Combusting biomass to produce electricity does not release any more carbon into the atmosphere than the plant absorbed during its lifetime. Although biomass releases pollutants such as particulate matter, sulfur oxides, and nitrogen oxides, these pollutants are not in the same quantity as with traditional coal power plants.[20]

Energy Balance: Although the net energy balance is positive, biomass has a much lower energy intensity than traditional carbon-based fuels. The result is the need for a greater quantity of biomass to produce the same amount of electricity, which results in greater transportation and handling costs.[21]

Cross-Industry Opportunities: Greater implementation of biomass as a fuel has the potential to help farmers in rural areas by providing a secondary market for their crops and waste residue. Additionally, switchgrass may be a feasible alternative for many tobacco farmers for use in closed-loop biomass plants.

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[18] http://www.jmu.edu/madisonscholar/feature005.shtml (last visited on 11/18/05).
[19] VCCER Study page 22.
[20] VCCER Study page C-33.
[21] VCCER Study page C-33.

C. Solar (Photovoltaic)

Solar energy is collected through two different processes: passive and photovoltaic. Passive solar energy encompasses a wide variety of devices and design techniques. Passive solar electricity is not a utility-scale application, but rather used as a tool to improve overall energy efficiency in the heating and cooling of homes and businesses. The typical commercial-scale solar technology, primarily located in the southwest, is a concentrating solar power (CSP) facility. These facilities are not feasible in Virginia due to the moderate solar resource.

In addition to passive solar and solar-concentrating applications, solar energy can be converted into direct current (DC) electricity through the use of photovoltaic (PV) cells. A power inverter can convert direct current to alternating current (AC) for typical household electricity demands. When used for powering equipment in remote locations, PV systems include batteries that store electricity for use at night or when the solar resource is low. The primary uses for PV panels are telecommunications, security and lighting systems, water pumps, and load management.[22] There has been significant investment in PV cells on the federal level, which has resulted in significant increases in efficiency. In recent years, much of the research into PV cells has focused more on producing electricity at a lower cost through cheaper manufacturing processes and cheaper materials as opposed to focusing solely on efficiency.

Despite the technical advancements made with PV cells, electricity generated from PV cells, even on a utility scale, is still several times the cost of traditional forms of electricity.

Cost: The cost of electricity from PV cells as reported in the VCCER Study ranges between $.23 to $.33 per kWh.[23]

Environment: The environmental benefit of solar energy, regardless of form, is the displacement of emissions from traditional power plants.

Cross-Industry Opportunities: Other than the direct employment of manufacturing plants and potential for manufacturing associated components for PV systems, there is little opportunity to involve other industries in Virginia.

D. Hydroelectric

Hydroelectric resources in the Commonwealth are limited because the utility-scale technology requires a large volume of water and a significant drop in elevation to produce electricity. Although the cost of electricity generated from a hydroelectric plant is cost competitive with other carbon-based forms of energy, Virginia has a relatively low

[22] http://www.eere.energy.gov/state_energy/technology_overview.cfm?techid=1#solarfp (last accessed on 11/8/05).
[23] VCCER Study page A-13.

potential for future development.[24] One barrier to future development is lack of a suitable resource; however, impacts on the environment, cultural resources, scenic attributes, and land rights are all issues that have hindered similar projects across the U.S. The most significant advances in hydroelectric production in Virginia would come from retrofitting current reservoirs with more efficient turbines. The VCCER Study suggests there is the technical potential to gain an additional 200 MW of production capacity over the current 750 MW of installed capacity through retrofitting.[25]

[24] http://www.eere.energy.gov/state_energy/tech_hydropower.cfm?state=VA (last visited on 8/11/05).
[25] VCCER Study page 19.

VII. CONCLUDING OBSERVATIONS

Due to the complicated nature of economic impact analyses associated with job creation, energy costs, and tax implications, this report is limited to a basic educational tool for considering the options for mature renewable energy technologies and resources. As the report came to completion, the need for a comprehensive study became even more apparent.

This report reviewed several different types of renewable energy for use in the transportation sector and electricity market and the best options are listed below. The first three technologies listed below have the potential to provide the greatest benefit at the lowest cost because they have the potential of providing a secondary market to the farming industry in Virginia. By focusing on benefits to Virginia, there is a greater chance that any investment in the following technologies would provide the greatest return.

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WIND: Wind energy is a mature technology that can produce electricity at a cost-competitive level with traditional energy sources.

The four renewable energies list above are already on the market or will soon be ready for the market. However, if Virginia is to remain proactive in terms of meeting growing energy demand, continued research and development is necessary in other areas of renewable energy. Of the resources and technologies not listed, those associated with the marine environment hold the most promise for greater generation capacity. Marine energy technologies are a broad class of energy converting devices that harness wind, wave, and tidal energy in the marine zone and on the Outer Continental Shelf (OCS). Although many marine energy technologies are currently in the pre-commercial testing phase, the Commonwealth may want to consider commenting on the proposed rulemaking for the regulatory program to be adopted by the Minerals Management Service (MMS) pursuant to the Energy Policy Act of 2005. The regulations eventually adopted by the MMS will control development on the OCS, which extends seaward from the three mile limit on state jurisdiction. The deadline for the submission of comments for the regulations is February 28, 2006.[26]

[26] 30 CFR Part 285. Advanced Notice of Proposed Rulemaking; RIN 1010-AD30.