III. OVERVIEW AND BACKGROUND

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. 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. The reasons alternative energy and renewable energy have not reached wider adoption vary depending on the technology.

Renewable and alternative energy will not provide a magic bullet capable of producing limitless energy at little to no cost. Rather than approaching future energy issues looking for a magic bullet, it is more appropriate to focus on proven technologies that take advantage pre-existing regional strengths and resources. Although any approach to the future energy needs of the Commonwealth must take into account research and development in technologies that have not yet come to maturity, the focus of this report will be identifying different forms of alternative energy and which of those would provide the greatest benefits to the citizens of the Commonwealth.

Any investment of time or money must be made in a technology that will provide concrete benefits to the citizens. With limited resources the Commonwealth must identify those technologies that will yield the greatest benefit for the state at the lowest cost. Any analysis performed must limit its scope. Although fuels such as hydrogen hold promise for the future, the focus of this report will be on those technologies that present economically viable options in today's market. Additionally, many forms of alternative energy are resource dependent. Some forms of alternative energy are effective in other states because those states possess a superior resource. When appropriate, this report will identify those technologies that are resource dependent and comment on the quantity and quality of the resource within in the Commonwealth.

Criteria for Evaluating Efficacy

Efficacy is the ability or power to produce a desired effect. Depending on the desired effect of implementing alternative energy technologies, the efficacy of any given option may vary. Listed below are several criteria that are frequently used to evaluate different alternative energy technologies.

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.

Environment: Although cost is a major factor, the environmental benefits of alternative 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 alternative 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. Even if a transportation fuel has a negative net energy balance, the energy needed to produce the fuel can come from domestic sources such as coal, hydro, and nuclear.

Payback Period: Rather than evaluating the energy balance associated with a given alternative energy, in situations where the technology is used to generate heat or electricity the best criterion for evaluating cost-effectiveness is the payback period. The payback period is the time it takes for the technology to produce enough electricity or energy to pay for itself.

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 alternative 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. Any discussion on how to save money on transportation fuel, electricity, and energy in general must begin with reviewing the concept of energy efficiency and conservation.

IV. ENERGY EFFICIENCY

Energy efficiency is best explained by understanding the concept that it is far cheaper to save a kilowatt than generate a kilowatt of electricity. Energy efficiency is arguably the least sexy way of increasing the energy and electricity supply but certainly the most cost effective solution.

Virginia ranked 15th in the United States in total energy consumption in 1999, with consumers spending $13 billion on energy.[1] The level of energy intensity in Virginia, the amount of energy consumed per dollar of gross state product (GSP) was 9.2 BTU/$. This compares with the national average of 10.3 BTU/$ for that year.[2] As a metric of energy efficiency, Virginia is ahead of the national average in terms of leveraging energy use to generate gross state product.

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

Two of the largest energy efficiency resources in Virginia are commercial and residential buildings.[3] 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.[4] Though minimum standards of energy efficiency for appliances are set at a federal level, the Commonwealth can encourage increased efficiency of these products through 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 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 power plants of 57 MW or enough to power 1,048 homes.[5] Virginia has millions of square feet of building space including state office buildings, hospitals, schools, and libraries. Energy savings of more than 20% are usually achievable by retrofitting these facilities with energy efficiency measures.[6]

V. TRANSPORTATION FUELS

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 most recent 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

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

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 nitrous 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 and the U.S. Department of Energy. 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.[7] 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.[8]

Ethanol

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 percent ethanol and 15 percent 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 2 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 percent 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 most recent cost analysis for E85 in the September 2005 Clean Cities Alternative Fuel Price Report:

	E85	**Gasoline**
Lower Atlantic	$2.50	$2.84

[7] *Life Cycle Inventory of Biodiesel and Petroleum Diesel for use in an Urban Bus: Final Report*. Sheehan, John, et. al. May 1998 (pg. 33)
[8] Regulatory Announcement from the EPA
[9] http://www.eere.energy.gov/afdc/afv/eth_vehicles.html (last visited on 11/16/05)
[10] Id.

National Average	$2.41	$2.77

Environment: The benefits of ethanol are slightly different than that 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.

Hydrogen

Hydrogen as an alternative form of energy has not come to maturity and will not do so without a high level of continued federal and private investment. In his State of the Union Address in January of 2003 President Bush announced his Hydrogen Fuel Initiative. The initiative received funding of $156 million in FY 2004 and 225 million in FY 2005.

Some of the challenges that face expanded use of hydrogen are safety issues, distribution facilities, cost of producing hydrogen, cost of fuel cells, and the energy demand of producing hydrogen on a large scale basis. Processing hydrogen into its elemental form using conventional energy sources results in a net energy loss. Consequently, one of the major factors behind expanding the use of hydrogen is that of energy independence. Coal, nuclear, wind, hydro, and other domestic and renewable resources can be used to make hydrogen for use in the transportation sector, which is almost exclusively petroleum based.

Given the relative infancy of the technology compared to other forms of renewable energy, supporting any initiative on the state level would not yield any short-term benefits to the Commonwealth. However, as more federal funding and support is invested in hydrogen, there may be partnership opportunities with the federal government that would be highly beneficial for the Commonwealth.[12]

Hybrid-Electric

Hybrid-electric vehicles entered the U.S. automobile market in 2000 and their numbers have steadily grown over the past five years. Starting at 9,500 in 2000, the number of

[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.
[12] See http://www.fueleconomy.gov/feg/fuelcell.shtml (last visited on 11/16/05) (see for more info)

new hybrids sold in 2004 was 100,000 and expected to double for 2005.[13] Car manufacturers are introducing new hybrid models every year and demand continues to grow.

VI. ELECTRICITY AND ENERGY GENERATION

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.[14] 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.[15] 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 on shore. Each of these categories has a different cost for electricity produced as well as a different payback period resulting from different installation costs and resource quality.

Cost: Utility On-Shore: The cost of electricity generated by wind turbines is currently around 5 cents per kilowatt hour, which includes the 1.5 cent per kilowatt Production Tax Credit (adjusted for inflation).[16] The price of electricity generated by modern wind turbines located in an area with a good resource is cost competitive with electricity generated by new coal or gas-fired plants.[17]

Cost: Utility Off-Shore:

Cost: Small-Scale:

Environment: Environmental critics of on-shore wind turbines typically focus on bird or bat kills, which studies show are far less frequent than with other man-made objects.[18] Other related environmental concerns such as noise and light flicker can be mitigated by

[13] http://www.iags.org/n011504t1.htm
[14] http://www.awea.org/faq/tutorial/wwt_statistics.html (last visited on11/18/05)
[15] http://www.jmu.edu/madisonscholar/feature005.shtml (last visited on 11/18/05)
[16] http://www.awea.org/faq/tutorial/wwt_costs.html (last visited on 11/18/05)
[17] Id.
[18] http://www.awea.org/faq/tutorial/wwt_environment.html#Bird%20and%20bat%20kills%20and%20other%20effects (last accessed on 11/18/05)

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 visual impact, commonly referred to as Not In My Back Yard (NIMBY), has been the primary environmental barrier to wind development across the U.S.

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 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.

Payback Period: Utility On-Shore:

Payback Period: Utility Off-Shore:

Payback Period: Small Scale:

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.[19] In counties such as Highland, with little economic development outside of the farming community generating tax revenue is a major priority.

One of the major challenges for offshore wind is anchoring the turbines to the seabed in deep waters. Offshore wind turbines employ essentially the same technology as offshore oil and gas platforms. As with other marine renewable resources, there would be a potential to take advantage of the shipbuilding and manufacturing industries in the Virginia Beach and Hampton Roads area.

Waste to Energy and Biomass

[Need to identify different technologies]

Cost:

Environment:

Energy Balance:

Cross-Industry Opportunities:

Solar

Solar energy is collected using two different processes: passive and photovoltaic. Passive solar energy encompasses a wide variety of devices and design techniques. One form of

[19] http://www.jmu.edu/madisonscholar/feature005.shtml (last visited on 11/18/05)

passive solar energy is as simple as elongating a residential home along an east-west axis thereby creating a large area of exposure to the south. By placing large windows on the southern side of the house and using tile or some other material with similar thermal properties, a homeowner will be able to benefit from the heat stored in the tile during the day.

Another popular means of passively collecting solar energy is through the use of flat plate collectors. Flat plate collectors are most frequently used to heat water and can be seen on the roofs of many homes in states with significant solar resources. These collectors have thermal properties that allow them to reach very high temperatures. Flat plate collectors circulate water over the heated surface and feed the water into a home's traditional hot water heater thereby reducing the amount of electricity or gas needed to heat water for a home.

A third form of solar energy is a utility scale system known as a concentrating solar power (CSP) facility. These facilities are typically located in remote or desert areas in the southwest and use large mirrors the focus sunlight at a tower which in turn uses the heat to create steam for a turbine.

In addition to passive solar devices and techniques, 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.[20] 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.

Cost:

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

Payback Period:

Cross-Industry Opportunities:

<u>Marine Energy Technologies</u>

Marine energy technologies are a broad class of energy converting devices that harness wave and tidal energy. These devices are currently in the pre-commercial testing phase

[20] http://www.eere.energy.gov/state_energy/technology_overview.cfm?techid=1#solarfp (last accessed on 11/8/05)

with small facilities being placed off the coast of several states. There is no current cost data available in the U.S. because there are no operating commercial units. Marine energy technologies may eventually become cost competitive with traditional sources of energy but the technology is still a decade away from becoming commercially feasible.

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 potential for future development.[21] 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.

VI. CONCLUDING OBSERVATIONS

VII. APPENDIX

[21] http://www.eere.energy.gov/state_energy/tech_hydropower.cfm?state=VA (last visited on 8/11/05)