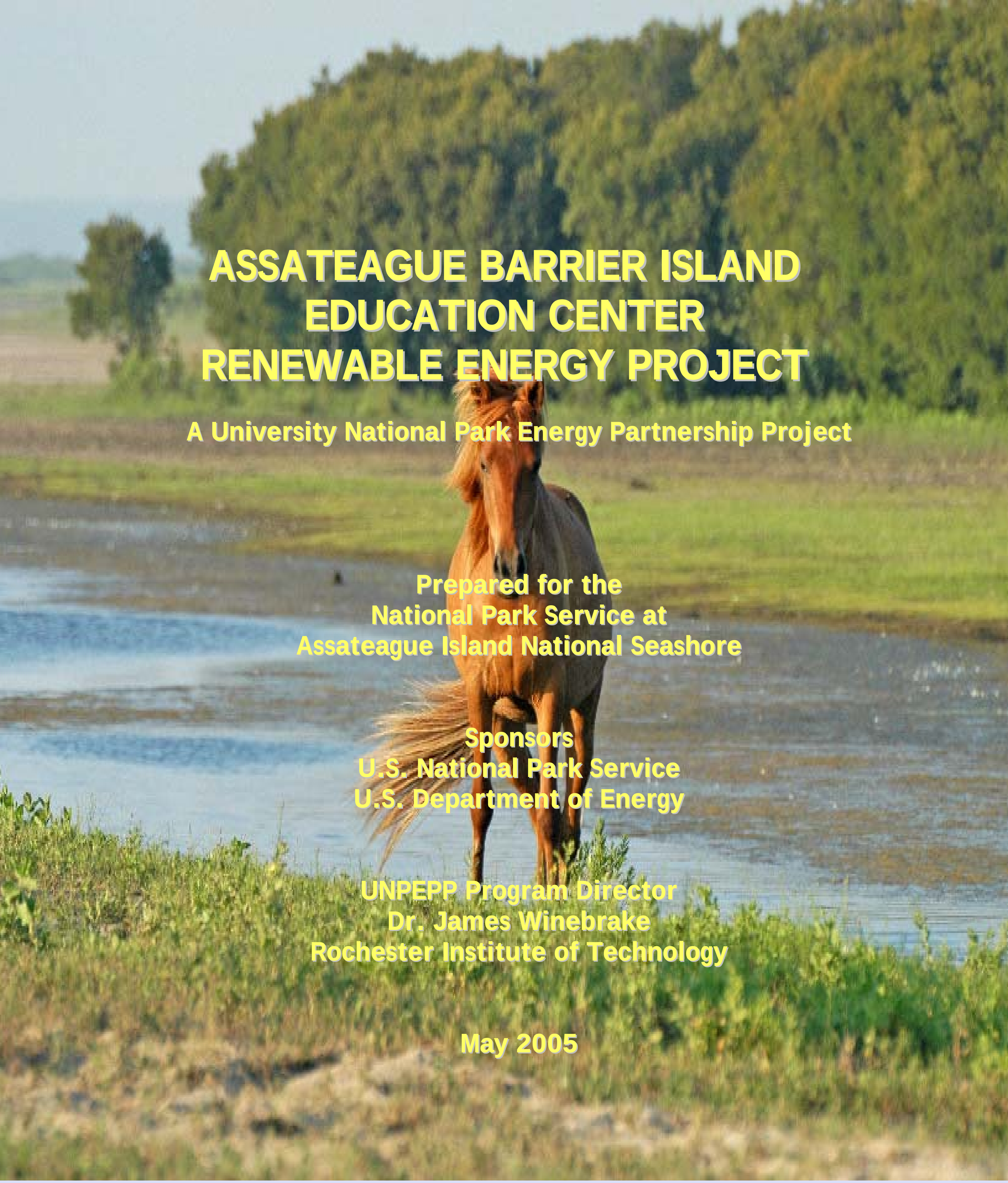

ASSATEAGUE BARRIER ISLAND EDUCATION CENTER RENEWABLE ENERGY PROJECT

A University National Park Energy Partnership Project

Prepared for the
National Park Service at
Assateague Island National Seashore

Sponsors
U.S. National Park Service
U.S. Department of Energy

UNPEPP Program Director
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May 2005

Center for Energy and Environmental Policy

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1. Introduction

Assateague Island National Seashore, a barrier island complex in Maryland and Virginia, contains over 37 miles of pristine beach. More than 300 wild ponies wander the beaches, inland pine forest, and salt marshes. It is administered to provide for recreational use and enjoyment consistent with the perpetuation and maintenance of the seashore's natural environment. The Maryland section of the Seashore, where this project is located, receives around 1 million visitors annually. As this park seeks to expand its educational capacity by providing a new Education Center, it is important that this center reflect the environmental values of the Park.

In this regard, the Education Center at the National Seashore is a highly appropriate place to install a renewable energy system that will help to meet the Center’s electricity needs in an environmentally benign way. In order for the system to bring about environmental, educational, and even economic benefits, its implementation needs an appropriate strategy. As the Education Center is not yet built, now is an ideal time to evaluate and advise on renewable energy and efficiency options.

The Assateague Barrier Island Education Center Renewable Energy Project evaluated several combinations of renewable energy and efficiency technologies to determine the economics of incorporating these environment-friendly options into the building design. This report describes these technologies and their economic and environmental benefits, discusses our technical and economic analysis, and presents results which Park Service staff may use to guide their energy and efficiency choices for the new building.

1.1 University National Park Energy Partnership Project

The University National Park Energy Partnership Project (UNPEPP), A Green Energy Parks program, was initiated in 1997 by the National Park Service, the Department of Energy’s Federal Energy Management Program, the Alliance to Save Energy, Shenandoah National Park and James Madison University. Since then, the program has expanded and now supports several university-national park partnerships each year. The program, currently sponsored by the National Park Service, the Department of Energy and Rochester Institute of Technology, provides “real world experience” for university students and provides valuable assistance to national parks in their efforts to reduce energy use (UNPEPP N.D.).

1.2 Goals of Study

The Assateague Barrier Island Education Center Renewable Energy Project seeks to address the future energy needs of the proposed Education Center through the use of energy technologies that are environmentally sound, of high efficiency, and cost-effective. The project will identify several cost-effective packages of renewable energy and efficiency measures.

As the Education Center developers wish to achieve a LEED rating with the building, the project has a goal of meeting 10% of the electricity needs of the building with renewable energy, which will earn 2 LEED points for the building.

2. Background

The Education Center, under the administration of the US National Park Service, is located in the Maryland district of Assateague Island National Seashore, a barrier island complex stretching across the upper and lower eastern borders of Virginia and Maryland respectively. The Seashore has proposed to build a new Education Center that will serve as the primary facility for visitor services in this part of the park. The proposed Education Center, located on the mainland, separated from the islands by a bay, will include a classroom and a theater, an educational exhibit hall including aquariums, staff offices, various spaces providing visitor services, and a restroom separated from the main building.

Figure 1: Life-Saving Station. Ocean City, MD.

The Center will be designed to resemble a turn-of-the-century life-saving station (see Figure 1). The area of the main building is to be 7,248 sq feet. There are two additional buildings, connected by covered walkways: a restroom and a seasonal classroom. The main building includes a 20 x 60 ft covered porch. The front of the building will be a glass wall to provide a good view of the bay.

The Center will be open year-round, from 8am to 8pm daily, and toilet facilities will be available 24 hours a day year-round. It is estimated that approximately 6 to 10 staff members and volunteers will be working at the center and that 5 to 150 visitors will be in the Center at any given time during open hours. As noted earlier, around 1 million people visit the Maryland side of the park annually. Peak visitation occurs in the summer and there is fairly low visitation in the winter. Main visitor activities include watching films and viewing exhibits.

Figure 2: Proposed Education Center. Source: Keith MacNeir

As the site is to be used as an eco-tourism/research destination, an integral aspect of this development is its energy requirements. In the Center, electricity will be needed to run a microwave, a refrigerator, a cash register, computers, printers, fax machines, aquarium pumps and lighting, air conditioning, and theater equipment. The most critical loads include the server, emergency lighting, exit lighting and the aquarium. The seasonal classroom (rectangular building in Figure 2) will have no heating or cooling, only ventilation and minimal plumbing. The energy requirements of the appliances and space conditioning services above can be at least partially addressed with renewable energy.

2.1 Renewable Energy in U.S. National Parks

Through the "Green Energy Parks Program," the United States federal government supports the use of sustainable alternative energy sources in its national parks. This program is jointly implemented by Department of Interior and Department of Energy in collaboration with the U.S. National Park Services. It promotes energy efficiency and encourages the use of renewable technologies by providing funding and technical assistance to the projects. In addition to the benefits of saving energy and thereby reducing expenditures as well as avoiding the release of pollutants directly or indirectly in order to serve NPS facilities, the goal of the program is to educate the visiting public about the benefits of these technologies. As of 2001, the National Park Service had over 700 photovoltaic applications in use that range from single modules powering monitoring stations to large systems like the 115 kW array at Glen Canyon National Recreation Area (NPS 2001). Although wind energy has not been used at that level, it could still provide reliable electricity alone or in combination with other sources. A successful example of such combination is the 22.6 kW Wind/PV hybrid system at Channel Islands National Parks in California (see Figure 3).

Figure 3: Ranger Station, Channel Islands N.P.
Source: http://www.p2pays.org/ref/20/19637.htm

2.2 Efficiency Technologies

Since this study required electrical load calculations to determine renewable energy system size and there is no actual data available for the proposed Education Center, efficiency technologies were studied to determine their impact on the potential building load, as it is likely that the Park Service staff will not produce a building of only average energy efficiency, especially considering its pursuit of a LEED rating.

2.2.1 Thermal Envelope of the Building Shell

The extent to which a building will store heat in the winter and allow for cooling in the summer is influenced by its materials and design. Certain materials have higher insulating (“R”) values than others. A building designed to be energy efficient (that is, to have decreased requirements for heating and cooling) will use materials with high R-values. Improved insulation keeps heat in or out of a building, as do tight construction and tight ducts. Energy can also be saved by using windows with improved frame materials, multiple glazings, glass coatings, gas fill, warm edge spacers or weather stripping.

2.2.2 Heating Ventilation and Air-conditioning (HVAC)

The proposed Education Center is expected to have a Ground Source Heat Pump (GSHP) for its HVAC system. The U.S. Department of Energy (DOE) recommends the use of a GSHP for climates that are cold in the winter and hot in the summer, like in Maryland, and explains that “ground-source heat pumps can provide an energy-efficient, cost-effective way to heat and cool Federal facilities” (2001). The DOE also offers that “a conventional water-source heat pump design is transformed to a unique means of utilizing thermodynamic properties of earth…in essence, the ground (or groundwater) serves as a heat source during winter operation and a heat sink for summer cooling” (2002). Due to these factors, a GSHP is less expensive to operate than almost all other heating and cooling systems, and should compliment a renewable energy system.

2.2.3 ENERGY STAR Appliances

ENERGY STAR is a program administered by the U.S. Environmental Protection Agency. Through ENERGY STAR, producers of energy-efficient appliances can label products so that consumers recognize their electricity-saving benefits. The EPA and DOE apply strict energy efficiency criteria to determine if a product can use the ENERGY STAR label. Products that have ENERGY STAR standards include computers, refrigerators, lighting, heating and cooling equipment, copiers, fax machines, televisions, printers, and scanners. To meet ENERGY STAR requirements, refrigerators must use 15% less energy than minimum government standards, office equipment must enter “sleep mode” after a period of inactivity, and light bulbs must use 2/3 less energy than conventional incandescent bulbs (EPA N.D.).

2.3 Renewable Energy Technologies

With an increasing degree of environmental degradation due to the use of conventional energy, renewable energy technologies have been employed as an alternative to meet energy demand. These technologies include photovoltaics, wind generation, solar thermal, geothermal, hydropower, and biomass power generation. Among them, this project explores the use of photovoltaics and wind energy generation.

The per kilowatt cost of electricity from a renewable energy system is often much higher than that of electricity provided by a utility based on today’s energy prices. However, installing a renewable energy system can be economically feasible when combined with a building design that improves energy efficiency and choosing more energy-efficient appliances to be used in the building.

2.3.1 Photovoltaic (PV)

Solar cells are made of semiconductor materials that convert sunlight directly into electricity, through a process called the photovoltaic effect. The first photovoltaic cells were used mostly as backup for satellites. It was in the 1980s that terrestrial applications took off as the industry began to mature. Since then, PV technology has expanded worldwide in diverse forms of application, from rural electrification of remote areas mostly in the developing world, to peak load shaving and integration in buildings design in the developed world.

PV technology has been developed successfully to a very high level. Cell efficiency is in the range of 15-18%. High reliability has been achieved with modules that last more than 20 years, and the average market growth for PV has been above 30% for the last decade (Byrne et al, 2004; Hegedus, 2003). Equipment has become easier to integrate into the design of new or existing buildings. The enhancement in technology is attracting investment in the market and reducing the overall cost of PV.

2.3.2 Wind Energy

Wind turbines produce energy by converting the natural power in blowing wind into mechanical energy. Besides its original mechanical applications of water pumping, irrigation, or sailing, wind has been used for electricity generation for small-scale off-grid applications (homes, farms, etc…) and large scale centralized grid-connected systems. Recent advances in technology as well as improved turbine performance and reliability have resulted in lowering the installed cost per kilowatt and the maintenance cost. Wind energy is the fastest growing and most economically competitive of all renewable sources.

2.4 Assateague Endangered Species and Renewable Energy

From early spring to August, Assateague Island National Seashore is home to the piping plover, (*Charadrius melodus*) a bird species listed as "threatened" under the Endangered Species Act. As such, it is crucial that any new development not harm the population that visits Assateague Island. Several ornithologists were contacted. Most of the birds' travel is likely to be on the island, but they do fly from the ocean beach-nesting habitat to more productive foraging habitat on the bayshore (Fraser, 2005; Jenkins, 2005). Piping plovers often fly without incident near buildings when they are located in between nesting and foraging areas (Fraser, 2005). As the Education Center is to be located inland from the bayshore, it is unlikely that piping plovers will be present in the area of the building. It was concluded that a renewable energy system is unlikely to negatively impact the piping plover population.

2.5 Approaches Taken

Meteorological, electrical, and financial data were collected. Meteorological data – solar, wind, and ambient temperature, specifically – were obtained from data sets assembled by NREL and NASA. Electrical load was estimated from such factors as the size and structure of the building, visitor and working hours, and appliances to be used. Financial data such as system costs and electricity rates were obtained from manufacturers and the utility.

Analyses were conducted for electricity outputs from renewable energy systems and for electrical load differences (in kW and kWh) through efficiency improvements of the building. RREAD (Rural Renewable Energy Analysis and Design Tool), software developed by Center for Energy and Environmental Policy (CEEP), was used for renewable energy output analysis (please see Byrne et al, 1998 for details). A spreadsheet model, called PV Planner, was also used to estimate the break-even cost of Photo Voltaic modules for the dispatchable configurations. PV Planner can easily and quickly assess the technical and economic performance of grid-connected PV applications. The model was developed at the University of Delaware's Center for Energy and Environmental Policy under a National Renewable Energy Laboratory contract (please see Byrne et al, 1995 for details).

Electrical loads were calculated for two scenarios—"Energy Efficient" and "Business as Usual"—from information on appliances with different efficiencies as well as by using software developed by the Architecture Energy Corporation of Boulder, Colorado to determine heating and cooling needs for the building. The electrical and economic differences between the two loads were determined to demonstrate the benefits of energy efficiency. Lastly, the economics of several combinations of hybrid renewable system coupled with efficiency improvements were analyzed by calculating Net Present Value, Cost-Benefit Ratio and Payback Year.

3. Data

3.1 Meteorological Data

Meteorological data needed for the analysis is hourly average global horizontal solar insolation, hourly average ambient temperature, hourly wind speed, and monthly wind speed distribution.

3.1.1 Solar Insolation

For global horizontal solar insolation, we used resource hourly data for one typical day in each month (288 records), which, according to tests, will produce nearly identical results as the analysis using 8,760 hours solar data. Global horizontal solar insolation and average ambient temperature were obtained from Typical Meteorological Year (TMY) data sets assembled by National Renewable Energy Laboratory (NREL). It provides estimates of these data based on 30-year records made at weather stations throughout the country. TMY data for Baltimore, the nearest area for which data was available, were used. See Figure 4 for monthly solar resource.

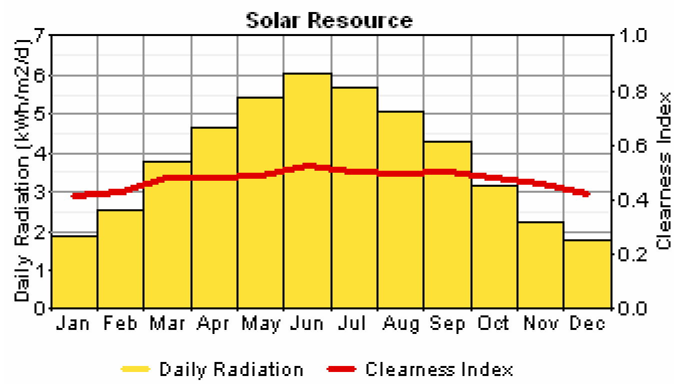

Figure 4. Monthly Solar Resource
Source: http://rredc.nrel.gov/solar/old_data/nsrdb/bluebook/

3.1.2 Wind Speed

For wind data, a Surface Solar Energy Data Set assembled by NASA provided average monthly wind speed data for exact locations at specific heights. Data used for this analysis is monthly averaged wind speed at 10 m above sea level for terrain similar to airports (m/s), at latitude 38.07 and longitude -75.2. Based on this monthly wind speed data, hourly wind speed data was calculated by HOMER. HOMER is a computer model developed by NREL that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone and distributed generation (DG) applications. It also has optimization and sensitivity analysis options to allow for evaluation of the economic and technical feasibility of renewable technology. After 8,760 hour wind speed data was obtained from HOMER, RREAD was used to calculate the monthly wind distribution, or number of hours each month during which wind blows at a certain speed, which is required for the estimation of output.

Wind resources are categorized into classes depending on the wind speed at specific height of measurement. In general, for cost effective wind electricity generation, a minimum of 13 mph or 5.8 meters per second (mps) wind speed is required. At a height of 10m above sea level, Assateague Island has a wind speed above 6 mps from November to March (NASA average monthly wind speed). This is a class 4-wind speed category, which is considered "good" for wind electricity generation. See Figure 5 for monthly wind resource.

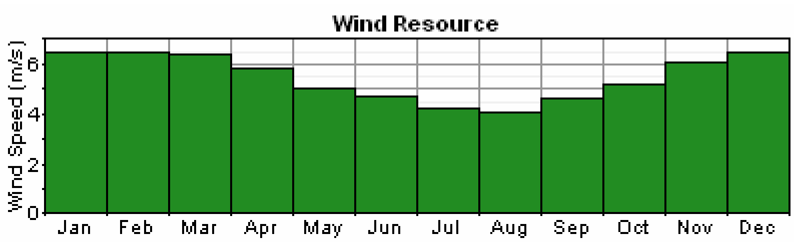

Figure 5. Monthly Wind Speed at 10 m for terrain similar to airports from NASA
Source: http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?na+s01#s01

Good solar radiation is available in summer when wind speed is low, and wind speeds increase in the winter when the solar resource is reduced. PV- or wind-only systems may have unsatisfactory output for parts of the year. Given the year-round availability of resources, a hybrid wind/PV system is well suited for providing the electricity need of Assateague Island. The hybrid systems can produce more energy and provide a steady level of service throughout the year.

3.2 Electricity Supply

The Education Center will be connected to the grid and served by a local utility, Choptank Electric Cooperative, which purchases its energy from Old Dominion Electric Cooperative. The primary sources of electricity for the Cooperative are coal (57%) and nuclear (29%). Oil (7%), gas (4%) and hydropower (3%) are important sources of electricity as well (see Figure 6).

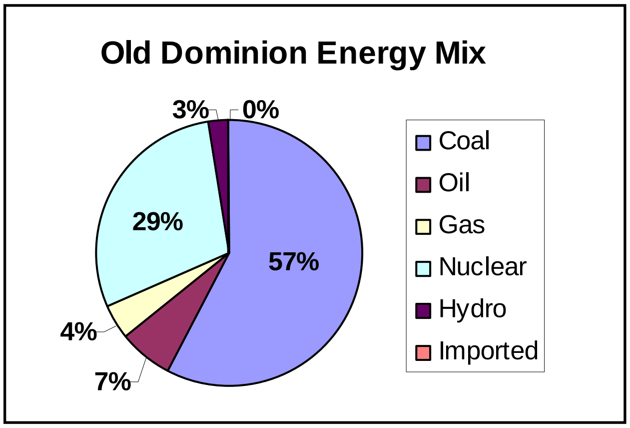

Figure 6. Fuel mix for Assateague.

3.3 Emissions Data

Conventional sources of energy such as coal, oil and gas emit harmful gases – NO_x, SO_x, and CO_2 – when burned in power plants for electricity. NO_x and SO_x both seriously damage human health and are causes of acid rain, which is associated with the acidification of soils, lakes, and streams and accelerated corrosion of buildings and monuments. NO_x is also one of the greenhouse gases, which cause global warming by trapping heat in the atmosphere. CO_2 is the primary greenhouse gas.

Renewable energy systems are free from emissions of these harmful gases when generating electricity. The amount of emissions to be displaced from the grid by the installation of renewable energy system and efficiency measures can be estimated from the kilowatt hours generated with renewable energy and kilowatt hours avoided by efficiency measures, and the fuel mix of the displaced energy (Figure 6), and the emissions factors for the different fuels that are being avoided (see Table 1).

Table 1: Emissions for Fuel Types

Source	**Average Heat Rate (BTU/kWh)**	**SO_X Content (gram/MBTU)**	**NO_X Content (gram/MBTU)**	**CO_2 Content (gram/MBTU)**
Coal	11500	3.4	0.8	202
Oil	9800	1.42	0.5	165
Gas	7800	0	0.3	117
Nuclear	10000	0	0	0
Hydropower	0	0	0	0

Source: CEEP 1996.

3.4 Financial Inputs

PV and wind system performance and cost, as well as financial data and utility rates were collected for the analysis.

Performance and cost of PV systems are varied and thus, what are considered to be mid-range values for cost and average performance were used for analysis. The installed cost for PV used in this analysis is $7,000/kW (SEIA 2004). The wind component costs $1,058 (including shipping and an inverter) per 300 W wind turbine (CNATIEC 2005). Operation and maintenance costs of both systems were estimated based on what is generally considered to be average. For PV, O&M was assumed to be 2% of initial capital costs, annually (Moore 2004, Lenardic 2004). For wind, O&M was assumed to be 2% of initial capital costs, annually (DWIA 2003, Sagrillo 2002).

The electricity rate was obtained from Choptank Electric Cooperative. Having a demand of less than 100 kW, the proposed Education Center would be on the General Service-Small rate that is 5.003 cents per kWh for energy charge and $7.18 per kW for demand charge (see Appendix A).

In State of Maryland, there are no financial incentives available for installation of renewable energy system at federal facilities except net metering, which is applicable to PV and wind system up to the size of 80 kW. Net metering enables customers to use their own generation to offset their consumption by allowing their electric meters to turn backwards when they generate electricity. This offset means that customers receive retail prices for the excess electricity they generate.

The cost of upgrading a building from a standard shell to a high efficiency design was estimated at $16,539. The initial cost for energy efficient appliances is $1,063 more than the cost of standard appliances. See Table 2 for cost estimate information.

Table 2: Cost of Upgrade to Energy-Efficient Scenario

Insulation	Business as Usual Building R-value	Thick/ inch	Cost	"Energy-Efficient" Building R-value	Thick/ inch	Cost	Upgrade Cost
9,624 sq. ft. walls	11	3.44	$2,791	21	6.56	$5,293	$2,502
8,544 sq. ft. slab	10	3.13	$2,221	25	7.81	$5,554	$3,333
14,160 sq ft ceiling & roof	25	7.81	$9,204	32	10	$11,753	$2,549
	$25 per square foot			$30 per square foot			
Windows	U-value	SHGC	Cost	U-value	SHGC	Cost	
1,631 sq. ft. windows	0.4	0.5	$40,775	0.35	0.35	$48,930	$8,155
Insulation*+ window cost			$54,991			$71,530	$16,539
Appliances	W	kWh	Cost	W	kWh	Cost	
Lighting	16,208	62,565	$445	4,952	17,128	$1,488	$1,043
Refrigerator	180	481.6	$709	180	438	$729	$20
Microwave	1100	147.1	$99	650	87	$99	
****Computer**	259	2271		46	399		
****Printer**	110	738		88	576		
****Copier**	174	1523		111	974		
****Fax Machine**	43	377		3	26		
****Cash Register**	47	25		14	7		

Cost of building B, $200 per square feet x (8,544 sq.ft.) equals $1,708,800
(excluding landscaping, walks, roads, and parking)

Total Cost of Upgrade to Efficiency $17,602

*As a complete set of specifications do not exist at this time, only one type of insulation, cellulose, is used for our estimates. When the building is constructed, it may have more than one type of insulation in it, matching standard types of insulation to typical configurations of building components. However, for calculating heating/cooling loads, and costs, estimating the use of cellulose with an R-value of 3.2 per inch at an installed cost of $1.00 per cubic foot should allow for cost estimates similar to those for several combinations of building components and insulation. Virtually the same R-values may be achieved in many ways. The REM/Rate software used for calculating heating and cooling loads used standard combinations of building materials and insulation. Its estimate included the R-values and air infiltration rates for all building components.
**For several appliances, including computers, printers, copiers, fax machines and cash registers, costs were found not to be greatly affected by efficiency, and therefore it is impossible to compare the costs of upgrading to efficient appliances.

4. Scenario Analysis

4.1 Efficiency Scenarios

Two scenarios with different electricity consumption for the proposed center were created and compared. From these two scenarios, electrical load was estimated from the size and structure of the building, visitor and working hours, and appliances to be used.

- A “business-as-usual (BAU)” scenario represents appliances with typical energy-efficiency ratings, and increased heating and cooling needs due to a much less energy efficient building. This building would minimally meet energy building codes.

- An “energy-efficient” scenario represents appliances and indoor lighting as being Energy Star rated, with extra insulation and high performance windows, enabling heating and cooling needs to be kept at a minimum. The building envelope R-Values, window U-Values, and window shading heat gain coefficients (SHGC) would be more energy-efficient in this scenario. If the Energy-Efficient scenario Education Center is constructed, and then tested by the DOE/EPA Energy Star Home Program, it could easily achieve the top rating of “5 Stars Plus” (REM/Rate, 2005).

4.1.1 Resistance to Heat Gain or Loss

The heating and cooling load analysis was performed using the Architectural Energy Corporation of Boulder, Colorado’s “REM/Rate software v11.31 Expanded Rating Score.” It automatically estimates passive solar gains that undesirably contribute to cooling loads. Also, it estimates many other things, like friction losses and air leakage in ducts that impact the performance of the GSHP HVAC system.

Peter Smith, an Energy Rater for the EPA/DOE ENERGY STAR Homes program, estimates that the average ratio of windows to wall area is 20% (Smith, 2005). The proposed Education Center is estimated to have 17% glass-to-wall area. Most of the glass will be facing south and protected by a large roof overhang. The overhang will screen out much of the passive solar heat gain in the summer (thus not increasing the cooling load drastically), while in the winter passive solar energy may be gained due to the winter sun’s lower azimuth (thus reducing the heating load).

There is estimated to be only 322 square feet of doors (other than ones with glass being counted as windows), which reduces heat loss. The designs do not contain any skylights (or horizontal glass), which tend to gain and lose heat at the wrong times of year in terms of energy-efficiency.

The following is a comparison of the “Resistance to Heat Gain or Loss” (R-Values):

- The BAU Center has walls = R-11, slab = R-10, and ceiling and roof = R-25.
- Energy-Efficient Center has walls = R-21, slab = R-25, and ceiling and roof = R-32.

Please note that the building envelope for the Energy-Efficient scenario has approximately twice the R Value of the BAU scenario.

The windows in the building for the Energy Efficient scenario are also much more energy-efficient. Their U-Value (which is a reciprocal of R-Value, but on a scale of one) is 0.35, and the shading heat gain coefficient (SHGC) was also estimated to be 0.35.

Due to these differences in thermal envelope, in the efficient scenario, 15.6 MMBtu of cooling is required annually, compared to 21.1 MMBtu for the BAU scenario.

Water heating requirements are assumed to be the same in both scenarios: 6.5 MMBtu annually.

4.1.2 Appliances

The appliances to be used in the building were determined through consultation with staff members of the existing visitor center on the island. Load for each appliance was assumed based on the information on a typical appliance, and from information from the Federal Energy Management Program website (http://www.eere.energy.gov/femp/technologies/technologies.cfm).

For the "Energy-Efficient" scenario, a small Sharp microwave, operating at 650W was assumed. In the BAU scenario, a larger Sharp microwave, operating at 1100W was assumed. It was assumed that the microwaves would be running more in the summer, when there are more employees at the center, and more around breakfast and lunchtime.

The refrigerators chosen for the analysis were General Electric refrigerators of 17.9 cu.ft. The least efficient model used 481kWh yearly, the most efficient 438 kWh. It was assumed that both operate at 180 W, and that the inefficient is in use 7.3 hours/day, and the efficient 6.7 hours/day.

The same 850W Sanyo coffee-maker was used in both scenarios. It was assumed that use would peak between 8 and 10 am, and continue sporadically throughout the day.

The load assumed 3 computers would be used. The efficiency scenario computers run on around 15 watts and the BAU computers run on around 29 W (FEMP 2005b). Computer use is assumed from 7am to 9pm, peaking from 9-5, and not varying with season.

Two printers were included from the load analysis. The efficient printers use 16 W, the inefficient 42 W (FEMP 2005b). Printers are in use from 7am to 7pm, and use peaks in the summer, as they may print out information for visitors.

One copier was assumed. The efficient copier runs on 111 W, the inefficient on 174 W (FEMP 2005b). Use is from 7am to 8pm.

One fax machine for the office was included. The efficient fax machine operates on 3 W, the inefficient 43 W (FEMP 2005b). Load peaks from 9am to 6pm.

It was assumed that one cash register would be used. For the efficient scenario, the cash register runs on 14W, in the inefficient, 47W (FEMP 2005b). Cash registers run from 8am to 9pm and use is much heavier in the summer months.

Finally, it was assumed that employees would bring some small appliances to work with them. An extra 20 W was added onto the load for employees' cell phone chargers, radios, etc. The peak use of these appliances would occur during working hours.

The specialized equipment required for the aquarium and the theater were assumed to be the same under both scenarios. The two 500 gallon aquariums each require 1000 W lighting, a 190 W chiller, and a 390 W pump (AquaDirect 2004). Maximum load for the aquarium is 3160 watts. The theater is assumed to use a 330 W projector and 600 W of audio equipment (CPRSG 2004). Maximum load from the theater is 930 W.

4.1.3 Lighting

Estimated lighting load per square feet was multiplied by the total area of the building excluding the area of the theater. Lights are assumed to be on from 7am to 9pm. Theater lighting was assumed to be minimal, in use only when people are entering or exiting the area. The lighting outdoors which is not to be directly run on renewable system, includes motion sensor lighting by doors in the center, and flood lighting. Lighting for the efficient scenario was provided by compact fluorescent bulbs of 60 lumens that use 15 Watts. For the BAU scenario, 60 Watt incandescent lightbulbs only were used. The efficient scenario had 3,072 W of installed indoor lighting while the BAU scenario had 12,288 W.

In regards to outdoor lighting, it is assumed that there is no difference between the efficient and BAU scenarios. The outdoor lighting requirement is around 2 MWh yearly.

4.1.4 Overall Electrical Loads

The BAU Education Center uses 87, 504 kWh annually, has a maximum demand of 35.4 kW, and an average load of 10 kW. The "energy-efficient" Education Center will use approximately 37,286 kWh annually, with maximum demand of 26.6 kW and an average load of 4.3 kW. See Figure 7 for average daily load by month for both scenarios.

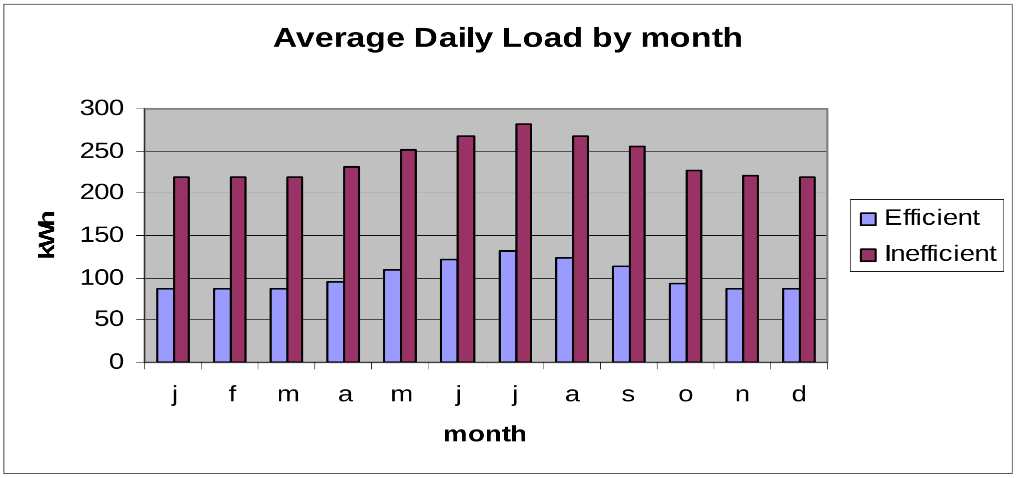

Figure 7: Average Daily Load, "Energy-Efficient" and BAU

4.2 System Sizing and Composition

Systems sizes for our analysis were selected from viable PV and wind combinations determined by RREAD, based on their ability to meet the project's goal of 10% building energy being provided by renewables.

RREAD considers that output of the PV system is proportional to the size of the PV module. Changing the size of PV, the software can determine the monthly output of PV.

In terms of output of wind power, several kinds of wind turbines were compared based on performance at specific wind speeds, as well as installation costs. RREAD uses power performance curves of specific turbines to make an estimation of output. The power of turbines at different wind speeds is required for RREAD. For more information on RREAD, please see Appendix B.

Analysis showed that small wind turbines below 1 kW are most appropriate for the local wind speed. Taking price and performance into consideration, 200 W and 300 W wind turbines made in China were chosen for the analysis. Turbines appropriate for the Assateague site are not yet manufactured in the U.S. These products are widely used for off-grid rural electrification projects in developing countries. With the low price and good performances at low and middle speed, these turbines provide electricity very well.

The price and performance are listed in the following tables. The average wind speed of Assateague Island ranges from 4.1 (summer) to 6.5 (winter) m/s. The wind turbines chosen perform well at low and modest wind speeds suitable for local resources. From the Table 3, we can see that the power increases dramatically at the low wind speed.

Table 3: Turbine Performance at Various Wind Speeds

Wind Speed (m/s)	2	3	4	5	6	7
300 W Turbine	24W	30W	60W	105W	170W	250W

Source: (CNATIEC 2005).

4.3 Net Present Value, Benefit-Cost Ratio and Payback Year Calculations

The costs of efficiency measures and renewable energy were determined for each year of the 25-year study period. These costs include initial capital costs, replacement costs for efficient appliances (as the difference between these costs and those costs for the BAU scenario) and renewable energy components and operation and maintenance costs. Costs for each year were added and a discount rate of 4.9% (the FEMP discount rate, valid for energy and water conservation and renewable energy analyses conducted between April 1, 2005 and March 31, 2006) was applied (FEMP 2005a). Benefits were calculated through determining the value of the displaced electricity that is given to the National Park through net metering. A 3% electricity price escalation rate was applied, and annual benefits were discounted by 4.9%. To determine the net present value, the discounted costs and benefits were both summed for the 25-year period (producing net present costs and benefits) and then the net present costs were subtracted from the net present benefits. The benefit-cost ratio was determined by dividing the net present benefit by the net present cost. The payback year was calculated as the year in which the cumulative discounted benefits exceeded the cumulative discounted costs.

5. Results

5.1 Efficiency Measures

If the building were to upgrade from the BAU to the "Energy-Efficient" scenario, the project would have a strongly positive net present value (see Table 4). While the initial costs of such an upgrade would be around $17, 600 more than having a standard building shell, appliances and lighting, this cost would pay itself back in three years. The benefits of the efficiency measures include electricity cost savings of around 50,000 kWh annually and replacement cost savings from longer lasting light bulbs.

Table 4: Performance of Efficiency Measures over 25 Years

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$17,600	4.95	3	$69,492

5.2 Renewable Energy without Efficiency Measures

In the BAU scenario, the building would consume 87,500 kWh. To meet 10% of the buildings electrical needs with renewable energy, system output would have to be at least 8,750 kWh. Several combinations of photovoltaics and wind power can provide these kWh.

5.2.1 Photovoltaics Only (4.6 kW PV)

A 4.6 kW photovoltaic system would be required to meet 10% of the building's needs.

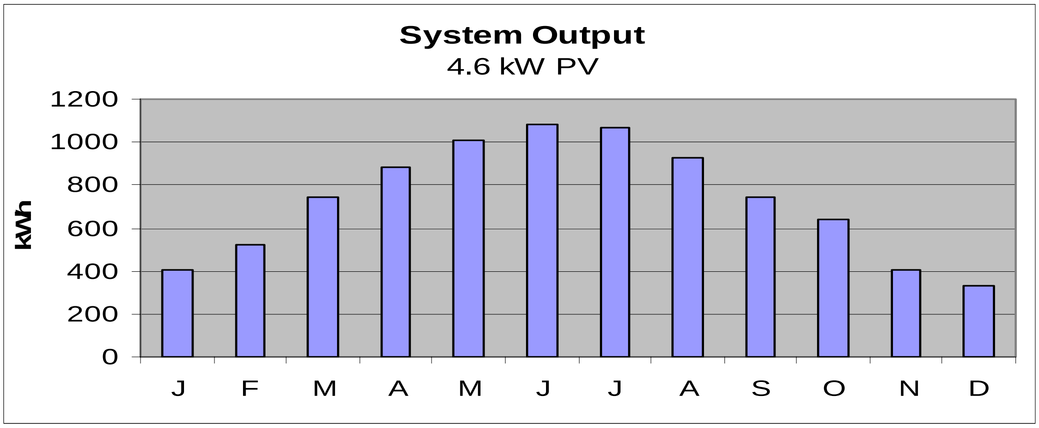

Figure 8: PV System Output

The initial cost of the system is $32,200. The annual output of the system is 8,769 kWh. The net present costs outweigh the net present benefits (see Table 5).

Table 5: PV System Only (4.6 kW)

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$32,200	0.3	N/A	-$28,886

5.2.2 Wind Only (10 300W (3.0 kW) Wind Turbines)

Ten 300 W turbines would be required to meet 10% of the buildings electricity needs.

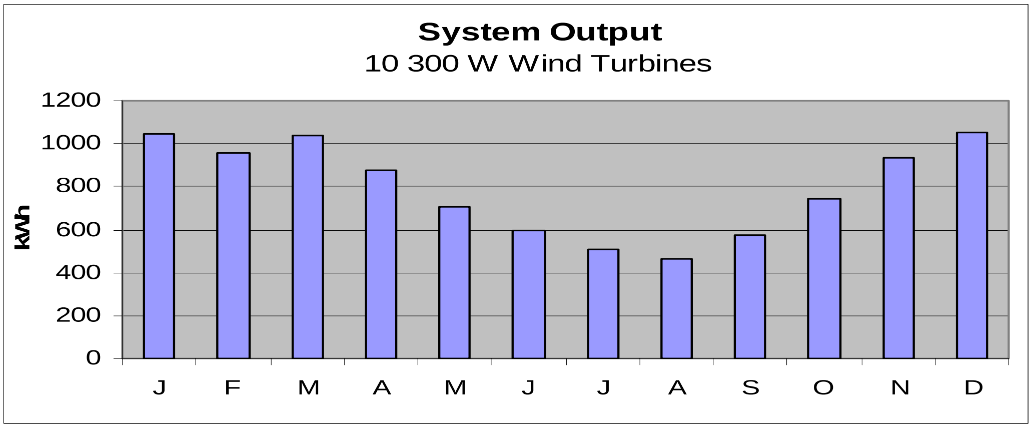

Figure 9: Wind System Output

The initial cost of the system is $10,580. The annual output of the system is 9,504 kWh. Table 6 summarizes additional economic information.

Table 6: Wind System Only (10 300W (3.0kW) Wind Turbines)

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$10,580	0.72	N/A	-$5,289

5.2.3 Hybrid Systems

CEEP has pioneered the analysis of Wind-PV hybrid systems for off-grid electrical generation. Often, the two remarkable sources furnish combined electrical outputs that yield stable monthly supply levels.

1.6 kW Photovoltaics and 6 300W (1.8 kW) Wind Turbines

This combination provides wind and solar energy in an approximate 1:1 ratio of installed capacity.

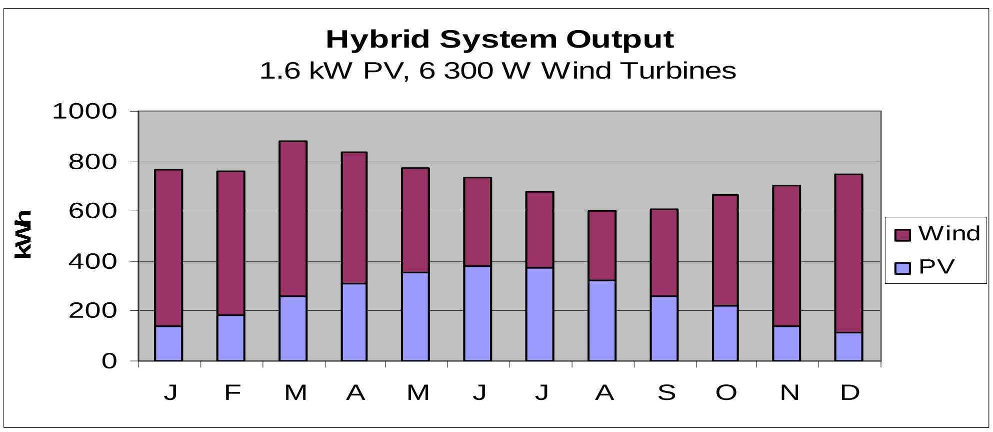

Figure 10: Hybrid System Output

Figure 10 shows the estimated monthly outputs from this PV and wind system over the course of a year and demonstrates the seasonal complementary relationship of these two resources.

The annual output of the system is 8,753 kWh. Economic information can be found in Table 7 below.

Table 7: 1.6 kW PV and 6 300 W (1.8 kW) Wind Turbines

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$17,548	0.51	N/A	-$12,616

3.1 kW Photovoltaics and 3 300 W Wind Turbines

The annual output of the system is 8,761 kWh. The increase in size of the more expensive technology, PV, affects the NPV and BCR (see Table 8).

Table 8: 3.1 kW PV and 3 300 W Wind Turbines

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$24,874	0.40	N/A	-$20,232

5.3 Renewable Energy and Efficiency Measures

By coupling the benefits of efficiency measures with renewable energy measures, an environmentally friendly energy package with a positive net present value can be obtained for a variety of combinations of photovoltaics and wind power.

5.3.1 Photovoltaics with Efficiency Measures (2 kW PV System)

A photovoltaic system size of around 2 kW would be required to meet 10% of the electricity needs of the center. The initial costs of the renewable energy component of this energy improvement would be around $14,000, while initial costs of all improvements (efficiency and renewables) is $31,591 (See Table 9). The annual output of this system is 3,812 kWh. This combination of renewable energy and efficiency measures produces a strongly positive NPV.

Table 9: 2 kW PV

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$31,591	2.60	8	$56,938

5.3.2 Wind with Efficiency Measures (4 300 W (1.2 kW) Turbines)

The initial cost of the renewable energy system alone is $4,232. The annual output of this system is 3,801 kWh. This system is most economically attractive package of efficiency improvements and renewable energy found in this analysis (see Table 10).

Table 10: 4 300 W Turbines

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$21,823	3.69	4	$67,429

5.3.3 Hybrid Systems with Efficiency Measures

3 300 W (0.9 kW) Wind Turbines, 500 W Photovoltaics

The initial cost of the renewable energy system alone is $6,675. The annual output of this system is 3,804 kWh. With an NPV of $64,736, this is the most economically beneficial of the hybrid systems studied (see Table 11).

Table 11: 3 300 W Wind Turbines, 500 W PV

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$24,265	3.33	6	$64,736

2 300 W (0.6 kW) Wind Turbines, 10 kW Photovoltaics

The initial cost of the renewable energy system itself is $9,116. The annual output of this system is 3,807 kWh. By increasing the share of PV in this system over the above hybrid system, payback time is increased by one year (see Table 12).

Table 12: 2 300 W Wind Turbines, 10 kW PV

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$26,707	3.04	7	$62,136

1 300 W (0.3 kW) Wind Turbine, 1.5 kW Photovoltaics

The initial cost of the renewable energy system alone is $11,558. The annual output of this system is 3,810 kWh. Though this system has a lower BCR and NPV than the system above, it will also recover investments in seven years (see Table 13). While the NPV of this configuration is modestly lower than other hybrid options investigated for this report, there is greater ease of siting the system (because there is only one wind turbine needed) and its reliability may be greater (because solar radiation tends to exhibit less hourly and daily variation).

Table 13: 1 300 W Wind Turbine, 1.5 kW PV

Initial Cost	Benefit-Cost Ratio	Pay Back Year	Net Present Value
$29,149	2.8	7	$59,537

5.4 Emissions Reductions

By implementing any of the above improvements in efficiency or installations of renewable energy technology (R.E.), emissions are greatly reduced from those that would occur under the BAU scenario (see Table 13). In the BAU scenario, 2.05 metric tons of SO_X, 0.5 metric tons of NO_X and 129.5 metric tons of CO_2 would be emitted annually in the production of energy for this building. With efficiency measures however, emissions of 1.18 metric tons of SO_x, 0.29 metric tons of NO_x, and 73.75 metric tons of the greenhouse gas (CO_2) are avoided annually. This represents a 58% emissions reduction from those that would occur under the BAU scenario. The greatest emissions reductions (62% below BAU) occur when both efficiency measures and renewable energy are employed: Annual emissions are reduced by 1.26 metric tons SO_X, 0.31 metric tons NO_X, and 79.81 metric tons of CO_2.

Table 14: Annual Building Energy Usage and Emissions

R.E. and Efficiency Options	kWh	SO_X (metric tons)	NO_X (metric tons)	CO_2 (metric tons)	Emission Reduction from BAU
BAU	87,500	2.05	0.5	129.5	0%
Energy-Efficient	37, 286	0.87	0.21	55.25	58%
10% R. E. & BAU	78,750	1.84	0.45	116.57	10%
10% R.E. & Energy-Efficient	33,557	0.79	0.19	49.69	62%

Further, with efficiency measures, emissions of 29.4 metric tons of SO_x, 7.2 metric tons of NO_x, and 1,857 metric tons of CO_2 are avoided over the lifetime of the system. With both efficiency measures and renewable energy, lifetime emissions are reduced by 31.5 metric tons SO_X, 7.7 metric tons NO_X, and 1,996 metric tons of CO_2.

6. Conclusions and Discussion

This study has investigated renewable energy and efficiency options for the Assateague Barrier Island Education Center. The low cost of grid-supplied electricity can make the use of photovoltaics and/or wind energy seem economically unattractive. However, when coupled with efficiency improvements of the building, the use of renewable energy systems becomes cost-effective, and produces payback periods of less than 10 years. The study also found that the proposed center can be easily upgraded to include efficiency measures.

Solar and wind resources at Assateague Island National Seashore were found to be satisfactory to meet the targeted amount of electricity, which is 10% of electricity needs of the building. Five renewable energy systems coupled with efficiency improvements, were determined to have positive net present values and payback periods of less than 10 years.

A system of wind turbines only (4 300 W turbines) is the most economically beneficial, having a net present value of $67,429, and a payback period of four years.

The most expensive renewable energy system, PV only (2 kW), when coupled with efficiency measures has a net present value of $56,938, and pays back investments in eight years.

Of the hybrid systems, the combination of 3 300 W wind turbines and 500 W photovoltaics was found to be the most economically favorable with a six year payback period and a net present value of $64,736.

A system of two 300 W turbines and 1.0 kW PV has a payback period of seven years and a net present value of $62,136, and a hybrid system consisting of 1 300 W (0.3

kW) wind turbine and 1.5 kW PV also has a payback period of seven years with a net present value of $59,527.

If siting considerations and reliability of supply are important, the hybrid configuration involving 1.5 kW of PV and a single 300 W wind turbine may be the most practical. In addition to reduced energy costs, the use of efficiency measures and renewable energy benefits the natural environment by avoiding the emissions of harmful gases such as SO_X, NO_X, and CO_2. Environmentally friendly energy choices are compatible with the NPS mission of conserving natural resources and wildlife.

Taking into consideration the economical, environmental, and educational benefits found by this analysis, this study suggests that Park Service staff should consider an environmentally enhanced building that includes higher energy efficiency measures than would be found in a typical building, and renewable energy systems that are prominently displayed.

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8. Appendix A

Assumptions

PV costs (per kW installed)	$7,000
Wind costs (per 300W turbine)	$1,058
Electricity escalation rate	3%
Discount rate	4.9%
Annual maintenance	
PV	2% of initial cost
Wind	2% of initial cost
Power Conditioning System Overhaul	$150 every 20 years
Wind Turbine replacement	every 15 years
Period of analysis	25 years

9. Appendix B

RREAD

The data input module of RREAD (See Byrne et al, 1998 for details) consists of six sets of data: a renewable energy resource profile, household load data, technical specification of system configuration, system costs, financial data and policy scenario information. TMY and hourly wind data are required for the renewable energy resource profile description.

RREAD estimates hourly energy output of a PV array and/or wind turbine for an entire year. For PV output, global horizontal irradiance, DC conversion efficiency of a PV array, the size of the array, and ambient temperatures are used in an algorithm found within the model to estimate hourly production values during a year.

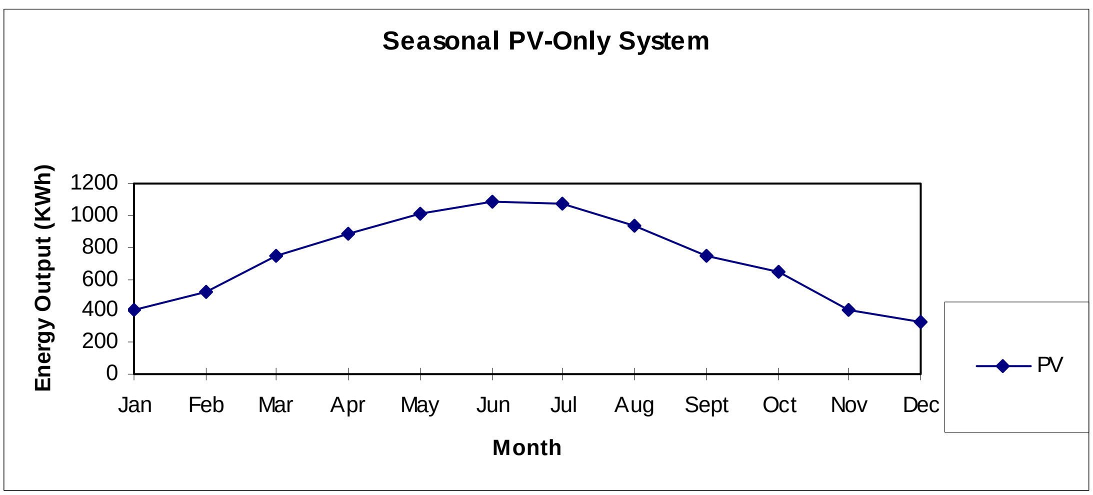
For wind turbine output, hourly wind speeds measured at hub height and the turbine’s power curve are used to estimate hourly production values throughout an entire year. Since significant variations in wind speed can occur from one year to the next, a multiple-year wind database is needed to produce an accurate wind profile.

10. Appendix C

Monthly Output for Selected Renewable Energy Systems

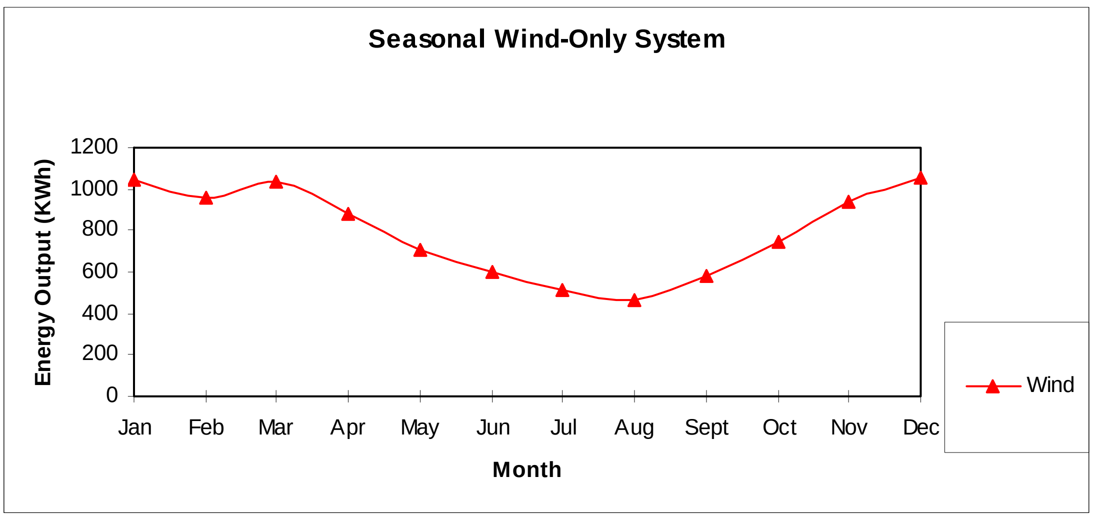
i) 4.6 kW PV (only) system

Month	**System Output (kWh)**
Jan	405.19
Feb	522.64
Mar	743.25
Apr	884.84
May	1011.64
Jun	1083.42
Jul	1067.83
Aug	929.12
Sept	746.17
Oct	639.24
Nov	406.62
Dec	329.01
Total Power	**8768.97**



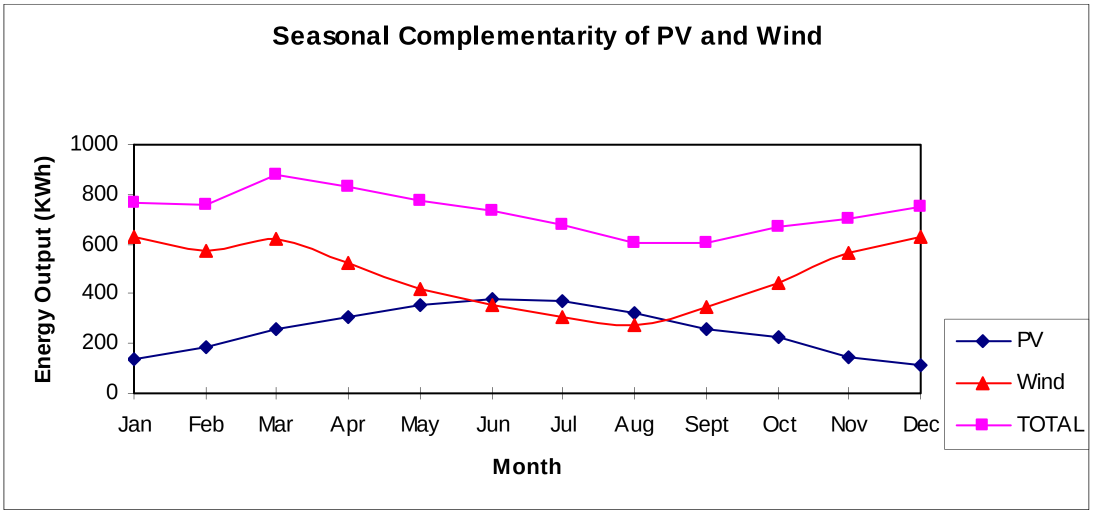
ii) 10 300 W wind (only) system

Month	System Output (kWh)
Jan	1044.24
Feb	958.22
Mar	1038.99
Apr	877.11
May	705.02
Jun	596.13
Jul	509.9
Aug	463
Sept	576.13
Oct	741.81
Nov	938.49
Dec	1055.01
Total Power	**9504.05**



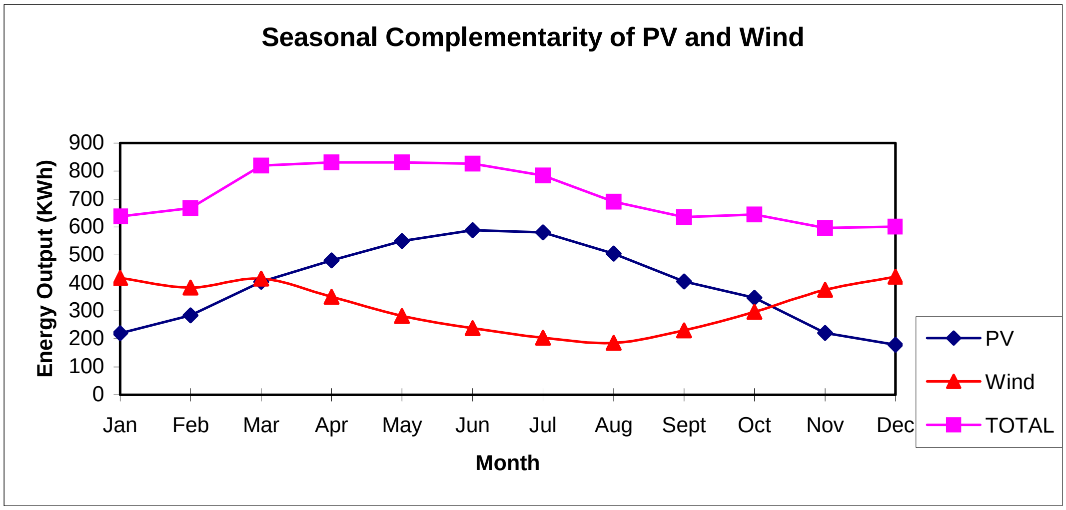
iii) 1.6 kW PV and 6 300W Wind turbines

Month	PV (kWh)	Wind (kWh)	System Output (kWh)
1	140.93	626.54	767.47
2	181.79	574.93	756.72
3	258.52	623.4	881.92
4	307.77	526.27	834.04
5	351.87	423.01	774.88
6	376.84	357.68	734.52
7	371.42	305.94	677.36
8	323.17	277.8	600.97
9	259.54	345.68	605.22
10	222.34	445.09	667.43
11	141.43	563.09	704.52
12	114.44	633.01	747.45
Total Power	**3050.06**	**5702.44**	**8752.5**



iv) 2.5 kW PV and 4 300W Wind turbines

Month	PV (kWh)	Wind (kWh)	System Output (kWh)
1	220.21	417.7	637.91
2	284.04	383.29	667.33
3	403.94	415.6	819.54
4	480.89	350.84	831.73
5	549.8	282.01	831.81
6	588.81	238.45	827.26
7	580.34	203.96	784.3
8	504.95	185.2	690.15
9	405.53	230.45	635.98
10	347.41	296.72	644.13
11	220.99	375.39	596.38
12	178.81	422	600.81
Total Power	**4765.72**	**3801.61**	**8567.33**



v) 3.1 kW PV and 3 300W Wind Turbines

Month	PV (kWh)	Wind (kWh)	System Output (kWh)
1	273.06	313.27	586.33
2	352.21	287.46	639.67
3	500.89	311.7	812.59
4	596.3	263.13	859.43
5	681.76	211.51	893.27
6	730.13	178.84	908.97
7	719.63	152.97	872.6
8	626.14	138.9	765.04
9	502.86	172.84	675.7
10	430.79	222.54	653.33
11	274.03	281.55	555.58
12	221.73	316.5	538.23
Total Power	**5909.53**	**2851.21**	**8760.74**