ABSTRACT

Title of Document: IDENTIFICATION AND ASSESSMENT OF POTENTIAL WIND ENERGY PROJECT SITES IN THE STATE OF MARYLAND

Erin M. Conroy, David A. Green, Phillip M. Hannam, Matthew R. Kosmer, Alexander S. Meiseles, Emma K. Roach, Sumegha K. Singhania, Amy D. Zhang

Directed By: Professor Jungho Kim, Mechanical Engineering

The international scientific community has reached consensus that greenhouse gas emissions must be reduced to minimize global climate change impacts on the environment, economy, and public health. In 2007, the University of Maryland's Climate Action Plan Workgroup was tasked with charting the University's path toward carbon neutrality. To aid in this effort, this report identifies the best sites in Western Maryland for wind development. Geographic information systems data on wind speed, land protections, and transmission infrastructure were used to assign scores for physical, social and environmental characteristics of prospective sites. Attribute scores were entered into a systematic weighting system to determine overall site suitability. A financial analysis was conducted for the highest ranked sites using RETScreen software, which generated projections for payback periods and return on investment. The list of suitable sites produced through this research provides the University with a starting point for exploration of off-site wind power production.

IDENTIFICATION AND ASSESSMENT OF POTENTIAL WIND ENERGY PROJECT SITES IN THE STATE OF MARYLAND

By

Team Renewables at UMD

Erin M. Conroy, David A. Green, Phillip M. Hannam, Matthew R. Kosmer, Alexander S. Meiseles, Emma K. Roach, Sumegha K. Singhania, and Amy D. Zhang

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Advisory Committee:
Dr. Jungho Kim, Mentor
Mrs. Joan Kowal
Mrs. Heather Lair
Mr. Mark Werner Stewart
Mrs. Carol Kennedy-Hearle
Dr. Daniel Kirk-Davidoff
Dr. Kenneth Conca

Dedication

We dedicate this research to those who will, and must, continue to strive for sustainability on campus long after we have left. And to their children, whose world we hope will be better as a result.

Acknowledgements

This project would not have been possible if it were not for the collective efforts of the University community in its advancement of the goals of sustainability. Particularly, we thank the Climate Action Plan Workgroup, and its stewards in the Campus Sustainability Office, for providing motivation and a forum for this research. At the beginning of this four-year endeavor, the Campus Energy Manager, Mrs. Joan Kowal, provided many of the sources, figures and background to get our team off to a good start. Dr. James Wallace and Dr. Rebecca Thomas, the directors of the Gemstone Office, kept the team on track by providing deadlines and constructive feedback for the numerous iterations of our research methodology. Most importantly, we thank the efforts of our mentor, Dr. Jungho Kim, for providing tough love, in just the right dose.

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List of Abbreviations

AWEA: American Wind Energy Association

BLM: Bureau of Land Management

CAP: Climate Action Plan Workgroup

CHP: Combined heat and power

CO_2: Carbon dioxide

CSP: Concentrating Solar Power

DNR: Department of Natural Resources

DOD: Department of Defense

DOE: Department of Energy

EIA: Energy Information Administration

EIS: Environmental Impact Statement

ESA: Endangered Species Act

FSEC: Florida Solar Energy Center

g: Grams

g/kWh: grams per kilowatt hour

GHG: Greenhouse gas

GIS: Geographic Information Systems

GWe: Gigawatt electrical

HTF: Heat Transfer Fluids

IEA: International Energy Agency

IPCC: Intergovernmental Panel on Climate Change

IRR: Internal rate of return

kV: kilovolts

kWh: Kilowatt hours

LIHI: Low Impact Hydropower Institute

MALPF: Maryland Agricultural Land Preservation Foundation

MATLAB: Matrix laboratory

MBTA: Migratory Bird Treaty Act

MDE: Maryland Department of Environment

MDP: Maryland Department of Planning

MET: Maryland Environmental Trust

$MTCO_2$: Metric tons carbon dioxide

$MTCO_2e$: Metric tons carbon dioxide equivalents

MWe: Megawatt electrical

MWh: Megawatt hours

NEPA: National Environmental Policy Act

NIMBY: Not In My Backyard

NO_x: Nitrogen oxide

NREL: National Renewable Energy Laboratory

O&M: Operation and maintenance

PJM: Pennsylvania New Jersey Maryland Interconnection LLC

PPA: Power Purchase Agreement

ppm: Parts per million

PPRP: Power Plant Research Program

REC: Renewable Energy Credit

REPI: Renewable Energy Production Incentive

RETScreen: Renewable Energy Project Analysis Software

RPS: Renewable Portfolio Standard

RTO: Regional Transmission Organization

SO_2: Sulfur dioxide

TWh: Terawatt hour

UNEP: United Nations Environment Programme

US DOE: U.S. Department of Energy

USFWS: U.S. Fish and Wildlife Service

VERA: Vermont Environmental Research Associates

WHTP: Wind and Hydropower Technologies Program

W/m^2: Watts per square meter

Chapter 1: Introduction

The University of Maryland currently uses electricity that is primarily generated through the combustion of carbon-based fossil fuels. The University generates most of this electricity using a natural gas-fired power plant located next to the campus, and supplements it from distributed grid power that relies primarily on a mix of coal, natural gas, oil, and nuclear fuels. Mounting scientific evidence suggests that the carbon dioxide released through combustion of fossil fuels is enhancing the "greenhouse effect," causing the earth's surface to warm and accelerating global climate change. Even optimistic scientific projections indicate that the potential damage caused by global warming is "unequivocal," and may cause mass extinctions of plant and animal species, while also placing considerable strain on existing human environments (Intergovernmental Panel on Climate Change [IPCC], 2007).

In 2006, the University of Maryland, College Park signed the President's Climate Commitment, an agreement stating that the University intends to reduce its net carbon emissions to zero by 2050. As a milestone to reaching this goal, UMD will reduce its energy consumption by 10% within five years. Also, at least 15% of the UMD's energy will be purchased or produced from renewable energy. To facilitate the development of a plan to reach carbon neutrality, the Climate Action Plan Workgroup was formed on campus, on which Team Renewables was represented. The workgroup decided that off-site renewable energy purchasing will be part of the emission reduction plan. Of the over 350,000 megatons of CO_2 equivalent that must be reduced to meet carbon neutrality goals, approximately 50,000 megatons will be reduced by purchasing off-site renewable energies (CAP, 2009).

Our research study examines the potential for reducing carbon dioxide emissions at the University of Maryland by identifying sites in Western Maryland that would be prime candidates for the development of renewable wind energy farms. Renewable technologies tend to emit very little carbon dioxide, and typically displace energy that would have otherwise been produced largely from carbon-intensive fossil energy sources. Renewable energy’s high upfront costs relative to fossil fuels can be reduced by considering environmental externalities, as well as governmental policies to make the cost of renewable energy more competitive. Still, renewable energy is not widely implemented. This study intends to examine potential land sites for wind energy development based on the site’s wind availability and environmental, technological and social suitability. Through a flexible analysis, the study presents sites in Western Maryland that may be best suited for wind energy developments by the University of Maryland. This research contributes to carbon emission reduction goals that can have lasting benefits for the environment, economy, and society as a whole.

Chapter 2: Objectives

The research objective of this project is to identify potential wind development sites in Western Maryland based on site suitability and wind availability. Site suitability was judged specifically on the physical attributes of the land, the social and community infrastructure, regulations, and environmental concerns. Based on these findings, recommendations of economically feasible sites for wind projects are made to the University.

The sites examined were all situated in Western Maryland in Garrett, Washington and Alleghany counties, which had the highest overall wind speeds. Land outside of Maryland was not studied because of the University of Maryland's interests, as a state-funded institution, to meet state renewable energy goals and improve the local environment. Off-shore sites were also not considered because of the lack of existing financial and regulatory data for U.S. domestic projects on which to base our analysis. Though our research speculates where there will be higher receptivity to construction based on a site's proximity to local population, we are unable to address the localized social implications of wind developments for each site. Our analysis is tailored to prioritize mainly cost efficiency and regulatory land use obstacles of the sites when suggesting sites for the University to consider, though the analysis framework is flexible to accommodate changing priorities. In performing environmental and economic analyses, we consulted current regulations and market-based prices, though we recognize that these could change substantially over the course of a wind farm's lifetime. Whenever possible, we used conservative economic projections to accommodate for the impacts of a weak economy on project finance.

Chapter 3: Literature Review

Exigency

The exigency for action against anthropogenic global warming has warranted this research. Most scientists agree that global warming is a severe threat to humanity, one justifying immediate and drastic action (IPCC, 2007). Carbon dioxide is a naturally occurring greenhouse gas that traps solar radiation close to Earth's surface, allowing the planet to maintain a temperature suitable for sustaining life. However, anthropogenic increases in carbon dioxide emissions have intensified this "greenhouse effect" causing global warming that far exceeds natural levels. This phenomenon is linked to polar and arctic ice melt, sea level rise, redistributed precipitation patterns, increased regional flooding and increased drought (Socolow, 2006). Additionally, massive losses in biodiversity are anticipated if rapid global climate change continues (Graziano, 2007).

Though politicians, the public, and even some scientists were initially skeptical of the existence of mankind's role in this warming process, leading scientists across the globe have stated that it is "very likely" that current warming trends are attributed to human activities, especially the burning of fossil fuels for energy conversion (IPCC, 2007). Ice core samples demonstrate a rapid increase in the concentration of carbon dioxide in the atmosphere since pre-industrial times (IPCC, 2007). Carbon dioxide concentrations, with which global surface temperature increases are correlated, have risen from a historic average of 290 parts per million (ppm) to beyond 379 ppm since the industrial revolution. The rate of increase in the atmospheric carbon dioxide concentration is accelerating as the citizens of developing nations such as China and India adopt increasingly energy intensive lifestyles. Some predictions suggest that atmospheric levels of carbon dioxide above 450 ppm will result in "catastrophic" results (Graziano, 2007). Due to the current global emissions trajectory, reaching 450 ppm is a very real possibility.

There is a clear relationship between the rise in carbon dioxide emissions and the increase in the earth's temperature. Climate sensitivity, as defined by the IPCC, refers to this relationship and is specifically the change in global temperature caused by a two-fold increase in carbon dioxide emissions from preindustrial levels; from 280 ppm to 560 ppm (IPCC, 2007). The term, climate sensitivity, can also be applied to the doubling of carbon dioxide equivalents. Current climate sensitivity estimates range from 2 – 4.5°C, with 3°C being most likely (IPCC, 2007).

Modeling climate sensitivity plays an important role in determining Earth's future temperature rise. However, with the capability of oceans to absorb much of the heat, it is difficult to determine the precise temperature increase because there is a time lapse between when the gases are emitted and when their global warming potential stops impacting the global temperature (Dawson, 2009). Scientists have estimated that global temperatures could increase by another 1.5-2.0°C by 2050 if greenhouse gas emissions continue at current rates (IPCC, 2007).

To understand how to mitigate the forces contributing to global warming, one must understand the factors increasing the atmospheric carbon dioxide concentration. A primary reason for the high levels of carbon dioxide emissions by the United States is its coal intensive electricity production infrastructure and high per capita energy consumption. On a worldwide scale, coal is responsible for 40 percent of all carbon dioxide emissions, but that is expected to rise to nearly 80 percent as development continues and the global population grows (Schrag, 2007). Though some developing nations are increasing their energy usage rapidly, the nations that contribute most to this atmospheric carbon dioxide are industrialized nations, particularly the United States, which is the largest industrialized carbon dioxide emitter (Socolow, 2006).

Globally, approximately seven billion tons of carbon-based fossil fuels are burned every year (Socolow, 2006). The consumption of these fuels produces immense quantities of greenhouse gases, which negatively impact both human health and the environment and are not accounted for in the price of the fuel itself. These negative externalities—the consequences of fossil fuel consumption that consumers and producers do not pay for—are at the heart of the global climate change problem and are evidence that the fossil fuel pricing mechanism is not operating efficiently.

Economic theory suggests that government intervention becomes necessary when society is faced with economic inefficiency. To address the climate change externalities of fossil fuels, which are presently excluded from these fuels' market price, the government can take several actions to decrease carbon dioxide emissions. One method to alleviate the externalities involves altering energy demand, such as through increased product efficiency. Increased efficiency decreases overall energy consumption of a product on a per-use basis. Additionally, the price of fossil fuel consumption can be increased to account for negative externalities. This can be accomplished through one of several policy tools, including a carbon tax or a carbon trading (cap-and-trade) scheme. A carbon tax or cap-and-trade program establish a price for each ton of carbon dioxide emitted; by making it more expensive to consume fossil fuels, these policies effectively cause a decrease in demand for the fuels contributing to global warming. Through efficiency measures and price increases, demand for fossil fuels can be decreased, minimizing greenhouse gas emissions.

Government intervention to alter fossil fuel supplies, particularly by lowering the price of alternatives, shows promise in efforts to decrease carbon dioxide emissions. Renewable energy requirements, such as Maryland's Renewable Portfolio Standard, require a certain amount of renewable energy to be produced. This new renewable energy capacity can decrease consumption of fossil fuels and resultant greenhouse gas emissions, increasing social welfare. Renewable energy technology research, and development of emission abatement technologies such as capture and storage of anthropogenic carbon in the atmosphere, affects issues of energy supply and emissions. Any improvement in substitute technologies for fossil fuels, including renewable energy, makes investments in alternative energy technologies more cost-competitive. As prices for renewable energy become comparable to fossil fuels, a shift towards the alternatives will be seen, eventually reducing greenhouse gas emissions. Improvements in abatement and treatment technologies allow fossil fuel consumption to continue with decreased externalities, leading to decreased greenhouse gas concentrations in the atmosphere. Though these approaches differ, all achieve the goal of increasing social welfare and economic efficiency through decreasing negative externalities. In the case of greenhouse gas emissions, government intervention must occur, in any of these ways, to ensure maximum social welfare for ours and future generations.

Climate Action Plan

In response to calls from University stakeholders, the University of Maryland committed to the following discrete steps toward developing a carbon neutrality plan by signing the American College & University Presidents Climate Commitment (ACU PCC, 2007):

- The University must perform an emission inventory to gauge the sources of carbon and greenhouse gases on the University campus, or that can be attributed to University activities.
- Within two years of signing the document, the University must set a target date for achieving campus carbon neutrality and establish interim milestones for assessing progress.
- The University must implement immediate actions toward reducing carbon emissions by choosing from a list of short-term actions published in the American College & University Presidents Climate Commitment
- University curriculum must integrate sustainability concepts and make it part of the educational experience.
- The University must make publicly available its action plan, inventory and interim progress.

As part of this commitment, the University of Maryland created the Office of Sustainability in the summer of 2007. The Office's stated mission is to coordinate, promote, and track initiatives on campus that contribute to sustainability. A campus-wide greenhouse gas inventory tracked University emissions from 2002 to 2007 to serve as a tool for identifying sources of emissions. The 2005 emissions were established as a baseline to provide a reference for future emission reductions.

The University formed the Climate Action Plan Workgroup (CAP Workgroup) to develop plans to guide the emission reductions for the University in its pursuit of carbon neutrality. The workgroup consists of over forty University staff, faculty, and student representatives who were believed to collectively represent the campus's diverse needs (Ruth, 2008). Gemstone Team Renewables' mission of aiding University efforts to acquire off-campus renewable energy led to their involvement on the workgroup. Phillip Hannam, a co-author of this thesis, was appointed as a member of the CAP to represent the Gemstone team and to report findings of the team's research to the workgroup for review.

The campus carbon audit determined that the campus emitted a total of 351,855 $MtCO_2$ in 2005. Of this number, 41% was produced during electricity generation and another 23% from steam use, as is presented in Table 1 below.

Table 1: Major emission sources as presented on page 3 of the draft Climate Action Plan (CAP, 2009)

Major Emission Sources	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
Electricity Consumption	54%	53%	43%	41%	40%	41%
Steam Use	13%	14%	22%	23%	24%	24%
Transportation	30%	29%	30%	31%	32%	31%
*Other Sources**	3%	4%	5%	5%	4%	4%
Total Emissions - $MTCO_2e$	343,430	364,114	341,583	351,855	341,406	337,515

*Agriculture, Solid waste, Refrigeration, Stationary sources — Baseline Year (FY 2005)

Campus emission sources are disaggregated into broad categories below in Figure 1. Of the total campus emissions, 29% are attributable to purchased electricity, or approximately 102,038 $MtCO_2$. The large contribution of emissions from grid electricity is a result of the high carbon intensity of the grid electricity mix in the state of Maryland.

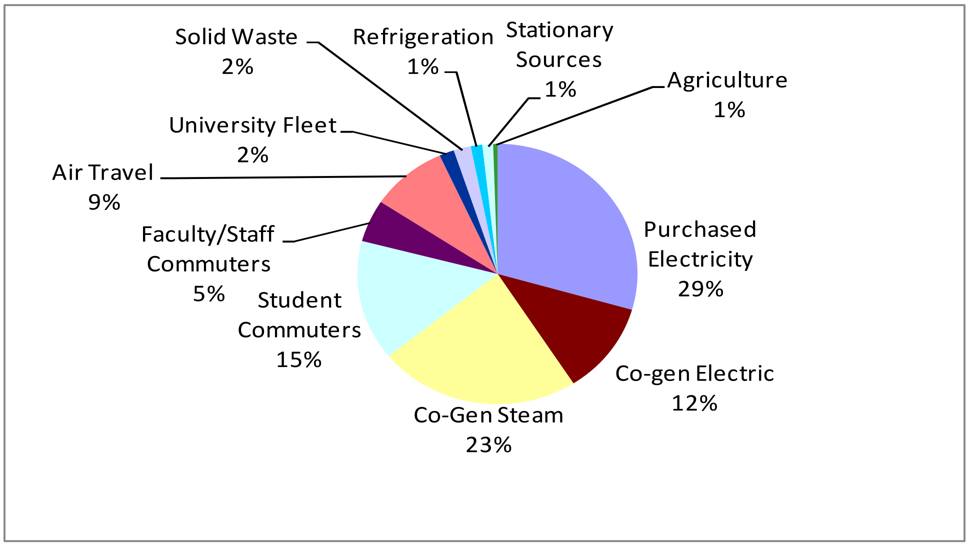


Figure 1: Major sources of campus emissions in 2005 as presented on page 3 of the draft UMD Climate Action Plan (CAP, 2009)

Figure 2, below, indicates that carbon-intensive coal comprises a larger share of the electricity grid than the national average. According to the Maryland Power Plant Research Program in Figure 3, 56% of Maryland electricity comes from coal, which releases more carbon per MWh of electricity than any other conventional fossil fuel source (PPRP, 2006).

The remainder of the state's electricity grid is comprised of nuclear energy at 26%, natural gas at 2%, hydroelectric at 5%, petroleum at 6% and "other" at 2%, which includes renewable electricity sources like wind and solar. It is important to note that nuclear and hydropower electricity generation is carbon-free. Natural gas has approximately half the carbon intensity of coal, but because the share of grid electricity from natural gas and petroleum sources is very small, coal's contribution to the campus's carbon emissions is significant.

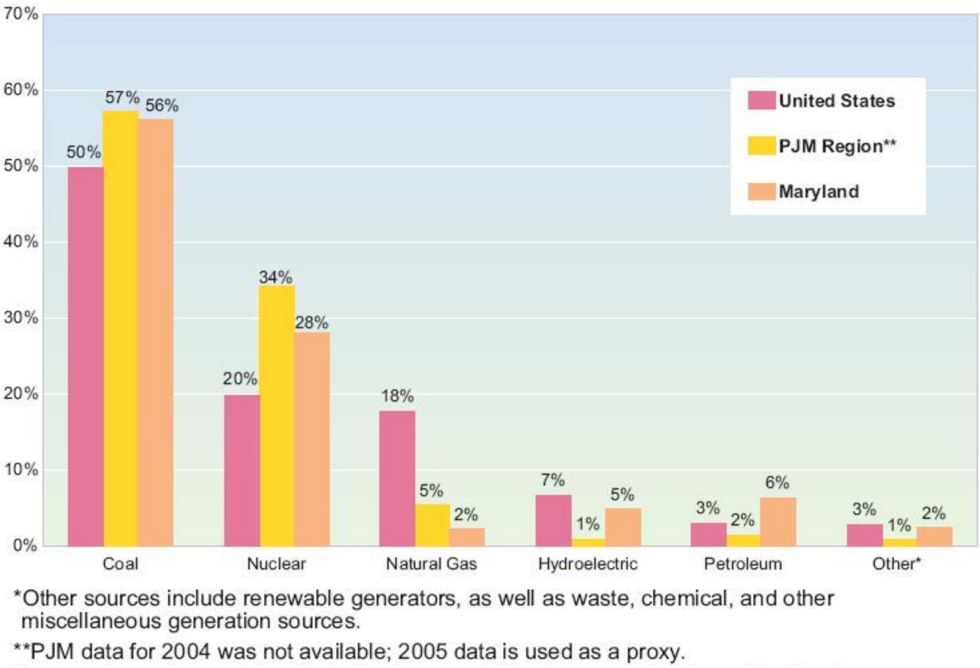


Figure 2: Grid electricity mix on the state, regional and national levels (PPRP, 2006)

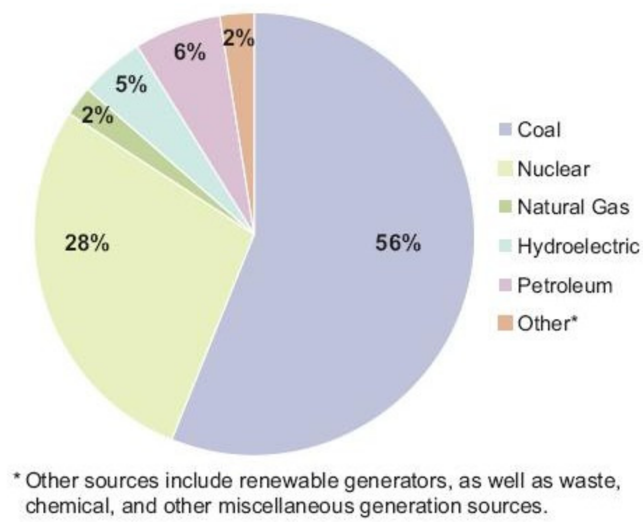


Figure 3: Grid electricity mix in the State of Maryland from the Energy Information Administration (PPRP, 2006)

Figure 1 shows that 12% of campus carbon emissions are released from the campus' natural gas co-generation power plant. The contribution from this source is significant, though the electricity generated per carbon output is lower for the plant because of the lower carbon intensity of natural gas, high plant efficiency, and low transmission losses because of the close proximity to the campus (PPRP, 2006). An additional 23% of the carbon emissions are also attributed to the co-generation plant to generate steam which is used to heat campus buildings during winter and power absorption chillers to provide summer cooling.

Table 2: Greenhouse gas reduction goals for the University of Maryland relative to State of Maryland Goals, as presented on page 6 of the draft UMD Climate Action Plan (CAP, 2009)

Fiscal Year	GHG Emissions (MTCO2e)	UM Reduction Goals	State of Maryland Goals
2005 (baseline)	365,335	N/A	N/A
2010	327,000	N/A	N/A
2012	310,535	15% below 2005 levels	10% below 2006 levels
2015	274,001	25% below 2005 levels	15% below 2006 levels
2020	182,668	50% below 2005 levels	25%-50% below 2006 levels
2025	151,000	60% below 2005 levels	N/A
2050	0	100% below 2005 levels	90% below 2006 levels

From this greenhouse gas inventory, the campus committed to reduce emissions to zero by 2050, surpassing a stated goal by the State of Maryland to achieve an emission reduction of 90% below 2006 levels by 2050 (CAP, 2009). A phased approach to campus emission reductions is shown in Table 2, indicating an emission reduction goal of 15% below 2005 levels by 2012, 50% by 2020, and 100% by 2050. Though the implementation of each of these goals becomes more uncertain the further the projection into the future, an effort to map individual strategies for emission reduction is made below in Figure 4. Each bar in the graph indicates a possible reduction below the baseline of 365,335 MtCO_2, collectively achieving a 100% reduction by 2050.

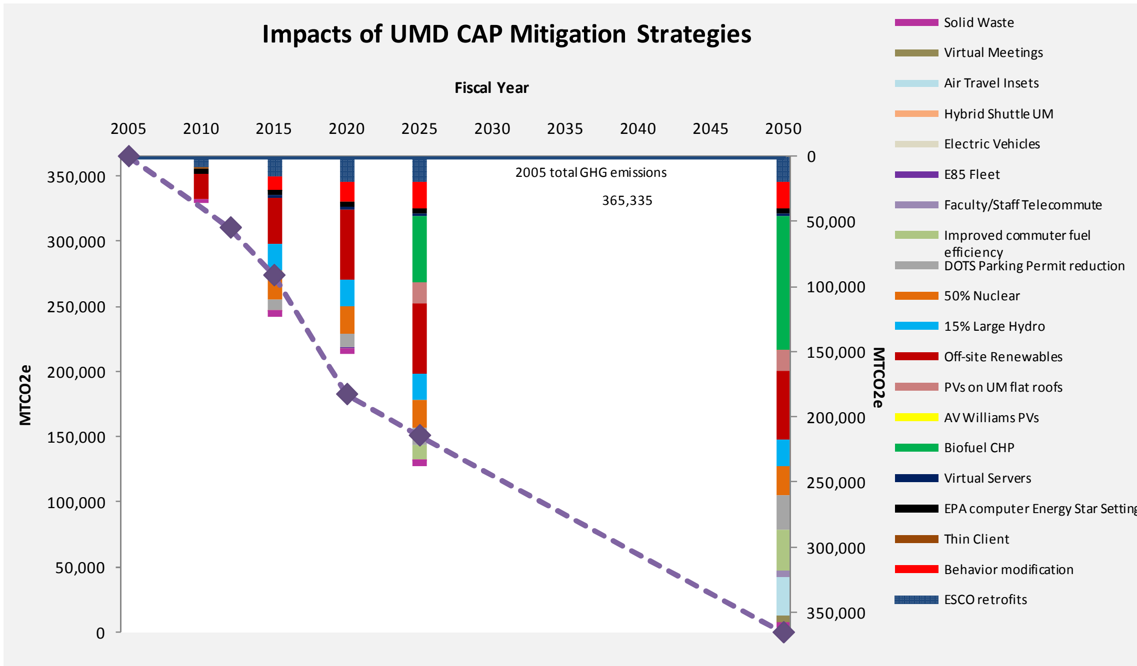


Figure 4: Impacts of proposed mitigation strategies as presented on page 7 of the draft UMD Climate Action Plan (CAP, 2009)

Mitigation strategies proposed by the Climate Action Plan Workgroup that achieve the largest emission reduction include ESCO retrofits, which result in greater building energy efficiency; behavioral modification that reduces per capita electricity consumption on campus; off-site renewable energy; low-carbon electricity purchasing that displaces high-carbon intensity fuels; parking permit reductions to reduce the number of student commuters; reductions in the generation of solid wastes; conversion of the co-gen plant to use bio-fuels instead of natural gas; implementation of photovoltaic electricity arrays on campus buildings; and offsets of air travel emissions, amongst several other reduction possibilities.

The mitigation strategy which is implemented most readily with the greatest impact is off-site renewable energy purchasing, which accounts for 25,000 $MtCO_2$

reduction by 2010. The emission reduction from this share steadily increases, ultimately to account for nearly a 50,000 $MtCO_2$ annual reduction by 2050.

Though no clearly defined methodology is laid out in the Climate Action Plan for specific off-site renewable energy sources, the purchase of wind energy through a University of Maryland commissioned site may be able to meet the ambitious CAP goals and serves as the subject of this thesis.

Renewable Energies

Introduction to Renewable Energy

Reducing the university's carbon dioxide emissions to achieve and maintain carbon neutrality requires an energy generation shift from non-renewable fossil fuels to renewable energy systems. Renewable energy resources occur naturally, regenerate, and are mainly derived from solar energy. However, because of regeneration and resupply rates, renewable energy use is limited per unit time. Renewable energy resources include biomass, hydropower, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

According the Energy Information Administration, about 90% of the energy consumed in the U.S. was from renewable energy resources in 1850. Today, the U.S. is heavily reliant on non-renewable fossil fuels for generating energy, namely coal, natural gas, and oil. In 2004, about 6% of all energy consumed and about 9% of total electricity production was from renewable energy resources (Energy Information Administration [EIA], 2007). One primary reason that renewable energy resources have been used less than non-renewable energy sources is because of costs; renewable energy is more expensive per unit of energy supplied. However, with escalation in the price of oil and climate change concerns, governments around the world are increasingly supporting legislation and incentives for renewable energy development and commercialization (United Nations Environment Programme [UNEP], 2007).

Ways to Acquire Renewable Energy

There are four primary ways in which the University of Maryland can acquire renewable energy for its electricity needs. The first is to acquire renewable energy from its local supplier or another local energy supplier owning or operating renewable energy facilities. The University can buy electricity produced by a renewable energy facility directly from this supplier.

The second method is through renewable energy certificates (RECs), sometimes referred to as "green tags." RECs do not require the University to have access to a local renewable energy supplier, which may make them an attractive option. RECs are sold separately from commodity electricity. Instead, a premium is paid to regional or non-regional companies that own renewable energy production facilities or invest money in new renewable energy infrastructure (US Department of Energy [USDOE], 2006). While RECs are not a direct method of purchasing electricity from renewable sources, they theoretically will generate the same environmental benefits of a direct purchase and the net carbon impact on the atmosphere would be the same (USDOE, 2006).

A third method is energy purchase through a contract with an energy utility constructing a renewable energy facility. For example, the Catholic University of America purchased the output of a 1.5 MW wind turbine for five years by funding its construction (Catholic University of America, 2002). For many universities and companies, this method of renewable energy purchase has been cost effective; it fixes the price of the renewable energy for the contract's period, reducing the institution's vulnerability to price fluctuations in the fossil fuel energy market (Putnam and Philips, 2006).

The fourth option for acquiring renewable energy for use by the University is to physically implement a renewable energy system on campus. Solar photovoltaic arrays are one commonly used renewable energy system that might reduce the University's energy demand from the grid. Globally, relatively few countries have installed large-scale photovoltaic capacity bases, instead relying on localized, on-site, small-scale generation (Montana Green Power, 2006). Significant potential may exist in constructing photovoltaic solar arrays on the roofs of campus buildings and as shading devices for parking lots. In the United States, thirty-nine states allow owners of small-scale photovoltaic systems to supply excess power to the electrical grid, a potential source of revenue from a small-scale system. By the end of 2004, use of photovoltaics to generate energy grew by 45% globally in a year (BP Global, 2006). Japan, the US, and Germany, all of which are leading manufacturers of photovoltaic cells, accounted for 94% of this total growth in photovoltaic system integrations.

The following sections discuss the common forms of renewable energy and technical feasibility for use by the University of Maryland.

Solar Power

Solar energy uses photovoltaic cells to convert the Sun's radiation into electricity through the photoelectric effect. In this process, light from the sun strikes the photovoltaic cell, energizing electrons and releasing them from their crystalline lattice. These freed electrons produce a voltage and current, providing power as they are transmitted through wires to an energy load or user. Typical commercially available single-crystal silicon photovoltaic cells operate with an efficiency of fourteen to sixteen percent (National Renewable Energy Laboratory, 2006). Researchers estimate that it would take 60 thousand square kilometers of photovoltaic cells to meet the energy requirements of the United States, given current efficiencies.

A typical photovoltaic module contributes a net increase of 30 to 45 g/kWh of carbon dioxide emissions to the atmosphere, primarily through the production of the silicon, glass and mounting structure that comprises a photovoltaic cell. These emissions are small compared to the net release of carbon dioxide from conventional fossil fuel sources, such as the 1000 g/kWh from coal, not including the carbon dioxide required to mine and transport the fuel. Due to the lower CO_2 emissions associated with solar energy, photovoltaic technology has the potential to become an economically viable and environmentally sustainable source of energy, especially when considering new carbon dioxide regulations and taxes the US government is contemplating (U.S. Department of Energy, 2006). However, until such regulations become law, it is unlikely that solar cells will be competitive with the low upfront costs of fossil fuels. Average costs for solar energy currently range from $0.23 to $0.35/ kWh for commercial usage (Energy Information Administration, 2008). In order for solar panels to be cost effective, they need to be installed in areas with abundant sunlight such as southern California or Arizona. Maryland lacks levels of sunlight that would maximize the efficiency of solar panels. Due to the high costs needed for photovoltaic installation and maintenance, solar power generation would not be the most cost-effective option at the University of Maryland.

Geothermal Power

Another form of renewable energy is geothermal power. Geothermal power plants utilize the energy in steam and hot water from underground sources to drive electric generators. The water is returned to the ground after use. The first of three types of geothermal power plants passes existing steam through power turbines. The second type of plant depressurizes hot water into steam, which then powers the turbines. The third type of plant uses the hot water to convert a second liquid, typically a fluid like isobutane that has a lower boiling point temperature, into steam which runs through a closed system to power the turbines. Geothermal energy is most easily utilized at plate tectonic fault lines.

In the United States, geothermal energy potential exists around the Ring of Fire, which refers to an area in the Pacific Ocean that experiences a great deal of tectonic activity; states such as California, Oregon, and Alaska possess this potential. Alaska opened a geothermal plant in 2006, and power plants have been built in California, as well. This technology is also utilized in other countries that are located along the Ring of Fire, such as Iceland and Indonesia (Fahey). Hundreds of millions of dollars have been invested over the past several years to expand this alternative source of energy. In order to harvest geothermal energy, a contractor must first drill for underground steam and water, while also constructing infrastructure in the area. There are also a number of geothermal units that are built on the Geysers in northern California.

Geothermal heat pumps use the constant temperature of the Earth below its surface to provide heating, cooling, and hot water. This technology could be utilized in the state of Maryland. However, geothermal electricity production does not have much potential on the east coast and is not a viable option for the University of Maryland.

Wind Power

Wind energy is a converted form of solar energy that is more cost effective to capture. The Sun's radiation heats different parts of the earth at different rates, most notably during the day and night, but also when different surfaces (i.e. water and land) absorb or reflect the Sun's rays at different rates. Denser, cooler air from higher-pressure areas moves towards lower pressure areas with warmer air, creating wind currents. The kinetic energy stored in the air's movement can be converted to mechanical work through the use of windmills (American Wind Energy Association [AWEA], 2006). However, wind energy potential varies across the globe, is intermittent, and does not necessarily coincide with areas of the highest electricity demand.

North America contains an estimated 14,000 TWh of land-based wind energy resources. According to the Energy Information Agency, the United States consumed 3,970 TWh of electricity in 2004. Based on these estimations, it is theoretically possible to power current US electrical consumption through only land-based wind systems (Boyle, 2004). Land-based wind sites can produce electricity at levelized costs of approximately \$0.04 to \$0.06/kWh, depending on the wind quality of the site. These costs are roughly comparable to costs for coal or natural gas fired plants, which are widely reported as being about \$0.05/kWh (Offshore Wind Collaborative Organizing Group, 2005). Wind pricing is primarily an upfront cost, while coal and natural gas plants must pay for fuel and transport. Because wind is free, wind power pricing is not subject to fuel price fluctuations. These cost estimations suggest that although wind and conventional, non-renewable energies are approximately equal in price, wind has smaller environmental impact compared to coal or other fossil fuels.

Ideal locations for wind power generation include high altitudes and wide, open lands. Such locations include hilltops and areas near shorelines (AWEA, 2006). Offshore wind energy seems to be an even more promising energy resource than land-based wind systems since offshore wind travels at higher speeds, has less wind shear, experiences lower levels of turbulence due to a lack of air-disrupting geographical features, and is typically closer to major coastal urban centers than land-based wind systems. Wind energy and offshore wind potential are explained in greater detail later in the literature review section.

Biomass

Electricity generated from biomass is another form of renewable energy. Examples of biomass energy include ethanol, biodiesel, waste pyrolysis, and methane capture from landfills. Biomass energy was popular in the past when trees were burned for power and this form is still used in some parts of the world (Tester, 2005). Energy from biomass can be converted and generated into useful energy by direct combustion. However, it is often necessary to convert the biomass to a liquid or gaseous state first through thermo-chemical, physical-chemical or bio-chemical processes. (Kaltschmitt, 2007).

Biomass power is effective in reducing the pollutants that cause acid rain, such as sulfur dioxide (SO_2). Since most forms of biomass contain very little amounts of SO_2, not much SO_2 is produced in the process. Coal on the other hand usually contains up to 5% sulfur. Biomass can be mixed with other fuels, such as coal, and by doing so the amount of SO_2 emitted from a biomass co-fired coal power plant can be reduced greatly compared to burning just coal (Tester 2005). Also, in tests done at coal-fired power plants using biomass, it was observed that NO_x emissions could be cut in half when using biomass, compared to coal-only operations (US DOE, 2008).

Energy from biomass can be a carbon neutral form of power generation, since it recycles carbon through the carbon cycle. Growing “energy crops” can also reduce CO_2 emissions. These crops create carbon sinks that sequester the carbon underground in their roots (US DOE Planet Power, 2008).

Electricity produced from methane resulting from the decomposition of biomass also has high potential and is already used around the world. Waste from landfills and animal manure produce methane, a powerful greenhouse gas, when they decompose. This methane can be captured and used to generate heat or electricity (US DOE, 2008).

Because biomass renewable energy comes from commonly found biological materials, it is readily available. It can be used as an energy source in many places around the world. Biomass energy can be also be generated from many different processes, which makes it versatile in its possible applications (Tester 2005).

Compared to fossil and nuclear-based energies, biomass energy has a higher price and lower efficiency (Tester 2005). It has a lower energy density (the amount of energy produced per volume or mass of product) than coal or petroleum, though proprietary torrefaction processes for increasing energy density of biomass pellets are promising. Energy efficiency is lower when biomass has moisture. Drying the material requires energy, contributing to the higher price (Tester 2005). Biological fuel sources are often grown specifically to be used for energy conversion, which uses large amounts of land and resources, such as fertilizer, to ensure sufficient growth (Tester, 2005). Therefore, certain processes that are typically undergone when utilizing biomass, such as growing and drying the fuel, result in a substantially higher cost to produce biomass electricity when compared to other forms of power. Nonetheless, the utilization of biomass to produce electricity has been expanded recently in neighboring states, such as Pennsylvania, where Governor Edward Rendell "recently announced the state will fund 49 clean energy and biofuel projects" (Voegele, 2009). Of these 49 projects, five that received funding are biomass-to-energy projects. However, these projects produce substantially less electricity than the University of Maryland requires and as a result, may not be well suited for in-depth University consideration.

Hydropower

Hydropower is renewable energy generated by converting potential energy contained the water as it flows from a higher elevation to a lower one. About 6% of the US's electricity came from hydropower as of 2007 (Energy Information Administration, 2009).

There are three ways this energy can be converted: impoundment, diversion or run-of-river, and pump storage. Impoundment hydropower uses a dam to create a reservoir of water from which potential energy is extracted. Diversion, or run-of-river, hydropower utilizes energy from flowing water. Pump storage hydropower is when water is pumped from either a lower basin to a higher plain or vice versa, depending on the demand for energy (Tester, 2005).

There are many positive aspects of using hydropower. During the electricity production process, there are no net CO_2, NO_x, and SO_x emissions. Hydropower has high conversion efficiency to electricity, often over 80% (Tester, 2005) high power generation capacity. A large installation such as the Three Gorges Dam in China, can produce up to 17,000 MWe (Tester, 2005). In addition to high efficiency, hydropower plants have low operating and maintenance costs associated with them. Also, the construction of these projects can improve the local economy. The construction of the Hoover Dam provided hundreds of jobs in the U.S. during an economic depression (Tester, 2005). Dams can be used to control floods and store water to be used for agricultural irrigation or consumption (Tester, 2005).

However, hydropower is not without negative attributes. One main issue is that large volumes of water must be stored for the system to work, which can lead to habitat loss, especially of aquatic species. A change in river flow can also affect surrounding habitats by changing fish migration patterns or depleting oxygen. Hydropower plants can displace people native to the area because the structures can be very large. Silt can build up and the lifetime of the structure can be shortened if it is not constructed properly. Since the technology depends on the amount of water present, the amount of energy generated varies–rainfall and snowfall affect how much electricity can be produced. Even though there are low operating and maintenance cost, there are high initial capital costs associated with constructing a hydropower structure. Getting enough money to start a plant can be difficult. Also, even though the facility can produce electricity for many decades, it takes many years to construct large projects.

Currently, hydropower is the largest producer of renewable electricity with a capacity of over 600 GWe (Tester, 2005). Canada and the US are the leading producers of hydropower. The best way to expand to hydropower is to utilize existing dams. The initial costs associated with implementing a project are high.

According to a United States Department of Energy assessment, Maryland only has one hydropower facility, which has a capacity of 20 MW. The undeveloped capacity in the state is projected as 0.10 MW (DOE, 1998). With such limited utilization of hydropower in Maryland and minimal potential for future hydropower production, hydropower can be deemed an unsuitable renewable energy option for the University of Maryland. Maryland possesses natural resources with greater power potential than its hydropower resources, and those options ought to be pursued.

Table 3: Summary of Renewable Energy Technologies

Technology	Advantages	Disadvantages
Solar: Photovoltaic	• Lower net release of CO_2	• High installation and

	• Relatively low price of energy production	maintenance costs • Not enough sunlight to make cost effective purchase
Solar: Solar Thermal	• Decreased utility bill • Short payback period • Inexpensive	• Limited range of application • Does not produce electricity as end product
Solar: Concentrating Solar Power (CSP)	• Ability for large scale energy production • Can construct hybrid facilities • Can store energy and produce electricity without sunlight later	• Possible soil contamination from HTF leak • Large amount of land required • High price of power generation
Geothermal	• Little CO_2 release	• Little potential in Maryland
Wind	• Low price of power generation • Reduces greenhouse gas emissions • High potential for development • Conserves water • Reduces hazardous waste	• Dependent on wind speed • Initial costs of project higher than for fossil fuel project • Social problems, such as local resistance • Turbines could impact wildlife
Biomass	• Reduces pollutants that cause acid rain • Can be mixed with other fuels • Reduces methane and odors • Readily available	• High price of production • Lower efficiency compared to fossil fuels • Lower energy efficiency • Better for small scale production
Hydropower	• CO_2, NO_x, SO_x and hydrocarbons not introduced into the atmosphere • High conversion efficiency to electricity • High conversion efficiency to electricity • Low operation and maintenance costs	• Large volumes of water must be stored which can lead to habitat loss • Energy generation dependent on amount of water present • High initial capital costs • Construction time of mega-sized project long

Kite Power

Kite power is a developing form of renewable energy, which utilizes kites to harvest high-altitude wind. Kites are able to reap the benefits of high-altitude wind, which blows at a higher speed than lower-altitude wind, and also blows more consistently, thereby making it a more dependable source of energy. Moreover, "It turns out that the power available from wind is tied to the cube of its speed, so the higher of these altitudes is a far more attractive option, giving almost four times as much power as that available at turbine height" (Brooks, 2008). In November 2007, Makani Power, a kite power developer, received a $10 million investment from Google (Brooks, 2008). While there seems to be a great deal of interest in this developing technology, kite power would not be available for use by the University of Maryland in the immediate future.

Future projections and obstacles to Renewable Energy Implementation

There is a much greater potential of using renewable energy than is currently being utilized. It has been argued that global energy demands can be met using existing renewable energy technologies. Cost and energy distribution remain the primary obstacles. Government policies could make it more feasible to utilize renewable energies by subsidizing the technology and creating investment incentives, thereby making it more competitive with fossil fuels (Kobos, 2006; Nuehoff, 2005). Current state governmental policies in Maryland give incentives for institutions and individuals to utilize renewable energy. Some basic legislative goals and strategies for increasing the usage of renewable energy were established in 2001. The legislation focuses on increasing sustainable energy usage by setting a goal of relying on six percent green energy for state-owned building operation (with less than half of the green energy produced coming from the incineration of municipal solid waste). The legislation, however, does not set up a specific timetable for attaining this goal. Also, the legislation outlines the creation of the Maryland Green Buildings Council, which will strive to increase green energy usage in Maryland (Maryland State Senate, 2001).

Maryland also offers loans to non-profit organizations, such as schools or other state properties that will help finance the purchase of renewable energy. The program started with $3.2 million in funding for such programs, and currently funds approximately $1.5 million in renewable energy projects each fiscal year (Maryland Energy Administration, 1989). There are also federal policies that encourage the use of renewable energy in Maryland's state-owned buildings. For example, renewable energy investment by a state institution could help the state meet air quality requirements established by the Clean Air Act (Putnam and Philips, 2006). The federal government also provides monetary incentives for non-profit organizations such as the University of Maryland under the Renewable Energy Production Incentive (REPI). Under this legislation, the Federal Government will pay non-profit organizations to produce renewable energy at a rate of $0.015/kWh (USDOE, 2006), which is further discussed in the Methodology Section.

Regardless of whether or not more federal, state and regional governmental policies are implemented to make renewable energy more affordable, green energy prices will continue to decline as the technology continues to improve and competitiveness in the market grows (Kobos, 2006; Nuehoff, 2005; Owen, 2004). Kobos developed a method for calculating future costs for renewable energies based on a price trajectory model of the declining prices of renewable energy technologies.

This model may be used to determine approximate costs for renewable energy systems for an institution (Kobos, 2006). A study by Owen includes a formula for calculating the approximate costs of externalities associated with various renewable energy technologies in different environments, which would be useful in assessments of potential system usage on a university campus (Owen, 2004).

Renewable Energy Implementation at the University of Maryland

A critical step in any renewable energy viability study is determining how to finance it. Studies suggest that technologies that have minimal impact on the surrounding landscape and wildlife are more likely to be accepted, and individuals are willing to pay extra for those environmentally sound technologies (Bergmann, 2006). The Bergmann study includes an economic model to calculate the public's willingness to pay for various green energy technologies (Bergmann, 2006). This model could be utilized to calculate how willing students would be to pay to support renewable energy. Many universities use student fees to fund renewable energy development on their campuses by either using a part of the current fees or by increasing fees to offset costs for the renewable energy (Putnam and Philips, 2006). According to one viability study, 74% of student voters at the University of North Carolina, Chapel Hill agreed to a $4.00 increase in fees per semester to fund renewable energy on campus (Putnam and Philips, 2006). Besides student fees, there are grants and loans offered by the state of Maryland as financial incentives for renewable energy (Putnam and Philips, 2006) that could make renewable energy a feasible option at a public academic institution.

Because of its current fossil energy use, the University of Maryland has significant potential for reducing carbon dioxide emissions, though the metrics for execution of these goals, community support, and financial limitations have not yet been quantified. To accomplish this task, this research will need to consider the different methods of obtaining renewable energy, determine what the University is willing to pay and how to finance the energy adjustment, and determine how feasible each method is in terms of cost and benefits. Many options exist for acquiring renewable energy for use by the University, and the costs of each of these options will likely decrease in the future, though the costs may seem prohibitive now. Also, there is an increasing amount of legislation that will facilitate renewable energy purchase, and incentives and grants put forth by the state of Maryland could make renewable energy a more viable option. Other Universities have succeeded in bringing renewable energy into their energy mix, financing these ventures through fees, grants, and other sources of revenue. Finally, there are many models available that can be used to calculate costs of renewable energies versus their long-term environmental, social and economic benefits through consideration of externalities. These advancements in renewable energy technology, policy and marketing will facilitate analysis of the University of Maryland's renewable energy options.

Wind Power Generation

Physical Attributes

After considering the many possible ways that the university could supply itself with renewable energy from an off-site location, wind energy stood out as the preferred method. According to a study done by researchers at Stanford University, if only 20% of the world's Class 3 or greater wind power was captured, it would satisfy 100% of the world's energy needs (Archer & Jacobson, 2005). However, climate change is affecting wind patterns. The change in temperature can, "produce focused regions for deep cumulonimbus convection," or different wind patterns. Thunderstorm patterns would also be affected since they depend on specific types of wind to develop (Cotton, 2007). A change in wind speeds means a change in the amount of wind generation. This could be a problem if the wind speed becomes too low or too high for the specific turbines to function effectively.

While there are certainly obstacles to harnessing this power potential, the study helps put into perspective the actual amount of wind power that could be developed globally. At present, there is a huge potential for wind energy to be harvested throughout the United States. According to the National Renewable Energy Laboratory (NREL), the US currently has the capacity to generate 25,170 MW of electricity from wind, which would be approximately the amount needed to power 7 million American homes. In 2008, the US became the world's leader in wind energy, having installed 8,358 MW of capacity in 2008, and growing its wind capacity by 50% ("US Wind Industry Takes Global Lead.", 2009). This rapid growth within the industry highlights the ability of wind to provide a clean, renewable source of energy for this country, while also creating growth within the economy. According to the American Wind Energy Association (AWEA), wind energy contributed over $17 billion dollars into the US economy and employed about 85,000 workers.

The wind energy now produced eliminates nearly 44 billion tons of carbon emissions, the equivalent of removing 7 million cars from the nation's roads ("US Wind Industry Takes Global Lead," 2009). The Department of Energy's Wind and Hydropower Technologies Program (WHTP) states that wind power within the United states is "abundant", and that the advantages of developing wind power include reducing greenhouse gas emissions, conserving water, lowering natural gas prices, expanding manufacturing, and generating local revenues ("Advantages and Disadvantages of Wind Energy", 2008). At the same time, the WHTP notes that wind power is one of the least-expensive renewable technologies available, costing between 4 and 6 cents per kilo-watt hour ("Advantages and Disadvantages of Wind Energy", 2008). All of these advantages in concert have ensured that wind energy is the fastest-growing energy source in the world.

Within the state of Maryland, DOE's Wind Program and NREL have found that there is wind potential for utility-scale production, generally in areas with above either Class 3 or Class 4 winds. In addition, several areas within the state contain good to excellent wind speeds ("Maryland Wind Resource Map", 2008).

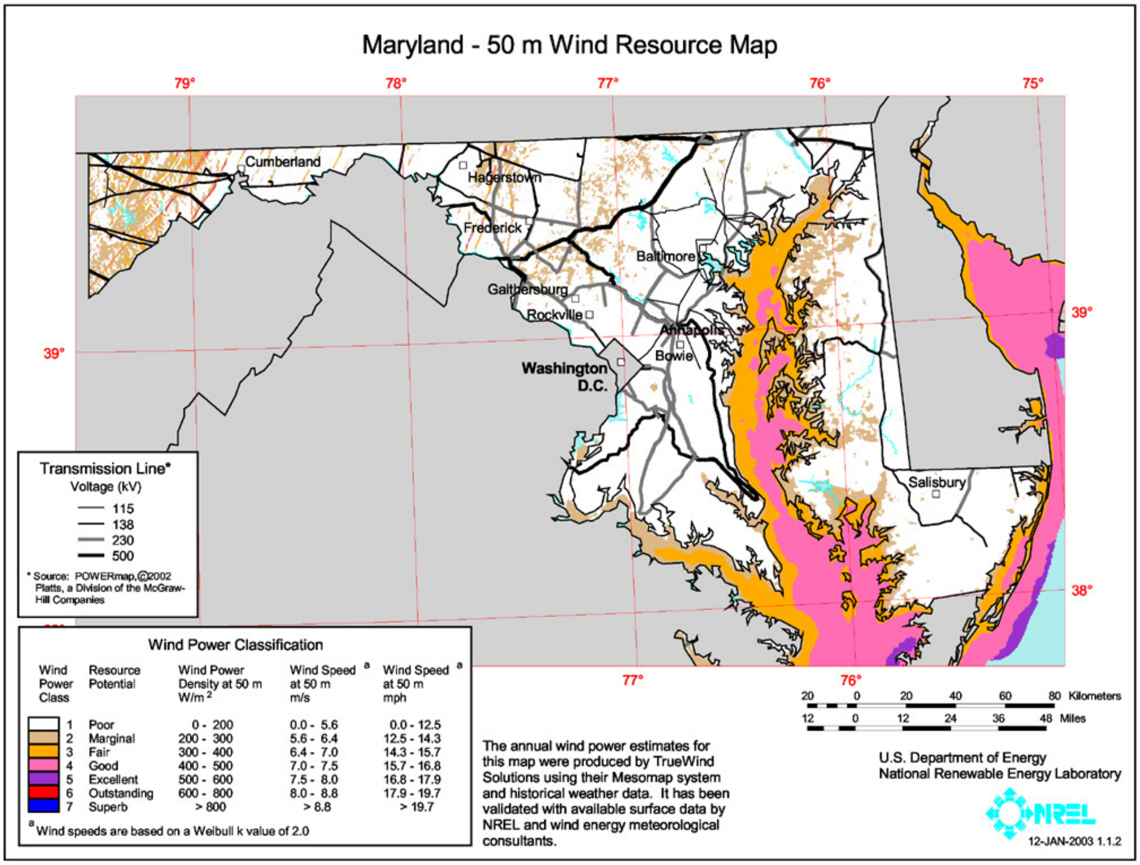


Figure 5: Maryland Wind Resources at 50 meters

One area that is particularly well endowed with wind is the mountainous region in the western part of the state, with streaks of wind that are classed as outstanding (Figure 5). As of August 2008, several companies have begun to develop wind projects throughout Maryland, and Governor Martin O'Malley has pledged his support for exploring commercial-scale wind power, both on-shore and off-shore (Shay, 2008). Given DOE and NREL's wind map findings, the state of Maryland has many untapped wind energy resources that can be developed.

However, while there is clearly a huge potential for wind energy development around the world, in the United States, and the state of Maryland, there are some disadvantages to this technology. Wind energy must compete with established technologies on a cost basis, which greatly depends on the amount of wind available in that geographic location. Additionally, the start-up costs for wind power are higher than fossil fuel plants, though the price has been declining over the years ("Wind Energy FAQs for Consumers", 2008).

Perhaps the greatest obstacle to wind energy development is the wind itself. Since the wind speed in a given area is intermittent, there will not be a constant flow of energy but rather spikes in the production and power may not be available when it is needed ("Advantages and Disadvantages of Wind Energy", 2008). Also, the best sites for the wind are often in remote areas, which are hard to reach or far from where the electricity would be used. Lastly, there are social concerns that must be addressed within the community regarding the impact the wind development has on the people and the environment in the area.

While wind energy is clean and can be a profitable investment, there are start-up, infrastructure and maintenance costs involved in the development of this technology. The cost of wind turbines depends on the type and size of turbine that is selected, which in turn is dependent on the amount of wind at the site, the size of the site, and the efficiency of the turbine at that particular wind speed ("Wind Energy FAQs for Consumers", 2008). Next, the turbines need to be connected to the energy grid. This can lead to additional costs beyond simply that of connectivity, if the turbines are sited in an area that is far from any power lines ("Wind Energy FAQs for Consumers", 2008). For example, additional costs will be incurred if the developers must site and construct new power lines so that they can reach the grid. Last, an inverter is needed to convert the turbine power output so that it is compatible with the power grid ("Wind Energy FAQs for Consumers", 2008).

Social/Infrastructure

While numerical values can fairly easily be assigned to the environmental and economic impact of constructing a wind turbine, it is far more difficult to measure the social impact. This can pose quite a problem for developers, because despite its difficult-to-measure nature, social concerns can often be of the greatest importance to the community and stakeholders in the project.

These effects can include a wide range of aspects that affect the community, but mainly fall into two categories: visual and noise. In the visual category, one major problem is referred to as “NIMBYism”, which is a commonly used tern to reference “Not In My Backyard” complaints within the wind farm’s view field ("Advantages and Disadvantages of Wind Energy", 2008). Local residents may be concerned that the wind turbines will decrease the natural beauty of their property, effectively lowering their quality of life and land values. They do not wish to see large structures out of their windows, particularly since the areas that have the best wind are often situated in mountainous areas where land is prized for its scenery. Other people become concerned that their home may lie in the area of land that falls within the shadow of the turbines (Asmus, 2008). Overall, the majority of these visual problems occur because people feel that the turbines do not belong in the landscape of these typically rural areas.

There are a few noise-related complaints that wind developers must address. First, turbines naturally make a certain amount of noise, which has the potential to disturb both the people and the wildlife living in the area. Also, when the wind farm is being developed, there will be construction in the area. This may be noisy and disruptive to residents, particularly if they are located in a rural area that is typically very quiet. When choosing a site for wind turbines, it is important to consider these factors, among others, because the community opposition can prevent completion of the project.

Environmental Regulations and Legislation

The environmental regulations and legislation that have already been implemented in the United States represent a critical factor that will undoubtedly impact wind development, just as social concerns do. Due to the relatively limited implementation of wind energy projects in the United States, the federal government lacks a regulatory structure tailored to wind development projects. Regulation of wind projects is therefore based upon existing environmental statutes and as well as newer policies.

The existing environmental statutes carry the most weight in the legal realm. One statute that applies to all projects is the National Environmental Policy Act (NEPA). NEPA requires the completion of an Environmental Impact Statement (EIS) when a federal agency may impact environmental health. Federal agencies must complete an EIS when they are undertaking, permitting, funding or licensing a project. An EIS assesses the projected impacts of a proposed action and its alternatives, and it often involves comment and analysis by federal agencies beyond the acting agency (42 U.S.C. 4371). Any federal entity engaged in a wind development project, through funding, permitting, licensing, or taking direct actions, must complete an EIS by law, which will undoubtedly delay the project and may even eliminate the possibility of its existence.

The Endangered Species Act of 1973 (ESA) must also be considered when assessing a site for potential wind development. The ESA is a strict liability statute designed to protect species from extinction due to human activities. To discourage actions that could potentially harm species, the ESA penalizes violators financially. Through the ESA, the U.S. Fish and Wildlife Service manages a list of threatened and endangered species. The listing of a species is based solely on science, with no consideration given to the costs of species protection. Once a species is listed, it becomes illegal for an individual to "take" an organism of that class. Section 9 of the ESA defines "take" to mean "…to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." "Harm" was later defined as any act altering a species' behavior, breeding habits, or ability to survive in general (16 U.S.C. 1531-1544). The effects of this legislation on wind energy could be far-reaching. If a listed species is damaged by a wind turbine, that turbine's owner would be held financially liable for a taking. Before wind turbines can be sited, an extensive analysis of listed species in the region must be undertaken.

Two other acts related to wildlife must be considered during the construction of wind turbines: the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act. Both of these are strict liability statutes, as is the case with the Endangered Species Act, and have equally noble goals. As is the case with the ESA, the MBTA makes the taking or possession of a protected species illegal.

> "Unless and except as permitted by regulations … it shall be unlawful at any time, by any means, or in any manner to pursue, hunt, take, capture, kill … possess, offer for sale, sell … purchase … ship, export, import … transport or cause to be transported… any migratory bird, any part, nest, or eggs of any such bird … [The Act] prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Department of the Interior." (16 U.S.C. 703-712)

Individuals and organizations can be found guilty of a misdemeanor or felony under the MBTA, which can result in financial penalties and even imprisonment. Under the Bald and Golden Eagle Protection Act, any individual found guilty of the above offenses is subject to charges for a felony and possible jail time (16 U.S.C. 668-668d).

Under the Endangered Species Act, the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act, the element of intent is not needed for conviction. An individual or organization may unknowingly jeopardize the safety of a species, and if any individual organisms are harmed, legal action may come to pass. Again, this emphasizes the importance of pre-construction biological assessments of potential wind development sites.

The policies that have been formulated as the popularity of wind energy has grown within the United States span several government agencies, and seek to address environmental concerns arising from the construction of wind turbines. The Department of Energy (DOE) created a Wind and Hydropower Technologies

Program to address information and research needs related to wind power. In an assessment undertaken by DOE, private consulting firms, and the American Wind Energy Association, the feasibility of 20 percent of U.S. electricity coming from wind power by 2030 was studied. The report found there to be significant challenges to this goal, but believed that given significant dedication of resources, it could be done (U.S. Department of Energy, 2008).

The prospect of wind energy development on federally-owned lands falls under the authority of the Bureau of Land Management (BLM). The BLM underwent a Programmatic Environmental Impact Statement (EIS) in 2005 to determine the effects of wind energy development on BLM lands in the western United States. Since then, BLM has issued a guidance policy on best management practices to mitigate damage to wildlife and habitat through the construction of wind turbines. The Lands and Realty Management Program housed in the BLM has permitted 192 right-of-ways for wind energy production on public lands to date. The total installed capacity of 25 authorizations is 327 megawatts (U.S. Department of Interior, 2009).

To ensure the protection of wildlife, the U.S. Fish and Wildlife Service (USFWS) created the Service's Wind Turbine Siting Working Group. After much research and analysis, the Group produced a guidance document titled "Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines." The guidelines offer a systematic process for assessing wildlife vulnerability within wind resource areas (U.S. Fish and Wildlife Service, 2007). However, these guidelines posed by USFWS are not legally binding, and wind developers need not comply.

Agencies less directly involved in the environmental implications of wind turbine siting have produced statements on wind energy. The Department of Defense (DOD) released a document articulating their stance on wind development. DOD stated that it did not oppose any wind development, so long as military readiness is not compromised (Pease, 2007). A policy letter produced jointly by DOD and the Department of Homeland Security had previously announced this position (Kingsmore, 2006).

The State of Maryland and Wind Energy

The government of Maryland has proven to be committed to renewable energy production and consumption over the last decade. In 2004, Senate Bill 869, entitled "Electricity Regulation - Renewable Energy Portfolio Standard and Credit Trading - Maryland Renewable Energy Fund," required electricity providers to incorporate renewable energy into the mixes they provide (Maryland State Senate, 2004). This bill was signed into law by Republican Governor Robert Ehrlich and served as the first major step in Maryland creating its renewable energy future.

In the 2007 legislative session, Maryland Governor Martin O'Malley signed into law the EmPower Maryland Initiative. This initiative pledges that Maryland will reduce energy consumption 15 percent by 2015. In addition, O'Malley vowed that the state's energy consumption would consist of 20 percent renewable energy by 2022 (Office of the Governor "Governor O'Malley Urges…", 2008). Both of these legislative moves under the O'Malley-Brown Administration indicate a progressive shift in state leadership and intent to increase the prevalence of renewable energy in Maryland.

Though Maryland's leadership has indicated interest in utilizing renewable energy, a policy decision made in early 2008 barred commercial wind development on state lands. This decision was made following a contentious public review process over a proposed wind energy project in the Savage River State Forest.

U.S. Wind Force, a private company, had plans to build roughly 100 wind turbines on the land, which would require the clearing of approximately 500 acres of forest. The revenue generated by this wind energy project was projected to be $30 million in twenty years.

The Savage River Project was received with hostility by many citizens of Garrett County, where the Savage River State Forest is located, exemplifying the effect of social concerns on the construction of turbines. Eighty-three percent of public comments received by the Maryland Department of Natural Resources (DNR), the agency charged with overseeing state forests and parks, were against the proposed commercial wind project. Many of the objections centered around the NIMBYism argument, or that the aesthetic value of land would be lost following the construction of a wind farm, along with the land's existence as a public trust (Piotrowski, 2008). The minority that was found to support the proposed project cited the fact that state forests are currently harvested for timber. These individuals believed that since state forests are currently being utilized for commercial purposes, a wind development would be minimally different (Tidwell, 2007). Traditional arguments on climate change and a need for decreased greenhouse gas emissions were also noted. Additionally, Maryland has an increasing demand for energy, which may lead to rolling blackouts as soon as 2011 unless more capacity can be added, according to PJM (Office of the Governor "Maryland Strategic Energy Investment Fund", 2008).

O'Malley's decision has no implications on wind energy projects on private lands, and multiple proposals on private lands are being assessed in western Maryland currently. DNR is planning to consider small-scale, non-commercial renewable energy projects in the future, where it may be appropriate on state lands.

Environmental Benefits of Wind Energy

Wind energy stands to greatly decrease the United States' dependence on fossil fuels, thereby significantly decreasing the greenhouse gas emissions that contribute to the acceleration of global warming. Aside from the clear benefits derived here, wind energy decreases the emissions of other air pollutants and hazardous wastes. In general, the utilization of wind turbines for power generation can significantly decrease air pollution and hazardous waste problems in the United States (U.S. Environmental Protection Agency, 2000).

Environmental Drawbacks of Wind Energy

The major environmental concern that arises with wind power generation is of its effect on wildlife. These impacts can be either direct or indirect, but both can pose serious threats to the survival and health of various species. However, large holes remain in the literature on these topics. Before the implications of wind power on organism health can be truly understood, more research must be conducted.

Impacts on Birds and Bats

Despite being pitched as an environmentally-friendly alternative to fossil fuels, wind turbines have been deemed responsible for several negative environmental impacts. Opponents of wind energy often highlight the threat that wind turbines pose to bats and birds, implicating it with environmental regulations, such as the ones previously discussed. Turbines tend to occupy air space through which avian species and bats pass. With turbine tip speeds reaching up to 180 mph, birds and bats often cannot detect the blade. Some scientists attribute bird deaths to a bird's inability to register the movement of a blade when in close proximity to it. According to University of Maryland Professor William Hodos, "motion smear" may play a substantial role in bird deaths at the blades of wind turbines. "Motion smear" occurs when objects close to the eyes pass over the retina at such a speed that only a clear blur registers. "The eye cannot process the information once the bird gets close enough to rapidly moving blades," Hodos said. "They become transparent" (Cohn, 2008).

The United States' first wind farm, Altamont Pass Wind Farm, raised suspicions that wind turbines threatened avian species when a large number of dead birds were found around the site (Cohn, 2008). Since then, extensive studies of bird deaths in connection with wind energy facilities has been conducted.

Experts estimate that three to eleven birds are killed by each wind turbine in a given year; when one takes into account the number of turbines in the United States, this amounts to about 100,000 birds (Cohn, 2008). Each year, millions of birds die from other human causes. Dale Strickland, president of Western Ecosystems

Technology, Inc. claims these deaths to be roughly 50 million from communication tower collisions, 80 million from car collisions, and 3.5 million from window collisions (Cohn, 2008).

The phenomenon behind wind turbine related bat fatalities differs from that of bird fatalities, according to some researchers. Research biologist Paul Cryan believes bats are drawn to blade rotation and often chase after the blades (Cohn, 2008). Some biologists believe that the killed bats' echolocation capabilities failed them and made them unable to sense the blades in their path. Others suggest that high-pitched tones may be emitted by turbines, which attract nearby bats (Williams, 2004). The cause of death of these bats seems to be less simple than the clear collision-related deaths of birds. Nearly 70 percent of deceased bats at wind turbine sites seem to have no broken bones or signs of collision. Instead, these organisms appear ruptured, indicating that they may have been caught in the wind vortex created by the wind farm (Cohn, 2008). Still others suggest that the animals may be getting caught in wind shear associated with the turning turbines.

Obtaining an accurate estimate of the number of bat deaths attributed to wind turbines proves to be tougher than estimating bird deaths. Biologist Albert Manville from the U.S. Fish and Wildlife Service believes only a small portion of bats killed by wind turbines are accounted for due to the small size of bats relative to plants, other organisms, and the environment as a whole (Williams, 2004).

A 2007 report from the Wildlife Society estimated that over 50 bats are killed per turbine each year, which is nearly five times the number of birds killed by the same technology (Cohn, 2008). A synthesis of 21 studies of 19 wind energy operations in North America showed that bat fatality estimates were highest in forests of the eastern United States and lowest in the Rocky Mountains (Arnett, 2008). Of all bat deaths from wind farms in the United States, three-fourths come from either the eastern red, hoary, or silver-haired bat variety (Cohn, 2008). Migratory bats seem most susceptible to turbine-related death (Arnett, 2008). August and September prove to be the deadliest months for bats, which are migrating during this period (Cohn, 2008). Another analysis suggested that the peak in bat death by turbine surfaced in midsummer to fall (Arnett, 2008). Thus, these two independent studies indicate a nearly identical timeframe for the peak number of bat fatalities.

Though a significant number of bat and bird deaths seem connected to wind energy facilities, progress in wind farm siting and assessment processes creates a better environment for all organisms in the area. Though Altamont Pass Wind Farm, built in the 1980s, has been responsible for the death of at least 22,000 birds, minimal pre-construction studies were conducted to determine the suitability of the site for wind power generation. Had such research been conducted, developers would have recognized that the proposed wind farm lay on a key migratory route traveled by golden eagles and other raptor species (Whittelsey, 2007).

As the United States has become more accustomed to wind development, greater efforts to protect avian organisms have been taken. The wind industry has shifted wind turbine design in a new direction. Modern wind turbines strive for minimal bird perching sites, while also trying to deter birds and bats from entering the area (Cohn, 2008).

Others groups demand greater efforts by the wind industry to protect birds and bats from wind turbines. Some want the federal government, namely the U.S. Fish and Wildlife Service, to regulate the wind power facility siting process as well as the operation process (Cohn, 2008). Some worry that construction wildlife studies are insufficient in length due to industry demands for power production now. Though the U.S. Fish and Wildlife Service suggested a minimum study period of two years, the suggestion is nonbinding, and the agency lacks enforcement power unless a species listed as threatened or endangered per the Endangered Species Act is at risk (Williams, 2004).

Despite growing efforts to study bat and bird fatalities around wind turbines, additional information is needed. Post-construction studies of all wind turbines in the United States are essential to grasping the relationship between wind power production and wildlife fatalities. Biologists must dedicate more time to understanding what attracts birds and bats to turbines, so that efforts can be made to minimize this attraction. In addition, more needs to be understood about bat and bird migration so that future wind power facilities can avoid high-traffic routes.

Habitat Fragmentation

An additional environmental impact of wind turbines, which receives substantially less attention than the deaths of birds and bats, is habitat fragmentation. When a wind farm is constructed, extensive infrastructure is required for the construction of the facility, as well as its continued operation and maintenance. This infrastructure includes transmission lines and roads, which break apart natural landscapes and ecological corridors into discontinuous chunks, thereby decreasing organisms' abilities to access diverse food, habitat, and breeding opportunities.

One study suggests that wind turbines make habitats unusable by bird species. In that study, bird densities in areas without turbines were higher than those near turbines. The authors believed the turbines or a characteristic of such deterred the birds from locating near this project (Kuvlesky, 2007).

When transmission lines arise in an area, they prove to be a significant threat to birds and bats, because electrical transmission lines possess electrocution potential for these species (Kuvlesky, 2007). When near bodies of water, transmission lines pose a great threat to swans, geese, ducks, and cranes. In more land-locked regions, raptor species and passerines face the greatest threat for electrocution (Kuvlesky, 2007).

Roads pose a considerable threat to wildlife at wind turbine sites as well. Loss of biodiversity occurs through habitat fragmentation and is inextricably linked with road growth. When a habitat is split into smaller pieces, quality and quantity of the habitat diminishes along with biodiversity (Kuvlesky, 2007). Aside from decreasing the flow of native organisms, roads tend to encourage an influx of invasive species to the wind turbine site. Invasive plants have been known to flourish around roads, allowing them to eventually overtake native species (Kuvlesky, 2007).

To understand the full effects of wind farm induced habitat fragmentation, more studies are necessary. Wind power facilities should be studied over the course of their lifetime, including both pre- and post-construction phases. By examining the evolution of a site over time, the consequences of habitat fragmentation can be more accurately gauged.

Promising Practices in Wind Power: Wind Power and Cellular Phone Towers

As renewable energies become increasingly prevalent across the globe, it is probable that they will become more incorporated into the everyday lives of people. This phenomenon has already occurred to an extent, in that some cellular phone towers have recently begun to harness wind energy. In October 2008, Ericsson released a "wind-powered Tower Tube," which is designed to "improve energy efficiency, reduce environmental impacts and lower the costs of mobile networks for operators." This Tower Tube currently utilizes small turbine blades attached to a cellular phone tower, which produce electricity and reduce the outside electrical consumption of the phone tower. Thus, it is clear that there could be technologies in the future that may condense the needs of a wind farm with those of cellular phone towers.

Offshore Wind Development

Offshore Wind Projects in the United States

Ideal locations for wind power generation include those with high altitudes and wide, open lands. Such locations include tops of hills and areas near shorelines (AWEA, 2006). The Great Plain states of the United States Midwest contain most of the U.S.'s inland wind resources (AWEA, 2006). Unfortunately, much of Maryland lacks the geographical features and terrain favorable for on-shore wind power generation. However, offshore wind energy could be a promising energy resource. Offshore wind travels at higher speeds, have less wind shear, experience lower levels of turbulence due to a lack of air-disrupting geographical features, and tend to be closer to major coastal urban centers than land-based wind programs.

There have been a number of proposals to construct offshore wind turbines along the Atlantic Coast of the United States. In 2003, the New York-based company Winergy LLC applied to for federal permits to build thousands of steel and fiberglass wind turbines at several sites off the stretch of land along the Atlantic shoreline known as the Mid-Atlantic Bight, which extends from the Massachusetts to North Carolina. The company identified possible sites to build offshore wind farms based on criteria including water depth, nearby fishing activity, and wind resources. Winergy planned to build 2,000 turbines off the coasts Delaware, Maryland, and Virginia, and began to complete pre-application notices for federal permits from the Army Corps of Engineers (Alliance for the Chesapeake Bay, 2003). However, their progress for obtaining permission to begin the Maryland and Virginia projects was slowed by the federal government’s lack of solid rules and regulations for issuing zoning permits. In the meantime, the company has diverted its energy to obtaining a permit to construct a wind farm off the coast of Long Island, New York, and along the offshore regions of either Rehoboth Beach or Bethany Beach in Delaware (Fahrenthold, 2007).

Winergy is not the only company that has been interested in developing a wind farm off the coast of Delaware’s popular beach attractions. An offshore wind project is being considered by the Delaware state government and community as an alternative to constructing additional power plants that would burn coal or natural gas to produce more power in the state, after electricity prices there spiked in 2006. The idea was welcomed in Delaware after legislators called for more power production to deal with the state’s recent electricity price surge. Concerned about the rising electricity rates, the Delaware General Assembly passed House Bill 6 in 2006. The bill called for the local utility company Delmarva Power & Light to direct and contract with new power resources that will guarantee stable prices for electricity. In addition, the state legislature passed Senate Bill 74, a Renewable Portfolio Standard (RPS) requiring that 20 percent of the state's electricity to come from renewable sources by the year 2019 (Bluewater Wind, 2009).

Bluewater Wind, a New Jersey-based company, proposed to build the offshore wind project approximately 11.5 nautical miles off the Rehoboth Beach shore. Their proposal called for a 150 turbine offshore wind farm that would generate a 450 MW nameplate capacity. Each turbine would extend 263 feet high and contain three 150-foot blades. Bluewater Wind estimated that such a project could be completed by 2012 (Bluewater Wind, 2009). Bluewater Wind has built a land-based wind farm in Montana, but has never built an offshore farm (Fahrenthold, 2007). In their 2006 bid submission, Bluewater Wind proposed three possible sites with specifications and pricing for each. Two of the proposed facilities were in the Atlantic Ocean and would produce a nameplate capacity of 600 MW using 200 Vestas V90-3.0 turbines. Calculations by University of Delaware scientists showed that the wind resource in this area would have a capacity factor of about 40 percent, yielding an average of 240 MW for a 600 MW nameplate capacity facility (Dhanju, Whitaker, & Kempton, 2007). The third site proposed by Bluewater Wind would have been located in the Delaware Bay. The facility would have been slightly smaller than the ones proposed for the Atlantic Ocean along with a slightly lower capacity factor because its location (Dhanju, Whitaker, & Kempton, 2007).

Bluewater Wind's proposal was faced with expected opposition by representatives of the coal and gas plants, who also are competing for the bid from the Delaware state government. They claim that the wind farm would be an unreliable source of energy, since the wind is intermittent and does not blow all the time, potentially forcing the state to buy power from elsewhere. On the other hand, they claimed that there would be no such problems with coal, because the U.S. has an abundant supply of it. Some of the Delaware officials and staff members recommended a combination of a smaller wind farm and a gas plant that could supply power when the wind does not blow (Fahrenthold, 2007).

Other obstacles remain for the proposed Delaware offshore wind project. The biggest concern is that Delmarva Power, the utility company that operates in the Rehoboth Beach and Bethany Beach vicinities, would need to agree to buy electricity from the wind farm. The company publicly announced that it was against all of the proposals, and that none were cost-effective. Also, some local business owners were concerned that the windmills along the shoreline view might drive tourists away. However, it seems that the wind farm has generated significant public support, including that from the Delaware Audubon Society, which stated that the windmills could probably be built in a way that will not pose a serious threat to migrating birds (Fahrenthold, 2007).

A 2007 study by Dhanju, Whitaker, and Kempton at the University of Delaware College of Marine and Earth Studies research group affirmed that Delaware has immense wind energy resource. In their study, the researchers estimated an average annual output of over 7,000 MW in the waters off the Delaware coast out to a depth of 50 meters (Dhanju, Whitaker, & Kempton, 2007). This is over five times the current electrical consumption of the entire state of Delaware. At current local electricity market prices, this would produce just over $2 billion per year in revenue (Dhanju, Whitaker, & Kempton, 2007). In addition to an analysis on the state's offshore wind resource potential, the study also included a statewide survey which indicated that Delaware residents are strongly in favor of offshore wind power as a future energy source for the state. In the survey, 949 Delaware residents were asked to select from a variety of sources to help the state increase its energy supply. Over 90 percent of respondents supported an offshore wind option in which wind turbines as tall as 40-story buildings would be erected off the coast to generate electricity, even if the option were to add between $1 and $30 per month to their electric bills. Fewer than 10 percent of those surveyed opted for an expansion of coal or natural gas power at current prices (Dhanju, Whitaker, & Kempton, 2007). Marine policy scientists Jeremy Firestone and Willett Kempton, both on the faculty of the University of Delaware's College of Marine and Earth Studies, and doctoral student Andrew Krueger, suggested that the overwhelming majority of Delaware residents they surveyed would rather pay more to support offshore wind turbines than support coal or natural gas sources at lower prices.

The policy scientists who conducted the study were themselves surprised at their results. In 2004 and 2005, Kempton and Firestone had conducted two surveys of residents of Cape Cod, Massachusetts about the controversial Cape Wind project, in which Energy Management Incorporated proposed to establish a wind farm of 130 wind turbines in the Nantucket Sound. Those results showed that “a plurality of Cape Cod residents was opposed to that project" (Bryant, 2007). However, they found that nearly 78 percent of Delawareans statewide would “give a project identical to Cape Wind a thumbs-up if it were located in Delaware,” and only 4 percent would oppose such an idea, with the remainder unsure (Bryant, 2007). With such great support, Firestone said that, “based on our results, Delaware could become the Denmark of the United States when it comes to relying on offshore wind power as a major energy source” (Bryant, 2007).

The researchers proposed a number of factors that could be contributing to the Delawareans’ positive outlook toward offshore wind power. One reason may be because the offshore wind proposal includes a “well-financed opposition,” namely the local utility company Delmarva Power & Light. Local residents may believe that Delmarva is primarily responsible for the recent electricity rate spikes, making them eager to welcome a proposal from an energy company with a new concept and fundamentally different approach to solving the problem. Additionally, Delaware residents may generally be more aware of and concerned about the rate of climate change, global warming, and its health effects. While the study did not do any actual research on the reason for Delawareans’ support of wind energy, they plan to determine these factors through additional research in the near future (Dhanju, Whitaker, & Kempton, 2007; Bryant, 2007).

The University of Delaware survey also included questions to determine any potential effects on beach visitation by in-state residents. The survey asked participants how their vacation plans would be affected if a large, 500-turbine wind farm were installed six miles off the state's coast. While "88.6 percent would continue to go to the same beach they last went to in Delaware even if a large wind farm were constructed offshore there," 5.6 percent said they would switch to another beach in Delaware, another 3.5 percent said they would go to a beach outside Delaware, and 2.4 percent said they would visit no beach at all. Another question asked if respondents would be inclined at least once to visit a Delaware beach that they did not typically frequent if a wind farm was visible offshore. A high response of 84 percent said "yes," suggesting that the wind turbines would actually draw visitors instead of driving them away (Dhanju, Whitaker, & Kempton, 2007).

In June 2008, Bluewater Wind and Delmarva Power and Light signed a Power Purchase Agreement (PPA) under the order of the Delaware Public Service Commission. The PPA states that Bluewater Wind agrees to build a 150 turbine, 450 MW wind facility in the Atlantic Ocean approximately 12.5 miles off the Rehoboth Beach shore. Delmarva Power agrees to buy up to 300 MW at any one time. Delmarva ratepayers will pay a cost of 10.56 cents per kWh for energy and capacity in 2007 dollars (Delaware Public Service Commission, 2008). Delmarva has also stated that it will be purchasing RECs associated with its energy purchases (Firestone, 2008). According to the state of Delaware's independent consultant, the "typical 1000 kWh/month Delmarva household" would see an estimated rate impact on its energy bill of $6.46 per month (New Energy Opportunities, La Capra Associates, Merrimack Energy Group, & McCauley Lyman, 2007). The rate impact is defined as a comparison of the known Bluewater price for wind power and the estimated future market price of other power, which is subject to uncertainties in the cost of natural gas and carbon allowances (Firestone, 2008).

Bluewater Wind has also had its sights set on building an offshore wind park in waters off the Maryland state coastline. The company has issued a proposal to build an offshore wind farm near Ocean City, Maryland's most popular beach vacation destination. In the fall of 2007, Bluewater Wind began discussing its proposal to put 150 turbines approximately 11.5 miles off the coast of Ocean City with Governor Martin O'Malley and other Maryland state officials. If approved, the proposed wind farm could provide enough electrical power for 110,000 local homes (Associated Press, 2007).

From the Ocean City beach, the turbines would look like toothpicks far out at sea. However, some local residents and business owners have voiced apprehension about how their visibility could negatively affect business and tourism to the area. In contrast, supporters of the project emphasize the importance of using alternative forms of energy to retard the accelerating rate of global warming, which could directly affect coastal areas like Ocean City because of predicted rising sea levels over the next few decades. Mike Tidwell of the Chesapeake Climate Action Network replied to the locals' worries over the potential aesthetic damage the wind turbines might cause by saying, "if you say you don't want a dime-size windmill in the distance, we'll have to abandon all the hotels and all the houses and all the restaurants because the ocean's coming to swallow them" (Associated Press, 2007).

The project has yet to formally contact other agencies, including the Maryland Public Service Commission and the Department of Natural Resources, which are critical deciding bodies for the approval of the project. Governor O'Malley's spokesman Rick Abbruzzese said that after preliminary talks with Bluewater about the proposal, he found the project to be "an intriguing idea," but wanted to obtain additional information, admitting that Maryland "needs to find ways to produce alternative forms of energy" (Associated Press, 2007).

These proposals by wind development companies, to construct offshore wind farms of up to several hundred turbines along the coastal lines of the mid-Atlantic states, suggest that there is great promise in this region for producing significant amounts of energy. As the study by Dhanju, Whitaker, and Kempton shows, the small coastal state of Delaware has the potential to generate an annual output of over 5,000 MW, which would offset more than four times the state's total average electrical consumption. With similar terrain and geographical characteristics along its coastal regions, the neighboring state of Maryland could undoubtedly produce a considerable amount of wind energy, which would help offset the state's current electricity use and carbon footprint. Maryland is not only a bigger state by measure of its total geographical area, but also contains a larger proportion of the Atlantic continental shelf, naturally giving it greater potential to host more wind turbines for the proposed projects along its eastern shore.

Offshore Wind Projects Outside the United States

Several countries in Europe have had notable success in the development of offshore wind power in the last decade. Europe currently is the global leader in offshore wind power development, owing largely to rich wind resources and the shallow waters of the North Sea and Baltic Sea. With eight operational wind farms, and 590 MW of nameplate capacity installed, the United Kingdom is the world's leading generator of offshore wind power. Denmark comes in at a close second with seven currently operational farms, and 410 MW of nameplate capacity. In 1991, the first offshore wind farm, Vindeby, was constructed in Denmark with a capacity of just 5 MW. As of 2009, the Lynn and Inner Dowsing Wind Farm off the coast of Lincolnshire, in the United Kingdom, is the world's largest offshore wind farm. It consists of 54 turbines and generates a capacity of 194 MW, enough to power 130,000 homes (Byrne & Houlsby, 2003). There are five more wind farms currently under construction in the United Kingdom, which are all planned to be completed by 2011. One of them, called The Greater Gabbard, will consist of up to 140 turbines to be built 23 km off the coast of Suffolk, and will generate a planned capacity of 500 MW (Scottish and Southern Energy, 2008). Another offshore wind project called the Thanet is scheduled to be completed in 2009, will be composed of 100 turbines, and will generate a planned capacity of 300 MW, enough to supply approximately 240,000 homes per year (Warwick Energy, 2008).

In Denmark, the Nysted Wind Farm is the largest in the country, and was previously the largest offshore wind farm in the world before the Lynn and Inner Dowsing Wind Farm was completed in 2008. The wind farm is a joint Danish-

Swedish venture built in 2003, with 72 turbines and a total capacity of 166 MW. Its annual production is approximately 595 million kWh, which is equivalent to the electricity consumption of 145,000 Danish homes, and is projected to save up to 500,000 tons of carbon dioxide emissions (Dong Energy, Vattenfall, Danish Energy Authority, & Danish Forest and Nature Agency, 2006). Another large wind farm built in Denmark is the Horns Rev offshore wind farm in the North Sea, which was constructed by DONG Energy, formerly known as Elsam. The wind park consists of 80 turbine units, and generates a total capacity of 160 MW. In 2005, the wind farm was bought by Vattenfall, which continues to operate it today (Dong Energy, Vattenfall, Danish Energy Authority, & Danish Forest and Nature Agency, 2006). A 2006 report from Danish energy and environmental government agencies said that based on an eight-year study of Horns Rev and Nysted, both wind farms are expected to double in size in the coming years. In an evaluation of the two wind farms' impact on the aquatic ecosystem, including birds, fish, and seals found on the surrounding seabed, the International Advisory Panel of Experts on Marine Ecology had a positive reaction to the projects, and concluded that they "operate in harmony with the surrounding environment" (Hansen, 2006).

Indirect Renewable Energy Delivery

Renewable Energy Credits

Renewable Energy Credits (RECs) constitute one of the simpler ways that the University of Maryland can works towards fulfilling its Presidents' Climate Commitment promise of inevitably reaching complete carbon neutrality. The Center for Resource Solutions' Green-e Certification Program represents the "…nation's leading independent renewable energy certification and verification program," according to the program's website. In fact, as of 2005 Green-e certified more than 53 percent of the renewable energy sold in the United States. RECs, by the Green-e standards, are created when electricity is generated by facilities utilizing renewable energy. A REC "…represents all of the environmental attributes or benefits of a specific quantity of renewable generation, namely the benefits that everyone receives when conventional fuels….are displaced." Essentially, when a REC is purchased, the buyer is paying to offset the environmental impact of the non-renewable energy source that is otherwise being paid for and utilized.

It is clear that RECs can be used to offset the University's carbon emissions that result from purchasing other types of power, such as coal, oil, or gas, thereby working towards the University's stated goal of carbon neutrality. While there are currently no RECs produced in the state of Maryland, if the University were to generate renewable energy through the construction of wind turbines, the Green-e Certification and Verification Process could be followed in order to get this energy certified as renewable. These RECs that the University's wind turbines would generate would offset the carbon emissions produced at the actual College Park campus. Indeed, the purchase of RECs has been utilized by a number of large universities throughout the United States in an effort to offset these institutions' carbon emissions.

Limitations of Using Renewable Energy Credits

There is debate about how to regulate RECs effectively and efficiently within the environmental community. Of the two primary viewpoints taken, "the more conservative camp believes that regulatory regimes should never allow RECs to be sold separately from the energy that generated them" (Castro, 2008). This group reasons that if the benefits of RECs are separated from their energy source, large consumers of electricity who are forced to adhere to environmental regulations would be paying this premium, essentially, for the right to pollute. The opposing viewpoint is that "renewable energy development will benefit more if RECs and their associated energy are allowed to be sold separately" (Castro, 2008). This group suggests that this market-based exchange of the benefits that RECs represent will encourage greater investment in renewable energy generation, which will lead to an increase in overall renewable energy development. However, there has been some controversy regarding the success and effectiveness of RECs in the United States, as some firms have recently purchased and traded them for profit (Aston, 2007). While RECs do represent the offset of carbon emissions, it is less clear if their trade has any negative impacts upon their purchaser. Moreover, in 2006 "Clean Air-Cool Planet, a nonprofit global warming group, released 'A Consumer's Guide to Retail Offset Providers,' a report that questioned the use of RECs as carbon offsets" (Barcott, 2007). This report suggested that RECs, by definition, were unable to represent the offset of carbon emissions, and should not be traded as a commodity of this nature. Thus, although it is still generally accepted that RECs can serve to offset carbon emissions at institutions like the University of Maryland, more direct options would be preferred over RECs.

In general, there are a number of issues that threaten the expansion of the generation of renewable energy and RECs. Federal renewable energy tax credits will expire this year, meaning that companies that supply renewable energy will no longer be able to take advantage of these benefits. This is problematic since such tax credits help to make renewable energy more affordable (it is currently more expensive to generate wind energy, in particular, compared to energy generated by a coal or oil fueled power plant). According to Vic Abate, General Electric vice president, "Without [tax credits]… new wind power installations could drop by 90 percent." It is therefore clear that these tax credits provide major incentive to build wind turbines, which supply renewable energy. In addition, it is projected that if tax credits no longer exist, this "would lead to the loss of $19 billion in investments and 116,000 job opportunities through 2009." Therefore, the financial return on investing in wind energy is significantly reduced through the elimination of tax credits, and few investors would be willing to offer capital for the reduced returns that would exist without the tax credits. Moreover, investment in wind energy seems to have positive externalities other than the environmentally-friendly nature of energy production, especially the generation of jobs. Thus, it appears that if the United States intends to transition towards more sustainable energy practices, it must provide tax credits to these developing energy industries, particularly the wind power industry. In any case, the University of Maryland could work to operate its own wind turbines, which could generate RECs and offset the University's carbon output. If the University's goal is not necessarily to profit, but instead to offset carbon emissions in a financially viable way, then the construction of wind turbines could be quite practical.

In response to these concerns of wind energy producers, Congressional Global Warming committee members have suggested that the primary goal should be to create permanent tax credits, which would quell any uncertainty in the marketplace and encourage greater investment of capital in renewable energy. Then-ranking committee member James Sensenbrenner (Wisconsin – Republican) has "most favored the research and development and production tax credits." If the United States government commits to promoting the development of renewable energy, then the nation would certainly benefit from this aid, transitioning quicker towards the sustainable generation of electricity. Accordingly, those companies that develop renewable energy would be able to offer RECs at more competitive prices, thereby benefitting institutions such as the University of Maryland. Furthermore, if the University did, indeed, elect to construct its own turbines, the University could take advantage of any applicable incentives. Hence, if greater investment in renewable energies is encouraged through legislation, it should only become easier for the University to work towards its goal of carbon neutrality.

Recent legislation passed in October 2008 will likely impact the REC market in the aforementioned manner. Passed as part of the United States financial bail-out plan, "this legislation provides an extension of the existing renewable tax credits, but also includes provisions for new tax incentives as well as bonds and the relaxation of regulations for industry and changes for major utilities (Conlin, 2008).” Lawmakers have elected to extend the current tax credits for generating renewable energies, which should encourage renewable energy expansion and may make it more advantageous for the University to look towards generating its own renewable energy. This recent legislation suggests that the United States government is committed to encouraging renewable energy development, and the University of Maryland may be able to benefit as a result.

Universities and Renewable Energy

Many other institutions have already started consuming renewable energy on their campuses. There are two main ways that universities use renewable energy. There are institutions that are buying Renewable Energy Credits (RECs), and there are institutions that have projects to construct renewable energy infrastructure.

Several universities throughout the United States, both public and private, have already begun to utilize RECs to offset their carbon emissions. Northwestern University, which is a private university of 14,000 undergraduate students in Illinois, currently purchases 40 million kWh of RECs annually, according to the U.S. Department of Energy. This purchase represents 20 percent of Northwestern’s annual electrical consumption, and dramatically reduces their carbon footprint. Similarly, the University of Colorado at Boulder purchases 8.8 million kWh of RECs each year, which provides electricity for three student-run buildings on campus. Finally, Duke University purchases 54 million kWh of RECs annually, and the Fuqua School of Business at Duke offsets 100 percent of its electrical consumption through the purchase of RECs. Thus, a number of institutions similar to the University of

Maryland in size, as well as a geographically local school in Duke, have begun to utilize RECs to offset their electrical purchases. It would not be unreasonable to think that the University can begin to do the same, which would work towards the University's stated goal of carbon neutrality.

RECs in Maryland

It is clear that RECs can be used to offset the University's carbon emissions that result from purchasing other types of power, such as coal, oil, or gas, thereby working towards the University's stated goal of carbon neutrality. While there are currently no Green-e certified RECs produced in the state of Maryland, if the University were to generate renewable energy through the construction of wind turbines, the Green-e Certification and Verification Process could be followed in order to get this energy certified as renewable. There are currently RECs being produced in Maryland at the Conowingo Hydroelectric Project that have been certified by the Low Impact Hydropower Institute (LIHI), which focuses on certifying the electricity produced by low-impact hydropower dams. However, while it is important to note that there are RECs currently being produced in the state of Maryland, the LIHI certification would not be applicable if the University attempted to produce RECs through the use of wind turbines. The RECs that the University's wind turbines would generate through the use of wind turbines would offset the carbon emissions produced at the actual College Park campus, and could be certified by Green-e. Indeed, the purchase of RECs has been utilized by a number of large universities throughout the United States in an effort to offset these institutions' carbon emissions.

Additionally, a 2008 study by the National Wildlife Federation cites a number of "Exemplary Schools for Environmental or Sustainable Goal-Setting." Schools in this category that are large, state institutions similar to the University of Maryland include Michigan State University, University of Arizona, University of Minnesota, University of South Carolina, and the University of Virginia. According to the report, "these schools have taken the lead in setting and reviewing goals for conservation and environmental or sustainability issues" (National wildlife Federation, 2008). George Washington University, which is close to the University of Maryland, also falls into this category. As leaders in this area, these institutions have demonstrated the ability to establish goals for campus sustainability that are both feasible and environmentally friendly. The University of Maryland should undoubtedly make an effort to establish a clear, effective plan of this nature, because it will signal an even stronger commitment to its stated goals of sustainability. Moreover, this study identifies a number of schools similar to the University that "are noteworthy for having both recruiting programs for students and for offering interdisciplinary degree programs in environmental or sustainability studies" (National Wildlife Federation, 2008). In particular, Arizona State University, University of California at Los Angeles, University of Illinois, and the University of Wisconsin are identified, in addition to other institutions that were mentioned previously. It is obvious that programs of this nature would contribute to creating an environmentally-conscious student body at an institution, since students already possessing an advanced interest in the environment or sustainability would be attracted to these programs. The University of Maryland, through programs of this nature, would be more likely to have students support environmental or sustainable initiatives, and would also have more students on campus obtain education about these subjects. This would certainly be beneficial for the University as it works towards the fulfillment of the Presidents' Climate Commitment.

The University of Maryland is identified by this 2008 study as an "Exemplary School for On-Campus Clean Energy Sources and CoGeneration" (National Wildlife Federation, 2008). The University meets these criteria due to its on-campus combined heat and power (CHP) plant, which generates heat and electricity. Thus, the study does suggest that the University utilizes some technologies that are environmentally beneficial, although there is clearly the opportunity for expansion into other sustainable methods for energy generation. Unfortunately, this is the only program that the University currently has in place, or has made plans to put in place, that the study identifies as "Exemplary" (National Wildlife Federation, 2008). It is therefore evident that the University of Maryland still has a great deal of work to do if it wishes to demonstrate a genuine commitment to sustainability.

Constructing renewable energy infrastructure is a method that is commonly being used to offset a large portion of the carbon footprint of small colleges. For these small schools building the infrastructure represents a onetime investment that can replace a large portion of the institution's energy usage. For larger institutions, such as the University of Maryland, a much larger one time investment would be necessary to offset the same percentage of the carbon footprint. For example, Carleton College is a small institution in Northfield, Minnesota that currently enrolls about 2,000 students. In 2004, the college spent $1.8 million to build a 1.65 MW wind turbine near campus. This 1.65 MW turbine produced 40% of the college's total energy usage (Heinz, 2006).

Some smaller colleges are funding renewable energy projects that completely offset the institution's carbon footprint. For example, Middlebury College is a small college in Vermont which enrolls about 2,300 students. In 2006, the college pledged to attain complete carbon neutrality by 2016. Since then, the college has built a 10 kW wind turbine, roughly 10 kW worth of solar panels, and a $12 million biomass gasification boiler. The university is funding these projects through their endowments, as well as donations from students and local residents (Green Report Card, 2009).

Some larger universities have grass roots programs that fund small energy projects. For example, the University of Vermont authorized an organization that was formed in May 2008 called the "The Clean Energy Fund." This organization created a $10 per semester charge for all students, totaling about $20,000 per year. This money will be used to fund small renewable energy projects starting as early as fall 2009 (Vermont, 2009).

There are a few large universities that have constructed large renewable energy projects. These are large projects that are built off campus, depending on where conditions are optimal. For example, Colorado State University announced plans in March 2007 to build a wind farm that will produce more energy than the university consumes. The 11-acre wind farm is still under construction, and will have 25 turbines rated at 4 MW. When complete, the wind farm will produce about 65 MW, which is significantly larger than the university's average electrical consumption of roughly 16 MW (Green Report Card, 2009). Unfortunately, large projects like this are unusual for large universities. In general, larger institutions such as the University of Maryland buy RECs in order to diminish their carbon footprint.

Geographic Information Systems (GIS)

Introduction to Geographic Information Systems (GIS)

Geographic Information Systems (GIS) is an increasingly popular spatial analysis tool being utilized across disciplines ranging from epidemiology, to crime control, to resource management. GIS software installed upon a user's computer allows him or her to analyze relationships between geographic characteristics and other attributes through the generation of a digital map (Kures, 2009).

In order to conduct spatial analysis, the GIS user combines two or more groups of data, known as layers, into a single digital map document (Kures, 2009). Each of these layers contains data linking geographic areas to other attributes. The linked attributes can communicate any data the user wishes to link to that geographic entity. In planning and policymaking, these attributes most often highlight demographic factors, environmental health, human health, or land use.

Once these layers are combined into a single digital map, many analytical tools are available to system users. Functions allow users to hone in on specific geographic areas, overlay data from multiple layers into a single one, and create buffers around geographic shapes.

GIS layer data can be obtained through many sources. Basic boundary files are often available with the purchase of GIS software. Shapefiles, the file type of a

GIS data layer, can be downloaded from many federal entities, including the U.S. Census Bureau, the National Renewable Energy Laboratory, and the Environmental Protection Agency. For the state of Maryland, the Department of Natural Resources and Department of Planning have extensive GIS resources available.

GIS and Wind Energy

GIS has been utilized to analyze potential wind power potential in several projects to date. In 2001, a report delved into the development and application of GIS to wind farm location in the United Kingdom. This approach designated rankings of importance to the layers included in the map. The resulting areas were ranked on a scale of 0 to 10, with 0 representing ideal wind farm sites and 10 indicating unsuitable locations (Baban, 2001).

In a 2003 report to the Vermont Department of Public Works, Vermont Environmental Research Associates, Inc. (VERA) analyzed wind power potential on Vermont's public lands. As part of their methodology, VERA used GIS technology. First, analysts mapped areas of Vermont having wind speeds of category 3 or above, levels at which wind power generation is at least marginally productive. Once these areas were pinpointed, public lands data was imported to the map with level of development protection indicated. By overlaying data on suitable wind strength with land protection categories, analysts were able to hone in on possible sites for wind farm development in Vermont (Vermont Environmental Research Associates, Inc., 2003).

A 2006 study of Northern California depended upon GIS analysis to select potential wind power sites in nine counties. This project incorporated socioeconomic elements into its analysis. The result was a model indicating which areas of the region may be suitable for wind power development. The model's predictions have been largely accurate when compared to proposed and installed large-scale wind power development sites (Rodman, 2006). Hence, it is clear that GIS can be utilized as a tool to analyze potential sites for wind power development, and that it has been used effectively in this area in several studies already.

Chapter 4: Methodology

Summary

A total of twenty-six sites in Garrett, Allegany and Washington Counties were identified as having adequate wind energy potential to warrant a cursory wind energy review. Heterogeneity within several of these sites necessitated further revision into sub-sites for more detailed analysis. Attributes were characterized for each site and generated measurements of land use protection, suitability for construction on the site, and approximate proximity of the windy regions to roads, transmission infrastructure, and nearby populations. Attributes were assigned scores between 1 and 5, where a score of 5 characterized the best suited condition of that attribute to warrant wind farm development.

Wind speed measurements at 50m height along with the length and width of individual sites characterized as rectangles, were input into a MATLAB algorithm that calculated the number of turbines and capacity of turbines on the site, based on the most efficient packing structure for the turbines and the best suited turbine size. The capacity factor of the site and the energy generation potential were then assigned scores on a scale of 1 to 5 based on how they compared to each of the other sites in our analysis.

Weights assigned to each attribute were determined through a systematic subjective process based on the perceived priorities of the University and the conditions that would make the site best suited for University implementation. The weights for each factor were added to produce a final score between 1 and 5. This score was used to rank the sites relative to the others to establish the best suited sites for University development.

Additional data on financial viability were generated based on the capacity factor, number of turbines on the site, and each turbine's generation potential. Upfront capital costs of the wind farm included turbine expenses, as well as an "Other" category that included transmission, connectivity, and site and labor costs. Operations and Maintenance costs were also incorporated. The financial feasibility assumed a regionally appropriate rate for "Electricity Export Rate", transmission losses, and financial parameters including debt ratio, debt term, and inflation rate. The resulting analysis output a "Cumulative Cash Flow" graph showing cash flows for the life of the wind farm, and approximations for the Equity payback time, and Pre-tax IRR for equity.

The above methodology is explained in more detail in the following sections.

Generating Wind Energy Site Assessment Maps Using GIS

To conduct an analysis of potential wind power generation sites in Maryland, we used Geographical Information Systems software (GIS). Through GIS, maps are created using combinations of data layers which link geographic entities to nongeographic attributes.

For our analysis, we chose to focus on three specific qualities linked to wind energy siting feasibility. First, we examined the wind speed as categorized in National Renewable Energy Laboratory(NREL) data. Secondly, we looked at the level of legal and environmental protection afforded to geographic areas. Finally, we analyzed proximity to transmission lines of suitable voltages. This information was constrained by the political boundaries of the three westernmost Maryland counties—Alleghany, Garrett, and Washington. By investigating these three components in GIS software within these counties, potential sites could be labeled and analyzed using our suitability model.

Geographically Defining our Focus Area

To evaluate locations for wind turbine construction suitability, we examined potential onshore lands in Maryland on a county-by-county basis. This approach allowed us to focus geographically only on regions in Maryland with high wind power potential, most notably counties with mountainous terrain in western Maryland (refer to Figure 5). Consequently, our research was focused on collecting land use and wind power data from Allegany, Garrett, and Washington counties in Maryland. Data on land use protections and orthotopography were provided primarily through the commissioner's office of each county.

Element 1: Wind Speed

Data Source: Our assessment of potential sites for wind turbine construction through the state of Maryland depended on the NREL's national wind resource assessment of the continental United States. The national wind resource assessment was created for the U.S. Department of Energy (DOE) in 1986 by the Pacific Northwest Laboratory and is documented in the *Wind Energy Resource Atlas of the United States* (US DOE, 1986). It provides an estimate of the annual average wind resource for the contiguous U.S. and high-resolution wind data.

Our data estimates are consistent with NREL's classifications for wind power from *Wind Energy Resource Atlas of the United States* (US DOE, 1986). The wind resource assessment divided the continuous U.S. into grid cells measuring ¼ degree of latitude by 1/3 degree of longitude. Each grid cell was assigned a wind power class based on a classification system ranging from class 1 (least windy) to class 7 (most windy). Each assigned wind power class represents a range of mean wind power densities (in units of W/m^2) or equivalent mean wind speed at the specified height(s) above ground that are likely to occur at exposed sites within a grid cell (Table 4).

Table 4: NREL Wind Classifications

Classes of wind power density at 10 m and 50 m(a)				
Wind Power Class	**10 m (33 ft)**		**50 m (164 ft)**	
	Wind Power Density (W/m 2)	**Speed (b) m/s (mph)**	**Wind Power Density (W/m 2)**	**Speed (b) m/s (mph)**
1	0	0	0	
2	100	4.4 (9.8)	200	5.6 (12.5)
3	150	5.1 (11.5)	300	6.4 (14.3)
4	200	5.6 (12.5)	400	7.0 (15.7)
5	250	6.0 (13.4)	500	7.5 (16.8)
6	300	6.4 (14.3)	600	8.0 (17.9)
7	400	7.0 (15.7)	800	8.8 (19.7)
	1000	9.4 (21.1)	2000	11.9 (26.6)

The wind resource assessment was based on surface wind data, coastal marine area data, and upper-air data. The wind power estimates apply to areas free of local obstructions to the wind and to terrain features that are well-exposed to the wind such as open plains, tablelands, and hilltops. Within areas containing mountainous terrain, the wind resource estimates apply to exposed ridge crests and mountain summits.

Our Analysis: When the Maryland wind resource shapefile was imported into ArcGIS for our analysis, we limited the data expressed to wind classes greater than or equal to three. NREL considers areas designated Class 3 or greater to be suitable for most wind turbine applications, whereas Class 2 areas are marginal and Class 1 areas are generally not suitable for wind turbine applications. For the purposes of our research, we regarded areas of Class 3 and above as those with potential for wind turbine construction and focused our efforts on these areas.

Element 2: Classifying Land Protections

Data Source: In order to identify sites that had potential for wind turbine construction based on availability and inhibition by state and federal land protections, we relied on land protection classifications within our counties of interest as represented by the Maryland Department of Natural Resources (DNR). As the overseer and manager of over 400,000 acres of public land in Maryland, DNR classifies the state's land units according to their significance, resource management practices and recreational focus, or by a program created by the Maryland General Assembly. DNR's GIS resources divided land into ten different designations related to protection level:

- Maryland Agricultural Land Preservation Foundation (MALPF) Easements

- County Parks
- Maryland Department of Natural Resources (DNR) Lands
- Maryland Environmental Trust (MET) Easements
- Federal Lands
- Forest Legacy Easements
- Private Conservation Properties
- Rural Legacy Areas
- Targeted Ecological Areas

Our Analysis: A very significant part of wind power siting is assessing the level of legal protection afforded to potential sites. To gain a grasp on the spatial relationship between different land protection levels and wind speeds, DNR's data on land protection was added to our maps. The classes of protection included in the GIS resources of DNR—and therefore included in this study—are mentioned in the "Data Source" section above (page 74). Lands not encompassed in one of these categories will be referred to as "all other lands."

For the purposes of our research, we used these DNR land protection designations and re-classified them into three land protection categories to communicate the implications of land use protections on wind energy development. These three categories classify lands as being under "Full Protection," "Potential Conflict," or "No Conflict." A detailed description of each of these categories and their components follows:

- *Full Protection*: Sites labeled as such outlaw development or limit it to agricultural or similar low disturbance activities. Most of these categories rely on an easement, which is a legal contact restricting activity upon the property. A majority of such easements limit development on that property in perpetuity. Any areas under this categorization were excluded from the list of possible wind power generation sites and were represented by black polygons in the GIS map, and include:

  - MALPF Easements
  - MET Easements
  - Forest Legacy Easements
  - Rural Legacy Lands

- *Potential Conflict*: Geographic areas falling in this category featured some limitations on development, but due to uncertainties in policy or discrepancies in level of protection afforded, they were not excluded from the analysis. Though hurdles may exist to wind energy development on these sites, the uncertain strength of their protections makes their incorporation in our analysis a possibility.

  - County Parks: The idea of using county park-land for wind power production seems absent in the literature and news. Because no specific statute or policy exists on this matter, potential exists for wind turbines to be constructed in county parks.
  - DNR Lands: As discussed in the literature review, the state of Maryland has outlawed commercial wind development on state lands, which are held in the public trust. However, the University of Maryland could potentially legally challenge this policy in respect to

University wind power development on state lands; this could be disputed from the angle that such development would not be commercial or that development would be an exercise of holding the land in the public trust.

  - Federal Lands: The federal government lacks clear policy on wind power development on public lands and seems to be evaluating proposals on a case-by-case basis. This indicates the University has an opportunity to pursue this option.
  - Private Conservation Properties: The stipulations of private conservation lands differ and would need to be examined on a case-by-case basis. One cannot assume wind power production would be an outlawed activity upon them because of variances in the covenants.
  - Targeted Ecological Areas: Though these areas are viewed as environmentally significant, no legal doctrine explicitly protects these properties from development. However, it is likely that highly sensitive areas under this category would be aggressively protected by conservationists and environmentalists from both the private and public sectors.

- *No Conflict*: All locations without any of the above land protections were assumed to have no direct conflict with wind power production. We recognize, however, that land protection plans unbeknownst to DNR may exist on these properties, so further research will be required to analyze them if the site selection process were to proceed.

Once the wind speed and land protection layers were overlaid, potential wind production sites were selected. This process is described in more detail in the section titled "Creating Focus Sites Based on Areas with Viable Wind Speeds" (page 77).

Element 3: Proximity to Transmission Lines

Data Source: PJM Interconnection is the name of a regional transmission organization (RTO) that coordinates the movement of wholesale electricity across parts of the mid-Atlantic states of central and eastern Pennsylvania, and virtually all of New Jersey, Delaware, western Maryland, Washington, D.C, along with other states. PJM operates this region's wholesale electricity market and manages its high-voltage electricity grid, which serves over 51 million people.

Our Analysis: In order to maximize the amount of power reaching consumers, it is essential that wind power facilities be sited near adequate transmission lines. This was the third element of our GIS analysis. A layer indicating power lines of four classes was added to our digital map. These classes were indicative of the following voltages: 115 kV, 116-138 kV, 139-230 kV, and 231-500 kV.

For each of the 26 sites targeted through the overlay of element 1 and element 2, proximity to transmission lines needed to be measured. Through a GIS measuring tool, the center of each site was found. From there, a measurement from the site's center straight to the nearest transmission line was taken.

Creating Focus Sites Based on Areas with Viable Wind Speeds

Once all of the data layers were placed onto the GIS map, the data was ready to be analyzed. In order to focus the analysis, the maps were divided into small sections which represent separate sites for wind farm development. Each section is approximately 16 square miles, and contains an area of at least Class 3 wind speeds. The map was divided into these areas in two steps. First, the maps were divided into windy (Class 3 or higher) and no-wind areas. Then, the windy areas were broken down into small squares.

Examination of the map indicated there were small areas with sufficient wind for energy production surrounded by large areas devoid of wind. Since the other layers in the GIS maps were not homogenous, an analysis of large stretches of wind would not be valid. A mountain ridge has high wind speeds, but land use protections could potentially apply in some areas but not others. For example, Sites H and M are both along the same mountain ridge and have similar wind speeds. However, they have very different protection regulations as well as grid connectivity. Another division was necessary in order to properly analyze the GIS maps. Sixteen square miles was judged to be large enough to conduct a feasibility study, but small enough to be roughly homogenous. The three counties were divided into 26 sites (A-Z) and each was separately analyzed (Figure 6, Figure 7, and Figure 8).

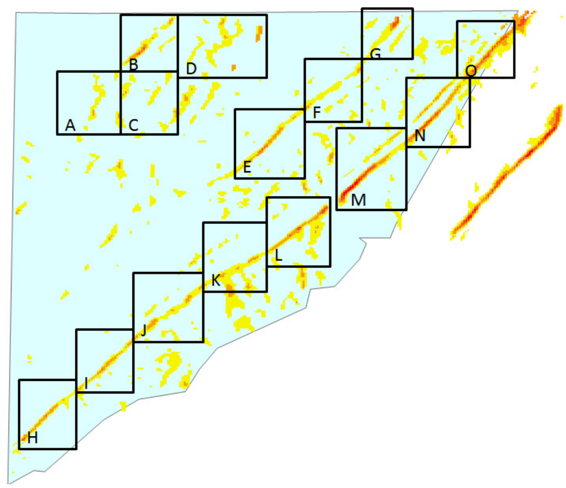


Figure 6: Garrett County Sites

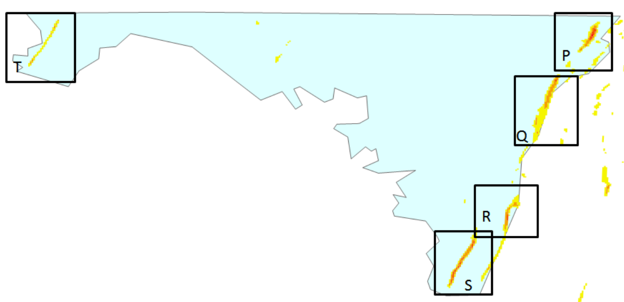


Figure 7: Washington County Sites

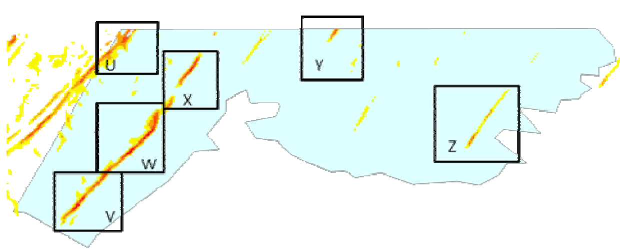


Figure 8: Allegany County Sites

Applying GIS Results in an Excel Site Analysis Model

In an effort to consistently and systematically rate sites based on their viability for purchase by the University of Maryland, with the intention of constructing wind turbines, a Microsoft Excel spreadsheet was utilized. In this model, a value for Overall Suitability was determined by assigning rankings to multiple criteria comprising Site Suitability and Energy Availability. Rankings were derived through evaluation of GIS maps and a power production model.

Weighting Differences

The influence that each criterion would have on the site score—the weighting—was determined by a subjective analysis using an Analytic Hierarchy Process (AHP) to evaluate the relative importance of the criteria. Selected criteria and their assigned weights reflect the collective sentiments of the research group based on reviewed literature and similar analyses conducted.

AHP is a method of ranking criteria that is commonly employed by engineering design firms. This system entails comparing the criteria in pairs, then using the scores from the individual comparisons to create a weighting scheme. The advantage of AHP is the fact that it allows for human judgment while simultaneously running a mathematical analysis that checks for fallacies in the subjective ratings.

First, each criterion is all paired with all of the other criteria for the comparisons. Then, from each pair, one of the two criteria is judged to be more important than the other. The criterion from each pair that is judged to be more important receives a score from 1 to 9, 1 being equally important, and 9 being vastly more important. The criterion that is judged to be less important receives a score that is the reciprocal of the other score (on a scale of 1 to .111). Generally, every score is an odd number, or the reciprocal of an odd number. This is done for two reasons. First of all, this system minimizes ambiguity. For example, a score of 5 is decidedly greater than a score of 3. However, a score of 5 is not so clearly greater than a score of 4. This helps keep the data consistent. Also, the even numbered scores are reserved for tie breakers. Next, the eigenvectors of the matrix are calculated. The weights of the criteria are the normalized values of the first column of υ (Dieter, 2009).

For example, say that four criteria were to be compared through AHP (Criteria A-D). First, the criteria need to be paired. The pairs would be AA, AB, AC, AD, BB, BC, BD, and so on, in that fashion. Next, the criteria need to be subjectively compared. For the pair AB, if A was judged to be slightly more important than B, then A would receive 3 points. B, at the same time would receive .333 points. For the pair AC, if A was judged to be significantly more important than C, then A would receive 5 points while C would receive 0.2 points. This is done for all of the pairs, and placed into the matrix as shown in Table 5. In the matrix, the criteria in the column on the left are the dominant criteria. For example, since A was judged to be slightly more important than B, the 3 points are placed in the "A" row, not the "A" column. Similarly, the .333 points are placed in the "B" row. The scores are placed into a matrix as shown below (Dieter, 2009).

Table 5: AHP Example

	A	B	C	D
A	1	3	5	7
B	0.333333	1	5	7
C	0.2	0.2	1	3
D	0.142857	0.142857	0.333333	1

Next, the eigenvectors of matrix shown in Table 5 are calculated. For this analysis, MATLAB was used. The following code was entered into the program to find the eigenvectors for the matrix, which is named "A": [W,λ] = eig (A). The weights are the values in the far left column on the matrix shown in Table 6.

Table 6: Weighting for AHP Example

0.8553	0.8714	0.8714	0.8783
0.4891	-0.0698+.464i	-0.0698 - 0.4640i	-0.4232
0.1533	-0.1255 - 0.0135i	-0.1255 + 0.0135i	0.1945
0.0753	-0.0066 - 0.0674i	-0.0066 + 0.0674i	-0.1082

As seen in Table 6, the sum of the weights is more than 1. In order to find the weights that will go into the decision matrices, it is necessary to normalize each value by the sum of the values. The sum of the weights in Table 6 is 1.573. Dividing through, it is found that the weight of criterion A is 54.374%, the weight of criterion B is 31.093%, the weight of criterion C is 9.746%, and the weight of criterion D is 4.787%.

An important aspect of the AHP tool to note is the fact that there is a consistency calculation that is performed in order to find out whether or not the subjective ratings contradict each other. The principle eigenvalue of λ is used to calculate the Consistency Index (CI), and subsequently the Consistency Ratio (CR). If this ratio is less than 0.10, then the data is considered to be sufficiently consistent.

The λ matrix of the aforementioned example is shown below in Table 7.

Table 7: Consistency Check for AHP Example

4.2281	0	0	0
0	-0.0138 + 0.9792i	0	0
0	0	-0.0138 - 0.9792i	0
0	0	0	-0.2004

In Table 7, the principle eigenvalue that will be used for a consistency check is 4.2281. The CI is calculated by the equation $\frac{\lambda - n}{n-1}$, where n is the number of criteria that are being compared. In the case of the example, n is equal to 4. Plugging values into this equation, the Consistency Index of this example is .076. Next, the Consistency Ratio is calculated by the equation $\frac{CI}{RI}$, where RI is the Ratio Index. Shown below in Table 8 are the values of the Ratio Index based on the number of criteria being compared.

Table 8: Ratio Index Values

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In this example, there are 4 criteria being compared, so the Ratio Index, found in Table 8, is 0.9. Plugging this value into the Consistency Ratio equation, it is found that the Consistency Ratio in this example is 0.844. Since this value is below 0.10, the subjective ratings are consistent with each other throughout the matrix. If the CR is above 0.10, then it is necessary to change the input of Table 5 in order to eliminate any inconsistency in the subjective ratings.

For the purpose of this study, there were eight different criteria considered in the Pairwise-Decision Matrix. The criteria are grid connectivity (voltage suitability), grid connectivity (distance to center), road connectivity, land protection, suitability for construction, nearby populations, capacity factor, and overall power production. Shown below in Table 9 is the rating matrix that was used for this analysis.

Table 9: AHP rating matrix

	Grid Connectivity (Voltage Suitability)	Grid Connectivity (Distance to Center)	Road Connectivity	Land Protection	Suitability for Construction	Nearby Populations	Capacity Factor	Power Production
Grid Connectivity (Voltage Suitability)	1	0.2	0.333333	0.111111	0.2	0.142857	0.111111	0.111111
Grid Connectivity (Distance to Center)	5	1	3	0.111111	0.2	0.333333	0.111111	0.2
Road Connectivity	3	0.333333	1	0.111111	0.333333	0.2	0.111111	0.2
Land Protection	9	9	9	1	5	7	0.333333	3
Suitability for Construction	5	5	3	0.2	1	1	0.142857	0.333333
Nearby Populations	7	3	5	0.142857	1	1	0.142857	0.333333
Capacity Factor	9	9	9	3	7	7	1	5
Power Production	9	5	5	0.333333	3	3	0.2	1

Next, it was necessary to assure that these ratings are consistent throughout the matrix. The λ matrix is shown below in Table 10.

Table 10: Consistency Matrix for AHP

8.9259	0	0	0	0	0	0	0
0	.181+2.685i	0	0	0	0	0	0
0	0	.181-2.685i	0	0	0	0	0
0	0	0	-.324+.88i	0	0	0	0
0	0	0	0	-.324-.88i	0	0	0
0	0	0	0	0	-.238+.248i	0	0
0	0	0	0	0	0	-.238-.248i	0
0	0	0	0	0	0	0	-0.1636

As shown in Table 10, the principle eigenvalue of λ is 8.9259. Plugging this value into the CI equation, using a value of n=8, the CI of this analysis is .1323. In order to find the CR, it is necessary to use Table 8 to find the correct value of the Ratio Index. When comparing eight criteria, the Ratio Index is 1.4. Plugging this value into the CR equation, it is found that the CR is 0.0945. Since the CR value is less than 0.10, the rating analysis shown in Table 8 is considered to be sufficiently consistent.

Next it is necessary to use MATLAB in order to find the weightings for each criterion. The weighting matrix is shown below in Table 11.

Table 11: Weighting Matrix for AHP

-0.0319	.016-.036i	.016+.036i	-.025-.037i	-.025+.037i	.043+.024i	.043-.024i	-0.0305
-0.0731	-.077-.028i	-.077+.028i	.119+.031i	.119-.031i	.006+.015i	.006-.015i	0.0146
-0.0494	-.01-.04i	-0.01+.04i	-.028+.074i	-.028-.074i	-.057-.052i	-.057+.052i	0.033
-0.519	.307+.38i	.307-.38i	.285+.274i	.285-.274i	.502+.142i	.502-.142i	-0.68
-0.1407	-.061+.11i	-.061-.11i	-.106-.345i	-.106+.345i	.029-.159i	.029+.159i	-0.002
-0.1393	-.101+.052i	-.101-.052i	.022+.016i	.022-.016i	-.026+.176i	-.026-.176i	-0.093
-0.7839	0.83	0.83	0.691	0.691	-0.798	-0.798	0.6329
-0.2611	.034+.179i	.034-.179i	-.354+.294i	-.354-.294i	-.093-.127i	-.093+.127i	0.361

The sum of the weightings in Table 10 is -1.9984. Normalizing the weightings with regard to this value gives a weighting scheme as shown below in Table 12.

Table 12: Normalized Weighting from AHP

Criterion	Weight
Grid Connectivity (Voltage Suitability)	0.0160
Grid Connectivity (Distance to Center)	0.0366
Road Connectivity	0.0247
Land Protection	0.2597
Suitability for Construction	0.0704
Nearby Populations	0.0697
Capacity Factor	0.3923
Power Production	0.1307

As shown in the weighting table, the most important factor in site selection is capacity factor, followed by land protection. Also, Site Suitability is weighted at 47.72% of the total score whereas Energy Availability is weighted at 52.28%.

It is pertinent to note that the low weighting of the power production at 13.07% helps to justify arbitrary selection of the boundaries of sites and sub-sites. The size of each site matters little, relative to the capacity factor dictated by wind speeds, which is weighted much higher. The financial analysis discussed later further supports this assertion.

Site Suitability

Within the Site Suitability category, Infrastructure, Environmental, and Social considerations were all considered. Specifically, Grid Connectivity was assessed within the Infrastructure, by assigning weight of 0.016 to voltage suitability and weight of 0.0366 to the distance from the center of the land site to the nearest power line. The capacity of the nearby power lines were quantified in this system by using a value of 2 to represent low voltage lines, or those of 115 kV; 3 to represent lines with voltages of 116-138 kV; 4 to represent lines of 139-230 kV; and 5 to represent lines with voltages of 231-500 kV. If the nearby power line has higher voltage capabilities, it is better equipped to efficiently receive the power generated by constructed wind turbines, since high voltage transmission systems lose less power than their low voltage counterparts over the same transmission distance (Tester, 2005). It is therefore evident that power lines with higher voltage capacities are advantageous and thus receive a higher value as a result.

To incorporate the importance of the transmission distance from the wind turbines into the nearby power lines, approximate measurements were taken from the center of the potential sites to the nearest power line, with a ranking of 5 being given to a distance of 1.9 km or less; 4 representing a distance of 2-4.9 km; 3 representing a distance of 5-10.9 km; 2 representing a distance of 11-22.9 km; 1 representing a distance of 23-46.9 km; and 0 representing a distance of greater than 47 km. Since longer transmission distances result in greater losses of energy and larger costs of installation, shorter distances are given a greater value than longer distances.

The final aspect of infrastructure suitability that was considered in the analysis is road connectivity. The rankings given to the road connectivity of each site were identical to those given to the distance from the site to the power line rankings.

Within the Environmental category, assessment of the site's land use protection was given a weight of 0.2597, while the suitability of the site for immediate construction was given a weight of 0.0704. The land use protection ratings of each site were given ratings of 0, 2.5, or 5. These ratings represent "Full Protection" of the site and little to no chance that a wind power facility could be constructed; "Potential Conflict" with a project, indicating a moderate possibility of wind power production; and "No Conflict" with wind power, indicating no perceived sign of conflict, respectively. The suitability of the land for construction was also ranked on a 0-5 scale, with 0 representing land conditions that suggest that it would be nearly impossible to build on the land, and 5 representing an extremely stable site that should be ready for immediate construction of wind turbines. These rankings were determined by inspecting Google Earth imagery of each site's terrain conditions.

Within the Social category, the presence of nearby populations was used to assess if there would be any likely resistance to the construction of wind turbines, and was given a weighting of 0.0697. Rankings ranging from 1-5 were used in this category, with 1 representing a population distribution that would be likely to prohibit development, and 5 representing a population distribution that would be unlikely to have any negative impact upon the construction of wind turbines at the site. Again, imagery from Google Earth was used to determine the rankings for this category.

The total Site Suitability value was calculated using the values assigned within the Infrastructure, Environmental, and Social categories, as well as their aforementioned weights. As previously stated, the total Site Suitability was given a weight of 0.4772 towards the determination of overall site suitability. Thus, for each of the 26 sites analyzed in Western Maryland, the Site Suitability as defined through Infrastructure, Environmental, and Social considerations represents 47.72% of the weight towards the final value given to each site.

Energy Availability

In order to quantify the amount of wind energy that can be extracted from each site, two values must be calculated: the maximum number of turbines that can be placed within the confines of the site and the capacity factor at which the turbines operate (a value which represents the percentage of a turbine's maximum rated power production that it actually achieves). For the purposes of this analysis, each site was approximated as a rectangle based on the average length and width of the strip of Class 3 or higher NREL wind data.

Turbine spacing is an important design choice and represents a tradeoff between the number of turbines and efficiency. As wind passes through a turbine, it slows down and becomes more turbulent such that when it reaches the next turbine in line, there is less power to be extracted. Placing turbines closer together allows more turbines to fit onto one site, but in turn, each turbine becomes less efficient. In our analysis, we separated turbines by a distance of ten rotor diameters, which keeps the inter-turbine wake losses below 10% (Dhanju A, Et al., 2007). A MATLAB algorithm was written to determine the optimal method of placing turbines for each site, choosing between rectangular and staggered layouts, as shown in Figure 9. Another consideration included in the algorithm is whether larger, more powerful turbines or smaller, less powerful turbines can produce more power in a given area. In each site, we compared the two most common wind turbines used in the United States: General Electric's 1.5 MW and 2.5 MW turbines (US DOE, 2008). The type and number of turbines for a site were then determined based on the maximum possible power production (for full algorithm, see appendix on page 232).

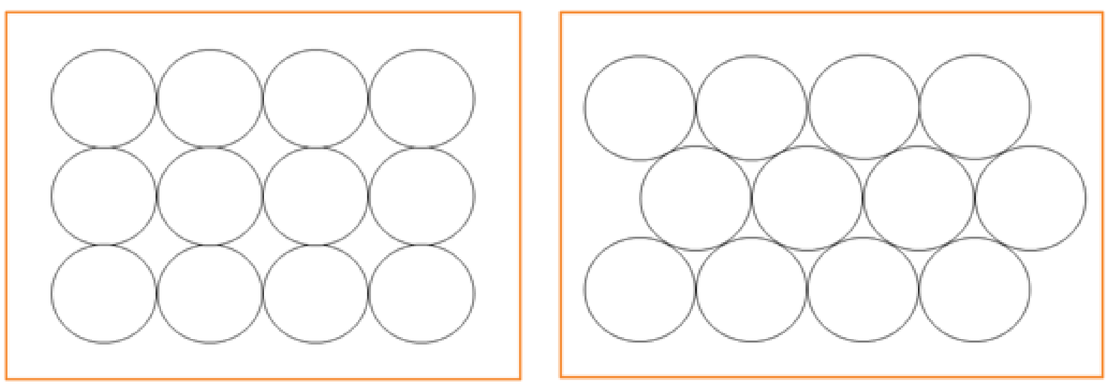


Figure 9: Rectangular vs. Staggered Layouts

In order to calculate the capacity factor of a site, wind speed data was translated into turbine power output based on the turbine manufacturer's power curves (Figure 10 and Figure 11). This was then divided by the rated power capacity to obtain the capacity factor. For example, at an average wind speed of 8 meters per second, a 1.5 MW turbine manufactured by GE produces 0.6 MW of power; since 0.6 MW is 40% of the rated 1.5 MW capacity, this turbine would operate at a 40% capacity factor (GE Energy, 2008a)

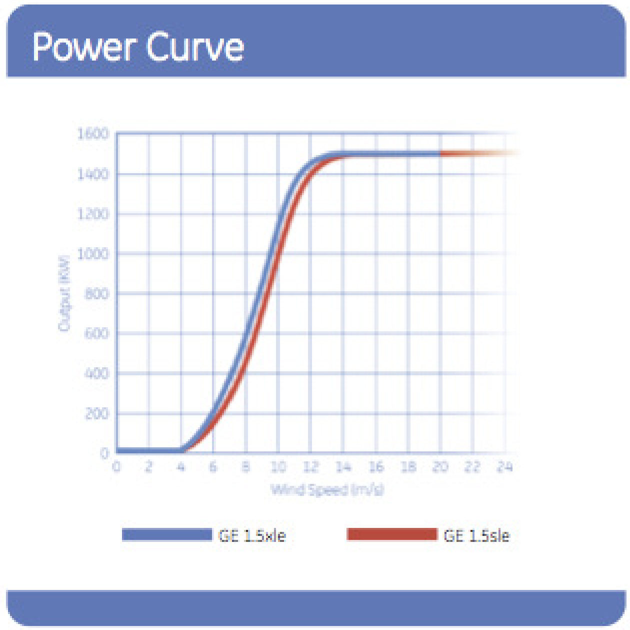


Figure 10: GE 1.5MW Power Curve (GE Energy, 2008a)

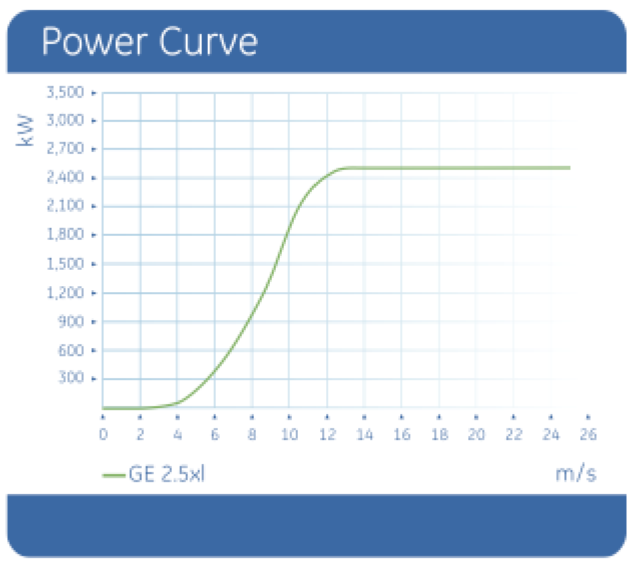


Figure 11: GE 2.5MW Power Curve (GE Energy, 2008b)

Once values for the capacity factor and expected power production were determined for each site, we gave each criterion a normalized ranking between zero and five based on where it fell in the overall range of values for the 26 sites (Table 13). Capacity factor received a weight of .3923 while power production was weighted at .1307. Capacity factor was weighted more heavily because it is paramount in making a wind farm economically feasible. As capacity factor increases, the ratio of money generated to operational costs also increases, increasing the wind farm's annual profits (more information on the financial analysis is given in the section "RETScreen Financial Analysis" on page 94).

Table 13: Energy Availability Ranking Criteria

Capacity Factor (%)	Normalized Rank	Expected Power Production (MW)	Normalized Rank
< 20	0	< 2.9	0
20-22.9	1	3-4.9	1
23-24.9	2	5-6.9	2
25-26.9	3	7-8.9	3
27-28.9	4	9-10.9	4
> 29	5	> 11	5

Excluded Factors

While the majority of factors impacting overall site suitability were considered in this analysis, there were several factors excluded for various reasons. Bird flyways—migratory routes integral to the lifecycle of some bird species—are an environmental factor that would undoubtedly impact the viability of constructing a large number of wind turbines on a given land site, yet we excluded this particular factor from our analysis. Information on the locations of these flyways was unavailable at high enough resolutions to make a meaningful contribution to our site-by-site analysis.

In addition, certain lands in Western Maryland have historical value because of their roles in the Civil War, which could be perceived as being compromised through the construction of wind turbines. Due to a lack of GIS compatible data, this factor could not be incorporated into the analytical framework, but could be assessed on a site-by-site basis in the future.

Thus, while there are some factors that could affect the overall suitability of a site which were not explored, this analysis is intended to be prefatory. It was deemed acceptable to exclude less quantifiable factors, which can be analyzed by the University of Maryland in greater depth should it elect to pursue the construction of wind turbines on one of these sites.

Data Approximations

When the data were collected, certain approximations of the metrics were needed. In order to determine the number of turbines that could be placed, the site areas had to be measured. These sites were estimated as rectangles, with defined measurements based on their average length and width. By doing so, the calculation of the total available area was simplified in order to fit with the algorithm calculating turbine count and power production. If a site had an irregular shape, it was broken up into a few smaller rectangles to get the best approximation of the area.

The distance from a transmission line to each site was also measured to determine land suitability. This is important because the further energy has to travel, the more energy that will be lost and also the higher the cost of constructing new transmission lines. When making this measurement, the closest power line was found and a linear path from it to the center of the site was measured. This was the simplest, most consistent way of measuring this distance among all of the sites. In some instances, there were two power lines of different voltages that were nearby. In this case, the measurement to the closer power line, not to the power line with the higher voltage, was used. Distance was more important than voltage because of the cost involved in constructing new transmission lines.

Flexibility of Weightings

An important feature of this analysis is the ability to alter the decision matrices created and therefore change the site rankings. The University may have different priorities than anticipated in this study, so the weights of different aspects for the site rankings can easily be changed to reflect them. For example, suppose the University's top priority is to achieve carbon neutrality as soon as possible. In order to achieve this, they want the site that can produce the most energy, regardless of the number of turbines it would take or the efficiency of these turbines. To do so, the weight for energy produced could be increased to reflect this new target. Similarly, if the University felt that land use protections could be easily overcome in the construction of a wind farm, the weighting for this category could be reduced, thereby increasing the rating of sites which were previously ranked poorly due to heavy land use protections. By having dynamic decision matrices, the University can pick sites based on its own agendas and changing regulations and trends, making this data even more useful and applicable.

RETScreen Financial Analysis

The energy production data were also used to produce a financial feasibility analysis based on RETScreen software, which is used internationally to gauge wind farm site viabilities. RETScreen is software that was released by the Canadian government with the purpose of facilitating the development of renewable energy products with the idea that, with the use of RETScreen, less investment would be necessary for the pre-feasibility study. The software has been used for 20 wind farm projects that are in construction or online that total 100 MW (RETScreen, 2004a).

Financial analyses created using RETScreen accompany each site's final site suitability score for consideration by the University.

Using data from NREL's annual report on U.S. wind power installation, cost, and performance trends from 2007 as our inputs to software, we produced a financial summary of each site's wind farm over the next 30 years (US DOE, 2008). NREL found the initial investment in wind turbine projects to be linearly related to the installed capacity of the project and that no evidence of economies of scale exists for wind farms on a project-by-project basis. In other words, a 20 MW farm can be predicted to cost the same amount per MW as a 200 MW farm.

The majority of the costs for a wind farm come from the purchase of wind turbines. In 2007 for example, the average cost of turbines for a wind farm was $1,240 per KW. The remainder of the costs come from the infrastructure that must be built around the wind farm such as operational facilities, transmission lines, access roads, grid connections, etc. Over the period spanning 2004-2007, total project costs averaged $1,540 per KW (US DOE, 2008). In our financial analyses, we used a value of $1,600 per KW for the total installation costs, which included $1,300 per KW for turbines and $300 per KW for infrastructure costs.

The remainder of the costs of a wind farm are found in the annual costs of operation and maintenance, or O&M. These costs are more difficult to estimate as they vary with the age of the turbines. For example, the average yearly O&M cost over the period from 2000 through 2007 (expressed in dollars per MWh of annual energy production) were $30/MWh for projects built in the 1980s, $20/MWh for projects built in the 1990s, and $9/MWh for projects built after 2000. This decline in the cost of O&M can be attributed to two possible factors. First, as turbines get older, the cost of maintaining them increases such that a 20-year-old wind project will cost more to maintain than a 10-year-old project. Second, as turbines have become larger and more sophisticated, the initial costs of O&M have decreased (US DOE, 2008). As such, we had to estimate the average annual cost of O&M over the course of a project's approximately 30-year lifespan. For the purposes of our financial analysis, we used a value of $15/MWh annual O&M costs.

The last monetary value that needed to be input into the RETScreen analysis was the price of electricity sold to the grid, called the electricity export rate, which is a measure of how much money a wind farm will receive for the energy it produces. This value varies by region across the United States ranging from $30/MWh to over $60/MWh. In 2007, the average value of electricity export rate for wind farms in the eastern United States was approximately $50/MWh, which is the value we use in our financial analysis (US DOE, 2008).

Finally, RETScreen requires the user to input a series of financial parameters that describe the flow of money over the course of the project life; suggested values for most of these are found in the RETScreen user manual (RETScreen, 2004b). The first parameter is the rate of inflation that the model will simulate. In North America, inflation over the next 25 years is predicted to be approximately 2-3%- a value of 2.0% was used. The project life, which typically ranges from 20 to 30 years for a wind farm, was selected to be 30 years, in order to see the performance of each potential wind farm over its maximum expected lifetime. The debt ratio represents the percentage of the total initial costs which will be paid via loans. The RETScreen manual suggests that values of 50%-90% are most common for the debt ratio, so a debt ratio of 50% was selected, i.e., half of the project costs would be paid with loans. The debt interest rate, the yearly interest assessed on the loans, was set to be 5% and the debt term, the period over which the loans will be paid back, was set to be 8 years, approximately one fourth of the project lifespan.

In addition to the capital and maintenance costs of the wind development, government grants and incentives are available to stimulate wind energy development. The State of Maryland offers the "Maryland Renewable Electricity Production Tax Credit" which awards $0.085 per kWh of electricity that is exported by the farm to the grid. For the purposes of our study, this credit was maintained over the entirety of the wind farm life, though policy change may alter the amount or duration of credit. Local and regional governments are signaling an increased emphasis on renewable energy, which argue for retaining the credit.

A Federal Production Tax Credit (FPTC) is also offered for wind developers at a lower rate of $0.019/ kWh, for the first ten years of wind farm operation. Extension of the FPTC beyond the first ten years is possible, though this cannot be assured to wind developers. Figure 12, below, shows the amount of added capacity of wind developments each year since 1999. In years when the PTC is active, development is significantly more active than in years when the PTC has expired, even if temporarily.

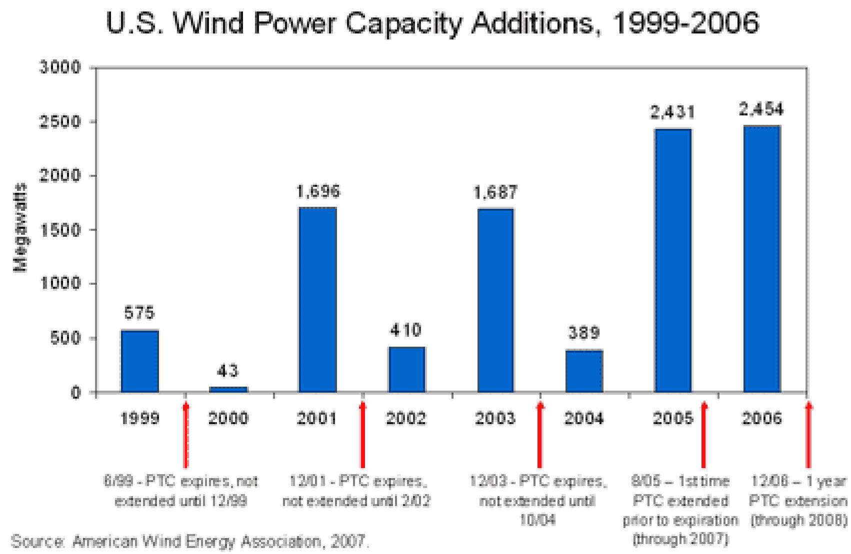


Figure 12: Dependence on Production Tax Credit for wind development (AWEA, 2007 in UCS, 2009)

Since the RETScreen tool is unable to accommodate removal of the FPTC after 10 years, the annual benefit is normalized over the 25 year lifetime. At $0.019/ kWh for ten years, the equivalent credit received by the electricity producer would be $0.0076/ kWh over the 25 year lifespan. This approximation negatively impacts the payback period, though pre-tax IRR-equity value should be equivalent. The value of the wind farm at the end of its lifetime is approximately the same as if the FPTC were phased properly. Regardless, the FPTC is so small that the impact is minor, and the approximation is reasonable.

For use in RETScreen, the added economic incentives of the FPTC and Maryland Renewable Electricity Production Tax Credit are aggregated and inserted as "Incentives and grants" as a function of the kWh produced by the wind farm. Additional value may be added to the wind site through the sale of Renewable Energy Credits (RECs) to third party vendors. These vendors buy RECs from wind generators, and then sell them back to the market for a higher price.

One reputable third party vendor recommended by the Maryland Department of Natural Resources (Rice, 2009) is Evolution Markets. In figure 13, below, the bid price is the amount paid by Evolution Markets to the electricity producer for a single REC. One REC represents 1 MWh of electricity. The offer price is the price offered by Evolution Markets for purchase.

DAILY PRICING

SPEC	TERM	BID PRICE	OFFER PRICE
MA Class I	2008	$18.00	$23.00
MA Class I	2009	$30.00	$34.00
MD Tier I	2007	$0.35	$0.75
MD Tier I	2008	$0.50	$1.25
MD Tier I	2009	$1.25	$2.00
NJ Class I REC	2009	$4.00	$6.00
NJ Class I REC	2010	$15.50	$18.00
TX REC	2008	$0.85	$1.40
TX REC	2009	$1.00	$1.50

Figure 13: Renewable Energy Credit pricing for purchase from generator and sale to end user (Evolution Markets, 2009)

The value of Renewable Energy Credit sales is manually added to the “Annual Savings and Income” tab of RETScreen. The 2009average price per REC received by the electricity producer is approximated to be $1.25 in Maryland, though this value has increased steadily since 2007. RECs are an interstate trading commodity and limitations for REC trading are specified by some states’ Renewable Portfolio Standards (RPS). A more mature RPS, in Massachusetts for instance, causes a much higher market price for RECs. Given the low cost of RECs in Maryland, there is currently little incentive for generators to produce them. However, as interstate markets are integrated, supply and demand forces are expected to normalize interstate pricing. Maryland’s low-cost RECs, for instance, will cause higher demand and will drive the price up over time. The approach of using the 2009 MD bid price, therefore, is conservative.

One option of the RETScreen software that was not included in this analysis was the environmental and financial benefits detailed in the program's emission analysis. Because wind turbines do not produce any emissions, there is a considerable reduction in the production of greenhouse gases (GHG) compared to a conventional fossil fuel plant. Recently proposed cap and trade systems governing the release of GHG are poised to increase the cost of energy produced by fossil fuel plants without changing the cost of energy produced by wind farms (Obama, 2009). As a result, the profitability of wind farms compared to that of fossil fuel plants would increase, theoretically stimulating growth in the industry. However, because a cap and trade system on GHG emissions is not yet in place, we excluded this portion of the RETScreen analysis from our analysis. The potential impact of these policies is discussed further through a sensitivity analysis in the results.

From this data, RETScreen calculates a number of important financial statistics including the Internal Rate of Return on equity (IRR), the equity payback period, and a graph of the year-to-date cumulative cash flow over the project's lifespan. A site's IRR is an indication of how profitable it will be over the course of its operation. For example, the amount of money made from a site with an IRR of 6% is comparable to the money made by taking the entire cost of building the site and placing it instead into a savings account with a 6% interest rate. The equity payback period is the length of time it will take for the site to pay back its initial investment and begin to earn a profit. This value, as well as others such as maximum levels of debt and profit for the project, can be seen on the cash flow graph. This financial analysis is presented alongside the rankings and power production for each site in the following section.

Chapter 5: Results

The first result of this analysis is a ranked list of 26 sites in Maryland for the construction of a wind energy project. The cumulative effect of each site's wind power potential, capacity factor, proximity to infrastructure, land use protection, suitability of land for development, and proximity to population centers is factored into their overall rankings. Presented alongside these rankings is a financial analysis of each site's anticipated financial characteristics. While financial outputs do not influence the site scores directly or their ranking, their importance is internalized in the weighted decision analysis mainly because capacity factor is an important input to both the weighted decision matrix and financial analysis models. In addition, site images were taken from Google Earth for each site, and the approximate location of the wind farm on the site is sketched to show the affected land area.

The site scores are summarized below in Table 14, ordered by their site scores to suggest a prioritization of future investigation by the University. The table also summarizes the Pre-Tax IRR-equity and Equity payback for each site. The five most suitable sites according to the weighted decision matrix are Site M1, Site N1, Site X, Site V, Site U and Site W. Each site is discussed in the following section.

To further clarify the value of each site, an additional weighted decision and RETScreen analysis was performed within sites where there were concentrations of the highest wind speeds. The results of this "sub-site" analysis are reported in Table 15, and the best sub-sites that correspond to the best sites are discussed.

Table 14: Site summary ranked by "Overall Site Score"

Site	Overall suitability	Pre-tax IRR-equity (%)	Equity Payback (years)
M1	4.0981	8.1	13.5
N1	2.7102	6.2	15.3
X	2.6246	5.2	16.4
U	2.591	5	16.7
V	2.5735	5.5	16.1
O	2.3614	5.5	16.1
W	2.2877	4.8	16.8
L	2.2305	5.5	16.1
G	2.2202	5.2	16.4
S	2.1732	4.4	17.4
F	2.1195	3.2	19
Q	2.0999	5.9	15.7
M2	2.0939	2.9	19.5
H	2.0751	4.3	17.6
T	1.9846	5.5	16.1
I	1.9411	4.1	17.9
D2	1.9055	5.2	16.4
B1	1.8897	5.1	16.5
E	1.7388	4.2	17.6
N2	1.6439	4.5	17.2
J	1.5838	3.4	18.8
Y	1.4955	4.4	17.4
Z	1.4331	3.6	18.5
R	1.4226	3.6	18.5
B2	1.3901	3.1	19.2
K1	1.2968	3.7	18.3
C	1.1851	3.2	19
K2	1.1837	3.2	19
P	1.1832	2.7	19.9
D1	1.1135	2.9	19.5
A1	0.981	4	20
A3	0.788	2.7	19.9
A2	0.396	1.8	21.4

Table 15: Sub-Site summary ranked by "Overall Sub-Site Score"

Site	Overall Sub-Site Score	Pre-tax IRR-equity (%)	Equity Payback (years)
18	3.081	9.3	12.6
17	3.0635	9.5	12.5
4	2.9989	8.7	13.1
6	2.9565	10.3	11.9
21	2.9329	9	12.8
3	2.9231	8.7	13.1
15	2.8529	9	12.8
7	2.8022	8.7	13.1
9	2.796	8.7	13.1
16	2.7712	9.7	12.3
8	2.7461	8.7	13.1
20	2.6931	8.7	13.1
2	2.6716	8.7	13.1
12	2.6343	8.7	13.1
13	2.6231	9.1	12.7
5	2.6155	8.7	13.1
19	2.5938	8.7	13.1
1	2.4125	9.4	12.5
10	2.346	8.7	13.1
11	2.346	9.4	12.5
14	Error	10	12.1

Detailed Site Analyses

Site M

Site M is located on a mountain chain in eastern Garrett County that was identified as having high wind speeds from a cursory view of the Maryland NREL wind data maps. A more detailed review of the site investigated the land use of the entire county as shown in figure 14. According to the MD Department of Planning Legend in the appendix, Site M is located in a forested region classified as "evergreen forest" (MD DNR, 2009). The dense forest cover presents a moderate obstacle for construction, so the site received a ranking of 3 for "Suitability of Land for Construction." There were some visible agricultural areas in the immediate proximity of the wind farm, and the site is very close to Big Savage Mountain state park (MD DNR, 2009), which is common venue for outdoor recreation. There is little likelihood of population impacts in this rural site, though tourist industries may object to obstructed or altered views from the wind farm. The site received a ranking of 4 for "nearby populations".

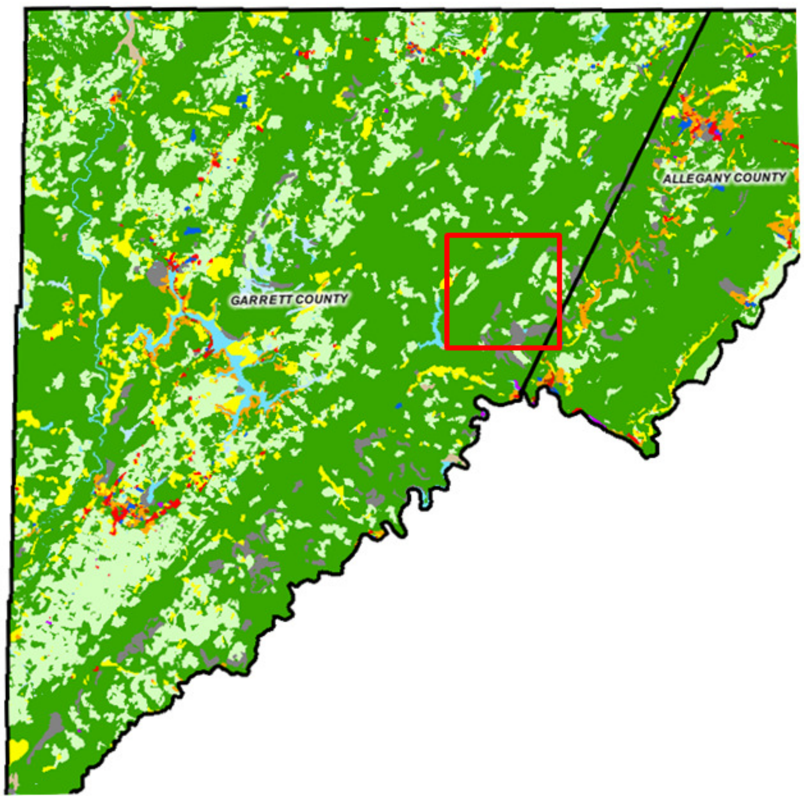


Figure 14: Garrett County Land Use from MD Department of Planning (MDP, 2009), showing Site M in red box

Big Savage Mountain state park is the largest park facility in the State of Maryland forest system. Though wind projects are not legally prohibited on this site, there are direct environmental and tourism impacts that must be assessed before site development. Figure 15, below, shows the available wind potential on the site in yellow, orange and red. The pink coloration outlines the extent of the Big Savage Mountain state park, and adjacent protected lands. Because there is clear overlap of the potential development area for the wind farm and the state park, the "land use protection" attribute is given a ranking of 2.5, to represent a potential development conflict.

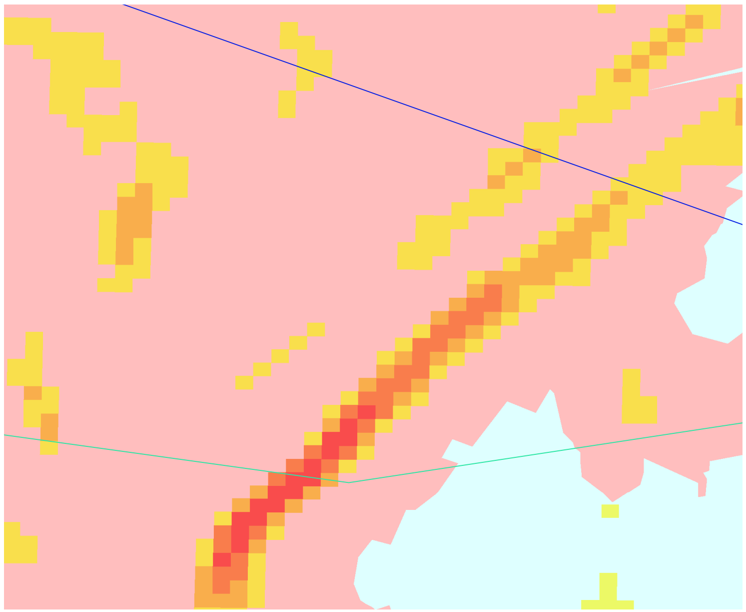


Figure 15: GIS Image of Site M (Scale is 1:40,000)

The wind potential on Site M is constituted of two strong parallel bands of high wind speeds, with measurements at 50m indicating speeds ranging between 6.4 and 8 meters per second. Because of potentially different attributes of the two bands, and simplicity of inputting rectangular approximations of site dimensions into the MATLAB algorithm, Site M assessment was disaggregated into two sub-sites, Site M1 and Site M2. Site M1 is the stronger of the two bands, located south of Site M2.

For Site M1, a strong central strip of "good" wind is surrounded by "fair" wind at the strip's borders. A contiguous thin string of "excellent" wind is also on the strip. The wind speed ranking was determined be assigning a weight to each wind strength in the string. The averaged rank was assigned as 2.65. For Site M2, the majority of the wind was "fair" with a thin, discontinuous strip of "good" wind that constituted only a small fraction of the strip. The site ranking was assigned as 1.2. The dimensions of land with available wind were approximated as a rectangle for both sites. The length for Site M1 was 8.38 km x 0.82 km. The length for Site M2 was 5.68 km x 0.52 km. The land dimensions and wind speed ranking were input into MATLAB algorithm to determine optimized energy characteristics for each sub-site. The program determined that for Site M1, the GE Wind 1.5 MW turbine is most suitable for the site, and that 22 turbines can be placed on the site with an optimal packing structure, producing 33 MW at maximum capacity. Expected power output was determined to be 10.2 MW based on the wind characteristics of the site relative to the power curve of the selected wind turbine. The expected power output, divided by the maximum turbine power, yielded a 31% capacity factor, which was the highest of any other site in this study. Site M2 had more modest potential corresponding to the weaker wind, planning for the use of GE Wind 2.5MW turbines with an optimized packing structure allowing six turbines. The maximum power output was 15 MW, with an anticipated output of 3.2 MW. The associated capacity factor was 21.2%.

It is important to note that the surface characteristics of the land impact the wind speed gradient with increasing height above the ground. This feature is represented through the shear exponent of the site, with a higher shear exponent for forested, mountainous regions, and low shear exponents for open water and fields. The effect of shear exponent was not considered in this analysis because the heights of both types of considered turbines are much taller than the wind measurement at 50m. Considering the wind speeds at the hub height of the turbine as the same as the wind speeds at 50m is a conservative estimate, as greater speeds are observed at higher heights.

The GIS image in Figure 15 also revealed that the center of the windy region of the site M1 was 1.8 km away from a 116-138 kV transmission line, corresponding to rankings of 3 and 5 for “voltage suitability” and “transmission distance”, respectively. The center of Site M2 is measured as 0.77 km from a 231-500 kV transmission line, corresponding to rankings of 5 for both “voltage suitability” and “transmission distance.” The Google Earth image in Figure 16 shows a road running through the site M1 at approximately 0.4 km from the windy region’s center, corresponding with a ranking of 5 for “road connectivity.” Site M2 also received a ranking of 5 for “road connectivity” because the site has a different road running less than 0.1 km from the site center.

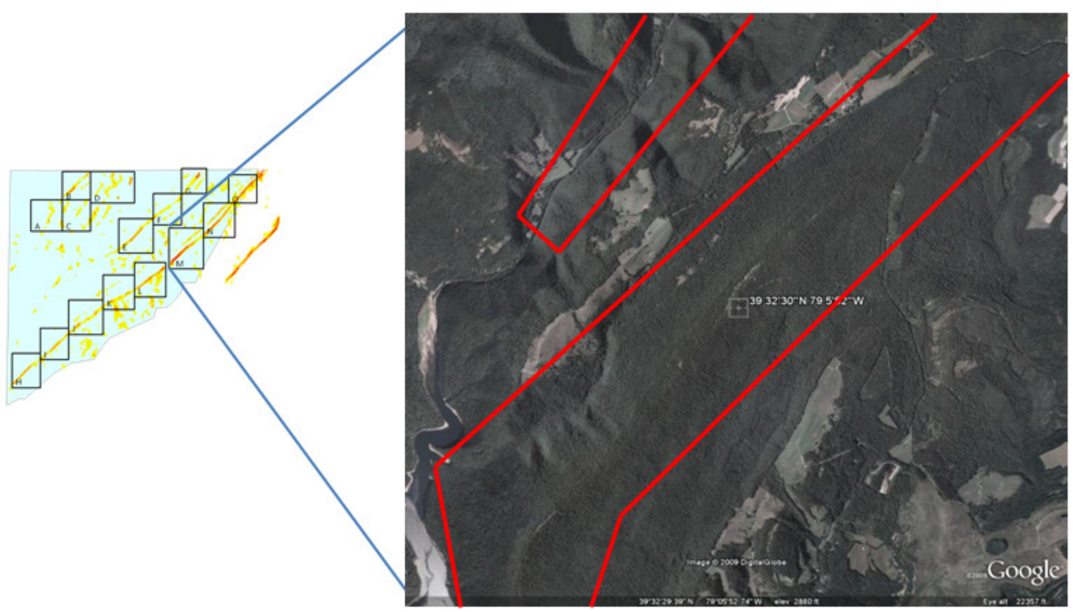


Figure 16: Aerial image of Site M

Each of these site and energy rankings were put into the weighted scoring matrix in Table 16, below, yielding a site value of 3.38 and 3.29 for sites M1 and M2, respectively. These values constitute 47.7% weight of the final overall score in the weighted decision matrix. Site M1 received a high ranking of 5 for capacity factor with 39.2% weight, and a rank of 4 for energy generated. The overall Site M1 score accounting for 100% of these inputs is 4.10. Site M2 received a very low ranking of 1 for capacity factor, and energy generated rank of 1. Corresponding to these poor rankings, the overall suitability of Site M2 is 2.09. It is important to notice that the "Value of site" based on site suitability characteristics is higher for Site M2 than for M1, even though M1 is distinguished as a far superior site based on its energy characteristics.

Table 16: Overall Site Suitability Scoring Matrix for Site M.1 and M.2

Garrett County Site M

		Characterization			Site Suitability						
					Infrastructure			Environmental		Social	
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area
Region M1	Value		39° 32'29" N	79°05'52" W	116-138	1.8	0.4	x	x	x	x
	Ranking				3	5	5	2.5	3	4	3.3838
	Weight	x	x	x	0.016	0.037	0.025	0.26	0.7004	0.0697	0.4772
Region M2	Value		39°34'28" N	79°04'36" W	231-500	0.77	0.1	x	x	x	x
	Ranking				5	5	5	2.5	3	4	3.2923
	Weight	x	x	x	0.016	0.037	0.025	0.26	0.7004	0.0697	0.4772
	unit				kV	km	km	x	x	x	

		Energy Availability									
		Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region M1	Value	8.38 km	0.82	x	22	33	0.31	77	1.5	10.23	**4.0981**
	Ranking	x	x	2.65	x	x	5	x	x	4	
	Weight	x	x	x	x	x	0.392	x	x	0.131	
Region M2	Value	5.68km	.52 km	x	6	15	0.212	100	2.5	3.18	**2.0939**
	Ranking	x	x	1.2	x	x	1	x	x	1	
	Weight	x	x	x	x	x	0.392	x	x	0.131	
	unit	km	km	m/s	x	MW	x	m	MW	MW	

RETScreen analyses revealed financial indicators of feasibility for Sites M1 and M2, though discussion of M2 is for completeness and comparison purposes only, and does not constitute an endorsement of that site. RETScreen utilized the capacity factor and number and size of turbines to estimate an output of 89,600 MWh of annual generation from the Site M1 wind farm. Using the financial parameters listed in the "RETScreen Financial Analysis" section on page 94, it was determined that the initial upfront plant costs would be $52,800,000. This figure includes plant power system costs and "other" costs at $9,900,000, which internalizes site purchase costs, transmission interconnect, substation costs, and road connections. Operations and maintenance costs were expected to be ~$1,340,000 annually. The cumulative cash flows graph and worksheet are presented below in Figure 17Figure 17.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	42,900,000	81.3%
Other	$	9,900,000	18.8%
Total initial costs	$	52,800,000	100.0%
Incentives and grants	$	8,298,330	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,344,222	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,084,656	
	$		
Total annual costs	$	5,428,878	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	4,480,740	
	$	112,019	
Total annual savings and income	$	4,592,759	
Financial viability			
Pre-tax IRR - equity	%	8.1%	
Pre-tax IRR - assets	%	2.8%	
Simple payback	yr	13.7	
Equity payback	yr	13.5	

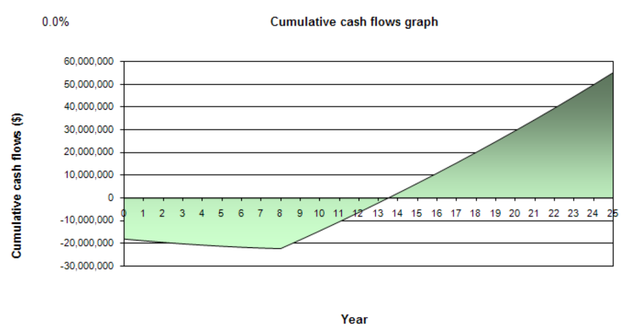


Figure 17: Financial Analysis for Site M.1

RETScreen utilized the capacity factor, and number and size of turbines, to estimate an output of 27,900 MWh of annual generation from the Site M2 wind farm. Using the financial parameters listed in the "RETScreen Financial Analysis" section, it was determined that the initial upfront plant costs would be $24,000,000. This figure includes plant power system costs and "other" costs at $4,500,000. Operations and maintenance costs were expected to be $418,000 annually. The cumulative cash flows graph and worksheet are presented below in Figure 18.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	19,500,000	81.3%
Other	$	4,500,000	18.8%
Total initial costs	$	24,000,000	100.0%
Incentives and grants	$	2,579,540	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	417,852	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,856,662	
	$		
Total annual costs	$	2,274,514	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,392,840	
	$	34,821	
Total annual savings and income	$	1,427,661	
Financial viability			
Pre-tax IRR - equity	%	2.9%	
Pre-tax IRR - assets	%	-0.8%	
Simple payback	yr	21.2	
Equity payback	yr	19.5	

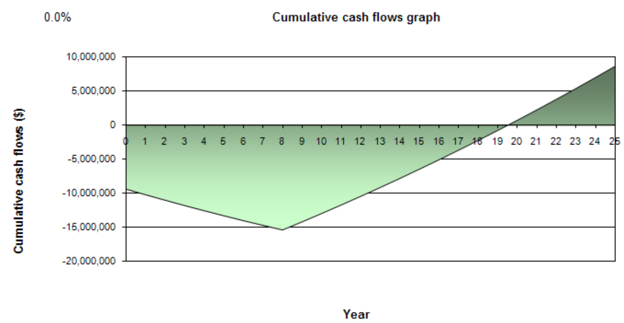


Figure 18: Financial Analysis for Site M.2

It was determined that the Site M1 wind farm would begin making profit after 13.5 years of operation, which is equivalent to an investing the upfront costs with 8.1% interest. A cursory RETScreen emission analysis determined that the site would annually displace 53,800 tCO_2 that would otherwise be generated by an average electricity fuel mix in the United States. This is the equivalent of 45,700 acres of forested land absorbing CO_2 from the atmosphere over the course of the year.

A wind farm on Site M2 would begin making profit after a much longer period of 19.5 years of operation, which is equivalent to an investing the upfront costs with 2.9% interest. An emission analysis determined that the site would annually displace 16,700 tCO_2 that would otherwise be generated by an average electricity fuel mix in the United States. This is the equivalent of 14,200 acres of forested land absorbing CO_2 from the atmosphere over the course of the year.

It is apparent that the Site M1 wind farm is a better investment for the University given its shorter payback time and high energy production. The economies of scale do not significantly affect the financial viability of Site M2, though the low capacity factor effectively ensures that the site will not have a preferable payback period relative to a project with a higher capacity factor.

Site M1 – Sub-Site 6:

The contiguous strong band of wind categorized as "5" and "6" (between 7.5 and 8.8 meters per second) by NREL was isolated for detailed sub-site analysis. The region is significantly smaller, though by focusing on the best wind, our analysis will reflect the best possible use of the site by the University with the fastest payback period possible. The strong winds of sub-site 6 are shown below in Figure 19, and the relative location of the site and aerial photograph are shown in Figure 20.

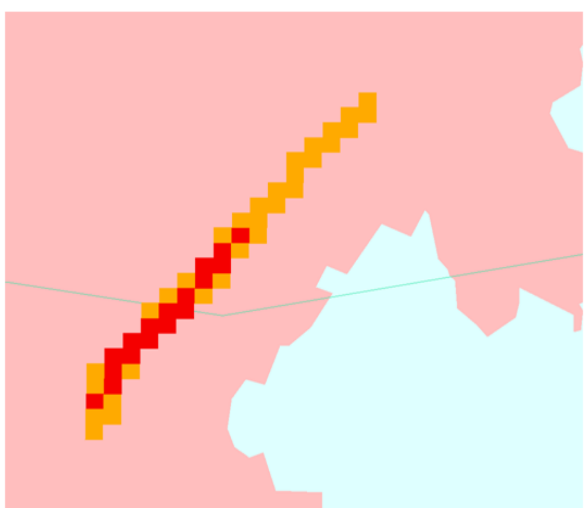


Figure 19: GIS Image of Sub-Site 6

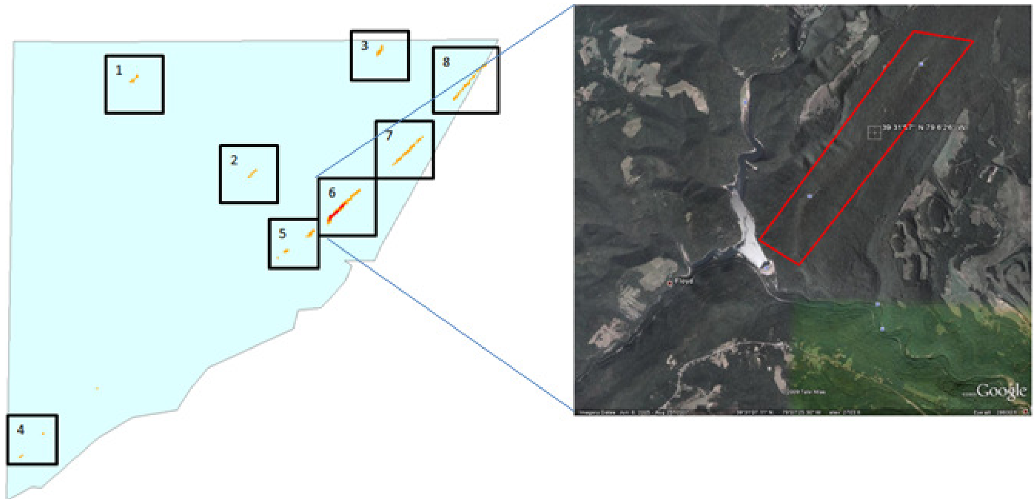


Figure 20: Aerial image of Sub-Site 6

Sharing many of the same physical characteristics as Site M1, the weighted decision matrix is provided below in Table 17. The value of the site is 1.54 and the capacity factor is significantly higher than any of the site analyses at 35%, though that criterion cannot be awarded a score higher than 5. The energy generation at 5.25 MW receives a score of 2. Overall suitability is 2.96, which is the fourth highest amongst sub-sites.

Table 17: Overall Site Suitability Scoring Matrix for Sub-Site 6

	Garrett County Site 6																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 6 Value		39°31'57" N	79°6'26" W	116-138	0.8	1	x	x	x	x	5.1	0.5	x	6	15	0.35	100	2.5	5.25	2.9565
Region 6 Ranking				3	5	4	2.5	3	5	1.5388	x	x	3.5	x	x	5	x	x	2	
Region 6 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The most important feature of sub-site 6 is its strong financial attributes. With its high capacity factor, the site is expected to have an equity payback of 11.9 years, over two years sooner than the main Site M1. The Pre-tax IRR-equity is also higher at 10.3%.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	19,500,000	81.3%
Other	$	4,500,000	18.8%
Total initial costs	$	24,000,000	100.0%
Incentives and grants	$	4,258,674	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	689,850	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,856,662	
	$		
Total annual costs	$	2,546,512	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,299,500	
	$	57,488	
Total annual savings and income	$	2,356,988	
Financial viability			
Pre-tax IRR - equity	%	10.3%	
Pre-tax IRR - assets	%	4.1%	
Simple payback	yr	11.8	
Equity payback	yr	11.9	

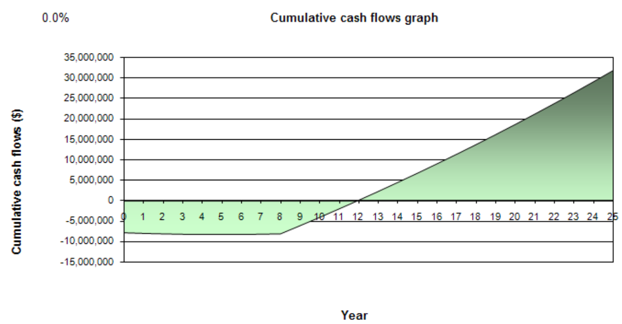


Figure 21: Financial Analysis for Sub-Site 6

The difference between a capacity factor of 35% and 31% is significant, and it is a weakness in the weighted decision matrix and the assigned ranking ranges which prevents the higher capacity factor to be rated above 5.

Site N

Despite Site N1 having the second highest overall site suitability, Site N has been excluded from in depth discussion in this section because the corresponding sub-site within the region, sub-site 7, did not rank highly and is not considered a priority site for in depth review. The findings for Site N and sub-site 7 are located in the appendix.

Site X

Site X is located in the Dans Mountain range in south Allegany County, and was identified as having high wind speeds. Review of the site's land use in Figure 22, below, indicates that the land is largely undeveloped. According to the MD Department of Planning Legend in the appendix, the windy regions of Site X are located in "evergreen forest" (MD DNR, 2009). The dense forest cover presents a moderate obstacle to build, though there is also some cleared land used currently in agriculture that would simplify development, as is shown in the Figure 24 Google Earth image. Because some of the site is conducive to development, it receives a favorable ranking of 4 for "Suitability of Land for Construction."

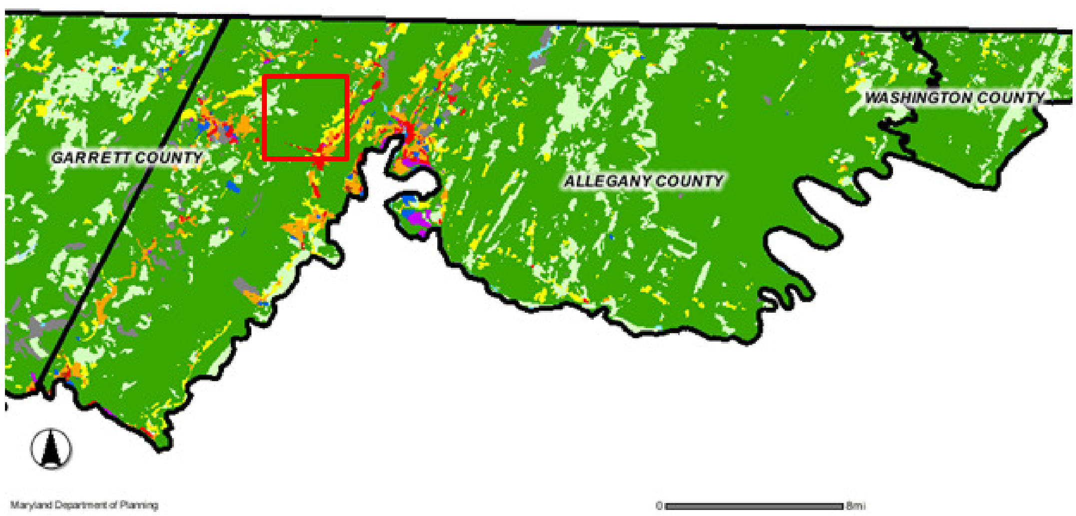


Figure 22: Allegany County Land Use from MD Department of Planning (MDP, 2009), showing Site X in red box

The site is mainly wooded, though the GIS image below in Figure 23 indicates that there are no land use protections in proximity to the regions of high wind speed that would prohibit development. A thorough analysis of the site would still require an investigation of impacts on local ecology, though the site's "land use protection" is given a ranking of 5, to represent no anticipated conflict.

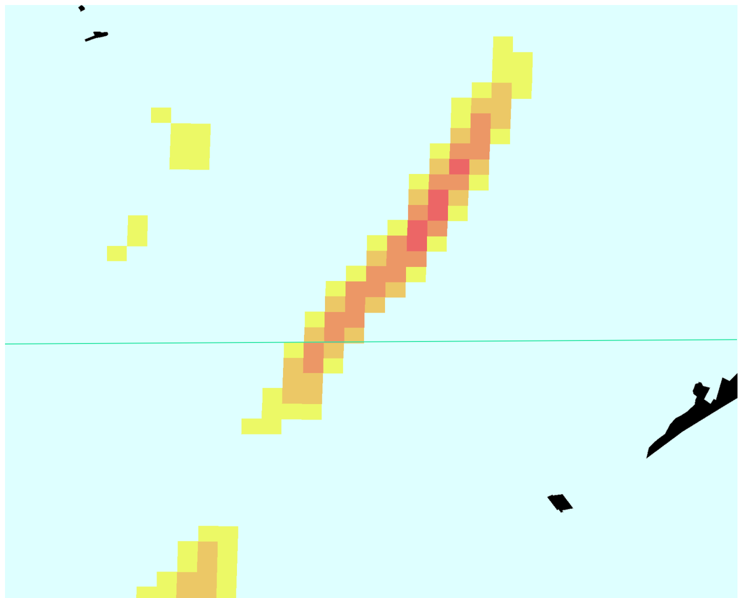


Figure 23: GIS Image of Site X (Scale 1:25,000)

Figure 23, above, shows the available wind potential on the site in yellow, orange and red. The best wind on Site X is available in a contiguous band, with measurements at 50m indicating speeds ranging between 6.4 and 8 meters per second. A strong central strip of "good" wind runs through the wind pattern, and is surrounded by "fair" wind at the strip's borders. Some "excellent" wind is centralized through the middle of the strip. The site's wind characteristics are ranked as 1.9, which is between "fair" and "good," based on the approximate percentage of land occupied by each classification of wind. The dimensions of land with available wind were approximated as a rectangle with length 6.0 km and width of 1.0 km. The land dimensions and wind speed ranking were input into MATLAB algorithm to determine that the GE Wind 2.5 MW turbine is most suitable for the site, and that 12 turbines can be placed on the site, producing 30 MW at maximum capacity. Expected power generation was determined to be 7.62 MW based on the wind characteristics of the site relative to the power curve of the selected wind turbine. Expected power output divided by the maximum turbine power yielded a 25.4% capacity factor.

The GIS image also revealed that the center of the windy region of the site was 1.6 km away from a 116-138 kV transmission line, corresponding to a ranking of 3 and 5 for "voltage suitability" and "transmission distance," respectively. The Google Earth image in Figure 24 shows a road running through the site, with a perpendicular distance of 0.3 km from the center. This corresponds with a ranking of 5 for "road connectivity."

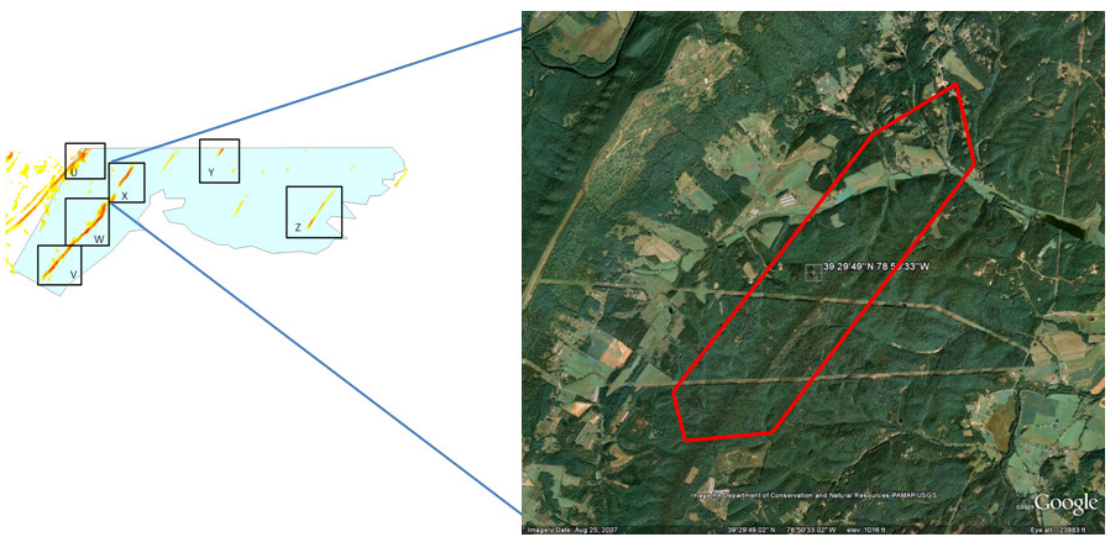


Figure 24: Aerial image of Site X

Each site and energy attribute rankings were put into the weighted scoring matrix in Table 18 below, yielding a site value of 2.21 with 47.7% weight, a ranking of 3 for capacity factor, and energy generated rank of 3. The overall site score was 2.62.

Table 18: Overall Site Suitability Scoring Matrix for Site X

Allegany County Site X																				
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region X1 Value		39°29'49" N	78°50'33" W	116-138	1.6	0.3	x	x	x	x	6	1	x	12	30	0.254	100	2.5	7.62	2.6246
Region X1 Ranking		x	x	3	5	5	5	4	4	2.2134	x	x	1.9	x	x	3	x	x	3	
Region X1 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kv	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The financial analysis using RETScreen utilized the capacity factor, and number and size of turbines, to estimate an output of 66,800 MWh of annual generation from the Site X wind farm. The initial upfront plant costs would be $48,000,000. This figure includes plant power system costs and "other" costs at $9,000,000. Operations and maintenance costs were expected to be $1,001,000 annually. The cumulative cash flows graph and worksheet are presented below in Figure 25.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	39,000,000	81.3%
Other	$	9,000,000	18.8%
Total initial costs	$	48,000,000	100.0%
Incentives and grants	$	6,181,161	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,001,268	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	3,713,324	
	$		
Total annual costs	$	4,714,592	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,337,560	
	$	83,439	
Total annual savings and income	$	3,420,999	
Financial viability			
Pre-tax IRR - equity	%	5.2%	
Pre-tax IRR - assets	%	0.8%	
Simple payback	yr	17.3	
Equity payback	yr	16.4	

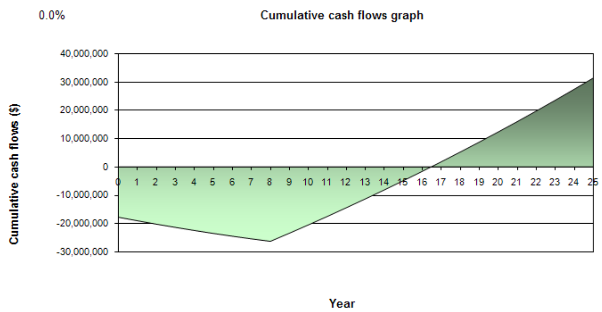


Figure 25: Financial Analysis for Site X

It was determined that the wind farm would begin making profit after 16.4 years of operation, which is equivalent to an investing the upfront costs with 5.2% interest. A cursory RETScreen emission analysis determined that the site would annually displace 40,000 tCO_2 that would otherwise be generated by an average electricity fuel mix in the United States. This is the equivalent of 34,000 acres of forested land absorbing CO_2 from the atmosphere over the course of the year.

Site X – Sub-site 18:

The analysis of site X was then focused on the areas that had a wind speed of category 5 and higher. Figure 27 shows the GIS image of the site with wind speeds of category 5 and 6. Figure 26 shows the aerial view of the sub-site.

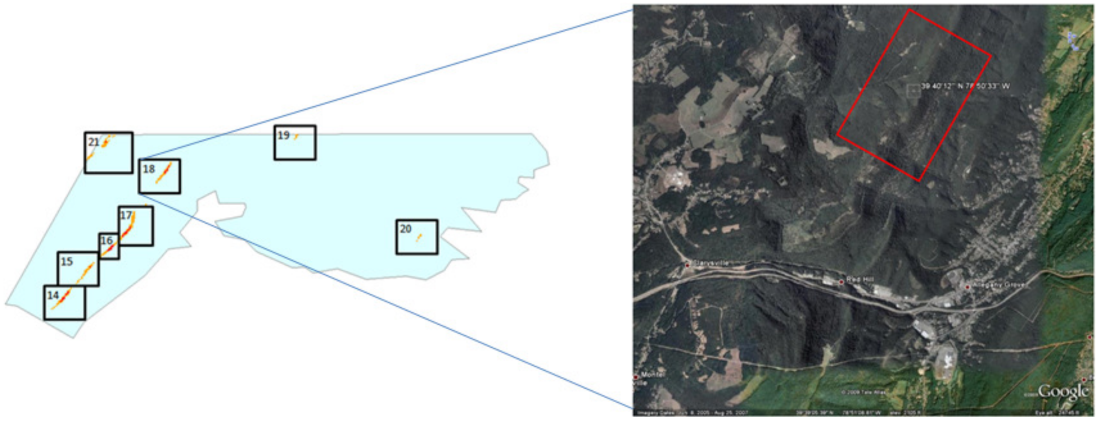


Figure 26: Aerial image of Sub-Site 18

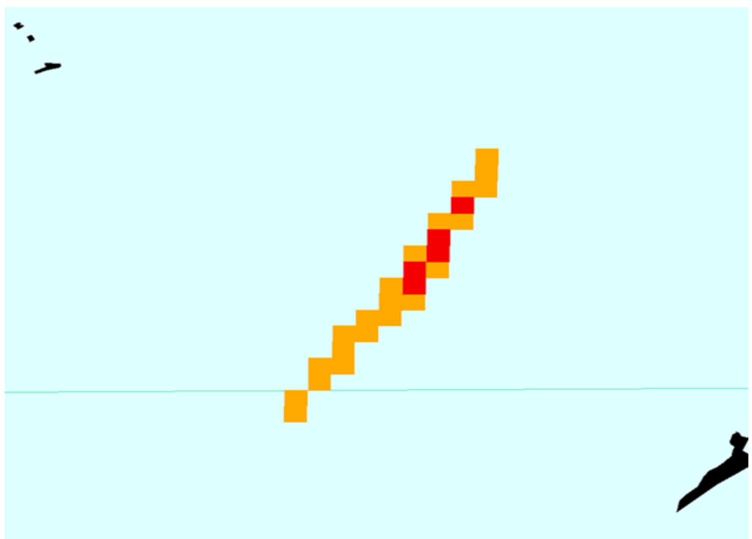


Figure 27: GIS Image of Sub-Site 18

The weighted decision matrix for Sub-Site 18 is shown below in Table 19. Since Sub-Site 18 is located within Site X, many of the properties are the same. The value of the site is 3.1, which makes it the highest scoring Sub-Site. This high score features a capacity factor of 33.2% and a total power output of 3.32 MW.

Table 19: Overall Site Suitability Scoring Matrix for Sub-Site 18

Allegany County Site 18																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 18 Value		39°40'12" N	78°50'33" W	116-138	1.3	0.3	x	x	x	x	3.5	0.3	x	4	10	0.332	100	2.5	3.32	**3.081**
Region 18 Ranking				3	5	5	5	3	3	2.0733	x	x	3.2	x	x	5	x	x	1	
Region 18 Weight	x	x	x	0.016	0.0366	0.0247	0.26	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

One major strength of Sub-Site 18 is its financial attributes, which are detailed in Figure 28. This Sub-site has payback period of 12.6 years. This value is significantly lower than the payback period of Site X, which had a payback period of 16.4 years. Also, the IRR of Sub-Site 18 is 9.3%, which higher than that of the larger Site.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	13,000,000	81.3%
Other	$	3,000,000	18.8%
Total initial costs	$	16,000,000	100.0%
Incentives and grants	$	2,693,104	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	436,248	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,237,775	
	$		
Total annual costs	$	1,674,023	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,454,160	
	$	36,354	
Total annual savings and income	$	1,490,514	
Financial viability			
Pre-tax IRR - equity	%	9.3%	
Pre-tax IRR - assets	%	3.5%	
Simple payback	yr	12.6	
Equity payback	yr	12.6	

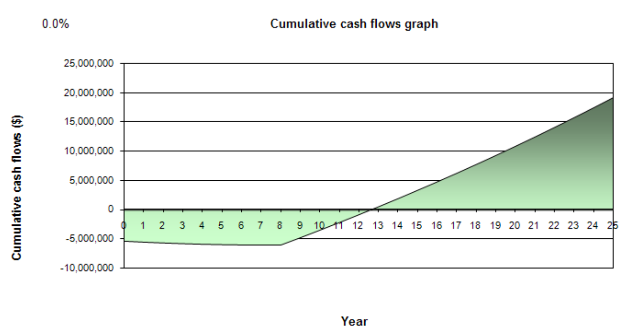


Figure 28: Financial Analysis for Sub-Site 18

Site U

Site U is located on a mountain chain on the north-west corner of Allegany County north of Frostburg on the border with Pennsylvania. The site was identified as having high wind speeds from a cursory view of the Maryland NREL wind data. A more detailed review of the site investigated the land use of the entire county as shown in Figure 29, below. According to the MD Department of Planning Legend in the appendix, Site U is located in a forested region classified as "evergreen forest" (MD DNR, 2009), though inspection of the aerial image from Google Earth in Figure 28 reveals that the site is mixed use.

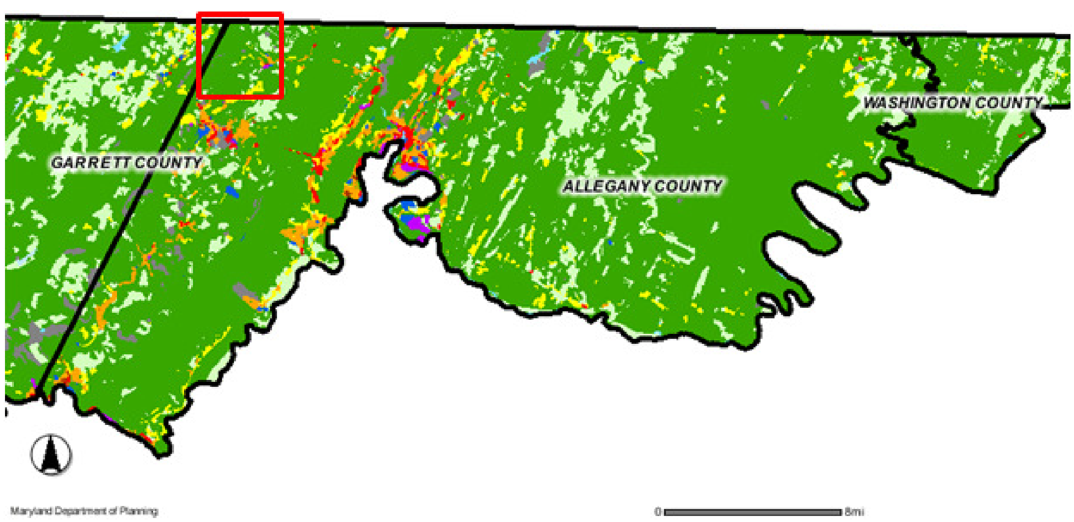


Figure 29: Allegany County Land Use from MD Department of Planning (MDP, 2009), showing Site U in red box

There appears to also be non-coal surface mining in the proximity of the site, as shown by the yellow indicator number "2" in Figure 30, below. Proximity to a mining site may be well suited for development because of the need for environmental reclamation at mining sites to prevent soil erosion and environmental damage.

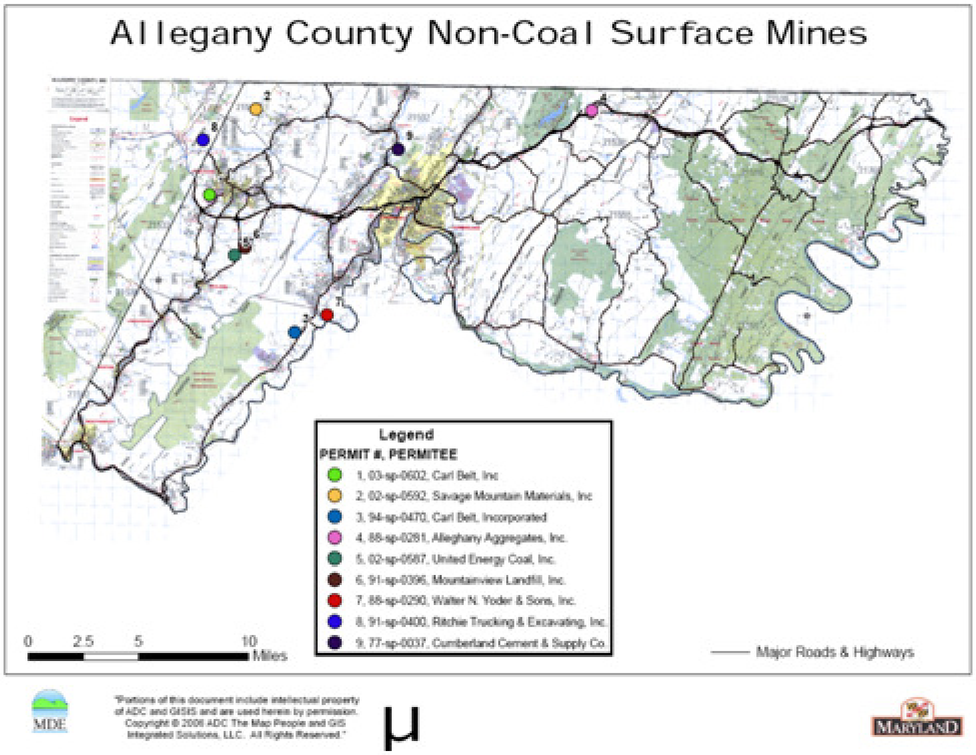


Figure 30: Map of Allegany County from MD Department of Environment (MDE, 2009) showing non-coal surface mines

The dense forest cover and site preparation from a mine would likely present a moderate obstacle to build, warranting a ranking of 3 for "Suitability of Land for Construction." The site does not appear to have inhabited lands nearby and is not used for tourism, though agricultural and mining activities nearby may prevent some objection from "nearby populations." The site receives a 4 for this attribute.

The GIS image below in Figure 31 indicates that there is a full-protection region on the site that overlaps with some of the windy areas of the site. The reason for classification of these areas as "full protection" must be further investigated before a site can be developed on Site U, though since the majority of windy area is located on "no protection" areas, the region is given a ranking of 5 for "land use protection," to represent no anticipated conflict.

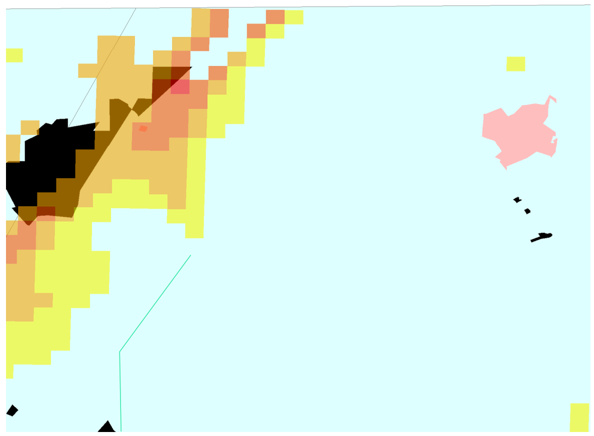


Figure 31: GIS Image of Site U

Figure 31, above, shows the available wind potential on the site in yellow, orange and red. Wind on Site U is available in an irregular pattern, with measurements at 50m indicating speeds ranging between 6.4 and 8 meters per second. Some “excellent” wind is centralized through the middle of the strip, though only “good” and “fair” wind is available at the perimeter. The site wind characteristics are approximated with a ranking of 1.8 because of the prevalence of “fair” wind. The dimensions of land with available wind were approximated as a rectangle with length 6.4 km and width of 1.4 km. The output of the MATLAB algorithm indicated that the GE Wind 2.5 MW turbine is most suitable for the site, and that 14 turbines can be placed on the site, producing 35 MW at maximum capacity. Expected power generation was determined to be 8.68 MW based on the wind characteristics of the site relative to the power curve of the selected wind turbine. Expected power output divided by the maximum turbine power yielded a 25% capacity factor.

The GIS image in Figure 31 also revealed that the center of the windy region of the site was 1.8 km away from a 116-138 kV transmission line, corresponding to a ranking of 3 and 5 for “voltage suitability” and “transmission distance,” respectively. The Google Earth image in Figure 32 shows a road running through the site, with a perpendicular distance of 0.3 km from the center. This corresponds with a ranking of 5 for “road connectivity.”

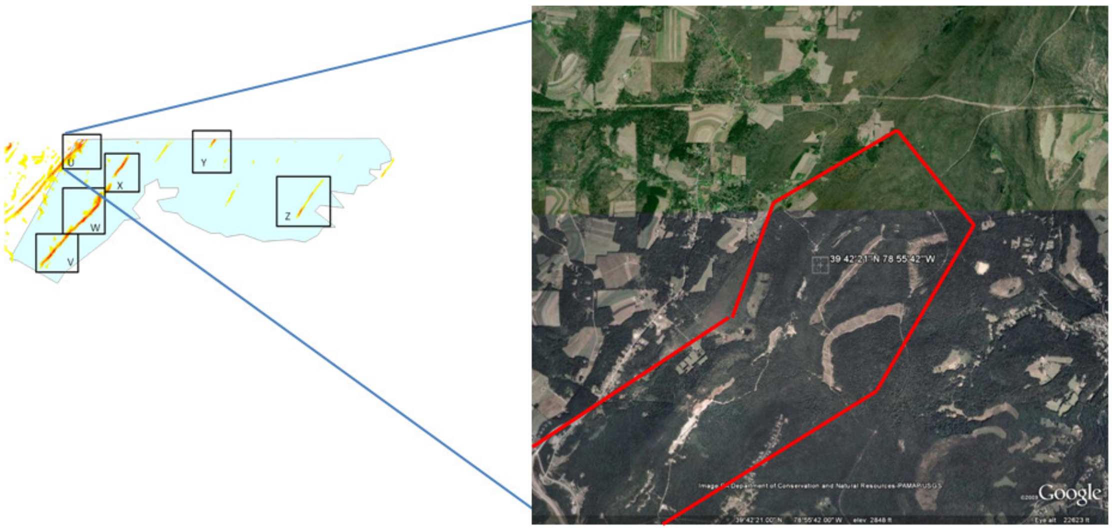


Figure 32: Aerial image of Site U

Each site and energy attribute rankings were put into the weighted scoring matrix in Table 20 below, yielding a site value of 2.143 with 47.7% weight, a ranking of 3 for capacity factor with 39.2% weight, and energy generated rank of 3. The overall site score is 2.59.

Table 20: Overall Site Suitability Scoring Matrix for Site U

		Allegheny County Site U																		
		Characterization			Site Suitability							Energy Availability								
					Infrastructure			Environmental		Social										
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region U1	Value		39°42'21" N	78°55'42" W	116-138	1.8	0.3	x	x	x	x	6.5	1.4	x	14	35	0.25	100	2.5	8.68	**2.591**
	Ranking				3	5	5	5	3	4	2.143	x	x	1.8	x	x	3	x	x	3	
	Weight	x	x	x	0.016	0.0366	0.0247	0.26	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The financial analysis using RETScreen utilized the capacity factor, and the number and size of turbines, to estimate an output of 76,700 MWh of annual generation from the Site U wind farm. The initial upfront plant costs would be $56,000,000. This figure includes plant power system costs and "other" costs at $10,500,000. Operations and maintenance costs were expected to be $1,150,000 annually. The cumulative cash flows graph and worksheet are presented below in Figure 33.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	45,500,000	81.3%
Other	$	10,500,000	18.8%
Total initial costs	$	56,000,000	100.0%
Incentives and grants	$	7,097,790	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,149,750	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,332,211	
	$		
Total annual costs	$	5,481,961	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,832,500	
	$	95,813	
Total annual savings and income	$	3,928,313	
Financial viability			
Pre-tax IRR - equity	%	5.0%	
Pre-tax IRR - assets	%	0.7%	
Simple payback	yr	17.6	
Equity payback	yr	16.7	

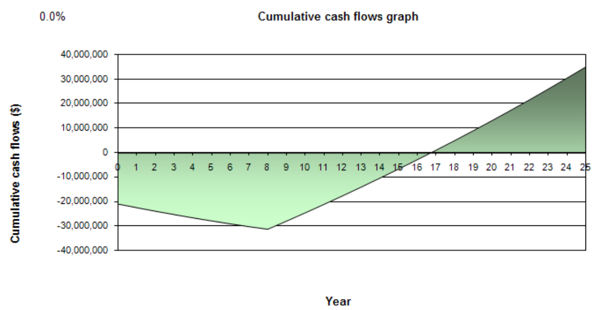


Figure 33: Financial Analysis for Site U

It was determined that the wind farm would begin making profit after 16.7 years of operation, which is equivalent to an investing the upfront costs with 5.0% interest. A cursory RETScreen emission analysis determined that the site would annually displace 46,000 tCO_2 that would otherwise be generated by an average electricity fuel mix in the United States. This is the equivalent of 39,000 acres of forested land absorbing CO_2 from the atmosphere over the course of the year.

Site U – Sub-site 21:

Site U was then focused into Sub-site 21, which only had wind of category 5 and 6. The high wind speeds are shown in the GIS form in Figure 35, and the Google Earth image is shown in Figure 34.

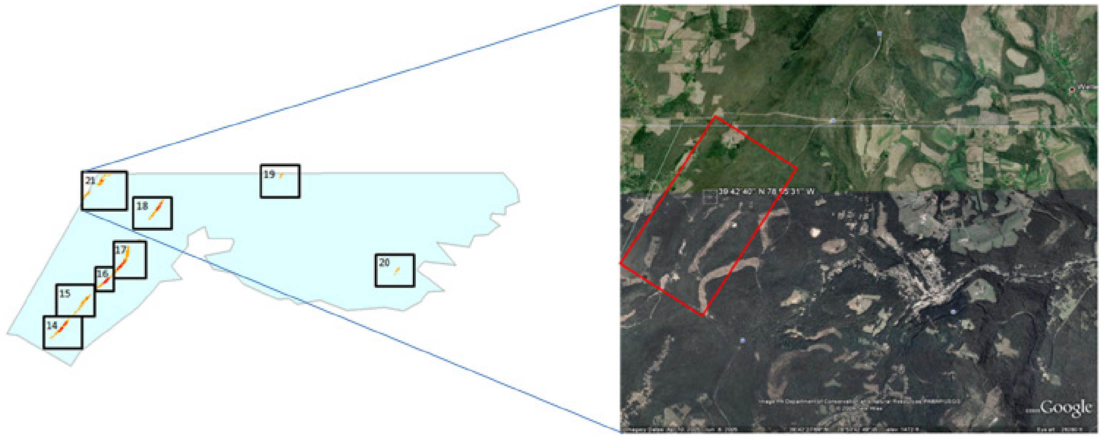


Figure 34: Aerial image of Sub-Site 21

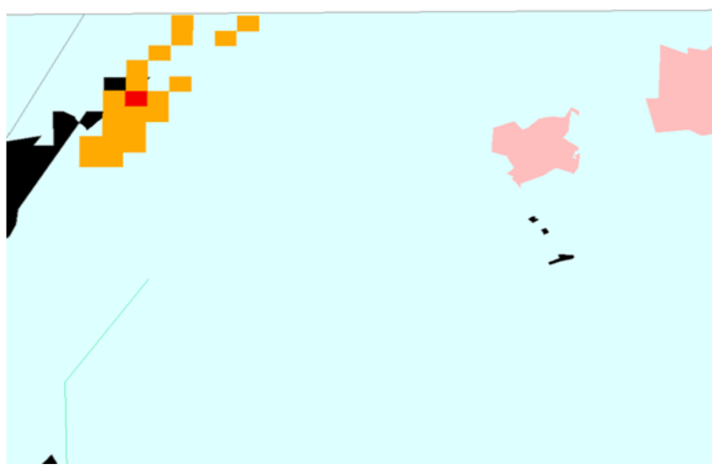


Figure 35: GIS Image of Sub-Site 21

The site suitability and energy availability factors were analyzed using the weighted decision matrix. Sub-Site 21 received an Overall Suitability score of 2.9, which is the fifth highest score for a Sub-Site. This Sub-Site has a capacity factor of 32.6%, which received a score of 5. Also, the Sub-Site produces a total of 1.63 MW, which receives a score of 0.

Table 21: Overall Site Suitability Scoring Matrix for Sub-Site 21

Allegany County Site 21																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region 21	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Value		39°42'40" N	78°55'31" W	116-138	2.2	0.4	x	x	x	x	1.8	0.4	x	2	5	0.326	100	2.5	1.63	**2.9329**
Ranking				3	4	5	5	3	3	2.0367	x	x	3.1	x	x	5	x	x	0	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The financial attributes of Sub-Site 21 were measured using RETScreen. The results from the analysis are shown in Figure 36. The payback period for Sub-Site 21 is 12.8 years, which is less than the payback period for Site U. Sub-Site 21 also has an IRR of 9.0%, which is higher than that of the larger Site U.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	16,250,000	81.3%
Other	$	3,750,000	18.8%
Total initial costs	$	20,000,000	100.0%
Incentives and grants	$	3,305,542	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	535,455	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,547,218	
	$		
Total annual costs	$	2,082,673	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,784,850	
	$	44,621	
Total annual savings and income	$	1,829,471	
Financial viability			
Pre-tax IRR - equity	%	9.0%	
Pre-tax IRR - assets	%	3.3%	
Simple payback	yr	12.9	
Equity payback	yr	12.8	

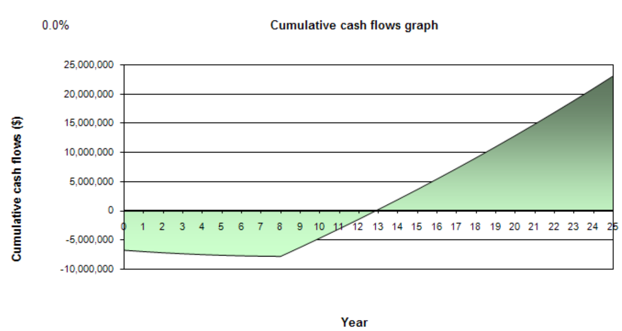


Figure 36: Financial Analysis for Sub-Site 21

Site V

Site V is located on a mountain chain in south-west Allegany County that was identified as having high wind speeds from a cursory view of the Maryland NREL wind data maps. A more detailed review of the site investigated the land use of the entire county as shown in Figure 37, below. Site V is located in a forested region classified as "evergreen forest" (MD DNR, 2009). The dense forest cover presents a moderate obstacle to build, so the site receives a ranking of 3 for "Suitability of Land for Construction." There are agricultural or developed areas in the immediate proximity, corresponding to a ranking of 5 for "nearby populations". Local population impacts are unlikely to play a significant role in commissioning this wind site.

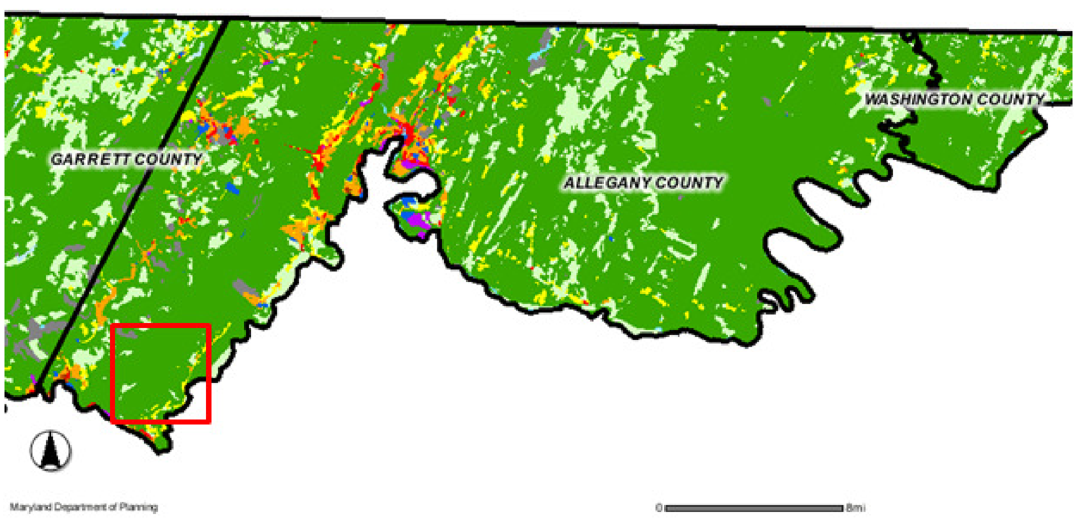


Figure 37: Allegany County Land Use from MD Department of Planning (MDP, 2009), showing Site V in red box

The site includes Dans Mountain State Wildlife Management Area, which is a 9,200 acre contiguous tract of forest famous for its numerous species of songbirds and wildlife (DNR, 2009). Though wind projects are not legally prohibited on this site, there are direct environmental impacts that must be assessed before site development. Figure 38, below, shows the available wind potential on the site in yellow, orange and red. The pink coloration outlines the extent of the Dans Mountain State Wildlife Management Area. Because there is clear overlap, the "land use protection" is given a ranking of 2.5, to represent a potential development conflict.

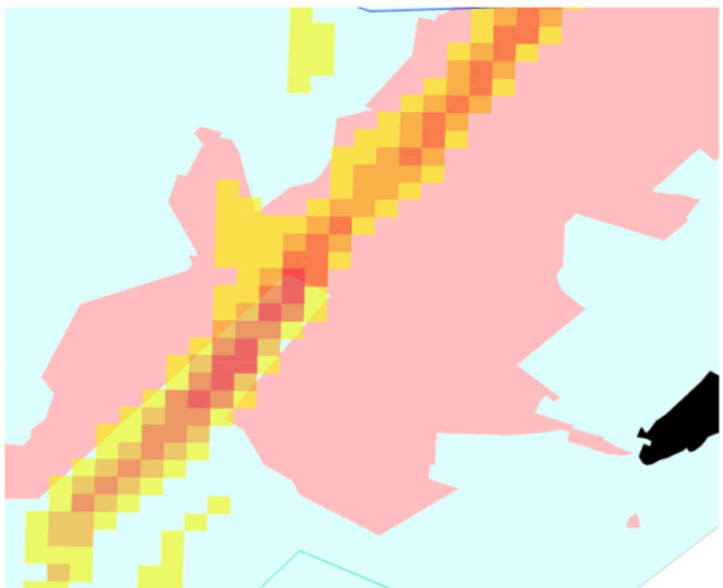


Figure 38: GIS data image of Site V

The wind pattern on Site V is very strong, with measurements at 50m indicating speeds ranging between 6.4 and 8 meters per second. A strong central strip of "good" wind runs through the wind pattern, and is surrounded by "fair" wind at the strip's borders. A few patches of "excellent" wind are on the strip also. The site's wind characteristics are approximated as "good" between 7 and 7.5 meters per second, corresponding to a ranking of 2. The dimensions of land with available wind were approximated as a rectangle with length 10.9 km and width of 1.3 km. The land dimensions and wind speed ranking were input into MATLAB algorithm to determine that the GE Wind 2.5 MW turbine is most suitable for the site, and that 22 turbines can be placed on the site with an optimal packing structure. Expected power output was determined to be 14.3 MW based on the wind characteristics of the site relative to the power curve of the selected wind turbine. The expected power output, divided by the turbine power of 55 MW (assuming 100% output), yielded the capacity factor of 26%.

The GIS image in Figure 38 also revealed that the center of the windy region of the site was 3.5 km away from a 351-500 kV transmission line, corresponding to a ranking of 5 and 4 for "voltage suitability" and "transmission distance," respectively. The Google Earth image in Figure 39 shows a road running through the site at approximately 0.7 km from the windy region's center, corresponding with a ranking of 5 for "road connectivity."

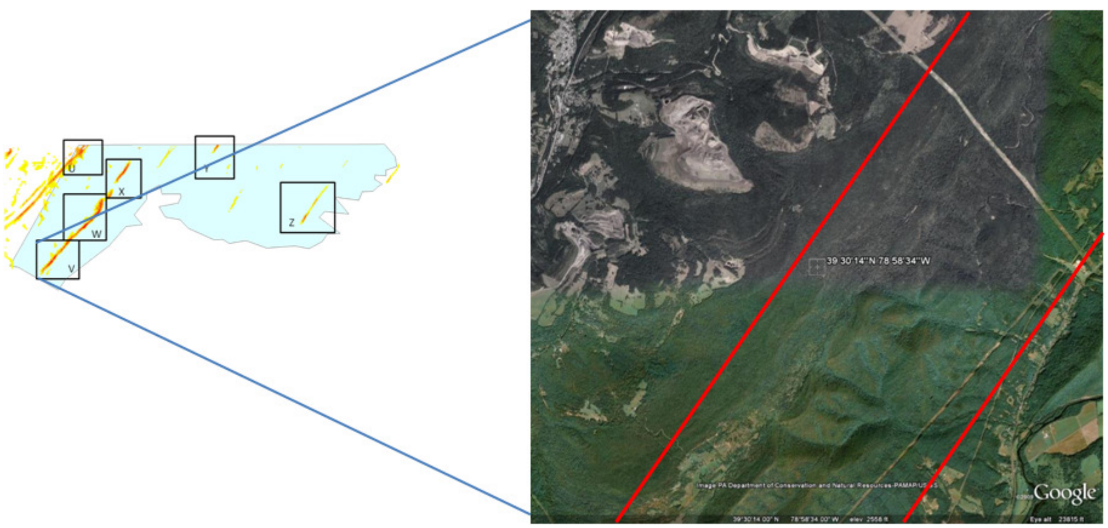


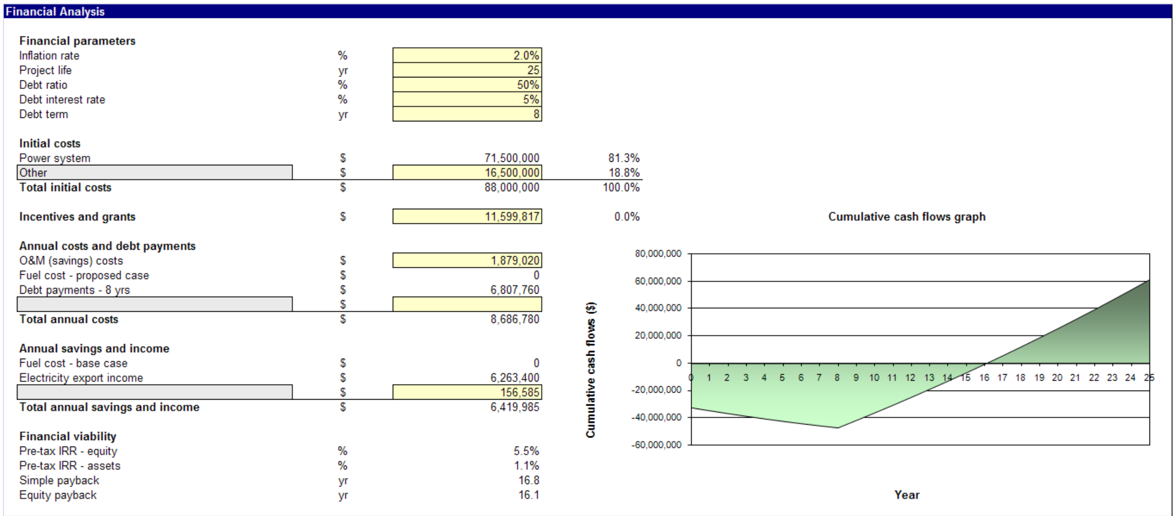
Figure 39: Aerial image of Site V

Each of these site and energy rankings were put into the weighted scoring matrix in Table 22, below, yielding a site value of 1.56 with 47.7% weight, a ranking of 3 for capacity factor , and energy generated rank of 5. The overall site score accounting for 100% of these inputs is 2.5735.

Table 22: Overall Site Suitability Scoring Matrix for Site V

		Allegheny County Site V																			
		Characterization			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region V1	Value		39°30'14" N	78°58'34" W	231-500	3.5	0.7	x	x	x	x	10.9	1.3	x	22	55	0.26	100	2.5	14.3	2.5735
	Ranking				5	4	5	2.5	3	5	1.559	x	x	2	x	x	3	x	x	5	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.477	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The financial analysis using RETScreen estimated an output of 125,000 MWh of annual generation from the Site V wind farm. It was determined that the initial upfront plant costs would be $88,000,000. This figure includes plant power system costs and "other" costs, which internalizes site purchase costs, transmission interconnect, substation costs, and road connections. Operations and maintenance costs were expected to be $1,880,000 annually. The cumulative cash flows graph and worksheet are presented below in Figure 40.



Financial Analysis			
Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	71,500,000	81.3%
Other	$	16,500,000	18.8%
Total initial costs	$	88,000,000	100.0%
Incentives and grants	$	11,599,817	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,879,020	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	6,807,760	
	$		
Total annual costs	$	8,686,780	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	6,263,400	
	$	156,585	
Total annual savings and income	$	6,419,985	
Financial viability			
Pre-tax IRR - equity	%	5.5%	
Pre-tax IRR - assets	%	1.1%	
Simple payback	yr	16.8	
Equity payback	yr	16.1	

Figure 40: Financial Analysis for Site V

It was determined that the wind farm would begin making profit after 16.1 years of operation, which is equivalent to an investing the upfront costs with 5.5% interest. A cursory RETScreen emission analysis determined that the site would annually displace 75,200 tCO_2 that would otherwise be generated by an average electricity fuel mix in the United States. This is the equivalent of 63,900 acres of forested land absorbing CO_2 from the atmosphere over the course of the year.

Site V also contains sub-sites 14 and 15, though those sub-sites are not included here for discussion. Sub-site 15 did not receive an overall site score that placed it amongst the strongest sub-sites. An error occurred in the weighted decision matrix analysis for sub-site 14, so it has been excluded altogether from the rankings, though the incomplete data may be viewed in the appendix.

Site W

Site W is located on a mountain chain in south Allegany County overlapping with Dans Mountain State Wildlife Management Area that was discussed in the Site

V analysis. The site was identified as having high wind speeds from a cursory view of the Maryland NREL wind data maps. A more detailed review of the site investigated the land use of the entire county as shown in Figure 41, below. According to the MD Department of Planning Legend in the appendix, Site W is located in a forested region classified as "evergreen forest" (MDP, 2009), and the windy regions as shown in Figure 42 show that there is little human infrastructure on the potential development site.

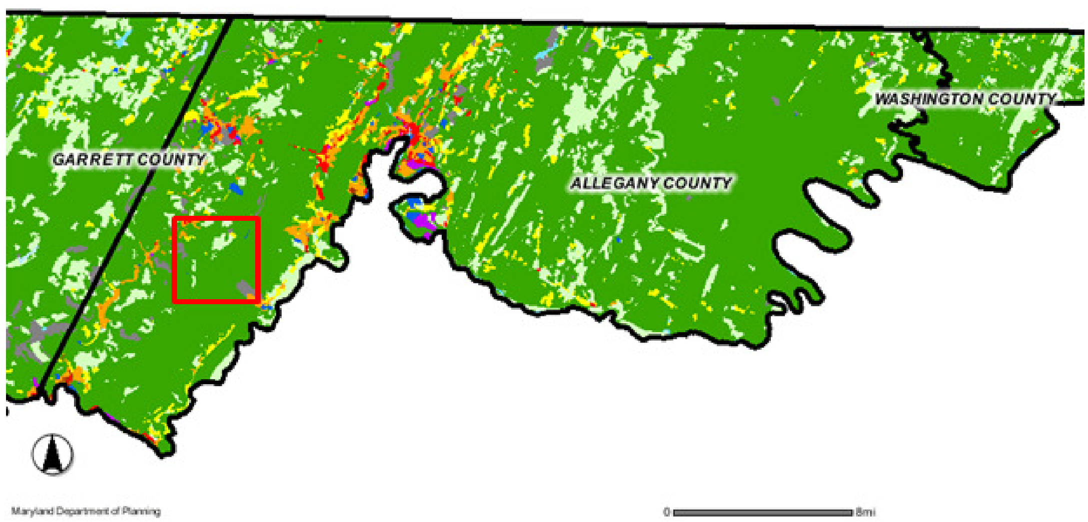


Figure 41: Allegany County Land Use from MD Department of Planning (MDP, 2009), showing Site W in red box

The dense forest cover warrants a ranking of 3 for "Suitability of Land for Construction." The site does not appear to have inhabited lands nearby but may be used for tourism because of its proximity to the wildlife area. The site receives a 4 for "nearby populations."

The GIS image indicates that half of the site is no protection (5), while the other half is partial protection (2.5). The average reveals our ranking of 3.75 for "land use protection."

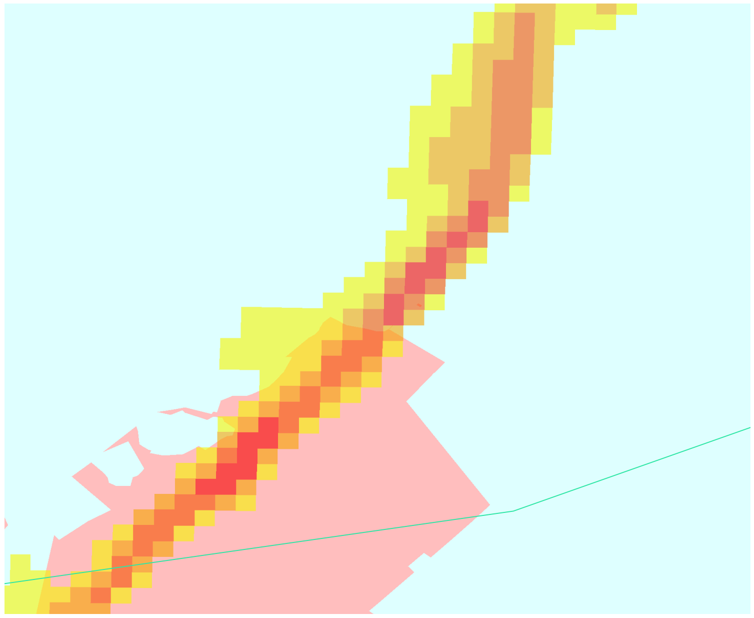


Figure 42: GIS Image of Site W (Scale 1:25,000)

Figure 42, above, shows the available wind potential on the site in yellow, orange and red. Wind on Site W is available in a contiguous strip. Some "excellent" wind is centralized through the middle of the strip, though only "good" and "fair" wind is available at the perimeter. The site wind characteristics are approximated with a ranking of 1.8 because of the prevalence of "fair" wind.[1] The dimensions of land with available wind were approximated as a rectangle with length 12 km and width of 2.2 km. The output of the MATLAB algorithm indicated that the GE Wind 2.5 MW turbine is most suitable for the site, and that 36 turbines can be placed on the site, producing 90 MW at maximum capacity. Expected power generation was determined to be 22.32 MW based on the wind characteristics of the site relative to the power curve of the selected wind turbine. Expected power output divided by the maximum turbine power yielded a 24.8% capacity factor.

[1] *Though intended as an objective process for assessing wind speed rankings, uncertainty oftentimes exists in the measure of relative proportions of each wind classification. Resultantly, the Site W wind characteristics may be judged to be as high as 2.8, which would significantly increase the site's value.*

The site's GIS image also revealed that the center of the windy region was 4.0 km away from a 116-138 kV transmission line, corresponding to a ranking of 3 and 4 for "voltage suitability" and "transmission distance," respectively. There is a road in close proximity to the site, with a perpendicular distance of 0.2 km from the center, corresponding to a ranking of 5 for "road connectivity."

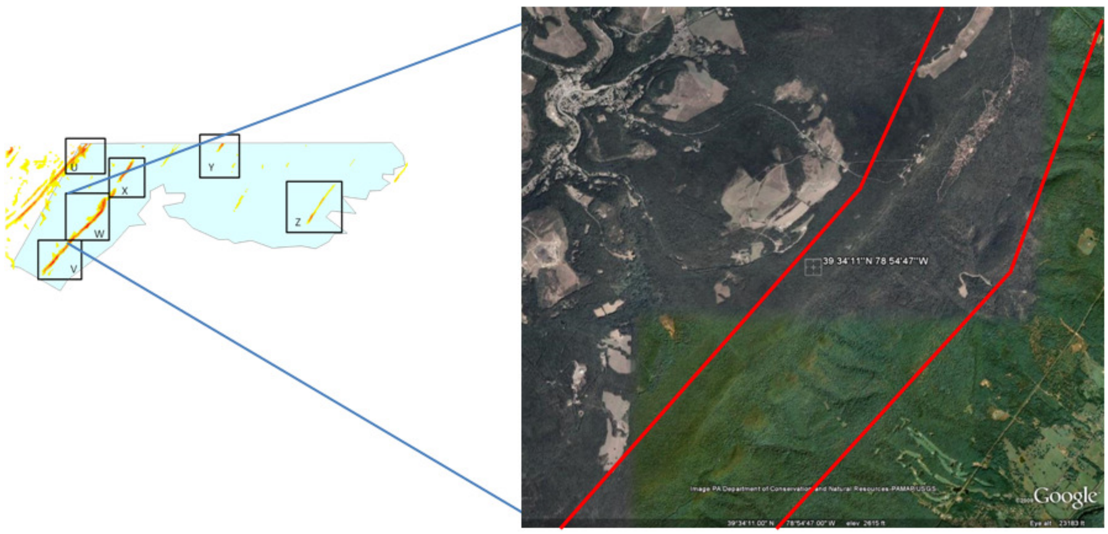


Figure 43: Aerial image of Site W

Each site and energy attribute rankings were put into the weighted scoring matrix in Table 23, below, yielding a site value of 1.78 with 47.7% weight, a ranking of 2 for capacity factor with 39.2% weight, and energy generated rank of 5. The overall site score accounting for 100% of these inputs is 2.29.

Table 23: Overall Site Suitability Scoring Matrix for Site W

Allegany County Site W																				
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region W1 Value		39°34'11"N	78°54'47" W	116-138	4.04	0.2	x	x	x	x	12	2.2	x	36	90	0.248	100	2.5	22.32	**2.2877**
Region W1 Ranking				3	4	5	3.75	3	4	1.7818	x	x	1.8	x	x	2	x	x	5	
Region W1 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				V	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The financial analysis using RETScreen utilized the capacity factor, and the number and size of turbines, to estimate an output of 196,000 MWh of annual generation from the Site W wind farm. The initial upfront plant costs would be \$144,000,000. This figure includes plant power system costs and "other" costs at \$27,000,000. Operations and maintenance costs were expected to be \$2,933,000 annually. The cumulative cash flows graph and worksheet are presented below in Figure 44.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	117,000,000	81.3%
Other	$	27,000,000	18.8%
Total initial costs	$	144,000,000	100.0%
Incentives and grants	$	18,105,448	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	2,932,848	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	11,139,971	
	$		
Total annual costs	$	14,072,819	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	9,776,160	
	$	244,404	
Total annual savings and income	$	10,020,564	
Financial viability			
Pre-tax IRR - equity	%	4.8%	
Pre-tax IRR - assets	%	0.6%	
Simple payback	yr	17.8	
Equity payback	yr	16.8	

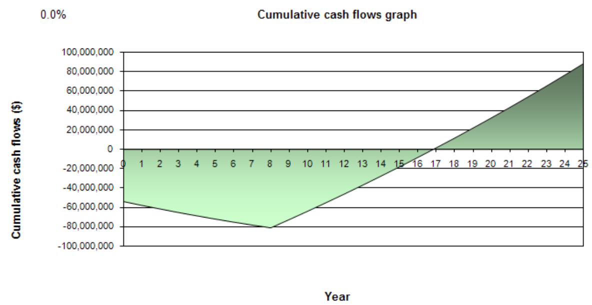


Figure 44: Financial Analysis for Site W

It was determined that the wind farm would begin making profit after 16.8 years of operation, which is equivalent to investing the upfront costs with 4.8% interest. A cursory RETScreen emission analysis determined that the site would annually displace 117,000 tCO_2 that would otherwise be generated by an average electricity fuel mix in the United States. This is the equivalent of 100,000 acres of forested land absorbing CO_2 from the atmosphere over the course of the year.

Site W – Sub-site 17:

Site W was then focused into Sub-site 17, which only had wind of category 4 and 5. The high wind speeds are shown in the GIS form in Figure 46, and the Google Earth image is shown in Figure 45.

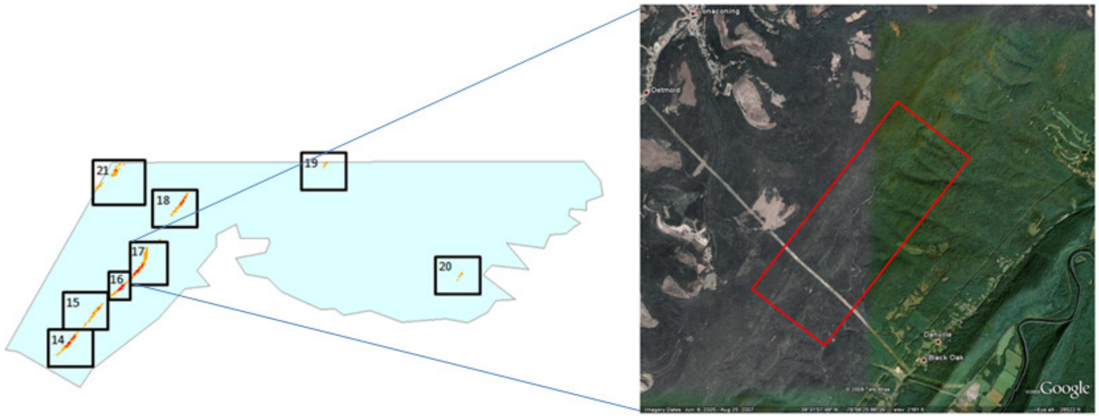


Figure 45: Aerial image of Sub-Site 17

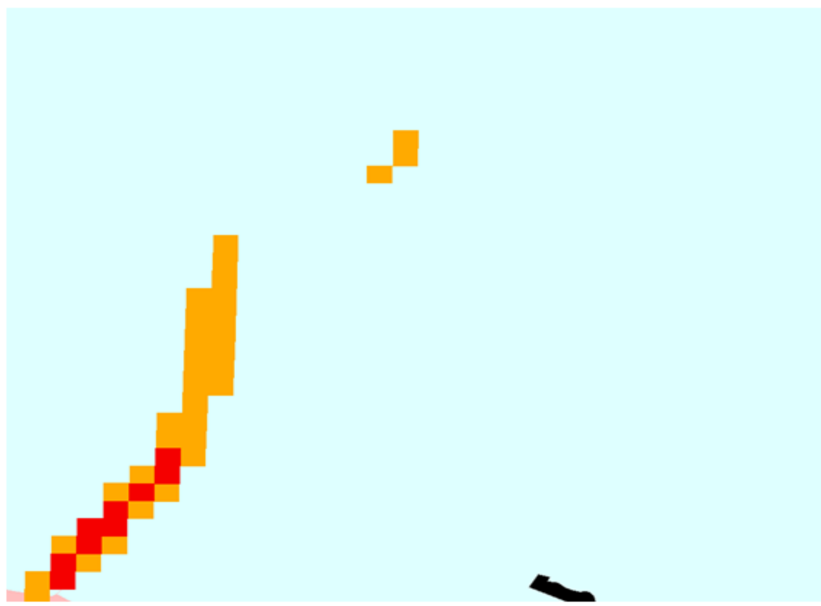


Figure 46: GIS Image of Sub-Site 17

The site suitability and energy availability factors were then analyzed using the weighted decision matrix shown in Table 24. Sub-Site 17 received an Overall Suitability score of 3.1, which is the second highest score for a Sub-Site. This Sub-Site has a capacity factor of 33.5%, which received a score of 5. This is significantly higher than the capacity factor of the larger site. Also, the Sub-Site produces a total of 4.19 MW, which receives a score of 1. This is significantly lower than the total power output of the larger site.

Table 24: Overall Site Suitability Scoring Matrix for Sub-Site 17

Region 17	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
	Allegany County Site 17			Site Suitability: Infrastructure			Environmental		Social		Energy Availability									
Value		39°35'23" N	78°53'35" W	116-138	3.5	0.1	x	x	x	x	4.2	0.4	x	5	12.5	0.3352	100	2.5	4.19	3.0635
Ranking				3	4	5	5	3	3	2.0367	x	x	3.25	x	x	5	x	x	1	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

The financial attributes of Sub-Site 17 were measured using RETScreen. The results from the analysis are shown in Figure 47. The payback period for Sub-Site is 12.5 years, which is less than the payback period for Site U. Sub-Site 21 also has an IRR of 9.5%, which is higher than that of the larger Site U.

Financial Analysis

Financial parameters	Unit	Value	
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	16,250,000	81.3%
Other	$	3,750,000	18.8%
Total initial costs	$	20,000,000	100.0%
Incentives and grants	$	3,396,800	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	550,238	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,547,218	
	$		
Total annual costs	$	2,097,456	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,834,125	
	$	45,853	
Total annual savings and income	$	1,879,978	
Financial viability			
Pre-tax IRR - equity	%	9.5%	
Pre-tax IRR - assets	%	3.6%	
Simple payback	yr	12.5	
Equity payback	yr	12.5	

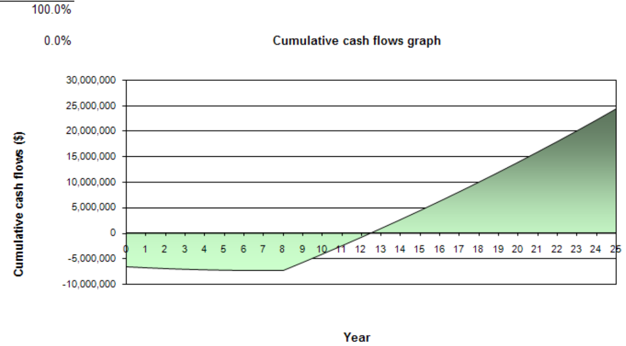


Figure 47: Financial Analysis for Sub-Site 17

Site W also contains sub-site 16, which is included in the appendix but not in this discussion. The site's characteristics did not qualify it amongst the best sub-sites.

Performance of the Weighted Decision Matrix:

It is important to consider the validity of each series of results, particularly regarding the efficacy of the weighted decision matrix in predicting financial feasibility of the site. Financial feasibility is an important consideration for any off-site renewable project. A low equity payback period is one indicator of a high potential site. In Figure 48, the overall site scores for each of the sites were plotted in descending order, and a trendline was added. Each site's corresponding equity payback period was also plotted. There is a strong increasing trend of the equity payback as the overall site score decreases. This behavior indicates that poor site scores correlate with poor equity payback periods. This attests to the strength of the Weighted Decision Matrix analysis.

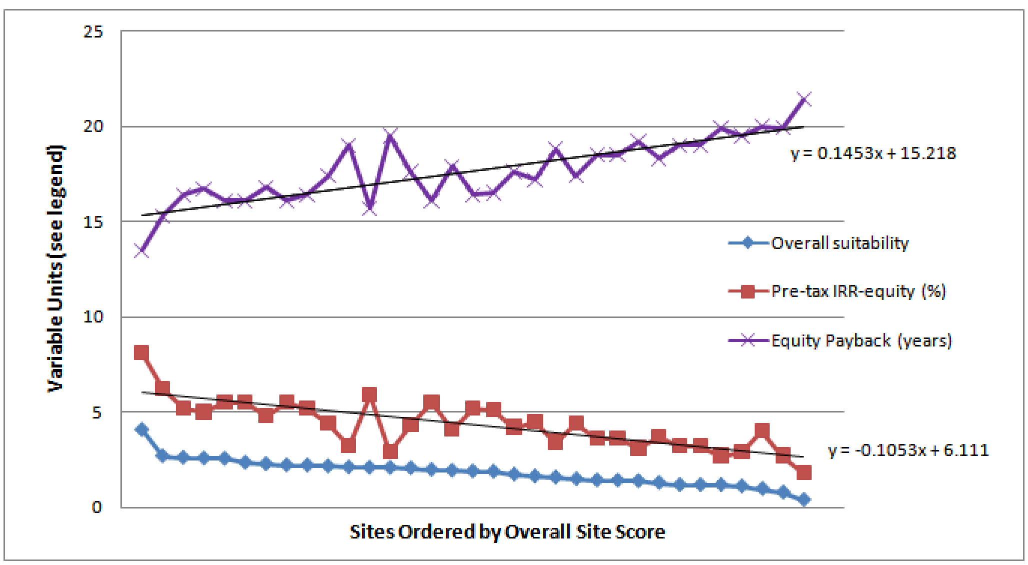


Figure 48: Relationships between Overall Site Score and other site viability parameters

Additionally, the performance of the weighted decision matrix for the innately stronger sub-sites can also be assessed. Relationships between the overall sub-site scores from the weighted decision matrix and the RETScreen financial outputs are much less apparent than those in the site plot in Figure 48, above. Figure 49, below, shows the financial parameters specified for each sub-site ordered by the overall sub-site scores from highest to lowest. Very weak correlations exist between the best sub-site score and a high Pre-tax IRR – equity and low equity payback period. The trendlines for the pre-tax IRR – equity data and equity payback indicate that pre-tax IRR – equity decreases slightly with decreasing site score, as would be anticipated, though the correlation is weak and poorly fit. With similar utility, a weak correlation for equity payback shows increasing payback periods as the sub-site scores get worse. The weak correlation results from several factors. Firstly, each of these sites have very high capacity factors that were awarded a score of "5" for capacity factor in the weighted decision matrix. The equity payback period and pre-tax IRR – equity is strongly correlated with capacity factor, and as a result strong correlations between sub-site scores and financial parameters would exist. However, because attribute scores cannot surpass "5", differences within these best sub-sites were not reflected in the weighted decision matrix. This result effectively "washed out" the contribution of capacity factor from the weighted decision matrix, causing significant distortion of the sub-site values. Resultantly, the relative value of the weighted decision output for each sub-site indicates the value of the physical site attributes, particularly land protection. These inputs have no impact on the RETScreen financial analysis, causing the weak correlations discussed above.

In future analyses, this issue could be addressed by adjusting capacity factor attribute score ranges to reward the highest capacity factors relative to others.

However, this would skew the value of the sub-site scores relative to the site scores. Alternatively, the range of attribute scores could be extended, for example, by assigning a value of "6" for the highest capacity factors. This approach would remove some of the intentionally included margin of error which is assured by using only round measures of attribute value.

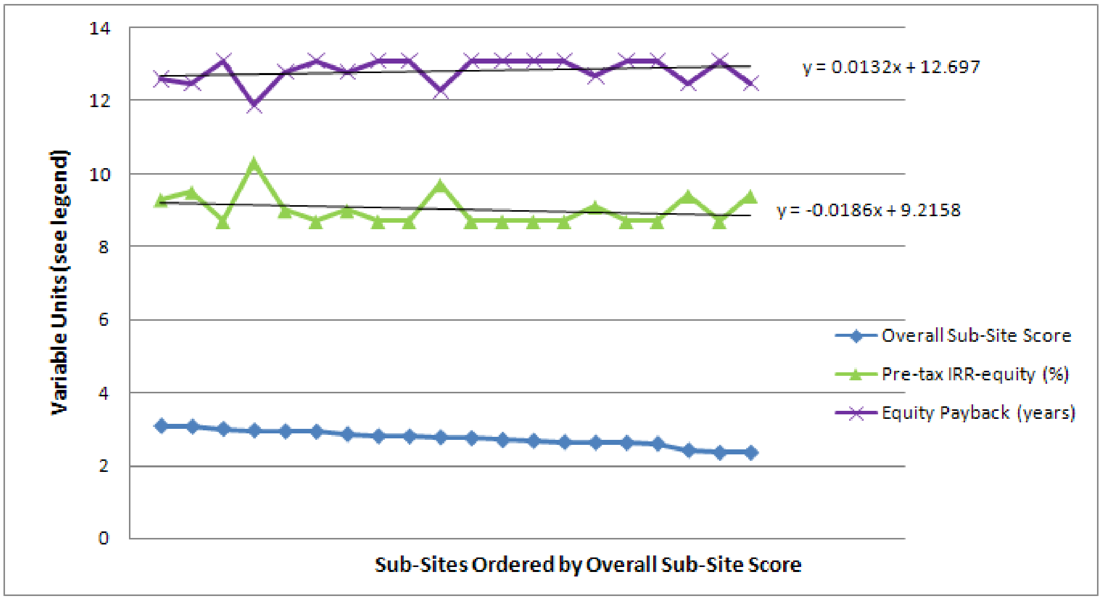


Figure 49: Relationship between overall sub-site score and RETScreen Outputs

Sensitivity of RETScreen Financial Analysis

Policy change can significantly impact the Equity Payback and Pre-tax IRR-equity of any wind development. According to the IPCC report (IPCC, 2007c), economic instruments that could increase renewable energy production include capital grants, feed-in tariffs, quote obligation and permit trading, greenhouse gas taxes, and tradable emissions permits. As discussed in the methodology, MD state and federal government policies have already stimulated wind development since the end of the 1990's. Further policies could enhance demand for wind, primarily by increasing the price of carbon intensive energy development.

RETScreen simulations were performed to predict the impact of a carbon price on the Equity Payback and Pre-tax IRR – equity. The size of the tax, the number of carbon sources the tax encompasses, and the complimentary government policies to alleviate high electricity prices all influence the impact of the carbon tax on the wind farm site. Here, an upper end estimate of the tax's value is intended to suggest a reasonable maximum benefit.

Table 25: Greenhouse Reduction income parameter assumptions at the upper limit of sensitivity analysis

GHG reduction income		
GHG reduction credit rate	$/tCO2	35.00
GHG reduction credit duration	yr	10
GHG reduction credit escalation rate	%	2.0%

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	19,500,000	81.3%
Other	$	4,500,000	18.8%
Total initial costs	$	24,000,000	100.0%
Incentives and grants	$		0.0%
Annual costs and debt payments			
O&M (savings) costs	$	689,850	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,856,662	
	$		
Total annual costs	$	2,546,512	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,299,500	
GHG reduction income - 10 yrs	$	966,324	
	$		
Total annual savings and income	$	3,265,824	
Financial viability			
Pre-tax IRR - equity	%	12.2%	
Pre-tax IRR - assets	%	6.1%	
Simple payback	yr	9.3	
Equity payback	yr	9.4	

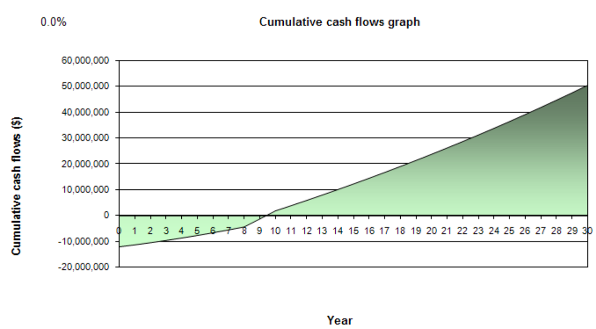


Figure 50: Financial Analysis with upper limit greenhouse reduction income

The RETScreen software intends for the emission reduction credit fields to be used in conjunction with a policy like the Kyoto Protocol's Clean Development Mechanism, or for Joint Implementation Projects. These projects reward renewable energy projects that can demonstrate an emission reduction above a baseline scenario where the project would not have otherwise been implemented. Though the United States has not ratified the Kyoto Protocol, and a post-Kyoto international climate treaty to govern carbon emission reductions is unlikely to resemble the Kyoto Accords, the level of this crude analysis allows for a broad estimate of the impact of a policy that awards emission reductions of a ton-by-ton CO_2 basis. Prices for emission reduction credits range on the present market from $1 to $35, depending on whether the market is voluntary or mandatory, traded publicly or privately, traded regionally, nationally or internationally, and other factors. The upper value of $35 was selected for this emission analysis to understand the current extent of impact possible. Clean Development Mechanism projects use a fixed crediting period of 10 years, which is maintained for this crude analysis.

For simplicity, the benefit of the Renewable Energy Credits has been removed, assuming that the carbon reduction credit will be larger and would take the place of any RECs in future markets. The other federal and state incentives and grants are also removed, assuming that the emission reduction credit supplements them as the primary means for policy-driven emission reductions. The escalation rate accounts for inflation in the emission reduction credit rate over the duration of the credit period.

The result of the analysis indicates that a pricing of carbon at $35 per ton of CO2 reduced results in an equity payback period reduction from 11.9 years to 9.4 years, which is a significant reduction. Future carbon policy will increase the profitability of any of the proposed sites and sub-sites.

Chapter 6: Summary and Conclusions

The purpose of this study was to assess one possible means for the University of Maryland to purchase renewable electricity produced in the state of Maryland. This University objective is laid out in the campus's Climate Action Plan. Though significant potential exists in other states, as well as along the Atlantic coast of Maryland and in the Chesapeake Bay, this study aimed only to assess wind resources in Western Maryland. Maryland regions that had commercially exploitable wind energy potential were broken into sites for analysis. Each site was judged based on eight criteria:

- The suitability of nearby transmission based on voltage
- The distance to nearby transmission lines
- The distance to roadways
- The suitability of the site land for construction
- Proximity to nearby populations
- Land use protection
- Energy Generated
- Capacity factor

An analysis using Analytical Hierarchy Process (AHP) determined weightings for each criterion, concluding that capacity factor and land use protection were the most important criteria for assessing overall site suitability. Criterion rankings were assigned to each site, and based on each criterion's weight, a relative score was produced – indicating the best suited sites for development. Further site investigation using RETScreen financial analysis software further supported the value of our criteria in determining site value, particularly the influence of capacity factor on site score. More extensive analysis of selected "sub-sites" indicated the value of the sites if the University were to build on only the lands with the highest winds.

Should the University of Maryland choose to pursue its goals of buying renewable electricity from off-campus sources as outlined in the Climate Action Plan via the construction of wind turbines, the sites analyzed in this report provide a firm starting point for more thorough feasibility studies. Additionally, the flexibility of this analysis provides a framework for the determination of other potential areas for wind development.

Through our cursory analysis of 26 potential wind-farm sites in western Maryland, we have shown that the top 5 sites are capable of producing between 8 and 22 MW of power. Additionally, these sites show the potential of having equity payback periods as low as 13.5 years, and pre-tax internal rates of return as high as 8.1%. Sub-sites identified for their high wind speeds may have equity payback periods as low as 11.9 years and Pre-tax IRR-equity as high as 10.3%. Not only do they represent a sound way of fulfilling the University's Climate Action Plan, these sites may also represent a sound investment. Also, with our flexible weighting system, which can be tailored to reflect current priorities, other sites can be identified which may show more potential as circumstances change in the future than they currently do in our analysis. The influence of emerging policies on renewable energy development cannot be overstated, and the RETScreen tool is capable of accommodating greenhouse gas emission regulations.

As the need for renewable energy increases, it becomes increasingly important to identify available resources. Wind power represents an important source of renewable energy, one that is currently underutilized and rapidly developing in the state of Maryland.

Appendix

Land Use

MARYLAND LAND USE\LAND COVER CLASSIFICATION SCHEME

The land use\land cover classification scheme described below has been used to identify the predominant usage of land that could be interpreted from high altitude aerial photography and satellite imagery. The LU_CODE field, in each county land use shape file, contains the 2 or 3 digit integer numbers identified below.

In general, only land uses greater than 10 acres in size have been identified. Transportation features such as roads, highways, rail lines and utility lines have not been included in this GIS database. Transportation features are better represented by the point and line files available from the Maryland State Highway Administration.

Urban Built-Up

11 Low-density residential - Detached single-family/duplex dwelling units, yards and associated areas. Areas of more than 90 percent single-family/duplex dwelling units, with lot sizes of less than five acres but at least one-half acre (.2 dwelling units/acre to 2 dwelling units/acre).

12 Medium-density residential - Detached single-family/duplex, attached single-unit row housing, yards, and associated areas. Areas of more than 90 percent single-family/duplex units and attached single-unit row housing, with lot sizes of less than one-half acre but at least one-eighth acre (2 dwelling units/acre to 8 dwelling units/acre).

13 High-density residential - Attached single-unit row housing, garden apartments, high-rise apartments/condominiums, mobile home and trailer parks. Areas of more than 90 percent high-density residential units, with more than 8 dwelling units per acre.

14 Commercial - Retail and wholesale services. Areas used primarily for the sale of products and services, including associated yards and parking areas.

15 Industrial - Manufacturing and industrial parks, including associated warehouses, storage yards, research laboratories, and parking areas.

16 Institutional - Elementary and secondary schools, middle schools, junior and senior high schools, public and private colleges and universities, military installations (built-up areas only, including buildings and storage, training, and similar areas), churches, medical and health facilities, correctional facilities, and government offices and facilities that are clearly separable from the surrounding land cover.

17 Extractive - Surface mining operations, including sand and gravel pits, quarries, coal surface mines, and deep coal mines. Status of activity (active vs. abandoned) is not distinguished.

18 Open urban land - Urban areas whose use does not require structures, or urban areas where non-conforming uses characterized by open land have become isolated. Included are golf courses, parks, recreation areas (except areas associated with schools or other institutions), cemeteries, and entrapped agricultural and undeveloped land within urban areas.

Continued…

Figure 51: Maryland land use classifications from MD DNR

Agriculture

21 Cropland - Field crops and forage crops.

22 Pasture - Land used for pasture, both permanent and rotated; grass.

23 Orchards/vineyards/horticulture - Areas of intensively managed commercial bush and tree crops, including areas used for fruit production, vineyards, sod and seed farms, nurseries, and green houses.

241 Feeding operations - Cattle feed lots, holding lots for animals, hog feeding lots, poultry houses.

242 Agricultural building breeding and training facilities, storage facilities, built-up areas associated with a farmstead, small farm ponds, commercial fishing areas.

25 Row and garden crops - Intensively managed truck and vegetable farms and associated areas.

40 Forest

41 Deciduous forest - Forested areas in which the trees characteristically lose their leaves at the end of the growing season. Included are such species as oak, hickory, aspen, sycamore, birch, yellow poplar, elm, maple, and cypress.

42 Evergreen forest - Forested areas in which the trees are characterized by persistent foliage throughout the year. Included are such species as white pine, pond pine, hemlock, southern white cedar, and red pine.

43 Mixed forest - Forested areas in which neither deciduous nor evergreen species dominate, but in which there is a combination of both types.

44 Brush - Areas which do not produce timber or other wood products but may have cut-over timber stands, abandoned agriculture fields, or pasture. These areas are characterized by vegetation types such as sumac, vines, rose, brambles, and tree seedlings.

Water - Rivers, waterways, reservoirs, ponds, bays, estuaries, and ocean.

Wetlands - Forested or non-forested wetlands, including tidal flats, tidal and non-tidal marshes, and upland swamps and wet areas.

Barren land

71 Beaches - Extensive shoreline areas of sand and gravel accumulation, with no vegetative cover or other land use.

72 Bare exposed rock - Areas of bedrock exposure, scarps, and other natural accumulations of rock without vegetative cover.

73 Bare ground - Areas of exposed ground caused naturally, by construction, or by other cultural processes.

Transportation - Miscellaneous Transportation features not elsewhere classified.

Figure 52:Maryland land use classification from MD DNR, continued

Potential Conflict Maps

The maps below indicate reference lands that may conflict with wind development sites. Use of the wind farm as environmental reclamation for mining sites, however, may increase their economic value.

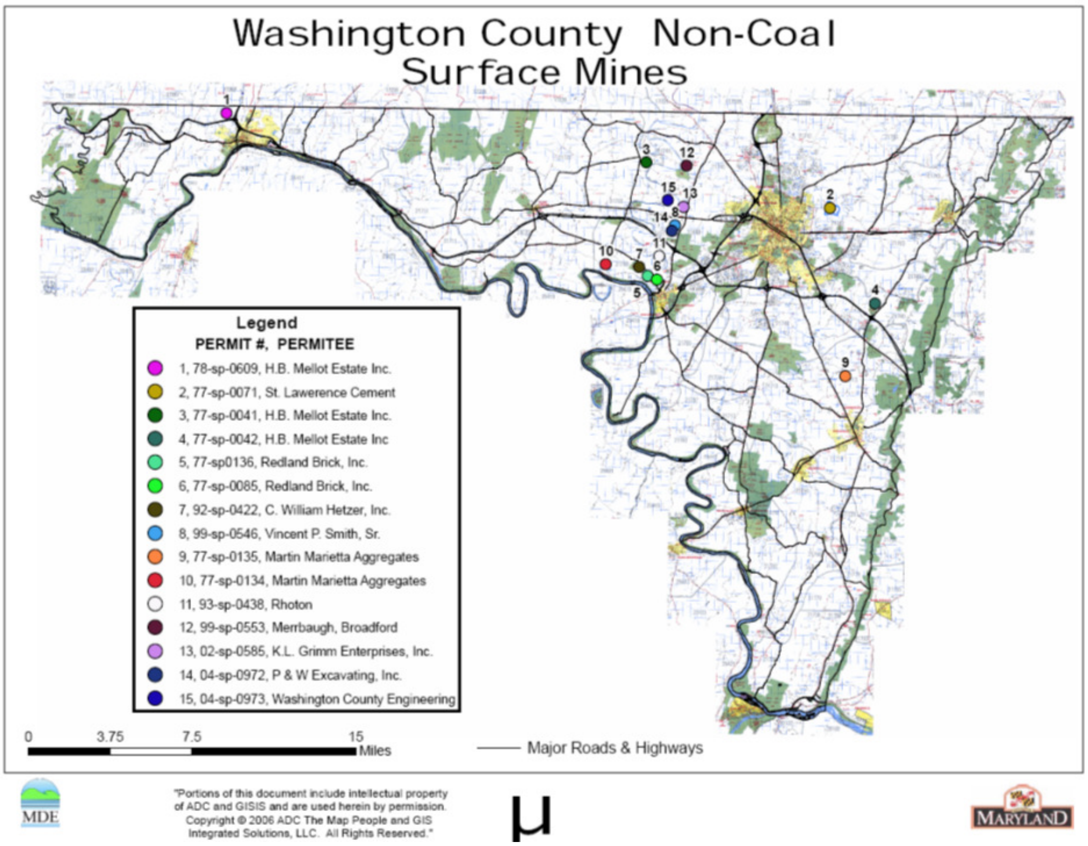


Figure 53: Map of Washington County from MD Department of Environment (MDE, 2009) showing non-coal surface mines

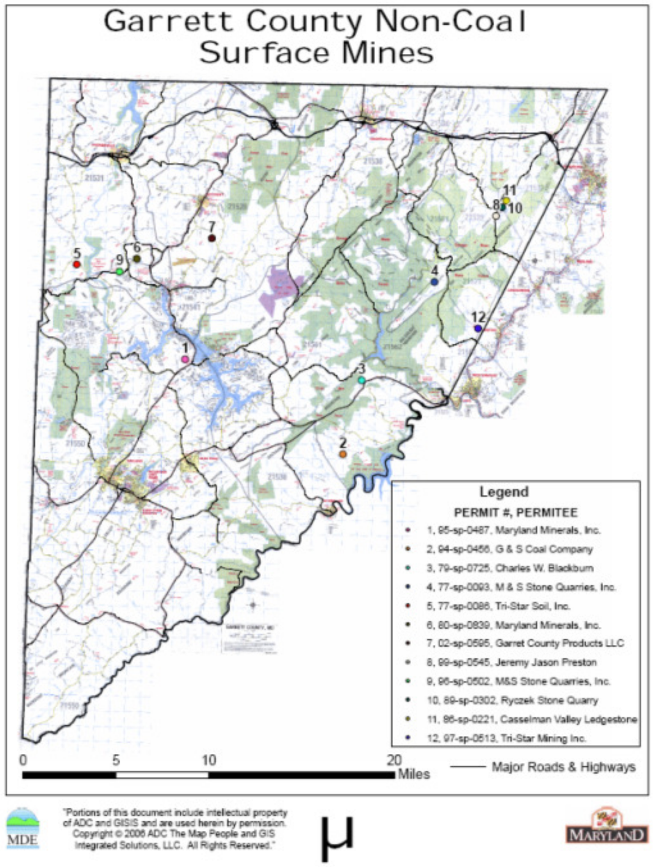


Figure 54: Map of Garrett County from MD Department of Environment (MDE, 2009) showing non-coal surface mines

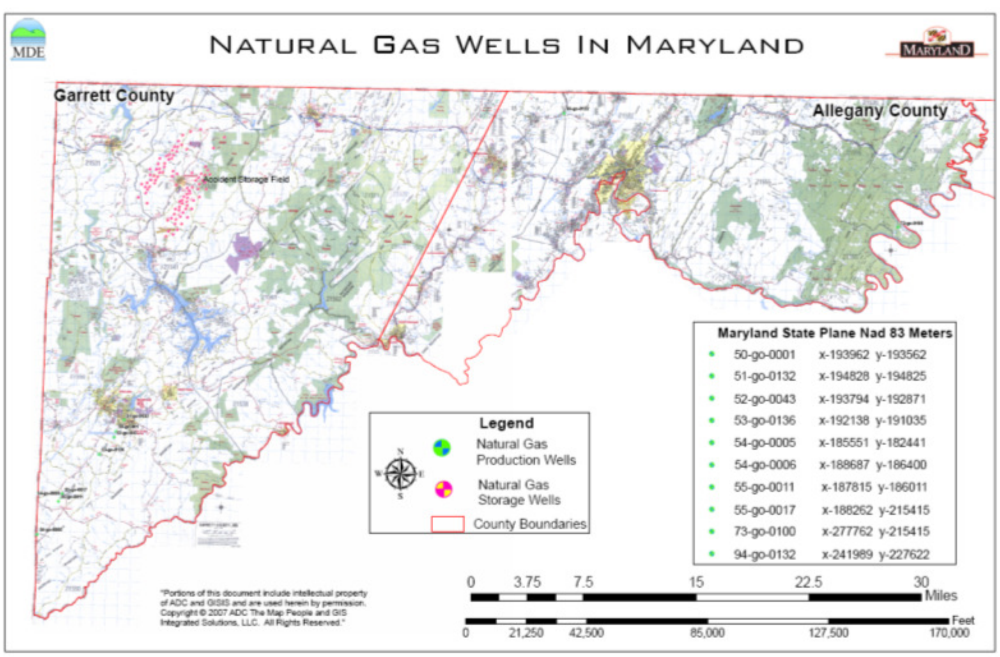


Figure 55: Map of Allegany and Garrett Counties from MD Department of Environment (MDE, 2009) showing locations of MD natural gas wells

Individual Site Data and Characterization

Site A: Data

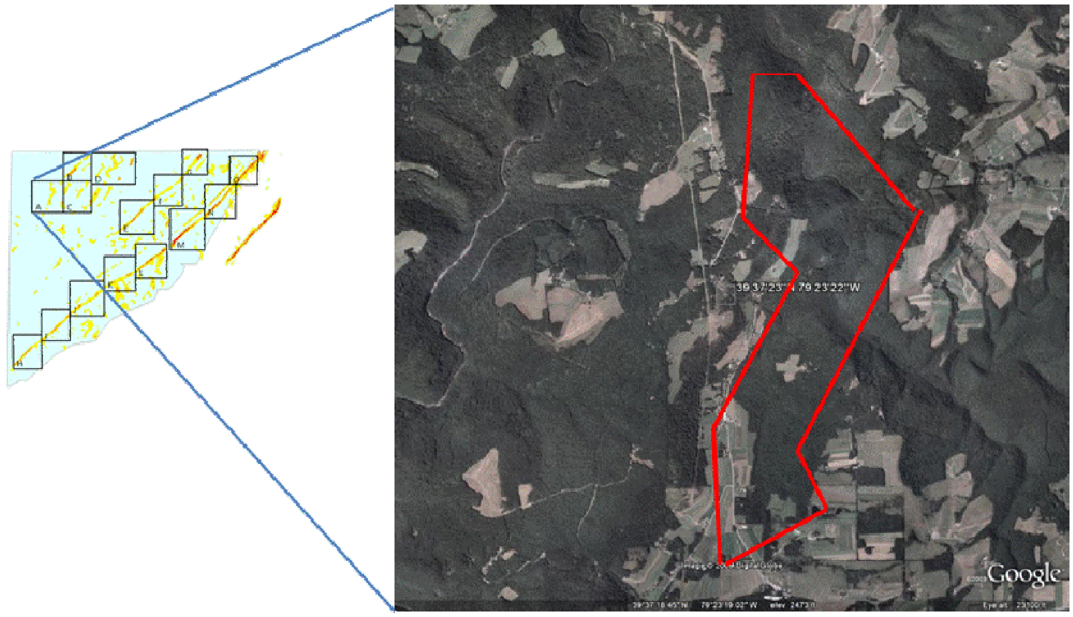


Figure 56: Aerial image of Site A

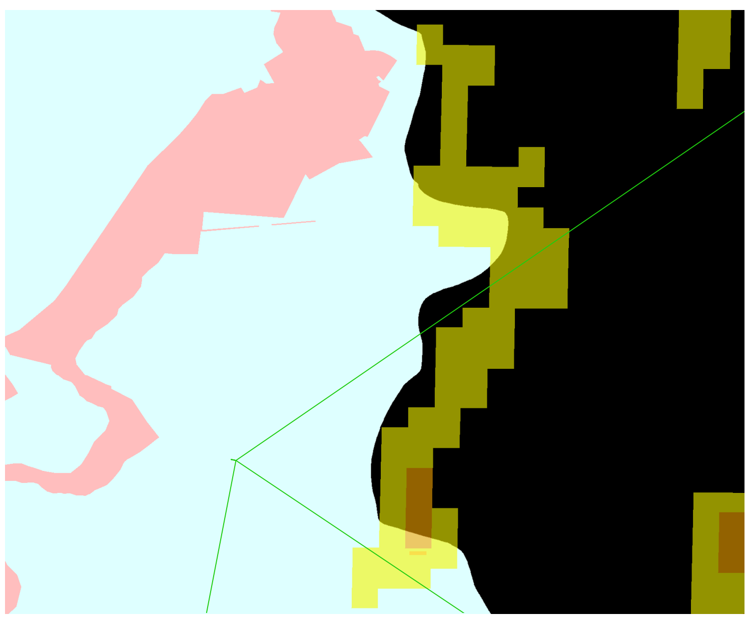


Figure 57: GIS image of Site A

Table 26: Overall Site Suitability Scoring Matrix for Site A.1, A.2, and A.3

	Garrett County Site A																			
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region A1 Value		39 °37'23" N	79° 23'22" W	115	0.8	0.1	x	x	x	x	6	0.6	x	6	15	0.206	100	2.5	3.09	0.9185
Region A1 Ranking				2	5	5	0	4	3	0.8292	x	x	1	x	x	1	x	x	1	
Region A1 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
Region A2 Value		39°37'59" N	79°21'41" W	115	1.3	0.2	x	x	x		2	0.6	x	3	8	0.199	100	2.5	1.59	0.3957
Region A2 Ranking				2	5	5	0	4	3	0.8292	x	x	1	x	x	0	x	x	0	
Region A2 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
Region A3 Value		39°35'53" N	79°22'00" W	115	1.4	0.3	x	x	x		2	0.8	x	6	9	0.207	77	1.5	1.86	0.7879
Region A3 Ranking				2	5	5	0	4	3	0.8292	x	x	1	x	x	1	x	x	0	
Region A3 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	19,500,000	81.3%
Other	$	4,500,000	18.8%
Total initial costs	$	24,000,000	100.0%
Incentives and grants	$	2,506,534	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	406,026	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,856,662	
	$		
Total annual costs	$	2,262,688	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,353,420	
RECs	$	33,836	
Total annual savings and income	$	1,387,256	
Financial viability			
Pre-tax IRR - equity	%	4.0%	
Pre-tax IRR - assets	%	0.7%	
Simple payback	yr	21.9	
Equity payback	yr	20.0	

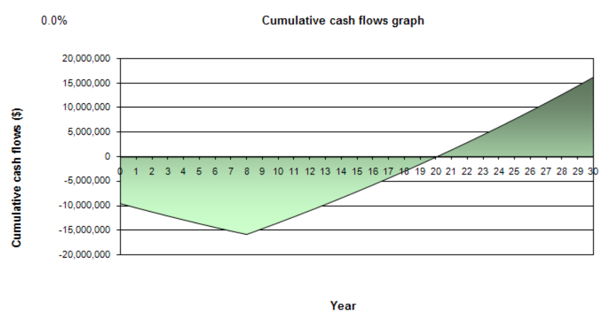


Figure 58: Financial Analysis for Site A.1

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	9,750,000	80.2%
Other	$	2,400,000	19.8%
Total initial costs	$	12,150,000	100.0%
Incentives and grants	$	1,210,680	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	209,188	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	939,935	
	$		
Total annual costs	$	1,149,123	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	653,715	
	$	16,343	
Total annual savings and income	$	670,058	
Financial viability			
Pre-tax IRR - equity	%	1.8%	
Pre-tax IRR - assets	%	-1.6%	
Simple payback	yr	23.7	
Equity payback	yr	21.4	

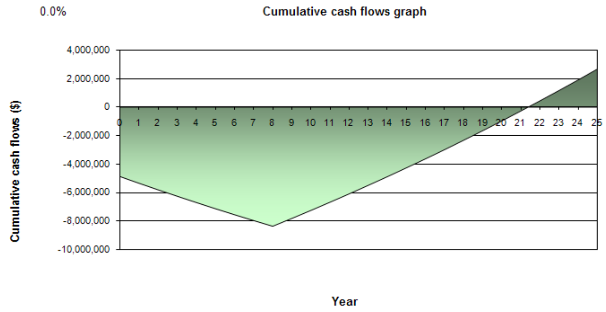


Figure 59: Financial Analysis for Site A.2

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	11,700,000	81.3%
Other	$	2,700,000	18.8%
Total initial costs	$	14,400,000	100.0%
Incentives and grants	$	1,511,221	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	244,798	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,113,997	
	$		
Total annual costs	$	1,358,795	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	815,994	
	$	20,400	
Total annual savings and income	$	836,394	
Financial viability			
Pre-tax IRR - equity	%	2.7%	
Pre-tax IRR - assets	%	-1.0%	
Simple payback	yr	21.8	
Equity payback	yr	19.9	

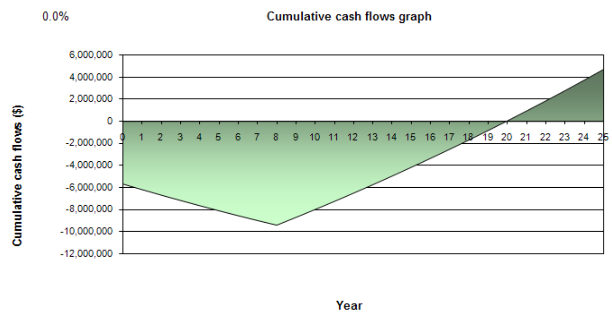


Figure 60: Financial Analysis for Site A.3

Site B: Data

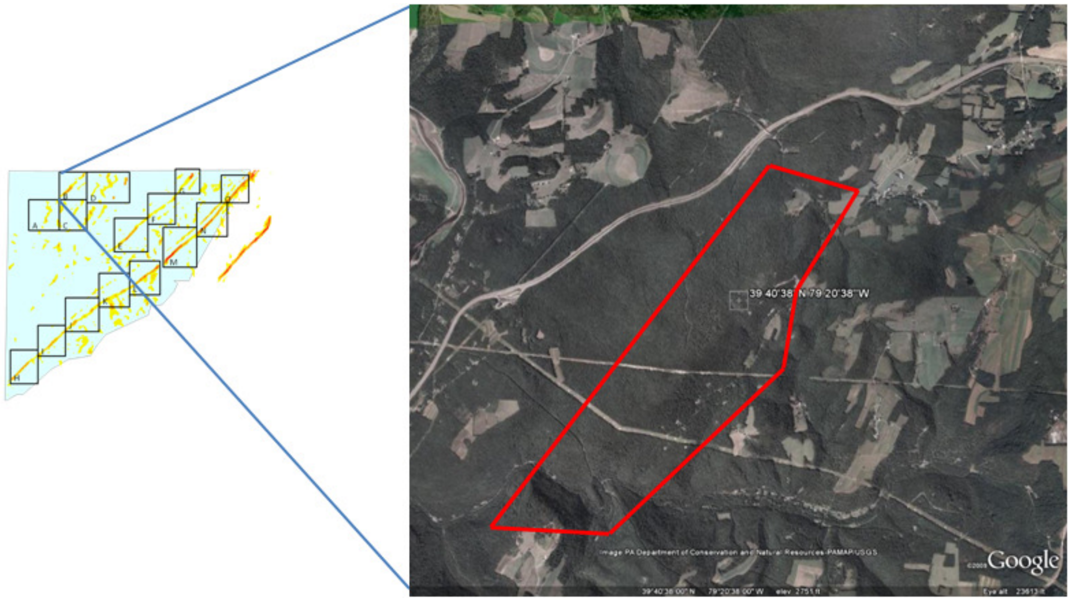


Figure 61: Aerial image of Site B

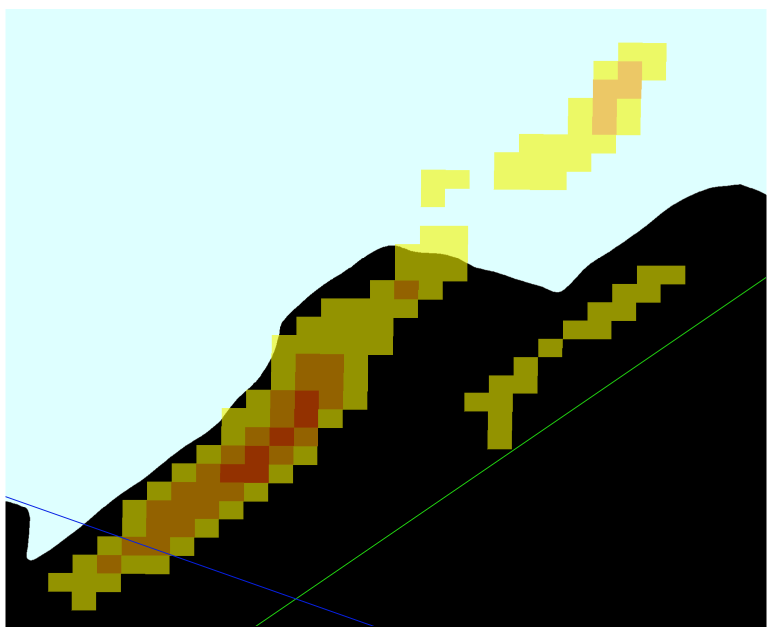


Figure 62: GIS Image for Site B

Table 27: Overall Site Suitability Scoring Matrix for Site B.1 and B.2

Garrett County Site B

	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region B1 Value		39°40'38" N	79°20'38" W	231-500	1.5	0.4	x	x	x	x	4.9	0.9	x	14	21	0.253	77	1.5	5.32	**1.8897**
Region B1 Ranking				5	5	5	0	4	4	0.9469	x	x	1.8	x	x	3	x	x	2	
Region B1 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
Region B2 Value		39°42'27" N	79°18'27" W	115	2.3	0.1	x	x	x		1.7	0.5	x	2	5	0.215	100	2.5	1.075	**1.3901**
Region B2 Ranking				2	4	5	5	4	3	2.0911	x	x	1.25	x	x	1	x	x	0	
Region B2 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	x
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	27,300,000	81.3%
Other	$	6,300,000	18.8%
Total initial costs	$	33,600,000	100.0%
Incentives and grants	$	4,309,778	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	698,128	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,599,326	
	$		
Total annual costs	$	3,297,454	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,327,094	
	$	58,177	
Total annual savings and income	$	2,385,271	
Financial viability			
Pre-tax IRR - equity	%	5.1%	
Pre-tax IRR - assets	%	0.8%	
Simple payback	yr	17.4	
Equity payback	yr	16.5	

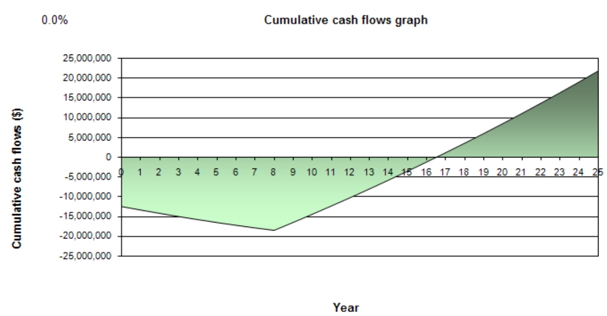


Figure 63: Financial Analysis for Site B.1

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	6,500,000	81.3%
Other	$	1,500,000	18.8%
Total initial costs	$	8,000,000	100.0%
Incentives and grants	$	872,014	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	141,255	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	618,887	
	$		
Total annual costs	$	760,142	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	470,850	
	$	11,771	
Total annual savings and income	$	482,621	
Financial viability			
Pre-tax IRR - equity	%	3.1%	
Pre-tax IRR - assets	%	-0.6%	
Simple payback	yr	20.9	
Equity payback	yr	19.2	

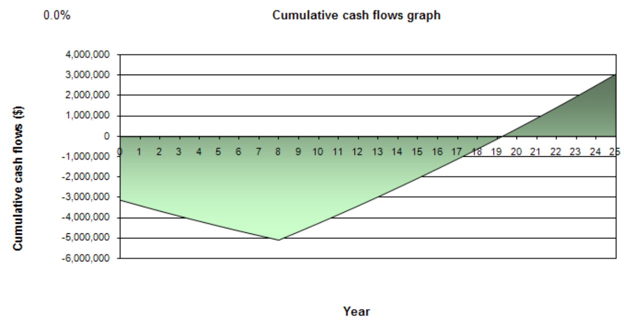


Figure 64: Financial Analysis for Site B.2

Site C: Data

Figure 65: Aerial image of Site C

Figure 66: GIS Image for Site C

Table 28: Overall Site Suitability Scoring Matrix for Site C

Garrett County Site C	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region C1 Value		39°36'56" N	79°17'48" W	231-500	3	0.1	x	x	x	x	6.4	1	x	13	32.5	0.218	100	2.5	7.085	**1.18513**
Region C1 Ranking				5	4	5	0	4	3	0.841	x	x	1.3	x	x	1	x	x	3	
Region C1 Weight	x	x	x	0.016	0.037	0.025	0.26	0.0704	0.0697	0.5	x	x	x	x	x	0.3922	x	x	0.131	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	42,250,000	81.3%
Other	$	9,750,000	18.8%
Total initial costs	$	52,000,000	100.0%
Incentives and grants	$	5,747,182	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	930,969	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,022,767	
	$		
Total annual costs	$	4,953,736	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,103,230	
	$	77,581	
Total annual savings and income	$	3,180,811	
Financial viability			
Pre-tax IRR - equity	%	3.2%	
Pre-tax IRR - assets	%	-0.5%	
Simple payback	yr	20.6	
Equity payback	yr	19.0	

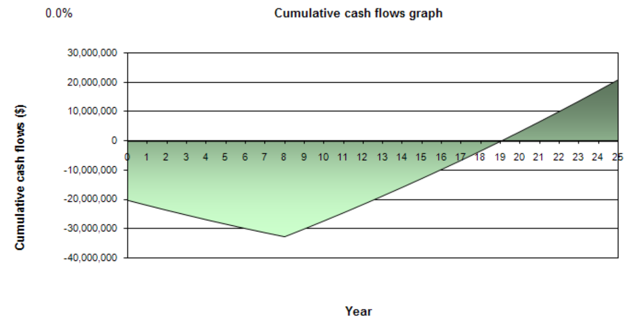


Figure 67: Financial Analysis for Site C

Site C – Sub-site 1:

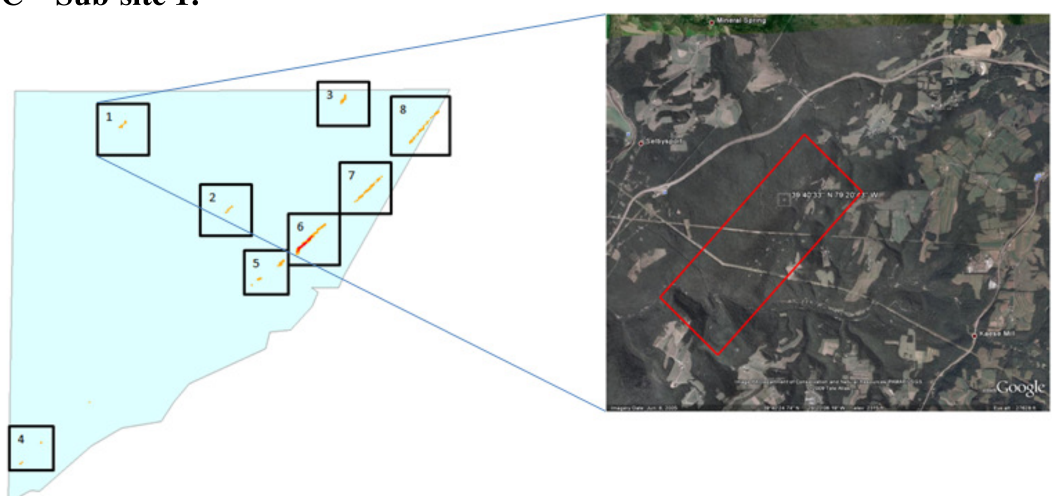


Figure 68: Aerial image of Sub-Site 1

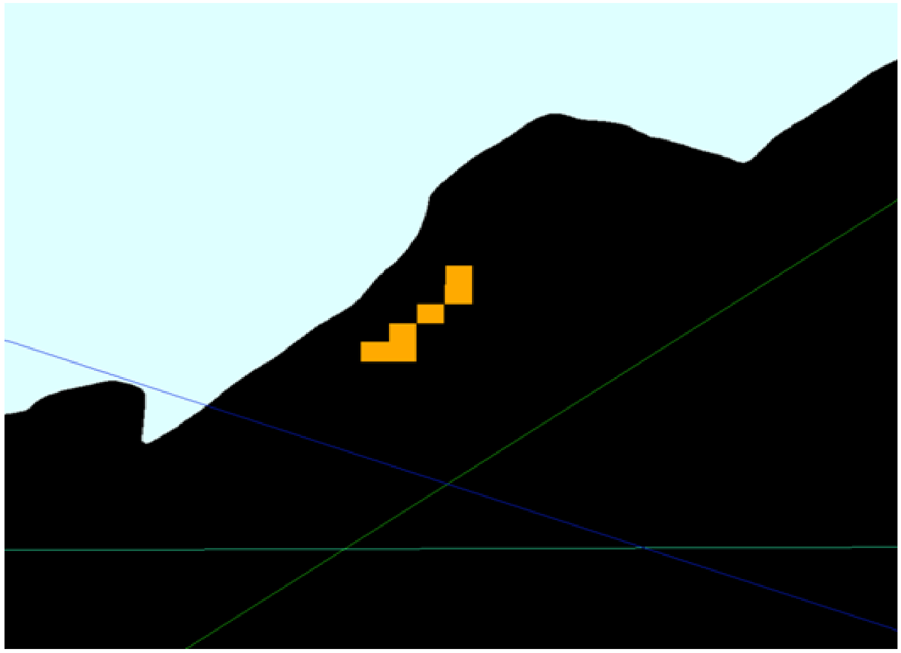


Figure 69: GIS Image of Sub-Site 1

Table 29: Overall Site Suitability Scoring Matrix for Sub-Site 1

		Garrett County Site 1																			
		.			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 1	Value		39°40'33" N	79°20'43" W	231-500	1.4	0.5	x	x	x	x	1	0.3	x	2	3	0.33333	77	1.5	1	**2.4125**
	Ranking				5	5	5	0	3	5	0.9462	x	x	3	x	x	5	x	x	0	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	3,900,000	81.3%
Other	$	900,000	18.8%
Total initial costs	$	4,800,000	100.0%
Incentives and grants	$	810,365	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	131,269	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	371,332	
	$		
Total annual costs	$	502,601	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	437,562	
Renewable Energy Credits	$	10,939	
Total annual savings and income	$	448,501	
Financial viability			
Pre-tax IRR - equity	%	9.4%	
Pre-tax IRR - assets	%	3.6%	
Simple payback	yr	12.6	
Equity payback	yr	12.5	

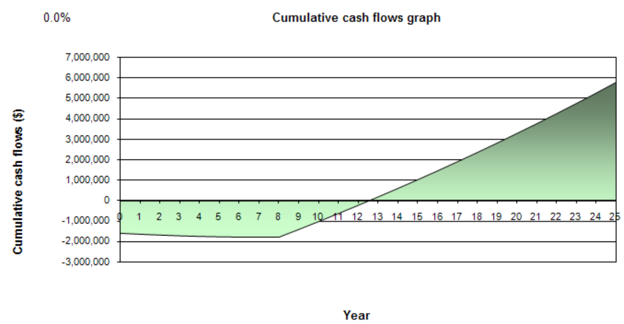


Figure 70: Financial Analysis for Sub-Site 1

Site D: Data

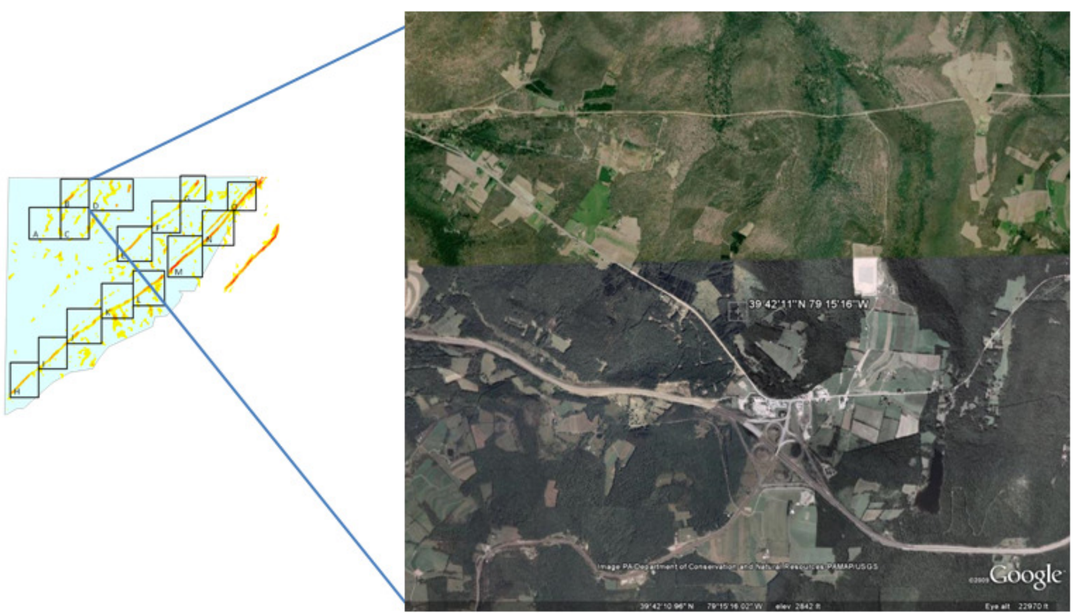


Figure 71: Aerial image of Site D

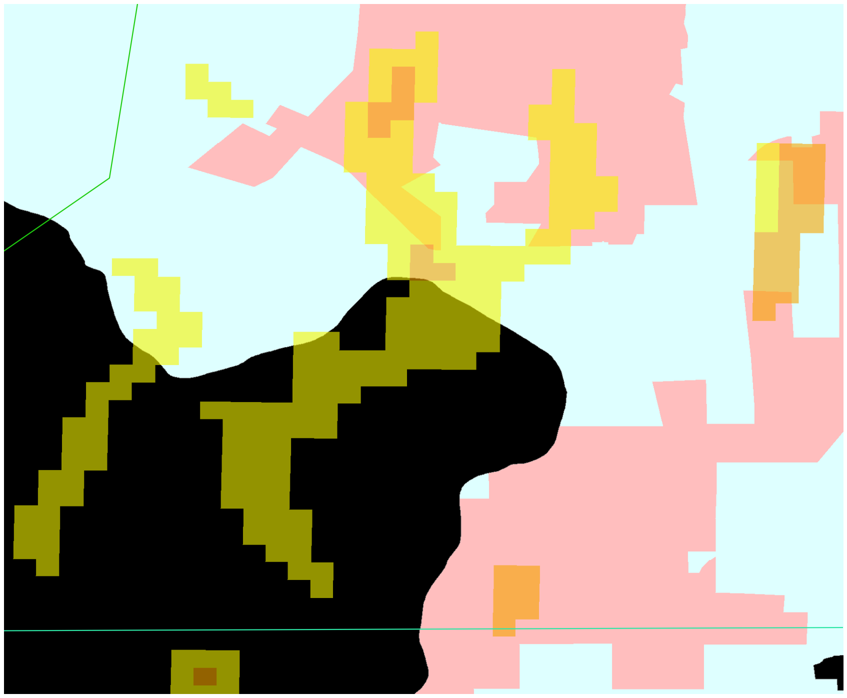


Figure 72: GIS Image for Site D

Table 30: Overall Site Suitability Scoring Matrix for Site D.1 and D.2

		Garrett County Site D																			
		Characterization			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region D1	Value		39°42'11" N	79°15'16" W	115	2.3	0.1	x	x	x	x	2.7	0.7	x	3	7.5	0.212	100	2.5	1.59	**1.1135**
	Ranking				2	4	5	2.5	4	4	1.512	x	x	1.2	x	x	1	x	x	0	
	Weight	x	x	x	0.016	0.037	0.025	0.26	0.0704	0.0697	0.477	x	x	x	x	x	0.3922	x	x	0.131	
Region D2	Value		39°41'56" N	79°12'53" W	116-138	4.7	0.3	x	x	x		2.1	0.6	x	3	7.5	0.254	100	2.5	1.905	**1.9055**
	Ranking				3	4	5	2.5	4	4	1.528			1.9			3			0	
	Weight	x	x	x	0.016	0.037	0.025	0.26	0.0704	0.0697	0.477	x	x	x	x	x	0.3922	x	x	0.131	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	9,750,000	81.3%
Other	$	2,250,000	18.8%
Total initial costs	$	12,000,000	100.0%
Incentives and grants	$	1,289,770	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	208,926	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	928,331	
	$		
Total annual costs	$	1,137,257	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	696,420	
	$	17,411	
Total annual savings and income	$	713,831	
Financial viability			
Pre-tax IRR - equity	%	2.9%	
Pre-tax IRR - assets	%	-0.8%	
Simple payback	yr	21.2	
Equity payback	yr	19.5	

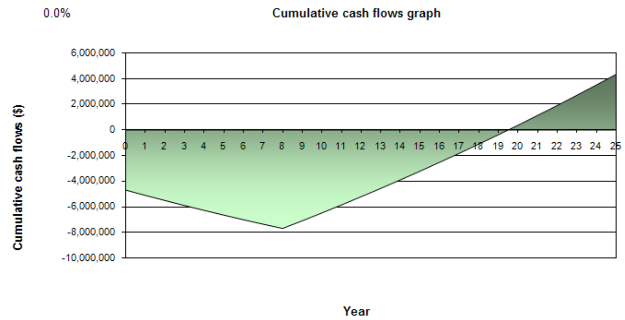


Figure 73: Financial Analysis for Site D.1

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	9,750,000	81.3%
Other	$	2,250,000	18.8%
Total initial costs	$	12,000,000	100.0%
Incentives and grants	$	1,545,290	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	250,317	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	928,331	
	$		
Total annual costs	$	1,178,648	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	834,390	
	$	20,860	
Total annual savings and income	$	855,250	
Financial viability			
Pre-tax IRR - equity	%	5.2%	
Pre-tax IRR - assets	%	0.8%	
Simple payback	yr	17.3	
Equity payback	yr	16.4	

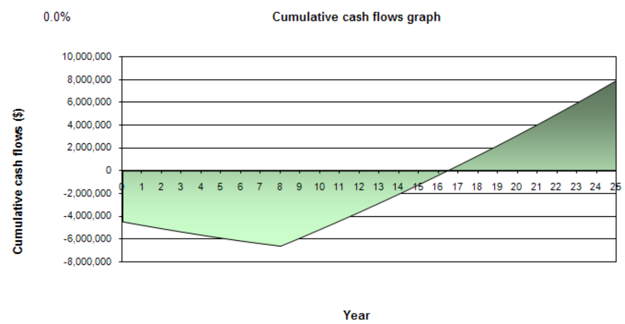


Figure 74: Financial Analysis for Site D.2

Site E: Data

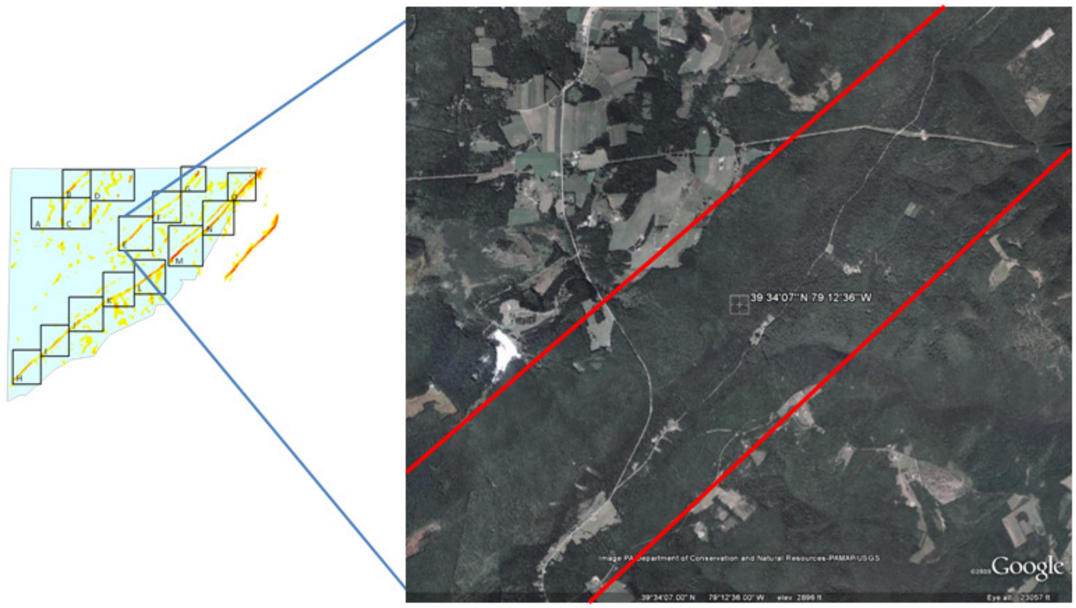


Figure 75: Aerial image of Site E

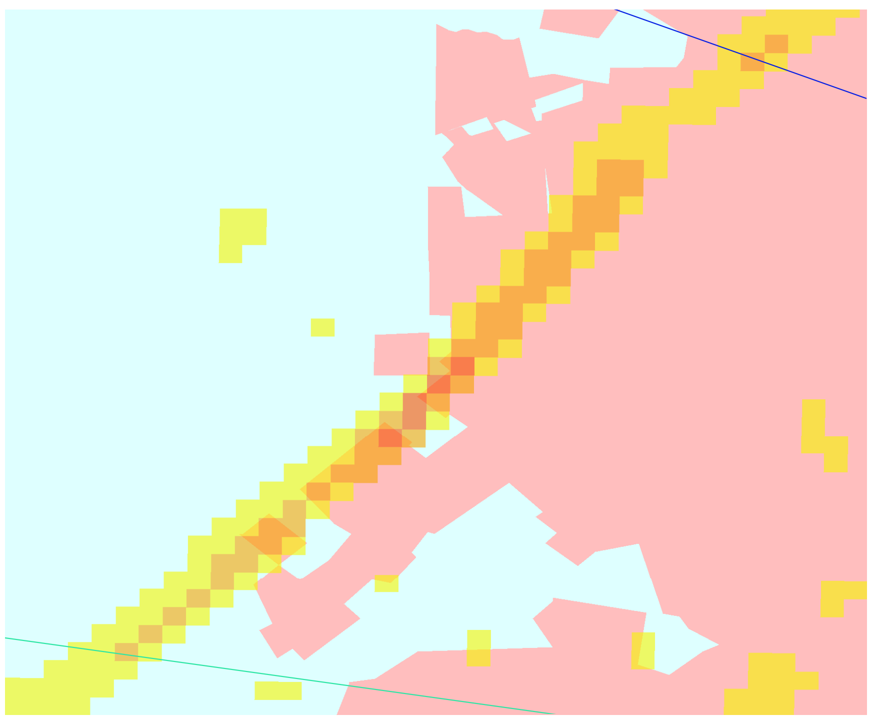


Figure 76: GIS image of Site E

Table 31: Overall Site Suitability Scoring Matrix for Site E

Garrett County Site E		Characterization			Site Suitability							Energy Availability								
					Infrastructure			Environmental		Social										
Region E1		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region E1	Value		39°34'07" N	79°12'36" W	231-500	4.8	0.1	x	x	x	x	9.4	0.4	1.6	10	25	0.236	100	2.5	5.9	1.7388
Region E1	Ranking				5	3	5	2.5	3	4	1.45255	x	x	x	x	x	2	x	x	2	
Region E1	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.13	x
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	32,500,000	81.3%
Other	$	7,500,000	18.8%
Total initial costs	$	40,000,000	100.0%
Incentives and grants	$	4,785,938	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	775,260	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	3,094,436	
	$		
Total annual costs	$	3,869,696	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,584,200	
	$	64,605	
Total annual savings and income	$	2,648,805	
Financial viability			
Pre-tax IRR - equity	%	4.2%	
Pre-tax IRR - assets	%	0.2%	
Simple payback	yr	18.8	
Equity payback	yr	17.6	

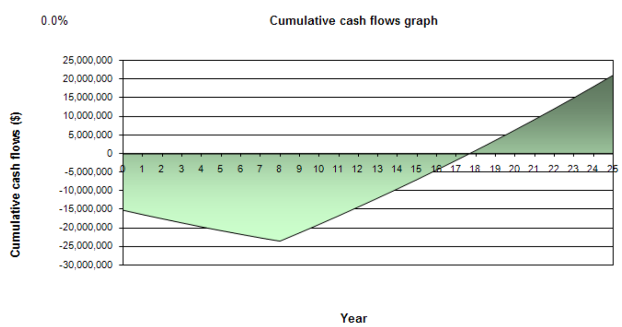


Figure 77: Financial Analysis for Site E

Site E – Sub-Site 2:

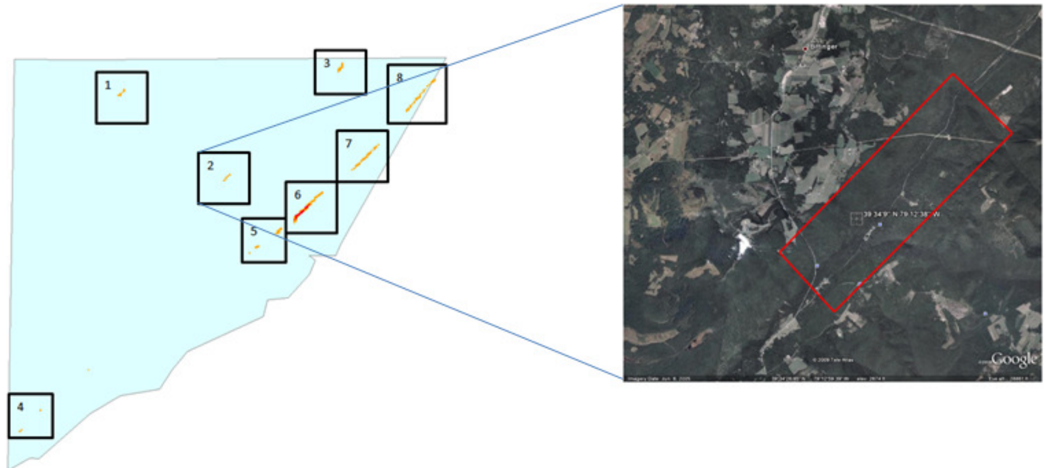


Figure 78: Aerial image of Sub-Site 2

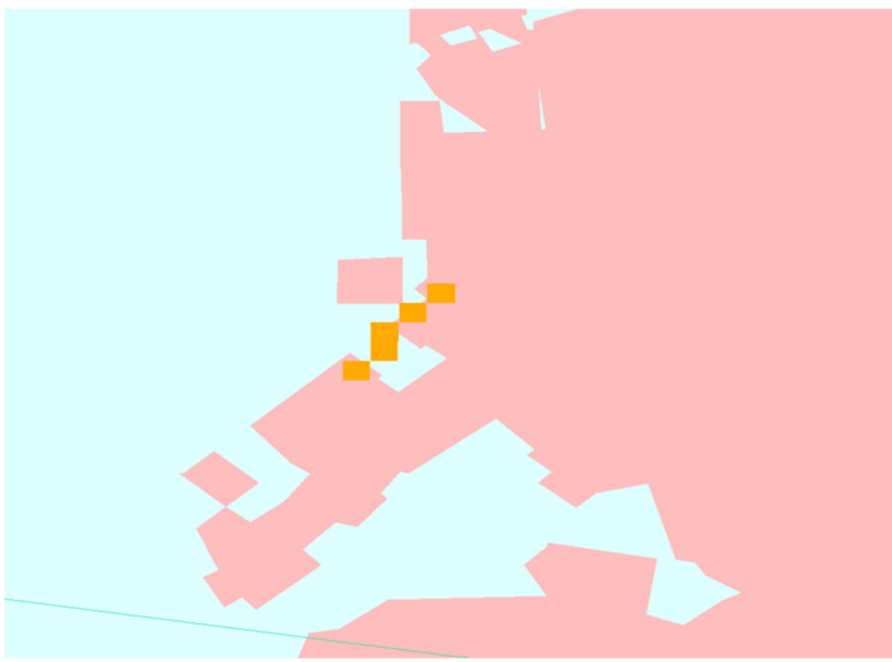


Figure 79: GIS Image of Sub-Site 2

Table 32: Overall Site Suitability Scoring Matrix for Sub-Site 2

Garrett County Site 2																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 2 Value		39°34'9" N	79°12'38" W	231-500	4.6	0.2	x	x	x	x	1.2	0.3	x	2	5	0.32	100	2.5	1.6	2.6716
Region 2 Ranking				5	4	5	2.5	3	4	1.4892	x	x	3	x	x	5	x	x	0	
Region 2 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	6,500,000	81.3%
Other	$	1,500,000	18.8%
Total initial costs	$	8,000,000	100.0%
Incentives and grants	$	1,297,882	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	210,240	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	618,887	
	$		
Total annual costs	$	829,127	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	700,800	
Renewable Energy Credits	$	17,520	
Total annual savings and income	$	718,320	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

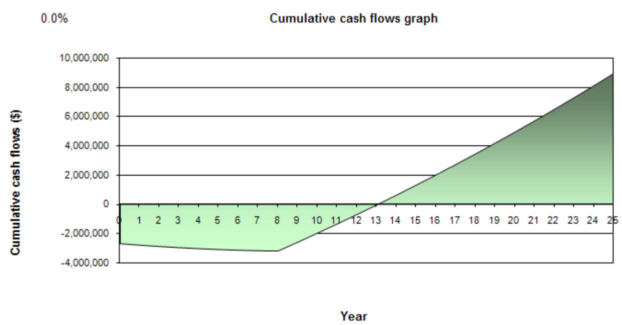


Figure 80: Financial Analysis for Sub-Site 2

Site F: Data

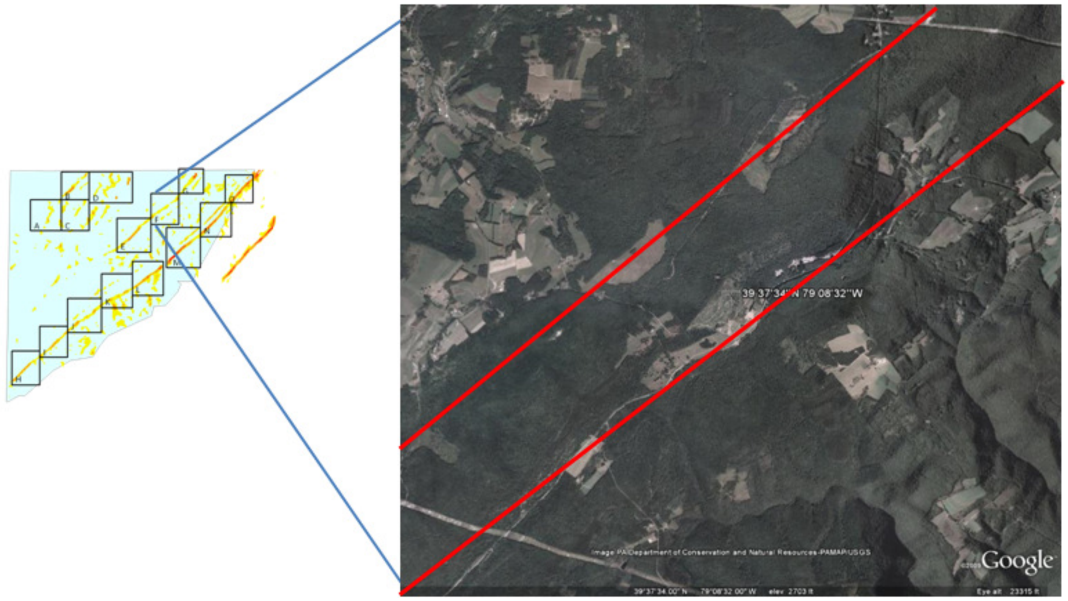


Figure 81: Aerial image of Site F

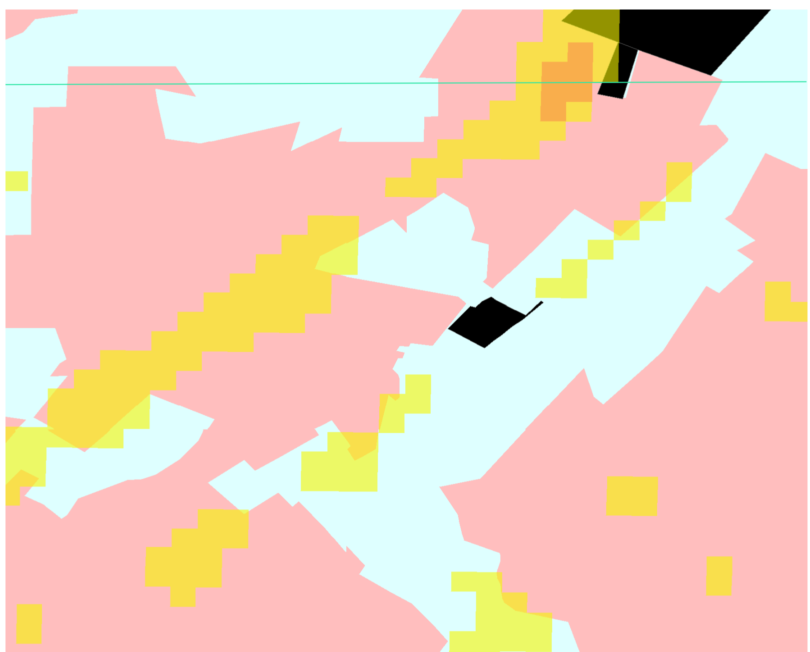


Figure 82: GIS Image of Site F

Table 33: Overall Site Suitability Scoring Matrix for Site F

Garrett County Site F		Characterization			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region F1	Value		79°08'32" N	39°37'34" W	231-500	2.7	0.1	x	x	x	x	8.1	0.7	1.3	9	22.5	0.218	100	2.5	4.905	2.1195
Region F1	Ranking				5	5	5	2.5	3	3	3.34605	x	x	x	x	x	1	x	x	1	
Region F1	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.7004	0.0697	0.5	x	x	x	x	x	0.392	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	29,250,000	81.3%
Other	$	6,750,000	18.8%
Total initial costs	$	36,000,000	100.0%
Incentives and grants	$	3,978,818	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	644,517	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,784,993	
	$		
Total annual costs	$	3,429,510	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,148,390	
	$	53,710	
Total annual savings and income	$	2,202,100	
Financial viability			
Pre-tax IRR - equity	%	3.2%	
Pre-tax IRR - assets	%	-0.5%	
Simple payback	yr	20.6	
Equity payback	yr	19.0	

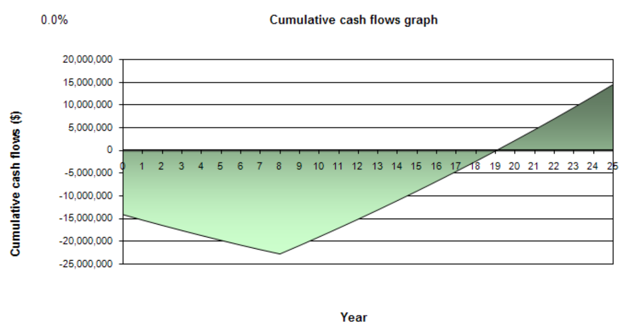


Figure 83: Financial Analysis for Site F

Site G: Data

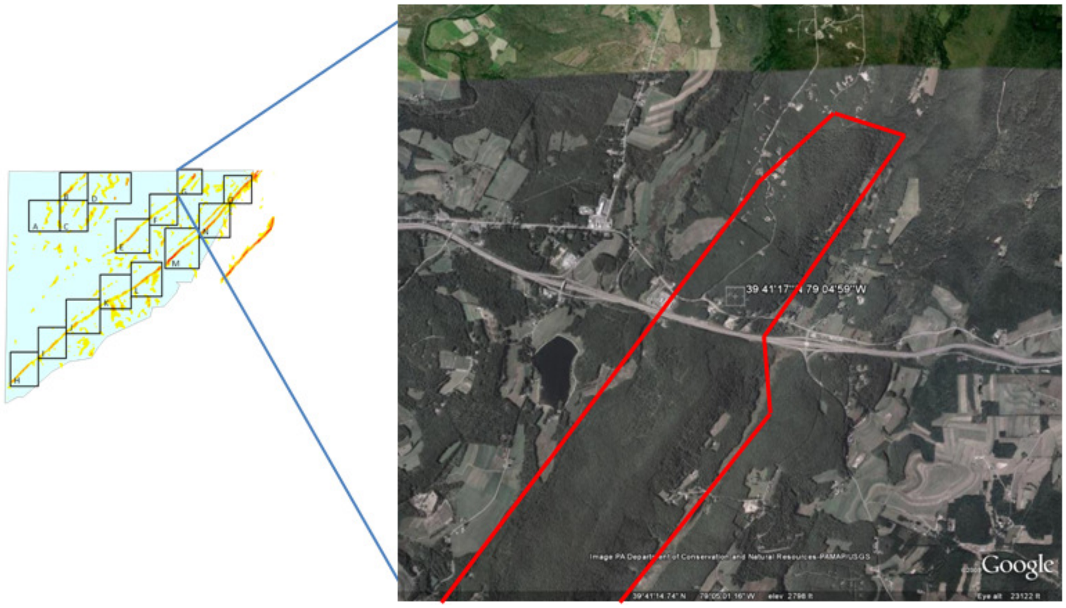


Figure 84: Aerial image of Site G

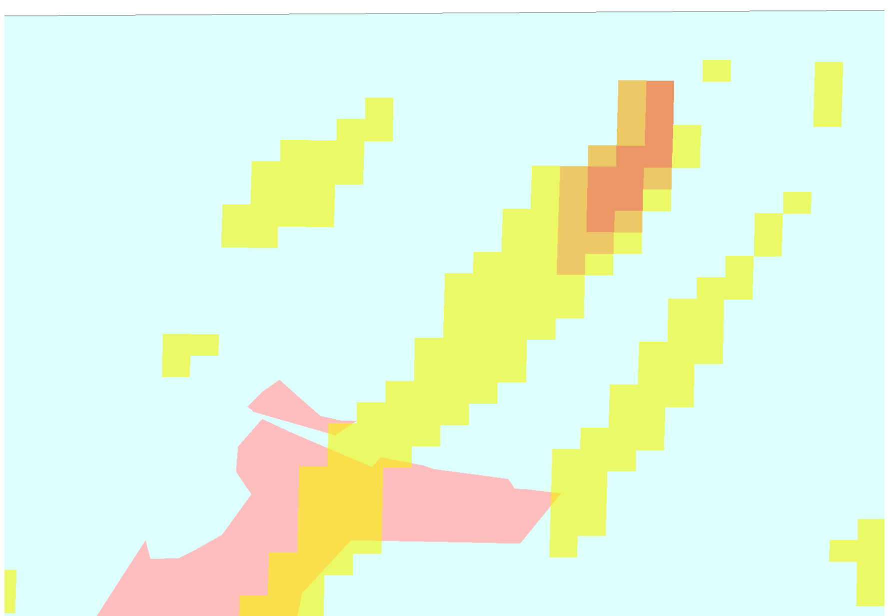


Figure 85: GIS Image of Site G

Table 34: Overall Site Suitability Scoring Matrix for Site G

Garrett County Site G

	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region G1 Value		39°41'17" N	79°4'59" W	116-138	4.1	0.1	x	x	x	x	4.1	0.8	x	11	17	0.2588	77	1.5	4.4	2.2202
Region G1 Ranking				3	4	5	5	3	3	1.913	x	x	2	x	x	3	x	x	1	
Region G1 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.477	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	21,450,000	80.8%
Other	$	5,100,000	19.2%
Total initial costs	$	26,550,000	100.0%
Incentives and grants	$	3,466,561	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	578,554	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,053,932	
	$		
Total annual costs	$	2,632,486	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,871,793	
	$	46,795	
Total annual savings and income	$	1,918,588	
Financial viability			
Pre-tax IRR - equity	%	5.2%	
Pre-tax IRR - assets	%	0.9%	
Simple payback	yr	17.2	
Equity payback	yr	16.4	

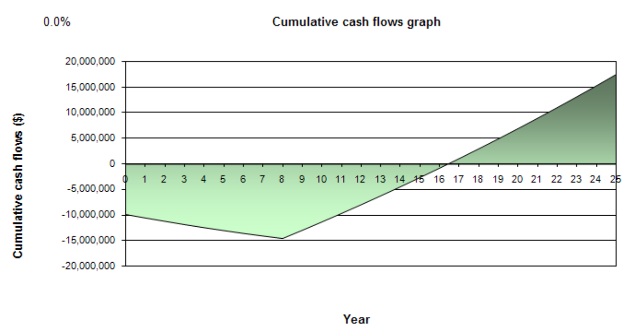


Figure 86: Financial Analysis for Site G

Site G – Sub-Site 3:

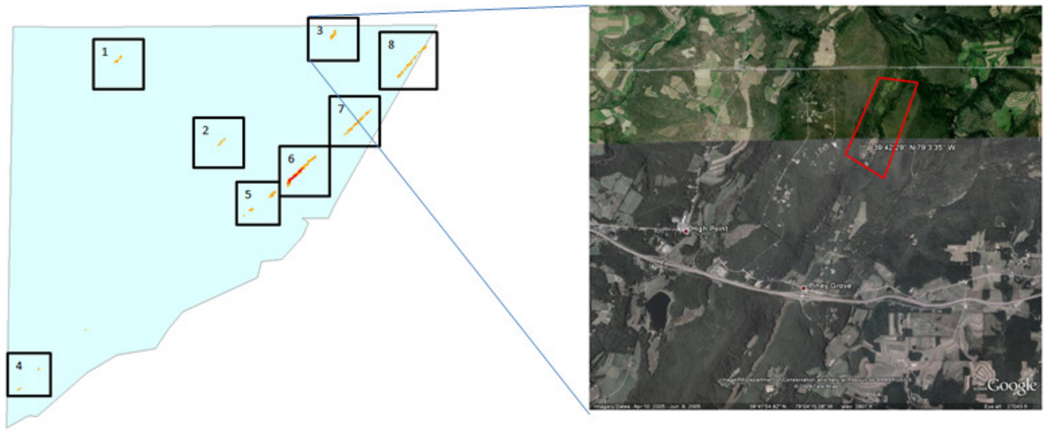


Figure 87: Aerial image of Sub-Site 3

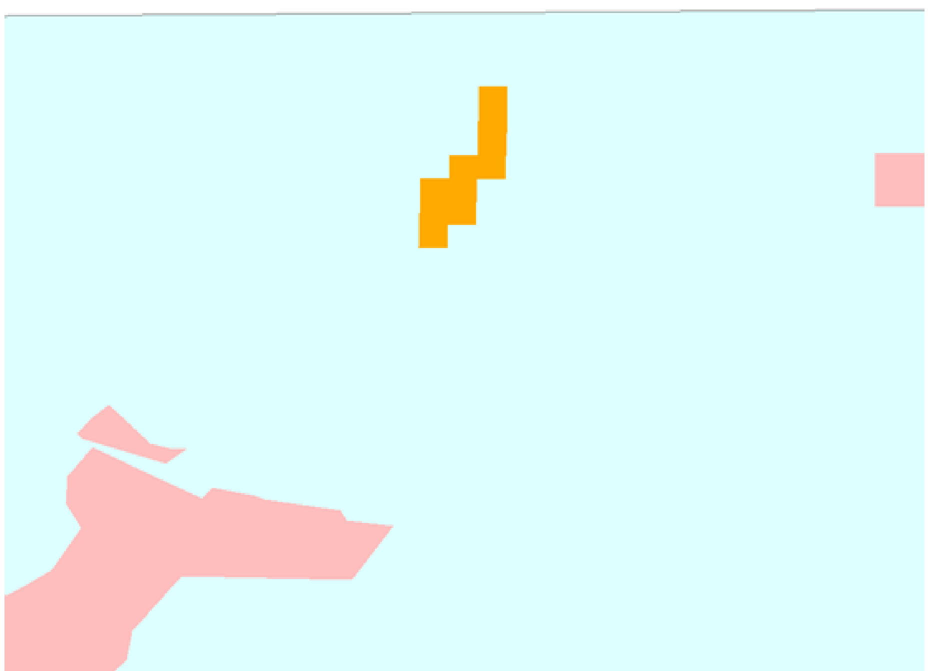


Figure 88: GIS Image of Sub-Site 3

Table 35: Overall Site Suitability Scoring Matrix for Sub-Site 3

	Garrett County Site 3																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 3 – Value		39°42'29" N	79°3'35" W	116-138	5.7	0.1	x	x	x	x	1.1	0.4	x	2	5	0.32	100	2.5	1.6	**2.9231**
Region 3 – Ranking				4	3	5	5	3	3	2.0161	x	x	3	x	x	5	x	x	0	
Region 3 – Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	6,500,000	81.3%
Other	$	1,500,000	18.8%
Total initial costs	$	8,000,000	100.0%
Incentives and grants	$	1,297,882	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	210,240	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	618,887	
	$		
Total annual costs	$	829,127	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	700,800	
RECs	$	17,520	
Total annual savings and income	$	718,320	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

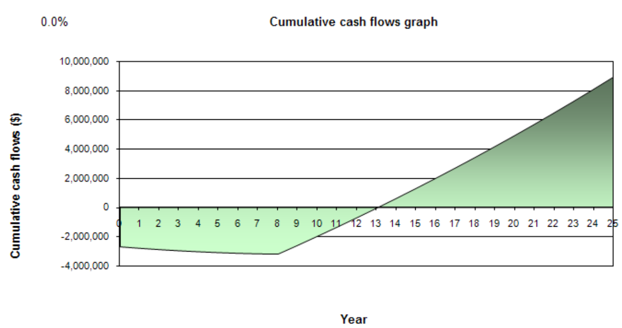


Figure 89: Financial Analysis for Sub-Site 3

Site H: Data

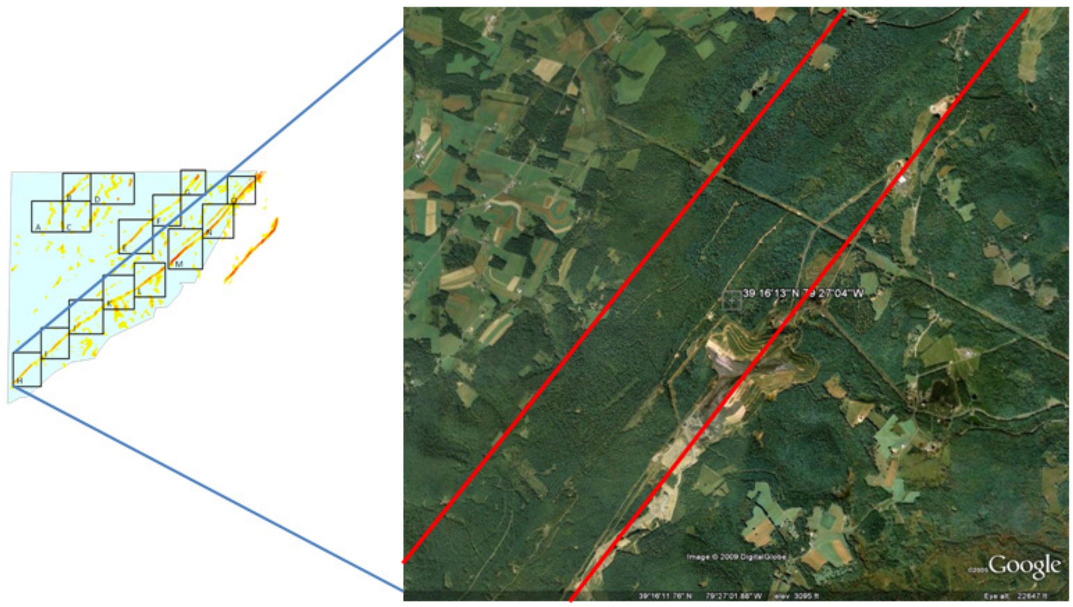


Figure 90: Aerial image of Site H

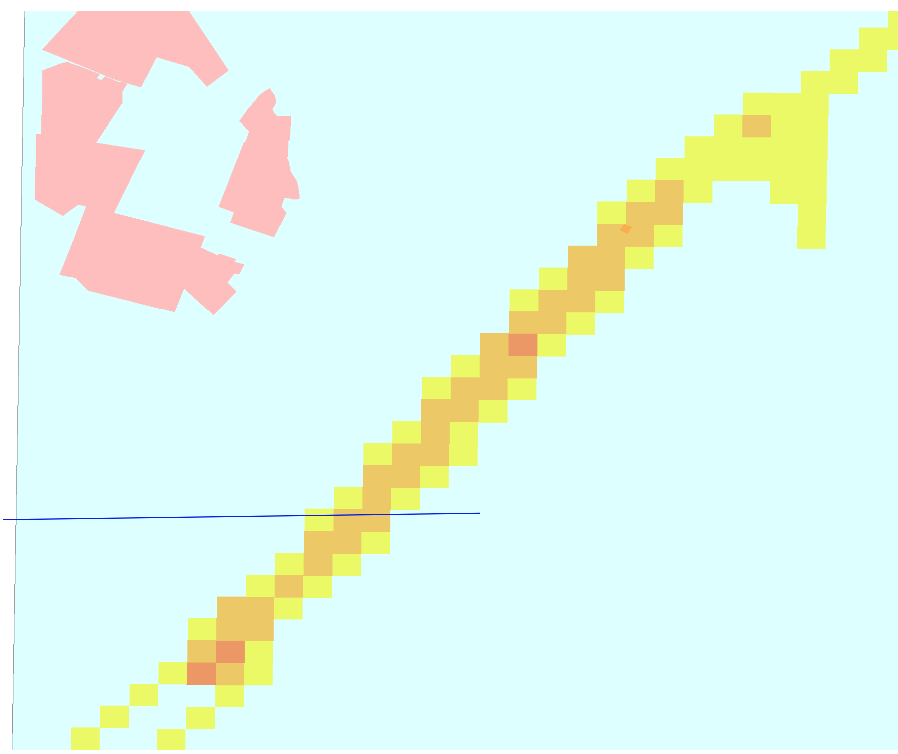


Figure 91: GIS Image of Site H

Table 36: Overall Site Suitability Scoring Matrix for Site H

	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Garrett County Site H																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region H – Value		39°16'13" N	79°27'4" W	231-500	1.4	0.2	x	x	x	x	7	0.7	x	7	18	0.24111	100	2.5	4.34	2.0751
Region H – Ranking				5	5	5	5	2	4	2.431	x	x	1.8	x	x	2	x	x	1	
Region H – Weight	x	x	x	0.106	0.0366	0.0247	0.2597	0.0704	0.0697	0.477	x	x	x	x	x	0.3922	x	x	0.13	
unit			,	kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	22,750,000	80.8%
Other	$	5,400,000	19.2%
Total initial costs	$	28,150,000	100.0%
Incentives and grants	$	3,421,135	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	570,013	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,177,710	
	$		
Total annual costs	$	2,747,723	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,847,265	
	$	46,182	
Total annual savings and income	$	1,893,447	
Financial viability			
Pre-tax IRR - equity	%	4.3%	
Pre-tax IRR - assets	%	0.2%	
Simple payback	yr	18.7	
Equity payback	yr	17.6	

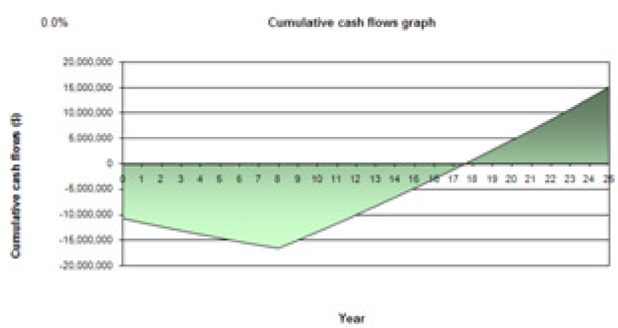


Figure 92: Financial Analysis for Site H

Site H – Sub-site 4:

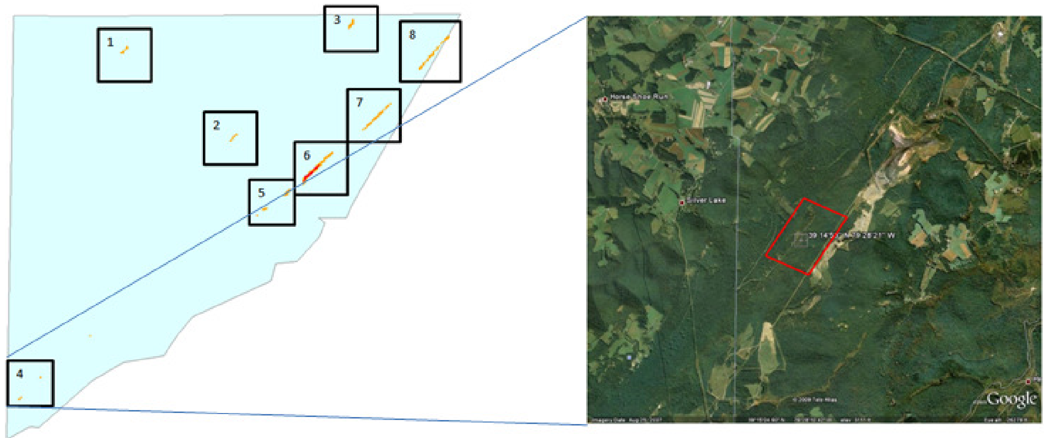


Figure 93: Aerial image of Sub-Site 4

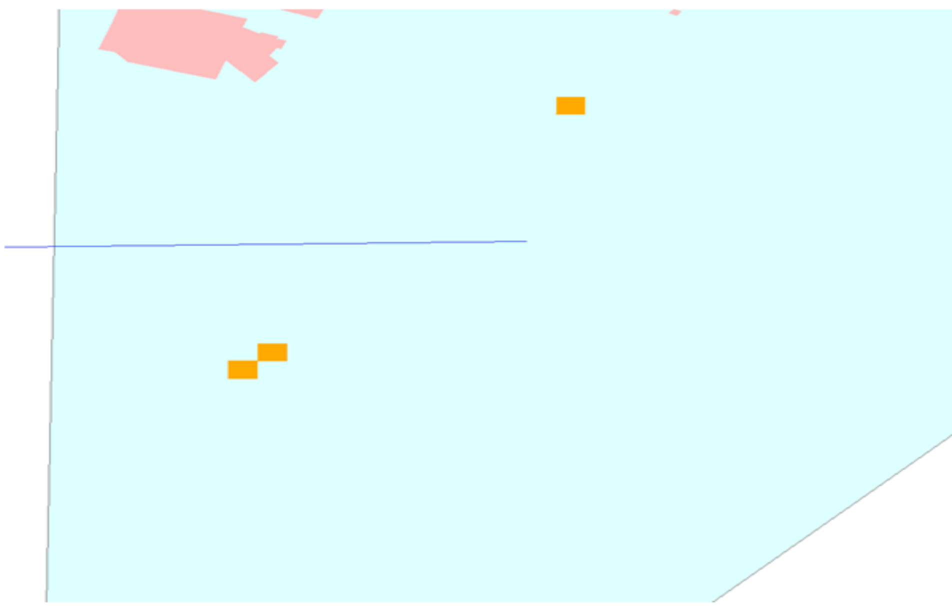


Figure 94: GIS Image of Sub-Site 4

Table 37: Overall Site Suitability Scoring Matrix for Sub-Site 4

	Garrett County Site 4																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 4 — Value		39°14'53" N	79°28'21" W	231-500	1.3	0.1	x	x	x	x	0.6	0.3	x	1	2.5	0.32	100	2.5	0.8	**2.9989**
Region 4 — Ranking				5	5	5	5	3	4	2.175	x	x	3	x	x	5	x	x	0	
Region 4 — Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	3,250,000	81.3%
Other	$	750,000	18.8%
Total initial costs	$	4,000,000	100.0%
Incentives and grants	$	648,941	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	105,120	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	309,444	
	$		
Total annual costs	$	414,564	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	350,400	
RECs	$	8,760	
Total annual savings and income	$	359,160	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

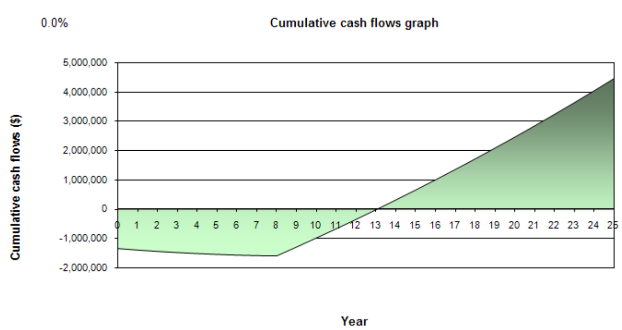


Figure 95: Financial Analysis for Sub-Site 4

Site I: Data

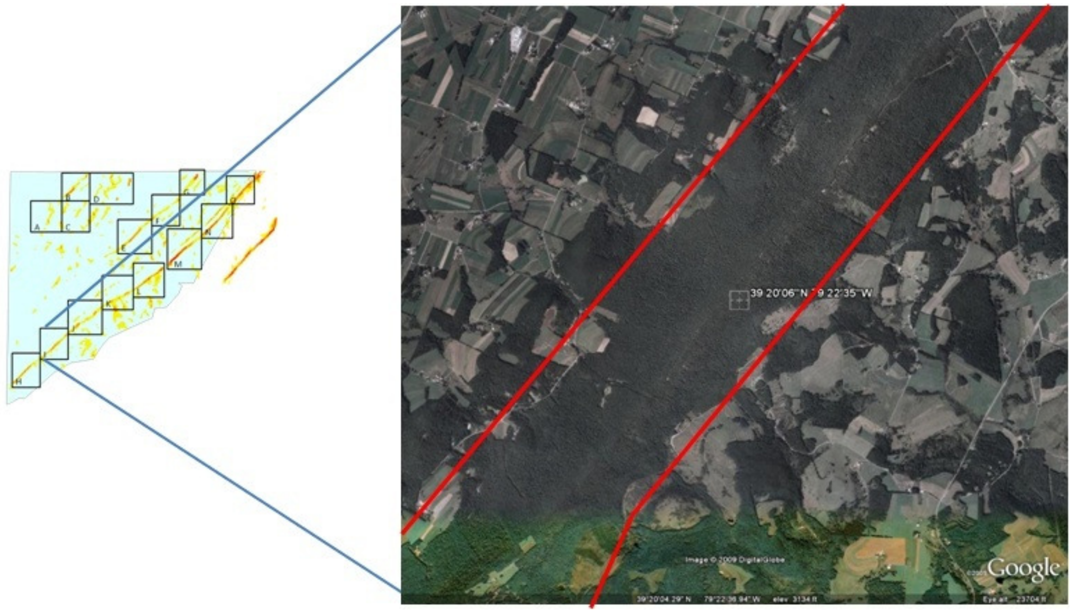


Figure 96: Aerial image of Site I

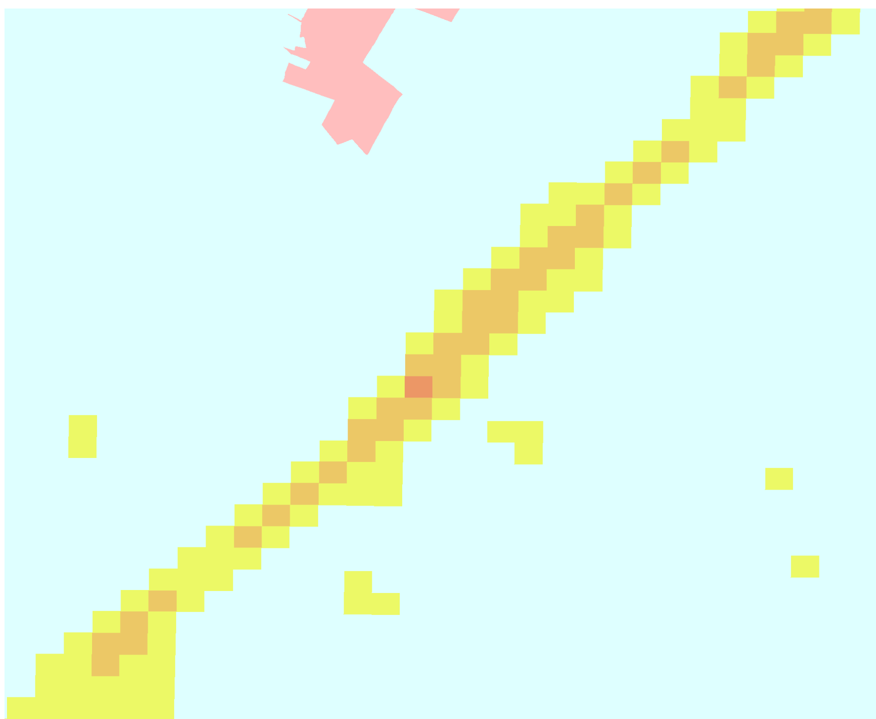


Figure 97: GIS Image of Site I

Table 38: Overall Site Suitability Scoring Matrix for Site I

Garrett County Site I																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental	Social												
Region I1	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Value		39°20'06" N	79°22'35" W	116-138	6.2	0.6	x	x	x	x	9.6	0.7	x	10	25	0.233	100	2.5	5.825	**1.9411**
Ranking				3	3	5	5	3	3	1.8766	x	x	1.55	x	x	2	x	x	2	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters		
Inflation rate	%	2.0%
Project life	yr	25
Debt ratio	%	50%
Debt interest rate	%	5%
Debt term	yr	8
Initial costs		
Power system	$	32,500,000	81.3%
Other	$	7,500,000	18.8%
Total initial costs	$	40,000,000	100.0%
Incentives and grants	$	4,725,100	0.0%
Annual costs and debt payments		
O&M (savings) costs	$	765,405
Fuel cost - proposed case	$	0
Debt payments - 8 yrs	$	3,094,436
	$	
Total annual costs	$	3,859,841
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	2,551,350
	$	63,784
Total annual savings and income	$	2,615,134
Financial viability		
Pre-tax IRR - equity	%	4.1%
Pre-tax IRR - assets	%	0.1%
Simple payback	yr	19.1
Equity payback	yr	17.9

Cumulative cash flows graph

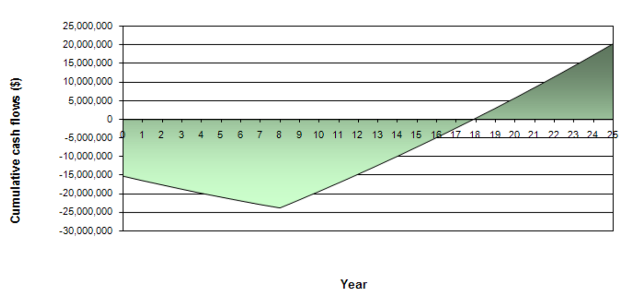


Figure 98: Financial Analysis for Site I

Site J: Data

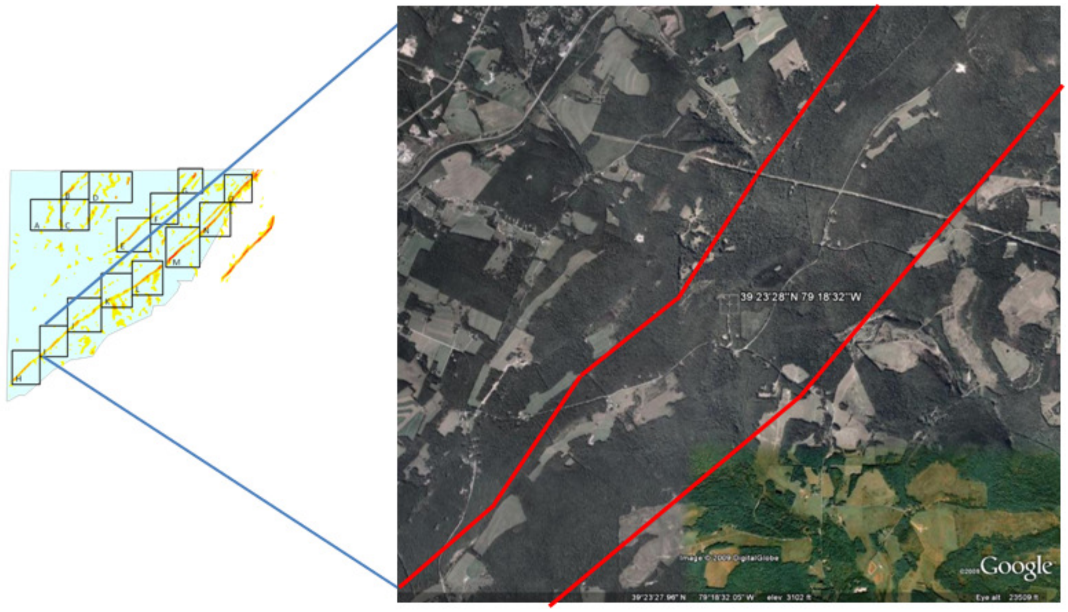


Figure 99: Aerial image of Site J

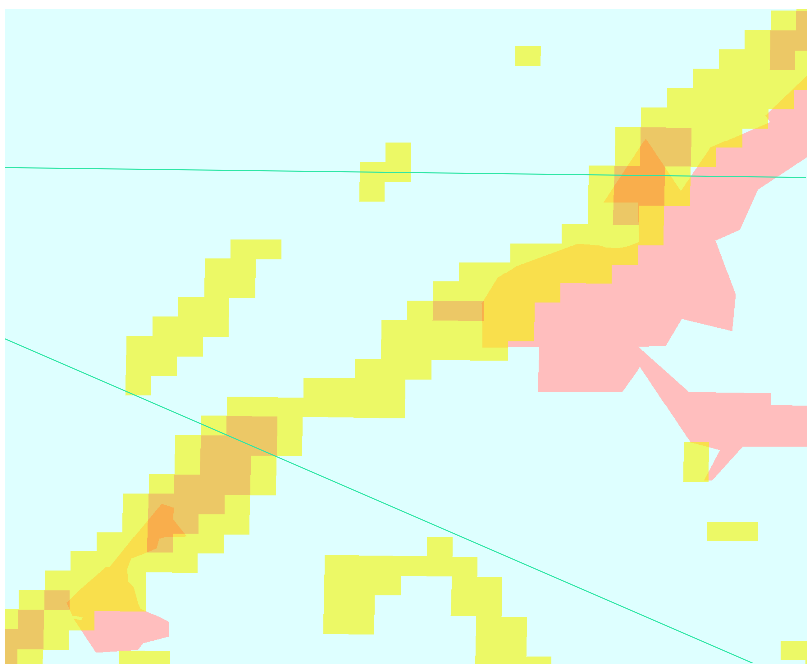


Figure 100: GIS Image of Site J

Table 39: Overall Site Suitability Scoring Matrix for Site J

Garrett County Site J																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region J1	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Value		39°23'28" N	79°18'32" W	116-138	1.3	0.1	x	x	x	x	6.8	0.8	x	18	27	0.22	77	1.5	5.94	**1.5838**
Ranking				3	5	5	5	3	3	1.9498	x	x	1.3	x	x	1	x	x	2	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	35,100,000	81.3%
Other	$	8,100,000	18.8%
Total initial costs	$	43,200,000	100.0%
Incentives and grants	$	4,818,385	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	780,516	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	3,341,991	
	$		
Total annual costs	$	4,122,507	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,601,720	
	$	65,043	
Total annual savings and income	$	2,666,763	
Financial viability			
Pre-tax IRR - equity	%	3.4%	
Pre-tax IRR - assets	%	-0.4%	
Simple payback	yr	20.3	
Equity payback	yr	18.8	

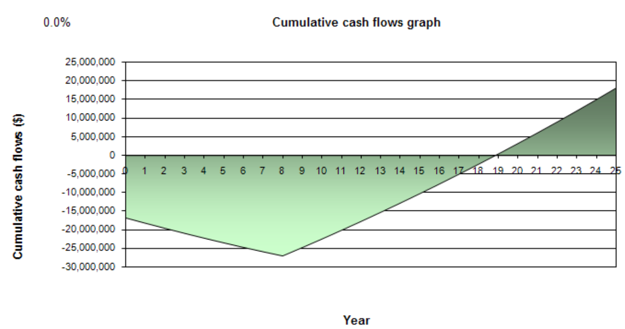


Figure 101: Financial Analysis for Site J

Site K: Data

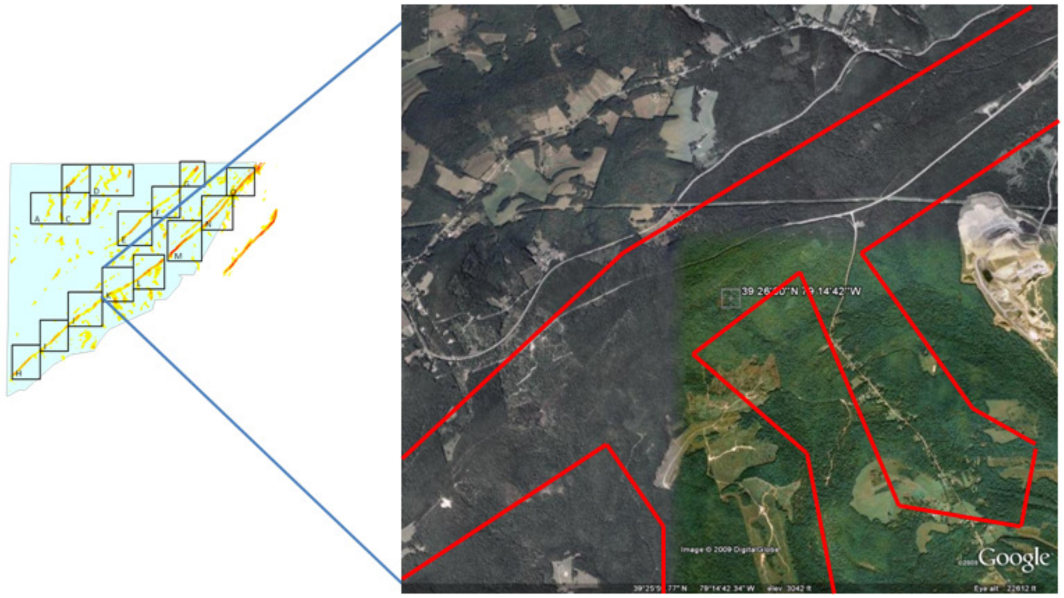


Figure 102: Aerial image of Site K

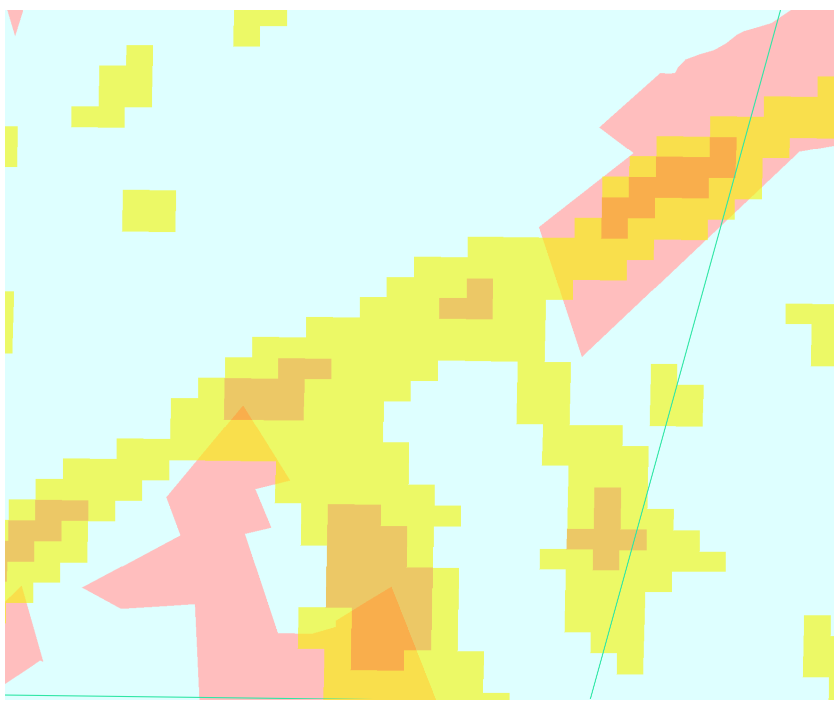


Figure 103: GIS Image of Site K

Table 40: Overall Site Suitability Scoring Matrix for Site K.1 and K.2

Garrett County Site K		.			Site Suitability								Energy Availability									
					Infrastructure			Environmental			Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Wildlife vulnerability	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region K1	Value		39°26'00" N	79°14'42" W	116-138	2.4	0.2		x	x	x	x	7.5	0.8	x	20	30	0.2267	77	1.5	6.8	**1.2968**
	Ranking				3	4	5		2.5	3	4	1.33365	x	x	1.4	x	x	1	x	x	2	
	Weight	x	x	x	0.016	0.0366	0.025		0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3992	x	x	0.1306	
Region K2	Value		39°4'30" N	79°14'40" W	116-138	1.1	0.9		x	x	x	x	4	1.3	x	8	20	0.218	100	2.5	4.36	**1.1837**
	Ranking				3	5	5		2.5	3	4	1.37025	x	x	1.3	x	x	1	x	x	1	
	Weight	x	x	x	0.016	0.0366	0.025		0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3992	x	x	0.1306	
	unit				kV	km	km		x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	39,000,000	81.3%
Other	$	9,000,000	18.8%
Total initial costs	$	48,000,000	100.0%
Incentives and grants	$	5,524,109	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	894,834	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	3,713,324	
	$		
Total annual costs	$	4,608,158	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,982,780	
	$	74,570	
Total annual savings and income	$	3,057,350	
Financial viability			
Pre-tax IRR - equity	%	3.7%	
Pre-tax IRR - assets	%	-0.2%	
Simple payback	yr	19.6	
Equity payback	yr	18.3	

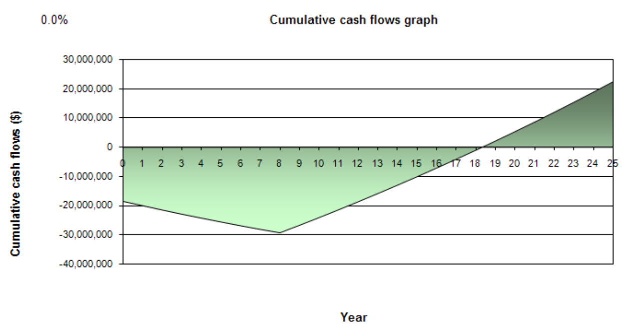


Figure 104: Financial Analysis for Site K.1

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	42,900,000	81.3%
Other	$	9,900,000	18.8%
Total initial costs	$	52,800,000	100.0%
Incentives and grants	$	6,959,890	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,127,412	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,084,656	
	$		
Total annual costs	$	5,212,068	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,758,040	
	$	93,951	
Total annual savings and income	$	3,851,991	
Financial viability			
Pre-tax IRR - equity	%	5.5%	
Pre-tax IRR - assets	%	1.1%	
Simple payback	yr	16.8	
Equity payback	yr	16.1	

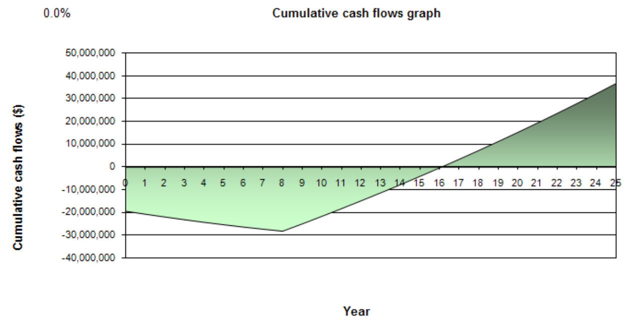


Figure 105: Financial Analysis for Site K.2

Site L: Data

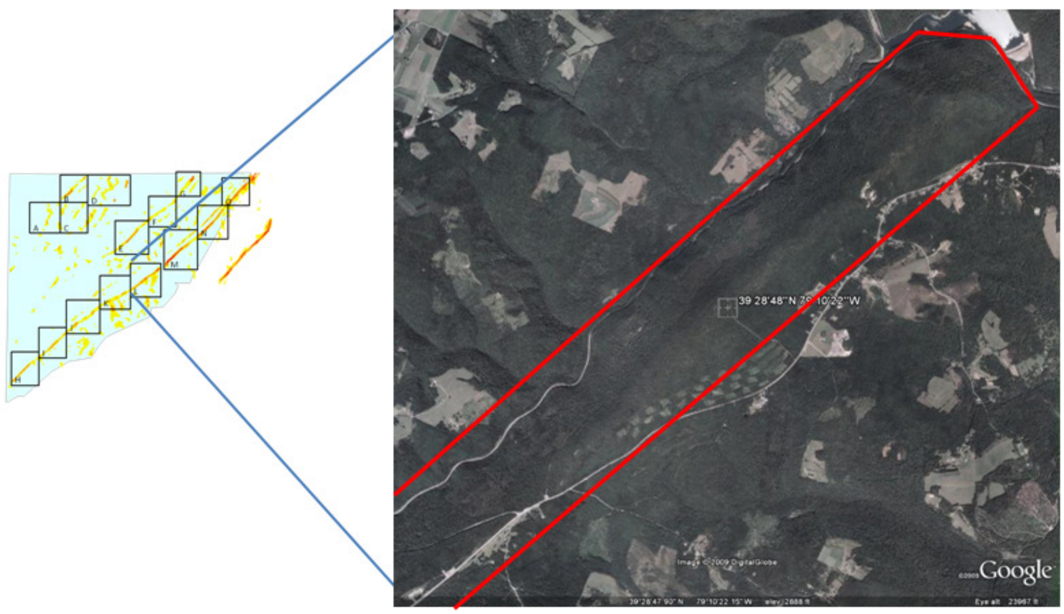


Figure 106: Aerial image of Site L

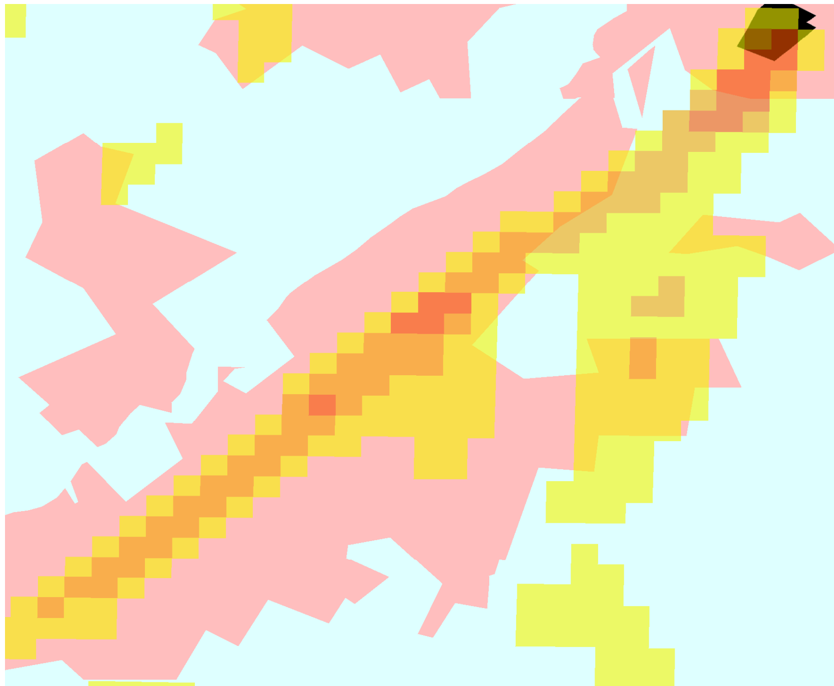
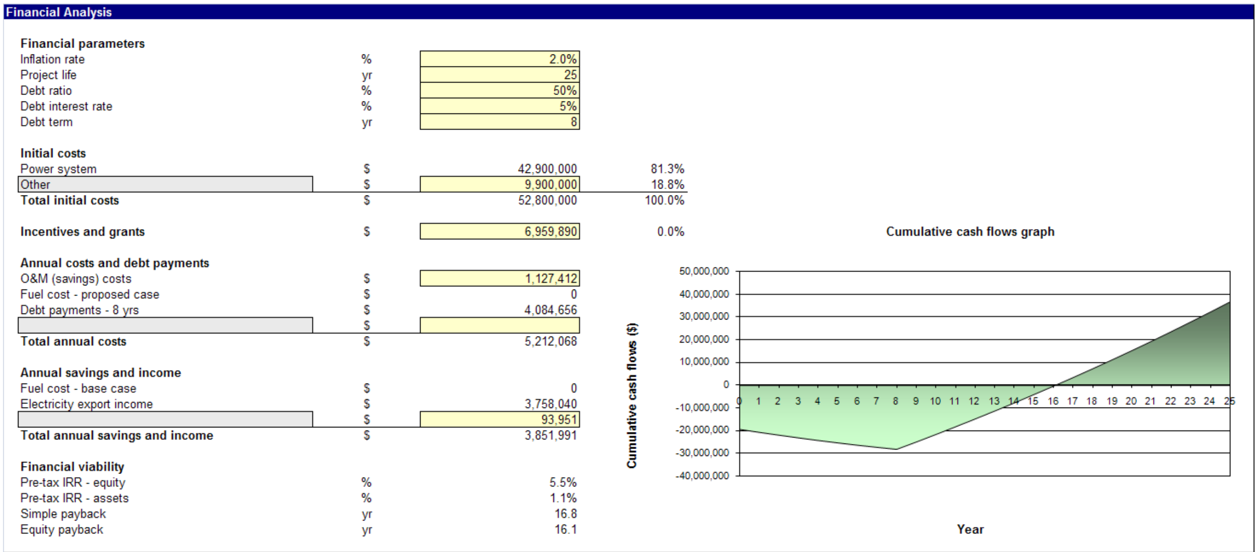


Figure 107: GIS Image of Site L

Table 41: Overall Site Suitability Scoring Matrix for Site L

Garrett County Site L																				
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region L1 – Value		39°28'48" N	79°10'21" W	116-138	3.38	0.1	x	x	x	x	8.02	0.866	x	22	33	0.26	77	1.5	8.58	2.2305
Region L1 – Ranking				3	4	5	2.5	3	3	1.38745	x	x	2.1	x	x	3	x	x	3	
Region L1 – Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	



Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	42,900,000	81.3%
Other	$	9,900,000	18.8%
Total initial costs	$	52,800,000	100.0%
Incentives and grants	$	6,959,890	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,127,412	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,084,656	
	$		
Total annual costs	$	5,212,068	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,758,040	
	$	93,951	
Total annual savings and income	$	3,851,991	
Financial viability			
Pre-tax IRR - equity	%	5.5%	
Pre-tax IRR - assets	%	1.1%	
Simple payback	yr	16.8	
Equity payback	yr	16.1	

Figure 108: Financial Analysis for Site L

Site L – Sub-site 5:

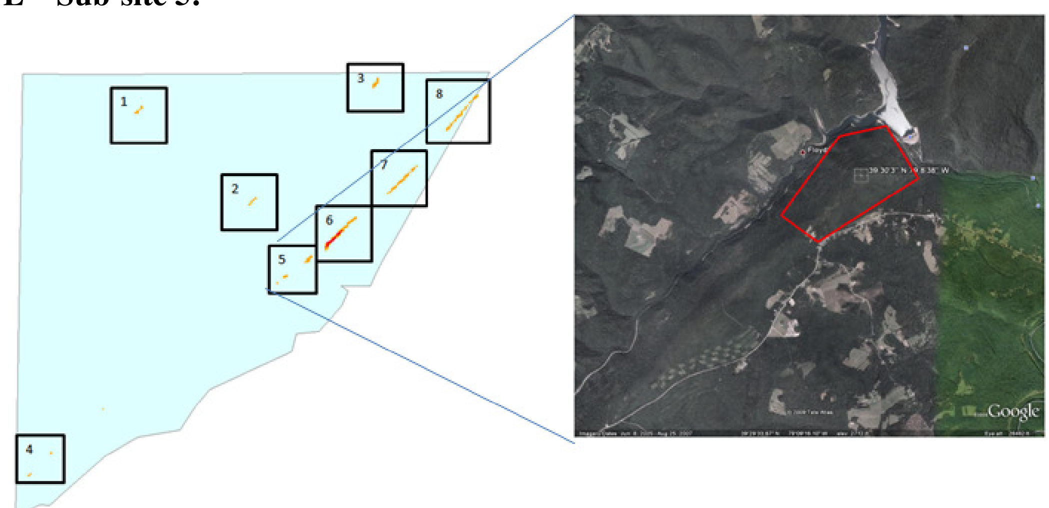


Figure 109: Aerial image of Sub-Site 5

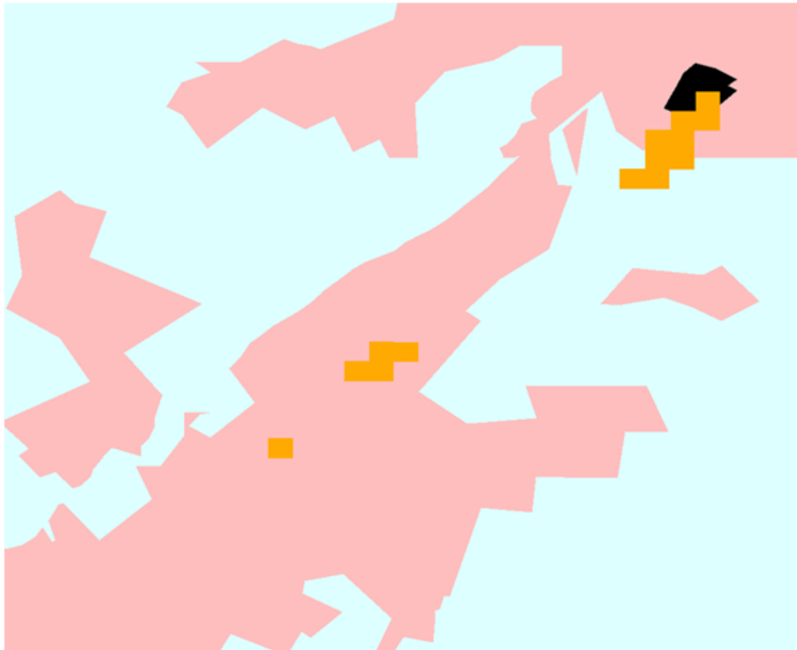


Figure 110: GIS Image of Sub-Site 5

Table 42: Overall Site Suitability Scoring Matrix for Sub-Site 5

	Garrett County Site 5																			
	.			**Site Suitability**							**Energy Availability**									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 5 Value		39°30'3" N	79°8'38" W	115	3.3	0.8	x	x	x	x	1.2	0.3	x	2	5	0.32	100	2.5	1.6	**2.6155**
Ranking				2	4	5	2.5	3	3	1.3715	x	x	3	x	x	5	x	x	0	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	6,500,000	81.3%
Other	$	1,500,000	18.8%
Total initial costs	$	8,000,000	100.0%
Incentives and grants	$	1,297,882	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	210,240	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	618,887	
	$		
Total annual costs	$	829,127	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	700,800	
	$	17,520	
Total annual savings and income	$	718,320	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

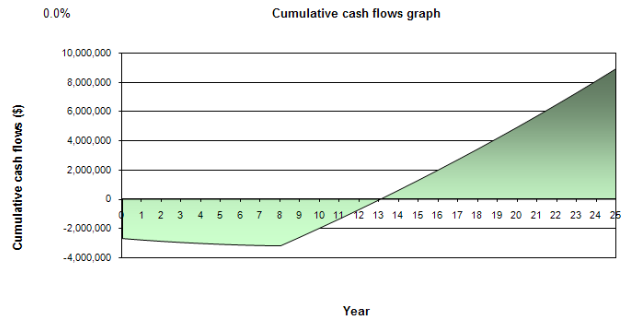


Figure 111: Financial Analysis for Sub-Site 5

Site M (and sub-site 6) is discussed in the Results section on page 96.

Site N: Data

Figure 112: Aerial image of Site N

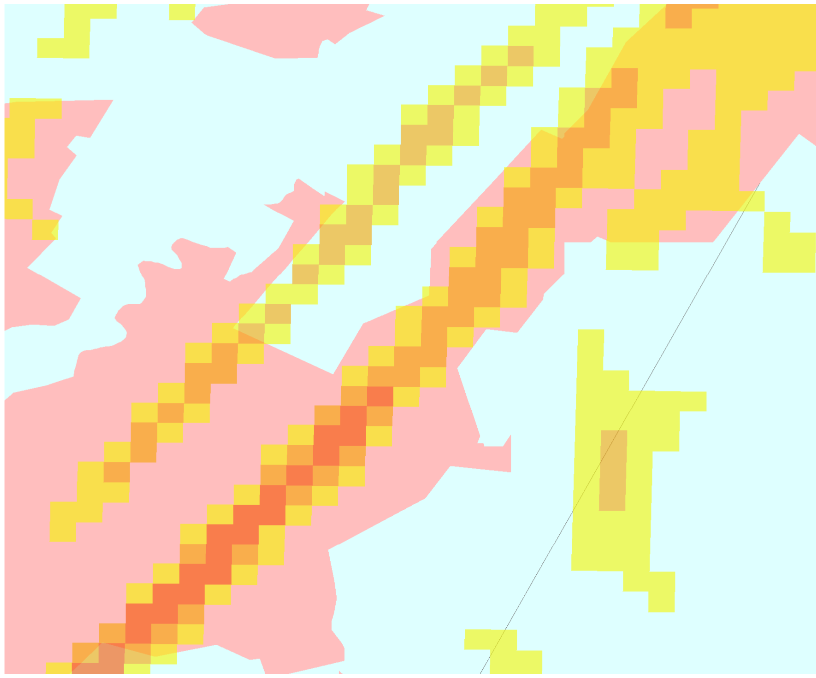


Figure 113: GIS Image of Site N

Table 43: Overall Site Suitability Scoring Matrix for Site N.1 and N.2

		Garrett County Site N																			
		Characterization			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region N1	Value		39°36'40" N	79°00'59" W	116-138	5.05	0.3	x	x	x	x	9.92	0.81	x	26	39	0.273	77	1.5	10.66	**2.7102**
	Ranking				3	3	5	2.5	3	4	1.2971	x	x	2.1	x	x	4	x	x	4	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
Region N2	Value		39°37'32" N	79°01'03" W	116-138	3.39	0.2	x	x	x	x	7.53	0.64	x	8	20	0.242	100	2.5	4.84	**1.6439**
	Ranking				3	4	5	2.5	4	4	1.5276	x	x	1.7	x	x	2	x	x	1	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit					kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	50,700,000	81.3%
Other	$	11,700,000	18.8%
Total initial costs	$	62,400,000	100.0%
Incentives and grants	$	8,636,591	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,399,016	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,827,321	
	$		
Total annual costs	$	6,226,336	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	4,663,386	
	$	116,585	
Total annual savings and income	$	4,779,971	
Financial viability			
Pre-tax IRR - equity	%	6.2%	
Pre-tax IRR - assets	%	1.5%	
Simple payback	yr	15.9	
Equity payback	yr	15.3	

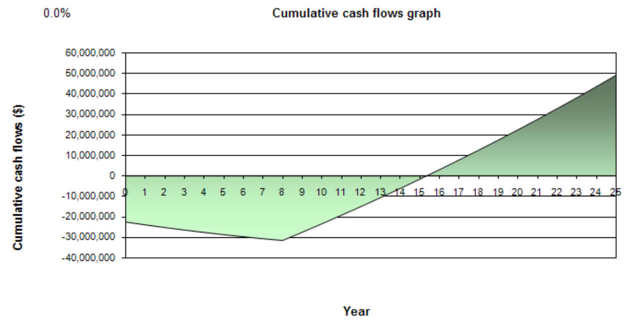


Figure 114: Financial Analysis for Site N.1

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	26,000,000	81.3%
Other	$	6,000,000	18.8%
Total initial costs	$	32,000,000	100.0%
Incentives and grants	$	3,926,092	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	635,976	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,475,549	
	$		
Total annual costs	$	3,111,525	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,119,920	
	$	52,998	
Total annual savings and income	$	2,172,918	
Financial viability			
Pre-tax IRR - equity	%	4.5%	
Pre-tax IRR - assets	%	0.4%	
Simple payback	yr	18.3	
Equity payback	yr	17.2	

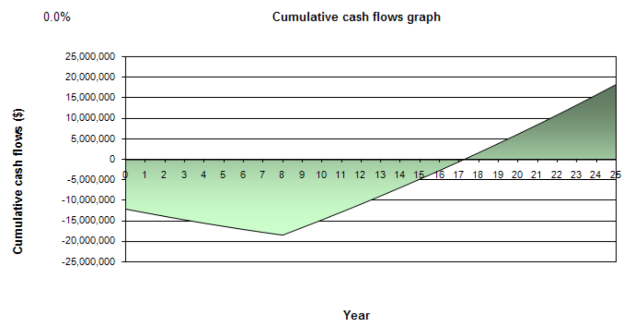


Figure 115: Financial Analysis for Site N.2

Site N1 – Sub-site 7:

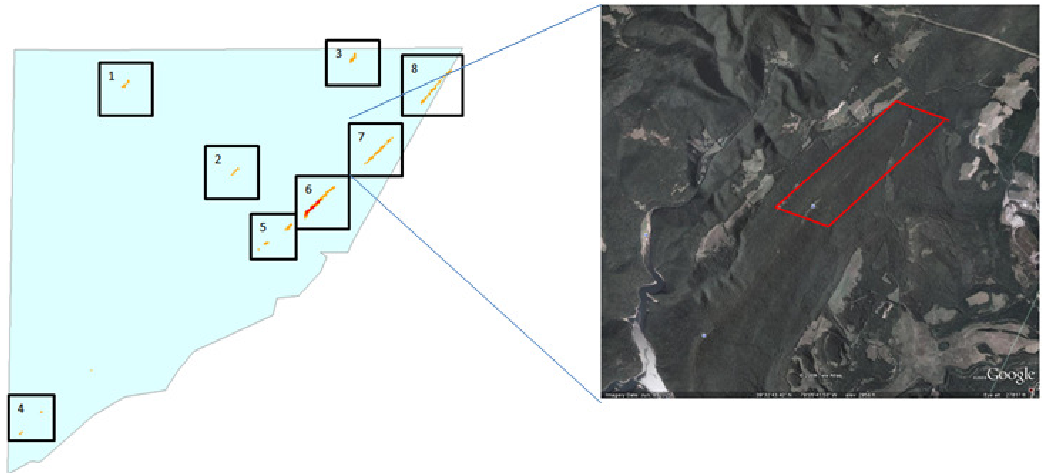


Figure 116: Aerial image of Sub-Site 7

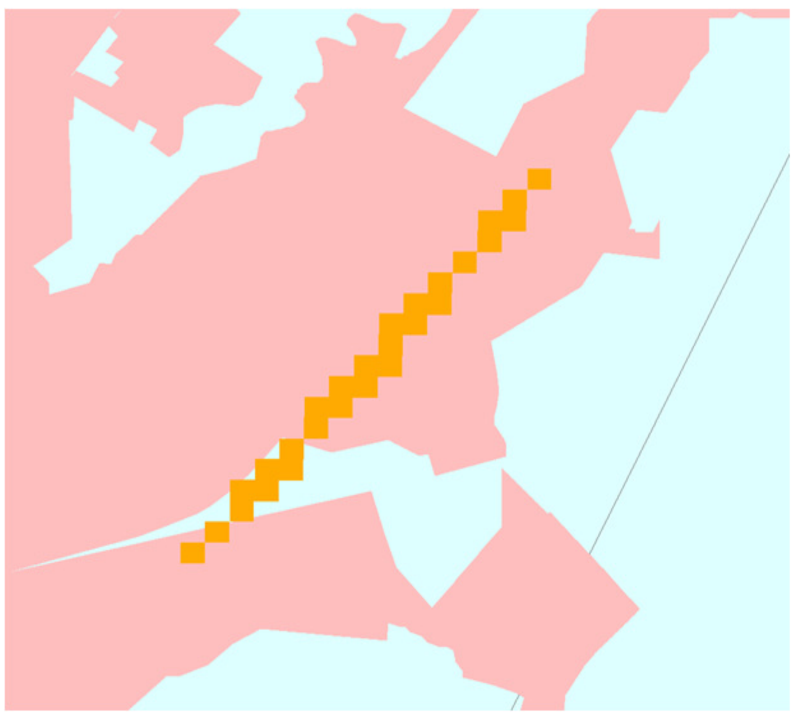


Figure 117: GIS Image of Sub-Site 7

Table 44: Overall Site Suitability Scoring Matrix for Sub-Site 7

Garrett County Site 7	.			Site Suitability – Infrastructure			Site Suitability – Environmental		Site Suitability – Social		Energy Availability									
Region 7	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Value		39°35'48" N	79°1'50" W	231-500	4.5	0.1	x	x	x	x	4.7	0.4	x	5	12.5	0.32	100	2.5	4	2.8022
Ranking				5	4	5	2.5	3	4	1.4892	x	x	3	x	x	5	x	x	1	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters		
Inflation rate	%	2.0%
Project life	yr	25
Debt ratio	%	50%
Debt interest rate	%	5%
Debt term	yr	800%

Initial costs			
Power system	$	16,250,000	81.3%
Other	$	3,750,000	18.8%
Total initial costs	$	20,000,000	100.0%
Incentives and grants	$	3,244,704	0.0%

Annual costs and debt payments		
O&M (savings) costs	$	525,600
Fuel cost - proposed case	$	0
Debt payments - 8 yrs	$	1,547,218
	$	
Total annual costs	$	2,072,818

Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	1,752,000
	$	43,800
Total annual savings and income	$	1,795,800

Financial viability		
Pre-tax IRR - equity	%	8.7%
Pre-tax IRR - assets	%	3.1%
Simple payback	yr	13.2
Equity payback	yr	13.1

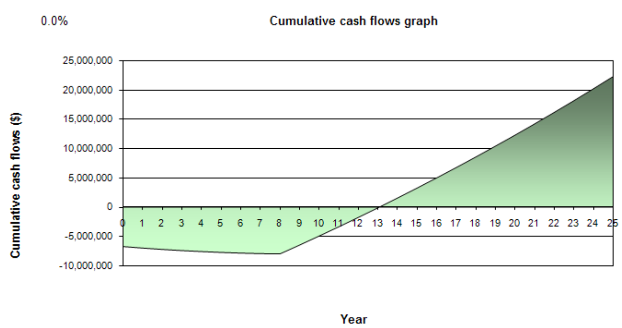


Figure 118: Financial Analysis for Sub-Site 7

Site O: Data

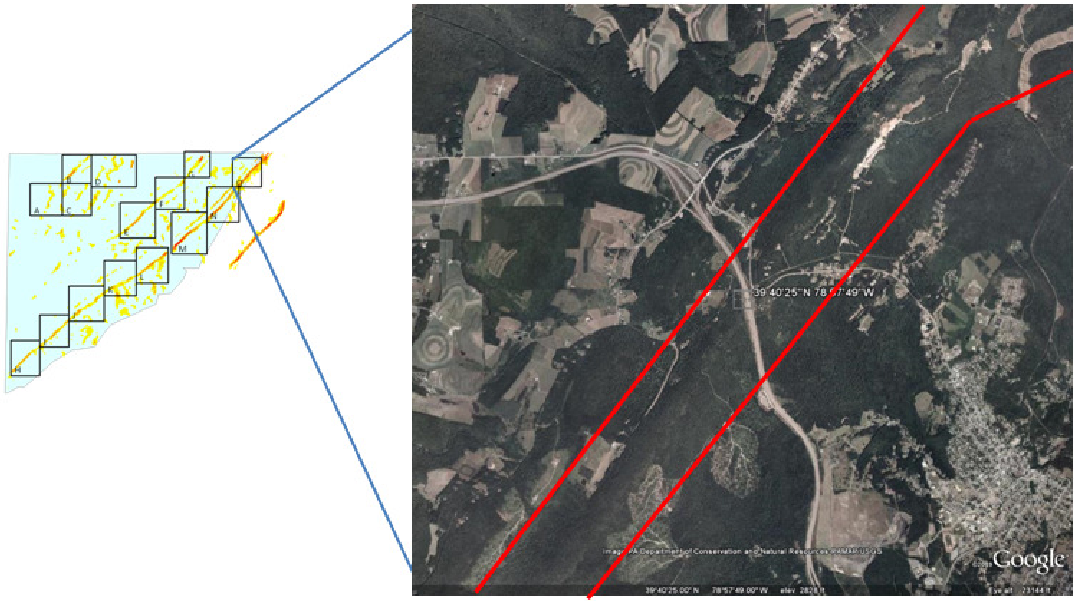


Figure 119: Aerial image of Site O

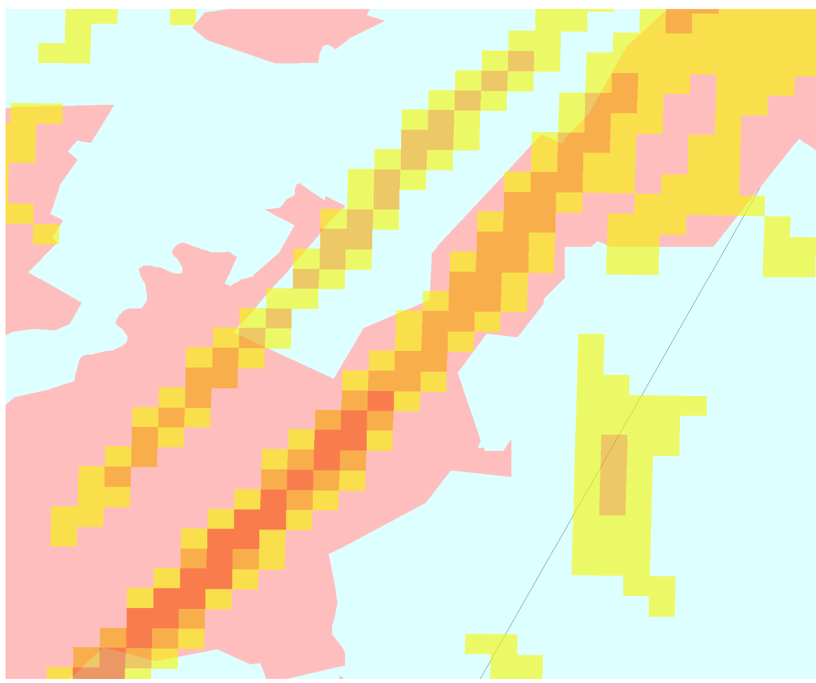


Figure 120: GIS Image of Site O

Table 45: Overall Site Suitability Scoring Matrix for Site O

	Garrett County Site O																			
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region 01	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Value		39°40'24" N	78°57'48" W	116-138	1.87	0.1	x	x	x	x	7.086	1.058	x	14	35	0.26	100	2.5	9.1	2.3614
Ranking				3	4	5	2.5	4	2	1.3882	x	x	2	x	x	3	x	x	4	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	x
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	45,500,000	81.3%
Other	$	10,500,000	18.8%
Total initial costs	$	56,000,000	100.0%
Incentives and grants	$	7,381,702	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,195,740	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	4,332,211	
	$		
Total annual costs	$	5,527,951	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,985,800	
	$	99,645	
Total annual savings and income	$	4,085,445	
Financial viability			
Pre-tax IRR - equity	%	5.5%	
Pre-tax IRR - assets	%	1.1%	
Simple payback	yr	16.8	
Equity payback	yr	16.1	

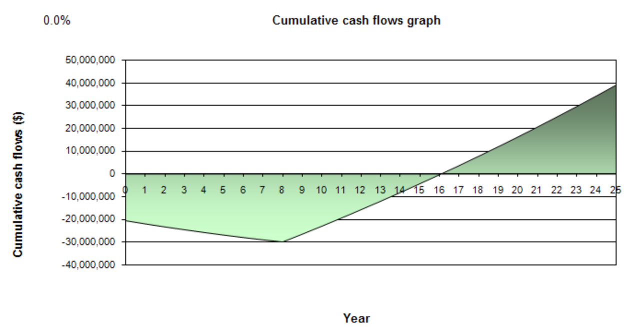


Figure 121: Financial Analysis for Site O

Site O – Sub-Site 8:

Figure 122: Aerial image of Sub-Site 8

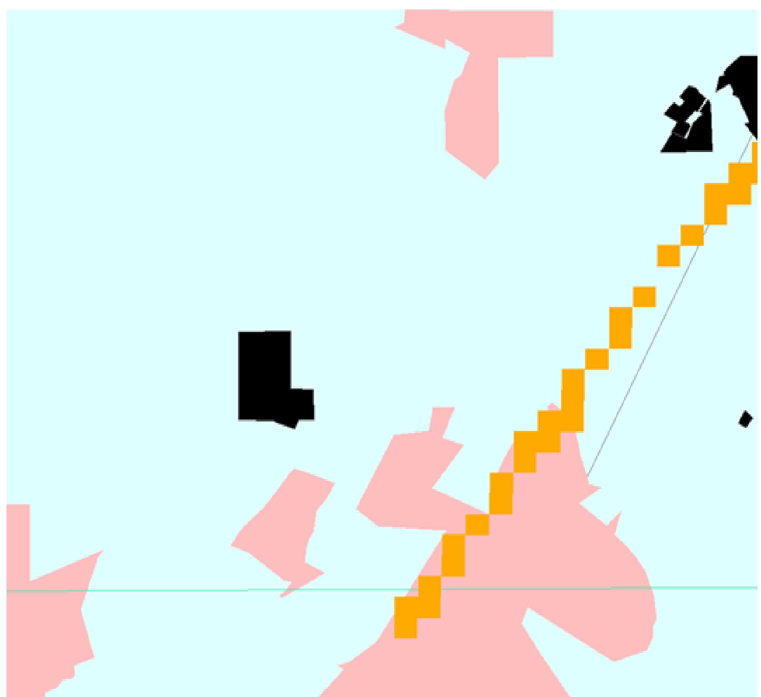


Figure 123: GIS Image of Sub-Site 8

Table 46: Overall Site Suitability Scoring Matrix for Sub-Site 8

		Garrett County Site 8																			
		.			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 8	Value		39°40'31" N	78°57'44" W	115	2.3	0.1	x	x	x	x	5.5	0.3	x	6	15	0.32	100	2.5	4.8	**2.7461**
	Ranking				2	4	5	2.5	3	3	1.3715	x	x	3	x	x	5	x	x	1	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	19,500,000	81.3%
Other	$	4,500,000	18.8%
Total initial costs	$	24,000,000	100.0%
Incentives and grants	$	3,893,645	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	630,720	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,856,662	
	$		
Total annual costs	$	2,487,382	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,102,400	
RECs	$	52,560	
Total annual savings and income	$	2,154,960	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

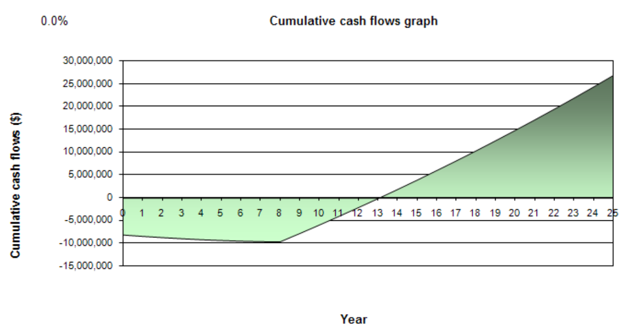


Figure 124: Financial Analysis for Sub-Site 8

Site P: Data

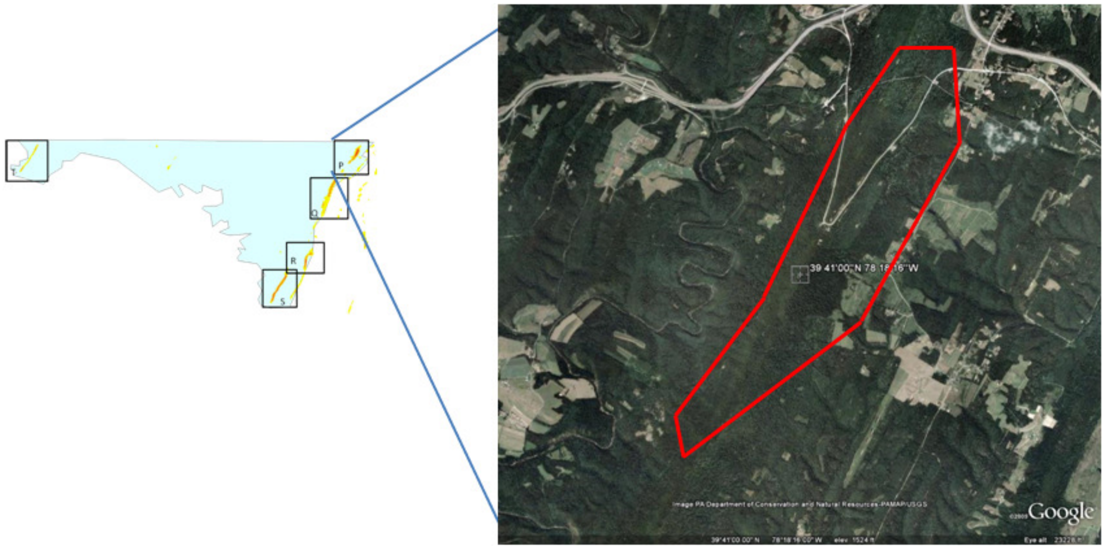


Figure 125: Aerial image of Site P

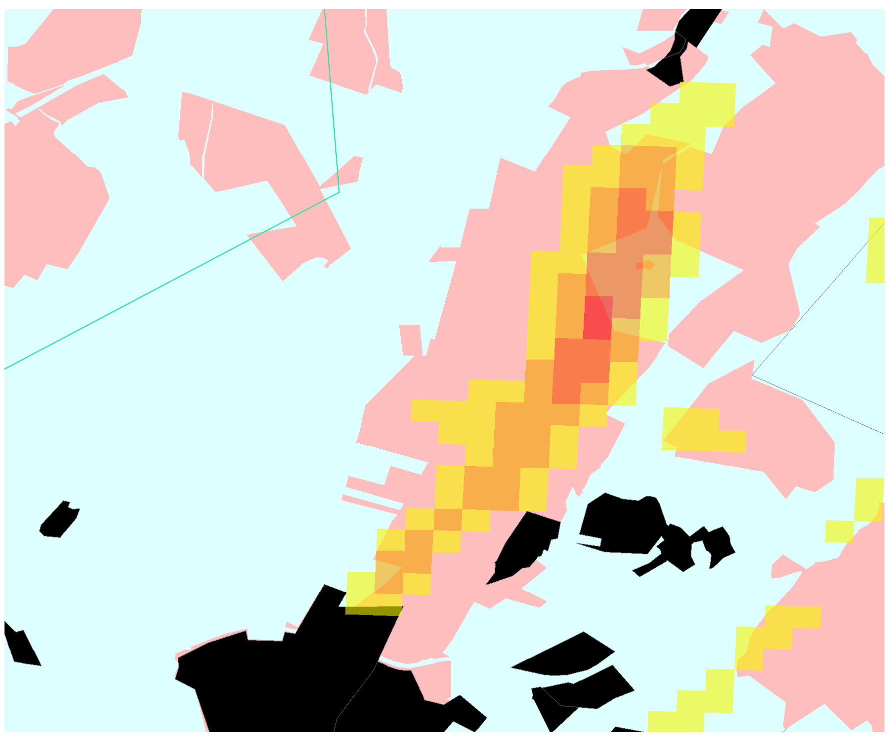


Figure 126: GIS Image of Site P

Table 47: Overall Site Suitability Scoring Matrix for Site P

Washington County Site P	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region P1	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Value		39°41'00" N	78°18'15" W	116-138	15	0.8	x	x	x	x	8.3	0.3	x	9	23	0.2074	100	2.5	4.77	**1.1832**
Ranking				3	2	5	2.5	3	4	1.384	x	x	1.2	x	x	1	x	x	1	
Weight	x	x	x	0.016	0.037	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	29,250,000	81.3%
Other	$	6,750,000	18.8%
Total initial costs	$	36,000,000	100.0%
Incentives and grants	$	3,778,052	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	611,996	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,784,993	
	$		
Total annual costs	$	3,396,988	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,039,985	
	$	51,000	
Total annual savings and income	$	2,090,985	
Financial viability			
Pre-tax IRR - equity	%	2.7%	
Pre-tax IRR - assets	%	-1.0%	
Simple payback	yr	21.8	
Equity payback	yr	19.9	

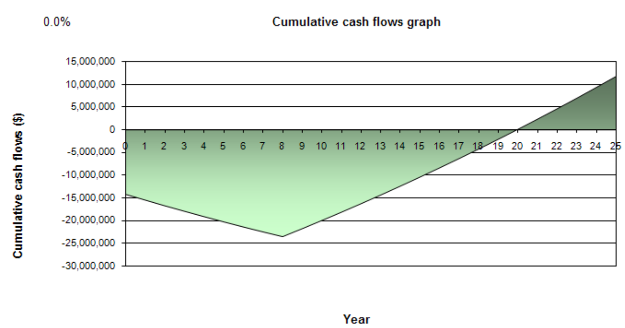


Figure 127: Financial Analysis for Site P

Site P – Sub-site 13:

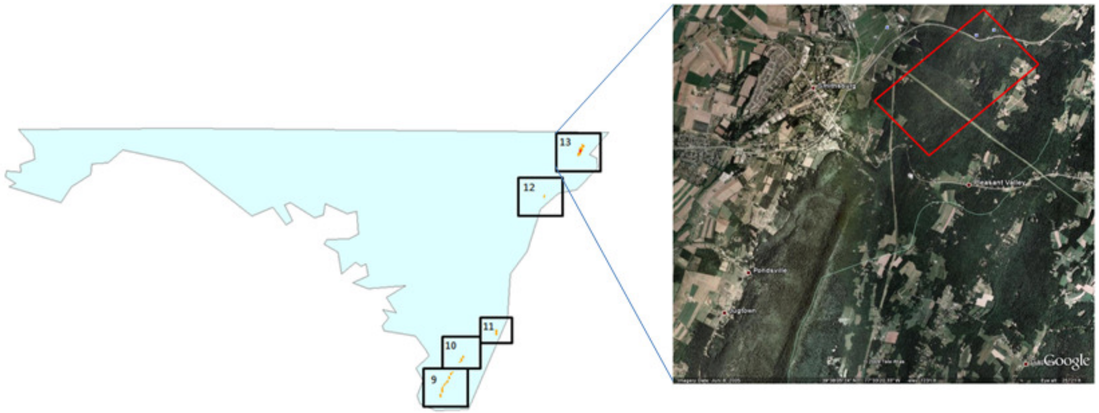


Figure 128: Aerial image of Sub-Site 13

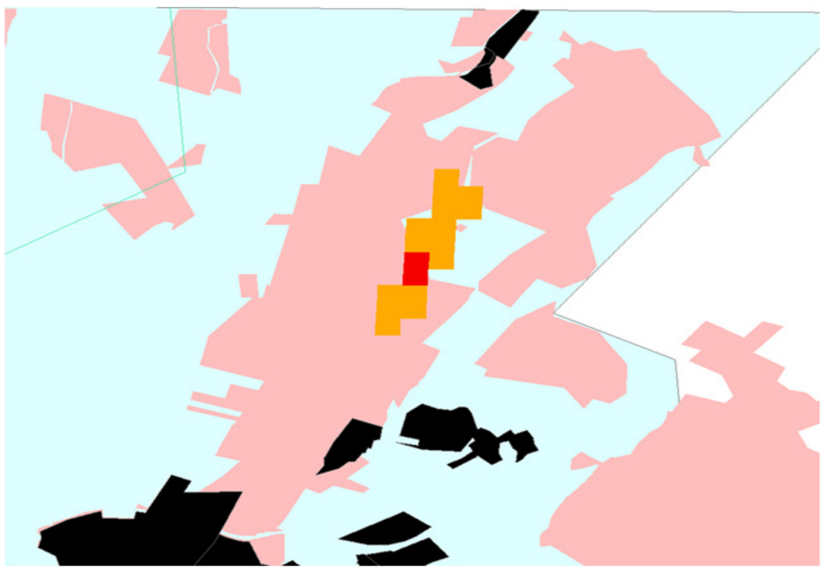


Figure 129: GIS Image of Sub-Site 13

Table 48: Overall Site Suitability Scoring Matrix for Sub-Site 13

Washington County Site 13																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 13 Value		39°41'40" N	77°30'55" W	116-138	2.2	0.1	x	x	x	x	1.9	0.4	x	2	5	0.328	100	2.5	1.64	2.6231
Region 13 Ranking				3	4	5	2.5	3	3	1.3875	x	x	3.13	x	x	5	x	x	0	
Region 13 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	6,500,000	81.3%
Other	$	1,500,000	18.8%
Total initial costs	$	8,000,000	100.0%
Incentives and grants	$	1,330,329	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	215,496	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	618,887	
	$		
Total annual costs	$	834,383	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	718,320	
	$	17,958	
Total annual savings and income	$	736,278	
Financial viability			
Pre-tax IRR - equity	%	9.1%	
Pre-tax IRR - assets	%	3.4%	
Simple payback	yr	12.8	
Equity payback	yr	12.7	

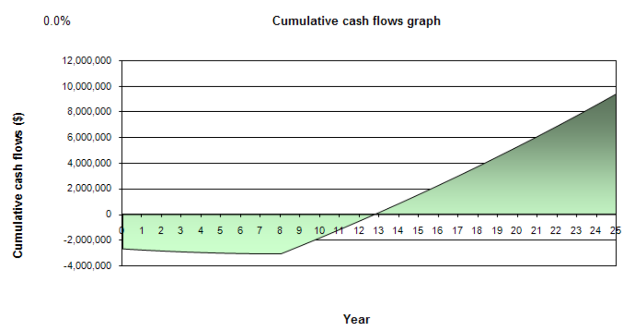


Figure 130: Financial Analysis for Sub-Site 13

Site Q: Data

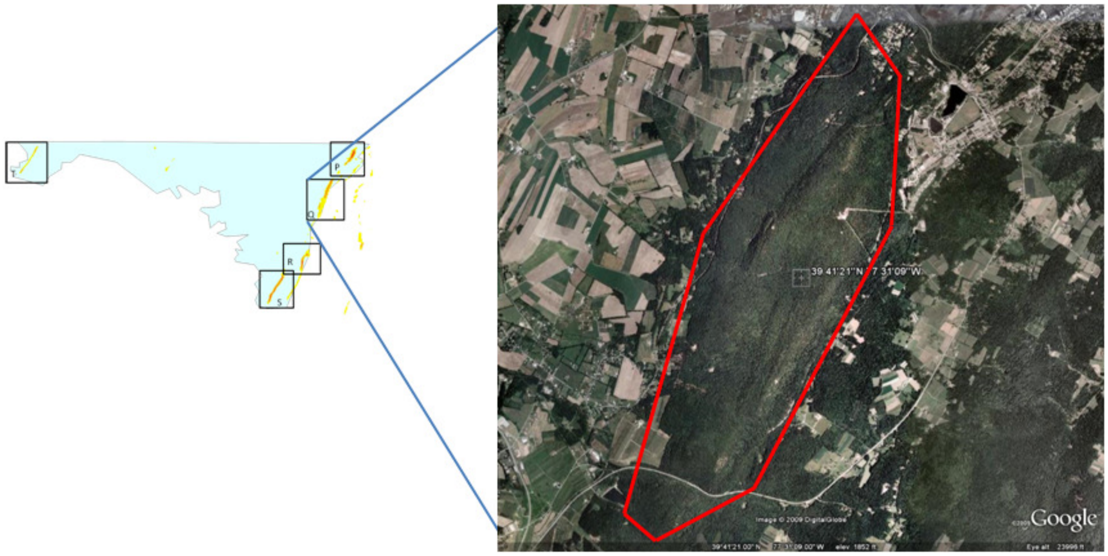


Figure 131: Aerial image of Site Q

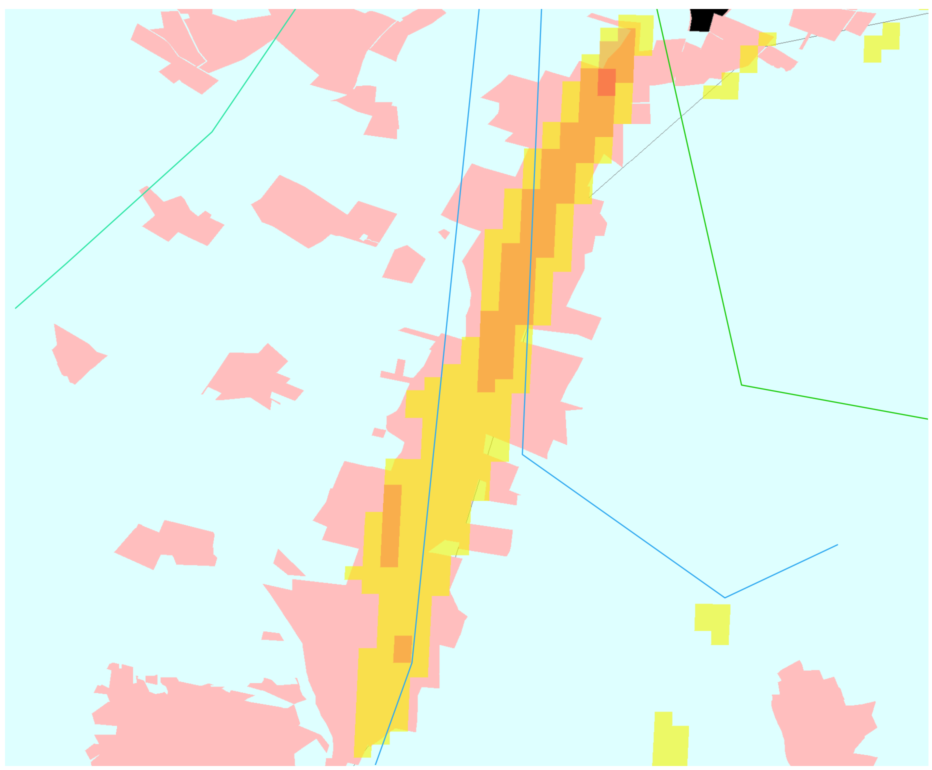


Figure 132: GIS Image of Site Q (Scale 1:50,000)

Table 49: Overall Site Suitability Scoring Matrix for Site Q

Washington County Site Q																				
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region Q1 Value		39°41'20" N	77°31'08" W	116-138	2.2	0.6	x	x	x	x	5.3	0.9	x	14	21	0.267	77	1.5	5.6	**2.0999**
Ranking				3	4	5	2.5	3	3	1.3875	x	x	2	x	x	3	x	x	2	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	27,300,000	81.3%
Other	$	6,300,000	18.8%
Total initial costs	$	33,600,000	100.0%
Incentives and grants	$	4,548,264	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	736,760	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	2,599,326	
	$		
Total annual costs	$	3,336,086	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,455,866	
	$	61,397	
Total annual savings and income	$	2,517,263	
Financial viability			
Pre-tax IRR - equity	%	5.9%	
Pre-tax IRR - assets	%	1.3%	
Simple payback	yr	16.3	
Equity payback	yr	15.7	

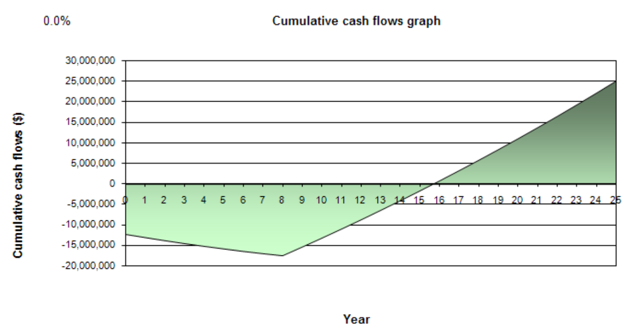


Figure 133: Financial Analysis for Site Q

Site Q – Sub-site 12:

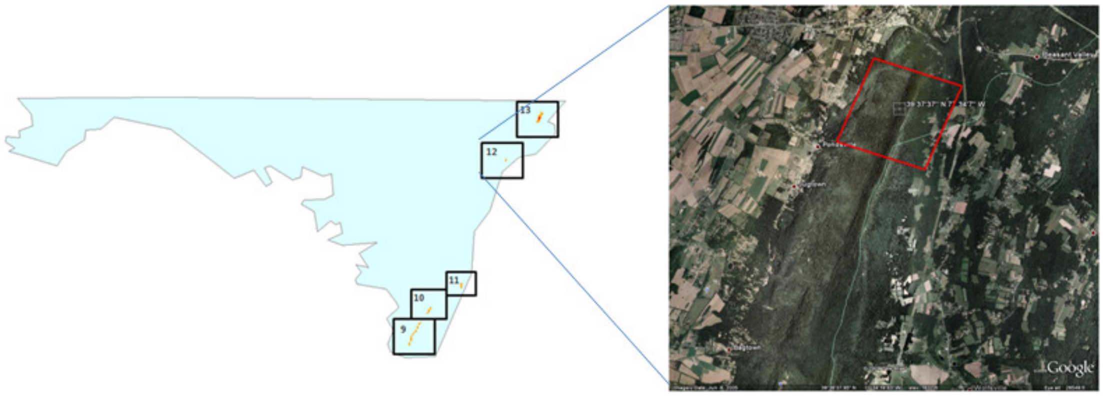


Figure 134: Aerial image of Sub-Site 12

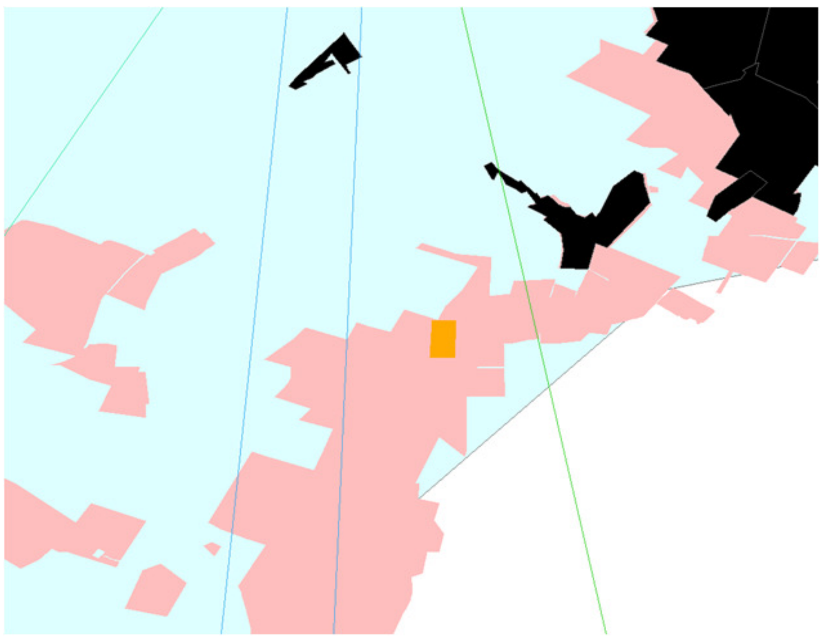


Figure 135: GIS Image of Sub-Site 12

Table 50: Overall Site Suitability Scoring Matrix for Sub-Site 12

Washington County Site 12																					
		.			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 12	Value		39°37'37" N	77°34'7" W	139-230	0.8	1.3	x	x	x	x	0.4	0.2	x	1	3	0.32	100	2.5	0.8	**2.6364**
	Ranking				4	5	4	2.5	3	3	1.4154	x	x	3	x	x	5	x	x	0	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters		
Inflation rate	%	2.0%
Project life	yr	25
Debt ratio	%	50%
Debt interest rate	%	5%
Debt term	yr	800%
Initial costs		
Power system	$	3,250,000	81.3%
Other	$	750,000	18.8%
Total initial costs	$	4,000,000	100.0%
Incentives and grants	$	648,941	0.0%
Annual costs and debt payments		
O&M (savings) costs	$	105,120
Fuel cost - proposed case	$	0
Debt payments - 8 yrs	$	309,444
	$	
Total annual costs	$	414,564
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	350,400
	$	8,760
Total annual savings and income	$	359,160
Financial viability		
Pre-tax IRR - equity	%	8.7%
Pre-tax IRR - assets	%	3.1%
Simple payback	yr	13.2
Equity payback	yr	13.1

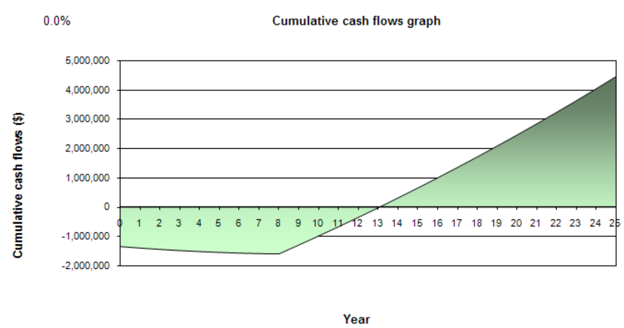


Figure 136: Financial Analysis for Sub-Site 12

Site R: Data

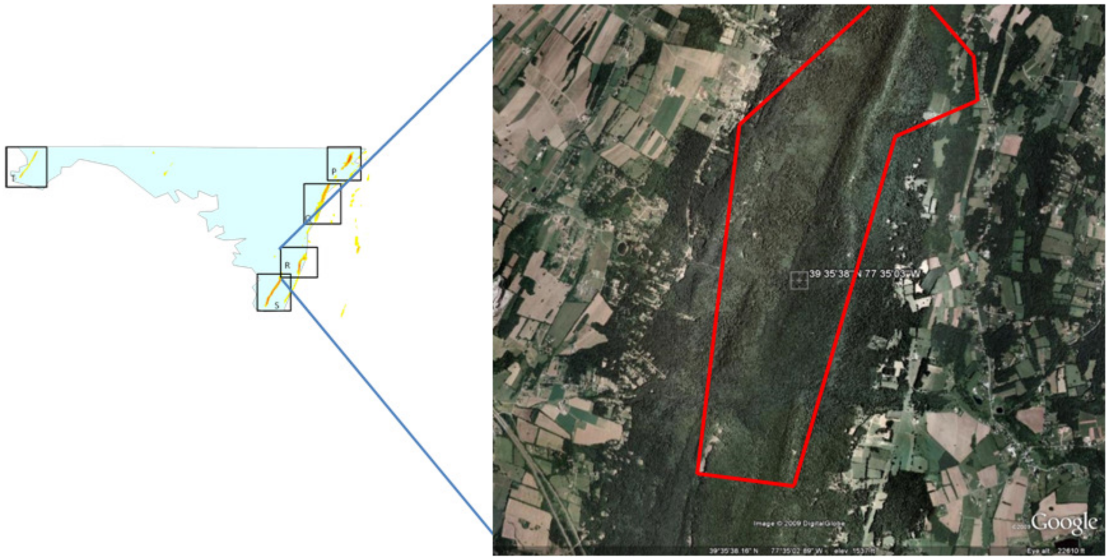


Figure 137: Aerial image of Site R

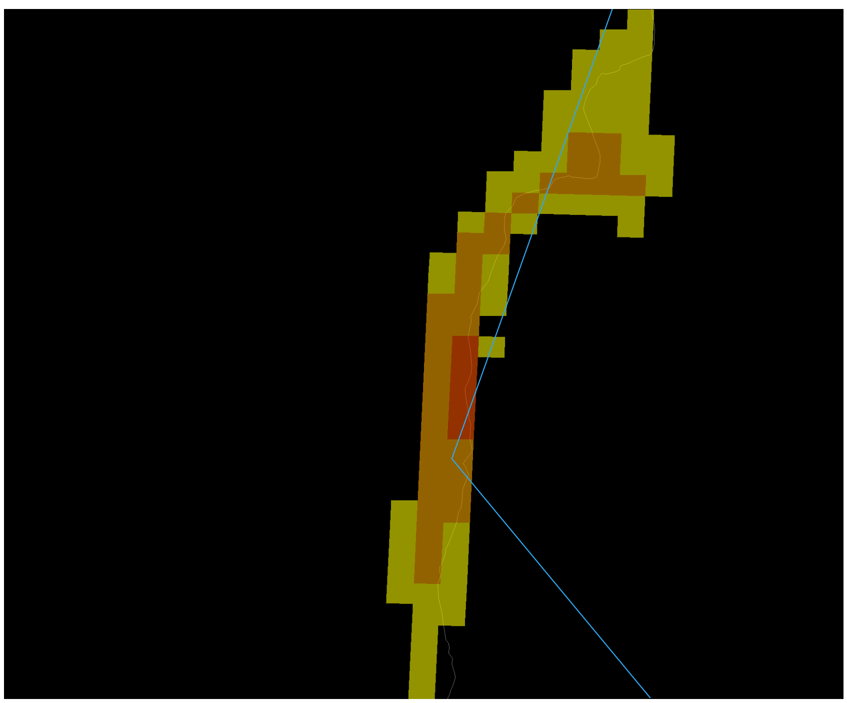


Figure 138: GIS Image of Site R

Table 51: Overall Site Suitability Scoring Matrix for Site R

Washington County Site R		Characterization			Site Suitability: Infrastructure			Site Suitability: Environmental		Site Suitability: Social		Energy Availability									
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region R1	Value		39°35'37" N	77°35'02" W	139-230	0.4	0.6	x	x	x	x	11	1	x	22	55	0.224	100	2.5	12.32	**1.4226**
	Ranking				4	5	5	0	3	3	0.7908	x	x	1.4	x	x	1	x	x	5	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.131	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	71,500,000	81.3%
Other	$	16,500,000	18.8%
Total initial costs	$	88,000,000	100.0%
Incentives and grants	$	9,993,688	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,618,848	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	6,807,760	
	$		
Total annual costs	$	8,426,608	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	5,396,160	
	$	134,904	
Total annual savings and income	$	5,531,064	
Financial viability			
Pre-tax IRR - equity	%	3.6%	
Pre-tax IRR - assets	%	-0.3%	
Simple payback	yr	19.9	
Equity payback	yr	18.5	

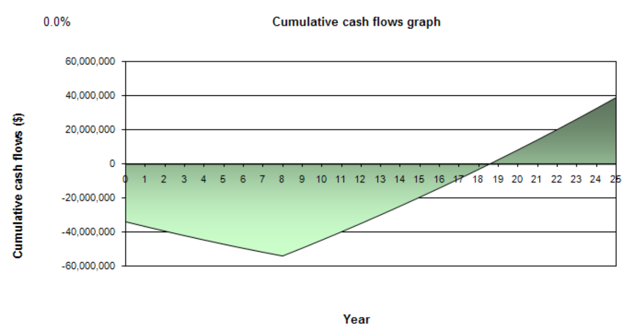


Figure 139: Financial Analysis for Site R

Site R – Sub-site 11:

Figure 140: Aerial image of Sub-Site 11

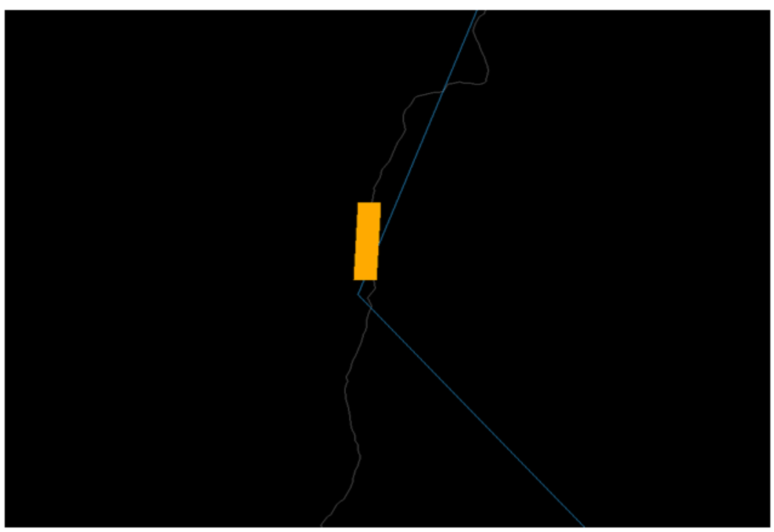


Figure 141: GIS Image of Sub-Site 11

Table 52: Overall Site Suitability Scoring Matrix for Sub-Site 11

Washington County Site 11																				
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region 11	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Value		39°25'50" N	77°36'2" W	231-500	0.2	0.1	x	x	x	x	1	0.3	x	2	3	0.3333	77	1.5	1	2.346
Ranking				5	5	5	0	3	3	0.8068	x	x	3	x	x	5	x	x	0	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	3,900,000	81.3%
Other	$	900,000	18.8%
Total initial costs	$	4,800,000	100.0%
Incentives and grants	$	810,365	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	131,269	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	371,332	
	$		
Total annual costs	$	502,601	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	437,562	
Renewable Energy Credits	$	10,939	
Total annual savings and income	$	448,501	
Financial viability			
Pre-tax IRR - equity	%	9.4%	
Pre-tax IRR - assets	%	3.6%	
Simple payback	yr	12.6	
Equity payback	yr	12.5	

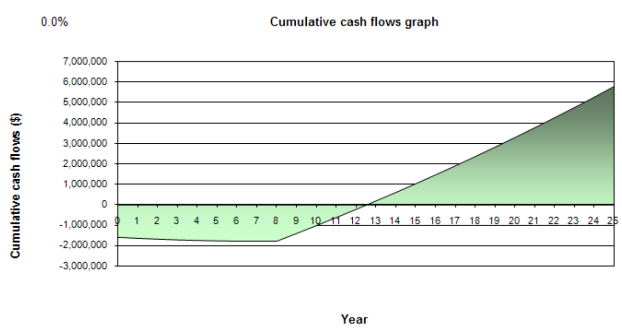


Figure 142: Financial Analysis for Sub-Site 11

Site S: Data

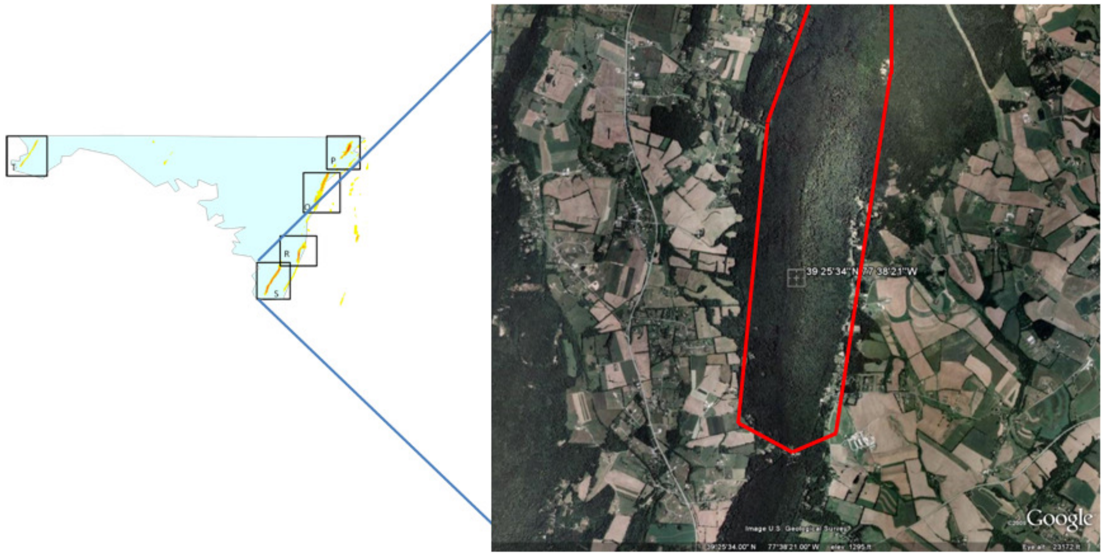


Figure 143: Aerial image of Site S

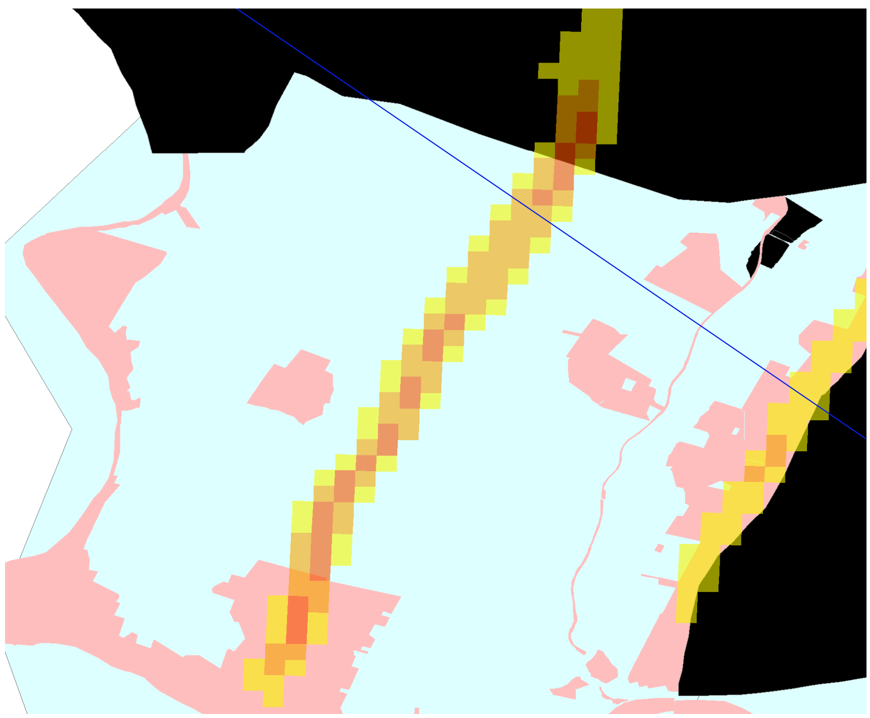


Figure 144: GIS Image of Site S (Scale 1:40,000)

Table 53: Overall Site Suitability Scoring Matrix for Site S

Washington County Site S																				
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region S1 Value		39°25'33" N	77°38'21" W	139-230	0.1	0.9	x	x	x	x	8.0	0.8	x	21	32	0.24	77	1.5	7.56	**2.1732**
Region S1 Ranking				4	5	5	5	3	3	2.0893	x	x	1.6	x	x	2	x	x	3	
Region S1 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.131	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

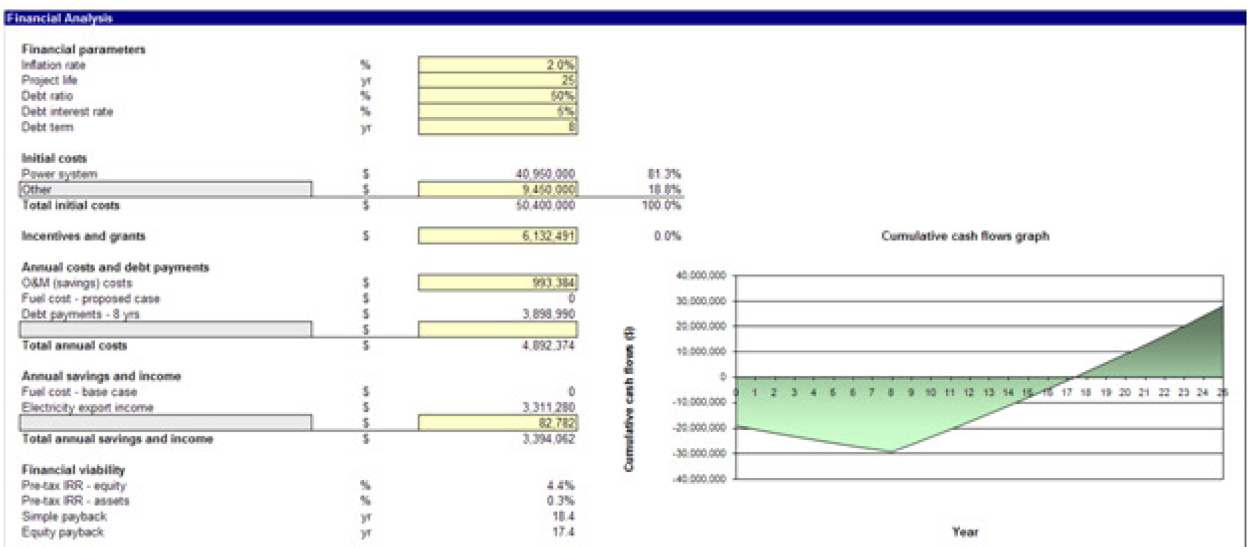


Figure 145: Financial Analysis for Site S

Site S – Sub-Site 9:

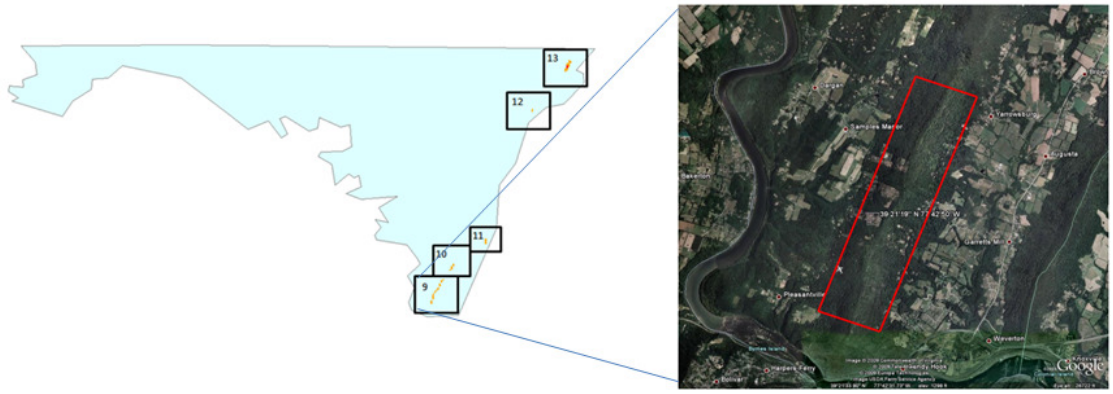


Figure 146: Aerial image of Sub-Site 9

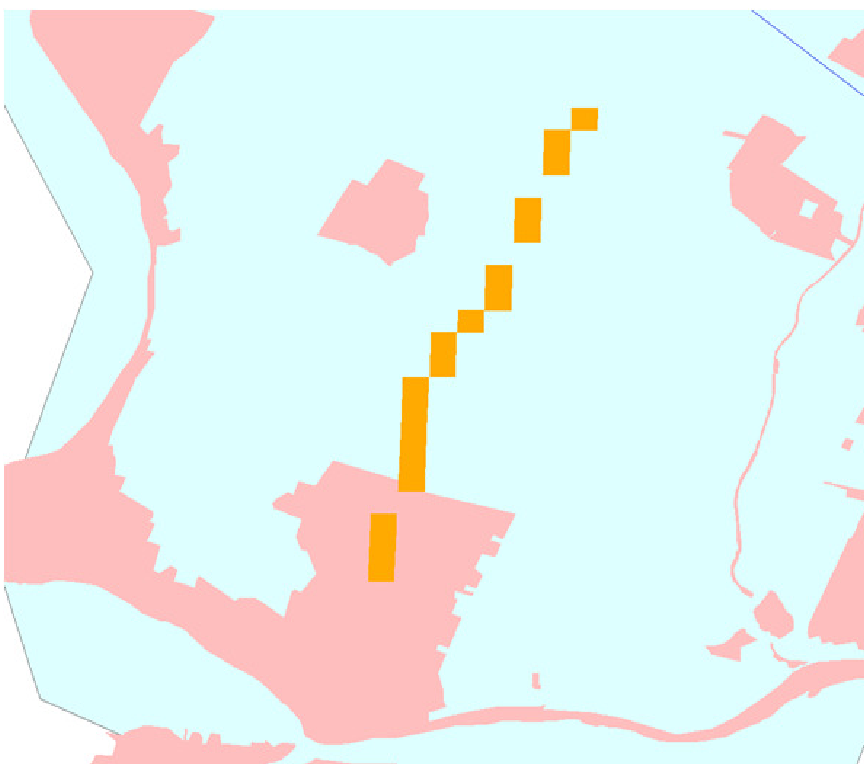


Figure 147: GIS Image of Sub-Site 9

Table 54: Overall Site Suitability Scoring Matrix for Sub-Site 9

	Washington County Site 9																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 9 Value		39°21'19" N	77°42'50" W	231-500	3.9	0.3	x	x	x	x	3.5	0.2	x	4	10	0.32	100	2.5	3.2	2.769
Region 9 Ranking				5	4	5	2.5	3	3	1.4195	x	x	3	x	x	5	x	x	1	
Region 9 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	13,000,000	81.3%
Other	$	3,000,000	18.8%
Total initial costs	$	16,000,000	100.0%
Incentives and grants	$	2,595,763	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	420,480	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,237,775	
	$		
Total annual costs	$	1,658,255	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,401,600	
	$	35,040	
Total annual savings and income	$	1,436,640	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

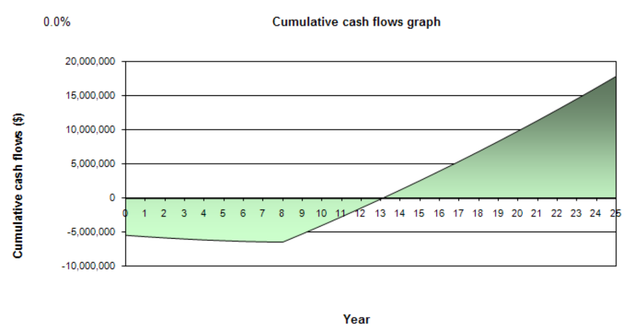


Figure 148: Financial Analysis for Sub-Site 9

Site S – Sub-site 10:

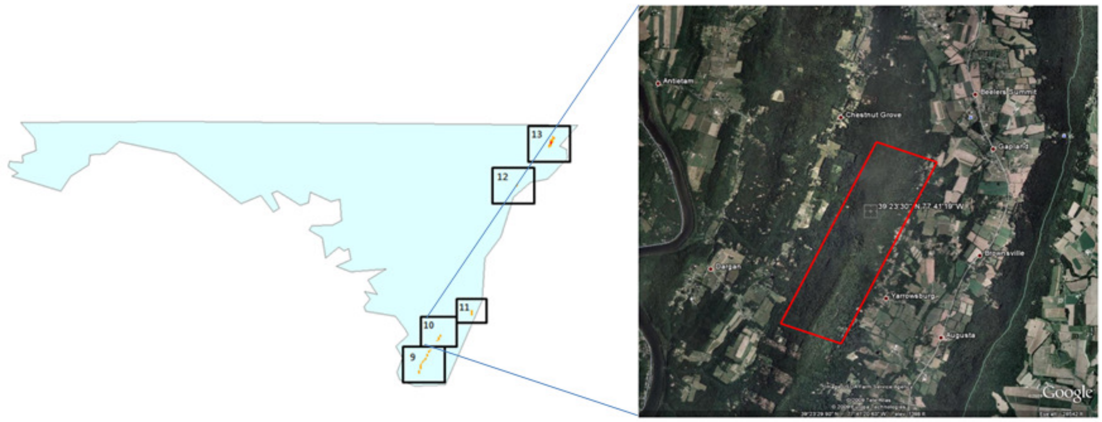


Figure 149: Aerial image of Sub-Site 10

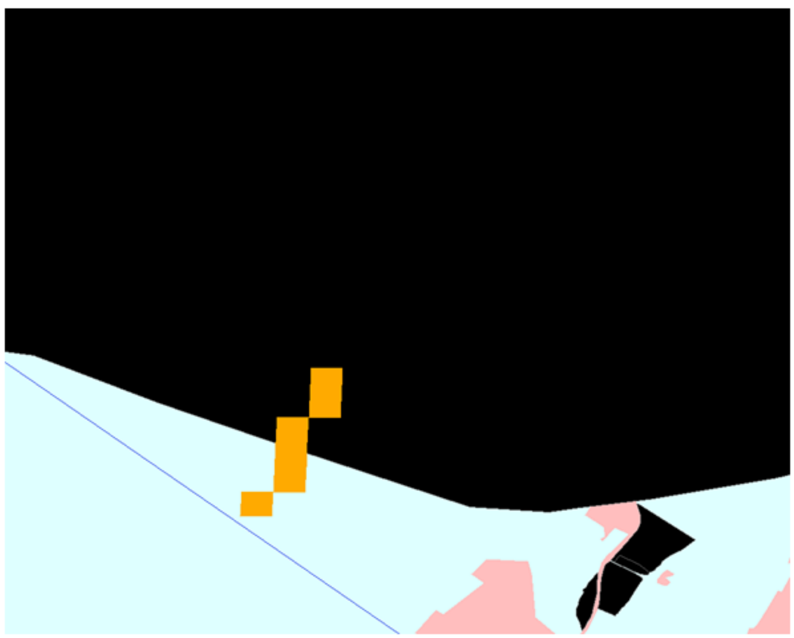


Figure 150: GIS Image of Sub-Site 10

Table 55: Overall Site Suitability Scoring Matrix for Sub-Site 10

	Washington County Site 10																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 10 Value		39°23'30" N	77°41'19" W	231-500	0.6	0.9	x	x	x	x	1.1	0.2	x	2	5	0.32	100	2.5	1.6	2.346
Ranking				5	5	5	0	3	3	0.8068	x	x	3	x	x	5	x	x	0	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	2,080,000	81.3%
Other	$	480,000	18.8%
Total initial costs	$	2,560,000	100.0%
Incentives and grants	$	415,322	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	67,277	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	198,044	
	$		
Total annual costs	$	265,321	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	224,256	
Renewable Energy Credits	$	5,606	
Total annual savings and income	$	229,862	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

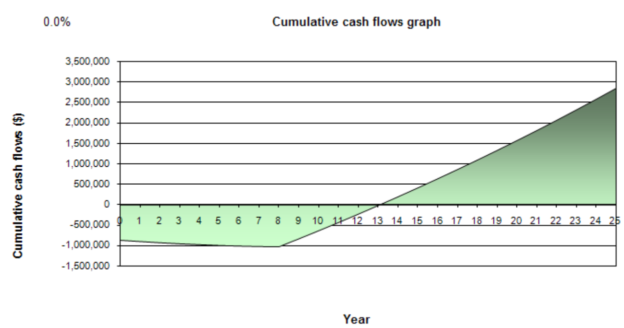


Figure 151: Financial Analysis for Sub-Site 10

Site T: Data

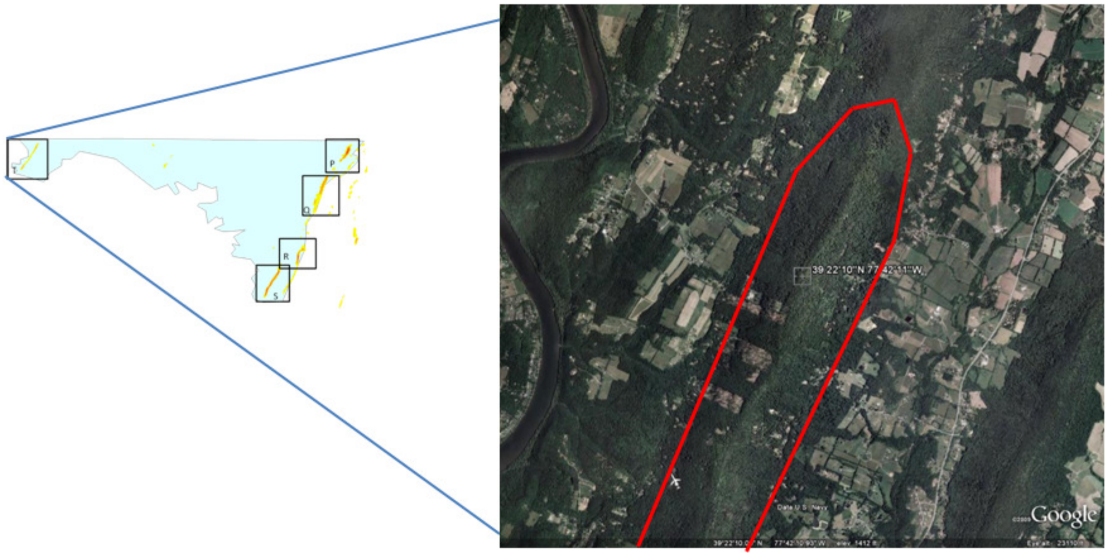


Figure 152: Aerial image of Site T

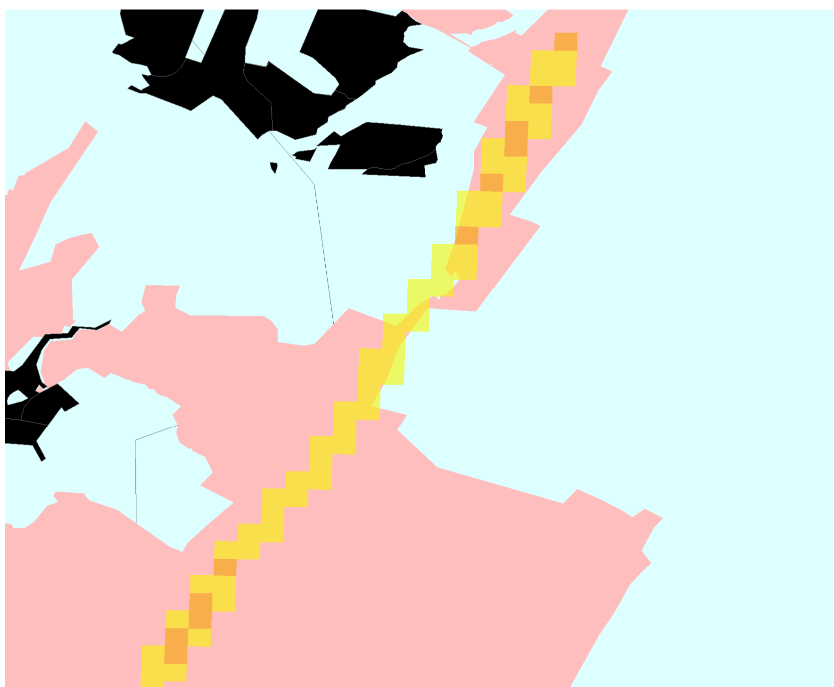


Figure 153: GIS image of Site T (Scale 1:35,000)

Table 56: Overall Site Suitability Scoring Matrix for Site T

Allegheny County Site T																					
		Characterization			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region T1	Value		39°22'10" N	77°42'10" W	231-500	2	0.3	x	x	x	x	2.8	0.8	x	8	12	0.26	77	1.5	3.12	1.9846
	Ranking				5	4	5	2.5	3	3	1.4195	x	x	1.9	x	x	3	x	x	1	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	15,600,000	81.3%
Other	$	3,600,000	18.8%
Total initial costs	$	19,200,000	100.0%
Incentives and grants	$	2,530,869	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	409,968	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,485,329	
	$		
Total annual costs	$	1,895,297	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,366,560	
	$	34,164	
Total annual savings and income	$	1,400,724	
Financial viability			
Pre-tax IRR - equity	%	5.5%	
Pre-tax IRR - assets	%	1.1%	
Simple payback	yr	16.8	
Equity payback	yr	16.1	

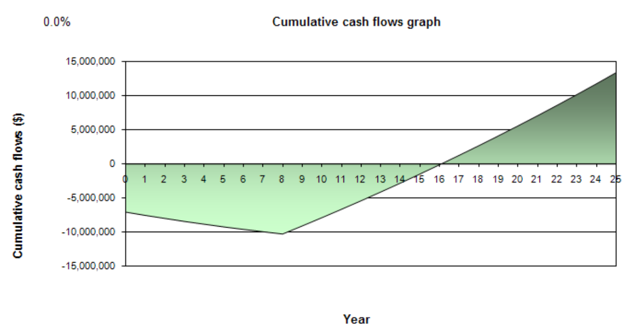


Figure 154: Financial Analysis for Site T

Site U is discussed in the Results section, on Page 119.

Site V: Data

Site V is discussed in the Results section, on Page 112.

Site V – Sub-site 14:

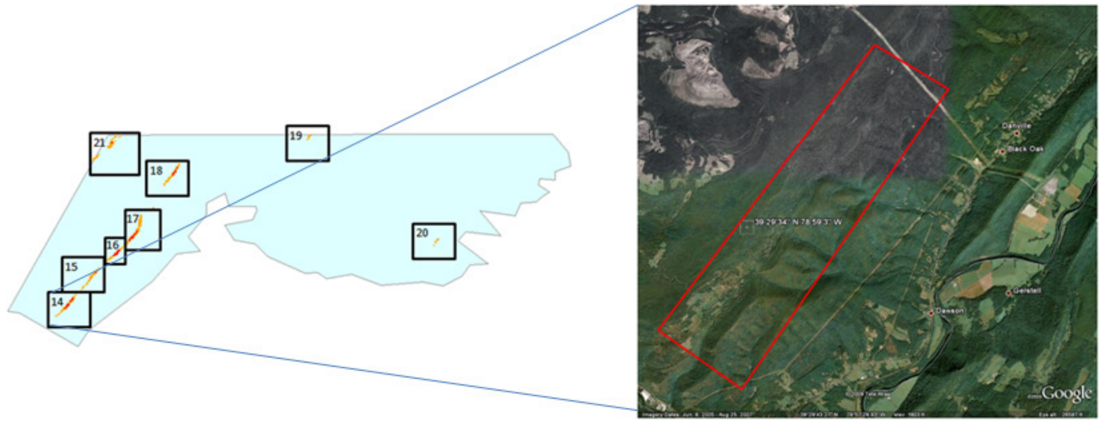


Figure 155: Aerial image of Sub-Site 14

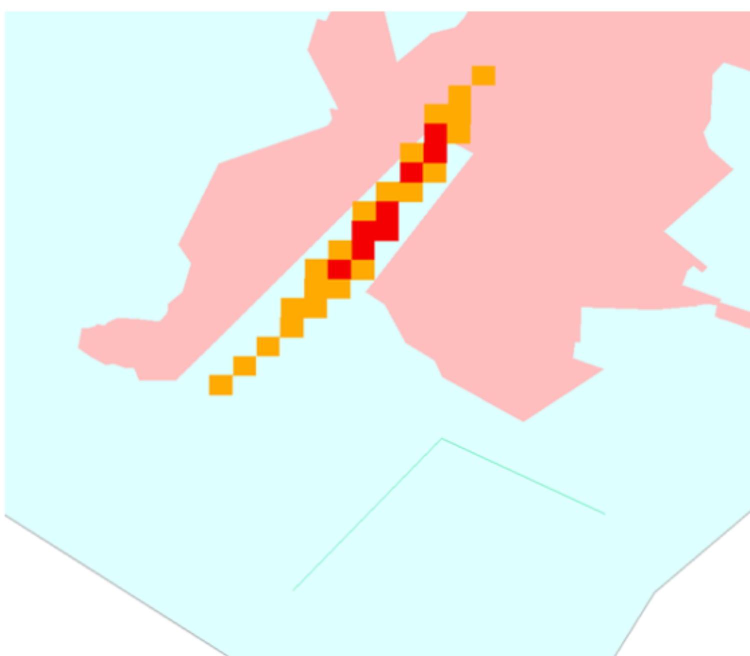


Figure 156: GIS Image of Sub-Site 14

Data error with Sub-site 14 weighted decision matrix. Data excluded.

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	13,000,000	81.3%
Other	$	3,000,000	18.8%
Total initial costs	$	16,000,000	100.0%
Incentives and grants	$	2,790,445	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	452,016	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,237,775	
	$		
Total annual costs	$	1,689,791	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,506,720	
	$	37,668	
Total annual savings and income	$	1,544,388	
Financial viability			
Pre-tax IRR - equity	%	10.0%	
Pre-tax IRR - assets	%	3.9%	
Simple payback	yr	12.1	
Equity payback	yr	12.1	

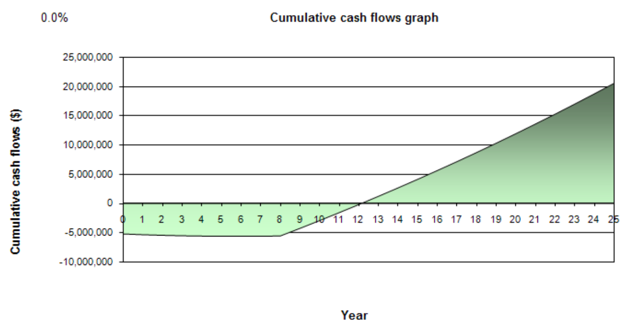


Figure 157: Financial Analysis for Sub-Site 14

Site V – Sub-site 15:

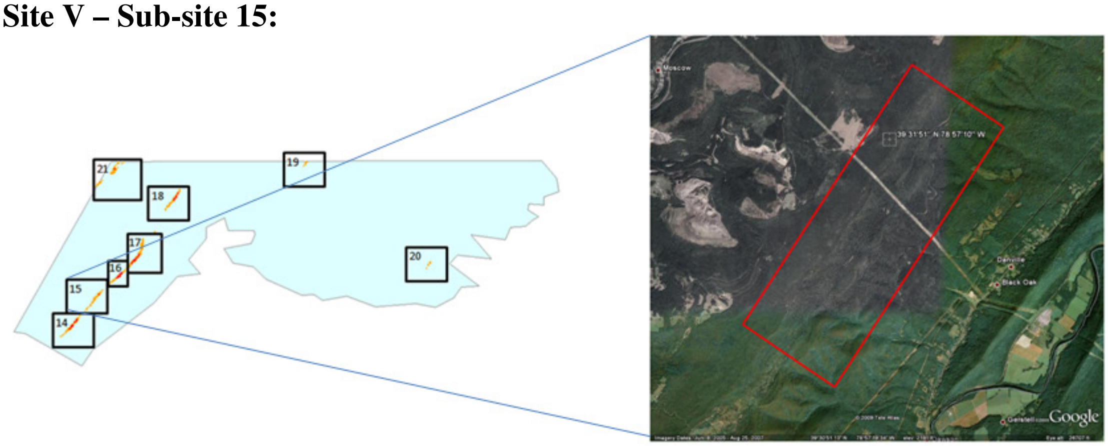


Figure 158: Aerial image of Sub-Site 15

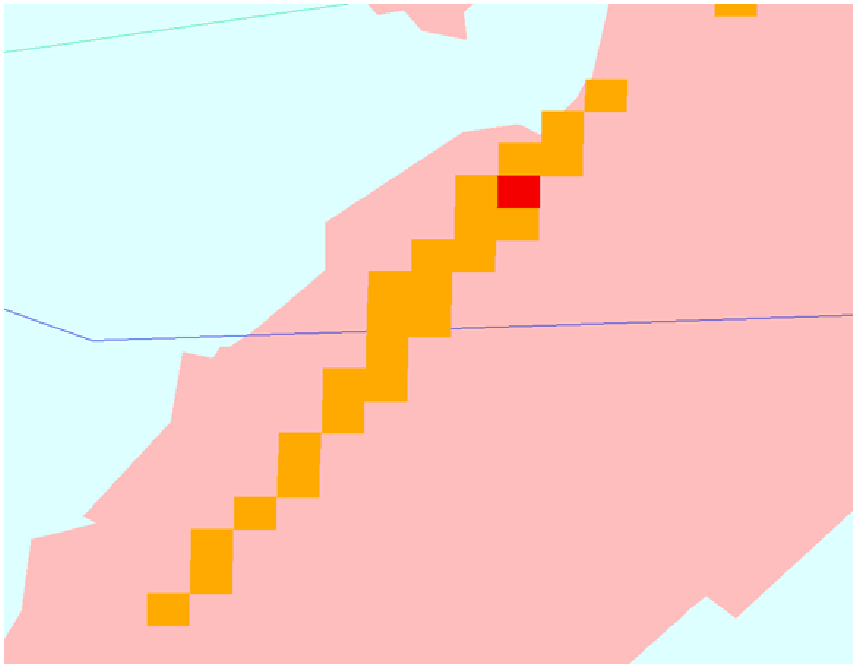


Figure 159: GIS Image of Sub-Site 15

Table 57: Overall Site Suitability Scoring Matrix for Sub-Site 15

	Allegany County Site 15																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region 15	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Value		39°31'51" N	78°57'10" W	231-500	0.1	0.5	x	x	x	x	3.8	0.3	x	4	10	0.326	100	2.5	3.26	2.8529
Ranking				5	5	5	2.5	3	5	1.595	x	x	3.1	x	x	5	x	x	1	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.477	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	13,000,000	81.3%
Other	$	3,000,000	18.8%
Total initial costs	$	16,000,000	100.0%
Incentives and grants	$	2,644,434	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	428,364	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,237,775	
	$		
Total annual costs	$	1,666,139	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,427,880	
	$	35,697	
Total annual savings and income	$	1,463,577	
Financial viability			
Pre-tax IRR - equity	%	9.0%	
Pre-tax IRR - assets	%	3.3%	
Simple payback	yr	12.9	
Equity payback	yr	12.8	

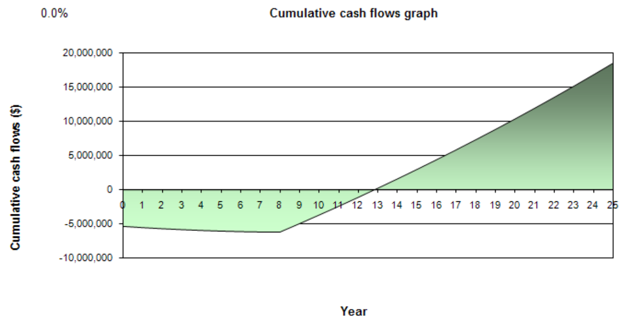


Figure 160: Financial Analysis for Sub-Site 15

Site W: Data

Site W (and sub-site 17) is discussed in the Results section, on Page 125.

Site W – Sub-site 16:

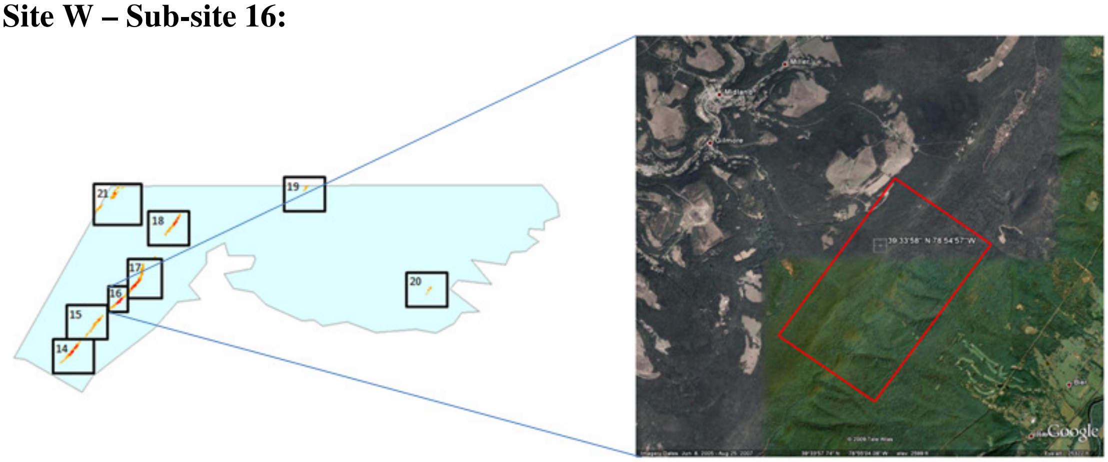


Figure 161: Aerial image of Sub-Site 16

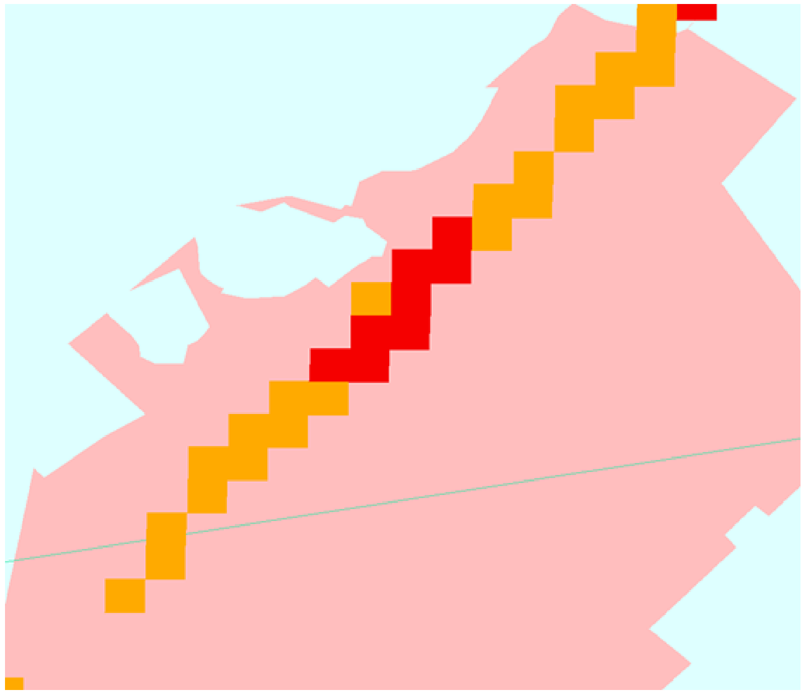


Figure 162: GIS Image of Sub-Site 16

Table 58: Overall Site Suitability Scoring Matrix for Sub-Site 16

	Allegany County Site 16																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Region 16 Value		39°33'58" N	78°54'57" W	116-138	1.3	0.7	x	x	x	x	3.8	0.3	x	4	10	0.338	100	2.5	3.38	2.7712
Ranking				3	5	5	2.5	3	3	1.4241	x	x	3.3	x	x	5	x	x	1	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	800%	
Initial costs			
Power system	$	13,000,000	81.3%
Other	$	3,000,000	18.8%
Total initial costs	$	16,000,000	100.0%
Incentives and grants	$	2,741,775	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	444,132	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,237,775	
	$		
Total annual costs	$	1,681,907	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,480,440	
	$	37,011	
Total annual savings and income	$	1,517,451	
Financial viability			
Pre-tax IRR - equity	%	9.7%	
Pre-tax IRR - assets	%	3.7%	
Simple payback	yr	12.4	
Equity payback	yr	12.3	

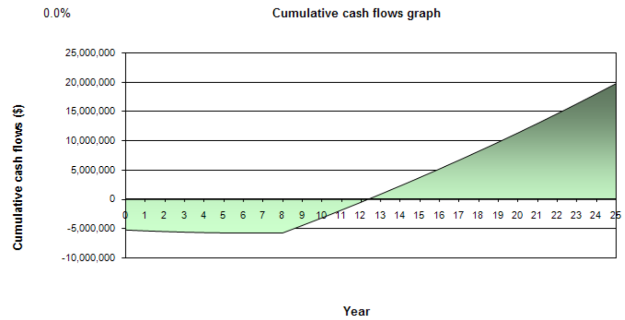


Figure 163: Financial Analysis for Sub-Site 16

Site X (and sub-site 18) is discussed in the Results Section, on page 105.

Site Y: Data

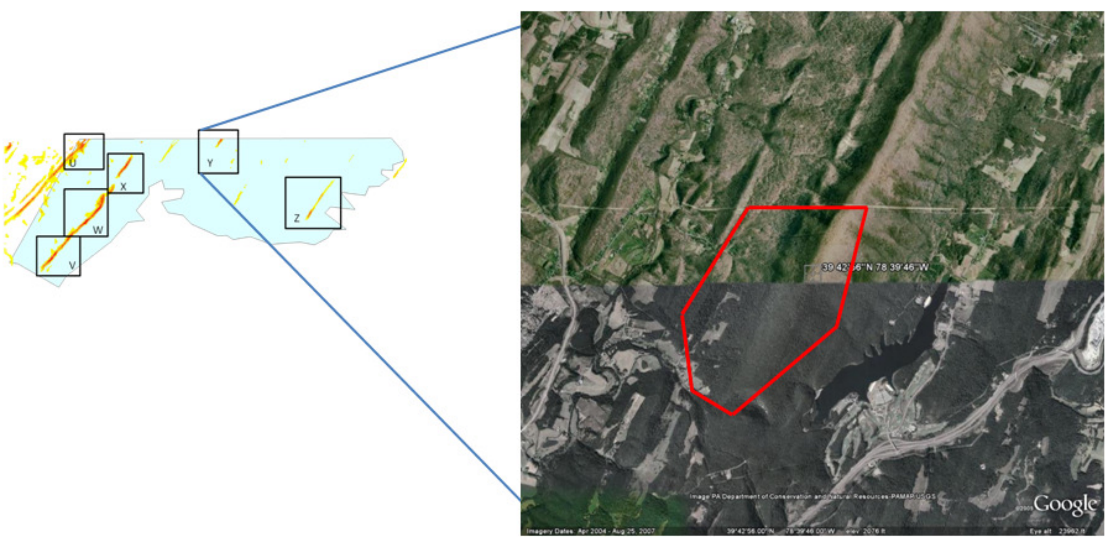


Figure 164: Aerial image of Site Y

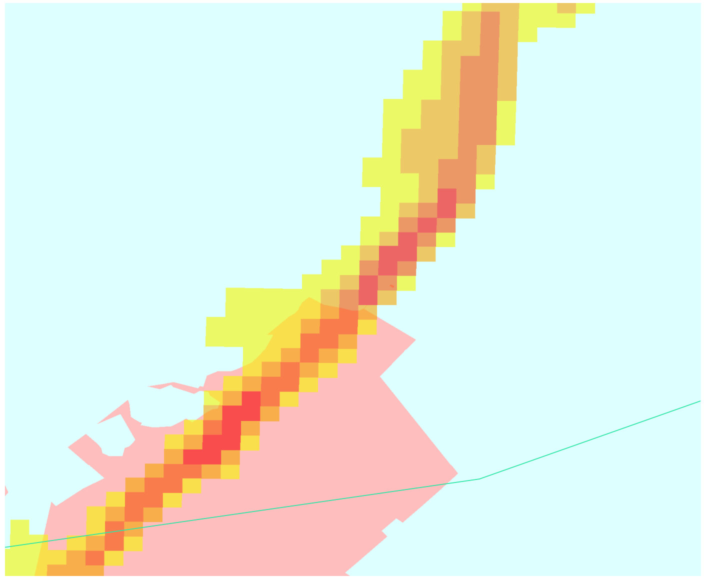


Figure 165: GIS Image of Site Y

Table 59: Overall Site Suitability Scoring Matrix for Site Y

		Allegany County Site Y																			
		Characterization				Site Suitability							Energy Availability								
						Infrastructure			Environmental		Social										
		Central Point information	Latitude	Longitude	Elevation	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region Y1	Value		39°42'56" N	78°39'46" W		116-138	6.25	1.4	x	x	x		2.7	0.75	x	7	11	0.2386		1.5	2.625	**1.4955**
	Ranking					3	3	5	2.5	3	5	1.4903	x	x	1.75	x	x	2	x	x	0	
	Weight	x	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit					kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	13,650,000	81.3%
Other	$	3,150,000	18.8%
Total initial costs	$	16,800,000	100.0%
Incentives and grants	$	2,035,646	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	329,748	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	1,299,663	
	$		
Total annual costs	$	1,629,412	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	1,099,161	
	$	27,479	
Total annual savings and income	$	1,126,640	
Financial viability			
Pre-tax IRR - equity	%	4.4%	
Pre-tax IRR - assets	%	0.3%	
Simple payback	yr	18.5	
Equity payback	yr	17.4	

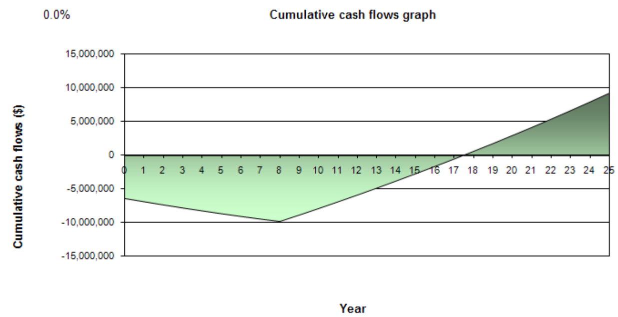


Figure 166: Financial Analysis for Site Y

Site Y – Sub-site 19:

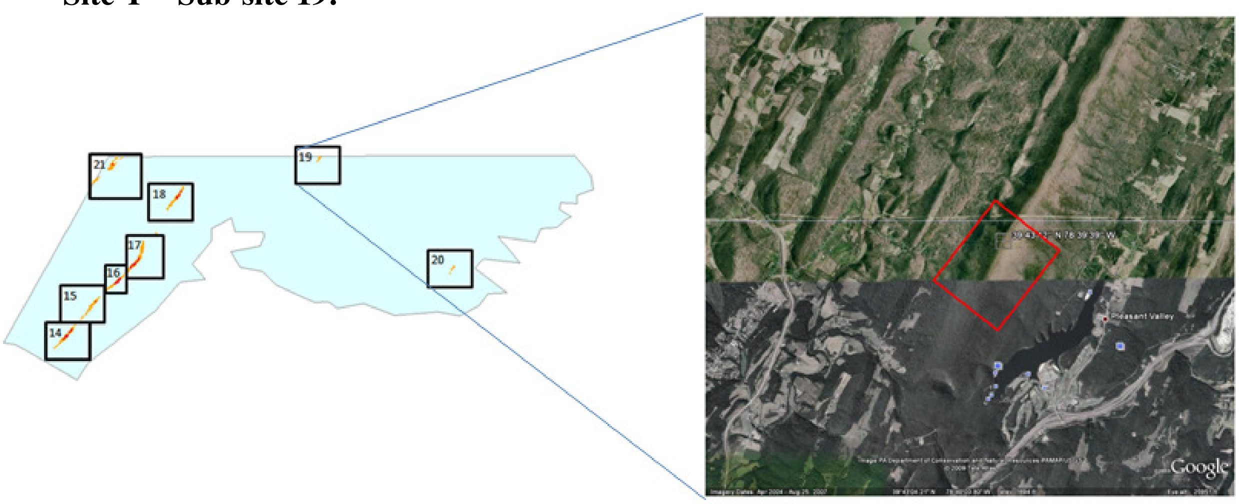


Figure 167: Aerial image of Sub-Site 19

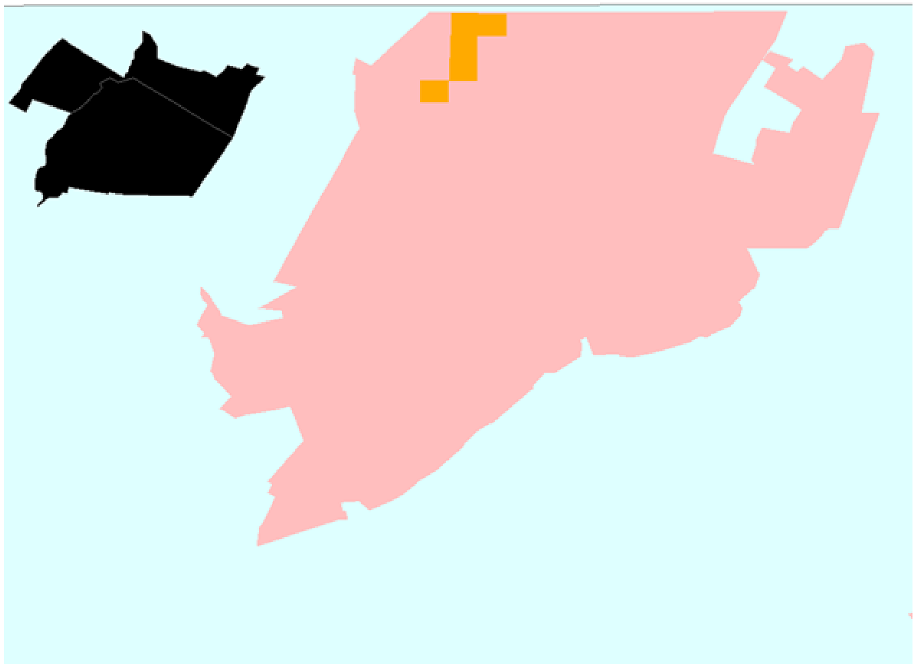


Figure 168: GIS Image of Sub-Site 19

Table 60: Overall Site Suitability Scoring Matrix for Sub-Site 19

		Allegany County Site 19																			
		.			Site Suitability							Energy Availability									
					Infrastructure			Environmental		Social											
		Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 19	Value		39°43'12" N	78°39'39" W	116-138	6.9	1.2	x	x	x	x	0.7	0.3	x	1	3	0.32	100	2.5	0.8	2.5938
	Ranking				3	3	4	2.5	3	3	1.3262	x	x	3	x	x	5	x	x	0	
	Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
	unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	32,500,000	81.3%
Other	$	7,500,000	18.8%
Total initial costs	$	40,000,000	100.0%
Incentives and grants	$	6,489,408	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	1,051,200	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	3,094,436	
	$		
Total annual costs	$	4,145,636	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	3,504,000	
	$	87,600	
Total annual savings and income	$	3,591,600	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

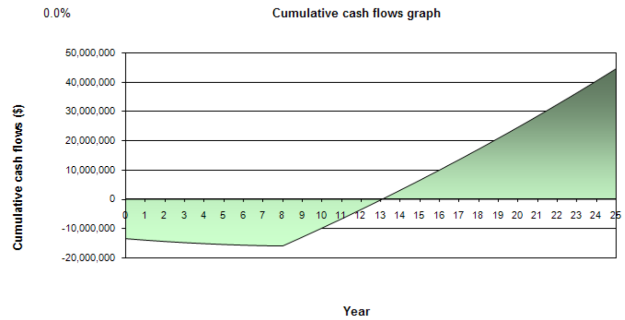


Figure 169: Financial Analysis for Sub-Site 19

Site Z: Data

Figure 170: Aerial image of Site Z

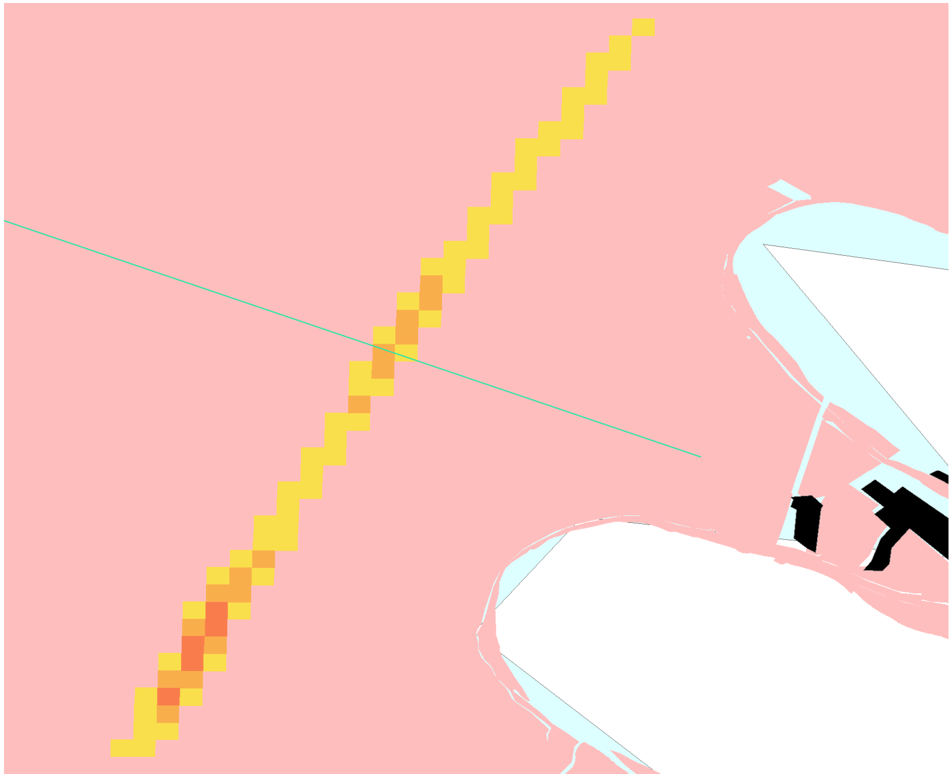


Figure 171: GIS Image of Site Z (Scale 1:40,000)

Table 61: Overall Site Suitability Scoring Matrix for Site Z

	Allegany County Site Z																			
	Characterization			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
Region Z1	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Turbine efficiency	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	**Overall suitability**
Value		39°36'17" N	78°28'22" W	116-138	0.67	1.9	x	x	x	x	9.72	0.6	x	10	25	0.224	100	2.5	5.6	**1.4331**
Ranking				3	5	5	2.5	4	5	1.6339	x	x	1.4	x	x	1	x	x	2	
Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.131	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	32,500,000	81.3%
Other	$	7,500,000	18.8%
Total initial costs	$	40,000,000	100.0%
Incentives and grants	$	4,542,586	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	735,840	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	3,094,436	
	$		
Total annual costs	$	3,830,276	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	2,452,800	
	$	61,320	
Total annual savings and income	$	2,514,120	
Financial viability			
Pre-tax IRR - equity	%	3.6%	
Pre-tax IRR - assets	%	-0.3%	
Simple payback	yr	19.9	
Equity payback	yr	18.5	

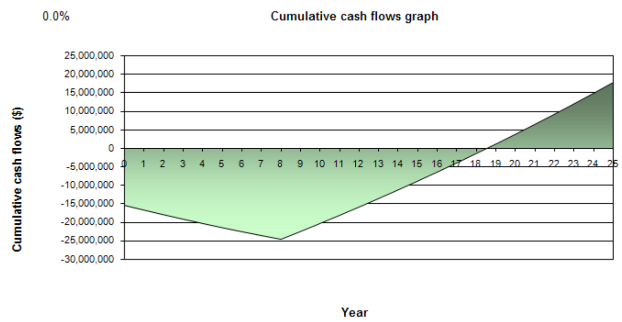


Figure 172: Financial Analysis for Site Z

Site Z – Sub-Site 20:

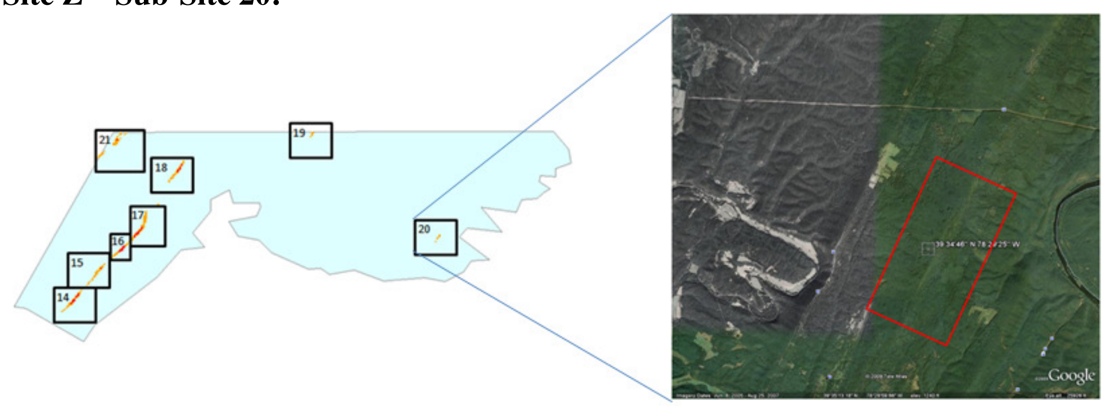


Figure 173: Aerial image of Sub-Site 20

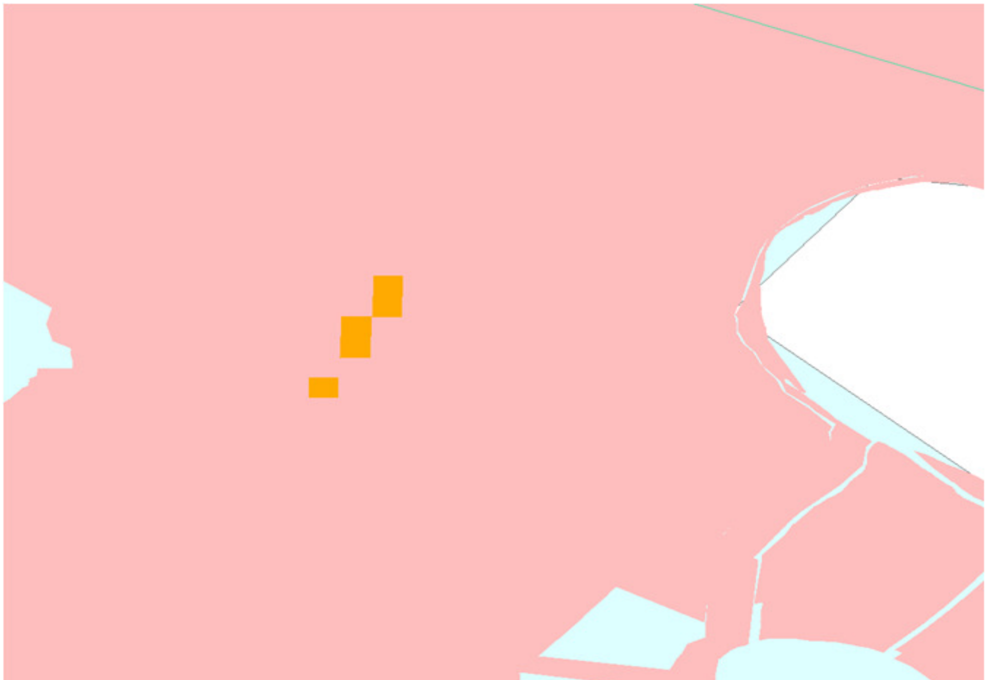


Figure 174: GIS Image of Sub-Site 20

Table 62: Overall Site Suitability Scoring Matrix for Sub-Site 20

	Allegany County Site 20																			
	.			Site Suitability							Energy Availability									
				Infrastructure			Environmental		Social											
	Central Point information	Latitude	Longitude	Grid connectivity (voltage suitability)	Grid connectivity (distance to center)	Road connectivity	Land use Protection	Suitability of land for construction	Nearby populations	Value of site/ area	Mean Length	Mean Width	Wind Speed	Number of turbines	Turbine Power	Capacity Factor	Turbine Rotor Diameter	Type of turbine suitable	Energy generated (turbine optimization method)	Overall suitability
Region 20 Value		39°34'46" N	78°29'25" W	231-500	3.9	1.6	x	x	x	x	0.9	0.2	x	1	2.5	0.32	100	2.5	0.8	2.6931
Region 20 Ranking				5	4	4	2.5	3	5	1.5342	x	x	3	x	x	5	x	x	0	
Region 20 Weight	x	x	x	0.016	0.0366	0.0247	0.2597	0.0704	0.0697	0.4772	x	x	x	x	x	0.3922	x	x	0.1306	
unit				kV	km	km	x	x	x		km	km	m/s	x	MW	x	m	MW	MW	

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	25	
Debt ratio	%	50%	
Debt interest rate	%	5%	
Debt term	yr	8	
Initial costs			
Power system	$	3,250,000	81.3%
Other	$	750,000	18.8%
Total initial costs	$	4,000,000	100.0%
Incentives and grants	$	648,941	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	105,120	
Fuel cost - proposed case	$	0	
Debt payments - 8 yrs	$	309,444	
	$		
Total annual costs	$	414,564	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	350,400	
	$	8,760	
Total annual savings and income	$	359,160	
Financial viability			
Pre-tax IRR - equity	%	8.7%	
Pre-tax IRR - assets	%	3.1%	
Simple payback	yr	13.2	
Equity payback	yr	13.1	

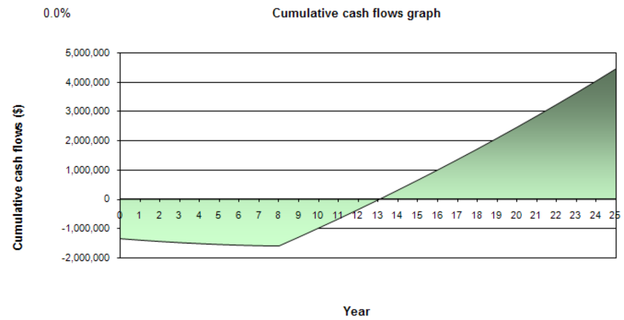


Figure 175: Financial Analysis for Sub-Site 20

MATLAB Algorithm

Below is commented code which can be utilized in MATLAB to calculate turbine count, layout, power production, and capacity factor for GE 1.5 and 2.5 MW turbines.

```
L0=input('Enter length of land strip in kilometers\n'); L=L0*1000;
W0=input('Enter width of land strip in kilometers\n');  W=W0*1000;
Wrank=input('Enter Wind Ranking Value\n');
Wspd = 6+.5*Wrank;
Turbines = [1,1.5,77/2;2,2.5,50];
%Matrix rows: turbine type number, rated power (MW), blade length (m)
%Calculate wind power based on power curves
P(1) = (200*Wspd - 1000)/1000;
P(2) = (300*Wspd - 1450)/1000;
TSize = size(Turbines);
for i=1:TSize(1)
    r=Turbines(i,3);
%Interturbine spacing based on blade length
R=10*r;
%Determine stacking method M = 0 for square, 1 for staggered
Nw0=floor((W-2*r)/(2*R))+1;
Nw1=floor((W-2*r)/(R*sqrt(3)))+1;
if Nw0>=Nw1
    M=0;
    Nw=Nw0;
    Nl=floor((L-2*r)/(2*R))+1;
    N=Nl*Nw;
else
    M=1;
    Nw=Nw1;
    Nl=(floor((L-2*r)/R)+2)/2-0.5; %ends in .5 if different numbers per row
    if (Nl-floor(Nl))==0
        N=Nl*Nw;
    else
        if ((-1)^(abs(Nw)))==-1     %odd
            N=Nl*Nw+0.5;
        elseif ((-1)^(abs(Nw)))==1  %even
            N=Nl*Nw;
        end
    end
end
fprintf('\n');
fprintf('Number of GE %g MW Turbines = %g \n',Turbines(i,2),N);
fprintf('Area = %g km^2 \n',L0*W0);
if M==0
    disp('Rectangle Format')
    fprintf('%g turbines wide by %g turbines long \n',Nw,Nl);
elseif M==1
    disp('Staggered Format')
    fprintf('%g turbines wide by %g turbines long \n',Nw,Nl);
end
fprintf('Rated Power Capacity = %g MW\n',N*Turbines(i,2));
fprintf('Average Power Production = %g MW\n',N*P(i));
fprintf('Capacity Factor = %g %%\n',100*N*P(i)/(N*Turbines(i,2)));
fprintf('\n');
end
```

Figure 176: MATLAB Algorithm

Glossary

ArcGIS: Software allows users to work with GIS data as a means of spatial analysis.

Bald and Golden Eagle Protection Act: A strict liability statute making it illegal to take or possess a protected species. The hunting, pursuit, taking, capturing, killing, possession, sale, purchase, import, export of either species, its nest, or its eggs is grounds for financial penalty and incarceration.

Carbon Neutral: Term commonly used in reference to a process or entity that is responsible for zero net carbon emissions. Though a process or entity may produce directly, or be responsible for, carbon emissions, a net emission of zero may be achieved through other activities which extract or prevent an equivalent amount of carbon from the atmosphere.

Easement: A legal contract restricting activity upon a property, typically enduring in perpetuity. Easements are typically made between a private landholder and a private or public conservation organization. Individual easements may have varying covenants regarding activity upon the property, but typically, land use is restricted to agriculture, forest, or some other "natural" landscape.

EmPower Maryland Initiative: Maryland legislation signed into law in 2007 by Governor Martin O'Malley. It pledges that Maryland will reduce energy consumption 15% by 2015.

Endangered Species Act (ESA): a strict liability statute designed to protect species from extinction. It requires the biological assessment of species to determine if they are threatened or extinct; if they are deemed to be such, they are listed. If a person or organization engages in a "taking" of a listed species, that party faces financial sanctions and possible incarceration.

Environmental impact statement (EIS): a document that federal agencies must complete, as described in the National Environmental Policy Act, before undertaking an action that may affect environmental quality. It outlines the purpose and need of the action, the details of the proposed action, possible alternative actions, and the projected environmental impacts of all actions (proposed and alternative).

Forest Legacy Easements: Easements designed to protect forests from conversion to other uses. The United States Department of Agriculture (USDA) works with state agencies to operate this program. Private forests are targeted for protection. In Maryland, the Maryland Department of Natural Resources is in charge of administering the Forest Legacy Program, and the USDA matches bids for Forest Legacy easements.

Full Protection: Defined in this research as areas that outlaw development or limit it to agricultural or similarly low disturbance activities.

Geographic information systems (GIS): spatial analysis tool that allows users to analyze relationships between geographic characteristics and other attributes through the generation of digital maps.

Habitat Fragmentation: The division of habitat by human development. Construction of infrastructure, commercial establishments, and residential areas breaks apart natural landscapes into discontinuous chunks, which decrease organisms' abilities to access diverse food, habitat, and breeding opportunities. This leads to decreased genetic diversity within populations and can hinder the success of species.

Maryland Agricultural Land Preservation Foundation (MALPF) Easements: Easements ensuring the protection of forests and farmlands from development pressures. MALPF was created in 1977 to protect farms and forests to ensure the continued provision of food and wood for Maryland citizens. The procedure for enrolling one's property in MALPF is a lengthy, competitive process. Once land is enrolled in this easement program, however, it is protected in perpetuity from the pressures of suburban sprawl and development.

Maryland Department of Natural Resource Lands: Lands managed by DNR, which include state forests and state parks. These lands are meant to be held in the public trust for the benefit of Maryland citizens.

Maryland Environmental Trust (MET) Easements: Easements managed by the Maryland Environmental Trust. MET was created to "conserve, improve, stimulate, and perpetuate the aesthetic, natural, health and welfare, scenic, and cultural qualities of the environment, including but not limited to land, water, air, wildlife, scenic qualities, open spaces, buildings or any interests therein." To serve this purpose, MET manages easements donated by private landowners; these donations are tax deductible for landowners.

Maryland Rural Legacy Areas: Large tracts of land in rural uses protected from development. The Rural Legacy Program was founded in 1997. Parties interested in conservation of Maryland lands—land trusts, county governments, and interest groups—work with landowners to target sites as potential Rural Legacy Areas (RLAs). Those parties serve as sponsors for RLAs that they nominate, crafting a long-term conservation and funding plan. Plans are presented to the Rural Legacy Board, which then recommends to the Board of Public Works what sites ought to be designated as RLAs and funded. The Board of Public Works makes the final decision on whether a site is designated as a Rural Legacy Area.

Migratory Bird Treaty Act: A strict liability statute making it illegal to take or possess a protected species. Specifically, it states that it is illegal "to pursue, hunt, take, capture, kill … possess, offer for sale, sell … purchase … ship, export, import … transport or cause to be transported… any migratory bird, any part, nest, or eggs of any such bird … (The Act) prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Department of the Interior."

National Environmental Policy Act (NEPA): A statute signed into law by Richard Nixon in 1970. NEPA holds federal agencies responsible for environmental health by requiring the completion of an environmental impact statement by the acting agency in any case where environmental quality may be affected.

No Conflict: Defined in this research as areas not under the jurisdiction of land protections listed in the methodology section. For the purpose of this analysis, they were assumed to be compatible with development.

Potential Conflict: Defined in this research as areas that feature some limitations on development, but due to uncertainties in policy or discrepancies in level of protection afforded, some development may be acceptable.

Shapefile: The file type of a GIS data layer.

Taking: Defined in Section 9 of the Endangered Species Act as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." "Harm" was later defined as any act altering a species' behavior, breeding habits, or ability to survive in general. A "taking" is illegal under the ESA.

Targeted ecological area: Areas DNR defines as meeting a particular ecological baseline.

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