The Net Benefits of Utility-scale Wind Generated Electricity in Western North Carolina

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1. Introduction

Wind has moved beyond being just a renewable energy source; it has become an economically viable energy source for many areas. Over the past 20 years, the cost of electricity from utility-scale wind systems has decreased over 80 percent. The initial utility-scale systems installed in the early 1980s generated electricity at a cost of 30 cents per kilowatt-hour (kWh). Today, the newest generation of wind turbines for utility-scale systems provides electricity for as low as 4 cents per kWh. Wind has long been the low cost renewable energy source, but now wind is often cost competitive with traditional energy sources.

The decline in cost per kWh along with increased environmental concerns has caused wind energy to be the fastest growing source of electricity in the world. Wind energy generating capacity grew at an annual average of 25 percent between 1990 and 2000, while nuclear, oil and natural gas increased at less than a 2 percent rate, and coal decreased at a 1 percent rate (Worldwatch, 2001). By 2003, global generating capacity exceeded 31,000 MW, providing 65 billion kWh of electricity annually (AWEA, 2003). The U.S. accounted for 18 percent of the global generating capacity, and California and Texas accounted for about two thirds of the U.S. total (AWEA, 2002; USDOE, 2003).

The economic viability of wind power varies across locations based on operating and social factors—including wind speed and variability, land attributes and availability, turbine size and design, viewshed effects, environmental impacts and public policies. These and other factors dictate the benefits and costs associated with a particular project and the net benefits will vary from site to site. Consequently the specificity of a net benefits estimate will be dictated by the generalization of the location. This report examines the benefits and costs associated with wind projects located in western North Carolina. As with any cost-benefits investigation, the analysis attempts to consider and weigh all of the impacts on society associated with the project. The negative impacts are considered costs while the positive impacts are benefits. Naturally, the decision rule is to pursue a project only if the benefits outweigh the costs.

Costs and benefits associated with the project may be categorized as direct or indirect. Direct costs refer to explicit expenditures incurred during production that generally entail a receipt of sale. Examples of such costs include materials, labor, maintenance, lease payments, labor, etc. Direct benefits refer to explicit gains received during consumption, including all residential and commercial activity sustained with energy. One aspect of the direct benefits is that they are independent of the energy source, as is evident in that people are unaware of the energy source consumed from the grid. The direct costs and benefits are the incentives that generate the market for energy producers and consumers. Market activity generates a price that reflects the price rationing value of energy that producers compare with their costs and consumers compare with their benefits.

Indirect costs and benefits are implicit impacts imposed on individuals that may or may not be producers or consumers of the energy. Indirect costs capture the implicit detriment imposed on individuals in which people may or may not be compensated for their loss. Examples of indirect costs include decreases in property values, avian impacts, noise, biodiversity losses, etc. The magnitude of such implicit costs will be dependent on the location of the project. For instance, viewshed impacts will depend on the area's scenic quality and population while avian impacts will depend on how bird migration patterns intersect with the area. Political opposition to a wind farm often arises from the project's expected implicit costs. There have been instances of people being compensated for bearing the implicit costs, which can be argued as appropriate on welfare distributional grounds while also mitigating any political opposition.

Indirect benefits include the implicit gains received by individuals in which those people may or may not pay for directly, such as improved air quality, increased health conditions, etc. These implicit positive impacts provide a primary motivation for the development and use of alternative and renewable energy sources such as wind. Consequently, ignoring these indirect benefits decrease the viability of wind energy, but efforts have been made to allow people to pay for these implicit gains (e.g., green energy programs).

The direct costs and direct benefits are the determinants of the monetary profitability of a wind project from the producers and consumers perspective (i.e., the market). The information on direct impacts provides the necessary information for firms and people to make a profitable decision, but it does not consider society's interests. To examine whether a project is beneficial to society, the indirect costs and benefits must be incorporated into the analysis. Further, understanding the indirect impacts enables policymakers to change institutional rules to internalize these indirect costs and benefits (e.g., green energy programs, tax incentives, etc.) which would establish an energy market that would cause producers and consumers of energy to not only act in their own best interest but also act in the best interest of society.

2. Direct Costs

Direct costs include startup and reoccurring costs. Startup costs are those one-time expenditures incurred during the development of the site, e.g., construction, turbines, roads, permitting, etc. Reoccurring costs include those expenses incurred periodically during the operation of the site, e.g., maintenance, lease, insurance, etc. The following cost information is from a representative 45 MW wind project consisting of 25 Vestas V-80 1.8 MW turbines. The figures provide an approximation and a benchmark to discuss how costs vary with the attributes of the project.

2.1 Startup Costs

Startup costs are grouped into one of four categories: turbine costs, other per turbine costs, construction costs, and soft costs. Turbine costs include the turbine, controller, tower, sales tax, delivery to site, and turbine installation. Other per turbine costs include foundation construction, trafo pad, conduits, grounding, engineering, transformers, monitoring system, FAA lights, electrical installation, roads, grading, fences, permits, and contingency. Per turbine costs vary with the size of the project, and for very large projects which consist of 50 MW or more, it is usual for developers to receive quantity discounts from the turbine supplier. Although our hypothetical project does nearly meet that scale, we have not assumed any quantity discount in our per turbine cost. Construction costs include overhead lines, substation construction, reseeding, engineering (civil, tower, electrical, zone change), construction management, and spare parts. We have also included soft costs, which consist of legal fees, technical review, construction insurance, meteorologist fees, and development costs. These soft costs do not change significantly with project size, and thus as a wind project grows, the soft cost per turbine decreases.

Table 2 provides the estimated total and per turbine direct construction costs for the hypothetical project (Giusana, 2002). The total cost of the project is estimated at $52, 246, 875 which translates into a per turbine cost of 2,089,875 dollars. Examining the subcategories of the startup costs, the figures indicate that turbine and other per turbine costs comprise over 90 percent of the total and per turbine startup costs. Further, the expense of the turbine and tower represents approximately 70 percent of the total and per turbine startup costs. This corresponds to an industry generalization that turbine and tower installation is approximately $1,000 per kilowatt electrical power—less than half the cost in the early 1980s (Reeves, 2003). Therefore the construction cost associated with variants of the benchmark example will vary $1000 per kW.

The reported figures presume the existence of developed roads that lead to the general site area. Access roads are generally 18 to 20 feet wide and consist of compacted rock. If there are not roads present, the cost of developing new roads for a project generally comprises a trivial share of the project cost even considering the relative difficulty of developing roads in the mountainous region of western North Carolina. The cost numbers also presume the existence of transmission lines within the project site area, and the presence of a substation within the area. If there are no existing transmission lines within the project area, the cost of developing new 345 Kv lines varies from $350,000 to $500,000 per mile (Giusana, 2002). Often the best locations for wind turbines lack transmission lines and the process to construct new lines is a lengthy and difficult process due to obtaining right of ways and dealing with environmental concerns. The cost figures also presume the typical case of land acquisition occurring through leases rather than purchases. Land leases therefore contribute to a project's recurring costs. In the case of purchasing, the illustrative 45 MW project would require 675 to 1350 acres of land because wind projects generally occupy between 15-30 acres of land per MW of installed capacity. At $5,000/acre price, the illustrative project may require a 3.5 to 7.0 million dollar land acquisition cost (Renville-Sibly, 2003). Whether land is acquired with leases or purchases, the land values in western North Carolina vary widely with many areas having prices high relative to national averages. The cost of land leases and purchases therefore will vary depending on the specific site, though such costs make up a small share of total costs.

The startup costs associated with wind projects generally account for 70 percent of the total cost of energy and is typically about $1000 per kW of generating capacity. While the upfront capital costs are significantly greater than fossil-fueled generation projects, wind projects avoid the continued fuel costs over the life of a fossil-fuel project (Reeves, 2003).

2.2. Reoccurring Costs

Reoccurring direct costs include those expenses that arise periodically, such as land lease, property taxes, scheduled maintenance, park maintenance, substation maintenance, management, insurance, electricity usage, unscheduled maintenance, miscellaneous costs, and warranty costs. Table 3 summarizes the reoccurring costs (Giusana, 2002). The various forms of maintenance costs, including scheduled, unscheduled, park and substation maintenance, generates approximately $66,000 of cost per turbine and $1,650,000 for the project. Maintenance costs for newer generations of turbines generally range between 1.5 and 2.0 percent of the initial capital investment, and as one may expect such costs are relatively low at the beginning and increase over the life of the project. Maintenance costs typically account for approximately 20 percent of the total cost of energy with a larger proportion arising from unscheduled, but statistically predictable, maintenance. Maintenance costs are roughly proportional to energy production and experience reveals that such costs are about $0.005 per kWh (Reeves, 2003).

Management and insurance impose costs of about $22,000 per turbine and $550,000 for the project. Warranty costs will substitute for the scheduled and unscheduled costs during the initial two years of the project. This reduces the total maintenance cost by $26,000, which translates into a $650,000 decrease in expenses during this period.

For land lease cost, we have used a 2% per turbine rate, which is the average amount used throughout the country. This percentage varies from a low of about 1% to a high of about 5%. This translates to an annual lease payment of about $3000 per MW. It is also possible for lease payments to be structured as a fixed per turbine rate. Property tax is assumed to be 1.1 percent which generates $566,466 in expense each period. This figure corresponds to industry approximation of $10,000 in property taxes per MW of generating capacity (Flowers, 2002).

We now address tax considerations, which vary from state to state and project to project. Wind projects in the United States receive very favorable federal and possibly state depreciation status on the capital cost. The cost may be written off over a period of five years on an accelerated basis. The enacted Energy Policy Act of 1992 included the Renewable Electricity Production Credit—also referred to the wind energy Production Tax Credit. The production tax credit provides a per kilowatt-hour credit for the initial 10 years of operation. In 2002, the credit provided approximately 1.8 cents per KWh and will increases each year with inflation according to the consumer price index (CPI). The credit is available during the first 10 years of operation and projects installed by December 31, 2003 qualify, though new legislation may provide an extension.

3. Indirect Costs

Beyond the direct costs incurred by the developer and operator, a wind project will also impose implicit costs on local residents and other members of society. These negative impacts are generally the motivating factors of opposition to wind projects. Indeed, people that are supportive of the development of wind energy may strongly oppose the presence of a project in their area. This is often referred to the NIMBY (not in my backyard) phenomenon. Such behavior is sensible, but it can hinder reaching an optimal decision if the behavior is overvalued or driven by inaccurate information. Accurately determining the indirect costs will enable developers to manage the NIMBY problem in two ways. First, the information will facilitate improved understanding of the negative impacts by local residents and public officials, and therefore increase the chances of rational decisions based on fact rather than irrational decisions based on hearsay. Second, the estimated costs represent the compensation to local residents that would make the project mutually advantageous. Compensating local residents for bearing implicit costs associated with the project not only dramatically reduces local opposition but also provides an equitable solution to sharing the positive net benefits from a viable project.

There are four major categories of implicit negative impacts associated with wind development: noise, viewshed impacts, avian impacts, and other possible considerations. While these types of indirect costs arise for all wind projects, the magnitude of these costs will vary dramatically depending on the size and location of the project. Specifically estimating the costs for projects in western North Carolina requires additional analysis and support. Herein, we identify the indirect costs and provide some discussion and existing data that will provide insights regarding the indirect costs that may confront wind development in western North Carolina.

3.1 Noise

Noise is measured in the logarithmic unit of decibels (dB). Given the logarithmic nature, an increase of 3dB is a noticeable increase in the sound level while an increase of 10dB is interpreted as a doubling of the sound level. When considering the impact on local residents, an A-weighted decibel measure (dBA) is more instructive because it only measures those frequencies that are detected by humans. HUD guidelines have established the upper limit of 65dBA for acceptable residential development and 75dBA for acceptable commercial development. The EPA suggests that noise levels below 55dBA will not adversely impact the health and well-being of individuals. Further, the Federal Interagency Committee on Noise (FICON, 1992) examine the relationship between noise levels and community annoyance and find that noise levels at or below 55dBA will have minimal impact on the community with only four percent of people being highly annoyed.

Two related issues will significantly determine the impact of noise from wind turbines: the size of the local population and the existing activities occurring in the local area. Both will dictate the level of background noise, which will provide the relative benchmark for local residents. In other words, the impact of additional activity that generates noise levels of 50dBA will have less of an impact on an area with background noise levels of 65dBA than one with levels of 45dBA.

The case of a rural setting with low background noise levels will provide an upper bound since it will generate the largest impact per person. We note however that such a situation may provide the lowest aggregate impact since it will affect relatively few people. Background noise levels in a rural setting generally range between 40dBA and 50dBA. How does this compare to the noise levels generated by wind turbines? Naturally it depends on the distance from the turbine—as distance from the turbine increases, the sound level decreases. At the base of the turbine, noise levels due to the operation of the turbine are approximately 100dBA. But moving just 100 meters from the turbine, the sound level falls to 53dBA—well below the limit set by

HUD and less than the lowest threshold set by the EPA. Indeed, the expected noise level just 100 meters from the turbine will correspond to the existing background noise found in most quiet rural settings. Moving 400 meters from the turbine, noise levels are expected to be only 37dBA (SOEDP, 1994). In addition to background noise, other factors such as tonal frequency and topography are important considerations in addition to decibel levels (Global, 2002). Local noise regulation should therefore be set locally to account for the relevant attributes of the area. Table 4 provides two examples of local noise restrictions for wind turbine operations. Most local regulation restrict noise as a relative measure against background noise with limits being 5 to 8 decibels above background noise levels (Global, 2002).

Concerns about noise from wind turbines often arise from stories of unpleasant historical experiences that utilized outdated technology. Advancements in technologies have dramatically reduced the impact of noise on residents living near a wind turbine. Aerodynamic noise has been reduced by an adjustment of blade thickness and orientation on the turbine tower. Noise associated with the mechanical components of wind turbines has also diminished dramatically with new technologies. Surveys generally indicate people feel the wind turbine noise is less intrusive than previously feared (Wolsink, 1988)), but there are cases however in which local residents indicate significant noise problems (UW Extension, 2004; MAIWAG, 2003).

The primary issue in managing the noise issue is establishing the appropriate turbine setback from residential structures. For instance, residents of Lincoln Township (WI) expressed significant displeasure in turbine noise until local officials hired a noise consulting firm to evaluate the noise level. While the wind farm was found to be in compliance of noise limits, insufficient setbacks generated a noise issue by allowing the turbine site to be close to residential structures (UW Extension, 2004). Residents south of Cumbria England have expressed similar complaints concerning four Powergen Renewables wind projects in their villages. Insufficient setbacks have generated noise and other problems which have prompted the residences of four adjacent communities to initiate a series of court actions to remedy their concerns (MAIWAG, 2003). Table 5 provides examples of setbacks imposed for other wind projects that have been more successful in managing the impact of noise. Setbacks are often stated in terms of multiples of structure height. For instance, Alameda County CA set turbine setback from residential structures as three times the structure's height (Global, 2002).

Appropriate setbacks should consider two issues specific to western North Carolina. First, the region is largely rural with low levels of background noise and second, the mountainous terrain may channel and concentrate noise from particular arrangements of turbines. Given appropriate setbacks and current technology, the impact from noise related to wind turbine operation should be low relative to typical commercial development.

3.2 Viewshed

All large scale wind projects will produce a substantial visual impact on the immediate area. This will affect the surrounding residents as well as visitors and passersby. The magnitude of the visual impact will be determined by site-specific attributes such as relative scenic beauty, elevation changes, and the size of the relevant population. Estimating the value of the visual impacts (and noise) can be undertaken by examining the impact of wind farms on property values. The presence and magnitude of any visual impact on the viewshed will be reflected in the market price of the affected properties. While capturing much of the visual impact, property values will not reflect the impact on visitors and passersby. The magnitude of visual impacts will vary across sites, but one must turn to generalizations since it is not possible to undertake such an analysis prior to construction at the site in question.

The dilemma in gaining a general understanding of the impact of wind turbines on local real estate values is issue is the lack of indubitable research on this topic. Much of the past research consists of public opinion surveys rather than collecting and analyzing market data. While public opinion may provide some insight to the issue, research has repeatedly shown that stated preferences may be significantly different than actual preferences. Recent work however is turning towards the more rigorous and accurate methodologies of econometric market analysis. Solid empirical analysis still remains illusive and so does a clear answer to a critical question.

A review of existing empirical work provides mixed evidence that wind turbines have an impact on surrounding property values. Munksgaard and Larsen (1996) report that wind farms in Denmark have a relatively small negative impact on property values. In addition to reporting 13 percent of nearby residents consider the turbines as a nuisance, they estimate the turbines decreased housing prices in the range of \$2,900 to \$16,800. The findings would be more insightful if the authors had reported their findings in real terms. Glenn Schleede of Energy Market and Policy Analysis reports similar findings from a 14-turbine wind farm in Lincoln Wisconsin. Schleede reports that 52 percent of area residents would rather not live within 2 miles of the turbines and more than 50 percent of those living adjacent to the turbines believe the turbines adversely affected their health and safety (Schleede, 2003). Due to the negative effects, the utility eventually purchased adjacent residential properties. Other reports provide additional evidence that wind turbines can significantly lower property values (e.g., Jordal-Jørgensen, 1996 and Pritchard, 2003; Sellars, 2003).

But some studies report wind turbines have no impact on property values. In a study funded by the Washington State Office of Community, the Trade and Economic Development and the Energy Foundation, Dr. Stephen Grover, a senior economist at ECONorthwest, analyzed data from a nation-wide survey of tax assessors in areas with wind turbines and found that views of wind turbines do not negatively affect property values. Similarly, real estate representatives familiar with housing markets among existing wind farms state the wind projects had no impact on property values (RENEWWisconsin, 2000). Sterzinger, Beck and Kostiuk of the Renewable Energy Policy Project examine housing market data to evaluate the wind turbines on property values. Their 2003 report examines housing market data in proximity of wind turbines throughout the country and concludes that wind turbines do not negatively impact property values (Sterzinger et al., 2003). The empirical results however may be questioned on empirical methodology issues shown to be substantially influential to the results (Hamilton and Schwann, 1995).

Much of the research on this topic has utilized survey methodologies and consistently shown support for wind development at the macro level while support is mixed at the micro level. Generally, survey results are consistent with the not-in-my-backyard (NIMBY) phenomenon. Essentially, people would prefer wind energy over traditional sources, but they would prefer either to be elsewhere. The fears however may be unduly influenced by negative stories of old technology or poorly panned projects. While some ex post attitudes about nearby wind farm operations are negative, Wolsink (1988) examined survey data that indicates substantial ex-ante support for a proposed wind project but also finds this support increases ex-post. Fifty-two percent of respondents indicated the project turned out better than expected, while only two percent indicated the project turned out worse than expected. Surveys at other locations generally yield similar results, but there are some instances in which residents feel projects turned out worse than expected—e.g., Lincoln Township, Wisconsin (UW Extension, 2004).

While the impact from wind turbines on local viewsheds and property values has been a topic of interest, the question remains unclear. A draft report of a forthcoming study by The Energy Center of Wisconsin and the Wisconsin Division of Energy suggest previous research fails to accurately assess the impact of wind turbines on property values, and that data limitations may prohibit any reliable estimate (Wisconsin, 2004). More complete analyses for other viewshed obstructions (e.g., transmission lines, decreased open space, and industrial noise) have shown negative impacts on property values (e.g., Hamiton and Schwann, 2001; Peiser and Schwann, 1993), and one would expect that wind turbines could also have a negative impact on property values. The magnitude of the impact is the question, but the answer will certainly be context dependent with the magnitude depending on the degree that property values are determined by the viewshed. For instance, property values in relatively scenic areas are higher all else equal due to the viewshed, and such viewshed premiums can be substantial. Research has shown that vistas can add as much as 150 percent to a property's market value (Rinehart and Pompe, 1999). The level of a viewshed premium will largely dictate how the introduction of wind turbines will impact property values. Given the scenic nature of western North Carolina, the impact of turbines on property values may raise legitimate concerns by property owners. Assuming that the turbines will affect the viewshed of 1000 to 2000 households, an average impact of $20,000 per household would yield an aggregate indirect cost of $20-40 million. It is vital to recognize this value is a one-time cost that is diminished over time relative to the repeated annual values associated with other factors.

Installing turbines that negatively impact property values essentially takes an attribute of the property that the owner paid for within the purchase price. The pareto solution would be to compensate the property owner for this 'taking' and this could be done by transferring some of the social benefits received by the larger population from the wind project to the local population negatively affected by the project. While complex, the approach has been utilized by wind energy developers. In Dunbeath England, developers providing local residents with an annual monetary payment for the life of the project to compensate them for any negative aspects of the project (e.g., noise, viewshed, etc.). FPL Energy proposed to pay an 'impact fee' of 3 million dollars to the Town of Addison Wisconsin as part of its proposal to develop a 28 to 33 turbine wind project (Lawton, 2002). Powergen Renewables provided financial compensation to a fishing club for the negative impacts that turbines caused to adjacent waters. While such a policy of transferring benefits is feasible for any socially optimal project, political issues may impede the implementation of programs. For instance, in the case of FPL Energy and the Town of Addison, state officials investigated whether the proposed impact fee constituted a bribe.

While this approach has merits, the main being making everyone better off without hurting anyone, it should be noted that taking attributes from property owners without compensation is common with all types of development and policies. For instance, commercial development often negatively affects landowners without compensation. The issue is magnified with utility scale wind projects because of the relative size and reach of the visual impacts. As with any development, the level of local opposition will be determined by the proposed site's relative scenic and environmental quality.

3.3 Avian

Avian impacts, or bird kills occur in varying regularity at some farms throughout the country. While there may be negative effects on activities directly related to bird populations (e.g., bird watching), concerns of avian impacts generally revolve around diminished ecosystem services. The issue arose after substantial bird kills were discovered at California's Altamont Pass facility (Howell and Didonato, 1991; Orloff and Flannery, 1992; Howell, 1997). The extensive absolute avian mortality figures raised concern but the figures are less startling considering that over 5,000 turbines exist in the Altamont wind resource area. The primary cause for concern was the avian impact on threatened or endangered species because the area is a primary habitat for birds of prey such as the red-tail hawk and golden eagle (Hunt et al., 1999; Orloff and Flannery, 1996).

The concern was that the impact observed at Altamont Pass would exist at other locations. While the issue has remained a topic of interest, research at other sites around the country (e.g., Colorado, Wyoming, Vermont, and New York) has shown that in most instances wind turbines have a very small impact on local and migratory bird populations (Kerlinger and Curry, 1999; Higgins et al., 1996; McCrary et al., 1986a). In some cases, studies have shown that no avian mortalities resulted from wind turbines in Iowa, Vermont and Pennsylvania (Demastes and Trainer, 2000; Kerlinger, 1997).

Individual research studies have reported the number of bird fatalities per turbine per year to be between 0 at the Searsburg, Vermont (Kerlinger, 1997) and Algona, Iowa (Demastes and Trainer, 2000) sites to 4.45 at the Buffalo Ridge Phase III, Minnesota site (Johnson et al., 2000b). But the high avian mortality rate observed at the Buffalo Ridge Phase III site may be misleading due to a heavy fatality event occurring on a single day. Indeed, avian mortality rates were substantially lower at the Buffalo Ridge Phase I and II sites, 0.88 and 2.27 respectively

(Johnson et al., 2000b). The findings suggest that, on average, there are 1 to 2 bird kills per turbine each year.

The species valuation literature provides insights on the impact of bird kills and habitat destruction on the net benefits of a project. The specific value associated with avian and environmental impacts will be dictated by the attributes of the specific site and affected species. For instance, the value of an impact on plentiful species will differ greatly from equivalent impact on endangered species. In the case of species extinction, the value to prevent kills that led to extinction can be substantial--$1.5 billion in the case of the red-cockaded woodpecker (Watts-Reaves et al., 2000). When the species is able to recover with no long term effect, the value of kills has been estimated at $10 per kill (Olinger, 2003). Evidence indicates that approximately 2 bird kills per year for each turbine. A rough estimate of $25 per kill therefore implies each turbine imposes approximately a $50 indirect annual cost on society due to avian kills. The avian social cost from the proposed 25 turbine 45MW project is estimated at about $1000 per year.

Given approximately 15,000 operational wind turbines in the United States, approximately 35,000 birds die annually due to collision with wind turbines—over 85 percent of which are protected species (Erickson et al., 2001). This finding however should be put in context of the general impact of human structures. In 1979 for instance, avian fatalities associated with colliding with vehicles was estimated to be 2.7 to 96.25 per road mile, which translates to a midpoint estimate of 57.2 million bird deaths annually (Banks, 1979). Updating these figures with recent road and vehicle data suggests the current number of bird deaths due to collision with vehicles exceeds 80 million. Buildings also provide a significant source of avian fatalities. Klem (1990) estimates annual bird fatalities due to collision with buildings approaches

500 million. Therefore bird deaths due to wind turbines are extremely low relative to other human structures. Erickson et al. (2001) estimates that only 0.01 percent of all avian fatalities in the United States are due to wind turbines. Communication towers account for up to 100 times more fatalities (2 percent), while buildings account for up to 50 percent. The relative impacts, of course, are largely due to the relative numbers of structures and will adjust as the number of turbines increase relative to other structures.

Avian impacts essentially may or may not be an issue, largely depending on migration patterns and the risk to threatened or endangered species. Consequently, this is strongly a site-specific issue that is not likely to present a substantial problem—but site-specific research on bird counts and migration patterns is necessary to determine the best course of action regarding avian impacts. In Wyoming, for example, turbines at one facility were deliberately placed back from the edge of a mesa once pre-siting research discovered raptors tended to fly along the ridge or just beyond it (Johnson et al., 2001). Continued efforts are improving the understanding and management of the avian impacts of wind turbines (Anderson et al., 1999; Erickson et al., 2000a). And the threat of litigation over the killing of birds that are protected by the Migratory Bird Treaty and the Endangered Species Act provides incentives for developers to carefully examine this issue prior to development.

3.4 Other considerations

Additional site-specific considerations to consider include erosion, cultural resources, ecology, public lands, and transportation. Erosion is primarily a concern in specific habitats such as desert soils, where the soil tends to erode quickly when it is disturbed and where landscaping is difficult. In most climates, including North Carolina, erosion can easily be avoided through proper installation of the turbines and landscaping techniques. As such, erosion is an impact that is expected to be quite manageable for any project in western North Carolina.

Ecological concerns to consider during siting extend beyond avian impacts. Just as any development, wind projects may entail forest fragmentation that could negatively impact the ecosystem in the area. In addition, construction and operation may alter the ecological balance of vegetation and wildlife. As previously mentioned, this is especially important when development may impact threatened or endangered species. The presence of cultural resources may also present difficulties in select locations. For instance, public lands, historical structures and archeological sites may impede or prohibit development. Estimating the implicit costs associated with these and other nonmarket attributes is feasible but not straightforward.

In the end, the most significant, if not the only significant, indirect cost is likely the impact on property values (i.e., viewshed)—with it possibly being a larger problem in western North Carolina than in most areas due to the region's scenic vistas being such a vital component of its quality of life and economic development. Beyond viewshed impacts, the potential indirect costs or negative impacts should be minimal and not significantly different from typical commercial development in the region.

4. Direct Benefits

The direct benefits of wind-generated energy arise from the activities associated with the consumption of energy, including all residential and commercial power. The preferred measurement of direct benefits is calculated by summing the difference of the consumer's willingness to pay and the market price. This so-called consumer surplus provides the market generated benefits for society. Individual willingness to pay however is difficult to obtain. An alternative and satisfactory method of measuring the direct benefits is to calculate the market value of the electricity—price multiplied by kWh purchased. The market value is the ideal measure for developers because it only considers what consumers pay rather than what they are willing to pay. Because of this, market value understates the consumer surplus because a consumer's willingness to pay may be greater than what they must pay.

A 1.8 MW turbine will supply enough electricity for at least 500 U.S. households, which consume on average 10,000 kWh per year. Using 25 1.8 MW turbines, our project will supply 125 million kWh of electricity to 12,500 U.S. households each year. At a market rate of 7 cents per kWh, this generates annual direct benefits of $8.75 million.

It should be noted that the direct benefits are independent of energy source. Energy from difference sources are perfect substitutes, as is illustrated by the fact all energy (regardless of source) is transmitted and drawn from the same grid. Therefore, in terms of direct benefits, there is no tradeoff faced by society across energy sources. Green energy premiums or subsidies however are not included in the market value calculation because such market adjustments do not reflect the direct benefits of the green energy; rather the premium reflects the indirect benefits.

5. Indirect benefits

Indirect benefits of wind-generated energy largely arise from the welfare increases associated with improvements to non-market factors—including air quality, recreational amenities, health levels, bequest value and ecosystem services. In the market, the indirect benefits of alternative energy sources are often ignored, but the avoidance of health and environmental costs are just as valid and important to society as the avoidance of capital costs. If such indirect benefits are ignored, energy resources will be allocated inappropriately—relatively too much fuel generated energy and too little wind generated energy. So it is vital for society's well-being that the indirect benefits are incorporated in the electricity market, which would lead to a more appropriate use of energy resources. Policies and programs are available to policymakers to do just that. Examples include subsidies such as tax credits for wind energy and green energy programs that allow consumers to pay a premium for electrical units generated by renewable energy sources. The difficulty arises in establishing the appropriate value for the subsidies and premiums because the magnitude of the change in relative incentives across energy sources will dictate the relative use of the different sources. This report provides the first estimate of indirect benefits received by state residents from wind generated electricity in western North Carolina. For a more thorough and rigorous presentation of the results, see Cherry and Whitehead (2004).

To estimate the indirect benefits, the study employs a technique firmly grounded within economic valuation research—contingent valuation. Contingent valuation provides a means to estimate non-market benefits by establishing a hypothetical market where people can indicate their preferences and willingness to pay (WTP) (i.e., values). The technique has been used over the last few decades to estimate the total value of many non-market items such as environmental quality, public parks, downtown beautification projects, ecosystem preservation, and health risks. The technique is applied to this study to estimate North Carolina residents' value of the indirect benefits of wind energy generated in western North Carolina. Appendix A provides the technical details of the estimation model and empirical procedure.

The estimation of indirect benefits arising from wind energy revolves around individual stated values and behavior concerning a green energy program that allows people to pay a premium for electrical units generated by renewable sources. By observing stated behavior over varying degrees of premiums and indirect benefits, individual and group indirect benefits from wind energy can be statistically estimated.

Results indicate state residents know very little or nothing about the state's North Carolina Green Power program but were very interested in the program. Seven-seven percent had heard nothing about the program while 88 percent were very or somewhat interested in the program. Further, 42 percent indicated they would sign up for the program while 34 percent said they would not. Findings suggest that people were relatively certain of whether they would or would not sign up for the program. The most important reasons for people's willingness to sign up for the program were: better environment (42%), better human health (15%), and for future generations (13%). The most important reasons for people's unwillingness to sign up were: the cost is too high (40%), not enough income (13%), and not trusting the power companies (8%).

The estimated individual value of the indirect benefits arising from wind generated electricity is approximately $12 per month. Results indicate that, on average, electricity consumers are willing to pay $12 more per month for wind generated electricity than electricity from traditional sources. This value represents approximately a 13% increase in the average monthly power bill of respondents. The general individual result can be extrapolated in three ways. First, the indirect benefit for society per 1.8 MW turbine is valued to be approximately $60,000 per year—more generally $33,300/MW/year. Second, the indirect benefit for society arising from the proposed 45 MW project is estimated as $1.5 million per year. And third, the indirect benefits for society exceed $37 million per year if 10 percent of North Carolina households consumed wind generated electricity—which would require approximately 620 1.8MW turbines.

Other indirect benefits often cited include economic development and tax receipts. While the local economy will observe temporary increases in activity during the 6 to 12 months of construction, the long term economic development for the local area will be minimal. Wind plants are generally staffed with one person per 10 to 20 turbines which would translate to only 2 additional local jobs for our illustrative project. A rule of thumb is that temporary increased employment during construction of a utility-scale wind system is 1-2 jobs per MW and permanent operation and maintenance employment is approximately 3 jobs per 75 MW (Flowers, 2002).

Local government tax receipts may represent a significant economic benefit for the local community. Generally, property tax revenue from wind farm development is approximately $10,000 per MW per year (Flowers, 2002). Obviously such increased local tax revenue can increase public services such as education, health and infrastructure (or decrease tax rates). Stallmann, Evans and Jones (2001) examine the potential economic impacts of a wind turbine farm in Pecos County TX and find the local community may realize approximately 4 to 8 million dollars in temporary development during construction and approximately 2 million dollars per year during the life of the project.

6. Net Benefits and Conclusion

The analysis now moves from general identifications of the flows of benefits and costs to a specific comparison to arrive at a broad estimate of net benefits for wind projects in western North Carolina. Estimating the net benefit of a 20 year project entails comparing benefit and cost values over the life of the project. Benefit and cost flows may be a one time event (e.g., construction) or a reoccurring event (operation and maintenance). For an accurate comparison, future values must be discounted to allow for comparison in present or current value terms. Choice of the discount rate therefore can influence the final estimate—lower rates will place more weight on future values. This issue is especially critical when evaluating wind projects because costs are realized up front while the benefits are realized over time. The analysis initially uses a 4 percent discount rate, but a discussion is provided on how alternative rates alter the findings.

Table 6 provides a summary of the nominal (non-discounted) benefit and cost flows over the life of the proposed project. The reported values are given in their respective year of the project with some being one-time and others being reoccurring. The derivations of the values are discussed in detail in the preceding sections. Discounted values of the benefit and cost flows are provided in table 7. Aggregating the costs reveals that the project has approximately $121 million in costs and approximately $139 million in benefits. The project is therefore estimated to generate nearly $18 million in positive net benefits. From a social standpoint, the project provides positive net benefits and should be undertaken. The question is less clear for the developer. With $20 million of the benefits arising from indirect sources such as environmental and health, the financial viability of the project depends on the internalization of these benefits in the market. This is achieved with subsidies and green power programs. Our results show that implementation of subsidies and green power programs is not only appropriate but may be necessary for wind energy development.

Now consider some variations of the factors determining the net benefit estimate. Each variant is considered in isolation relative to the baseline estimate of $18 million. Inferring how combinations of the variants alter the baseline estimate can be done by merging the individual impacts. First, varying the discount rate can substantially influence the estimated net benefits of the project. If the discount rate is set at 6 percent, net benefits of the project are estimated at approximately $6 million. And with an 8 percent rate, net benefits are projected to be negative—nearly $10 million.

Second, disentangling the property tax effect may alter the final estimate. This may be of interest if the business interests are not of interest to the decision—e.g., it may be of interest that a NC jurisdiction receives tax revenue while not being of interest that a non-NC company pays the tax liability. Incorporating local property tax revenue as additional benefits from the project causes the estimated net benefits to approach $30 million. Third, lowering the impact on property values by 50 percent changes the estimated net benefits from $18 million to $32 million. This may be warranted due to fewer homes being affected or the viewshed being half as important in determining property values.

Fourth, it may be more appropriate to assume concavity rather than linearity in indirect benefits given the principle of marginal diminishing returns. If so, estimated net benefits will be excessive—possibly substantially so. Ecological production functions particular to a specific site would be needed to calculate specific changes in the estimate. Fifth, avian impacts are insignificant in determining net benefits of the project. Increasing or decreasing the avian impact does not significantly alter the final estimate. Additional variations of the project—such as fewer or smaller turbines—can be calculated from the marginal values provided in the text.

In sum, the proposed project provides a benchmark for evaluating projects of various sizes and different sites. The results indicate that wind generated energy has become a viable consideration as an energy source and may be marginally competitive with current market alternatives. First, consider the developer’s perspective. Only factoring in the direct benefits and costs (i.e., market forces), the illustrative project yields positive net benefits and can generate electricity at approximately 5.8 cents per kWh. Note this estimate does not incorporate any discounts or tax credits and is based on a 4 percent discount rate—which may be low if only considering developer's interests.

Now consider North Carolinian's perspective. Factoring in the direct and indirect impacts, the project may become more viable. But the viability of the project depends on the magnitude of the indirect impacts—primarily the impacts on environmental quality, health, and property values. For instance, the viability of the project improves dramatically if the project affects fewer than 1000 households. Under favorable conditions, however, the illustrative project may generate electricity at a rate as low as 4.7 cents per kWh. Note that the indirect benefits (e.g., environmental and health effects) will accrue to people beyond North Carolina borders, and considering those benefits will only increase the estimated net benefits of the project. Generally, results indicate that wind generated electricity may be a viable undertaking in western North Carolina from the developer's perspective and from North Carolina's perspective.

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Table 1. Estimated Construction Schedule of a Utility-scale Wind Power Plant

Project Categories	Individual Tasks	Category Time	Cumulative Time
Site Prospecting	Wind Resource Assessment Site Use Issues Permitting Financing	19-24 Months	19-24 Months
Site Preparation	Access Roads Foundations Substation/Grid Interconnection O&M Building	2-6 Months	21-30 Months
Turbine Installation	Receive Tower and Turbine Components Set Tower Base Sections Complete Tower Assembly Install Nacelle and Rotor	1-2 Months	22-32 Months
Construction Completion	Complete Internal Turbine Assembly Energize Project Site Commission and Test Turbine Functions	1-2 Months	23-34 Months
Post Construction	Performance Testing	1-3 Months	24-37 Months

Table 2. Startup Costs

Category			Per Turbine	Project
Turbine costs	Turbine, controller		1,175,000	29,375,000
	Tower		250,000	6,250,000
	Sales tax		106,875	2,671,875
	Delivery to site		20,000	500,000
	Turbine installation, including crane		120,000	3,000,000
	Subtotal		1,671,875	41,796,875
Other per turbine costs	Foundation, trafo pad, conduits, grounding,		70,000	1,750,000
	Transformers	1750 KVA 575/35,000 volts	0	0
	Monitoring System		4,000	100,000
	FAA Lights		5,000	125,000
	Electrical installation		40,000	1,000,000
	Roads, grading, fences		30,000	750,000
	Permits		10,000	250,000
	Contingency		100,000	2,500,000
	Total turbine costs		1,930,875	48,271,875
Other construction costs	Overhead lines			100,000
	Substation	40 MVA 35,000/220,000 volts		2,500,000
	Reseeding			25,000
	Engineering, civil, tower, electrical, zone change			150,000
	Construction management			200,000
	Spare Parts			250,000
			129,000	3,225,000
Soft costs	Legal			250,000
	Technical review			100,000
	Construction insurance			100,000
	Meteorologist			50,000
	Development costs			250,000
			30,000	750,000
Total Startup Costs			2,089,875	52,246,875

Table 3. Reoccurring Expenses

Category	Per Turbine	Project
Land Lease	2.00%	Var
Personal Property Tax	1.10%	566,466
Scheduled Maintenance (Start Year 3)	25,000	625,000
Park Maintenance	10,000	250,000
Substation Maintenance/Usage	6,000	150,000
Management	10,000	250,000
Insurance	12,000	300,000
Electricity Usage	1,200	30,000
Unscheduled Maintenance (Start Year 3)	25,000	325,000
Miscellaneous	25,000	625,000
Warranty Costs Years 1 - 2	24,000	600,000

Table 4. Examples of Noise Regulation for Wind Turbine Operations

Location	Noise Regulation
Martinsburg, NY	Noise from individual turbines shall not exceed 50 dbA as measured at the boundaries of all the closest parcels that are owned by non-site owners and abut the site parcels.
Riverside, CA	Noise from individual turbines shall not exceed 50 to 55 decibles depending on size of project and location Certain conditions may trigger an acoustic study Low frequency noise between 5 and 100 hertz s limited to 67 to 75 decibles.

Table 5. Examples of Wind Turbine Setback from Residences/Property Lines

Location	Setback Regulation
Fenner/Stockbridge, NY	1.5 times structure height plus rotor radius from residence
Martinsburg, NY	1500 feet from residence
Alameda County, CA	3 times structure height or 500 feet from residence, whichever is greater
Contra Costa County, CA	3 times structure height or 500 feet from property line, whichever is greater
Cook County, MN	Tower height from property line
Wasco County, OR	5 times rotor diameters from property line

Table 6. Nominal Benefit Cost Estimates

	DIRECT COSTS											INDIRECT COSTS		BENEFITS	
(year of project)	Construction	Land Lease	Warranty	Scheduled Maintenance	Unscheduled Maintenance	Park Maintenance	Substation Maintenance	Management	Insurance	Electricity	Misc	Household	Avian/Envir	Direct	Indirect
(0)	52,246,875	0	0	0	0	0	0	0	0	0	0	30,000,000	0	0	0
(1)	0	135,000	600,000	0	0	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(2)	0	135,000	600,000	0	0	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(3)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(4)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(5)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(6)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(7)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(8)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(9)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(10)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(11)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(12)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(13)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(14)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(15)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(16)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(17)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(18)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(19)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000
(20)	0	135,000	0	625,000	625,000	250,000	150,000	250,000	300,000	30,000	625,000	0	1,500	8,750,000	1,500,000

NOTES:

1. direct benefits is measured with the mkt value and is determined by multiplying the N.C. residential rate multiplied by the average household consumption and the number of houses served by the project
2. indirect benefit of the project is the estimated using the per MW benefit estimate of $33,300 in report
3. indirect cost associated with avian impacts is calculated using data from the literature (3 bird kills per year per turbine and a $20 value per bird)
4. indirect costs for households result from viewshed and noise factors and will arise in property value changes. The calculation conservatively assumes viewshed and noise impacts on 500 houses valued at an average of $25,000 per house.
5. direct costs are derived from table 2 and 3.
6. discount rate is assumed to be 4 percent.
7. The net property tax effect is zero and is omitted for succintness.

Table 7. Present Value of Benefit Cost Estimates

	DIRECT COSTS											INDIRECT COSTS		BENEFITS	
(year of project)	Construction	Land Lease	Warranty	Scheduled Maintenance	Unscheduled Maintenance	Park Maintenance	Substation Maintenance	Management	Insurance	Electricity	Miscellaneous	Household	Avian/Envir	Direct	Indirect
(0)	52,246,875	0	0	0	0	0	0	0	0	0	0	30,000,000	0	0	0
(1)	0	129,808	576,923	0	0	240,385	144,231	240,385	288,462	28,846	600,962	0	1,442	8,413,462	1,442,308
(2)	0	124,815	554,734	0	0	231,139	138,683	231,139	277,367	27,737	577,848	0	1,387	8,089,867	1,386,834
(3)	0	120,015	0	555,623	555,623	222,249	133,349	222,249	266,699	26,670	555,623	0	1,333	7,778,718	1,333,495
(4)	0	115,399	0	534,253	534,253	213,701	128,221	213,701	256,441	25,644	534,253	0	1,282	7,479,537	1,282,206
(5)	0	110,960	0	513,704	513,704	205,482	123,289	205,482	246,578	24,658	513,704	0	1,233	7,191,862	1,232,891
(6)	0	106,692	0	493,947	493,947	197,579	118,547	197,579	237,094	23,709	493,947	0	1,185	6,915,252	1,185,472
(7)	0	102,589	0	474,949	474,949	189,979	113,988	189,979	227,975	22,798	474,949	0	1,140	6,649,281	1,139,877
(8)	0	98,643	0	456,681	456,681	182,673	109,604	182,673	219,207	21,921	456,681	0	1,096	6,393,539	1,096,035
(9)	0	94,849	0	439,117	439,117	175,647	105,388	175,647	210,776	21,078	439,117	0	1,054	6,147,634	1,053,880
(10)	0	91,201	0	422,228	422,228	168,891	101,335	168,891	202,669	20,267	422,228	0	1,013	5,911,186	1,013,346
(11)	0	87,693	0	405,988	405,988	162,395	97,437	162,395	194,874	19,487	405,988	0	974	5,683,833	974,371
(12)	0	84,321	0	390,373	390,373	156,149	93,690	156,149	187,379	18,738	390,373	0	937	5,465,224	936,896
(13)	0	81,078	0	375,359	375,359	150,144	90,086	150,144	180,172	18,017	375,359	0	901	5,255,023	900,861
(14)	0	77,959	0	360,922	360,922	144,369	86,621	144,369	173,243	17,324	360,922	0	866	5,052,907	866,213
(15)	0	74,961	0	347,040	347,040	138,816	83,290	138,816	166,579	16,658	347,040	0	833	4,858,564	832,897
(16)	0	72,078	0	333,693	333,693	133,477	80,086	133,477	160,172	16,017	333,693	0	801	4,671,697	800,862
(17)	0	69,305	0	320,858	320,858	128,343	77,006	128,343	154,012	15,401	320,858	0	770	4,492,016	770,060
(18)	0	66,640	0	308,518	308,518	123,407	74,044	123,407	148,088	14,809	308,518	0	740	4,319,246	740,442
(19)	0	64,077	0	296,652	296,652	118,661	71,196	118,661	142,393	14,239	296,652	0	712	4,153,121	711,964
(20)	0	61,612	0	285,242	285,242	114,097	68,458	114,097	136,916	13,692	285,242	0	685	3,993,386	684,580
TOTALS	52,246,875	1,834,694	1,131,657	7,315,145	7,315,145	3,397,582	2,038,549	3,397,582	4,077,098	407,710	8,493,954	30,000,000	20,385	118,915,356	20,385,490

TOTAL ESTIMATED COST	121,676,375
TOTAL ESTIMATED BENEFIT	139,300,845
NET BENEFIT ESTIMATE	**17,624,470**

NOTES:

1. direct benefits is measured with the mkt value and is determined by multiplying the N.C. residential rate (Duke Power) multiplied by the average consumption per house and the number of houses served by the project (0.07*10,000*22500)

2. indirect benefit of the project is the estimated using the per MW benefit estimate of $33,300 in report

3. indirect cost associated with avian impacts is calculated using data from the literature (3 bird kills per year per turbine and a $20 value per bird)

4. indirect costs for households result from viewshed and noise factors and will arise in property value changes. The calculation assumes conservatively assumes viewshed and noise impacts on 500 houses valued at an average of $25,000 per house.

5. direct costs are derived from table 2 and 3.

6. discount rate is assumed to be 4 percent.

7. The net property tax effect is zero and is omitted for succintness.