# EVALUATING THE ECONOMICS OF SMALL WIND POWER IN NORTH CAROLINA


by

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April 30, 2010

Masters project submitted in partial fulfillment of the requirements

for the Master of Environmental Management degree in

the Nicholas School of the Environment of Duke University

2010

## Acknowledgements

I would like to express my sincere gratitude to my advisor Dr. Randall Kramer, Nicholas School of the Environment and Earth Sciences, Duke University, for supervising this research project and providing regular feedback and advice; Jared Lawrence from Duke Energy Corporation for his time and data regarding small wind power development; Lena Hansen and Kitty Wang from Rocky Mountain Institute for providing me original thoughts and feedback on small-scale renewable energy policy in the U.S.; and most importantly my best friend Yuechao Wang and my parents, who supported and encouraged me throughout this endeavor.

## Abstract

"Small wind" is defined as wind-powered electric generators with rated capacities of 100 kilowatts (kW) or less. Compared with utility-scale wind systems, small wind enjoys many economic and social advantages including reducing costs of building transmission lines, helping the public reduce peak power demand, diversifying the energy supply portfolio, and increasing regional economic growth.

This Master's Project is designed to evaluate the costs and benefits of small wind systems in North Carolina from the perspective of residents and communities. It establishes a basic Cost Benefit Analysis (CBA) Model to calculate Net Present Value (NPV), Levelized Cost of Energy (LCOE), and Payback Period (PP) of a specific small wind project in Class 3 wind region in North Carolina. The project addresses the impact of a potential carbon tax, a potential state rebate program, and a state tax credit without a cap on the economics of the typical small wind system in North Carolina. The results indicate that a potential carbon tax would not have a significant impact on small wind economics, but the combination of a state rebate program and a non-capped tax credit makes investments in small wind much more attractive. It is  recommended that North Carolina adopt a combination of a state rebate program and a non-capped tax credit to stimulate the development of small-scale wind power.

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## Introduction

Given the growing concerns about energy security and global warming, renewable energy has become one of the main foci of current energy development in the U.S. Among various renewable resources, according to the U.S. Department of Energy, wind power will become a major contributor to America's electricity supply over the next three decades, and the U.S. plans to achieve an ambitious goal: 20% wind energy by 2030.[1] This project will examine the economics of small wind power development in North Carolina.

### *Why Small Wind?*

Two alternatives for developing wind power are utility-scale wind systems and small wind systems. "Small wind" is defined as wind-powered electric generators with rated capacities of 100 kilowatts (kW) or less. An average household requires a wind turbine ranging from 5 to 10 kW to meet the energy needs. A small wind system may include a turbine, tower, inverter, wiring, battery (off-grid), and foundation.[2] This Master's Project will only focus on grid-connected systems, because the current small wind market has become dominated by grid-connected units (in kilowatt base), which combine wind turbine with nearby utilities to establish net metering and require no backup charging batteries.

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[1] The American Wind Energy Association. 20% Wind Energy by 2030: Wind, Backup Power, and Emissions. www.awea.org/pubs/factsheets/Backup_Power.pdf.

[2] The American Wind Energy Association. AWEA Small Wind Turbine Global Market Study 2009.

Compared with utility-scale wind systems, small wind enjoys many economic and social advantages. Above all, there is no need to build long-distance transmission lines for small wind. Long-distance transmission lines associated with utility-scale wind systems will bring many problems for the public. 1) It is hard to address the extremely high expenses; 2) Cost allocation among the company building the lines, the end-users, and the ratepayers is highly disputed; 3) The discrepancy between federal regulations and state regulations makes siting of the lines become a big issue; 4) It usually takes more a decade to build new transmission lines to pave the path for renewable energy.[3] Moreover, developing small wind systems will help the public reduce peak power demand, diversify the energy supply portfolio, and increase regional economic growth. On the other hand, compared with those who buy electricity from utilities, owners of small wind systems enjoy personal energy independence, relief from high and volatile prices of other energy resource, ability to support clean energy, and increased property values. [4]

***Benefits and Costs for the Small Wind Owner, and the Impact of a Carbon Tax***

The main costs for adopting small wind systems mainly are capital costs, including wind turbine, grid connection, developing and engineering costs, licensing procedures, consultancy and permits, and monitoring systems. A small-scale wind system, like utility-scale wind generations, is capital-intentive. The capital costs can be as much as 75%~80% of the total cost of the wind project over its entire lifetime, with variations

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[3] Kate Rowland (2009, July/August). To Build or Not to Build: The Transmission Question. Energy Biz. 6(4), 11. http://www.nxtbook.com/nxtbooks/energycentral/energybiz0709/index.php?startid=11#/12

[4] American Wind Energy Association (2008 September). In the Public Interest How and Why to Permit for Small Wind Systems: A Guide for State and Local Governments

between markets and locations. Other costs are operating and maintenance costs, including provisions for repair and spare parts and maintenance of the electric installation, and federal and state taxes.[5]

On the other hand, the general benefits are mainly the direct benefit coming from the electricity generated by wind. A small-scale wind system can provide part or all of the power needs of a single residence. These benefits highly vary with the price of electricity and annual energy output of the small wind system. The latter depends on average wind speed, the type of the wind turbine, and the height of the site and the tower.[6]

All the above are based on market value, which neglects the emission benefits of wind power. The increasing capacity of wind generation displaces conventional generation, which has an impact on the emissions of carbon dioxide (CO2), sulphur dioxide (SO2), and nitrogen oxides (NOx). Since the magnitude of CO2 emissions is much larger than the other two emissions[7], this Master's Project will focus only on the impact of CO2 emission benefits on the cost and benefit analysis of small wind systems. Here, the project will use a potential carbon tax, to evaluate the benefits that the wind owners can obtain from their support for clean energy instead of conventional energy. Other environmental benefits will be ignored, due to the challenges of estimating them. Also, these are social benefits that do not accrue to the private investor.

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5 Marı´ a Isabel Blanco, The Economics of Wind Energy, *Renewable and Sustainable Energy Reviews* 13 (2009) 1372-1382

6 Marı´ a Isabel Blanco, The Economics of Wind Energy, Renewable and Sustainable Energy Reviews 13 (2009) 1372-1382

7 Eleanor Denny and Mark O'Malley, Quantifying the Total Net Benefits of Grid Integrated Wind, *IEEE Transactions on Power Systems*, VOL. 22, NO. 2, May 2007

Currently, the price of electricity includes none of the costs associated with devastating climate change. This missing element of the electricity price obviously slows down the transformation from conventional "dirty" energy to clean energy. A carbon tax is a tax on the carbon dioxide emissions from burning fossil fuels – coal, oil and gas, which are traditional energy source for electricity. There is growing support from public officials, scientists, economists, and the public for a carbon tax that can be an efficient mechanism for reducing carbon emission[8]. Although a carbon tax should be above a certain level to create the required price incentives, it will need to be phased in to give individuals and businesses the opportunity to adjust. According to the Carbon Tax Center, a tax growing 5-10% annually from a "starter tax" of $37 per ton of carbon, equivalently 10 cents per gallon of gasoline, can create the required price signal.[9] The net benefits and payback period for the small wind owner are expected to be influenced by assumed future carbon tax.

***Incentives for Small Wind in North Carolina***

The US market for small wind turbines grew 78% in 2008.[10] The growth is driven in part by technical advancement and cost improvement, but most importantly, by favorable federal and state economic incentives. The eight-year federal Investment Tax Credit passed by Congress in October 2008 and augmented in February 2009 is equal to 30% of expenditures, with no maximum credit for small wind turbines.[11] Undoubtedly, this new

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[8] Carbon Tax Center: Supporters. Retrieved March 2010, from http://www.carbontax.org/who-supports/.

[9] Carbon Tax Center. Retrieved January 2010, from http://www.carbontax.org.

[10] The American Wind Energy Association. AWEA Small Wind Turbine Global Market Study 2009.

[11] The American Recovery and Reinvestment Act of 2009, enacted in February 2009.

30% federal tax credit will affect the cost and benefit balance for the small wind owners, and thus spur the development of small wind. However, according to a Berkeley Lab analysis based on the Small Wind Analysis Tool (SWAT), under the same federal incentives, small wind economics across states are highly variable due to the type of state financial incentives available. [12]

Figure 1 illustrates the Break-Even Turnkey Cost (BTC) of 10km small wind across 25 states with most favorable small wind economics. BTC is the aggregate installed system cost that would balance total customer payments and revenue over the life of the system. The most economically attractive states, such as New York, California, and New Jersey, are states with cash incentives (either up-front capital rebates or production-based incentives). These states can support small wind with installed cost of over $2.50/Watt. Figure 2 shows that the most economically attractive states are generally the states where state financial incentives make the largest difference.

**Figure 1. BTC of 10kW Small Wind System in 25 States with the Most Favorable Economics, for Wind Classes 2 through 4[13]**

[12] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

[13] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

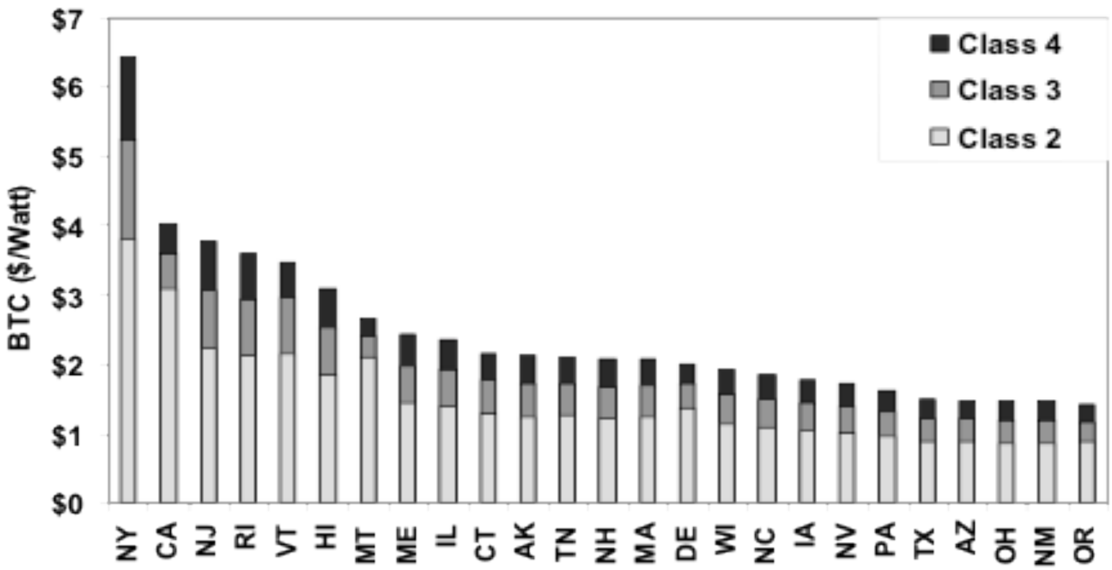
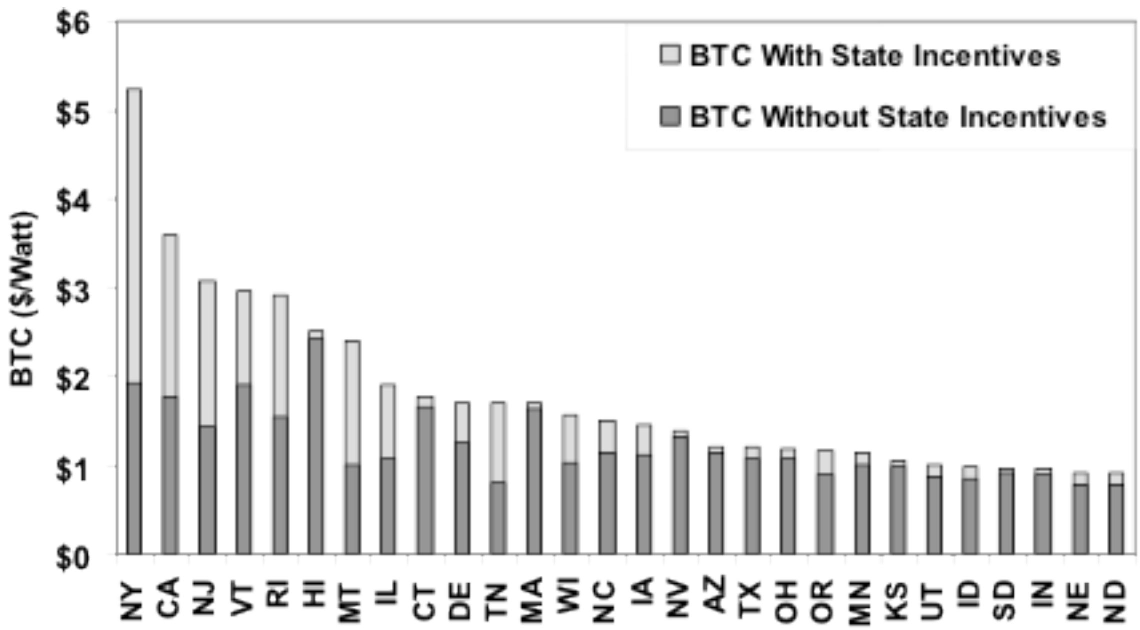



**Figure 2. BTC With and Without State Financial Incentives (Class 3 Resource)**[14]




Compared with states offering the best incentive packages such as New Jersey, New York, Rhode Island, and California, North Carolina does not have favorable state incentives for small wind (Table 1). It can only support small wind in a Class 3 site with

[14] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

installed cost less than $1.50/Watt. The main reason is that North Carolina fails to provide cash incentives, which are essential for increasing small wind economics.

**Table 1. Financial Incentives for Small Wind in North Carolina**[15]

| Financial Incentives | Details |
|---|---|
| Cash Incentives | None |
| State Property Tax Exemptions | None |
| Income Tax Credit (ITC) | 35% with a maximum of $10,500 per installation |
| Low-interest Loan Program | No more than 8% interest rate, and no longer than 15-year loan term |

Moreover, although North Carolina offers the most favorable ITC program in the U.S., it only increases the customer BTC by less than $0.40/Watt in a Class 3 site.[16] The reason is that the cap of $10,500 per installation is limiting for systems above 10kW.

## Objectives

This Master's Project is designed to evaluate costs and benefits of small wind systems in North Carolina from the perspective of residents and communities. The objectives are as follows:

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[15] Database of State Incentives for Renewables & Efficiency. Retrieved January 2010, from http://www.dsireusa.org/incentives/index.cfm?re=1&ee=0&spv=0&st=0&srp=1&state=NC.

[16] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

1. Establish a basic cost and benefit model to calculate the Net Present Value (NPV), Levelized Cost of Energy (LCOE), and Payback Period (PP) for a typical small wind system in the Class 3 wind region in NC;
2. Address the impact of a potential carbon tax, a potential state rebate program, and a state tax credit without a cap on the economics of the typical small wind system in NC; and
3. Provide a set of policy recommendations based on the result of the cost benefit analysis.

## Methodology

The methodology of this Master's Project is composed of three stages. First, an Annual Energy Production(AEP) Model is used to calculate the annual wind production for a typical residential small-scale wind project in Class 3 wind region in western North Carolina. The annual electricity production is essential for estimating the direct benefits coming from small wind. Second, a basic Cost Benefit Analysis (CBA) Model for small wind is designed to calculate Net Present Value (NPV), Levelized Cost of Energy (LCOE), and Payback Period (PP) for a small wind owner, under the available incentives in North Carolina. Last, the basic CBA model is modified to evaluate the impact of an assumed carbon tax, an assumed state rebate program, and a state tax credit without cap on small wind economics.

### *Estimating the Annual Energy Output*

The annual energy output for a typical small wind system in North Carolina is calculated with the Annual Energy Production (AEP) Model.[17] The calculations are for a hypothetical small wind project. The AEP model is designed by SWIIS (Small Wind Industry Implementation Strategy) Consortium to help small wind turbine users to estimate whether or not particular turbines can meet the required Annual Energy Production (AEP) of a project. The assumptions made for the parameters and inputs of the model are mainly based on the geographical features of western NC and a specific small wind turbine.

The AEP Model estimates the annual energy production according to the wind speed probability. Based on wind speed, wind resource is usually categorized into wind power classes ranging from Class 1 (the lowest) to Class 7 (the highest). In general, wind power Class 4 and above at 50 meters are suitable for utility-scale wind generation.[18] For small wind, Class 3 wind can also be regarded as good resource. This Master's Project will only focus on Class 3 wind for small wind generation, since North Carolina is not rich in high level wind power. Figure 3[19] indicates that Class 3 winds and above are mainly concentrated in two regions in North Carolina: the Atlantic coast and the high ridge in western North Carolina. This project locates the hypothetical small wind system in the

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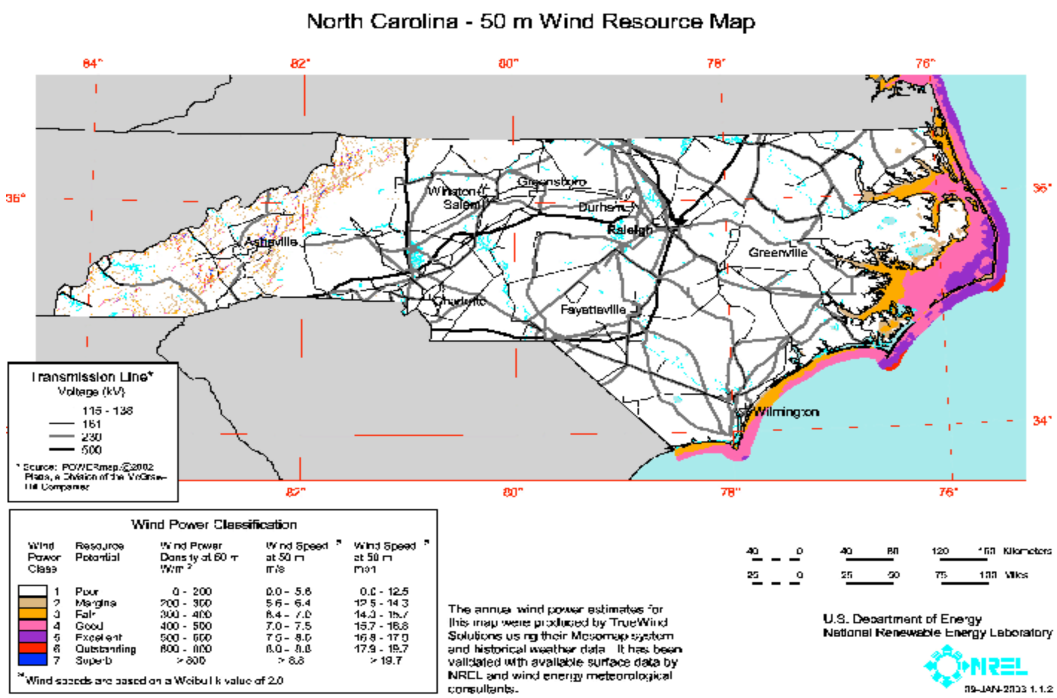
[17] SWIIS (Small Wind Industry Implementation Strategy) Consortium. Retrieved January 2010, from http://www.smallwindindustry.org/index.php?id=124.

[18] Basic Principles of Wind Resource Evaluation. American Wind Energy Association. Retrieve January 2010, from http://www.awea.org/faq/basicwr.html.

[19] North Carolina Wind Resource Map. Wind Powering America. U.S. Department of Energy – Energy Efficiency & Renewable Energy. Retrieved January 2010, from http://www.windpoweringamerica.gov/maps_template.asp?stateab=NC.

Class 3 wind region in western NC. This region is the best area to develop residential small-scale wind systems in NC.

**Figure 3. North Carolina Wind Resource Map – 50 Meter**




Wind speed probability in AEP Model is estimated according to a Weibull curve defined by Annual Mean Wind Speed (AMWS) $V_{mean}$, and a shape factor k. The Weibull distribution offers an approximate model for the probability of natural phenomena. For a long time, the Weibull distribution has been used to model the wind speed distribution due to its flexibility and good fit to experimental data.[20] Basically, a Weibull Model of Wind Speed Distribution can be described as:

$$P(V) = (k/A)*(V/A)^{k-1}*exp(-V/A)^{k})$$

where:

P: Wind Speed Distribution

[20] Isaac Y. F. Lun and Joseph C. Lam (December 1999). A study of Weibull parameters using long-term wind observations. *Renewable Energy* (Volume 20, Issue 2, June 2000).

V: Annual Mean Wind Speed

k: Weibull Shape Parameter

A: Weibull Scale Parameter

The k parameter indicates the shape of the wind data distribution.[21] It ranges from 3 to 5 in trade wind zones.[22] In this Master's Project, based on the wind zone of North Carolina, the k parameter is assumed as 2 for inland small wind systems. A shares the same unit with V. A can be calculated based on V and k:

A=V/(1+(1/k))

For this project, the annual mean wind speed (V) is assumed as 6.5m/s.

Besides Annual Mean Wind Speed and Weibull Shape Parameter, the inputs of the AEP model such as Site Altitude, Wind Shear Exponent, and Turbulence Factor[23] are also assumed based on geographical characteristics of NC. Site Altitude is associated with the reduction of air density. Small wind power generation is proportional to air density. The higher altitude, the lower air density. Topography (Figure 4.)[24] shows that wind power inland Class 3 mainly distributes in the region with an altitude ranging from 300 to 600 meters. For this Master's Project, Site Altitude is assumed as 450 meters.

**Figure 4. North Carolina Elevation Map**

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[21] M. Jafarian, A. Soroudi and M. Ehsan. The Effects of Environmental Parameters on Wind Turbine Power PDF Curve. Department of Electrical Engineering, Sharif University of Technology, Tehran, Iran. 2008 IEEE.

[22] Small Wind Industry Implementation Strategy (SWIIS). Retrieved January 2010, from www.smallwindindustry.org.

[23] Small Wind Industry Implementation Strategy (SWIIS). Retrieved January 2010, from www.smallwindindustry.org.

[24] North Carolina Elevation Map. Retrieved January 2010, from http://www.netstate.com/states/geography/mapcom/nc_mapscom.htm.


The Wind Shear Exponent is assumed as 0.143 for most cases other than very tough or smooth terrain. Here, it is assumed as 0.143. Turbulence Factor is "a derating coefficient for site turbulence, product variability, and other performance influencing factors".[25] Rolling hills or mountainous terrain usually use 0.05 to 0.15 for Turbulence Factor. Here, we use 0.1.

The specific small wind turbine adopted in this Master's Project is a typical grid-connect small wind turbine 10kW BWC EXCEL-S[26], which is America's best selling full-sized residential wind turbine. Both Anemometer Height (m) above ground level and Tower Height are assumed as 30 (m), based on Bergey Windpower dataset. Besides, the

25 Small Wind Industry Implementation Strategy (SWIIS). Retrieved January 2010, from www.smallwindindustry.org.
26 Bergey Windpower. Retrieved January 2010, from http://www.bergey.com/.

parameters for power production in Weibull Performance are correlated with this 10K small wind turbine. The turbine costs approximately $29,500. The costs of the entire system including a turbine, a 30m tower, installation, and grid connection are around $65,000.

The inputs and outputs of the Annual Energy Production (AEP) are summarized in Tables 2 and 3.

**Table 2. Inputs for the Annual Energy Production Model**

| **Inputs** | |
|---|---|
| Average Wind Speed (m/s) | 6.5 |
| Weibull Shape Parameter K | 2 |
| Site Altitude (m) | 450 |
| Wind Shear Exp. | 0.143 |
| Anemometer Height (m) | 30 |
| Tower Height (m) | 30 |
| Turbulence Factor | 0.1% |

**Table 3. The Expected Outcomes from the Annual Energy Production Model**

| Outcomes | Details |
|---|---|
| Hub Average Wind Speed | Corrected wind speed for wind shear<br>*= Ave. Wind *((Tower Height/Anem. Height)^Wind Shear Exp.)* |
| Air Density Factor | The coefficient of reduction from sea level performance<br>*= -(Site Altitude*0.0000918)* |
| Average Output Power (kW) | Average continuous equivalent output of the turbine |

| | |
|---|---|
| Daily Energy Output (kWh) | Average energy produced per day |
| **Annual Energy Output (kWh)** | **Average energy produced annually** |
| Monthly Energy Output (kWh) | Average energy produced per month |
| Percent Operating Time | The time that the turbine produces energy. (Wind Speed Bin larger than 3). |

***Basic Cost Benefit Model for Small-scale Wind System***

The basic model for cost benefit analysis for small wind is established to calculate Net Present Value (NPV), Levelized Cost of Energy (LCOE), and Payback Period (PP) for small wind owners in North Carolina, without carbon tax and state rebate program for small wind in North Carolina. The inputs for this basic model are correlated to the characteristics of BWC Excel-S Wind Turbine, wind energy characteristics in North Carolina, and the policy background in North Carolina.

The outputs of the basic cost benefit cash flow model for a small wind system are indicated as below:

- Net Present Value (NPV)[27]: The NPV measures the change in potential welfare that accrues from investing in the small wind project. It is the additional premium over investment costs for the project, with an assumed discount rate of 0.50% annually[28].

[27] Glenn P. Jenkins & Arnold C. Harberger. *Cost-benefit Analysis of Investment Decisions*. 2003 Edition.
[28] Board of Governors of the Federal Reserve System: Economic Research & Data. Retrieved January 2010, from http://www.federalreserve.gov/econresdata/default.htm.

- Levelized Cost of Energy (LCOE)[29]: The LCOE is the cost of generating a kWh of electricity over the lifetime of the system. It can be used to compare the cost of the electricity generated by small wind and the general electricity price.
- Payback Period (PP): The PP is the number of years it takes a small wind owner to break even the initial investment costs. The PP is usually not a recommended alternatives for cost and benefit analysis, for 1) It measures the time period for a zero NPV but not the size of the NPV; 2) It does not consider the potential follow-up payment after the initial investment. The cost and benefit model for this Master's Project is designed to investigate the PP, because 1) Operating time is diverse and important for small wind projects; 2) It is assumed that there would be no more follow-up payments that would change the PP after the initial investment.

The cash flow for cost and benefit analysis is designed for a residential small wind project at a 30-year period under two circumstances: cash purchase and purchase with financing (loan), which is explained as follows.

**Table 4. The Basic Cost and Benefit Model for the Small Wind Project**

| **Cost & Benefit** | **Details** |
|---|---|
| *Cash In* | |
| Net Energy | The direct benefit coming from the electricity generated by small wind. Since net metering is available in North Carolina, excess turbine electricity output is valued at a full retail rate.[30] |

[29] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

| | |
|---|---|
| | For the first year,<br>= *(Annual Energy Output * (Electricity Cost * (1+Electricity Inflation Rate)^(Year-1)))*(1-Month Installed/12)*<br>For the next 29 years,<br>= *Annual Energy Output * (Electricity Cost * (1+Electricity Inflation Rate)^(Year-1))* |
| *Cash Out* | |
| Initial Investment | The capital cost in year 0.<br>For cash purchase,<br>= *Total Cost * (1-Federal Tax Credit) - Total Cost * (1-Federal Tax Credit)*State Rebate - Total Cost * (1- Federal Tax Credit)*(1-State Rebate)*State Tax Credit*<br>For purchase with financing,<br>= *Down Payment* |
| O & M Costs | Operating and Maintenance Costs increase with the operating year. This project assumes that O & M Costs start from year 6. For a new turbine, O & M Costs are negligibly small at the beginning.<br>For year >=6,<br>= *(Annual Energy Output * O & M Cost) * (1+O & M Inflation Rate)^(Year-1)* |
| Net Depreciation | Modified Accelerated Cost-Recovery System (MACRS) and First-year 50% Bonus Depreciation are assumed not available for residential small-scale wind project. (Bonus Depreciation expired on December 31, 2009.)[31] For this Master's Project, the depreciation for small wind is assumed as 0. |

[30] North Carolina – Net Metering. Incentives/ Policies for Renewable Energy. Retrieved January 2010, from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC05R&re=1&ee=0.

[31] Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008-2009). Federal Incentives/Policies for Renewables & Efficiency. 26 USC § 168. Retrieved January 2010, from http://www.dsireusa.org/documents/Incentives/US06F.htm.

| | |
|---|---|
| Net Loan Payments | For cash purchase, all the capital costs are paid off in Year 0. There are no loan payments in the following years.<br>For purchase with financing, owners of small wind in North Carolina can take the advantage of local low-interest loan program.[32]<br>For the first year,<br>*= IF (Year <= Loan Term, (12-Month Installed)* Net Monthly Payment, 0)*<br>For the next 29 years,<br>*= IF (Year<=Loan Term, IF ((Year-1)=Loan Term, Month Installed * Net Monthly Payment, 12 * Net Monthly Payment), 0)* |

**Table 5. The Inputs for the Basic Cost and Benefit Model**

| Inputs | Assumptions | Details |
|---|---|---|
| Total Installed Cost ($) | $65,000 | The costs of the wind turbine with a 30m tower, installation, and other initial investment.[33] |
| Annual Energy Output (kWh) | See Table 2 | Outputs from the Annual Energy Production Model (AEP) |
| Electricity Cost ($/kWh) | 0.1084 | Average Retail Price of Electricity to Ultimate Customers in North Carolina in Oct-09[34] |
| Electricity Inflation Rate | 2 | General assumption |

32 Local Option – Revolving Loan Program for Renewable Energy and Energy Efficiency. North Carolina Incentives/Policies for Renewable Energy. Retrieved January 2010, from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC76F&re=1&ee=0.

33 http://www.bergey.com.

34 Table 5.6. A. Average Retail Price of Electricity to Ultimate Customer by End-Use Sector, by State, October 2009 and 2008 (Cents per kilowatthour). U.S. Energy Information Administration. Retrieved January 2010, from http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html.

| | | |
|---|---|---|
| (%) | | |
| Loan Down payment (%) | 100 (cash purchase); 10 (purchase with financing) | N/A |
| Down Payment ($) | 35,000 (cash purchase); 3,500 (purchase with financing) | *= Initial Costs * Loan Down payment* |
| Amount of Loan ($) | 0 (cash purchase); 21,000 (purchase with financing) | *= Initial Costs – Down Payment* |
| Interest Rate (%) | 8 | The maximum interest rate for North Carolina Loan Program for small wind.[35] |
| Loan Term (Years) | 8 | N/A |
| Month Installed | 0 | Assume that the wind turbine starts to work as soon as the project begins. |
| Net Federal Tax Rate (%) | 35 | N/A |
| Net State Tax Rate (%) | 8 | N/A |
| O & M Cost ($/kWh) | 0.005 | Estimated input for BWC 10kw |
| O & M Inflation Rate (%) | 3 | Estimated input for BWC 10kw |
| State Rebate (%) | 0 | There is no rebate program for small wind in NC. |
| State Tax Credit ($) | 10,500 | North Carolina offers the most favorable Renewable Energy Tax Credit (Personal) in the U.S. at 35 |

35 Local Option – Revolving Loan Program for Renewable Energy and Energy Efficiency. North Carolina Incentives/Policies for Renewable Energy. Retrieved January 2010, from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC76F&re=1&ee=0.

| | | |
|---|---|---|
| | | percent of the wind system cost and a cap of $10,500.[36] For this project, 35% of *Total Cost * (1-Federal Tax Credit)* exceeds $10,500 (even with the rebate program). Thus, a maximum of $10,500 will be used to represent State Tax Credit. |
| Federal Tax Credit (%) | 30 | Federal Investment Tax Credit, augmented in February 2009[37] |

An intermediate product of this model is Net Monthly Payment (for purchase with financing), which is Monthly Payment deducted by Value of Interest Deduction.

Monthly Payment = *PPMT*[38]*(Interest Rate/100/12, Loan Term*12/2, Loan Term*12, Amount of Loan) + IPMT*[39] *((Interest Rate/100/12, Loan Term*12/2, Loan Term*12, Amount of Loan)*

Value of Interest Deduction = *IPMT (Interest Rate/100/12, Loan Term*12/2, Loan Term*12, Amount of Loan)*(Net Federal Tax Rate/100)*

### ***I. Modified Cost and Benefit Model with the Adoption of Carbon Tax***

In order to consider the benefits that the small wind system owners would obtain for adopting clean energy resource, the basic cost and benefit model is modified to reflect an

[36] Renewable Energy Tax Credit (Personal). North Carolina Incentives/Policies for Renewable Energy. Retrieved January 2010, from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC20F&re=1&ee=0.

[37] The American Recovery and Reinvestment Act of 2009, enacted in February 2009.

[38] PPMT: Returns the payment on the principal for a given period for an investment based on periodic, constant payment, and a constant interest rate.

[39] IPMT: Returns the interest payment for a given period for an investment based on periodic, constant payment, and a constant interest rate.

assumed carbon tax. The forgone payment of carbon tax is regarded as cash in for a small wind project.

It is assumed that electricity consumption per household is 900 kWh per month (10,800 kWh annually), corresponding with 14,796 pounds CO2 emissions.[40] The amount of CO2 emissions is equal to around 4,035 pounds of carbon (2.02 tons). It is very hard to foresee the bottom line on carbon taxes. Although an assumed starter tax of $37 per ton of carbon with an annual increasing rate ranging from 5% to 10% is thought reasonable[41], the overall impact of high carbon tax on lower-income consumers cannot be neglected.[42] Thus, the modified model tests a carbon tax of $10, $25, and $40 with an annual increasing rate of 5% to evaluate the impact of different carbon tax on small wind economics.

***II. Modified Cost and Benefit Model with the Adoption of Rebate Program***

Currently, there is no state rebate program available for a small-scale wind system in North Carolina. It is assumed that up-front cash incentives would have a significant impact on the small wind economics. Thus, the model is modified by adding a presumptive NC rebate program to the existing incentive portfolio to evaluate the impact quantitatively.

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[40] A Look at Residential Energy Consumption in 2001. U.S. Energy Information Administration 2004. http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html.

[41] Carbon Tax Center. www.carbontax.org.

[42] Eliot Metzger (July 2008). Bottom Line on Carbon Taxes. World Resources Institute.

Referring to the existing or previous state rebate program[43] in other states, the state rebate program for NC is assumed as 25% of the initial investment costs.

### *III. Modified Cost Benefit Model with a Non-capped State Tax Credit*

NC offers the most favorable State Tax Credit rate in the nation. However, the credit fails to create great financial incentives to small wind power development due to its cap of $10,500 per installation for residential wind-energy systems.[44] With an assumed upfront cost of $65,000 in this hypothetical 10kW project, a 35% tax credit will be $15,925 after 30% Federal Tax Credit, and will be $11,943 after 30% Federal Tax Credit and hypothetical 25% State Rebate Program in Modified Model II. Thus, the basic model only takes $10,500 as State Tax Credit for the small wind system, which is much smaller than an actual 35% credit. In this modified model, the $10,500 cap will be removed to evaluate the impact of a non-capped 35% State Tax Credit on small wind power economics. The cost reduction due to the credit will be $15,925 in the modified model.

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[43] Database of State Incentives for Renewables & Efficiency. www.dsireusa.org.

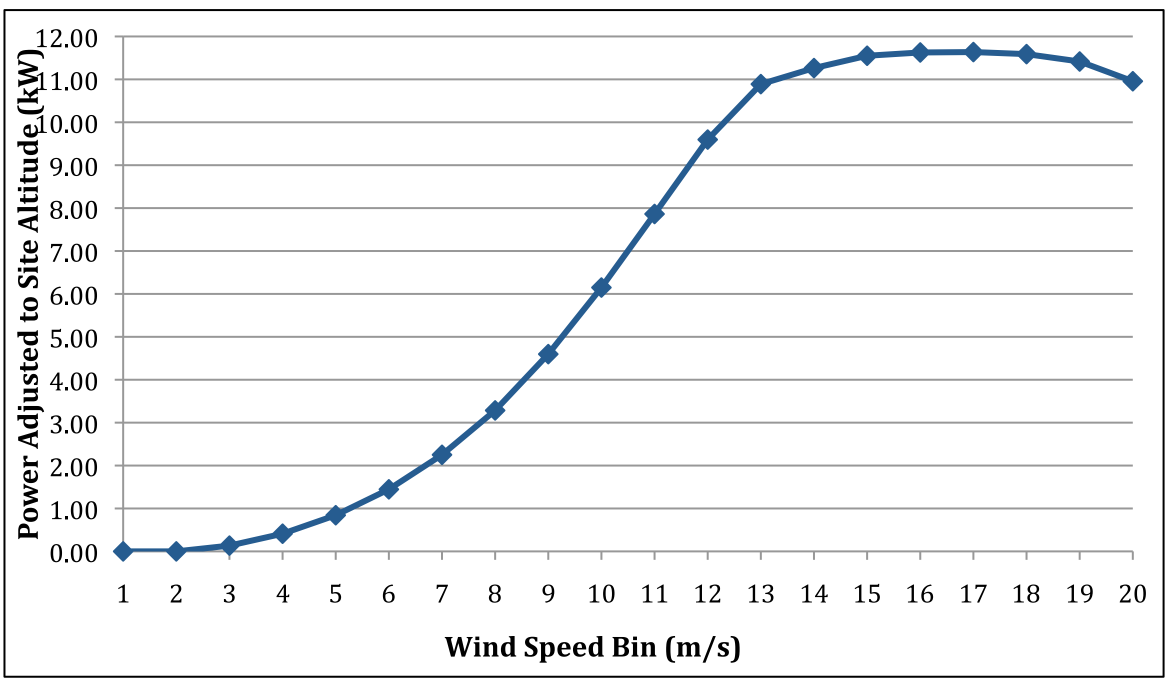
[44] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

## Results

***The Annual Energy Production for the Typical Small Wind System***

The Annual Energy Production Model is used to estimate the annual energy output for the specific small wind system. The first intermediate output is Wind Power Generation (kW) according to each wind speed bin. It shows how much power the small wind turbine can produce with different wind speeds, which is correlated with Turbulence Factor and Air Density Factor. The Wind Power Curve (Figure 5) shows that the wind power increases with the increasing wind speed at the beginning. After it reaches its maximum around Wind Speed Bin 16 and 17[45], the wind power decreases with the continuous increasing wind speed.

**Figure 5. Wind Power Curve for the Small Wind Project with Wind Class 3**

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[45] Wind Speed Bin: the wind range is broken down into "bins" of 1m/s in order to facilitate integration. For each wind speed bin, the model solves the Weibull equation and gives the Weibull wind speed probability percentage of time.

The second-level intermediate outputs for AEP Model are Wind Probability (f) and Output Power (kW) (Table 7). The latter is the product of the former and Wind Power Generation (kW). Wind Probability is correlated with Hub Average Wind Speed (m/s), Weibull K, and Wind Speed Bin (m/s). Due to the impact of wind probability, actual wind power output is much smaller than the initial generation. Moreover, the output power reaches its peak level at Wind Speed Bin 10 but not around 16 and 17.

**Table 6. The Weibull Performance Calculations for the Project**

| Wind Speed Bin (m/s) | Power (kW) | Wind Probability (f) | Output Power (kW) |
|---|---|---|---|
| 1 | 0.00 | 3.68% | 0.000 |
| 2 | 0.00 | 6.96% | 0.000 |
| 3 | 0.13 | 9.50% | 0.013 |
| 4 | 0.41 | 11.11% | 0.046 |
| 5 | 0.84 | 11.73% | 0.099 |
| 6 | 1.45 | 11.46% | 0.166 |
| 7 | 2.25 | 10.47% | 0.236 |
| 8 | 3.29 | 9.04% | 0.297 |
| 9 | 4.60 | 7.39% | 0.340 |
| 10 | 6.15 | 5.75% | 0.354 |
| 11 | 7.86 | 4.27% | 0.336 |
| 12 | 9.60 | 3.02% | 0.290 |
| 13 | 10.89 | 2.05% | 0.223 |
| 14 | 11.26 | 1.33% | 0.150 |
| 15 | 11.55 | 0.83% | 0.096 |
| 16 | 11.63 | 0.49% | 0.057 |
| 17 | 11.64 | 0.28% | 0.033 |
| 18 | 11.59 | 0.16% | 0.018 |
| 19 | 11.42 | 0.08% | 0.009 |
| 20 | 10.96 | 0.04% | 0.005 |
| Total | 127.50 | 99.65% | **2.766** |

The sum of Output Power is Average Output Power (kW). Then we can get our final output Annual Energy Output (kWh) by multiplying Average Output Power with hours. (Table 7)

**Table 7. The Output from the Annual Energy Outputs Model**

| **Outputs** | |
|---|---|
| Hub Average Wind Speed (m/s) = | 6.50 |
| Air Density Factor = | -4% |
| Average Output Power (kW) = | 2.77 |
| Daily Energy Output (kWh) = | 66.4 |
| **Annual Energy Output (kWh) =** | **24,230** |
| Monthly Energy Output (kWh) = | 2,019 |
| Percent Operating Time (%)= | 79.5% |

Based on the outputs in Table 7, a small-scale wind system with Class 3 Wind in western NC is estimated to generate approximately 24,230 kWh annually with most of actual wind output in Wind Speed Bins 3~8. In reality, due to the range of average wind speeds in the Class 3 region and the variability of site altitude, the annual output could be higher or lower.

***Basic Cost Benefit Analysis for the Small Wind Project in NC***

The basic cost benefit analysis for the small wind is done for cash investment and loan investment separately in order to analyze the difference between these two kinds of investments. Moreover, NPV and LCOE are calculated in Year 10, Year 20, and Year 30 respectively in order to evaluate the impact of project timeline on the small wind economics. The cash flow analysis starts in Year 0 (2010). (Appendix I, II)

NPV, LCOE and PP for two kinds of investment are shown in Table 8 and Table 9. Figure 6 and 7 indicate the accumulated NPV in the two kinds of investment according to the timeline.

**Table 8. The Output of the Basic Cost Benefit Model with Cash Investment**

| Outputs | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| NPV ($) | (7,754.61) | 22,946.49 | 58,345.09 |
| LCOE ($) | 0.1474 | 0.0773 | 0.0545 |
| PP (year) | 13 | | |

**Figure 6. Accumulated NPV for a 30-year Small Wind Cash Investment**

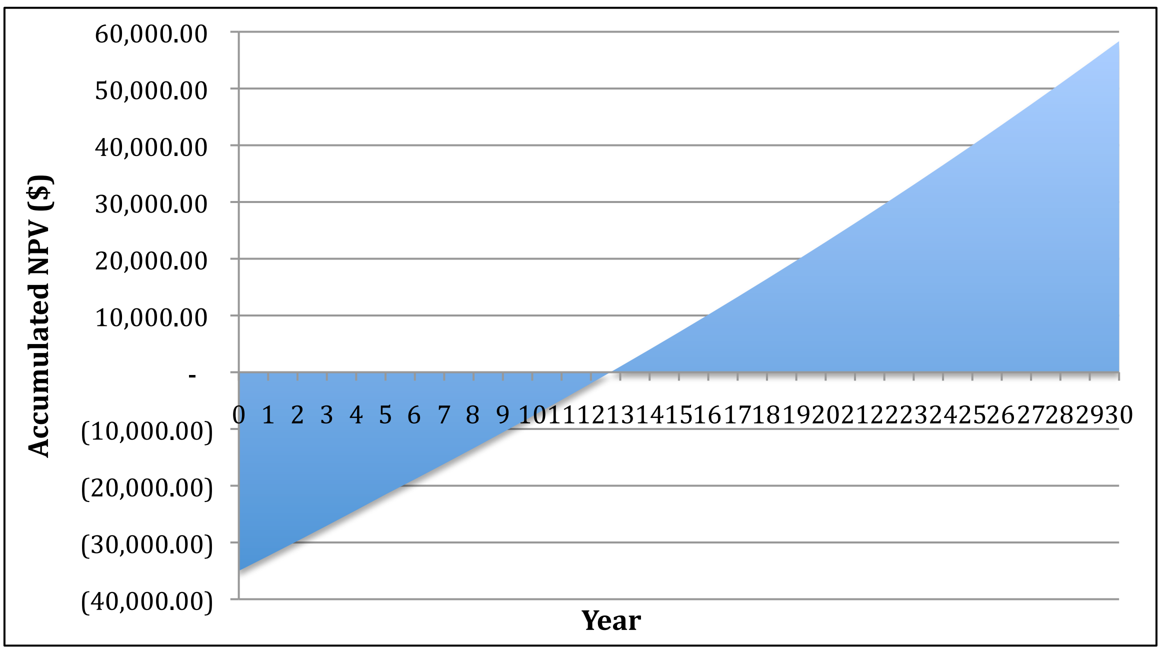



**Table 9. The Output of the Basic Cost Benefit Model with Loan Investment**

| Outputs | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| NPV ($) | ($6,898.73) | $23,802.37 | $59,200.97 |

| | | | |
|---|---|---|---|
| LCOE ($) | 0.1439 | 0.0755 | 0.0534 |
| PP (year) | 13 | | |

**Figure 7. Accumulated NPV for a 30-year Small Wind Loan Investment**

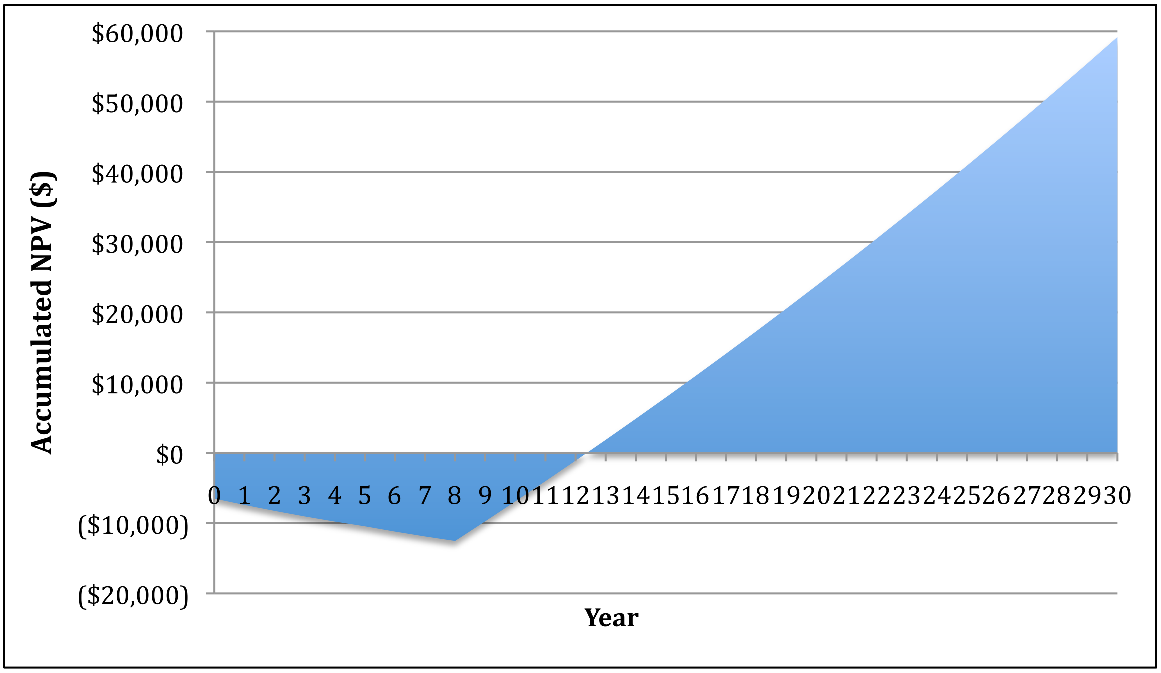



Table 8 and Table 9 indicate that for both cash investment and loan investment, the accumulated NPV is negative in Year 10, and positive in Year 20 and Year 30. While the NPV for cash investment is a straight increasing line (Figure 6), the NPV for loan investment experiences a reduction in the first eight years because of the loan payment, and then starts increasing with a constant rate after that (Figure 7). Payback Periods for both kinds of investments are the same.

As for LCOE, both cash investment and loan investment have a LCOE higher than the retail electricity price in NC in Year 0 ($0.1084/kWh). LCOEs for both investment types appear to be lower than the retail price in Year 20 and Year 30. However, a small wind turbine typically lasts around 20 years[46], so many small wind investors usually will not operate their small wind systems more than 20 years or even 30 years. LCOE decreases to the value almost the same as current electricity price in NC in Year 14 for both cash investment and loan investment. In other words, a small wind investor can obtain a cost of electricity lower than the current retail price if the small wind turbine works for more than 14 years, no matter what kind of investment is made.

***Cost Benefit Analysis with the Adoption of Carbon Tax***

Tables10~12 provide NPV, LCOE, and PP for a small wind system, assuming that the government establishes a carbon tax of $10, $25, and $40 per ton with an increasing rate of 5% annually.

**Table 10. The Output of the Modified CBA Model with a Carbon Tax of $10 per ton**

| **Outputs** | **Year 10** | **Year 20** | **Year 30** |
|---|---|---|---|
| NPV ($) | (7,507.88) | 23,575.57 | 59,566.66 |
| LCOE ($) | 0.1464 | 0.0760 | 0.0529 |
| PP (year) | 13 | | |

**Table 11. The Output of the Modified CBA Model with a Carbon Tax of $25 per ton**

| **Outputs** | **Year 10** | **Year 20** | **Year 30** |
|---|---|---|---|
| NPV ($) | (7,137.78) | 24,519.18 | 61,399.02 |
| LCOE ($) | 0.1449 | 0.0740 | 0.0503 |
| PP (year) | 13 | | |

46 RenewableUK. http://www.bwea.com/small/faq.html#lifetime.

**Table 12. The Output of the Modified CBA Model with a Carbon Tax of $40 per ton**

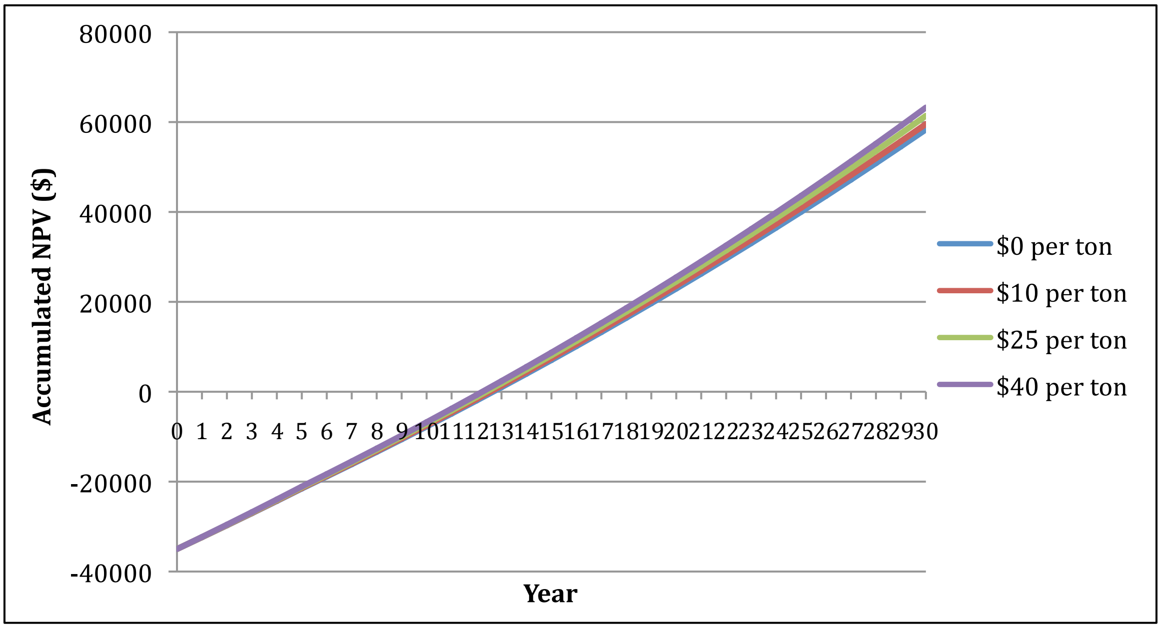
| Outputs | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| NPV ($) | (6,767.69) | 25,462.79 | 63,231.38 |
| LCOE ($) | 0.1433 | 0.0721 | 0.0478 |
| PP (year) | 13 | | |

The results show that the Payback Period with three different carbon taxes remains 13 years, the same as that without a carbon tax. Carbon tax is taken as a benefit for people adopting clean energy due to the avoided tax on electricity not purchased. As expected, the accumulated NPV for each year increases with the increase in the carbon tax (Table 13), although the impact does not seem to be very significant (Figure 8). The impact of the carbon tax on NPV is more significant in the later period of the project than in the earlier period. Compared with the NPV without a carbon tax, the growth rate of NPV in Year 30 reaches 21.97% with a carbon tax of $40 per ton.

**Table 13. The Growth Rate of NPV with Different Carbon Tax Levels**

| Carbon Tax | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| $10 per ton | 3.18% | 2.74% | 2.09% |
| $25 per ton | 7.95% | 6.85% | 5.23% |
| $40 per ton | 12.72% | 10.97% | 21.97% |

**Figure 8. Accumulated NPV with a Carbon Tax of $0, $10, $25, and $40 per ton**




As expected, the LCOE for small wind projects with different operating times decreases with the increase in the carbon tax (Table 14). Similar to NPV, the impact of the carbon tax on LCOE is more significant for a longer project than for a shorter project. Compared with LCOE without the carbon tax, the decline rate of LCOE for a 30-year project reaches 12.30% with a carbon tax of $40 per ton.

**Table 14. The Decline Rate of LCOE with Different Carbon Tax Levels**

| Carbon Tax | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| $10 per ton | -0.68% | -1.68% | -2.94% |
| $25 per ton | -1.67% | -4.27% | -7.71% |
| $40 per ton | -2.78% | -6.73% | -12.30% |

***Cost Benefit Analysis with the Adoption of a Rebate Program***

The assumed rebate program in NC only affects the initial investment of a small wind project. Thus, the 25% initial cash rebate only significantly increases the intercept of the NPV curve at Y-axis (Figure 9). The increase rate of accumulated NPV over time with the rebate program is the same as that without the rebate. The cash rebate decreases the Payback Period to 9 years (Table 15), and increases NPV and decreases LCOE significantly (Table 16). LCOE in Year 10 is lower than the current retail electricity price in NC ($0.1084/kWh). Compared with the outputs of projects with different carbon tax levels, the initial cash rebate has a much greater impact on small wind economics.

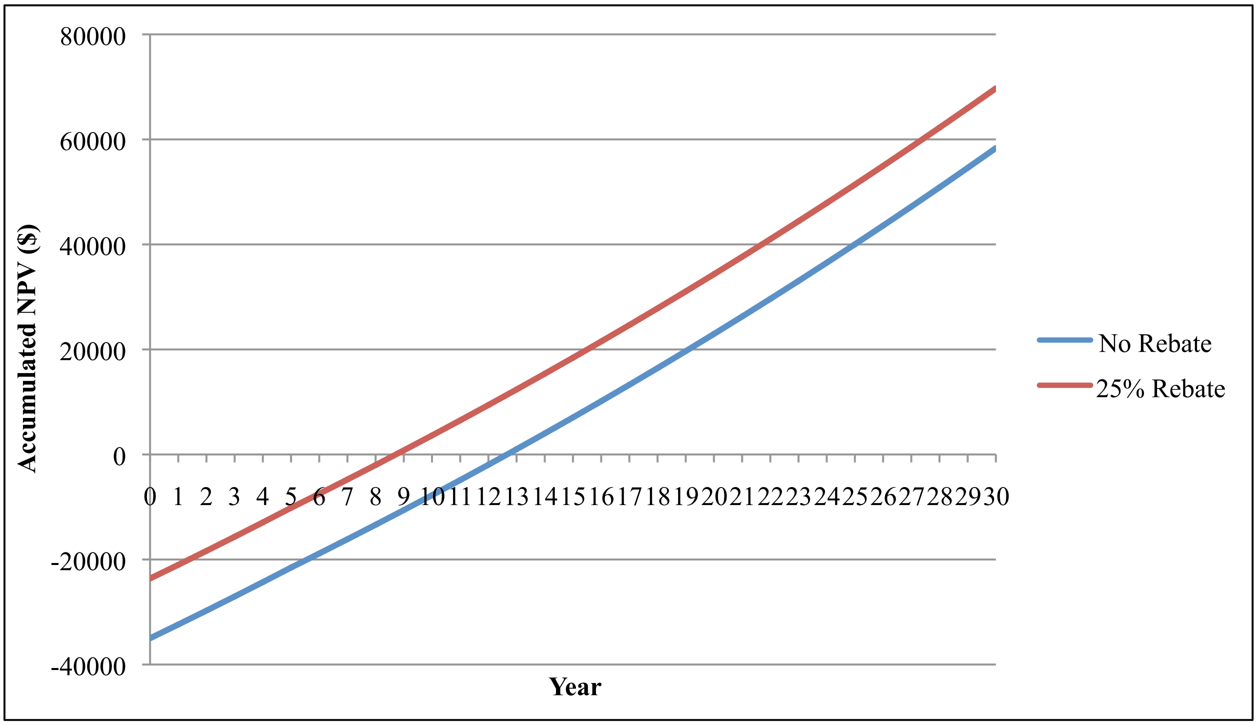
**Table 15. The Output of the Modified CBA Model with 25% Rebate Program**

| Outputs | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| NPV ($) | 3,620.39 | 34,321.49 | 69,720.09 |
| LCOE ($) | 0.1005 | 0.0538 | 0.0389 |
| PP (year) | 9 | | |

**Table 16. The Change of NPV and LCOE with 25% Rebate Program**

| Carbon Tax | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| NPV ($) | 146.69% | 49.57% | 19.50% |
| LCOE ($) | -31.82% | -30.40% | -28.62% |

**Figure 9. Accumulated NPV with a 25% Rebate Program**




***Cost Benefit Analysis with a Non-capped State Tax Credit***

Similar to the effects of the assumed Rebate Program, the non-capped State Tax Credit only has impact on the initial investment of a small wind project. The 35% credit significantly increases the intercept of the NPV curve with the Y-axis by $15,925 (Figure 10). The increased rate of accumulated NPV over time without a tax credit cap is the same as that with capped tax credit. The Payback Period decreases to 11 years after removing the cap (Table 17), and increases NPV and decreases LCOE significantly (Table 18). The impact is less than the cash rebate but greater than the carbon tax.

**Table 17. The Output of the Modified CBA Model with a Non-capped State Tax Credit**

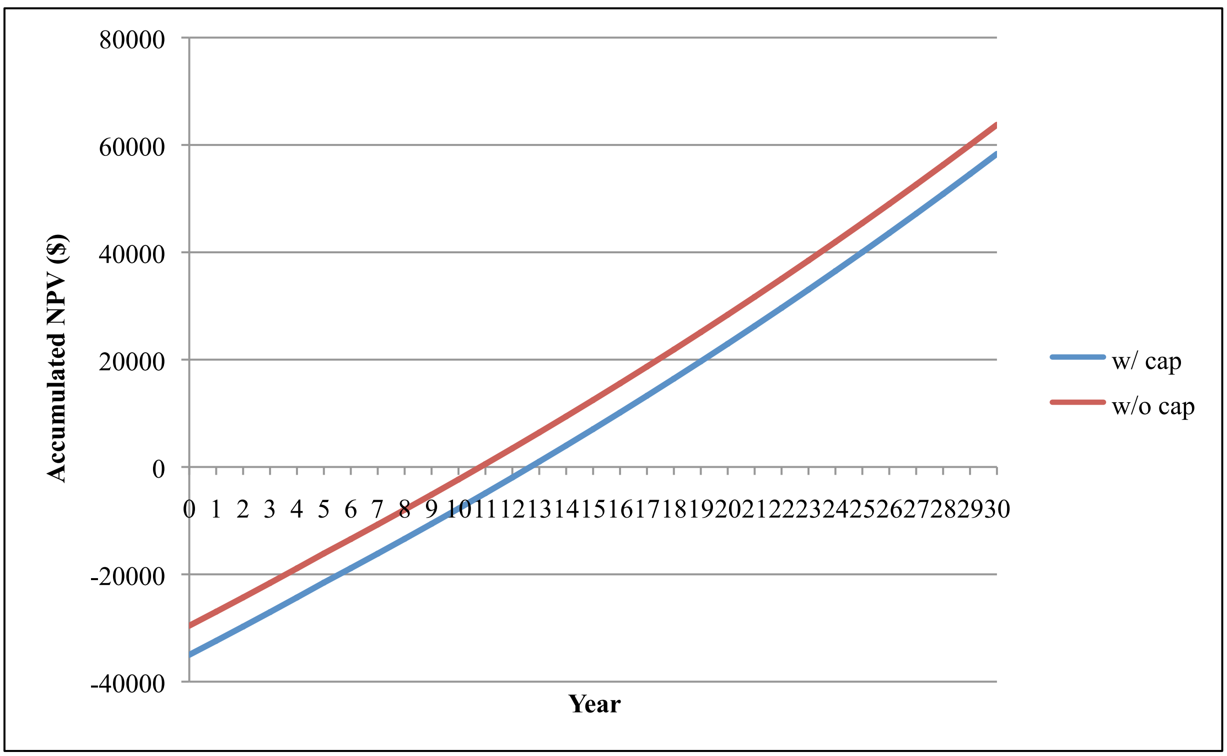
| **Outputs** | **Year 10** | **Year 20** | **Year 30** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| NPV ($) | (2,329.61) | 28,371.49 | 63,770.09 |
| LCOE ($) | 0.1250 | 0.0661 | 0.0471 |
| PP (year) | 11 | | |

**Table 18. The Change of NPV and LCOE with a Non-capped State Tax Credit**

| Carbon Tax | Year 10 | Year 20 | Year 30 |
|---|---|---|---|
| NPV ($) | 69.96% | 23.64% | 9.30% |
| LCOE ($) | -15.20% | -14.49% | -13.58% |

**Figure 10. Accumulated NPV with a Non-capped State Tax Credit**



## Discussion

The hypothetical residential small wind project in this Master's Project is a 10kW small wind system located in a Class 3 wind region in western NC, for an assumed total installed cost of $6.50/Watt. The basic Cost Benefit Model estimates that the Payback Period (PP) for both cash and loan investments is 13 years. The Levelized Cost of Energy for both investments decreases to the electricity retail price in NC in year 14 of the project. The results indicate that there is no obvious difference in small wind economics between cash and loan investments. The estimated LCOE and PP are a bit different from the results of the Berkley Lab analysis in 2004, based on the Small Wind Analysis Tool (Figure 11 and 12)[47]. This Master's Project predicts much better small wind economics than the previous report.

**Figure 11. Cost of Energy Generated by Small Wind by States (Installed Costs of $4.00/Watt and $2.50/Watt, Class 3 Resource)**

[47] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

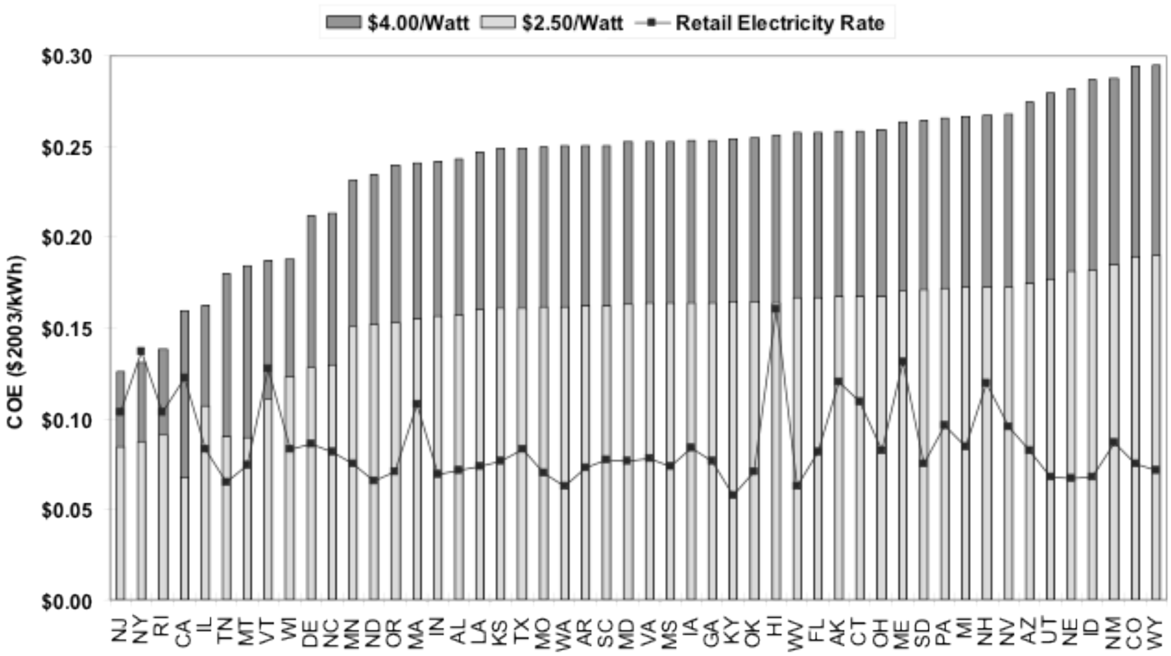
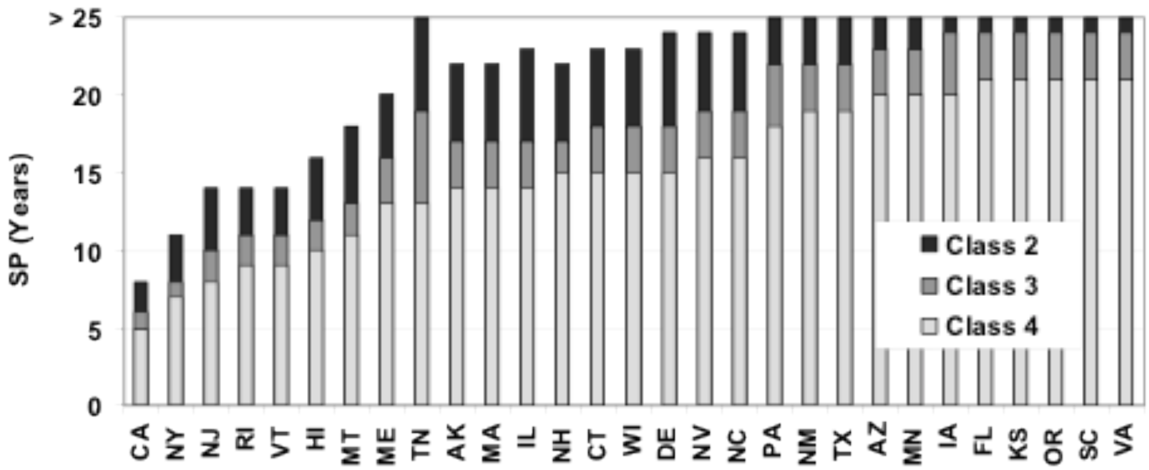



**Figure 12. Payback Period for Small Wind by States (Installed Costs of $2.50/Watt)**




The Berkeley report assumes that the lifetime of a small wind system is 25 years. For this Master's Project, the LCOE with the model for cash investment is only $0.064 in Year 25, much lower than that in the Berkeley report, even though the installed costs in the Master's Project are higher. The Payback Period for Class 3 wind with $2.50/Watt installed cost is around 18 years in the Berkeley report, 5 more years than that in this project. The main reasons for such a large difference are non-capped Federal Investment

Tax Credit augmented in 2009, Net Metering in NC enacted in 2005, and the higher electricity price in NC. The Federal credit allows the taxpayer to claim 30% of qualified expenditures for a residential small wind project, which decreases the upfront investment dramatically. Net Metering creates financial incentives for small wind owners by providing benefits for excess production. Finally, the electricity price in NC in the Berkeley report is the retail price in 2003, which is around $0.08/kWh, more than 25% lower than the current price. The higher price encourages residential electricity users to produce power themselves and makes grid-connected systems more beneficial.

***Factors that Affect the Assumptions of the Cost Benefit Model***

The results of the basic Cost Benefit Model can be affected by two key assumptions. First of all, net metering is a complicated issue. The North Carolina Utilities Commission (NCUC) requires Duke Energy, Progress Energy and Dominion North Carolina Power to make net metering available to small wind owners.[48] It allows small wind owners to use the excess electricity production to offset their electricity use during the other billing time. However, it usually cannot guarantee that all the extra small wind output could be sold at the local retail price because the utilities often buy electricity from small power producer at a "avoided cost", which is lower than the retail price.[49] This situation will definitely decrease the electricity cost savings that the small wind owner can obtain from the production incentive. The savings are highly correlated with the difference between the "avoided cost" and retail cost. It is predicted that the general difference is $10~40 per

[48] North Carolina – Net Metering. Incentives/ Policies for Renewable Energy. Retrieved January 2010, from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC05R&re=1&ee=0.
[49] Bergey Windpower. http://www.bergey.com/School/FAQ.Net-Metering.html.

month for a 10kW small wind system. [50] It is expected that this factor will decrease NPV for the project and increase LCOE and PP.

Second, it is very hard to predict electricity prices. The Model uses an inflation rate of 2 percent, which according to economists is normal retail price inflation. However, electricity prices did not follow the pace of general retail price inflation for many years. While general prices increased at a rate of 2.4 percent per year from 1985 to 2000, electricity prices only increased by 1.1 percent per year.[51] The Consumer Price Index for electricity for the previous year (Jan. 2009~Jan. 2010) is -1.9 percent[52], which shows that the recent electricity price is actually decreasing rather than increasing. This condition is the opposite of the assumption (annual inflation rate of 2 percent) in the Cost Benefit Model. Since only the direct benefit coming from the energy generated by the small wind system is associated with electricity price, NPV will not be as high as that in the predicted Model if the electricity price rises at a rate lower than 2 percent per year or even decreases in the project period. LCOE and PP tend to increase.

***The Impact of a Carbon Tax on Small Wind Economics***

One advantage of a carbon tax over cap-and trade is that a carbon tax makes electricity prices more predictable while the latter may fail to mitigate the price volatility.[53] The stable electricity price will encourage the investments in renewable energy and carbon-

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[50] FAQ – Net-Metering. Bergey Windpower. http://www.bergey.com/School/FAQ.Net-Metering.html
[51] Edison Electric Institute. Rising Electricity Costs: A Challenge for Consumers, Regulators, And Utilities. May 2006.
[52] United States Department of Labor. Bureau of Labor Statistics. Consumer Price Index Summary. February 19, 2010. http://www.bls.gov/news.release/cpi.nr0.htm.
[53] Carbon Tax Center. Retrieved January 2010, from http://www.carbontax.org.

reducing energy efficiency. In other words, a carbon tax is expected to have a positive impact on residential small wind development. However, the results of this Master's Project show that the carbon tax may not make the residential small wind projects more profitable for individuals. The modified cost and benefit model with the adoption of different carbon tax indicates that even a tax of $40 per ton does not change the PP of the hypothetical small wind systems. A carbon tax may have an expected beneficial impact on investment of utility-scale renewable industries, but a carbon tax would have little effect on small wind economics in North Carolina.

***Policy Recommendations on Improving the Economic Feasibility of Small Wind in North Carolina***

The modified Cost Benefit Models in this Master's Project indicate the significant impact of two financial incentives on small wind economics in North Carolina: The State Rebate Program and a non-capped Personal Tax Credit both greatly decrease the initial installation costs. For capital-intensive investments such as small wind projects, the effect is within expectation. Other studies have shown that in places with the combination of a rebate program and a state tax, such as California, small wind system owners can recoup their upfront costs under than 10 years[54]. This Master's Project provides policy recommendation to stimulate small wind development in NC by suggesting the adoption of these two incentives.

54 American Wind Energy Association (AWEA). Small Wind Factsheets. http://www.awea.org/smallwind/toolbox2/factsheets_home.html.

### *I. Appropriate State Rebate Program*

The results show that a potential 25% upfront cost rebate program can reduce PP to 9 years and make LCOE lower than the retail electricity price even with a 10-year small wind project. The Berkeley report confirmed that "State cash incentives – typically structured as rebates on installed system costs – are the most significant individual factor in the economics of residential wind systems."[55] In some states, the addition of the state rebate program more than doubles the net returns to investments in small wind (Figure 10. Edwards L. Dec. 2004)

The CBA model used in this Master's Project assumes a straight 25% rebate program without a cap for NC. In reality, the form of rebate program can be quite flexible. Table 19 shows three rebate programs for other states. Besides a straight cash rebate (e.g. IL), NC could also consider a rebate program with different rates towards different sizes of small wind power (e.g. CA), or with a cap of maximum cash rebate or maximum system size (e.g. WI).

**Table 19. The Existing or Previous State Rebate Program for Small Wind Projects**

| State | State Rebate Program | Details |
|---|---|---|
| CA | Emerging Renewables Program | $2.50/W for first 7.5kW and $1.50/W for increments > 7.5 kW and <30 kW |
| IL | Solar and Wind Energy Rebate Program | 30% of the initial costs |

[55] Jennifer L. Edwards, Ryan Wiser, and Mark Bolinger (December 2004). Evaluating State Markets for Residential Wind Systems: Results from an Economic and Policy Analysis Tool. Ernest Orlando Lawrence Berkeley National Laboratory.

| | | |
|---|---|---|
| WI | Renewable Energy Cash-Back Rewards | Lesser of $35,000 or 25% costs for residential (for wind systems 20 kW or less) |

***II. Removing the Cap on Personal Tax Credit***

Compared with the current state tax credit with a maximum of $10,500 per installation, a tax credit without a cap can reduce the PP of small wind to 11 years. Although the impact of the non-capped tax credit on LCOE is not as great as that of a state rebate program, the resulting improvement in small wind economics is still significant. For a 30-year project, it decreases LCOE by 13.58%. It should be noted that with a 30% Federal Tax Credit there would be no difference between the current credit and a non-capped credit if the initial investment were lower than $23,077. That is to say, if we assume an installed cost of $6.00/Watt, a small wind project with a size smaller than 3.8kW will not be affected by removing the cap on the tax credit. (If the cost is $4.00/Watt, the threshold size is 5.8kW.) Households generally require wind turbines ranging from 5 to 10 kW to meet their energy needs. Thus, removing the State Tax Credit cap will benefit most small wind owners. It can be expected that the current favorable tax credit with a small cap in NC does not create financial incentives for small wind larger than 5kW.

The Berkeley report points out that the states where financial incentives have a significant impact on small wind economics are those that adopt a portfolio of incentives. Further analysis with the addition of both 25% rebate program and non-capped 35% tax credit to the Cost Benefit Model of the hypothetical small wind project indicates that LCOE starts to be less than the retail electricity price in Year 9. This result confirms that the combination of a rebate program and state tax credit can dramatically improve economic feasibility small wind investments in North Carolina.

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Table 5.6. A. Average Retail Price of Electricity to Ultimate Customer by End-Use Sector, by State, October 2009 and 2008 (Cents per kilowatthour). U.S. Energy Information Administration. Retrieved January 2010, from http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html.

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United States Department of Labor. Bureau of Labor Statistics. Consumer Price Index Summary. February 19, 2010. http://www.bls.gov/news.release/cpi.nr0.htm.

## Appendix

### I. Basic Cost Benefit Model for a Small Wind Project with Cash Investment

| Year | Net Energy | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|
| 0 | | | | | ($35,000) | ($35,000) | (35,000.00) |
| 1 | $2,627 | $0 | $0 | $0 | $2,627 | $2,613.46 | (32,386.54) |
| 2 | $2,679 | $0 | $0 | $0 | $2,679 | $2,652.47 | (29,734.06) |
| 3 | $2,733 | $0 | $0 | $0 | $2,733 | $2,692.06 | (27,042.00) |
| 4 | $2,787 | $0 | $0 | $0 | $2,787 | $2,732.24 | (24,309.76) |
| 5 | $2,843 | $0 | $0 | $0 | $2,843 | $2,773.02 | (21,536.74) |
| 6 | $2,900 | ($140) | $0 | $0 | $2,759 | $2,678.10 | (18,858.64) |
| 7 | $2,958 | ($145) | $0 | $0 | $2,813 | $2,716.72 | (16,141.92) |
| 8 | $3,017 | ($149) | $0 | $0 | $2,868 | $2,755.88 | (13,386.04) |
| 9 | $3,077 | ($153) | $0 | $0 | $2,924 | $2,795.58 | (10,590.46) |
| 10 | $3,139 | ($158) | $0 | $0 | $2,981 | $2,835.85 | **(7,754.61)** |
| 11 | $3,202 | ($163) | $0 | $0 | $3,039 | $2,876.68 | (4,877.93) |
| 12 | $3,266 | ($168) | $0 | $0 | $3,098 | $2,918.08 | (1,959.85) |
| 13 | $3,331 | ($173) | $0 | $0 | $3,158 | $2,960.06 | 1,000.22 |
| 14 | $3,398 | ($178) | $0 | $0 | $3,220 | $3,002.63 | 4,002.85 |
| 15 | $3,466 | ($183) | $0 | $0 | $3,282 | $3,045.80 | 7,048.65 |
| 16 | $3,535 | ($189) | $0 | $0 | $3,346 | $3,089.56 | 10,138.21 |
| 17 | $3,606 | ($194) | $0 | $0 | $3,411 | $3,133.94 | 13,272.15 |
| 18 | $3,678 | ($200) | $0 | $0 | $3,478 | $3,178.94 | 16,451.10 |
| 19 | $3,751 | ($206) | $0 | $0 | $3,545 | $3,224.57 | 19,675.66 |
| 20 | $3,826 | ($212) | $0 | $0 | $3,614 | $3,270.83 | **22,946.49** |
| 21 | $3,903 | ($219) | $0 | $0 | $3,684 | $3,317.73 | 26,264.23 |
| 22 | $3,981 | ($225) | $0 | $0 | $3,756 | $3,365.29 | 29,629.52 |
| 23 | $4,061 | ($232) | $0 | $0 | $3,828 | $3,413.51 | 33,043.03 |
| 24 | $4,142 | ($239) | $0 | $0 | $3,903 | $3,462.40 | 36,505.43 |
| 25 | $4,225 | ($246) | $0 | $0 | $3,978 | $3,511.97 | 40,017.39 |
| 26 | $4,309 | ($254) | $0 | $0 | $4,055 | $3,562.22 | 43,579.61 |
| 27 | $4,395 | ($261) | $0 | $0 | $4,134 | $3,613.17 | 47,192.78 |
| 28 | $4,483 | ($269) | $0 | $0 | $4,214 | $3,664.83 | 50,857.61 |
| 29 | $4,573 | ($277) | $0 | $0 | $4,296 | $3,717.20 | 54,574.80 |
| 30 | $4,664 | ($285) | $0 | $0 | $4,379 | $3,770.29 | **58,345.09** |

## II. Basic Cost Benefit Model for a Small Wind Project with Loan Investment

| Year | Net Energy | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|
| 0 | | | | | ($6,500) | ($6,500) | ($6,500) |
| 1 | $2,627 | $0 | $0 | ($3,534) | ($907) | ($902.67) | ($7,402.67) |
| 2 | $2,679 | $0 | $0 | ($3,534) | ($855) | ($846.17) | ($8,248.84) |
| 3 | $2,733 | $0 | $0 | ($3,534) | ($801) | ($789.18) | ($9,038.02) |
| 4 | $2,787 | $0 | $0 | ($3,534) | ($746) | ($731.68) | ($9,769.70) |
| 5 | $2,843 | $0 | $0 | ($3,534) | ($691) | ($673.66) | ($10,443.36) |
| 6 | $2,900 | ($140) | $0 | ($3,534) | ($774) | ($751.43) | ($11,194.79) |
| 7 | $2,958 | ($145) | $0 | ($3,534) | ($720) | ($695.75) | ($11,890.55) |
| 8 | $3,017 | ($149) | $0 | ($3,534) | ($666) | ($639.62) | ($12,530.17) |
| 9 | $3,077 | ($153) | $0 | $0 | $2,924 | $2,795.58 | ($9,734.58) |
| 10 | $3,139 | ($158) | $0 | $0 | $2,981 | $2,835.85 | **($6,898.73)** |
| 11 | $3,202 | ($163) | $0 | $0 | $3,039 | $2,876.68 | ($4,022.05) |
| 12 | $3,266 | ($168) | $0 | $0 | $3,098 | $2,918.08 | ($1,103.97) |
| 13 | $3,331 | ($173) | $0 | $0 | $3,158 | $2,960.06 | $1,856.09 |
| 14 | $3,398 | ($178) | $0 | $0 | $3,220 | $3,002.63 | $4,858.73 |
| 15 | $3,466 | ($183) | $0 | $0 | $3,282 | $3,045.80 | $7,904.52 |
| 16 | $3,535 | ($189) | $0 | $0 | $3,346 | $3,089.56 | $10,994.09 |
| 17 | $3,606 | ($194) | $0 | $0 | $3,411 | $3,133.94 | $14,128.03 |
| 18 | $3,678 | ($200) | $0 | $0 | $3,478 | $3,178.94 | $17,306.97 |
| 19 | $3,751 | ($206) | $0 | $0 | $3,545 | $3,224.57 | $20,531.54 |
| 20 | $3,826 | ($212) | $0 | $0 | $3,614 | $3,270.83 | **$23,802.37** |
| 21 | $3,903 | ($219) | $0 | $0 | $3,684 | $3,317.73 | $27,120.10 |
| 22 | $3,981 | ($225) | $0 | $0 | $3,756 | $3,365.29 | $30,485.39 |
| 23 | $4,061 | ($232) | $0 | $0 | $3,828 | $3,413.51 | $33,898.90 |
| 24 | $4,142 | ($239) | $0 | $0 | $3,903 | $3,462.40 | $37,361.30 |
| 25 | $4,225 | ($246) | $0 | $0 | $3,978 | $3,511.97 | $40,873.27 |
| 26 | $4,309 | ($254) | $0 | $0 | $4,055 | $3,562.22 | $44,435.49 |
| 27 | $4,395 | ($261) | $0 | $0 | $4,134 | $3,613.17 | $48,048.66 |
| 28 | $4,483 | ($269) | $0 | $0 | $4,214 | $3,664.83 | $51,713.48 |
| 29 | $4,573 | ($277) | $0 | $0 | $4,296 | $3,717.20 | $55,430.68 |
| 30 | $4,664 | ($285) | $0 | $0 | $4,379 | $3,770.29 | **$59,200.97** |

## III. Modified Cost Benefit Model with a Carbon Tax of $10 per ton

| Year | Net Energy | Carbon Tax | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | ($35,000) | ($35,000) | (35,000.00) |
| 1 | $2,627 | $20 | $0 | $0 | $0 | $2,647 | $2,633.56 | (32,366.44) |
| 2 | $2,679 | $21 | $0 | $0 | $0 | $2,700 | $2,673.47 | (29,692.96) |
| 3 | $2,733 | $22 | $0 | $0 | $0 | $2,755 | $2,714.00 | (26,978.96) |
| 4 | $2,787 | $23 | $0 | $0 | $0 | $2,811 | $2,755.16 | (24,223.80) |
| 5 | $2,843 | $25 | $0 | $0 | $0 | $2,868 | $2,796.97 | (21,426.83) |
| 6 | $2,900 | $26 | ($140) | $0 | $0 | $2,785 | $2,703.12 | (18,723.71) |
| 7 | $2,958 | $27 | ($145) | $0 | $0 | $2,840 | $2,742.86 | (15,980.85) |
| 8 | $3,017 | $28 | ($149) | $0 | $0 | $2,896 | $2,783.19 | (13,197.66) |
| 9 | $3,077 | $30 | ($153) | $0 | $0 | $2,954 | $2,824.12 | (10,373.54) |
| 10 | $3,139 | $31 | ($158) | $0 | $0 | $3,012 | $2,865.66 | **(7,507.88)** |
| 11 | $3,202 | $33 | ($163) | $0 | $0 | $3,072 | $2,907.83 | (4,600.05) |
| 12 | $3,266 | $35 | ($168) | $0 | $0 | $3,133 | $2,950.62 | (1,649.43) |
| 13 | $3,331 | $36 | ($173) | $0 | $0 | $3,195 | $2,994.06 | 1,344.63 |
| 14 | $3,398 | $38 | ($178) | $0 | $0 | $3,258 | $3,038.15 | 4,382.79 |
| 15 | $3,466 | $40 | ($183) | $0 | $0 | $3,322 | $3,082.91 | 7,465.70 |
| 16 | $3,535 | $42 | ($189) | $0 | $0 | $3,388 | $3,128.34 | 10,594.03 |
| 17 | $3,606 | $44 | ($194) | $0 | $0 | $3,455 | $3,174.45 | 13,768.49 |
| 18 | $3,678 | $46 | ($200) | $0 | $0 | $3,524 | $3,221.27 | 16,989.75 |
| 19 | $3,751 | $49 | ($206) | $0 | $0 | $3,594 | $3,268.79 | 20,258.54 |
| 20 | $3,826 | $51 | ($212) | $0 | $0 | $3,665 | $3,317.03 | **23,575.57** |
| 21 | $3,903 | $54 | ($219) | $0 | $0 | $3,738 | $3,366.00 | 26,941.57 |
| 22 | $3,981 | $56 | ($225) | $0 | $0 | $3,812 | $3,415.72 | 30,357.29 |
| 23 | $4,061 | $59 | ($232) | $0 | $0 | $3,888 | $3,466.20 | 33,823.48 |
| 24 | $4,142 | $62 | ($239) | $0 | $0 | $3,965 | $3,517.44 | 37,340.93 |
| 25 | $4,225 | $65 | ($246) | $0 | $0 | $4,043 | $3,569.48 | 40,910.40 |
| 26 | $4,309 | $68 | ($254) | $0 | $0 | $4,124 | $3,622.30 | 44,532.71 |
| 27 | $4,395 | $72 | ($261) | $0 | $0 | $4,206 | $3,675.95 | 48,208.65 |
| 28 | $4,483 | $75 | ($269) | $0 | $0 | $4,289 | $3,730.41 | 51,939.06 |
| 29 | $4,573 | $79 | ($277) | $0 | $0 | $4,375 | $3,785.72 | 55,724.78 |
| 30 | $4,664 | $83 | ($285) | $0 | $0 | $4,462 | $3,841.88 | **59,566.66** |

## IV. Modified Cost Benefit Model with a Carbon Tax of $25 per ton

| Year | Net Energy | Carbon Tax | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | ($35,000) | ($35,000) | ($35,000.00) |
| 1 | $2,627 | $51 | $0 | $0 | $0 | $2,677 | $2,663.71 | ($32,336.29) |
| 2 | $2,679 | $53 | $0 | $0 | $0 | $2,732 | $2,704.97 | ($29,631.32) |
| 3 | $2,733 | $56 | $0 | $0 | $0 | $2,788 | $2,746.91 | ($26,884.41) |
| 4 | $2,787 | $58 | $0 | $0 | $0 | $2,846 | $2,789.55 | ($24,094.86) |
| 5 | $2,843 | $61 | $0 | $0 | $0 | $2,904 | $2,832.89 | ($21,261.97) |
| 6 | $2,900 | $64 | ($140) | $0 | $0 | $2,824 | $2,740.66 | ($18,521.31) |
| 7 | $2,958 | $68 | ($145) | $0 | $0 | $2,881 | $2,782.07 | ($15,739.24) |
| 8 | $3,017 | $71 | ($149) | $0 | $0 | $2,939 | $2,824.16 | ($12,915.09) |
| 9 | $3,077 | $75 | ($153) | $0 | $0 | $2,999 | $2,866.92 | ($10,048.16) |
| 10 | $3,139 | $78 | ($158) | $0 | $0 | $3,059 | $2,910.38 | **($7,137.78)** |
| 11 | $3,202 | $82 | ($163) | $0 | $0 | $3,121 | $2,954.55 | ($4,183.24) |
| 12 | $3,266 | $86 | ($168) | $0 | $0 | $3,184 | $2,999.44 | ($1,183.80) |
| 13 | $3,331 | $91 | ($173) | $0 | $0 | $3,249 | $3,045.06 | $1,861.26 |
| 14 | $3,398 | $95 | ($178) | $0 | $0 | $3,315 | $3,091.44 | $4,952.70 |
| 15 | $3,466 | $100 | ($183) | $0 | $0 | $3,382 | $3,138.58 | $8,091.27 |
| 16 | $3,535 | $105 | ($189) | $0 | $0 | $3,451 | $3,186.50 | $11,277.77 |
| 17 | $3,606 | $110 | ($194) | $0 | $0 | $3,521 | $3,235.22 | $14,512.99 |
| 18 | $3,678 | $116 | ($200) | $0 | $0 | $3,593 | $3,284.75 | $17,797.74 |
| 19 | $3,751 | $122 | ($206) | $0 | $0 | $3,667 | $3,335.11 | $21,132.85 |
| 20 | $3,826 | $128 | ($212) | $0 | $0 | $3,742 | $3,386.32 | **$24,519.18** |
| 21 | $3,903 | $134 | ($219) | $0 | $0 | $3,818 | $3,438.40 | $27,957.58 |
| 22 | $3,981 | $141 | ($225) | $0 | $0 | $3,896 | $3,491.36 | $31,448.94 |
| 23 | $4,061 | $148 | ($232) | $0 | $0 | $3,976 | $3,545.23 | $34,994.16 |
| 24 | $4,142 | $155 | ($239) | $0 | $0 | $4,058 | $3,600.01 | $38,594.18 |
| 25 | $4,225 | $163 | ($246) | $0 | $0 | $4,141 | $3,655.74 | $42,249.92 |
| 26 | $4,309 | $171 | ($254) | $0 | $0 | $4,226 | $3,712.43 | $45,962.35 |
| 27 | $4,395 | $180 | ($261) | $0 | $0 | $4,314 | $3,770.11 | $49,732.46 |
| 28 | $4,483 | $189 | ($269) | $0 | $0 | $4,403 | $3,828.79 | $53,561.25 |
| 29 | $4,573 | $198 | ($277) | $0 | $0 | $4,494 | $3,888.50 | $57,449.75 |
| 30 | $4,664 | $208 | ($285) | $0 | $0 | $4,587 | $3,949.27 | **$61,399.02** |

## V. Modified Cost Benefit Model with a Carbon Tax of $40 per ton

| Year | Net Energy | Carbon Tax | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | ($35,000) | ($35,000) | ($35,000.00) |
| 1 | $2,627 | $81 | $0 | $0 | $0 | $2,707 | $2,693.86 | ($32,306.14) |
| 2 | $2,679 | $85 | $0 | $0 | $0 | $2,764 | $2,736.47 | ($29,569.67) |
| 3 | $2,733 | $89 | $0 | $0 | $0 | $2,822 | $2,779.82 | ($26,789.85) |
| 4 | $2,787 | $94 | $0 | $0 | $0 | $2,881 | $2,823.93 | ($23,965.92) |
| 5 | $2,843 | $98 | $0 | $0 | $0 | $2,941 | $2,868.81 | ($21,097.10) |
| 6 | $2,900 | $103 | ($140) | $0 | $0 | $2,863 | $2,778.19 | ($18,318.92) |
| 7 | $2,958 | $108 | ($145) | $0 | $0 | $2,922 | $2,821.28 | ($15,497.63) |
| 8 | $3,017 | $114 | ($149) | $0 | $0 | $2,982 | $2,865.12 | ($12,632.51) |
| 9 | $3,077 | $119 | ($153) | $0 | $0 | $3,043 | $2,909.72 | ($9,722.79) |
| 10 | $3,139 | $125 | ($158) | $0 | $0 | $3,106 | $2,955.10 | **($6,767.69)** |
| 11 | $3,202 | $132 | ($163) | $0 | $0 | $3,171 | $3,001.27 | ($3,766.42) |
| 12 | $3,266 | $138 | ($168) | $0 | $0 | $3,236 | $3,048.25 | ($718.17) |
| 13 | $3,331 | $145 | ($173) | $0 | $0 | $3,303 | $3,096.06 | $2,377.89 |
| 14 | $3,398 | $152 | ($178) | $0 | $0 | $3,372 | $3,144.72 | $5,522.60 |
| 15 | $3,466 | $160 | ($183) | $0 | $0 | $3,442 | $3,194.24 | $8,716.85 |
| 16 | $3,535 | $168 | ($189) | $0 | $0 | $3,514 | $3,244.66 | $11,961.51 |
| 17 | $3,606 | $176 | ($194) | $0 | $0 | $3,588 | $3,295.98 | $15,257.49 |
| 18 | $3,678 | $185 | ($200) | $0 | $0 | $3,663 | $3,348.24 | $18,605.72 |
| 19 | $3,751 | $194 | ($206) | $0 | $0 | $3,740 | $3,401.44 | $22,007.16 |
| 20 | $3,826 | $204 | ($212) | $0 | $0 | $3,818 | $3,455.62 | **$25,462.79** |
| 21 | $3,903 | $214 | ($219) | $0 | $0 | $3,898 | $3,510.80 | $28,973.59 |
| 22 | $3,981 | $225 | ($225) | $0 | $0 | $3,981 | $3,567.00 | $32,540.59 |
| 23 | $4,061 | $236 | ($232) | $0 | $0 | $4,065 | $3,624.25 | $36,164.85 |
| 24 | $4,142 | $248 | ($239) | $0 | $0 | $4,151 | $3,682.58 | $39,847.43 |
| 25 | $4,225 | $261 | ($246) | $0 | $0 | $4,239 | $3,742.01 | $43,589.43 |
| 26 | $4,309 | $274 | ($254) | $0 | $0 | $4,329 | $3,802.56 | $47,391.99 |
| 27 | $4,395 | $287 | ($261) | $0 | $0 | $4,421 | $3,864.27 | $51,256.26 |
| 28 | $4,483 | $302 | ($269) | $0 | $0 | $4,516 | $3,927.17 | $55,183.43 |
| 29 | $4,573 | $317 | ($277) | $0 | $0 | $4,612 | $3,991.29 | $59,174.72 |
| 30 | $4,664 | $333 | ($285) | $0 | $0 | $4,711 | $4,056.65 | **$63,231.38** |

## VII. Modified Cost Benefit Model with a 25% Rebate Program

| Year | Net Energy | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|
| 0 | | | | | ($23,625) | ($23,625) | ($23,625.00) |
| 1 | $2,627 | $0 | $0 | $0 | $2,627 | $2,613.46 | ($21,011.54) |
| 2 | $2,679 | $0 | $0 | $0 | $2,679 | $2,652.47 | ($18,359.06) |
| 3 | $2,733 | $0 | $0 | $0 | $2,733 | $2,692.06 | ($15,667.00) |
| 4 | $2,787 | $0 | $0 | $0 | $2,787 | $2,732.24 | ($12,934.76) |
| 5 | $2,843 | $0 | $0 | $0 | $2,843 | $2,773.02 | ($10,161.74) |
| 6 | $2,900 | ($140) | $0 | $0 | $2,759 | $2,678.10 | ($7,483.64) |
| 7 | $2,958 | ($145) | $0 | $0 | $2,813 | $2,716.72 | ($4,766.92) |
| 8 | $3,017 | ($149) | $0 | $0 | $2,868 | $2,755.88 | ($2,011.04) |
| 9 | $3,077 | ($153) | $0 | $0 | $2,924 | $2,795.58 | $784.54 |
| 10 | $3,139 | ($158) | $0 | $0 | $2,981 | $2,835.85 | **$3,620.39** |
| 11 | $3,202 | ($163) | $0 | $0 | $3,039 | $2,876.68 | $6,497.07 |
| 12 | $3,266 | ($168) | $0 | $0 | $3,098 | $2,918.08 | $9,415.15 |
| 13 | $3,331 | ($173) | $0 | $0 | $3,158 | $2,960.06 | $12,375.22 |
| 14 | $3,398 | ($178) | $0 | $0 | $3,220 | $3,002.63 | $15,377.85 |
| 15 | $3,466 | ($183) | $0 | $0 | $3,282 | $3,045.80 | $18,423.65 |
| 16 | $3,535 | ($189) | $0 | $0 | $3,346 | $3,089.56 | $21,513.21 |
| 17 | $3,606 | ($194) | $0 | $0 | $3,411 | $3,133.94 | $24,647.15 |
| 18 | $3,678 | ($200) | $0 | $0 | $3,478 | $3,178.94 | $27,826.10 |
| 19 | $3,751 | ($206) | $0 | $0 | $3,545 | $3,224.57 | $31,050.66 |
| 20 | $3,826 | ($212) | $0 | $0 | $3,614 | $3,270.83 | **$34,321.49** |
| 21 | $3,903 | ($219) | $0 | $0 | $3,684 | $3,317.73 | $37,639.23 |
| 22 | $3,981 | ($225) | $0 | $0 | $3,756 | $3,365.29 | $41,004.52 |
| 23 | $4,061 | ($232) | $0 | $0 | $3,828 | $3,413.51 | $44,418.03 |
| 24 | $4,142 | ($239) | $0 | $0 | $3,903 | $3,462.40 | $47,880.43 |
| 25 | $4,225 | ($246) | $0 | $0 | $3,978 | $3,511.97 | $51,392.39 |
| 26 | $4,309 | ($254) | $0 | $0 | $4,055 | $3,562.22 | $54,954.61 |
| 27 | $4,395 | ($261) | $0 | $0 | $4,134 | $3,613.17 | $58,567.78 |
| 28 | $4,483 | ($269) | $0 | $0 | $4,214 | $3,664.83 | $62,232.61 |
| 29 | $4,573 | ($277) | $0 | $0 | $4,296 | $3,717.20 | $65,949.80 |
| 30 | $4,664 | ($285) | $0 | $0 | $4,379 | $3,770.29 | **$69,720.09** |

## VII. Modified Cost Benefit Model with a Non-capped State Tax Credit

| Year | Net Energy | O&M Costs | Net Deprec. | Net Loan Payments | Annual Cash Flow | NPV | Accumulated NPV |
|---|---|---|---|---|---|---|---|
| 0 | | | | | ($29,575) | ($29,575) | (29,575.00) |
| 1 | $2,627 | $0 | $0 | $0 | $2,627 | $2,613.46 | (26,961.54) |
| 2 | $2,679 | $0 | $0 | $0 | $2,679 | $2,652.47 | (24,309.06) |
| 3 | $2,733 | $0 | $0 | $0 | $2,733 | $2,692.06 | (21,617.00) |
| 4 | $2,787 | $0 | $0 | $0 | $2,787 | $2,732.24 | (18,884.76) |
| 5 | $2,843 | $0 | $0 | $0 | $2,843 | $2,773.02 | (16,111.74) |
| 6 | $2,900 | ($140) | $0 | $0 | $2,759 | $2,678.10 | (13,433.64) |
| 7 | $2,958 | ($145) | $0 | $0 | $2,813 | $2,716.72 | (10,716.92) |
| 8 | $3,017 | ($149) | $0 | $0 | $2,868 | $2,755.88 | (7,961.04) |
| 9 | $3,077 | ($153) | $0 | $0 | $2,924 | $2,795.58 | (5,165.46) |
| 10 | $3,139 | ($158) | $0 | $0 | $2,981 | $2,835.85 | **(2,329.61)** |
| 11 | $3,202 | ($163) | $0 | $0 | $3,039 | $2,876.68 | 547.07 |
| 12 | $3,266 | ($168) | $0 | $0 | $3,098 | $2,918.08 | 3,465.15 |
| 13 | $3,331 | ($173) | $0 | $0 | $3,158 | $2,960.06 | 6,425.22 |
| 14 | $3,398 | ($178) | $0 | $0 | $3,220 | $3,002.63 | 9,427.85 |
| 15 | $3,466 | ($183) | $0 | $0 | $3,282 | $3,045.80 | 12,473.65 |
| 16 | $3,535 | ($189) | $0 | $0 | $3,346 | $3,089.56 | 15,563.21 |
| 17 | $3,606 | ($194) | $0 | $0 | $3,411 | $3,133.94 | 18,697.15 |
| 18 | $3,678 | ($200) | $0 | $0 | $3,478 | $3,178.94 | 21,876.10 |
| 19 | $3,751 | ($206) | $0 | $0 | $3,545 | $3,224.57 | 25,100.66 |
| 20 | $3,826 | ($212) | $0 | $0 | $3,614 | $3,270.83 | **28,371.49** |
| 21 | $3,903 | ($219) | $0 | $0 | $3,684 | $3,317.73 | 31,689.23 |
| 22 | $3,981 | ($225) | $0 | $0 | $3,756 | $3,365.29 | 35,054.52 |
| 23 | $4,061 | ($232) | $0 | $0 | $3,828 | $3,413.51 | 38,468.03 |
| 24 | $4,142 | ($239) | $0 | $0 | $3,903 | $3,462.40 | 41,930.43 |
| 25 | $4,225 | ($246) | $0 | $0 | $3,978 | $3,511.97 | 45,442.39 |
| 26 | $4,309 | ($254) | $0 | $0 | $4,055 | $3,562.22 | 49,004.61 |
| 27 | $4,395 | ($261) | $0 | $0 | $4,134 | $3,613.17 | 52,617.78 |
| 28 | $4,483 | ($269) | $0 | $0 | $4,214 | $3,664.83 | 56,282.61 |
| 29 | $4,573 | ($277) | $0 | $0 | $4,296 | $3,717.20 | 59,999.80 |
| 30 | $4,664 | ($285) | $0 | $0 | $4,379 | $3,770.29 | **63,770.09** |