WESTERN WINDS AND THE LEVELIZED COST OF POWER

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ABSTRACT

High frequency power computations are done to estimate the economic feasibility of wind power in the Western states. Power output was calculated at various sites in the Western United States, there is a strong case for wind power in the Western states. The Federal production tax credit has a small impact on power costs. The production cost of electricity produced by wind power is substantially below the current state average retail costs. This feasibility suggests that additional research and potential investment in distribution channels of electricity produced by wind power for the Western United States needs to proceed forth worth. Current margins are clearly large enough to facilitate investment in transmission and distribution.

Keywords: Levelized costs, Western wind speeds.

INTRODUCTION

The demand for energy continues to increase rapidly both world-wide and in the United States.
The economic health of the United States is bound to our ability to link an abundant supply of energy to reasonable prices. Estimates by the Energy Information Agency (EIA) project electricity consumption to increase in the United States by 32% from 2005 to 2030. An important question is how to meet this increasing demand at the lowest cost in the face of political, social, and environmental constraints. Increasingly environmental concerns like global warming are playing an important role in the decision making process. Nevertheless, the economic feasibility of each potential source of power is and will remain a salient consideration.
To meet these needs, electricity can be generated by several different methods and total generation of energy should be seen as a portfolio of different energy producing assets. The Energy Information Agency (EIA) reported that the distribution of electrical power by production sources was coal plants 49.6%, oil 1.9%, natural gas 19.5%, nuclear 19.3%, and renewable 9.7% in 2005. In addition, EIA (2007) forecasts that in 2030, coal plants will increase their production to 57.5%, oil, 1.9%, natural gas 16.4%, nuclear 15.5%, and renewable 9.0%. These forecasts are based on EIA projections of fuel prices and assumptions of future availability of fuel sources. They do not take into account environmental factors and political consideration associated with those environmental concerns. Given those consideration, it seems plausible that renewable will have a much larger role. The Department of Energy has been studying the feasibility of a much larger role for sources such as wind power.
The average cost of wind energy is approximately 20% of what it was in the 1990s, and that downward trend is expected to continue as larger multi-megawatt turbines are mass-produced. The price of wind generated electricity in the United States is now competitive with the cost of coal and natural gas generated electric power. The installed base of alternative energy in the United States is still relatively low but the decreases in its levelized costs will increase their installation. In addition, a unique attribute of wind energy, and some other alternative energy sources, is that their marginal cost either approaches

or is zero. These factors have led wind power to be the fastest growing source of energy, growing annually at about 38%. The largest installed base of wind energy is in the western states.

This paper will concentrate on the costs of wind energy in the western states using a new data set created by the National Renewable Energy Laboratory. Section two develops a methodology for determining average costs for producing electricity and includes the impact of federal taxes, depreciation, and the Production Tax Credit. The third section presents the data; the next section discusses the results, while the last section draws conclusions.

LEVELIZED COST OF ENERGY

Financial analysis of electricity plants has focused on recovery of capital costs after accounting for operational costs because of the large initial investment in nuclear and fossil fuel plants. One approach is to use the equivalent annual cost of each plant and treat recovery of capital costs as an annuity using the weighted average cost of capital as the discount rate. The advantage of this approach is that it properly adjusts for differences in useful life of each plant but gives minimal attention to the role of depreciation and taxation [10]. This approach calculates the average cost of electricity generated at the plant (bus-bar costs) [4,7].

A basic equation for determining the average annual cost of operating an energy power source over time is as follows:

$$CoE = \frac{CAPEX \times CRF - \frac{SV_t}{(1+i)^t} + OPEX}{AEP} \quad (1)$$

where:

CoE	is the average cost of energy;
CAPEX	is the capital expense for the energy producing unit;
CRF	is the capital recovery factor;
AEP	is the net annual energy production;
OPEX	is the average operating expense;
OP	is the option value of the asset;
SV	is the salvage value at time t;
I	is the weighted average cost of capital; and,
T	is the life of the project.

The capital expenditures on a windmill include: development costs and the components of the windmill which include: a blade or rotor, an enclosure (nacelle) that contains a gearbox and generator, a platform and tower, electrical equipment to connect to the transformer, the transformer, and grid. The total installed cost of windmill show a steady decreased to a low of $1.5 million dollars per megawatt (MW) following a learning curve reduction in costs. The surge in steel, copper, and concrete prices starting in 2002 increased the install cost to $2.2 million dollars per MW in 2008 but recent reductions in commodity prices have seen a 20 percent reduction in installed costs. This cost should decrease through the learning curve and with the development of mass-produced large windmills. This study uses $1.8 million dollars per installed megawatt for the capital costs.

The final variable in the calculation of energy costs is the financial lifetime of the technology. This study uses a twenty year financial life span, although the actual economic usefulness can exceed twenty years.

The capital recovery factor is an extension of the annuity formula and is defined as the ratio of a constant annuity to the present value receiving that annuity over the life over a given time period. CRF is expressed as follows:

$$CRF = \frac{WACC \times (1 + WACC)^N}{(1 + WACC)^N - 1} \quad (2)$$

where i is the weighted average cost of capital (WACC). A limitation of this approach is that it assumes constant payments to equity over the life span of the project. This study follows a cash flow model that allows for uneven payments to equity. This means that equity can be repaid sooner if the cash flows are available, thereby reducing the risk of the project and to reduce the levelized cost of electricity.

The production of electricity is capital intensive and its cost is highly sensitive to the cost of capital. The weighted average cost of capital (WACC) is:

$$WACC = e\left(\frac{E}{D+E}\right) + d\left(\frac{D}{D+E}\right)(1 - TR) \quad (3)$$

where e is the return to equity, d is the cost of debt, E is the amount of equity financing, D is the amount of debt financing, and TX is the corporate tax rate. This study assumes a 10% return to equity and a 6% cost of debt. The difference between the return to equity and the cost of debt should normally not exceed 4%.

The operating expense at time for the energy source consists of the present value of fuel and fuel waste disposal costs (F), labor (L), rent and insurance (R), and maintenance costs (MT). The operating costs at time t are:

$$OPEX = F + L + R + MT \quad (4)$$

An important component of maintenance costs is related to blade and gear failures because of fatigue. Maintenance costs may be reduced over time with improvements in online monitoring, diagnostic, and control systems. This study assumes maintenance costs of $ 0.2 per kilowatt produced, which includes insurance, leases, and scheduled maintenance and is considerable higher than other estimates [3].

The annual energy production from a power plant is given as follows:

AEP = CF * Maximum Available Power (5)

where CF is the capacity or load factor. The capacity (load) factor is defined as follows:

CF = Actual Power Production/Potential Power Production (6)

An important question when calculating the cost of energy is how to model the capacity factor. Most researchers [8,11,12] specify CF to be exogenous and constant, however, it has been argued that CF may be modeled as an endogenous variable [2]. For instance, recent high natural gas prices have reduced the capacity factor for natural gas-fired combined cycle power plants. Similarly variations in wind speeds and sun radiation at different sites and changing weather patterns have an impact for wind and solar PV electricity production. The capacity factors in this study are determined by the individual site and the efficiency of the windmill turbine. The power curve used is from a Gamesa G90 2.0 megawatt turbine.

Three tax concepts that are applied. These include the Modified Accelerated Cost-Recovery System, the Production Tax Credit, and the carry-forward tax rule. Under the federal Modified Accelerated Cost-Recovery System (MACRS) firms operating windmills may recover over a five year period. The MACRS depreciation schedule is available from the IRS. The Renewable Electricity Production Tax Credit (PTC) is a per-kilowatt-hour tax credit for electricity generated by qualified energy sources (including wind). The credit is offered in the amount of 2.1 cents per kWh produced and sold for the first ten years of the facility's operation. Finally, carry-forward is a tax rule that allows firms to apply their losses in one year to future income up to twenty years.

DATA

Wind velocity data were obtained from the National Renewable Energy Laboratory's Western Wind Resources Dataset. This dataset provides ten minute time-series wind data for 2004, 2005, and 2006 for 30,000 sites in the western United States. This provides a consistent set of wind profiles for analyzing potential wind plants across the area. One site was chosen for each state based on the highest capacity factors. Thus, the total number of observations was 788,475. For each observation a power output computation is done using the higher of two potential power productions estimates assuming one of two windmill types. The total output for each site was then sum for the year to get the monthly and the yearly energy output. A strong advantage of our study is that precise estimates of power production are made in frequent intervals.

The average wind velocity for the western states was 9.47. The states with highest wind speed in this study were Wyoming, Colorado, New Mexico, and Montana. Wyoming and Montana did not appear in Table 2 as a state with large installed wind turbines because of a lack of transmission lines at the source of wind energy. There is considerable seasonal variation in the wind velocities. The windiest months are in late fall, winter and early spring, while the summer months have the lowest wind velocities. This seasonal variation may have implications for managing electrical power levels. Actual power curves from a G90 2.0 megawatt wind turbine was used to generate potential electrical production from each site.

RESULTS

Levelized costs for the western states are presented in Table 1 for three different costs of capital and with and without the Production Tax Credit. The states with the lowest cost of energy from wind power are Wyoming, New Mexico, Colorado, Oregon, and Texas. The issue of continuing the production tax credit is a continuing issue in the Congress. To address the controversy we estimate the levelized costs of power with and without the credit. Our estimates show the impact of the PTC makes a small difference in the cost of energy while differences in capital costs are more pronounced. Nevertheless, the PTC may be marginally important in attracting tax equity investors.

Table 1: Levelized Costs with Tax Considerations for Western States.

State	**Site ID number**	**Levelized Costs (KWh)**						
		d=6%, e=10%		d=5%, e=9%		d=7%, e=11%		State Electrical Prices
		With PTC	Without PTC	With PTC	Without PTC	With PTC	Without PTC	
Arizona	5051	5.4044	5.4751	4.9834	5.0573	5.8229	5.8987	11.30
California	4426	4.9760	5.0775	4.6336	4.7074	5.3768	5.4526	15.91
Colorado	11005	4.5319	4.6026	4.2158	4.2896	4.8440	4.9198	10.42
Idaho	25170	5.3366	5.4443	4.9563	5.0302	5.7884	5.8641	8.44
Montana	28133	4.8366	4.9074	4.4839	4.6533	5.1859	5.2617	9.46
Nebraska	15837	5.0819	5.1526	4.6996	4.8771	5.4611	5.5368	9.90
Nevada	6944	5.3163	5.3412	4.9395	4.9395	5.7068	5.7485	12.88
New Mexico	8070	4.5529	4.5721	4.2628	4.2628	4.8535	4.8856	10.72
Oklahoma	7233	5.0006	5.0231	4.6596	4.7590	5.3539	5.3916	8.79
Oregon	23098	4.6592	4.6792	4.3571	4.4451	4.9724	5.0058	9.07
South Dakota	26036	4.9224	4.9444	4.5903	4.6871	5.2665	5.3032	9.27
Texas	1508	4.6636	4.6836	4.3609	4.4491	4.9772	5.0107	12.68
Utah	12210	5.2774	5.3020	4.9050	4.9050	5.6633	5.7045	9.11
Washington	27067	5.4376	5.4635	5.0470	5.0470	5.8424	5.8856	7.93
Wyoming	15896	4.4133	4.5105	4.1348	4.2086	4.7407	4.8165	9.07

Public policies which tend to reduce the risk of wind investments and their associated required return on equity capital will significantly decreased the levelized costs. Regulation like the Public Utilties Regulatory Policies Act (PURPA) which was passed in 1978 stabilize the markets for alternative energy production. Purpa was passed to encourage the used of cogenerated and renewal able energy sources. A key aspect of PURPA is that the electric utilities must connect with and purchase power from any qualified facility. The act requires that the incumbent utility buy power from the qualifying facility at the utilities own avoided costs. The requirements of mandatory interconnection and the requirement to purchase power at avoided costs serve to greatly stabilize the price of investment capital with regard to wind power. Policies that guaranteed purchase of power by electrical companies clearly lower the cost of capital for wind. Additional recent legislation which requires a quota of energy produced by wind or alternative energy source has similar salutary effects.

CONCLUSIONS

Using a high frequency source of wind data and recent estimates of power curves from modern wind power generators we are able to make relatively accurate high frequency power computations. The 10 minute data and contemporaneous power computations we use to calculate the power output at various sites in the Western United States results in fairly reliable estimates of annual power production. Using these electrical power computations we estimate the economic feasibility of wind power in the Western states. Using much more conservative estimates than other studies for administration and maintenance costs, we find that there is a strong case for wind power in the Western states.

Our results does not support the need for a continuation of the Federal production tax credit. The credit does little to affect our results. The economic feasibility issue is most a function of capital costs. Our study shows that the production cost of wind power is substantially below the current state average retail costs. Additional research and potential investment in distribution channels of wind power for the Western United States is warranted. Even assuming relatively large transmission costs there is clearly room for additional electrical power generation from wind in the Western United States.

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