Economics of Offshore Wind Power

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Introduction

The December, 2004 Louisiana Energy Topic gave an overview of wind generated electricity and how it relates to Louisiana. It can be downloaded in Adobe PDF format at: http://www.dnr.state.la.us/sec/execdiv/techasmt/newsletters/index.htm. This month's edition focuses on the economics of offshore wind generated electricity. A simple economic analysis will be presented for a nominal 50 MW offshore wind farm after a discussion of the key inputs and assumptions. This economic analysis will present data at three different prices of electricity and three different wind classes. It will also present a breakeven price of electricity for each wind class.

The economics of land-based wind power are fairly well established, but much less so for offshore wind power as no offshore wind farms have actually been built in the U.S., although several have been built in Europe. Wind farms are more expensive to build offshore than onshore. The higher cost is mainly due to costs involved with transmitting the power back to land and because it is generally more expensive to build anything over water than land (something in which Louisiana industries are adept).

Inputs and Assumptions

The economics of an offshore wind farm will vary greatly depending on the specifics of a particular wind farm. As such, this analysis is only meant to show a range of possible scenarios and shed some light on the information used in such an analysis. It is based on the assumptions discussed below and even relatively small changes in these assumptions can lead to very different results.

The cost to install a utility-scale wind farm on land is in the neighborhood of $1000/kW [1]. Estimates for offshore wind farms range from $1500 to $2000/kW [2]. The middle price of $1750/kW was chosen which puts the installation cost at $84,700,000. Operation and maintenance cost for an offshore wind farm should differ little from land wind farms which run about 2% [1] of the original turbine investment. These costs were set at 2% of the installation cost which is more than just the turbine cost, so this figure is somewhat over-estimated. General and administrative costs are an estimate of basic costs needed to run the company that manages the wind farm and were set at 15%. Turbine lifespan was deemed to be 25 years. Land based turbines commonly last 20 years before a major overhaul is needed. Offshore wind turbines are designed to be more rugged due to the harsh marine environment and are subject to less turbulent wind patterns due to the smooth water surface. In reality, offshore wind turbines may last 30 years or more. Finally, a corporate tax rate of 35% was chosen, and the federal 1.8 cents/kWh tax credit was also taken into account. For tax purposes the depreciation would be accelerated.

The biggest assumption that must be made is that of energy production from the wind farm. Energy production from a wind farm is completely dependent on how hard and how often the wind blows. Small changes in wind effect large changes in energy output from a wind turbine. The offshore wind regime is still something of an unknown. To a smaller degree, the selection of a particular wind turbine for a given advertised capacity will determine how much power is produced.

A wind farm consisting of 22, 2.2 MW wind turbines was chosen for a total rated capacity of 48.4 MW. The Danish Wind Industry Association website [1] was consulted to provide a power curve for such a turbine and calculate its annual power production. The annual power production was calculated for wind classes 3, 4, and 5 as defined by the National Renewable Energy Laboratory's wind resource map [3]. Each wind class has a range of values. The average value for each wind class was used. The values were 15.0 mph, 16.3 mph, and 17.4 mph for wind classes 3, 4, and 5 respectively. The energy output is summarized in **Table 1**.

Table 1. Energy Output

Wind Class (mph)	Energy Output per Turbine (kWh/year)	Total Energy Output (kWh/year)
Class 3 (15.0)	4,925,000	108,350,000
Class 4 (16.3)	5,782,000	127,204,000
Class 5 (17.4)	6,531,000	143,682,000

Source: LA DNR Technology Assessment Division

Variables not taken into account here include: ancillary service costs, renewable energy credits, and renewable portfolio standards. Ancillary service costs are the costs associated with integrating wind power into the grid. These costs are estimated to be negligible when wind is a small fraction of the total electricity supply. Renewable portfolio standards and renewable energy credits do not directly affect the cost of wind power, but would alter the economics by placing a higher value on wind power.

Results

The results show that electricity generation from this particular wind farm could break even at 4.2 cents/kWh in a class 5 wind resource; however, the rate of return only begins to become attractive at an electricity price of 8 cents/kWh in a class 5 wind resource. For comparison, the average price of electricity per kWh to Louisiana customers in 2002 was as follows: overall = $0.0599, residential = $0.0710 (range of $0.0271 - $0.0994), commercial = $0.0664, industrial = $0.0442. Securing capital for rates of return at these low levels would appear be a controlling factor in the viability of such a project. The results of the analysis are shown in **Tables 2 - 4** according to wind class.

Table 2. Class 3 Wind

Annual Figures	Electricity Price ($/kWh)			
	0.04	0.06	0.08	0.056*
Revenue	$4,334,000	$6,501,000	$8,668,000	$ 6,067,600
Operating & maintenance expense	1,694,000	1,694,000	1,694,000	1,694,000
Gross profit	2,640,000	4,807,000	6,974,000	4,373,600
General & administrative expense	650,100	975,150	1,300,200	910,140
Depreciation depletion & amortization	3,388,000	3,388,000	3,388,000	3,388,000
Operating profit	-1,398,100	443,850	2,285,800	75,460
Taxes	0	155,348	800,030	
Production tax credit	1,950,300	1,950,300	1,950,300	
Net taxes	0	0	0	
Net after taxes	-1,398,100	443,850	2,285,800	
Cash flow	1,989,900	3,831,850	5,673,800	
Internal rate of return	-3.73%	0.97%	4.43%	

*Break even

Source: LA DNR Technology Assessment Division

Table 3. Class 4 Wind

Annual Figures	Electricity Price ($/kWh) 0.04	0.06	0.08	0.048*
Revenue	$5,088,160	$7,632,240	$10,176,320	$6,105,792
Operating & maintenance expense	1,694,000	1,694,000	1,694,000	1,694,000
Gross profit	3,394,160	5,938,240	8,482,320	4,411,792
General & administrative expense	763,224	1,144,836	1,526,448	915,869
Depreciation depletion & amortization	3,388,000	3,388,000	3,388,000	3,388,000
Operating profit	-757,064	1,405,404	3,567,872	107,923
Taxes	0	491,891	1,248,755	
Production tax credit	2,289,672	2,289,672	2,289,672	
Net taxes	0	0	0	
Net after taxes	-757,064	1,405,404	3,567,872	
Cash flow	2,630,936	4,793,404	6,955,872	
Internal rate of return	-1.86%	2.87%	6.52%	

*Break even

Source: LA DNR Technology Assessment Division

Table 4. Class 5 Wind

Annual Figures	Electricity Price ($/kWh) 0.04	0.06	0.08	0.042*
Revenue	$5,747,280	$8,620,920	$11,494,560	$6,034,644
Operating & maintenance expense	1,694,000	1,694,000	1,694,000	1,694,000
Gross profit	4,053,280	6,926,920	9,800,560	4,340,644
General & administrative expense	862,092	1,293,138	1,724,184	905,197
Depreciation depletion & amortization	3,388,000	3,388,000	3,388,000	3,388,000
Operating profit	-196,812	2,245,782	4,688,376	47,447
Taxes	0	786,024	1,640,932	
Production tax credit	2,586,276	2,586,276	2,586,276	
Net taxes	0	0	0	
Net after taxes	-196,812	2,245,782	4,688,376	
Cash flow	3,191,188	5,633,782	8,076,376	
Internal rate of return	-0.46%	4.37%	8.21%	

*Break even

Source: LA DNR Technology Assessment Division

Conclusion

The results of this economic analysis indicate that small changes in any of the variables could make or break a particular project. Such is the current state of wind power in general. The results also indicate that a minimum class 5 wind resource is required for an economically viable wind farm in Louisiana with current technology. Wind turbine capacity will become less expensive as turbine efficiencies improve, and turbine prices will come down as economies of scale materialize. As these happen, wind farms may become viable in less than class 5 wind resources.

References

1. **Danish Wind Industry Association**
   www.windpower.org
2. **National Wind Coordinating Committee**
   www.nationalwind.org
3. **National Renewable Energy Laboratory**
   http://www.nrel.gov/wind/wind_map.html

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