Prospects for Wind Farm Installation in Wapakoneta, Ohio: An Initial Study on Economic Feasibility

An Application Portfolio
By Katherine Dykes
12/04/2007

In partial fulfillment of class requirements for ESD 71

Professor: Richard de Neufville
TA: Michel-Alexandre Cardin
TA: Thomas Rand-Nash

Prospects for Wind Farm Installation in Wapakoneta, Ohio: An Initial Study on Economic Feasibility

Project Description

There has been a lot of political activity in recent years across many states in adoption Renewable Portfolio Standards (RPS) that require the use of alternative energy sources such as wind, hydraulic, biomass and solar power. Though lagging behind its neighbors, such as Pennsylvania, in adoption such standards Ohio is likely to follow the lines of other states in adopting an RPS in the coming years. A commercial wind farm is considered to be a cost effective way of achieving an RPS and merits proper evaluation. The benefits of this would be largely regulatory but in terms of the general benefits of RPS standards: commercial wind would reduce the reliance on coal and natural gas for electricity production as well as reduce emissions such as NO_x, CO_2, SO_2 etc that are associated with the burning of fossil fuels.

Green Energy Ohio (GEO) is a not-for-profit organization dedicated to promoting policy for and educating Ohioans about "environmentally and economically sustainable energy" technologies and practices.[1] For the past several years, the organization has led a DOE-funded effort to conduct wind assessment studies at heights up to 100 m. No earlier attempts to measure wind data had been performed at such heights and the information from the study was used to validate forecast models and improve state wind maps.[2] To conduct the study, 4 sites across the state of Ohio were selected including sites at Wapakoneta, Cuyahoga Falls, Sullivan and Bryan. Over the 18 month period of study, the performance at the Wapakoneta site was consistently the strongest of the four sites.[3] Normalizing to historical trend in annual wind speed averages, Wapakoneta even outperformed the Bowling Green site which was monitored from 2000 to 2001. This is significant since the study at Bowling Green led to successful installation and operation of four commercial 1.8 MW wind turbines via a joint-venture program between 10 northern-Ohio municipal utilities and American Muncipal Power (AMP)-Ohio, a non-profit electricity supplier and advocate for the municipal utilities.[4] The next step in assessing the prospects for a wind farm in Wapakoneta involve an evaluation of the economic feasibility of such a project.

In order to do an economic feasibility study of the potential for a wind farm at any given test site, a good idea of the wind performance, an understanding of the detailed structure of the utility involved (including economic savings from wind turbine operation), knowledge of applicable regulatory incentives, as well as costs of turbine installation and operation are all necessary. In this case, the thorough testing at 100 m for the Wapakoneta site coupled with knowledge of technical specifications for various manufacturers' turbines gives us an idea of the amount of energy output that can be

---

[1] http://www.greenenergyohio.org/page.cfm?pageID=3
[2] http://www.greenenergyohio.org/page.cfm?pageID=439 , http://www.windexplorer.com/Ohio/ohio.htm
[3] Dykes, K. Wapakoneta final report (available on request)
[4] http://www.amp-ohio.org/pdf/OMEGA_JV6_2005_Annual_Report.pdf

expected from wind turbines on an annual basis.[5] If necessary, information is available to break down wind characteristics on a seasonal or monthly even hourly performance. However, with respect to the other 3 areas listed above: utility price structure, regulatory incentives, and project costs, significant uncertainty exists. In order to accurately assess the economic feasibility of a wind farm at Wapakoneta, these uncertainties should be appropriately explored.

Detailed Discussion of Uncertainties Involved in Project

The first uncertainty mentioned above is with respect to utility price structure. Power produced from wind is likely to be a small fraction of overall electricity provided to Wapakoneta. Thus, the main benefit, in economic terms, from the wind farm project is offsetting demand for electricity that would have to be purchased from a wholesale electricity supplier (negotiated via AMP-Ohio). Thus, the price of substitute electricity generation determines the "revenue" for the wind farm and uncertainty associated with the evolution of this price will directly impact the project's economic viability. In terms of the utility structure for Wapakoneta, the municipality runs 8 electric substations.[6] These substations are all powered by electricity provided by AMP-Ohio, and the dominant source of fuel for the generation stations are coal and natural gas.[7] AMP runs generation stations and negotiates wholesale electric power for its member communities, adds a small service fee and then sells the electricity to the municipalities.[8] Real time wholesale prices for both peak and off-peak electricity in the region of Ohio are available from ICE.[9] However, because AMP-Ohio has some generating capacity of its own (capacity to produce approximately 50% of the electricity by its municipal consumers), the prices that AMP passes on to its customers are not perfectly correlated with regional wholesale prices.[10] AMP-Ohio's yearly average electricity sale prices are available for the period from 1998 to 2006 in AMP-Ohio's annual report:

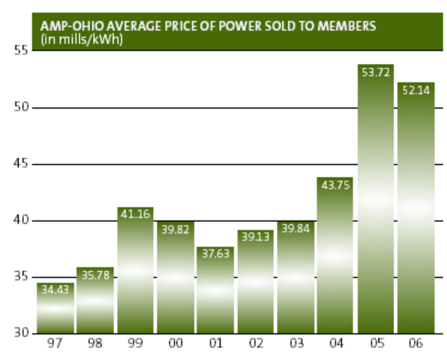

Figure 1: Average annual electricity prices from AMP-Ohio to its members[11]

[5] Dykes, K. Wapakoneta final report (available on request)
[6] http://www.wapakoneta.net/electric/
[7] http://www.amp-ohio.org/aboutus.html
[8] http://www.amp-ohio.org/aboutus.html
[9] https://www.theice.com/marketdata/indices/
[10] http://www.amp-ohio.org/pdf/AMP_Ohio_2006_Annual_Report.pdf
[11] Ibid.

Thus, based on this historical information, a Geometric Brownian Motion (GBM) model can be used to forecast AMP-Ohio's electricity prices into future year. The drift for yearly increase in the above data is 5.07% and the volatility is 9.31%. These values can be used with a GBM model starting with the 2006 price $52.14/MWh in order to forecast prices into future years.

Wholesale electricity prices represent the dominant source of uncertainty for the project, but there are other sources of uncertainty as well. One area of uncertainty that has affected the development of the wind industry since the 1970's is the extent to which regulatory incentives favor wind farm projects.[12] There are periodic federal and state programs to provide grants, tax credits, and low-interest loans for renewable energy programs such as the project proposed for Wapakoneta. However, the timing of the programs depends on the political climate and there may be more demand for such programs in many cases than the funding can support.[13] Thus, there is a large amount of uncertainty surrounding which incentives will be available to Wapakoneta even in the near future let alone 10 to 15 years. For this case, a range of expected outcomes which encompass the different types of cases that could occur is the most practical way to address this type of uncertainty:

1. No grant, loan, or tax incentives: this case represents the worst possible situation in which Wind has to compete head on with coal, natural gas and other types of electricity generation without any policy incentives whatsoever
2. Some grants, loans or tax incentives available: this represents the current political climate without change.[14] In this case, as listed on the DSIRE website of the Ohio Consumer's council, there are a variety of incentives in the form of grants up to $150,000 for a large commercial wind project, production incentives of $0.01/kWh, property tax exemption on the state level and $0.015/kWh production incentives as well as tax exemptions at the federal level.
3. Increase in grants, loans or tax incentives available: this represents the best case scenario in which the previously mentioned incentives are available and potentially augmented. In addition, financing incentives are also added to the mix.

In addition to electricity price and regulatory incentives, the cost of turbines may change over time. The likelihood is that cost for turbines will trend downwards as technology and economies of scale come into play. This of course is dependent on the growth of the wind industry as a whole. The dominance of coal and natural gas as sources for electricity production may continue into the future and stifle the growth of the wind industry. An arbitrary reference for turbine installation cost from the American Wind Energy Association (AWEA) is about $1,000,000 / MW turbine capacity installed.[15] Economies of scale are expected to reduce this as the capacity is increased (ie. a 26 MW commercial wind farm is expected to cost about $20,000,000 for installation).[16]

---

[12] Cason, Bill. Wind Energy in America U. Oklahoma Press: 2006.
[13] http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=OH&RE=1&EE=1
[14] http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=OH&RE=1&EE=1
[15] http://www.awea.org/pubs/factsheets/10stwf_fs.PDF
[16] Ibid.

There has been only one successful commercial wind generation project in Ohio to date at Bowling Green in a joint-venture project run by AMP-Ohio and various northern Ohio municipalities. The installation costs for the 4 1.8 MW turbines (7.2 MW total) was $9,861,000 or $1,369,583.33 / MW.[17] In general, there is a downward trend in wind cost as found by groups such as AWEA, NREL, and the EERE (shown below):

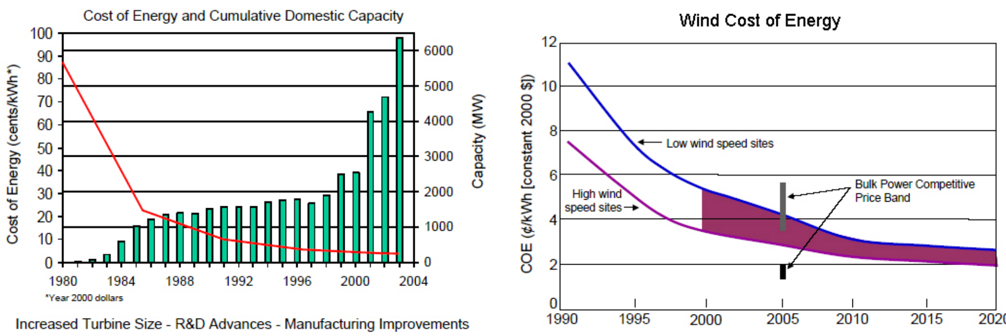

Figure 2: Cost projections for wind energy from EERE[18]

In this case, the uncertainty revolves around the reliability of forecasts by experts from these various organizations. In general, the cost seems to be leveling off as seen in the above trend; however, the experts are still projecting some cost reduction as the wind industry grows which would need to be considered for decisions of timing for when and how many turbines to install. More accurate information on costs of installation and maintenance could be obtained from wind developers and current project owners, such as at Bowling Green, but this information is difficult to access and information from Bowling Green may not be applicable for the current project under consideration.

Since cost information is difficult to obtain and regulatory incentives are difficult to predict and cover only a fraction of the project costs, the focus of uncertainty for this study will thus be the wholesale electricity price from AMP-Ohio to its member utilities. Using this main source of uncertainty, the trade-offs between a decision involving a small-scale (3 MW) wind farm as a pilot project versus upfront investment in a large-scale (26 MW) wind farm will be evaluated. This will be done in two ways. The first analysis will evaluate the effects of a decision to build a small wind farm at first to "test the waters" versus diving in with installation of a large wind farm. This will be done using a decision tree that incorporates chance outcomes based on the uncertainty from wholesale electricity prices. In the second analysis, the effects on the above small farm / large farm decision will be considered via the addition of an option of closing the wind farm due to sluggish growth in wholesale electricity prices.

<u>Discussion of Project Options: To Build (Big) or Not to Build (Big)</u>

One of the big decisions that a community, such as Wapakoneta, interested in wind projects faces is the scale of the project. Should a community start off by installing a few turbines and assess the initial success of the program or should the community take

[17] http://www.amp-ohio.org/pdf/OMEGA_JV6_2005_Annual_Report.pdf
[18] http://www.eere.energy.gov/windandhydro/windpoweringamerica/ne_economics.asp

advantage of the economies of scale associated with installation of a large-scale commercial wind turbine? This analysis will look at the potential trade-offs of large number wind turbine program economies of scale versus small number flexible wind turbine programs. Specifically, 3 different scenarios will be analyzed with differing degrees of flexibility:

1. Installation of a large scale commercial wind farm of 26 turbines and 20 MW of electricity generation capacity
2. Installation of 4 test turbines and 3 MW initial capacity which can be scaled after 10 years in the "second phase" of the project if conditions seem favorable
3. Installation of 4 test turbines initially and sequential installations every 10 years of 4 turbines at a time if conditions seem favorable

The "conditions" referred to above in option 2 and 3 are those pertaining to the main source of uncertainty surrounding these programs, namely, the wholesale electricity price. The next step to be described here is a comparison of three different planning scenarios. The first scenario involves the upfront investment of a large 20 MW wind farm. The advantage of this approach is that there are significant economies of scale involved in wind farm development. The next approach is a more conservative approach. Since the coast of wholesale electricity in the future is difficult to predict, it may make sense to install a smaller number of turbines upfront (3 MW capacity) and then if prices of wholesale electricity over the next 10 years escalate, a larger wind farm can be developed. The third approach is to monitor prices for wholesale electricity periodically and sequentially determine if increased capacity is desirable (i.e. a plan where 3MW is added at a time based on wholesale prices in the current time period).

<u>Analysis Using a Decision Tree</u>

These three scenarios will be compared using three different outcomes for wholesale electricity prices: low-growth of <4%/year, medium growth of 4 to 6%/year and high growth of >6%/year on average. In all cases, a Geometric Brownian Motion trend function was used based on price data from 1997 to 2006 (see Dykes_AP2 for details) where the drift was found to be 5.07%/year, the volatility 9.31%/year, and the 2006 wholesale electricity price was $52.14/kWh. In part 2, a few other sources of uncertainty were mentioned such as incentives and cost structure. For the sake of simplicity, only the wholesale price uncertainty will be analyzed in this section. Other sources of uncertainty will be incorporated later on in subsequent steps.

On the following page is the data used for the analysis. The numbers are not exact data from wind developers since such information is proprietary and thus hard to access. The below information comes from predominantly two sources: AWEA wind fact sheets and the Windustry Community Wind Development Calculator.[19] AWEA suggests in a report that economies of scale reducing wind turbine prices to ~$1 Million / MW for 20MW+ wind farms; the Windustry model suggests that small installations (<=

---

[19] http://www.awea.org/pubs/factsheets/10stwf_fs.PDF & http://www.windustry.org/your-wind-project/community-wind/community-wind-toolbox/chapter-3-project-planning-and-management/wi

3MW) cost ~$1.9 Million/MW. Thus, small installations in this model will incur the Windustry cost and large installations will incur the AWEA cost.

For maintenance costs, economies of scale should play a less significant role and thus the Windustry model costs will be used across the board for all scenarios. The Windustry model forecasts growth in maintenance costs for a range of variables; this forecast will be used directly in the scenarios without modification. In future steps where uncertainty in cost structure is considered, these figures will be revisited and possibly modified for a different range of outcomes. The price data for wholesale electricity comes from the AMP-Ohio 2006 annual report as described in part 2.[20] The Geometric Brownian Motion forecast is derived directly from this data. A discount rate for the NPV calculations of 8% is used in this case since this was the recommended discount rate from the Windustry model. Finally, a list of incentives is given (highlighted in pink); at the present time, these variables are left out of the analysis. In subsequent steps, the effects of these incentives on the outcomes for the different scenarios will be evaluated.

Plan 1: large upfront investment for large-scale wind turbine farm

Turbine #	26	
Size Turbine	750	kW
Total MW	19.5	MW
Yearly kWh production / turbine	1,408,464.65	
Total Cost	20,000,000.00	
Economies of Scale?	yes	
Maintenance Costs / MW	63,000.00	
Total Maintenance Costs	1,638,000.00	
Current Price per MWh	52.14	
Total Savings	1,909,371.02	
ODOD grant (150K per proj)	0.00	
Production fed / state (0.03 / kWh c	0.00	per kWh
Discount Rate	0.08	
NPV		
Amount Borrowed	20,000,000.00	
Interest Rate Available	0%	Fed Bond Incentive

20 http://www.amp-ohio.org/pdf/AMP_Ohio_2006_Annual_Report.pdf

Plan 2: small upfront investment for small-scale wind turbine farm (scalable)		
Turbine # / installation	4	
Size turbine	750	kW
Total MW	3	MW
Yearly kWh production / turbine	1,408,464.65	
Total Cost	5,700,000.00	
Economies of Scale?	no	
Maintenance Costs / MW	63,000.00	
Total Maintenance Costs	252,000.00	
Current Price per MWh	52.14	
Total Savings	293,749.39	
ODOD grant (150K per proj)	0.00	
Production fed / state (0.03 / kWh c	0.00	per kWh
Discount Rate	0.08	
NPV		
Amount Borrowed	5,700,000.00	
Interest Rate Available	0%	Fed Bond Incentive

Plan 3: small upfront investment for small-scale wind turbine farm (scalable)		
Turbine # / installation	4	
Size turbine	750	kW
Total MW	3	MW
Yearly kWh production / turbine	1,408,464.65	
Total Cost	5,700,000.00	
Economies of Scale?	no	
Maintenance Costs / MW	0.00	
Total Maintenance Costs	0.00	
Current Price per MWh	52.14	
Total Savings	293,749.39	
ODOD grant (150K per proj)	0.00	
Production fed / state (0.03 / kWh c	0.00	per kWh
Discount Rate	0.08	
NPV		
Amount Borrowed	5,700,000.00	
Interest Rate Available	0%	Fed Bond Incentive

Figure 3a-c: Model characteristics for each wind farm project plan

For this model a 2-stage decision process is used to compare case 1, large wind farm, versus case 2, a few test turbines and then ramp up if conditions in 10 years are favorable. The third cases involves several decisions at multiple time periods and is thus not included for the 2-stage decision analysis (though simulation results for case 3 will be described later on in the results section). As specified previously, the low, medium and high growth conditions are defined as <4%/year, 4-6%/year and >6%/year growth. This is based on the GBM results so that the probabilities of outcomes resulting in these categories would be 1/3 in each case. This was done for two reasons: 1) a large-wind farm is economically viable in the model over a 40 year period if growth is on average >4%/year and 2) a simulation of GBM forecast prices resulted in a case where final prices reflected growth rates that corresponded to each of the above conditions ~1/3 of the time. Below is the decision tree and expected values of the different outcomes for the two scenarios:

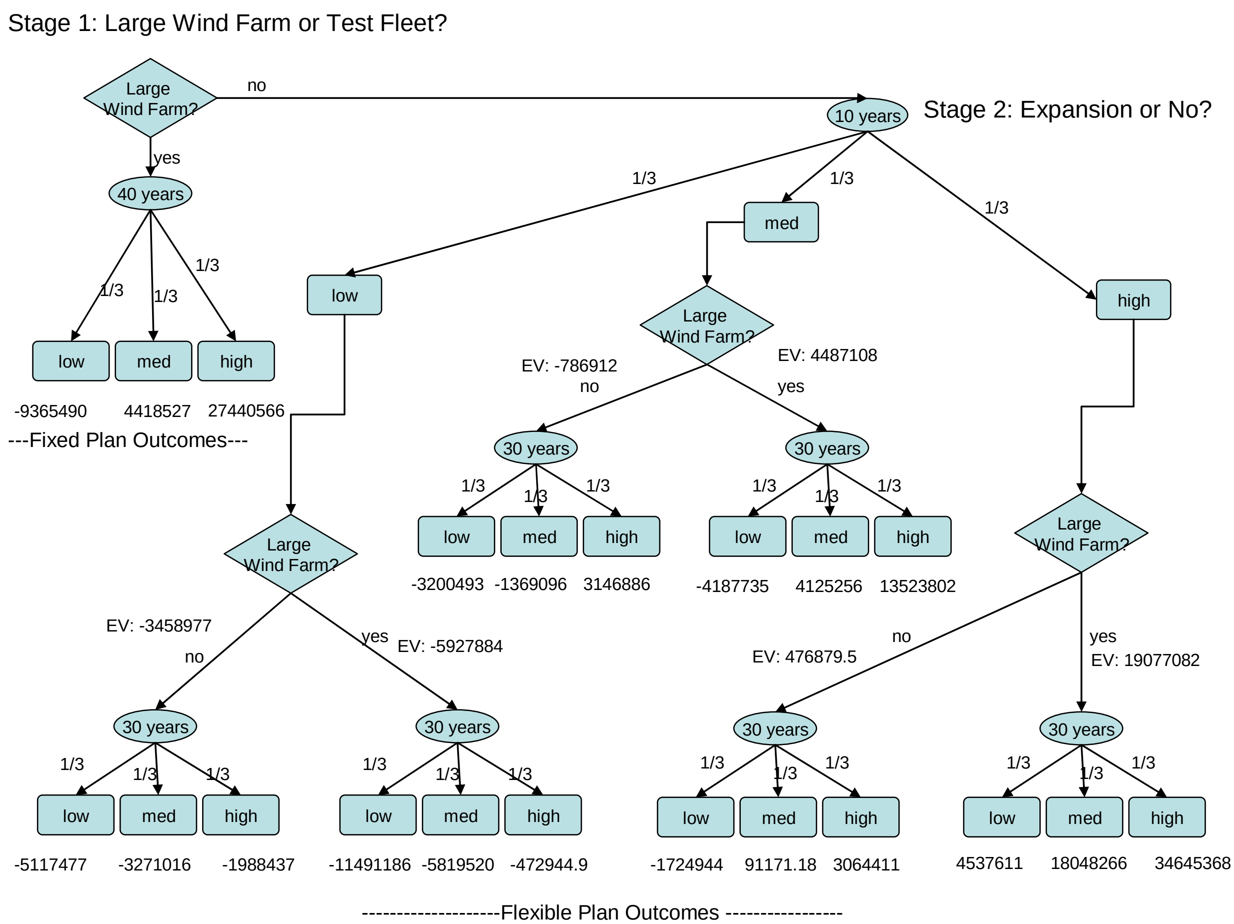

Figure 4: Decision Tree Analysis of option to build a small test wind farm versus upfront investment in a large wind farm

Based on the expected value of the different outcomes for the flexible plan decision to build or not build, the optimal decision in the second stage is to not expand to a large wind farm if wholesale price growth was low over the first 10 years and oppositely, to expand if wholesale electricity price growth is medium or high. Below is a table of the Expected NPV results for plans 1, plans 2 and plans 3 based on 50 year timescale and 750 simulations using the optimal decision strategy described above for plan 2. [21]

[21] This timescale will be reevaluated as well in future steps based on expected lifetime for wind turbines and replacement / reconditioning costs which are still being researched.

	Expected Value
Plan 1	$7,497,867.58
Plan 2	$6,701,737.62
Plan 3	$116,919.39

Table 1: Expected Value of different project plans for a Wapakoneta wind farm

As can be seen in the table above, Plan 1 outperforms plan 2 in this simulation and plan 3 is barely profitable. Running the simulations several times, plan 2 sometimes would outperform plan 1 in terms of expected value. In general, the NPV for plan 1 and plan 2 were roughly on track with each other while the expected value for plan 3, where only incremental installation of turbines was allowed, performed poorly in most cases. Below are the cumulative distribution plots for a particular run of 750 simulations:

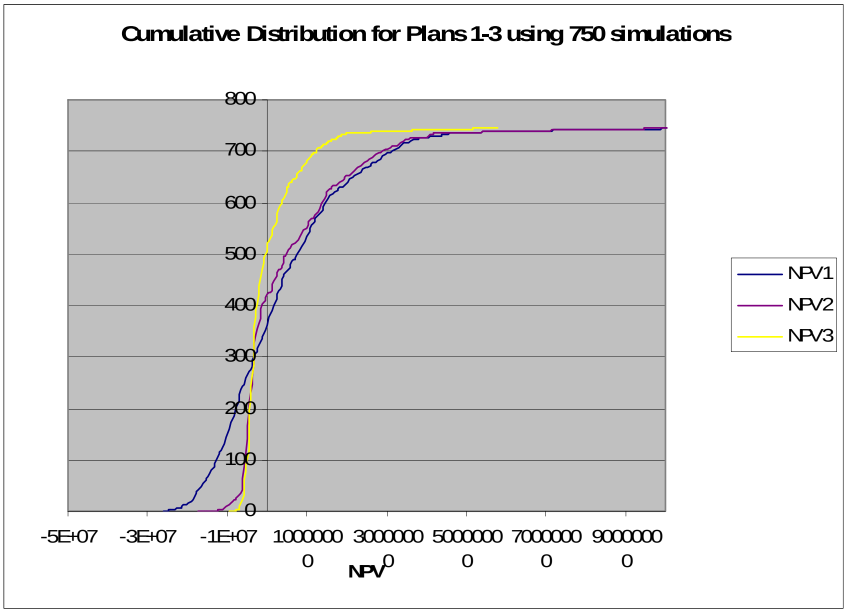

Figure 5: VARG curves for the NPV of the different wind farm plans for Wapakoneta

The resulting VARG curves and expected values above are representative of what was found after repeating the simulation run several times. The mean NPV for Plan 1 and 2 were always extremely close together and significantly above the mean NPV for plan 3. However, the minimum NPV for plan 3 was less negative in almost all cases as compared to the minimum NPV for both plan 1 and 2. The minimum NPV for plan 1, the fixed case, was always substantially lower than for the other two cases. Thus, under low-growth conditions, the large upfront investment required for plan 1 causes substantial problems for NPV and choosing either plan 2 or 3 is likely to limit the exposure to downside risk associated with plan 1. For plan 3, however, the inability to capture the benefits of economies of scale as could be done in either plan 1 or 2 meant that on average, the expected value, or NPV, of the outcome was lower than for the other plans. Thus, incremental installation of wind turbines on a particular site is not a good option unless some sort of economies of scale could in fact be obtained. As the model is designed above, there are no economies of scale that can be obtained for plan 3. In addition, the fact that under initial low growth conditions, the expected value of the project is negative, reevaluation of the pilot installation project might be wise. That is, a better alternative may be simply to wait 10 years, or “X” number of years, evaluate wholesale electricity prices and then if growth of prices continues to be strong, then installing a large wind farm. This way, the downside risk of low growth in the first 10 years could be eliminated.

Alternatively, a second way of reducing the downside risk of low wholesale would be through the use of an option to close the wind farm and sell off the assets if growth of the wholesale electricity prices were to remain stagnant. This alternative will be explored in a second analysis that uses a binomial tree lattice to assess the value of an option to close either a small wind farm if wholesale electricity prices do not grow as expected in the first 10 years of operation (during stage 1).

Analysis Using a Binomial Tree

Using a Lattice Decision Analysis, next we will model the Option of Closing a Small-Scale Wind Farm due to non-performance. The first step in the process involves the creation of a binomial lattice for the price of wholesale electricity based on the historical trend with a drift of 5.07%, a volatility of 9.31% and a starting price of $52.14 /MWh for the most recent year (2006). This resulted in an upside factor of 1.0976, a downside factor of 0.9111, and an upside probability of 0.7723. The resulting binomial lattice probabilities and corresponding price values for the wholesale electricity price are shown in the figures below.

	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	t = 6	t = 7	t = 8	t = 9	t = 10	t = 11	t = 12	t = 13	t = 14	t = 15
Price ($/kWh)	0.05214	0.05723	0.06281	0.06894	0.07567	0.08305	0.09115	0.10005	0.10981	0.12052	0.13228	0.14519	0.15935	0.17490	0.19197	0.21070
		0.04750	0.05214	0.05723	0.06281	0.06894	0.07567	0.08305	0.09115	0.10005	0.10981	0.12052	0.13228	0.14519	0.15935	0.17490
			0.04328	0.04750	0.05214	0.05723	0.06281	0.06894	0.07567	0.08305	0.09115	0.10005	0.10981	0.12052	0.13228	0.14519
				0.03943	0.04328	0.04750	0.05214	0.05723	0.06281	0.06894	0.07567	0.08305	0.09115	0.10005	0.10981	0.12052
					0.03593	0.03943	0.04328	0.04750	0.05214	0.05723	0.06281	0.06894	0.07567	0.08305	0.09115	0.10005
						0.03273	0.03593	0.03943	0.04328	0.04750	0.05214	0.05723	0.06281	0.06894	0.07567	0.08305
							0.02982	0.03273	0.03593	0.03943	0.04328	0.04750	0.05214	0.05723	0.06281	0.06894
								0.02717	0.02982	0.03273	0.03593	0.03943	0.04328	0.04750	0.05214	0.05723
									0.02476	0.02717	0.02982	0.03273	0.03593	0.03943	0.04328	0.04750
										0.02256	0.02476	0.02717	0.02982	0.03273	0.03593	0.03943
											0.02055	0.02256	0.02476	0.02717	0.02982	0.03273
												0.01872	0.02055	0.02256	0.02476	0.02717
													0.01706	0.01872	0.02055	0.02256
														0.01554	0.01706	0.01872
															0.01416	0.01554
																0.01290

Figure 6: Binomial Lattice for wholesale electricity price outcomes based on starting price, drift and volatility values as described above

	t=0	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8	t=9	t=10	t=11	t=12	t=13	t=14	t=15
Probabilities:	1.00	0.77	0.60	0.461	0.356	0.275	0.212	0.164	0.127	0.098	0.075	0.058	0.045	0.035	0.027	0.021
for wholesale electricity price		0.23	0.35	0.407	0.420	0.405	0.375	0.338	0.298	0.259	0.223	0.189	0.159	0.133	0.111	0.092
			0.05	0.120	0.186	0.239	0.277	0.299	0.308	0.306	0.295	0.279	0.258	0.236	0.212	0.189
				0.012	0.036	0.070	0.109	0.147	0.182	0.210	0.232	0.247	0.254	0.255	0.251	0.242
					0.003	0.010	0.024	0.043	0.067	0.093	0.120	0.145	0.168	0.188	0.203	0.214
						0.001	0.003	0.008	0.016	0.027	0.042	0.060	0.079	0.100	0.120	0.139
							0.000	0.001	0.002	0.005	0.010	0.018	0.027	0.039	0.053	0.068
								0.000	0.000	0.001	0.002	0.004	0.007	0.012	0.018	0.026
									0.000	0.000	0.000	0.001	0.001	0.003	0.005	0.008
										0.000	0.000	0.000	0.000	0.000	0.001	0.002
											0.000	0.000	0.000	0.000	0.000	0.000
												0.000	0.000	0.000	0.000	0.000
													0.000	0.000	0.000	0.000
														0.000	0.000	0.000
															0.000	0.000
																0.000
Cumulative Prob	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 7: Probability values associated with respective wholesale electricity price outcomes as shown in Figure 6 above.

Using the values above, a lattice model was developed to assess an option for closing the wind turbine if the trend in price was not favorable to continued operation of the wind farm. Several assumptions were needed in order to make this analysis viable:

1) Up front costs for investment in the small wind farm were assumed to be funded by debt with a 0% interest rate (i.e. special government program for renewable energy investment) and a term of 15 years. Actual debt for wind farm installed by AMP-Ohio at Bowling Green also carries a term of 15 years but the interest rate is set by an index currently at 2.88%
2) From the above, the debt was thus divided into equal installments of $5.7 Million over 15 years and each yearly payment was rolled into the operating costs along with maintenance costs of $252,000.
3) It was assumed that at any time if the plant was closed, no future costs would be incurred (i.e. the wind turbine farm could be sold to pay off the remaining debt). This is an unrealistic assumption, but was done in order to make the analysis more manageable. Thus, the decision for shutting down is based on whether operating revenue is less than the operating costs as defined above.
4) The discount rate is the same as suggested by earlier application portfolios and comes from AWEA specifications for wind programs at 8%

Below is a depiction of the scenario for closure and the effects on NPV. The value of the option to close in this case is found to be $710,807.00.

	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	t = 6	t = 7	t = 8	t = 9	t = 10	t = 11	t = 12	t = 13	t = 14	t = 15
PV(Net Revenue)	585,185	894,774	863,316	828,789	570,874	266,293	56,160	365,687	645,387	883,087	1,066,292	1,180,375	1,208,156	1,129,511	920,939	555,051
WITH OPTIONS		949,549	923,436	894,774	863,316	828,789	675,090	412,034	130,257	129,317	349,060	516,837	618,819	638,771	557,688	353,380
(check next year)			973,342	949,549	923,436	894,774	863,316	828,789	734,080	494,527	246,320	33,972	129,606	231,404	256,150	185,971
				995,019	973,342	949,549	923,436	894,774	863,316	828,789	731,702	491,202	276,493	106,755	5,842	47,004
					1,014,769	995,019	973,342	949,549	923,436	894,774	863,316	828,789	613,599	387,463	201,941	68,354
						1,032,763	1,014,769	995,019	973,342	949,549	923,436	894,774	863,316	620,480	374,424	164,113
							1,049,158	1,032,763	1,014,769	995,019	973,342	949,549	923,436	813,910	517,602	243,603
								1,064,095	1,049,158	1,032,763	1,014,769	995,019	973,342	949,549	636,456	309,589
									1,077,704	1,064,095	1,049,158	1,032,763	1,014,769	995,019	735,118	364,364
										1,090,104	1,077,704	1,064,095	1,049,158	1,032,763	817,017	409,834
											1,101,401	1,090,104	1,077,704	1,064,095	885,003	447,578
												1,111,694	1,101,401	1,090,104	941,438	478,910
													1,121,072	1,111,694	988,285	504,919
														1,129,616	1,027,174	526,509
															1,059,455	544,431
																559,308

Figure 8: Present Value of revenue streams for different outcomes in a binomial tree analysis using wholesale electricity prices derived from a binomial lattice

	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	t = 6	t = 7	t = 8	t = 9	t = 10	t = 11	t = 12	t = 13	t = 14	t = 15
Shut Down?	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
WITH OPTIONS		YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
(check next year)			YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO
				YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO
					YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
						YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO
							YES	YES	YES	YES	YES	YES	YES	NO	NO	NO
Value of option =	585,185							YES	YES	YES	YES	YES	YES	YES	NO	NO
-	1,295,992								YES	YES	YES	YES	YES	YES	NO	NO
	710,807									YES	YES	YES	YES	YES	NO	NO
											YES	YES	YES	YES	NO	NO
												YES	YES	YES	NO	NO
													YES	YES	NO	NO
														YES	NO	NO
															NO	NO
																NO

Figure 9: Recommended decision to close (or not to close) small-scale wind farm based on performance of wholesale electricity prices derived from a binomial lattice

The results of this analysis indicate that in the first few years of operation, the option to shut down should be exercised as the wholesale electricity price is too low to merit operation of a small-scale wind farm. However, further along if the price for the first few years is consistently high then operation of a small scale wind farm does become viable. This is an important result, since the tree shows that later on the small-wind farm does have positive revenue streams. Using a binomial tree, this can be seen explicitly. However, regardless of the approach the overall revenue streams for the first 15 years of operation for the small-scale wind farm are still negative. Unfortunately, even the inclusion of the "option to close" does not make a small-scale pilot project wind farm look economically attractive.

Discussion and Conclusion

Based on these initial results, it is possible to say that a large-scale wind farm will certainly provide advantages in terms of economies of scale so long as the growth in wholesale electricity prices does not fall substantially. However, significant downside risk can be avoided by adopting a flexible plan in which small turbine capacity (3MW) is installed initially. This downside risk can further be mitigated by an "option to close" if the wholesale prices in the first few years after installation do not rise in accordance with the historical trend of 5%. Provided wholesale prices in the first few years do show strong growth, assessment at a later data will can be used to make a decision to expand to a 20 MW wind farm. An alternative to this entire process is simply to "wait it out"; that is, to monitor wholesale electricity prices, regulations, and wind costs over the coming years. If wholesale electricity prices show strong growth, wind farm costs fall, or regulations begin to favor investment in renewable energy programs, then a wind farm could be installed at Wapakoneta at any later date.

Of the three major sources of uncertainty mentioned above, only uncertainty in wholesale electricity prices was considered. Uncertainty from maintenance and installations costs as well as policy incentive programs have been ignored to make this analysis more manageable for the given scope and time constraints of course project. More thorough analysis will need to consider these additional sources of uncertainty. With respect to regulatory incentives, this is especially important considering the fact that for a given project, most incentive programs are capped at a certain amount. Thus, the same amount of incentive funding is likely to be accessible for a small-scale wind farm as for a large scale wind-farm. For instance, funding for large commercial wind programs is capped in Ohio at $150,000 and production incentives are similarly capped beyond a certain dollar amount per "project".[22] Thus, the fraction of upfront costs covered for a small wind farm and each year there after will be substantially more than for a large wind-farm. This in turn may affect the overall analysis and make the small-wind farm appear more economically attractive than this analysis has suggested.

With respect to cost uncertainties, improved collaboration with wind developers or an economic feasibility study that incorporates developer input would be beneficial. A lot of information concerning costs for installation and maintenance is proprietary. In this analysis, estimations were made for all such costs. The economies of scale that a project may face were substantial in this analysis as suggested by the information accessible via AWEA and Windustry. However, this needs to be validated by talking with developers and thoroughly researching existing projects to see what cost values may be more realistic and to attempt to quantify additional uncertainty for such costs.

The above analysis is a first step towards an economic feasibility study for a wind farm in Wapakoneta, Ohio. Initial analysis recommends either investing in a large wind-farm of 20 MW size in order to capture economies of scale, or waiting a few more years in order to monitor the development of wholesale electricity prices as well as costs of wind turbine programs and regulatory incentives for renewable energy. However, all of

[22] http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=OH&RE=1&EE=1

this economic analysis above overlooks many non-monetary benefits that would accrue from the wind-farm such as reduction in emissions from fossil-fuel electricity plants. If an RPS is implemented in Ohio in the near future, Wapakoneta might also benefit from being a pioneering municipality in Ohio with respect to being the second commercial and perhaps first large-scale wind farm project in Ohio. In order to make any decision regarding wind power for Wapakoneta, an extensive analysis that includes a detailed economic feasibility study as well as environmental impact is recommended. This report seeks only to show that in designing an economic feasibility study, uncertainty in the various underlying determinants of the project's success should be considered and that incorporating flexibility into the design of the wind farm can improve the overall economic viability of the project.