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

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ESD 71 – Prof. de Neufville

Bowling Green, Ohio Wind Farm

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Problem Description

> Why wind in Wapakoneta?
– Two Year DOE Tall Tower Wind Assessment Study shows that wind speeds at Wapakoneta, Ohio site outperform all other sites tested including Bowling Green, Ohio where the first Ohio commercial-scale wind farm was installed in 2001
– Because Wapakoneta is a municipal utility, outside the jurisdiction of the large multi-state utility providers, pursuing a wind farm is more straightforward process
– In addition, the city owns a large body of land near the test site and the highway that would help enable wind farm installation, maintenance and visibility
– Finally, there is community interest from Wapakoneta officials for such a project and various local businesses would profit from investment in the project

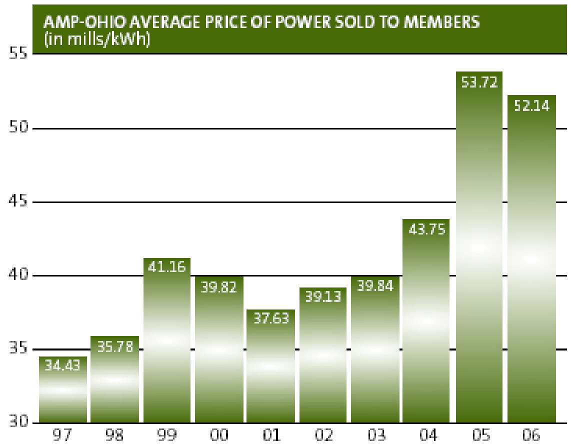
Problem Description

> What are the next steps?

- Following on the wind assessment study, other information is necessary prior to going ahead with such a large-investment project for the city
- Key to this is an economic feasibility study that incorporates:
  - project costs
  - offsets in electricity costs to the community
  - Regulatory incentives
- All of the above involve a large amount of uncertainty
- Any thorough economic feasibility study will accurately address these uncertainties
- This analysis will show a preliminary study of how to address such sources of uncertainty

Description of Uncertainty

> Three major sources of uncertainty beyond traditional economic factors:
  - Wholesale electricity price
    - Wholesale electricity sold to Wapakoneta sub-stations from AMP-Ohio; trend in electricity prices for past several years shown below[1]
    - Calculated price drift for 10 year period is 5.07% and volatility is 9.31%

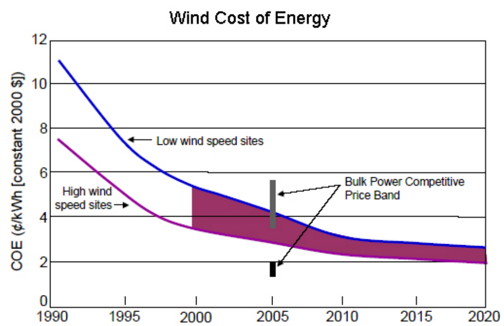


[1] http://www.amp-ohio.org/pdf/AMP_Ohio_2006_Annual_Report.pdf

Description of Uncertainty

– Regulatory Incentives
  - Presently, there are a variety of incentives[2]:
    - Grants up to $150,000 for a large commercial wind project
    - Production incentives of $0.01/kWh
    - $0.015/kWh production incentives as well as tax exemptions at the federal level
  - However, presence of incentives and changes to incentives in future periods are unknown (incentive value could increase or decrease)

– Installation and Maintenance Costs
  - Project Costs for Wind expected to fall slightly in coming years but not by a large amount[3]:



[2] http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=OH&RE=1&EE=1
[3] http://www.eere.energy.gov/windandhydro/windpoweringamerica/ne_economics.asp

Description of Uncertainty

> Dominant source of uncertainty of the above three sources is wholesale electricity price
  - Regulatory incentive value as compared to overall project costs likely to be small
  - Costs of projects not likely to change substantially in the future and collaboration with developers likely to provide a large amount of information to clarify this source of uncertainty

> Wholesale electricity in recent years has been extremely volatile:
  - Due to fossil fuel price volatility, especially natural gas
  - In the future, potential for regulation on CO2 emissions could also cause significant increase in electricity prices

> Next step: analyze what effects the uncertainty in wholesale electricity projects could have on 1) project size and 2) continued wind farm operation after installation

Real Option Analysis 1: Big vs. Small

> Use a 2-stage decision tree analysis to look at the trade-off between upfront investment in large-scale (20 MW) versus small-scale (3 MW) wind farm
  - Below are project costs ignoring regulatory incentives and using cost estimates as provided by the Windustry model (see reference below)

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

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

Project Cost Information:
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

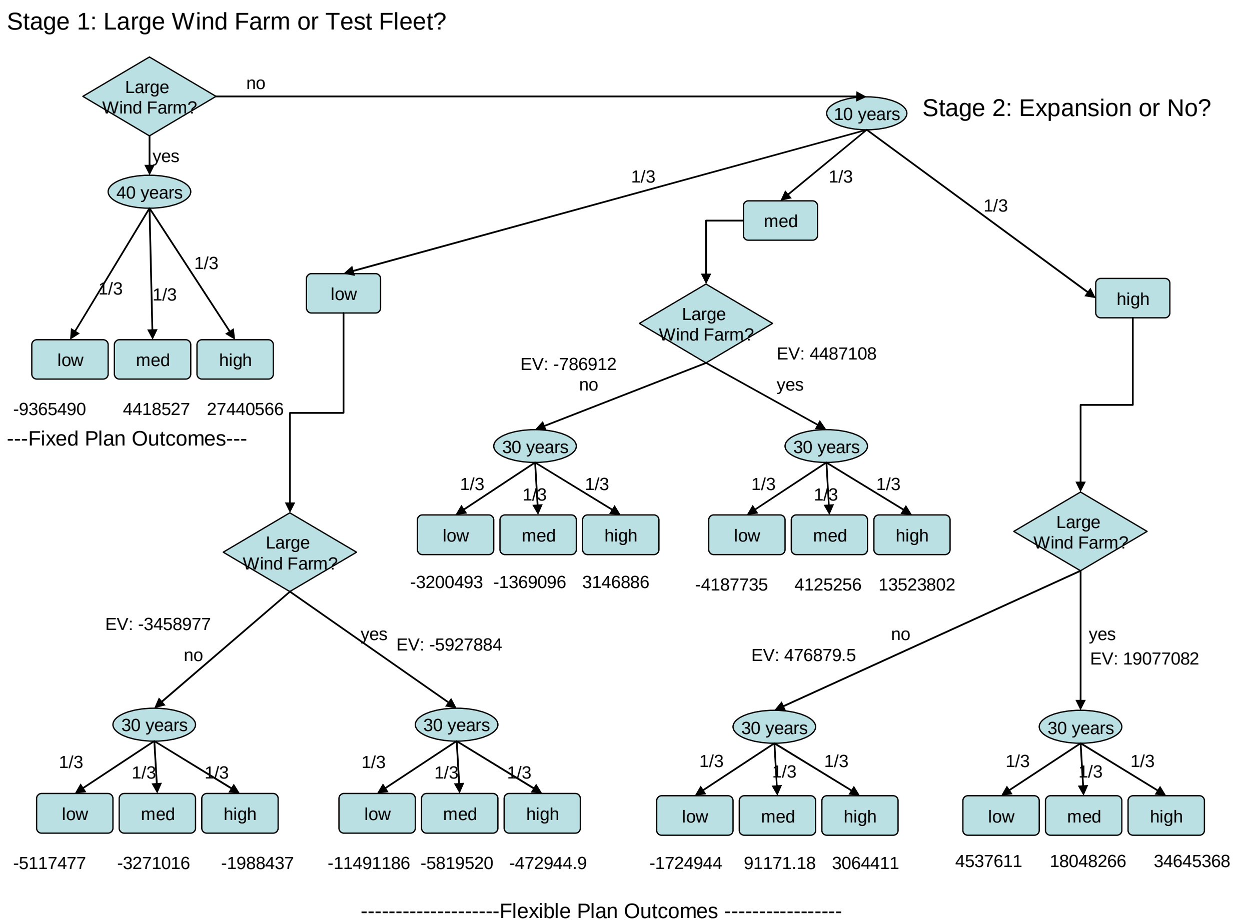
Real Option Analysis 1: Big vs. Small

> Decision Tree model:

- Wholesale electricity prices projected using Geometric Brownian Motion model with drift 5.07% and volatility 9.31%
- Includes two options:
  - Upfront investment in small or large wind farm
  - Option in stage two to upgrade small to large wind farm
- 750 simulations performed to get expected economic results for all scenarios under decision tree

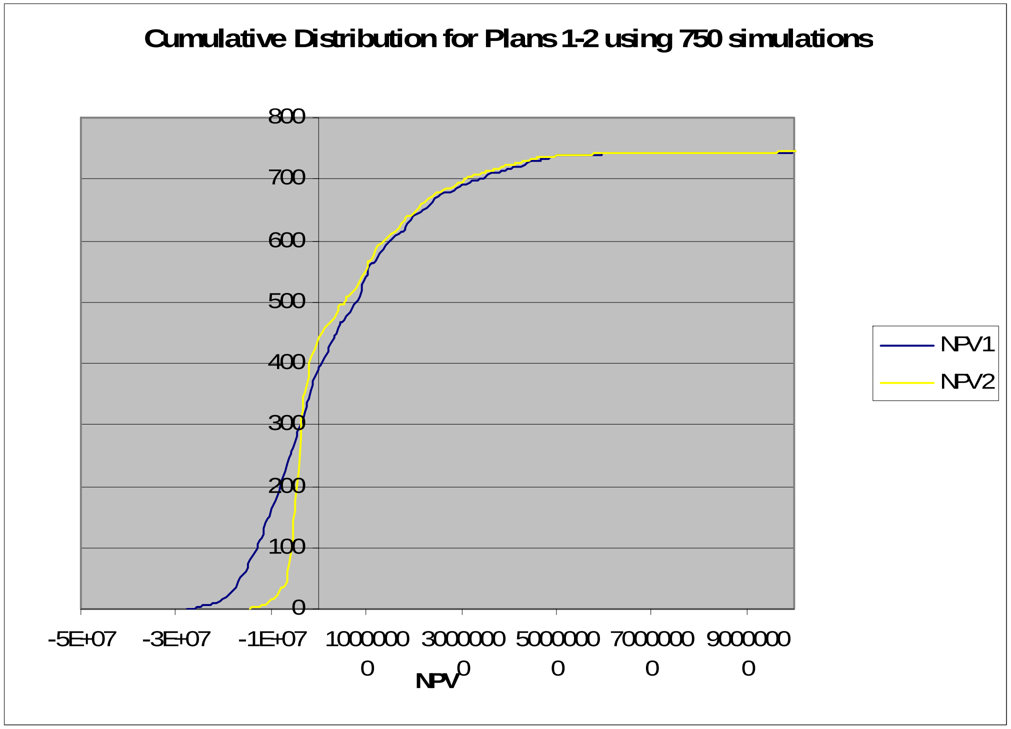
Real Option Analysis 1: Big vs. Small

> Decision Tree Results, Graphical Form:



Real Option Analysis 1: Big vs. Small

> Decision Tree Results, VARG curves:



Real Option Analysis 1: Big vs. Small

- Results indicate that large economies of scale in project make small-wind farm project less attractive economically even after incorporating flexibility
- However, the small-scale wind farm is effective at eliminating some of the downside risk since it requires less up front investment

	Plan 1 (Fixed / Big)	Plan 2 (Flex / Small)
Initial Capex	-$20,000,000.00	$5,700,000.00
Minimum NPV	-$28,502,968.63	-$15,006,328.03
Maximum NPV	$100,829,161.90	$97,604,899.62
Expected NPV	$7,497,867.58	$6,701,737.62

Real Option Analysis 2: Option to Close

> Attempt to remedy economic performance of small-wind farm by including another option:
  - Close small wind farm and sell off turbines if wholesale electricity prices do not rise as expected

> Pursue analysis using Binomial Tree Model
  - Using drift of 5.07% & volatility of 9.31%,
    - Upside factor = 1.0976
    - Downside factor = 0.9111
    - Upside probability = 0.7723

	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

	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

Real Option Analysis 2: Option to Close

> Perform binomial tree analysis using above probability / price values and assuming:
  - Plant can be closed at any time
  - Turbines can be sold off to cover outstanding debt
  - Potential life of project in this case shortened to 15 years

	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

Real Option Analysis 2: Option to Close

> Value of Option = $710,807

	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

> However, even under unrealistic assumptions and using option to close, small wind-farm does not show positive NPV in 15 years

> But, if performance in first few years for electricity is high, project does become attractive; this again highlights the importance of the trend in wholesale electricity prices on overall economic viability of the wind project

Discussion and Conclusions

- Initial analysis for a Wapakoneta wind project indicate that economies of scale are significant and a large-scale wind farm fares better than a small-scale wind farm with option for later expansion but requires substantially more investment
- This analysis leaves out regulatory incentives which may favor a small-scale wind farm due to percentage of costs covered being greater for a small-scale wind farm versus a large-scale wind farm
- This analysis also relies on rudimentary estimates of project cost; collaboration with wind developers needed to validate assumptions here
- Overall, much more extensive analysis is needed in order to evaluate the economic feasibility of a wind farm in Wapakoneta; this analysis is meant only to show the importance of incorporating uncertainty and flexible design into any future analysis for such a project