Spatial and Economic Impacts of Wind Turbines on the Economy of Oklahoma

The year I got my driver's license crude oil was selling for over $100 a barrel. When my parents were getting their driver's license, crude oil was selling around $30 a barrel. Prices do fluctuate, but the trend for the cost of energy is rising. With generally higher prices and extremely volatile markets, getting into the energy industry can be a very lucrative option for many Oklahoman farmers and ranchers. My project was designed to create an enterprise analysis from the farmer or rancher's point of view with six common agricultural systems practiced in Oklahoma.

Enterprise Analysis

The purpose behind this research is to provide Oklahoman agriculturalists an opportunity to compare the economic benefits of their current agricultural enterprise to a wind energy enterprise. An enterprise in this sense is a possible business venture. A farmer may have a wheat enterprise, a corn enterprise, a cow-calf or stalker enterprise, etc. They can also have an energy enterprise with wind, oil or natural gas. To analyze the different enterprises available to an Oklahoman producer, I have obtained enterprise budgets from Oklahoma State University's Agricultural Economics Department so that I can list exactly what the costs and benefits are for each enterprise as well as give an average value to each expense and revenue. The enterprises I chose to look at are dryland wheat production in Garfield County, dryland corn production and dryland soybean production in Kay County, irrigated corn production in Texas County, dryland wheat with stocker cattle in Garfield County, and native pasture with a cow-calf operation in Woodward County.

In this enterprise analysis we will be concerned about opportunity costs. An opportunity cost is the potential benefit (we are interested in profit gained, which are revenues-expenses) that

you will forgo to entertain a different enterprise. Having wind turbines on land that would normally be used for agricultural production creates the opportunity costs. The profit lost from losing the harvest that land would have produced is the opportunity cost. Never before has there been a project that undertook the tracing of every piece of land that was lost to agricultural production to allow to construction and operation of wind turbines. The next section of this paper outlines the process taken to identify the amount of land utilized by a wind energy enterprise.

Mapping

The majority of time spent on this project was dedicated to the mapping of every wind turbine, substation, transformer and unloading zone in the state of Oklahoma. It was necessary to know how much land was taken out of agricultural production so that a farmer or rancher could easily see what would happen to his or her other enterprises if they allowed the development of wind turbines on their property. Google Earth Pro was the program used to trace every turbine. This program worked extremely well with the only downside being that the satellite imagery, while recent, isn't keeping pace with the wind turbine installs. There was at least one project the Oklahoma Chamber of Commerce had recorded as active that was not trace able because the imagery date was not recent enough. However, all the farms that were captured in the satellite imagery were complete according to the data that the chamber had provided meaning that the data collected is only full of complete farms.

In order to trace the farms, they had to be located. Oklahoma's Chamber of Commerce has a spreadsheet with the approximate location of each farm, giving the county or counties it is in as well as the closest town. This made locating the farms much easier on Google Earth Pro. On the spreadsheet there was also the number of turbines believed to be in each project. These numbers helped ensure that turbines weren't overlooked in the process. There was not an

estimate as to how many off site transformers, unloading zones, or substations there were for a project, but in the process of tracing the roads between the turbines you get to see a lot of land surrounding the turbines helping you find all the support structures for the farm.

To distinguish the turbine pad from the roadway, we started tracing the pad as soon as the roadway began widening. For consistency purposes we applied this to all the turbines in Oklahoma. We traced the turbines first and then traced all the roads that connected the turbines. We only traced the road segments that were built to access the turbines. City, county, or state roads already in place were not traced. These roads and the ground they cover would be out of agricultural use with or without the wind farms being installed. While tracing the road segments it was very common to come across an unloading zone, a substation or a transformer. When we came across them we would either trace them then or take note of their location and trace them after the road segment currently being traced was finished.

After each object was traced, we recorded its measurements in an excel spreadsheet and attached a name to the measurement that matched the name used in Google Earth Pro. By recording the measurements before saving them, we were able to record them down to the hundredth of a square foot. When we were finished with the tracing project, we had a detailed list of every piece of wind energy land and its size recorded. In addition to this data being helpful for a partial budget analysis, the 2015 Oklahoma Legislature is using the data to guide the law making process used to govern this new source of energy.

The tracing of these turbines took well over a hundred hours to complete. Never before has a project like this been done in the state of Oklahoma. The data collected is not only the first of its kind, but it proved that the research conducted on these turbines across Oklahoma was a

very beneficial project. We found that the industry standard given to determine the acres used per turbine is grossly overestimated.

Results

In the table you can see the land used by each farm as well as what the turbine average is. While the correlations have not yet been ran, it is assumed that the amount of land taken up by each turbine is not determined by the size of the turbine as much as it is by the land that it is placed on. Following is an example: in the Blue Canyon project, the turbines are placed on very rocky soil, meaning that the opportunity cost is very low. In a project like this, more land per turbine will be used than in a project like Chisholm View, where the turbines were placed on high yielding dryland wheat farmland.

Project	Turbines	Capacity (MW)	Avg. Turbine Spacing (ft.)	Turbines (ac)	Avg. pad size	Roads (ac)	Support Systems (ac)	Total Land Used (ac)	Total land use per MW (ac)	Total land use per turbine (ac)
Big Smile Dempsey Ridge	66	132.0	1046	9.99	0.15	27.86	0.02	38.02	0.29	0.58
Blackwell Wind Farm	26	59.8	1698	1.76	0.07	13.34	4.74	19.91	0.33	0.77
Blue Canyon I	45	74.3	875	3.66	0.08	23.21	4.27	31.22	0.42	0.69
Blue Canyon II	84	151.5	1239	4.97	0.06	52.72	1.32	59.07	0.39	0.70
Blue Canyon V	66	99.0	1072	8.75	6.72	48.22	6.72	70.41	0.71	1.07
Blue Canyon VI	55	99.0	975	11.51	6.72	49.26	6.59	74.08	0.75	1.35
Buffalo Bear	9	18.9	2257	2.08	0.23	5.41	0.27	7.99	0.42	0.89
Canadian Hills Wind Farm	135	322.5	1184	6.51	0.05	61.97	4.84	73.37	0.23	0.54
Centennial Wind Farm	80	120.0	722	6.50	0.08	26.14	5.00	37.72	0.31	0.47
Chisholm View Wind Project	139	233.5	1283	4.73	0.03	72.40	15.69	92.85	0.40	0.67
Crossroads Wind Farm	98	227.5	1314	21.69	0.22	91.25	5.91	119.06	0.52	1.21
Elk City Wind Energy Center	43	98.9	1539	2.25	0.05	46.16	6.97	55.43	0.56	1.29
Elk City II	48	74.6	2026	1.60	0.03	36.89	2.76	41.29	0.55	0.86
Keenan II Wind Project	66	151.8	1069	3.86	0.06	30.50	8.87	43.29	0.29	0.66
Minco I, II, and III	188	300.8	1622	6.31	0.03	137.24	19.81	163.41	0.54	0.87
Novus I	40	80.0	1640	8.19	0.20	30.54	7.44	46.38	0.58	1.16
Novus II	20	40.0	1572	6.13	0.31	17.61	0.00	24.04	0.60	1.20
Oklahoma Wind Energy Center	68	102.0	602	3.11	0.05	15.37	0.07	18.59	0.18	0.27
OU Spirit Wind Farm	44	101.0	1072	6.10	0.14	23.73	50.36	80.33	0.80	1.83
Red Hills Wind Farm	82	123.0	663	1.90	0.02	35.24	6.13	43.29	0.35	0.53
Rocky Ridge Wind Project	93	148.8	1151	3.27	0.04	45.67	5.14	54.11	0.36	0.58
Sleeping Bear Wind Project	45	94.5	919	5.69	0.13	31.14	3.80	40.75	0.43	0.91
Taloga Wind Farm	54	130.0	1630	4.81	0.09	31.10	3.94	39.93	0.31	0.74
Weatherford Wind Energy Center	95	142.5	773	13.55	0.14	59.65	2.37	75.72	0.53	0.80
								Averages	0.46	0.87

Without knowing that a correlation exists between larger turbines and more land usage, I will use the average acre per turbine in my calculations with the enterprise analysis. The average acres used per turbine, which was the sum of all land used divided by the total number of turbines, came out to 0.87 acres per turbine. To figure revenues, you must know how large the turbine is. The weighted average of the size of a turbine in Oklahoma is 1.78 MW per hour capacity. To calculate the estimated payment to the farmer, there will be a few variables estimated. The size of the turbine is 1.78 MW/hour, the number of hours in a year are 8760, the capacity factor (percentage of capacity at which the turbines operate) is 40%, the power purchase agreement (PPA) price of energy is $0.04 per kWh (that converts to $40 per MW), and the farmer negotiated a 4% royalty payment of the gross revenues. Here is a table showing how the revenues were calculated.

Wind Turbine Revenue		
Size of Turbine	1.78	MW/hour
Capacity Factor	40%	
Price of Power	$40.00	per MW
Hours per Year	8760	
Landowner Royalty	4%	
Annual Payment	$9,979.39	

Now, with the enterprise budgets provided by OK State Ag Econ we can estimate the lost profits per acre from the agricultural enterprise. It is very important to note that there are other revenues a farmer of rancher may receive for which the enterprise budgets don't account. We are researching the economic benefits, so intangible values a farmer may receive, such as the aesthetical value of a golden wheat field or the pride in knowing that he/she uses their centennial farm in the same way their parents and grandparents did, are not and should not be factored in. However, it is a possibility that an Oklahoman farmer or rancher would have the chance to

receive insurance payments on their fields and this could increase their revenues about the numbers used to compare enterprises. It is even more likely that an Oklahoman farmer or rancher would receive agricultural subsidies on the products they produce increasing their revenues even further. These are both economic factors that haven't been included in the research but could play an important role under some production practices in making the decision on whether or not a producer should allow turbines on their property.

We have the data to estimate the profitability of agricultural enterprises and with the research done through tracing we know the number of acres lost to a turbine, and with the industry averages and facts previously established, we can find the estimated revenue stream gained from the turbines. Below shows the enterprise analysis for the six agricultural systems with the turbine revenue included and listed with the data is the county that the data was based on that was used to conduct the analysis.

Dryland Wheat Enterprise Budget – Garfield County

Enterprise	Dryland Wheat	Per Acre	Per Turbine
Revenue Forgone			
	35 bu @ 5.5	($192.50)	($167.48)
Costs Forgone			
	Wheat Seed	$15.30	$13.31
	Fertilizer	$45.42	$39.52
	Pesticide	$27.61	$24.02
	Crop Insurance	$7.00	$6.09
	Annual Operating Capital	$4.84	$4.21
	Machinery Labor	$11.85	$10.31
	Custom Hire	$5.15	$4.48
	Fuel, Lube and Repairs	$37.70	$32.80
	Lost profit	($37.63)	($32.74)
Gained Revenue			
	Turbine	$11,470.56	$9,979.39
Profit Gain		$11,432.93	$9,946.65

This analysis shows all the costs associated with the production of dryland wheat in Garfiled County, OK per acre as well as its revenues per acre. By converting the per acre costs and revenues into a per turbine basis, the famer or rancher is able to see is able to see at a much quicker glance what adding a turbine will do for their operation, especially if more than one turbine is being placed on their farm. This was accomplished by multiplying all the per acre costs and revenues by 0.87, the average number of acres that a turbine and its support structures occupy. A Garfield County dryland wheat farmer would increase profits by $9,946.65 per turbine added to his/her operation.

Dryland Corn Enterprise Budget – Kay County

Enterprise	Dryland Corn	Per Acre	Per Turbine
Revenue Forgone			
	90 bu @ 3.5	($315.00)	($274.05)
Costs Forgone			
	Corn Seed	$53.75	$46.76
	Fertilizer	$52.36	$45.55
	Pesticide	$22.78	$19.82
	Crop Insurance	$10.00	$8.70
	Annual Operatin	$5.51	$4.79
	Machinery Labo	$17.70	$15.40
	Custom Hire	$0.00	$0.00
	Fuel, Lube and F	$68.29	$59.41
	Lost profit	($84.61)	($73.61)
Gained Revenue			
	Turbine	$11,470.56	$9,979.39
Profit Gain		$11,385.95	$9,905.78

This analysis shows all the costs associated with the production of dryland corn in Kay County, OK per acre as well as its revenues per acre. By converting the per acre costs and revenues into a per turbine basis, the famer or rancher is able to see is able to see at a much quicker glance what adding a turbine will do for their operation, especially if more than one turbine is being placed on their farm. This was accomplished by multiplying all the per acre costs and revenues by 0.87, the average number of acres that a turbine and its support structures occupy. A Kay County dryland corn farmer would increase profits by $9,905.78 per turbine added to his/her operation.

Dryland Soybean Enterprise Budget - Kay County

Enterprise	Dryland Soybean	Per Acre	Per Turbine
Revenue Forgone			
	23 bu @ 9.2	($211.60)	($184.09)
Costs Forgone			
	Soybean Seed	$47.00	$40.89
	Fertilizer	$0.00	$0.00
	Pesticide	$10.40	$9.05
	Crop Insurance	$8.00	$6.96
	Annual Operating Capital	$1.50	$1.31
	Machinery Labor	$7.65	$6.66
	Custom Hire	$0.00	$0.00
	Fuel, Lube and Repairs	$33.67	$29.29
	Lost profit	($103.38)	($89.94)
Gained Revenue			
	Turbine	$11,470.56	$9,979.39
Profit Gain		$11,367.18	$9,889.45

This analysis shows all the costs associated with the production of dryland soybeans in Kay County, OK per acre as well as its revenues per acre. By converting the per acre costs and revenues into a per turbine basis, the famer or rancher is able to see is able to see at a much quicker glance what adding a turbine will do for their operation, especially if more than one turbine is being placed on their farm. This was accomplished by multiplying all the per acre costs and revenues by 0.87, the average number of acres that a turbine and its support structures occupy. A Kay County dryland soybean farmer would increase profits by $9,889.45 per turbine added to his/her operation.

Dryland Wheat with Winter Stockers Enterprise Budget – Garfield County

Enterprise	Dryland Wheat	Per Acre	Per Turbine
Revenue Forgone			
	35 bu @ 5.5	($192.50)	($167.48)
	Small Grain Pasture	($67.10)	($58.38)
	Stockers	($1,925.24)	($1,674.96)
Costs Forgone			
	Wheat Seed	$20.40	$17.75
	Fertilizer	$58.24	$50.67
	Pesticide	$27.61	$24.02
	Crop Insurance	$7.00	$6.09
	Annual Operating Capital	$4.77	$4.15
	Machinery Labor	$11.85	$10.31
	Custom Hire	$5.15	$4.48
	Fuel, Lube and Repairs	$37.70	$32.80
	Stockers	$1,575.00	$1,370.25
	Pasture	$67.15	$58.42
	Hay	$11.25	$9.79
	Salt	$0.16	$0.14
	Minerals	$0.21	$0.18
	Vet Services/Medicine	$5.15	$4.48
	Vet Supplies	$0.89	$0.77
	Marketing	$10.00	$8.70
	Mach/Equip Fuel, Lube, Repairs	$19.65	$17.10
	Mach/Equip Labor	$24.00	$20.88
	Other Labor	$28.13	$24.47
	Annual Operating Capital	$26.55	$23.10
	Lost profit	($243.98)	($212.26)
Gained Revenue			
	Turbine	$11,470.56	$9,979.39
Profit Gain		$11,226.58	$9,767.13

This analysis shows all the costs associated with the production of dryland wheat with the dual purpose of grazing in Garfield County, OK per acre as well as its revenues per acre. By converting the per acre costs and revenues into a per turbine basis, the famer or rancher is able to

see is able to see at a much quicker glance what adding a turbine will do for their operation, especially if more than one turbine is being placed on their farm. This was accomplished by multiplying all the per acre costs and revenues by 0.87, the average number of acres that a turbine and its support structures occupy. A Garfield County dryland wheat farmer who ran stockers would increase profits by $9,767.13 per turbine added to his/her operation.

Irrigated Corn (Interrupted Pivot) Enterprise Budget – Texas County

Enterprise	Irrigated Corn	Per Acre	1/4 section
Revenue Forgone			
	225 bu. @ 3.5	($787.50)	($51,187.50)
Expenses Forgone			
	Corn Seed	$86.00	$5,590.00
	Fertilizer	$135.58	$8,812.70
	Pesticide	$22.78	$1,480.70
	Crop Insurance	$20.00	$1,300.00
	Annual Operating Capital	$10.70	$695.50
	Machinery Labor	$14.55	$945.75
	Irrigation Labor	$3.60	$234.00
	Machinery Fuel, Lube and Repairs	$69.44	$4,513.60
	Irrigation Fuel, Lube and Repairs	$57.79	$3,756.35
Profit Lost from No irrigated Corn			($23,858.90)
Expenses Gained			
	Wheat Seed	($10.20)	($645.25)
	Fertilizer	($37.39)	($2,365.29)
	Pesticide	($27.91)	($1,765.59)
	Crop Insurance	($5.00)	($316.30)
	Annual Operating Capital	($4.17)	($263.79)
	Machinery Labor	($10.80)	($683.21)
	Custom Hire	($5.15)	($325.79)
	Fuel, Lube and Repairs	($35.73)	($2,260.28)
Gained Revenue			
	Crop or Pasture benefit	$132.00	$8,350.32
	Turbine (2 minimum)	$22,941.13	$19,958.78
Profit Gain			($4,175.30)

This analysis shows all the costs associated with the production of irrigated corn in Texas County, OK per acre as well as its revenues per acre. This particular analysis could not be broken into a per acre basis, so I went with a quarter section (160 acre) breakdown. In Oklahoma there is one center pivot irrigation system that has been interrupted by the placement of two wind

turbines inside of its circle. This situation is very rare, and not ideal as there are generally dryland corners that the turbine could be placed in. However, for experimental purposes I assumed a regular center pivot with no swinging arm was cut in half where the original 130 acres that used to get watered are now only 65 acres.

The opportunity cost for this particular project is leaps and bounds higher as you are not only pulling 1.74 acres (2 turbines) out of production, but the other 63.26 acres that do not fall under the pivot are no longer as profitable, but at the same time, that revenue isn't lost. You can see that the lost profit from not growing irrigated corn on the dry half of the circle was $23,858.90. That opportunity cost is offset by growing a suitable dryland crop on the same ground. With the satellite imagery we can see that this particular farmer did grow wheat on his dryland portion of the circle. The dryland wheat increased revenue by $8,350.32. But it also increased expenses by $8,625.50. This shows a net loss of $275.18. At a glimpse it looks like you shouldn't grow wheat, but it is important to know that there will be other revenues from growing wheat on those acres. Through insurance payments and government subsidies, it will most likely turn out to produce a profitable enterprise. Without counting for the loss of agronomic revenues, there was an increase of $19,958.78 in revenues by the adding of two wind turbines to the quarter section.

In the end it is close and with varying years, having turbines would be more profitable than irrigating the whole circle, however with these estimations, you should not put turbines on your land if it requires you to cut 65 irrigated acres. The irrigated corn farmer in this scenario lost $4175.30 in profits by adding turbines to his operation and replacing the irrigated corn crop with dryland wheat.

Cow-Calf Enterprise Budget – Woodward County

Enterprise	Cow-Calf	Head	Per Acre	Per Turbine
Revenue Forgone				
	Steer Calves	($598.54)	($23.94)	($20.83)
	Heifer Calves	($216.39)	($8.66)	($7.53)
	Cull Cows	($266.80)	($10.67)	($9.28)
	Cull Replacement Heifers	($78.38)	($3.14)	($2.73)
Expenses Forgone				
	Pasture	$80.00	$3.20	$2.78
	Hay	$27.09	$1.08	$0.94
	Protein Supplement	$57.00	$2.28	$1.98
	Minerals	$12.75	$0.51	$0.44
	Vet Services/Medicine	$6.58	$0.26	$0.23
	Vet Supplies	$2.91	$0.12	$0.10
	Marketing	$8.36	$0.33	$0.29
	Equip Fuel, Lube, Repairs	$32.35	$1.29	$1.13
	Equip Labor	$39.75	$1.59	$1.38
	Other Labor	$88.50	$3.54	$3.08
	Other Expenses	$5.00	$0.20	$0.17
	Annual Operating Capital	$15.10	$0.60	$0.53
	Lost profit	($784.72)	($31.39)	($27.31)
Gained Revenue				
	Turbine		$11,470.56	$9,979.39
Profit Gain			$11,439.17	$9,952.08

This analysis shows all the costs associated with a cow-calf operation in Woodward County, OK per acre as well as its revenues head and per acre. I used a population rate of 25 acres per mother cow to get the costs and revenues per acre. By converting the per acre costs and revenues into a per turbine basis, the rancher is able to see at a much quicker glance what adding a turbine will do for their operation, especially if more than one turbine is being placed on their ranch. This was accomplished by multiplying all the per acre costs and revenues by 0.87, the

average number of acres that a turbine and its support structures occupy. A Woodward County cow-calf rancher would increase profits by $9,952.08 per turbine added to his/her operation.

Conclusion

Through the enterprise analysis, we can see that installing wind turbines is profitable under the agricultural systems we analyzed, with an exception of only installing two turbines in the path of a center pivot irrigation system resulting in a 65 acre loss of irrigated farm land. The returns on wind turbines estimated in this research are phenomenal. The industry is moving to larger turbines and as they do, if the same revenue calculations are kept, the payments to landowners will increase substantially. As time continues and the turbines get bigger and more efficient, the royalty payments will increase. To the tune of nearly $10,000 in revenue increases, I strongly recommend that any Oklahoman farmer or rancher who is interested in their project's profitability, with strategic placement, to accept the offer from wind energy companies to put turbines on their land.