Regional Economic Impacts of Renewable Energy Production: A Case Study of Wisconsin

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Executive Summary

The overreliance upon conventional monocrop farming has created a variety of issues for the 21st-century farmer, much of which rooted in the price fluctuations within agricultural commodity markets. The farming community is looking far and wide for a panacea to cope with tomorrow's uncertainty. Renewable energy production has the potential to 'save the farm' for Wisconsin crop producers. The purpose of this report is to illuminate the economic benefits of renewable energy production through a series of enterprise budgeting models and compare the results with two base case scenarios 1) corn (for grain) production and 2) soybean production. The scope of this analysis is limited to corn and soybeans and focuses on the six-county region of east-central Wisconsin. Results suggest that both corn and soybean farms have much to gain by incorporating wind power and solar photovoltaic (solar PV) into its crop producing regime. Incorporating wind on to the farm will increase the economic productivity of the land by 38% for corn (for grain) and 17% for soybeans. Converting half of farmland from corn to solar PV or from soybeans to solar PV increases economic productivity of the land by 75% and 50%, respectively. This report also evaluates the economic benefits accrued by local governments for hosting renewable energy projects, and the revenue streams for the project developer.

Acknowledgments

I would like to give my fullest appreciation to Dave Marcouiller for providing guidance to me throughout the making of this report. This work would not be possible without his efforts. I also would like to thank everyone at RENEW Wisconsin for helping me foster the thesis of this report and being a motivating force in my everyday life.

1. Introduction & Literature Cited

The economic landscape of conventional agricultural production in the United States has changed dramatically in the last 50 years. For some, however, not all of this change has been positive. In fact, in 2017 and 2018, Wisconsin led the nation in number of farm bankruptcies.[1] Rising interest rates, on-site equipment depreciation, high input costs and low market prices has had adverse effects on non-corporate farms. In an attempt to "save the farm", farmers are seeking sustainable solutions to revenue generation in the wake of highly variable commodity markets.

This analysis will consider a different source of farming as a means to improve the economic landscape of the rural upper Midwest and Great Plains states; renewable energy production. Although the technical and economic viability of renewable energy production varies across regions within the United States, the geographic area of study within this analysis shares similar renewable energy resources and, in turn, similar economic outcomes. The six-county region analyzed in Wisconsin offers robust wind and solar resources, and robust conventional crop production. Renewable energy as an economic development tool for rural communities is making its way up local policy agendas across the United States. In this report I give particular attention to how large-scale renewable energy production, particularly wind and solar, benefits the host communities through a regional economic analysis lens.

Agricultural land-use practices in the Midwestern United States have changed dramatically in the past 50 years. Much of this change can be attributed to improved crop yields through advances in seed resilience, fertilizer and pesticide application, and technological advancements in farm-related equipment.[2] Farmers, however, are at the whim of volatile commodity prices for corn and soybeans and are turning to more stable forms of revenue generation. There are a variety of different functions a farm can employ when it comes to energy production, food production or a combination of energy and food production.

According to Bassam (2001), a viable farming system model is one that combines non-polluting energy production, as well as food production. This is referred to as an "integrated renewable energy farm (IREF)" and as Bassam concludes provides the opportunity for famers to transform the global production of energy and food.[3] As Munday et al. (2011) note, "[The] geographical coincidence between wind energy and rurality has brought with it attractive policy narratives - that renewable energy in general, and wind energy in particular, represents an opportunity for sustainable rural development."[4] Additionally, large-scale solar photovoltaic (PV) in rural areas presents another appealing opportunity for economic development that was previously unfeasible because of high upfront costs.[5] Renewable energy costs fell dramatically between 2008 and 2015: the cost of electricity fell 41% for wind and 64% for utility-scale

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[1] Schultz, Rob. 2019. "*State leads nation in farm bankruptcies again, dairy farm closing hits record high in 2018*". Wisconsin State Journal.

[2] Xu, Z., D.A. Hennessy, K. Sardana, and G. Moschini. 2013. "The Realized Yield Effect of Genetically Engineered Crops: U.S. Maize and Soybean." *Crop Science* 53: 735–745.

[3] Bassam, E. 2001. "Renewable Energy for Rural Communities". *Renewable Energy* 24, 3-4: 401-408.

[4] Munday, M. 2011. "Wind farms in rural areas: How far do community benefits from winds represent a local economic development opportunity?". *Journal of Rural Studies* 27: 1-12.

[5] Ellabban, O. et al. 2014. *"Renewable energy resources: Current status, future prospects and their enabling technology"*. Renewable and Sustainable Energy Reviews 29: 748-764.

PV.[6] The costs have continued to decline since 2015, and developers and utilities are taking notice in Wisconsin.

In order to capture the effects of revenue generation created by renewable energy production this analysis will employ an aggregated enterprise budgeting model. The purpose of the aggregated enterprise budgeting model is to illustrate the direct economic impacts from *solar farming*, *wind farming*, and a mix of conventional crop farming and renewable energy production.

The remainder of this report is structured as follows. Section 2 outlines the data required for each land input in question and the assumptions made for carrying out the regional economic impact model. Section 2 also consists of the analysis used to demonstrate the regional economic benefits relative to each scenario. Section 3 describes each established agricultural land-use and its accompanying economic benefits and takes the form of the 'Results and Discussion Section' of the analysis. Section 4 summarizes the results of the model to draw key conclusions for policy makers, developers, farmers, and community stakeholders. Section 4 also puts forward a series of limitations for the report and suggestions for future research areas with focus on the synergies of food production, renewable energy production, and regional economic impacts.

2. Methods

2.1 Data & Analysis

To understand how alternative land uses impact regional economies, I employ an enterprise budgeting model analyzing various types of land uses. In order to determine the net revenue generated from renewable energy production, I use National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM). Supplemental data for conventional harvesting of corn and soybeans comes from United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS), University of Wisconsin-Extension, and the USDA Economic Research Service (ERS). For the purpose of this report, the model inputs are employed on seven different scenarios. Scenario 1 and Scenario 2, corn production and soybean production respectively, represent base case scenarios which provide the basis for the economic comparison of alternative land uses. The remaining scenarios investigate the economic impacts associated with each alternative land use as it compares to the base case scenarios.

Types of Land-use

1) Conventional harvesting of corn (for grain)
2) Conventional harvesting of soybeans
3) Wind and corn harvesting
4) Wind and soybean harvesting
5) Solar and corn harvesting
6) Solar and soybean harvesting

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[6] Obama, Barack. 2017. "The irreversible momentum of clean energy". Science Magazine Volume 355 Issue 6321: 126-129

Corn (for grain) Data & Analysis

I. Land Coverage & Market Conditions

While corn (for grain) and soy production yields have increased, commodity prices have remained low. From 1982 to 2017, corn (for grain) yields in Wisconsin have increased by 59%[7] yet the price per bushel has painstakingly fluctuated over the 35-year period (see Figure 1). According to the USDA ERS, the average acreage of harvested land analyzed for corn production in Wisconsin in 2016 was 146 acres.[8]

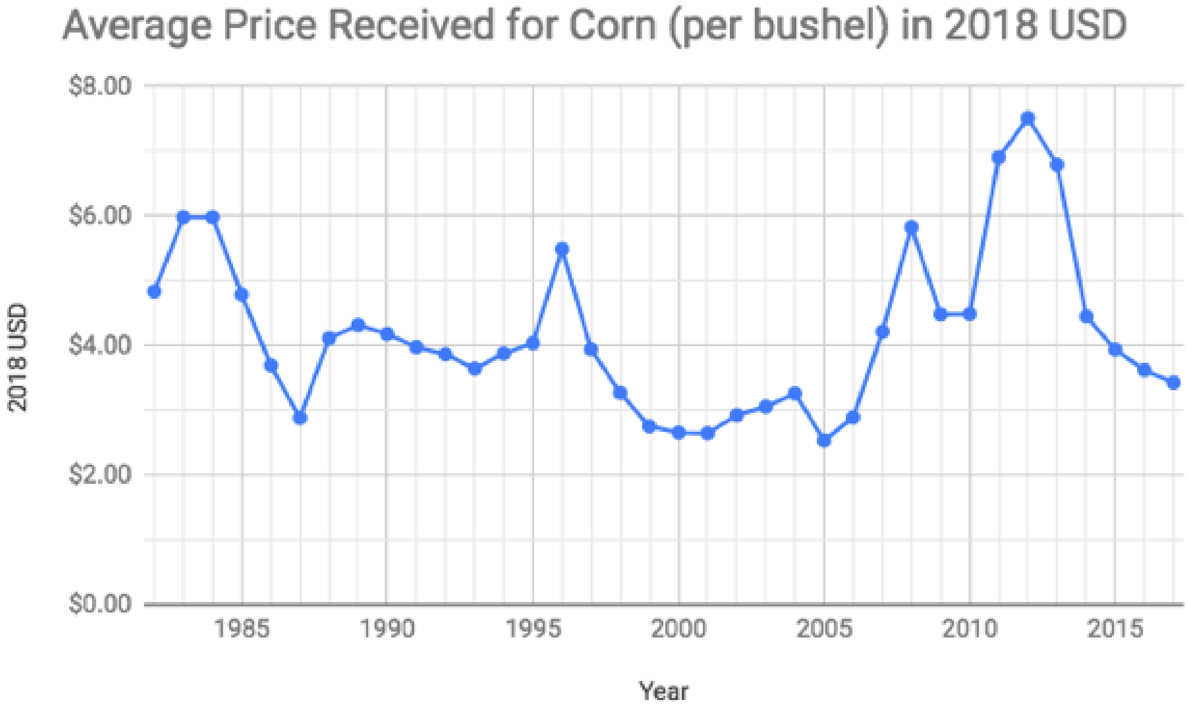

Figure 1. Average Price of Corn Received by Farmer
(*University of Illinois at Urbana-Champaign, farmdoc.illinois.edu*)

II. Financial Parameters

Table 1 provides a summary of the financial assumptions used for the enterprise budgeting model under Section 3.1. This data is provided by the United States Department of Agriculture Economic Resource Service, or USDA ERS. The ERS report pulls from 2016 data and updated yearly. The report analyzes input costs based on farming regions within the United States. Wisconsin falls under the 'Northern Crescent' region of the United States and used a proxy for the input costs for the study area of this report.

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[7] USDA National Agricultural Statistics Service. 2017-2018. Statistics by State. Wisconsin.
[8] USDA Economic Research Service. 2019. *"Commodity Costs and Returns"*.

Table 1. Financial Parameters for Enterprise Budgeting Model (USDA ERS)

Item	USD
Primary product: Corn grain	546.05
Secondary product: Corn silage	8.93
Total, gross value of production	554.98
Operating costs:	
Seed	91.37
Fertilizer	126.38
Chemicals	28.23
Custom operations	23.87
Fuel, lube, and electricity	17.03
Repairs	25.77
Purchased irrigation water	0.00
Interest on operating capital	0.72
Total, operating costs	313.37
Allocated overhead:	
Hired labor	4.23
Opportunity cost of unpaid labor	35.30
Capital recovery of machinery and equipment	90.48
Taxes and insurance	11.73
General farm overhead	26.07
Total, allocated overhead	167.81
Total, costs listed	481.18
Supporting information:	
Yield (bushels per planted acre)	163
Price (dollars per bushel at harvest)	3.35
Enterprise size (planted acres)	146

III. Analysis

In conducting an enterprise budget model for corn production, the following equation (Equation 1) generates annual net revenue for a single 146-acre corn farm and aggregated to county-wide level found in Section 3.1.

Equation 1. Net Revenue Generated from Corn Production

$$\text{Total Net Revenue} = ((C_Y \text{ x } C_{MP}) \text{ x } A_F) - (C_{IC} \text{ x } A_F)$$

Total gross revenue is found by multiplying corn yield (C_Y) by the market price of corn (C_{MP}) all multiplied by the size of the farm (A_F). To produce a total net revenue figure for a 146-acre corn farm, I subtract gross revenue by the function of input cost of corn per acre (C_{IC}) multiplied by the size of the farm (A_F).

Soybean Data & Analysis

I. Land Coverage and Market Conditions

Like large-scale corn production, soybean yields have increased over time while commodity prices have fluctuated. Figure 2 illustrates the fluctuation of price for soybeans in the commodity market. Unlike corn production in Wisconsin, however, the amount of land allocated for soybean harvest has grown since the 1990s. In fact, since 1982 to 2017, the amount of land used for soybean production has increased by 88%.[9] Typically, row crop farmers rotate between corn and soy in order to maintain the soil nutrient levels required to grow corn the subsequent year.

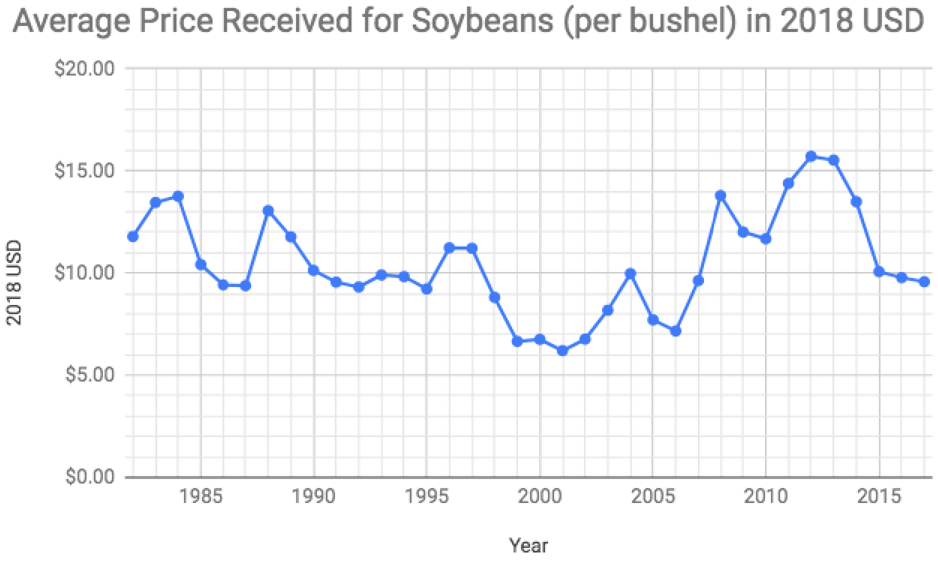

Figure 2. Average Price Received for Soybeans
(*University of Illinois at Urbana-Champaign, farmdoc.illinois.edu)*

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[9] USDA Economics, Statistics and Market Information System (ESMIS). 2017.

II. Financial Parameters

Table 2 provides a summary of the financial assumptions used for the enterprise budgeting model found in section 3.2. This data is also provided by the United States Department of Agriculture Economic Resource Service, or USDA ERS. The ERS report pulls from 2016 data and updated yearly. Like the data used for corn, I use the 'Northern Crescent' region as proxy for the input costs for the study area of this report.

Table 2. Soybean enterprise budgeting financial assumptions (USDA ERS)

Item	**USD**
Primary product soybeans	499.79
Total, gross value of production	499.79
Operating Costs:	
Seed	63.06
Fertilizer	38.85
Chemicals	22.34
Custom services	13.31
Fuel, lube, and electricity	9.84
Repairs	19.69
Purchased irrigation water	0.00
Interest on operating capital	0.39
Total, operating costs	167.48
Allocated overhead:	
Hired labor	1.83
Opportunity cost of unpaid labor	19.36
Capital recovery of machinery and equipment	75.68
Taxes and insurance	10.99
General farm overhead	22.88
Total, allocated overhead	130.74
Costs listed:	
Total, costs listed	298.22
Supporting information:	
Yield (bushels per planted acre)	53
Price (dollars per bushel at harvest)	9.43
Enterprise size (planted acres)	136

III. Analysis

In conducting an enterprise budget model for soybean production, the following equation (Equation 1) generates annual net revenue for a single 136-acre soybean farm and aggregated to county-wide level found in Section 3.2.

Equation 2. Net Revenue Generated from Soybean Production

$$\text{Total Net Revenue} = ((S_Y \text{ x } S_{MP}) \text{ x } A_F) - (S_{IC} \text{ x } A_F)$$

Total gross revenue is found by multiplying corn yield (S_Y) by the market price of corn (S_{MP}) all multiplied by the size of the farm (A_F). To produce a total net revenue figure for a 146-acre corn farm, I subtract gross revenue by the function of input cost of corn per acre (S_{IC}) multiplied by the size of the farm (A_F).

Wind Data & Analysis

I. Land Coverage & Use

According to NREL, a wind project occupies an average of 56 acres per megawatt (MW) of installed capacity[10]. Less than 1% of the 56 acres, however, is occupied by service roads, turbine foundations and other equipment. In other words, the direct impact of land from a utility-scale wind turbine is between .74 acres per MW. The remaining land indirectly impacted by the wind turbine can be used for conventional crop production, cattle grazing, or recreational use. Because of this, the analysis does not include a scenario where said land is occupied solely by wind turbines. A 2.5 MW wind turbine will indirectly occupy 140 acres of farm land, however, only 1.85 acres of land is directly occupied by the wind turbine and its associated uses.

II. Turbine Specifications & Financial Parameters

I ran a System Advisor Model (SAM) analyzing one Vensys 112m 2.5-megawatt (MW) turbine. Vensys is a German-based wind turbine manufacturer with over 36,000 MW of rated capacity deployed worldwide[11]. The ‘112m’ figure represents the diameter of the rotor, measured in meters. A 112-meter rotor is the measurement of the swept area of the turbine’s blades. The larger the sweep of the blade the more kinetic energy is converted into mechanical energy and lastly, converted into electrical energy. Another variable impacting a wind turbine’s electricity production is the hub height, which is assumed to be 80 meters. The wind turbine hub height is the rotor's height above ground. The specifications of the turbine directly impact the amount of electricity it can produce and, in turn, the economic output it generates. Figure 3 shows the power curve for a 2.5 MW Vensys 112m turbine. The ‘cut-in speed’ required for electricity generation starts at 3 m/s (meters/second) and achieves its maximum power rating at about 12 m/s. Figure 4 and Figure 5 illustrate the annual average wind speed across the U.S. and regional annual average wind speed, respectively.

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[10] Denholm, P. et al., 2009. *“Land-Use Requirements of Modern Wind Power Plants in the United States”*. NREL/TP-6A2-45834

[11] Vensys Energy. www.vensys.de

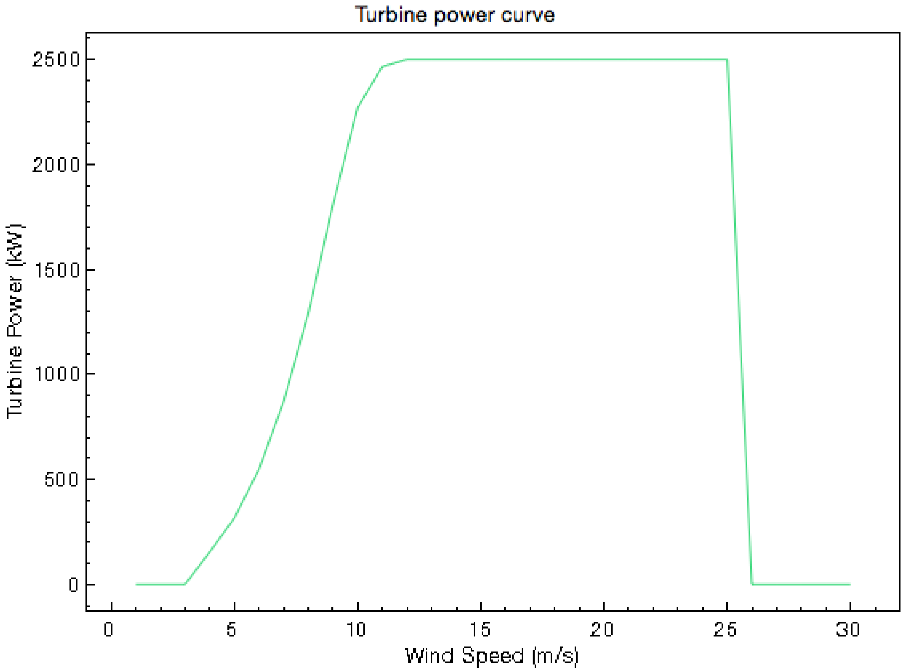
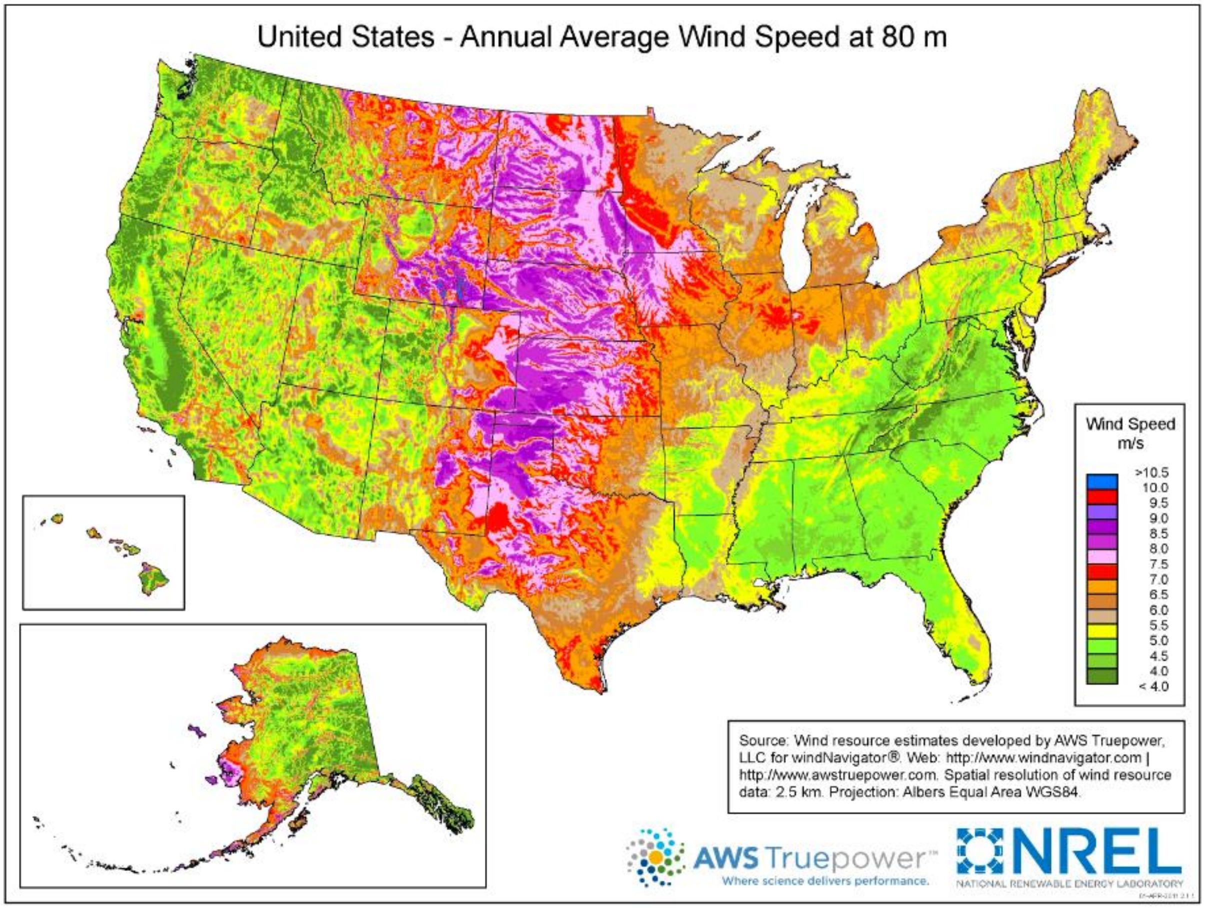


Figure 3. Vensys 2.5 MW Turbine Power Curve *(NREL)*



Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.

Figure 4. Annual Average Wind Speed at 80m Hub Height

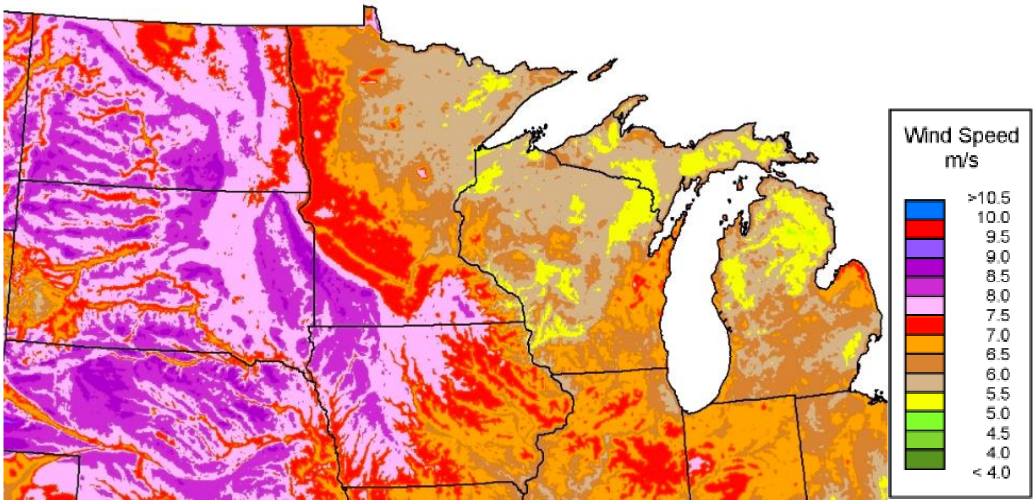


Figure 5. Annual Average Wind Speed at 80m Hub Height

Table 3 details the financial assumptions used within NREL's System Advisor Model (SAM) in order to generate the NPV of net revenue from a single 2.5 MW Vensys Wind Turbine. The assumptions in Table 3 also apply to the theoretical maximum density of wind turbines (on corn and soybean harvested land) throughout the six-county region shown in Table 11.

Table 3. Financial Assumptions

Item	Value	Source
Installed Capacity Cost	$1,454/ kW	NREL SAM
Fixed Operation and Maintenance Costs	$44/ kW-yr	NREL SAM
Production Tax Credit	$.022/ kWh	NREL SAM
Production Tax Credit Duration	10 years	NREL SAM
Production Tax Credit Escalation Rate	2.5%	NREL SAM
Inflation Rate	2%-yr	EPA
Real Discount Rate	5%-yr	EPA
Nominal Discount Rate	7.1%-yr	EPA
Debt-to-Equity Ratio	0.5	NREL
Return on Equity	5%	NREL
Year Internal Rate of Return is Achieved	10	NREL
Power Purchase Agreement (PPA)	$.055/kWh	NREL SAM
Property Tax Rate (of Gross Revenue)	1.5%	Author's Assumption
Job Creation (FTE)	.6/MW	NREL

III. Analysis

Equation 3 is used generate the annual net present value of net revenue from a 2.5 MW utility-scale wind turbine.

Equation 3. Annual NPV of Net Revenue Formula

$$(NR_T - (\sum_{n=1}^{25} L_p + \sum_{n=1}^{25} G_P))$$

Within the System Advisor Model (SAM), the financial assumptions detailed in Table XXY produce a present value of net revenue from the wind project. SAM does not account for lease payments or payments to local governments. Equation 3 accounts for this deficiency within SAM. The sum of lease payments to farmers (L_P) plus the sum of payments to local governments (G_P) less the total net revenue produces the real total net revenue from a 2.5 MW wind turbine, and once aggregated, the maximum allowable wind capacity in each area of study (Section 3.3)

Equation 4. Acres Displaced by Wind

Step 1) T_A / 140 acres-turbine = T_T
Step 2) T_T / 1.85 acres-turbine = T_{LA}

In order to find the amount of land directly displaced for wind energy production, first take the total number of acres in the county of study (T_A) and divide by 140 (minimum amount of land required for a 2.5 MW Turbine) producing the total number of turbines per county (T_T). Second, take T_T and divide by 1.85 (direct land taken for wind energy produced) producing the total amount of lost acres to wind (T_{LA}). This method was applied to Table 10, Table 11, Table 12, and Table 13 to conduct an enterprise budgeting model for revenue lost from displaced land and revenue gained from replacing corn or soy with wind.

Solar Data & Analysis

I. Land Coverage and Use

According to NREL, utility-scale solar photovoltaic (solar PV) occupies five to eight acres of land per megawatt of rated capacity (alternating current). For the purpose of this report, I assume a land use ratio of 1 MWac every 6.1 acres.[12] Unlike wind, solar PV is typically installed in parallel rows that occupy all the land within its designated area. For the purpose of this report, I only consider a farming scenario where row crops are produced on a specified portion of the available land and the remainder of the land not designated for crop production is allocated for solar PV. For example, one scenario will assume all harvested corn (for grain) and soybean land is converted to utility-scale solar PV. The other scenario will consider half of all corn and soybean land is harvested but with the other half set aside for utility-scale solar PV.

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[12] NREL. 2019. “Land Use by System Technology”.

II. Solar PV Specifications, Energy Potential, and Financial Parameters

Employing NREL's System Advisor Model (SAM), I analyzed 2.5 megawatt in alternating current (MWac) of single-axis tracking premium monocrystalline solar panels. Single-axis tracking allows the project to capture more solar radiation throughout the day by minimizing the angle of incidence between the sunlight and the panels. The total system losses assumed for this model is 13.19%, these losses account for soiling, shading, wiring, snow, and connections. I assume lease payments to be \$700/acre.[13] Figure 6 illustrates the average amount of solar irradiance hitting the earth's surface per square kilometer and, in turn, the energy potential of every square mile in the United States. Figure 7 provides the same information but on a regional level, with emphasis on Wisconsin. These two maps provide a visualization of the technical energy potential for a designated location from solar PV. Finally, Table 4 details the financial assumptions used for SAM to determine the economic benefits from solar PV.

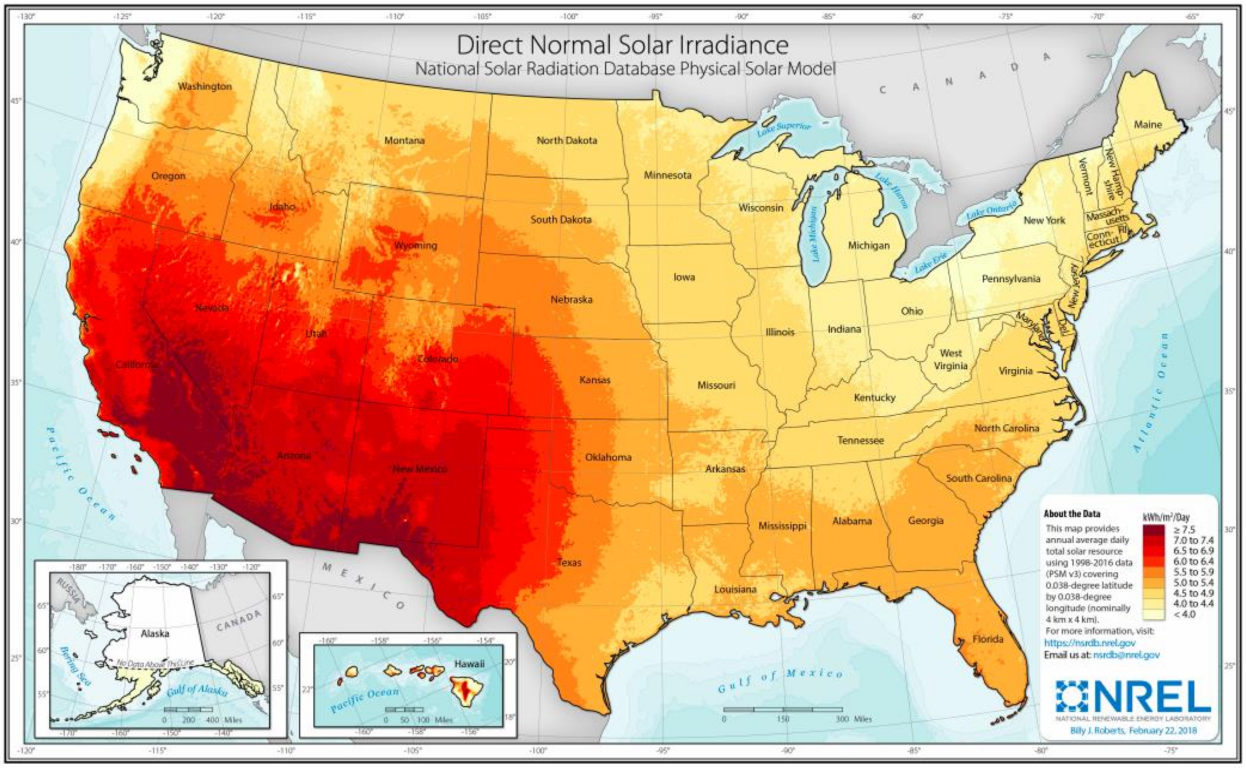

Figure 6. Energy Potential from solar PV measured in kWh/m²- day

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[13] Strategic Solar Group. 2019. *"What is the average farm lease rate?"*.

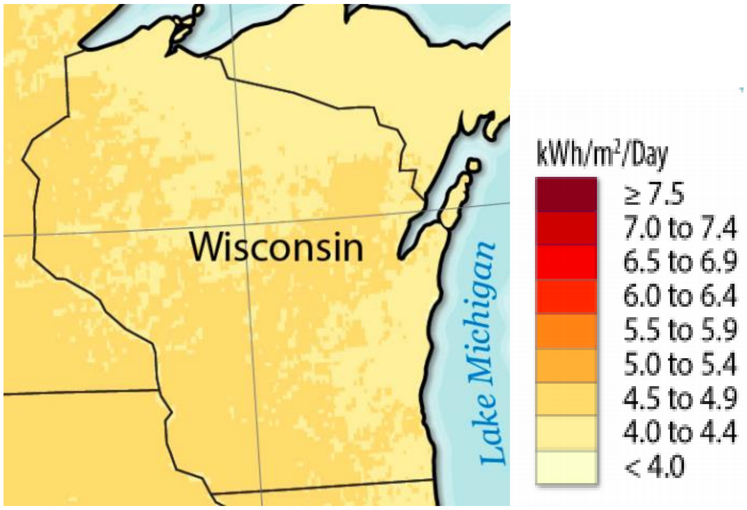

Figure 7. Regional Energy Potential from solar PV measured in kWh/m^2- day

Table 4. Financial Assumptions

Item	**Value**	**Source**
Installed Capacity Cost	\$950/ kWdc	NREL SAM
Fixed Operation and Maintenance Costs	\$9/ kW-yr	NREL SAM
Investment Tax Credit	30%	NREL SAM
Inflation Rate	2%-yr	EPA
Real Discount Rate	5%-yr	EPA
Nominal Discount Rate	7.1%-yr	EPA
Debt-to-Equity Ratio	0.5	NREL
Return on Equity	5%	NREL
Year Internal Rate of Return is Achieved	10	NREL
Power Purchase Agreement (PPA)	\$.055/kWh	NREL SAM
Property Tax Rate (of Gross Revenue)	1.5%	Author’s Assumption
Job Creation (FTE)	1.6/MWac	NREL

III. Analysis

Equation 4 is used generate the annual net present value of net revenue from a 2.5 MW utility-scale solar PV project.

Equation 4. Annual NPV of Net Revenue Formula

$$(NR_T - (\sum_{n=1}^{30} L_p + \sum_{n=1}^{30} G_P))$$

Within the System Advisor Model (SAM), the financial assumptions detailed in Table 4 produce a present value of net revenue from the wind project. SAM does not account for lease payments or payments to local governments. Equation 4 accounts for this deficiency within SAM. The sum of lease payments to farmers (L_P) plus the sum of payments to local governments (G_P) less the total net revenue produces the real total net revenue from a 2.5 MW solar project, and once aggregated, the maximum allowable solar PV capacity in each area of study (Section 4.3)

3. Results & Discussion

3.1 Corn (for grain)

Table 6 expands upon Table 5 by providing a county wide aggregation of all corn (for grain) production in 2016. It is worth noting that while corn is produced on a higher scale in south central and central Wisconsin, the area of focus produces corn yields consistent with the state average. In 2016, the average corn yield in Wisconsin was just above 178 bushels per acre harvested.[14]

Table 5. Aggregated Enterprise Budget for Six-County Region for One 146-Acre Farm (USDA NASS)[15]

WI County	Yield (bushels/acre)	Gross Revenue (USD)	Total Input Costs (USD)	Annual Net Revenue (USD)
Brown	174	85,103	70,252	14,851
Calumet*	165	80,702	70,252	10,450
Fond Du Lac	186	90,973	70,252	20,721
Kewaunee	171	83,636	70,252	13,884
Manitowoc	178	87,060	70,252	16,808
Winnebago	156	76,300	70,252	6,048

*Data from 2015

Table 6. Aggregated Enterprise Budget for Six-County Region for All Harvested Acres of Corn (USDA NASS)[16]

WI County	Yield (bushels/acre)	Gross Revenue (USD)	Total Input Costs (USD)	Annual Net Revenue (USD)
Brown	174	19,702,020	16,263,884	3,438,136
Calumet*	165	16,416,675	14,291,046	2,125,629

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[14] USDA National Agricultural Statistics Service. 2017-2018. Statistics by State. Wisconsin.

[15] USDA National Agricultural Statistics Service. 2017-2018. Statistics by State. Wisconsin.

[16] Ibid

Fond Du Lac	186	54,209,700	41,862,660	12,347,040
Kewaunee	171	13,862,970	11,644,556	2,218,414
Manitowoc	178	20,870,500	16,841,300	4,029,200
Winnebago	156	18,918,210	17,418,716	1,499,404

*Data from 2015

3.2 Soybeans

Table 7 details the economic conditions for soybean production within each of the six counties in the region of study and represents the second of two base case scenarios. Table 8 expands upon Table 7 by providing a county wide aggregation of all soybean production in 2016.

Table 7. Aggregated Enterprise Budget for Six-County Region for One 136-Acre Farm (USDA NASS)

WI County	Yield (bushels/acre)	Gross Revenue (USD)	Total Input Costs (USD)	Annual Net Revenue (USD)
Brown	54.5	69,895	40,558	29,337
Calumet	60	76,949	40,558	36,391
Fond Du Lac	58.5	75,025	40,558	34,467
Kewaunee	54	69,254	40,558	28,696
Manitowoc	57	73,101	40,558	32,543
Winnebago	54	69,254	40,558	28,696

Table 8. Aggregated Enterprise Budget for Six-County Region for All Harvested Acres of Soybeans (USDA NASS)

WI County	Yield (bushels/acre)	Gross Revenue (USD)	Total Input Costs (USD)	Annual Net Revenue (USD)
Brown	54.5	11,460,751	6,650,306	4,810,445
Calumet	60	14,145,000	7,455,500	6,689,500
Fond Du Lac	58.5	26,975,930	14,582,958	12,392,972
Kewaunee	54	5,906,952	3,459,352	2,447,600

Manitowoc	57	14,566,521	8,081,762	6,484,759
Winnebago	54	20,216,034	11,839,334	8,376,700

3.3 Wind

Table 9 details the economic benefits of a single Vensys wind turbine to the community, developers, and land owners hosting a wind turbine. I begin with the Net Present Value (NPV) of the project's net revenue over the life of the wind turbine. From there, I generate an average annual net revenue figure for each county by dividing the NPV of Net Revenue by 25 (number of years the wind turbine is assumed to generate electricity). Borrowing from NREL's findings on the amount of land required for a utility-scale wind turbine (56 acres/MW), a 2.5 MW Vensys Turbine has a 140-acre footprint. Albeit, as noted above, only .74 acres of land per MW is directly occupied by the wind turbine and its associated uses. Landowners hosting a wind project are typically paid $3,000/MW of rated capacity, annually, for the life of the project.[17] These payments are provided by the project developer in the form of annual lease payments and are included within the annual operating expenses of the project owner and shown in Table 9. Additionally, under the Wisconsin revenue sharing formula, a qualifying wind farm will contribute a total of $4,000 per MW of rated capacity to local governments.[18]

Table 9 also illustrates the average annual energy production from a 2.5 MW Vensys turbine, full-time equivalent jobs, and value added from the wind project. The two tables following Table 9 (Table 10 & Table 11) detail the economic benefits of joint wind and corn production. Table 10 details the economic benefits from incorporating wind on a 146-acre corn farm and Table 11 analyzes the theoretical maximum amount of wind capacity in each county with continued corn production. The direct land use impact of wind power per turbine (2.5 MW) is equal to 1.85 acres taken out of production for corn and soy. Table 11 and Table 12 illustrates the added economic benefit from displacing corn and soy with wind compared to the base case scenarios, respectively. Again, the direct land use impact of utility-scale wind power is estimated at .74 acres/MW and allows for a conventional crop producing farm to continue to harvest and sell corn and soybeans.

While a turbine in one county might be higher compared to another county, this does not automatically mean that the more active turbine generates a higher net revenue. Wind speed, for example, in Brown County is likely higher over more sustained periods of time compared to wind speed in Kewaunee. Such a scenario would allow for the turbine to generate more energy given a higher point on the power curve (see Figure 3). Other endogenous parameters such as variable operation and maintenance, curtailment, and fluctuations in wind speed, ultimately contribute the economic output of the turbine. These variables are often difficult to control for within SAM but is likely to explain the non-uniformity of net revenue in Table 9 and Table 10.

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[17] U.S. Department of Energy. 2017. "*Wind Energy: A New Era for Wind Power in the United States*".
[18] Wisconsin Legislative Fiscal Bureau. 2019. *"Shared Revenue Program: Information Paper".*

Table 9. Economic Benefits of One 2.5 MW Wind Turbine (NREL SAM)

WI County	Average Annual Energy Production (MWh)	NPV of Net Revenue (USD)*	Average Annual NPV of Net Revenue (USD)	Annual Lease Payments to Farmer (USD)	Annual Payments to Local Government (USD)	Job Creation: Full Time Equivalent
Brown	9,379	421,972	16,879	7,500	10,000	1.5
Calumet	9,115	444,271	17,771	7,500	10,000	1.5
Fond Du Lac	9,358	414,815	16,593	7,500	10,000	1.5
Kewaunee	9,553	391,112	15,644	7,500	10,000	1.5
Manitowoc	9,270	425,374	17,015	7,500	10,000	1.5
Winnebago	8,631	341,597	13,663	7,500	10,000	1.5

*Includes O&M expenses, Property tax expenses, lease payments, and local government payments

Table 10. Economic Benefit of Corn and Wind in Six-County Region for a 146-Acre Farm

WI County	Land taken out of production for Wind (acres)	Lost Net Revenue from Land Conversion from Corn to Wind (USD)	Total Allowable Wind Capacity (MW)	Lease Payments (USD)	New Net Revenue from Corn Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	1.85	188	2.5	7,500	22,163	10,000
Calumet	1.85	133	2.5	7,500	17,817	10,000
Fond Du Lac	1.85	263	2.5	7,500	27,958	10,000
Kewaunee	1.85	170	2.5	7,500	22,214	10,000
Manitowoc	1.85	213	2.5	7,500	24,095	10,000
Winnebago	1.85	79	2.5	7,500	13,479	10,000

The results from Table 10 showcase the economic benefit of incorporating wind on to the farm. The economic efficiency of a 146-acre corn and wind farm is improved by a six-county average of 38%. In other words, if a farmer were to add just one 2.5 MW turbine to their farm it would increase the economic output of the farm's operation by 38%. It is worth noting that the analysis in Table 10 is scaled to a 146-acre corn and wind farm, but the total footprint of a 2.5 MW turbine is 140 acres. The remaining six acres are assumed to be land harvested for corn (in addition to the other land less the 1.85 acres devoted to wind) and reflect in the new net revenue as such. The results from Table 11 illustrate the economic benefit of incorporating wind across all the harvested corn land within each county studied and the annual payments to local government. In comparing the base case corn and soy production scenarios to wind, economic productivity of the crop land increases by 38% and 17%, respectively (see Table 13).

Table 11: Total Allowable Wind Capacity with Corn Production in Six-County Region (NREL & USDA NASS)

WI County	Land taken out of production for Wind (acres)	Lost Net Revenue from Land Conversion from Corn to Wind (USD)	Total Allowable Wind Capacity (MW)	Lease Payments (USD)	New Net Revenue from Corn Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	435	44,248	587.5	1,762,500	5,156,388	2,350,000
Calumet	392.5	28,091	530	1,590,000	3,687,538	2,120,000
Fond Du Lac	1149.6	163,151	1552.5	4,657,500	16,841,389	6,210,000
Kewaunee	317.1	29,069	427.5	1,282,500	3,471,845	1,710,000
Manitowoc	462.5	53,243	625	1,875,000	5,850,957	2,500,000
Winnebago	478.4	19,815	645	1,935,000	3,414,589	2,350,000

Table 12. Economic Benefit of Soybeans and Wind in Six-County Region for a 136-Acre Farm

WI County	Land taken out of production for Wind (acres)	Lost Net Revenue from Land Conversion from Soy to Wind (USD)	Total Allowable Wind Capacity (MW)	Lease Payments (USD)	New Net Revenue from Soy Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	1.85	399	2.5	7,500	36,438	10,000
Calumet	1.85	495	2.5	7,500	43,396	10,000

Fond Du Lac	1.85	469	2.5	7,500	41,498	10,000
Kewaunee	1.85	390	2.5	7,500	35,806	10,000
Manitowoc	1.85	443	2.5	7,500	39,600	10,000
Winnebago	1.85	390	2.5	7,500	35,806	10,000

Table 13. Total Allowable Wind Capacity with Soy Production in Six-County Region (NREL & USDA NASS)

WI County	Land taken out of production for Wind (acres)	Lost Net Revenue from Land Conversion from Soy to Wind (USD)	Total Allowable Wind Capacity (MW)	Lease Payments (USD)	New Net Revenue from Soy Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	303	155,900	410	1,229,779	5,974,788	1,640,000
Calumet	340	192,414	460	1,378,676	7,977,180	1,840,000
Fond Du Lac	665	366,952	899	2,696,691	14,921,082	3,596,000
Kewaunee	158	80,352	213	639,706	3,054,011	852,000
Manitowoc	369	198,148	498	1,494,485	7,891,032	1,992,000
Winnebago	540	274,998	730	2,189,338	10,452,090	2,920,000

3.4 Solar Photovoltaic

I consider a slightly more nuanced economic analysis for utility-scale solar PV (as I alluded to in Section 2) in order to illustrate the economic benefits of exclusive *solar farming* and a mix of conventional crop production and *solar farming*. With wind, conventional crops can grow underneath the blades of the turbine and allows for a more fluid mix of row crop production and renewable energy generation. Solar PV does not allow for conventional crop production to occur underneath the racking system and panels, however, this does not preclude prospective farmers from growing row crops and hosting a part or a whole utility-scale solar PV project. Table 14 shows the economic benefits of a 2.5 MW alternating current (MWac) solar PV electricity generating facility. Table 15 showcases the economic benefits from converting half of 146-acre corn farm into solar PV production. Table 16 details the economic benefits of converting half of all harvested corn land into solar PV plus net revenue generated from the remaining land set aside for corn production. Table 17 will demonstrate the results from converting half of 136-acre soybean farm into solar PV. Last, Table 18 details the economic benefits of converting half of all harvested soybean land into solar PV plus net revenue generated from the remaining land set aside for soybean production.

Table 14. Economic Benefits of 2.5 MW Solar PV Farm (NREL SAM)

WI County	NPV of Net Revenue (USD)*	Average Annual NPV of Net Revenue (USD)	Annual Lease Payments to Farmer (USD)	Annual Payments to Local Government (USD)	Job Creation: Full Time Equivalent
Brown	490,860	16,362	10,675	10,000	4
Calumet	491,260	16,375	10,675	10,000	4
Fond Du Lac	491,260	16,375	10,675	10,000	4
Kewaunee	466,252	15,541	10,675	10,000	4
Manitowoc	486,884	16,229	10,675	10,000	4
Winnebago	491,260	16,375	10,675	10,000	4

*Includes O&M expenses, Property tax expenses, lease payments, and local government payments

Table 15 analyzes a single farm employing half of its land for solar energy generation and half for corn production. If a farmer were to convert have of their 146-acre plot of land to solar PV, the economic efficiency of said land goes up by 75%. Alternatively, converting conventional corn harvesting to solar PV increases the economic output of said land by 75%. Like wind projects, Wisconsin’s revenue sharing formula applies for solar PV projects as well. The total payments to local government for a 2.5 MW solar farm, for example, would be $10,000 annually.

Table 15. Economic Benefits of one Corn and Solar PV farm (73 acres each, 146 acres total)

WI County	Land taken out of production for solar PV (acres)	Lost Net Revenue from Land Conversion from Corn to Solar (USD)	Total Allowable Solar Capacity (MW)	Lease Payments (USD)	New Net Revenue from Corn Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	73	7,426	12	51,100	58,526	48,000
Calumet	73	5,225	12	51,100	56,325	48,000
Fond Du Lac	73	10,360	12	51,100	61,460	48,000
Kewaunee	73	6,692	12	51,100	57,792	48,000
Manitowoc	73	8,404	12	51,100	59,504	48,000
Winnebago	73	3,024	12	51,100	54,124	48,000

Table 16. Aggregate Economic Benefits of Corn and Solar PV (50% Solar & 50% Corn)

WI County	Land taken out of production for solar PV (acres)	Lost Net Revenue from Land Conversion from Corn to Solar (USD)	Total Allowable Solar Capacity (MW)	Lease Payments (USD)	New Net Revenue from Corn Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	16,900	1,719,068	2,770	11,830,000	13,549,068	11,080,000
Calumet	14,850	1,062,815	2,434	10,395,000	11,457,815	9,736,000
Fond Du Lac	43,500	6,173,520	7,131	30,450,000	36,623,520	28,524,000
Kewaunee	12,100	1,109,207	1,984	8,470,000	9,579,207	7,936,000
Manitowoc	17,500	2,014,600	2,869	12,250,000	14,264,600	11,476,000
Winnebago	18,100	749,702	2,967	12,250,000	13,419,702	11,868,000

Table 17. Economic Benefits of one Soybean and Solar PV farm (68 acres each, 136 acres total)

WI County	Land taken out of production for solar PV (acres)	Lost Net Revenue from Land Conversion from Soy to Solar (USD)	Total Allowable Solar Capacity (MW)	Lease Payments (USD)	New Net Revenue from Soy Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	68	14,689	11	47,600	62,269	44,000
Calumet	68	18,196	11	47,600	65,795	44,000
Fond Du Lac	68	17,234	11	47,600	64,834	44,000
Kewaunee	68	14,348	11	47,600	61,948	44,000
Manitowoc	68	16,271.5	11	47,600	63,872	44,000
Winnebago	68	14,348	11	47,600	61,948	44,000

Table 18. Aggregate Economic Benefits of Soybeans and Solar PV (50% Solar & 50% Soybeans)

WI County	Land taken out of production for solar PV (acres)	Lost Net Revenue from Land Conversion from Soy to Solar (USD)	Total Allowable Solar Capacity (MW)	Lease Payments (USD)	New Net Revenue from Soy Production & Lease Payments (USD)	Annual Payments to Local Government (USD)
Brown	11,150	2,405,222	1,828	7,805,000	10,210,222	7,311,475
Calumet	12,500	3,344,750	2,049	8,750,000	12,094,750	8,196,721
Fond Du Lac	24,450	6,196,486	4,008	17,115,000	23,311,486	16,032,787
Kewaunee	5,800	1,223,800	951	4,060,000	5,283,800	3,803,279
Manitowoc	13,550	3,242,380	2,221	9,485,000	12,727,380	8,885,246
Winnebago	19,850	4,188,350	3,254	13,895,000	18,083,350	13,016,393

The key takeaway from the solar and soybean analysis is Table 18 shows a six-county wide increase in economic output by 50%. In other words, switching half of all harvested soybean land to solar PV increases the economic productivity of the land by 50%.

4. Conclusion

4.1 Summary

Benefits of renewable energy come in a variety of forms. Wind and solar PV generate electricity without releasing harmful air pollutants, greenhouse gases, or ozone. These two rapidly emerging energy applications do not require the use of water during its electricity generating phase or adversely effects the land by which it occupies. Today wind and solar PV also provide real economic benefits for all involved. I hope to have provided a robust economic case for renewable energy production in east-central Wisconsin. Project developers, host farmers, local and regional electric utilities, and local governments all benefit from renewable electricity generation. My analysis has showcased the flow of revenue from developer to host farmer and developer to local government while accounting for conventional uses of agricultural land such as corn and soybean production.

Incorporating wind on to a farm will increase the economic productivity of the land by 38% for corn (for grain) and 17% for soybeans. Converting half of farmland from corn to solar PV or from soybeans to solar PV increases economic productivity of the land by 75% and 50%, respectively. In addition to substantial income increases for host farmers, local governments would see a sizeable increase in its budget just by hosting a renewable energy project within its own county or township. In short, rural communities would benefit considerably from incorporating solar and wind into its farming regime and provide myriad inter-generational economic and environmental benefits.

4.2 Policy Implications and Limitations

For rural areas to host large-scale renewable energy projects, a variety of factors are considered. Most importantly, project developers require locations with adequate solar or wind resources. Economic development organizations and stakeholders would benefit greatly from engaging with local decision makers about the benefits of renewable energy production well before project developers or utilities come to the community. Finally, I recommend local planning commissions continue to allow for the use of conditional-use permitting on land that is zoned exclusively for agriculture (when applicable). Wind and solar energy production is a form of farming, a 21st-century form of farming. With respect to limitations, this report would benefit greatly from taking a wider range of commodity prices for conventional agricultural goods in order to provide a sensitivity upon my analysis. Another limitation of this report is the scope of the analysis. It would be of great use to have enterprise budgeting data for all forms of agricultural land use and across all counties in Wisconsin.