SOLAR AND AGRICULTURAL LAND USE REPORT

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RENEW WISCONSIN

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EXECUTIVE SUMMARY

Solar fields can supply abundant, clean electricity – almost one-third of Wisconsin's consumption by 2050 – using only a small portion of the state's agricultural land. Nonetheless, solar energy development in agricultural areas raises new discussions of land use in Wisconsin. This report aims to explore Wisconsin's agricultural trends and outline the potential solar energy has to sustain the state's agricultural heritage, keep Wisconsin farmers in business, and provide environmental and economic benefits to the greater public.

Wisconsin's agricultural economy has changed substantially over the last several decades due to technological advancements, improved farm practices, evolving market conditions, and other macroeconomic trends. The amount of actively cultivated farmland has decreased by 23% since 1982, alongside the number of farm operations (from 90,000 to 64,100 in 2022). At the same time, due to advancements in practices and technology, corn and soybean yields have increased dramatically (69% for corn and 75% for soybeans). However, commodity price volatility has added financial uncertainty for farmers, as actual prices for corn in 2022 are 51% lower than in 1940 and 42% lower than in 1980.

Recent trends have allowed farmers to incorporate solar developments into a portion of their property and, at the same time, continue farming and sustaining their agricultural businesses. Solar fields offer stable revenue streams for Wisconsin farmers and financial support to local governments through the state's shared revenue formula. RENEW Wisconsin's collaborative report, *Achieving 100% Clean Energy in Wisconsin,* shows that solar development opportunities will grow for Wisconsin farmers over the next few decades. According to the report, solar energy will be the predominant source of new emission-free electricity generation for Wisconsin to achieve a net-zero economy.

SOLAR FIELDS CAN SUPPLY ABUNDANT, CLEAN ELECTRICITY – ALMOST ONE-THIRD OF WISCONSIN'S CONSUMPTION BY 2050 – USING ONLY A SMALL PORTION OF THE STATE'S AGRICULTURAL LAND.

In the most economical net-zero scenario explored in the report, 28.3 Gigawatts (GW) of utility-scale solar would be installed by 2050. This would require approximately 198,000 acres of land to host utility-scale solar in Wisconsin by 2050. Building 28.3 GW of utility-scale solar capacity would require 0.57% of Wisconsin's total land area (34.7 million acres). This would equate to 1.4% of total agricultural land (14.2 million acres) and 2.4% of field cropland (8.4 million acres) in Wisconsin.

LAND USE	LAND AREA (million acres)	SHARE OF LAND NEEDED FOR SOLAR BY 2050 (%)
Total WI land area	34.7	0.57%
Actively cultivated farmland	14.2	1.39%
Field crop land	8.4	2.35%
Total corn grain land	3.0	6.60%
Total ethanol land	1.1	17.84%

Table 1: Land use requirements for 28.3 GW / 198,000 acres of utility-scale solar in Wisconsin by 2050.

Farming for energy production is already common in Wisconsin, with about 37% of the corn grown used for ethanol. Wisconsin would only need to convert about 18% of corn-ethanol land to solar energy production by 2050 to achieve 28.3 GW of capacity. With a likely decrease in demand for corn-based ethanol needed by 2050 (due to the adoption of electric vehicles and substitution toward non-food crop feedstocks for biofuels), incorporating solar generation on farms is a way for Wisconsin farmers to help sustain their businesses.

WISCONSIN WOULD ONLY NEED TO CONVERT ABOUT 18% OF CORN-ETHANOL LAND TO SOLAR ENERGY PRODUCTION BY 2050 TO ACHIEVE 28.3 GW OF CAPACITY.

INTRODUCTION

Agriculture is a significant part of Wisconsin's economic and cultural identity. Much of the state's land (around 40%) is farmland or devoted to some form of agricultural activity. Due to optimal siting characteristics, solar farms have predominately been sited on agricultural land. As the pace of solar development has quickened in recent years, particularly involving utility-scale projects, questions have surfaced regarding the quantity of farmland that could be converted to solar fields. In recent years, solar has been Wisconsin's fastest-growing renewable energy source and has the potential to help the state reach net zero carbon emissions by 2050. The relative stability of solar lease payments, diverse soil health and ecosystem service benefits, and local economic benefits make solar generation an attractive land-use option for Wisconsin farmers.

The first section of this *Solar and Agricultural Land Use* report will summarize historical trends in agricultural land use and operations in Wisconsin using data from the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS). It includes analyses of the consolidation of farms for economic purposes, changes to crop selection and yields, and historical corn price trends. Lastly, there is a discussion of the USDA Conservation Reserve Program.

Section two will analyze land use for utility-scale solar in Wisconsin, including projections using the *Achieving 100% Clean Energy in Wisconsin* report. We analyzed several land use categories (total harvested cropland, field cropland, etc.) to illustrate the relatively small amount of land needed for solar capacity by 2050. We also discuss ethanol production in Wisconsin and how it relates to solar development.

SOLAR HAS BEEN WISCONSIN'S FASTEST-GROWING RENEWABLE ENERGY SOURCE AND HAS THE POTENTIAL TO HELP THE STATE REACH NET ZERO CARBON EMISSIONS.

1. AGRICULTURAL LAND USE

Agricultural production in Wisconsin has seen substantial changes over the last few decades, as explored in a previous RENEW agricultural land use report [1]*. Data from the most recent NASS shows that Wisconsin had 14.2 million acres of actively cultivated farmland in 2022 [2]. This number has been steadily decreasing over the last 40 years. For example, since 1982, the state's total acreage of operated farmland has decreased by 23%. Over the same period, Wisconsin's number of farm operations declined from 90,000 to 64,100 [3]. While Wisconsin has fewer farms today, the average farm size is growing. Figure 1 below shows the historical data for total farm operations and acres for the state.

* See endnotes for citations in brackets.

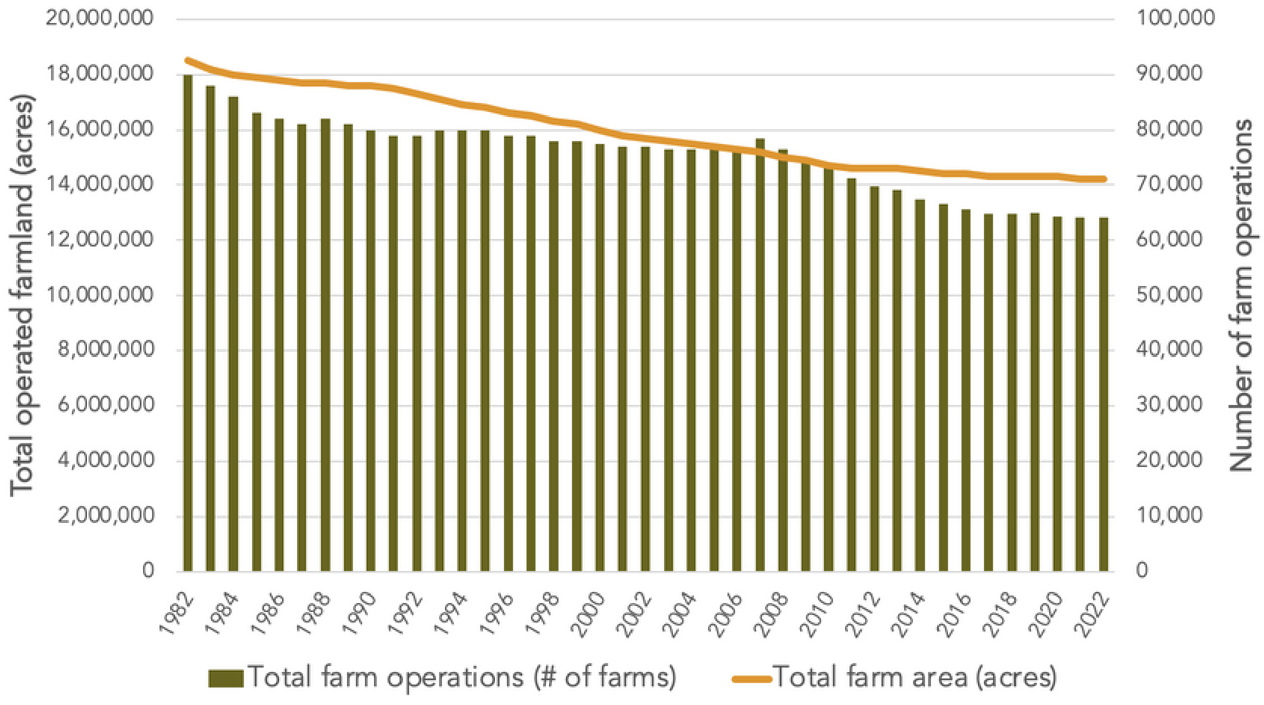

Figure 1: Total farm operations and total farm acres, 1982-2022

There is less of a clear trend when examining Wisconsin's total harvested cropland acreage. According to the Census of Agriculture historical data, harvested acres of all crops decreased dramatically between 1982 and 1997 [4], partly due to government programs promoting soil conservation. Total harvested cropland then gradually increased with each census until 2017. Over the entire period (1982-2017), total cropland harvested dropped by about 8% in Wisconsin, as shown in Figure 2.

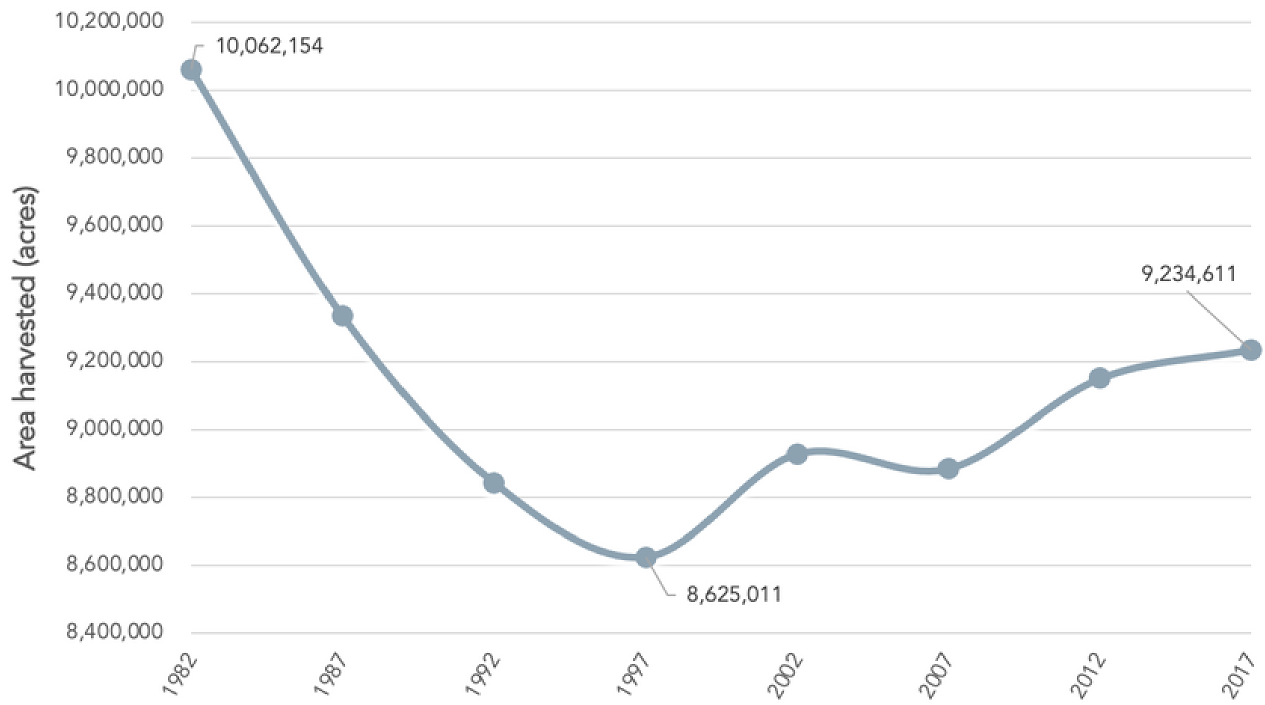

Figure 2: Harvested total crop land area, 1982-2017

1.1 FIELD CROPS: CORN AND SOYBEANS

Looking specifically at field crop data from the USDA NASS*, we see a slight downward trend in the total harvested acres in Wisconsin over the last 30 years (Figure 3). However, the land areas used to harvest corn and soybeans increased in this period – a moderate 26% for corn and an enormous 261% increase for soybeans (Figure 4).

*The USDA NASS "field crop" category includes the following crops: barley, canola, corn, cotton, hay, hops, lentils, oats, peanuts, peas, potatoes, rice, sorghum, soybeans, sugar beets, sugarcane, tobacco, wheat, and some other less common crops

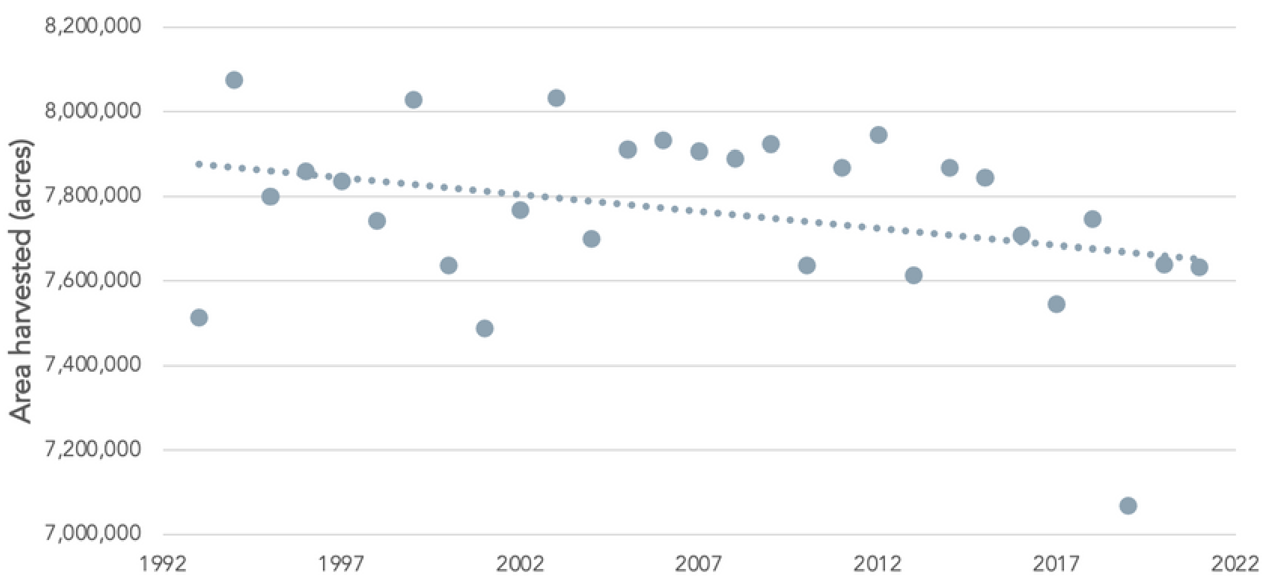

Figure 3: Harvested field crop land area, 1992-2022

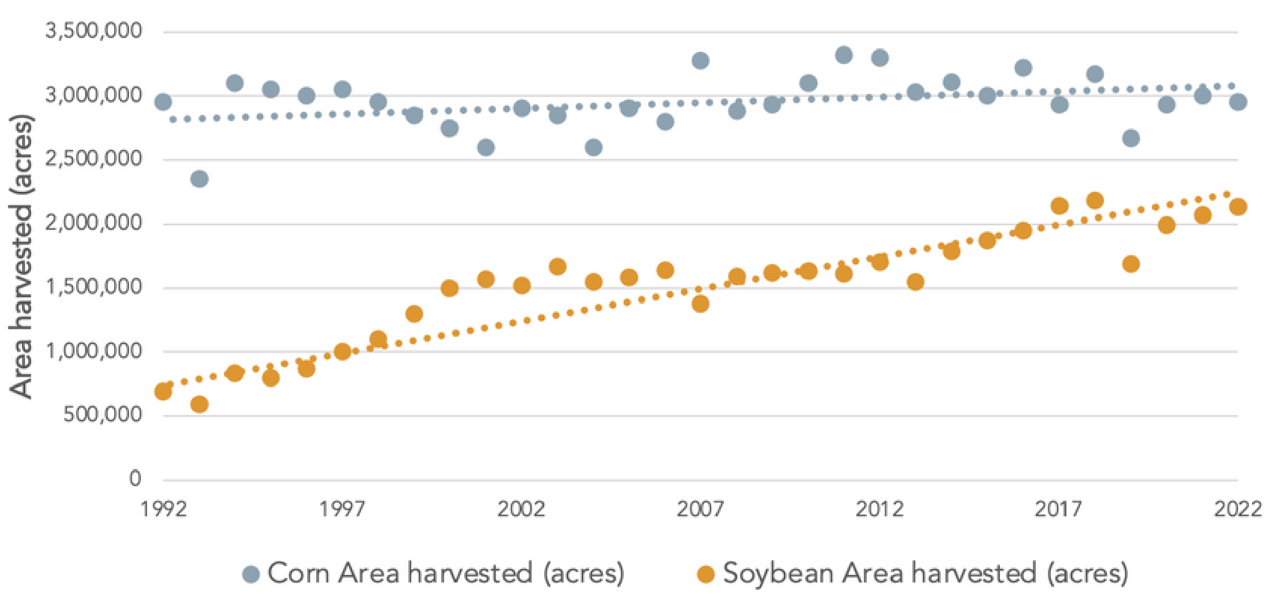

Figure 4: Harvested corn and soybean land area, 1992-2022

Improving seed resilience and farming practices have also increased yields for corn and soybeans. As seen in Figure 5 below, corn yields increased from 108 bushels per acre in 1982 to 182 bushels per acre in 2022, a 69% increase. Soybean yields have seen similar growth during that period, rising from 31 bushels per acre to 54 bushels per acre – a 75% increase.

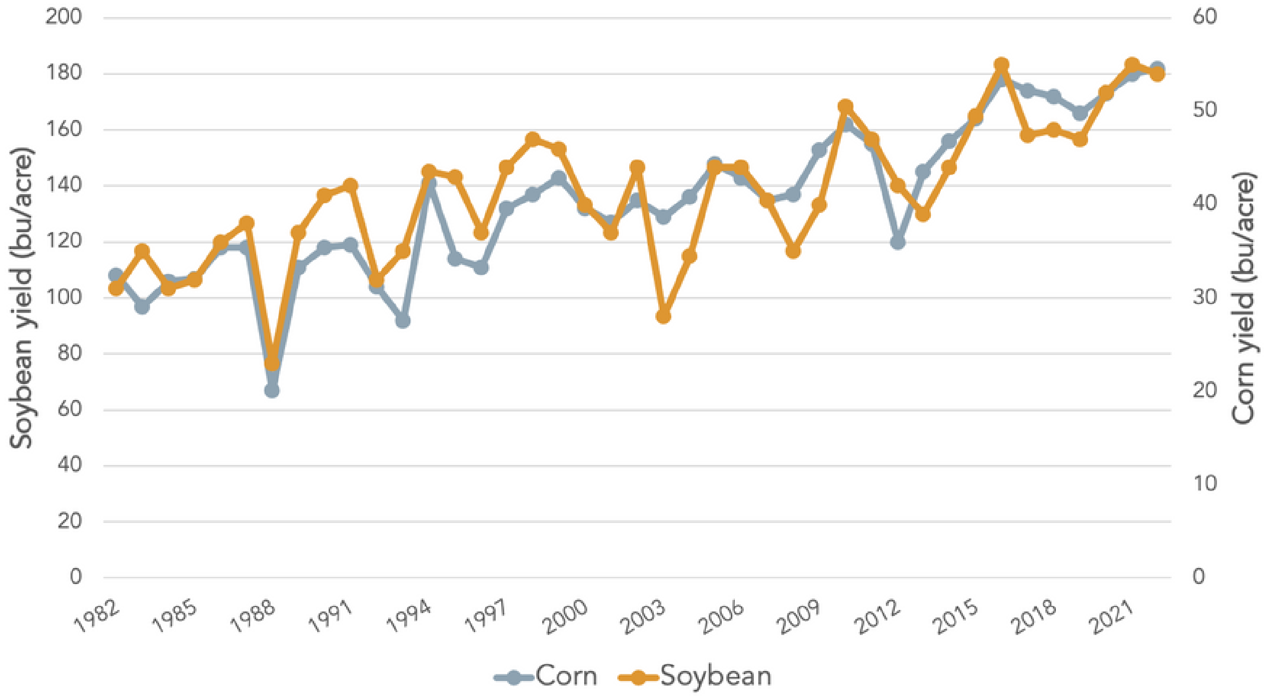

Figure 5: Corn & soybean yields, 1982-2022

1.2 CORN PRICES: REAL VS RECEIVED

Price is a prominent factor in the decision-making process of agricultural producers, but it is essential to distinguish between nominal and real prices when analyzing trends over time. The nominal corn price is the per-bushel price received by farmers, measured by the average price for corn grain that year. This means that the nominal price reflects the current year's value of corn only and does not account for inflation. In Wisconsin, the price received by farmers for corn (the nominal price) has been increasing on average since 1909.

However, looking at nominal prices alone can be deceiving when examining historical trends. Because the cost of goods and services across the economy has increased over time, adjusting for inflation allows for comparing prices by tying the value of money to one particular year. A very different picture exists when looking at real prices or prices adjusted for inflation. Today's dollar isn't worth nearly as much as in 1909. Calculating historical prices in 1984 dollars by adjusting with the Consumer Price Index (CPI)* shows real prices for corn have gradually decreased since 1909 [5,6]. The previously mentioned surge in corn yields has oversupplied the corn market relative to demand, decreasing real prices. In short, this means that the nominal price of corn has not increased as fast as the nominal prices of other goods and services. Figure 6 shows the historical relationship between received (nominal) prices and real (inflation-adjusted) prices in Wisconsin.

* Real prices are calculated by multiplying the nominal price by the ratio of base year CPI to the current year CPI (real price = nominal price*(CPIbase year/CPIcurrent year). The choice of the base year, or the year that real dollars are chained to, only affects the scale of the y-axis and not the overall trend. Using inflation from 1909, 1984, 2022, or any other year would depict the same historical trend. We adjusted to 1984 dollars because its' CPI is roughly in the median for the entire period, making the prices fit on one axis for clear comparison.

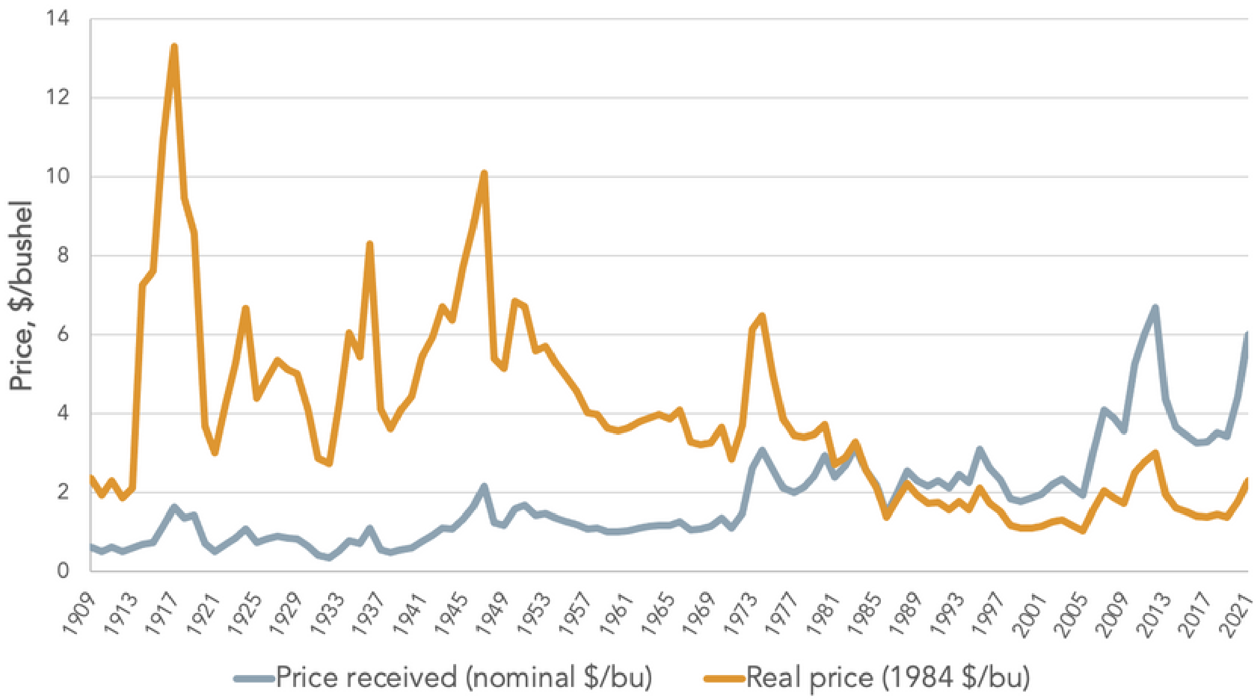

Figure 6: Nominal corn price (price received) vs real price (inflation-adjusted), 1909-202

Commodities like corn naturally have volatile prices due to the inelasticity of their supply and demand. In this case, inelasticity means that producers and consumers cannot easily adjust the quantity supplied or demanded of corn. As a result, corn prices are vulnerable to large swings due to extreme weather, geopolitical events, or new policy. For example, yields/supply may be lower in one year due to drought, but if demand remains constant, prices increase because of the new supply-demand equilibrium. According to a study by the University of Illinois, there are four distinct periods* of corn price trends in US history [7]. To illustrate the magnitude of corn price volatility, we analyzed the percent deviation of each year's corn price from the period mean using the average received price during each of the four periods. Figure 7 shows how much each year's corn price varies from the average price within its respective period as defined by the University of Illinois study.

*According to the University of Illinois study referenced above, the first period (1909-1945) saw relatively stable nominal corn prices. Second, there was an increase in the average received price in the 1946-1972 period, mostly due to demand from the economic boom around World War II. The third period from 1973-2005 included large increases in exported corn, while the fourth period (2006-2022) saw a surge in demand for food inputs, ethanol, and animal feed that resulted in large increases in nominal prices.

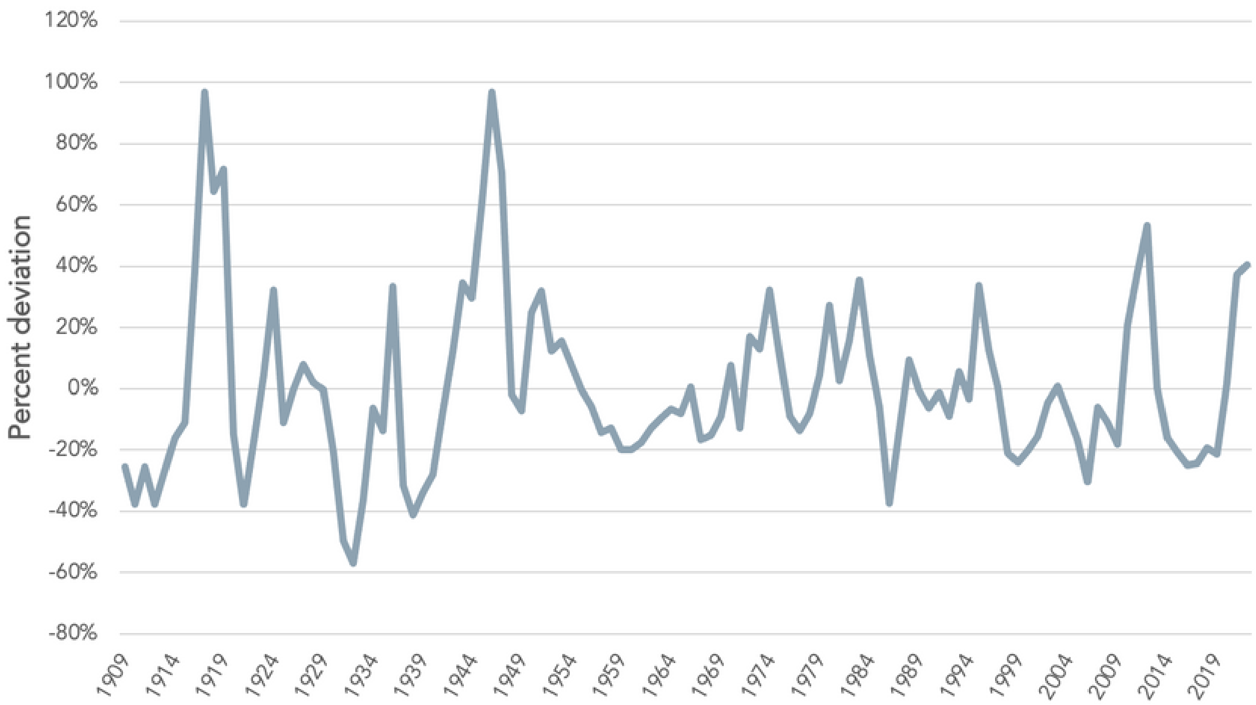

Figure 7: Corn price deviation from periodic means, 1909-2022

The downward trend in real prices and constant volatility in nominal prices shows why corn producers and other Wisconsin farmers face growing pressure to scale up their operations or sell their land. Without alternative business options for farmers, government intervention may be needed to support the agricultural economy. As we will discuss later, solar developments involve long-term land leases that provide a stable revenue stream, creating a more diversified portfolio for farm businesses that can help sustain Wisconsin farm operations.

1.3 CONSERVATION RESERVE PROGRAM

The USDA's Conservation Reserve Program (CRP) is an ecosystem services program aimed at improving soil health and managing the oversupply of crops [8]. Landowners voluntarily retire a portion of their actively cultivated agricultural land – taking the land out of crop production and planting covers like grasses, trees, and native plants – in exchange for an annual payment from the federal government, paid for with federal tax dollars. In Wisconsin, over 200,000 acres of land were kept out of production under the CRP in 2020 [9]. The total acres enrolled in the CRP in the state have been decreasing since the early 2000s (Figure 8). Numerous factors are responsible for this decline. Commodity prices have been higher than their historical average since 2006, raising the costs of the CRP as payments must compete with market returns. In addition, the Farm Bill of 2008 dramatically reduced the maximum allowed enrolled acres, effectively capping the program's size. In the last 20 years, Wisconsin has seen a 66% decrease in the total acres conserved under the CRP. The USDA Economic Research Service found that 79% of the land withdrawn from the CRP from 2013 to 2016 was returned to crop production [10].

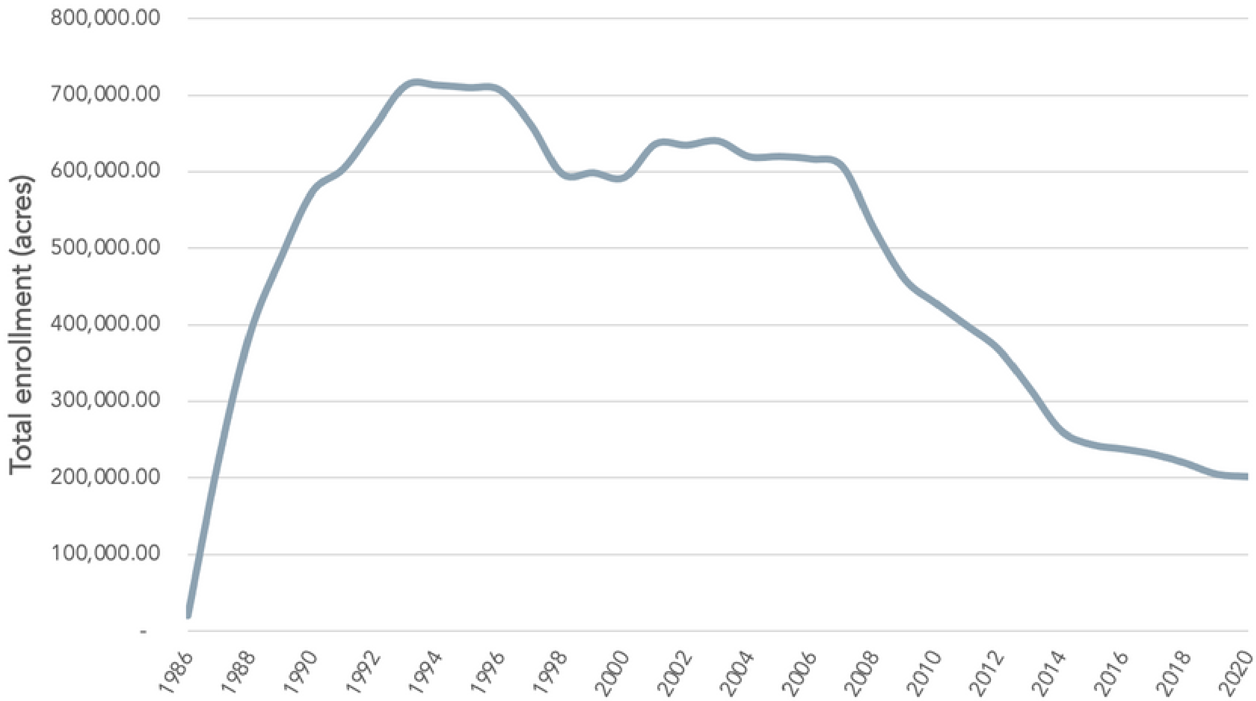

Figure 8: Conservation Reserve Program enrollment, 1986-2020

Solar projects can provide similar ecosystem services to farmers and landowners in Wisconsin as the CRP. Solar farms can last up to 35 years, allowing the land and soil underneath the arrays to rest and recover. Once a solar installation is decommissioned, the land can be farmed again. It will be more fertile when replanted, unlike residential or commercial development, which is much more permanent when complete [11]. Planting native plants and grasses amongst the arrays is becoming a standard practice, improving soil health and serving as pollinator environments [12]. In addition, advancements in design and technology have spurred research into agrivoltaics, or the simultaneous land use of solar energy generation and conventional agricultural activities [13]. This co-location of activities provides many additional benefits, including dual revenue streams for the landowner and reduced heat stress on crops or grazing animals due to the shade of the solar panels. By altering the panels' standard configurations and tilt schedules, researchers are investigating how to optimize crop yields and energy production [14].

2. SOLAR LAND USE: ZERO CARBON BY 2050

RENEW's collaborative report, *Achieving 100% Clean Energy in Wisconsin* (RENEW Zero Carbon Report), provides model results for various scenarios of an economy-wide transition to zero carbon by 2050 in Wisconsin. An overview of the RENEW Zero Carbon Report results, additional context, and insight into the next steps can be found in RENEW's zero carbon study blog [15].

Net Zero Economy-Wide (NZEW) is the most cost-effective renewable energy deployment and transmission capacity development scenario modeled in the RENEW Zero Carbon Report. In the NZEW scenario, widespread decarbonization is achieved in our state's electricity generation, transportation, building, and industrial sectors. In this scenario, Wisconsin's annual demand for electricity in 2050 will increase by over 160% from today due to economy-wide electrification.

Solar energy is the fastest-growing renewable source in Wisconsin, thanks to steady technological advancements that have lowered the cost building, installing, and maintaining these systems. At the beginning of 2023, Wisconsin had energized about 720 MW of utility-scale solar PV, almost all of it coming online since 2020. Figure 9 shows the resource capacity mix required to achieve net-zero economy-wide by 2050 according to the NZEW scenario. Based on the RENEW Zero Carbon Report modeling analysis, solar will continue to be the predominate source of new generation to meet the state's electricity demand: about 31 GW of solar generation will be needed by 2050 in the NZEW scenario. Based on economic potential assumptions from a separate Wisconsin Rooftop Solar Potential Report authored by Cadmus, 2.5 GW would come from rooftop solar PV, resulting in about 28.3 GW of utility-scale solar in Wisconsin [16].

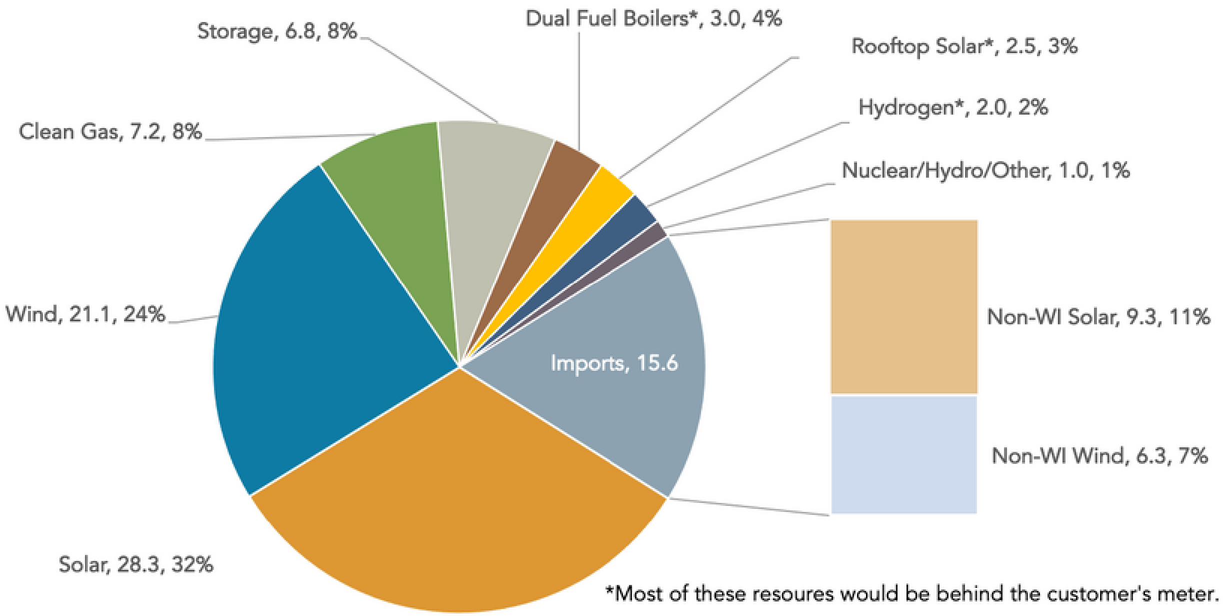

Figure 9: Net Zero Economy-wide Capacity by 2050 (Resource, GW, % of Total)

2.1 ACREAGE REQUIREMENTS FOR SOLAR

Due to the need for open, flat, and dry land, these solar farms have predominately been sited on agricultural land. Wisconsin has over 14 million acres of actively cultivated farmland, 8.4 million acres of which is field cropland.

The acreage required to site 1 MW of utility-scale solar PV is estimated to be 7 to 10 acres. Some developers and analysts use values at the higher end of the range to account for access roads, alternative panels sites and other land uses involved with solar farms [17]. Our analysis assumed 7 acres per MW of utility-scale solar PV to account for the increased productivity of solar panels over time. As one of the leading renewable resource technologies for the clean energy transition, solar panel design and installation layout will likely improve in the coming years, meaning solar fields will generate more electricity with fewer total inputs – including land. Put another way, as solar fields become more productive per square foot, they will occupy less land to generate the same amount of electricity [18]. With that in mind, we believe that a conversion factor of 7 acres per MW is a reasonable, if not conservative, assumption to use for 2050 projections.

2.2 RELATIVE AGRICULTURAL LAND USE

Assuming the land footprint for 1 MW of utility-scale solar is 7 acres, the 28.3 GW of solar required by 2050 would use about 198,000 acres.* Using that conversion factor, utility-scale solar generation would only occupy about 1.4% of total agricultural land (Figure 10) and 2.4% of field cropland in Wisconsin by 2050 if this high solar penetration scenario comes to fruition.

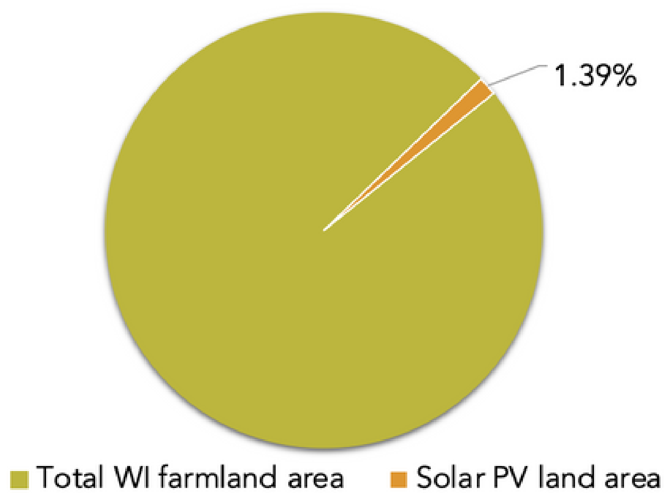

Figure 10: Wisconsin actively cultivated farmland relative to land needed for solar by 2050

Solar fields can supply almost one-third of Wisconsin's electricity consumption in 2050 using a small portion of agricultural land. In fact, the land acreage required for solar farms in 2050 is about equal to that currently enrolled in the Conservation Reserve Program. To put this land use figure in perspective, we analyzed several categories to illustrate what this means for Wisconsin: total Wisconsin land area, actively cultivated farmland, field cropland, land used for growing corn grain, and land devoted to growing corn grain for ethanol. The percentages in Figure 11 reflect the share of the land use category that utility-scale solar PV would use if all of the required solar by 2050 were sited there. These figures are presented purely for the basis of comparison. Figure 12 represents the land use requirements as pie charts, illustrating the small portion of each category that would be used by utility-scale solar.

*Using a 10-acre per megawatt assumption, the land use requirement for utility-scale solar by 2050 would amount to about 283,000 acres. This equates to 0.82% of Wisconsin's total land area, 1.99% of actively cultivated farmland, and 3.37% of field cropland.

LAND USE	LAND AREA (million acres)	SHARE OF LAND NEEDED FOR SOLAR BY 2050 (%)
Total WI land area	34.7	0.57%
Actively cultivated farmland	14.2	1.39%
Field crop land	8.4	2.35%
Total corn grain land	3.0	6.60%
Total ethanol land	1.1	17.84%

Figure 11: Land use requirements in Wisconsin by 2050 for 28.3 GW of utility-scale solar (198,000 acres).

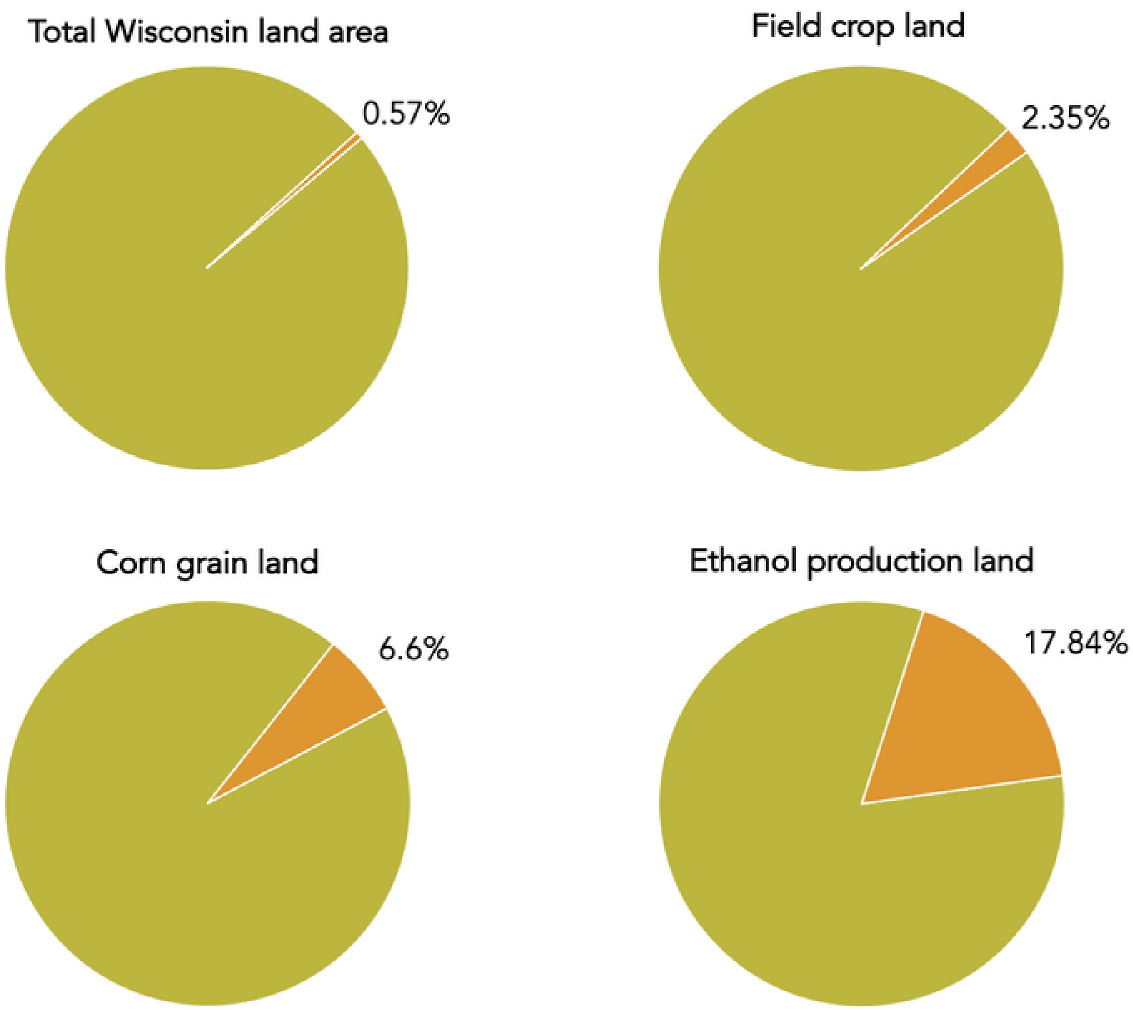

Figure 12: Pie charts representing land for utility-scale solar by 2050 in different land use categories.

2.3 ETHANOL LAND

Wisconsin farmers are already in the energy production business by growing corn grain for ethanol. According to the Wisconsin Corn Growers Association, about 37% of the corn grown in Wisconsin is used for ethanol [19]. As an engine fuel and fuel additive, ethanol played an early role in decarbonizing domestic agricultural operations and cleaning up gasoline-powered internal combustion engines (in the United States, gasoline is sold as E10, meaning 10% ethanol content). Wisconsin currently produces about 587 million gallons per year, more than twice the volume of ethanol consumed annually in the state [20].

Just over 1 million acres of farmland are dedicated to growing corn for ethanol in Wisconsin. Even if all the utility-scale solar PV needed by 2050 were placed on existing ethanol production land, solar farms would only use about 18% of it. As Wisconsin transitions to a net zero economy, beneficial electrification of the transportation sector should lead to the increasingly rapid adoption of electric vehicles. With this dynamic comes decreasing demand for gasoline and a correspondingly diminishing need for ethanol. With all else held constant, this trend will inexorably dampen corn prices received by the growers supplying local ethanol plants, as explored in a recent Ecological Economics paper [21]. In addition, the IEA World Energy Outlook 2022 states that around 90% of liquid biofuels produced in 2050 must be advanced biofuels – non-food crop feedstocks that do not directly compete for land with food crops – to achieve a net zero world economy [22]. Incorporating solar generation on farms is a way to sustain agriculture in Wisconsin, providing farmers with a stable revenue stream for years.

CONCLUSION

When analyzed together, the trends in agricultural land use illustrate a changing agricultural landscape in Wisconsin. While total field cropland is decreasing, agricultural land used to grow corn and soybeans has increased over the same period. Wisconsin farmers are planting more corn and soybeans on their cropland and growing fewer other field crops. At the same time, the average farm size is increasing while the number of active farms is declining. The 2022 Wisconsin Agricultural Statistics publication, released by the USDA NASS Wisconsin Field Office and Wisconsin Department of Agriculture, Trade and Consumer Protection, reports that the average sale price of agricultural land converted to other uses in 2021 increased to $32,158 per acre – a 158% increase from the previous year and its highest level in history. The authors explain that this massive escalation in price was driven by commercial real estate development pressure in the southeastern part of the state. Urban and suburban development pressure has been a leading cause of the decline in total agricultural land in Wisconsin in recent years [23]. Solar development offers a revenue solution to integrate into Wisconsin's agricultural landscape and sustain businesses. Ultimately, solar land leases protect against economic uncertainties that leave farmers and landowners vulnerable to permanently converting their land into commercial development.

Solar energy is an affordable, clean source of electricity generation that has the potential to help Wisconsin reach net zero carbon emissions in the future. As panel and racking technology continues to advance, solar fields require less land today to generate a megawatt-hour of electricity than they did five years ago. Although solar farms will continue to be sited primarily on agricultural land, the quantity of land needed for utility-scale solar developments is relatively minuscule compared with the total expanse of farmland in Wisconsin. To achieve a net zero economy by 2050, 198,000 acres of utility-scale solar would be needed, equivalent to 0.57% of Wisconsin's total land area. From another perspective, this is equivalent to 1.39% of actively cultivated farmland or 2.35% of field cropland. Solar fields do more than generate electricity – they provide a stable revenue source for farmers and landowners, restore soil health, provide beneficial ecosystem services, and provide financial support to local governments through the state's shared revenue formula. Overall, large-scale solar development can help sustain the state's agricultural heritage, keep Wisconsin farmers in business, and provide environmental and economic benefits to the greater public.

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