AGRIVOLTAICS: RESEARCH AND OPPORTUNITIES FOR WISCONSIN

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RENEW WISCONSIN

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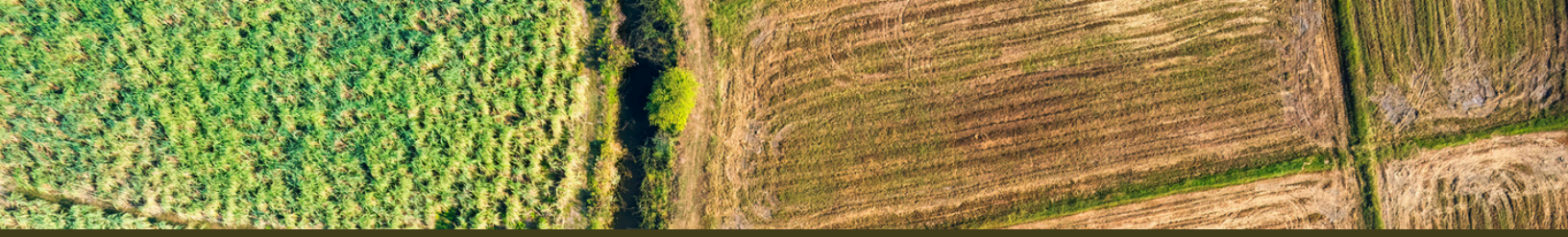


1. INTRODUCTION

According to the National Renewable Energy Laboratory, "agrivoltaics pairs solar with agriculture, creating energy and providing space for crops, grazing, and native habitats under and between panels." This RENEW report summarizes ongoing global and local research efforts on this topic and provides information and policy recommendations on how agrivoltaics can be included in Wisconsin's clean energy planning and policies.

Key Concepts and Commonly Used Terms

The term agrivoltaics could reflect different practices in place, wherever solar is paired with agriculture. Will Fulwider, researcher and educator at the University of Wisconsin-Madison Extension, believes that we might need several names for agrivoltaics depending on the integration and land use.

Agrivoltaics could include planting pollinator-friendly and native species of plants. Agrivoltaics may also include some form of agricultural production within a solar facility's project area. The following terms are commonly used when discussing the integration of solar projects within existing agricultural settings.

Commonly used terms

Agrivoltaics: Dual land use that combines both solar and farming activities
Dual-Use Benefits: Income diversification for farmers through enhanced land productivity
Agrisolar: Solar energy production that includes any agricultural activity
Dual-Use Solar: Simultaneous land use for both solar energy and agricultural activities; a term often used in regulatory and policy documents
Solar Farming: Farmers leasing land solely for solar production, or integrating solar panels with agricultural practices
Solar Grazing: Grazing livestock under solar panels
Multi-Use Land: Various combinations of land use that include integration of solar energy production with agriculture, conservation, or other activities
Agro Photovoltaics (APV): A term used in Europe.[1]
Solar sharing: A term used by Akira Nagashima in 2004 based on research in Japan.[2]

[1] See Germany section
[2] See Japan section

BENEFITS

All solar projects generate clean energy that powers Wisconsin's homes and businesses and create stable revenue opportunities for farmers and landowners who temporarily lease their land. Stable land lease revenues provide farmers an opportunity to diversify their businesses and protect against housing and commercial development pressures that would permanently convert the land for purposes other than agricultural use. The prospect of agrivoltaics has the potential to create additional benefits, as the land would be used for both energy and other agricultural production.

Looking at environmental benefits, dual-use solar offers beneficial ecosystem services like supporting soil health restoration. The shade provided by the panels could help to optimize water usage for some crops by reducing the transpiration of water from plants and the evaporation of water from soil. Additionally, the panels reduce direct light and heat stress, which can have an adverse effect on photosynthesis for some crop types.

When native, pollinator-friendly seed mixes are integrated into dual-use solar projects, this promotes biodiversity by providing habitat for pollinators and suitable ground for other beneficial organisms to thrive. Pollinator habitats are critical in supporting agricultural production of healthy foods, like fruits, vegetables, nuts, and legumes, that provide key nutrients to our diets while protecting against non-communicable disease.

The Solar and Agricultural Land Use study by RENEW Wisconsin has documented the co-benefits of solar energy on farms. This study highlights that agrivoltaics offers dual benefits by enabling land use for both solar energy production and agriculture. This approach provides farmers with a stable income through solar lease payments and helps hedge against market uncertainties, all while improving soil health and biodiversity through native plantings under the panels. Additionally, solar farms support pollinator habitats and reduce heat stress on crops, potentially contributing to better agricultural productivity for some crops. These co-benefits make agrivoltaics a sustainable land-use strategy that supports both energy and food production. For Wisconsin and similar agricultural states in the Midwest, dual-use solar helps preserve the rich agricultural heritage.

ALL SOLAR PROJECTS GENERATE CLEAN ENERGY THAT POWERS WISCONSIN'S HOMES AND BUSINESSES AND CREATE STABLE REVENUE OPPORTUNITIES FOR FARMERS AND LANDOWNERS WHO TEMPORARILY LEASE THEIR LAND.

2B. RESEARCH AND DEVELOPMENT - GERMANY

Research on Agrivoltaics is being conducted by Fraunhofer Institute for Solar Energy Systems ISE, which is the largest solar research institute in Europe. Fraunhofer Institute adopted agrivoltaics in 2011 following research by Prof. Adolf Goetzberger, whose article, "Potatoes under the Collector," inspired projects relating to agriculture and PVs. Some of these projects, like the Lake Constance installation, installed in 2015 on 2.5 hectares of land, with the APV system approximately covering one-third hectare, grows wheat, trefoil, potatoes, and celeriac. This research project aims to help demonstrate solar co-existence with traditional crops, while understanding which crops do best with APV installations. Crop yields under the APV must ideally be at least 80% compared to those under the control plots. Lake Constance has a temperate climate, similar to Wisconsin's humid continental climate with warm summers and cold winters, which makes these findings more applicable to Wisconsin. For example, berries and vegetables could be grown under PV structures in Wisconsin, using the Lake Constance model.

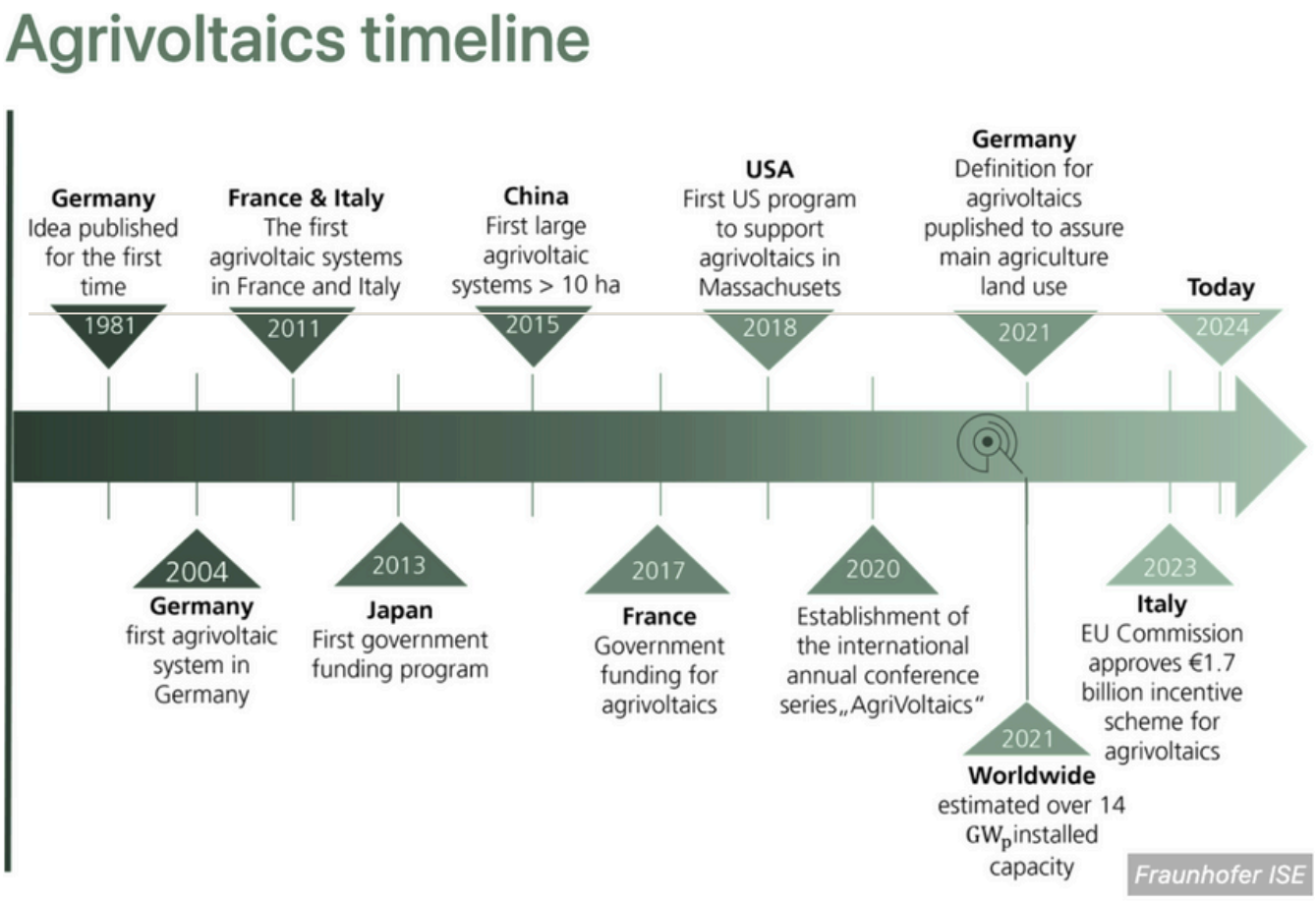


Figure 1. Agrivoltaics timeline (Fraunhofer Institute for Solar Energy Systems ISE)

2A. RESEARCH AND DEVELOPMENT - CHINA

Efforts in China have included more than 500 agrivoltaics projects since 2011. These dual-use projects include a variety of approaches to agrivoltaics, such as crop cultivation, livestock grazing, aquafarming, greenhouses, and tea plantations. For example, in Dongying City, PV systems were mounted in pond beds with the panels rising above the waterline and over aquaculture farms. This practice not only generates electricity but also cools the water for agricultural production. According to the World Resources Institute, this practice increased shrimp and sea cucumber yields by 50%. In Hainan, photovoltaic (PV) greenhouses were utilized to combine solar energy production with year-round vegetable cultivation, which helped serve a substantial portion of the population. Wisconsin has a strong aquaculture industry, especially in Great Lakes fisheries and inland fish farms. Floating solar over fish ponds could be an area of exploration.

WISCONSIN HAS A STRONG AQUACULTURE INDUSTRY, ESPECIALLY IN GREAT LAKES FISHERIES AND INLAND FISH FARMS.

2C. RESEARCH AND DEVELOPMENT - JAPAN

Japan has arguably the largest number of agrivoltaic farms to date, with at least 120 cultivated plant species within agrivoltaic projects. Japan's success can be credited to Akira Nagashima's research. Nagashima is a retired agricultural machinery engineer who coined the term "Solar Sharing" in 2023. Nagashima established the first agrivoltaic farm in Japan, Chiba prefecture, in 2004. This farm was used as a test site to study the impact of photosynthesis on plants, where at certain saturation points, the amount of sunlight plants receive might be damaging to them, and then studying how plants under solar PV might do better because of the shading provided by the panels. Results of this project, while to be used as guidelines for farmers, indicate that about a 32% shading rate for a farmland space will achieve adequate growth of crops. Similar to the Fraunhofer Institute, annual crop yields of cultivated solar farmlands must be 80%. This research has been used by some farmers to grow crops during winter like peanuts, yams, eggplants, cucumber, tomatoes, taros, and cabbages. For Wisconsin, the results from this research could be adopted by farming communities that are thinking of implementing the same technology. But more importantly, Japan's regulatory framework allows farmers to integrate PV systems without reclassifying farmland, a model that Wisconsin policymakers could explore.

BUT MORE IMPORTANTLY, JAPAN'S REGULATORY FRAMEWORK ALLOWS FARMERS TO INTEGRATE PV SYSTEMS WITHOUT RECLASSIFYING FARMLAND, A MODEL THAT WISCONSIN POLICYMAKERS COULD EXPLORE.

2D. RESEARCH AND DEVELOPMENT - AFRICA

In the early 2010s, interest in agrivoltaics began to grow, with researchers and organizations starting to explore the potential of combining solar power generation with farming. This period marked the beginning of pilot projects and feasibility studies on agrivoltaics across the African continent.

Kenya has been one of the leaders in integrating solar technology with agriculture. The first pilot project in Africa, "Harvesting the Sun Twice," was launched to explore the potential of agrivoltaics in improving crop yields while providing solar electricity to rural communities through international partnerships. An international team of researchers at the University of Arizona, the University of Sheffield, and World Agroforestry in Kenya and Tanzania identified crops that fare well under panels. The crops tested included beans, leafy greens, maize, onions, and more. Their research demonstrates that agrivoltaics systems in hot climates can simultaneously generate electricity, produce food for extended growing seasons, and conserve water. The project also saw an overall increase in crop yields compared to the control plots without solar panels. Agrivoltaics provides rural African farmers with diversified sources of income by growing high-value crops with reduced irrigation. The panels' transpiration, which provides cooling that increases food production over small plots of land.

2E. RESEARCH AND DEVELOPMENT - UNITED STATES
i. NATIONWIDE

Compared to other leading countries, the United States has lagged behind in agrivoltaics research and development. The National Renewable Energy Laboratory (NREL) began investigating the potential of agrivoltaics in 2010 and became a pioneer of agrivoltaics through the InSPIRE project. InSPIRE, in collaboration with AgriSolar Clearinghouse, has supported replication and scaling-up of agrivoltaics research and deployment. InSPIRE partnered with several institutions and organizations to demonstrate that agrivoltaics can be successfully developed in real-world applications. These InSPIRE efforts to plant different crops in different climates continue to provide evidence to farmers and solar developers interested in agrivoltaics.

Jack's Solar Garden is a family-owned social enterprise, partnering with InSPIRE, the National Renewable Energy Laboratory (NREL), Colorado State University, and the University of Arizona. The farm's solar array produces 1.2 megawatts (MW) on 4 acres in Longmont, Colorado. A variety of crops are grown on the farm, including herbs, berries, vegetables, and more. Jack's Solar Garden provides valuable research and partnerships with institutions and community members on the future of agrivoltaics in the US. This farm also offers educational tours for those interested in learning about agrivoltaic technologies. Although the project operates in a semi-arid climate with low annual precipitation rates, Wisconsin could draw lessons from growing vegetables and other crops under panels in addition to the sheep grazers learning some best practices from the American Solar Grazing Association.

In partnership with the University of Arizona, the Barron-Gafford group in the southwestern United States demonstrated agrivoltaic improvements in renewable energy resilience and agricultural productivity. The site boasts a 21.6-kW solar PV array, shading a 9×18-meter garden. Results from this research show that solar panel shading, especially in a dry land climate, provides an increased retention of soil moisture and lower temperatures, which benefits crop growth and solar panel efficiency, according to Barron-Gafford studies. This site demonstrates how agrivoltaics technology can benefit Wisconsin by extending growing seasons, especially during hot summers. Additionally, the panels protected against frost, as the site tested different microclimates. The species planted included a mix of vegetables - tomato, pepper, herbs, eggplant, and melon being the most prominent.

2E. RESEARCH AND DEVELOPMENT - UNITED STATES
i. NATIONWIDE

Several research groups are working hard to further research and develop agrivoltaic concepts. Madison Fields Solar Project, a 180 MW solar site in Madison County, Ohio, is a partnership between Ohio State University and Savion Renewable Energy. This project is one of North America's largest test sites for agrivoltaics, with more than 1,900 acres testing and growing hay, alfalfa, wheat, soybeans, and corn. This large-scale research project will explore how solar and farming can co-exist, which will help shape best practices for future projects.

Ohio State University also partnered with the U.S. Department of Energy Foundation Agrivoltaic Research for Megawatt Scale (FARMS) program. FARMS will investigate four priority areas, including best management practices for establishing forages, integrating complementary grazing strategies, maximizing soil health using remediation techniques, and utilizing precision agriculture technologies and equipment to minimize error and risk.

The U.S. Department of Agriculture (USDA) is actively funding several agrivoltaics projects through various partnerships under the FARMS program. The FARMS funding program supports research that examines how agrivoltaics can provide new economic opportunities to farmers, rural communities, and the solar industry. Some of the university recipients of this program include Iowa State, Ohio State, Rutgers, Solar and Storage Industries Institute, University of Alaska Fairbanks, and University of Arizona. The Rural Energy for America Program (REAP) project will provide 700 loan and grant awards to support agricultural producers and rural small business owners as they make energy efficiency improvements and renewable energy investments. Farmers and landowners looking to diversify and invest in agrivoltaics will benefit from this program.

THE RURAL ENERGY FOR AMERICA PROGRAM PROJECT WILL PROVIDE 700 LOAN AND GRANT AWARDS TO SUPPORT AGRICULTURAL PRODUCERS AND RURAL SMALL BUSINESS OWNERS AS THEY MAKE ENERGY EFFICIENCY IMPROVEMENTS AND RENEWABLE ENERGY INVESTMENTS.

2E. RESEARCH AND DEVELOPMENT - UNITED STATES
ii. MIDWEST AND WISCONSIN

The UW-Madison Kegonsa Research Campus solar array is part of Alliant Energy's Customer-Hosted Renewables program, in which Alliant Energy partners with customers to host an Alliant Energy-owned solar farm or other renewable source in exchange for a monthly lease payment. The array features three distinct types of racking and various spacing between rows of the solar array to facilitate research, education, and demonstration. The 2.25 MW (AC) / 2.87 MW (DC) solar array will produce the electricity equivalent of about 450-500 Wisconsin homes. This living laboratory is designed to advance knowledge and education about win-win opportunities for pairing renewable energy with agricultural activities and research across the State of Wisconsin. Proposed research and demonstration include horticulture, forage trials, pollinator monitoring, ecohydrology, microclimate, and more.

Photo Credit: Audra Koscik

"The UW-Madison and Alliant Energy partnership at the Kegonsa Research Campus demonstrates benefits of dual-use solar, where renewable energy is co-located with agricultural practices or ecosystem services. Projects like this and others help raise awareness about opportunities to sustain Wisconsin's agricultural tradition while powering our clean energy future."

— Josh Arnold, Project Manager, UW-Madison Office of Sustainability

2E. RESEARCH AND DEVELOPMENT - UNITED STATES
ii. MIDWEST AND WISCONSIN

OneEnergy Renewables is an independent developer of distributed generation, community solar, and large utility solar projects, and designs solar projects that integrate with agricultural settings. OneEnergy agrivoltaics projects are planted with either a deep-rooted, perennial pollinator prairie mix or a pasture seed mix underneath the tracking solar arrays. Today, OneEnergy boasts 948 acres of developed pollinator habitat and 155 acres of solar grazing with sheep. The Mastodon Solar portfolio, built in 2021 across Wisconsin and Minnesota, is a group of eight OneEnergy projects, totaling 24 MW of arrays that harvest solar power over pollinator-friendly prairie seed mixes.

Cannon Valley Graziers (CVG) of Southern Minnesota has been providing solar grazing programs since 2018 as a land management company for solar companies. CVG helps demonstrate how sheep farmers can gain access to land to graze through vegetation management of solar projects, as the owners, Arlo and Josie, transport their flock of sheep from site to site. This model creates a new source of revenue for the sheep farmers and provides ample forage for the sheep themselves. CVG currently grazes four OneEnergy sites in eastern Minnesota and western Wisconsin.

Wiscovery Farm in Fitchburg is the first solar sheep grazer in Dane County, with over one hundred sheep. Similar to CVG, the Wiscovery Farm model is to raise sheep as a solar land management service for solar and utility companies. Beau Stafford, the owner of Wiscovery Farm, offered solar sheep grazing services to a 6 MW solar site on about 30 acres for the Tyto Solar project. Tyto Solar's 13,000 solar panels power about 1,400 households.

Halbur's Heavenly Hill is a farm in Fond du Lac, owned by Olivia Halbur, a fourth-generation farmer. Halbur's farm raises Texel sheep that graze under the 5 MW Ledgeview Solar project within her 32-acre pasture. Halbur is paid a rental price to host the solar and a contractor feed to conduct vegetation management using their sheep.

The agrivoltaics project at Iowa State University is a public-private partnership with Alliant Energy. The project aims to determine agrivoltaic practices that can benefit local production systems in the Midwest and identify resources needed to assist multiple stakeholders.

Further research and development of agrivoltaics projects in the US, Midwest, and right here in Wisconsin show promise to meet the type of success already achieved by global leaders in Japan, Germany, and elsewhere.

2F. FUNDING OPPORTUNITIES FOR RESEARCH

The American-Made Large Animal and Solar System Operations (LASSO) Prize is funded by the U.S. Department of Energy (DOE) and offers more than $8 million in funding to support projects. This prize is designed to bring together solar developers, farmers, ranchers, and other stakeholders. The LASSO Prize concentrates on forming partnerships that result in building impactful projects that will deepen the public's understanding of the co-location of solar and cattle grazing operations, which is also known as cattle agrivoltaics. Additionally, the USDA, through partnerships with the DOE, is offering funds to support agrivoltaics work, and as seen in our case studies, research institutions have been some of the beneficiaries of these funds.

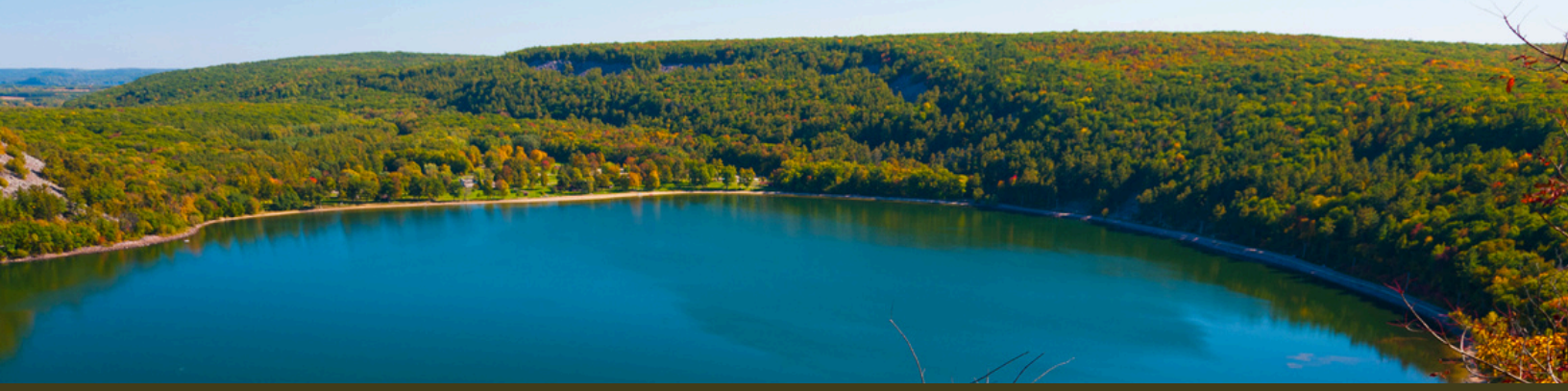
THIS PRIZE IS DESIGNED TO BRING TOGETHER SOLAR DEVELOPERS, FARMERS, RANCHERS, AND OTHER STAKEHOLDERS.

2G. CHALLENGES AND OPPORTUNITIES

Partnerships between solar developers, landowners, and farmers are required to successfully implement agrivoltaics projects. By understanding the unique perspectives and experiences of solar developers, farmers, and landowners, it is possible to build collaborative relationships and overcome potential challenges to create successful dual-use solar projects.

Based on RENEW's zero-carbon study, Wisconsin will need to develop over 28 Gigawatts of solar by 2050. RENEW's Solar and Agricultural Land Use report used this outlook and an assumption of 7 acres per 1 MW of solar to translate this amount of solar into land use. This approach results in approximately 200,000 acres needed to host utility-scale solar projects in Wisconsin to meet carbon-free goals by 2050. Much of this land will likely be in agricultural settings. With this outlook in mind, agrivoltaics offers an immense opportunity to pair solar and agriculture together. For agrivoltaic practices to be fully utilized in this zero-carbon scenario, our report suggests that more robust research and development will be needed to seize this opportunity and pave a path for successful agrivoltaics projects in Wisconsin.

PARTNERSHIPS BETWEEN SOLAR DEVELOPERS, LANDOWNERS, AND FARMERS ARE REQUIRED TO SUCCESSFULLY IMPLEMENT AGRIVOLTAICS PROJECTS



3. POLICY RECOMMENDATIONS

1. Create a Clear but Flexible Regulatory Framework

Wisconsin should develop clear yet adaptable guidance to support the adoption of agrivoltaics in a way that respects the diverse needs of individual farms and project developers.

2. Prioritize Research and Development and Expand Across Diverse Regions of Wisconsin

Continued research is needed to evaluate how different agrivoltaic systems perform across Wisconsin's varied agricultural zones. Pilot projects should be distributed across regions with different land uses, such as dairy and crop rotation operations in the Driftless Area, vegetable and row crops in the Central Sands, grazing systems in northern counties, and aquaculture in the Great Lakes basin.

3. Support Regional Trials and Crop Compatibility Studies

Building on successful models like the Dairy Innovation Hub, Wisconsin should fund collaborative pilot projects between farmers, solar developers, and institutions such as universities and technical colleges. These trials should test a variety of crops, forages, and grazing systems across Wisconsin's soil types and climate zones.

4. Develop Model Business Partnerships and Financing Agreements

The state should support the development of model contracts and guidance for solar land leases, grazing agreements, and revenue-sharing partnerships. Resources should be made publicly accessible and designed to accommodate farms and projects of varying scales.

CONTINUED RESEARCH IS NEEDED TO EVALUATE HOW DIFFERENT AGRIVOLTAIC SYSTEMS PERFORM ACROSS WISCONSIN'S VARIED AGRICULTURAL ZONES

3. POLICY RECOMMENDATIONS

5. Provide Workforce Training and Technical Assistance

Wisconsin should invest in workforce development to equip farmers, landowners, and local workers with the knowledge and skills needed to manage agrivoltaic systems. Practical training and technical assistance should be delivered through UW-Extension offices, farm outreach offices, and technical colleges.

6. Expand Financial Tools to Support Voluntary Adoption

While many agrivoltaics projects may qualify for existing federal and state incentives, Wisconsin could also explore ways to support voluntary adoption through targeted grants, cost-share programs, or low-interest loans.

7. Promote Public-Private Collaboration for Education and Knowledge-Sharing

Wisconsin should encourage collaboration between public institutions and private partners, such as utilities, developers, farm organizations, and academic institutions, to support education, research, and data-sharing around agrivoltaics.

8. Avoid Premature Mandates and Preserve Choice

Given the early stage of agrivoltaics, policies should focus on enabling experimentation rather than requiring it. Mandating specific agrivoltaic practices or designs could limit innovation and disproportionately impact small or family farms that may not be ready to adopt new technologies.

WISCONSIN SHOULD INVEST IN WORKFORCE DEVELOPMENT TO EQUIP FARMERS, LANDOWNERS, AND LOCAL WORKERS WITH THE KNOWLEDGE AND SKILLS NEEDED TO MANAGE AGRIVOLTAIC SYSTEMS.

4. CONCLUSION AND SUMMARY

AGRIVOLTAICS PRESENTS A PROMISING OPPORTUNITY TO ALIGN WISCONSIN'S CLEAN ENERGY GOALS WITH ITS AGRICULTURAL HERITAGE, BUT SUCCESS DEPENDS ON FLEXIBLE, LOCALLY-INFORMED POLICY.

Agrivoltaics presents a promising opportunity to align Wisconsin's clean energy goals with its agricultural heritage, but success depends on flexible, well-informed policy. Policies should protect farmers' freedom to manage their land, avoid unnecessary government mandates, and encourage voluntary adoption that supports economic diversification in rural communities. It is critical that family farms, not just large agribusinesses, have the opportunity to benefit from this emerging technology. Because agrivoltaics is still in its early stages of viability and commercialization, early efforts should prioritize education, pilot projects, and real-world demonstrations tailored to Wisconsin's diverse farm landscapes. Policy should also support independent decision-making, ensure that economic impacts on farmers and local communities are well understood, and preserve the rights of landowners and developers to choose what works for their business.