Applicant Exhibit 26A

BEFORE
THE OHIO POWER SITING BOARD

In the Matter of the Application of Oak Run Solar Project, LLC for a Certificate of Environmental Compatibility and Public Need to Construct a Solar-Powered Electric Generation Facility in Madison County, Ohio.	)))))	Case No. 22-549-EL-BGN
In the Matter of the Application of Oak Run Solar Project, LLC for a Certificate of Environmental Compatibility and Public Need to Construct a Transmission Line in Madison County, Ohio.	))))	Case No. 22-550-EL-BTX

SUPPLEMENTAL DIRECT TESTIMONY OF

Sarah Moser
Director Farming Operations & Agrivoltaics
Savion

on behalf of
Oak Run Solar Project, LLC

May 11, 2023

/s/ *Christine M.T. Pirik*
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1. Please state your name, current title, business address, and background in these proceedings.

My name is Sarah Moser. I am the Director of Farming Operations & Agrivoltaics for Savion, LLC. My business address is 422 Admiral Blvd, Kansas City, MO 64106 but, I do work remote and reside in northwest Ohio. As I stated in my initial direct testimony filed on May 2, 2023, I support the information in the Application for a Certificate of Environmental Compatibility and Public Need ("Certificate") filed with the Ohio Power Siting Board ("Board") by Oak Run Solar Project, LLC ("Applicant" or "Oak Run"), including: the Applicant's commitment to employ agrivoltaics throughout the Oak Run Project area; the Applicant's memorandum of understanding term sheet presented to Madison County; the Applicant's partnership with The Ohio State University College of Food, Agricultural, and Environmental Science; and the grant programs the Applicant is part of and pursuing.

2. What is the purpose of your supplemental testimony?

The purpose of my supplemental testimony is to support the Joint Stipulation and Recommendation ("Stipulation") entered into by the Signatory Parties to the Stipulation, Oak Run, Dr. John Boeckl, the Ohio Environmental Council, the Ohio Partners for Affordable Energy, the International Brotherhood of Electrical Workers Local Union 683, and the Ohio Farm Bureau Federation ("Signatory Parties") that was filed in these proceedings on May 11, 2023.

My initial direct testimony and supplemental testimony, together with the other witnesses testifying for Oak Run in this case and the testimony of witnesses by the Signatory Parties, supports the Board's approval of Oak Run's Application for a Certificate to construct the Project.

3. Have you reviewed the Stipulation that was filed in these proceedings on May 11, 2023, and the Certificate Conditions recommended in the Stipulation?

Yes. I have.

4. Please summarize the requirements in Condition 31 of the Stipulation.

Condition 31 of the Stipulation enhances the condition recommended by the Board's Staff in the Staff Report of Investigation filed on March 28, 2023. The enhancement to Condition 31 includes: more agrivoltaics opportunities and is not limited to just sheep grazing; and provides for mapping for ingress and egress points, staging areas, and safe passage areas for farm equipment. In addition, as stated in my direct testimony filed on May 2, 2023, Oak Run commits to consult with the Madison County Soil and Water Conservation District regarding implementation of generally accepted and beneficial conservation practices. Further, in support of the Applicant's commitment to agrivoltaics and in response to comments related to agrivoltaics by the local community, I spearheaded a review of the agricultural economic impacts from the Project (*See* Supplement Attachment SM-1, Agricultural Economic Impacts in Oak Run Solar Project, May 2023).

5. Please summarize the conclusions found in Supplement Attachment SM-1, Agricultural Economic Impacts in Oak Run Solar Project.

The report iterates the amazing opportunity agrivoltaics introduces to the Oak Run Solar Project. Facts indicate that in year one alone, the implementation of agrivoltaics will offset unintended changes to the agribusiness industry. While the solar Project brings hundreds of jobs and economic revenue to the county and agrivoltaics is additive, it specifically focuses the potential suited to the agricultural industry. The outputs display that subsequent years of agrivoltaic operations will contribute to greater job growth in Madison County in ag fields than what keeping the current status quo provides, and again, this is in addition to all the other economic benefits the Project brings.

6. Does the Application, as agreed to through the Stipulation and supported through the testimony of expert witnesses, enable the Board to determine the nature of the probable environmental impact of the facility?

Yes. The Stipulation, as supported by my initial direct testimony filed on May 2, 2023, the Applicant's expert witnesses, and the testimony of the witnesses for the Signatory Parties, confirms that the Board will be able to determine the nature of the probable environmental impact of the facility.

7. Based on the Applicant's commitments in the Application, along with the conditions in the Stipulation, as supported through the testimony of the expert witnesses, does the facility represent the minimum adverse environmental impact, considering the state of available technology and the nature and economics of the various alternatives, and other pertinent considerations?

Yes. The Stipulation, as supported by my initial direct testimony filed on May 2, 2023, the Applicant's expert witnesses, and the testimony of the witnesses for the other Signatory Parties, confirms that the facility will represent the minimum adverse environmental impact, considering the state of available technology and the nature and economics of the various alternatives, and other pertinent considerations.

8. Does this conclude your supplemental testimony?

Yes. However, I reserve the right to update my testimony to respond to any further testimony, reports, and/or evidence submitted in this case.

CERTIFICATE OF SERVICE

The Ohio Power Siting Board's e-filing system will electronically serve notice of the filing of this document on the parties referenced in the service list of the docket card who have electronically subscribed to these cases. In addition, the undersigned certifies that a copy of the foregoing document is also being served upon the persons below this 11th day of May, 2023.

/s/ Christine M.T. Pirik
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Oak Run Solar Project LLC
Case No. 22-549-EL-BGN
Case No. 22-550-EL-BTX

Supplement Attachment SM-1

Agricultural Economic Impacts In Oak Run Solar Project

May 2023

DICKINSON WRIGHT PLLC

AGRICULTURAL ECONOMIC IMPACTS IN OAK RUN SOLAR PROJECT

May 2023

Requested by Oak Run Solar Project, LLC

Report created by Learnewable, LLC

Table of Contents

I. Executive Summary of Findings

Savion's Oak Run Solar Project in Madison County, Ohio will deliver substantial economic benefits to stakeholders and community members through dual land use of solar and agriculture. While the economic benefits of the 800-megawatt (MW) solar system have been explored, this paper will amend those findings with figures on the economic impact of the project's agricultural component.

When executed strategically, agrivoltaics can improve both the efficiency of panels and the agricultural productivity beneath them. This can result in both short- and long-term gains in productivity depending on the types of agriculture pursued.

The purpose of this analysis is to compare the differential impact of performing agriculture on the 6,050-acre project area's available land with the impact of conventional farming practices in the same area. We will base estimates on average agricultural yields and IMPLAN-generated output data. Baseline data will stem from academic research and interviews with subject matter experts and Savion's development team.

Key findings related to agricultural production are as follows. Jobs are in full-time equivalents (FTEs):

Jobs and outputs at 1,000 sheep and 2,000 acres of agriculture:
Madison County: 23.9 FTEs; $2,630,445
Ohio: 40.6 FTEs; $3,717,941

Jobs and outputs at 3,000 sheep and 4,000 acres of agriculture:
Madison County: 47.3 FTEs; $5,103,616.59
Ohio: 80.2 FTEs; $7,213,952

Jobs and outputs due to capital expenditures:
Madison County: over 37 jobs; $3,678,600
Ohio: over 51 jobs; $5,018,538

Table 17. Economic Impact From Current Production, Year 1 of Agrivoltaics, Year X of Agrivoltaics.

		Employment	Labor Income	Value Added	Output
Current Agricultural Production	County Impact	30.4	$ 1,888,255	$ 1,663,794	$ 6,275,031
	State Impact	50.3	$ 2,177,372	$ 3,103,973	$ 8,942,684
Year 1 Agrivoltaics	County Impact	23.9	$ 935,215	$ 961,102	$ 2,630,445
	State Impact	40.6	$ 987,660	$ 1,542,733	$ 3,717,941
Year X Agrivoltaics	County Impact	47.3	$ 1,857,590	$ 1,885,975	$ 5,103,617
	State Impact	80.2	$ 1,945,795	$ 3,015,663	$ 7,213,952

I. Agrivoltaics Overview

In this section we provide detail on the growth of agrivoltaics as a nascent industry, examine an example project in Colorado, and assess agrivoltaics' growth potential in Ohio.

A. Background and Growth

As solar panels continue to fall in price after having decreased by 99.6% in less than five decades, they have become an increasingly attractive solution to both the climate crisis and the growing demand for electricity (Roser, 2020; National Grid, 2023).

The question of how and where to install solar projects looms large across the country and planet. As developers attempt to integrate solar into various areas of human activity, the comparative demand for space quickly becomes evident: though less material- and carbon-intensive, solar electricity requires far more land area than fossil fuel plants to achieve an equivalent output (Groom, 2022).

In terms of per-acre profits, solar energy competes with both managed forests and croplands in the United States. This puts a strain on these crucial economic and ecological resources, which are already dwindling (van de Ven et al, 2021; FAO & UNEP, 2020; Statista, 2023). Cropland in particular is in high demand when it comes to solar development. This is because land that is optimal for arable farming, i.e. land that is sunny and flat, is also ideal for solar production (Adeh et al, 2019). Such land has also been prepared for open navigation, has few if any obstructions, and had been tilled for an extended period, all of which reduce its risk as a site for development. Furthermore, the financial yields from solar production generally outweigh those of agriculture by a significant margin, making it more profitable for landowners to use land for solar than for crops (Loomis et al, 2022). Concerns about lost farmland, aesthetic incongruity with rural landscapes, and environmental damage have resulted in growing opposition to solar farming (Groom, 2022).

Agrivoltaics is a promising solution to mitigate competing claims for land use. By simultaneously using the same piece of land for both solar and agriculture, agrivoltaics can exhibit a protective effect on farmland as utility-scale renewables projects continue to ramp up.

The first academic treatment of agrivoltaics came in 1981 from German researchers Adolf Goetzberger and Armin Zastrow, who published an article called "Kartoffeln unter dem Kollektor," or "Potatoes Under the Collector." As the cost of solar fell in the intervening years, the economic feasibility of agrivoltaics improved; in 2014, the group Agrivoltaics: Contribution to Resource-Efficient Land Use (APV-RESOLA) was formed to expand research in the field. The German government helped fund a feasibility pilot project at Heggelbach farm in southern Germany.

Due to falling costs and increased utility-scale solar capacity, global installed agrivoltaic capacity increased by 280,000% between 2012 and 2021 alone (Trommsdorff et al, 2022). Continued rapid growth of utility-scale solar is expected with a 12.15% projected compound annual growth rate (CAGR) between 2022 and 2030 (Precedence Research, 2022). Commercial agrivoltaics has not grown hand-in-hand with utility-scale solar installation; however, this leaves a large market gap for research and solutions through the integration of more farming practices with utility-scale installations around the globe.

B. Case Study: Jack's Solar Garden

Among the most publicized and groundbreaking projects on U.S. soil is Jack's Solar Garden, located in Boulder County, Colorado (Siegler, 2021). Located on a 24-acre family farm, Jack's Solar Garden features a 1.2-MW solar array comprising 3,276 panels over a four-acre pasture. The panels are situated on single-axis trackers along a north-south axis and are situated either 8 ft (33%) or 6 ft (66%) off the ground (Corbley, 2022).

The farm's first agrivoltaic growing season was in 2021. Beneath the panels grow 40 types of plants, including lettuce, sage, tomatoes, blackberries, chard, kale, herbs, and other types of fruits and vegetables. Irrigation is provided by a drip system, and several thousand shrubs, trees, and plants around the panels provide pollinator and bird habitat. The team also collects honey from a beehive on the edge of the solar pasture. Through research and experimentation, Jack's Solar Garden and their collaborators seek to optimize agricultural production by exploiting synergies with the panels above.

Not only has dual-use agriculture allowed the owner and his family to generate new revenue streams, but it was also the deciding factor that saved the farm from bankruptcy. It was economically untenable for the farming family to support themselves on agriculture alone.

C. Agrivoltaic Energy vs. Corn Ethanol

Part of what makes corn a valuable commodity crop is its ability to be converted into ethanol, an energy-dense fuel. About 45% of U.S. corn is processed into ethanol (USDA ERS, 2023).

The following is a thought experiment that compares the energy potential of ethanol with that of agrivoltaic solar power. We assume each is harvested using one acre of land. For the agrivoltaic array, a 25% reduction is assumed in solar power due to larger spacing between rows of panels compared with conventional ground-mount systems. However, this is a conservative approach that will not necessarily apply to projects in Ohio.

In a growing season, an acre of corn can produce around 462 gallons of ethanol (equivalent to roughly 10.3 MWh), which is enough to drive an ethanol-powered vehicle 8,126 miles (Nussey, 2021; Nebraska, 2023). For reference, this is roughly the distance to drive roundtrip from Columbus, Ohio to Anchorage, Alaska.

The same acre of an agrivoltaic installation would produce around 296 MWh over the course of a year, which is enough to drive a Tesla Model Y electric vehicle 1.1 million miles (Bolinger et al, 2022; O'dell, 2022; Weaver, 2022). This is enough for two round-trip drives to the moon and nearly six laps around earth's equator, a factor of 29 times more energy than the same acre of corn used to produce ethanol. Additionally, with agrivoltaics best practices and utilization of ≥70% of the space for crop production, research indicates that this same acre can simultaneously produce agricultural harvests that compete with non-solar acres, though this is highly dependent on conditions like crop selection, site design, and climate.

It is this vast difference in economic output that creates competition between agriculture and solar. However, the ability of agrivoltaics to accomplish both makes it a promising candidate for not only reducing this conflict but being a better solution all around.

D. Agrivoltaic Crop Yields

Because solar arrays create both shading and microclimate changes, the yields of crops grown are subject to a high degree of variability. Certain crops, particularly those that prefer full sunlight, may experience reduced yields and moisture-related problems like fungus (Ramos-Fuentes, 2023; Lydersen, 2022). Others, particularly shade-tolerant crops, can benefit from reduced heat stress and more favorable water retention, which can increase the rate of photosynthesis (Markings, 2018; AL-agele et al, 2021).

In this paper we will examine a number of crops studied for agrivoltaic compatibility. These include:

- Pasture forage (particularly for smaller ruminants like sheep)
- Pollinator habitat
- Leafy greens (kale, chard, broccoli, lettuce, Brussels sprouts, spinach)
- Tomatoes
- Peppers

According to Precedence Research (2022), leafy greens are likely to constitute the largest market share of agrivoltaic crops from now until 2030 since they "grow efficiently with the assistance of agrivoltaic technology." However, Fraunhofer ISE (2022) notes that interspace systems on permanent foraging grassland are most cost-effective, which may entail additional investment in engineering and design.

E. Growth Potential of Agrivoltaics in Ohio

In terms of photovoltaics, Ohio has 268 solar companies, including manufacturers, installers, developers, and other industry players. The Ohio solar industry sector employs over 7,400 workers. The state currently has multiple utility-scale solar farms comprising 370 MW of total installed capacity, which combined with residential solar brings the state's total to around 927 MW. Currently, the largest array is Hillcrest Solar with an installed capacity of 265 MW.

Companies like Meta, Amazon, and Campbell Soup Co. all run their Ohio operations on solar energy. The following map shows solar projects in Ohio as of April 2023:

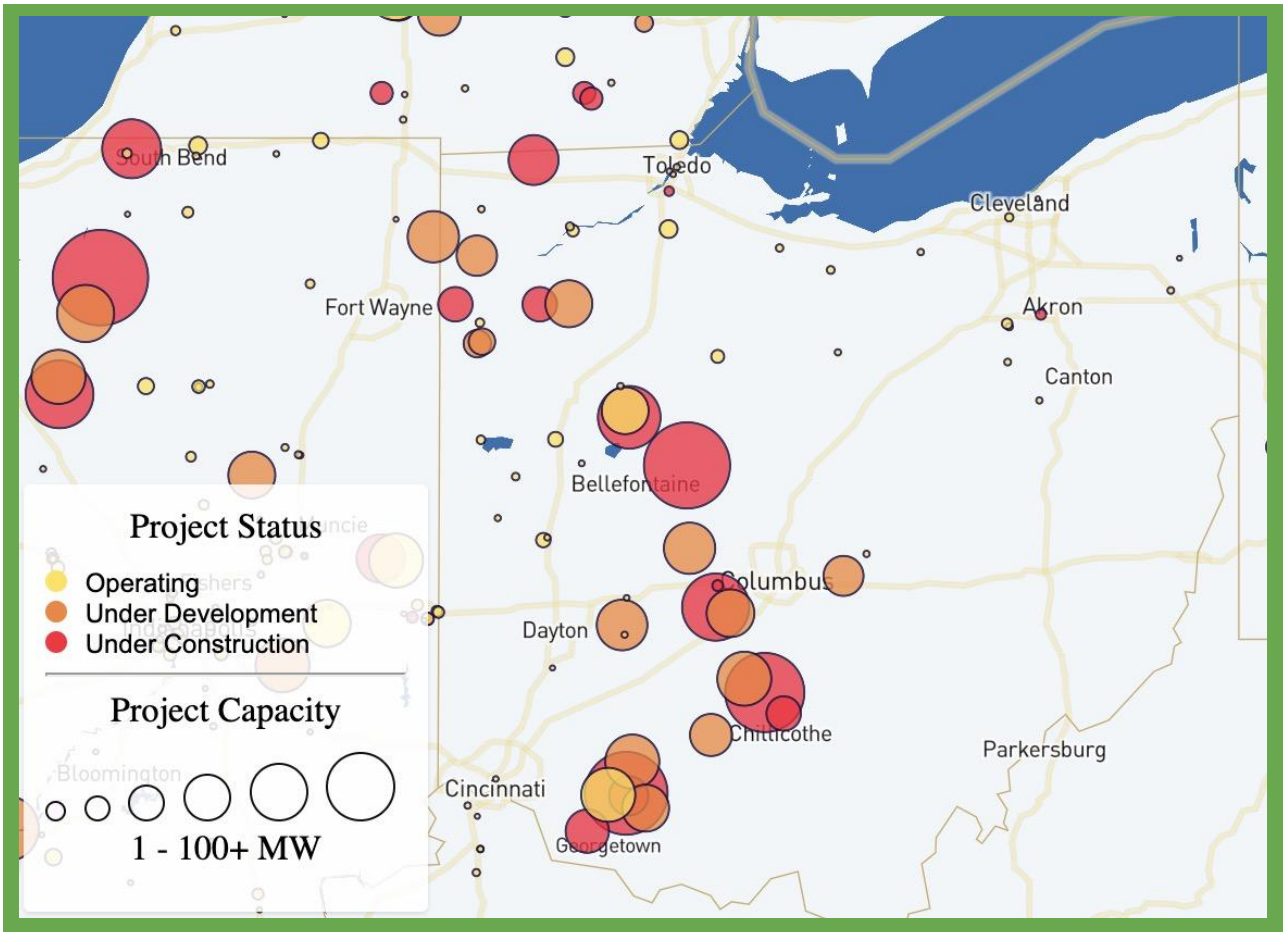


Image source: [Project Location Map, SEIA]

Though Ohio currently ranks 26th for installed solar capacity among U.S. states, it ranks 4th for five-year growth projections, with 8,252 MW of expected installation by 2027. Other nearby states are currently ahead of Ohio in terms of installed solar capacity:

- Illinois in 15th
- Indiana in 18th
- Wisconsin in 23rd
- Pennsylvania in 24th
- Michigan in 25th

As of March 16, 2023, there are 51 solar projects in the operational, approved, pending, or pre-application phases, totaling 9,367 MW on 92,746 acres (Ohio Power Siting Board, 2023).

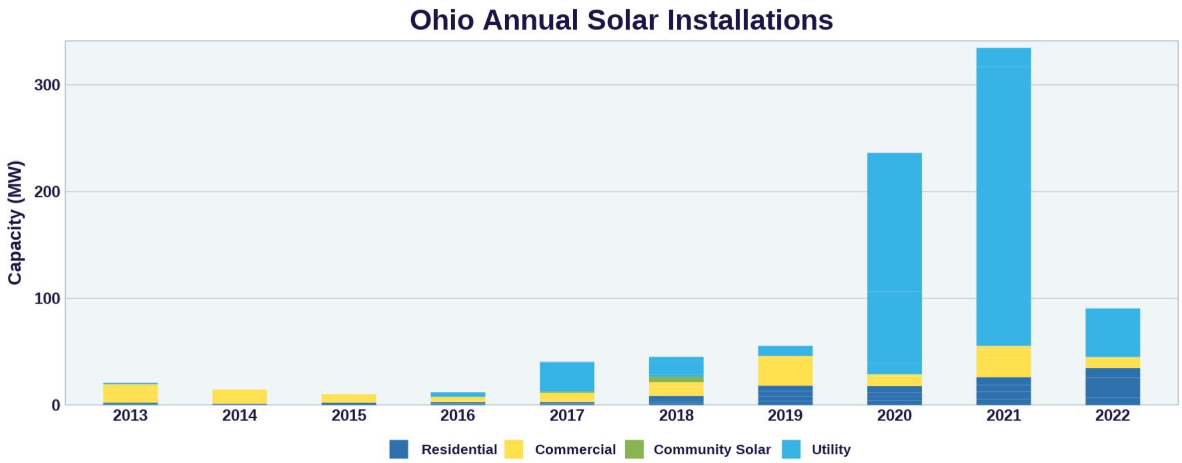


Image source: [Ohio Solar, SEIA]

The state of Ohio has 28.7 million total acres of land, of which 13.5 million acres were farmland as of 2021, representing a farmland allocation of roughly 47%. Ohio lost 100,000 acres of farmland between 2020 and 2021 to development (0.735%), a trend mostly caused by urban and suburban residential development (USDA, 2022; Hunter et al, 2022). This is nearly triple the national average of 0.249% farmland loss per year, which emphasizes the potential promise of agrivoltaics to preserve farmland in the state (Shahbandeh, 2023).

Despite these losses, field crop values increased by 25% in 2021 compared with 2020, largely due to greater corn, wheat, and soybean yields combined with higher prices for these commodity crops. This increase was consistent with national trends (USDA, 2022).

In Madison County, Ohio, roughly 84% of land (around 252,000 acres) is agricultural (Census, 2017). At 6,050 acres, Orelton Farms represents 2.4% of this land. Infrastructure for the Oak Run Solar Project is expected to occupy around 1,700 acres of the farm, or just 0.67% of agricultural land in the county, and the developer's plans include expanding agricultural activities to all available acres of the site as the project progresses.

Agrivoltaics represents a potential path for Ohio to capture the projected economic growth from solar development without exacerbating farmland loss. With a proposed capacity of 800 MW, the Oak Run project would nearly double the state's current solar capacity. Below, we detail the economic impacts of farming up to 71.6% of this farmland. While there will be a decrease in the number of farmed acres due to space occupied by infrastructure, including supports, equipment, and operations buildings, agrivoltaics can exploit synergistic relationships between panels and crops to compensate for lost acreage with added jobs, agricultural output, and clean energy production.

III. Best Agricultural Practices for Agrivoltaics in Madison County, Ohio

Because of the inherently high variability of agriculture, any list of best practices for agrivoltaic cultivation must be built on a foundation of local conditions and realities. This list of best practices pertains to agrivoltaics in the climate of Madison County, Ohio. It draws on academic research and takes a conservative approach in areas where consensus has not been reached.

Here we make use of the “five C’s” best practices framework put forth by the National Renewable Energy Laboratory (NREL) in 2022, and apply them specifically to agricultural production within a utility-scale solar array. These are as follows:

A. Climate, Soil, and Environmental Conditions

Conditions of climate, soil, and environment are largely beyond the control of project stakeholders like developers, operators, farmers, and researchers. However, it is possible to mitigate the effects of these realities through array design and agricultural practices:

- **Deploy solar panel arrays strategically** to:
  - Protect delicate crops from heavy rain or hail (Trommsdorf, 2022).
  - Moderate temperature extremes.
  - Control soil moisture (Barron-Gafford, 2019).
- **Use rotational grazing to increase biodiversity, soil carbon, and productivity** (Whitehead, 2020).

B. Configurations, Solar Technologies, and Designs

The choice and design of solar technology and site layout have a pronounced effect not only on solar generation but also on agricultural yields. As outlined in case studies by Fraunhofer ISE (2022), strategic integration of solar modules and plants can create synergistic effects on crops.

The following are best practices for agrivoltaic designs in Ohio:

- **Choose bifacial panels for greater efficiency and light penetration**. In addition to absorbing reflected solar radiation on the backside of the panels, bifacial panels allow some sunlight to pass between cells, providing more light to crops below (Bellini, 2022).
- **Use smart tracking technology if possible.** This technology reduces row-on-row shading and optimizes for changes in weather and crop needs. Tracking technology benefits crops by allowing more flexible shading, which can be programmed to deliver more or less light to targeted rows of crops during certain weather conditions, times of day, or periods in which the cash value of electricity is lower (Marrou et al, 2012). It also distributes each row’s drip edge over both sides of the row since the panels will change tilt over the course of a day, which can reduce erosion.

- **Panel shading on any one area should be kept to 25% or lower** to avoid stunting crop growth (Touil, 2021). Designing rows along a north-south axis can alleviate static shading, as the east-west movement of the sun will distribute the drop shadow over a wider spread of ground.
- **Agricultural activities should comprise ≥70% of total land area in a solar installation**. Italy's latest national agrivoltaics guidelines recommend "maintaining a significant percentage with respect to the 'continuity' of the activity that was practiced prior to the installation of the plant," which they set at 70% (Parra, 2022).
- **Inter-row spacing should be determined with respect to this 70% threshold, the realities of terrain and soil, and the needs of crops below panels.**
- **Panels should be mounted high enough to allow agricultural activities to be safely carried out beneath.** This must take into account both human and livestock activity beneath.
- **Mitigate erosion** through techniques like crop placement and/or manual water management. In addition to smart tracker technologies, gutters mounted along drip edges can be useful provided winter weather realities are taken into consideration.
- **Carefully plan substructures to avoid subsurface drainage tiles and conduits,** or design new tile installations to fit the array installation design.
- **During construction, avoid excessively compacting native soil.** Establish clearly defined drive lanes and keep all traffic confined to them. When possible, use a cover crop for soil stabilization prior to construction and avoid using excessive gravel.

C. Crop Selection, Vegetation Designs, and Management Approaches

To generate meaningful returns on agricultural activities below panels, it is essential to choose crops that can either tolerate or benefit from increased shade beneath and between agrivoltaics arrays. Developers should take a holistic design approach to optimize for synergies between panels and crops, all while accounting for the environmental realities of the site.

It is important to note that, while all crops require light for photosynthesis, **different varieties have different tolerances for incident light**. Photosynthesis rates stagnate after a certain point, and in general, the lower a crop's light saturation point, the more compatible that crop is with cultivation underneath solar arrays (Barron-Gafford, 2019):

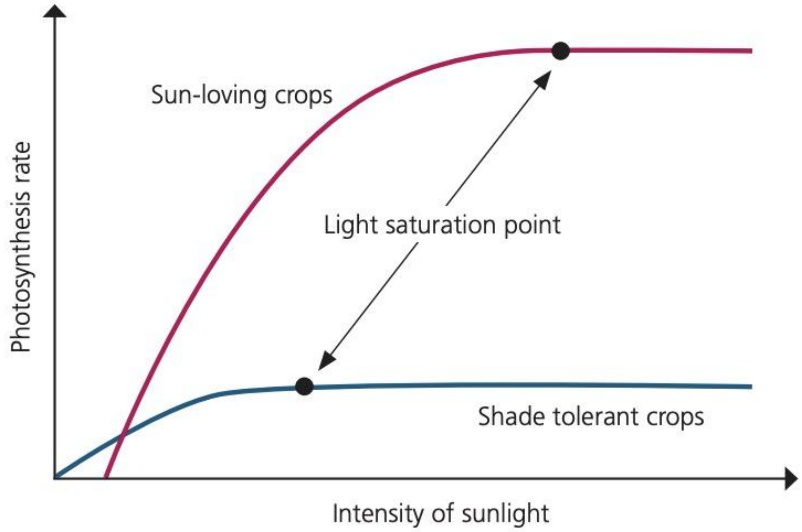


Image source: [Fraunhofer ISE]

The following recommendations for crops and agricultural practices take into account current research and the climate of Madison County, Ohio:

Pasture for Sheep

Agrivoiltaic arrays have demonstrated an **excellent degree of compatibility** with pasture sheep. Sheep are unlikely to damage panels, substructures, or electrical components, and reduce maintenance costs such as mowing and weed control.

Notably, research has demonstrated that grazing time increases in pastures with solar panels due to their providing shelter from the elements. They also increase soil moisture and shade, which consequently increases plant protein content and digestibility (Kampherbeek et al, 2022).

The following are best practices for solar grazing:

- **Allow forage to achieve a well-rooted, stable structure at target grazing height before regular grazing commences.** To help seed better establish a root system, an initial light grazing under dry conditions is recommended (Maine Department of Agriculture Conservation & Forestry, 2021).
- **Ensure solar cabling and equipment are protected from damage by animals.**
- **Adjust grazing frequency with growth rate fluctuations.** Seasonal and weather patterns will cause grass to grow differently, i.e. during spring flushes, heat waves, or droughts. Adjust grazing frequency or stocking rates up or down as needed to avoid overgrazing.
- **Use rotational grazing best practices to continuously improve soil health.** Strategically rotating flocks across paddocks and allowing for recovery periods reduces soil erosion, maximizes soil water infiltration, reduces flock illness risk, and ensures more productive and nutrient-dense forage.
- **Determine proper paddock size and keep the residency period below five days.** A rule of thumb is four adult sheep, or 3 lamb-ewe pairs, per acre. The Maine Department of Agriculture Conservation & Forestry has developed a worksheet to determine ideal paddock size and stocking rate.
- **Use "start grazing" and "stop grazing" forage heights to determine rotation times.** Bring sheep to pasture when forage reaches a "start grazing" height (typically 6-8 inches). Move sheep when plant height reaches a "stop grazing" threshold (typically 4 inches) or after five days, whichever comes first.
- **Recovery periods should average 30 days.** Recovery periods will generally be shorter in spells of ample rainfall and sunshine and longer in dry periods such as late summer and fall.
- **Use portable electric polywire fencing to create paddocks.** The location of array substructures will influence paddock shapes and locations.
- **Pursue value-added sheep products.** The large acreage and corresponding flock sizes of the Oak Run Solar Project open up economies of scale, creating market viability for sheep products like wool, hides, and lanolin.

Lettuce

Lettuce and solar arrays have demonstrated an **excellent degree of compatibility** due to the shade-tolerant nature of most lettuces. Research by Marrou et al. (2013) showed that lettuces grown under shading exhibited higher total leaf area despite having fewer leaves, likely due to improved radiation interception efficiency.

The following are best practices for growing lettuce under agrivoltaic arrays:

- **Aim for lettuces to receive at least 70% of photosynthetically active sunlight**. Research has demonstrated that a ~30% reduction in incident light has little appreciable effect on lettuce yields.
- **Monitor for positive lettuce head growth.** Lettuces grown in reduced light may adapt through structural changes such as reduced self-shading and increased head size and leaf area.

Kale, Chard, and Brussels Sprouts

Studies on kale, chard, and Brussels sprouts have shown an **excellent degree of compatibility** with agrivoltaic arrays. In particular, kale appears able to produce comparable levels of biomass in lower sunlight levels, whereas chard requires a higher amount of sunlight (Hudelson & Lieth, 2021). There is little available research on growing Brussels sprouts under agrivoltaic arrays beyond associations with other leafy greens (Simon I, 2020; Precedence Research, 2022).

The following are best practices for growing kale and chard:

- **Locate kale in a position that receives 55% to 85% of full sunlight,** as this will likely produce comparable yields to that grown in full sunlight.
- **Locate chard in a position that receives at least 85% of full sunlight**. Chard appears to require higher levels of sunlight than kale to avoid reduced yields.

Note that research on kale and chard was conducted in central California, hardiness zone 9, whereas Madison County, Ohio has a hardiness zone of 6.

Broccoli

Research on broccoli grown under agrivoltaic arrays has shown an **excellent degree of compatibility.**

In particular, broccoli grown under the partial shade of solar panels was greener and had a “higher level of consumer preference” compared with broccoli grown under full sunlight, and had no significant reductions in antioxidant levels, yields, or glucosinolates (Chae et al, 2022).

The following are best practices for growing broccoli under agrivoltaic arrays:

- **Aim for 85% of full sunlight to maximize biomass.** Research by Hudelson and Lieth (2021) showed that broccoli grown at this amount of light produced “significantly more harvestable head biomass,” and that levels below 85% reduced harvests.

Note that research on broccoli by Chae et al. was conducted in Naju, South Korea, which has a hardiness zone of 8a.

Tomatoes

Research on different varieties of tomatoes indicates a **good to excellent degree of compatibility** with agrivoltaics, depending on a number of factors including shading, species, and irrigation.

Yields of tomatoes were 40% to 60% lower at a research site in Oregon (AL-agele et al, 2021), 200% higher at a site in Arizona (Barron-Gafford et al, 2019), and comparable at a site in California (Hudelson and Lieth, 2021).

The following are best practices for growing tomatoes within an agrivoltaics array:

- **Aim for at least 55% of full sun for tomato plants, though more sunlight will likely improve yields.** Research conducted in Oregon indicates that total tomato yield decreases as shading increases, while research conducted in central California showed consistent harvestable biomass at sunlight above 55%.
- **Position tomato plants to take advantage of shading for water productivity.** Garden tomatoes require 1 to 2 inches of water per week, and reducing evaporation through strategic shading can help reduce irrigation needs. Agrivoltaic systems can “improve water productivity even for crops that are traditionally considered shade-intolerant,” according to AL-agele et al (2021).
- **Greatest productivity has been observed with species *Solanum lycopersicum* var. *Cerasiforme*,** commonly called “cherry tomato,” though this research took place in Arizona, a warmer, drier, and sunnier environment than Ohio.

Peppers

Certain types of peppers have demonstrated an **excellent degree of compatibility** with agrivoltaic arrays. Of particular note, chiltepin peppers showed a 300% yield increase when grown under panels near Tucson, Arizona. Jalepeño peppers had a slightly lower yield but substantially better water productivity (Barron-Gafford et al, 2019).

Pollinator Habitat

Pollinator habitat has demonstrated an **excellent degree of compatibility** with agrivoltaic arrays. While not a direct source of revenue, a healthy pollinator population can substantially improve per-acre yields of crops.

In a 2015 study, Kleijn et al. found that wild bee communities contributed over $1,316 per acre to crop production, similar to the contribution of actively managed honey bees. This enhancement will benefit not only agriculture under the array installation, but also adjacent and surrounding landowners. The Food and Drug Administration (2018) estimates that bees alone are responsible for around a third of all food eaten by Americans. In fact, even crops that aren't dependent on pollinators, such as soybeans, show increased yields when they are present.

The following are best practices for integrating pollinator habitat into agrivoltaics:

- **Choose the region-appropriate pollinator seed mix.** In Madison County, Ohio, this includes:
    - Shrubs like sumac, pussy willow, viburnum, and ninebark
    - Perennials like purple coneflower, milkweed, hyssop, and aster
    - Annuals like zinnia, sunflower, marigold, and cosmos
    - Herbs like oregano, lavender, catmint, borage, and basil (Ellsworth, 2015)
- **Choose a pollinator mix that provides nectar and pollen before *and* after crop bloom**. This will support bees that pollinate your crops.
- **Flowering trees, which can double as visual screening for the community, are also pollinator habitats.** Consider planting trees like serviceberry, linden, crabapple, and maple along field perimeters.
- **Plant pollinator habitat along field borders or unproductive corners**. This will make better economic use of otherwise unproductive space.
- **Plant pollinator habitat as intercrop insectary strips** so that pollinators can have better infiltration of crops and perform pest control.
- **Establish pollinator habitat as understory plantings beneath panels.** This will make use of areas that may otherwise be too shaded for crop production, and will also serve to cool the panels above for higher electrical efficiency.
- **Plant pollinator-friendly plants as filter strips to limit runoff into drainage areas.**
- **Plant flowering cover crops like buckwheat and allow them to bloom before terminating.**
- **Consider harvesting honey from bee boxes for greater value-added use of space.**
- **Take advantage of custom-tailored pollinator mixes, planting, and consultation.** These come from organizations like Pollinator Habitat Establishment & Management Guide and Seed a Legacy Program.

Regenerative Agriculture

Regenerative agriculture involves prioritizing soil health using ecological principles, which leads to greater productivity, resilience to pests, and resource conservation over time.

The following are best practices for incorporating regenerative agriculture techniques into the Oak Run project:

- **Utilize no-till planting whenever possible.** Tilling causes air pockets to form in the soil, converting soil carbon into CO_2 that escapes during the next tilling cycle (Cooper et al, 2021). Agricultural disc seeders or drills are effective ways to plant crops with minimal disturbance to soil structure. Note that tilling may occasionally be needed to break up poorly composted manure or to manage soil acidity (Cherlinka, 2020).
- **Plant cover crops to avoid soil oxidation and erosion.** For acreage where annual harvests take place, cover crops improve soil health by supporting microbes and their ability to build organic matter. As noted above, cover crops like buckwheat, clover, and rye are common choices in Ohio.
- **Use minimal, if any, pesticides and fertilizers.** Long-term synthetic fertilizer use is associated with reduced soil organic matter, fungal diversity, nitrogen, nitrate-nitrogen, and phosphorous contents in soil (Bai et al, 2020), and pesticides have been demonstrated to reduce soil microbial diversity (Devi, 2018). Using grazing animals as an alternative can effectively manage weed pressure, while ecological services like pollinator habitat and owl boxes can help mitigate pests.
- **Use adaptive multi-paddock rotational grazing.** As noted above, carefully managed grazing can strengthen soil health, leading to more nutrient-dense forage and crops that require fewer inputs.

D. Compatibility and Flexibility

Throughout the design process, a holistic approach should be taken to ensure compatibility with all stakeholders' needs, including landowners, solar operators, agricultural workers, and researchers.

While this research and that of Loomis et al. (September 2022) focus on the economic impacts of agricultural and electrical production in agrivoltaics, it is important to take a broader view when making design decisions to include community members, maintenance crews, and other stakeholders.

E. Collaborations and Partnerships

A common factor among successful agrivoltaic implementations is the spirit of collaboration with research institutions, community organizations, and other interested parties. This can help bolster public support and drive continuous improvements in techniques and best practices. These collaborations also extend to legal agreements, permitting, siting, and other logistical activities.

Entrepreneurship and academic programs can also be implemented in the local area to foster an atmosphere of ownership, increase motivation toward involvement and economic efficiency, and optimize overall returns for all parties.

IV. Methodology

In order to assess the economic impact of Savion's agrivoltaic project, we begin by determining the size of the potential farming operation after the solar portion of the project is complete. Due to substructures, outbuildings, and other equipment, a certain amount of land within a solar array will be unavailable for agriculture. For this analysis it is assumed that 2,000 acres will be allocated to: corn (750 acres), soy (750 acres), hay (250 acres), and alfalfa (250 acres), 15 acres will be dedicated to vegetables or another specialty crops, 100 acres to pollinator habitat, and the rest of the array will be seeded with a hayable pasture mix for rotational grazing sheep. We assume potentially 4,300 total usable acres in subsequent years of the 6,000 acre total, which comprises 71.7% of agricultural land area, thereby aligning with best practices.

With input from the developer, it was determined that the vast majority of the solar farm would be accessible for grazing livestock. Because sheep represent the best animal option, as they are able to efficiently use pasture without posing a risk of damaging solar panels or cabling or significant design modifications, they are assumed in this representation. It was also determined that the best starting point for specialty crop production was to dedicate 15 acres under and between panels.

Recommended crops were selected based on several criteria:

- Productive capability under partial shade conditions
- Availability of research on integration with agrivoltaic arrays
- Compatibility with the environmental conditions of Madison County, Ohio

Habitat for pollinators was also included, as it is both economically beneficial to crops and aligns with regenerative practices for soil health. Again, it was decided that this agricultural component should be applied conservatively at first to mitigate financial risk. We assume 100 nucleus colonies (nucs) of honey bees and 100 acres of land dedicated to flower gardens and flowering cover crops, which will provide habitat for bees and other pollinators. We recommend distributing this land throughout the farm in accordance with the best practices described in section III.

The next step was to research the production costs associated with sheep, selected crops, and pollinator habitat. Enterprise budgets from academic universities in the U.S. including the University of Kentucky, Ohio State University, and North Carolina State University were utilized to determine the factors that make up variable and fixed costs for these enterprises and production levels.

The following table illustrates the acreage devoted to different enterprises on the agrivoltaic portion of the farm, building up to the ultimate limit of 4,300 acres to be utilized for agricultural production. Of the 15 acres dedicated to specialty crops, tomatoes are assumed in this example to be produced using the entire acreage. Pollinator habitat will account for 100 acres total, while the sheep and lambs (1000 head) will use 327 acres initially. In addition, the table provides the capital costs for each part of the farm and the expected gross returns that are needed to calculate the economic impact of the agricultural portion of the agrivoltaic project.

Table 1. Agricultural Enterprises and Their Acreages and Gross Returns

Labor Requirements	Dollar Value of Hours
Corn and Soybeans	$ 37,688
Sheep and Lamb	$ 75,000
Alfalfa and Hay	$ 26,625
Tomatoes	$ 21,867
Honey and Pollinators	$ 6,480
	$ 167,660

The expected gross returns in the above table were calculated using the acreage for each enterprise, the production per acre on the crops, and the price per hundredweight produced. These yields were sourced from research performed at the University of Kentucky on a small-scale, 5.5-acre community-supported agriculture (CSA) project that took place over several years. Excellent record-keeping allowed for per-crop production numbers to be calculated. The prices referenced are USDA wholesale prices for each crop averaged over the last 10 years.

Lastly, so that economic impact results could be aligned with employment impacts, the labor requirements were determined for each enterprise in order to verify the corresponding IMPLAN-generated employment impact numbers. The average price of labor for this analysis is $15.00 per hour.

Table 2. Labor Requirements for Different Agricultural Activities

Crops and Livestock	Acres Devoted	Gross Returns
Corn and Soybeans	1,500	$ 1,066,605
Sheep and Lamb	327	$ 108,750
Alfalfa and Hay	500	$ 341,769
Tomatoes	15.0	$ 258,750
Honey and Pollinators	100	$ 15,660
		$ 1,791,534

V. Current Economics of Orelton Farm

A. Background and Assumptions

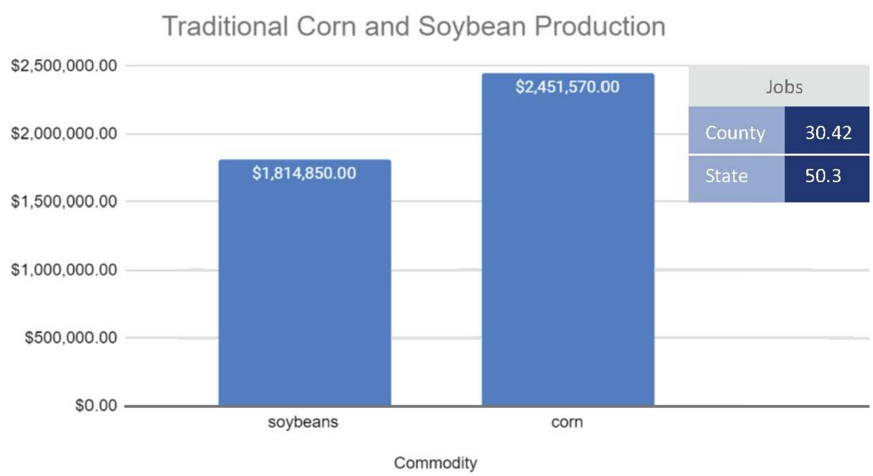
In its current state, Orelton Farm represents a typical large grain farm in Ohio, where corn and soybeans are the most common row crops. The farm is made up of over 6,000 acres and has mostly flat terrain with no fencing. It is intersected by roadways. The surrounding land area is also in agricultural production.

This analysis assumes a 50-50 allocation of corn and soy across the 6,000 acres of row crop land, as well as annual crop rotation to hedge against disease and market fluctuations. We use historical corn production figures for this region of Ohio as well as a 10-year NASS average for corn of $4.37/bushel (bu). We then multiply this by 187 bu, which is the average yield of corn per acre for Ohio, to calculate the potential revenue for corn (USDA NASS, 2023). The revenue of farming 3,000 acres of corn is estimated at $2,451,570 annually.

To estimate revenue from soybeans, we use the 10-year NASS average for soybeans of $10.90/bu and multiply it by the average yield of corn for Ohio per acre of 55.5 bu (USDA NASS, 2023). We repeat our calculations to determine the average annual revenue for soybeans. The revenue of farming 3,000 acres of soybeans is estimated at $1,814,850 annually.

B. Total Revenue Potential

The Orelton farm in Ohio currently has the potential to earn approximately $4,266,420 annually given average grain prices and average Ohio corn and soybean yields. Conventional solar farming practices would result in an agricultural loss by the farm, as no agricultural activity would occur within the array.



Based on these output numbers we can determine the economic impact the grain farm has on the state currently on an annual basis. Using IMPLAN, the two tables below show the direct impact in terms of output and labor and the indirect and induced impacts, as well from growing corn and soybeans on Orelton Farm. The first table shows the economic impact at the county level whereas the next table shows the impact at the overall state level.

Table 3. Economic Impact of Current Grain Production at the County Level in Madison County OH for the Orelton Farm at 6,000 Acres.

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	18.86	$1,210,520.14	$691,945.49	$4,266,420.00
2 - Indirect	8.07	$544,674.12	$677,801.16	$1,500,551.23
3 - Induced	3.48	$133,060.52	$294,047.38	$508,059.52
	30.42	$1,888,254.77	$1,663,794.03	$6,275,030.75

Within the county, it is expected that this farm will have a direct impact on employment of 18.86 FTEs and a total impact of 30.42 with both indirect and induced numbers added in. It also shows that this farm has a total output impact of over $6.2 million annually.

Table 4. Economic Impact of Current Grain Production at the State Level in Ohio for the Orelton Farm at 6,000 Acres.

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	23.19	$808,199.79	$685,458.13	$4,226,420.00
2 - Indirect	18.44	$888,488.17	$1,546,458.35	$3,195,642.37
3 - Induced	8.68	$480,684.00	$872,056.22	$1,520,622.04
	50.31	$2,177,371.96	$3,103,972.70	$8,942,684.41

At the state level, we estimate a direct impact on employment of 23.19 FTEs and a total impact of 50.31. The total output impact from the farm at the state level is over $8.9 million.

Below, we examine the potential revenue with agriculture performed under and around the solar array on the farm.

VI. Economic Impacts of Agrivoltaics on the Oak Run Solar Project

A. Background

The economic impact analysis in this report includes a model for Ohio. In economic impact analysis, output is the value of all sales transactions in the economy; employment is the number of part-time and full-time jobs in the economy, while average wages and benefits are income for these jobs. Value added is equal to sales less the costs of purchased inputs (Shaffer, 2004) or equivalent to the term gross state product.

Economic impacts result from a multiplier effect that begins with input expenditures stimulating business spending, personal income, employment, and tax revenue. This analysis uses estimated data from different phases of plant operation.

Economic impacts can be estimated with input-output models, such as IMPLAN, which separate the economy into various industrial sectors such as agriculture, construction, manufacturing, trades, and services. The input-output model then calculates how a change in one industry changes output, income, and employment in others. These changes, or impacts, are expressed in terms of direct and indirect effects. Impacts are interpreted as the contribution of the enterprise to the total economy:

- Direct effects represent the initial impact on the economy of either construction or operations of an enterprise.
- Indirect effects are changes in other industries caused by direct effects of an enterprise and include changes in household spending due to changes in economic activity generated by direct effects.

Thus, the total economic impact is the sum of direct and indirect effects. Input-output analysis can interpret the effects of an enterprise in a number of ways, including output (sales), labor income (employee compensation and proprietary income), employment (jobs), and tax revenue.

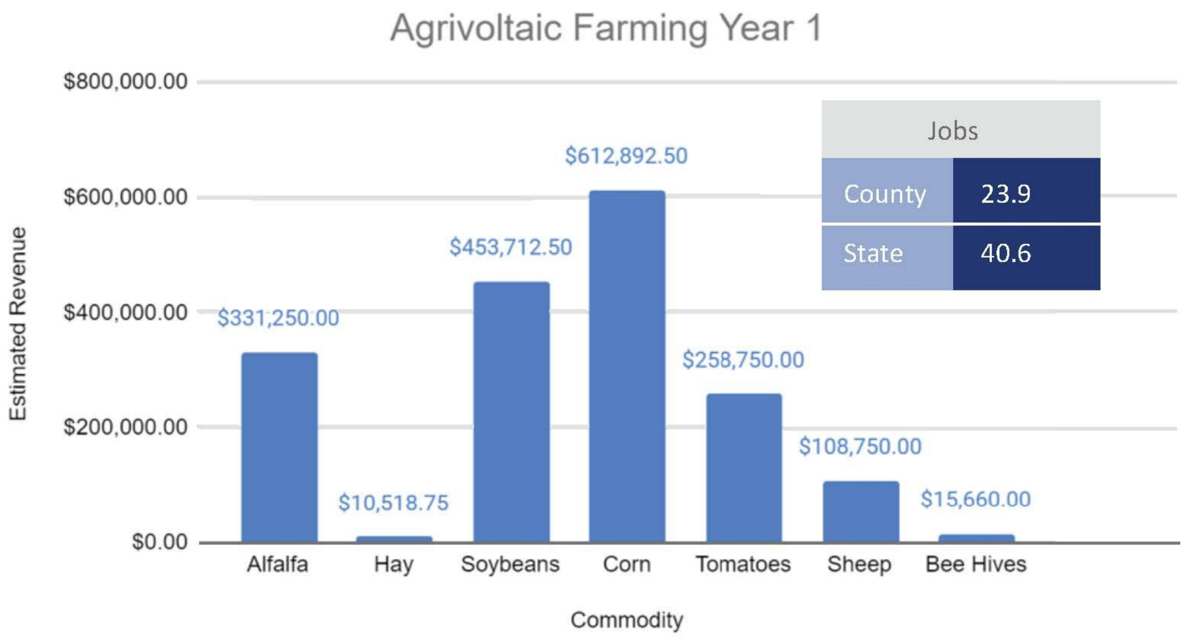
IMPLAN models include a regional purchase coefficient (RPC) for each impact variable that represents the percentage of demand that is satisfied by production within an impact area. Demand for inputs not satisfied within the impact area represents leakages that have no indirect impacts in the impact area. Enterprises vary in their multiplier effects due to differing expenditure levels, RPCs, and sectors in which their expenditures are directed. Impact analysis involves quantification of spending levels and proper allocation to impacted sectors.

Output impacts are a measure of economic activity that results from enterprise expenditures in a specific industrial sector. Output is equivalent to sales, and this multiplier indicates how initial economic activity in one sector leads to sales in other sectors. Labor income impacts for employees and proprietors measure purchasing power that is created due to the output impacts. This impact provides the best measure of how standards of living are affected for residents in the impact area.

An enterprise involves a specified number of employees that is determined by the technology of the enterprise. Employment multipliers indicate the effect on employment resulting from the enterprise initiating economic activity. IMPLAN indirect employment includes both full-time and part-time jobs without any distinction. Jobs calculated within an IMPLAN industrial sector are not limited to whole numbers; fractional amounts represent additional hours worked without an additional employee. With no measure of hours involved in employment impacts, IMPLAN summations for industrial sectors which include fractional employment represent both jobs and job equivalents. Since employment may result from some employees working additional hours in existing jobs, instead of terming indirect employment impacts as "creating" jobs, a more accurate term is "involving" jobs or job equivalents.

B. Farming Operations

Moving forward with the project, agricultural production will continue to have a positive impact on sales and employment in both Madison County and the state of Ohio. The following figure shows the expected income generated by the Agrivoltaic Farm in the first year for each of the enterprises. The model assumes 1,000 sheep, 750 acres each of the two row crops, 15 acres of tomatoes, 100 bee hives, and 500 acres of forage crop (250 acres alfalfa and 250 acres regular hay).



Tables 5 and 6 present the direct, indirect, and induced effects of an initial benchmark for farming operations on the County and State.

Table 5. Impacts of Savion's Agricultural Production at 1,000 Sheep and 2,000 crop acres Including Alfalfa and Hay on Madison County's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	19.4	$ 681,343	$ 580,356	$ 1,881,952
2 - Indirect	2.8	$ 188,851	$ 237,086	$ 500,272
3 - Induced	1.7	$ 65,021	$ 143,660	$ 248,220
	23.9	$ 935,215	$ 961,102	$ 2,630,445

At the county level, there will be a total of 19.4 jobs, generating a total output of $1,881,952 associated with the production occurring on the farm and utilizing 2,115 acres for crops and 327 for sheep. There will be a total of 23.9 jobs created in the county when including indirect and induced impacts with a total economic impact on output of $2,630,445.

Table 6. Impacts of Savion's Agricultural Production 1,000 Sheep and 2,000 crop acres Including Alfalfa and Hay on Ohio's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	29.9	$ 442,729	$ 580,390	$ 1,881,952
2 - Indirect	6.7	$ 326,944	$ 566,870	$ 1,156,394
3 - Induced	3.9	$ 217,987	$ 395,473	$ 689,595
	40.6	$ 987,660	$ 1,542,733	$ 3,717,941

At the state level, there will be a total of 29.9 jobs from the production output of $1,881,952 with 2,115 acres for crops and 327 for sheep. There will be a total of 40.6 jobs created statewide when indirect and induced impacts are considered and a total economic impact of $3,717,941.

To show the eventual potential agricultural production on the agrivoltaic farm, we increased production output and additional time and calculated the gross income potential for year "X". The figure on the following page shows the impact from raising the crops to 3,000 acres of production, the forages to 1,000 and the sheep to 3,000 head.

Tables 7 and 8 show the economic impact of increasing row crop production to 3,000 acres, forages to 1,000 acres, and bringing the sheep herd to 3,000 head in year X. The state economic impact shows employment that is directly attributable to production on the farm; as Table 8 illustrates, it rises from 59.4 FTEs to 80.2 when induced and indirect impacts are considered. The output level reaches $7,213,952 when the indirect and induced effects are considered at the state level.

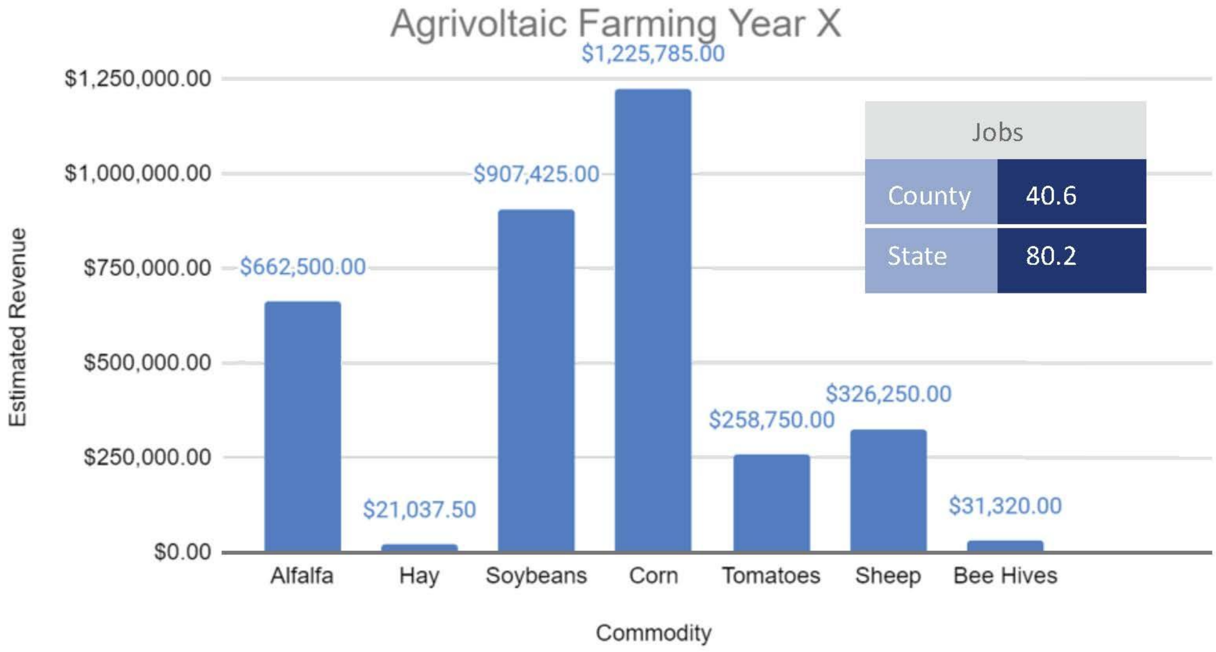


Table 7. Impacts of Savion's Agricultural Production at 3,000 Sheep and 4,000 Crop Acres Including Alfalfa and Hay on Madison County's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	38.6	$ 1,364,495.69	$ 1,143,238.81	$ 3,639,934.86
2 - Indirect	5.3	$ 363,008.14	$ 455,293.26	$ 967,031.78
3 - Induced	3.4	$ 130,086.40	$ 287,442.63	$ 496,649.95
	47.3	$ 1,857,590.25	$ 1,885,974.70	$ 5,103,616.59

Table 8. Impacts of Savion's Agricultural Production at 3,000 Sheep and 4,000 Crop Acres Including Alfalfa and Hay on Ohio's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	59.4	$ 887,079	$ 1,144,346	$ 3,639,935
2 - Indirect	13.0	$ 628,909	$ 1,091,565	$ 2,234,350
3 - Induced	7.8	$ 429,808	$ 779,752	$ 1,359,667
	80.2	$ 1,945,795	$ 3,015,663	$ 7,213,952

C. Individual Crop/Livestock Impacts

Tables 9-16 present county and state impacts for sheep, vegetables, and honey individually. Note that Tables 15 and 16 show the state and county economic impact from 100 acres of honey bee habitat on the farm and 100 hives. The project is not limited to this number and could possibly expand in future years if desired.

These tables emphasize that the sheep enterprise in particular has a significant impact at both the county and state level. While smaller in value, the vegetable and pollinator operations still produce a significant economic impact at both levels.

Table 9. Impacts of Producing 1,000 Sheep on Madison County's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	2.4	$ 72,331.44	$ 124,249.39	$ 174,804.29
2 - Indirect	0.3	$ 14,435.58	$ 24,601.22	$ 51,484.60
3 - Induced	0.5	$ 24,983.54	$ 45,318.04	$ 79,019.26
	3.2	$ 111,750.57	$ 194,168.64	$ 305,308.15

Table 10. Impacts of Producing 1,000 Sheep on Ohio's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	10.4	$154,249.47	$144,092.96	$341,769.00
2 - Indirect	0.41	$28,651.89	$35,821.80	$66,431.26
3 - Induced	0.32	$12,309.94	$27,163.74	$46,936.63
	11.13	$195,211.31	$207,078.50	$455,136.89

Table 11. Impacts of 250 Acres of Alfalfa Production on Madison County's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	2.1	$ 114,246.15	$ 124,107.14	$ 176,518.57
2 - Indirect	0.1	$ 4,714.00	$ 6,530.97	$ 12,718.87
3 - Induced	0.3	$ 9,840.80	$ 21,764.77	$ 37,604.28
	2.4	$ 128,800.95	$ 152,402.88	$ 226,841.72

Table 12. Impacts of 250 Acres of Alfalfa Production on Ohio's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	18.85	$97,636.70	$144,092.96	$341,769.00
2 - Indirect	1.05	$50,971.49	$88,878.12	$176,076.24
3 - Induced	0.75	$41,682.88	$75,628.58	$131,877.99
	20.65	$190,291.06	$308,599.67	$649,723.24

Table 13. Impacts of 15 Acres of Tomato Production on Madison County's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	0.48	$ 25,888.75	$ 28,123.30	$ 40,000.00
2 - Indirect	0.03	$ 1,068.23	$ 1,479.95	$ 2,882.15
3 - Induced	0.05	$ 2,229.98	$ 4,932.00	$ 8,521.33
	0.55	$ 29,186.95	$ 34,535.25	$ 51,403.48

Table 14. Impacts of 15 Acres of Tomato Production on Ohio's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	0.55	$ 16,551.40	$ 28,431.65	$ 40,000.00
2 - Indirect	0.08	$ 3,303.25	$ 5,629.43	$ 11,781.08
3 - Induced	0.10	$ 5,716.93	$ 10,370.00	$ 18,081.78
	0.73	$ 25,571.58	$ 44,431.10	$ 69,862.85

Table 15. Impacts of 100 Acres of Honey Production on Madison County's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	1.79	$85,438.02	$112,251.26	$258,774.00
2 - Indirect	0.24	$18,294.43	$23,866.51	$43,225.45
3 - Induced	0.2	$7,470.59	$16,499.27	$28,508.35
	2.23	$111,203.04	$152,617.04	$330,507.80

Table 16. Impacts of 100 Acres of Honey Production on Ohio's Economy

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	2.3	$54,159.81	$112,251.26	$258,774.00
2 - Indirect	0.71	$36,111.47	$61,146.38	$118,141.22
3 - Induced	0.46	$25,432.82	$46,142.43	$80,460.35
	3.47	$115,704.10	$219,540.07	$457,375.57

D. Potential for Agriculture 4.0 Impacts

Agriculture 4.0 describes the next generation of agricultural technologies and practices, specifically more focus on precision agriculture, Internet of Things (IoT) integration, big data, and automation.

Savion Energy is actively collaborating with equipment manufacturers and innovators to develop new machinery and technologies for agrivoltaic-specific farming. Due to the large size of the Oak Run Solar Project, using the site as a proving ground for new technologies could position Madison County as a player in Agriculture 4.0 developments, bringing further economic growth to the area.

E. Summary of Economic Impacts

The economic impact from grain farming 6,000 acres in Madison County is $6.275 million at the county level and $8.942 million at the state level when one includes the induced and indirect impacts for corn and soybeans. These activities also lead to an employment level of 30.42 at the county level and 50.31 at the state given the same assumptions.

When the farm achieves its initial targets of producing 1,000 sheep, 1,500 acres of grain, 500 acres of alfalfa and hay, 15 acres of tomatoes, and 100 acres of pollinator habitat with bees, the economic impact of these activities will total $3.7 million in output and 40.6 jobs, in addition to the economic impacts of solar power generation.

It is important to note that these are baseline figures that Savion can expand upon. If in 10 years the farm increases sheep production to 3,000 and grows 3,000 acres of grain and 1,000 acres of hay, it has the potential to reach an estimated total economic output of $7,213,952 with total state employment just over 80. This figure places the project within 80% of the $8.9 million impact of the traditional farming operation, and is in addition to the impacts from solar generation.

F. Avoided Costs for the State of Ohio

It is worth noting certain costs the Oak Run project will avoid for the State of Ohio, notably the H2Ohio Program and subsidies.

The H2Ohio Water Fund is a statewide effort to improve water quality and reduce algal blooms through incentivizing farms to use cover crops on their fields. In 2021, the program received its second appropriation of $168 million, which it uses to fund outreach and adoption of cover-cropping. The Oak Run Solar Project will employ cover crops as part of its operating model and will not take money from the H2Ohio Water Fund.

Secondly, agriculture on the current farm is subsidized; agricultural activities on the Oak Run Solar Project will not be subsidized, conserving governmental funds.

Regarding tax concerns, the project will pay an established rate that is higher than Current Agricultural Use Value (CAUV) or regular property taxes. This means the project does not need farming to maintain CAUV status; in fact, the state of Ohio designates utility-scale solar projects as Qualified Energy Projects that do not depend upon CAUV status or other zoning distinctions.

VII. Addressing Community Concerns With Findings

The findings in this report indicate that agricultural productivity will continue to be an integral part of Orelton Farm after the installation of solar. Below we reference and address concerns expressed by local citizens at a public hearing in April 2023:

A. Lost farmland

The following concerns were expressed on the record:

- “No other county in the State of Ohio has lost this many acres of prime farmland.” - Michael Vallery
- “I am not opposed to solar panels but they should not be on prime farmland.” - Dale King
- “I do recognize the need for the electrical power generation. However, the conversion of prime farmland for the development of a solar power generation plant I believe to be detrimental to the area.” - Brent Zimmerman

The results of this research indicate that the agrivoltaics array at Oak Run can preserve over 70% of the farmland it occupies for agricultural use, which is in alignment with best practices and offers the opportunity for both energy and food production.

Based on our estimates, yields for sheep farming, crop and pollinator cultivation, plus corn and soybeans on the remainder of the farm will result in around 76% of previous farm revenue as a starting point. In subsequent years, the job creation potential for the county and state will both increase, as will potential production growth as the soil health increases and the agricultural team optimizes land allocation.

The transition from conventional farming to agrivoltaic practices will utilize smaller equipment. Traditional farming equipment has grown, resulting in gross vehicle weights (GVW) ranging from 60,000 lbs. (tractors) to 180,000 lbs. (loaded grain carts at harvest). This massive equipment leads trafficked soils to become compacted, which reduces macropore space for air and water and compromises soil health and the ability to sequester carbon. Concomitant reductions in soil biological activity decrease nutrient uptake and use efficiency by crops (Shearer, 2023). Furthermore, wetter growing seasons have resulted in fewer available field working days during spring and fall field operations. Ohio farmers are being required to adjust operations by selecting new crop varieties/hybrids, new crop mixes/rotations, deploying new technologies and practices to sustain soil health and improve nutrient use efficiency, and formulate better logistics to conduct field applications. Agrivoltaics proposes putting all of these conditions into practice while producing clean, renewable energy.

Finally, agrivoltaic development protects farmland from other types of development such as housing, parking lots, and commercial buildings, which do not allow for concurrent agricultural production or a return to farmland.

B. Poor Location Siting

The following concern was expressed on the record:

- “Warehouse rooftops, parking lots, and reclaimed strip mining land would be a much more suitable location for them.” - Dale King

While the possibility of locating solar arrays over hardscaping and brownfields is often explored before farmland, our findings indicate an overall positive effect for agriculture on Orelton Farm. Agrivoltaics preserve and protect farmland from the types of development (such as housing) that take it out of commission for the foreseeable future. Note that just 0.5% of agricultural land in the U.S. is needed to provide all of our solar needs by 2050 (Solar Energy Technologies Office, 2021).

Land-use efficiency has been demonstrated to increase by roughly 60% per acre when agriculture and solar are combined (Trommsdorf et al, 2022). Benefits include improved soil health, diversified agricultural products, an increase in domestic sheep production, and job creation for farmers and farmhands.

C. Loss of Indirect Economic Impacts

The following concerns were expressed on the record:

- “Some quick math shows that using $1000 per acre of inputs (fertilizer, chemicals, seed, insurance premiums, equipment/parts etc.) over the course of 30 years would be a loss of over 470 million dollars to the Madison County economy in that time period and it will be much more as inputs will increase in the future.” - Michael Vallery (Note: incorrect math)
- “In Savion's Oak Run Project application, nothing was said about the impact of lost jobs due to reduced fertilizer sales, grain sales, and equipment sales.” - Dale King

Our findings indicate with the current agricultural production on the site there is a county-wide economic impact of $6.275 million and 30 jobs annually, while the state impact is $8.942 million with 50 jobs. The first agricultural benchmark at Oak Run (1,000 sheep + 2,115 acres of agricultural production) will contribute nearly 24 jobs and $2,630,445 to Madison County’s economy annually, as well as over 40 jobs and $3,717,941 to Ohio’s economy. A subsequent benchmark (3,000 sheep + 4,300 acres of agricultural production) could contribute over 47 jobs and $5,103,616.59 to Madison County’s economy annually, as well as over 80 jobs and $7,213,952 to Ohio’s economy. See Table 17 below.

Table 17. Economic Impact From Current Production, Year 1 of Agrivoltaics, Year X of Agrivoltaics

		Employment	Labor Income	Value Added	Output
Current Agricultural Production	County Impact	30.4	$ 1,888,255	$ 1,663,794	$ 6,275,031
	State Impact	50.3	$ 2,177,372	$ 3,103,973	$ 8,942,684
Year 1 Agrivoltaics	County Impact	23.9	$ 935,215	$ 961,102	$ 2,630,445
	State Impact	40.6	$ 987,660	$ 1,542,733	$ 3,717,941
Year X Agrivoltaics	County Impact	47.3	$ 1,857,590	$ 1,885,975	$ 5,103,617
	State Impact	80.2	$ 1,945,795	$ 3,015,663	$ 7,213,952

By maintaining a growing flock of sheep, Oak Run has the potential to contribute to reclaiming the U.S. domestic sheep market. This market has become increasingly reliant on imports from countries like Australia, which provide over half of our lamb and mutton (Shabandeh, 2023). Furthermore, Oak Run will rely on local livestock processing facilities, of which there are more than a dozen in the state of Ohio.

D. Ecological Impacts

The following concerns were expressed on the record:

- "...Wildlife patterns will be affected, waterways and creeks put at risk." - Brent Thomas
- "...We moved into a rural area and we love it for the nature. We're nature lovers. I'm actually a beekeeper. We take drives many nights to go just watch deer, which is another animal that is going to be affected by these solar projects." - Heather Crum

By introducing pollinator habitat, pasture land, and regenerative agricultural techniques, Oak Run is likely to have a similar or improved environmental impact compared with the farm's current status. (Holsether et al, 2023).

According to the Audubon Society, "adopting renewable energy is critical to reducing pollution, lowering global temperatures, and preserving the places that birds need to survive. That's why Audubon strongly supports renewable energy—including solar, wind, and geothermal power—that is properly sited in ways that avoid, minimize, and mitigate negative impacts on birds and other wildlife" (Audubon, 2023). Because the Oak Run Solar Project will include 100+ acres of pollinator habitat plus shrubs and trees, it will have the effect of increasing biodiversity and wildlife habitat. Additionally, rotational sheep grazing is likely to decrease the usage of fertilizers and pesticides while increasing nitrogen fixing and reducing phosphorous runoff, which has been cited as the cause for toxic algal blooms (Toor et al, 2020).

E. Soil Erosion

The following concern was expressed on the record:

- "Soil erosion will destroy the natural habitat of the Little Darby." - Elizabeth Finke

Soil erosion is less likely to occur with rotational grazing than with tilled monoculture crops. The beneficial shift from conventional farming to agrvoltaics will incorporate these practices. Furthermore, pollinator habitat planted as filter strips along waterways can help improve water quality during heavy rainfall (Natural Water Retention Measures, 2023).

VIII. References

- Adeh EH, Good SP, Calaf M, Higgins CW. Solar PV power potential is greatest over croplands (published online August 7, 2019). *Scientific Reports.* doi: 10.1038/s41598-019-47803-3
- AL-agele HA, Proctor K, Murthy G, Higgins C. A case study of tomato (Solanum lycopersicon var. Legend) production and water productivity in agrivoltaic systems (published online March 6, 2021). *Sustainability.*
- Audubon. Renewable energy and birds (accessed May 5, 2023). *Audubon.org.*
- Bai YC, Chang YY, Hussain M, et al. Soil chemical and microbiological properties are changed by long-term chemical fertilizers that limit ecosystem functioning (published online May 8, 2020). *Microorganisms.* doi: 10.3390/microorganisms8050694
- Barron-Gafford GA, Pavao-Zuckerman MA, Minor RL, et al. Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands (published online September 2, 2019). *Nature Sustainability*. doi: 10.1038/s41893-019-0364-5
- Bellini E. Optimal topology for agrivoltaics based on bifacial PV modules (published online January 21, 2022). *PV Magazine.*
- Bolinger M, Bolinger G. Land requirements for utility-scale PV: an empirical update on power and energy density (published online January 10, 2022). *IEEE Journal of Photovoltaics*. doi: 10.1109/JPHOTOV.2021.3136805
- Census of Agriculture. Ohio state and county data (published online 2017). *United States Department of Agriculture*.
- Chae S-H, Kim HJ, Moon H-W, Kim YH, Ku K-M. Agrivoltaic systems enhance farmers' profits through broccoli visual quality and electricity production without dramatic changes in yield, antioxidant capacity, and glucosinolates (published online June 12, 2022). *Agronomy*. doi: 10.3390/agronomy12061415
- Cherlinka V. No-till farming: methods & how they affect agriculture (published online September 24, 2020). *EOS Data Analytics.*
- Cooper HV, Sjögersten S, Lark RM, Mooney SJ. To till or not to till in a temperate ecosystem? Implications for climate change mitigation (published online April 27, 2021). *Environmental Research Letters.* doi: 10.1088/1748-9326/abe74e
- Corbley A. Largest farm to grow crops under solar panels proves to be a bumper crop for agrivoltaic land use (published online February 3, 2022). *Agritecture.*
- Devi YB, Meetei TT, Kumari N. Impact of pesticides on soil microbial diversity and enzymes: a review (published online June 7, 2018). *International Journal of Current Microbiology and Applied Sciences.* doi: 10.20546/ijcmas.2018.706.113
- Elamri Y, Cheviron B, Lopez JM, Dejean C, Belaud G. Water budget and crop modelling for agrivoltaic systems: application to irrigated lettuces (published online 2018). *Elsevier*.
- Ellsworth D. Attracting pollinators to the garden (published online February 25, 2015). *Ohioline: Ohio State University Extension.*
- FAO and UNEP. The state of the world's forests 2020: forests, biodiversity and people (published 2020). doi: 10.4060/ca8642en
- Farm Office: Ohio State University Extension. Data and statistics (accessed April 30, 2023).
- Food and Drug Administration. Helping agriculture's helpful honey bees (updated July 30, 2018).

- Gertner D, Dennis E, Saner R, McClure G. University of Nebraska Lincoln sheep budget tool (published April 1, 2021). *University of Nebraska Agricultural Economics.*
- Groom N. Special Report: U.S. solar expansion stalled by rural land-use protests (published online April 7, 2022). *Reuters.*
- Holsether FT, Reid GF. 5 benefits of regenerative agriculture – and 5 ways to scale it (published online January 11, 2023). *World Economic Forum.*
- Hudelson T, Lieth JH. Crop production in partial shade of solar photovoltaic panels on trackers (published online June 28, 2021). *AIP Conference Proceedings.* doi: 10.1063/5.0055174
- Hunter M, Sorensen A, Nogeire-McRae T, Beck S, Shutts S, Murphy R. 2022. Farms under threat 2040: choosing an abundant future (published online June 29, 2022). *American Farmland Trust.*
- Iowa State University: Extension & Outreach. Beekeeping: enterprise budget series (accessed April 30, 2023). *Iowa State University: Extension & Outreach.*
- Kampherbeek EW, Webb LE, Reynolds BJ, et al. A preliminary investigation of the effect of solar panels and rotation frequency on the grazing behavior of sheep (Ovis aries) grazing dormant pasture (published online November 23, 2022). *Applied Animal Behaviour Science.*
- Kleijn D, Winfree R, Bartomeus I, et al. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation (published online June 16, 2015). *Nature Communications.* doi: 10.1038/ncomms8414
- Solar Power World. Largest agrivoltaic research project in U.S. advances renewable energy while empowering local farmers (published online June 10, 2021). *Solar Power World*.
- Loomis DG, Loomis B, Thankan C. Economic impact and land use analysis of Oak Run Solar Project (published September 2022). *Strategic Economic Research.*
- Lydersen K. Solar panels and crops can coexist, but more study needed on how and where (published online October 17, 2022). *Energy News Network.*
- Macknick J, Hartmann H, Barron-Gafford G, et al. The 5 Cs of agrivoltaic success factors in the United States: lessons from the InSPIRE Research Study (published online August 2022). *National Renewable Energy Laboratory*.
- Maine Department of Agriculture Conservation & Forestry. Solar farm grazing best management practices (BMPs) for sheep (published August 2021). *The University of Maine Cooperative Extension.*
- Markings S. The effect of temperature on the rate of photosynthesis (published online March 9, 2018). *Sciencing.*
- Marrou H, Wéry J, Dufour L, Dupraz C. Productivity and radiation use efficiency of lettuces grown in the partial shade of photovoltaic panels (published online September 7, 2012). *European Journal of Agronomy.*
- Mow B. Solar sheep and voltaic veggies: uniting solar power and agriculture | state, local, and tribal governments (published online June 6, 2018). *NREL*.
- National Grid. How will our electricity supply change in the future? (accessed April 27, 2023). *National Grid.*
- Natural Water Retention Measures. Filter strips (accessed May 3, 2023). *NWRM.*
- Nussey B. An acre of corn-grown ethanol vs an acre of solar panels. For the environment and the farmers, it's not even close (published online September 20, 2021). *LinkedIn.*

- O'Dell J. Making the EV transition: understanding kilowatts (published online May 6, 2022). *Forbes.*
- Ohio Power Siting Board. OPSB solar generation projects (accessed May 5, 2023). *OPSB.*
- Ouzts E. Farmers, experts: solar and agriculture 'complementary, not competing' in North Carolina (published online August 28, 2017). *Energy News Network*.
- Parra MJJ. Italy publishes new national guidelines for agrovoltaic plants (published July 5, 2022). *PV Magazine.*
- Pascaris AS, Handler R, Schelly C, Pearce JM. Life cycle assessment of pasture-based agrivoltaic systems: Emissions and energy use of integrated rabbit production (published online July 22, 2021). *Cleaner and Responsible Consumption*.
- Precedence Research. Agrivoltaics market - Global Industry Analysis, Size, Share, Growth, Trends, Regional Outlook, and Forecast 2022-2030 (published online October 2022). *Precedence Research.*
- Proagrica. What is agriculture 4.0? (accessed May 5, 2023). *Proagrica.*
- Public Utilities Commission. Public hearing before the Ohio Power Siting Board (published online April 11, 2023). *Ohio Public Utilities Commission.*
- Ramos-Fuentes IA, Elamri Y, Cheviron B, Dejean C, Belaud G, Fumey D. Effects of shade and deficit irrigation on maize growth and development in fixed and dynamic AgriVoltaic systems (published online February 7, 2023). *Agricultural Water Management.*
- Roser M. Why did renewables become so cheap so fast? (published online December 1, 2020). *Our World in Data.*
- Shaffer R, Deller S, Marcouiller D. Rethinking community economic development (published online February 2006). *Economic Development Quarterly.* doi: 10.1177/0891242405283106
- Shahbandeh M. Total area of land in United States farms from 2000 to 2022 (in 1,000 acres) (published online March 13, 2023). *Statista.*
- Shahbandeh M. U.S. total lamb and mutton imports and exports from 2006 to 2023 (in million pounds) (published online March 6, 2023). *Statista.*
- Shearer S. Realizing climate-smart agriculture through digitization (unpublished white paper; accessed May 5, 2023). *Molly Caren Agricultural Center, The Ohio State University.*
- Siegler K. This Colorado 'solar garden' is literally a farm under solar panels (published online November 14, 2021). *NPR.*
- Simon I. Agrivoltaics: enough sunlight for electricity and crops (published online April 16, 2020). *Verve Ventures.*
- Solar Energy Technologies Office. Solar futures study (published online September 8, 2021). *Energy.gov.*
- Solar Energy Industries Association (SEIA). Ohio solar. Accessed April 29, 2023. *SEIA.*
- Solar Energy Industries Association (SEIA). State solar spotlight: Ohio (published online June 7, 2022). *SEIA.*
- Toor GS, Yang YY, Morris M, et al. Phosphorus pools in soils under rotational and continuous grazed pastures (published online September 17, 2020). *Agrosystems, Geosciences, & Environment.* doi: 10.1002/agg2.20103
- Touil S, Richa A, Fizir M, Bingwa B. Shading effect of photovoltaic panels on horticulture crops production: a mini review (published online March 26, 2021). *Reviews in Environmental Science and Bio/Technology.* doi: 10.1007/s11157-021-09572-2

- Trommsdorff M, Dhal IS, Özdemir ÖE, Ketzer D, Weinberger N, Rösch C. Agrivoltaics: solar power generation and food production (published online June 24, 2022). *Solar Energy Advancements in Agriculture and Food Production Systems.* doi: 10.1016/B978-0-323-89866-9.00012-2
- Trommsdorff M, Gruber S, Keinath T, et al. Agrivoltaics: Opportunities for Agriculture and the Energy Transition (published April 2022). *Fraunhofer ISE*.
- University of Nebraska Institute of Agriculture and Natural Resources. Bioenergy corn (accessed May 2, 2022). *Cropwatch.*
- USDA. Agriculture across Ohio: 2021 crop values summary (published March 2022). *USDA National Agricultural Statistics Service, Great Lakes Region.*
- USDA. Specialty crops terminal markets standard reports (accessed April 30, 2023). *Agricultural Marketing Service.*
- USDA National Agricultural Statistics Service. Ohio Field Office (published online June 10, 2020). *USDA.*
- USDA ERS. Feed grains sector at a glance (accessed May 5, 2023). *USDA.*
- USDA NASS. Ohio annual crop summary (published online January 12, 2023). *United States Department of Agriculture National Agricultural Statistics Service Great Lakes Region.*
- Valle B, Simonneau T, Sourd F, et al. Increasing the total productivity of a land by combining mobile photovoltaic panels and food crops (published online October 7, 2017). *Applied Energy.*
- van de Ven DJ, Capellan-Peréz I, Arto I, et al. The potential land requirements and related land use change emissions of solar energy (published online February 3, 2021). *Scientific Reports*. doi: 10.1038/s41598-021-82042-5
- Weaver JF. Solar+food in ethanol fields could fully power the United States (published online March 10, 2022). *PV Magazine.*
- Weselek A, Ehmann A, Zikeli S, Lewandowski I, Schindele S, Högy P. Agrophotovoltaic systems: applications, challenges, and opportunities. A review (published online June 19, 2019). *Agronomy for Sustainable Development*.
- Whitehead D. Management of grazed landscapes to increase soil carbon stocks in temperate, dryland grasslands (published online October 28, 2020). *Frontiers in Sustainable Food Systems.* doi: 10.3389/fsufs.2020.585913

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