Solar

Agrivoltaics: Considerations for Co-locating Solar and Agricultural Practices

Agrivoltaics—blending solar energy with farming—offers a potential dual-use land strategy, but is dependent upon site-specific environmental and economic considerations.

What is Agrivoltaics?

Agrivoltaics refers to dual use areas with the careful integration of agricultural practices and solar energy generation on the same plot of land.

Agricultural practices that—when paired with solar generation—constitute agrivoltaics can include:

- Certain small livestock grazing
- Crop cultivation
- Pollinator-friendly vegetation
- Beekeeping

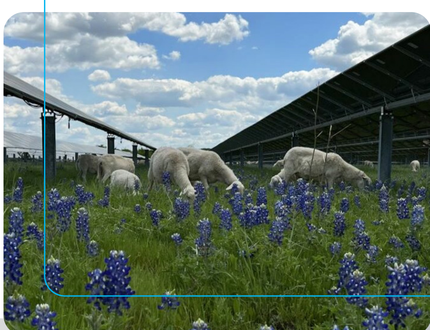

Image courtesy of lightsource bp. Sheep grazing, and pollinator habitat vegetation planted around and under solar panels at 163 MW Elm Branch Solar in Texas.

Image courtesy of ENGIE. Inter-row crop Agrivoltaics: Utility-scale asparagus cultivation trials in Sicily.

Size & Configuration of Agrivoltaic Projects

Agrivoltaic projects can range in size and configuration. Typical utility-scale ground-mount photovoltaic (PV) systems have panel heights low to the ground and are only compatible with a limited range of agrivoltaic formats—particularly beekeeping and pollinator-friendly vegetation. But even these require a site-specific feasibility assessment.

Other considerations that affect size and configuration include:

Small Livestock and Sheep Grazing: Sheep grazing at solar project sites requires extra consideration, like raising the panels up higher and protecting electrical cables. This can have an impact on economic feasibility. Elevating panels higher—including addressing engineering requirements to ensure stability during extreme weather—increases material use and costs.

Crop Agrivoltaics: Like sheep grazing, crop agrivoltaics also require extra considerations that can have an impact on economic feasibility. Crop agrivoltaics works best with low-stature plants that grow well in partial shade. Crop agrivoltaics can be carried out between PV rows (**inter-row crop agrivoltaics**) or beneath PV panels (**elevated crop agrivoltaics**).

- **Inter-Row Crop Agrivoltaics:** In inter-row crop agrivoltaics, single-axis trackers (which rotate panels on a single cylinder to track the sun's movements during the day) or vertical-bifacial mounts (which generate electricity from both the ground facing and sky facing sides of the panel) are most often used (as opposed to south-facing fixed-tilt racks on which panels are stationary). This provides a more uniform sun exposure to crops, and the distances between PV rows must be widened to accommodate the operations of agricultural machinery. Other facility features, such as above-ground DC cabling and different motor tracking systems, also need to be considered in layout to avoid creating obstacles for crop production.
- **Elevated Crop Agrivoltaics:** In elevated crop agrivoltaics, PV system heights must be greater than the height of the crops, which may vary significantly. Elevated crop agrivoltaics is more commonly found at smaller, community-sized solar projects that are more likely to economically be able to incorporate elevated PV systems at heights to accommodate crop growth and space the PV rows at distances that allow tractors and other equipment for crop cultivation underneath the PV canopy. These projects are generally under 20 megawatts (MW) and not representative of most utility-scale PV projects, given the additional expense of the technical infrastructure.

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Agrivoltaics Today: In Practice

Crop Agrivoltaics: There are several dozen MWs of inter-row crop agrivoltaics projects already in operation in Europe and Asia. However, in the U.S. this type of agrivoltaics is less common.

Inter-row agrivoltaics and elevated crop agrivoltaics are not mutually exclusive. Medium-height projects with crop cultivation both beneath and between arrays exist, such as the 1 MW system at the Colorado Agrivoltaic Learning Center.

The implementation of crop agrivoltaics is still a relatively new practice in the United States and has so far only seen some success on a small scale.

Pollinator and Livestock Grazing: Relative to crop agrivoltaics, there has been comparably much more activity in pollinator and sheep grazing agrivoltaics, with some successful projects deployed at facilities 100 MW and larger. Livestock grazing—including more than 20,000 acres of sheep grazing—has been implemented at several solar projects, and is being evaluated for cost effectiveness and feasibility at various scales.

While scaling agrivoltaic practices to larger utility-scale solar facilities presents unique challenges, it also offers potential opportunities to optimize land use and the economics of utility-scale solar development domestically. There is ongoing research in the solar and farming industries in partnership with national labs and academic institutions to test methods of reducing the technical, financial, safety, regulatory, and other barriers to scaling agrivoltaics, while ensuring regulatory frameworks allow for flexibility in co-locating agriculture and solar energy generation based on project-specific assessments and factors.

Considerations for Agrivoltaic Projects

A site suitable for a utility-scale solar project may not be inherently suitable for agrivoltaics. Whether to deploy agrivoltaics, and, if so, of what variety, always requires a site-specific review. Developers need to be able to assess what, if any, of the agrivoltaic options may work in a specific location and what can be done given the economic limitations of the project.

Grazing: If there is interest in solar grazing, a developer needs to understand if there are sufficient flocks of sheep and qualified grazing managers to oversee them available in the area.

Ecology: Implementing crop cultivation or grazing could mean foregoing pollinator-friendly vegetation that would have different ecological benefits.

Spacing: Larger spacing between panel rows to support the limited types of crops tested at the pilot stage to grow around the panels means a developer needs more acreage to generate the same amount of electricity. This could undermine project economics and raise costs in quantities that may not be compensated by the crop yield. That may or may not be an acceptable trade-off if a community is concerned about the overall solar footprint.

Property Tax: The property tax status may be impacted by changes in land use. Tax benefits are specific to land use categories and may not account for co-locating agriculture and solar energy development.

Water: Access to water is essential to the success of livestock and irrigated crop operations. Many potential solar sites are selected because they do not have existing irrigation infrastructure, which makes construction easier—but also would make them potentially less compatible with agrivoltaic options.

Vegetation: With respect to pollinator seed mixes, considerations include whether any and which seed mixes are likely to be successful in the specific location based on soil, precipitation and other factors, whether seed mixes are available in sufficient quantities, and the budget impact. There are also potentially legal implications if plants attract pollinators that are listed as threatened or endangered under federal law that need to be understood and considered. Developers also need to ensure vegetation choices do not create an elevated fire risk for a site or negative impact productivity of the solar panels via shading.

Partners: A successful agrivoltaic site requires a landowner, partner farmer, or contracted farmer to continue—or begin—agricultural operations on the property that are compatible with the facility for the approximate thirty-year lifetime of the solar project.

Crop Flexibility: Farming requires flexibility, and some agrivoltaic project designs will inherently limit what can be grown or produced on the land. Factors like soil nutrients, commodity prices, and local demand can influence what a farmer decides to grow on their land year to year. Agrivoltaics may commit the land to a particular set of products for the lifetime of a solar facility that each have various tradeoffs, though some flexible agrivoltaic formats such as vertical-bifacial arrays are compatible with a broader range of crops.

Labor: An agrivoltaic project also requires maintenance of both the agricultural operations and the solar energy facility. As these activities utilize different skill sets, agrivoltaic projects not only require additional labor, but close coordination between farmers and solar technicians.

Image courtesy of lightsource bp. Sheep grazing under and around the solar panels at 173 MW Bellflower Solar near Indianapolis.

Additional Benefits from Agrivoltaics

Recent studies[1] suggests that utility-scale solar installations with pollinator seed mixes incorporated may have similar ecological benefit as Conservation Reserve Program (CRP) enrolled lands. Additionally, the research shows that creating pollinator habitats at 217 of the identified utility-scale solar facilities in the studied states could potentially generate $120 to $164 million USD of pollination value.

In drylands, agrivoltaics can have synergistic effects such as improving crop production by retaining soil moisture under the shade canopy of solar panels, reducing plant drought stress, and reducing PV panel heat stress.[2]

US Agrivoltaics Resources

Some states have programs to encourage the construction of agrivoltaics through research or incentives. Some programs include the Solar Massachusetts Renewable Target (SMART) program, Colorado and New York's research funding and Colorado's property tax incentives for agrivoltaics, and New Jersey's agrivoltaics pilot program through Rutgers New Jersey Agricultural Experiment Station (SETO 2023).

Additionally, the Department of Energy Solar Energy Technologies Office (SETO) has funded AgriSolar Clearinghouse,[3] a project that connects farmers, solar developers, researchers, and other stakeholders to support further development of co-located solar and sustainable agriculture. The clearinghouse information is designed to be highly accessible rather than technical content and includes an AgriSolar Atlas which maps agrivoltaic sites in the U.S.

Image courtesy of lightsource bp. Pollinator habitat vegetation planted around solar panels at 260 MW Impact Solar in Texas.

The Future of Agrivoltaics

Traditional solar projects deliver meaningful lease payments to landowners, substantial tax revenue to states and counties, and hundreds of jobs during construction.

Many developers and landowners are exploring agrivoltaics to layer an additional benefit, especially for landowners that wish to continue agricultural activities alongside and within the solar facility. Co-locating solar power production facilities and agriculture has also become a topic of interest within State legislatures and local permitting authorities.

While agrivoltaics represents an opportunity, **developers and landowners require flexibility in the regulatory framework to allow agrivoltaics as an option and not an overarching requirement on a project-by-project basis.**

Emphasis should not be on maintaining the same agricultural production if it does not complement the solar installation. Rather, agricultural use of the site can change to a crop or grazing that can be adapted for solar.

> Currently, the most practical agrivoltaic opportunities for projects and communities are sheep and small livestock grazing, pollinator habitat plantings, and beekeeping; however, with future advancements in agrivoltaics, crop production may become more feasible on a utility scale.

Since agrivoltaic projects can often raise costs, may reduce potential energy generation, and require special design and operational considerations, both developers and landowners must weigh such considerations between the economic and environmental benefits of solar power with those of paired agricultural benefits.

Agencies like the U.S. Department of Agriculture (USDA) in collaboration with the Department of Energy can further support the gradual development of advanced agrivoltaics. Focusing on a balance between farm viability and renewable energy production, agencies like the USDA can provide funding through grants to eligible institutions to conduct research. The USDA can serve as a trusted resource for community-level discussions, education, and outreach to support and facilitate fact-based decision-making related to the use of land for large-scale clean energy projects.

However, the primary purpose of a solar energy facility is the generation of clean, affordable energy. Proposals to mandate agrivoltaics—especially more advanced types of agrivoltaics—are likely to increase costs and risks to solar generation if not done thoughtfully and with the consultation of the clean energy industry.

While agrivoltaics represents an opportunity, developers and landowners require flexibility in the regulatory framework to allow agrivoltaics as an option and not an overarching requirement on a project-by-project basis.

1 Shruti Khadka Mishra *et al 2023 Environ. Res. Commun.* **5** 065006. Valuation of pollination services from habitat management: a case study of utility scale solar energy facilities in the United States - IOPscience.

2 Barron-Gafford, G.A., Pavao-Zuckerman, M.A., Minor, R.L. *et al.* Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. *Nat Sustain* **2**, 848–855 (2019). https://doi.org/10.1038/s41893-019-0364-5

3 Department of Energy Solar Energy Technologies Office (SETO). "The Potential of Agrivoltaics for the U.S. Solar Industry, Farmers, and Communities." April 2023. Available: The Potential of Agrivoltaics for the U.S. Solar Industry, Farmers, and Communities | Department of Energy