

## Developing crop-based agrivoltaic systems: A case study of Jack's Solar Garden

Tyler Swanson,<sup>a\*</sup> Andrea K. Gerlak,<sup>b</sup> Greg A. Barron-Gafford,<sup>c</sup> and Laurel Bellante<sup>d</sup>  
University of Arizona

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### Abstract

Solar developers seek agricultural lands as sites for new projects because of their high suitability for energy generation, and a growing number of farm-

ers are interested in selling or leasing their land to developers as a form of financial diversification. However, many local governments and communities perceive the development of solar energy on farmland as a threat to the rural landscape, motivating enactment of restrictive solar energy land use policies. Agrivoltaics, the co-production of

<sup>a\*</sup> *Corresponding author:* Tyler Swanson, MA Candidate and Graduate Research Assistant, School of Geography, Development & Environment, University of Arizona.

Swanson is now Graduate Research Assistant, Department of Community Sustainability, Michigan State University; Natural Resources Building, 480 Wilson Road, Room 131; East Lansing, MI 48824 USA; +1-815-914-0393; [Swans383@msu.edu](mailto:Swans383@msu.edu);

 <https://orcid.org/0000-0001-5293-8664>

<sup>b</sup> Andrea K. Gerlak, Professor and Director, Udall Center for Studies in Public Policy, University of Arizona; 803 East 1<sup>st</sup> Street; Tucson, AZ 85719 USA;

 <https://orcid.org/0000-0002-2198-6679>

<sup>c</sup> Greg A. Barron-Gafford, Professor, Associate Director of the School Garden Workshop, School of Geography, Development & Environment, University of Arizona; 1064 East Lowell Street; Tucson, AZ 85721 USA;

 <https://orcid.org/0000-0003-1333-3843>

<sup>d</sup> Laurel Bellante, Associate Professor of Practice and Assistant Director, Center for Regional Food Studies, University of Arizona; 1064 East Lowell Street; Tucson, AZ 85721 USA;

 <https://orcid.org/0000-0002-3107-135X>

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### Author Note

This work is adapted from a master's thesis by Tyler Swanson titled "Beyond solar farms: A case study of the motivations, challenges, and benefits associated with developing agrivoltaics at Jack's Solar Garden" (Swanson, 2025).

### Conflict of Interest Disclosure

Authors Tyler Swanson, Andrea K. Gerlak, and Greg A. Barron-Gafford are all members of a University of Arizona research lab that conducts experiments at Jack's Solar Garden; however, only Greg A. Barron-Gafford is actively involved in research experimentation at the site. To limit bias, the research team sought to speak with a diverse array of stakeholders and reflexively analyzed the data to ensure factual accuracy and a faithful representation of the events documented in the manuscript.

agriculture and solar energy on the same parcel of land, is increasingly proposed as a solution to the single-use nature of solar energy development in rural landscapes. Agrivoltaic systems featuring crop production may provide a range of benefits for farmers and local food systems, but they are uncommon in practice. This article presents a mixed-methods case study of Jack's Solar Garden (JSG), a crop-based agrivoltaic site in Colorado, U.S., to explore why a farmer might pursue a crop-based agrivoltaic system, what challenges are involved in project development and maintenance, and what benefits such a project may yield for both a farm and a local food system. Utilizing interviews, document analysis, and media analysis, we find that crop-based agrivoltaic systems can serve as an acceptable compromise between farmers and local government while providing a wide range of community benefits. We emphasize the importance of public-private partnerships for the effective implementation of crop-based agrivoltaic systems and close with insights for potential agrivoltaic practitioners and suggestions for further research.

### **Keywords**

Agrivoltaics, AgriSolar, dual-use solar, local food systems, land access, farmers, rural landscapes, productivism, solar energy, partnerships

### **Introduction**

The development of solar energy-generating infrastructure on agricultural lands raises concerns regarding future rural landscape compositions. Policies mandating the development of renewable energy (Database of State Incentives for Renewables & Efficiency, 2023), combined with the affordability and suitability of rural, agricultural lands (Christophers, 2024; Katkar et al., 2021), have led to widespread development of solar energy facilities in rural landscapes (Spangler et al., 2024), a trend projected to continue (Office of Energy Efficiency & Renewable Energy, 2021). In response, many local governments have been establishing new land use regulations for solar energy facilities to preserve what they view as traditional rural landscapes. As of 2023, 116 U.S. counties have banned or restricted solar energy development within their jurisdictions (Weise et al., 2024).

Despite local government efforts to restrict solar energy production on agricultural land (Guarino & Swanson, 2023), many farmers view a lease to a solar developer as a source of long-term financial stability for their operations (Spangler et al., 2024).

The concentration of agricultural production value on larger farms (MacDonald et al., 2018) places heightened financial pressure on small and medium-sized farms (Hoppe et al., 2010). Smaller farm businesses are thus motivated to diversify their income stream by adopting new production crops, developing an agritourism business, or implementing new selling practices (Barbieri & Mahoney, 2009). Such diversification enterprises foster multiple uses of the land, highlighting its productive and recreational potential. In contrast, the composition of solar energy facilities more closely resembles the industrial-scale, monocultural land use that has defined rural landscapes for nearly a century (O'Sullivan et al., 2020). Recently the development of solar energy in rural landscapes has become so significant that some scholars suggest it comprises a new era of rural restructuring that re-entrenches industrial-scale production ideals with an emphasis on energy rather than agricultural outputs (Nilson & Stedman, 2023).

Despite its growing prevalence, the single use of land for large-scale solar energy production need not be the only approach to solar energy in rural communities. Agrivoltaics, the dual use of land for agricultural and solar energy production (Dinesh & Pearce, 2016), is rapidly gaining popularity as an alternative model for rural solar energy production facilities. Current literature comparing public perceptions of agrivoltaic and traditional photovoltaic projects finds that agrivoltaic systems yield greater support from communities than traditional solar energy development because of expected benefits to farmers and improved compatibility with the landscape (Pascaris et al., 2022; Rand et al., 2024; Swanson et al., 2025). Some farmers view agrivoltaics as a favorable alternative to single-use solar (Cuppari et al., 2024) and an opportunity to generate diverse income streams (Wagner et al., 2024).

However, the development of agrivoltaic systems is not without challenges. Agrivoltaic systems combine two individually complex systems: solar energy and agricultural production. Project devel-

opment thus requires coordinating unique sets of actors and interest groups (Moore et al., 2022; Pascaris et al., 2023). Solar developers often take the lead in designing agrivoltaic systems, limiting farmers' agency to make meaningful contributions to a project design (Guarino & Swanson, 2022). Examples of agrivoltaic development in France (Carrausse & de Sartre, 2023), China (Hu, 2023), and the U.S. (Stedman & Nilson, 2021) suggest that promotion of agrivoltaics by governments and energy companies may result in prioritizing energy over agricultural production. Energy-centric agrivoltaic systems can result in adverse outcomes for food systems, such as transition away from traditional crop production (Nakata & Ogata, 2023), dispossession of smallholder farmers (Hu, 2024), and loss of ecosystem benefits (Chen & Huang, 2025).

Previous negative social outcomes from agrivoltaic projects led by governments and solar developers warrant an exploration into ways that agrivoltaics can be deployed to benefit both farmers and surrounding communities. We intend to examine the relationships between agrivoltaic systems and local food systems. Crop-based agrivoltaics and local food systems feature two primary points of synergy: environmental stewardship and economic development. Agricultural production in local food systems incentivizes farmers to adopt more environmentally friendly practices (Abate, 2008; Enthoven & van den Broeck, 2021), and crop-based agrivoltaics can support regenerative agricultural practices (Nakata & Ogata, 2023), improve carbon uptake in crops, and reduce irrigation needs (Barron-Gafford et al., 2019). Furthermore, local food systems benefit communities economically by retaining money locally and revitalizing rural areas (Enthoven & van den Broeck, 2021). Crop-based agrivoltaic systems have similar potential, as they can create employment opportunities in rural communities, in the form of on-farm jobs (Chopdar et al., 2024) and supporting businesses (Kochendoerfer & Thonney, 2021).

Crop-based agrivoltaic systems may also be particularly suited to addressing two challenges facing local food systems: land access and seasonality. A lack of available land and resulting high land costs present significant barriers for new farmers

(Dennis, 2015). Agrivoltaic systems avoid the conversion of farmland to single-use solar development, keeping more farmland in production (Brunswick & Marzilier, 2022). Additionally, traditional solar production systems can be converted to agrivoltaic systems, providing farmers with access to land that may not otherwise be in agricultural production (Hazzard, 2024). Agrivoltaic systems may help increase the supply and avoid the conversion of farmland, helping reduce barriers to entry of high land cost and low land availability. Another challenge facing local food systems is seasonality, limiting the ability to continually produce in-demand crops. Current literature demonstrates that agrivoltaic systems can increase crop productivity (Barron-Gafford et al., 2019), improve production during weather extremes (Weselek et al., 2021), and extend growing seasons (Sturchio et al., 2024). While these benefits do not solve all challenges of seasonality, they may help to increase overall supply and extend the growing season for longer than it may otherwise be.

This research attempts to address two gaps in the literature on the viability of combining crop-based agrivoltaic and local food systems. First, research on social impacts of agrivoltaics in the U.S. has focused primarily on stakeholder perceptions of potential project scenarios (Pascaris et al., 2022), with a dearth of research assessing actual projects. Second, current literature does not engage with questions about how agrivoltaics may be integrated with local food systems, limiting our understanding of why integration would be pursued, what problems would need to be overcome, and what benefits could arise from it. Therefore, we posed the question: What are the motivations, challenges, and benefits of implementing a crop-based agrivoltaic operation within a local food system?

To address the research question, we conducted a case study of Jack's Solar Garden (JSG) in Colorado, U.S. JSG is notable for three reasons. First, the project's development was initiated by a farmer rather than an energy company, providing a key example of how agrivoltaics can benefit agricultural producers with limited land and financial resources. Second, JSG was developed without agrivoltaic-specific policy incentives, making it unique among crop-based agrivoltaic systems in

the U.S. that generally rely on research funding or state incentives. Third, JSG has become a prominent community gathering space, hosting community-supported agriculture (CSA), tours, and farm-to-table events, thus showcasing the multifunctional potential of crop-based agrivoltaic systems. This case study yields significant findings that advance our understanding of crop-based agrivoltaics and their role in local food systems. JSG highlights the potential for agrivoltaic systems to facilitate compromises between farmers seeking to diversify their operation's income stream through solar energy production and local governments seeking to protect rural landscapes. The case study emphasizes the role of collaboration through public-private partnerships (P3s) in overcoming project development and operation challenges. Finally, JSG showcases the range of farm and community benefits that can arise from crop-based agrivoltaic systems and identifies best practices for developing similar projects.

### Study Subject Background

JSG is a 1.2 megawatt (MW), five-acre crop-based agrivoltaic system on a 24-acre third-generation family farm at the rural-urban interface in Boulder County, Colorado. Since its establishment in the 1970s, the farm has produced hay; however, hay production was no longer financially viable on the farm's small acreage by the mid-2010s, which motivated a transition to solar energy generation (Hammon, 2022). JSG was constructed on the farm in 2020 and primarily features crop production, including tomatoes, potatoes, beans, and a variety of leafy greens and herbs. The site also includes a pollinator habitat border and a small sheep grazing paddock under a few rows of panels (Jack's Solar Garden, 2024).

A range of individuals and groups developed JSG and are now engaged in its ongoing operation and management. The primary operator is a member of the family farm who became the farm manager and initiated the project. Researchers from Colorado State University (CSU), the National Renewable Energy Laboratory (NREL), and the University of Arizona (UA) helped design the array to support agrivoltaic production, and conduct research on-site (Agrisolar Clearinghouse, 2022).

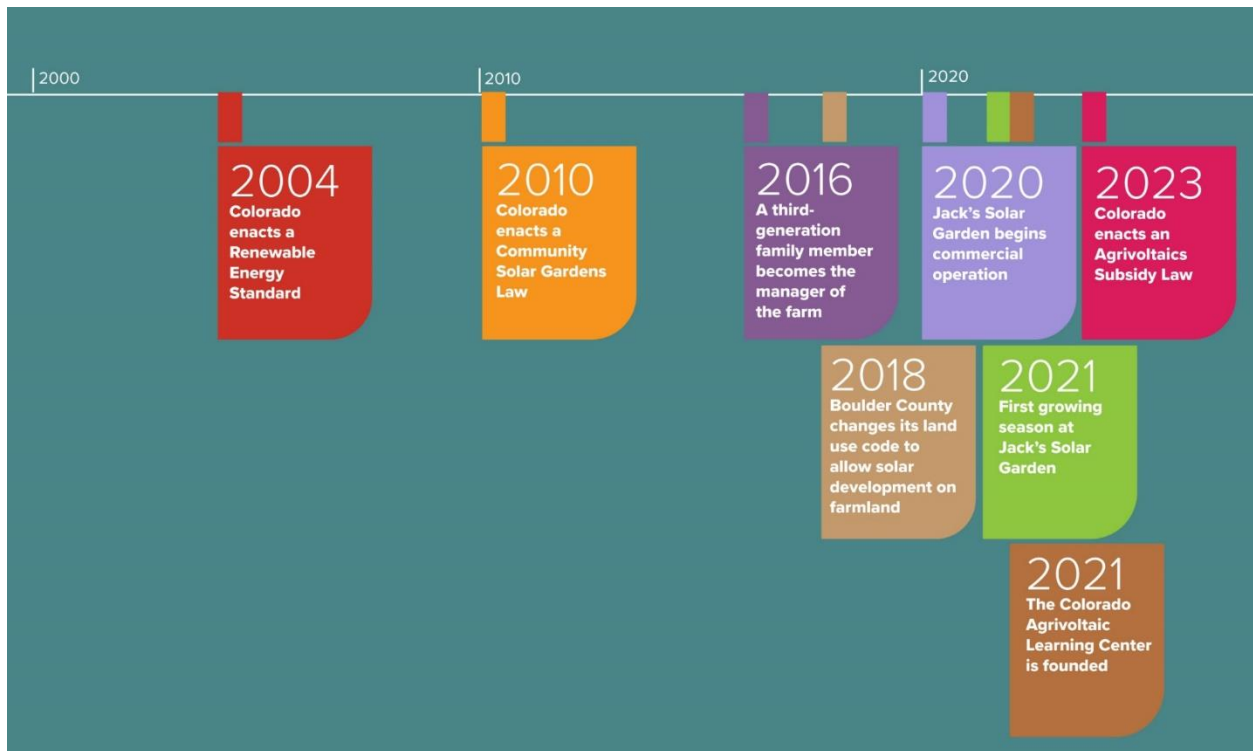
The nonprofit Sprout City Farms (SCF) manages agricultural production and operates a CSA at JSG, in addition to donating crops throughout the community (Agrisolar Clearinghouse, 2022). The Colorado Agrivoltaic Learning Center (CALC) is a nonprofit that hosts tours and organizes on-site events in addition to developing educational and policy materials (Agrisolar Clearinghouse, 2022). While other crop-based agrivoltaic projects feature farmer ownership, research, community energy production, and land access opportunities, JSG is the only agrivoltaic system in the U.S. to incorporate each of these into a single project (Innovative Solar Practices Integrated with Rural Economies and Ecosystems, n.d.). Figure 1 provides a timeline of key events that contributed to the development of JSG, along with notable site operation outcomes.

### Methodology

This case study was conducted between June and September 2024. A mixed-methods approach was utilized, incorporating semi-structured interviews ( $n = 20$ ), policy documents ( $n = 8$ ), and media ( $n = 18$ ) as data sources for analysis. Interviewees included agricultural workers at JSG and its nonprofit partner SCF ( $n = 6$ ), outreach and education employees at CALC and CSU extension ( $n = 6$ ), researchers at CSU, NREL, and UA ( $n = 6$ ), and policymakers in the Colorado General Assembly ( $n = 2$ ) (Table 1). Interviews were recorded with the interviewee's consent and followed a semi-structured approach, allowing the interviewees to provide in-depth reflections on their experiences and explore unique points of view (Adams, 2015). Policy documents were identified through conversations with interviewees, and include state legislation, local planning documents and ordinances, and energy utility programs (Appendix A). Media analyzed as part of the case study include news articles, op-eds, podcast interviews, and a case study by the AgriSolar Clearinghouse that provides some background information on the site and its key actors (Agrisolar Clearinghouse, 2022). Each of these media served to supplement the information gathered through interviews (Appendix B).

All interviews were transcribed for analysis in NVivo 14 qualitative analysis software. The data

**Figure 1. Key Events that Contributed to the Development of Jack’s Solar Garden (JSG) and Notable Outcomes of the Project’s Operation**



were analyzed according to the thematic analysis framework by Braun and Clarke (2006). Data analysis was inductive, allowing the data to guide the findings and generate emergent themes rather than imposing a predeveloped framework. We first read through the data to identify common themes and topics of interest. The data were then reviewed

again, creating codes that organized the themes and topics identified in the initial readthrough. Codes were reflexively analyzed to reduce overlap and ensure accuracy, and were then organized into broad themes. Policy and media documents are referred to in the text with their respective IDs. Quotes from and references to interviews are denoted by

**Table 1. A Summary of the Economic and Social Benefits Resulting from the Operation of Jack’s Solar Garden (JSG) and the Primary Beneficiaries of the Benefits**

<b>Economic and Social Benefits</b>	<b>Primary Beneficiaries</b>
Additional income source from the sale of solar energy	Farm owner
Energy generated by the solar array as part of the community solar garden program	Boulder County residents and businesses
Local food production resulting from ongoing research on agrivoltaic systems	Researchers, Sprout City Farms (SCF), Residents
Improved working environment due to the shade provided by the solar panels.	Researchers, SCF
Development of educational, policy, and outreach materials following the creation of the Colorado Agrivoltaic Learning Center (CALC)	Educational institutions, policymakers, and residents

the category and ID of the interviewee: farmer, educator, researcher, and policymaker.

## Results

Results are presented in a chronological narrative, utilizing the themes that were identified in the data analysis to delineate key events in the implementation and operation of JSG. Starting with the initial motivation to develop a solar energy facility, subsections that follow discuss the decision to develop an agrivoltaic project, the reasoning behind incorporating various stakeholder groups, financing the project, challenges identified during operation, and the benefits that JSG has brought to the broader community.

### *Motivations for Development and Initial Challenges*

JSG development began in 2016 when a third-generation member of the family farm became the farm manager, and realized that hay production was no longer financially viable for the farm and that keeping the farm family-run would require diversification into a new enterprise that would at least cover the farm's cost of operation (Media-14; Media-17). Three reasons led to solar energy generation emerging as the preferred means of enterprise diversification. First, because at the time the farm manager lacked experience with other forms of production beyond the farm's historical hay production, implementing a new crop was assessed as unacceptably high-risk (Media-3). Second, neighboring farms had already diversified (e.g., equestrian and forestry operations). The proliferation of new on-farm businesses in the community led to concerns about potential market saturation and competition (Media-17). Third, solar energy was perceived as a low-risk venture compared to agricultural crop production that would provide a stable revenue stream for the farm, perhaps for several decades (Media-8). JSG emerged as a plan for developing a small-scale community solar array on the farm that would provide energy for residents and businesses within the county through a partnership with Xcel Energy, the utility managing the grid. It is important to note that while the proposed array was to be named Jack's Solar Garden, the initial site design only featured pollinator habi-

tat and was not to engage in crop production. "Solar garden" is the proper legal term in Colorado for a solar energy facility with a maximum capacity of two MW and at least ten local customers purchasing energy output.

Two supportive state laws further encouraged the decision to develop JSG. The first was a renewable energy standard (RES) enacted in 2004 that set a target for utilities operating in Colorado to generate 30% of their energy from renewable sources by 2020 (Policy-6). The second was the community solar gardens law of 2010, which required energy utilities operating in Colorado to purchase energy from community solar gardens (Policy-2). The Colorado RES created a general demand for renewable energy, and the community solar gardens law created a demand for projects at the scale appropriate for the JSG concept.

Local land use policies did present a critical barrier to JSG development. At the time that JSG was proposed to the Boulder County government, the county did not allow solar energy development over 100 kW on any lands designated in its comprehensive plan as Agricultural Lands of Significance. Land with high soil quality or valuable agricultural production, including that planned for the development of JSG, could not legally accommodate significant solar energy development. Consequently, in June 2018, the County Planning Commission rejected the initial conceptualization of JSG, viewing the provision of pollinator habitat as an insufficient substitute for crop production or livestock grazing.

### *Building Partnerships to Overcome Challenges*

The development and operation of JSG encountered a range of challenges. After the rejection by the planning commission, the farm manager connected with researchers at NREL and UA, who suggested developing an agrivoltaic system featuring crop production rather than only pollinator habitat as a compromise between the farm's wish to generate solar energy and the county's wish to preserve agricultural land. As a researcher explained:

I think when [the farm manager] first went to talk to some of the policy people, they

told him that's not possible. And before, I had had all the legal pushback in Arizona in terms of knowing what that was. I said "Well, why don't you tell them that you're still doing agriculture, but you're adding the solar?" (Researcher-3).

This initial connection soon became a formal collaboration. The farm manager agreed to design the array to support the researchers' interests, which included studying the performance of various crops, grasses, and pollinator plantings under and in-between rows of solar panels (Researcher-3; Researcher-12). In return, the researchers would accompany the farm manager to county government meetings to provide information on agrivoltaics and discuss their planned research (Researcher-3; Researcher-12). The partnership between the farm manager and the researchers, as well as Boulder County's own goals of increasing renewable energy production established in their comprehensive plan, contributed to the success of the new proposal for JSG that featured agrivoltaics (Farmer-1, Researcher-3, Policy-4). In November 2018, the Boulder County Board of Commissioners amended its land use code, allowing for the development of ground-mounted solar energy systems on significant agricultural lands on the condition of satisfactory planning procedures and efforts to minimize land disturbance, such that agricultural production could continue (Policy-4). In the case of JSG, proposing an agrivoltaic system featuring crop production directly influenced the county government decision to revise the local land use code and allow the generation of solar energy on agricultural land. While the county deemed pollinator habitat on its own to be insufficient, the suggestion by the farm's new research partners to develop an agrivoltaic system featuring crop production served as an effective compromise between the farm's desire to diversify into solar energy production and the county's desire to preserve agricultural landscapes.

The final proposed design of JSG featured five acres of land divided among the research groups for studies of pollinator habitat, grassland, and crop production. The site perimeter was lined with a border of pollinator plantings, and the panel

heights were divided so that one half was raised six feet above the ground and the other half raised eight feet, which allowed for novel experiments testing the unique shading, water distribution, and temperature patterns that the differing panel heights may create. Images of the project are displayed in Figure 2. Seeing that the site design aligned with their objectives, NREL set out to establish JSG as a "shining star for research" on agrivoltaic system design and agronomic outcomes within agrivoltaic systems (Researcher-12). NREL played the role of convener, recruiting UA researchers to study crop production and CSU researchers to study grassland production on site, while NREL studied pollinator habitat.

The farm manager and researchers also wanted to include market garden crop farming on the site to demonstrate the feasibility of market crop production in an agrivoltaic system (Researcher-3; Researcher-12; Media-17). Sprout City Farms (SCF), a local nonprofit specializing in farming underutilized land, was chosen to farm the site for three reasons. First, crop production on site would primarily feature vegetable production, with which the current farm manager was unfamiliar. Having SCF at the site overcame this challenge due to their expertise in vegetable production. Second, the multi-acre scale of the research taking place on site created more work than the research teams could manage on their own, and SCF could provide the labor needed to ensure that research could progress on schedule. Third, the researchers at JSG had no use for the crops produced in their experiments after harvesting them. The surplus crops, and with SCF's experience in the local community, allowed the organization to establish a CSA operation and other local distribution networks. A leader of the SCF organization explained their interest in farming at JSG:

The land under solar panels is typically underutilized, but [Jack's Solar Garden] is another space that we saw that we could bring a food-producing oasis into. ... We have a big focus on education and farmer training. ... So, I think it is a really good space for us to be able to come in and trailblaze. (Media-13)

**Figure 2. Photos of Jack's Solar Garden (JSG) Taken by the Author During a Visit to the Site in September 2023**

Top left: Tomato production between rows of solar panels. Top right: Sheep grazing in a small pen under a row of solar panels. Bottom left: A tractor used to move supplies around the farm. Bottom right: Leafy green vegetables growing between rows of solar panels.



Including crop-based agrivoltaics in the design of JSG soon proved to be a helpful marketing tool in addition to overcoming local policy barriers. The farm won a bid for development through Xcel Energy's community solar program (Media-17) shortly after recruiting its new partners, enabling

the project to sell energy to homes and businesses in Boulder County. The selection of JSG was attributed to the unique services provided by the array resulting from the collaboration between the farm manager, researchers, and SCF (Media-17). Initially, the farm manager intended to lease the

land to a solar developer who would construct and operate the array, with the farm receiving payments from the developer. After reviewing several offers from developers, the farm manager determined that owning the solar array was a more financially lucrative option, but it was also quite an expensive investment. The 1.2 MW solar array's construction would cost \$2 million, presenting another barrier to project development.

Like the initial efforts to revise the Boulder County land use code, the farm manager and researchers collaborated to pitch the project to community members to secure enough subscribers to fund project construction (Farmer-1; Researcher-3). During these informational sessions, the manager discussed the reasoning behind developing solar energy on the farm while the researchers explained the concept of agrivoltaics and the nature of the research they would conduct on-site. Over time, enough community members subscribed to the array to finance half the project cost, with half financed by a bank loan using the farm as collateral (Media-13). Construction of JSG began in 2020, and the site reached commercial operation in November of that year. The unique marketing of JSG as an agrivoltaic project helped pitch sales of the project's energy to local subscribers. However, using the farm as collateral for the solar array meant that retaining ownership of the farm now depended on the success of the new enterprise.

Once constructed, the operation of JSG required cooperation between its various partner groups. The diverse interests held by each partners occasionally led to tension among groups as they sought to achieve their individual goals. For example, construction delays during the first production season resulted in only a partial crop season (Media-14). After constructing the solar array, preparing the site for agricultural production necessitated additional steps, including installing an irrigation system and mitigating soil compaction (Farmer-18). This need to prepare the site led to tensions between researcher goals of collecting data and SCF's goals of establishing a healthy soil base for the following growing season (Farmer-18). Ultimately, the researchers and SCF reached a compromise in which SCF would plant research crops on a small portion of the site for the

researchers and cover-crop the rest of the site for the following year (Researcher-3; Researcher-12; Farmer-18). While the soil only needed to be remediated once, instances where the needs of one actor conflicted with those of another pose a recurring challenge for the different groups operating at JSG. A common lesson learned from navigating these recurring challenges is the importance of establishing clear, codified expectations and agreements that delineate responsibilities for site operation (Farmer-1; Researcher-12; Farmer-18). As one researcher attests:

It's life, it's a farm, it's a solar project. Things happen every single month that you're not expecting, and those agreements help you address those things that always come up and again, give sort of clear expectations on what's needed for everyone. So, I would say that's a big lesson learned is making sure you've got these rock-solid partnerships and understandings...among all partners nailed down from the beginning. (Researcher-12)

### *On-Farm and Community Benefits of Operation*

The operation of JSG has brought many benefits to the farm, researchers, SCF, and the broader community (Table 1). Some benefits, such as additional farm income brought in by the sale of solar energy and the production of energy and food for the local community, are not individually novel; rather, they are made unique by their co-location on the same site. Other benefits of JSG would not have been possible without agrivoltaics, such as the improved working environment resulting from the shade provided by panels. Nearly all the interviewees who had worked under the solar array remarked that the shade provided a cool working environment throughout the day, which could become increasingly valuable as temperatures rise. (Researcher-2; Researcher-3; Farmer-4; Farmer-8; Researcher-12; Farmer-18). Another more general benefit is the activities of the Colorado Agrivoltaic Learning Center (CALC), which extends the merits of JSG through education, policy, and outreach work.

Several project partners collaborated to establish the CALC after the first successful crop har-

vest in 2021 (Farmer-1; Researcher-3), with a mission of advancing education, policy, and adoption of agrivoltaics in Colorado (Farmer-1; Researcher-3; Educator-5; Educator-9; Educator-14). The CALC operates with funding from large organizations such as the Walton Family and Cielo Foundations, along with the support of local donors and businesses. As part of its mission, the CALC hosts public and school tours of JSG (Educator-5; Educator-9; Educator-14) and creates educational curricula on agrivoltaics for Colorado schools (Educator-9; Educator-14). From its creation to the time of writing, the CALC has interacted with over 8,200 students and members of the public through on-site and off-site presentations, high school tours, and college outreach events (Educator-14). Policy research is another key aspect of the CALC mission; the organization provided information to state policymakers in the development of Colorado Senate Bill 23-092, which provided grant funding for new agrivoltaic projects in the state (Policy-maker-10; Educator-14; Policy-7). When SB 23-092 passed the Colorado General Assembly in 2023, Governor Jared Polis signed the bill into law at JSG (Media-18).

The CALC is expanding its operations with a program that will connect people who have farming experience, but no access to land with solar developers. Participating solar facilities will make a portion of their land available for farmers to begin crop production, creating agrivoltaic systems out of traditional solar arrays. (Educator-5; Educator-13; Educator-14; Educator-15). This program expands the potential for agrivoltaics to resolve ongoing challenges of farmer land access and ownership by increasing the supply of land available for agricultural use. While this new project is still in development, it may yield important results for future agrivoltaics uses. All the efforts of the CALC, SCF, and researchers are showcased at an annual farm-to-table event at JSG, where community members can visit the farm, learn about the work done on-site, and sample the produce grown on the farm.

## Discussion

JSG provides a unique case of agrivoltaic development that sheds light on the motivations, challenges, and benefits of operating a crop-based agri-

voltaic system within a local food system. Three significant lessons emerge from this case study. First, JSG illustrates the potential for agrivoltaics to play a significant role in facilitating compromise between those seeking to establish solar energy-generating facilities on farmland and local governments seeking to preserve rural agricultural landscapes. Second, collaboration among subject experts is integral to overcoming challenges that might otherwise prevent implementation of an agrivoltaic system. Third, JSG illustrates that agrivoltaic systems can produce valuable benefits that would not otherwise occur in a traditional solar array or farm operation. Each finding provides valuable insights for practitioners and fruitful avenues for further research.

### *Agrivoltaics as a Policy Compromise*

The motivations for adopting solar energy and crop-based agrivoltaics in the case of JSG are best understood as separate ideas. JSG was initially conceived of as a pollinator-friendly community solar facility that would provide a diversified income stream to the farm through selling energy or leasing land to an energy company. Crop production was not included in the project's design until the county board rejected the initial proposal. The farm manager and researchers intended integration of crop-based agrivoltaics as a compromise between the farm's desires to develop a solar array and the county's desires to preserve agricultural land. Utilizing agrivoltaic systems as a compromise between competing land use desires is notable. Current literature posits that increased farm incomes resulting from the operation of an agrivoltaic system constitute a primary benefit of adoption (Cuppari et al., 2024; Pascaris et al., 2020). While this may be true in scenarios where the productive output of the agrivoltaic system aligns with the skillset available at the farm, JSG demonstrates that a farm manager can utilize an agrivoltaic system design with the primary purpose of securing approval to develop a solar energy facility and allow a separate entity to use the land for agricultural production. In this case, the agreement between JSG and SCF worked out well for both parties, enabling JSG to secure a steady stream of income from selling solar energy and helping SCF expand its market garden opera-

tions. However, it is possible that such agreements between landowners and agricultural producers could be abused. In Taiwan, agreements between aquaculture producers and solar developers quickly led to trends of depeasantization, as smallholder farmers and tenant farmers were replaced with larger-scale operations (Chen & Huang, 2025). Retaining farmer leadership in agrivoltaic projects, as in the case of JSG, may help ensure that agrivoltaic systems do not harm smallholders, tenant farmers, or local food systems.

Using a crop-based agrivoltaic system design to help facilitate new local policy development and enable solar energy production on farmland is a novel finding that is not emphasized in current literature, which suggests that lack of an established regulatory or incentive framework specifically addressing agrivoltaics presents a key barrier to development (Guarino & Swanson, 2022; Karhoff et al., 2024; Pascaris et al., 2023). However, the development of crop-based agrivoltaics at JSG occurred in a state policy environment with no incentives for agrivoltaic system design, and a local zoning environment that was initially very restrictive of solar energy development on agricultural land. The collaboration between the farm manager and researchers to propose an agrivoltaic project in the absence of pre-existing local definitions or regulations for its design provides valuable insight into how agrivoltaic projects can navigate barriers of local regulatory silence (Guarino & Swanson, 2022) and the patchwork of solar zoning codes that exist across the U.S. (Jackson et al., 2024).

### *The Importance of Partnerships in Overcoming Challenges*

The case of JSG highlights three primary challenges that may occur in the development of a farmer-owned, crop-based agrivoltaic system: local zoning policies that restrict solar energy development on farmland, financing project construction, and successfully operating the different aspects of a crop-based agrivoltaic system. Our findings corroborate claims in current literature relating to agrivoltaic policy and perception studies, which suggest that regulatory barriers (Guarino & Swanson, 2022), implementation costs (Cuppari et al., 2024), and knowledge gaps (Moore & Lobell, 2024) are

primary barriers to development. A crucial finding in the case of JSG is the value of P3s in overcoming these challenges.

JSG would not be possible without collaboration between public and private institutions to overcome each of the project's challenges. Both the researchers and SCF had the funding necessary to conduct agrivoltaics research and maintain a site. However, the farm's capital was ultimately necessary to ensure a solar array could be developed. Guidance for developing agrivoltaics in the U.S., published by NREL after the development of JSG, emphasizes the importance of collaboration and partnerships when navigating zoning laws, engaging with community members, and understanding individual priorities (Macknick et al., 2022). While a rich literature examines the role of P3s in agricultural innovations broadly (Guerrero-Ocampo et al., 2022; Moreddu, 2016), agrivoltaics literature has yet to engage with this theme. The case of JSG reinforces the importance of partnerships in developing agrivoltaic systems and suggests that P3s may be critical in overcoming capital and knowledge barriers.

### *New Community Spaces and Land Access Opportunities*

JSG provides an example of how solar energy facilities can create new opportunities in communities that neither traditional solar energy projects nor standard market garden operations could accomplish on their own. Current literature frames agrivoltaics primarily as a financial opportunity for farmers (Cuppari et al., 2024) or an opportunity for solar developers to overcome public opposition to proposed projects (Pascaris et al., 2023). JSG demonstrates that beyond these benefits, agrivoltaic systems can also foster the development of new community spaces and potentially improve land access opportunities for producers within local food systems. By hosting educational tours, farm-to-table dinners, and CSA production, JSG has become a multifaceted gathering place that might otherwise have remained a single-use space for energy or food production. Furthermore, the partnerships between the farm manager, researchers, and SCF resulted in a new source of local food production that may not otherwise have occurred. If an agrivoltaic system had not been established at JSG, the opportunity to

partner with the researchers and SCF would not have come to pass. Embedding these activities in JSG is a useful example of how renewable energy projects can better align with rural development goals (Clausen & Rudolph, 2020).


Finally, this case study demonstrates two ways that agrivoltaic systems may help alleviate land use barriers for small-scale producers in local food systems. The arrangement between the farm and SCF that allows the nonprofit organization to cultivate crops within the solar array is an example of how a landowner can pursue solar energy production and design it with agriculture in mind using an agrivoltaic system. On the other hand, the CALC program to connect landless farmers with solar developers demonstrates that farmland that had been taken out of production due to solar energy-generating infrastructure can be retrofitted into an agrivoltaic system that returns agricultural production to the land. Both these land access structures are novel approaches to agrivoltaic systems, and they warrant further research to understand the different scenarios in which they may occur.

SCF viewed solar facilities as an underutilized space for agriculture and sought to partner with JSG to determine strategies for practicing crop-based agrivoltaics (Media-13). As land costs and availability are critical barriers for farmers (Dennis, 2015), agrivoltaic projects, such as JSG, may help overcome them. The arrangement of farming at JSG is an example of shared farming on privately owned land, a common type of land access discussed by Wittman et al. (2017). However, it is a unique ownership structure for agrivoltaic projects. In this case, the energy, infrastructure, and land are all owned by one farmer, while access to the land and agricultural production rights are freely given to SCF. The CALC project connecting landless farmers with solar developers is similar, although in this case a solar company, rather than a farmer, is the key owner of the land. These ownership structures warrant further research to determine the best practices for facilitating farmer land access through agrivoltaics.

## Conclusion

Our case study of JSG, exploring the motivations, challenges, and benefits associated with developing

a crop-based agrivoltaic system, yields valuable findings for researchers and practitioners alike. First, decisions to adopt crop-based agrivoltaic systems may be motivated by something other than the potential for additional income. In this case, crop-based agrivoltaics presented a means to overcome local policy barriers and gather support for developing a solar project. Second, local land use policy, project cost, and partner coordination present significant development challenges; however, developing P3s with clearly established responsibilities and agreements is critical to overcoming challenges such as access to capital and knowledge and ensuring the successful implementation of crop-based agrivoltaic projects. Third, crop-based agrivoltaics can provide a range of unique benefits beyond those commonly expected of local energy and food production, including policy compromise and marketing advantages, land access for farmers, and the development of community gathering and learning spaces.

The findings of this case study suggest several avenues for further research. Future studies could assess the impact of livestock grazing and pollinator habitat agrivoltaic projects on community and government perceptions of developing solar energy on farmland. The findings from such work could clarify the potential for agrivoltaics to resolve barriers to solar energy development and reduce land use tensions between agriculture and energy production. Research could closely examine the interactions between project partners in implementing and operating agrivoltaic projects. Understanding the formation of projects and their outcomes could provide valuable insight for furthering the development of community-supported agrivoltaic projects. Finally, the impact of full farmer ownership on agrivoltaic project outcomes warrants further study. Few agrivoltaic projects in the U.S. are wholly owned by the farmer; understanding how this and other ownership structures affect project development and operation may contribute to establishing best practices for ownership. Answering these questions allows communities to reimagine how solar energy and agriculture can look in a new era of rural landscape transition. 

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## Appendix A. Document Analysis List

Document ID	Citation
Policy-1	2023 Boulder County Colorado sustainability, climate action & resilience plan. (2023). Boulder County Government. <a href="https://bouldercounty.gov/climate/sustainability-plan/#:~:text=Boulder%20County%20Sustainability%20Plan.%20The%202023%20Boulder%20County%20Sustainability%20Plan">https://bouldercounty.gov/climate/sustainability-plan/#:~:text=Boulder%20County%20Sustainability%20Plan.%20The%202023%20Boulder%20County%20Sustainability%20Plan</a>
Policy-2	Colorado Revised Statutes Title 40. Utilities § 40-2-127. (2010; last updated 2022, January 1). Community energy funds--community solar gardens--definitions--rules--legislative declaration--applicability--repeal. FindLaw.com. <a href="https://codes.findlaw.com/co/title-40-utilities/co-rev-st-sect-40-2-127/">https://codes.findlaw.com/co/title-40-utilities/co-rev-st-sect-40-2-127/</a>
Policy-3	Docket DC-18-0002: Proposed Amendments to the Boulder County Land Use Code related to Solar Energy Systems. (2018, July 23). Boulder County Board of Commissioners.
Policy-4	Docket DC-18-0002: Amendments to the Boulder County Land Use Code for Solar-related Uses and Regulations. (n.d.). Boulder County Board of Commissioners.
Policy-5	Resolution 2019-118. (2018, November 27). Boulder County Board of Commissioners.
Policy-6	Renewable Energy Standards - Qualifying Retail and Wholesale Utilities - Definitions - Net Metering - Legislative Declaration - Rules, 40-2-124 Colorado Revised Statutes. (2004). <a href="https://advance.lexis.com/api/document/collection/statutes-legislation/id/62NH-97S3-CH1B-TOH7-00008-00?cite=C.R.S.%2040-2-124&amp;context=1000516">https://advance.lexis.com/api/document/collection/statutes-legislation/id/62NH-97S3-CH1B-TOH7-00008-00?cite=C.R.S.%2040-2-124&amp;context=1000516</a>
Policy-7	Concerning Opportunities For Voluntary Emission Reductions In Agriculture, And, In Connection Therewith, Making An Appropriation, General Assembly of The State of Colorado, SB 23-092. (2023). <a href="https://leg.colorado.gov/sites/default/files/documents/2023A/bills/2023a_092_enr.pdf">https://leg.colorado.gov/sites/default/files/documents/2023A/bills/2023a_092_enr.pdf</a>

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## Appendix B. Media Analysis List

Media ID	Citation
Media-1	AgriSolar Clearinghouse. (2022, August 10). Case Study: Jack’s Solar Garden. <i>AgriSolar Clearinghouse</i> . <a href="https://www.agrisolarclearinghouse.org/case-study-jacks-solar-garden/">https://www.agrisolarclearinghouse.org/case-study-jacks-solar-garden/</a>
Media-2	Allen, G., & Hickman, T. (2023, January 22). Why the ground under Colorado solar panels is ripe for growing food. <i>The Colorado Sun</i> . <a href="https://coloradosun.com/2023/01/22/colorado-solar-agriculture-agrivoltaics-lawmakers/">https://coloradosun.com/2023/01/22/colorado-solar-agriculture-agrivoltaics-lawmakers/</a>
Media-3	Ashoka Contributor Group. (2024, March 23). Solar is here to stay—Let’s do it right. <i>Forbes</i> . <a href="https://www.forbes.com/sites/ashoka/2024/03/21/solar-is-here-to-stay-lets-do-it-right/">https://www.forbes.com/sites/ashoka/2024/03/21/solar-is-here-to-stay-lets-do-it-right/</a>
Media-4	<i>Daily Camera</i> . (2023, July 15). Community members learn about farming alongside solar panels at Jack’s Solar Garden. <a href="https://www.dailycamera.com/2023/07/15/community-members-learn-about-farming-alongside-solar-panels-at-jacks-solar-garden/">https://www.dailycamera.com/2023/07/15/community-members-learn-about-farming-alongside-solar-panels-at-jacks-solar-garden/</a>
Media-5	Hammon, K. (2022, April 24). Jack’s Solar Garden south of Longmont grows interest in ‘agrivoltaics.’ <i>Times-Call</i> . <a href="https://www.timescall.com/2022/04/24/jacks-solar-garden-south-of-longmont-grows-interest-in-agrivoltaics/">https://www.timescall.com/2022/04/24/jacks-solar-garden-south-of-longmont-grows-interest-in-agrivoltaics/</a>
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