COLORADO AGRIVOLTAICS SURVEY REPORT

FARMER SURVEY FINDINGS & INITIAL RECOMMENDATIONS

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Executive Summary

The "Colorado Agrivoltaics Outreach and Engagement Project," led by the American Farmland Trust (AFT) in collaboration with Agrisolar Consulting, Colorado Open Lands, and Colorado State University Extension, was designed to advance understanding of Colorado agricultural sector interests and concerns with agrivoltaics. The project's central effort was to deploy a survey that targeted 6,000 producers across the state. The survey received approximately 300 responses, which provided valuable, novel information on producer attitudes and awareness regarding agrivoltaics. Key takeaways from the survey data include significant concerns among Colorado producers about the negative impacts of climate change on farming and a strong preference for siting solar projects on less productive or underutilized farmland. The importance of continued farming activity and land restoration after solar projects was also emphasized. Further, the survey findings suggest that providing financial incentives and improving the environmental benefits of projects can increase adoption and support for agrivoltaics. These results underscore the need for targeted education, technical assistance, and supportive policies to promote agrivoltaics as a viable solution for integrating renewable energy with agricultural practices in Colorado. By addressing the concerns and promoting the motivations of the agricultural community highlighted by this survey, Colorado can better advance its renewable energy goals while maintaining agricultural viability and sustainability through agrivoltaic solutions.

Objectives of this report:

1. **Elevate Farmer Perspectives**: Gather and analyze farmer perspectives regarding the implementation and impact of agrivoltaic systems.
2. **Identify Barriers and Opportunities**: Identify the key barriers to and opportunities for the adoption of agrivoltaic systems, providing a comprehensive understanding of the landscape.
3. **Assess Demographic Differences**: Examine the perceptions and attitudes towards agrivoltaic systems across different demographic groups to tailor strategies effectively.
4. **Interpret Survey Results:** Analyze survey data to identify trends and patterns in stakeholder responses.
5. **Conduct Impact Assessment**: Based on survey results, assess the potential environmental, economic, and social impacts of agrivoltaic systems. Determine the perceived benefits and drawbacks of agrivoltaic systems from the perspective of different stakeholder groups.

6. **Develop Recommendations for the Future:** Based on survey findings and stakeholder feedback, identify gaps in current knowledge and propose areas for future research, engagement, and policies that support agricultural producers.

Keywords: Agrivoltaics, Photovoltaics, Solar, Agriculture, Renewable Energy, Sustainability, Land-Use, Colorado, Farmland Conservation, Farm Viability, Agriculture, Energy, Climate Resistance, Survey, Farmer Attitudes, Producer Awareness

Recommendations for Promoting Agrivoltaic Systems in Colorado

Prepared for the Colorado Department of Agriculture

1. **Educational Outreach:** Partner with Colorado State University Extension and other trusted organizations to facilitate peer-to-peer learning and novel demonstrations through workshops, training courses, and informational materials that explain the benefits, costs, installation considerations, long-term land lease agreement options, and life cycle analysis of agrivoltaic systems.

2. **Technical Assistance:** Establish a technical assistance program to support producers by leading feasibility studies, site assessments, and project planning services for agrivoltaic installations.

3. **Incentives:** Introduce targeted tax incentives, grants, and low-interest loan programs to reduce the initial investment by developers required for agrivoltaic systems, which would make projects more accessible to a wider range of farmers and landowners. Provide additional funding or incentives for agrivoltaic projects that incorporate multiple co-benefits, such as water conservation, crop production, habitat creation, diversification, or community benefit agreements.

4. **Partnerships:** Create inter-agency and cross-sectoral partnerships to foster collaboration between state government agencies, academic research institutions, agricultural producers, electric utilities, and solar developers. This could include public-private partnerships and joint funding opportunities for shared research and demonstration projects across Colorado's diverse geographies, and across community and utility-scale projects.

5. **Regulation:** Work with local governments to create clear zoning regulations and land-use policies that enable agrivoltaic projects, ensuring that ground-mounted solar is an acceptable agricultural land use if projects meet agrivoltaic objectives.

6. **Sustained Stakeholder Engagement:** Manage regular communication channels and discussion forums through surveys, focus groups, and advisory committees to gather input from farmers, landowners, and other stakeholders and to co-develop state research and development priorities. This engagement can be used to proactively adjust policies and programs as needed.

7. **Accessibility to Information:** Develop a long-term outreach and engagement toolkit that is composed of several resources for the agricultural community, and can be used by CDA, CSU Extension, and other organizations. As part of the engagement toolkit, an online resource portal can provide access to peer-to-peer learning opportunities, research findings, technical guides, research & demonstration plots, funding opportunities, and best practices in Colorado for agrivoltaics.

8. **Just Transitions, Equity, and Inclusion**: Ensure that research and partnerships actively focus on promoting diversity, equity, and inclusion to enhance broad participation and ensure the benefits of agrivoltaic systems are accessible to all communities.

Project Impact / Overview

Over the next three decades, the transition from a fossil-fuel-dependent electric power sector to a distributed and decarbonized energy network will be driven by market dynamics and ambitious state and federal policies. Solar and other forms of renewable energy are more cost-competitive than ever before; coupled with policies aimed at addressing climate change that require substantial increases in renewable energy, primarily solar, the United States is projected to experience a large-scale deployment of solar in the near future. A U.S. Department of Energy's Solar Futures study projects that solar energy could rise from 4% to 45% of the nation's total energy production by 2050 (DOE, 2021). In Colorado, the Greenhouse Gas Pollution Reduction Road Map aims for a 90% reduction in greenhouse gas emissions from 2005 levels, necessitating significant increases in solar photovoltaic (PV) capacity, bolstered by funding and tax incentives from the Inflation Reduction Act.

Achieving these energy goals could require nearly 7.4 million acres by 2040 and over 10 million acres by 2050, with approximately 90% of this development projected to occur in rural communities (DOE, 2021). According to modeling by the American Farmland Trust's *Farms Under Threat* report, 83% of new solar installations by 2040 could be sited on agricultural lands, with almost half on highly productive land for food and crops (AFT, 2023). In Colorado, ongoing urban and peri-urban development pressures could lead to the loss or conversion of 417,500 acres of farmland and ranchland by 2040 (AFT, 2023). This displacement could negatively impact agricultural productivity, farm viability, and food security while increasing adverse environmental and rural development impacts. Solar development in rural areas can reshape landscapes and economies, potentially generating public backlash and slowing decarbonization efforts.

Agricultural producers in Colorado face challenges such as drought and water supply issues, which could result in more fallowed land. Multi-benefit land repurposing projects, including Smart Solar and agrivoltaics, are key to enhancing agricultural resilience to climate change. This project aimed to engage and support Colorado's agricultural producers by promoting agrivoltaics as a strategy for renewable energy deployment, while also ensuring farm viability and protecting productive agricultural lands.

The project involved extensive outreach and engagement with Colorado farmers and ranchers to understand their awareness, attitudes, interests, and concerns in agrivoltaics. This report assesses perceptions of benefits, costs, and obstacles to adoption, providing valuable insights for future research, system design, education, training, technical assistance, and policy support. By addressing knowledge gaps and technical concerns, and fostering collaboration between producers and developers, the project identifies barriers to agrivoltaics adoption in Colorado.

Engaging in community conversations, smart planning, and project design is critical for scaling up agrivoltaics in Colorado. The outcomes from this project are intended to inform policies, programs, and resources to support agrivoltaics, as well as to guide future incentives, funding, and technical assistance for farmers.

Ultimately, this project aims to help Colorado achieve its renewable energy goals by facilitating the responsible co-utilization of agricultural lands for solar energy production.

The insights derived provide valuable directives to inform effective policies and programs, and this initial effort serves as a platform for continued agrivoltaics engagement with the agricultural community. Most importantly, this project has elevated the voices of Colorado agricultural producers in the broader conversation about solar energy and agrivoltaics.

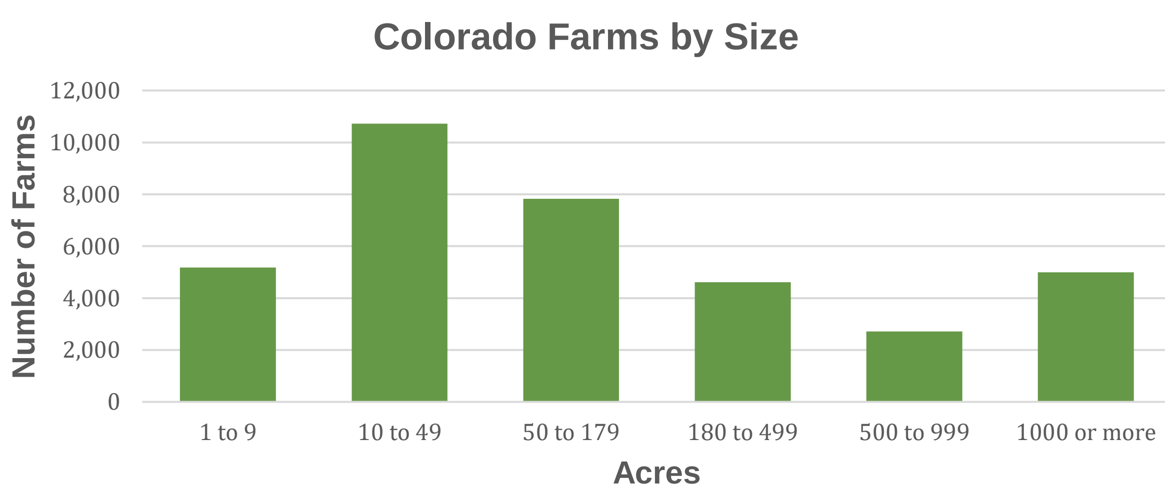
Agriculture in Colorado

Colorado's agricultural sector is a vital part of the state's economy and culture, providing a diverse range of products, including livestock, crops, and specialty farming. However, the industry faces significant challenges such as climate change, water scarcity, and economic pressures.

Colorado has 36,056 farms encompassing 30,213,899 acres of agricultural land. The average size of a farm is 838 acres, while the median size is 75 acres. The estimated market value of land and buildings averages $2,011,854 per farm and $2,401 per acre. Additionally, the estimated market value of all machinery and equipment totals $4,938,560,000, with an average value of $136,973 per farm.

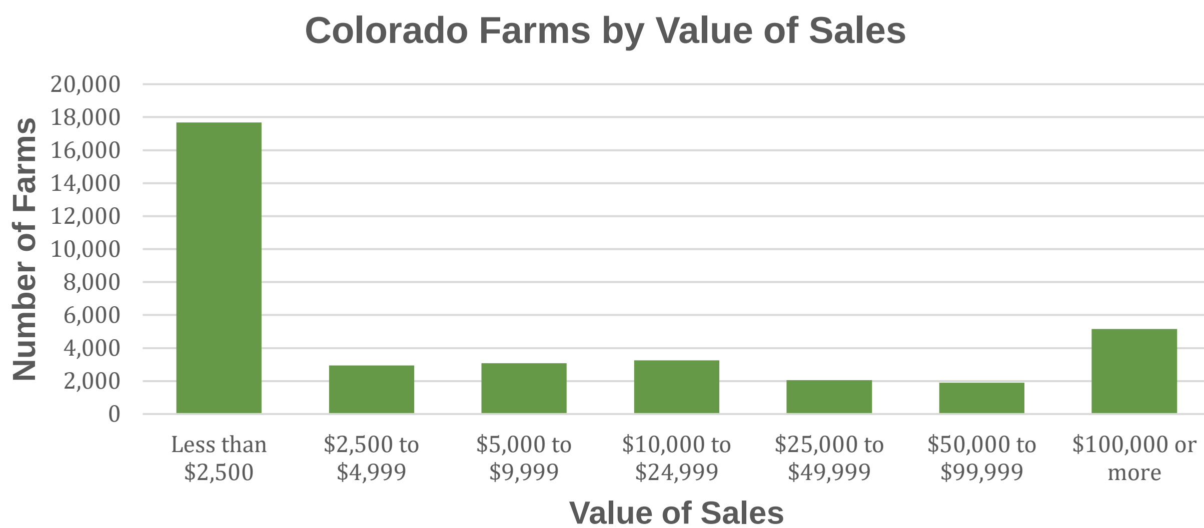
Colorado Farms by Size

The majority of farms in Colorado fall within 10 to 49 acres, comprising nearly 30% of all farms. Farms sized between 50 to 179 acres also represent a significant portion, accounting for about 21.70%. Smaller farms (1 to 9 acres) make up approximately 14.37%, while the largest farms (1,000 acres or more) represent 13.86% of the total. Farms in the 180 to 499 acres range constitute about 12.81%, and those in the 500 to 999 acres range are the least common, making up 7.53%.



Colorado Farms by Sales Value

In terms of sales value, 49.06% of farms have sales less than $2,500, 8.16% have sales between $2,500 to $4,999, 8.54% have sales between $5,000 to $9,999, 9.01% have sales between $10,000 to $24,999, 5.71% have sales between $25,000 to $49,999, 5.25% have sales between $50,000 to $99,999, and 14.28% have sales of $100,000 or more.



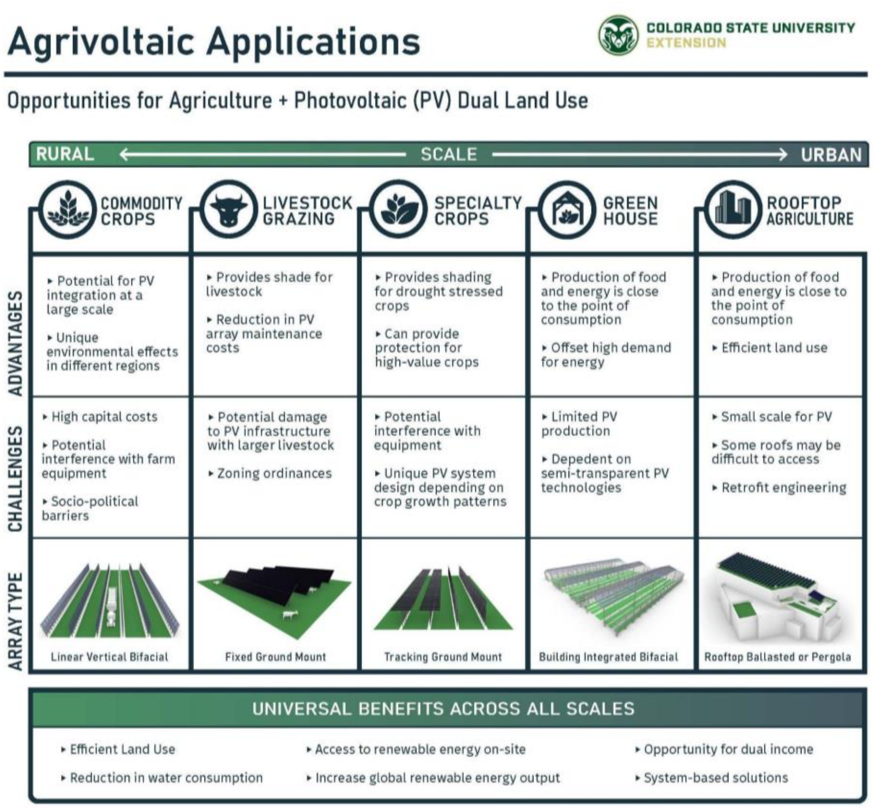
Data From: (2022 Census by State - Colorado | 2022 Census of Agriculture | USDA/NASS)

Agrivoltaics in Colorado

Agrivoltaics has the potential to significantly contribute to the sustainability and resilience of Colorado's agricultural and energy sectors. The integration of solar panels with agricultural activities, such as crop production, livestock grazing, and apiary management, provides multiple benefits. These include creating microclimates that protect crops, reduce water evaporation, and support biodiversity through habitat creation.

Agrivoltaics Overview

Agrivoltaics is the practice of co-locating solar energy installations and agriculture, with crops or grazing land beneath or between rows of photovoltaic panels (CDA, 2023). The hallmark characteristic of agrivoltaics is thus the sharing of sunlight between the two energy conversion systems: photovoltaics and photosynthesis. Agricultural activities include practices that satisfy human food, fiber, and fuel needs as well as activities that enhance environmental quality and the natural resource base upon which the agricultural economy depends (adapted from the U.S. Department of Agriculture (USDA)) (U.S. Department of Agriculture, 2007). To date, agrivoltaics in the United States has included crop production, livestock grazing, apiary management, and other activities that intentionally involve the provision of ecosystem services (e.g., habitat creation, support for beneficial pollinating and predatory insects, native vegetation restoration, or cover cropping for soil health benefits and carbon sequestration). It is important to note that not all PV installations on farms can be considered agrivoltaics. An essential component of an agrivoltaics system is that the solar and agricultural activities have an influence on each other. Therefore, installing rooftop PV on a barn, where there is no direct impact of the PV system on the vegetation, soil, or livestock, would not be considered an agrivoltaic project. Similarly, conventional ground-mounted solar infrastructure adjacent to agricultural land with no direct vegetation, soil, or livestock integration would not be considered an agrivoltaic project. Moreover, simply using electricity from a solar installation to power farm-related activities is not considered agrivoltaics. However, there can still be value in on-farm production and usage of solar energy outside of agrivoltaics. Solar Power Europe has proposed to specifically designate the term agrisolar as a broader umbrella term that can encompass agrivoltaics as well as non-agrivoltaic solar energy on agricultural properties.



Source: CSU Extension Agrivoltaic Fact Sheet 2022
Design: Thomas Hickey

Colorado has emerged as a pioneering state in the development and implementation of agrivoltaics, leveraging its legislative and financial commitments to advance research within the field. Under the leadership of Senator Sonya Jaquez Lewis, the bill's prime sponsor, Colorado became the first state to establish agrivoltaics in statute and allocate state funding to support these projects. This legislative framework demonstrates the state's commitment to combining agricultural productivity with renewable energy generation, positioning Colorado as a leader in this field.

Governor Jared Polis, in his State of the Union address, has articulated an ambitious vision for Colorado's energy future, aiming for 100% of the state's electricity to be sourced from renewable energy by 2040. This vision is detailed in policy documents such as the "Roadmap to 100% Renewable Energy by 2040 and Bold Climate Action" (May 2019) and the "Greenhouse Gas Pollution Reduction Roadmap" (January 2021). Xcel Energy, a major utility provider in Colorado, has also set a target to achieve 100% carbon-free electricity before 2050. These frameworks set the stage for significant advancements in renewable energy infrastructure, with agrivoltaics playing a key role.

Several notable agrivoltaic projects across various scales illustrate Colorado's leadership in this field, including Jack's Solar Garden, CSU ARDEC South, and Denver Botanical Gardens - Chatfield, with several more demonstration-scale projects in the pipeline. One proposed upcoming project - the Garnet Mesa Solar Project, will have an 80-megawatt capacity and plans to integrate 1,000 local sheep. This project is sixty times larger than Jack's Solar Garden demonstrating the scalability and potential impact of recent policy initiatives. Projects like this enable the examination of large-scale agrivoltaic applications and the analysis of their economic, environmental, and social impacts.

The commitment to renewable energy extends past state initiatives, with 14 counties and towns in Colorado, including Denver, Pueblo, Boulder, Fort Collins, Summit County, Frisco, Aspen, Glenwood Springs, Breckenridge, Longmont, Lafayette, Nederland, and Golden, setting their own 100% renewable energy goals as of 2019. This municipal commitment highlights the grassroots support for renewable energy and fosters a collaborative research environment where local governments, academic institutions, and private enterprises can work together to address common challenges and share best practices.

The state's diverse geographic and climatic conditions offer unique research opportunities. Colorado's varied topography, ranging from high plains to mountainous regions, allows for the study of agrivoltaic systems in different environmental contexts. Research can focus on optimizing agrivoltaic designs for specific climatic conditions, evaluating the resilience of agrivoltaic systems to extreme weather events, and assessing the long-term sustainability of these systems in diverse agricultural landscapes.

These 5 things have been identified as key pillars for successful agrivoltaic project implementation by the National Renewable Energy Laboratory (NREL):
NREL's framework, the 5 C's for agrivoltaic success, can be used as a reference to understand the necessary components for successful projects (Macknick et al., 2022). C5: Collaboration, and C4: Compatibility include collaborations through stakeholder engagement and agreements; and compatibility of not only technology but also compatibility of stakeholder needs and interests. Collaboration and Compatibility set the foundation for C3: Crops, C2: Configuration, and C1: Climate, and must be prioritized in the earliest stages of project origination.

"The 5 Cs":

- Climate, Soil, and Environmental Conditions (C1): The ambient conditions and factors of the specific location that are beyond the control of the solar owners, solar operators, agrivoltaic practitioners, and researchers.
- Configurations, Solar Technologies, and Designs (C2): The choice of solar technology, the site layout, and other infrastructure that can affect light availability and solar generation.
- Crop Selection and Cultivation Methods, Seed and Vegetation Designs, and Management Approaches (C3): The methods, vegetation, and agricultural approaches used for agrivoltaic activities and research.
- Compatibility and Flexibility (C4): The compatibility of the solar technology design and configuration with the competing needs of the solar owners, solar operators, agricultural practitioners, and researchers.
- Collaboration and Partnerships (C5): Understandings and agreements made across stakeholders and sectors to support agrivoltaic installations and research, including community engagement, permitting, and legal agreements.

Survey Materials, Methods & Limitations

Survey Design

In December 2023, AFT convened an Advisory Committee with representation from the Colorado Department of Agriculture, AgriSolar Consulting, Colorado Open Lands, and Colorado Agrivoltaic Learning Center, that collaborated on the design and distribution of a state-wide survey of producer perspectives on agrivoltaics.

The survey instrument was co-designed by project partners and the Advisory Committee to identify potential opportunities and challenges, from an agricultural perspective, associated with integrating solar energy and farming practices (agrivoltaics) in Colorado. The target population included farmers, ranchers, and farmland or ranchland owners within the state. The survey instrument was developed based on prior work by AFT and AgriSolar Consulting in the state of Connecticut, focusing on agricultural producers' opinions about solar development on agricultural land, experiences with solar projects, perspectives on agrivoltaics, and general demographic information (Pascaris et al., 2023).

The main survey objectives were to:

○ Identify producers' perceived interests and benefits of agrivoltaics.

○ Assess factors of concern and reasons for opposition towards agrivoltaics.

○ Determine what type of information and resources producers are interested in related to agrivoltaics

The survey was divided into five unique sections that included:

1. Introduction / Qualifier.
2. Solar on Agricultural Lands & Agrivoltaics.
3. Solar on "Your" Agricultural Land.
4. Information about Solar & Agriculture.
5. Demographics.

The survey included 33 questions of varying length and type, with a total expected user completion time between 15-20 minutes.

Survey Distribution

The survey was distributed with the assistance of the project Advisory Committee to ensure wide coverage across the entire state of Colorado. Additional partners for survey distribution included statewide agricultural organizations like Rocky Mountain Farmers Union, Colorado Fruit and Vegetable Growers Association, Colorado Livestock Association, land trusts such as Colorado Community Land Trust and AFT, the Colorado Land Board, Colorado Agrivoltaic Learning Center, and the CSU Extension network. The initial outreach began in January 2024, targeting approximately 6,000 producers to achieve the desired response rate of at least 200 completed surveys. The targeted response rate was informed by previous experience with similar surveys. As an incentive, all respondents who chose to provide information were entered into a drawing to win one of five $100 Visa gift cards.

Data Collection

The survey was administered online using Qualtrics Software (Qualtrics, Provo, UT), an online survey tool that was used to build and distribute the survey, collect responses, and perform the initial analysis of response data. The survey was launched on January 23rd, 2024, and was closed to new responses on May 10th, 2024. Once the survey instrument was launched, it was promoted through agricultural networks and project partners, at outreach events across the state, through CSU Extension, and the State of Colorado Land Board. A total of 312 survey responses were obtained.

Data Analysis

While the survey was live, preliminary results were analyzed by AgriSolar Consulting to inform upcoming outreach and engagement activities while guiding ongoing survey distribution strategy.

At the conclusion of the survey, AgriSolar Consulting utilized R Studio (RStudio, Boston, MA) and Qualtrics Software (Qualtrics, Provo, UT) for the final survey data analysis, which streamlined the handling and processing of the dataset. Data manipulation and visualization were conducted to uncover patterns and trends. Data analysis includes descriptive metrics from all five sections of the survey to summarize attitudes and awareness levels, preferences, and demographic factors influencing opinions on agrivoltaics.

Survey Limitations

The survey conducted as part of this research faced limitations that must be acknowledged for proper interpretation of the findings. Primarily, the survey was constrained by the timeframe of the grant cycle, which restricted the duration available for data collection. The survey was launched on January 23, 2024, and was closed on May 10, 2024. The latter half of the survey period falls in line with the planting season for certain crops in Colorado, thereby reducing the survey’s priority for respondents.

The online survey's accessibility was another noteworthy limitation. The survey was exclusively administered digitally in English, creating barriers for non-English speakers and those with limited internet access or digital literacy, particularly older farmers. The geographic scope was also limited, potentially failing to encompass all regions equally and thus affecting the diversity of responses. This geographic constraint, coupled with the small sample size, raises concerns about the representativeness of the findings for all producers in Colorado.

The survey design itself presented several biases. Most questions did not require mandatory responses, leading to variations in the total number of valid responses. The length and complexity of the survey likely contributed to survey fatigue, possibly causing participants to either hastily complete or abandon the survey altogether. The technical language used could have been inaccessible to some, potentially deterring individuals without an advanced educational background from participating meaningfully.

Finally, the lack of trust in the survey's purpose among participants may have compromised the validity of the responses, as indicated in the open-ended comments provided by respondents.

Despite these survey instrument and distribution limitations, the resulting data has undergone rigorous analysis and the findings derived have been interpreted through the lens of the listed limitations. The producer perspectives captured by this survey are not intended to be statistically generalizable to all producers in Colorado but are intended to be logically representative of producers with similar characteristics, which is insightful for many stakeholders and satisfies the research purpose. The survey and its findings remain a valid contribution to ongoing agrivoltaic research and development in Colorado.

Survey Ethics & Data Confidentiality

Participation in the survey was voluntary, with informed consent obtained from all respondents shared at the beginning of the survey. Confidentiality was maintained by anonymizing responses and securely storing data in the Qualtrics database. All reported results have been de-identified to protect the privacy of survey participants.

Survey Response Metrics

- 225 complete responses + 87 partial responses, totaling 312 survey responses.

Survey Results & Discussion

Overview of Concerns and Barriers

- Environmental Concerns - One of the foremost concerns among respondents is the potential negative impact of solar projects on land conservation and farm productivity. A substantial 61% of respondents expressed being very concerned about the impacts on land conservation, while 57% shared similar levels of concern regarding farm productivity and the visual landscape. These concerns are rooted in the fear that the installation of solar panels might disrupt the ecological balance, leading to soil degradation and loss of biodiversity. Farmers are particularly weary of the initial land disturbance during construction and the long-term ecological footprint of these projects.

- Information Barriers - The survey identified a need for more accessible and clear information about agrivoltaic systems, and solar energy development in general. Specifically:
    - Information about land lease agreements, risk, liability, insurance, asset ownership, and scalability.
    - Guidance on relevant local, state, and federal regulations or incentives.
    - Knowledge exchange and access related to technical assistance and ongoing project management.
    - Information addressing concerns about the durability and maintenance of solar panels, particularly in harsh weather conditions.

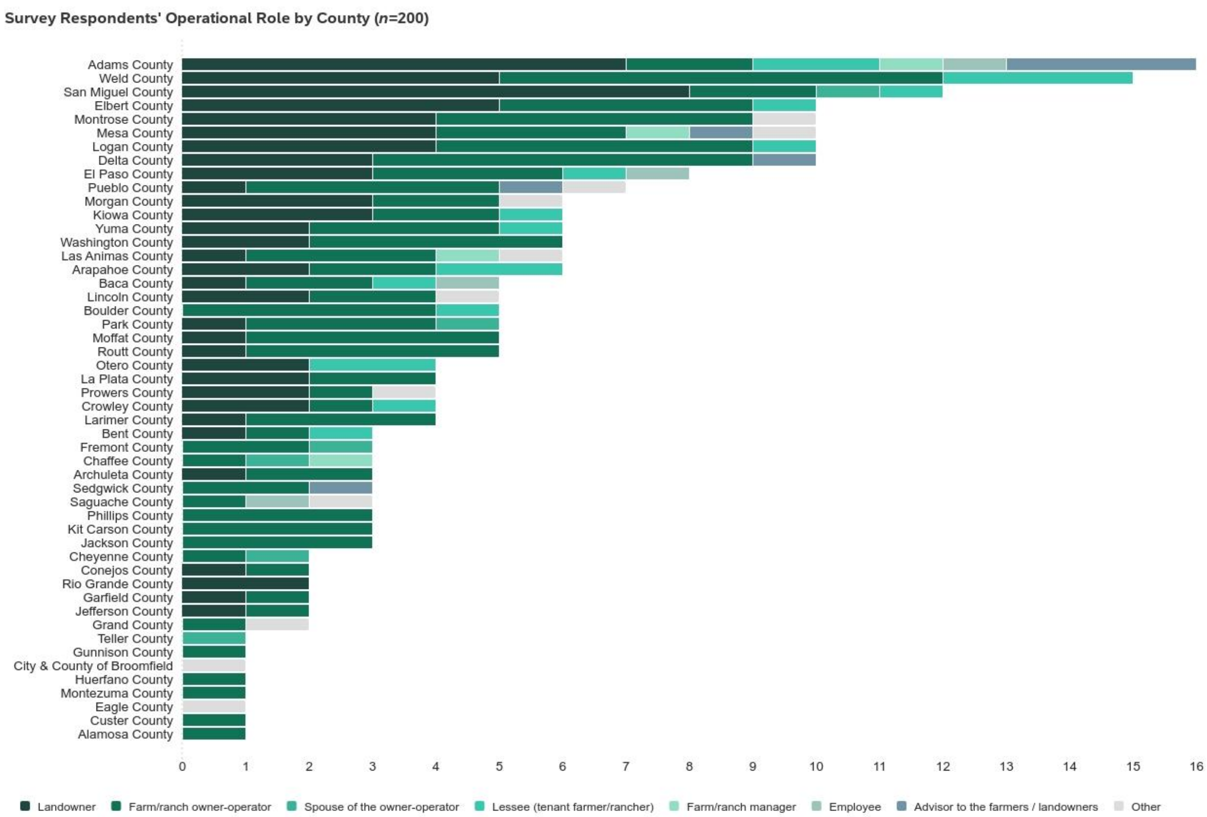
Overview of Opportunities

- Most producers are willing, or possibly willing to engage with most agrivoltaic activities (48%-65%).
- Integrating agricultural benefits and additional revenue streams into solar development projects to gain greater support from the agricultural community. Support for solar increases if specific steps within solar/agrivoltaic development are taken. Ensuring that the land is returned to a state with equal or improved agricultural viability at the end of the project life significantly boosts support (57%), while guaranteeing the solar developer maintains access to the land for continued agricultural production (55%), designing solar project for dual use (54%), and generating additional revenue for the landowner (52%) also increase support.

- Economic Opportunities - 61% of survey respondents indicated that the opportunity to provide supplementary income would influence their motivation to lease land for solar development, while 39% indicated that the ability for solar to support their operation would influence their motivation to lease land.
- Solar adoption is perceived as a strategy to boost long-term farm viability.

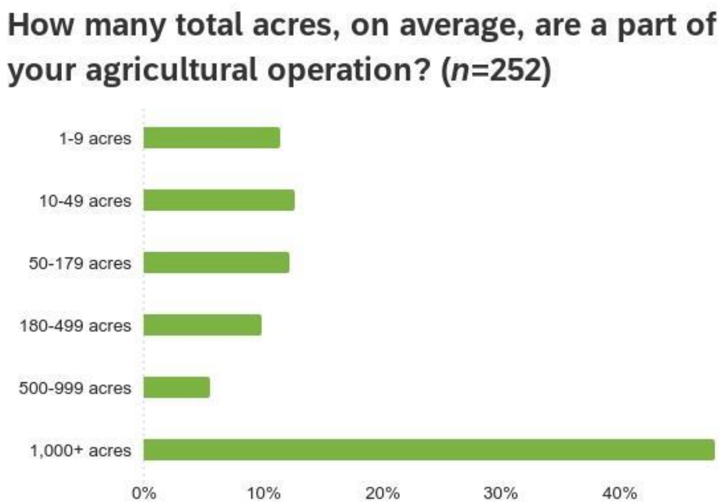
Survey Response Demographics

Respondent County / Location



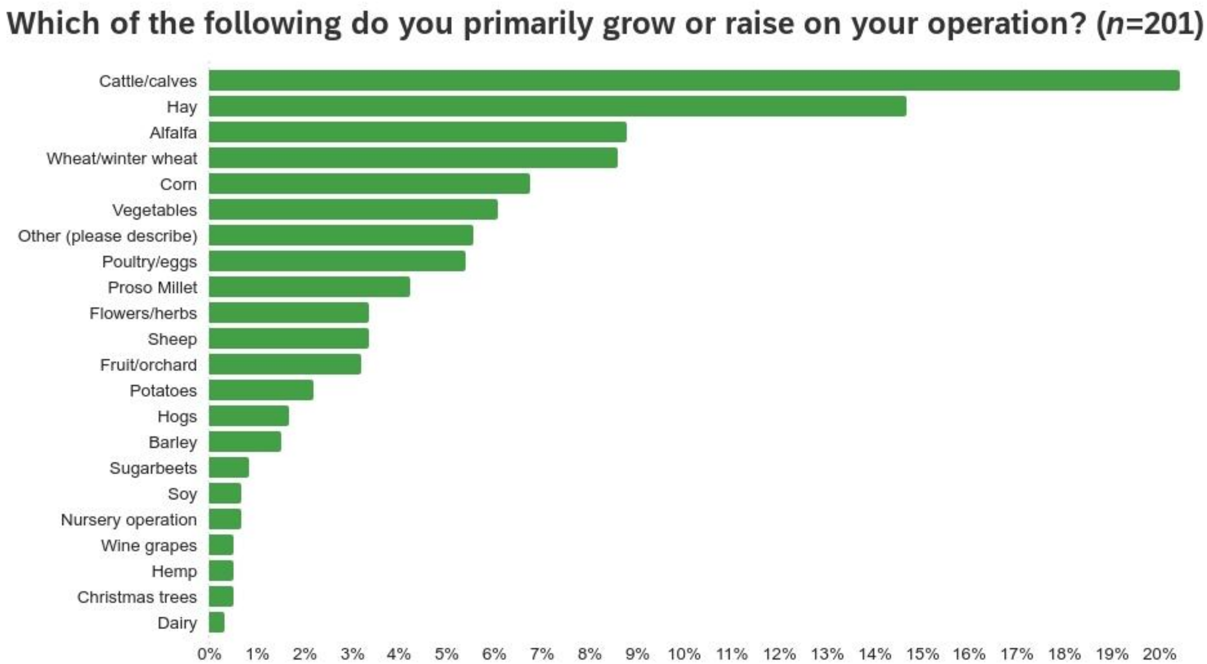
This graph illustrates the distribution of locations (counties), paired with agricultural operation roles among 200 survey respondents, specifying the counties where their farms are situated. Adams County is the most common location, with about 8% of respondents representing this location. In total, 50 out of Colorado's 64 counties were represented in the survey.

How many total acres, on average, are a part of your agricultural operation?



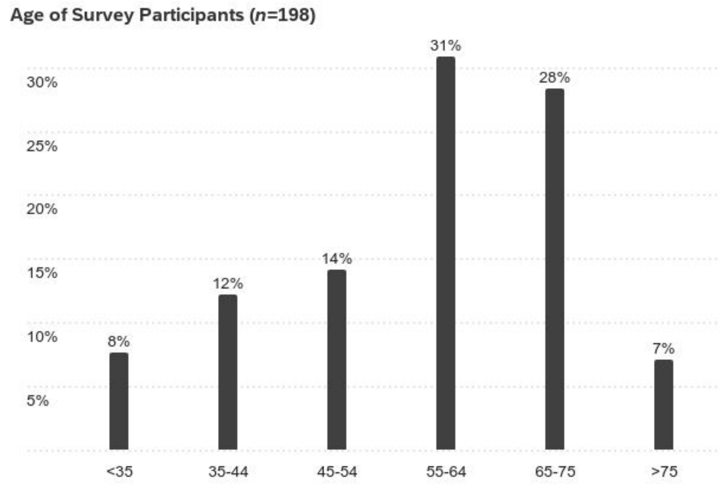
This graph shows the distribution of farm sizes among 252 respondents, measured by the total acres of their agricultural operations. The majority, over 40%, manage farms larger than 1,000 acres. Smaller operations of 1-9 acres, 10-49 acres, and 50-179 acres each represent roughly 10% to 15% of respondents. Mid-sized farms of 180-499 acres account for about 15%, while farms between 500-999 acres are the least common, making up just under 10%. This distribution highlights that large-scale farming operations dominate the sample, while smaller and mid-sized farms are less prevalent.

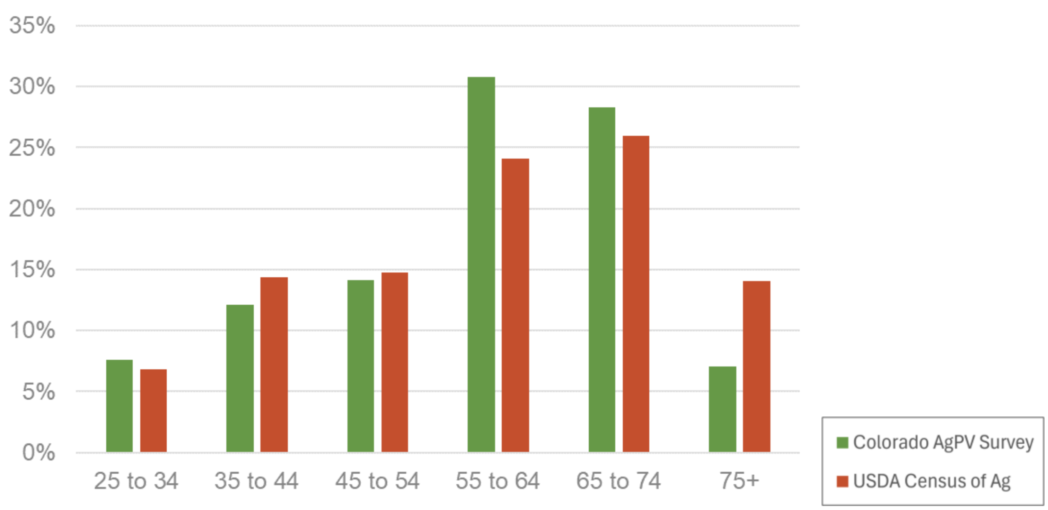
Type of Agricultural Operation



This graph depicts the primary agricultural products grown or raised by 201 respondents on their operations. The most common products are cattle/calves (20%) and hay (15%). Alfalfa and wheat/winter wheat each account for about 9%, while corn is cultivated by 7% of respondents. Vegetables are grown by 6%, and other unspecified products by 6%. Poultry/eggs and proso millet are each reported by 4.5%-6%. A variety of other products, including flowers/herbs, sheep, fruit/orchards, potatoes, hogs, barley, sugar beets, soy, nursery operations, wine grapes, hemp, Christmas trees, and dairy, are each reported by smaller percentages, ranging from 4% down to near 0%.

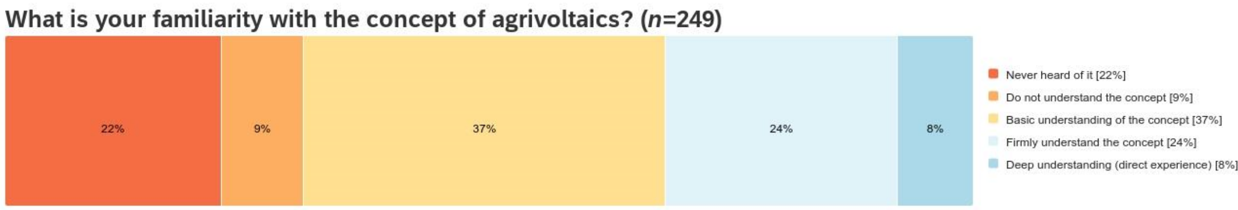
Age of Respondents





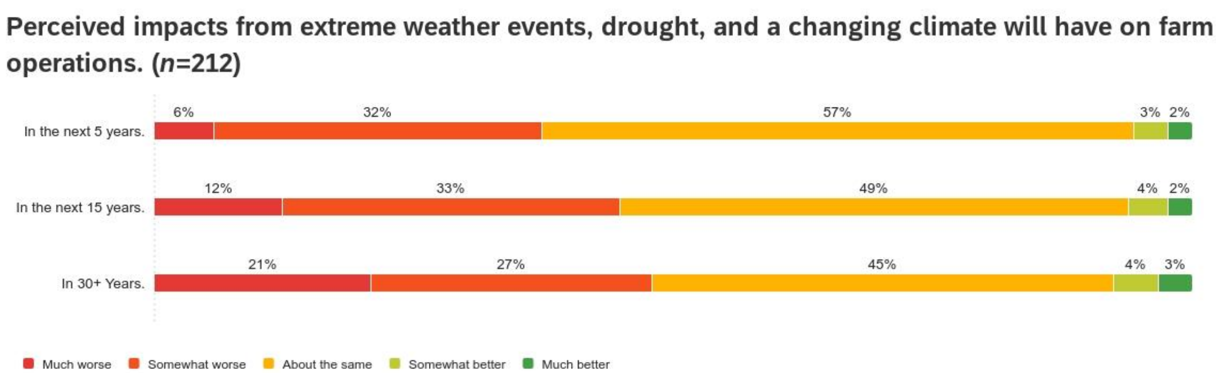
The survey's demographic data reveals insight into the respondent profiles. The above graph indicates that the majority of respondents are seasoned farmers, most of whom are aged over 50. A comparison of the ages of survey respondents against USDA Agricultural Census data suggests that the producers sampled in Colorado are generally representative of national age averages, besides that older producer (75+) are underrepresented and middle-aged producers (55-64) are overrepresented in the Colorado survey.

Understanding of Agrivoltaics Prior to Survey



The survey measured farmers' familiarity with the concept of agrivoltaics. The findings indicate that 22% of respondents have never heard of agrivoltaics, 9% do not understand the concept, 37% have a basic understanding, 24% firmly understand, and 8% possess a deep understanding with direct experience. This finding demonstrates that agrivoltaics is not well-known or widely practiced among the farming population in Colorado. To improve this, more education, research, supportive policies, and collaboration between agriculture and energy sectors are needed to make agrivoltaics more commonplace and effectively communicated.

Perceived impacts from extreme weather events, drought, and a changing climate will have on farm operations.

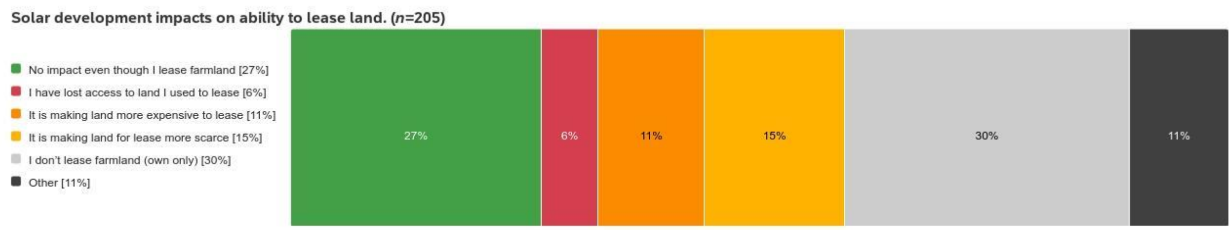


This graph illustrates perceptions of how extreme weather, drought, and climate change will impact farm operations among 212 respondents over three timeframes: the next 5 years, 15 years, and 30+ years. In the next 5 years, 6% expect much worse impacts, 32% somewhat worse, 57% about the same, and small percentages anticipate slight improvements. In the next 15 years, the anticipation of negative impacts increases slightly, with 12% expecting much worse and 33% somewhat worse conditions, while 49% foresee conditions remaining the same. Looking 30 years ahead, the expectation of negative impacts grows significantly, with 21% predicting much worse and 27% somewhat worse conditions, while 45% think conditions will remain unchanged. This trend indicates increasing concern over time about the adverse effects of climate change on farming, suggesting the need for long-term planning and adaptation strategies in the agricultural sector. In all three timelines, 3% or fewer respondents stated that they believe weather will have a positive impact on farm operations.

The data clearly shows an increasing concern about the negative impacts of climate change on farming over the next several decades. By integrating solar energy production with agricultural activities, agrivoltaics can help stabilize farm operations, protect crops from extreme weather, improve water use efficiency, and contribute to climate mitigation efforts.

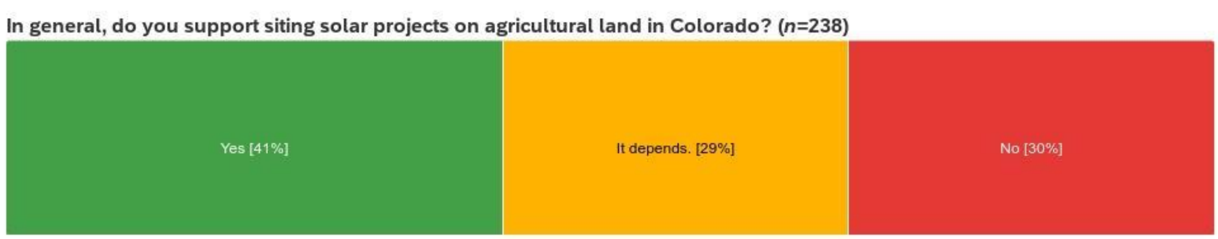
Solar on Agricultural Land & Agrivoltaics

Solar development impacts on the ability to lease land.



This graph illustrates the perceived impacts of solar development on the ability to lease farmland, based on responses from 205 participants. The data is categorized into six distinct impacts: no impact even though I lease farmland (27%), I have lost access to the land I used to lease (6%), it is making land more expensive to lease (11%), it is making land for lease scarcer (15%), I don’t lease farmland (own only) (30%), other (11%).

General Support for Solar on Agricultural Lands



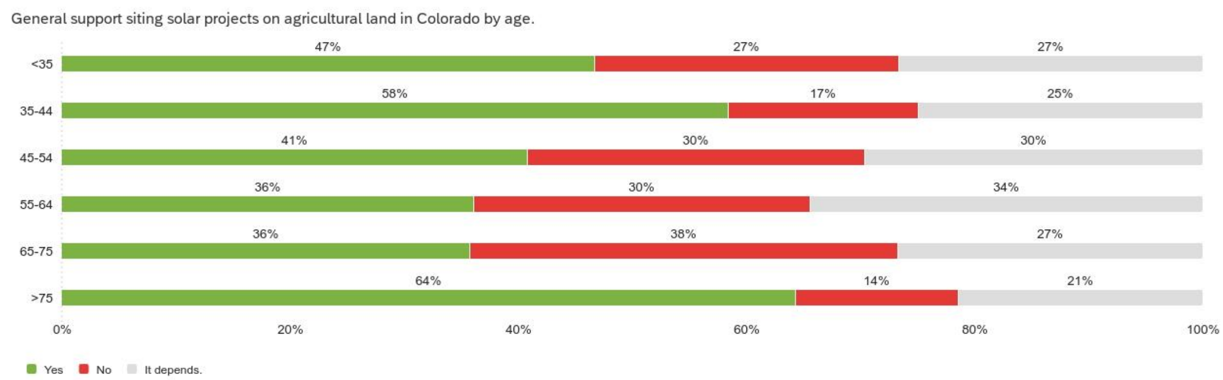
Out of 238 respondents, 41% support siting solar projects on agricultural land, while 30% oppose it, and 29% believe it depends on specific circumstances. Here are some elaborations on their answers:

"I believe that those in agriculture who want a solar project on their land should have the opportunity to investigate and accept or refuse that opportunity. I am most concerned that the initial disturbance of the land during construction might not be mitigated to the owner's satisfaction and that there would be little if any, legal remedy. Electric companies are notorious for this."

"I am 100% in support of small-scale solar, such as rooftop panels and discreet setups for personal use by landowners. However, I am nearly equally opposed to large-scale solar projects that industrialize the natural landscape Colorado is renowned for and disrupt its fragile ecosystems."

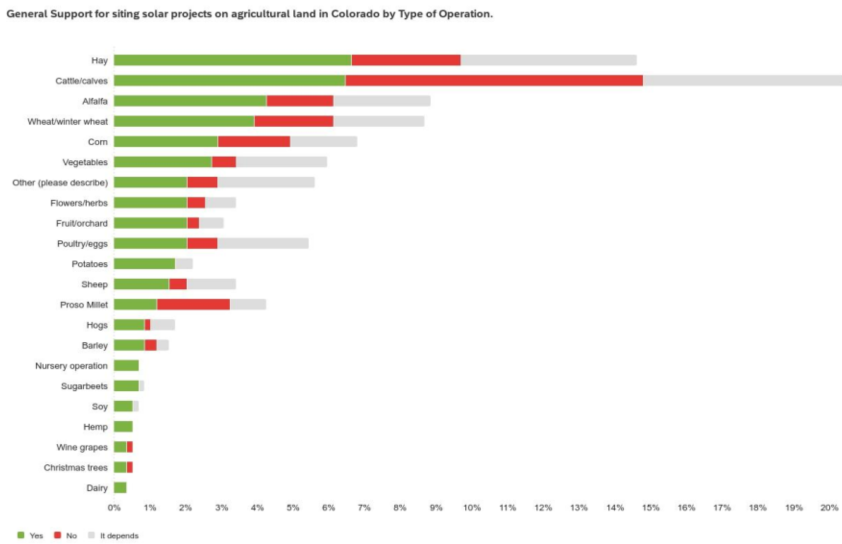
"I do not support solar projects on most large, rural plots of agricultural land. However, in the case of land that is located within, near, or adjacent to a municipality and that is not degrading contiguous wildlife habitat and productive range, I believe it is a beneficial land use."

General Support of Solar by Age



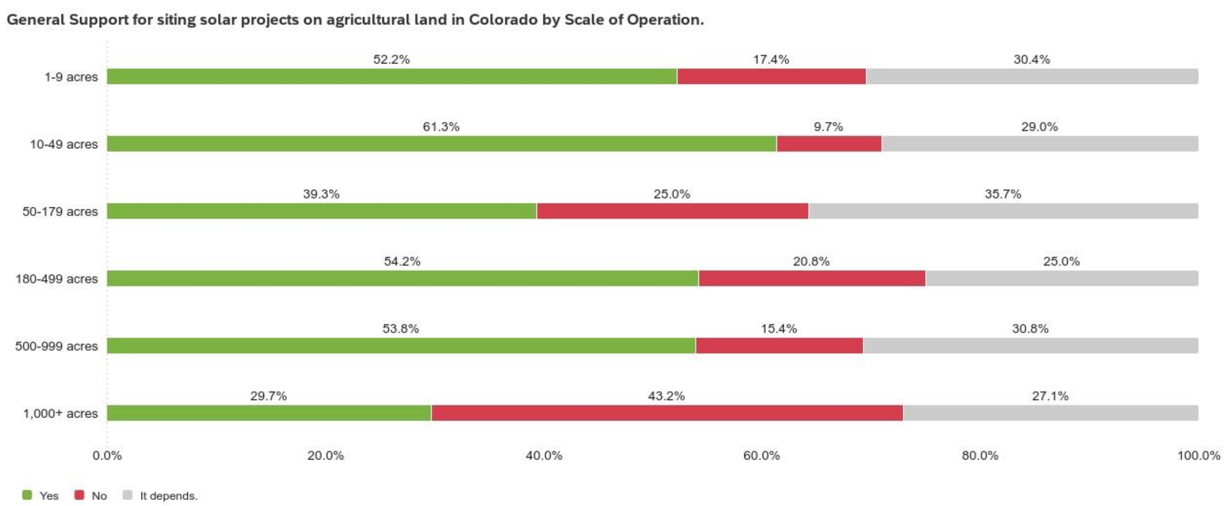
This graph illustrates the general support for siting solar projects on agricultural land in Colorado, categorized by age groups. Nearly half of the respondents under 35 support solar projects on agricultural land, while the remaining half is split evenly between opposition and conditional support. Ages 35-44 show the highest level of support among the younger cohorts, with a significant 58% in favor. Support is consistent at 36% for 55-64 and 65-75 year olds. However, the 65-75 age group has the highest level of opposition of all the age groups. Those over 75 are most supportive of siting solar on agricultural land with 64% indicating “yes”. Of the opposing stances within the 75+ group, one respondent elaborated: “It is too long a term to contract for use of my land, based on my age.”

General Support of Solar by Farm Operation Type



General support for solar by farm operation type, shown as a percentage of total responses.

General Support of Solar by Farm Size



This graph illustrates general support for siting solar projects on agricultural land in Colorado, segmented by the scale of agricultural operations, as indicated by acreage. The data is divided into six categories: 1-9 acres, 10-49 acres, 50-179 acres, 180-499 acres, 500-999 acres, and 1,000+ acres.

1-9 Acres:
Support: 52.2%
Opposition: 17.4%
Depends: 30.4%

Farmers with small-scale operations (1-9 acres) show moderate support for solar projects, with over half in favor, 17% opposed, and nearly a third stating that their support depends on various factors.

10-49 Acres:
Support: 61.3%
Opposition: 9.7%
Depends: 29%
This group demonstrates the highest level of support among all categories, with a significant majority (61%) in favor of siting solar projects, 10% opposed, and 29% contingent on certain conditions.

50-179 Acres:
Support: 39.3%
Opposition: 25%
Depends: 35.7%
Support decreases in this mid-range category, with 39% in favor, 25% opposed, and a larger portion (36%) expressing conditional support.

180-499 Acres:
Support: 54.2%
Opposition: 20.8%
Depends: 25%
Support rises again with 54% of farmers in this category favoring solar projects, 21% opposing, and a quarter indicating their decision depends on specific circumstances.

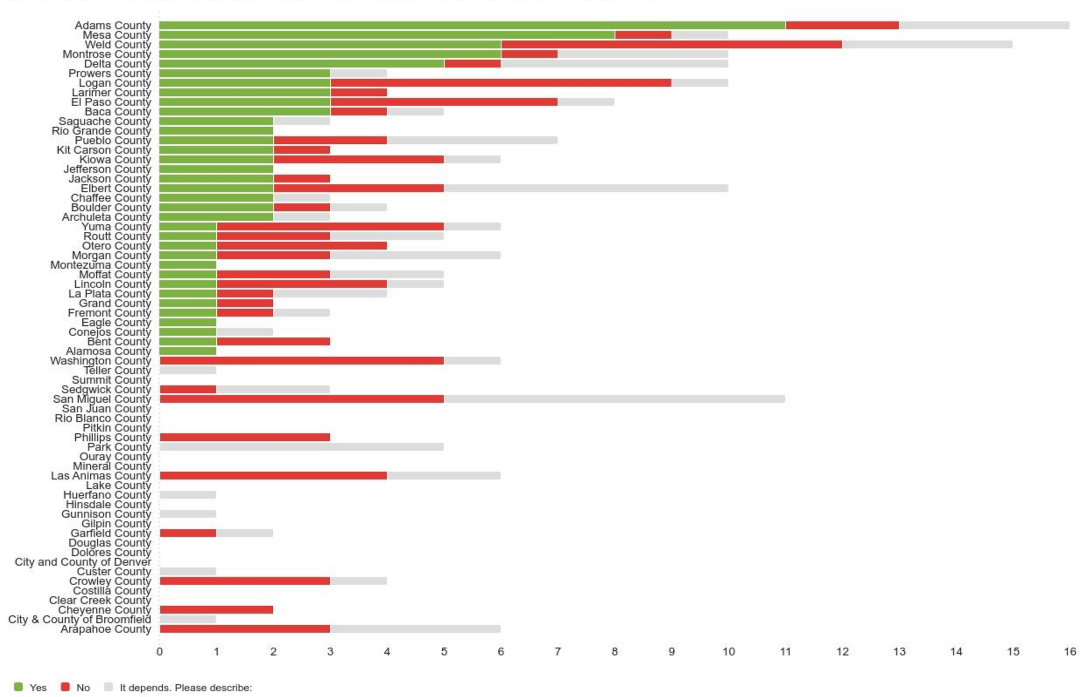
500-999 Acres:
Support: 53.8%
Opposition: 15.4%
Depends: 30.8%
Similar to the previous category, 54% support the projects, but with a lower opposition rate (15%) and a substantial portion (31%) depending on various factors.

1,000+ Acres:
Support: 29.7%
Opposition: 43.2%
Depends: 27.1%
Large-scale operations (1,000+ acres) show reduced support, with 30% in favor, the highest opposition rate (43%) among all categories, and 27% expressing conditional support.

Overall, support for siting solar projects on agricultural land varies by the scale of the operation. Smaller and medium-scale farms (1-9 acres and 10-49 acres) generally show more support, whereas large-scale operations (1,000+ acres) exhibit higher opposition. Conditional support remains significant across all categories, indicating that many farmers' decisions are influenced by specific factors such as project design, compensation, and potential impacts on their land and operations.

General Support by County

General Support for siting solar projects on agricultural land in Colorado by Type of County. (n=198)



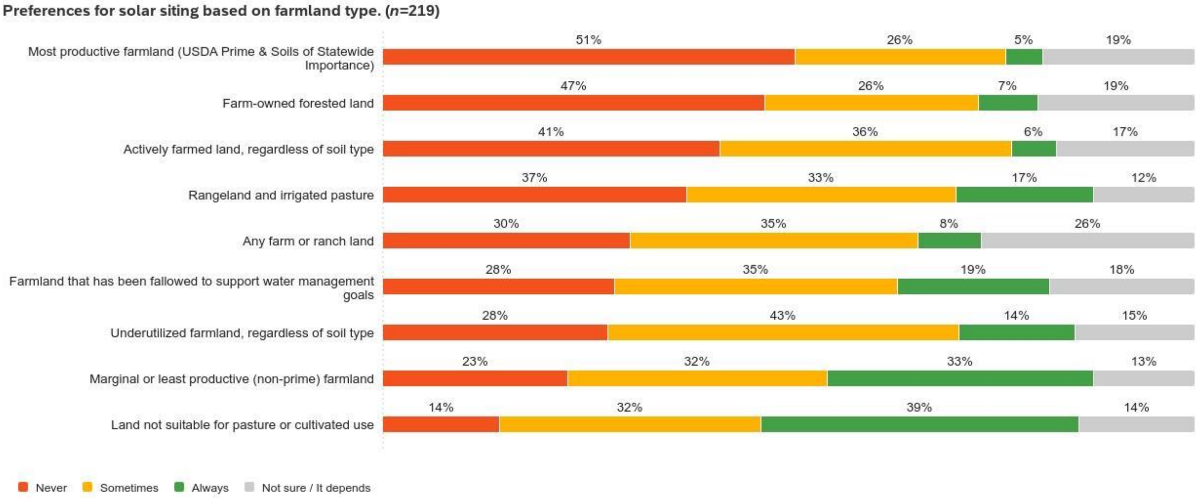
Level of Concern

Impacts of concern for solar development on agricultural land in Colorado (*n*=234)

This graph shows that out of 234 respondents, many are worried about the effects of solar projects on agricultural land in Colorado. Most are very concerned about impacts on land conservation (61%), farm productivity (57%), tenant farmers/ranchers/leases (57%), the visual landscape (57%), farm and ranch viability (57%), soil quality (56%), land prices and access (52%), and impact on agricultural water rights (51%). The remaining two options, impacts on the local community and local agricultural services and supply chains are of less concern at 43% and 42% respectively.

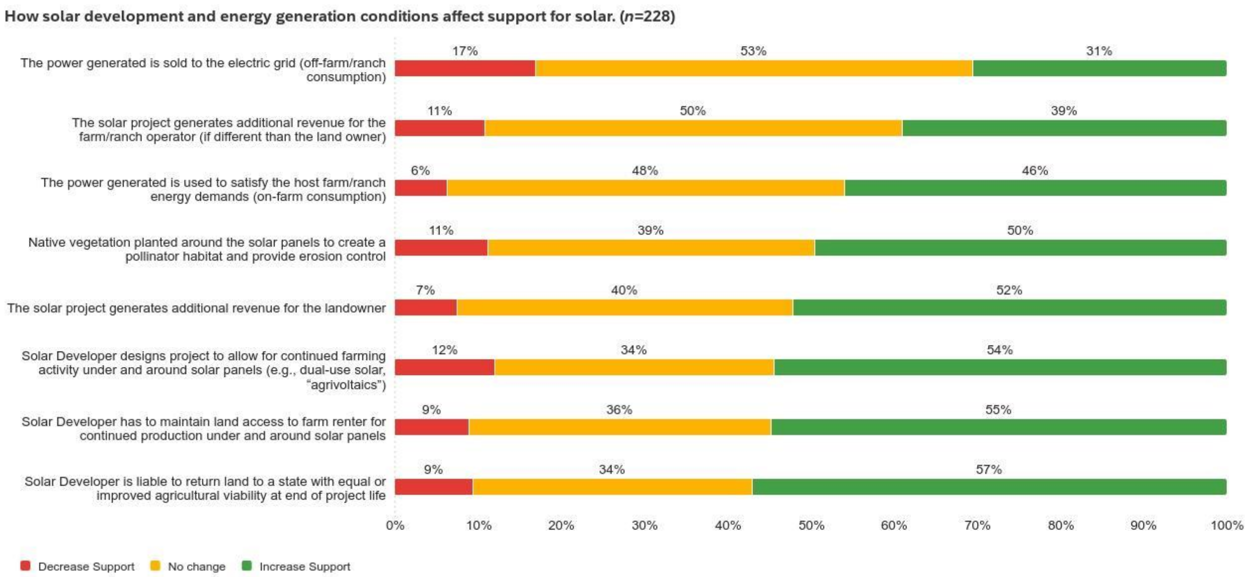
Opinions about solar development on specific land types

Preferences for solar siting based on farmland type. (*n*=219)



The data reveals a strong preference for siting solar projects on less productive or underutilized farmland rather than on highly productive or actively farmed land. Respondents show the highest support for using marginal or least productive land (39% always in favor) and land not suitable for pasture or cultivation (33% always in favor), indicating a strategic choice to minimize the impact on prime agricultural areas. There is significant opposition to placing solar projects on the most productive farmland (51% never in favor) and farm-owned forested land (47% never in favor), reflecting concerns about preserving these natural resources.

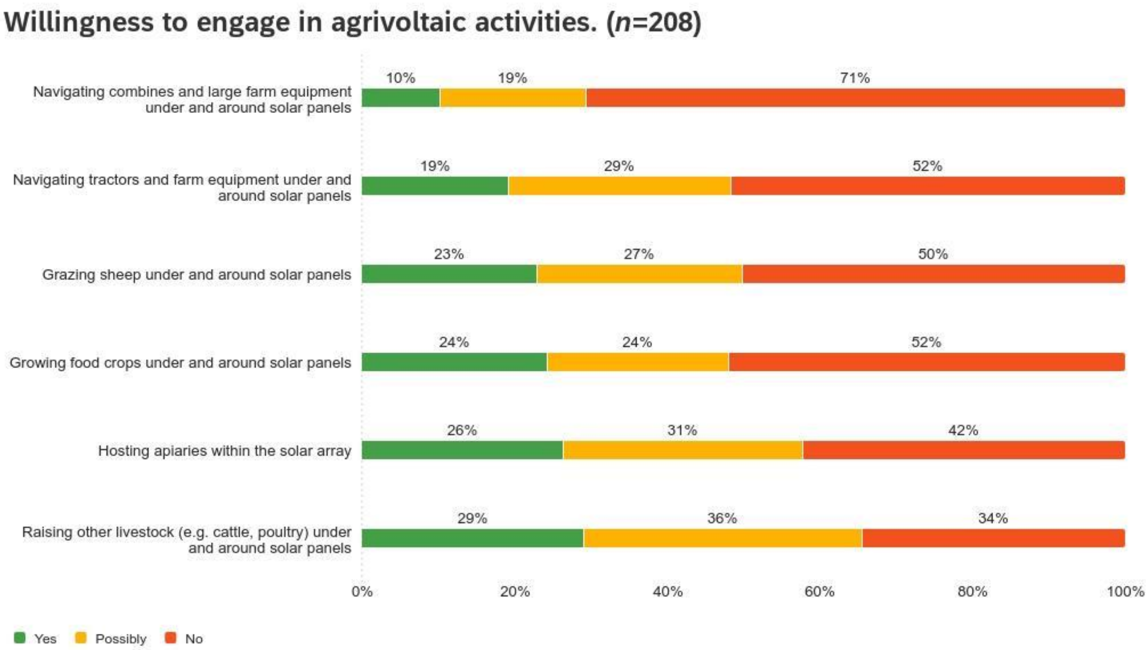
Factors that affect support for solar



When considering factors that affect support for solar development on farmland, long-term agricultural viability, continued land access, array design for agrivoltaic activities, and revenue generation for the landowner all increase support.

Solar on Your Agricultural Land

Willingness to engage in agrivoltaic activities



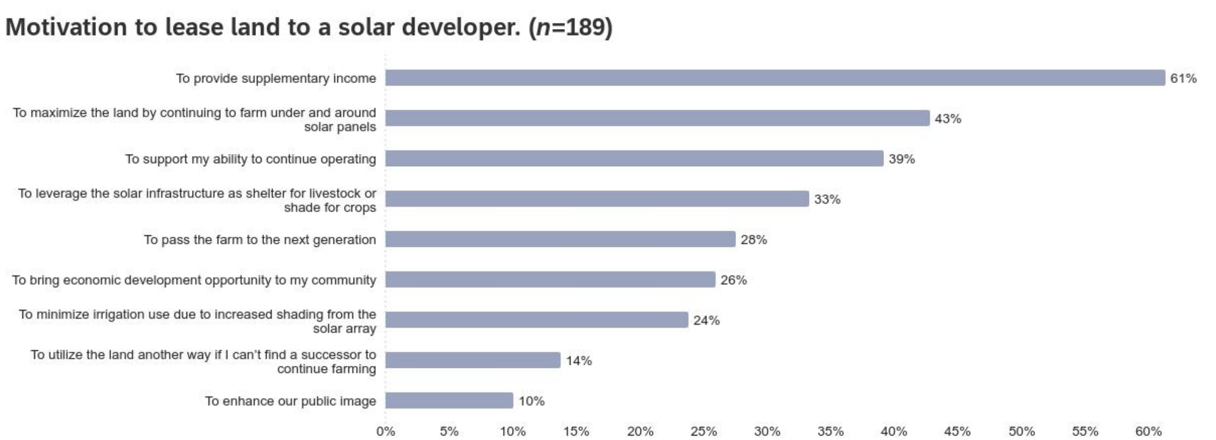
In an assessment of willingness to engage in agrivoltaic activities, trends in responses varied based on the type of agricultural activity and the necessity to involve equipment in the operation. Producers are least likely to engage in agrivoltaic operations that involve combines and large equipment (71%=No) but are most likely to engage in other agricultural activities like raising livestock (65% = Yes or Possibly), or hosting apiaries within the solar array (57% Yes or Possibly). Producers are split on willingness to engage in other activities such as navigating tractors (48% =Yes of Possibly), grazing sheep (50%=Yes or Possibly), or growing food crops (48% Yes or Probably); where the latter two have been implemented regularly across Colorado and other states.

Select producer quotes in response to this question: *"Which of the following considerations would apply to hosting a solar project on your land to generate electricity for off-farm/ranch consumption? (Please check all that apply)"*

- "Vertically mounted solar panels could provide cross fencing for intensive rotational grazing on all qualities of land."
- "I'm mostly interested in doing my own on-farm energy production, storage, and consumption."
- "I use solar for power for irrigation on my land."
- "I would need more info on the actual impacts on the land, the ability to farm around the panels, and actual income from solar farming"

- "We currently have a large amount of solar panels on the property. They came with the property when we purchased it. The amount of energy they produce is not even worth the damage to the environment from the materials collected to make the panels and they are toxic waste when they get to the end of their life cycle."
- "I utilize some small solar tools and love them. Electric fence solar chargers and solar to keep water troughs thawed. Beyond that, large-scale solar is too cost-inefficient and has severe environmental consequences to ecosystems. Recycling is also environmentally damaging and we are reliant on China for the supply of solar goods. Mining of rare earth minerals has a huge carbon footprint. We need a mix of energy, coal, natural gas, hydro, nuclear, hydrogen, solar, and wind. No single source of energy should be preferably subsidized and should stand on its own."
- "An outside solar developer would have to assure the local community that the power generated by the project will be utilized locally, and that a portion of the revenue stream supports the LOCAL economy. I think the days of exploitative energy (i.e. natural gas fields, oil drilling, etc.), which have left local communities high and dry, are over. We should not set up a similar structure with solar and other renewable energy projects."

Motivation to lease land to a solar developer.



Analysis of the motivations for leasing lands to solar developers also reveals an interplay of economic drivers paired with long-term farm viability considerations. The opportunity for solar to provide supplementary income is the top motivation to lease land for solar development, while maximizing the land use, and supporting the ability to continue the current operation are secondary motivators. However, fears noted by the respondents include land degradation, long-term financial viability, and ecological impacts of solar installations. This indicates that while economic benefits are persuasive, they should be coupled with assurances of environmental stewardship and long-term farm viability.

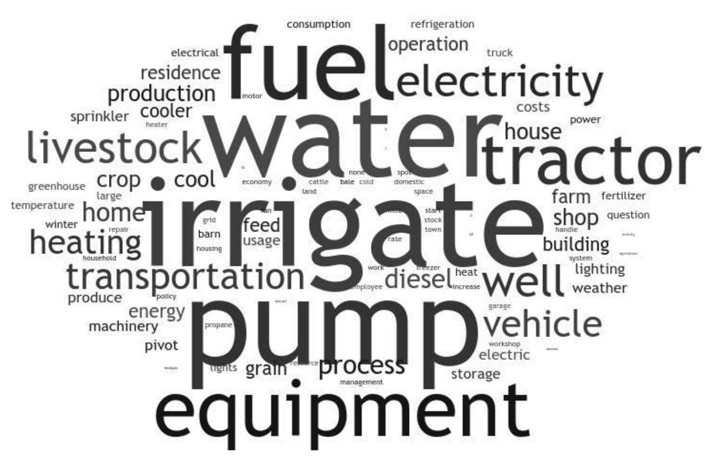
One respondent explained this sentiment: "Most every farm/ranch has less desirable farmland that may be a good fit for solar. Proper planning processes should be done, which includes working with knowledgeable stakeholders, such as local Conservation Districts, Extension specialists, and others that will properly guide landowners and solar companies, to find the best alternatives or NO options found at each operation."

Further, findings indicate producers are unsure about the upfront costs and the reliability of the long-term benefits (financial, environmental) of agrivoltaics over time. Respondents expressed a need for clear and accessible information about the financial logistics, and legal agreements when considering agrivoltaic projects.

- "If I could run the same amount of cattle on a SMALL portion of my land, if there were proven benefits of shade for grass and animals, and use that energy for my ranch it might be a consideration."
- "None. Solar and Wind projects are littered with hype and promises. They pose real issues for landowners and local communities when they reach end-of-life."
- "We will never ever ever lease our land to solar. It damages the land and creates too much radiant heat which damages the natural microclimates."
- “Conservation easement”
- "It is too long a term to contract for use of my land, based on my age"
- "Reputation and experience of developer"

On-farm energy Consumption

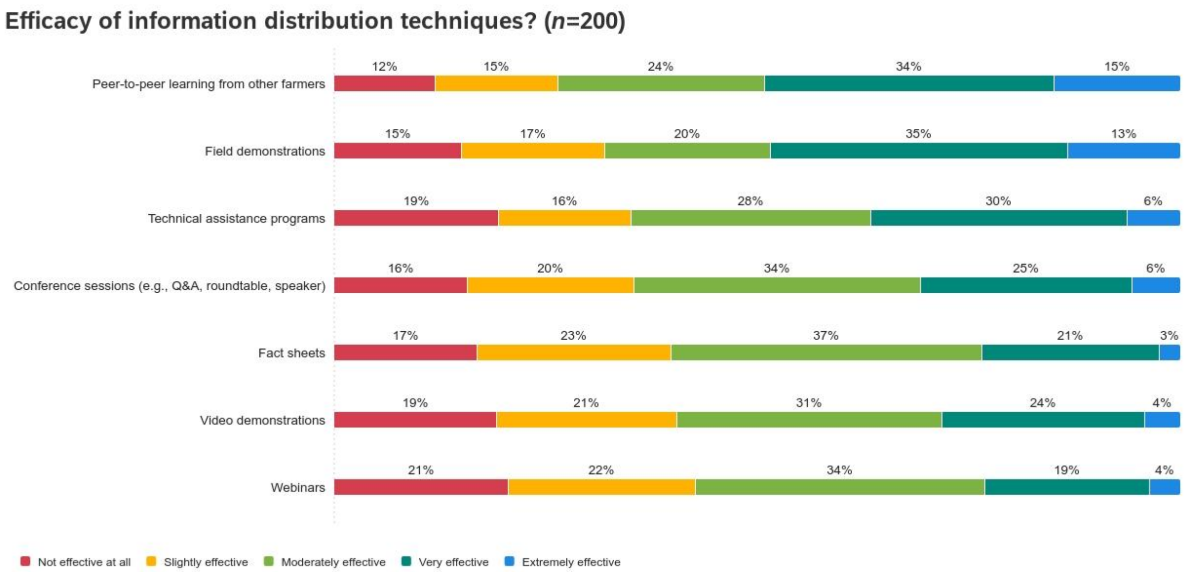
Top 3 drivers of on-farm energy consumption. (*n*=146)



In a qualitative analysis of the on-farm energy consumption, the word cloud visualizes trends in free responses. Irrigation, water, pump, fuel, and equipment were the top responses indicating that there is an opportunity to increase energy efficiencies and introduce renewable energy production to offset consumption in these key areas.

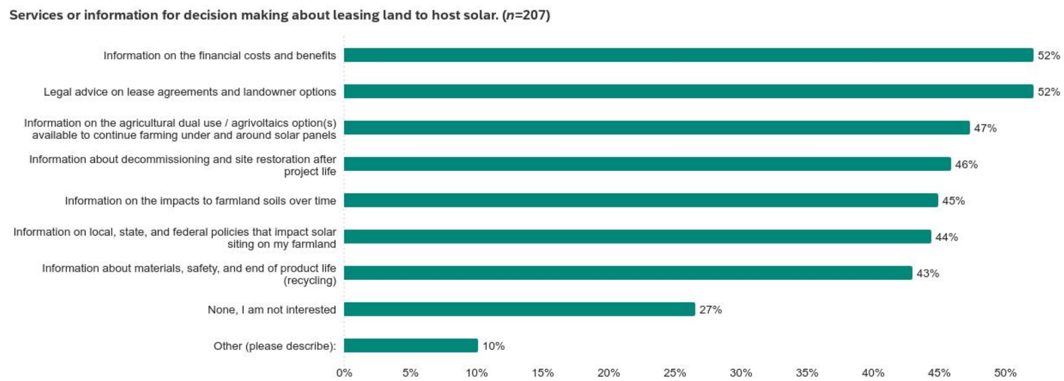
Information About Agrivoltaics

Information & Outreach Techniques



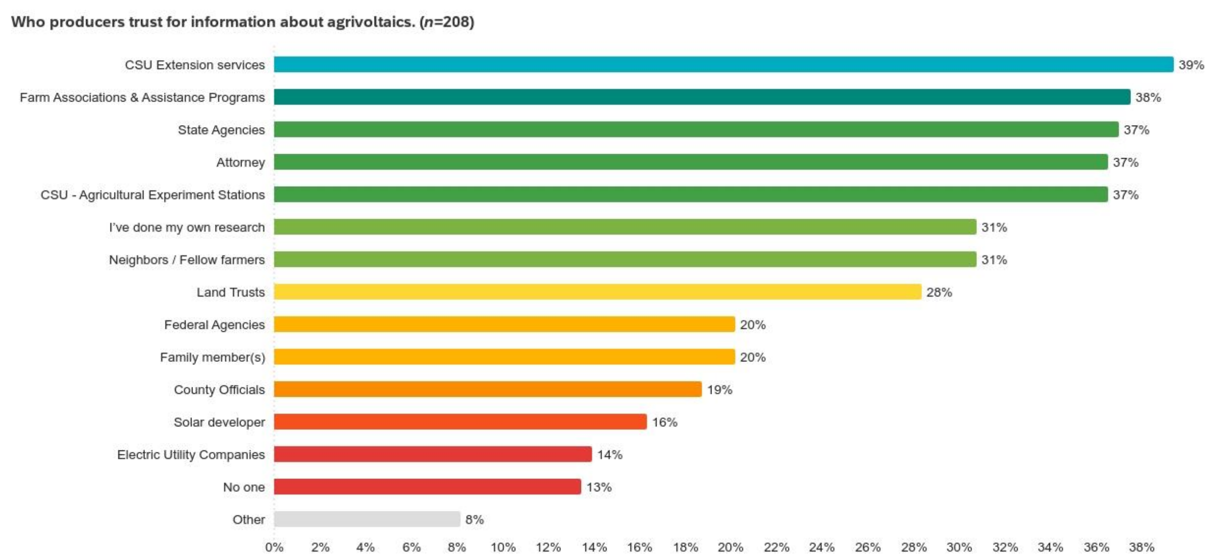
Effective and accessible information is critical to the adoption and implementation of agrivoltaic systems. These findings demonstrate that farmers prefer learning through field demonstrations, and peer-to-peer learning, and also find conference sessions and fact sheets to be effective means of information distribution. These preferences should guide the development of targeted information distribution strategies that address the diverse needs and concerns of the agricultural community.

Information and services for decision-making



Producers indicate that information about financial costs and benefits (52%) along with legal advice related to lease agreements and ownership (52%) are the most important when making decisions about leasing land for solar development.

Who do farmers trust for information?



This graph highlights a strong preference for traditional and established sources of agricultural information, such as extension services, farm associations, state agencies, and university-affiliated research stations. CSU extension services are the most trusted, with 82 out of 208 respondents relying on them. Similarly, farm associations, state agencies, attorneys, and CSU agricultural experimental stations each reflected confidence from 76-78 respondents. Utility companies such as Xcel are the least trusted sources.

The following quotes indicate "other" trusted sources of information:

- "Funding opportunities"
- "What happens when solar company go broke and moves on"

- "Oil and gas companies promised full remediation and restoration, but found ways to break those contracts. Information and education about how solar development contacts will be any different from past energy development schemes is needed."
- "I am interested in site-specific planning and design that would immediately offset the farmer's energy needs"
- "Information on research and development that reduces the land use impact (which is unfortunately over 75 times that of an oil pad currently)"
- "What the ecological impact is when panels have reached maximum use age and the biodegradable time, if any"

Overall, a significant portion of respondents had limited prior knowledge of agrivoltaics, with 22% never having heard of the concept and only 8% possessing a deep understanding, there is mixed support for solar projects on agricultural lands, with 41% in favor, 30% opposed, and 29% conditional on specific circumstances. Effective information distribution strategies are critical next steps, so producers may make informed decisions about agrivoltaics that they are confident in. Further, the survey findings emphasize that ensuring that information is accessible and tailored to different farm sizes and types is essential for broader adoption. To advance the appropriate deployment of agrivoltaics, the report recommends partnering with Colorado State University Extension and other educational institutions to create and deliver workshops, training courses, and informational materials. Establishing a dedicated technical assistance team within the Colorado Department of Agriculture to lead feasibility studies, site assessments, and project planning services is also advised.

Conclusion

The "Colorado Agrivoltaics Outreach and Engagement Project" survey, which garnered 312 responses from producers across Colorado, presents a foundation for future research, policy, and development by contributing preliminary insights concerning producer perspectives on agrivoltaics. With a robust and diverse agricultural sector that is challenged by drought, the state of Colorado is uniquely positioned to benefit from the ecological and economic advantages of agrivoltaics. The findings from this survey offer novel and actionable insights for the Colorado Department of Agriculture and other key stakeholders in the state to advance the deployment of agrivoltaics in a manner that reflects the interests, needs, and concerns of the agricultural community.

Quotes from the survey:

In general, do you support siting solar projects on agricultural land in CO? It depends:

- "The areas possibly suitable are typically very, very remote.. who is going to be RESPONSIBLE for clean up? The bond posted today will not even come close in the future.. Don't fool yourself" Financial concerns and responsibility- who will take care of the solar on the farm
- "I do not support solar projects on most large, rural plots of agricultural land. However, in the case of land that is located within, near, or adjacent to a municipality and that is not degrading contiguous wildlife habitat and productive range. I believe it is a beneficial land use."
- "If it is up to the private property owner yes. Never by govt force."
- "I believe that those in agriculture who want a solar project on their land should have the opportunity to investigate and accept or refuse that opportunity. I am most concerned that the initial disturbance of the land during construction might not be mitigated to the owner's satisfaction and that there would be little if any legal remedy. Electric companies are notorious for this."
- "San Miguel County serious issue w BLM section of generational leased land. Big water issue amongst others"
- "I am 100% in support of small-scale solar, such as rooftop panels and discreet setups for personal use by landowners. And I am nearly equally as opposed to large-scale solar projects that industrialize the natural landscape Colorado is known for and disrupt the fragile ecosystems"
- "Dryland pasture is a fragile environment that is wholly dependent on natural moisture to produce enough grass for cattle to graze. any disturbance of the land could take years to recover."

Please indicate whether you think solar developers should be allowed to site solar projects to generate electricity for off-farm/ranch consumption (utility-scale solar) on the following agricultural land categories throughout Colorado.

- "I had to choose "it depends" for all questions because you didn't draw any distinction on size. There's a difference between a land owner putting up solar panels for personal use and selling any excess at peak times back to the grid, and a major industrial application of panels covering hundreds of acres. I would even dare say there are suitable, barren locations in the state for the latter... It's just not near communities, wildlife habitats, tourist destinations, and scenic routes."

- "Put them in town"
- "Colorado can't afford to lose any more farm, ranch, and habit. There is plenty of surface area that can be utilized in cities that have 0 production or habitat value." parking lots
- "This is oil, gas, and minerals all over again. Colorado gets hit with sexy win-win ideas for farmers to sell off or lease land for natural resource extraction. The quick buck makes it worse. While solar is at least not a fossil fuel, the infrastructure will age and leave us wondering why we ever allowed this in a few decades. Our farmland here is absolutely hammered by oil and gas wells, and now an increasing amount of solar farms. Both make the farmer money today, but kill the farm tomorrow. I don't want to see my community overrun by another boom-bust idea that our kids will regret we dove into."
- "The scope of solar projects in rural areas is not acknowledged by politicians, local governments, adjacent landowners, nor the project land lessee. Rural Colorado cannot deal with the scope of construction traffic, construction workers, and maintenance workers after the project is completed. Nor is the land capable of recovery from the construction disturbance and maintenance traffic."
- "Most every farm/ranch has less desirable farmland that may be a good fit for solar. Proper planning processes should be done, which includes working with knowledgeable stakeholders, such as local Conservation Districts, Extension specialists, and others that will properly guide landowners and solar companies, to find the best alternatives or NO options found at each operations."
- "Usable land can be enhanced with careful and planned use. Just putting solar on farmland, whether or not it is usable, being used, or unusable in order to provide a product to non-farming areas must be approached with much consideration of "don't put that in my backyard" except it would be in their backyard."
- "I think adding in solar panels into any system will have negative consequences to the ecology, but may benefit society"
- "In general, if the addition of a solar development will maintain or increase the productivity of the ground it is sited upon, or potentially make use of underutilized or fallow ground, all without negative impact on wildlife/broader ecology, I support it."

<u>Climate</u>

- "With the influx of people into the state of Colorado...we are seeing people leave the cities and move into our small quiet towns bringing all their city problems with them. Agricultural land is being lost to growth!"
- "What does this question have to do with agrivoltaics? We have dealt with and adapted to weather events, drought, monsoons, blizzards, etc., along with a growing population

and continue to be viable, provide food for others, live in harmony with wildlife, and keep the prairie grasslands open and beautiful. Agriculture has become a scapegoat for global warming enthusiasts."

- "Extreme weather events (including drought) and climate changes (temperature fluctuations) come and go. Urban growth and the "Green Energy" mandates with their associated projects and infrastructures are a greater impact on the future operations of rural Colorado agriculture."
- "A good manager continually adapts to both weather and climate."

Which of the following considerations would apply to hosting a solar project on your land to generate electricity for off-farm/ranch consumption? (Please check all that apply) Other:

- "Vertically mounted solar panels could provide cross fencing for intensive rotational grazing on all qualities of land."
- "I'm mostly interested in doing my own on-farm energy production, storage, and consumption."
- "I use solar for power for irrigation on my land."
- "I would need more info on the actual impacts on the land, ability to farm around the panels, and actual income from solar farming"
- "We currently have a large amount of solar panels on the property. They came with the property when we purchased it. The amount of energy they produce is not even worth the damage to the environment from the materials collected to make the panels and they are toxic waste when they get to the end of their life cycle."
- "I utilize some small solar tools and love them. Electric fence solar chargers and solar to keep water troughs thawed. Beyond that, large-scale solar is too cost-inefficient and has severe environmental consequences to ecosystems. Recycling is also environmentally damaging and we are reliant on China for the supply of solar goods. Mining of rare earth minerals has a huge carbon footprint. We need a mix of energy, coal, and natural gas, hydro, nuclear, hydrogen, solar, and wind. No single source of energy should be preferably subsidized and should stand on its own."
- "An outside solar developer would have to assure the local community that the power generated by the project will be utilized locally and that a portion of the revenue stream supports the LOCAL economy. I think the days of exploitative energy (i.e. natural gas fields, oil drilling, etc.), which have left local communities high and dry, are over. We should not set up a similar structure with solar and other renewable energy projects."

Motivation for leasing land to a solar developer:

- "If I could run the same amount of cattle on a SMALL portion of my land, if there were proven benefits of shade for grass and animal, and use that energy for my ranch it might be a consideration."
- "None. Solar and Wind projects are littered with hype and promises. They pose real issues for landowners and local communities when they reach end-of-life."
- "We will never ever ever lease our land to solar. It damages the land and creates too much radiant heat which damages the natural microclimates."
- conservation easement
- "It is too long a term to contract for use of my land, based on my age"

Information/services that would help you make a decision to host solar on your farm in the future:

- "Funding opportunities"
- "What happens when solar company go broke and moves on"
- "Oil and gas companies promised full remediation and restoration, but found ways to break those contracts. Information and education about how solar development contacts will be any different from past energy development schemes is needed."
- "I am interested in site-specific planning and design that would immediately offset the farmers energy needs"
- "Information on research and development that reduces the land use impact (which is unfortunately over 75 times that of an oil pad currently)"
- "What the ecological impact is when panels have reached maximum use age and the biodegradable time, if any"

Plans for operation over the next 5 years:

- "We are hoping to add solar grazing to offset reducing our livestock production in order to reduce labor costs. So it's kind of a combo of diversifying and reducing."
- "If we can successfully build an agrivoltaic project with Xcel paying a reasonable amount for RECs we'll continue the farming operation. Otherwise, we'll sell out."
- "Depends if my land gets a solar lease or not."

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