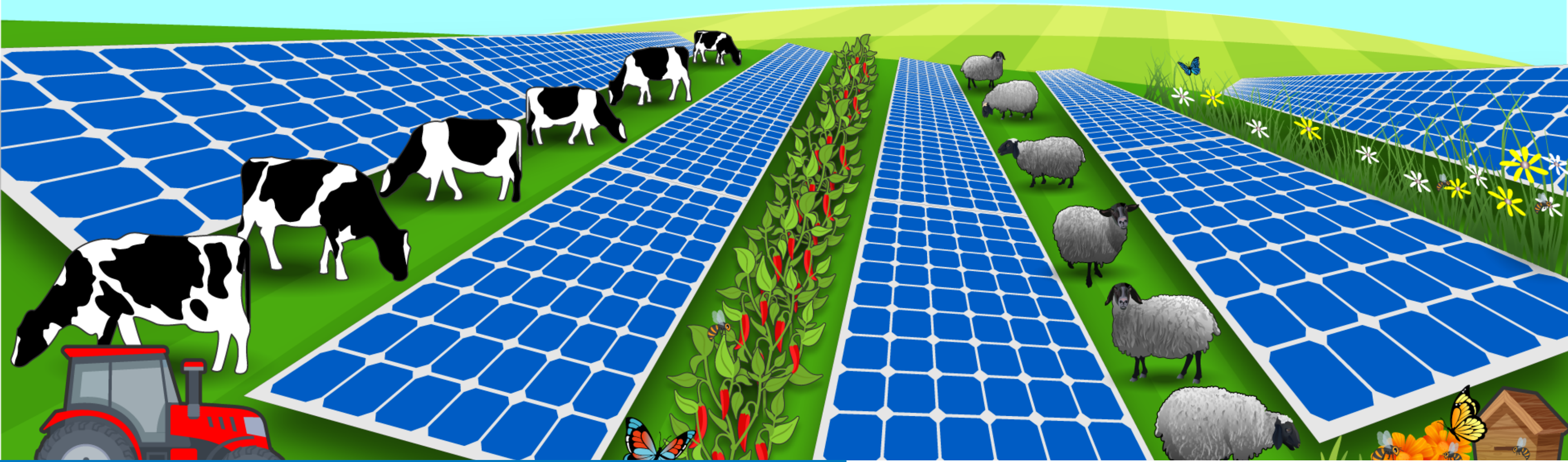
ASGA Presentation: NREL Agrivoltaics Tools

James McCall on behalf of the InSPIRE Project team

July 5th, 2023



What is Agrivoltaics?

Agricultural activities performed underneath and around solar arrays:

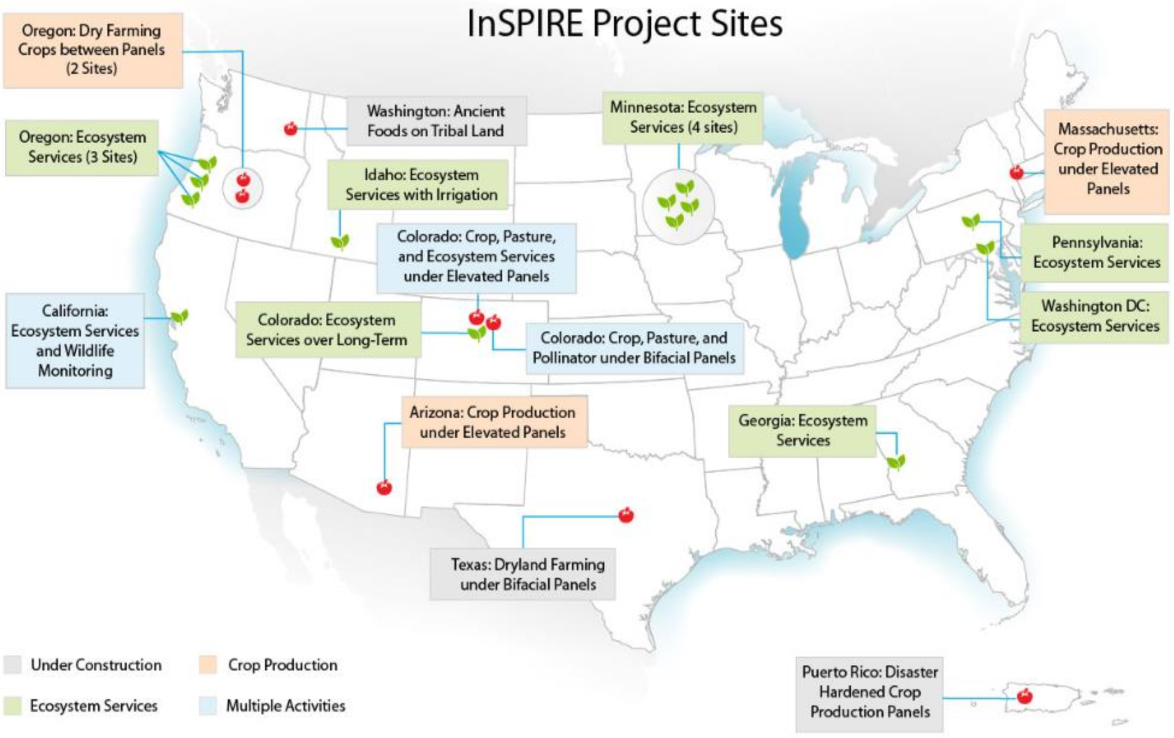
- ❖ Crop production
- ❖ Grazing
- ❖ Pollinator Habitat and Apiaries
- ❖ Solar Greenhouses

The InSPIRE Project-

Innovative **S**olar **P**ractices **I**ntegrated with **R**ural Economies and **E**cosystems

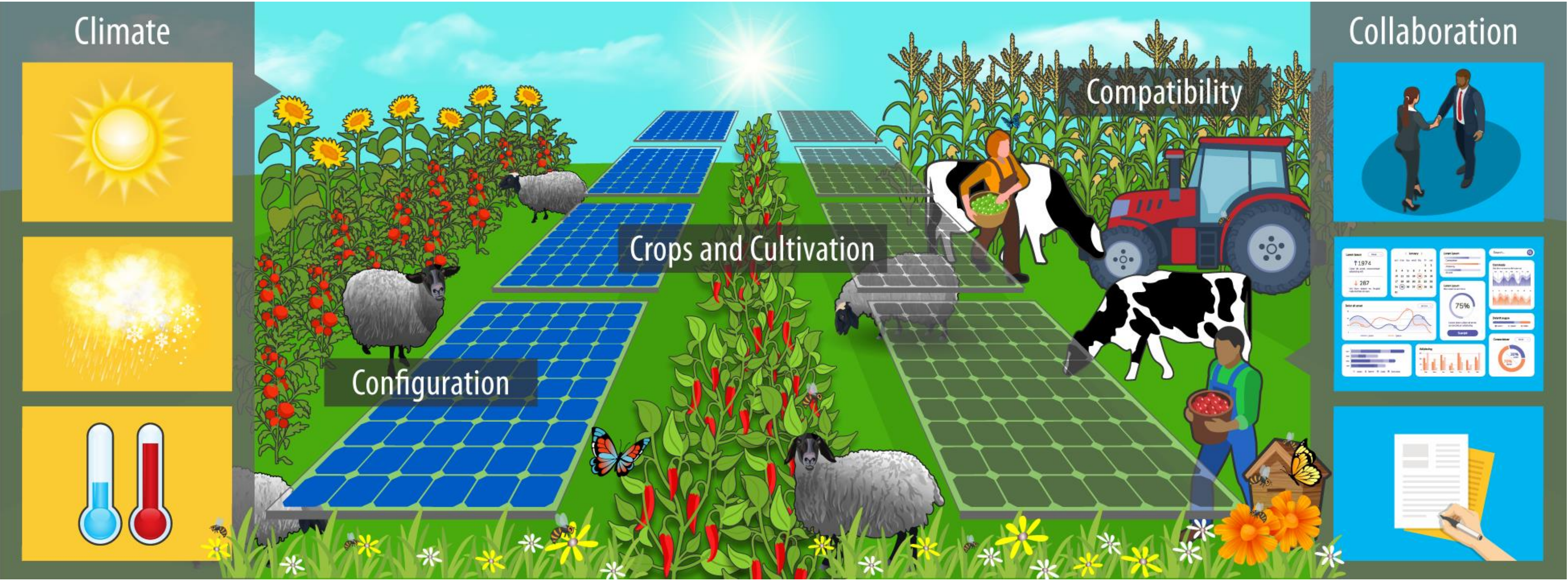
- Established in 2015
- InSPIRE has 22 active field research projects across the U.S.
- **Analytical research:**
  - Cost-benefit tradeoffs of different agrivoltaic configurations
  - Assessing research gaps and priorities
  - Tracking agrivoltaic projects across the U.S.
- **Field-based research:**
  - Novel agrivoltaic and traditional utility-scale PV designs integrated with multiple activities
  - Assessing agricultural yields and irrigation requirements in arid environments
  - Grazing standards and best practices
  - Pollinator habitat and ecological services

https://openei.org/wiki/InSPIRE



InSPIRE Project Research Sites

The 5 C's of Agrivoltaic Success



Macknick, Jordan, Hartmann, Heidi, Barron-Gafford, Greg, Beatty, Brenda, Burton, Robin, Seok-Choi, Chong, Davis, Matthew, Davis, Rob, Figueroa, Jorge, Garrett, Amy, Hain, Lexie, Herbert, Stephen, Janski, Jake, Kinzer, Austin, Knapp, Alan, Lehan, Michael, Losey, John, Marley, Jake, MacDonald, James, McCall, James, Nebert, Lucas, Ravi, Sujith, Schmidt, Jason, Staie, Brittany, & Walston, Leroy. The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons from the InSPIRE Research Study. NREL/TP-6A20-83566. https://doi.org/10.2172/1882930

Agrivoltaics Map

InSPIRE   Primer   Financial Calculator   Data Portal   Map   The 5 Cs   Research

Agrivoltaics Map

This dynamic map represents a census of agrivoltaic installations located across the United States. The map is constantly expanding as new sites are developed. If you are aware of agrivoltaic sites that should be added to the map or have a correction, please click on the "Contribute to the Agrivoltaics Map" button below.

Contribute to the Agrivoltaics Map

Displayed Results: 350

Test Filters

Agrivoltaic Activities

- [ ] Crop Production
- [ ] Habitat
- [ ] Grazing
- [ ] Greenhouse

Photovoltaic Technology

- [ ] Monocrystalline PV
- [ ] Bifacial PV
- [ ] Translucent PV

System Size MWdc

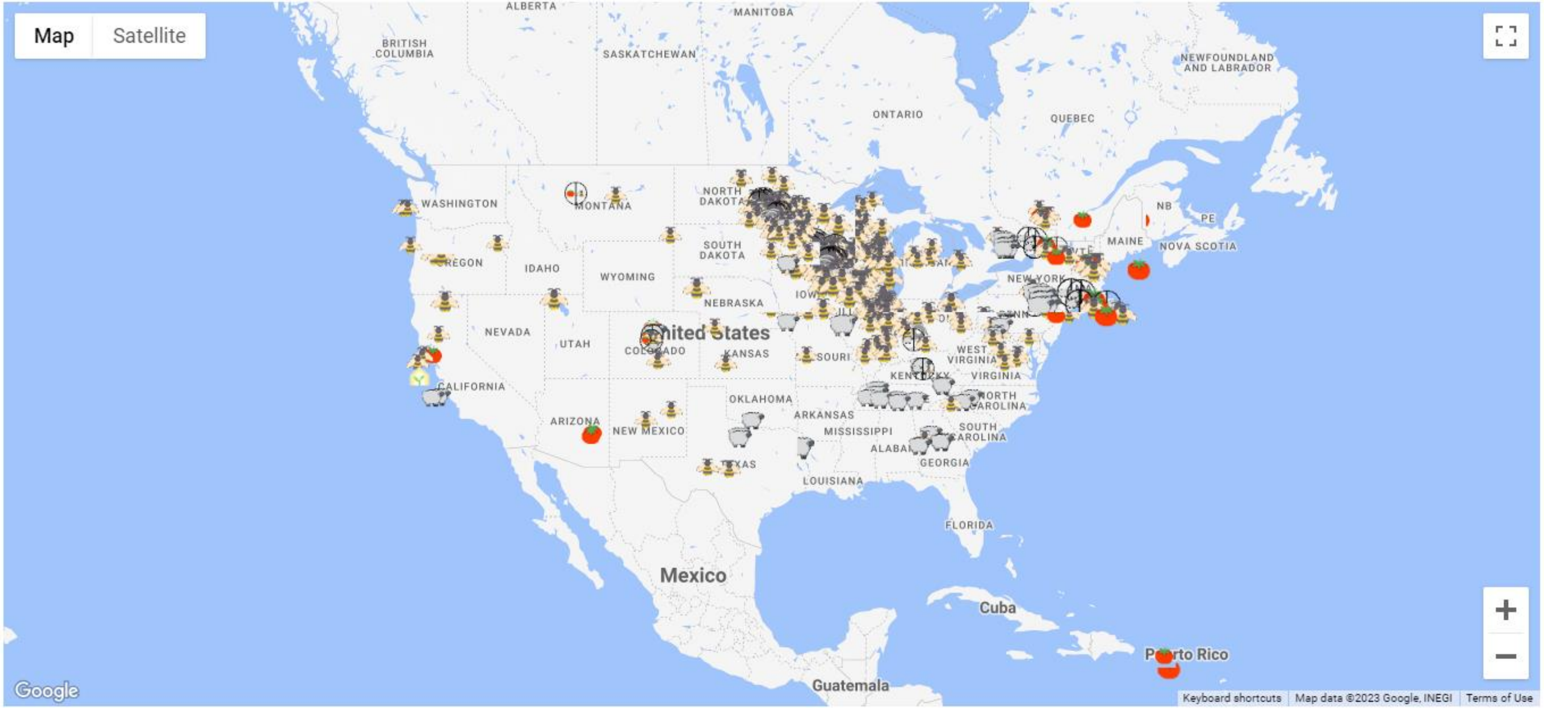
- [ ] < 1 MW
- [ ] 1-5 MW
- [ ] 5-10 MW
- [ ] >10 MW

Type of Array

- [ ] Fixed
- [ ] Single-axis Tracking
- [ ] Dual-axis Tracking

Active Research

InSPIRE Research Site



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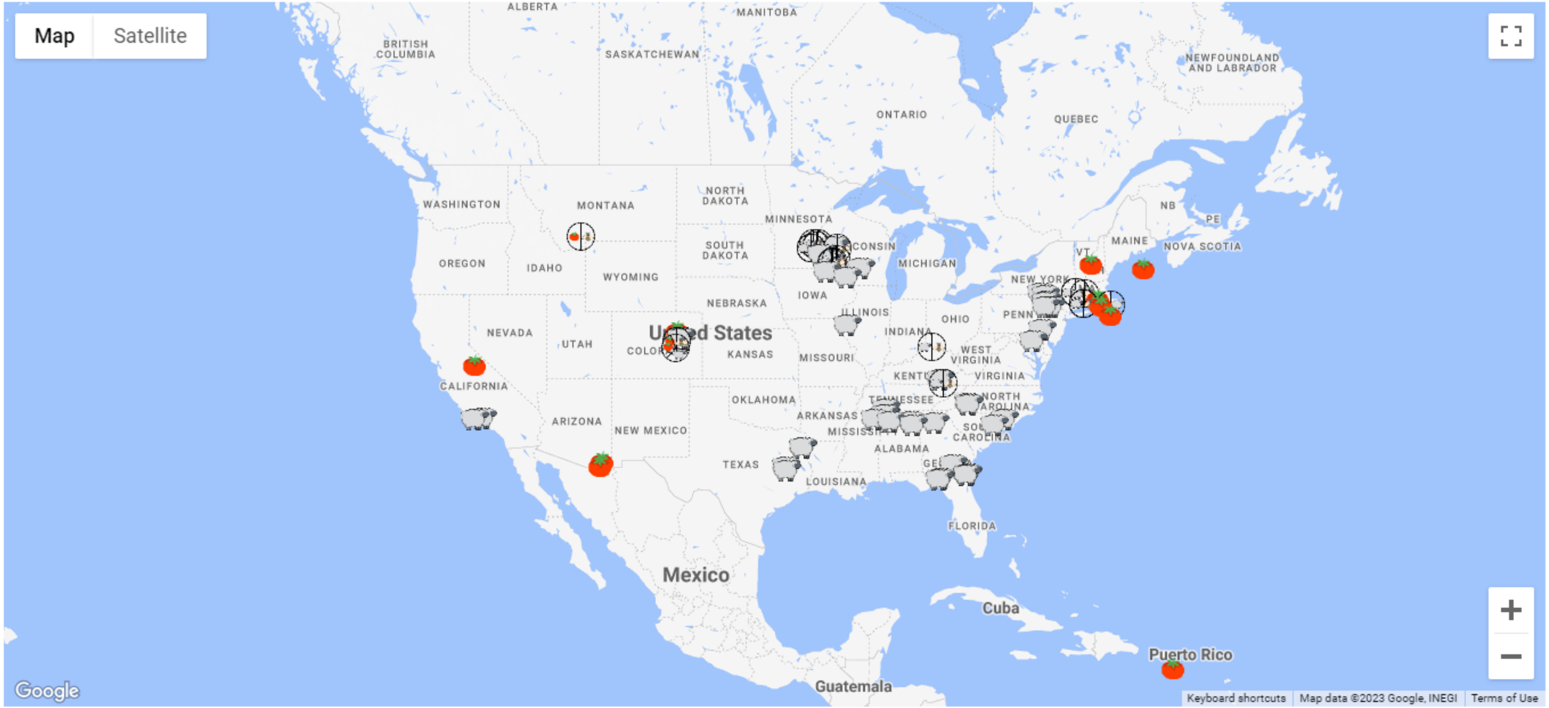

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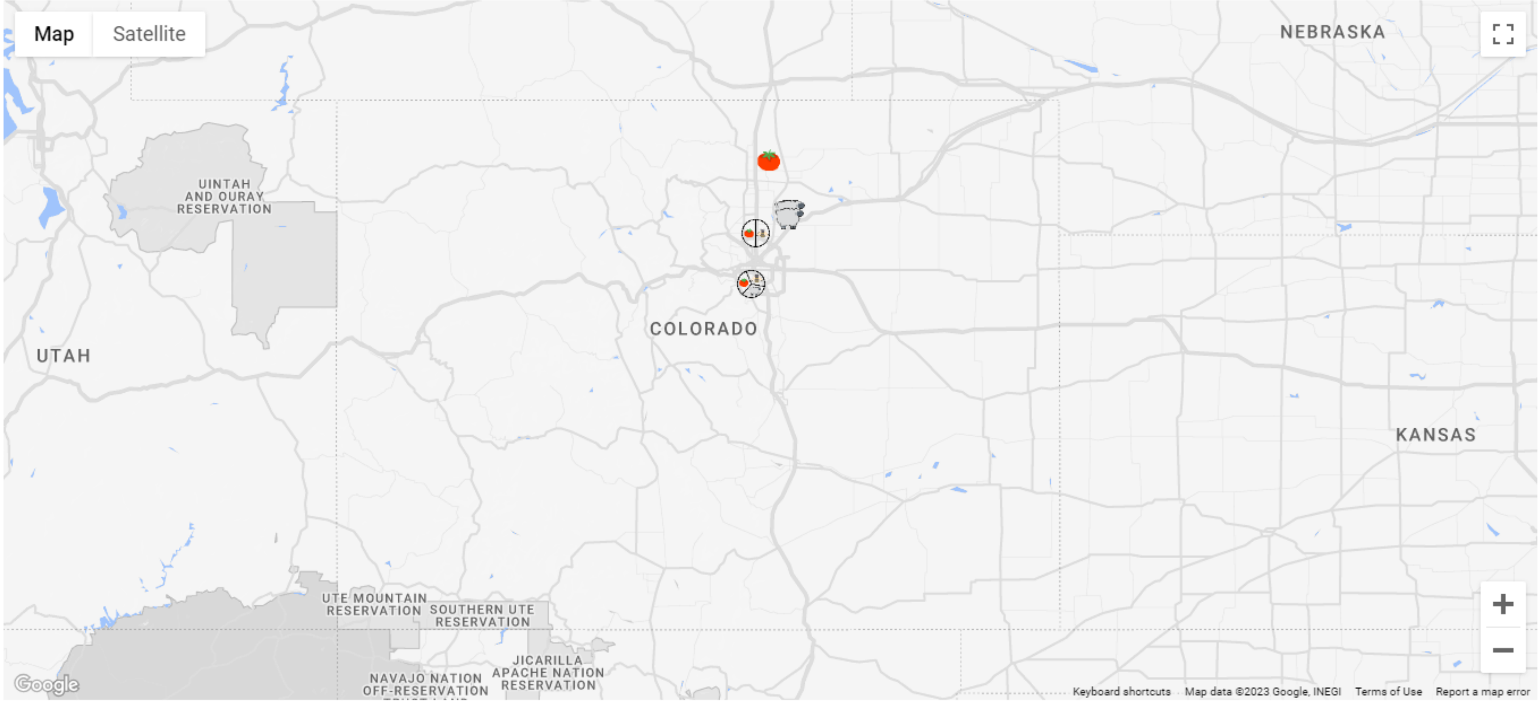

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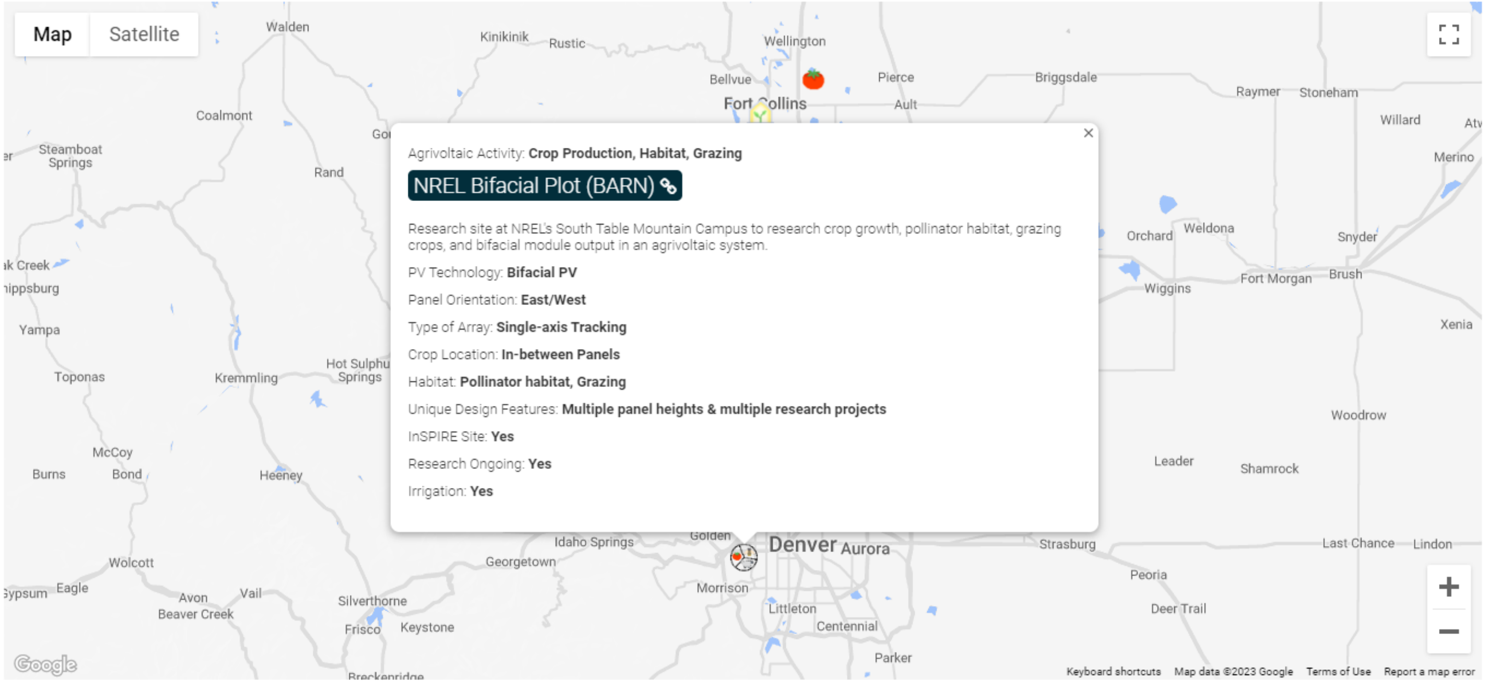

Name	Agrivoltaic Activities	System Size (MWdc)	Site Size (Acres)	PV Technology	Type of Array	Ecosystem Services	Crop Type	Animal Type	Research Ongoing	InSPIRE Site	State
A (2019)	Habitat	1.3	9.25	Monocrystalline PV	Fixed	Pollinator					MN
Abel	Habitat	2.4	17			Pollinator Friendly			No	No	IL
Agard-enfield	Grazing	2.31	4.5	Monocrystalline PV	Fixed			Sheep			NY
Agawam	Habitat	1.8	9			Pollinator Friendly			No	No	MA
Albany	Grazing, Habitat	15.23	100.8	Monocrystalline PV	Single-axis Tracking	Pollinator		Sheep			MN

InSPIRE

Primer | Financial Calculator | Data Portal | Map | The 5 Cs | Research

NREL Bifacial Plot (BARN)

Project Details

Research site at NREL's South Table Mountain Campus to research crop growth, pollinator habitat, grazing crops, and bifacial module output in an agrivoltaic system.

Project Owner	NREL
Crop Types	tomato, pepper, kale, chard, carrot, beans
Crop Location	In-between Panels
Cultivated Land	.1 Acres
Ecosystem Services	.2 Acres
Irrigation	Yes

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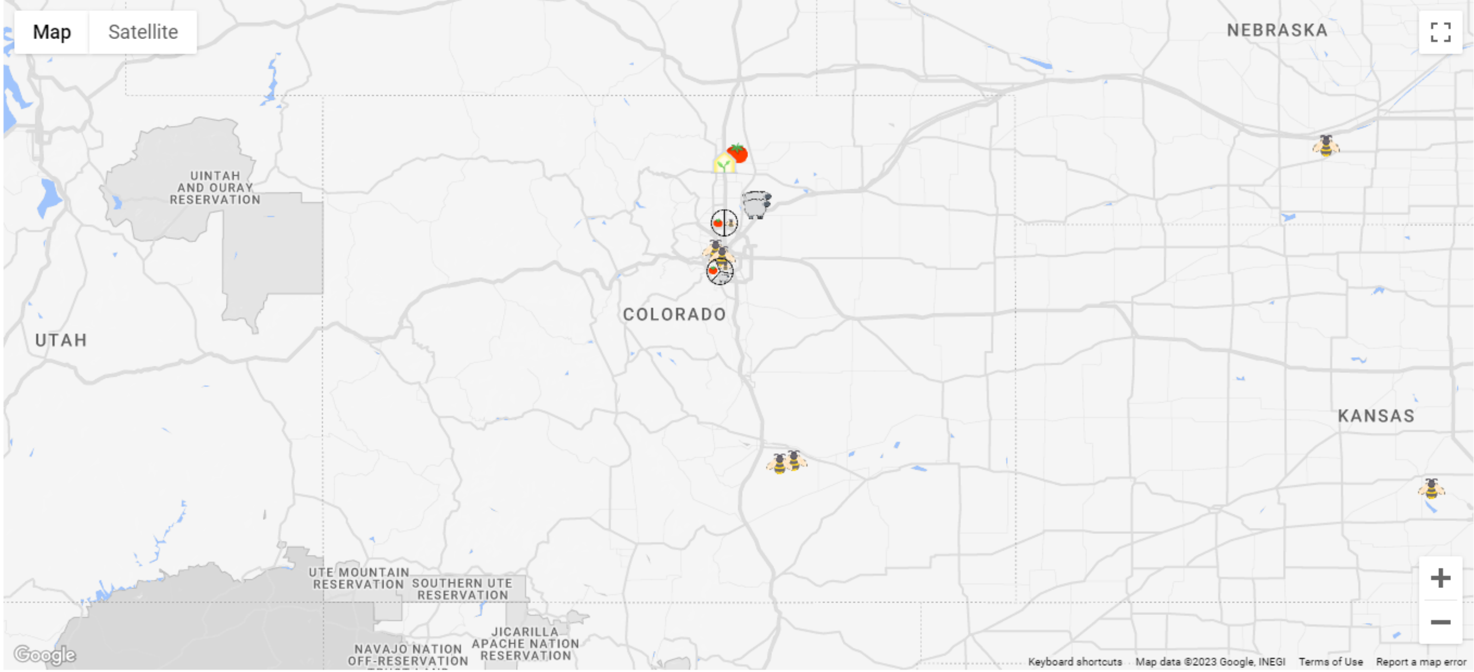

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Albany	Grazing, Ecosystem Services	15.23	100.8	Monocrystalline PV	Single-axis Tracking	Pollinator		Sheep			MN
Alburgh	Ecosystem Services	1.2	6			Pollinator Friendly			No	No	VT
Alden Road Harvard Solar 1	Ecosystem Services	2.5	15.1			Pollinator Friendly			No	No	IL
All In Solar	Ecosystem Services	1.2	8.5		Single-axis Tracking	Pollinator Friendly			No	No	MN
American Bottoms	Ecosystem Services	2.2	6			Pollinator Friendly			No	No	IL
Ames Electric Services Power Plant	Ecosystem Services	2.2	10			Pollinator Habitat					IA
Annandale	Ecosystem Services	9.14	66.22	Monocrystalline PV	Single-axis Tracking	Pollinator					MN
Anoka County Solar Project	Ecosystem Services	4.6	23	Monocrystalline PV	Fixed	Pollinator Habitat, Native Vegetation			Yes	Yes	MN
Anoka Solar	Ecosystem Services	4.08	18		Fixed	Pollinator Friendly			No	No	MN
Arcadia DPC	Ecosystem Services	6	7			Pollinator Friendly			No	No	WI
Arcadia Solar	Ecosystem Services	6	30			Pollinator Habitat					WI
Ash Ridge	Ecosystem Services	0.72	5.4			Pollinator Friendly			No	No	WI
Athens Solar	Ecosystem Services	7.92	40.3		Fixed	Pollinator Friendly			No	No	MN
Atwater - O	Ecosystem Services	5.89	26.1	Monocrystalline PV	Single-axis Tracking	Pollinator			Yes	Yes	MN
Auburn Renewables Solar Array	Ecosystem Services	14.7	55		Fixed	Pollinator Habitat			Yes		IN
B&B Solar	Ecosystem Services	1.2	6.9		Single-axis Tracking	Pollinator Friendly			No	No	MN

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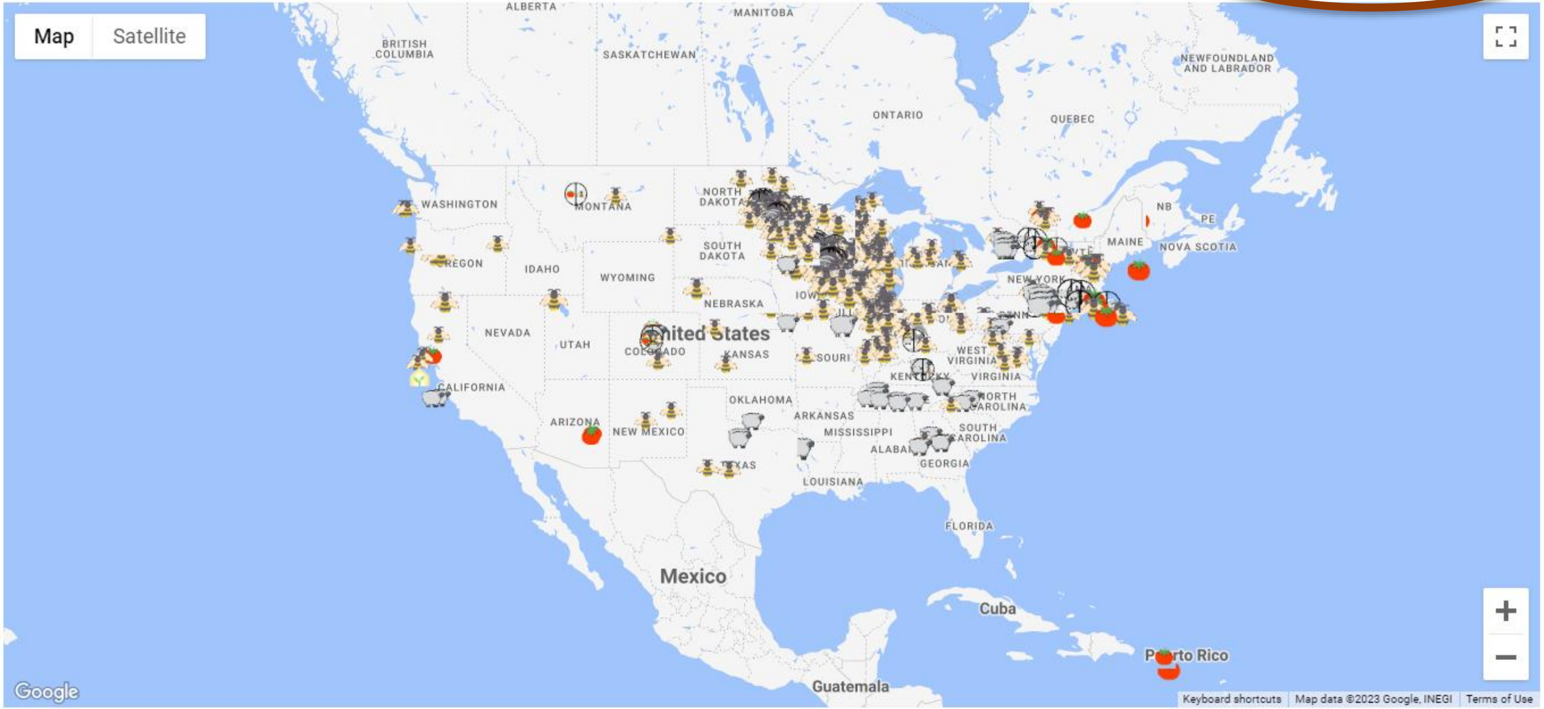
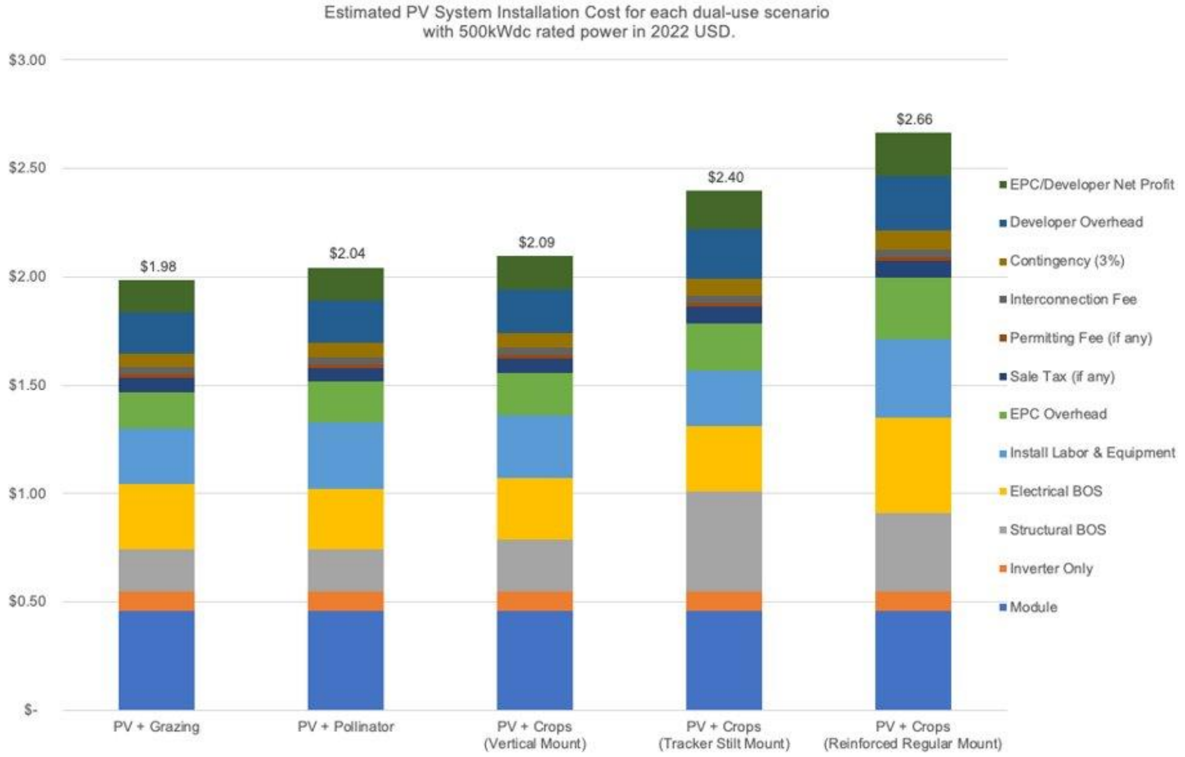


Financial Calculator

Cost Factors to Consider for Agrivoltaics

- Capital Cost Considerations
  - Module type and equipment
  - Panel height
  - Racking/Tracking system
  - Land acquisition costs
  - Installation labor costs
  - Site preparation costs
  - Risks



Results are for 500-kW systems. Results can vary at lower and higher installed capacities

Kelsey Horowitz, Vignesh Ramasamy, Jordan Macknick and Robert Margolis. 2020. *Capital Costs for Multi-Land Use Photovoltaic Installations*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77811
https://www.nrel.gov/docs/fy21osti/77811.pdf

CAPEX Scaling

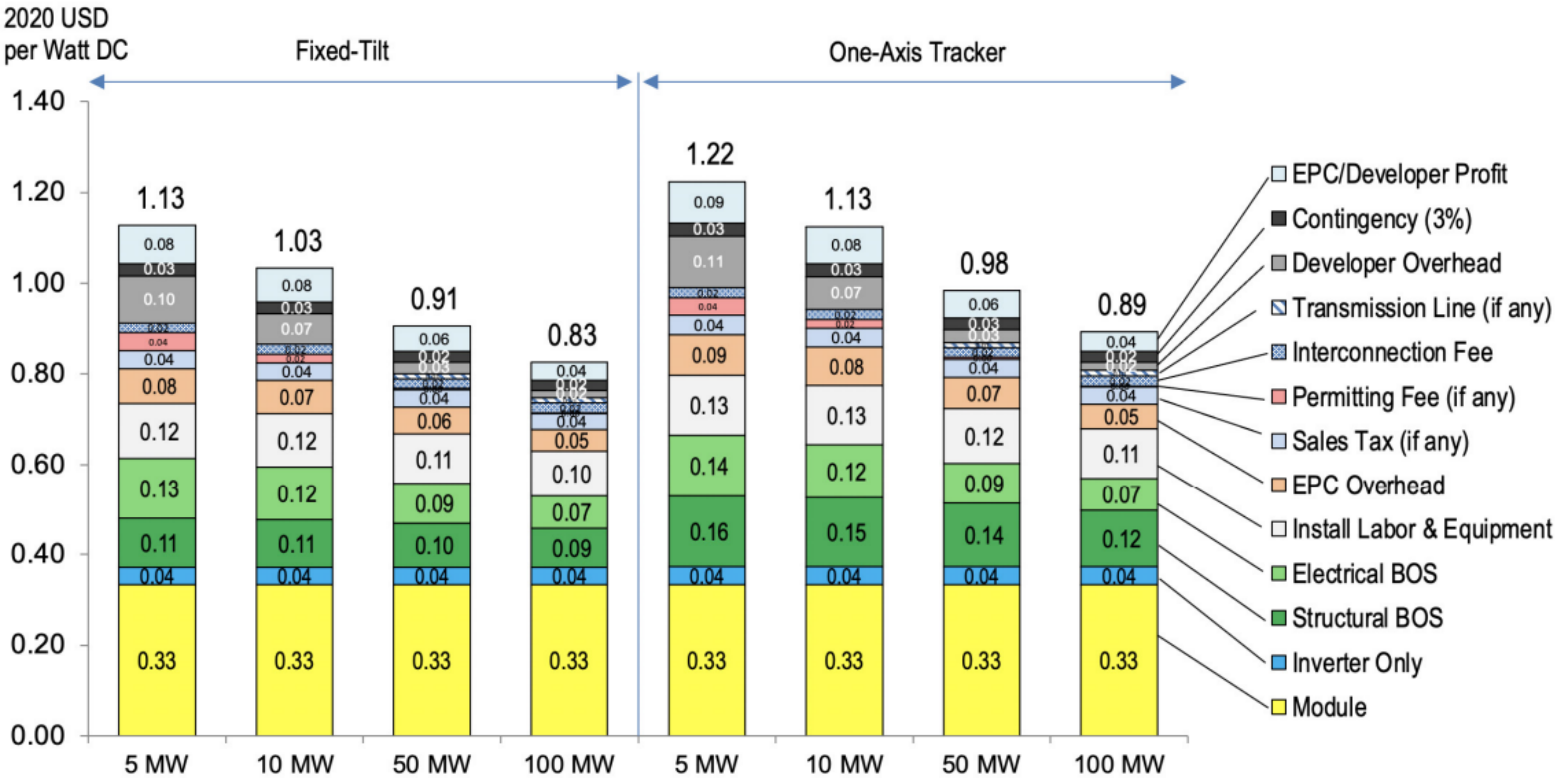
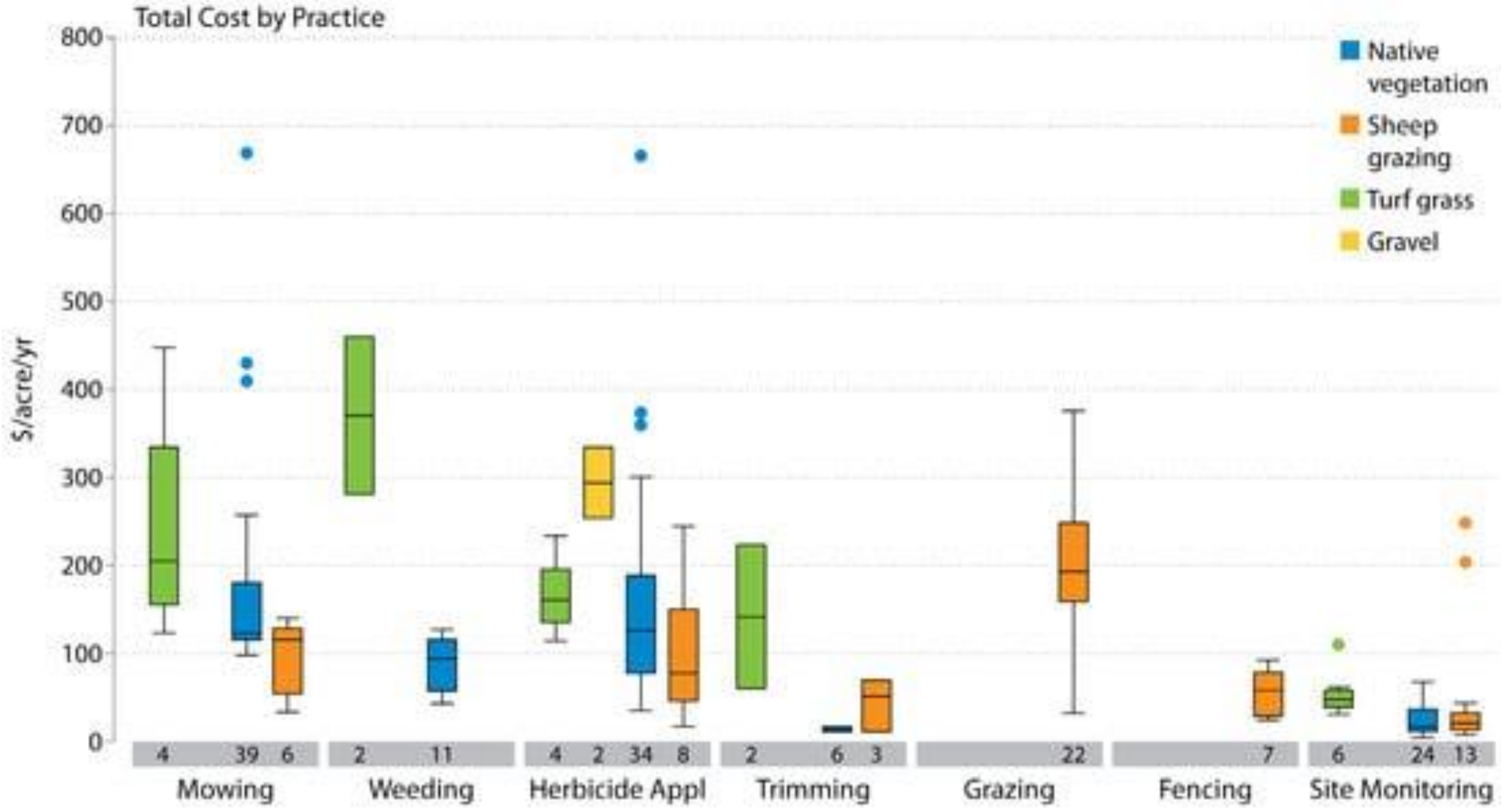


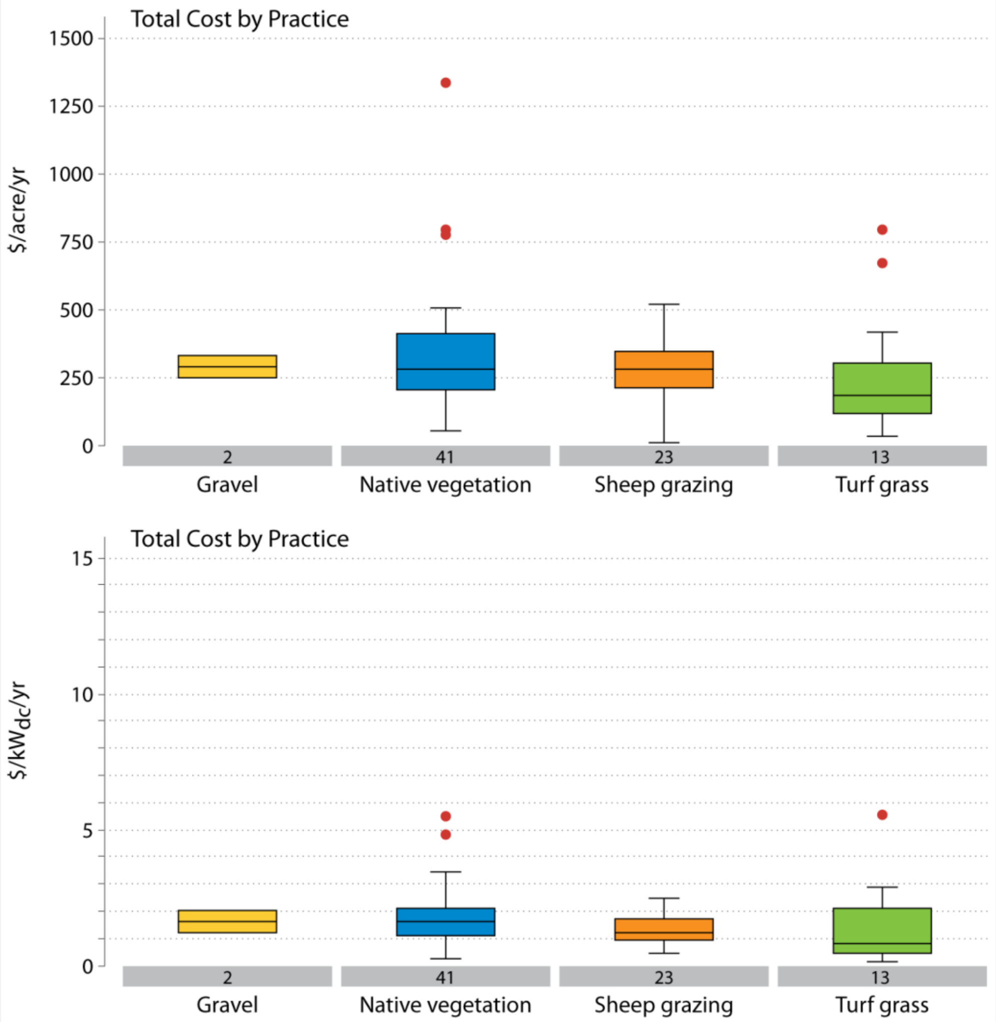
Figure 11. Q1 2021 U.S. benchmark: Utility-scale PV total cost (EPC + developer), 2020 USD/W$_{DC}$

Vegetation O&M cost by activity and ground cover



Source: McCall et al. 2023 https://www.mdpi.com/2071-1050/15/7/5895

Total O&M Cost by Practice

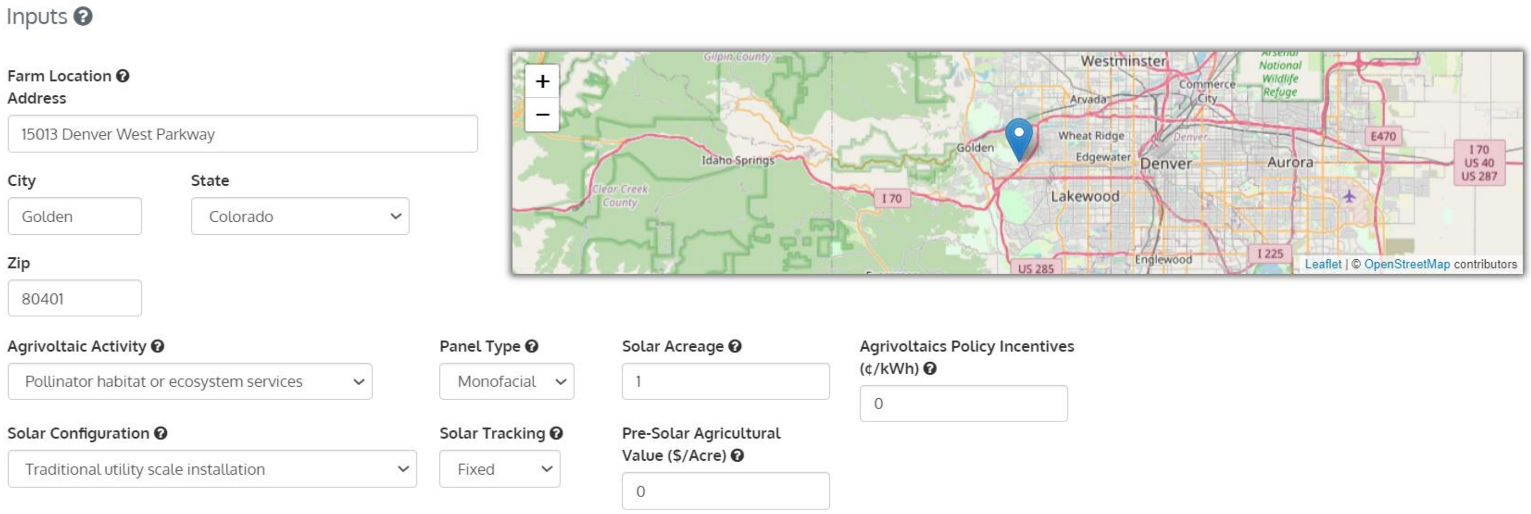


Source: McCall et al. 2023 https://www.mdpi.com/2071-1050/15/7/5895

More variation of O&M costs for native vegetation and turf grass, but all costs are comparable

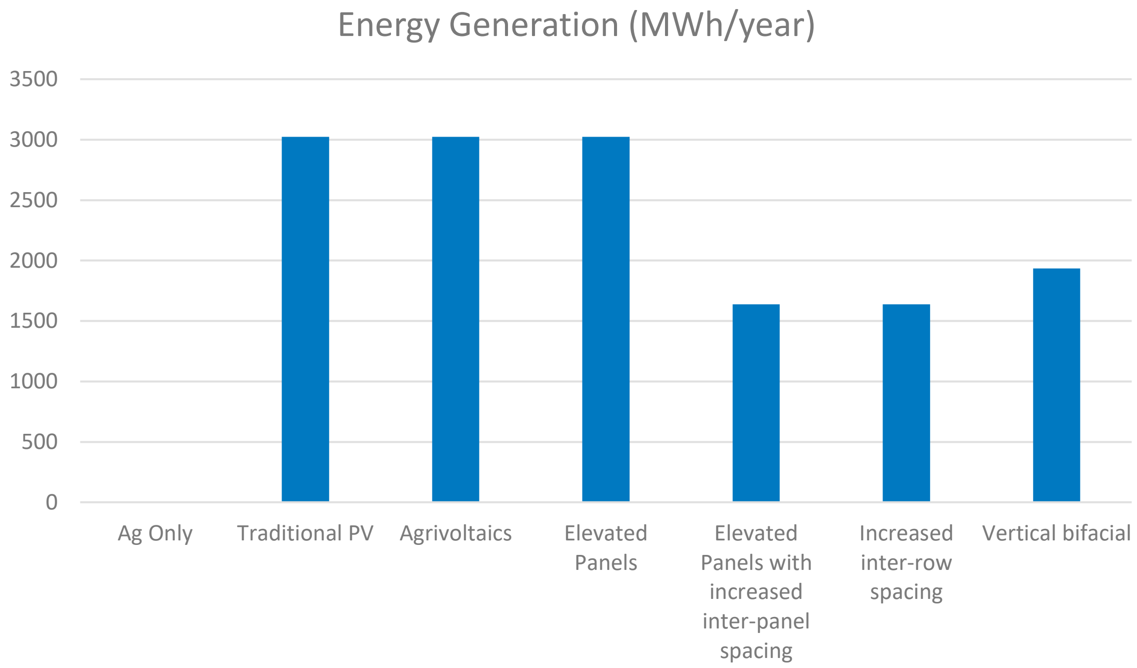
InSPIRE Agrivoltaics Financial Calculator

The InSPIRE financial calculator (https://openei.org/wiki/InSPIRE/Financial_Calculator) serves as the starting point for calculating economic viability of agrivoltaic projects

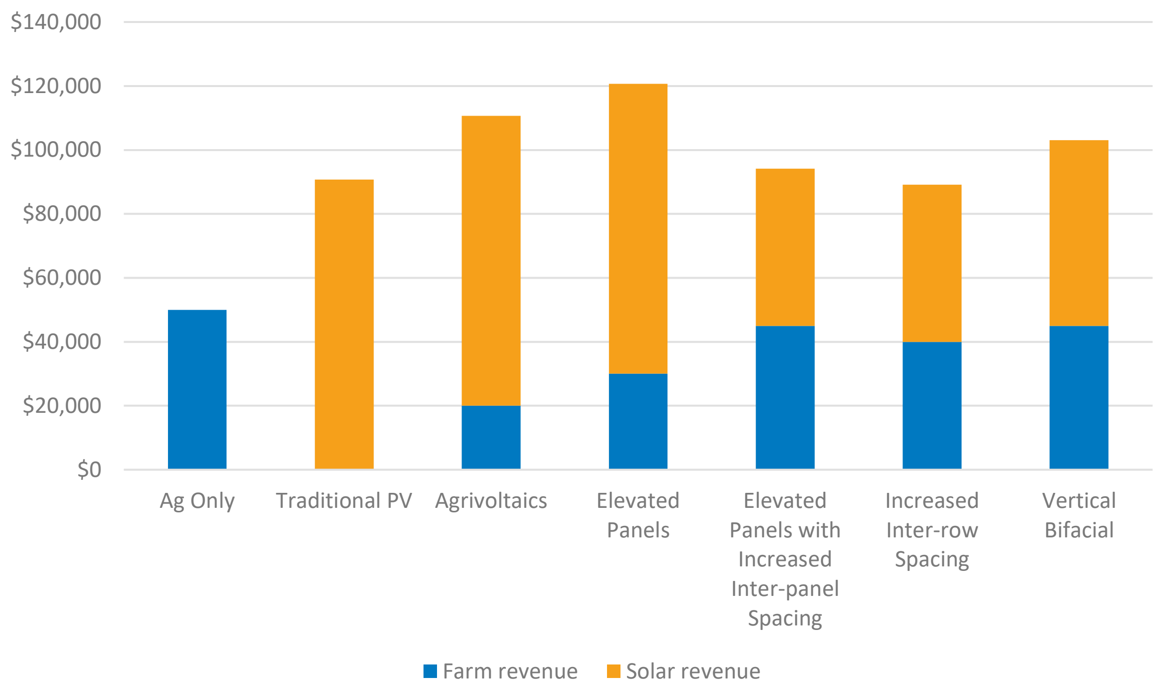


- Adapts available tools (e.g., System Advisor Model [SAM]) plus latest data (e.g., capital cost and O&M studies) for easy-to-use, online co-location techno-economic assessment tool
- Public-facing tool is customized for farmer use, but can also provide developers with validation and verification tools
- User answers set questions that feed inputs into SAM API that calculate performance and economic metrics
- Additional capabilities and customization available in non-public-facing version

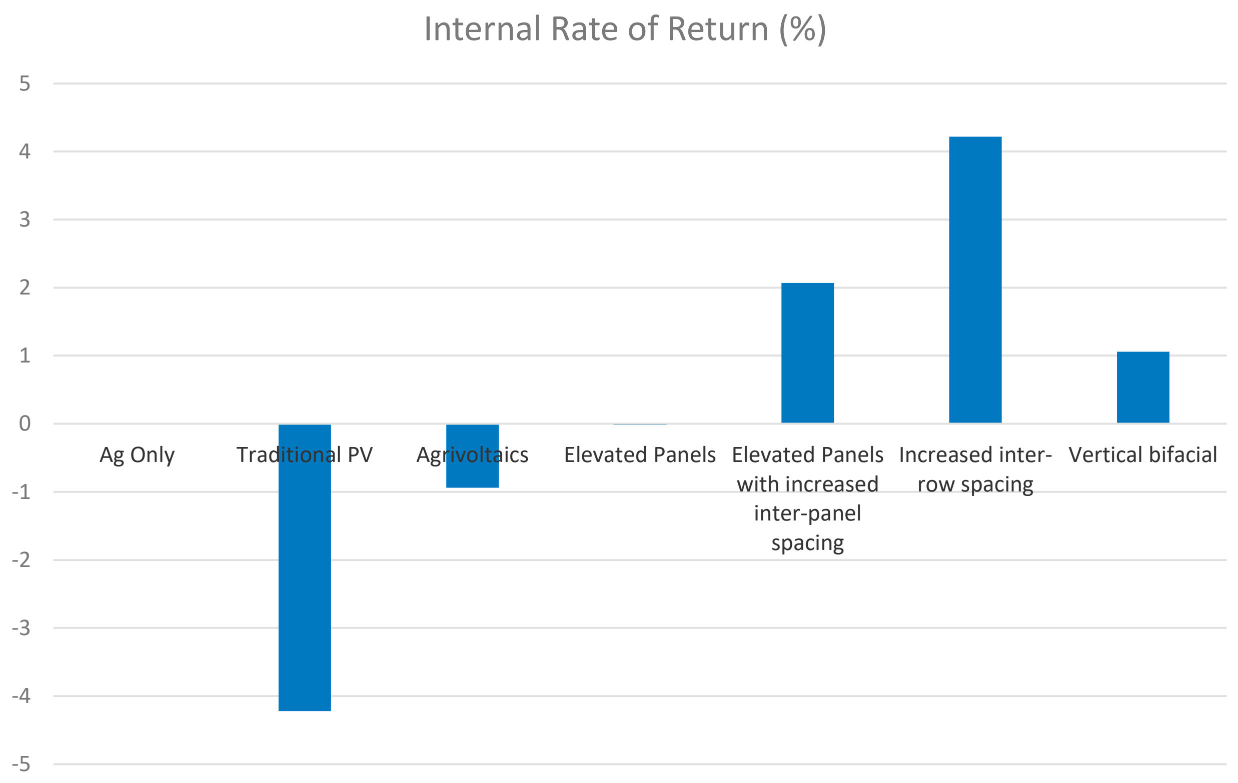
Comparison – Energy Generation



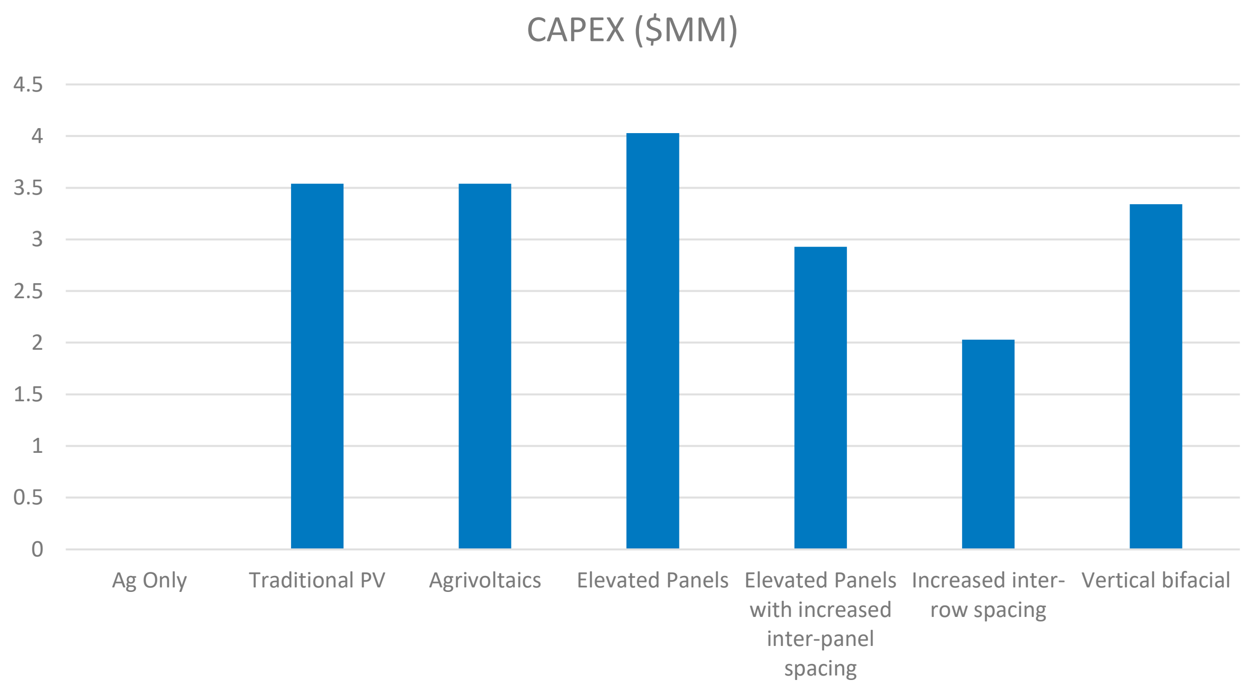
Comparison – Revenue per year



Comparison – Internal rate of return



Comparison – Solar Install Cost



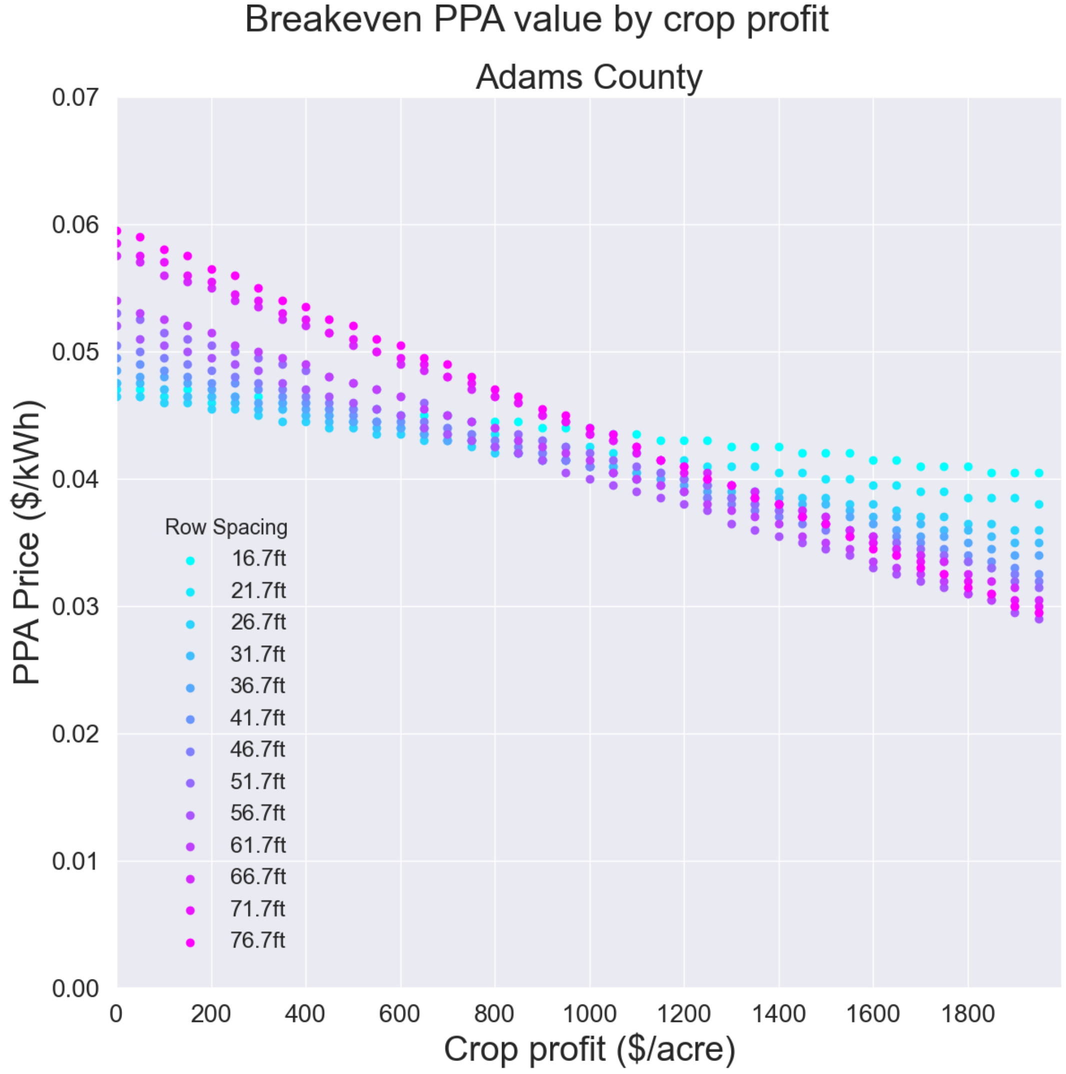
Row spacing, PV capacity, and agricultural production and revenue estimates

	Potatoes	Onions	Sugarbeets	Winter Wheat
PV Capacity (% capacity per acre compared to normal)	100%	100%	59%	28%
PV Row spacing (panel edge to panel edge within a row)	12 ft	12 ft	33 ft	67 ft
PV Capacity (MW) on a 100 acre field	16.9 MW	16.9 MW	10.0 MW	4.75 MW
Agricultural Production Ratio (% usable land per acre compared to normal)	67%	67%	80%	90%
Traditional Farm Yield per acre (average cwt per acre, no agrivoltaics)	399	448	33	38
Agrivoltaic Farm Yield per acre (average cwt per acre, given this agrivoltaic configuration)	267	300	26	35
Traditional Farm Revenue per acre ($/acre/yr, no agrivoltaics)	$4,278	$9,190	$1,016	$180
Agrivoltaic Farm Yield per acre ($/acre/yr, given this agrivoltaic configuration)	$2,866	$6,157	$813	$162

Breakeven PPA price by spacing

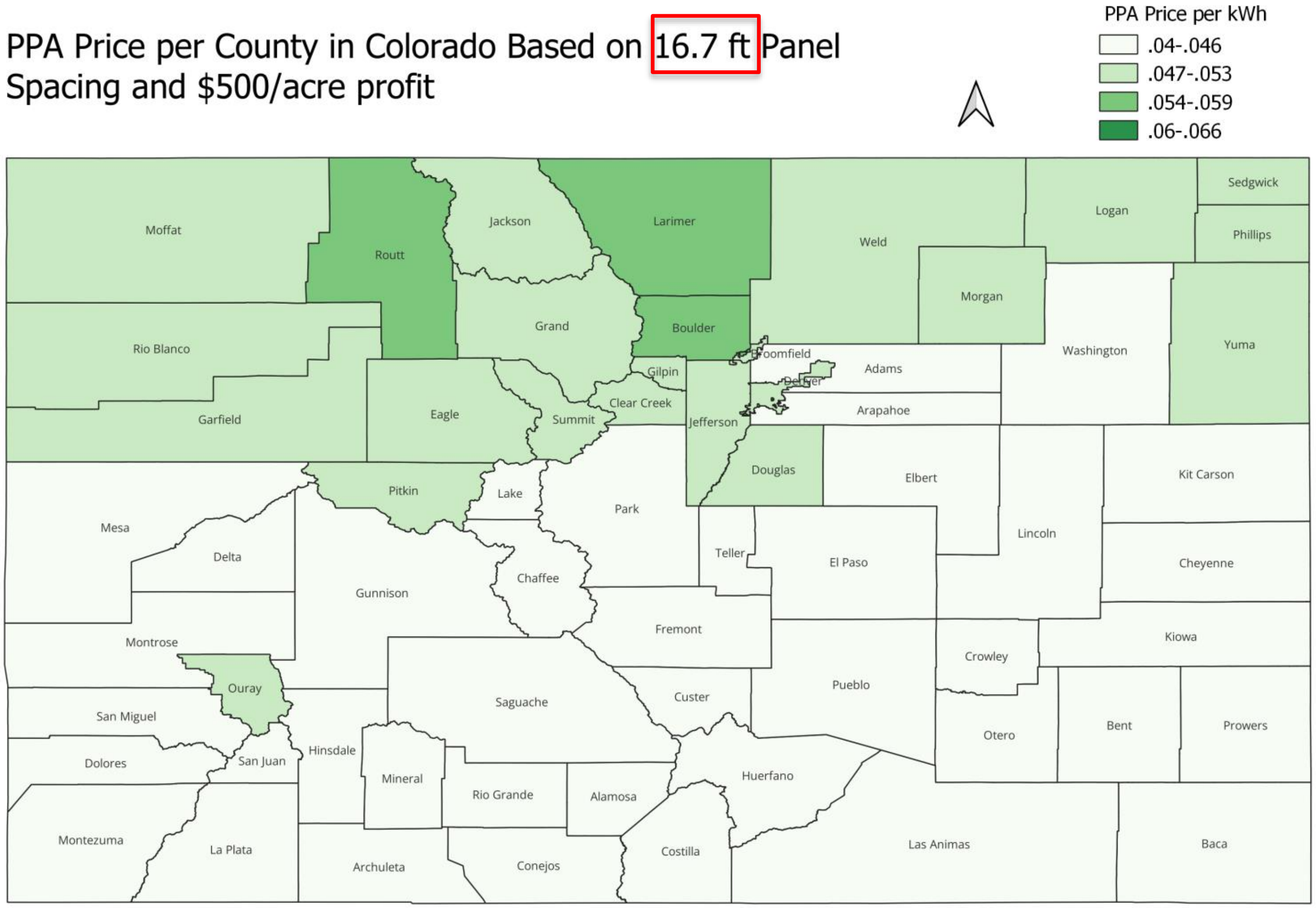
Different colors represent different spacing.

As spacing increases, the crop profit has a larger impact (steeper line) on breakeven PPA price

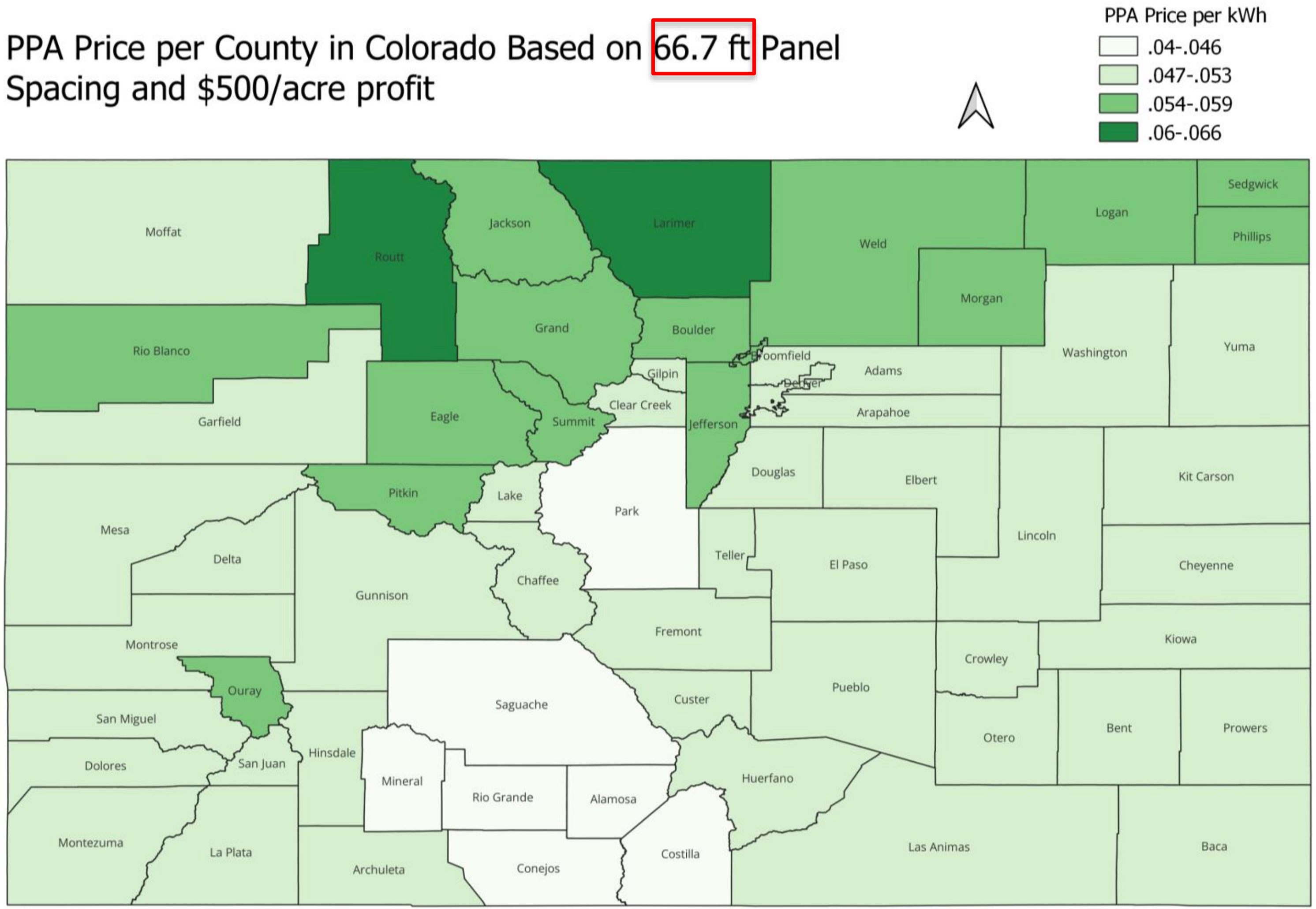


Regional Variation in Solar Resource on PPA price

Higher solar insolation in southern CO leads to lower PPA price



Higher spacing leads to higher PPA prices needed to break even



InSPIRE Literature Portal - https://openei.org/wiki/InSPIRE/Data_Portal

Data Portal

Search the Data Portal | Contribute to the Data Portal

showing 31 results for: Animal Grazing

reset all

search by keyword

Development Strategy | Topic | Geographic Scope

A First Investigation of Agriculture Sector Perspectives on the Opportunities and Barriers for Agrivoltaics

2020 A.S. Pascaris, C. Schelly, J.M. Pearce

Agrivoltaic systems are a strategic and innovative approach to combine solar photovoltaic (PV)-based renewable energy generation with agricultural production. Recognizing the fundamental importance of farmer adoption in the successful diffusion of the agrivoltaic innovation, this study investigates agriculture sector experts' perceptions on the opportunities and barriers to dual land-use systems. Using in-depth, semistructured interviews, this study conducts a first study to identify challenges to farmer adoption of agrivoltaics and address them by responding to societal concerns. Results indicate that participants see potential benefits for themselves in combined solar and agriculture technology. The identified barriers to adoption of agrivoltaics, however, include: (i) desired certainty of long-term land productivity, (ii) market potential, (iii) just compensation and (iv) a need for predesigned system flexibility to accommodate different scales, types of operations, and changing farming practices. The identified concerns in this study can be used to refine the technology to increase adoption among farmers and to translate the potential of agrivoltaics to address the competition for land between solar PV and agriculture into changes in solar siting, farming practice, and land-use decision-making.

A.S. Pascaris, C. Schelly, J.M. Pearce. 2020. A First Investigation of Agriculture Sector Perspectives on the Opportunities and Barriers for Agrivoltaics. Agronomy. 10(12):1-16.

Development Strategy:
Animal Grazing, Crop Production

Geographic Scope:
Country: United States

DOI:
https://doi.org/10.3390/agronomy10121885

Reference

Document type:
Journal Article