NREL
Transforming ENERGY

Trends, Insights, and Considerations for Agrivoltaics in the Northeast: Applying National Lessons Learned to the Case of Pennsylvania

Alexis Pascaris
National Renewable Energy Laboratory
Penn State Climate Symposium – May 2024

Vision: Mutual Benefits of Solar and Agriculture

Images: Werner Slocum, Dennis Schroeder, NREL; AgriSolar Clearinghouse

The InSPIRE Project

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

- InSPIRE has 24 field research projects across the United States
- **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
- **Analytical research:**
  - Cost-benefit tradeoffs of different agrivoltaic configurations
  - Tracking agrivoltaic projects across the United States
  - Assessing research gaps and priorities

https://openei.org/wiki/InSPIRE

Oregon State University · Cornell University · PINEGATE RENEWABLES · HYPERION SYSTEMS · Argonne National Laboratory · REGENERATE Integrated Systems for People and Place · Fresh Energy · The University of Arizona · University of Massachusetts Amherst · Colorado State University · NREL National Renewable Energy Laboratory · MNL · enel Green Power · Temple University

Tracking Agrivoltaics Projects – Map Resource

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

Totals tracked on the map:
537 Sites
9,885 MW DC
61,650 Acres

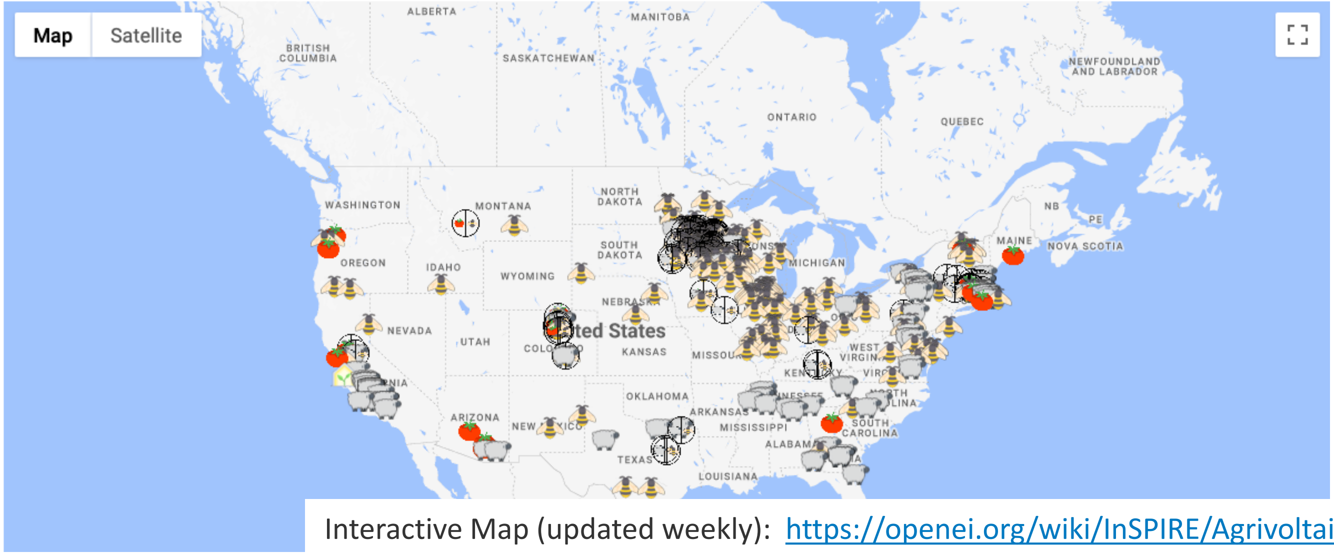
537	9885	61650
Sites	Megawatts	Acres

Agrivoltaic Activities
- Crop Production
- Habitat
- Grazing
- Greenhouse

Photovoltaic Technology
- Monofacial PV
- Bifacial PV
- Translucent PV

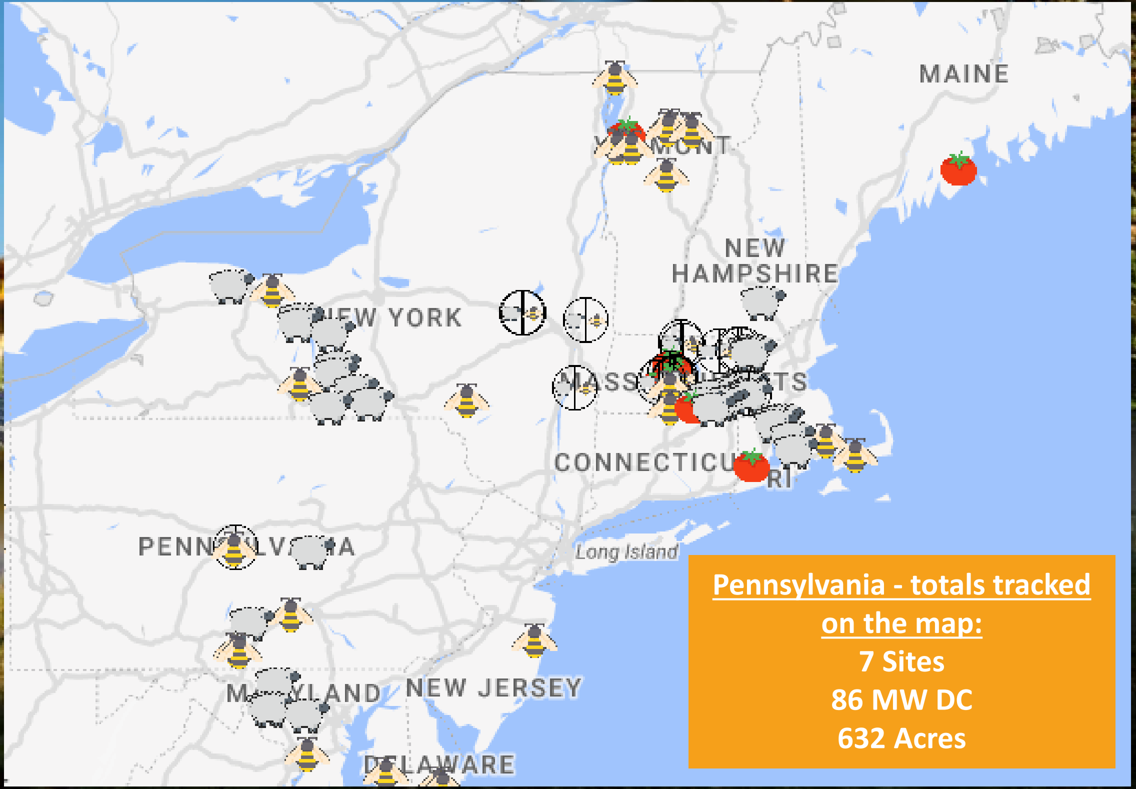
System Size MWdc
- < 1 MW
- 1-5 MW
- 5-10 MW
- 10-100 MW
- >100 MW

Type of Array
- Fixed
- Single-axis Tracking
- Dual-axis Tracking



Interactive Map (updated weekly): https://openei.org/wiki/InSPIRE/Agrivoltaics_Map

Tracking Agrivoltaics Projects – Northeast Snapshot

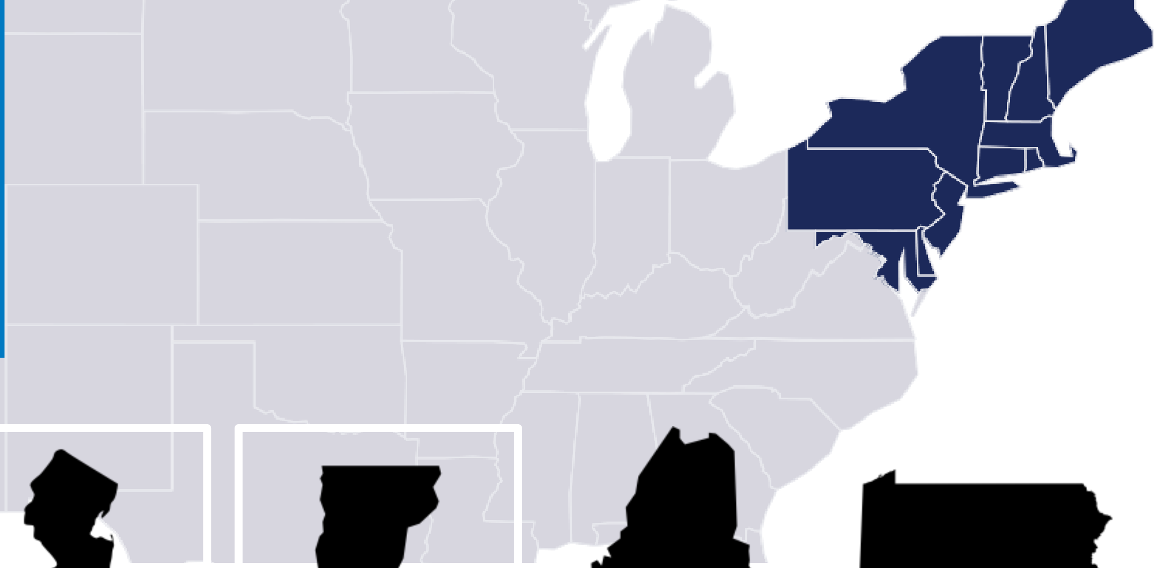


Pennsylvania - totals tracked on the map:
7 Sites
86 MW DC
632 Acres

Photo by Dennis Schroeder, NREL

Interactive Map (updated weekly): https://openei.org/wiki/InSPIRE/Agrivoltaics_Map

Agrivoltaics Research, Development, and Policy Activity in the Northeast



Massachusetts

- Incentive program - $0.06/kWh feed-in tariff
- State-wide field-based research (UMass Amherst)

New York

- Smart Solar Siting Scorecard + RFP Bid Preference
- Agrivoltaics R&D Incubator (NYSERDA)
- Field-based research (Cornell University)
- Smart Solar Siting Report (American Farmland Trust - AFT)

New Jersey

- Dual-use Solar Energy Pilot Program
- Rutgers Agrivoltaics Program
- New Jersey Agricultural Experiment Station

Vermont

- Field-based research – Saffron Solar Project (University of Vermont)
- Vertical bifacial system demonstration (Next2Sun)

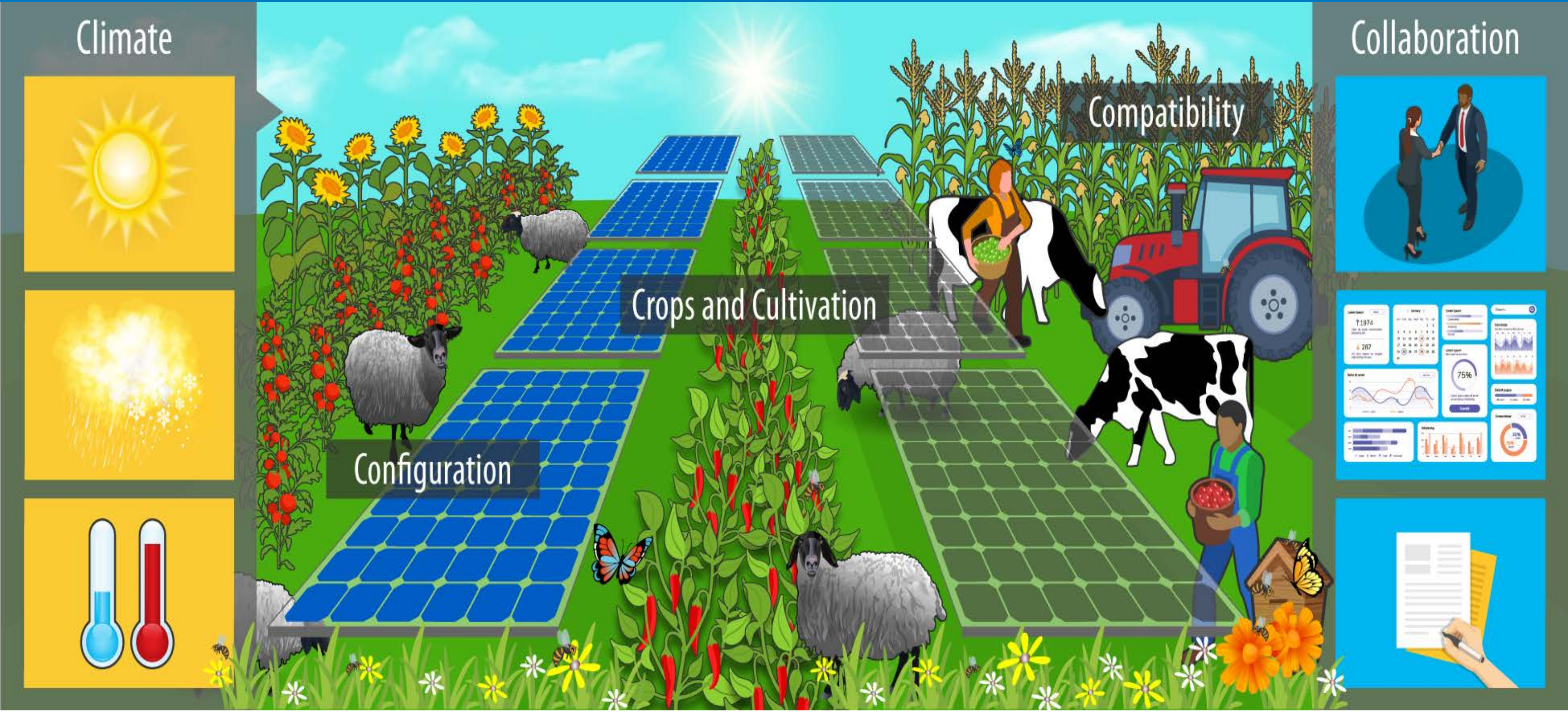
Maine

- Largest U.S. commercial and field-based research project – (University of Maine Extension)

Pennsylvania

- Field-based research (Temple University)
- Sustainable and Just Pathways Project (PSU)

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

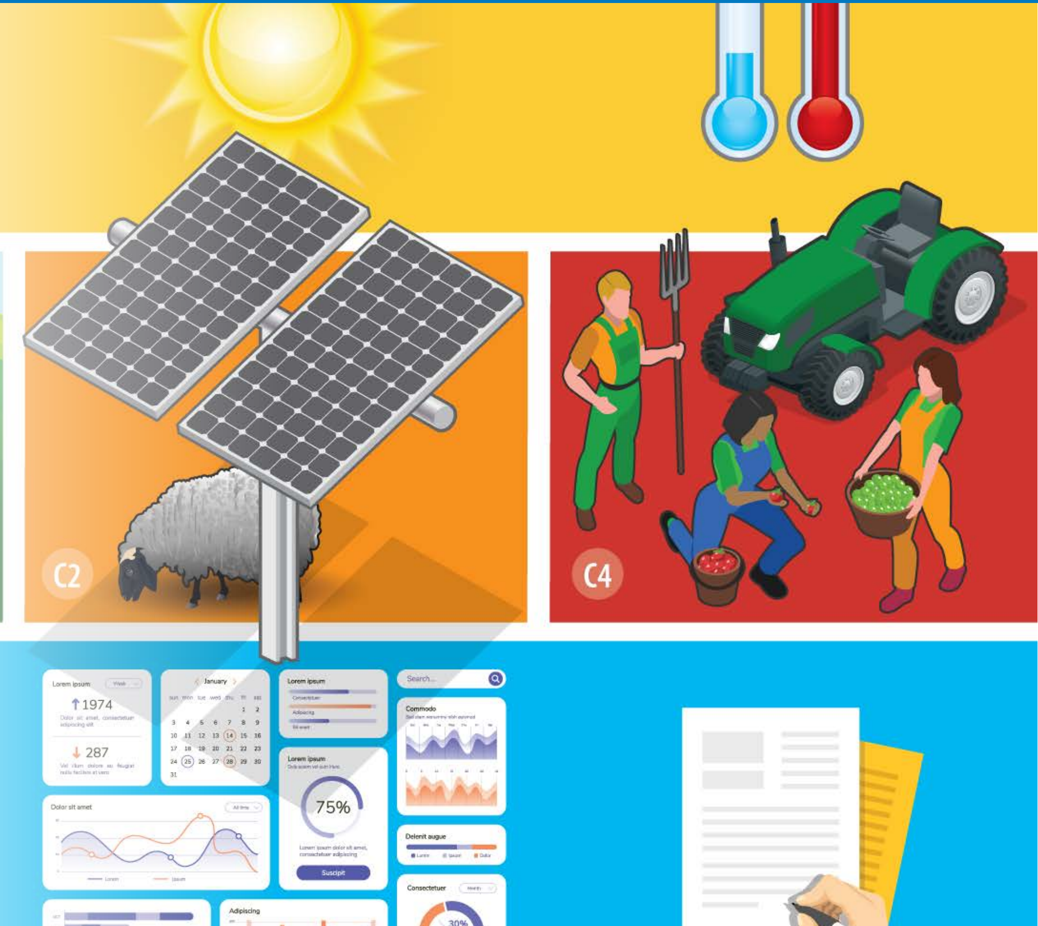
Social Considerations for Success – Compatibility and Collaboration

The growing body of social science literature on agrivoltaics emphasizes:

- Stakeholder engagement and adoption
- Participatory planning
- Rural community acceptance
- Fair agreements and business models
- Supportive legal frameworks

Ongoing work is dedicated to:

- **Improving the compatibility** of the solar technology design and configuration with the competing needs of the solar owners, solar operators, agricultural practitioners, and researchers.
- **Facilitating collaboration** on agreements across stakeholders and sectors to support agrivoltaic installations and research, including community engagement, permitting, and legal aspects.



(Moore et al., 2021; Levy et al., 2022; Brunswick & Marzillier, 2022; Goldberg, 2023; Pascaris et al., 2020; 2021; 2022; 2023; 2023b; Spangler et al. 2024)

Maximizing Agricultural Compatibility through Farmer Engagement

Photo by Werner Slocum, NREL

Concerns	Interests
Impacts on: • Soil • Crop/forage productivity • Land prices and access • Farmland preservation	-Enhanced farm viability -Economic and climate resilience -Co-benefits (regionally diverse)
Operational challenges with permanent infrastructure, flexibility	Revenue diversification, long-term succession planning
Decommissioning	Maximized land use, innovative dual-uses

(Moore et al., 2021; Levy et al., 2022; Pascaris et al., 2020; 2023b; Spangler et al., 2024)

Addressing Community Acceptance through Participatory Planning

Photo by Werner Slocum, NREL

Concerns	Interests
Distributional justice	Support local farmers
Land type, aesthetic	Local economic development
Impacts on cultural heritage and landscapes	Local food production

(Pascaris et al., 2022)

Improving Solar Co-benefits through Industry Innovation

Photo by Alexis Pascaris, NREL

Concerns	Interests
The “liability of newness” (Technical, economic, and political unknowns)	Maximize and deliver co-benefits
Cost-benefit analysis uncertainties, perceived higher costs	Improve community acceptance and company reputation
Political feasibility	Continued access to rural markets

(Guarino & Swanson, 2022; Pascaris et al., 2021; 2023a; 2023b)

Preliminary Findings: Case Study of Massachusetts

Goal: Investigate the commercial agrivoltaic development process to identify the key socio-political interactions that enable and constrain implementation.

Approach: Multi-stakeholder semi-structured interviews (26) – policy makers, extension agents, farmers, developers, community members

Initial Findings:

- Pros and cons of interagency collaboration + policy administration
- Important role of Extension:
  - Objective assessment of project feasibility
  - Constructive feedback and guidance for developers and farmers
  - Ensure project alignment with state program goals
- Research – should better reflect multi-crop regenerative agriculture and farm management at scale
  - Actionable insights for policy improvements
- Farmer agency and engagement is central to project success
- Program incentive enables business models that better support farm viability

(Pascaris et al., 2024 – in preparation)

Image: Alexis Pascaris, NREL

Applying National Lessons Learned to the Case of Pennsylvania

Key Lessons Learned

- Farm agency and compatibility is central to project success
- Extension provides critical service to stakeholder network
- Developers and policy makers still in early learning stages

Implications

- Early and iterative farmer engagement needed
- Cross-sector partnerships and program administration are key
- Research to better align with commercial operation realities and state goals

Considerations for PA

- Expand PA-relevant field-based research and farmer engagement
- Collaborate with regional Extension Network (led by Rutgers)
- Facilitate stakeholder listening sessions
- Participate in policy learning consortium

Photos by Werner Slocum, Dennis Schroeder, Thomas Hickey, NREL

Photo by Wener Slocum, NREL

What is Needed for Agrivoltaics to Grow?

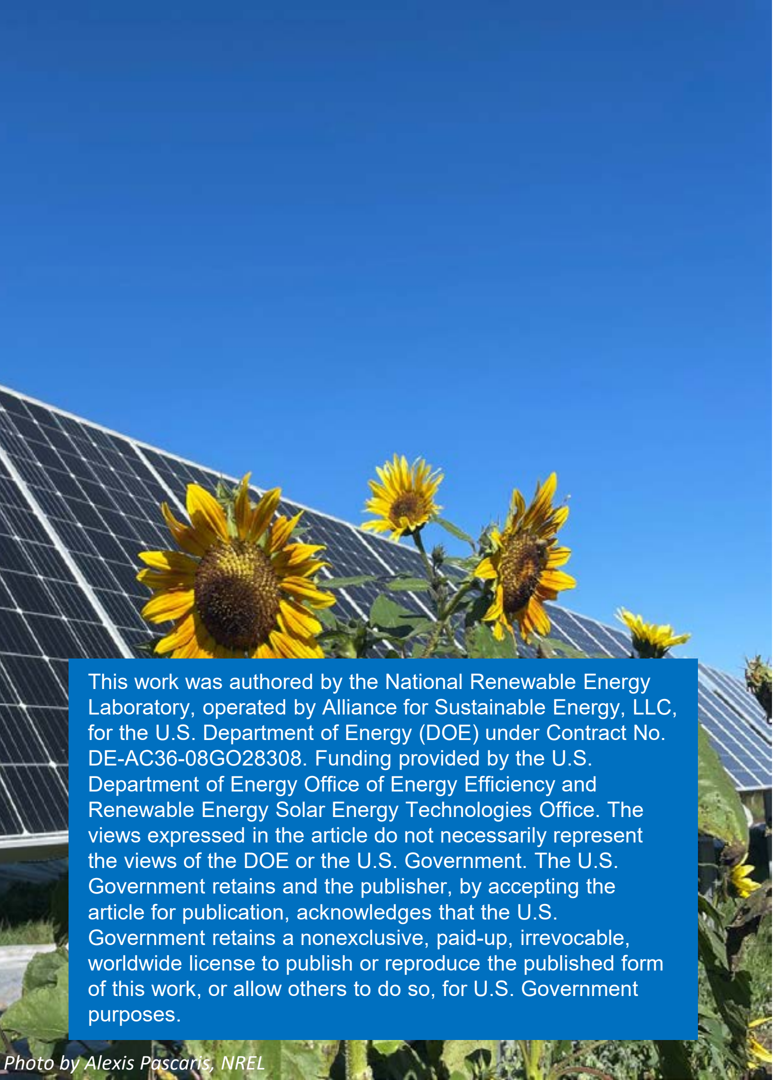
More research on:

- Agronomic impacts across geographies
- Environmental (soil and hydrologic) impacts
- Community acceptance
- Engagement and policy best practices
- Farm economics and operation impacts

Innovation in:

- Construction best management practices
- System hardware (e.g., racking)
- Farm equipment
- Cross-sector partnerships and cooperatives
- Business models

- Workforce development
- Training & curriculum



This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Photo by Alexis Pascaris, NREL

Thank You!

www.nrel.gov

https://openei.org/wiki/InSPIRE

Alexis.Pascaris@nrel.gov

NREL/PR-6A20-89890

NREL Transforming ENERGY

References

1. Brunswick, S., & Marzillier, D. (2022). The New Solar Farms: Growing a Fertile Policy Environment for Agrivoltaics. Minn. JL Sci. & Tech., 24, 123.
2. Goldberg, Z. A. (2023). Solar energy development on farmland: Three prevalent perspectives of conflict, synergy and compromise in the United States. Energy Research & Social Science, 101, 103145.
3. Guarino, J., & Swanson, T. (2022). Emerging Agrivoltaic Regulatory Systems: A Review of Solar Grazing. *Chi.-Kent J. Env't Energy L.*, *12*, 1.
4. Levy, S., Ruiz-Ramón, M., & Winter, E. (2022). *Smart Solar Siting on Farmland: Achieving Climate Goals While Strengthening the Future for Farming in New York*. Washington, DC: American Farmland Trust.
5. Macknick, J., Hartmann, H., Barron-Gafford, G., Beatty, B., Burton, R., Seok-Choi, C., ... & Walston, L. (2022). *The 5 Cs of agrivoltaic success factors in the United States: Lessons from the InSPIRE research study* (No. NREL/TP-6A20-83566). National Renewable Energy Lab.(NREL), Golden, CO (United States).
6. Moore, S., Graff, H., Ouellet, C., Leslie, S., & Olweean, D. (2021). Stakeholder Interactions Around Solar Siting on Agricultural Lands: Toward Socio-Agrivoltaic Interventions. *Available at SSRN 3981518*.
7. Pascaris, A. S., Schelly, C., & Pearce, J. M. (2020). A first investigation of agriculture sector perspectives on the opportunities and barriers for agrivoltaics. *Agronomy*, *10*(12), 1885.
8. Pascaris, A. S., Schelly, C., Burnham, L., & Pearce, J. M. (2021). Integrating solar energy with agriculture: Industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. *Energy Research & Social Science*, *75*, 102023.
9. Pascaris, A. S., Schelly, C., Rouleau, M., & Pearce, J. M. (2022). Do agrivoltaics improve public support for solar? A survey on perceptions, preferences, and priorities. *Green Technology, Resilience, and Sustainability*, *2*(1), 8.
10. Pascaris, A. S., Gerlak, A. K., & Barron-Gafford, G. A. (2023a). From niche-innovation to mainstream markets: Drivers and challenges of industry adoption of agrivoltaics in the US. *Energy Policy*, *181*, 113694.
11. Pascaris, A.S., Winter, E., Gazillo, C. (2023b). Smart Solar in Connecticut: Survey Findings and Initial Recommendations. *Northampton, MA: American Farmland Trust.*
12. Spangler, K., Smithwick, E. A., Buechler, S., & Baka, J. (2024). Just energy imaginaries? Examining realities of solar development on Pennsylvania's farmland. *Energy Research & Social Science*, *108*, 103394.