The InSPIRE Project: Agrivoltaic Research Across the United States
International Solar Energy Society
Jordan Macknick
February 10, 2022
Land Use Requirements of Solar Deployment Projections

2030: 0.8-1.2 million hectares
2050: 1.6-2.4 million hectares

Figure 3-6. Cumulative Installed PV and CSP Capacity in the SunShot Scenario in 2030 and 2050

2030 PV Capacity: 302 GW
2050 PV Capacity: 632 GW
Solar PV Power Potential is Greatest Over Croplands

Elnaz H. Adeh, Stephen P. Good, M. Calaf & Chad W. Higgins

Scientific Reports 9, Article number: 11442 (2019)  |  Cite this article

Farm profitability remains a challenge

American Bankers Association and the Federal Agricultural Mortgage Corporation release results of joint survey.

The next money crop for farmers: Solar panels
Resistance: Rural communities can oppose solar development on farms

Georgetown’s ‘green’ plan to destroy a forest for a solar farm is met with resistance

Solar projects increasingly meeting local resistance

He Set Up a Big Solar Farm. His Neighbors Hated It.

A push toward renewable energy is facing resistance in rural areas where conspicuous panels are affecting vistas and squeezing small farmers.
Vision: Mutual Benefits of Solar and Agriculture
InSPIRE: Innovative Solar Practices Integrated with Rural Economies and Ecosystems

Extensive Industry Partnerships
Field Research and Analytical Modeling

https://openei.org/wiki/InSPIRE
InSPIRE Project Sites
Overview of Field Research Activities at InSPIRE Agrivoltaic Sites

Vegetation Monitoring

Beneficial Insect Populations

Detailed Instrumentation

- Temperature Probe
- Soil Carbon
- Relative Humidity Probe
- Rain Gauge
- Soil Heat Flux Plate
- Soil Thermocouple
- Datalogger
- Wind Anemometer
- Pyranometer
- Soil Moisture Reflectometer
- PV Panel Thermocouple

Armstrong et al., 2016
Standard Protocols for Vegetation Evaluation

http://www.nrel.gov/docs/fy17osti/66218.pdf
Research and Outreach Advisory Group

Quarterly Zoom calls since Jan 2019

Feedback on research directions and study designs

Development of new InSPIRE research sites and activities

Coordinated outreach activities

Community leading to new collaborations
Unique Features of InSPIRE Research

- ASTRO advisory group
- Coordinator and convener for US agrivoltaics research projects
- Multiple agricultural activities
  - Crops, grazing, pollinator/ecosystem services, controlled environment
- Diverse geographic coverage
- Multiple solar configurations
- Long-term research sites (since 2010)
- Mission to support research community
Agricultural Crop Publications and Focus

- Tradeoffs in crop yields
- Irrigation water requirements
- Microclimate conditions
- Shading modeling
- Crop production in off-grid areas
Ecosystem Services
Publications and Focus

• Beneficial insect populations

• Potential impact of beneficial insects at solar sites on agricultural yields

• Approaches to revegetation of utility-scale solar projects

• Impacts of vegetation on soil and nutrient characteristics

• Impacts of vegetation on PV output
General Agrivoltaic Publications and Focus

• Capital cost impacts of Agrivoltaic configurations

• O&M cost impacts of different groundcovers

• Current groundcover of utility-scale PV projects

• Lessons learned from Agrivoltaic research projects

• Compatibility of agricultural activities with solar
InSPIRE Research Highlight: Ecosystem Services from Solar Sites in Minnesota

- InSPIRE Holistic Research Design in Minnesota
  - Vegetation and seed mix field study
  - Instrumentation for validation and connecting vegetation with PV performance
  - Pollinator population field study

- 3 sites with diverse soil/ecotypes and nine test seed mixes
- 9 acres of field research
- Partnerships with Enel Green Power, State of Minnesota, Minnesota Native Landscapes, University of Minnesota
Benefits of Pollinator-Friendly Solar Installations in Minnesota

Research at three utility-scale solar sites in different ecoregions in MN

- **Pollinator Habitat:** 5x increase in beneficial habitat from 2019-2021
- **Beneficial Insects:** 20x increase in pollinators from 2018-2021
- **Energy Production:** PV panel temperature differences
- **O&M Costs:** Establishment of pollinator habitat leads to fewer mowing events each year

Preliminary Results—Do Not Cite
InSPIRE Research Highlight: Ecosystem Services of Pollinator-Friendly Solar

Ecosystem Service tradeoffs associated with solar land use scenarios modeled from 30 sites


Leroy J. Walston, Yudi Li, Heidi M. Hartmann, Jordan Macknick, Aaron Hanson, Chris Nootenboom, Eric Lonsdorf, Jessica Hellmann

https://doi.org/10.1016/j.ecoser.2020.101227

Ecosystem benefits
- Increased biodiversity
- Storm water & erosion control
- Better soil quality and quantity
- Carbon storage
- Agricultural benefits
Over 800,000 acres of agricultural land would benefit if existing solar facilities had pollinator-friendly vegetation.

*Examining the Potential for Agricultural Benefits from Pollinator Habitat at Solar Facilities in the United States.*
• Data collected from NREL NWTC site
• Evaluation of soil moisture patterns underneath solar arrays
• Frontiers in Environmental Science

Publication Highlight: Capital Cost Tradeoffs of Agrivoltaic Systems

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

Figure 3. PV installed system costs for each dual-use scenario with benchmark assumptions for a PV system with 500 kW rated power.

Costs are based on a simple average of modeled costs in Oregon, Arizona, Michigan, Massachusetts, New York, Connecticut, California, and Illinois—states that currently have one or more types of dual-use PV systems installed.

https://www.nrel.gov/docs/fy21osti/77811.pdf
Publication Highlight: Off-Grid Agrivoltaics for Food and Energy Co-Benefits

Renewable and Sustainable Energy Reviews

Combined land use of solar infrastructure and agriculture for socioeconomic and environmental co-benefits in the tropics

The InSPIRE data portal (https://openei.org/wiki/InSPIRE/Data_Portal) serves as the starting point for hosting and contributing relevant agrivoltaic research data.
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.
InSPIRE 2022-2024 Foundational Research Services

1. Track US-Based Agrivoltaics Projects

2. Maintain and Update InSPIRE Data Portal and Website

3. Publish Standardized Research Protocols and Research Roadmap

4. Analyze Economics of Scaling Agrivoltaics
InSPIRE 2022-2024 Field Research

1. Agrivoltaic Crop Production and Irrigation Tradeoffs

2. Ecosystem Services at Long-Term and New Research Sites

3. Bifacial PV Agrivoltaics Groundcover

4. Sheep Grazing Evaluation Standards and Guidelines

5. Soil Quality at Solar and Agrivoltaic Sites
InSPIRE Active Field Research Site Locations 2022-2024

10 ecosystem services and pollinator habitat research sites

7 crop production research sites

Other sites to be confirmed
Lego Solar Farm

http://www.legosolarfarm.me/

- “It is amazing” - Jon Powers, former Federal chief sustainability officer
- “So fun!!” - Kelsey Misbrener, Senior Editor, Solar Power World
- “My son loved it!” - Jigar Shah, solar industry pioneer
- “Let’s do this” - Joel Makower, CEO, GreenBiz Group
- “Vote for this solar Lego kit!” - Julia Pyper, founder Political Climate Podcast
- “This is awesome!” - Elaine Hsieh, co-founder Third Derivative
Thank you

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https://openei.org/wiki/InSPIRE
We Turned Our Hay Field into …
… a 1.2 MW Solar Array
What We Created

Credit: Namaste Solar
How We Use Our Space

1. SCF Farm Production site
2. Pollinator and native vegetation test plot
3. Pollinator habitat test plot
4. Agricultural test plot
5. Water management test plot
6. Pasture/grassland/nutrient cycling test plot
7. Educational Zone
Growing Vegetables

Credit: Werner Slocum/NREL
Growing Vegetables

Credit: Werner Slocum/NREL
Supporting Pollinators

Credit: Werner Slocum/NREL
Hosting Events
Promoting Artists
Teaching Young People
Creating Community
We teach the next generation of sustainability leaders by connecting students, community members, and policymakers to clean energy, local food, and responsible land use management through agrivoltaic tours and events at Jack’s Solar Garden.

www.coagrivoltaic.org