



Research Directions and Recommendations for the Kegonsa Agrivoltaics Site



—
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Kegonsa Solar & Agricultural Research Site



- UW Kegonsa Research Campus - Physical Sciences Lab
 - Located ~10 miles to campus: Town of Dunn
 - Near existing transmission lines
- 2.25 MW facility built, owned, operated by Alliant Energy
 - Customer-hosted renewables program
- Interior parcel of research campus (~15/280 acres)
 - Interior location shields views from roads
 - South-facing slope ideally suited for solar
- Electricity goes to local Alliant distribution system



- Add nearly 1,100 MW of solar generation in Wisconsin by the end of 2023.
 - Enough energy to power more than 250,000 Wisconsin homes.



- Reduce carbon dioxide (CO₂) emissions from the electricity we generate by 50% by 2030.
 - Achieve net-zero emissions by 2050.



- Eliminate all coal from our generation fleet by 2040.
 - Replacing generation primarily with renewable resources like solar, battery storage and wind.

Project Plan and Deliverables



- **Task 1 - Literature review**

Review literature about current agrivoltaics research.

- **Task 2 - Market Characterization / Baseline Study**

Conduct a market characterization of solar PV and agrivoltaics in WI using available data and tools.

- **Task 3 - Case Studies**

Select several cases to investigate specific topics and concerns.

- **Task 4 - Recommendations for Agrivoltaics Research Agenda**

Provide a detailed research agenda to Alliant Energy based on previous tasks.

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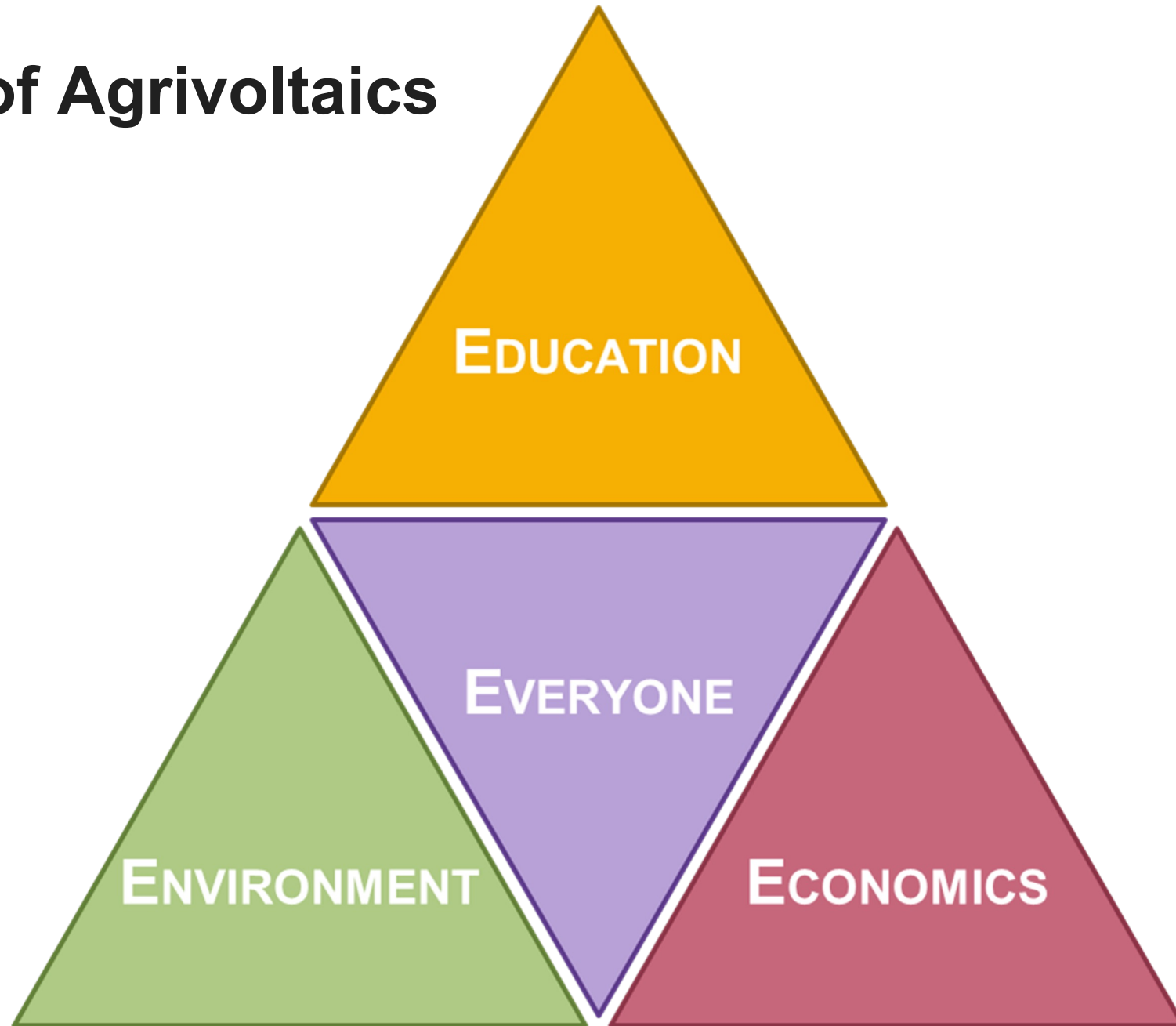
Arizona Peer Exchange



Visited University of Arizona, Biosphere 2 Agrivoltaics site, Manzo Elementary School Solar Garden. Talked with AgV researchers in Arizona to learn about their experiences and research.



The 4 E's of Agrivoltaics



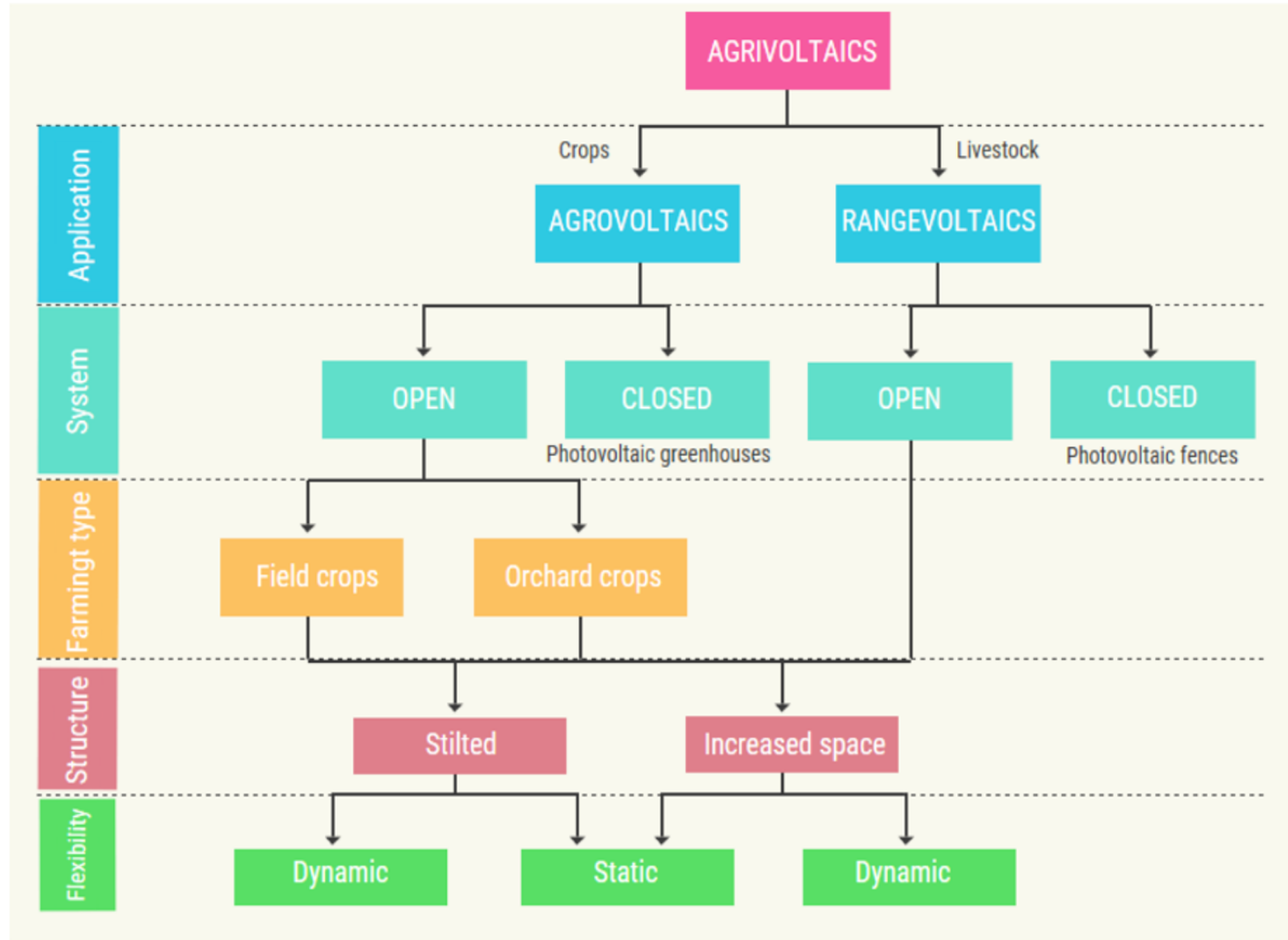


Recommendations on Research Agenda



1. Promote Standardization

Terms & Performance Indicators



Performance Indicators

1. Ground Cover Ratio (GCR)
2. Energy and Agricultural Yield
3. Agricultural Quality
4. Spatial Efficiency - Land Equivalent Ratio (LER)
5. Water Savings - Water Use Efficiency (WUE)
6. Human Comfort - Wet Bulb Globe Temperature
7. Economic Indicators - price-performance ratio (ppr), LCOE



2. Data and Research Priorities

2.1 - Choice of Agricultural Activities



Incorporating the agricultural heritage of the local community will be critical for continuous public support of projects

- Specific to geographic and cultural location
- Alleviate land use concerns, establish trust and support
- Field crops vs grazing animals



Interdisciplinary planning & consulting is needed for successful selection and planting of crops at the Kegonsa site

- Better planning and selection of crops to research
- Greater likelihood of successful research findings
- Improved local support for the project



Finding a Wisconsin specialty crop that performs well in the shade of solar panels will help promote the adoption of agrivoltaics in the state

- Result of local community & expert planning
- Chiltepin & Cliff Bar: Tucson, Arizona
- The Wisconsin Idea

2.2 Soil Data

Activity	Soil Impact	Health Impact
Solar Array Construction	Compaction, Disturbance [1]	(-)
Ground cover planting	Improved infiltration, Water storage capacity [2]	(+)
Agrivoltaics	Construction + Planting	?

- Overall lack of soil health research beneath PV installations
 - Opportunity for UW to become leader
- Proven increase in ecosystem services may justify future agrivoltaic incentives

[1] Chen Y., Day S.D., Wick A.F., Strahm B.D., Wiseman P.E., Daniels W.L. Changes in soil carbon pools and microbial biomass from urban land development and subsequent post-development soil rehabilitation. *Soil Biol. Biochem.* 2013;66:38–44. doi: 10.1016/j.soilbio.2013.06.022.

[2] <https://agcrops.osu.edu/newsletter/corn-newsletter/2018-03/soil-infiltration#:~:text=Best%20management%20practices%20to%20improve,water%20runoff%20which%20causes%20flooding.>

2.3 - Meteorological Data

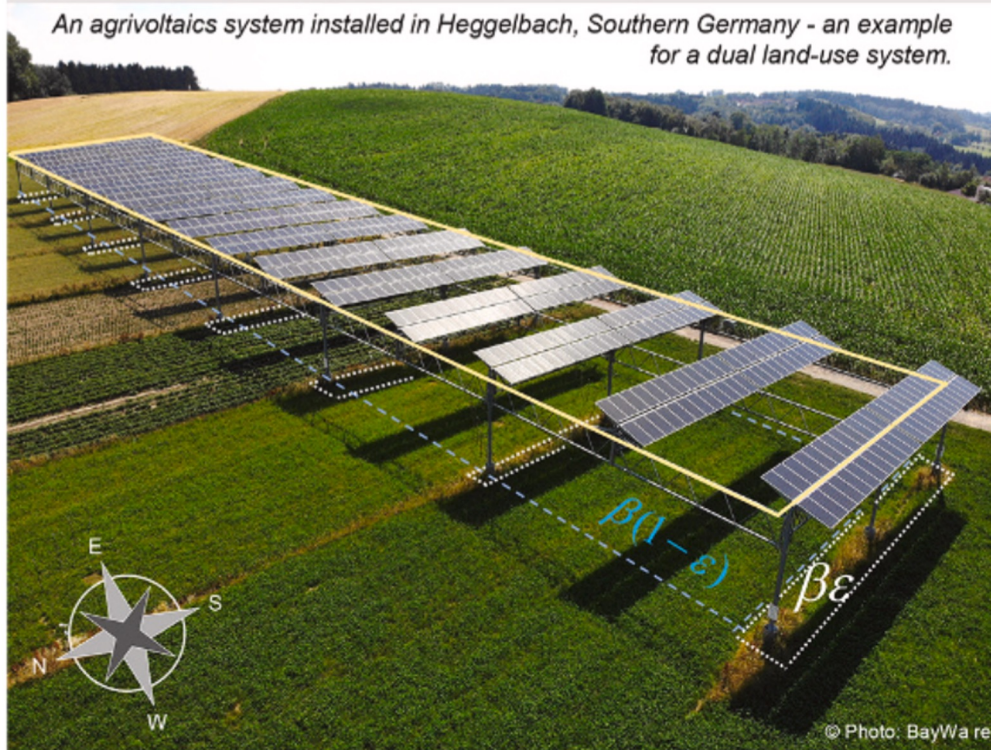
- Important for planting, seeding, irrigating, harvesting decisions.
- Develop deep understanding of microclimate conditions to inform crop choices.
- Comparisons possible with other agrivoltaics research sites.



μMETOS Weather Monitoring Instruments, developed by
METOS by Pessl Instruments, Italy.
<https://metos.at/en/weather-monitoring/>

2.4 - Economic Research

FEADPLUS: Framework to Assess the Economic Benefits and the Adoption Potential of Dual Land-Use Systems



$$\underbrace{\beta(1-\epsilon) \sum_{i=1}^I \left(U_i \delta_i - \sum_{v=1}^V C_{i,v} \gamma_{i,v} \right)}_{\text{Component C1: Change in agri. contribution margin due to shading and change in input costs (under the agrivoltaics (AV) system)}} - \underbrace{\beta\epsilon E_{Base}^{Agri}}_{\text{C2: Change in agri. contribution margin due to loss in cultivated area (under the AV system)}} + \underbrace{cap_{AV} (H ae ta - CRF INV - M)}_{\text{C3: Change in annual profit due to AV power production}} > 0$$

Component C1: Change in agri. contribution margin due to shading and change in input costs (under the agrivoltaics (AV) system)

C2: Change in agri. contribution margin due to loss in cultivated area (under the AV system)

C3: Change in annual profit due to AV power production

Where:

β = Area covered by dual land-use system
 ϵ = Share of land lost (due to mounting structure area) in area β
 δ_i = Change in yield of crop i
 U_i = Revenue of crop i
 $C_{i,v}$ = Cost of input use v in crop i
 $\gamma_{i,v}$ = Change in input intensity v in crop i
 E_{Base}^{Agri} = Agricultural contribution margin before adoption

cap_{AV} = Installed capacity of agrivoltaics (AV) system
 H = Full load hours
 ae = Average lifetime efficiency (PV)
 ta = Electricity tariff (€ kWh⁻¹)
 CRF = Capital recovery factor
 INV = AV investment cost
 M = AV maintenance cost

Feuerbacher et al. An analytical framework to estimate the economics and adoption potential of dual land-use systems: The case of agrivoltaics. Agricultural Systems, Volume 192, 2021.



3. Data Sharing and Transparency

Data Sharing and Transparency



**Alliant
Energy**TM

x Community Agrivoltaics

Overview

PV System Profile

Power Generated

Annual Comparison

Agriculture

Community



**Pick a site
from our
map to get
started!**

- Opportunity to continue sharing data like Alliant Energy did with the Madison Solar Demonstration Project
- Helpful with community outreach and education programs

Data Sharing and Transparency



x



WISCONSIN
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 **Kegonsa Research Campus**

Overview

PV System Profile

Power Generated

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Renewable Energy
Produced

 **170 kWh**
today

CO₂ Avoided

 **144 kg**
today

Current PV Power

1932 kW

PV System Power
2.25 MW

Commissioning Date
12/01/2023



Data Sharing and Transparency



x



WISCONSIN
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 **Kegonsa Research Campus**

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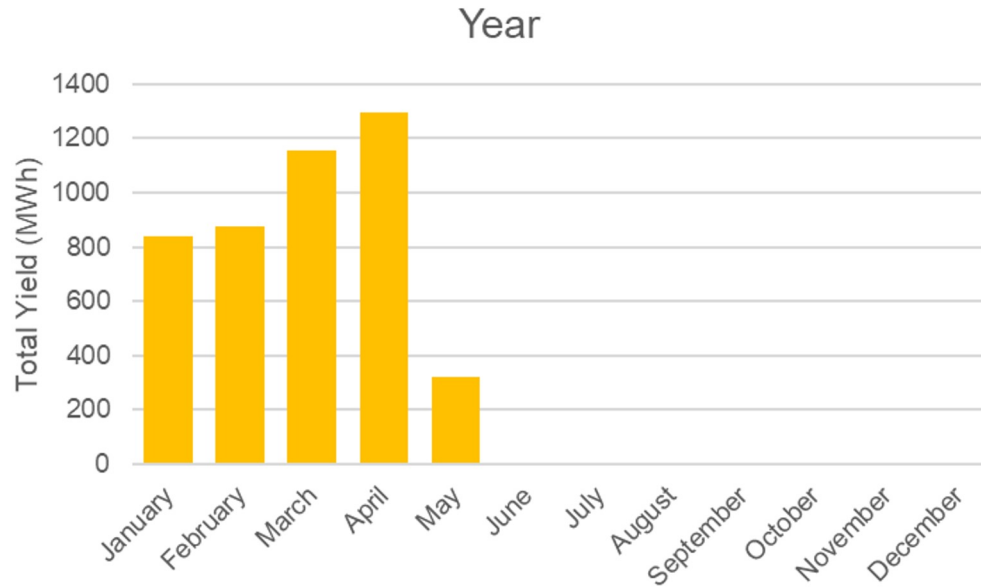
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Data Sharing and Transparency



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 **Kegonsa Research Campus**

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Data Sharing and Transparency



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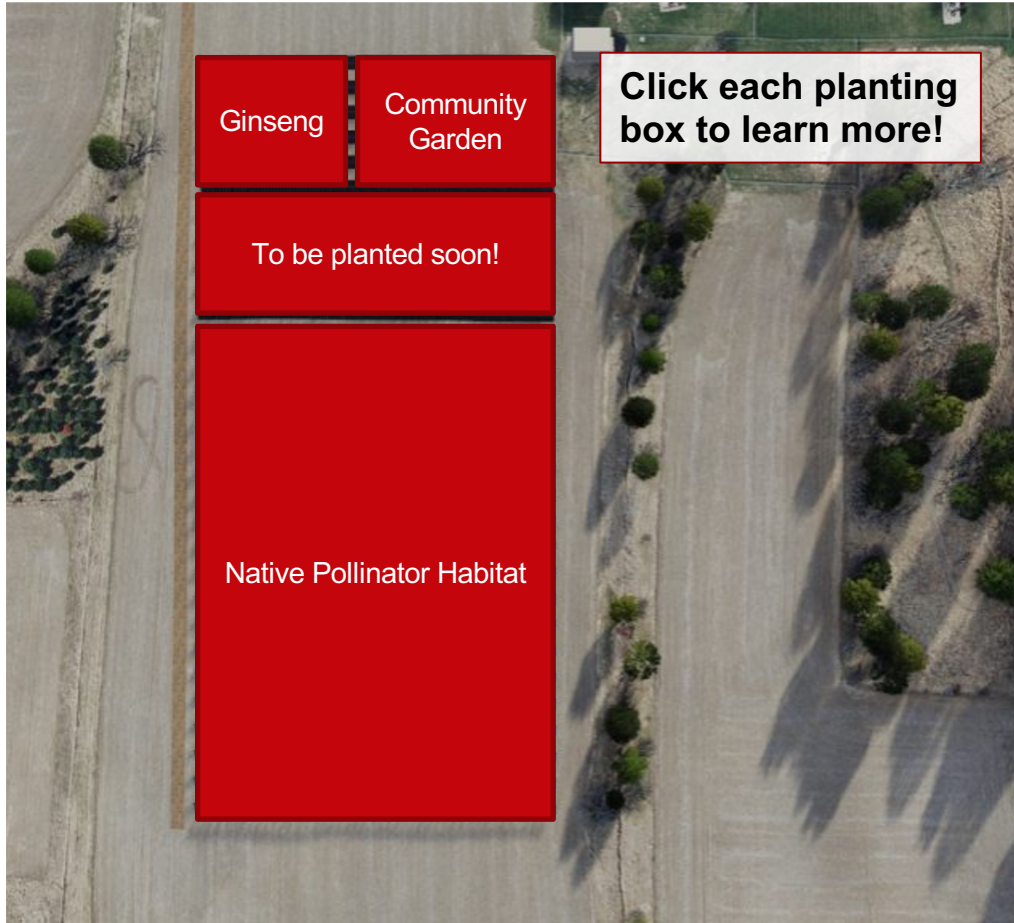
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4. Community Involvement and Outreach

Community Involvement and Outreach

Serve as a demonstration of agrivoltaics applications to the public

- Gain support from the public, industry, and agrivoltaics community
- Increase awareness and support for low-impact solar developments

Expand impact through community involvement, education, outreach

- Provide learning opportunities about solar energy, agriculture, etc. at the site
- Use resources generated to create a positive impact on the community



Extension

UNIVERSITY OF WISCONSIN-MADISON

Community Involvement and Outreach



Vegetables growing in shade at Manzo Elementary



Solar Garden at Manzo Elementary



Agrivoltaics-plant ecology research at Biosphere 2



Jack's Solar Garden, <https://www.jackssolargarden.com/>
Sprout City Farms, <https://sproutcityfarms.org/>



5. Involve Collaborative Multi-Sector Research

Involve Collaborative Multi-Sector Research



- Enabling comprehensive research from multiple departments could potentially increase both the practical and educational values of the site;
- May come up with advanced research outcomes, which could help “advertise” current and future agrivoltaic projects.



<https://www.nrel.gov/docs/fy22osti/83566.pdf>

Involve Collaborative Multi-Sector Research



- **Disciplines that could be integrated into the Kegonsa site**

1. soil science
2. social science
3. engineering
4. ecology
5. hydrology
6. agronomy
7. economics





6. Target Future Work with Owner-Operator Farmers

Target Future Work with Owner-Operator Farmers



Developing agrivoltaic sites on existing agricultural lands where farmers do not own the land, but only rent and farm on that land, could lead to tension and conflicts of interest. Farmers, who have been farming on the lands for decades, may be dismissed.

	Wisconsin				Dane			
	Number of Farms		Acres		Number of Farms		Acres	
Land in farms	64793		14318630		2566		506688	
Harvested cropland	49304		9234611		1914		379235	
Full owners	42174	65%	4453140	31%	1698	66%	121690	24%
Full owner - harvested cropland	27940	57%	1618791	18%	1080	56%	50240	13%
Tenants	3269	5%	570232	4%	165	6%	21922	4%
Tenants - harvested cropland	2657	5%	459531	5%	149	8%	18915	5%

https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Wisconsin/st55_2_0045_0045.pdf

Target Future Work with Owner-Operator Farmers



Specific approaches include:

1. Conduct surveys to learn about their concerns and perceptions;
2. Hold focus group discussions throughout project design and implementation;
3. Let researchers work closely with farmers to conduct pilot projects that aim to address specific challenges, such as soil and irrigation.



Thanks everyone!



EAP Program

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Kai Lepley

Nesrine Rouini

Caleb Ortega

Agroecology Capstone Group

Alliant Energy

Many other researchers who helped shape our learning during discussions throughout the semester

Questions?



Resources



“The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons from the InSPIRE Research Study” National Renewable Energy Laboratory (NREL), August 2022. <https://www.nrel.gov/docs/fy22osti/83566.pdf>

Department of Energy Market Research Study “Agrivoltaics” August 2022. <https://science.osti.gov/-/media/sbir/pdf/Market-Research/SETO---Agrivoltaics-August-2022-Public.pdf>

Electric Power Research Institute (EPRI) - Overview of Pollinator-Friendly Solar Energy <https://www.epri.com/research/products/000000003002014869>

Electric Power Research Institute (EPRI) - Feasibility of Co-locating Solar PV and Pollinator Habitat <https://www.epri.com/research/products/000000003002022293>

“Capital Costs For Dual-Use Photovoltaic Installations: 2020 Benchmark for Ground-Mounted PV Systems with Pollinator-Friendly Vegetation, Grazing, and Crops” National Renewable Energy Laboratory (NREL) <https://www.nrel.gov/docs/fy21osti/77811.pdf>

MISO Generator Interconnection Queue https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/

RENEW Wisconsin Solar Farms <https://www.renewwisconsin.org/solarfarms/>

NREL’s InSPIRE OpenEI database https://openei.org/wiki/InSPIRE/Agrivoltaics_Map

Public Service Commission of Wisconsin Case Management System, Docket 9811-CE-100: Application for a Certificate of Public Convenience and Necessity of Koshkonong Solar Energy Center LLC <https://apps.psc.wi.gov/APPS/dockets/content/detail.aspx?id=9811&case=CE&num=100>

Dane County Legislative Information Center, Zoning & Land Regulation Committee (File 02577: Dunn – Regent of Univ of Wis 310 Peterson Bldg) <https://dane.legistar.com/LegislationDetail.aspx?ID=5845924&GUID=D7D9B40E-2063-4232-9A21-9A4B55E25186>

Alliant Energy Customer-Hosted Renewables Program <https://www.alliantenergy.com/cleanenergy/whatyoucando/customerhostedrenewables>

Feuerbacher et al. An analytical framework to estimate the economics and adoption potential of dual land-use systems: The case of agrivoltaics. Agricultural Systems, Volume 192, 2021. <https://doi.org/10.1016/j.agsy.2021.103193>

Toledo, C.; Scognamiglio, A. Agrivoltaic Systems Design and Assessment: A Critical Review, and a Descriptive Model towards a Sustainable Landscape Vision (Three-Dimensional Agrivoltaic Patterns). Sustainability 2021, 13, 6871. <https://doi.org/10.3390/su13126871>

7 Performance Indicators



$$LER = \frac{E(Y_{agri,AV})}{E(Y_{agri,N})} + \frac{Y_{el,AV}}{Y_{el,N}}$$

When LER is greater than one, this indicates productivity of the combined agricultural and electricity production is greater than separate electric and agricultural production.

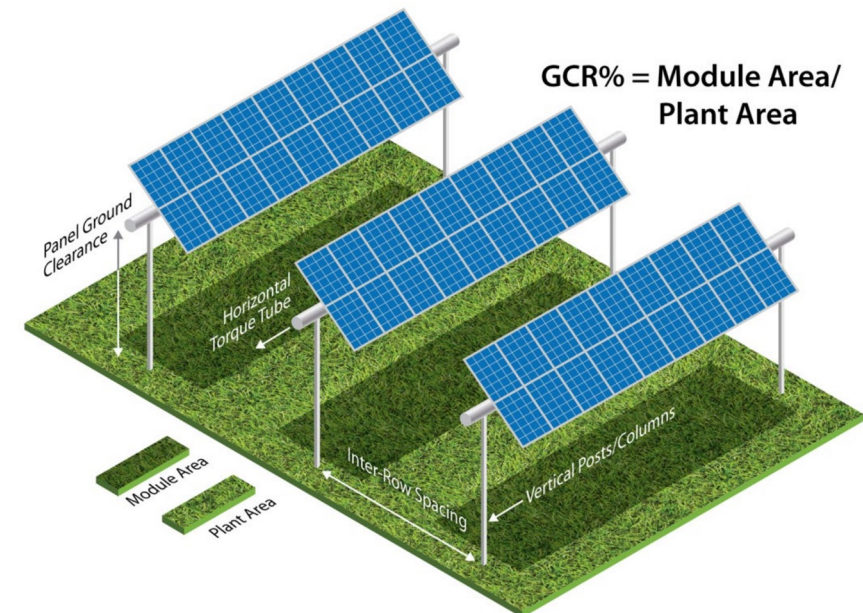
$$WUE = \frac{WUE_{PV} - WUE_{control}}{WUE_{control}}$$

WUE = unit of biomass produced per unit of water used.

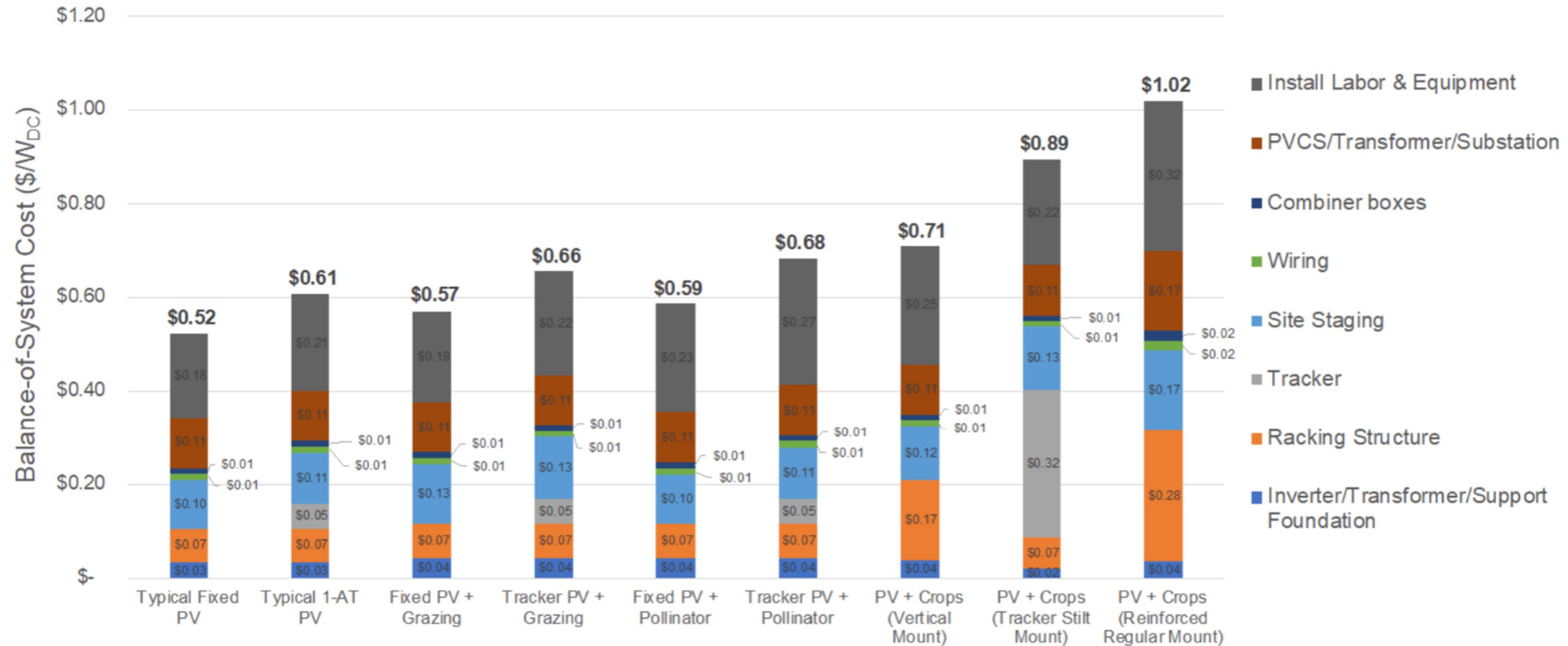
$$ppr = \frac{p}{pb}$$

If the ppr is less than 1 it indicates the agrivoltaic installation provides more benefits than the extra cost compared to conventional PV.

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2.1 - Choice of Agricultural Activities: Costs



Balance-of-system cost breakdown for dual-use scenarios, 500-kW rated power system, “Capital Costs for Dual-Use Photovoltaic Installations”, NREL 2020.

2.1 - Choice of Agricultural Activities: Public Opinion



DANE COUNTY LEGISLATIVE
INFORMATION CENTER, ZONING &
LAND REGULATION COMMITTEE



PSC DOCKET 9811-CE-100 ON
KOSHKONONG SOLAR CENTER
PUBLIC TESTIMONIES



COLUMBIA COUNTY BOARD
OF SUPERVISORS RESOLUTION
ON HIGH NOON SOLAR