

Agrivoltaics: Integrating Solar Electricity Production with Agriculture, Grazing and Native Habitats



Photo: UW-Madison graduate students discuss rooftop agrivoltaics with researcher at University of Arizona School of Environment and Natural Resources 2 building, Tucson, Arizona USA. March 13, 2023.
Photo: Josh Arnold



Josh Arnold, JD, MBA and Tom Bryan, Ph.D.
University of Wisconsin – Madison
13 November 2023



Your Presenters



Josh Arnold, JD, MBA
Project Manager, Solar Pilot
Office of Sustainability
University of Wisconsin – Madison

Energy Industry for 20+ years



Tom Bryan, Ph.D.
Teaching Faculty
Organic Agriculture and Agroecology
University of Wisconsin – Madison

Vegetable farmer for 10+ years



Agenda

- UW-Madison
- Context
- What is Agrivoltaics?
- UW-Madison project and research
- Resources
- Discussion
- Information about UW-Madison Research labs

Photo: UW Madison campus and Lake Mendota
(credit: Bryce Richter/UW-Madison)





University of Wisconsin–Madison



The University of Wisconsin–Madison is a public land-grant institution established in 1848.

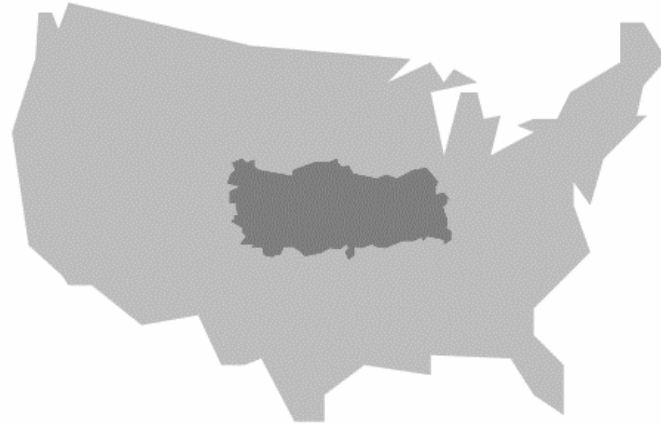
UW–Madison is Wisconsin’s flagship public university and a major research institution,

50,000 undergraduate, graduate and professional students from 116 countries

25,000 faculty and staff



Context



Total Area:

Türkiye is about **5x** size of State of Wisconsin, USA

Source: mapfight.xyz

Agricultural Land Use:

Türkiye features about **4x** as much land use in use for agriculture
23,000,000 hectares (56,000,000 acres) v. 6,000,000 hectares (14,000,000 acres)

Sources: statista.com; macro trends.net, U.S. Department of Agriculture, National Agricultural Statistics Service, 2021)

Solar:

Türkiye has about **20x** as much solar now as Wisconsin - with both areas forecast for rapid increases in the next 5 years (10 GW and 4 GW, respectively)

Sources: International Energy Agency, RENEW Wisconsin, Public Service Commission of Wisconsin

What is Agrivoltaics?



Solar Configurations for Agrivoltaics



Fixed mount – (Alliant Energy, Fond du Lac, Wisconsin, USA)



Vertical Panels – Under Construction at University of Jordan
(Photo: Dr. Osama Ayadi, School of Engineering, University of Jordan)



Single-axis tracker
(Madison Gas and Electric
Dane County Regional Airport
Madison, Wisconsin, USA)



Elevated panels:
Allow for yoga and recreation
(Photo: Jack's Solar Garden, Longmont, Colorado, USA)

National Renewable Energy Laboratory: 5C's of Agrivoltaics Success



Climate – including soil and environmental conditions

Configurations – solar technology, design and layout

Crop Selection – cultivation methods, seed and vegetation design and management

Compatibility – flexibility to accommodate multiple uses

Collaboration – communications, working together

Academic and Industry Collaborators



International Collaboration in Agrivoltaics

RAWABIT ("Connections") Program of the U.S.-Jordanian University Cooperation Network



THE UNIVERSITY OF
JORDAN



Agrivoltaics Pilot Project Team



UW-Madison

- Office of Sustainability
- Facilities Planning and Management
- Wisconsin Institute for Discovery
- Office of the Vice Chancellor for Research and Graduate Education
- College of Agriculture and Life Sciences
- Nelson Institute for Environmental Studies
- Division of Extension
- Students, Faculty and Staff



Office of Sustainability
UNIVERSITY OF WISCONSIN-MADISON



**Alliant
Energy**[®]

Investor-owned electric utility



Solar Development Services



Environmental Consultant



WEPA / EIA consultants

Key Activities

Campus Information Forum (April 2022)



Key Considerations:

- Project partners
- Aligned with our institutional mission
- Campus (student, staff, faculty) interest
- Finding the right location
- Financial and logistics planning

Integrated Design Site Visit (May 2022)



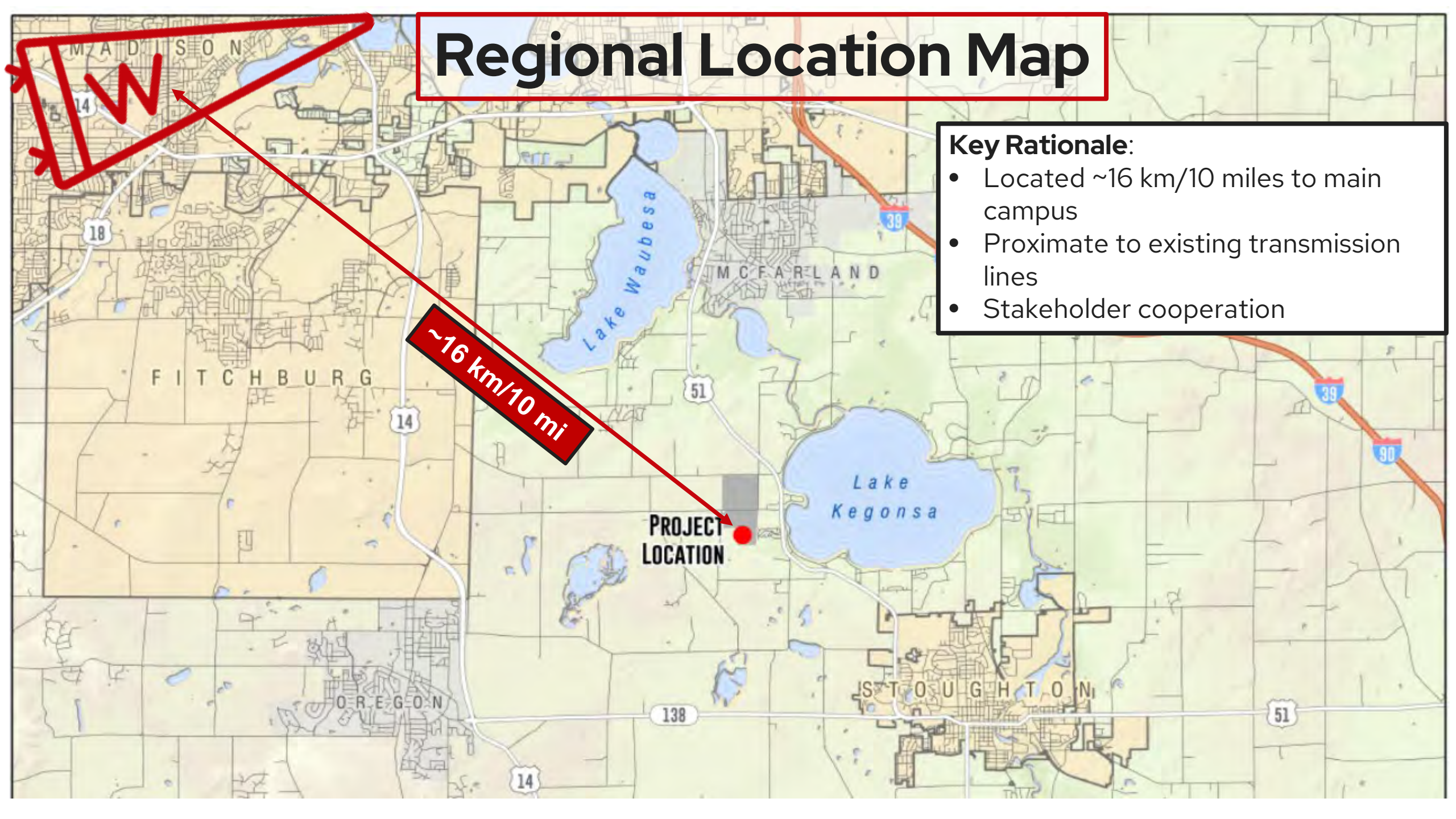
Regional Location Map

Key Rationale:

- Located ~16 km/10 miles to main campus
- Proximate to existing transmission lines
- Stakeholder cooperation

~16 km/10 mi

PROJECT LOCATION



Aerial View – UW Kegonsa Agrivoltaics Project

(Early Site Concept - 2022)

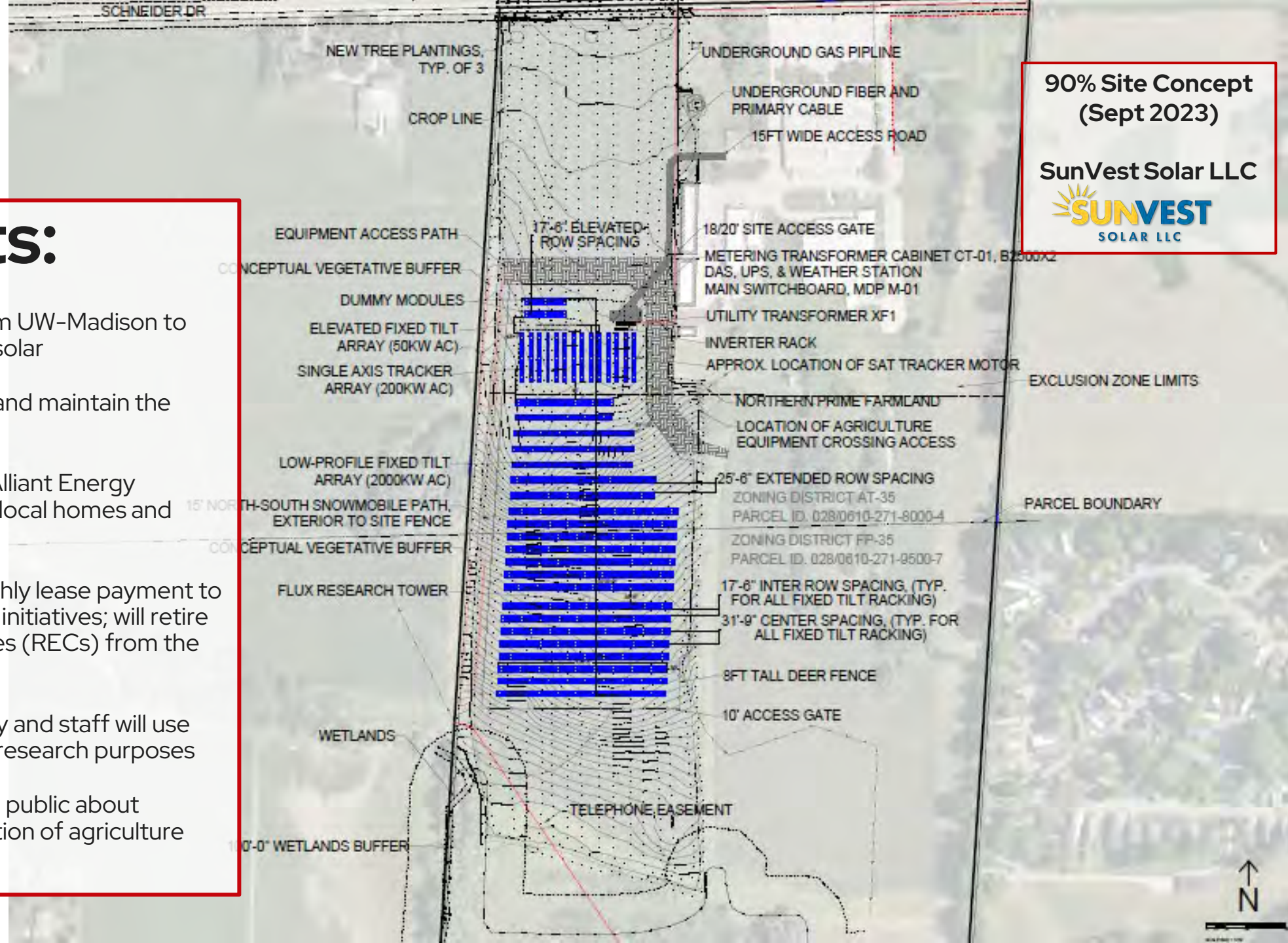
Interior Parcel Location:

- South-facing slope ideally suited for solar
- Small, interior parcel (~4 hectares/10 acres) of 113 hectares/280 acres)
- Near existing facilities at UW Physical Sciences Lab
- Interior location shields view from roads; with visual buffers to be added
- Remaining area continues farming/recreation as before
- Environmental Impact Assessment resulted in finding of no significant impact (FONSI) to environment, wildlife, etc.
- Site impacts to be studied by researchers



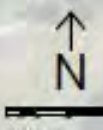
Quick Facts:

- Alliant Energy leases land from UW-Madison to place utility-owned 2.25 MW solar
- Alliant Energy will build, own, and maintain the facility
- Clean energy is delivered to Alliant Energy distribution system powering local homes and businesses
- UW-Madison receives a monthly lease payment to be reinvested in sustainability initiatives; will retire Renewable Energy Certificates (RECs) from the project
- UW-Madison students, faculty and staff will use the facility for education and research purposes
- Demonstration to the greater public about opportunities for the co-location of agriculture and solar

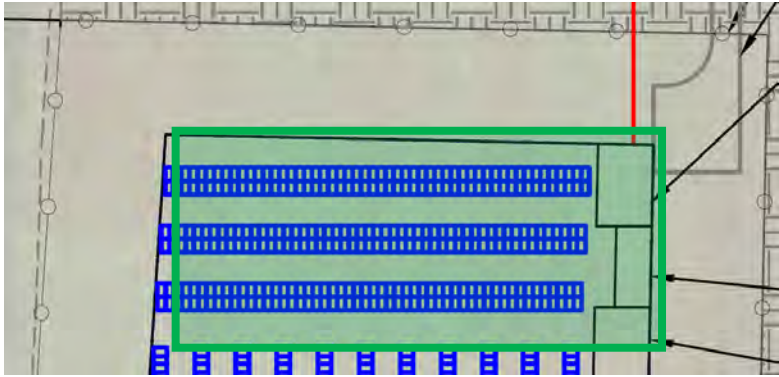


**90% Site Concept
(Sept 2023)**

SunVest Solar LLC

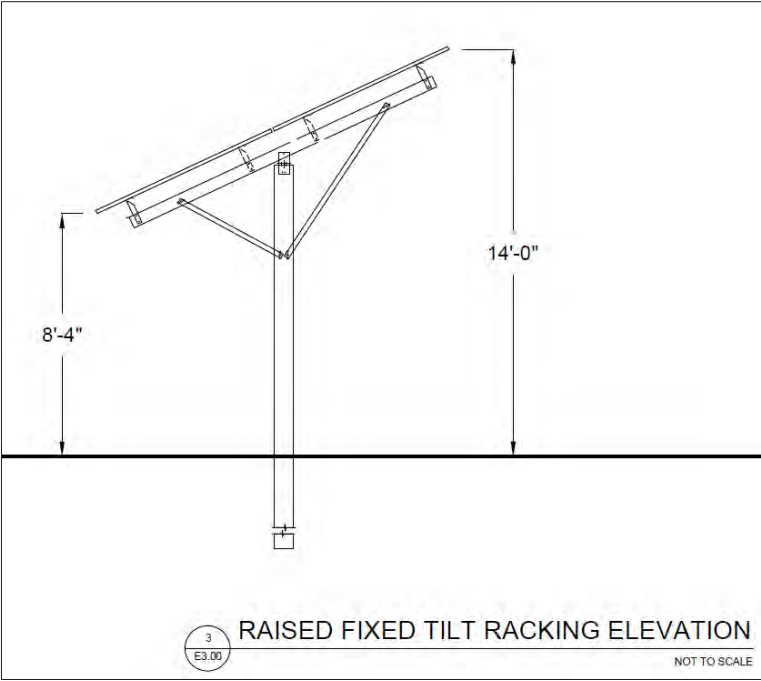


Zone 1: Elevated Fixed Tilt



50 kW planned

2.5 meters

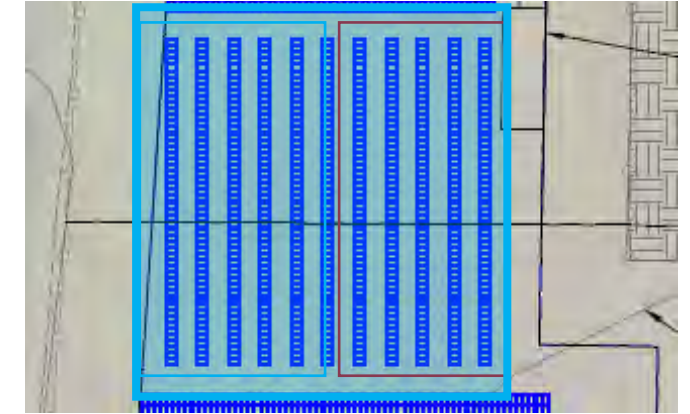


4.3 meters



Zone 2: Single-Axis Tracking

"torque tube" height
1.5 – 2.5 meters



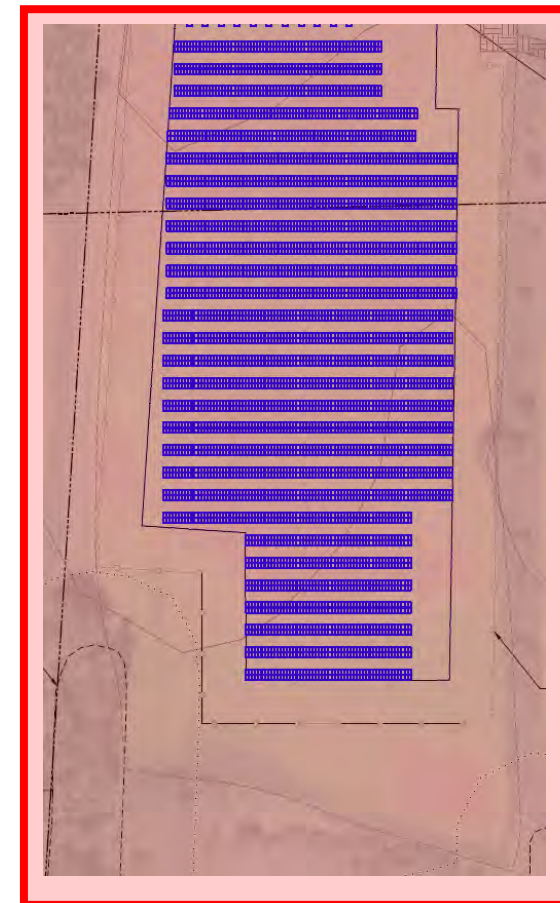
200 kW planned



Sample Single-Axis Tracking array time-lapse with backtracking capabilities
<https://www.youtube.com/watch?v=YfbMDrpd4vw>

Zone 3: Standard Fixed Tilt

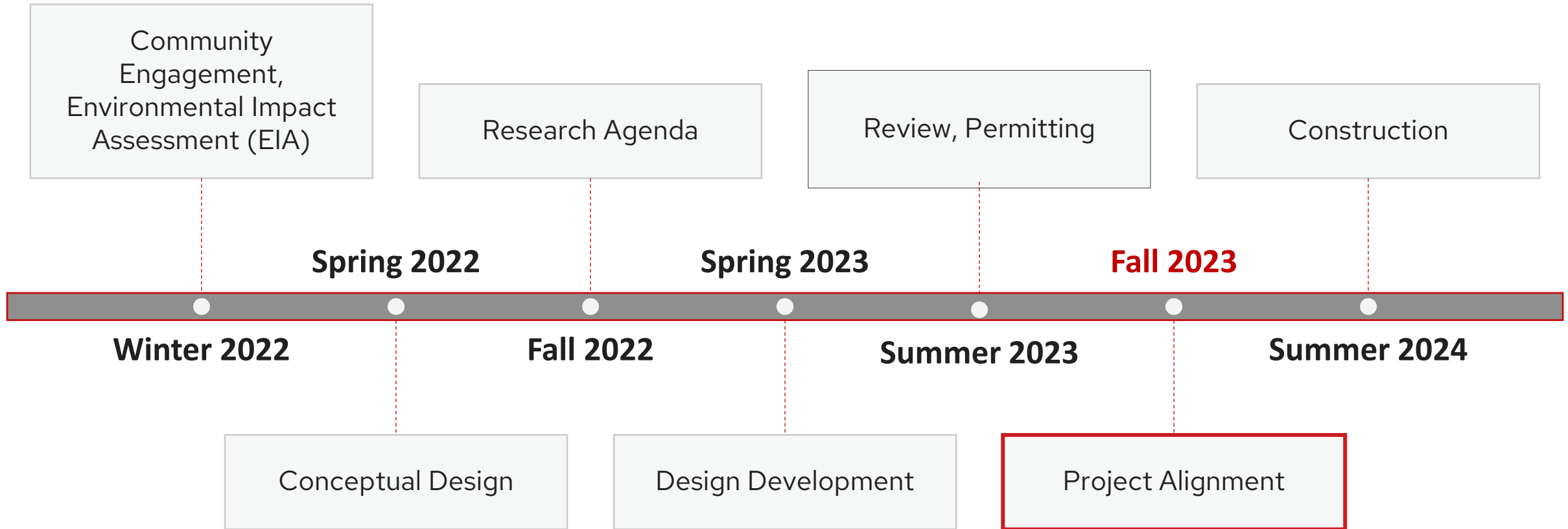
1.0 – 2.5 meters



2000 kW planned

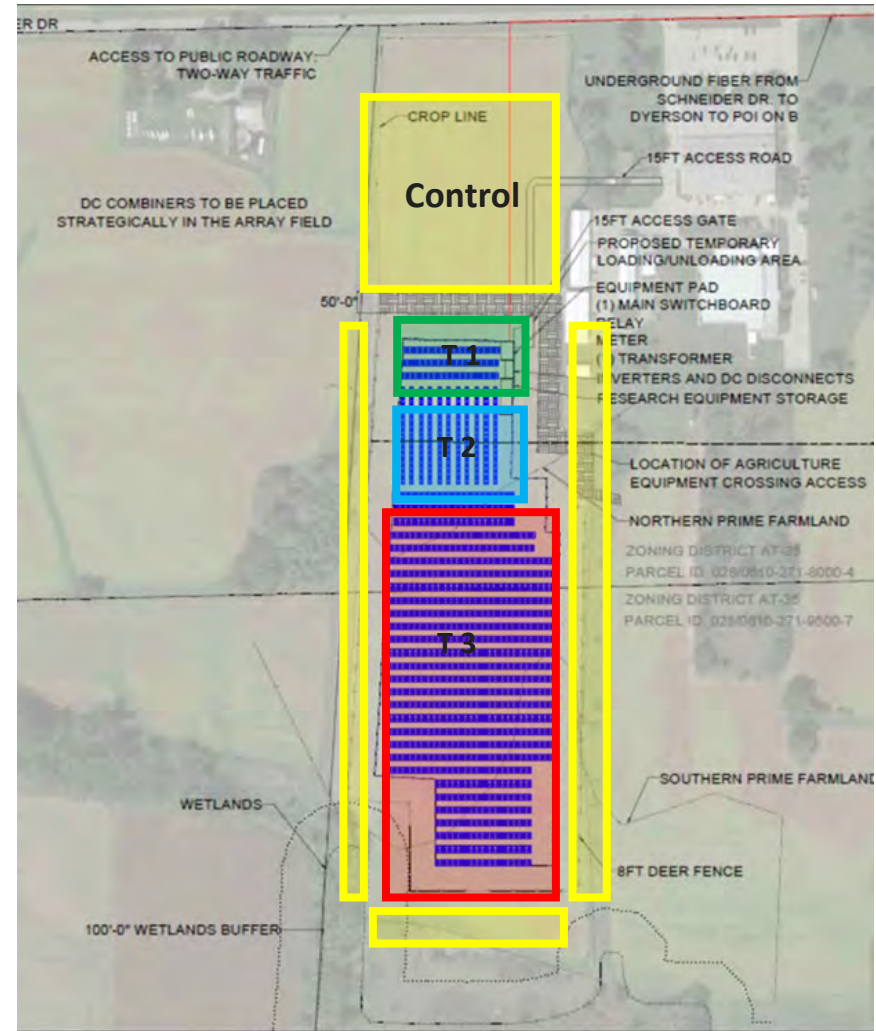
Pilot Project Timeline

(Schedule subject to change)



Examples of Proposed Research

- ✓ Greater understanding of community concerns
- ✓ Business models and innovation
- ✓ Soils
- ✓ Hydrology (runoff and groundwater, etc.)
- ✓ Temperature, humidity, wind speed
- ✓ Vegetation and ground cover options
- ✓ Trade-offs between energy production and plant production
- ✓ Pollinator interactions
- ✓ Wildlife, bird interactions
- ✓ Use of small stock animals to manage vegetation growth
- ✓ Demonstration and outreach



Midwest USA agrivoltaics horticultural outlook

"Agriculture is all about context"

Good

Non-elevated fixed tilt



- Minimal vertical & horizontal access
- Support piles not always centered
- Maximum shading

Perhaps most suitable for pollinators, small animal grazing (my hypothesis)

Better

Single axis trackers



- Moderate vertical & horizontal access
- Farmer-controlled horizontal access (planting, harvest)
- Support piles often centered

Perhaps most suitable for low-growing perennial crops (blueberry, strawberry, currant, honeyberry) or annual/perennial small grains (my hypothesis)

Best

Elevated fixed tilt



- Maximum vertical & horizontal access
- Support piles often centered
- Mid-summer shading minimized (Madison, WI USA – near 45°N latitude & ~150 frost free days)

Perhaps most suitable for annual vegetable production and large animal grazing (my hypothesis)

Goals: Inform, Engage, Inspire

Please contact us for more information

Thank you!



Agrivoltaics Resources

Electric Power Research Institute, Power in Pollinators

<https://www.epri.com/pages/sa/pollinators>

International Energy Agency, Photovoltaic Power Systems Programme

<https://iea-pvps.org/>

InSPIRE, U.S. Department of Energy, National Renewable Energy Laboratory,

<https://openei.org/wiki/InSPIRE>

National Center for Appropriate Technology, AgriSolar ClearingHouse

<https://www.agrisolarclearinghouse.org/>

RENEW Wisconsin, <https://www.renewwisconsin.org/solar-and-agricultural-land>

Solar Farm Summit <https://solarfarmsummit.com/>

Please feel free to add your resource suggestions in today's chat!

Contact Information



Josh Arnold, JD, MBA

Campus Energy Advisor
Office of Sustainability
University of Wisconsin-Madison

josh.arnold@wisc.edu

www.sustainability.wisc.edu



Tom Bryan, Ph.D.

Teaching Faculty
Department of Plant and Agroecosystems Science
University of Wisconsin-Madison

tbryan@wisc.edu

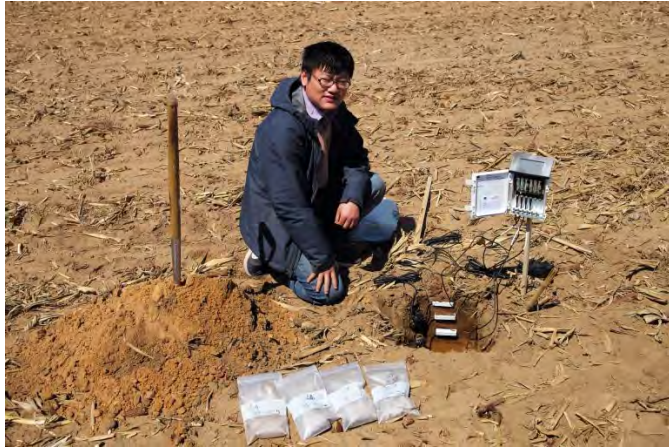
www.pasdept.wisc.edu

Research



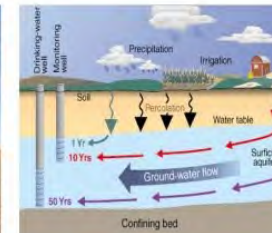
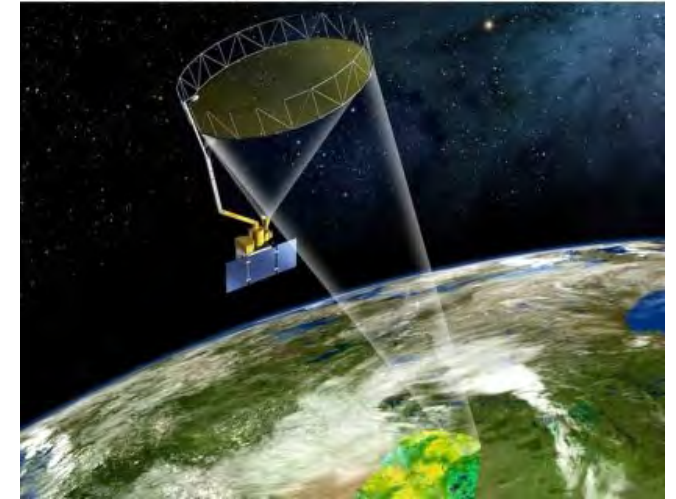
Soil Sensing & Monitoring Lab @ UW-Madison

Jingyi Huang, Assistant Professor, Department of Soil Science



Interests:

- Proximal and remote sensing
- Soil physics and process modeling
- Climate change
- Soil-human-environment interactions





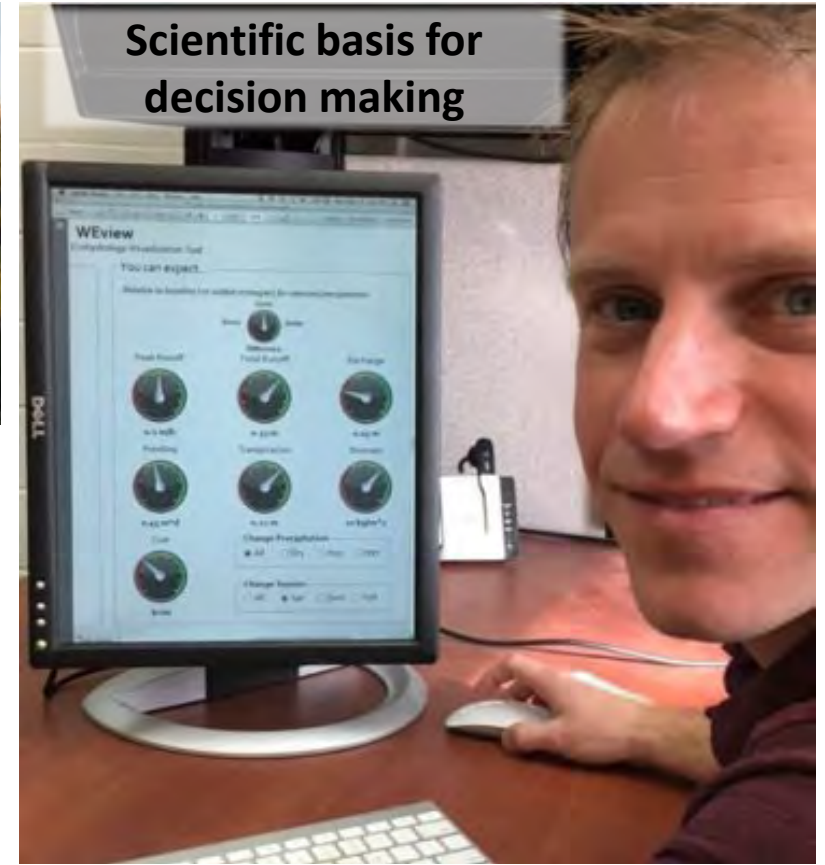
Green infrastructure for stormwater control



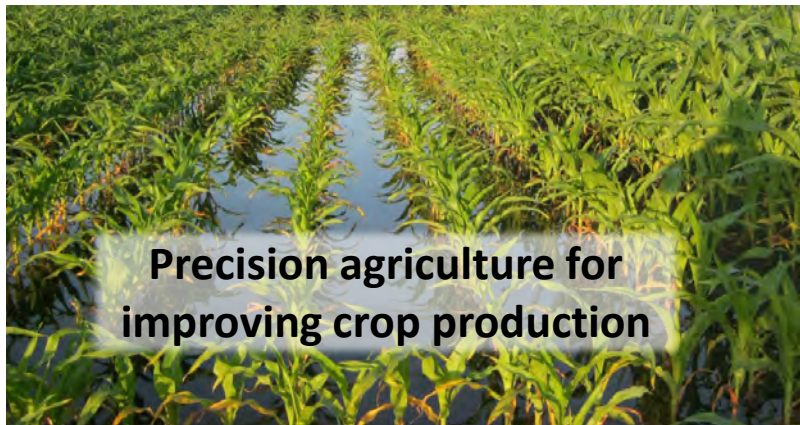
Designing ecosystem restoration



Drought resilient forests



Scientific basis for decision making



Precision agriculture for improving crop production

Loheide Ecohydrology Group

Investigating the interactions between ecological and hydrological processes to make more sustainable connections between natural and built systems

- Numerical modeling
- Technology development
- Field methods
- Remote sensing

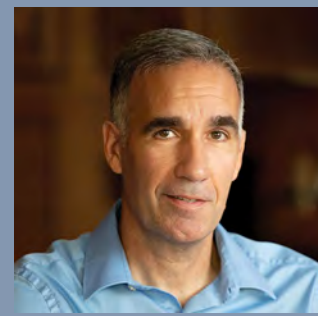
Kucharik Agroecology Lab @ UW-Madison

Investigating agroecosystems and finding ways to enhance the resiliency of ecosystems – and the services they provide – to drivers of global change.

Identify and quantify bi-directional feedbacks between land management, climate, and ecosystems

Quantify the impacts of varied land management and a changing climate on the ecosystem services we derive from landscapes

Support policy decision-making to help protect soils, water, and the climate system



Chris Kucharik
Prof. of Agronomy
and Environmental
Studies

Land use impacts on ecosystem services



Agronomic productivity



Crop development and photosynthesis



Water use and water quality



Weather variability and climate change impacts



Ecometeorology Lab @ UW-Madison

Ankur Desai

Professor of Atmospheric & Oceanic
Sciences

Interests:

- Role of vegetation in climate and weather systems
- Improving models and forecasts of carbon and water cycling in ecosystems and atmosphere
- Observing land-atmosphere fluxes of heat, momentum, water, carbon dioxide, methane particularly with eddy covariance flux towers --->



Central Sands, WI irrigated potato
evapotranspiration study



Solar grazing recommendations for Wisconsin



Extension

UNIVERSITY OF WISCONSIN-MADISON

Extension's mission is to connect people with the University of Wisconsin. We teach, learn, lead and serve, transforming lives and communities.



Diane Mayerfeld
Sustainable Ag
Coordinator, UW-
Madison Extension



Will Fulwider
Regional Crops
Educator, Dane &
Dodge Co. Extension



Carolyn Ihde
Small Ruminant
Outreach Specialist
Iowa State and UW-
Madison Extension



Jason Cavadini
Grazing
Specialist, UW-
Madison Extension

- The current, most practiced form of agrivoltaics is sheep grazing
- We lack research on forage (plants consumed by livestock) performance under and around solar panels
- Test forages and forage mixes at Badgervoltaics site in Kegonsa
- Provide recommendations on forages for agrivoltaics
- Work with solar developers to design more solar grazing-ready sites

GRATTON LAB



LANDSCAPE ECOLOGY OF INSECTS



Claudio Gratton

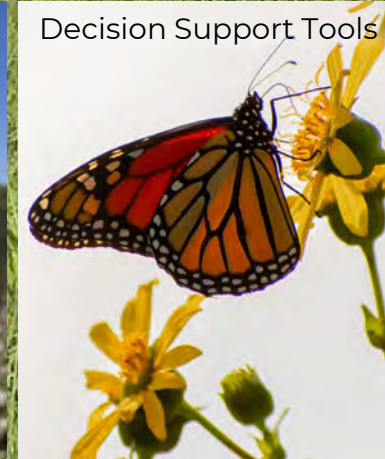
Department of Entomology
University of Wisconsin - Madison



Conservation of beneficial insects in agricultural landscapes



Effects of management and restoration on pollinators and ecosystem services



Decision Support Tools



Grassland management



Citizen Science



Prof. Mike Wagner
Department of Mechanical Engineering
Energy Systems Optimization Lab
Solar Energy Laboratory

-Develop simulation tools to accurately predict energy system behaviors over a time horizon

-Modelling of complex optical and thermal systems

-Optimization methodologies to improve energy system efficiency, lifetime, cost-effectiveness, and reliability.



Dr. Arganthaël Berson
Department of Mechanical Engineering
Solar Energy Laboratory