2020 JISEA Virtual Meeting Presenter Profile

Jordan Macknick is the Lead Energy-Water-Land Analyst for NREL. He is a member of the Strategic Energy Analysis Center's Systems Modeling team within the Resources and Sustainability Group. His primary work addresses the environmental impacts of energy technologies, while seeking opportunities for energy and ecological synergies. In his energy-water-land leadership capacity, Macknick analyzes national and regional implications of different energy pathways in the context of water and land resources, evaluates opportunities to improve the energy management of water infrastructure, and explores innovative approaches to co-locating solar and agricultural activities.

James McCall is a member of the Resources and Sustainability Group in the Strategic Energy Analysis Center. His interests include techno-economic analyses for various renewable technologies, economic and employment impacts, and systems analysis associated with the energy-water-food-nexus. Prior work experience was as a researcher at a utility law think tank at ASU and a project manager/facilities engineer for an upstream oil and gas producer

JISEA

Joint Institute for
Strategic Energy Analysis

Jordan Macknick and James McCall

Spanning the Nexus: Integrated Energy Research on Agriculture & Water Challenges

JISEA Virtual Meeting

April 9, 2020

NREL NATIONAL RENEWABLE ENERGY LABORATORY | COLORADO SCHOOL OF MINES | Colorado State University | MIT Massachusetts Institute of Technology | STANFORD UNIVERSITY | University of Colorado Boulder

Energy and Agriculture

Challenge: Land Use of Achieving SunShot Solar Deployment Goals

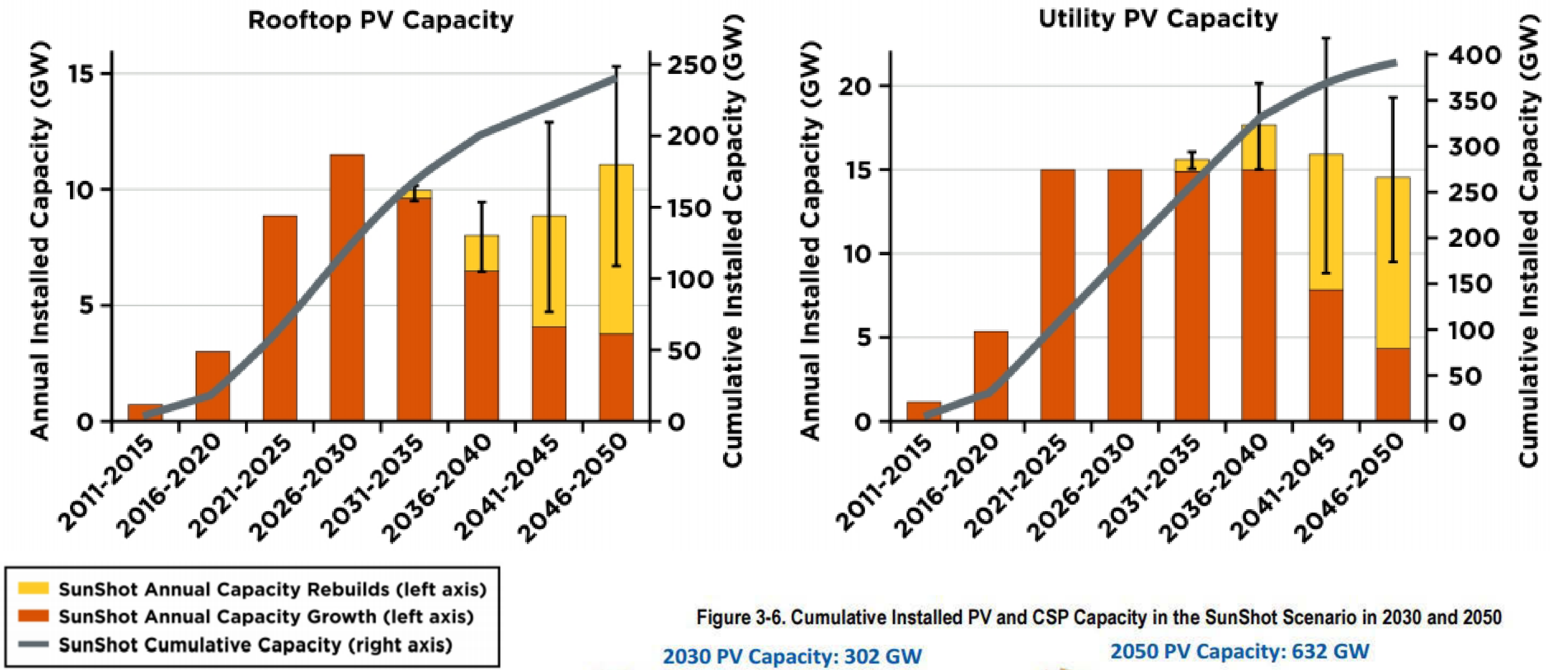
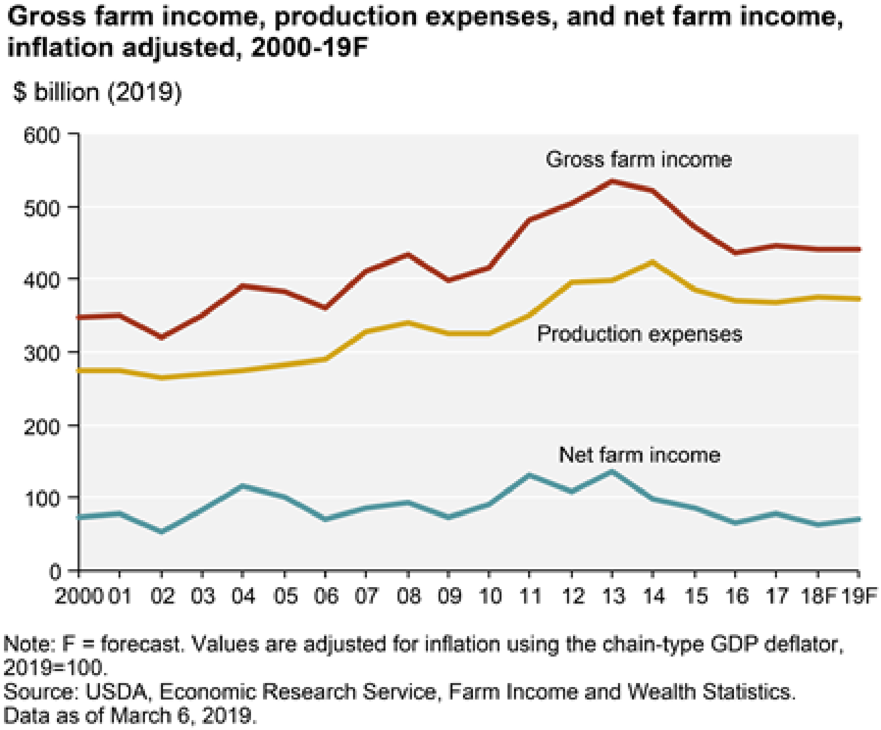


Figure 3-6. Cumulative Installed PV and CSP Capacity in the SunShot Scenario in 2030 and 2050

2030: 3 million acres
2050: 6 million acres

Challenge: Farm Profitability



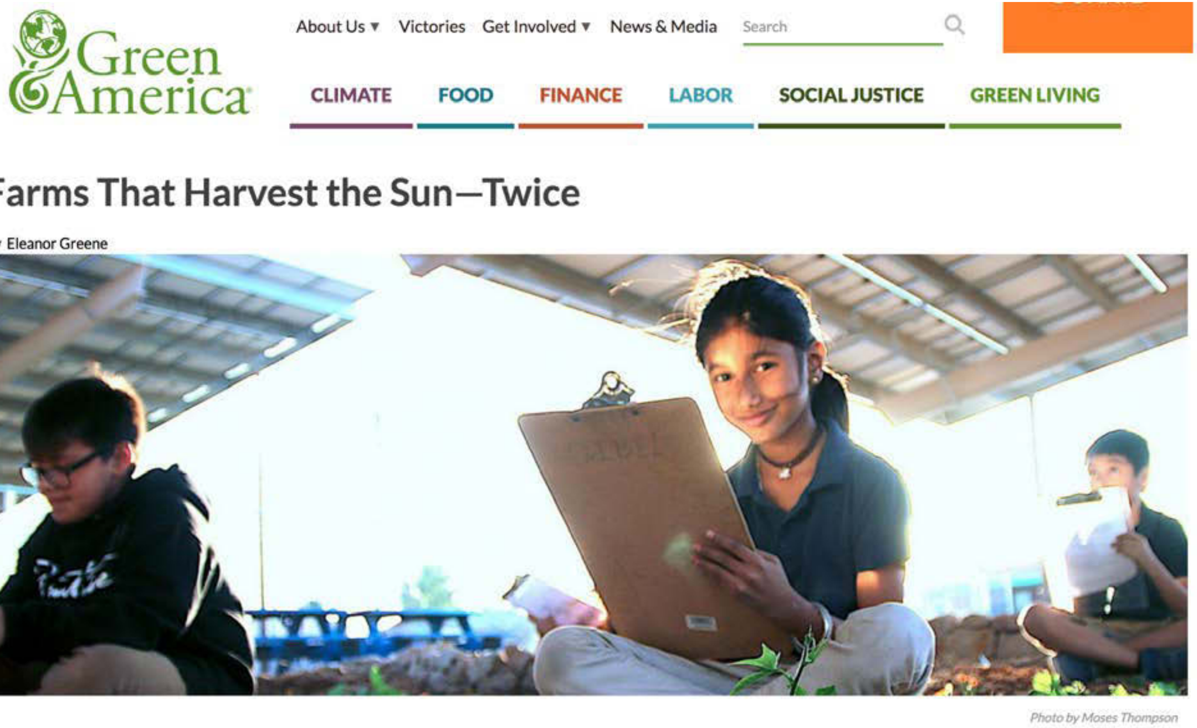

Farm profitability remains a challenge

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

https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=76952

Potential Solution: Agrivoltaics

Agrivoltaics = agriculture + photovoltaics



*photovoltaics (PV)= renewable energy production from solar panels

Ground mounted solar: What does it look like?

Photos courtesy of Rob Davis, Fresh Energy

Vision: Low-Impact Solar Development

InSPIRE Project Overview

Low-impact site preparation

Pollinator and native vegetation solar

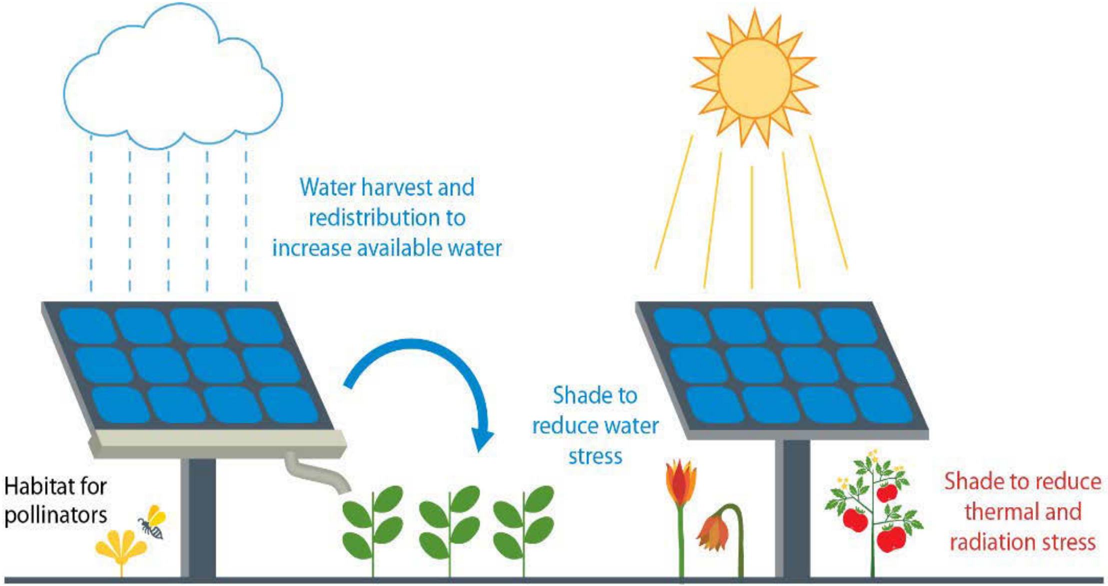
Solar-agricultural co-location

Department of Energy Funded (2015-2021)

Extensive Industry Partnerships

Field and Analytical Modeling Work

InSPIRE Project Overview



InSPIRE Project Sites

Select from the options below to display all sites using that technology.

- Beekeeping
- Co-location of Solar and Agriculture
- Native Vegetation
- Solar-Integrated Greenhouse
- Beneficial Predators
- Dryland Agriculture Co-location
- Pollinator Habitat

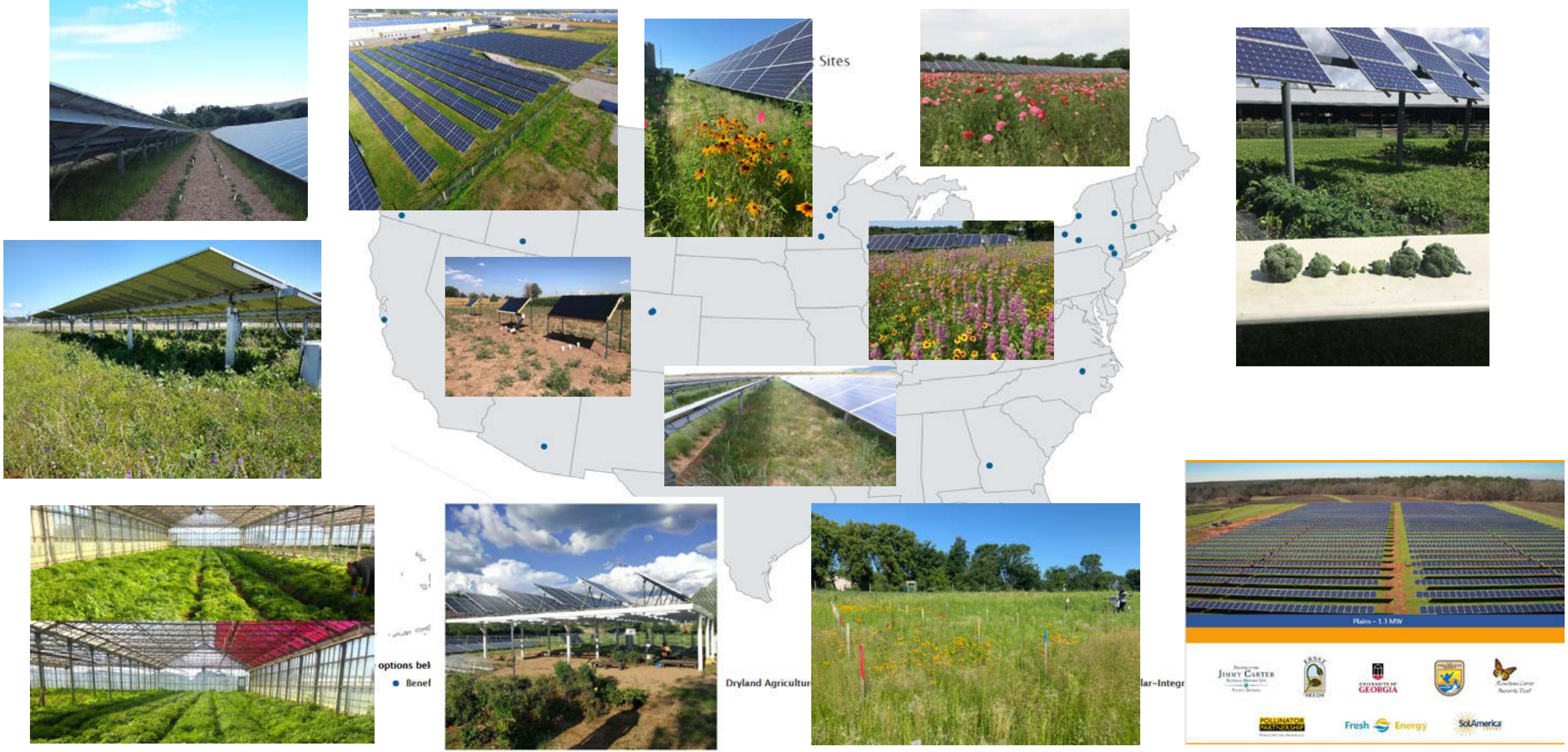
Field-based research topics:

(1) Economic viability of solar-agriculture co-location configurations
(2) Increasing agricultural yields in arid environments
(3) Energy, water, and food security in remote, off-grid areas
(4) Pollinator habitat and ecological services

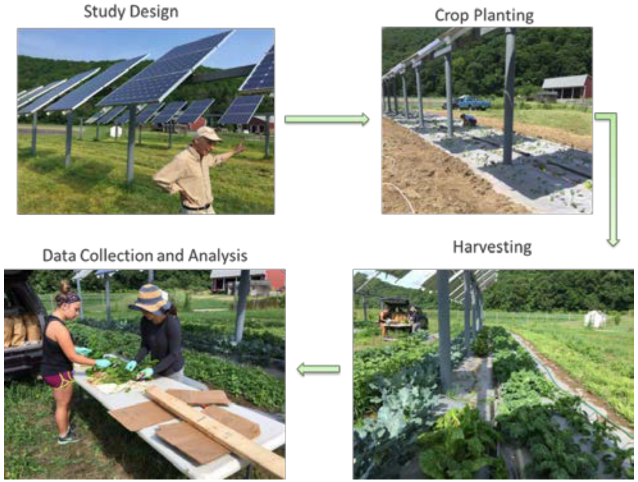
Analytical research topics:

(1) Satellite imagery analysis of current land groundcover practices
(2) Cost-benefit analysis of O&M ground cover practices
(3) Quantification of ecological services of groundcover options

InSPIRE Project Sites



Specific research activities for field studies



Soil Carbon

Temperature Probe

Relative Humidity Probe

Rain Gauge

Datalogger

Soil Heat Flux Plate

Wind Anemometer

Soil Thermocouple

Pyranometer

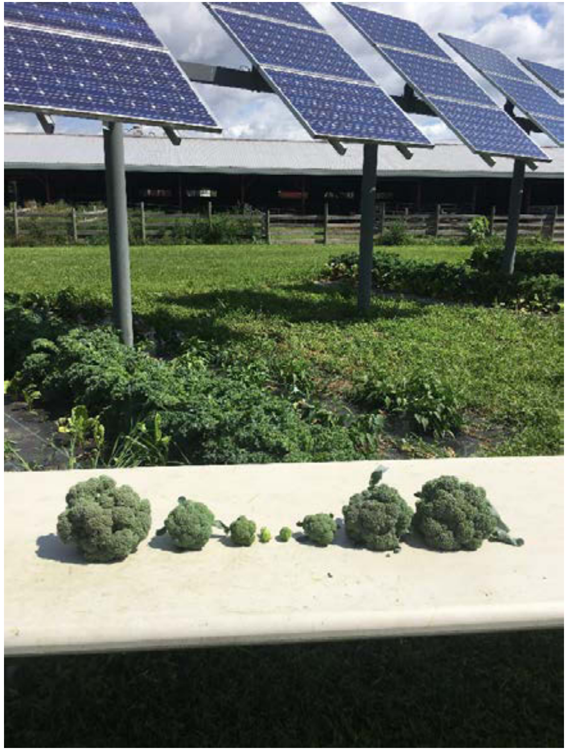
Armstrong et al., 2016

Soil Moisture Reflectometer

PV Panel Thermocouple

Agrivoltaics: Growing Crops Underneath Solar Panels

Massachusetts Test Facility

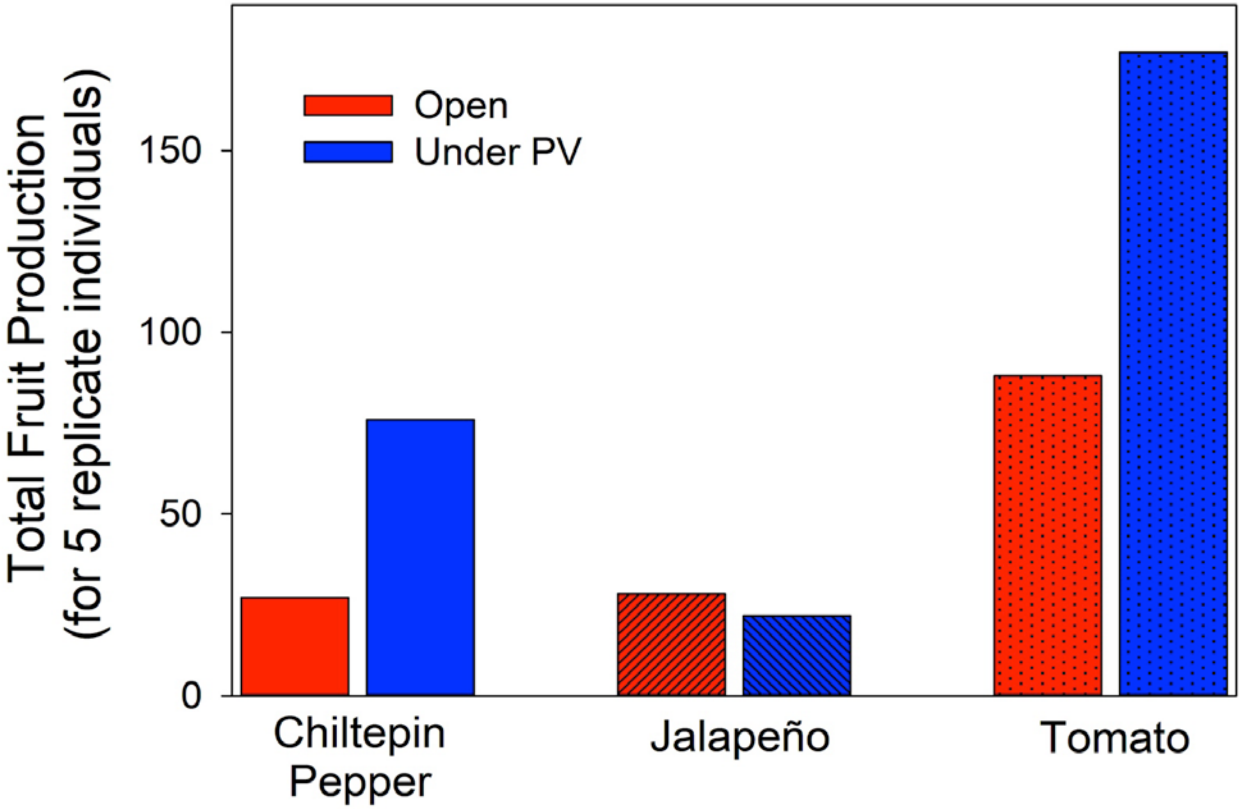


Preliminary results (broccoli)
Harvested August 10, 2019

InSPIRE Research Site: Agrivoltaics at the Biosphere 2 Living Lab

- Elevated (10 ft) solar panels
- Outside of Tucson, AZ
- Professor Greg Barron-Gafford
- Growing peppers, tomatoes, basil, carrots, broccoli, lettuce, melons, flowers, chard (plus more!) in full sun and underneath solar arrays

Food - a win for fruit production!

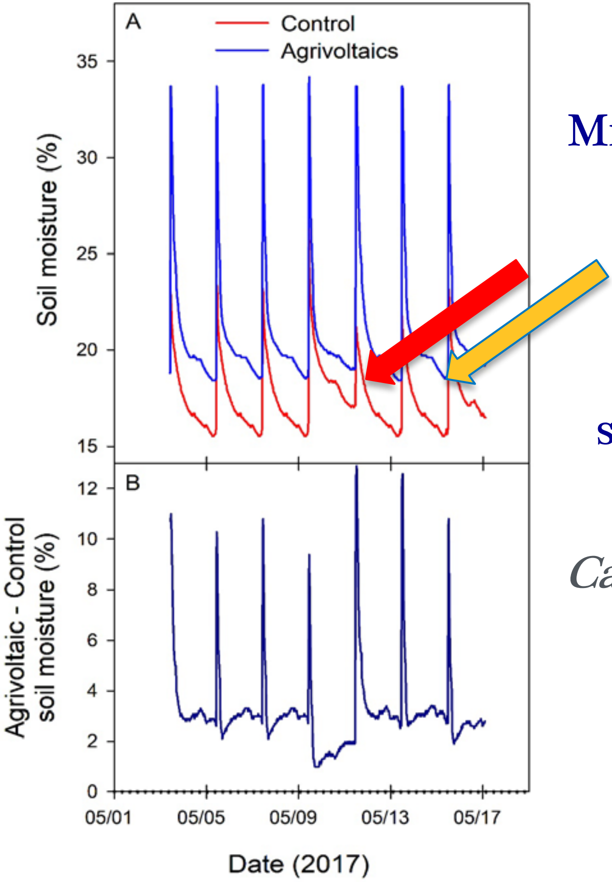


<u>Bottom Line:</u>

- 3x yield for Chiltepin Peppers
- ~ same yield for Jalapeno Peppers
- 2x yield for Tomatoes

Barron-Gafford et al. (*2019*) *Nature Sustainability*

Water - a win for irrigation savings!



Microclimate change under the panels
= water lasts longer in the soil

Soil moisture levels in agrivoltaic system after 2 days = control setting after about 2-3 hours

Can marginal lands now become arable lands?

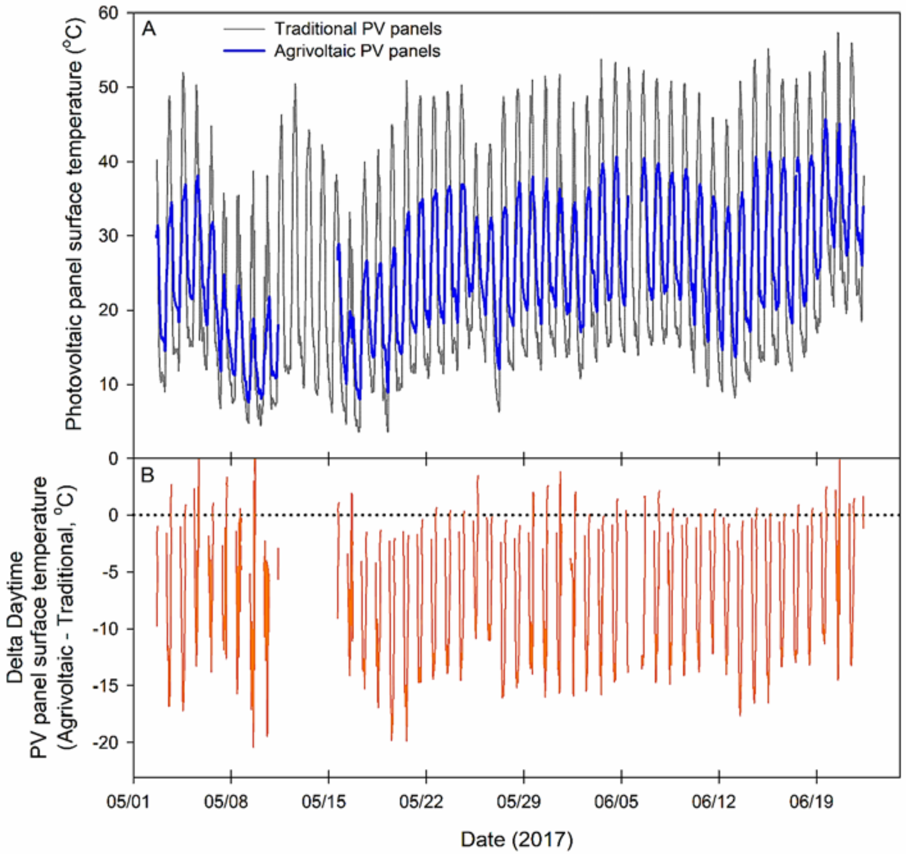
Can we actually reduce our irrigation water use?

Barron-Gafford et al. (*2009*) *Nature Sustainability*

Bottom Line:

- Peppers need 50% less water
- Tomatoes need 30% less water

Energy - a win for PV production!



Cooler temperatures = Increased PV efficiency and less wear-and-tear

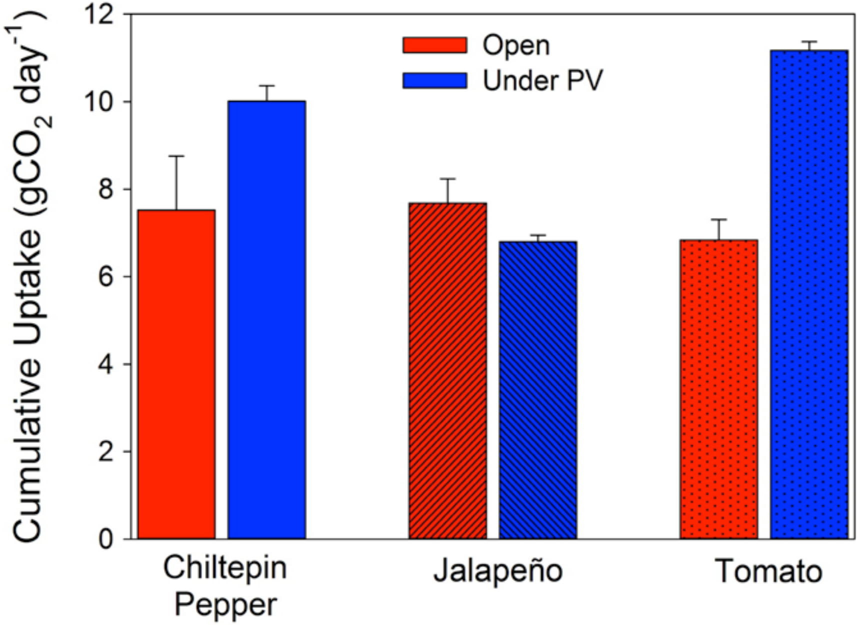
Summer time average cooling ~9°C

Bottom Line:

- 2% higher solar output due to crops

Barron-Gafford et al. (*2019*) *Nature Sustainability*

Climate - a win for carbon uptake!



Barron-Gafford et al. (*2019*) *Nature Sustainability*

Key Highlight: Solar-Integrated Grazing

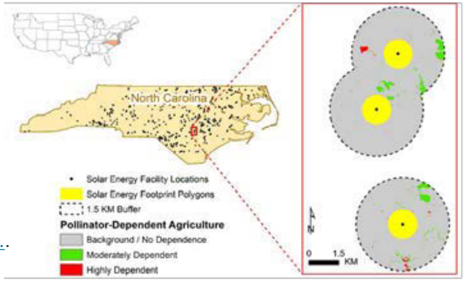
Sustainable grazing practices can improve soils

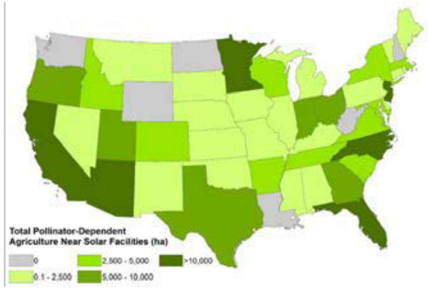
Cost reductions from standard mowing practices

Ongoing work evaluating pastureland performance

Key Highlight: Pollinator-Friendly Solar

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.].
Leroy J. Walston, Shruti K. Mishra, Heidi M. Hartmann, Ihor Hlohowskyj, James McCall,
Jordan Macknick 2018. Environmental Science & Technology Vol. 52 (13) 3 July 2018 pp. 7566-7576.


Solar Power World
TOP SOLAR CONTRACTORS SOLAR ARTICLES PRODUCTS LEADERSHIP SUBSCRIBE

Pine Gate Renewables, Old Sol Apiaries create largest solar farm apiary in America

By Kelsey Misbrener | June 15, 2018

Utility-scale solar developer Pine Gate Renewables, headquartered in Charlotte, North Carolina, is pleased to announce that honey bees are now living on Eagle Point solar farm in Jackson County, Oregon, thanks to the company's SolarCulture initiative.

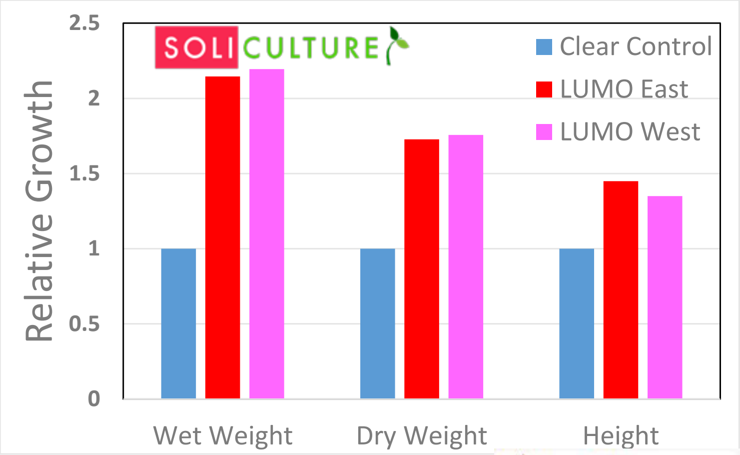
SolarCulture is a Pine Gate environmental stewardship initiative that promotes sustainable agriculture and collaborations with the community to support research for smarter solar development.

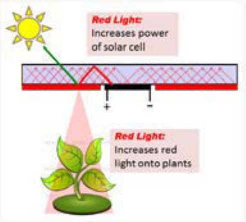
Key Highlight: Solar-Powered Honey Production

Hives can be located in or outside of project fence

Innovative branding and marketing opportunities

Ongoing work evaluating honeybee and native bee preferences



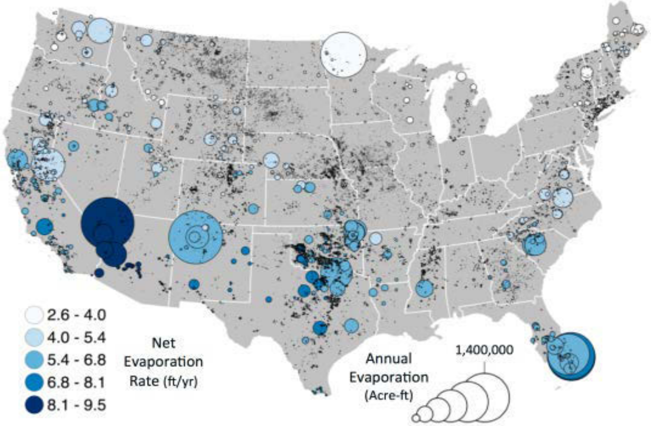


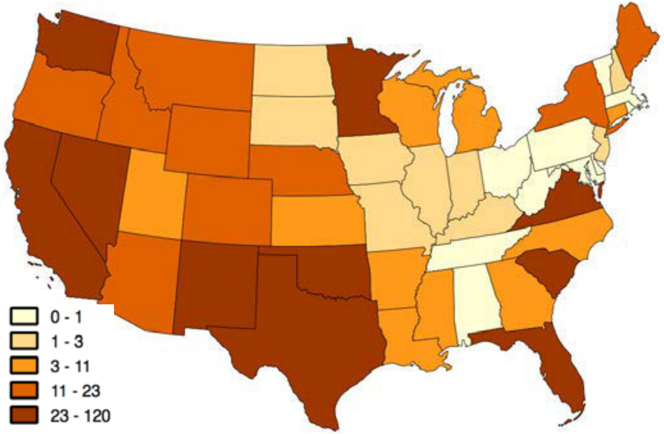
Key Highlight: Solar-Integrated Greenhouses can Improve Yields

Chervil: *annual herb related to parsley with a delicate anise-like flavor*

Plants that received the altered light spectrum of LUMO in the late afternoon performed significantly better than chervil grown under a greenhouse with clear covering.

Key Highlight: Floating Solar on Agricultural Reservoirs





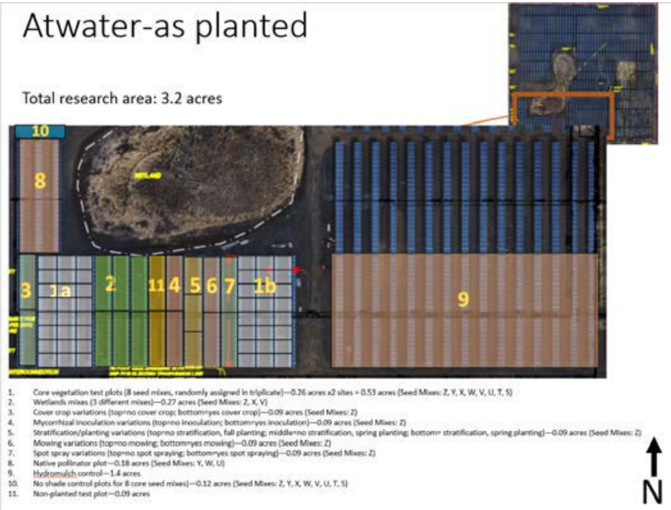
Generation Potential (TWh/year)

Siting on reservoirs can reduce evaporation and algae growth

Avoid conflicts with land used for agriculture

Recent NREL study identified over 25,000 man-made reservoirs that could supply 10% of U.S. power

[Floating Photovoltaic Systems: Assessing the Technical Potential of Photovoltaic Systems on Man-Made Water Bodies in the Continental United States.] Robert S. Spencer, Jordan Macknick, Alexandra Aznar, Adam Warren, and Matthew O. Reese. Environ. Sci. Technol., 2019, 53 (3), pp 1680–1689



Key Highlight: Education through field research

Educational benefits through internships, field trips, work experience, tours

Elementary school through PhD students

State agency, academic, and professional training

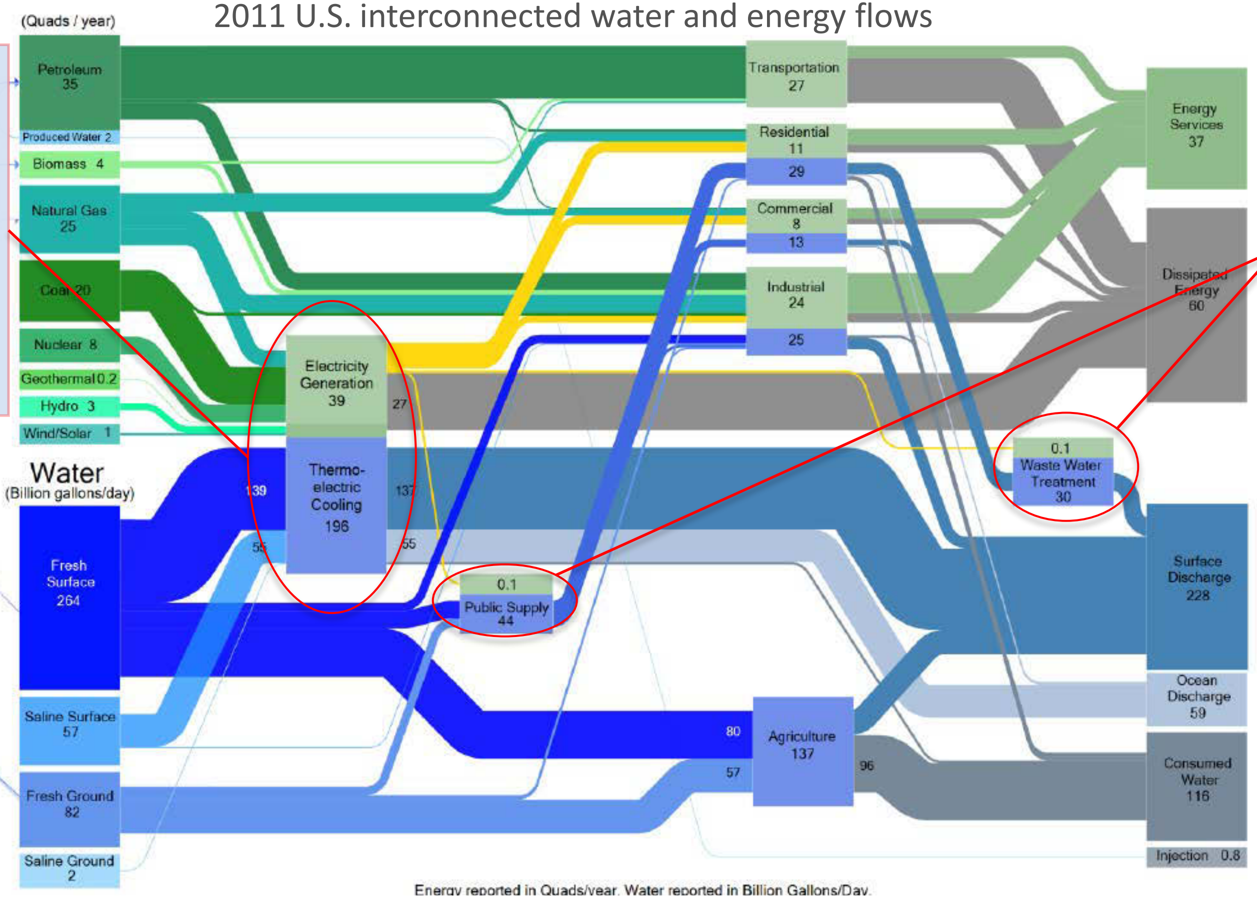
Energy and Water

Energy and Water are interconnected

2011 U.S. interconnected water and energy flows

Energy production requires water

- Thermoelectric cooling
- Hydropower
- Extraction and mining
- Fuel Production
- Emission controls

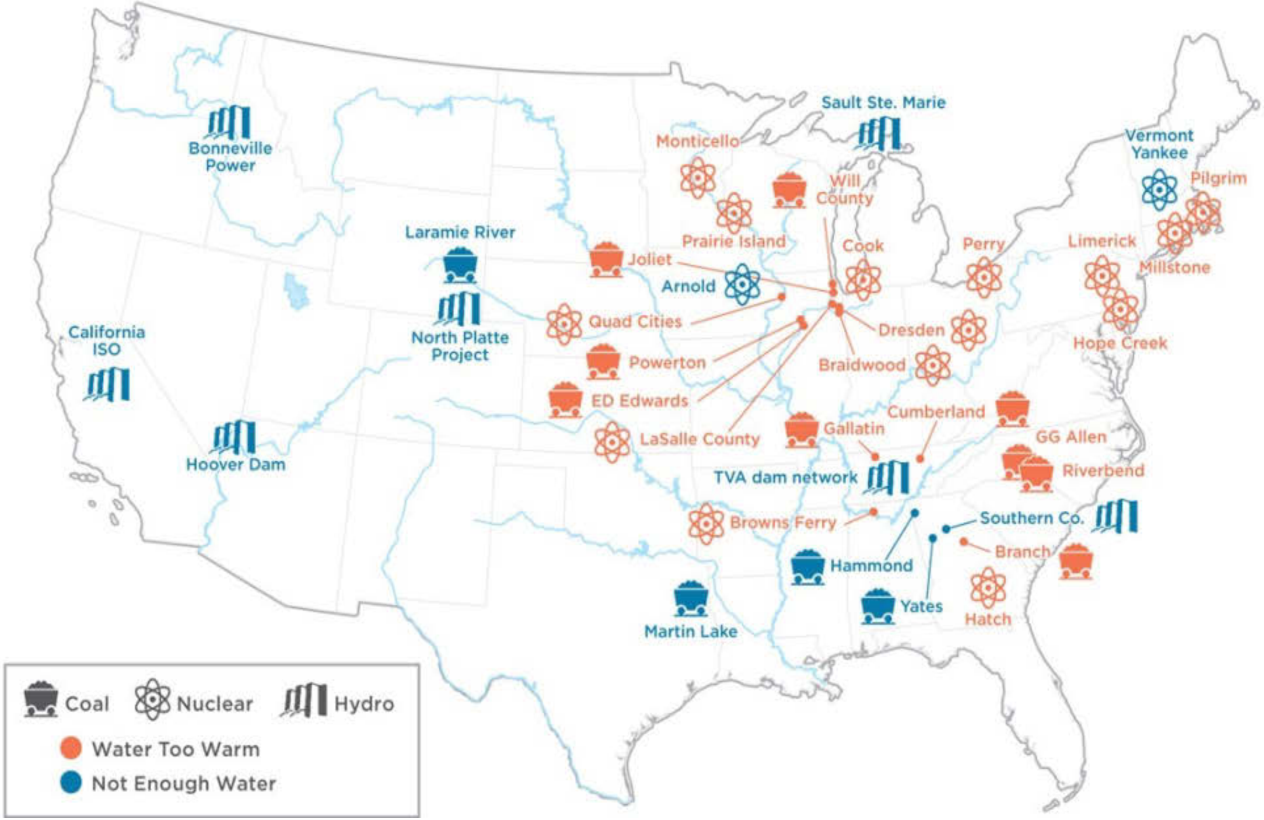


Water production, distribution and treatment require energy

- Pumping
- Treatment
- Transportation
- Heating (End use)

Source: The Water-Energy Nexus: Challenges and Opportunities, DOE, July, 2014

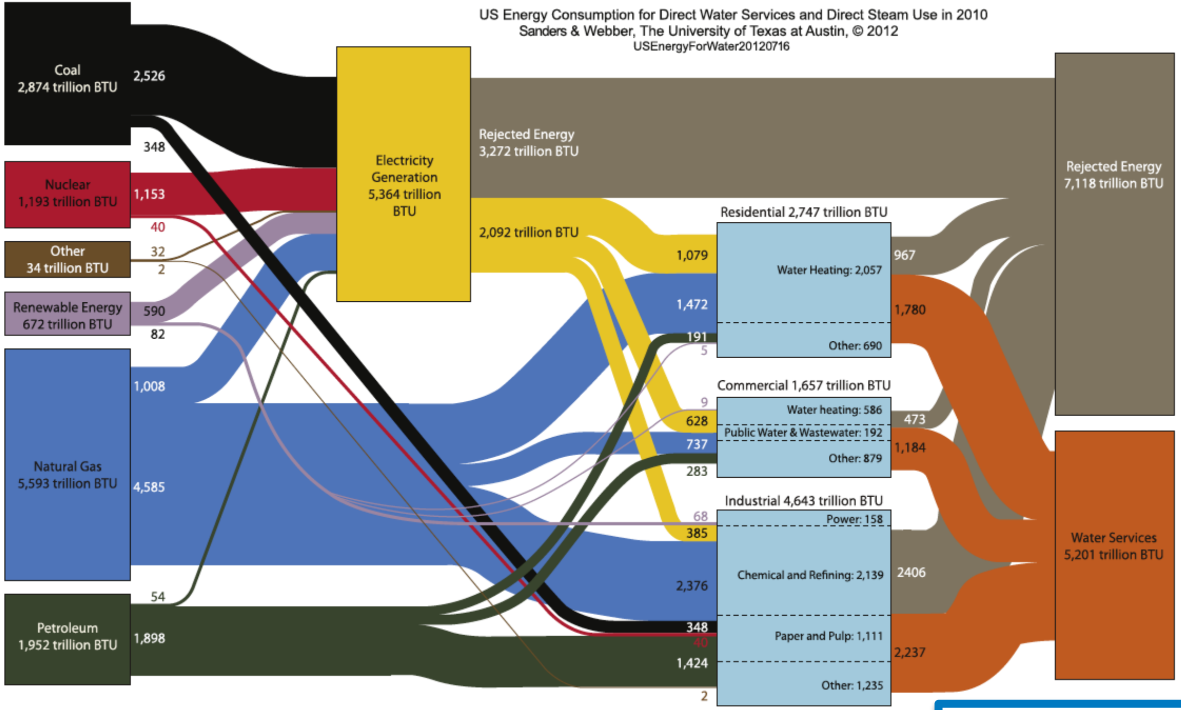
Reliance on water can lead to power sector vulnerabilities



Locations of power plants that shut down or curtailed output due to high water temperatures or lack of water

Source: Rogers, J., Averyt, K., Clemmer, S., Davis, M., Flores-Lopez, F., Frumhoff, P., Kenney, D., Macknick, J., Madden, N., Meldrum, J., Overpeck, J., Sattler, S., Spanger-Siegfried, E., and Yates, D. (2013). Water-smart power: Strengthening the U.S. electricity system in a warming world. Cambridge, MA: Union of Concerned Scientists.
Macknick, J.; Zhou, E.; O'Connell, M.; Brinkman, G.; Miara, A.; Ibanez, E.; Hummon, M. (2016). Water and Climate Impacts on Power System Operations: The Importance of Cooling Systems and Demand Response Measures. NREL/TP-6A20-66714. National Renewable Energy Laboratory, Golden, CO

Primary energy embedded in water infrastructure: US national



*Residential, Commercial, Industrial and Power sectors, (~70% of total US primary energy consumption). Transportation sector not included.

Energy use in the residential, commercial, industrial and power sectors* for direct water and steam services was approximately 13 Exajoules or ***12.6% of the 2010 annual primary energy consumption in the US***

Source: Sanders, K. and M. Webber, 2012. Evaluating the energy consumed for water use in the United States. 2012. Environ. Res. Lett. 7 034034.

National Alliance for Water Innovation (NAWI)

National Alliance for Water Innovation

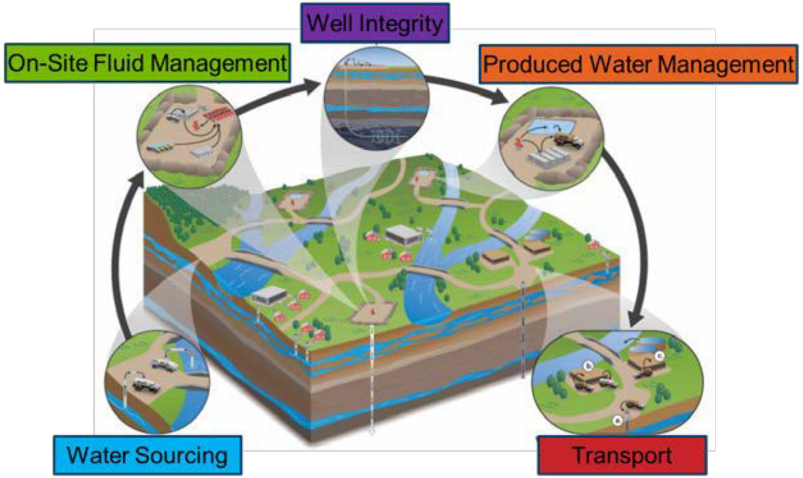
NAWI Goal: Secure a Resilient 21st Century Water Supply through Distributed Desalination and Reuse

- A five-year, $100-million Energy-Water Desalination Hub from DOE's Advanced Manufacturing Office
- Addresses water security issues and economic competitiveness across all economic sectors in the United States
- Focuses on early-stage R&D for water treatment technologies and ways to treat non-traditional water sources

To Participate in Water Technology Roadmapping activities in 2020, please reach out to: Jordan.Macknick@nrel.gov

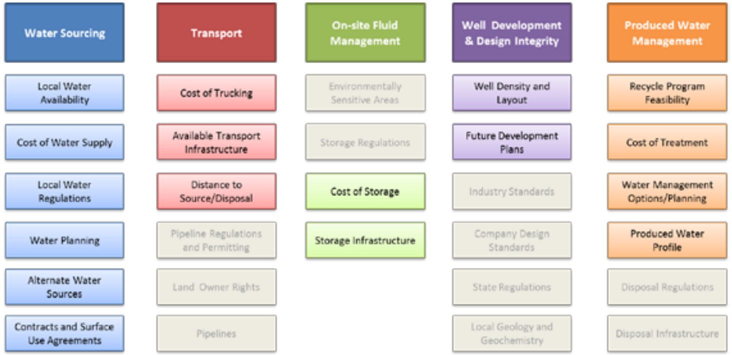
O&G Techno-economic and system analyses

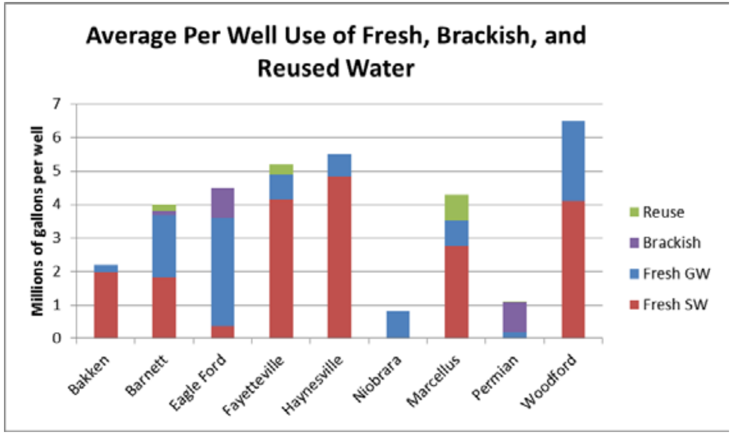
- Current/Past projects include:
  - Key principles for effective water management throughout life cycle of unconventional O&G operations
  - Characterization of water intensity (water use per energy output) of O&G operations based on location, geology, water usage, and EUR
  - Development of flexible produced water management options cost model and decision tree



Water sourcing variations and challenges

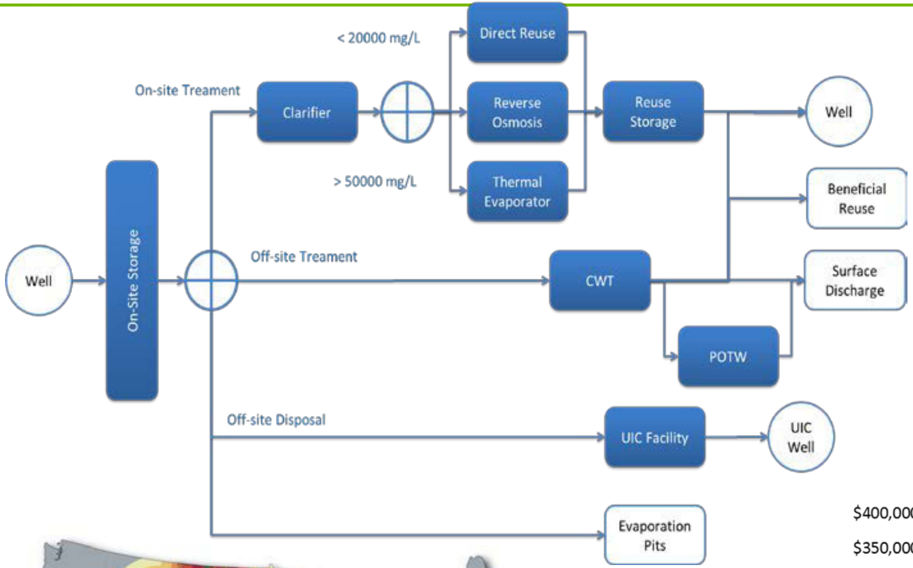
- Key Insights
  - Water sourcing decisions are affected by conditions and decisions of other life cycle stages (e.g., transport, on-site fluid management, well design, produced water management)
  - Systems approach is necessary to effectively characterize costs and optimize approaches
  - Inherent variability in water quality and quantity issues within and across plays





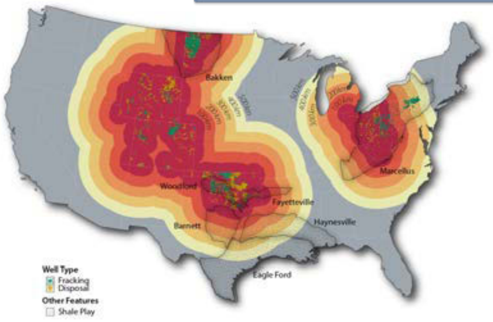
Data collected from: (Freyman 2014; Taylor 2012; Nicot et al. 2014; Nicot et al. 2012; Scanlon, Reedy, and Nicot 2014; Louisiana Ground Water Resources Commission 2012; EPA 2015a; BHP Billiton 2014; Hansen, Mulvaney, and Betcher 2013; Goodwin et al. 2014)

Produced water management risks

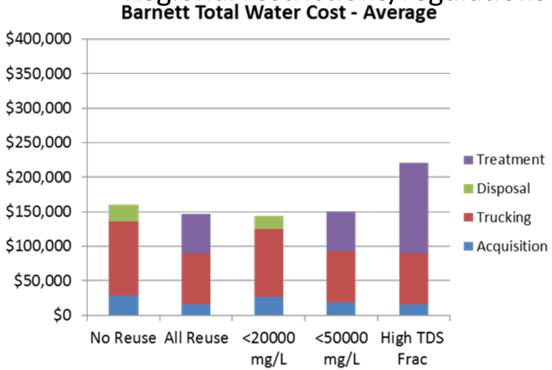


Evaluation of complex produced water management decisions based on multiple factors:

- Produced water quality and quantity
- Desired end-use and required quality
- Freshwater cost and availability
- Water treatment technology costs and characteristics
- Disposal well distance
- Regional restrictions/regulations



Distance to nearest disposal well



Example cost comparison scenarios

California's SB 1281 independent review

- Participated as a Steering Committee member for California Council of Science and Technology's (CCST) SB 1281 review [publication forthcoming]
- SB 1281 established new water reporting requirement for CA O&G operators
- CCST project was an independent review of data collected value and usability, while balancing increased burden on operators
- SB 1281 goals:
  - "ensuring appropriate data were available to assess the impact of O&G production on the water resources of the State;
  - assessing reuse potential of produced water on-site and off-site;
  - addressing concerns over the risks to human health and the environment posed by surface disposal, reuse for irrigation, or surface water streamflow augmentation"

Thank you

NREL/PR-6A50-76556

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