Overview of opportunities for co-location of agriculture and solar PV

Jordan Macknick

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Motivation: Department of Energy SunShot Solar Goals

- **2030**: 3 million acres
- **2050**: 6 million acres

**2030 PV Capacity**: 302 GW

**2050 PV Capacity**: 632 GW

Cumulative Installed PV and CSP Capacity in the SunShot Scenario in 2030 and 2050
Motivation: Conventional Utility-Scale Solar Land Preparation Approach
Site preparation costs and impacts

Site preparation costs for utility-scale solar projects are expected to account for 20% of utility-scale PV installed costs in 2020.

Reducing site preparation costs via low-impact site development can lead to cascading reductions in other environmental-related costs and risks.

<table>
<thead>
<tr>
<th>Site Preparation Practice</th>
<th>Cost Contribution</th>
<th>Estimated Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geotechnical Investigation</td>
<td>2.6% (0.7%)</td>
<td>0% - (25%)</td>
</tr>
<tr>
<td>Clearing and Grubbing</td>
<td>4.3% (1.2%)</td>
<td>25% - 90%</td>
</tr>
<tr>
<td>Soil stripping and stockpiling</td>
<td>1.5% (0.4%)</td>
<td>20% - 90%</td>
</tr>
<tr>
<td>Grading</td>
<td>4.2% (1.2%)</td>
<td>50% - 90%</td>
</tr>
<tr>
<td>Soil Compaction</td>
<td>1.9% (0.5%)</td>
<td>50% - 75%</td>
</tr>
<tr>
<td>Foundation for vertical support</td>
<td>22.1% (6.3%)</td>
<td>2% - 5%</td>
</tr>
</tbody>
</table>

Cost contribution values represent percent of total civil works costs; values in parentheses represent total installed capital costs for 100MW utility-scale PV.

<table>
<thead>
<tr>
<th>Other Cost Categories</th>
<th>Expected Impact</th>
</tr>
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<tbody>
<tr>
<td>Land Acquisition</td>
<td>5-10% reduction in land requirements</td>
</tr>
<tr>
<td>Permitting</td>
<td>1-5% reduction in permitting costs</td>
</tr>
<tr>
<td>O&amp;M for weed control</td>
<td>2-7% reduction in O&amp;M</td>
</tr>
<tr>
<td>Degradation</td>
<td>1-3% improvement in annual panel degradation</td>
</tr>
<tr>
<td>Efficiency</td>
<td>1-3% improvement in efficiency due to temperature impacts</td>
</tr>
</tbody>
</table>
Overview of InSPIRE

FY2016-FY2018 NREL Project through U.S. Department of Energy

Meeting SunShot Cost and Deployment Targets through: Innovative Site Preparation and Impact Reductions on the Environment (InSPIRE)

Reducing environmental impacts of solar projects through low-impact site preparation can have a cascading effect on lowering solar development costs:

![Cost Reduction Pathway](chart.png)

*Note: Assumed Module Price = $0.70 per W with 15% Module Efficiency, Capacity factor = 20%, Degradation = 0.5%, O&M = $20k/W/year (with 3% Escalator), WACC = 8.6%, Project life = 30 years.
Smart, low-impact siting designs and planning can reduce installation and operation costs, financial risks, and environmental impacts of commercial and utility-scale solar projects.
Partners and Stakeholders

Experienced project team leverages expertise from across US and world

- Enhanced stakeholder engagement ensures timely and relevant products to the market
  - Solar Energy Industry Association (SEIA) and the Large-Scale Solar Association (LSA)
  - EPA and BLM
- Results integrated into NREL’s soft cost and solar technology modeling tools
- Complementary, non-duplicative products informed by industry needs
- Frequent interaction and validation from industry
Solar and agriculture co-location: Research design

- Crop varieties
- Solar configurations
- Regional variations
- Field studies located throughout the U.S.
- Desktop analysis and modeling
Preliminary cost modeling estimates suggest that a portion of the strategies in this proposal could constitute:

- 3-8% of the $/W cost reductions and
- 5-19% of the $/kWh cost reductions necessary to achieve SunShot cost goals in 2020;

Additional cost reductions (e.g., reduced mitigation costs, construction timelines, litigation costs) will increase impact; Expansion of economically viable lands for solar development; Direct and frequent interaction with industry stakeholders.
Opportunities for low-impact solar development

- Solar Centric
  - Minimal changes to solar configuration
  - Low-lying vegetation for ground cover and habitat

- Vegetation Centric
  - Minimal changes to vegetation design
  - Large spacing in solar technologies

- Co-Location and Co-Optimization
  - Solar and vegetation configurations are designed jointly for maximum dual output
NREL Wind Site: Solar-Centric Approach

How well does vegetation grow underneath and between solar panels?
Sunflowers for oil production grown under panels in Wisconsin

Milwaukee Journal Sentinel, 2011
Solar and Agriculture Co-location

- Massachusetts Test Facility
- Innovative installation and structural design
- Multiple crop types
- U-MASS-Amherst
  - Agriculture
  - Structural Eng.
  - Electrical Eng.
  - Economics
Solar and Agriculture Co-location

Ranching and grazing
India: Aloe Vera

Ravi et al., 2016
Desert Southwest and Mexico: Agave

Ravi et al., 2014
Greenhouses

Red Light: Increases power of solar cell

Red Light: Increases red light onto plants
## Benefits of Co-Location of Solar and Agriculture

### Benefits to Land Owners

- Self-generation of electricity and reduced energy bills
- Additional income stream and increased revenue security
- Control of wind and soil erosion
- Compatible with grazing activities, provides shade and cover for livestock
- New market opportunities for shade tolerant crops
- Protection of natural habitat
- Safeguarding soil health
- Improved habitat for pollinator species

### Benefits to Solar Developers

- Reductions in site preparation and installation costs
- Reductions in O&M costs
- Reduced need for dust suppression
- Reduction in litigation vulnerability
- Decreased permitting time
- Increased solar energy production from cooler air zone created under modules
- Reduction in environmental mitigation investments
There are sufficient areas of disturbed and contaminated lands to meet U.S. Department of Energy SunShot Solar goals without utilizing one acre of agricultural land

Macknick et al., 2013
Closing Thoughts

• There are opportunities for synergies between agricultural and solar energy communities

• Solar projects can be designed and constructed in ways that minimize environmental impacts and reduce costs

• Test facilities and systematic demonstrations of various configurations are needed to quantify potential benefits

• Greater interaction with multiple stakeholders can improve viability of solar and agriculture in the future
Thank you
Jordan.Macknick@NREL.GOV