Pairing Solar Photovoltaics and Agriculture: Recommendations to the New Jersey Board of Public Utilities on the Dual-Use Solar Pilot Program

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Executive Summary

Agrivoltaics, or dual-use solar photovoltaics (PV), have the potential to provide many benefits to land-use constrained states with ambitious clean energy goals, such as New Jersey. New Jersey has seized this opportunity by creating the Dual-Use Solar Pilot Program in the hopes of driving widespread adoption of agrivoltaics. However, agrivoltaics still face challenges and complexities that call to question the commercial viability of the technology and its promised benefits.

How can the New Jersey Board of Public Utilities design the Dual-Use Solar Pilot Program in a way that unlocks the full potential benefits of agrivoltaics, while still encouraging innovation that lowers barriers towards its adoption? This project explores the economics of agrivoltaics in New Jersey through an Agrivoltaic Farm Model and by pairing its results with findings from interviews with agrivoltaic experts. As a result, this project urges that the Board of Public Utilities adopt the following changes to the Dual-Use Solar Pilot Program:

1. Limit the flexibility of the variable agrivoltaics "adder" to ensure that least-cost agrivoltaics designs are pursued
2. Prioritize project applications and determine "adder" based on farm type, crop value, and crop total acreage in New Jersey
3. Investigate novel agrivoltaic partnerships where solar developers and farmers share crop and solar profits

Methodology

This project uses two methodologies — a quantitative model and qualitative interviews — to execute the technology and policy assessment of agrivoltaics. The quantitative model, called the Agrivoltaic Farm Model, consists of a solar model and an agricultural model. The solar model is derived from the System Advisory Model (SAM) developed by the National Renewable Energy Laboratory (NREL) and implemented using pySAM in Python. The agricultural model consists of several crop budget models obtained from university extensions. This project considers the following scenarios:

- three technology adoption scenarios (farms adopting agrivoltaics, conventional PV, or no-solar systems) of varying system sizes (1 MW to 5 MW in capacity)
- three New Jersey farm types (vegetable, specialty, and commodity farms)
- two ownership scenarios (singular entity and dual entity partnerships)

This project then explores the effect of varying agrivoltaic incentives, crop profit values, and crop yield reductions across all scenarios.

The qualitative interviews aim to understand the drivers, challenges, and policy implications of agrivoltaics that are not captured by the quantitative model. The qualitative portion of this project includes interviews with 17 experts, ranging from agrivoltaics project managers, solar developers, and farmers. Site visits at existing crop and grazing agrivoltaic systems across California and Arizona complement the interview findings.

Findings

Agrivoltaics require different incentive levels for adoption to occur depending on the ownership scenario and crop type:

- For a singular entity ownership (consisting of a landowning farmer installing their own agrivoltaic system), an additional agrivoltaic incentive is not needed for high-value crops (>$1,700 per acre) for adoption to occur. However, an additional incentive is needed for low-value crops (<$1,700 per acre) for agrivoltaic adoption to occur.

- For a dual entity partnership (consisting of a landowning farmer and a solar developer), an additional agrivoltaic incentive is needed ($0.103/kWh SREC-II incentive value) regardless of crop profit.

Furthermore, the singular entity ownership scenario is unlikely to occur without government intervention, thus requiring an incentive program targeted for solar developers. The appropriate incentive levels and additional non-financial considerations are presented below.

Singular entity ownership results

If the agrivoltaic system is owned by a singular entity, the technology will be adopted even if there is no additional agrivoltaic incentive for high-value crops with a profit of roughly $1,700 per acre or greater, only receiving the standard "Large Net Metered Non-Residential Ground Mount" SREC-II incentive value of $0.080/kWh. As the crop profit decreases, the SREC-II incentive must be greater for the agrivoltaic system to be adopted, as shown by the values in Table 1.

Crop profit ($/acre)	SREC-II Incentive ($/kWh)
$0 to $210	$0.10 to $0.11
$210 to $950	$0.10
$950 to $1,700	$0.09
$1,700 to $3,000	$0.08

Table 1. SREC-II incentive level for agrivoltaic adoption to occur for each crop profit range for singular-entity agrivoltaic owners. Both crop profits and SREC-II values are rough estimates.

Assuming an agrivoltaic incentive of $0.10/kWh exists, the impact of crop yield reductions can still question the viability of agrivoltaics deployed on certain farm types. Vegetable farms are found to only take a 9-11% crop yield reduction for system sizes 1 MW to 5MW, respectively,

until they become less profitable than a traditional farm. However, commodity crop farms can take up to a 100% crop yield and remain more profitable than the traditional farm systems.

These findings correlate with past studies that show agrivoltaics can be profitable. However, the singular entity partnerships prove to be unlikely to occur. Nationally, 40% of farmers across the nation do not own their land, eliminating a significant portion of farmers able to install an agrivoltaic system. A typical landowning farmers will not have access to the capital and financing methods necessary to develop systems. Paired with the lack of proof of concept of the technology and inherent risk of innovation, agrivoltaic adoption is even less likely to occur.

Dual entity ownership results

On the other hand, when agrivoltaic systems involves two entities, a solar developer and a landowning farmer, the adoption structure changes. Both the solar developer and farmer must derive benefits from installing an agrivoltaic system. The quantitative results show that the farmer always gains from adopting agrivoltaics, with low-value crop farmers benefitting significantly more than high-value crop farmers. The solar developer, however, will never adopt agrivoltaics without an additional incentive due to the high capital expenses. The solar developer needs an SREC-II incentive level of roughly $0.103/kWh regardless of crop value to develop an agrivoltaics system instead of a PV system, which is 30% higher than the traditional SREC-II incentive level, but equal to the existing "Small Net-Metered Non-Residential located on Rooftop, Carport, Canopy and Floating Solar" SREC-II value.

However, the interview findings show that the increasing costs of conventional PV systems can decrease the cost difference between agrivoltaic and PV systems. Rural opposition to conventional utility-scale PV systems is becoming an added cost and barrier for many solar developers. By partnering with a farmer, the solar developer can overcome public opposition and avoid project delays. In addition, partnering with a farmer can lower vegetation management costs, which are becoming more of a concern for solar developers as labor costs rise. Farmers may need to be compensated to enter an agrivoltaic partnership, however, due to their skepticism of the technology and the value they place on crop uniformity, which can be compromised due to uneven shading caused by agrivoltaic systems.

Policy Recommendations

The Dual-Use Solar Pilot Program is under development by the Board of Public Utilities (BPU) and will begin to accept applications in mid-2024. Drawing from the quantitative and qualitative results and past studies, this project proposes several policy adjustments to be made to the Dual-Use Solar Pilot Program.

The BPU should limit the flexibility of the variable agrivoltaics "adder" to ensure that least-cost agrivoltaics designs are pursued.

The Dual-Use Solar Pilot Program will allow solar developers to name their own incentive level, a variable "adder," to build their system, without any limitations on the amount they can request. The flexibility of this incentive structure will drive solar developers to submit the highest possible agrivoltaic "adder," which will fail to encourage the innovation needed to close the gap between agrivoltaic and PV system costs. The variable "adder" covers any loss in generation revenue and cost differences compared to a conventional PV system, so solar developers will create designs with increased row spacing and high capital expenses. Since Pilot Program's many incentive levels will inform a permanent incentive program, solar developers will be even more motivated to inflate costs. Although a variable "adder" claims to give developers the opportunity to be more innovative in their designs, it will distort costs and result in agrivoltaics systems to never become cost-competitive with PV systems.

This study has shown that given current agrivoltaic system costs, an incentive level of $0.103/kWh is appropriate for solar developers participating in the dual entity ownership scenario. Similarly, if a singular entity ownership occurs, an incentive value of around $0.10/kWh to $0.11/kWh will drive agrivoltaic adoption for the lowest value crops. Therefore, the BPU should limit the variability of the "adder" to an amount close to the appropriate incentive level found in this study, around $0.105/kWh.

Furthermore, as found through qualitative interviews, certain crops, such as hay, may be planted between the rows of existing utility-scale single-axis tracking PV systems with very few adjustments. The BPU should prioritize designs that resemble the conventional PV industry standard to produce research that shows that agrivoltaics has the potential to become a feasible alternative to conventional PV systems.

The BPU should prioritize project applications and determine "adder" value based on farm type, crop value, and crop total acreage in New Jersey.

First, the BPU should prioritize agrivoltaic systems paired with low-value crops in the application pool. If no agrivoltaic incentive were to exist, the quantitative results show that low-value crop farmers are more likely to convert a portion of their farmland to conventional PV systems over agrivoltaics or traditional agriculture. Additionally, low-value commodity crops make up the greatest percentage of cropland in New Jersey, 89.4%, while vegetable crops only make up 7.4%, followed by specialty crops at 3.2%. If New Jersey aims to preserve agricultural land and develop as much solar capacity as possible, the Board should provide higher incentives for those low-value crops at risk of being replaced by conventional solar PV which already comprise a large percentage of the state's farmland. Additionally, low-value crop farmers under the dual entity partnership scenario benefit far more from agrivoltaics than high-value crop farmers, providing farmers that suffer from low margins with an added insurance against market and weather volatility.

If a project is proposed under the singular entity ownership, though unlikely to occur, the BPU should recognize that high-value crop farmers do not need an additional incentive to adopt agrivoltaics. On the other hand, low-value crop farmers that receive a profit of $950/acre or less need an SREC-II incentive level of $0.10/kWh or more to adopt agrivoltaics. However, it is important to recognize that the risk undertaken by high-value crop farmers is high due to potential crop yield reductions.

Therefore, the BPU should approve projects with variable "adders" that are financially justified based on the crop value and farm type, not just the solar system design. The BPU should expect to provide a higher additional incentive for low-value crops under a singular entity ownership, but they should also recognize that the additional incentive will do more to protect farmland than providing an incentive to a high-value crop farm.

The BPU should investigate novel agrivoltaic partnerships where solar developers and farmers share crop and solar profits.

The financial benefits of agrivoltaics found in this study and past literature stem from the increase in land-use efficiency under the singular entity ownership model. However, when the agrivoltaic system is developed under a dual entity ownership, the barriers to adoption

increase, lowering the financial benefits possible for both entities. By having an integrated dual entity ownership model where crop and solar profits are distributed among stakeholders, the full benefits of agrivoltaics can be attained. The BPU should aid in designing this shared ownership model to unlock these benefits and overcome some existing challenges for agrivoltaics.

Additionally, designing agrivoltaic partnerships have become a barrier to agrivoltaic adoption. The legal risks, compensation and cost allocation, security considerations, among many more issues, must be determined by the two entities before developing the system. Designing an agrivoltaic partnership can be costly and time consuming for both farmers and solar developers, especially with very few case studies available. The BPU can help the agrivoltaic industry by developing partnership designs that follow the legal guidelines of the Dual-Use Solar Pilot Program and result in lower barriers to adoption of agrivoltaics.

Future Work

- Validate the least-cost single-axis tracker design to ensure the $0.103/kWh SREC-II inventive level is sufficient for agrivoltaic systems to be more profitable than PV systems receiving the $0.080/kWh SREC-II incentive level.
- Research the impact of the solar land lease on the financial outcomes of an agrivoltaic system. This project only assumes one constant solar land lease. However, the solar land lease may change over time and by region. Additionally, the presence of an agrivoltaics incentive may increase the solar land lease for all agrivoltaic systems, which can distort the financial benefits received by each entity.
- Perform qualitative interviews with farmers and solar developers in New Jersey to gain a more state-specific qualitative perspective on agrivoltaics. This project mainly includes interviews with out-of-state agrivoltaic experts and only engages directly with a few of experts in New Jersey.