Title: Accounting for Water-Energy Co-Benefits of Floating Photovoltaics (FPV)

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Focal Area(s): Optimizing Energy-Water Interactions: Accounting for co-benefits from floating solar photovoltaics (FPV) and canopies over waterbodies in project planning and deployment as well as harnessing these benefits for the water, energy and agricultural sectors.

Existing Challenge: Floating photovoltaic projects, as well as those that span over waterways (i.e. canopy), present potential technological and economic advantages over ground-mounted systems that have fueled rapid global growth in installed capacity in recent years. Aside from expanding generation, FPV present numerous additional benefits (hereafter, co-benefits), such as improved panel efficiency and reduced land usage, others arising from hybrid FPV-hydropower systems (e.g., co-location and co-management), as well as others pertaining to water security, particularly in rural agricultural setting (e.g., reduced evaporation and water temperature from shading, improved water quality). The evidence for this wide range of co-benefits (Table 1) varies widely and measures of positive returns or advantages in FPV alternatives remain under-quantified (Gadzanku et al. 2021; Kakoulaki et al. 2023). **Without reliable assessment and modeling, co-benefits cannot be appropriately considered during project planning.**

FPV installations in the U.S. are rapidly expanding, with 10 megawatts (MW) added in 2022 (Bloomberg 2023). Large potential remains, with federally controlled reservoirs alone capable of producing half of future U.S. energy needs without demanding more land nor considering added resilience from co-management with existing hydropower installations (Rosenlieb et al. 2025). Canopy solar projects integrated with water delivery systems are also beginning to be developed, with opportunities to explore co-benefits. In 2024 and 2025, projects in Arizona and California installed nearly 3MW of solar over irrigation water delivery infrastructure, spanning 20-foot and 110-foot wide canal sections. Both projects may provide localized water quality co-benefits as well as downstream water savings for hydropower generation.

Co-location and co-management of FPV with hydropower generation and transmission presents some potentially energy co-benefits, but also tradeoffs between individual generation systems and resource impacts. An improved understanding and accounting of these synergies and tradeoffs during development is needed to inform permitting, incentive eligibility, utility-level planning, and return on investment forecasting to reduce project risk. New FPV and canopy projects developed to maximize co-benefits should also consider potential unintended environmental impacts and uncertainty in future weather and hydrological conditions. Reservoir owners and operators, water managers, and project developers need standardized tools and methodologies to anticipate potential co-benefits and impacts.

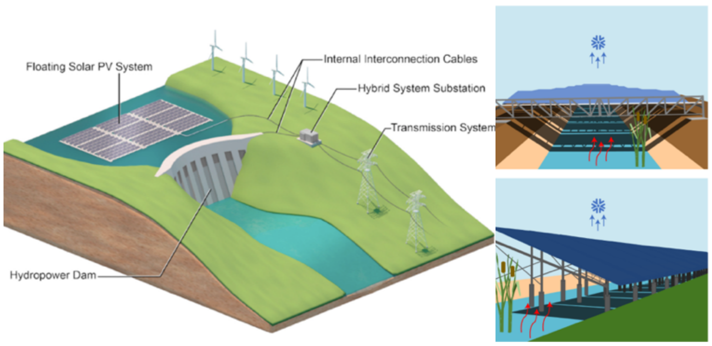

Figure 1: (Left) Depiction of floating PV-hydropower hybrid system where FPV and hydropower are jointly operated (from Lee et al. 2020) and (Right) canopy PV anchored over canals reduces panel heating as well as decrease evaporation and improve water quality (from McKuin et al. 2021).

Near-Term Opportunity: An improved understanding of project co-benefits and impacts on a per-acre basis, relative to alternatives, may support increasing deployment of FPV and canopy PV projects. For tradeoff analyses carried out by developers and regulators to reach technical potential and account for co-benefits, the following gaps must be addressed:

1. Develop co-benefit knowledge base: Data is scarce on the constraints, co-benefits and impacts of different project types and specifications (e.g., FPV vs canopy; for irrigation, reregulation, pumped storage, hybridized with hydropower) at site and regional scales (Table 1). A review of deployment technologies and co-benefits assessment methods is a first step towards understanding how siting decisions define interactions between designs, co-benefit provisioning, and resource impacts. A database of realized co-benefits should be assembled from available projects to develop models and extract lessons to maximize co-benefits (Table 1). Predictions of co-benefit metrics from site- to national-scales should be tested on compiled FPV data. *Because few such systems currently exist in the US, partnerships with FPV project developers, regulators, and other stakeholders (ex. irrigation districts), including international ones are key to evaluating novel designs and understanding which co-benefits drive project decisions.*

2. Define regulatory landscape for co-development: As co-development of FPV with hydropower and irrigation infrastructure is still burgeoning, the regulatory processes governing these developments are not yet fully understood (Levine et al. 2024) and could be a major factor in determining project viability. FPV projects on hydropower reservoirs are subject to Federal Energy Regulatory Commission (FERC) jurisdiction and additional required permitting and authorizations are an active area of research. Regulatory processes and the overall regulatory burden related to developing projects where there may be hydrological and/or environmental impacts may need to be further defined and understood to enable increasing installations.

3. Develop co-benefit assessment tools: Development of field validation methods and predictive tools (ex. limnological models of FPV on lakes, reservoirs and ponds) are key to enable project developers to explore potential trade-offs between anticipated co-benefits (ex. evaporative loss and water temperature) and environmental impacts (ex. reduced aquatic productivity) from various FPV/canopy designs. *Key partnerships and targeted audiences for this step include hydropower utilities, irrigation districts, and watershed managers that can incorporate "co-benefit metrics per FPV ha" into their planning.*

4. Integrate FPV co-benefits in water-energy sector planning: Several FPV co-benefits are magnified through their interactions with water and energy sectors, requiring projection of co-benefits using multi-sector modeling tools. The cumulative benefits from FPV expansion could be quantified through forecast-based multi-objective optimization engines at regional to national scales to enable consideration of alternate uses and demands for water and land. Modeling of the multi-sector implications of FPV (Binstead et al. 2021), alongside energy generation capacity, shortfall, and grid resilience could provide broad scenarios to guide permitting and deployment toward maximizing long-term co-benefits. *Audiences for these outputs include state and federal regulators.*

Success Measures: Previous work has identified a wide variety of measurable and predictable indicators which can be quantified and localized into "*co-benefit per hectare of FPV*" (Table 1).

Type	Co-benefits	System types	Body of Evidence	Metrics	Scale
Water & Land	Reduces conflict over land/water	S, H, C	**	avoided costs	Region
	Improves power sector resilience	S, H, C	*	kW under scenarios	Region
	Reduces evaporation	S, H	**	m3 water	Site
	Improves water quality	S, C	*	Chl-a, Turbidity	Site
	Reduces water temperature	S, H, C	*	degC	Site
	Provides power during drought	H	*	kW under water deficit	Region
	Dissolved gas emissions	S, H	*	CH4 flux	Site
Energy	Uses existing transmission capacity	S, H	*	avoided costs	Site
	Reduces curtailment	H	*	added generation	Site
	Extends system life	S, H	***	years or cost	Site
	Improves power quality	H	*	avoided energy shortfall/curtailment	Region

*Table 1: Water and Energy co-benefits from (S) standalone FPV on reservoirs, farm ponds, cooling ponds and hybrid with hydropower (H), land mounted canopy over canals (C). Strength of evidence signified as: *** = empirically confirmed, ** = theoretically confirmed, *=unconfirmed/understudied. The scale of the co-benefits can be evaluated and harnessed at either the scale of individual projects (Site) or over wider regions (or at the grid scale). The co-benefits were selected from a longer list from Gadzanku et al. 2021a.*

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