AquaPV: Regulatory and Environmental Considerations for Floating Photovoltaic Projects Located on Federally Controlled Reservoirs in the United States

Aaron Levine, Taylor L. Curtis, Ligia E.P. Smith, and Katie DeRose

National Renewable Energy Laboratory

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-6A20-86325
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Suggested Citation

Levine, Aaron, Taylor L. Curtis, Ligia E.P. Smith, and Katie DeRose. 2024. *AquaPV: Regulatory and Environmental Considerations for Floating Photovoltaic Projects Located on Federally Controlled Reservoirs in the United States*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-86325. https://www.nrel.gov/docs/fy24osti/86325.pdf.

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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office and Water Power Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

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Acknowledgments

The authors gratefully acknowledge the U.S. Department of Energy's Solar Energy Technologies Office and Water Power Technologies Office for their funding support. We also thank the following National Renewable Energy Laboratory staff for their time and expertise: Sika Gadzanku, Emily Dalecki, Jeff Cook, Dan Bilelo, Amy Brice (editor), and Besiki Kazaishvili (graphic design).

We also thank the following individuals for their time and expertise: Jack West, Alabama Rivers Alliance; Clark Bishop, Erin Foraker, Jason Kirby, and Cianna Wyshnytzky, Bureau of Reclamation; Dan Berger and Dana Olson, Det Norske Veritas; Hillary Berlin, Mark Carter, Cleo Deschamps, Robert Fletcher, Nick Jayjack, Jordan Joyce, John Katz, CarLisa Linton, and Vince Yearick, Federal Energy Regulatory Commission; Colleen McNally-Murphy, Hydropower Reform Coalition; Chonticha McDaniel, North Carolina Department of Environmental Quality; Robert Germann and Daniel Rabon, U.S. Army Corps of Engineers; Frankie Green, Julianne Rosset, Stefanie Stavrakas, U.S. Fish and Wildlife Service.

List of Acronyms

BLM	Bureau of Land Management
C.F.R.	Code of Federal Regulations
CWA	Clean Water Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
FPV	floating photovoltaics
GW	gigawatt
kV	kilovolt
LOPP	Lease of Power Privilege
MW	megawatt
NEPA	National Environmental Policy Act
NGO	nongovernmental organization
NHPA	National Historic Preservation Act
NHRE	Non-Hydropower Renewable Energy
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
PSH	pumped storage hydropower
PV	photovoltaics
RHA	Rivers and Harbors Act
ROW	right-of-way
TERA	Tribal Energy Resources Agreement
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service

Executive Summary

To meet the nation's decarbonization goals, the U.S. Department of Energy's Solar Futures study forecasts that installed solar photovoltaic (PV) capacity must increase nearly tenfold, from 80 gigawatts (GW) in 2020 to approximately 760 GW cumulative installed capacity by 2035 (DOE 2021). Ground-mounted PV is expected to dominate future solar deployment and will require more than 3.5 million acres of land to meet annual demand projections (of nearly 45 GW) by 2030 (DOE 2021). However, various competing demands for land (e.g., agricultural production, conservation) and high land acquisition costs in specific locations could be challenges to meeting future PV demand solely with ground-mounted PV deployment (Wood MacKenzie 2023; DOE 2021; Oliveira-Pinto and Stokkermans 2020). Floating photovoltaics (FPV) may be an alternative in locations where ground-mounted PV is not feasible and aid in reaching the nation's PV deployment and decarbonization goals (DOE 2021; Oliveira-Pinto and Stokkermans 2020; Hooper, Armstrong, and Vlaswinkel 2020; Gallucci 2019).

FPV is a newer siting approach in which a PV array is affixed to a floating apparatus and sited on a water body like a reservoir behind a dam. FPV systems may be stand-alone or co-located at new or existing hydroelectric facilities or pumped storage hydropower (PSH) facility reservoirs. Co-located FPV systems may or may not be operationally paired and work in tandem with the hydroelectric or PSH facility (Gadzanku and Lee 2022; Gadzanku et al. 2021a, 2021b; Lee et al. 2020; Oliveira-Pinto and Stokkermans 2020; Spencer et al. 2018).

Although FPV deployment in the United States is nascent with less than 30 projects installed, significant potential has been identified at existing U.S. reservoirs (Chopra and Garasa Sagardoy 2022). A 2018 National Renewable Energy Laboratory (NREL) study identified more than 24,000 manmade reservoirs (with a total surface area of more than 2 million hectares) in the United States with technical FPV potential; the largest opportunities were found at reservoirs owned by the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation). The NREL study estimated that, if fully realized, FPV systems on U.S. water bodies could have produce almost 10% of the nation's electricity generation in 2018 (approximately 786 terawatt-hours) (Spencer et al. 2018). A follow-on study completed by NREL in 2024 identified between 861 GW and 1,042 GW (corresponding to 1,221 terawatt-hours and 1,476 terawatt-hours) of technical resource potential across USACE, Reclamation, and Federal Energy Regulatory Commission (FERC)-licensed reservoirs.[1]

Current U.S. domestic FPV development is mostly limited to small-scale projects of less than 1 megawatt (MW) sited on closed-loop water bodies such as wastewater treatment plants, drinking water ponds, and irrigation water storage ponds (Chopra and Garasa Sagardoy 2022).[2] Nevertheless, the versatility, potential benefits, and resource potential of FPV have led to growing investment in recent years, which is expected to continue as PV developers look to

[1] Forthcoming publication "Floating Photovoltaic Technical Potential: A Novel Geospatial Approach on Federal Reservoirs in the United States" by Evan G. Rosenlieb, Marie Rivers, and Aaron Levine.

[2] Closed-loop systems typically have lower environmental impacts than open-loop systems because they are not continuously connected to a natural flowing water feature like a river, which means they potentially have less impact on aquatic and terrestrial species (Saulsbury 2020).

alternatives like FPV to meet growing demand (Wood MacKenzie 2023; Chopra and Garasa Sagardoy 2022).

This report provides novel analysis to understand the opportunities and challenges associated with developing stand-alone and co-located FPV projects on Reclamation reservoirs, USACE reservoirs, and FERC-licensed reservoirs in the United States. Specifically, the report explores potential environmental and energy benefits and environmental impacts associated with the siting, construction, and operation of FPV projects. The report also identifies and analyzes U.S. federal- and state-issued permits and authorizations required by federal laws to understand the licensing pathways and regulatory requirements for FPV projects sited on FERC-licensed reservoirs, Reclamation-powered and non-powered reservoirs, and USACE powered and non-powered reservoirs.

Of note, this report only analyzes the addition of FPV to reservoirs and does not consider FPV development on or above canal systems.

Key Report Findings

Environmental Considerations Associated With FPV Projects

Through a literature review, comparative FERC docket analysis, and semiformal interviews, this report identifies several potential environmental and energy benefits as well as environmental, health, and safety impacts or considerations for stand-alone and co-located FPV projects. To determine the full extent of any benefit or adverse impact associated with FPV projects, additional studies and empirical data collection from installed FPV systems are necessary.

Potential Environmental and Energy Benefits

Although further study is needed, stand-alone and co-located FPV systems may have the following potential environmental benefits, which may be site specific (Ramasamy and Margolis 2021; Oliveira-Pinto and Stokkermans 2020; Lee et al. 2020; DOE 2021; Spencer et al. 2018; Gadzanku et al. 2021a, 2021b; Gadzanku and Lee 2022; Pietro et al. 2019; Texeira et al. 2015; Almeida et al. 2022; Liu et al. 2019; Haas et al. 2020; Bontempo Scavo et al. 2020; Farrar et al. 2022; Abdelgaied et al. 2023):

- FPV systems require significantly less land than ground-mounted systems and reduce the need to clear, excavate, and grade land for site preparation.
- FPV systems can reduce evaporative water loss on water bodies by providing shade and acting as a windbreak across water surfaces, which may protect species habitat and provide recreational benefits for angling and boating activities. Reduced evaporative loss may also lead to improved water resource conservation, which may benefit areas experiencing drought, particularly in the western United States.
- Co-located FPV systems can provide improved recreational and environmental downstream benefits, including increased riparian habitat stability, reduced riverbank erosion, reduced water temperature fluctuations, and thermal stratification of the reservoir from optimized FPV-hydroelectric facility operations (e.g., by reducing the amount of

water released for the purpose of hydroelectric generation during peak demand by instead using FPV to provide a portion of peak demand).[3]

Potential Environmental, Health, and Safety Impacts and Considerations

Currently, there is limited experience with FPV development and its potential environmental impacts during siting, construction, and operation. This report identifies potential impacts to biological resources, water quality, recreational resources, and preexisting land uses as well as other site-specific FPV development considerations. Although further study is needed, stand-alone and co-located FPV systems may have the following environmental, health, and safety impacts or considerations (Alabama Power and Kleinschmidt 2022; Almeida et al. 2022; Gadzanku et al. 2021a; Hernandez et al. 2014):

- Siting and construction activities may cause short-term impacts to terrestrial, avian, and aquatic species as well as water resources from noise associated with staging and deploying FPV arrays, disturbance or removal of riparian vegetation, and temporary increase in sediment disturbance and turbidity.
- Operating FPV systems may impact fish, aquatic species, and habitat with thermal water pollution from the PV modules (transferring heat to the water body). Covering parts of a reservoir with PV modules could impact nutrient concentrations, dissolved oxygen levels, and/or dissolved carbon levels.
- Ultraviolet degradation of high-density polyethylene floats may impact water quality.
- Reflective PV modules could cause avian species to mistake modules for bodies of water and attempt to land on them, resulting in strandings, injuries, or mortalities.[4]
- FPV coverage could impact avian, terrestrial, and aquatic species by providing perching habitat for predatory birds and disrupting migration routes for terrestrial and aquatic species.[5]
- FPV could impact reservoir aesthetics and recreation opportunities.[6]
- Weather events like flash flooding and storms could cause FPV structures to become unmoored, causing damage to and inhibiting the use of existing dam infrastructure and creating human safety concerns.[7]
- FPV could be incompatible with existing reservoir operations, including irrigation, hydropower generation, flood control, and navigation.[8]

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[3] Jack West. Alabama River Alliance. Phone Interview. March 20, 2023.
[4] CarLisa Linton, Hillary Berlin, Robert Fletcher, and Mark Carter. FERC DHAC. Phone Interview. July 6, 2022; Frankie Green, Julianne Rosset, Stefanie Stavrakas. U.S. Fish and Wildlife Service (USFWS). Phone Interview. January 31, 2023.
[5] Frankie Green, Julianne Rosset, Stefanie Stavrakas. USFWS. Phone Interview. January 31, 2023.
[6] Jack West. Alabama River Alliance. Phone Interview. March 20, 2023; CarLisa Linton, Hillary Berlin, Robert Fletcher, and Mark Carter. FERC DHAC. Phone Interview. July 6, 2022; Clark Bishop, Cianna Wynshnytzky, Jason Kirby, Erin Foraker, Bureau of Reclamation. Phone Interview. July 11, 2022; Daniel Rabon, USACE. Phone Interview. July 8, 2022.
[7] CarLisa Linton, Hillary Berlin, Robert Fletcher, and Mark Carter. FERC DHAC. Phone Interview. July 6, 2022; Clark Bishop, Cianna Wynshnytzky, Jason Kirby, Erin Foraker, Bureau of Reclamation. Phone Interview. July 11, 2022; Daniel Rabon, USACE. Phone Interview. July 8, 2022.
[8] Clark Bishop, Michael Studiner, Jeffrey Papendick, Michael Inthavong, Jason Kirby, Erin Foraker, Bureau of Reclamation. Email Correspondence. May 20, 2024.

Authorization Requirements and Considerations for FPV Sited at Reclamation Reservoirs, USACE Reservoirs, and FERC-Licensed Reservoirs

During interviews, U.S. federal agency staff noted that absent a congressional mandate, Reclamation and USACE do not have authority to develop stand-alone or co-located FPV at reservoirs that they have jurisdiction over. The development of both stand-alone and co-located large-scale FPV projects by *nonfederal entities* at federal reservoirs and nonfederal reservoirs subject to FERC-licensing jurisdiction requires compliance with a complex set of federal laws and regulations. In addition, the types of authorizations required may depend on project location, ownership of the water body or reservoir where the project is sited, and operational characteristics specific to the project.

Because there are no stand-alone or co-located FPV projects at USACE or Reclamation reservoirs or at FERC-licensed hydroelectric or PSH facilities, the types of authorizations (e.g., licenses, permits, approvals) that may be required at these reservoirs is a developing area of analysis. Nevertheless, numerous federal and state agencies as well as Tribes may have a primary or cooperating authorizing role for stand-alone or co-located FPV projects sited at federally managed or licensed reservoirs. Depending on project location, FERC, Reclamation, and/or USACE may have a primary regulatory role in approving FPV projects considered or incorporated within authorizations or license applications for existing or proposed hydroelectric or PSH infrastructure. In addition, FERC, Reclamation, and/or USACE may act as a lead federal agency for environmental review for stand-alone or co-located FPV projects pursuant to NEPA. Federal land management agencies (e.g., Bureau of Land Management, U.S. Forest Service, Bureau of Indian Affairs) and Tribes may have a primary permitting role in granting land access rights-of-way and authorizations for FPV project development. For water quality considerations, state entities typically have a primary permitting role for Clean Water Act Section 401 water quality certifications or waivers, while USACE or the states of Florida, Michigan, and New Jersey have a primary permitting role for Clean Water Act Section 404 dredge and fill permits.

This report provides detailed analysis related to each of the three agencies that may play a primary role in approving FPV projects at federally controlled reservoirs:

- **FERC Regulatory Considerations:** FERC has authority over the construction, operation, and maintenance of FPV developed at a FERC-licensed hydroelectric or PSH project that is determined to be "a miscellaneous structure used and useful" in connection with the hydroelectric project or that is within the jurisdictional boundary (i.e., FERC license boundary) utilizing project lands and waters.
- **Reclamation Regulatory Considerations:** Reclamation has authority over the construction, operation, and maintenance of stand-alone FPV, co-located FPV-hydroelectric, or co-located FPV-PSH projects sited at Reclamation reservoirs subject to Reclamation jurisdiction (i.e., Reclamation reservoirs where FERC licensing jurisdiction has been withdrawn).
- **USACE Regulatory Considerations:** USACE has authority over the construction, operation, and maintenance of stand-alone or co-located federal FPV-hydroelectric sited at USACE reservoirs. In addition, for nonfederal hydropower, a co-located FPV-hydroelectric or FPV-PSH facility sited at a USACE reservoir with a proposed or existing

FERC-licensed hydroelectric or PSH facility will require both a USACE authorization and a FERC authorization.

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1 Introduction

Deploying solar photovoltaics (PV) is critical to achieving the Biden-Harris administration's decarbonization goals to create a 100% carbon-pollution-free power sector by 2035 and a net-zero emissions economy by 2050 (U.S. Department of Energy [DOE] 2021; U.S. Department of State 2021). To meet these decarbonization goals, the U.S. Department of Energy's Solar Futures study forecasts that installed PV capacity needs to increase nearly tenfold, from 80 gigawatts (GW)[9] in 2020 to approximately 760 GW cumulative installed capacity by 2035 (DOE 2021). Ground-mounted PV is expected to dominate future solar deployment and will require more than 3.5 million acres of land to meet annual demand projections (of nearly 45 GW) by 2030 (DOE 2021). At the highest deployment scenario in 2050, ground-mounted PV is expected to reach approximately 1,560 GW cumulative installed capacity, requiring a land area equivalent to approximately 0.5% of the contiguous U.S. surface area (DOE 2021). However, various competing demands for land (e.g., agricultural production, conservation) and high land acquisition costs in specific locations could be challenges to meeting future PV demand solely with ground-mounted PV deployment (Wood MacKenzie 2023; DOE 2021; Oliveira-Pinto and Stokkermans 2020). Floating photovoltaics (FPV) may be an alternative in locations where ground-mounted PV is not feasible and aid in reaching the nation's PV deployment and decarbonization goals (DOE 2021; Oliveira-Pinto and Stokkermans 2020; Hooper, Armstrong, and Vlaswinkel 2020; Gallucci 2019).

The versatility and potential benefits of FPV have led to growing, worldwide investment in recent years. Global FPV cumulative installed capacity has increased significantly since the first installations in 2007, from 195 kilowatts to 2.6 GW in early 2021 (Chopra and Garasa Sagardoy 2022). A May 2023 Wood MacKenzie projection anticipates the global FPV market to grow to more than 6 GW by 2031 as PV developers "struggle to meet growing solar demand and look to alternat[ive] generating technologies" (Wood MacKenzie 2023). As of this report, most of the global installed FPV capacity is concentrated in Asia. China, India, Indonesia, and South Korea are setting the pace with the largest amount of installed FPV capacity in 2022, and growth is expected in Vietnam, Thailand, Taiwan, Israel, and Malaysia through 2031 (Chopra and Garasa Sagardoy 2022; Gadzanku et al. 2021a).

FPV deployment in the United States has been slower than in Asia, with only 26 projects installed at the end of 2022 representing a cumulative installed capacity of 30.8 megawatts (MW) (Chopra and Garasa Sagardoy 2022). Most domestic FPV installations are characterized as small-scale projects of less than 1 MW sited on closed-loop water bodies such as wastewater treatment plants, drinking water ponds, and irrigation water storage ponds (Chopra and Garasa Sagardoy 2022). Closed-loop systems typically have lower environmental impacts than open-loop systems because they are not continuously connected to a natural flowing water feature like a river, which means they potentially have less impact on aquatic and terrestrial species (Saulsbury 2020). The average installed capacity across the 26 U.S. FPV projects is 1.18 MW, and only six projects are larger than 1 MW (Chopra and Garasa Sagardoy 2022). The two largest of those six FPV projects are the 4.8-MW FPV project on the Healdsburg Water/Wastewater

[9] In 2020, about 80 GW of solar (PV and concentrating solar power) powered approximately 3% of U.S. electricity demand – 97% of which was PV (DOE 2021; Davis et al. 2023)

Treatment Plant reservoir in Healdsburg, California, and the 8.9-MW FPV project on the Canoe Brook Water Treatment Plant reservoir in Short Hill, New Jersey (Lindner 2023; YSG Solar 2022).

Significant FPV potential has been identified at existing reservoirs across the United States. A 2018 National Renewable Energy Laboratory (NREL) study identified more than 24,000 manmade reservoirs (with a total surface area of more than 2 million hectares) in the United States with technical FPV potential. The largest technical resource potential was found at reservoirs owned by the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation)—the two primary agencies managing federal reservoirs and a key focus of this report. The NREL study estimated that, if fully realized, FPV systems on U.S. water bodies could have produced almost 10% of the nation's electricity generation in 2018 (approximately 786 terawatt-hours) (Spencer et al. 2018). A follow-on study completed by NREL in 2024 identified between 861 GW and 1,042 GW (corresponding to 1,221 terawatt-hours and 1,476 terawatt-hours) of technical resource potential across a total of 846 USACE, Reclamation, and Federal Energy Regulatory Commission (FERC)-licensed reservoirs.[10] Currently, there are no large-scale (defined here as more than 10 MW) stand-alone FPV projects in the United States, nor are there FPV projects sited on FERC-licensed reservoirs or on USACE or Reclamation reservoirs.

Although further study is needed, preliminary analysis has also identified several potential environmental benefits associated with FPV systems. Multiple studies have found that FPV systems may reduce evaporative water loss on the water body where they are deployed by providing shade from direct sunlight. They also act as a windbreak across the water surface, which may have several biological, recreational, and human health benefits (U.S. Environmental Protection Agency [EPA] 2023; Gadzanku et al. 2021b; Pietro et al. 2019; Denchak 2019). Reduced evaporative loss may also lead to improved water resource conservation, which could mitigate the impact of drought conditions, particularly in western states (Kao et al. 2021). However, FPV systems may also have impacts on species, water quality, recreation, safety, and existing infrastructure, which must be taken into account during construction and operation.

1.1 FPV Technology Overview

An FPV system is a PV array affixed to a floating structure sited on a water body, such as an impounding reservoir. FPV systems use the same PV module technology as ground-mounted systems, but the racks and mounts for the PV modules are affixed to a floating apparatus such as plastic floats or pontoons placed in a water body instead of on the ground. The floating apparatus is then moored or anchored to either the bottom or shore of the water body to stabilize the FPV system. Similar to ground-mounted PV module technology, FPV modules can be flat, tilted, or tracking (currently, most installations are tilted). Electrical equipment, such as inverters, resides on the shore or on a floating apparatus, and electricity is transmitted from the FPV system via floating or underwater cables (Spencer et al. 2018; Oliveira-Pinto and Stokkermans 2020). Figure 1 details a typical FPV system design sited on a non-powered reservoir.

[10] Forthcoming publication "Floating Photovoltaic Technical Potential: A Novel Geospatial Approach on Federal Reservoirs in the United States" by Evan G. Rosenlieb, Marie Rivers, and Aaron Levine.

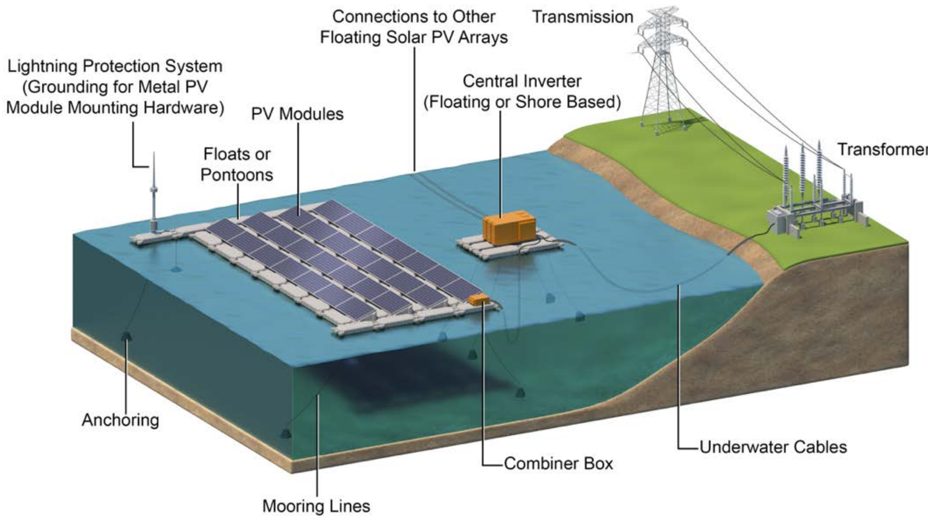

Figure 1. FPV system sited on a non-powered reservoir

Illustration by Besiki Kazaishvili, NREL

The majority of FPV systems deployed globally operate as stand-alone projects not co-located or interconnected with hydroelectric facilities or pumped storage hydropower (PSH) facilities[11] (Gadzanku and Lee 2022; Gadzanku et al. 2021a, 2021b; Lee et al. 2020).

FPV systems may also be co-located at new or existing hydroelectric (Figure 2) or PSH facility reservoirs (Figure 3). Co-located FPV systems may or may not be operationally paired with the hydroelectric or PSH facility. The first co-located FPV project was sited in Portugal at the existing 67-MW capacity Alto Rabagao PSH facility in 2017. This co-located 220-kilowatt FPV project was designed as a pilot demonstration with 840 PV modules covering approximately 2,500 square meters (0.6 acres) of the upper Alto Rabagao PSH facility reservoir, which has been operating since the 1960s (Lee et al. 2020; Kakoulaki et al. 2023). While co-located FPV projects are rare, some have been developed in China, Ghana, Thailand, and South Korea (Bui Power Authority 2024; Xiong et al. 2023; Gadzanku and Lee 2022; Bellini 2021; Malewar 2021). Most co-located FPV projects are sited on hydroelectric impounding reservoir systems[12] due to increased logistical challenges of installing and interconnecting FPV systems with run-of-river (diversion) hydroelectric facilities[13] and PSH facilities where water levels fluctuate more often (Gadzanku and Lee 2022).

[11] A PSH system is configured with two water reservoirs at different elevations. Power is generated as water runs down from one reservoir to the other, passing through a turbine to generate electricity. Power is required to pump water back into the upper reservoir (DOE 2023b).

[12] The most common type of hydroelectric system is an impoundment reservoir facility where a dam stores water in a reservoir and releases the water through a turbine, spinning it to generate electricity (DOE 2023a).

[13] A run-of-river facility diverts a portion of a river through a canal and/or penstock and uses the natural decline of the riverbed to move the water through the turbine to generate electricity (DOE 2023a).

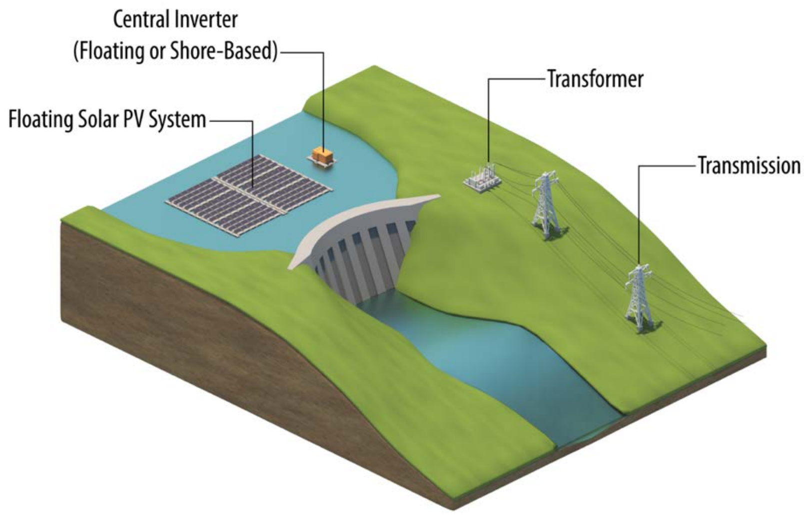

Figure 2. FPV sited on a hydroelectric reservoir

Illustration by Besiki Kazaishvili, NREL

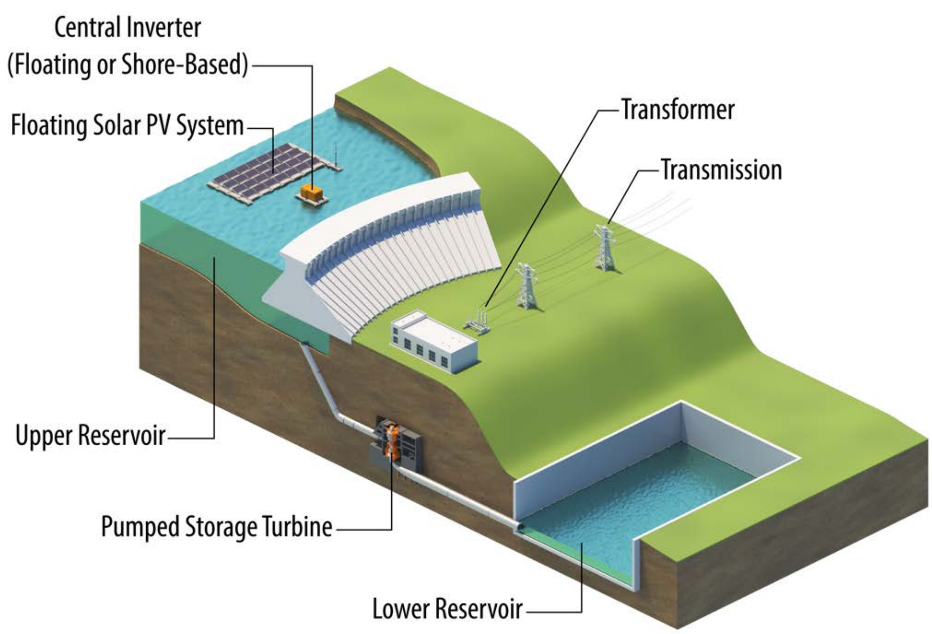

Figure 3. FPV sited on a PSH reservoir

Illustration by Besiki Kazaishvili, NREL

1.2 Report Roadmap

This report summarizes the potential environmental benefits and environmental, health, and safety impacts associated with developing stand-alone and co-located FPV projects on Reclamation reservoirs, USACE reservoirs, and FERC-licensed hydroelectric reservoirs in the United States. The report also identifies and analyzes U.S. federal and state-level permits and authorizations required under federal law to understand the licensing pathways and regulatory requirements for stand-alone and co-located FPV projects across a series of scenarios for USACE reservoirs, Reclamation reservoirs, and at FERC-licensed hydroelectric projects.

The report is divided into the following sections:

- **Section 2** summarizes the methodology used to conduct this study.
- **Section 3** provides the study's findings of the potential environmental benefits as well as potential environmental, health, and safety impacts associated with FPV siting, construction, and operation.
- **Section 4** provides a review of the regulatory process, including potential licenses, authorizations, permits, and other approvals required under federal law for FPV development. This section also includes a discussion of use cases developed to illustrate different permitting pathways for FPV.
- **Section 5** synthesizes the findings and key takeaways of the environmental and regulatory analysis and provides direction for additional research that may help reduce uncertainty and risk associated with FPV deployment in the United States.

2 Methodology

The report authors conducted a literature review to understand the characteristics as well as potential benefits and environmental impacts of both stand-alone and co-located FPV projects during the siting, construction, and operational phases. The literature review analyzed peer-reviewed journal articles as well as news reports, technical reports, and other gray literature related to FPV development. The literature review was used to inform the development of hypothetical use case scenarios for stand-alone and co-located FPV projects across a series of scenarios for USACE reservoirs, Reclamation reservoirs, and at FERC-licensed hydroelectric projects.

The literature review and interviews with the advisory firm DNV further informed the development of project characteristic assumptions for the use case scenarios. The FPV project characteristics were defined as:

- Stand-alone FPV projects or FPV projects on Reclamation or USACE powered and non-powered reservoirs
- Co-located FPV projects within an existing or proposed FERC-licensed hydroelectric or PSH project reservoir (i.e., projects that are not exempt from requiring a FERC license)
- FPV arrays for stand-alone FPV projects covering 1%, 5%, 10%, or 15% of reservoir surface area
- FPV arrays for FPV projects co-located at hydroelectric or PSH project reservoirs sized either at a 1:1 ratio of FPV to hydroelectric facility capacity or 1%, 5%, 10%, or 15% reservoir coverage, whichever is smaller
- FPV arrays assembled and staged on shore, before being deployed, moored, and anchored into the water body
- FPV floats constructed from high-density polyethylene
- FPV panels cleaned periodically for maintenance.

The authors also conducted legal analysis to identify federal and state permits, licenses, authorizations, and other approvals required under federal law to site, construct, and operate FPV projects in the United States under the FPV use case scenarios described in Section 4. The legal analysis included review of statutes, guidance, policy documents, and agency reports to understand the regulatory requirements that apply to the FPV use case scenarios. This analysis also identified key U.S. federal and state agency roles and responsibilities under federal laws in the permitting and regulation of the FPV projects.

The authors then conducted a series of semiformal interviews with U.S. federal and state agency staff identified as having a potential role in the regulation and permitting of the study's FPV use case scenarios. Federal agency participants included Reclamation, USACE, U.S. Fish and Wildlife Services (USFWS), and FERC. State agency participants included resource agency staff from the North Carolina Department of Environmental Quality. The report authors also interviewed nongovernmental organizations (NGOs), including staff from the Hydropower Reform Coalition and the Alabama Rivers Alliance. These interviews further informed the environmental and human health considerations and the permitting requirements and processes for the FPV use cases.

Finally, the authors analyzed FERC dockets for other energy and infrastructure projects to better understand the regulatory, environmental, and human health considerations that may also apply to FPV projects. Because FPV is a newer solar siting application, FERC has not yet (as of writing this report) licensed a hydroelectric or PSH project with co-located FPV. Instead, the report authors analyzed land-based PV projects, floating marinas and docks, wave energy conversion projects, underwater transmission lines, and battery storage projects integrated with and/or within a FERC-licensed hydroelectric or PSH project boundary.

3 Environmental and Energy Considerations of FPV

Through the literature review, comparative FERC docket analysis, and semiformal interviews, this report identifies several potential environmental benefits as well as environmental, health, and safety considerations for stand-alone and co-located FPV projects. This section summarizes the potential benefits from both stand-alone and co-located FPV projects as well as the environmental and human health considerations associated with the siting, construction, and operation phases of FPV project development. To determine the full extent of any benefit or adverse impact associated with FPV projects, additional studies and empirical data collection from installed FPV systems are necessary.

3.1 Environmental and Energy Benefits and Considerations

Previous studies have found that stand-alone and co-located FPV systems may provide several environmental benefits. Multiple studies have found that FPV systems can reduce evaporative water loss on the water body by providing shade from direct sunlight and acting as a windbreak across the water surface. Reduced evaporative water loss can protect habitat for aquatic vertebrates and invertebrates and for plant, avian, and terrestrial species. Reduced evaporative water loss can also benefit recreational activities on the water body such as angling and boating (Gadzanku et al. 2021b; Pietro et al. 2019). The shading effect from FPV systems may also impede photosynthesis of harmful algal blooms. Mitigating algal blooms can positively impact dissolved oxygen levels on the water body and improve aquatic species health. Reducing algal blooms can also benefit terrestrial species as well as humans by reducing exposure to dangerous toxins produced by harmful algal blooms (EPA 2023; Denchak 2019). Reduced evaporative loss may also lead to improved water resource conservation, which could mitigate the impacts of drought, particularly in western states. Climate change creates both increasing temperatures and intensifying rainfall and drought conditions. Annual U.S. temperatures are expected to increase from 1°F to 6°F across all seasons through 2059. Rising temperatures may lead to increased water evaporation at reservoirs across the country (Kao et al. 2022).

Co-locating FPV systems with hydroelectric facilities or PSH facilities may result in additional environmental and energy benefits compared to stand-alone FPV systems (Gadzanku and Lee 2022; Gadzanku et al. 2021a, 2021b; Lee et al. 2020; Spencer et al. 2018; Teixeira et al. 2015; Soares et al. 2008; Almeida et al. 2022; Liu et al. 2019; Haas et al. 2020; Bontempo Scavo et al. 2020; Farrar et al. 2022; Abdelgaied et al. 2023), including:

- Improved recreational and environmental downstream benefits, including increased riparian habitat stability, reduced riverbank erosion, reduced water temperature fluctuations, and thermal stratification of the reservoir from optimized FPV-hydroelectric facility operations (e.g., by reducing the amount of water released for the purpose of hydroelectric generation during peak demand by instead using FPV to provide a portion of peak demand)[14]
- Improved water resource conservation for hydroelectric and PSH reservoirs from reduced water evaporation

[14] Jack West. Alabama River Alliance. Phone Interview. March 20, 2023.

- Increased hydroelectric generation and PSH capacity from reduced reservoir water evaporation
- Reduced environmental impacts and capital costs when paired with an existing hydroelectric or PSH facility by using existing infrastructure and grid connections
- Improved load planning and operational flexibility to optimize system- and facility-level load balance by using water resources during wetter daily and seasonal conditions and offsetting hydroelectric generation with PV during dryer conditions.

3.2 Potential Environmental Impacts and Development Considerations

There is limited experience with FPV development and its potential environmental impacts during the siting, construction, and operational phases. Through the literature review, semiformal interviews, and analysis of FERC dockets for other energy and infrastructure projects, this report identifies potential impacts to biological resources, water quality, recreational resources, and preexisting land uses as well as other site-specific FPV development considerations. Although not analyzed in this report, other environmental considerations common with infrastructure projects may also apply to FPV development such as construction activities that may impact or otherwise damage cultural and historic resources or temporary visual impacts resulting from vegetation clearing and the presence of equipment and machinery (Levine et al. 2021).[15]

3.2.1 Potential Environmental Impacts Associated With FPV Project Siting and Construction

Siting and construction activities for both stand-alone and co-located FPV projects may cause short-term impacts to terrestrial, avian, and aquatic species as well as water resources. The following are potential environmental considerations that may be associated with the siting and construction of FPV projects (Almeida et al. 2022; Alabama Power and Kleinschmidt 2022; Gadzanku et al. 2021a; Pouran et al. 2022):

- Noise associated with staging and deployment of the FPV array may cause temporary disturbances and short-term displacement of species.
- Construction activities may cause temporary sediment disturbance and increased turbidity that could have short-term effects on aquatic species and water quality.
- Construction activities may result in the disturbance or removal of riparian vegetation on the shoreline, potentially impacting fish and other aquatic species.

3.2.2 Potential Environmental Impacts Associated With FPV Project Operation

FPV operations may also impact terrestrial, avian, and aquatic species; water resources; recreation; and human health and safety. The following are potential environmental, health, safety, and other considerations identified in the report that may be associated with the operation

[15] For more detail on other environmental considerations common with infrastructure projects, including hydroelectric or PSH projects and solar projects, see the technical report by Levine et al. (2021), *An Examination of the Hydropower Licensing and Federal Authorization Process*.

of an FPV system (Alabama Power and Kleinschmidt 2022; Almeida et al. 2022; Gadzanku et al. 2021a; Hernandez et al. 2014):

- Heat from PV modules may be transferred to the water body, which could impact fish, aquatic species, habitat, and water quality.
- Reflective PV modules may cause avian species to mistake FPV modules for bodies of water and attempt to land on them, which may result in strandings, injuries, or mortality.[16]
- Coverage of the reservoir by PV modules may cause potential impacts to aquatic species, water quality, and birds due to changes in nutrient level concentrations, dissolved oxygen levels, and/or dissolved carbon levels.
- Ultraviolet degradation of high-density polyethylene floats may impact water quality.
- The addition of FPV system infrastructure may create perching habitat for predatory bird species (e.g., raptors, cormorants), which can impact the mortality rate of other avian species as well as aquatic species.[17]
- Introduction of overwater structures may potentially result in the damage or removal of riparian habitat and disrupt migration routes for terrestrial and aquatic species.[18]
- Depending on project location, siting, and percentage of reservoir coverage, the addition of FPV could affect reservoir aesthetics and recreation (e.g., boating, fishing) opportunities and/or create a potential hazard for recreational users (e.g., boating collisions).[19]
- Intemperate weather (e.g., flash flooding and storms) could cause FPV structures to become unmoored, causing damage that inhibits the use of existing dam infrastructure and creating human safety concerns.[20]
- FPV could be incompatible with existing reservoir operations, including irrigation, hydropower generation, flood control, and navigation.[21]

3.2.3 Other FPV Project Development Considerations

Some types of reservoirs may be unsuitable for FPV development due to their location or site-specific attributes, particularly reservoirs subject to large fluctuations in fill level. Reservoirs with multiple beneficial uses (e.g., irrigation delivery, municipal and industrial delivery, flood

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[16] CarLisa Linton, Hillary Berlin, Robert Fletcher, and Mark Carter. FERC DHAC. Phone Interview. July 6, 2022; Frankie Green, Julianne Rosset, Stefanie Stavrakas. U.S. Fish and Wildlife Service (USFWS). Phone Interview. January 31, 2023.

[17] Frankie Green, Julianne Rosset, Stefanie Stavrakas. USFWS. Phone Interview. January 31, 2023

[18] Frankie Green, Julianne Rosset, Stefanie Stavrakas. USFWS. Phone Interview. January 31, 2023; Colleen McNally-Murphy. Hydropower Reform Coalition. Phone Interview. February 2, 2023.

[19] Jack West. Alabama River Alliance. Phone Interview. March 20, 2023; CarLisa Linton, Hillary Berlin, Robert Fletcher, and Mark Carter. FERC DHAC. Phone Interview. July 6, 2022; Clark Bishop, Cianna Wynshnytzky, Jason Kirby, Erin Foraker, Bureau of Reclamation. Phone Interview. July 11, 2022; Daniel Rabon, USACE. Phone Interview. July 8, 2022.

[20] CarLisa Linton, Hillary Berlin, Robert Fletcher, and Mark Carter. FERC DHAC. Phone Interview. July 6, 2022; Clark Bishop, Cianna Wynshnytzky, Jason Kirby, Erin Foraker, Bureau of Reclamation. Phone Interview. July 11, 2022; Daniel Rabon, USACE. Phone Interview. July 8, 2022.

[21] Clark Bishop, Michael Studiner, Jeffrey Papendick, Michael Inthavong, Jason Kirby, Erin Foraker, Bureau of Reclamation. Email Correspondence. May 20, 2024.

control, and/or hydropower generation) may see large operational fluctuations in surface water elevation during a given water year. These operational fluctuations in surface water elevation can be in excess of 50 feet. Additionally, prolonged critical or wet water year types can cause surface water elevation fluctuations in excess of 200 feet. Dynamic surface water level fluctuations may not be suitable for FPV. For example, upper reservoirs of PSH facilities may be subject to daily, weekly, and seasonal water level fluctuations and may not be suitable for FPV, unless the project is specifically designed to withstand significant fluctuations in fill level of the reservoir.[22]

Moreover, some NGO staff with a focus on river restoration and removal of non-beneficial dams expressed concern that the addition of FPV to an existing hydroelectric dam could provide an economic incentive to extend the lifespan of older and/or arguably environmentally unsound hydroelectric dams that might otherwise be considered for dam removal.[23]

[22] Clark Bishop, Cianna Wynshnytzky, Jason Kirby, Erin Foraker, Bureau of Reclamation. Phone Interview. July 11, 2022.
[23] Jack West. Alabama River Alliance. Phone Interview. March 20, 2023; Colleen McNally-Murphy. Hydropower Reform Coalition. Phone Interview. February 2, 2023.

4 FPV Authorization Considerations

As a newer siting approach in the United States, FPV permitting and regulation has been limited to small, closed-loop, stand-alone projects, which generally have minimal environmental impacts and a less complex authorization process. As of writing this report, there are no FPV projects co-located on FERC-licensed reservoirs or sited on USACE or Reclamation reservoirs.

This section provides findings from the report authors' statutory and regulatory analysis, semiformal interviews with regulators, and analysis of FERC hydroelectric licensing dockets to understand the regulatory authorization processes and federal and state agency roles for the siting, construction, and operation of stand-alone and co-located FPV projects sited across a series of scenarios for USACE reservoirs, Reclamation reservoirs, and at FERC-licensed hydroelectric projects.

While Reclamation has authority over projects that use Reclamation reservoirs and USACE has authority over projects that make use of or alter USACE-managed works, neither agency has express authority to develop federal FPV (43 U.S.C. § 373; 43 U.S.C. § 387; 16 U.S.C. § 590; FERC 2021d; 33 U.S.C. § 408(a)). Accordingly, interviews with agency representatives revealed that while Reclamation and USACE have authority over third-party siting of FPV that uses agency-managed assets, without express congressional authorization, Reclamation and USACE do not have authority to develop federal FPV projects on their own initiative. In addition, FERC has jurisdiction over adding FPV to FERC-licensed hydroelectric and PSH facilities. Accordingly, for the purposes of this report, only nonfederal (e.g., private) developers of stand-alone, co-located FPV-hydroelectric, and co-located FPV-PSH were considered for analysis. The term "developer" as it is used in Section 4 refers only to nonfederal (e.g., private) entities.

4.1 Licenses, Permits, Authorizations, and Other Approvals Applicable to FPV Projects

The development of both stand-alone and co-located FPV projects in the United States requires compliance with a complex set of federal, state, Tribal, and local laws and regulations. An FPV developer needs to obtain regulatory approvals from different federal regulatory agencies and, in some cases, Tribal, state, and/or local regulatory authorities, depending on the project design (e.g., stand-alone or co-located with a hydroelectric or PSH facility), site location, project ownership, potential environmental impacts, and ownership and/or management of the water body. Notably, the applicability of certain infrastructure licenses, permits, authorizations, or approvals (collectively referred to hereafter as "authorizations") is dependent on FPV project location and design, specifically whether the project is stand-alone, co-located with a hydroelectric or PSH facility, or co-located and operationally paired with a hydroelectric or PSH facility. Where relevant, the following sections provide a description of an FPV project as stand-alone, co-located with a hydroelectric or PSH facility, or co-located and operationally paired with a hydroelectric or PSH facility.

Table 1 provides a summary of the authorizations that may apply to FPV projects sited on Reclamation and USACE reservoirs, and FERC-licensed hydroelectric or PSH project reservoirs under the report's use case scenarios.

Table 1. Site-Specific Federal Statutory Authorizations for FPV Project Development

Authorizing Regulatory Agency	Authorization	Regulatory Requirement(s)
Infrastructure		
FERC	Federal Power Act (FPA) Original FERC License	A developer needs a FERC license to construct, operate, and maintain a proposed co-located FPV-hydroelectric or FPV-PSH project that is located on navigable waters of the United States; occupies U.S. federal land; utilizes surplus water or water power of a U.S. government dam (except in cases where FERC authorities have been withdrawn, e.g., for select Reclamation projects/project sites, subject to Lease of Power Privilege approval); or is located on a stream over which Congress has Commerce Clause jurisdiction, where the project construction or expansion occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce. The FPV portion of the project will either be classified as a "miscellaneous structure used and useful" in connection with the hydroelectric facility or a non-project use of project lands and waters within the FERC license boundary (16 U.S.C. §§ 791 – 823g; 161 FERC 61,078; 16 U.S.C. § 796(11)).
FERC	FPA New FERC License (Relicense)	A developer may seek to add FPV to an existing FERC-licensed hydroelectric or PSH facility at the time of relicensing (new license required for continued project operation) prior to the end of the original license expiration period. The FPV portion of the project will either be classified as a "miscellaneous structure used and useful" in connection with the hydroelectric facility or a non-project use of project lands and waters within the FERC license boundary (16 U.S.C. §§ 791 – 823g; 161 FERC 61,078).[24]
FERC	FPA Non-Capacity Amendment	A developer needs a Non-Capacity Amendment to construct, operate, and maintain an FPV project that is co-located and determined to be "a miscellaneous structure used and useful" (i.e., operationally paired) in connection with an existing FERC-licensed hydroelectric or PSH facility (16 U.S.C. §§ 791 – 823g; 18 C.F.R. §§ 4.200 – 4.202; FERC 2015).
FERC	FPA Non-Capacity Amendment for Non-Project Use	A developer needs a Non-Capacity Amendment for Non-Project Use to construct, operate, and maintain an FPV project that is co-located on lands and waters within the FERC license boundary but is not considered "a miscellaneous structure used and useful" (i.e., not operationally paired) in connection with an existing

[24] At least 5 years, but not more than 5.5 years, before the FERC license expiration date, a licensee must file a notice of intent with FERC stating whether they intend to seek a new license (relicense) (18 C.F.R. § 5.5; see Levine et al. [2021] for more details).

Authorizing Regulatory Agency	Authorization	Regulatory Requirement(s)
		FERC-licensed hydroelectric or PSH facility (16 U.S.C. §§ 791 – 823g; 18 C.F.R. §§ 4.200 – 4.202; FERC 2015).
Reclamation	Non-Hydropower Renewable Energy (NHRE) Use Authorization	A developer needs an NHRE Use Authorization to construct, operate, and maintain a stand-alone FPV project or to add FPV to an existing hydroelectric or PSH facility, where the FPV project occupies, uses, or resides on a Reclamation reservoir (43 U.S.C. § 387; 43 C.F.R. § 429).
Reclamation	NHRE Use Authorization and Lease of Power Privilege (LOPP)	A developer needs an NHRE Use Authorization and an LOPP to construct, operate, and maintain a proposed co-located FPV and (new) hydroelectric or PSH project at a Reclamation reservoir, where LOPP authorities exist (43 U.S.C. § 387; 43 C.F.R. § 429). An NHRE Use Authorization would be required to construct, operate, and maintain FPV that occupies, uses, or resides on a Reclamation reservoir. An LOPP would be required to authorize use of the Reclamation reservoir for hydroelectric power generation, where LOPP authorities exist (43 U.S.C. § 387; 43 C.F.R. § 429).
USACE	Rivers and Harbors Act (RHA) Section 14 "Section 408" Authorization	A developer needs a Rivers and Harbors Act Section 14 "Section 408" Authorization to construct, operate, and maintain a stand-alone FPV project or co-located FPV-hydroelectric or FPV-PSH facility, if the FPV uses or alters USACE infrastructure (e.g., dam, reservoir) (33 U.S.C. § 408(a)).
Land Access		
Bureau of Land Management (BLM)	Right-of-Way (ROW)	A developer needs a ROW if a stand-alone or co-located FPV-hydroelectric or FPV-PSH project requires access over, upon, under, or through BLM-managed lands (43 U.S.C. § 1761(a)).
U.S. Forest Service (USFS)	Special Use Authorization	A developer needs a Special Use Authorization if a stand-alone or co-located FPV-hydroelectric or FPV-PSH project requires access over, upon, under, or through USFS-managed lands (e.g., national forest system lands, other than those designated as wilderness areas) (43 U.S.C. §§ 1761(a), (d); 43 U.S.C. §§ 1761(a), (d); 36 C.F.R. § 251).
Bureau of Indian Affairs	Tribal Land ROW	A developer needs a Tribal Land ROW if a stand-alone or co-located FPV-hydroelectric or FPV-PSH project requires use of any lands held in trust by the United States for individual Indians or Indian Tribes, communities, bands, or nations or any lands now or hereafter owned to access the project site (25 U.S.C. § 323; 25 C.F.R. § 169).
Indian Tribe	Tribal Energy Resources Agreement (TERA)	A developer may need a TERA lease, ROW, or business agreement if a stand-alone or co-located

Authorizing Regulatory Agency	Authorization	Regulatory Requirement(s)
	Lease, ROW or Business Agreement	FPV-hydroelectric or FPV-PSH project requires access to land pursuant to an approved TERA (25 U.S.C. § 2218(a); 25 C.F.R. § 224).
Biological Resources		
USFWS	Eagle Incidental Take Permit	A developer needs an eagle take permit if the stand-alone FPV or co-located FPV-hydroelectric or FPV-PSH project will result in any take of bald or golden eagles that is necessary to protect an interest in a particular locality associated with, but not the purpose of, the activity; and cannot practicably be avoided (16 U.S.C. §§ 668-668d; 50 C.F.R. § 22.80).
National Oceanic and Atmospheric Administration (NOAA) Fisheries	Essential Fish Habitat Consultation	A federal agency that licenses, permits, or otherwise authorizes a stand-alone or co-located FPV-hydroelectric or FPV-PSH project must consult with NOAA Fisheries with respect to any action authorized, funded, or undertaken that may adversely affect any essential fish habitat (16 U.S.C. § 1855(b)(2)).
NOAA Fisheries	Marine Mammal Incidental Take Authorization	A developer needs a Marine Mammal Incidental Take Authorization if a stand-alone FPV or co-located FPV-hydroelectric or FPV-PSH project may result in the incidental take of marine mammals (16 U.S.C. § 1371(a)(5)(A)–(D); 50 C.F.R. § 18.27).
NOAA Fisheries/USFWS	Endangered Species Act (ESA) Section 7 Consultation	A federal agency (potentially with the assistance of a designated nonfederal representative) that licenses, permits, or otherwise authorizes a stand-alone or co-located FPV-hydroelectric, or FPV-PSH project must consult or confer with USFWS and/or NOAA fisheries if an agency action is likely to jeopardize the continued existence of any listed endangered or threatened species or result in the destruction or adverse modification of designated critical habitat (16 U.S.C. § 1536(a)(2)).
Pre-existing Land Use and Natural Resource Protection		
BLM/USFWS/ USFS/National Park Service	Wild and Scenic River Act Section 7 Consultation	A developer must consult with BLM, National Park Service, USFWS, or USFS to evaluate potential stand-alone FPV or co-located FPV-hydroelectric or FPV-PSH project effects on agency-managed designated wild and scenic rivers and congressionally authorized study rivers to protect the free-flowing condition and environment of designated and congressionally authorized study rivers (16 U.S.C. § 1278(a)-(b)).
Water Quality		
State Agency/ Environmental Protection Agency (EPA)/Indian Tribe	Clean Water Act (CWA) Section 401 Water Quality Certification	A developer needs a CWA Section 401 Water Quality Certification or waiver if a stand-alone or co-located FPV-hydroelectric or FPV-PSH project requires a federal license or permit, including but not limited to authorizing the construction or operation of facilities

Authorizing Regulatory Agency	Authorization	Regulatory Requirement(s)
		that may result in any discharge to navigable waters (33 U.S.C. § 1341(a)(1)).
USACE/State Agency	CWA Section 404 Dredge and Fill Permit	A developer needs a CWA Section 404 Dredge and Fill Permit if a stand-alone or co-located FPV-hydroelectric or FPV-PSH project will require the discharge of dredged or fill material into all waters of the United States, including wetlands (33 U.S.C. § 1344(a)).
Cultural Resources		
FERC/Reclamation/ USACE	National Historic Preservation Act (NHPA) Section 106 Consultation Process	A federal agency that licenses, permits, or otherwise authorizes a stand-alone or co-located FPV-hydroelectric or FPV-PSH project must consider the effect of the project on historic properties or resources that are eligible for listing or are listed on the National Register of Historic Places (54 U.S.C. § 306108). A federal agency will consult with state agencies (State Historic Preservation Officer) and/or Indian Tribes (Tribal Historic Preservation Officer) to identify culturally or historically important state and Tribal sites that may be affected by a stand-alone or co-located FPV-hydroelectric or FPV-PSH project (54 U.S.C. § 306108).
Environmental Review		
FERC/Reclamation/ USACE	National Environmental Policy Act (NEPA) Review Process	A federal agency (potentially with the assistance of a designated nonfederal representative) that licenses, permits, or otherwise authorizes a stand-alone or co-located FPV-hydroelectric, or FPV-PSH project must evaluate the environmental impact of the proposed project, any adverse environmental effects which cannot be avoided if the project is implemented, alternatives to the proposed project, the relationship between local-short-term use of the environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources which would be involved in the proposed project (42 U.S.C. § 4332(2)(C)).

4.2 Regulatory Agency Roles and Responsibilities for FPV Projects

The various authorizations for stand-alone and co-located FPV projects may require coordination between federal, state, and Tribal authorities (as applicable) prior to project development. Figure 4 provides a high-level summary of federal, Tribal, and state regulatory roles that may be applicable when authorizing FPV projects at USACE, Reclamation, or FERC-licensed reservoirs.

	FERC	Reclamation	USACE	BIA	BLM	EPA	NOAA Fisheries	NPS	USFS	USFWS	Indian Tribe	State Agency
Infrastructure Authorizations and Licenses												
FPA Original or New License	●											
FPA Non-Capacity Amendment	●											
NHRE Use Authorization		●										
Lease of Power Privilege		●										
RHA Section 14 "Section 408" Authorization			●									
Land Access												
Rights of Way				● [c]	●						● [c]	
Special Use Authorization									●			
Biological Resources Protection												
Endangered Species Act Section 7							● [c]			● [c]		
Other Biological Species Acts (BGEPA, EFH)							● [c]			● [c]		
Pre-Existing Land Use and Natural Resource Protection												
CZMA												●
WSRA Section 7					● [c]			● [c]	● [c]	● [c]		
Water Quality												
CWA Section 401						● [a]					●	●
CWA Section 404			●									● [d]
Cultural Resources												
NHPA Section 106	●	●	●								○	○
Environmental Review												
NEPA	● [b]	● [b]	● [b]		○	○	○	○	○	○	○	○

● = Primary Permitting Role

○ = Cooperating Permitting Role

a Authorized states and Indian Tribes are generally responsible for issuing Clean Water Act Section 401 water quality certifications or waivers; however, in cases where a state or Indian Tribe does not have authority, EPA is responsible for issuing a certification or waiver (33 U.S.C. § 1341).
b A lead agency or agencies takes primary responsibility for preparing a NEPA document. Federal, state, or Tribal authorities may act as cooperating agencies if involved in the same action.
c Primary responsibility is dependent on the type and/or location of the resource and who manages it.
d The states of Florida, Michigan, and New Jersey have assumed the CWA 404 program from USACE.

Figure 4. Summary of federal agency, state agency, and Indian Tribe roles under federal statutory authorizations for FPV project development

As depicted in Figure 4, numerous federal and state agencies as well as Indian Tribes may have a primary or cooperating authorizing role for stand-alone or co-located FPV projects sited at federally managed or licensed reservoirs. Depending on project location, FERC, Reclamation, and/or USACE may have a primary regulatory role in approving FPV projects considered or incorporated within authorizations or license applications for existing or proposed hydroelectric or PSH infrastructure. In addition, FERC, Reclamation, and/or USACE may act as a lead federal agency for environmental review for stand-alone or co-located FPV projects pursuant to NEPA. Federal land management agencies (e.g., BLM, USFS, Bureau of Indian Affairs) and Indian Tribes may have a primary permitting role in granting land access rights-of-way and authorizations for FPV project development. For water quality considerations, state entities typically have a primary permitting role for CWA Section 401 water quality certifications or waivers, while USACE or the states of Florida, Michigan, and New Jersey have a primary permitting role for CWA Section 404 dredge and fill permits.

4.3 Federal Authorization Pathways for Selected Use Case Scenarios

Regulatory authority for stand-alone or co-located FPV-hydroelectric and FPV-PSH projects depends on project ownership, project location, ownership of the water body or reservoir where the project is sited, and project-specific operational characteristics. Figure 5 shows different authorization pathways for the study’s use case scenarios for FPV project development.

Operational characteristics of the projects analyzed include stand-alone FPV or co-located FPV-hydroelectric or FPV-PSH projects where the:

- FPV arrays for stand-alone projects cover 1/5/10/15% of reservoir surface area
- FPV arrays for co-located FPV-hydroelectric or PSH projects are sized either at a 1:1 ratio of FPV to hydroelectric facility capacity or 1/5/10/15% reservoir coverage, whichever is smaller
- FPV arrays are assembled and staged on shore, before being deployed, moored, and anchored into the water body
- FPV floats constructed from high-density polyethylene
- FPV panels are cleaned periodically for maintenance.

FERC is the primary authority for the construction, operation, and maintenance of hydroelectric and PSH facilities by nonfederal developers (16 U.S.C. § 797(e); FERC 2023). As such, unless Congress has authorized otherwise, FERC has regulatory authority over nonfederal (1) FPV-hydroelectric and FPV-PSH projects that are co-located and operationally paired (i.e., determined to be a miscellaneous structure used and useful in connection with a new or existing FERC-licensed hydroelectric or PSH project), and (2) co-located (but not operationally paired) FPV projects located within a FERC license boundary of a hydroelectric or PSH facility.

Reclamation is the primary authority for the construction, operation, and maintenance of stand-alone or co-located FPV-hydroelectric or FPV-PSH sited within Reclamation’s LOPP jurisdiction at Reclamation reservoirs (43 U.S.C. § 485; 43 U.S.C. 387; FERC 2021c; FERC 2021d; Bureau of Reclamation 2020). Notably, FPV sited at a PSH reservoir that utilizes a reservoir within Reclamation’s LOPP jurisdiction and another reservoir within FERC’s jurisdiction may be subject to both FERC and Reclamation authorizations (Bureau of Reclamation 2020; Curtis et al. 2018).

USACE is the primary authority for the construction, operation, and maintenance of stand-alone or co-located federal FPV-hydroelectric, or federal FPV-PSH sited at a USACE reservoir (33 U.S.C. § 408(a); USACE 2023a). Notably, if co-located FPV-hydroelectric or FPV-PSH is sited at a USACE reservoir with a proposed or existing nonfederally operated hydroelectric or PSH facility that requires a FERC license, FERC and USACE have dual regulatory authority over the project (33 U.S.C. § 408(a); FERC 2021e).

The following sections discuss key federal infrastructure authorizations listed in Table 1 for stand-alone and co-located FPV-hydroelectric, and FPV-PSH projects sited at (1) hydroelectric or PSH project reservoirs requiring a FERC license, (2) Reclamation-owned reservoirs, and (3) USACE-owned reservoirs.

For the purposes of this report, the federal authorizations applicable to co-located FPV-hydroelectric and FPV-PSH facilities follow the same procedures. As such, in most instances, the report authors have combined analysis of the authorization processes applicable to both hydroelectric and PSH facilities within the use cases discussed in the following subsections.[25] Additionally, the use cases do not discuss federal authorizations related to land access, biological resources, preexisting land use and natural resources, water quality, cultural resources, and environmental review because they may depend on site-specific factors (e.g., the presence of migratory birds).

[25] In Section 4.3.2.3, the authorization processes are only applicable in the context of a co-located or co-located and operationally paired FPV-PSH project. Thus, these use cases are the only circumstance in the report where a discussion of authorizations applicable to FPV-hydroelectric and FPV-PSH are not discussed jointly.

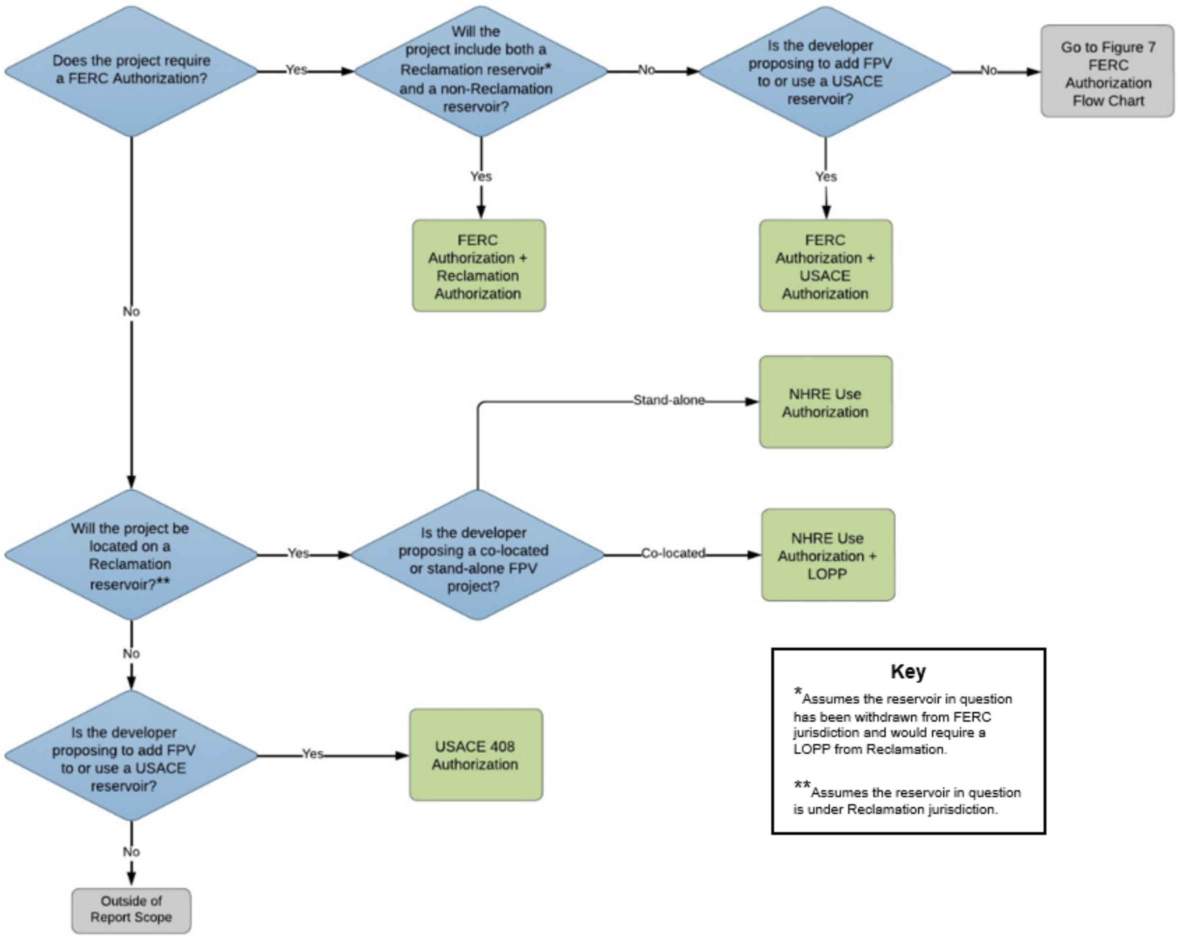

Figure 5. Regulatory authority flowchart

4.3.1 FPV Co-Located at Proposed or Existing Hydroelectric or PSH Projects Requiring a FERC License

This section discusses regulatory considerations and hypothetical use cases for FPV projects sited in hydroelectric and PSH project reservoirs that have or require a FERC license. FERC has regulatory authority over FPV considered part of the hydroelectric or PSH project unit[26] as a "miscellaneous structure used and useful in connection with the project" *or* that is within the FERC license boundary using project lands or waters (16 U.S.C. §§ 796(11); 797(e)).[27] Unless, Congress has authorized otherwise, FERC has jurisdiction to license hydroelectric and PSH projects (16 USC § 797(e)):

[26] The FPA defines hydroelectric projects as a "unit" that consists of a powerhouse; all water conduits, all dams and appurtenant works and structures; all directly connected storage, diverting, or forebay reservoirs; transmitting power lines; all miscellaneous structures used and useful in connection with the project; all water rights, rights-of-way, ditches, dams, reservoirs, lands, or interest in lands necessary for the maintenance or operation of the project (16 U.S.C. § 796(11)).
[27] Interview with John Katz, Vince Yearick, Cleo Deschamps, Jordan Joyce, Nick Jayjack. FERC. July 20, 2022.

- Located on navigable waters of the United States
- Occupying land of the United States
- Utilizing surplus water or water power of a U.S. government dam
- Located on a stream over which Congress has Commerce Clause jurisdiction, where project construction or expansion occurred on or after August 26, 1935, and the project affects the interests of interstate commerce.

FPV co-located at nonfederal hydroelectric and PSH projects may be authorized as part of a FERC original license or new license, non-capacity amendment, or non-capacity amendment for non-project use of project lands or waters. FPV may be authorized as part of an original license if a developer is proposing to construct and operate a co-located FPV-hydroelectric or FPV-PSH project at a non-powered reservoir. If a developer proposes to add FPV to an existing FERC-licensed hydroelectric or PSH facility that is near the expiration of its license term and requires a new license to continue operations, FPV may be authorized through the relicensing process. FPV that is added at a FERC-licensed hydroelectric or PSH facility that is not near the expiration of a license term may be authorized through a non-capacity amendment. The type of amendment depends on FERC's determination as to whether FPV is considered a "miscellaneous structure used and useful" in connection with the hydroelectric or PSH facility. FPV that is determined to be a "miscellaneous structure used and useful" (i.e., FPV is operationally paired with the hydroelectric or PSH facility) in connection with a hydroelectric or PSH facility may be authorized through a non-capacity amendment. FPV that is co-located but not determined to be a "miscellaneous structure used and useful" in connection with the hydroelectric or PSH facility may be authorized through a non-capacity amendment for non-project use of project lands or waters.

Figure 6 provides a flowchart depicting the different authorization scenarios that may be applicable to FPV located at FERC-licensed hydroelectric or PSH facility reservoirs.

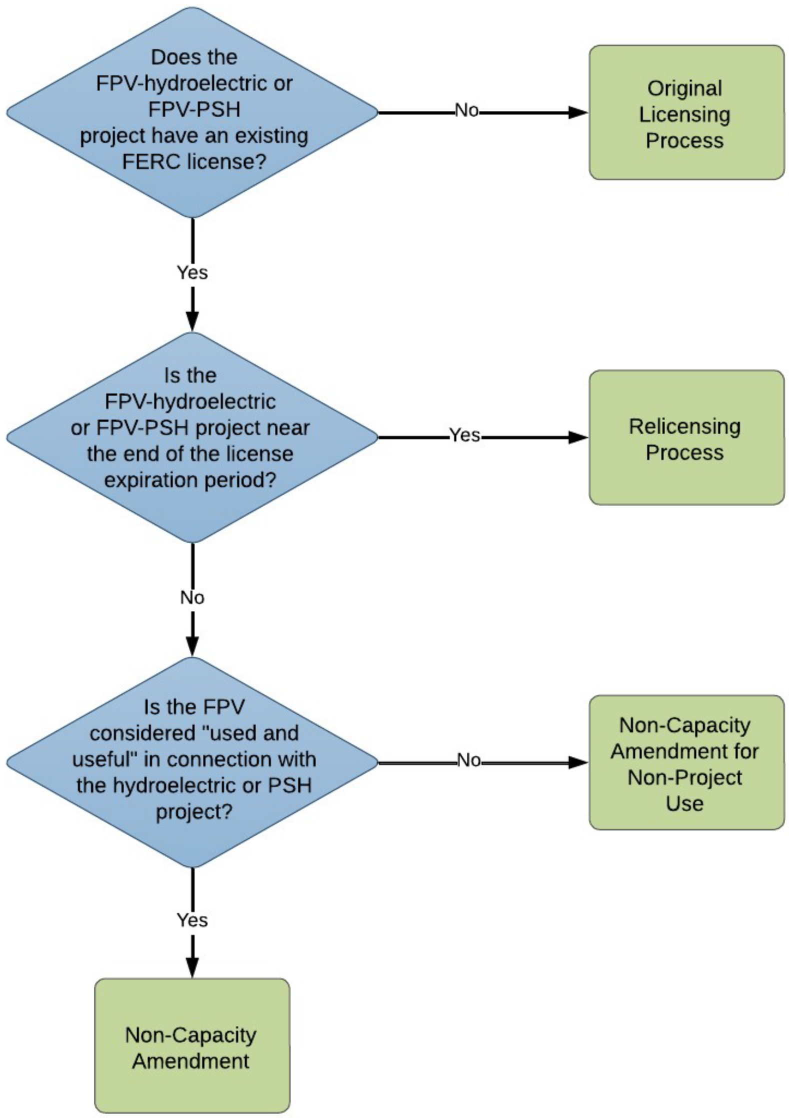

Figure 6. FERC licensing and authorization pathway flowchart

The following sections provide an overview of the processes and applicable use case scenarios for FPV projects authorized through FERC original licensing or relicensing, a non-capacity amendment, or a non-capacity amendment for non-project use of project lands or waters.

4.3.1.1 FPV Authorized Through an Original License or New License

FERC has the authority to issue licenses to construct, operate, and maintain nonfederal hydroelectric and PSH projects and authorize use of project lands or waters within the FERC license boundary (16 U.S.C. § 797(e)).[28] As such, FERC has the authority to approve co-located FPV projects that are proposed within an original license application to construct and operate a

[28] The default license term length for most FERC-licensed hydropower projects is 40 years; however, FERC hydropower licenses may be issued for a term of 30–50 years (16 U.S.C. 808(e); 161 FERC ¶ 61,078).

FERC-licensed hydroelectric or PSH project. In addition to original licenses, FERC has authority to issue new licenses (i.e., the relicensing process) to allow the continued operation of existing FERC-licensed hydroelectric and PSH projects after the expiration of a license term, including the authority to approve proposals to add FPV at existing hydroelectric or PSH facilities at the time of relicensing (16 U.S.C. § 797(e); FERC 2017).[29]

A developer would need to include all information relevant to the FPV installation (e.g., FPV project characteristics such as array size and reservoir coverage) at the beginning of the licensing or relicensing process to identify potential issues to be analyzed as part of the license application and NEPA review.[30] The FERC licensing process begins at the prefiling stage with the filing of a Notice of Intent/Pre-Application Document (18 C.F.R. § 5.6). The prefiling process includes identifying and consulting with relevant parties and other stakeholders (e.g., federal and state agencies, Indian Tribes, landowners, and NGOs) to gather information and identify issues like environmental resource concerns considered as part of the license application and associated NEPA review (FERC 2017; Levine et al. 2021).

Relicensing follows a procedure very similar to the original licensing process. A developer seeking to relicense an existing hydroelectric or PSH facility must file a Notice of Intent and Pre-Application Document with FERC at least 5 years, but no more than 5.5 years, before the expiration of the license term (18 C.F.R. § 5.5). The developer must then file a final license application at least 2 years before the existing license expires (18 C.F.R. § 5.17(a)).

In addition to FERC, the FPA requires the participation of federal and state agencies as well as Indian Tribes in the licensing process through issuance of mandatory license terms and conditions, license recommendations, or through other approvals required under federal law (e.g., NEPA review, ESA Section 7 consultation, CWA Section 401 water quality certification, NHPA Section 106) (FERC 2017; Levine et al. 2021). The following use cases provide scenarios where FPV is approved as part of the FERC licensing process.

Use Case 1. FPV Sited at a Non-Powered Reservoir Under FERC Jurisdiction

Use Case Description	FPV is sited at a non-powered reservoir that requires an original FERC license for a new/proposed hydroelectric or PSH facility
Reservoir Owner	Nonfederal or federal
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	New
Key Authorization(s)	Original License
Agency	FERC
Statutory Authority	FPA, 16 U.S.C. §§ 791 – 823g

[29] The default license term length for most FERC-licensed hydropower projects is 40 years; however, FERC hydropower licenses may be issued for a term of 30–50 years (16 U.S.C. 808(e); 161 FERC ¶ 61,078).
[30] For a detailed analysis and summary of the FERC hydropower licensing and federal authorization process, including different license and relicensing procedures, see Levine et al. (2021).

Use Case 2. FPV Sited at a Nonfederal Hydroelectric or PSH Facility Requiring Relicensing

Use Case Description	FPV is sited at a reservoir with an existing FERC-licensed hydroelectric or PSH facility with a license that is near the expiration of the initial license term
Reservoir Owner	Nonfederal or federal
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	Existing
Key Authorization(s)	Relicense
Agency	FERC
Statutory Authority	FPA, 16 U.S.C. §§ 791–823g

In Use Case 1, a developer is seeking an original license to construct, operate, and maintain a co-located FPV-hydroelectric or FPV-PSH project at a non-powered reservoir. In Use Case 2, a developer is seeking to add FPV at an existing FERC-licensed hydroelectric or PSH facility that is near the expiration of its license term and requires a new license to continue operations. In either case, the FPV may be operationally paired with the hydroelectric or PSH project (i.e., "a miscellaneous structure used and useful" in connection with the hydroelectric or PSH project) or co-located and used for purposes not related to the hydroelectric or PSH project. Even if FERC determines the FPV project is not "a miscellaneous structure used and useful" in connection with the project, FERC has authority to approve the siting of the FPV project within the project license boundary through the original or relicense application for the hydroelectric or PSH project as a non-project use of project land and water.[31]

4.3.1.2 FPV Authorized Through a FERC Amendment

FERC has authority to approve modifications of existing FERC-licensed hydroelectric and PSH projects through amendments to ensure that a hydroelectric or PSH project continues to operate effectively if an amendment is approved (18 C.F.R. § 4.200; FERC 2015). Accordingly, developers seeking to modify an existing FERC-licensed hydroelectric or PSH project with the addition of FPV that may result in changes in project structures, design, locations, or operations must obtain prior authorization from FERC through a non-capacity amendment or a non-capacity amendment for non-project use of project lands or waters (18 C.F.R. § 4.200; FERC 2015).[32]

A developer proposing to add FPV to an existing hydroelectric or PSH project through a non-capacity amendment or a non-capacity amendment for non-project use, must conduct prefiling consultation and comply with federal statutes and requirements (e.g., NEPA, CWA Section 401, ESA Section 7 consultation, NHPA, and the WSRA as required) (FERC 2015). In most cases,

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[31] Interview with John Katz, Vince Yearick, Cleo Deschamps, Jordan Joyce, Nick Jayjack. FERC. July 20, 2022.

[32] FERC typically classifies amendments as capacity related or non-capacity related (FERC 2015). Capacity-related amendments are defined as modifications that would increase a hydroelectric or PSH project's actual or proposed total installed capacity by 2 MW or more and increase hydraulic capacity by 15% or more (18 C.F.R. § 4.201(b)). Only the hydroelectric facility capacity is considered when analyzing whether a modification requires a capacity or non-capacity amendment. As such, FPV plays no role in the capacity amendment process and is not considered for analysis in this report.

both a non-capacity amendment and a non-capacity amendment for non-project use may only require a single stage of consultation with relevant federal and state resource agencies, Indian Tribes, and the public followed by a public comment period (18 C.F.R. § 4.38(a)(7); Levine, Curtis, and Kazerooni 2017). However, depending on complexity and/or impacts of the modification, some non-capacity amendments or non-capacity amendments for non-project use may require a three-stage consultation process (Levine, Curtis, and Kazerooni 2017).

Non-Capacity Amendment

The addition of FPV that is operationally paired with an existing FERC-licensed hydroelectric or PSH project may be considered "a miscellaneous structure used and useful" in connection to the existing facility and authorized through a non-capacity amendment. Through interviews conducted for this study, FERC staff noted that potentially analogous projects requiring a non-capacity amendment included large-format battery storage installations at hydroelectric reservoirs.

To gather information on the non-capacity amendment process, the authors analyzed four projects proposing to install large-format batteries at existing hydroelectric facilities through a non-capacity amendment (FERC 2020, 2021a, 2021b, 2022). The projects proposed installation of battery systems with a range of 16–20 megawatt-hours of battery storage that were interconnected with the existing hydroelectric substation. The purpose of installing battery storage was to increase the existing hydroelectric project's efficiency and transmit power from the existing hydroelectric project to the grid. As such, FERC determined that the proposed battery storage projects were "miscellaneous structures used and useful" in connection with the hydroelectric project and authorized the projects through non-capacity amendments (FERC 2020, 2021a, 2021b, 2022). Additionally, for these projects, the hydroelectric project licensees were required to consult with various federal and state agencies to identify potential project impacts to resources, including:

- State Historic Preservation Office pursuant to NHPA Section 106
- USFWS pursuant to ESA Section 7
- State resource agencies (e.g., State Department of Fish and Game, State Department of Environmental Protection) (FERC 2020, 2021a, 2021b, 2022).

Similarly, to the reviewed battery storage projects, FPV projects that improve system- and facility-level load balance by offsetting hydropower generation during dry conditions may be considered "miscellaneous structures used and useful" in connection to the hydroelectric or PSH facility.

Use Case 3. FPV Operationally Paired With an Existing FERC-Licensed Hydroelectric or PSH Facility

Use Case Description	FPV is sited at an existing FERC-licensed hydroelectric or PSH facility. The FPV is determined to be "a miscellaneous structure used and useful" in connection with hydroelectric or PSH facility.
Reservoir Owner	Nonfederal or federal
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	Existing
Key Authorization(s)	Non-Capacity Amendment
Agency	FERC
Statutory Authority	FPA, 16 U.S.C. §§ 791–823g

Non-Capacity Amendment for Non-Project Use of Project Lands or Waters

FPV that is not considered "a miscellaneous structure used and useful" in connection to the existing facility operations may be authorized through a non-capacity amendment for non-project use of project lands or waters (FERC 2015).[33] Through interviews conducted for this study, FERC staff noted that potentially analogous projects requiring a non-capacity amendment for non-project use included ground-mounted (land-based) solar PV installations located within the FERC license boundary, which were used for purposes not related to the hydroelectric facilities.

To gather information on the non-capacity amendment for non-project use process, the project team analyzed two projects[34] proposing construction and operation of ground-mounted solar PV on FERC project lands through non-capacity amendments for non-project use of project lands or waters (FERC 2011, 2013). The projects that proposed to install solar arrays were 2–2.2 MW on 10–12 acres of land within the FERC license boundary. The purpose of installing the ground-mounted solar PV projects was for the economic benefit of the licensee, including powering a visitor's center and selling any excess electricity to the grid. As part of the amendment process, prior to authorization the hydroelectric project licensees were required to conduct a natural resources survey that included analyzing potential impacts to visual and aesthetic resources, water resources, wildlife, and species habitat (FERC 2011, 2013). Additionally, for these

[33] Interview with Robert Fletcher, CarLisa Linton, Mark Carter, Hillary Berlin. FERC. July 6, 2022.

[34] The project team also identified two additional projects proposing construction and operation of ground-mounted solar PV arrays on FERC project lands (FERC 2014, 2016). However, due to the small size of the projects (less than 1-MW nameplate capacity and occupying less than 5 acres of FERC project land), these ground-mounted solar projects did not require prior authorization through a non-capacity amendment for non-project use from FERC to authorize the project (FERC 2014, 2016). Rather, the hydropower project licensee authorized the conveyance of project lands for non-project use through a standard license article, which provides that a licensee may convey an interest in project lands if (1) the amount of land is 5 acres or less; (2) conveyed land is located 75 feet from the reservoir; and (3) no more than 50 total acres of project lands for each development are conveyed under the article in any calendar year (FERC 2014, 2016). FPV, which would be located within a hydropower reservoir, would likely be outside the scope of activities contemplated by the standard license article, which allows for conveyances of land 5 acres of less located 75 feet from a reservoir. As such, authorization of FPV through standard license articles is not included for analysis within this report.

projects the hydroelectric licensees were required to consult with federal and state agencies, including:

- State Historic Preservation Office pursuant to NHPA Section 106
- USFWS pursuant to ESA Section 7
- State resource agencies (e.g., State Department of Fish and Game, State Department of Environmental Protection) (FERC 2011, 2013).

Similar to the reviewed ground-mounded solar PV installations within FERC license boundaries, FPV projects that are not operationally paired and are not considered “a miscellaneous structure used and useful” in connection with a hydroelectric or PSH facility may be authorized through a non-capacity amendment for non-project use of lands or waters.

Use Case 4. FPV Co-Located (Not Operationally Paired) at an Existing FERC-Licensed Hydroelectric or PSH Facility

Use Case Description	FPV is sited at a FERC-licensed hydroelectric or PSH facility that is not near the expiration of the initial license period. The FPV is not “a miscellaneous structure used and useful” in connection with the hydroelectric or PSH facility.
Reservoir Owner	Nonfederal or federal
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	Existing
Key Authorization(s)	Non-Capacity Amendment for Non-Project Use of Project Lands or Waters
Agency	FERC
Statutory Authority	FPA, 16 U.S.C. §§ 791–823g

4.3.2 FPV Projects Located at Reclamation Reservoirs

This section discusses regulatory considerations and hypothetical use cases for stand-alone, co-located FPV-hydroelectric, or co-located FPV-PSH projects sited at Reclamation reservoirs. Nonfederal renewable energy development is an acceptable, discretionary use of Reclamation lands, facilities, and waterbodies—provided it is compatible with underlying, authorized Reclamation project purposes, is in the best interest of the public, and is consistent with resource management and environmental considerations within the area. Accordingly, Reclamation has authority over the construction, operation, and maintenance of stand-alone FPV, co-located FPV-hydroelectric, or co-located FPV-PSH projects sited at Reclamation reservoirs subject to Reclamation jurisdiction (i.e., Reclamation reservoirs where FERC licensing jurisdiction has been withdrawn) (43 U.S.C. § 373; 43 U.S.C. § 387; 16 U.S.C. § 590; FERC 2021d).

Stand-alone FPV at Reclamation reservoirs require an NHRE Use Authorization from Reclamation to determine whether the project is compatible with Reclamation reservoir uses, purposes, operations, safety, and security.[35] In addition, if a developer proposes adding FPV at

[35] For more information on the Reclamation NHRE Use Authorization see https://www.usbr.gov/recman/lnd/lnd08-01.pdf.

an existing powered reservoir, the FPV would also require an NHRE Use Authorization.[36] However, if a developer proposes to construct, operate, and maintain a co-located FPV-hydroelectric or FPV-PSH project at a non-powered Reclamation reservoir *that is within the exclusive jurisdiction of Reclamation*, the hydroelectric or PSH portion of the project would require a LOPP to authorize hydroelectric generation, and the FPV portion of the project would require an NHRE Use Authorization to authorize use of the Reclamation reservoir.[37]

In certain cases, a co-located FPV-PSH project sited at a Reclamation reservoir may require a FERC authorization in addition to Reclamation authorization. Permitting authority for nonfederal hydroelectric or PSH project development is mutually exclusive, and projects will be authorized through a FERC license or a Reclamation LOPP (Bureau of Reclamation 2020; FERC 2021c, 2021d).[38] However, it is possible that a PSH project may require both a FERC license and a Reclamation LOPP if Reclamation has jurisdiction over one reservoir and FERC has jurisdiction over the other reservoir (Bureau of Reclamation 2020). Figure 7 provides a flowchart depicting the different authorization scenarios that may be applicable to FPV located at Reclamation reservoirs.

In all cases, a Reclamation LOPP or NHRE Use Authorization is a discretionary use of Reclamation land, facilities, and waterbodies. Reclamation is not obligated to initiate either process and may deny issuance or withdraw an issued LOPP or NHRE Use Authorization due to unsatisfactory environmental impacts, safety or security concerns, detrimental impacts to the Reclamation assets, or any other legitimate reason as determined by Reclamation.

[36] Interview with Clark Bishop, Cianna Wynshnytzky, Jason Kirby, and Erin Foraker. Bureau of Reclamation. July 11, 2022.

[37] For purposes of this report, section 4.3.2 assumes that Reclamation project reservoir development is within the exclusive jurisdiction of Reclamation (unless otherwise noted) and requires an LOPP. However, Reclamation does not have exclusive jurisdiction over all Reclamation reservoirs and those outside of the exclusive jurisdiction require a FERC-license for nonfederal hydropower development.

[38] The two agencies have developed two memoranda of understanding (MOU) that define jurisdictional boundaries and responsibilities (Bureau of Reclamation 2020; FERC 2021c, 2021d). Requests to develop hydroelectric projects at Reclamation assets are evaluated pursuant to the 1992 MOU to determine whether FERC or Reclamation have jurisdiction over the proposed project (Bureau of Reclamation 2020; Curtis et al. 2021).

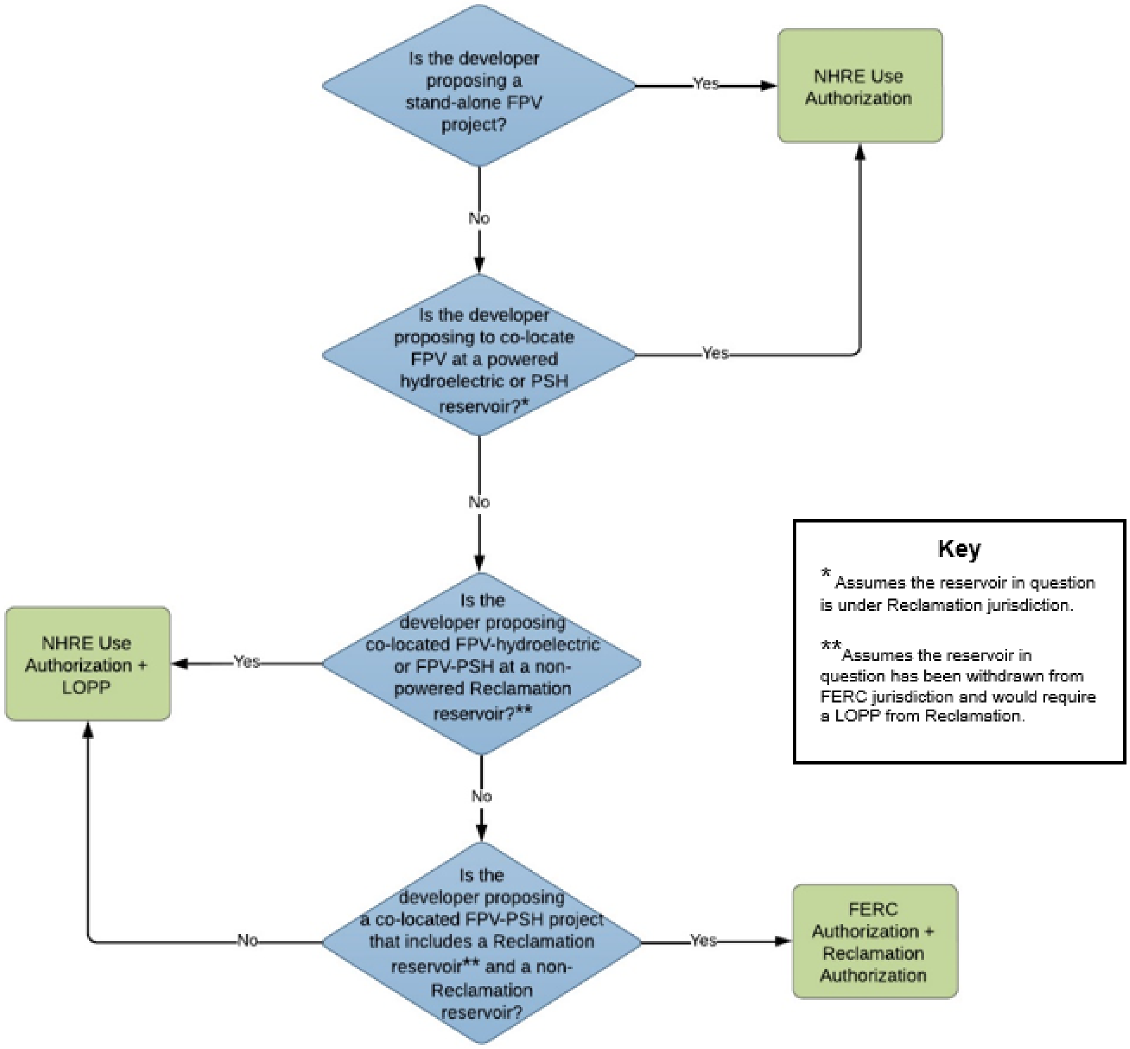

Figure 7. Reclamation authorization pathway flowchart

The following sections provide an overview of the processes and applicable use case scenarios for FPV projects sited at Reclamation reservoirs authorized through an NHRE Use Authorization or an NHRE Use Authorization and a LOPP, as well as FPV projects sited at Reclamation reservoirs that require both a FERC and Reclamation authorization.

4.3.2.1 FPV Approved Through an NHRE Use Authorization

Reclamation has the authority to approve discretionary uses of Reclamation reservoirs that may or may not be power-related through an NHRE Use Authorization (43 U.S.C. § 387; 43 C.F.R. § 429; Bureau of Reclamation 2015). As such, an FPV developer may need an NHRE Use Authorization for:

- Stand-alone FPV projects sited at Reclamation reservoirs

- FPV projects that are added to existing hydroelectric projects or FPV-PSH projects sited on Reclamation reservoirs.

To begin the NHRE process, a developer must submit an application to Reclamation that provides sufficient information about the FPV project to identify and analyze potential impacts to environmental resources, water operations, and/or hydroelectric or PSH projects (as applicable) (Bureau of Reclamation 2015). In determining whether an NHRE Use Authorization is appropriate, Reclamation may consider whether developing stand-alone FPV or adding FPV to an existing hydroelectric or PSH project is (43 C.F.R. § 429.14):

- Compatible with authorized project purposes, operations, safety, and security[39]
- Compliant with environmental regulations and requirements
- Compatible with public interests
- In conflict with federal policies and initiatives
- Compatible with public health and safety standards
- In the best interests of the United States.

Once an NHRE Use Authorization application has been submitted, Reclamation will determine the level of NEPA compliance required for the proposed FPV project. Reclamation must also comply with other federal statutory and regulatory requirements when informing their decision to approve the NHRE Use Authorization, including NHPA Section 106 and ESA Section 7 (Bureau of Reclamation 2015). The following use cases illustrate where an FPV project is approved through the Reclamation NHRE Use Authorization process.

Use Case 5. Stand-Alone FPV Sited at a Reclamation Reservoir

Use Case Description	FPV is sited at a Reclamation non-powered reservoir
Reservoir Owner	Reclamation
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	None
Key Authorization(s)	NHRE Use Authorization
Agency	Reclamation
Statutory Authority	Reclamation Project Act of 1939, 43 U.S.C. 387

[39] This may include water operations, power generation and pumping operations, dam safety risks, and transmission.

Use Case 6. FPV Added at a Powered Reclamation Reservoir

Use Case Description	FPV is added at a powered Reclamation hydroelectric or PSH reservoir
Reservoir Owner	Reclamation
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	Existing
Key Authorization(s)	NHRE Use Authorization
Agency	Reclamation
Statutory Authority	Reclamation Project Act of 1939, 43 U.S.C. 387

4.3.2.2 FPV Approved Through an NHRE Use Authorization and a LOPP

Through interviews conducted for this study, Reclamation noted that a developer proposing to construct, operate, and maintain a co-located FPV-hydroelectric or FPV-PSH project on a non-powered Reclamation reservoir would require both a LOPP and an NHRE Use Authorization.[40] Reclamation has authority to issue contractual rights to nonfederal developers to use a Reclamation reservoir for electric power generation consistent with Reclamation reservoir purposes, operations, safety, and security through a LOPP (43 U.S.C. 387; 43 C.F.R. § 429). As such, the hydroelectric or PSH portion of the project would require a LOPP to use the reservoir for hydroelectric or PSH power generation and the FPV portion of the project would require an NHRE Use Authorization as a discretionary use of a Reclamation reservoir.

To begin the LOPP process for a co-located FPV-hydroelectric or FPV-PSH project sited at a Reclamation reservoir, a nonfederal developer may submit a Formal Request for Development to the Reclamation office with jurisdiction (Bureau of Reclamation 2020; Curtis et al. 2018). The LOPP process for nonfederal hydroelectric or PSH projects located on Reclamation dams follows a competitive solicitation process during which Reclamation solicits proposals for hydroelectric projects through a public process to ensure fair and open competition (Bureau of Reclamation 2020; Curtis et al. 2018). After reviewing proposals, Reclamation will select an entity and issue a preliminary lease (Bureau of Reclamation 2020; Curtis et al. 2018).

During the preliminary lease phase, the lessee and Reclamation work together to identify all issues and necessary studies to evaluate project feasibility and impacts on the underlying Reclamation asset and public safety (Bureau of Reclamation 2020; Curtis et al. 2018). During the preliminary lease phase, Reclamation must comply with federal statutory, permitting, and consulting requirements, including NEPA, NHPA Section 106, and ESA Section 7 (Bureau of Reclamation 2020). All findings from preliminary lease activities, including all studies and environmental compliance activities are incorporated into the LOPP as terms and conditions.

Reclamation staff indicated that while this type of project would most likely require both a LOPP and an NHRE Use Authorization, the environmental review and analysis required for both authorizations would be analyzed within one NEPA document. The following use case illustrates

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[40] Interview with Clark Bishop, Cianna Wynshnytzky, Jason Kirby, and Erin Foraker. Bureau of Reclamation. July 11, 2022.

where co-located FPV-hydroelectric or FPV-PSH is approved through both a LOPP and an NHRE Use Authorization.

Use Case 7. FPV Sited at a Non-Powered Reclamation Reservoir With a Proposed Hydroelectric or PSH Facility

Use Case Description	FPV is sited at a Reclamation non-powered reservoir with a proposed hydroelectric or PSH facility	
Reservoir Owner	Reclamation	
Infrastructure Operator	Nonfederal	
Hydroelectric or PSH Facility	New	
Key Authorization(s)	NHRE Use Authorization	LOPP
Agency	Reclamation	Reclamation
Statutory Authority	Reclamation Project Act of 1939, 43 U.S.C. 387	Reclamation Project Act of 1939, 43 U.S.C. 387

4.3.2.3 FPV Approved Through a Reclamation Authorization and a FERC Authorization

In certain circumstances, a co-located FPV-PSH project will require both a Reclamation authorization and a FERC authorization. Reclamation and FERC have mutually exclusive authority over nonfederal hydroelectric or PSH development at Reclamation sites. However, a PSH project that involves a reservoir within Reclamation's jurisdiction and a reservoir outside of Reclamation's jurisdiction requires authorizations from both Reclamation and FERC. Accordingly, a developer proposing to construct, operate, and maintain a co-located FPV-PSH project sited within Reclamation's jurisdiction and another reservoir outside of Reclamation's jurisdiction (e.g., a new PSH upper reservoir outside of the Reclamation boundary) would require a LOPP from Reclamation and a license from FERC. In addition, the project may require an NHRE Use Authorization if Reclamation has jurisdiction over the reservoir where the FPV is being sited.

Use Case 8. Co-Located FPV-PSH Sited at a Reclamation Reservoir and a Non-Reclamation Reservoir (Both Non-Powered)

Use Case Description	FPV is sited at a Reclamation reservoir and a nonfederal reservoir (both non-powered)		
Reservoir Owner	Reclamation and nonfederal		
Infrastructure Operator	Nonfederal		
Hydroelectric or PSH Facility	New		
Key Authorization(s)	Original License	LOPP	NHRE Use Authorization
Agency	FERC	Reclamation	Reclamation
Statutory Authority	FPA, 16 U.S.C. §§ 791–823g	Reclamation Project Act of 1939, 43 U.S.C. 387	Reclamation Project Act of 1939, 43 U.S.C. 387

Use Case 9. Co-Located FPV-PSH Sited at a Reclamation Reservoir and a Non-Reclamation Reservoir

Use Case Description	FPV is sited at a Reclamation reservoir and a nonfederal reservoir	
Reservoir Owner	Reclamation and nonfederal	
Infrastructure Operator	Nonfederal	
Hydroelectric or PSH Facility	Existing	
Key Authorization(s)	FERC Authorization	NHRE Use Authorization
Agency	FERC	Reclamation
Statutory Authority	FPA, 16 U.S.C. §§ 791–823g	Reclamation Project Act of 1939, 43 U.S.C. 387

Note: In Use Case 9, the applicable FERC authorization may take the form of a new license, non-capacity amendment, or non-capacity amendment for non-project use.

4.3.3 FPV Projects Located at USACE Reservoirs

This section provides a discussion of regulatory considerations and hypothetical use cases for stand-alone or co-located FPV-hydroelectric and FPV-PSH projects sited at USACE reservoirs. USACE has regulatory authority over FPV projects that "take possession of, make use of, or build upon, alter . . . or impair the usefulness of any . . . work built by the United States for the preservation or improvement of any of its navigable waters" (33 U.S.C. § 408(a)). Accordingly, USACE may authorize construction, operation, and maintenance of stand-alone, co-located FPV-hydroelectric, or co-located FPV-PSH projects sited at USACE reservoirs.

USACE has authority to approve stand-alone or co-located FPV sited at USACE reservoirs through a Section 408 authorization. In addition, in certain situations, a co-located FPV-hydroelectric or FPV-PSH facility sited at a USACE reservoir with a proposed or existing nonfederally operated hydroelectric or PSH facility will require both a USACE Section 408 authorization as well as a FERC authorization (e.g., original license, relicense, non-capacity amendment, or non-capacity amendment for non-project use).

4.3.3.1 FPV Requiring a Rivers and Harbors Act Section 14 "Section 408" Authorization

USACE has authority to allow developers to alter USACE civil work projects through a Rivers and Harbors Act (RHA) Section 14 authorization, commonly referred to as a "Section 408" authorization (33 U.S.C. § 408(a); USACE 2023a). As such, a Section 408 authorization may be required for:

- Stand-alone FPV projects sited at USACE reservoirs, or
- Co-located FPV-hydroelectric or FPV-PSH projects sited on powered USACE reservoirs (e.g., FPV projects co-located with existing hydroelectric or PSH USACE reservoirs).

To begin the Section 408 authorization process, a developer must submit an application to USACE that provides sufficient information about the FPV project for USACE to verify that any alteration resulting from the FPV project will not be injurious to the public interest or impair the usefulness of the reservoir or existing infrastructure (33 U.S.C. § 408(a)). In determining whether the stand-alone or co-located FPV-hydroelectric or FPV-PSH project may be injurious to the public interest, USACE will analyze whether the project will impact:

- Wildlife, habitat, and the environment
- The economy
- Nearby historical, cultural, and archaeological sites
- Drinking water quality and quantity
- Flood hazards or floodplains
- The navigability of nearby waters
- Shore erosion or accretion
- Recreational resources such as lakes (USACE 2023b).

In addition, a Section 408 authorization for an FPV project requires compliance with other federal requirements including NEPA, ESA Section 7, and NHPA Section 106 (USACE 2023b). The following use cases provide scenarios where FPV is approved through the USACE Section 408 authorization process.

Use Case 10. Stand-Alone FPV Sited at a USACE Reservoir

Use Case Description	FPV is sited at a non-powered USACE reservoir
Reservoir Owner	USACE
Infrastructure Operator	Nonfederal
Hydroelectric or PSH Facility	None
Key Authorization(s)	Rivers and Harbors Act Section 14 Section 408 Authorization
Agency	USACE
Statutory Authority	RHA, 33 U.S.C. §408(a)

Use Case 11. Co-Located FPV Sited at a USACE Owned Hydroelectric or PSH Facility

Use Case Description	FPV is sited at an existing USACE owned hydroelectric facility
Reservoir Owner	USACE
Infrastructure Operator	USACE
Hydroelectric or PSH Facility	Existing
Key Authorization(s)	Rivers and Harbors Act Section 14 Section 408 Authorization
Agency	USACE
Statutory Authority	RHA, 33 U.S.C. §408(a)

4.3.3.2 FPV Requiring a Rivers and Harbors Act Section 14 Section 408 Authorization and a FERC Authorization

In certain situations, a co-located FPV-hydroelectric or FPV-PSH facility sited at a USACE reservoir with a proposed or existing nonfederally operated hydroelectric or PSH facility will require both a USACE Section 408 authorization as well as a FERC authorization (e.g., original license, relicense, non-capacity amendment, or non-capacity amendment for non-project use) (33 U.S.C. § 408(a); FERC 2021e). If a developer proposes to construct, operate, and maintain a co-located FPV-hydroelectric or FPV-PSH facility at a non-powered USACE reservoir, the project will require both a USACE Section 408 authorization and a FERC license. In addition, if a developer proposes to co-locate FPV at an existing FERC-licensed hydroelectric or PSH facility sited at a USACE reservoir, the project will require both a USACE Section 408 authorization and a FERC authorization (e.g., new license, non-capacity amendment, non-capacity amendment for non-project use). The following use cases provide scenarios where a hybrid FPV-hydroelectric or hybrid FPV-PSH facility requires approval from FERC and USACE.

Use Case 12. Co-Located FPV Sited at a Non-Powered USACE Reservoir

Use Case Description	FPV is sited at a non-powered USACE reservoir that requires a FERC license for a new/proposed hydroelectric or PSH facility	
Reservoir Owner	USACE	
Infrastructure Operator	Nonfederal	
Hydroelectric or PSH Facility	New	
Key Authorization(s)	Rivers and Harbors Act Section 14 Section 408 Authorization	Original License
Agency	USACE	FERC
Statutory Authority	RHA, 33 U.S.C. §408(a)	FPA, 16 U.S.C. §§ 791–823g

Use Case 13. Co-Located FPV Sited at a USACE Reservoir With an Existing FERC Licensed Hydroelectric or PSH Facility

Use Case Description	FPV is sited at a USACE reservoir with an existing FERC-licensed hydroelectric or PSH facility	
Reservoir Owner	USACE	
Infrastructure Operator	Nonfederal	
Hydroelectric or PSH Facility	Existing	
Key Authorization(s)	Rivers and Harbors Act Section 14 Section 408 Authorization	FERC Authorization
Agency	USACE	FERC
Statutory Authority	RHA, 33 U.S.C. §408(a)	FPA, 16 U.S.C. §§ 791–823g

Note: The type of FERC authorization may take the form of a new license, non-capacity amendment, or non-capacity amendment for non-project use.

5 Conclusion

Although approximately 800–1,200 GW of technical FPV resource potential has been identified at existing Reclamation, USACE, and FERC-licensed reservoirs across the United States, FPV is still a newer siting approach in the United States and has been limited to small-scale, stand-alone projects with an average installed capacity of 1.18 MW. However, using FPV as an alternative siting approach to ground-mounted PV may help alleviate land use constraints and aid in increasing PV deployment, which is critical to reaching the Biden-Harris administration's decarbonization goals to create a 100% carbon-pollution-free power sector by 2035 and net-zero emissions economy by 2050.

Currently, there are no stand-alone or co-located FPV projects sited on USACE or Reclamation reservoirs or at FERC-licensed hydroelectric or PSH facilities in the United States. Large-scale projects at federal and nonfederal reservoirs may have different environmental and development considerations as well as more complex authorization processes than small-scale FPV projects currently deployed in the United States. This report explored potential environmental and energy benefits, environmental impacts, and regulatory pathways to understand the opportunities and challenges associated with developing stand-alone and co-located FPV projects on Reclamation, USACE, and FERC-licensed reservoirs. In addition, through interviews conducted with federal and state agencies as well as NGOs, the report authors identified development considerations that require further analysis to better identify opportunities and challenges of siting large-scale FPV on reservoirs.

5.1 Potential Environmental and Energy Benefits of FPV

Recent studies indicate that due to the natural cooling effect provided by the water, FPV may operate more efficiently than ground-mounted PV systems, resulting in operational power production gains. However, the range in power production gains may depend on the FPV technology and location of the system. Accordingly, site-specific analysis is needed to understand potential power production gains resulting from FPV development at federally controlled reservoirs in the United States.

In addition, preliminary analysis indicates that FPV systems may provide certain environmental benefits. For example, recent studies have found that FPV systems can reduce evaporative water loss on water bodies by providing shade and acting as a windbreak across water surfaces, which may protect species habitat and provide recreational benefits for angling and boating activities. Although further study is needed, reduced evaporative loss may lead to improved water resource conservation, which may benefit areas experiencing drought, particularly in the western United States.

Co-locating FPV systems with hydroelectric facilities or PSH facilities may result in additional environmental and energy benefits compared to stand-alone FPV systems including:

- Improved recreational and environmental downstream benefits, including increased riparian habitat stability, reduced riverbank erosion, reduced water temperature fluctuations, and thermal stratification of the reservoir from optimized hydroelectric facility operations (e.g., only releasing water for hydroelectric generation during peak demand)

- Improved water resource conservation for hydroelectric and PSH reservoirs from reduced water evaporation
- Increased hydroelectric generation and PSH capacity from reduced reservoir water evaporation
- Reduced environmental impacts and capital costs when paired with an existing hydroelectric or PSH facility through use of existing infrastructure and grid connections
- Improved load planning and operational flexibility to optimize system- and facility-level load balance by using water resources during wetter daily and seasonal conditions and offsetting hydroelectric generation with PV during dryer conditions.

5.2 Potential Environmental Impacts

To date, there is limited experience with FPV development in the United States and the associated environmental impacts during the construction and operational phases. However, through a literature review and interviews with federal and state agencies as well as NGOs, this study identified potential construction and operational considerations as well as other development considerations for stand-alone and co-located FPV systems.

FPV siting and construction activities may produce short-term impacts to terrestrial, avian, and aquatic species, as well as water resources. For example, noise associated with staging and deployment of the FPV array may cause temporary disturbance and short-term species displacement. In addition, construction activities may result in the disturbance or removal of riparian vegetation and temporarily increase sediment disturbance and turbidity, potentially impacting aquatic species and water quality.

Through this study, interviewees also identified potential FPV operational activities that may impact terrestrial and avian species, water and recreation resources, and human health and safety. For example, federal agency and NGO staff expressed concern that reflective PV modules may cause avian species to mistake FPV modules for bodies of water and attempt to land on them, resulting in strandings, injuries, or mortality. In addition, federal agency staff noted that FPV reservoir coverage may impact nutrient levels and dissolved oxygen levels impacting aquatic species and water quality. Federal agency staff also expressed concern that FPV system infrastructure may potentially impact avian, terrestrial, and aquatic species by providing perching habitat for predatory bird species and disrupting migration routes for terrestrial and aquatic species. Several agencies and NGO representatives expressed concern that FPV could impact reservoir aesthetics and recreation opportunities, as well as create a potential hazard for recreational users (e.g., boat collisions). Ultimately, federal and state agency staff noted that studies analyzing these types of potential FPV operational impacts/considerations may be needed as part of an environmental review required for authorization (e.g., federal licenses, permits, and other approvals) prior to FPV system development.

5.3 Other Development Considerations Associated With FPV

Federal agency staff noted that some types of reservoirs may be unsuitable for FPV development. Reservoirs with multiple beneficial uses (e.g., irrigation delivery, municipal and industrial delivery, flood control, and/or hydropower generation) may see large operational fluctuations in surface water elevation during a given water year. These operational fluctuations in surface water elevation can be in excess of 50 feet. Additionally, prolonged critical or wet water year types can cause surface water elevation fluctuations in excess of 200 feet. Dynamic surface water level fluctuations may not be suitable for FPV.[41]

Moreover, some NGO staff with a focus on river restoration and removal of non-beneficial dams expressed concern that the addition of FPV to an existing hydroelectric dam could provide an economic incentive to extend the lifespan of older and/or arguably environmentally unsound hydroelectric dams that might otherwise be considered for dam removal.[42]

5.4 Authorization Requirements and Considerations for FPV Sited at Federal and Nonfederal Reservoirs

Currently, there are no stand-alone or co-located FPV projects at USACE or Reclamation reservoirs or approved FPV projects at FERC-licensed hydroelectric or PSH facilities. As such, the types of authorizations (e.g., licenses, permits, approvals) and associated analysis of impacts that may be required at federal and nonfederal reservoirs is a developing area of study. In the near term, this may result in protracted approval timelines while regulators become more familiar with this new siting approach.

Agency staff noted that that absent a congressional mandate, Reclamation and USACE do not have authority to develop federal stand-alone or co-located FPV at reservoirs that they have jurisdiction over. Accordingly, in the United States, currently only nonfederal (e.g., private) entities may develop stand-alone or co-located FPV sited at federal reservoirs.

The development of both stand-alone and co-located large-scale FPV projects at federal and nonfederal reservoirs may require compliance with a complex set of federal and state laws and regulations. In addition, the types of authorizations required may depend on project location, ownership of the water body or reservoir where the project is sited, and characteristics specific to project operations. Numerous federal and state agencies as well as Indian Tribes may have a primary or cooperating authorizing role for stand-alone or co-located FPV projects sited at federally managed or licensed reservoirs. Depending on project location, FERC, Reclamation, and/or USACE may have a primary regulatory role in approving FPV projects considered or incorporated within authorizations or license applications for existing or proposed hydroelectric or PSH infrastructure. In addition, FERC, Reclamation, and/or USACE may act as a lead federal agency for environmental review for stand-alone or co-located FPV projects pursuant to NEPA. Federal land management agencies (e.g., BLM, USFS, Bureau of Indian Affairs) and Indian Tribes may have a primary permitting role in granting land access rights-of-way and authorizations for FPV project development. For water quality considerations, state entities typically have a primary permitting role for CWA Section 401 water quality certifications or waivers, while USACE or the states of Florida, Michigan, and New Jersey have a primary permitting role for CWA Section 404 dredge and fill permits.

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[41] Clark Bishop, Cianna Wynshnytzky, Jason Kirby, Erin Foraker, Bureau of Reclamation. Phone Interview. July 11, 2022.

[42] Jack West. Alabama River Alliance. Phone Interview. March 20, 2023; Colleen McNally-Murphy. Hydropower Reform Coalition. Phone Interview. February 2, 2023.

This report provided detailed analysis related to the each of the three agencies that may play a primary role in approving FPV projects at federally controlled reservoirs:

- **FERC Regulatory Considerations:** FERC has authority over the construction, operation, and maintenance of FPV developed at a FERC-licensed hydroelectric or PSH project that is determined to be "a miscellaneous structure used and useful" in connection with the hydroelectric project or that is within the jurisdictional boundary (i.e., FERC license boundary) utilizing project lands and waters.
- **Reclamation Regulatory Considerations:** Reclamation has authority over the construction, operation, and maintenance of stand-alone FPV, co-located FPV-hydroelectric, or co-located FPV-PSH projects sited at Reclamation reservoirs subject to Reclamation jurisdiction (i.e., Reclamation reservoirs where FERC licensing jurisdiction has been withdrawn).
- **USACE Regulatory Considerations:** USACE has authority over the construction, operation, and maintenance of stand-alone or co-located federal FPV-hydroelectric sited at USACE reservoirs. In addition, for nonfederal hydropower, a co-located FPV-hydroelectric or FPV-PSH facility sited at a USACE reservoir with a proposed or existing FERC-licensed hydroelectric or PSH facility will require both a USACE authorization and a FERC authorization.

5.5 Concluding Thoughts

While to date no FPV projects have been sited at Reclamation, USACE, or FERC-licensed reservoirs, the resource potential is promising for future development. Ultimately, the environmental and energy benefits, environmental impacts, and regulatory pathways for development will not become completely clear and well known until sufficient deployment has occurred across these reservoir types. Project development and additional research into the following areas will help to address this uncertainty and likely improve the timeliness of the decision-making process:

- The evaporative loss savings associated with FPV development on reservoirs under a series of FPV reservoir coverage scenarios
- Impacts to biological resources, specifically aquatic species that inhabit the reservoir and avian species that may interact with the FPV and/or reservoir
- Compatibility with existing recreation and other public uses of the reservoir
- Compatibility with existing operations at Reclamation and USACE reservoirs (e.g., existing federal hydropower operations, water conveyance, flood control)
- Human dimension research, including insights into the perspectives of local community stakeholders.

Despite these uncertainties, FPV appears to be a viable alternative to ground-mounted PV under certain conditions where ground-mounted solar is not feasible and its future in the United States could be bright.

References

Abdelgaied, Mohamed, Abd Elnaby Kabeel, Martina Zeleňáková, and Hany F. Abd-Elhamid. 2023. "Floating Photovoltaic Plants as an Effective Option to Reduce Water Evaporation in Water-Stressed Regions and Produce Electricity: A Case Study of Lake Nasser, Egypt." *Water* 15(4): 635. https://doi.org/10.3390/w15040635.

Alabama Power Company and Kleinschmidt Associates (Alabama Power and Kleinschmidt). 2022. *Downstream Release Alternatives Phase 2 Report*. Birmingham, AL. prepared by Kleinschmidt. June 2022.

Almeida, Rafael M., Rafael Schmitt, Steven M. Grodsky, Alexander S. Flecker, Carla P. Gomes, Lu Zhao, Haohui Liu, Nathan Barros, Rafael Kelman and Peter B. McIntyre. 2022. "Floating Solar Power Could Help Fight Climate Change – Let's Get it Right." *Nature*. June 7, 2022. https://www.nature.com/articles/d41586-022-01525-1.

Bellini, Emiliano. 2021. "The World's First Large Scale Hybrid Hydro-Floating Solar Power Plant." *PV Magazine International*. September 13, 2021. https://www.pv-magazine.com/2021/09/13/the-worlds-first-large-scale-hybrid-hydro-floating-solar-power-plant/.

Bontempo Scavo, Fausto, Giuseppe Marco Tina, Antonio Gagliano, and Sandro Nižetić. 2020. "An Assessment Stud of Evaporation Rate Models on a Water Basin With Floating Photovoltaic Plants." *International Journal of Energy Research* 45(1): 167–188. https://doi.org/10.1002/er.5170.

Bui Power Authority. 2024. "Hydro Solar Hybrid." https://buipower.com/hyrdo-solar-hybrid/.

Bureau of Reclamation. 2015. *Guidebook – Use Authorizations for Non-Hydro Renewable Energy on Reclamation Lands*. Denver, CO: Bureau of Reclamation. https://www.usbr.gov/power/NHRE/Guidebook_NHRE_on_Rec_Lands.pdf.

_____. 2020. *Hydropower Program: Lease of Power Privilege (LOPP)*. https://www.usbr.gov/power/LOPP/.

Chopra, Sagar, and Daniel Garasa Sagardoy. 2022. *Floating Solar Landscape 2022*. Wood Mackenzie.

Curtis, Taylor, Aaron Levine, and Katie McLaughlin. 2018. *Bureau of Reclamation Hydropower Lease of Power Privilege: Case Studies and Considerations*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71092. https://www.nrel.gov/docs/fy18osti/71092.pdf.

Davis, Michelle, Sylvia Levya Martinez, Zoe Gaston, Sagar Chopra, Caitlin Connelly, Kaitlin Fung, Elissa Pierce, Amanda Colombo, Shawn Rumery, Colin Silver, Tyler Thompson, Justin Bac 2023. *U.S. Solar Market Insight Data Q4 2023.* Wood Mackenzie and Solar Energy Industries Association.

Denchak, Melissa. 2019. "Freshwater Harmful Algal Blooms 101." National Resource Defense Council. https://www.nrdc.org/stories/freshwater-harmful-algal-blooms-101.

[DOE] U.S. Department of Energy. 2021. *Solar Futures Study*. Washington, DC: DOE Office of Energy Efficiency & Renewable Energy. GO-102021-5621. https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf.

_____. 2023a. *Types of Hydropower Plants.* Water Power Technologies Office. Accessed October 7, 2023. https://www.energy.gov/eere/water/types-hydropower-plants.

_____. 2023b. *Pumped Storage Hydropower.* Water Power Technologies Office. Accessed October 7, 2023. https://www.energy.gov/eere/water/pumped-storage-hydropower.

[EPA] U.S. Environmental Protection Agency. 2023. "Harmful Algal Blooms" https://www.epa.gov/nutrientpollution/harmful-algal-blooms. Accessed October 5, 2023.

Farrar, Lewis W., AbuBakr S. Bahaj, Patrick James, Arif Anwar, and Nafn Amdar. 2022. "Floating Solar PV To Reduce Water Evaporation in Water Stressed Regions and Powering Water Pumping: Case Study Jordan." *Energy Conversion and Management* 260: 115598. https://doi.org/10.1016/j.enconman.2022.115598.

[FERC] Federal Energy Regulatory Commission. 2011. "Order Granting Application for Non-Project Use and Occupancy of Project Lands for Northfield Mountain Project (FERC No. 2485)." Federal Energy Regulatory Commission. May 19, 2011.

_____. 2013. "Order Granting Application for Non-Project Use and Occupancy of Project Lands for Sheldon Springs Hydroelectric Project (FERC No. 7186)." Federal Energy Regulatory Commission. February 19, 2013.

_____. 2014. "Notice Acknowledging Letter of Intent to Install a Solar Array for Non-Project Use of Project Lands Pursuant to Standard License Article for Clyde River Hydroelectric Project (FERC No. 2306)." Federal Energy Regulatory Commission. November 10, 2014.

_____. 2015. *Division of Hydropower Administration & Compliance: Compliance Handbook*. Washington, DC: Federal Energy Regulatory Commission (FERC), 2015. https://www.ferc.gov/sites/default/files/2020-04/ComplianceHandbook.pdf.

_____.2016. "Notice Acknowledging Letter of Intent to Develop a Solar Array for Non-Project Use of Project Lands Pursuant to Standard License Article for California Lower Mokelumne River Project (FERC No. 2916)." Federal Energy Regulatory Commission. December 9, 2016.

_____. 2017. *Hydropower Primer: A Handbook of Hydropower Basics*. Washington, DC: Federal Energy Regulatory Commission (FERC), February 2017. https://www.ferc.gov/sites/default/files/2020-05/hydropower-primer.pdf.

_____. 2020. "Order Amending License to Include Battery Systems for Ripogenus and Penobscot Projects (FERC No. 2572 and 2458)." Federal Energy Regulatory Commission. March 24, 2020.

_____. 2021a. “Order Amending License to Include Battery System for Bonny Eagle Hydroelectric Project (FERC No. 2529).” Federal Energy Regulatory Commission. March 23, 2021.

_____. 2021b. “Order Amending License to Include Battery System for Rumford Falls Hydroelectric Project (FERC No. 2333).” Federal Energy Regulatory Commission. June 3, 2021.

_____. 2021c. “1981 MOU Water and Power Resources Service of the Department of Interior.” Federal Energy Regulatory Commission. April 21, 2021. https://www.ferc.gov/media/1981-mou-water-and-power-resources-service-department-interior.

_____. 2021d. “1992 MOU Bureau of Reclamation of the Department of Interior.” Federal Energy Regulatory Commission. April 21, 2021. https://www.ferc.gov/media/1992-mou-bureau-reclamation-department-interior.

_____. 2021e. “2011 MOU Army Corps of Engineers.” Federal Energy Regulatory Commission. April 21, 2021. https://www.ferc.gov/media/2011-mou-army-corps-engineers.

_____. 2022. “Order Amending License to Include Battery System for Sawmill Project (FERC No. 2422).” Federal Energy Regulatory Commission. March 7, 2022.

_____. 2023. *Hydropower*. January 25, 2023. https://www.ferc.gov/industries-data/hydropower.

Gadzanku, Sika, and Nathan Lee. 2022. *Enabling Floating Solar Photovoltaic (FPV) Deployment: Exploring the Operational Benefits of Floating Solar Hydropower Hybrids.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-83149. https://www.nrel.gov/docs/fy22osti/83149.pdf.

Gadzanku, Sika, Laura Beshilas, and Ursula (Bryn) Grunwald. 2021a. *Enabling Floating Solar Photovoltaic (FPV) Deployment: Review of Barriers to FPV Deployment in Southeast Asia*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-76867. https://doi.org/10.2172/1787553.

Gadzanku, Sika, Heather Mirletz, Nathan Lee, Jennifer Daw, Adam Warren. 2021b. “Benefits and Critical Knowledge Gaps in Determining the Role of Floating Photovoltaics in the Energy-Water-Food-Nexus.” *Sustainability* 13(8): 4317. https://doi.org/10.3390/su13084317.

Gallucci, Maria. 2019. “No Land, No Problem. Floating Solar Panels Might Be the next Big Thing.” Blog. Grist. December 2, 2019. https://grist.org/article/no-land-no-problem-floating-solar-panels-might-be-the-next-big-thing/.

Haas, J, J. Khalighi, A. de la Fuente, S.U. Gerbersdorf, W. Nowak, and Po-Jung Chen. 2020. “Floating Photovoltaic Plants: Ecological Impacts Versus Hydropower Operation Flexibility.” *Energy Conversion and Management* 206: 112414. https://doi.org/10.1016/j.enconman.2019.112414.

Hernandez, R. R., S. B. Easter, M. L. Murphy-Mariscal, F. T. Maestre, M. Tavassoli, E. B. Allen, C. W. Barrows, et al. 2014. "Environmental Impacts of Utility-Scale Solar Energy." *Renewable and Sustainable Energy Reviews* 29: 766–779. https://doi.org/10.1016/j.rser.2013.08.041.

Hooper, Tara, Alona Armstrong, and Brigitte Vlaswinkel. 2020. "Environmental Impacts and Benefits of Marine Floating Solar." *Solar Energy* 219: 11–14. https://doi.org/10.1016/j.solener.2020.10.010.

Kakoulaki, G., R., Gonzalez Sanchez, A. Garcia Amillo, S. Szabo, M. De Felice, F. Farinois, L. De Felice, B. Bisselink, R. Seliger, I. Kougias, A. Jaeger-Waldau. 2023. "Benefits of pairing floating solar photovoltaics with hydropower reservoirs in Europe." *Renewable and Sustainable Energy Reviews* 171: 112989. https://doi.org/10.1016/j.rser.2022.112989.

Kao, Shih-Chieh, Moetasim Ashfaq, Deeksha Rastogi, Sudershan Gangrade, Rocio Uria Martinez, Alisah Fernandez, Goutam Konapala, Nathalie Voisin, Tian Zhou, Wenwei Xu, Huilin Gao, Bingjie Zhao, and Gang Zhao. 2022. *The Third Assessment of the Effects of Climate Change on Federal Hydropower.* Oak Ridge, TN: Oak Ridge National Laboratory. ORNL/TM-2021/2278. https://info.ornl.gov/sites/publications/Files/Pub168510.pdf.

Lee, Nathan, Ursula Grunwald, Evan Rosenlieb, Heather Mirletz, Alexandra Aznar, Robert Spencer, and Sadie Cox. 2020. "Hybrid Floating Solar Photovoltaics-Hydropower Systems: Benefits and Global Assessment of Technical Potential." *Renewable Energy* 162: 1415–1427. https://doi.org/10.1016/j.renene.2020.08.080.

Levine, Aaron, Taylor Curtis, and Borna Kazerooni. 2017. *Regulatory Approaches for Adding Capacity to Existing Hydropower Facilities*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70121. https://www.nrel.gov/docs/fy18osti/70121.pdf.

Levine, Aaron, Brenda Pracheil, Taylor Curtis, Ligia Smith, Jesse Cruce, Matt Aldrovandi, Christa Brelsford, Heather Buchanan, Emily Fekete, Esther Parish, Rocio Uria-Martinez, Megan Johnson, and Debjani Singh. 2021. *An Examination of the Hydropower Licensing and Federal Authorization Process*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79242. https://www.nrel.gov/docs/fy22osti/79242.pdf.

Lindner, Linda. 2023. "Canoe Brook Reservoir in Short Hills Debuts North America's Largest Floating Solar Array." ROI-NJ.com. https://www.roi-nj.com/2023/06/08/industry/energy-utilities/canoe-brook-reservoir-in-short-hills-debuts-north-americas-largest-floating-solar-array/.

Liu, Luyao, Qie Sun, Hailong Li, Hongyi Yin, Xiaohan Ren, and Ronald Wennersten. 2019. "Evaluating the Benefits of Integrating Floating Photovoltaic and Pumped Storage Power System." *Energy Conversion and Management* 194:173–185. https://doi.org/10.1016/j.enconman.2019.04.071.

Malewar, Amit. 2021. "World's Largest Hydro-Floating Solar Hybrid Project Begins Operation in Thailand." Inceptive Mind(blog). November 12, 2021. https://www.inceptivemind.com/egat-worlds-largest-hydro-floating-solar-hybrid-project-thailand/22022/.

Oliveira-Pinto, Sara, and Jasper Stokkermans. 2020. "Assessment of the Potential of Different Floating Solar Technologies – Overview and Analysis of Different Case Studies." *Energy Conversion and Management* 211: 112747. https://doi.org/10.1016/j.enconman.2020.112747.

Pietro Elia Campana, Louise Wästhage, Worrada Nookuea, Yuting Tan, Jinyue Yan. 2019. "Optimization and assessment of floating and floating-tracking PV systems integrated in on- and off-grid hybrid energy systems." *Solar Energy* 177: 782–795. https://doi.org/10.1016/j.solener.2018.11.045.

Pouran, Hamid M., Mariana Padilha Compos Lopes, Tainan Nogueira, David Alves Castelo Branco, and Yong Sheng. 2022. "Environmental and Technical Impacts of Floating Photovoltaic Plants as an Emerging Clean Energy Technology." *IScience* 25(11): 105253. https://doi.org/10.1016/j.isci.2022.105253.

Ramasamy, Vignesh and Robert Margolis. 2021. *Floating Photovoltaic System Cost Benchmark: Q1 2021 Installations on Artificial Water bodies*. Golden, Co: National Renewable Energy Laboratory. NREL/TP-7A40-80695. https://www.nrel.gov/docs/fy22osti/80695.pdf.

Saulsbury, Bo. 2020. *A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower*. Richland, WA: Pacific Northwest National Laboratory. PNNL-29157. https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf.

Soares, M. C. S., Marinho, M. M., Huszar, V. L. M., Branco, C. W. C., & Azevedo, S. M. F. O. (2008). "The effects of water retention time and watershed features on the limnology of two tropical reservoirs in Brazil." *Lakes & Reservoirs: Research & Management*, 13(4), 257–269. https://doi.org/10.1111/j.1440-1770.2008.00379.x.

Spencer, Robert S., Jordan Macknick, Alexandra Aznar, Adam Warren, and Matthew O. Reese. 2018. "Floating Photovoltaic Systems: Assessing the Technical Potential of Photovoltaic Systems on Man-Made Water Bodies in the Continental United States." *Environmental Science and Technology*. 53: 1680–1689. http://dx.doi.org/10.1021/acs.est.8b04735.

Teixeira, Luis, Johan Caux, Alexandre Beluco, Ivo Bertoldo, José Louzada, and Ricardo Eifler. 2015. "Feasibility Study of a Hydro PV Hybrid System Operating at a Dam for Water Supply in Southern Brazil." *Journal of Power and Energy Engineering* 3(9): 70–83. https://doi.org/10.4236/jpee.2015.39006.

[USACE] U.S. Army Corps of Engineers. 2023a. "The Section 408 Program." Accessed October 10, 2023. https://www.usace.army.mil/Missions/Civil-Works/Section408/#:~:text=The%20Section%20408%20Program&text=Examples%20of%20projects%20that%20need,maintained%20and%20surveyed%20by%20USACE.

_____. 2023b. *Section 408 Process Guide.* Accessed November 8, 2023. https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll11/id/6569.

U.S. Department of State and Executive Office. 2021. *The Long Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050.* Washington, D.C.: U.S. Department of State. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.

Wood Mackenzie. 2023. *Global floating solar to top 6 GW threshold by 2031.* https://www.woodmac.com/press-releases/global-floating-solar-to-top-6gwhttps://www.woodmac.com/press-releases/global-floating-solar-to-top-6gw-threshold-by-2031/-threshold-by-2031/.

Xiong, Lichao, Conghuan Le, Puyang Zhang, Hongyan Ding, and Jingyi Li. 2023. "Harnessing the power of floating photovoltaic: A global review." *Journal of Renewable and Sustainable Energy* 15:052701. https://doi.org/10.1063/5.0159394.

YSG Solar. 2022. "3 Largest Floating Solar Farms in the United States in 2022." YSG Solar. January 21, 2022. https://www.ysgsolar.com/blog/3-largest-floating-solar-farms-united-states-2022-ysg-solar.