Advanced Energy Partnership for Asia

ENABLING FLOATING SOLAR PHOTOVOLTAIC (FPV) DEPLOYMENT

Review of Barriers to FPV Deployment in Southeast Asia

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List of Acronyms

ESMAP	Energy Sector Management Assistance Program
FIT	feed-in tariff
FPV	floating solar photovoltaic
LCOE	levelized cost of energy
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
PV	photovoltaic
R&D	research and development
RD&D	research, development, and deployment
RDMA	Regional Development Mission for Asia
RE	renewable energy
RET	renewable energy technology
REZ	renewable energy zone
RPS	renewable portfolio standard
SE Asia	Southeast Asia
SERIS	Solar Energy Research Institute of Singapore
Wp	Watt-peak
W-dc	Watt-direct current
USAID	United States Agency for International Development

Executive Summary

The countries of Southeast Asia (SE Asia) are seeing rapid energy sector transitions, setting ambitious renewable energy (RE) goals, and, increasingly, exploring floating solar photovoltaic (FPV) and its potential benefits to diversify their energy mixes (ASEAN 2015). To meet these ambitious goals, as well as growing energy demand, the countries in the region will likely require significant amounts of new RE capacity. FPV systems may play a significant role in RE deployment in the region, while providing additional economic, societal, and environmental benefits. Recent work has identified the potential benefits of FPV systems to include lower land acquisition and site preparation costs, improved solar PV performance, and reduced capital costs when FPV is co-located with hydropower. Despite growing interest in and literature on FPV systems, our understanding of the policy landscape, including the opportunities and barriers to FPV deployment, remains limited.

The purpose of this work is to address this gap by:

1. Detailing potential barriers to FPV deployment with a focus on economic, environmental, cultural, regulatory, and technical barriers
2. Discussing best practices that may support FPV deployment.

We reviewed the relevant literature to understand the existing and potential policy landscape for FPV systems and to understand what policymakers can do to address some of these barriers. This review does not delve into the technical aspects of FPV systems and is not meant as a recommendation of policy pathways for FPV deployment. Rather, it is as an initial assessment of potential barriers to FPV deployment followed by various best practices to consider when addressing these barriers. Our review revealed a significant research gap in the policy landscape for FPV systems. With the exception of the World Bank Group, Energy Sector Management Assistance Program (ESMAP) and the Solar Energy Research Institute of Singapore (SERIS)'s extensive *Where Sun Meets Water* reports (2019b; 2019a), and reports from some FPV conferences detailing the policy landscape and potential barriers to FPV deployment in select countries, there is minimal publicly available information on the policy barriers facing the FPV industry.

In general, many of the barriers identified in this work (Table ES- 1) stem from insufficient data or uncertainty concerning financial incentives, policy, the environmental impacts of FPV systems, water body use and hybrid FPV-hydropower operation rules. Regulatory barriers in the form of uncertain regulations and unclear environmental approval processes can impact FPV deployment by extending approval processes and increasing development costs. Cultural barriers, including a lack of public buy-in and unfavorable public opinion due to perceived visual impacts, competing uses of water bodies, and previous negative experiences with other RE technologies, may also serve as obstacles to FPV project deployment. This report also discusses possible solutions based on emerging evidence from current international best practices (Table ES- 2). These include larger and consistent government support through funding for research and development (R&D), workforce development, and public education campaigns, as well as financial incentives. More transparent and straightforward regulations and robust equipment and installation standards may also help address some of the regulatory barriers. These best practices may help inform policy considerations for the creation of an enabling policy and regulatory environment for FPV deployment.

Table ES- 1. Key Barriers to FPV Deployment

Economic Barriers	• Subsidizing fossil fuels can create an uneven playing field making it difficult for FPV systems to compete in the market. • Phasing out incentives for emerging RE may stall the development of FPV systems. • Economic policy uncertainty may stall private sector interest in FPV systems. • Trained workforce shortages raise FPV deployment costs.
Environmental Barriers	• Uncertainty about FPV ecological impacts may increase public opposition to projects and lengthen the environmental review process.
Cultural Barriers	• Lack of public buy-in of FPV technology due to visual impacts and competing uses of water bodies could stall project development. • Previous negative experiences with RE projects may lead to an unfavorable public opinion of FPV systems.
Regulatory Barriers	• Uncertainty about water rights may delay FPV project development and increase costs. • Lack of interagency cooperation and coordination may stall FPV deployment. • Lengthy, expensive, and unclear environmental approval processes for FPV systems can make projects less financially appealing.
Technical Barriers	• Unclear and, in some cases, nonexistent FPV installation, operation, and maintenance (O&M) and equipment standards may lead to poor-quality FPV products and installation practices. • Uncertainty about climate change impacts on the occurrence and intensity of extreme weather events may lead to uncertainty about the suitability, reliability, and resilience of FPV installations to natural disasters. • Poor transmission planning may stall grid integration of utility-scale FPV systems, making them less profitable. • Difficulty in quantifying FPV system performance may impede efforts to conduct cost-benefit analysis of FPV systems.
Additional Hybrid Hydropower-FPV Considerations	• Nonexistent or unclear rules on the ownership, market participation, and operation of hybrid hydropower-FPV plants may complicate and stall project development.

Table ES- 2. Key Best Practice Considerations

Economic	• Creating clear, complementary, transparent, and consistent incentives for energy development can reduce uncertainty for FPV projects and reduce project development cost. • Consistent and targeted government support to FPV systems in the form of rebates, tax incentives and competitive RE auctions could help de-risk FPV systems and attract private sector financing. *Additional considerations for workforce development:* • Developing an FPV workforce through increased education and training for students and professionals can empower the local community, equip professionals to support the growing FPV industry, and help reduce FPV project development costs. • Workforce development efforts could also involve gender mainstreaming to help provide women with the equal opportunity to pursue careers in the FPV industry and other RE technology industries. • Conducting a national skills assessment to: (1) determine the current state of the FPV workforce, (2) identify the potential transferability of skills from the offshore, hydropower, water production and land-based solar industries, and (3) identify the types of skills or certifications needed in the FPV industry that could strengthen and grow the FPV workforce.
Environmental	• Government support for additional research and development (R&D), new management techniques, long-term monitoring and secure but collaborative data sharing processes can increase knowledge about environmental impacts of FPV systems, which could shorten the environmental review process, thereby reducing project development costs.
Cultural	• Prioritizing obtaining public buy-in and support through public outreach and engagement can avoid delays during the FPV project development process. • Developing educational programs to inform the public about the benefits of FPV systems and intentional analysis and tracking of public acceptance for floating solar to monitor progress can help obtain public support and buy-in.
Regulatory	• Clear policies around water rights for FPV projects could reduce uncertainty during the project development process, helping to de-risk the industry and attract more private sector investment. • Reforming FPV-permitting guidelines reduces permit fees and minimizes inconsistencies, which can make project development more accessible. • Engaging with policymakers and financial institutions to increase awareness of FPV systems can lead to increased support for investing in R&D and deployment projects. Policymakers lacking sufficient background knowledge of RE, in general, and FPV, in particular, and its benefits cannot design effective and targeted policies and regulations.
Technical	• Developing appropriate and consistent standards and reliable certifications can reduce policy uncertainty, create guidelines for O&M of FPV systems, and ensure the installation of high-quality FPV systems. • Supporting R&D on the resilience of FPV installations to natural disasters may increase confidence in FPV system performance during extreme weather events. • Proactive transmission planning through renewable energy zone (REZ) transmission planning can help reduce uncertainty about siting of transmission infrastructure and encourage investment in FPV projects. • Enhanced interconnection procedures and grid integration planning approaches can streamline the integration of FPV systems onto the grid.
Additional hybrid hydropower-FPV considerations	• Clear regulatory processes on the ownership and market participation models and valuation methods for FPV hydropower hybrid systems could provide useful clarity to all stakeholders and support an informed decision-making process. • Development of operational and engineering best practices and training of hydropower power plant operators could help ensure smooth operation of these hybrid systems.

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1 Introduction

This report focuses on the countries of Southeast Asia (SE Asia), a region with growing energy needs, ambitious renewable energy (RE) goals and a growing interest in floating photovoltaic (FPV) systems. The countries of this region are diverse and undergoing rapid energy transitions to ensure a reliable, secure, and cost-efficient energy future. The adoption of RE, including FPV systems, in the energy mix can diversify the power generation mix and decrease reliance on imported fossil fuels, strengthening the region's energy security.

Government policies and regulations can support or impede the adoption of FPV systems. Policies that are unfavorable, ineffective, or uncertain can distort the market, discouraging investment and stalling public support and acceptance for an emerging technology.[1] Specific, targeted, and consistent policies can create an enabling policy environment that leads to widescale technology adoption (Brown 2008; Byrnes et al. 2013). As such, policy and regulation play crucial roles in FPV development. Given the increasing interest in and deployment of FPV systems in Asia and high technical potential of standalone and hybridized FPV systems (Lee et al. 2020), stakeholders (government, power system planners, policymakers, and the private sector) are seeking a better understanding of the policy landscape for this technology. Specifically:

- What are some existing and potential barriers to FPV deployment?
- What can policymakers do to address some of these barriers?

To increase understanding of the FPV policy landscape in SE Asia, this report aims to communicate how policy barriers can hinder FPV deployment by discussing both the challenges present in the current policy landscape and the possible solutions found within current international best practices. These findings and considerations can help create an enabling policy and regulatory environment for FPV deployment in SE Asia that is best aligned with its clean energy goals.

This report is organized into five sections:

1. Introduction: RE goals in SE Asia, interest in FPV systems and need for additional research on FPV policy landscape
2. FPV Systems: Overview of FPV systems, their benefits, and applications with a focus on FPV systems installed on in-land, static fresh water bodies
3. Barriers to FPV Deployment: Existing and potential barriers to FPV deployment; best practices that may help address identified barriers
4. Country Examples of Best Practices: Best practices from current international deployment of FPV systems and cross-cutting policy considerations that can inform FPV policy design
5. Conclusion: Summary of the barriers identified and policy considerations that may help address the highlighted barriers.

[1] We define unfavorable policies as policies that may distort markets, placing renewable energy technologies (RETs) at a comparative disadvantage to more incumbent technologies. Ineffective policies are potentially flawed but well-intentioned policies that may undermine intended policy goals. Policy uncertainty refers to ambiguous and constantly changing policy environments that result in a "wait-and-see" demeanor ultimately discouraging investment and stalling RE development (Brown 2008).

2 FPV Systems

2.1 FPV System Overview

FPV systems are an emerging and increasingly competitive application of solar PV, wherein systems are sited on water bodies, such as lakes, ponds, or reservoirs (Rosa-Clot and Tina 2018a; Chandran 2019). The solar panels utilized in FPV systems are the same as in land-based systems; however, instead of fixing panels to land-based metal racks and mounts, they are affixed to plastic floats or pontoons as standalone systems or hybridized systems, as shown in Figure 1. These floats lock together to create a raft with power cables connecting the panels to equipment and transmission lines onshore. FPV systems are currently predominantly installed on artificial water bodies to avoid concerns that may arise when sited on natural water bodies (Sahu, Yadav, and Sudhakar 2016; Spencer et al. 2018). Additionally, though most existing commercial and utility-scale FPV installations are located on static fresh water bodies; emerging installations are considering installations on large fresh water bodies with inflow, near-shore seawater, and offshore seawater with high waves (Reindl and Paton 2020).

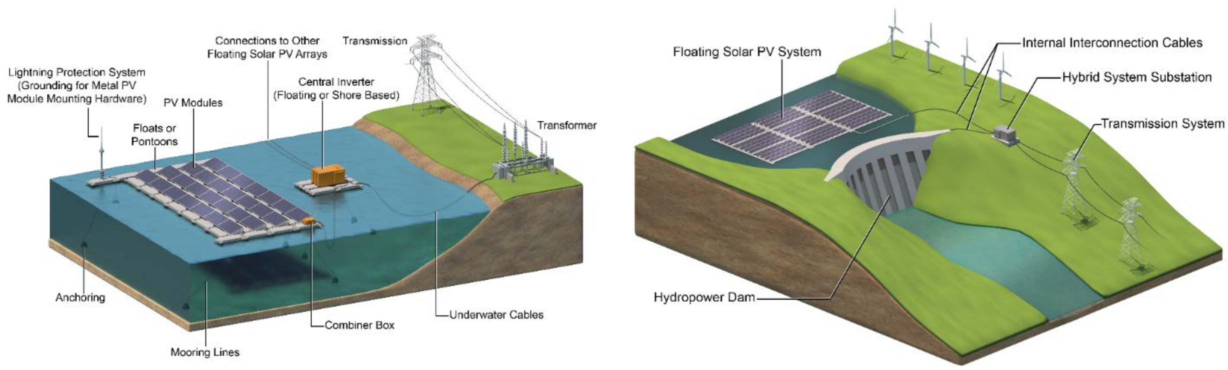

Figure 1. Schematics of: (top) a typical large-scale FPV system and key components; and (bottom) a representative hybrid FPV-hydropower plant

Source: Lee et al. 2020

Benefits

FPV systems may offer several economic and operational power system benefits, beyond the primary benefit of electricity generation (see Box 1) (Hernandez et al. 2014; Teixeira et al. 2015; Hoffacker, Allen, and Hernandez 2017; Ibeke et al. 2017; Cazzaniga et al. 2018; Rosa-Clot and Tina 2018b; Liu et al. 2019; Spencer et al. 2018). The actual benefits depend on several factors, including whether the FPV system is standalone or hybridized with other generation, such as hydropower generation (Gallucci 2019; Lee et al. 2020).

Global Technology Deployment

Since the first FPV system came online in 2007 at the Far Niente Winery in California, cumulative installed FPV capacity increased from 2 MW in 2007 to 2,579 MW in early 2021 (less than 1% of global solar PV capacity) (Gallucci 2019; Mesbahi and Minamino 2018; Versteeg, Szalay, and Schuuring 2021; Reindl and Paton 2020). There are currently more than 545 FPV systems (both standalone and hybridized) in operation with over 200 projects in the pipeline (Paton 2021). A majority of these projects are located in Asia, with over 85% of installed capacity located in the region (Reindl and Paton 2020). Most of this installed capacity is in China, Taiwan, Japan, and South Korea but FPV deployment is also growing in Southeast Asia. For example, Vietnam and Thailand lead in the region with ~160 MW and ~60 MW installed, respectively and Laos, Singapore and Indonesia have announced various utility-scale

FPV projects (Cox 2021). In the near-term, demand for FPV systems is expected to grow especially in countries with limited land space and high RE targets (Gallucci 2019; Mesbahi and Minamino 2018; Cox 2019).

Box 1. Benefits of FPV Integration

Utility-scale solar PV often requires significant parcels of land; however, land-constrained countries may have to prioritize land use for agricultural, forestry, or other needs. FPV systems offer an opportunity to scale up renewables while reducing potential competing land-use pressures by co-locating PV systems on water bodies (such as reservoirs). In addition to generation, FPV systems may offer the following benefits, particularly when sited with existing hydropower:

- Avoiding land-energy conflicts (such as energy versus food concerns for land-use designation)
- Lowering land acquisition and site preparation costs
- Gaining potential system efficiency and production due to temperature-regulating effect of water
- Improving solar PV performance due to reduced shading effects
- Increasing panel density for a given area (larger installed capacity per unit area)
- Converting potentially underused space into areas that allow for revenue-generating use.
- Power system benefits and reduced capital costs when co-located with hydropower.

Sources: (Hernandez et al. 2014; Teixeira et al. 2015; Hoffacker, Allen, and Hernandez 2017; Ibeke et al. 2017; Cazzaniga et al. 2018; Spencer et al. 2018; Rosa-Clot and Tina 2018b; Liu et al. 2019; Lee et al. 2020)

Adapted from Aznar, Lee, and Booth (2019)

Technology Costs

Questions remain about the actual costs of FPV systems and how they compare to land-based solar PV systems. FPV system costs are site-specific and can vary widely across countries based on a range of factors, including: the type of water body, water depth and distance to shore (which impact the type of floating, mooring, and anchoring systems needed), geography (which could impact soft costs such as labor and logistics), size of project, and differences in floating, mooring, and anchoring systems used (Dobrotkova 2020; Cox 2019; 2021). Per Wood Mackenzie, all-in FPV system costs based on completed and planned projects range widely from $0.52/W-dc in India for 20-80 MW-dc sized projects to $3.02/W-dc in Japan for 1-5 MW-dc sized projects (Cox 2021). The avoided costs due to avoided land use also varies based on land costs; a review of hypothetical FPV installations in Arizona, Florida, and Minnesota in the United States, estimated that compared to land-based PV systems, FPV systems could reduce the levelized cost of energy by 1.3%–1.7% due to avoided land costs (Spencer et al. 2018). Economies of scale and a transition to more utility-scale installations will lead to lower levelized cost of energy (LCOE) for FPV installations as the FPV industry is still a relatively young industry where a majority of installed FPV systems are small-scale installations, which typically have a higher LCOE.

3 Barriers to FPV Deployment

This section provides a breakdown of economic, environmental, cultural, and regulatory barriers impeding the commercialization and deployment of FPV systems. We define barriers as significantly influential market factors and challenges that may negatively impact the uptake of RE generation (including FPV), reducing pathways to meet power sector policy objectives (MacGillivray et al. 2013). Barriers can be technical and nontechnical, and the focus of this work is largely on nontechnical barriers (Box 2).

Box 2. Technical and Nontechnical Barriers to RE Deployment	
Technical barriers refer to operational and engineering system properties that impede technology adoption and integration. For example, uncertainty about the durability of panel materials in different water bodies is a potential technical barrier that will not be addressed in detail in this report.	Nontechnical barriers refer to economic, regulatory, institutional, and socio-cultural factors that impede technology adoption. For example, the lack of a trained FPV workforce is a nontechnical barrier to FPV deployment.

3.1 Economic Barriers

Barriers to FPV deployment may arise due to inconsistent, unfavorable, and uncertain economic policies. Well-designed and targeted economic policies can play an important role in driving deployment of emerging energy technologies, such as FPV, and generally take the form of price interventions that subsidize new technology costs, which help them make inroads in the power sector (Margolis and Zuboy 2006; Brown 2008; Breetz, Mildenberger, and Stokes 2018).

Box 3. Economic Barriers and Best Practices	
Impacts on FPV Deployment of Economic Barriers	• Subsidizing fossil fuels can create an uneven playing field making it difficult for FPV systems to compete in the market. • Phasing out incentives for emerging RE may stall the development of FPV systems. • Economic policy uncertainty may stall private sector interest in FPV systems. • Trained workforce shortages raise FPV deployment costs.
Best Practices (including to additional considerations around workforce development)	• Creating clear, complementary, transparent, and consistent incentives for energy development can reduce uncertainty for FPV projects and reduce project development cost. • Consistent and targeted government support to FPV systems in the form of rebates, tax incentives and competitive RE auctions could help de-risk FPV systems and attract private sector financing. *Additional considerations for workforce development:* • Developing an FPV workforce through increased education and training for students and professionals can empower the local community, equip professionals to support the growing FPV industry, and help reduce FPV project development costs.

	• Workforce development efforts could also involve gender mainstreaming to help provide women with the equal opportunity to pursue careers in the FPV industry and other RE technology industries (Morris, Greene, and Healey 2019). • Conducting a national skills assessment to: (1) determine the current state of the FPV workforce, (2) identify the potential transferability of skills from the offshore, hydropower, water production and land-based solar industries, and (3) identify the types of skills or certifications needed in the FPV industry that could strengthen and grow the FPV workforce.

Subsidizing Fossil Fuels Can Create an Uneven Playing Field Making It Difficult for FPV Systems to Compete in the Market

Policies that support or subsidize fossil fuel generation may distort the market in favor of fossil fuel generation, putting emerging renewable energy technology (RET) such as FPV at a disadvantage in markets. Subsidies to fossil fuel generation could impact the diffusion of RETs and FPV systems by: (1) making RE less cost-competitive, (2) reinforcing a fossil fuel generation-based system, (3) distorting private sector investment decisions, and (4) underpricing external costs (Bridle and Kitson 2014).

Phasing Out Incentives for Emerging RE May Stall Development of FPV Systems

The growing technological maturity of some RETs may lead to a phase out of incentives that could hurt the growth of the FPV industry. RE such as hydropower, land-based solar PV, and onshore wind are now increasingly cost-competitive with fossil fuel power plants in many parts of the world. Given the maturity of these technologies, some tax incentive policies for RETs are being phased out, which may be harmful to emerging and potentially more disruptive RETs such as FPV (Noll and Hart 2019).

Economic Policy Uncertainty May Stall Private Sector Interest in FPV Systems

Private sector players, especially in emerging industries, rely on a stable, transparent, and favorable policy environment that supports reliable and long-term energy markets (Vinci et al. 2014). If a policy environment is uncertain, private sector actors are less likely to pursue projects (Gokhale-Welch and Watson 2019). An uncertain policy and regulatory environment can stall deployment of new technologies because developers prefer regulatory certainty in their investment choices.

There are several examples that illustrate that a stable policy environment is key to continued technology deployment. At the federal level in the United States, tax policy is the main structure to incentive resource allocation. Tax policy has been one of the main policies for incentivizing utility-scale solar and wind projects (Mendelsohn and Harper 2012). Figure 2 highlights the impacts of an uncertain policy environment around these tax incentives in the United States on wind and solar deployment. The figure shows the two tax incentives that help reduce income tax obligations—the Investment Tax Credit and the Production Tax Credit—largely used for solar and wind project development, respectively (Mendelsohn and Harper 2012; Noll and Hart 2019). As shown in the figure, policy uncertainty on whether existing tax incentives will be extended has led to a boom-and-bust cycle in wind and solar deployment over the last 25–30 years (Frazier, Marcy, and Cole 2019; Tegen 2015). This boom-bust cycle is harmful to the RE industry because the costs to ramp-up and ramp-down production are expensive and players are deterred from making long-term investments (Barradale 2010). There is evidence that there is an association between energy policy uncertainty and RE investment in the United States (Burns 2019).

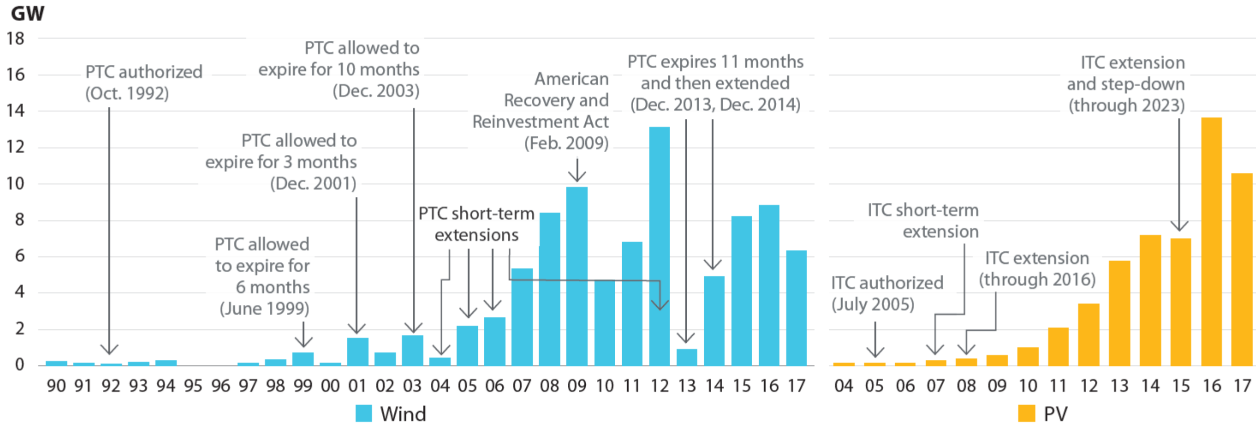

Figure 2. History of the Production Tax Credit with annual wind capacity additions and history of the Investment Tax Credit with annual PV capacity additions

Source: (Frazier, Marcy, and Cole 2019)

This pattern is seen elsewhere as well. For example, new investment in large-scale RE in Australia fell between 2018 and 2019. Australia's Clean Energy Investment Outlook (2019) found that this decline in investment is partially due to an absence of policy certainty. In addition, the report found that investors need certainty about the timing and plans for the phase-out of coal generation. Clear coal generation phase-outs can help investors understand future generation needs and wholesale power prices.

Trained Workforce Shortages Raise FPV Deployment Costs

The lack of a skilled workforce can impact the installation, operation, and maintenance costs of FPV systems. The shortage of a trained workforce and training institutes to build a trained FPV workforce can increase the costs of development and deployment of energy systems (Seetharaman et al. 2019). Additionally, insufficient investment or business interest in a technology can lead to a lack of interest from a prospective workforce. A workforce lacking the adequate technical, scientific, and manufacturing skills can stall broader technology deployment (Margolis and Zuboy 2006). As FPV deployment grows, the FPV workforce becomes more skilled in installation, leading to efficiencies during installation and reduced labor costs (Cox 2019).

3.2 Environmental Barriers

Different environmental barriers may impact FPV system deployment depending on the project size, site characteristics such as the ecosystem and use of the reservoir, along with other potential local environmental concerns. When planning an FPV system deployment, the entire area of influence of the project must be assessed, which includes the immediate environmental footprint of the system and associated facilities (such as substations, transmission lines and towers, and hydropower dams, among others), the deployment water body, and upstream and/or downstream waters and their associated users (World Bank, ESMAP, and SERIS 2019b). The installation of a pilot FPV system in Alto Rabagão, Portugal, highlighted the need to review environmental protection regulations, particularly if the FPV system is hybridized with a hydropower dam or a source of public drinking water, which may have special classification as critical infrastructure with additional associated development constraints (IHP and EDP 2018).

Box 4. Environmental Barriers and Best Practices	
Impacts on FPV Deployment of Environmental Barriers	• Uncertainty about FPV ecological impacts may increase public opposition to projects and lengthen the environmental review process.
Best Practices	• Government support for additional research and development (R&D), new management techniques, long-term monitoring and secure but collaborative data sharing processes can increase knowledge about the environmental impacts of FPV systems, which could shorten the environmental review process, thereby reducing project development costs.

Uncertainty About FPV Ecological Impacts May Increase Public Opposition and Lengthen the Environmental Review

The potential ecological impacts of FPV systems, especially their effect on the aquatic ecosystem, are not yet fully understood, and there is limited publicly available research on the impacts (Haas et al. 2020). This uncertainty may impede FPV deployment because this could complicate environmental review processes and raise public concerns about the unknown impacts of FPV deployment.

A 2016 study from Ciel et Terre, an international FPV installer, on FPV installations in California provides insight into possible ecological impacts of FPV systems; however, there remains a gap in understanding of how these systems may impact water evaporation, water quality, and aquaculture and the ecosystem.[2] There are a combination of factors to be considered to determine the impact of an FPV system on a water body, and impacts cannot be generalized.

3.3 Cultural Barriers

Box 5. Cultural Barriers and Best Practices	
Impacts on FPV Deployment of Cultural Barriers	• Lack of public buy-in of FPV technology due to visual impacts and competing uses of water bodies could stall project development. • Previous negative experiences with RE projects may lead to an unfavorable public opinion of FPV systems.
Best Practices	• Prioritizing obtaining public buy-in and support through public outreach and engagement can avoid delays during the FPV project development process. • Developing educational programs to inform the public about the benefits of FPV systems and intentional analysis and tracking of public acceptance for floating solar to monitor progress can help obtain public support and buy-in.

Lack of Public Buy-In of FPV Technology Due to Visual Impacts and Competing Uses of Water bodies Could Stall Project Development

Social acceptance plays an important role in RE deployment, and, despite technical and economic feasibility, public opposition to development of technologies such as FPV could hamper implementation

[2] Ciel et Tiere (2016) suggested that the reviewed FPV installations posed limited risk to wildlife due to: (1) FPV systems being sited on artificial water bodies that are not home to protected species; (2) A quick installation process that involves limited interaction with wildlife and aquaculture; (3) FPV component materials largely consisting of nontoxic materials; and (4) a straightforward and infrequent operation and maintenance process that does not use detergents or other pollutants (WRA Environmental Consultants 2016). Recommendations from the report included conducting high-level research on potential environmental restrictions based on existing state and federal laws, location of protected species, timing of bird seasons, among others, and adjusting project development as needed.

(Hofman 2015). To work towards community buy-in and support, it could be important to incorporate the elements below in community engagement efforts:

1. Engage with a desire of understanding the local context
2. Demonstrate how project will further the values of community (for example, concerns about climate change, job creation, etc.)
1. Present on the overall evaluation of costs, risks, and benefits of the technology and project
2. Provide clarity on the project development decision-making process
3. Develop an overall engagement approach that fosters trust in decision makers and other stakeholders.

Previous Negative Experiences with RE Projects May Lead to an Unfavorable Public Opinion of FPV Systems

In countries where there are land-energy use conflicts, unfairly applied resettlement and compensation practices can create a negative perception of RE projects (Urban et al. 2018). FPV systems may thus face public opposition due to negative public perceptions stemming from previous conflicts.

3.4 Regulatory Barriers

Regulatory barriers arise when legal restrictions enacted to achieve some social good begin to stifle innovation and competition (Brown 2008). Regulatory barriers often impact multiple stages of the FPV project development process.

Box 6. Regulatory Barriers and Best Practices	
Impacts on FPV Deployment of Regulatory Barriers	• Uncertainty about water rights may delay FPV project development and increase costs. • Lack of interagency cooperation and coordination may stall FPV deployment. • Lengthy, expensive, and unclear environmental approval processes for FPV systems can make projects less financially appealing.
Best Practices	• Clear policies around water rights for FPV projects could reduce uncertainty during the project development process, helping to de-risk the industry and attract more private sector investment. • Reforming FPV-permitting guidelines reduces permit fees and minimizes inconsistencies, which can make project development more accessible. • Engaging with policymakers and financial institutions to increase awareness of FPV systems can lead to increased support for investing in R&D and deployment projects. Policymakers lacking sufficient background knowledge of RE, in general, and FPV, in particular, and its benefits cannot design effective and targeted policies and regulations.

Uncertainty About Water Rights May Delay FPV Project Development and Increase Costs

Barriers to FPV deployment may arise at the intersection of energy and water policy. At the policy level, water law and rights can be a contentious issue due to the uncertain ecological impacts of FPV systems on natural versus artificial water bodies and the cross-sectoral uses of water bodies, and the uncertainty on how or whether various water right doctrines apply to FPV systems such as those developed on artificial reservoirs. Emerging evidence suggests that FPV systems are predominantly sited on artificial, impounded water bodies, as artificial reservoirs have likely previously undergone necessary permitting and regulatory processes and have the infrastructure to support FPV installation. Moreover, siting FPV systems on natural water bodies may raise additional environmental impact concerns (Spencer et al. 2018). Barriers may also arise in the areas of marine spatial planning and zoning for offshore energy deployment as emerging innovative FPV system designs are expanding to installations on large fresh water bodies with inflow, near-shore seawater installations, and offshore seawater installations. Overall, this uncertainty could increase FPV deployment costs as developers may have to invest significant time and money to gain clarity before formally applying for the rights and permission to site FPV systems on a given water body.

Lack of Interagency Cooperation and Coordination May Stall FPV Deployment

FPV deployment may require coordination between multiple agencies. Agencies may include:

- Energy agencies (such as the Department of Energy, power system regulator)
- Water management agencies (such as the Department of Water Resources and Management, water treatment plants, water conservations agencies, reservoir operators, and so on)
- Land management agencies (such as the Departments of Agriculture, Land Conservation, and so on)
- Recreation management agencies (if the body of water is used for recreational purposes)
- Environmental protection agencies.

Laws and regulations for the deployment and siting of energy projects often require reviews, approvals, and permits from multiple government entities. Coordination between these agencies can help streamline project approval and reduce redundancy, which can lead to a more efficient and effective review of projects, resulting in faster decision-making timelines (Morton 2012).

Lengthy, Expensive, and Unclear Environmental Approval Processes for FPV Systems Can Make Them Less Financially Appealing

Lack of clarity in licensing and permitting can present major barriers to RE deployment. The unique nature of FPV systems, especially siting on water bodies, may create additional layers of complexity. Additionally, permitting and licensing barriers may arise due to potential interagency cooperation needed between energy and water authorities (World Bank, ESMAP, and SERIS 2019b). The World Bank, ESMAP, and SERIS (2019b) note that FPV deployment can take between 3 months to several years for a project to move from the initiation to “shovel-ready.” As more regions and agencies gain experience with FPV systems, this period should shorten (World Bank, ESMAP, and SERIS 2019b); however, given the lack of experience that banks, insurers, and regulatory bodies currently have with FPV projects, permitting and financial closing is likely to take longer than it may for more familiar, ground-mounted solar PV projects (World Bank, ESMAP, and SERIS 2019b).

3.5 Technical Barriers

This section focuses on interconnection and transmission barriers, two technical barriers that can stall FPV deployment. Interconnection and transmission barriers can lead to stranded FPV assets due to poor power system planning and grid integration efforts and lead to the suboptimal siting of FPV power plants due to limited transmission infrastructure. More detail on this topic is examined in the World Bank Group Where Sun Meets Water: Floating Solar Handbook for Practitioners report (2019b).

Box 7. Technical Barriers and Best Practices	
Impacts on FPV Deployment of Technical Barriers	• Unclear and nonexistent FPV installation, operation, and maintenance (O&M) and equipment standards may lead to poor-quality FPV products and installation practices. • Uncertainty about climate change impacts on the occurrence and intensity of extreme weather events may lead to uncertainty about the suitability, reliability, and resilience of FPV installations to natural disasters. • Poor transmission planning may stall grid integration of utility-scale FPV systems, making them less profitable. • Difficulty in quantifying FPV system performance may impede efforts to conduct cost-benefit analysis of FPV systems.
Best Practices	• Developing appropriate and consistent standards and reliable certifications can reduce policy uncertainty, create guidelines for O&M of FPV systems, and ensure the installation of high-quality FPV systems. • Supporting R&D on the resilience of FPV installations to natural disasters may increase confidence in FPV system performance during extreme weather events. • Proactive transmission planning through renewable energy zone (REZ) transmission planning can help reduce uncertainty about siting of transmission infrastructure and encourage investment in FPV projects. • Enhanced grid integration planning approaches can streamline the integration of FPV systems onto the grid.

Unclear and Nonexistent FPV Installation, Operation and Maintenance and Equipment Standards May Lead to Poor-Quality FPV Productions and Installation Practices

A lack of consistent FPV installation and equipment standards may lead to poor-quality FPV products, installations, and system performance. Standards (and their enforcement) are a vital part of reliable power system operation because they provide manufacturers with a benchmark of performance requirements for their products, guide users during product selection, and help government agencies to incorporate them into workplace safety and health regulations (Baugh 2015). A new consortium, led by Norwegian consultancy, DNV GL, recently published the first recommend practice for FPV projects following a collaborative project with 24 industry participants (DNVGL 2021).[3]

Uncertainty About Climate Change Impacts on the Occurrence and Intensity of Extreme Weather Events May Lead to Uncertainty About the Suitability, Reliability, and Resilience of FPV Installations to Natural Disasters

Barriers to FPV deployment may arise due to climate change and the resulting changes to the hydrological cycle. These changes may lead to changes in the occurrence and intensity of extreme weather events such as floods and droughts, which could impact the host environment of various FPV

[3] The Solar Energy Research Institute of Singapore has also published a guidebook on installation and equipment, which lays out aspects such as decisive factors for selecting a water body for an FPV plant, engineering design, financial and legal considerations, and environmental and social considerations (World Bank, ESMAP, and SERIS 2019b).

installations. The uncertainty in the potential impacts on water bodies could raise doubts about the suitability, reliability, and resilience of FPV installations to these changes in the water bodies.

Poor Transmission Planning May Stall Grid Integration of Utility-Scale FPV Systems, Making FPV Systems Less Profitable

Transmission barriers for FPV systems will depend on existing transmission grid infrastructure and the systems in place for expanding transmission infrastructure to meet growing RE deployment. FPV systems may face grid access challenges if transmission lines are overloaded. For example, agricultural ponds and land-based solar fields are often located away from cities, which may require the construction of additional transmission lines to carry the power, or an increased loss of energy in transmission due to line resistance (Hartzell 2016). Insufficient transmission capacity can lead to stranded FPV assets due to poor power system planning and grid integration efforts and the suboptimal siting of FPV power plants because developers prioritize proximity to transmission infrastructure over the quality of the solar resource.

Additionally, FPV project development costs are very site-specific and may become more expensive if additional transmission infrastructure is needed to transport the energy produced. There is limited research on the proportion of FPV projects that require additional transmission infrastructure, but, overall, avoided land-use costs are a major benefit of FPV systems. One approach to identifying transmission needs is REZ transmission planning, which is a process of planning, approving and building transmission to connect REZs to the power system, specifically to load centers (Lee, Flores-Espino, and Hurlbut 2017). Lee et. al (2017) outline six steps, including process design and vision statements to transmission system upgrades that help ensure a thorough RE transmission planning process.

Difficulty in Quantifying FPV System Performance May Impede Efforts to Conduct Cost-Benefit Analysis of FPV Systems

There is currently not a uniform methodology or approach for quantifying the value and performance of FPV systems. This lack of a consistent approach may impede efforts to conduct cost-benefit analysis of FPV systems, which may stall private sector interest in this technology option.

3.6 Additional Considerations for Hybrid Systems

Box 8. Hybrid-Related Barriers and Best Practices	
Impacts on FPV Deployment of Hybrid Systems	• Nonexistent or unclear rules on the ownership, market participation, and operation of hybrid hydropower-FPV plants may complicate and stall project development.
Best Practices	• Clear regulatory processes on the ownership and market participation models and valuation methods for FPV hydropower hybrid systems could provide useful clarity to all stakeholders and support an informed decision-making process. • Development of operational and engineering best practices and training of hydropower power plant operators could help ensure smooth operation of these hybrid systems.

Nonexistent or Unclear Rules on the Ownership, Market Participation, and Operation of Hybrid Hydropower-FPV Plants May Complicate and Stall Project Development

Additional barriers may arise if an FPV system is hybridized with a hydropower system as market operation rules for this hybrid system type are less established, and there are multiple stakeholders involved (such as the owners and operators of the reservoirs, hydropower dams, and FPV systems) that may have conflicting interests. Project approval may face various barriers depending on the ownership model and market participation model (Dobrotkova 2020). Three potential ownership models are highlighted in Table 1: An all-publicly owned modeled (Option 1), a public-private partnership model (Option 2), and mostly private model (Option 3) (Dobrotkova 2019). For example, project developers might face a lengthy project approval process under Option 2 as the private FPV developer would need to engage with state-owned enterprises that operate the hydropower plant and manage the reservoir. There is also limited research on the barriers that arise due to the ownership and market participation model of a standalone FPV plant. Clear regulatory processes on the ownership and market participation models and operation methods for these hybrid systems could provide useful clarity to all stakeholders and support an informed decision-making process. However, because very few projects have been completed on hydropower dams, such rules remain largely unavailable for existing hydropower-FPV hybrid systems.

Table 1. Overview of Reservoir and Hydropower Plant Operation and Ownership Models for a Hydropower-FPV System (Adapted from (Dobrotkova 2019) with country examples included)

	Design and construction of FPV system	Operation of FPV system	Operation of hydropower plant	Management of reservoir	Hypothetical Country Examples[4]	Emerging Project-specific examples
Option 1: Pure public model	Public entity				Philippines, Thailand	Ghana[5], Thailand[6]
Option 2: Public-Private Partnership model	Private operator		Public entity		Philippines, Thailand	Vietnam
Option 3: Mostly private model	Private operator			Public entity	Cambodia, Indonesia, Laos	

[4] Using publicly available data, the authors evaluated hydropower plant ownership in 7 out of 10 Association of Southeast Asian Nations countries (Burma, Cambodia, Indonesia, Laos, Philippines, Thailand, and Vietnam). In this analysis, a country is categorized as having an "Option 1" and "Option 2" ownership model if majority of in-country hydropower plants are publicly owned and an "Option 3" ownership model if majority of its hydropower plants are privately owned. Burma and Vietnam were excluded from this list due to inconclusive publicly available data.

[5] Ghana recently commissioned a 5 MW FPV – 400 MW hydropower hybrid project. The 5 MW FPV installation is part of the first phase of a multi-phase 250 MW FPV project on the Bui Hydropower dam in Ghana. The reservoir, hydropower plant and FPV system are all owned and operated by the Bui Power Authority, a majority-government owned entity (Bui Power Authority 2020; RenewAfrica 2020).

[6] An FPV-hydropower hybrid system that will be the largest FPV hybrid system once completed in June 2021. It will hybridize a 45 MW FPV system with the 36 MW Sirindhorn Dam in Thailand. Both facilities will be owned by the state-owned Electricity Generating Authority of Thailand (VietnamPlus 2021).

4 International Examples of FPV Best Practices

In addition to the best practices presented in the previous section, this section provides country examples of FPV best practices alongside various cross-cutting policy considerations that may help support FPV deployment.

4.1 Survey of International Experience with FPV Incentives and Policies

The majority of FPV systems are installed in mainland China, Japan, Korea, Vietnam, Taiwan, and the Netherlands. China accounts for 50% of all FPV installed capacity, with Taiwan, Japan, Vietnam, Korea, and the Netherlands accounting for 12%, 11%, 6%, 4%, and 4% of total installed capacity respectively (Paton 2021). These countries, and others (including states in the United States), have adopted a range of incentives to support the nascent FPV industry. Feed-in-tariffs (FITs) were an initial policy instrument used to stimulate the deployment of FPV systems but is now largely being phased out in several countries. The following section details how and why FPV deployment has grown in select jurisdictions and the policies in place to encourage FPV adoption.

China

China has the largest installed capacity (~1.3 GW) of FPV systems, and this has largely been driven by its national RE targets and specific solar PV policies. Existing RE targets set under national policies has driven the demand for new RE projects as China's 2019 renewable portfolio standard requires the country source 20% of primary energy from non-fossil fuel sources by 2030. Utilities in every state must therefore develop capacity expansion plans that ensure they meet the renewable portfolio standard (Zhu and Song 2020). These national energy targets, in addition to environmental pollution laws in some provinces, have encouraged deployment of RE, including FPV systems. However, the majority of FPV deployment has been due to three solar PV policies – the standard FIT "Build Plan", the Poverty Alleviation program, and the Top Runner Program, the latter of which was instrumental to FPV deployment from 2017-2019 (Tan 2017). The FITs played an important initial role in spurring new investment in PV systems, but the government is transitioning to competitive auctions and phasing out FITs and other subsidies.

The Poverty Alleviation program provided economic support to support household-level, village-level, and utility-scale PV deployment. This program was key to FPV deployment on abandoned, flooded, and heavily polluted coal mines (which are unsuitable for many other purposes) (Pouran 2018). The Top Runner Program was also key to FPV deployment in China as it provided economic incentives to FPV systems and other innovative and emerging PV technologies. The program set minimum performance parameters for technologies to participate and then set up exclusive tenders for the qualifying technologies. Both programs have now been phased out, but both led to the installation of over 1,000 MW of FPV from 2017–2019 and China has quickly become one of the largest deployers of FPV systems worldwide (Acharya and Devraj 2019; Reindl and Paton 2020). It is home to some of the world's largest FPV systems such as the 70 MW installation covering over 63 hectares of flooded area in the Huainan province, which was completed in 2017. This project is sited on a collapsed coal mine and is part of larger efforts to build 1,000 MW of FPV on abandoned coal mines.

Overall, China offers lessons on encouraging FPV deployment:

- Support FPV deployment on otherwise unusable land and artificial water bodies, as opposed to natural water bodies that may have a more complex environmental review process; and

- Encourage RE deployment, including FPV deployment, via national targets and regional requirements.

India

India has ~92 MW of installed FPV capacity, and over 1,700 MW is under development. The Energy and Resources Institute (2019) estimates that India's water reservoirs could host approximately 28,000 MW of FPV capacity (Gupta 2020; Acharya and Devraj 2019). India offers multiple tax incentives and FPV-specific auctions. For example, in January 2020 the Solar Energy Corporation of India issued tenders for 4MW of FPV with 2MW/1MWh of battery storage in the Andaman islands (Tom Kenning 2020).

- Overall, India offers one lesson on encouraging FPV deployment: Support FPV deployment through economic incentives.

Japan

Japan has also become a leader in FPV, with at least 260 MW of FPV installed and the creation of a local job creating FPV industry. Japan's interest in FPV systems has largely been due to its unique power system needs, mountainous geography, and land constraints. In 2011, following the Fukushima nuclear accident, the country decided to deploy more RE. As such, the government increased its support for RETs, especially solar energy, through R&D support, subsidies for residential solar, generous FITs, and a renewable portfolio standard. The main incentive mechanism used to encourage solar PV deployment was initially in the form of FITs, but these FITs are currently being phased out to spur the deployment of cost competitive RE while reducing the financial cost incurred by the state. Additionally, various institutions such as the Japan International Cooperation Agency (JICA) and the Asian Development Bank (ADB) have supported solar PV deployment in and outside of Japan through technical support and project financing (Yamazaki, Osamu Ikki, and RTS Corporation 2019). Even though no specific measures have been taken to support FPV systems, the unique land use challenges and government support and investment in solar PV has reaped several benefits for Japan's FPV industry (Yamazaki, Osamu Ikki, and RTS Corporation 2019).

Overall, Japan offers lessons on encouraging FPV deployment:

- Incentivizing the deployment of FPV systems in land-constrained countries with competing land-use needs for agriculture and populations could ease land-use pressures while also aligning with policies for the provision of clean and affordable electricity;
- Clear, complementary incentives and restrictions for energy development, land-use and agriculture, and water resource management, could help to reduce barriers and risks for FPV deployment while respecting societal values for these systems;
- Encouraging FPV technology adoption requires multiple approaches, including R&D support, and funding pilot and demonstration projects;
- As a technology gains market share, opposition to continued government support is likely to grow;
- Ambitious RE targets can play a role in encouraging investment in emerging RETs; and
- Supporting the scale-up of emerging RETs is one tangible approach to diversifying the generation mix.

The Netherlands

Netherlands leads FPV deployment in Europe with about 110 MW of installed capacity. The government supports FPV projects as part of its larger RE strategy. In 2017, the country's Ministry of Infrastructure and Water Management created a consortium called "Zon op Water" ("Sun on Water") to work toward developing 2,000 MW of FPV by 2023 (Acharya and Devraj 2019; "About Sun on Water" 2017). The Netherlands also supports RE development under the Sustainable Energy Production Incentive grant program. This program reimburses the difference between the cost of generating energy from the FPV system and the prevailing wholesale market price (van de Ven 2019).

Overall, the Netherlands offers lessons on encouraging FPV deployment:

- Providing direct financial incentives like production-based incentives can help de-risk FPV systems; and
- Encouraging interagency cooperation can help encourage FPV development by reducing the administrative hurdles to deployment.

South Korea

South Korea supports solar PV deployment as part of its broader power sector decarbonization strategy. FPV systems have emerged as an attractive alternative to land-based PV systems because the government has faced some public opposition to using forest and agricultural land for solar developments (Alsharif, Kim, and Kim 2018). This focus on FPV systems has made South Korea a leader in FPV deployment (with at least 120 MW of FPV installed); the country recently announced a $3.96 billion, or 2,100-MW of offshore FPV projects (PV Magazine 2019).

Government support for FPV has consisted of financial support to R&D and national RE targets that are favorable to FPV systems and other emerging RETs. Since 2009, the government began supporting innovation of FPV systems at all levels, starting with funding initial research, development, and demonstration (RD&D) projects. In 2011, government support advanced to collaborating with independent power producers to finance pilot projects. In 2013, the Korean government revised its RPS, assigning the highest Renewable Energy Credit weighting within the solar class to FPV systems and rooftop PV systems (Kim et al. 2016; Korea Energy Agency 2020).

Overall, South Korea offers lessons on encouraging FPV deployment:

- Encouraging FPV adoption can create a local, job-creating FPV industry as well as help avoid land-energy conflicts caused by land-based PV systems competing with other land use needs; and
- Encouraging FPV technology adoption requires multiple approaches including R&D and deployment support.

Taiwan

Taiwan has a goal of developing at least 20 GW of solar generation by 2025 and it is one of the only jurisdictions that has a specific FIT for FPV projects (Executive Yuan 2019; PV Magazine 2020). It currently has ~300 MW of FPV installed (Paton 2021). Most FPV systems in Taiwan are installed on water retention reservoirs and irrigation dams (Acharya and Devraj 2019). In 2019, Taiwan offered generous FITs for solar PV systems. Within the first nine months of the year, solar PV deployment had grown by ~30 percent compared to the previous year. As such, starting in 2020, Taiwan lowered its FIT rates for solar PV, specifically for rooftop PV located in urban areas and FPV(Taiyang News 2020; Bureau of Energy, Ministry of Economic Affairs 2020).

Overall, Taiwan offers lessons on encouraging FPV deployment:

- Incentives for FPV systems must be carefully designed to not over-incentivize participation; and
- Enabling policies for FPV deployment must be coordinated with grid integration studies and proactive transmission planning to ensure that the grid is well-positioned to integrate large shares of solar generation. This is especially true for FPV systems and other emerging energy technologies, where the profitability of early projects is a key signal to developers.

The United States: Massachusetts

State-level policies are leading the FPV policymaking process in the United States, as there are no national-level FPV policies. For example, the state of Massachusetts offers incentives for FPV systems as part of its Solar Massachusetts Renewable Target Program. A location-based incentive is available at $0.03/kWh. FPV systems can qualify for this incentive if: (1) They are sited on water bodies that can still be used for the originally intended purpose; (2) They consist of a system that has been tested for potential water quality impacts; (3) They cover a maximum of 50% of the water body and avoid development on natural water bodies; and (4) They have minimal interaction with the ecosystem (Baker et al. 2018; Massachusetts Department of Energy Resources 2020). FPV deployment may still face barriers during deployment, as the uncertainty about the environmental impacts of FPV systems may lead to an extended environmental review process.

Overall, Massachusetts offers the following lesson on encouraging FPV deployment:

- A holistic, coordinated, and consistent approach to policy support for FPV adoption can help address multiple barriers that may exist across the project development chain.

4.2 Other Cross-Cutting Best Practice Considerations

In addition to the best practices highlighted in Sections 3 and 4.1, there are some cross-cutting policy considerations that could enable a more integrated and effective approach to designing a robust and enabling policy environment for FPV systems.

Outline and Enforce Ambitious RE Goals

RE goals come in many different forms. The International Renewable Energy Agency Spectrum of RE Targets (see Figure) illustrates the range of RE targets and how they compare to one another in terms of specificity, measurability, and binding characteristics (Kieffer and Couture 2015). RE targets that are aggressive are likely to stimulate the FPV market, especially in areas where land is scarce (Cox 2019). In countries with land and water scarcity problems, RE targets could especially incentivize FPV systems that address these one or both these issues (Cohen and Hogan 2018). Targets that are legally binding with clear enforcement mechanisms and penalties can drive and encourage investment in RE technologies because such targets provide clarity and stability (Kieffer and Couture 2015).

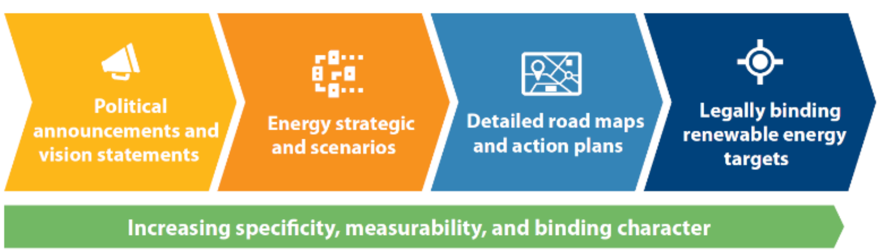

Figure 3. Spectrum of RE targets

Source: Adapted from (Kieffer and Couture 2015)

Increase Knowledge

FPV deployment can be encouraged by strengthening and expanding knowledge on FPV technology and benefits to all stakeholders, including policymakers, the workforce, financial institutions, developers, and utilities.

Support R&D

Government support for initial R&D and demonstration projects is often critical to technology maturity and innovation because it essentially subsidizes innovation and development and serves to de-risk emerging technology like FPV systems. More knowledge on the performance and costs of FPV could help inform more specific and more impactful policies, but government support and funding are important for initial RD&D projects. RD&D also involves the creation and implementation of standards and certifications for equipment and parts. Without standards, there can be confusion and uncertainty, which has been the case with FPV systems (Seetharaman et al. 2019). Investment in RE projects may be inhibit if there are not interconnection standards in place. This is because investors and developers do not know when or how projects can be connected to the grid and start generating revenue (Gokhale-Welch and Watson 2019).

Improve Financing

Consistent government support to FPV systems in the form of direct expenditures (grants, loans, and other financial assistance awards made directly to recipients), funds for R&D, tax benefits or preferences, and loan guarantees can provide foundational support for technology development and deployment and spur private sector investment. Sudden, unexpected changes to government support makes it difficult to attract investment in RE (Bowers et al. 2018; White et al. 2013). Financial institutions with insufficient knowledge on FPV systems are less likely to provide funding for projects (Seetharaman et al. 2019). Private sector investment is also an important source of financing and should be encouraged. For projects that involve foreign investment, investor confidence can be increased with government-backed sovereign guarantees that are specified in U.S. dollars (Gokhale-Welch and Watson 2019).

5 Conclusions and Takeaways

Southeast (SE) Asian countries are taking significant steps to meet growing energy needs while reducing the carbon footprints of their power sectors. The adoption of renewable energy, including floating solar photovoltaic (FPV) systems, can diversify the power generation mix and decrease reliance on imported fossil fuels, strengthening energy security. This report highlights a range of policy and regulatory barriers facing the growing FPV industry in Southeast Asia, which could impede robust growth of the industry. Our report reveals the cyclical nature of the knowledge gaps surrounding FPV technology policy. Gaps in literature create uncertainty about the benefits and value of FPV systems, making it more difficult to de-risk FPV systems at the level that is needed to encourage utility-scale deployment and financial investment from the private sector. Without investment, the industry cannot grow and provide evidence on the bankability and value of the technology. This lack of research and empirical data on system performance and benefits discourages investment and financing of the projects that would generate much-needed data (Cox 2019).

Table 2. Summary of Policy Considerations to Addressing Barriers to FPV Deployment

Type of Barrier	Impacts of Barriers on FPV Deployment	Best Practices to Consider Addressing Barriers	Additional Benefits and Trade-Offs
Economic	Subsidizing fossil fuels can create an uneven playing field making it difficult for FPV systems to compete in the market.		
	Phasing out incentives for emerging RE may stall the development of FPV systems.	• Creating clear, complementary, transparent, and consistent incentives for energy development can reduce uncertainty for FPV projects and reduce project development cost.	
	Economic policy uncertainty may stall private sector interest in FPV systems.	• Consistent and targeted government support to FPV systems in the form of rebates, tax incentives and competitive RE auctions could help de-risk FPV systems and attract private sector financing.	
	Trained workforce shortages raise FPV deployment costs.	• Developing an FPV workforce through increased education and training for students and professionals can empower the local community, equip professionals to support the growing FPV industry, and help reduce FPV project development costs. • Workforce development efforts could also involve gender mainstreaming to help provide women with the equal opportunity to pursue careers in the FPV industry and other RE technology industries. • Conducting a national skills assessment to: (1) determine the current state of the FPV workforce, (2) identify the potential transferability of skills from the offshore, hydropower, water production and land-based solar industries, and (3) identify the types of skills or certifications needed in the FPV industry that could strengthen and grow the FPV workforce.	• Workforce development is a long-term effort that may require significant financial investment. • Efforts that involve gender mainstreaming efforts could help provide women with the equal opportunity to pursue careers in the FPV industry and other RE industries.

Type of Barrier	Impacts of Barriers on FPV Deployment	Best Practices to Consider Addressing Barriers	Additional Benefits and Trade-Offs
Environmental	Uncertainty about FPV ecological impacts may increase public opposition to projects and lengthen the environmental review process.	• Government support for additional research and development (R&D), new management techniques, long-term monitoring and secure but collaborative data sharing processes can increase knowledge about environmental impacts of FPV systems, which could shorten the environmental review process, thereby reducing project development costs.	• Environmental research may uncover positive or negative impacts of FPV, which will reduce uncertainty and potentially increase adopter confidence.
Cultural	Lack of public buy-in of FPV technology due to visual impacts and competing uses of water bodies could stall project development.	• Prioritizing obtaining public buy-in and support through public outreach and engagement can avoid delays during the FPV project development process.	• Stakeholder engagement can be complex, lengthy, and expensive. • Early and well-done community engagement centering community needs could help ensure many multiple stakeholders reap the benefits of FPV deployment. • FPV development can lead to job creation and economic growth for the local community.
	Previous negative experiences with RE projects may lead to an unfavorable public opinion of FPV systems.	• Developing educational programs to inform the public about the benefits of FPV systems and intentional analysis and tracking of public acceptance for floating solar to monitor progress can help obtain public support and buy-in.	
Regulatory	Uncertainty about water rights may delay FPV project development and increase costs.	• Clear policies around water rights for FPV projects could reduce uncertainty during the project development process, helping to de-risk the industry and attract more private sector investment.	
	Lack of interagency cooperation and coordination may stall FPV deployment.		• Interagency cooperation is often a complex, long-term effort, but can ultimately yield a more efficient administrative process.

Type of Barrier	Impacts of Barriers on FPV Deployment	Best Practices to Consider Addressing Barriers	Additional Benefits and Trade-Offs
	Lengthy, expensive, and unclear environmental approval processes for FPV systems can make projects less financially appealing.	• Reforming FPV-permitting guidelines reduces permit fees and minimizes inconsistencies, which can make project development more accessible. • Engaging with policymakers and financial institutions to increase awareness of FPV systems can lead to increased support for investing in R&D and deployment projects. Policymakers lacking sufficient background knowledge of RE, in general, and FPV, in particular, and its benefits cannot design effective and targeted policies and regulations.	• Standards are a direct way to ensure all installers meet required standards. • Licensing and certification requirements may exclude smaller companies if there are steep financial and administrative costs involved.
Technical	Unclear and, in some cases, nonexistent FPV installation, operation, and maintenance (O&M) and equipment standards may lead to poor-quality FPV products and installation practices.	• Developing appropriate and consistent standards and reliable certifications can reduce policy uncertainty, create guidelines for O&M of FPV systems, and ensure the installation of high-quality FPV systems.	
	Uncertainty about climate change impacts on the occurrence and intensity of extreme weather events may lead to uncertainty about the suitability, reliability, and resilience of FPV installations to natural disasters.	• Supporting R&D on the resilience of FPV installations to natural disasters may increase confidence in FPV system performance during extreme weather events.	• An R&D ecosystem creates jobs and develops local expertise on FPV deployment that is tailored to address unique challenges facing a given local context.
	Poor transmission planning may stall grid integration of utility-scale FPV systems, making them less profitable.	• Enhanced grid integration planning approaches can streamline the integration of FPV systems onto the grid.	• Proactive transmission planning helps maximize benefits from FPV (and broader RE) deployment.
	Difficulty in quantifying FPV system performance may impede efforts to conduct cost-benefit analysis of FPV systems.		

Type of Barrier	Impacts of Barriers on FPV Deployment	Best Practices to Consider Addressing Barriers	Additional Benefits and Trade-Offs
Additional Considerations for Hybrid Systems	Nonexistent or unclear rules on the ownership, market participation, and operation of hybrid hydropower-FPV plants may complicate and stall project development.	• Clear regulatory processes on the ownership and market participation models and valuation methods for FPV hydropower hybrid systems could provide useful clarity to all stakeholders and support an informed decision-making process. • Development of operational and engineering best practices and training of hydropower power plant operators could help ensure smooth operation of these hybrid systems.	

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