IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 18 January 2024, accepted 18 February 2024, date of publication 21 February 2024, date of current version 1 March 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3368620

RESEARCH ARTICLE

Risk Assessment and Policy Recommendations for a Floating Solar Photovoltaic (FSPV) System

JEFFREY T. DELLOSA[1,3], (Member, IEEE), ELEONOR V. PALCONIT[2,3], AND NELSON H. ENANO JR.[2,3]
[1]Department of Electronics Engineering, Caraga State University, Butuan 8600, Philippines
[2]College of Engineering and Architecture, Ateneo de Davao University, Davao 8000, Philippines
[3]Mindanao Renewable Energy Research and Development Center (MREC), Ateneo de Davao University, Davao 8000, Philippines

Corresponding author: Jeffrey T. Dellosa (jtdellosa@carsu.edu.ph)

ABSTRACT This study provides a comprehensive overview of the risks and challenges associated with floating solar photovoltaic (FSPV) systems while identifying the best ways to promote the growth and success of this promising technology. Using a hazard identification and risk assessment methodology, this study categorizes risks into environmental, technical, regulatory, economic, and social risks. A risk assessment was conducted to determine the potential risks of a small-scale FSPV system in Philippine Lakes. Risks with high probability of occurrence and severity include health and safety, stability, installation and maintenance costs, and corrosion. This study proposes recommendations for mitigating these risks. This study also examines policies and programs from various countries that have successfully promoted the adoption of FSPV technology. Currently, countries such as China, Japan, and South Korea account for over 90% of the FSPV deployments. This study highlights the programs and incentives that accelerated FSPV deployments in these countries, such as the standard Feed-In-Tariff (FIT) "Build Plan," "Top Runner Program, and poverty alleviation program in China, significant FITs in Japan, and revised Renewable Portfolio Standards (RPS) and research and development (R&D) support in South Korea. Overall, this study provides valuable insights for policymakers, industry stakeholders, and other interested parties in the ongoing discussions of FSPV systems. Despite the risks and challenges associated with FSPV, the potential of this technology to play a significant role in the transition to a low-carbon, sustainable future cannot be ignored.

INDEX TERMS Floating solar photovoltaic system, risk assessment, policy formulation, risks, challenges in floating solar.

I. INTRODUCTION

The world's energy requirements are growing rapidly, and the need to transition to cleaner and more sustainable energy sources is imperative [1]. Climate change and rising concerns over greenhouse gas emissions have prompted many countries to prioritize the development and deployment of renewable energy sources, including solar power [2]. Although traditional land-based solar photovoltaic (PV) systems have made significant strides in recent years, new and innovative solutions, such as floating solar photovoltaic (FSPV) systems have emerged [3].

FSPV (FSPV) systems are essentially solar panels mounted on floating platforms anchored to water bodies [4]. This technology offers several advantages over traditional land-based systems, including increased energy production owing to the cooling effect of water, reduced water evaporation, and the ability to use land that would otherwise be unsuitable for solar installation. In addition, FSPV systems can provide aesthetic benefits by blending with surrounding water to become a part of the natural landscape [5].

Floating solar PV systems provide several unique advantages. Firstly, they significantly reduce water evaporation

The associate editor coordinating the review of this manuscript and approving it for publication was Giambattista Gruosso.

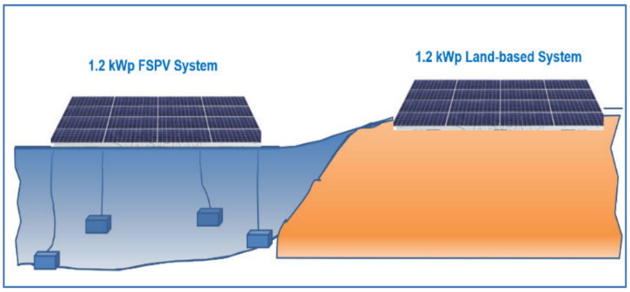

FIGURE 1. A small-scale FSVP system illustration (left part) with the land-based system (right) [4].

from the bodies they cover, a crucial benefit in regions facing water scarcity. Additionally, the cooling effect of water enhances the efficiency of the solar panels, which tend to lose efficiency when overheated [6]. This innovative approach also alleviates land-use conflicts, preserving valuable land for agriculture or natural ecosystems. From a technical perspective, these systems require robust mooring and anchoring to ensure stability, materials that are resistant to corrosion, and specialized electrical safety measures. While beneficial, they also prompt considerations regarding their environmental impact, particularly on aquatic ecosystems [7].

The FSPV is still a relatively new technology, and there are many questions regarding its feasibility and potential for widespread deployment [6]. However, their potential to provide clean and affordable energy while preserving valuable land resources makes them an important technology that deserves further investigation. In recent years, there has been a growing interest in FSPV, and many countries have started to explore the possibilities of using this technology on a large scale [7].

Some of the major challenges in FSPV systems (Figure 1) include exposure to environmental and technical risks such as harsh weather conditions, leaks and water infiltration, fire incidents, theft or vandalism, debris damage, and biofouling [8], [9], [10], [11], [12]. Hence, there is a need to conduct risk assessments and develop policies to ensure that FSPV systems are deployed in a safe, sustainable, and cost-effective manner and to develop policies to maximize their benefits for society.

Risk assessment is a systematic process of evaluating and identifying potential risks and hazards associated with the implementation of a project, specifically in FSPV systems [13]. The results of risk assessment can be used to develop risk-mitigation strategies and policies that can help reduce risks and improve the overall safety and reliability of FSPV projects.

Currently, there are no policies or regulations in the country that govern the technical, environmental, and social aspects of the implementation of the FSPV system, which has not yet been covered specifically by the Philippines' Renewable Energy Act of 2008 and its Implementing Rules and Regulations (IRR), mainly because of its emergence in the last decade. In 2016, the Lake Laguna Development Authority (LLDA) cautioned on the use of the floating solar PV system owing to the "lack of experience and sufficient policy tools" for the use of the lake with the emerging floating solar technology [14].

Floating solar photovoltaic (PV) systems have emerged as a promising technology for harnessing solar energy, particularly in countries with limited land availability [15]. Despite their potential benefits, the deployment of FSPV systems is still in its early stages, and several risks and uncertainties are associated with their implementation [8], [9], [16]. These risks include technical, financial, environmental, and social factors, which can affect the success of FSPV projects [8], [9], [10].

A. OBJECTIVES

The potential of FSPV systems to play a significant role in meeting the world's energy demands is the motivation for conducting risk assessments, and the basis for policy formulation for their widespread adoption. The main objective of this case study was to examine the risks and challenges associated with this technology and its potential impact on the environment, the economy, and communities.

The specific objectives of this case study were to: (1) identify the risks, challenges, and barriers associated with the development and deployment of FSPV systems have been identified through a literature review, (2) conduct a theoretical risk assessment based on a literature review of community-based FSPV systems, and (3) develop policy recommendations for FSPV systems that can be adopted by local or national governments. Ultimately, the objective of risk assessment and policy formulation for FSPV systems is to promote their widespread deployment and maximize their benefits to society [17], [18], [19], [20], especially in the Philippines.

B. IMPORTANCE OF RISK ASSESSMENT

The conduct of risk assessment and policy development for floating solar photovoltaics (PV) is considered important for several reasons: (1) ensuring FSPV project viability, (2) attracting investments, (3) protecting the environment, (4) protecting technology advancement, and (5) addressing social concerns.

- Ensuring project viability: By conducting a risk assessment, stakeholders can identify potential issues and challenges associated with FSPV projects and develop strategies to mitigate these risks. This helps ensure the viability and long-term success of FSPV projects.
- Attracting investment: By developing clear and effective policies, regulations, and standards for FSPV systems, governments and other stakeholders can create a more favorable investment environment and attract private sector investment.
- Protecting the environment: Risk assessment and policy development can help ensure that FSPV systems are deployed in an environmentally sustainable manner by

considering their potential impacts on the surrounding ecosystem and water bodies.
- Promoting technological advancement: By conducting risk assessments and developing policies and regulations, stakeholders can help drive technological innovation and improve the FSPV sector, resulting in more cost-effective and efficient solutions.
- Addressing social concerns: Risk assessment and policy development can help to address social concerns and ensure that FSPV systems are implemented in a manner that benefits all stakeholders, including the local communities of the project where this is intended for, who may be impacted by the projects.

The scope of risk assessment and policy development for FSPV includes technical, financial, environmental, social, and regulatory risks. Policy development reviews existing government policies and regulations from other countries that help promote the development and deployment of FSPV systems optimized to support the growth of this industry.

II. RISK ASSESSMENT AND POLICY FORMULATION

A. RISK ASSESSMENT AND MANAGEMENT

1) WHAT IS A RISK?

Risk was defined as the possibility of an adverse event or a negative outcome. In the context of business or finance, risk refers to the possibility of a loss or failure due to a particular action or investment. Risk can be characterized by the likelihood of its occurrence and the potential magnitude of its consequences. Risk can also be defined as the "effect of uncertainty on objectives and is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence" [21], [22], [23], [24].

Potential risks may arise from a multitude of sources such as market fluctuations, technological advancements, political instability, and natural disasters. To make well-informed decisions and take appropriate measures, it is essential to identify and evaluate such risks and devise strategies to either alleviate or handle them. This is the purpose of risk assessment, which involves evaluating the probability and impact of different risks and determining the best course of action to minimize their effects [25], [26], [27], [28].

2) RISK ASSESSMENT

Risk assessment is a systematic process of evaluating and identifying potential risks and hazards associated with a specific activity, system, or project [29]. The purpose of risk assessment is to identify potential threats to the success of an activity, system, or project and to evaluate the likelihood and consequences of these threats. The results of the risk assessment can be used to develop risk-mitigation strategies that can help reduce risks and improve the overall safety and reliability of an activity, system, or project [29], [30], [31], [32]. As shown in Figure 2 and 3, risk assessments typically involve several steps, including (a) hazard identification, identifying potential hazards and risks associated with the activity, system, or project; (b) risk evaluation, evaluating the likelihood and consequences of each identified hazard; (c) risk prioritization, prioritizing the risks based on the likelihood and consequences of each risk; (d) risk mitigation, developing, and implementing strategies to reduce the risks associated with the identified hazards; and (e) monitoring and review, monitoring, and reviewing the risk assessment to ensure that the identified risks are being effectively managed and mitigated [27].

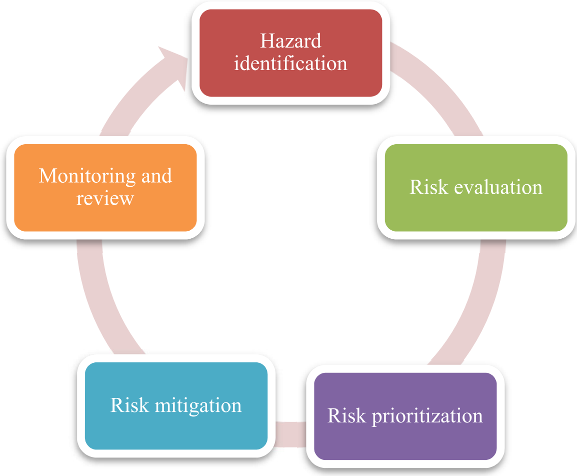

FIGURE 2. A general framework for risk assessment [27].

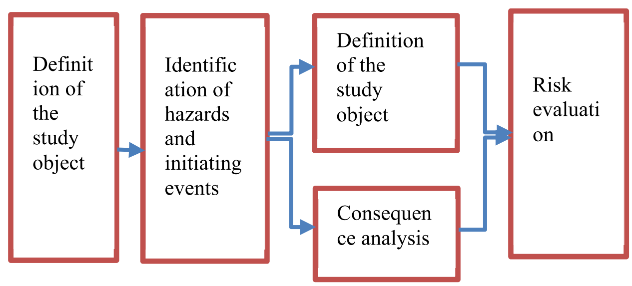

FIGURE 3. Risk assessment process main elements [33].

Risk assessments can be used in a variety of settings, including safety, engineering, environmental management, health, and safety. The level of detail and complexity of a risk assessment will depend on the nature of the activity, system, or project being assessed as well as the goals and objectives of the assessment. However, the overall aim of risk assessment is to identify and manage risks to ensure the safe and reliable operation of the activity, system, or project being assessed [32], [34], [35]. Conducting a risk assessment for FSPV systems requires tools to identify potential hazards, evaluate the likelihood and consequences of each hazard, and develop effective mitigation strategies, as shown in Figure 4 [36], [37], [38], [39], [40], [41], [42].

The scope of risk assessment and policy development for FSPV typically includes technical, financial, environmental, social, and regulatory risks [21].

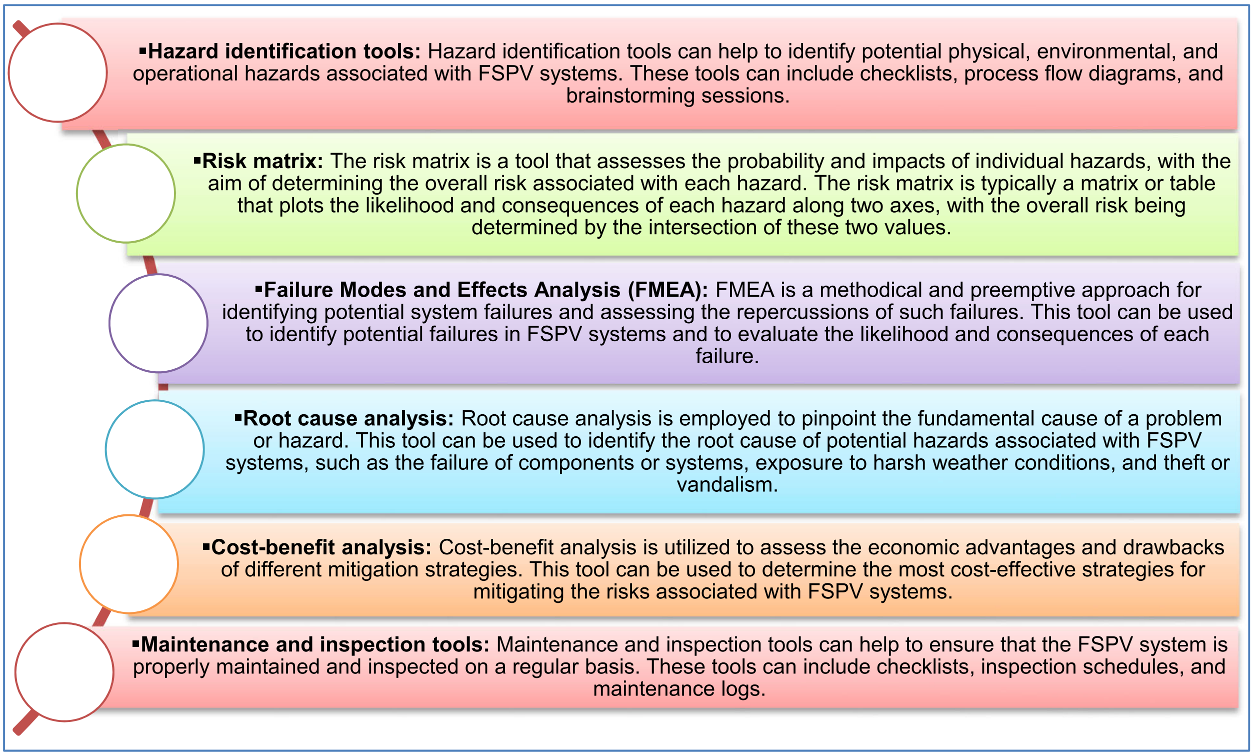

FIGURE 4. Risk assessment tools [27], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42].

- Technical risks: Evaluation of the technical feasibility of FSPV projects, including design, engineering, and construction of systems.
- Financial risks: Analysis of the financial viability of FSPV projects, including the cost of capital, operating expenses, and revenue projections.
- Environmental risks: Assessment of the environmental impact of FSPV projects, including their impact on water quality and the surrounding ecosystem.
    - Social risks: Evaluation of the social impact of FSPV projects, including their impact on local communities and the rights of stakeholders.
    - Regulatory risks: Analysis of the legal and regulatory framework for FSPV projects, including the development of regulations and standards to ensure the safety and reliability of systems.

B. POLICY DEVELOPMENT

A policy is a set of rules, guidelines, or principles that are established to guide decision making and ensure consistency and fairness in achieving specific objectives. Policies are often adopted by organizations, governments, or other entities to ensure that their actions align with their values, goals, and objectives. Policies can cover a wide range of topics, including but not limited to human resources, finance, the environment, health and safety, and ethical behavior [43], [44], [45], [46], [47].

Policies serve several purposes, including (a) providing direction and guidance: Policies help define the direction and priorities of an organization and provide guidance to decision-makers on how to act in specific circumstances; (b) maintaining consistency: Policies help ensure consistency in decision-making and actions across an organization, promoting fairness and impartiality; (c) managing risk: Policies can help organizations manage risks by outlining procedures and processes to follow in specific situations, reducing the likelihood of unintended consequences; (d) ensuring accountability: Policies help ensure accountability by setting clear expectations and responsibilities for individuals within an organization; and (e) promoting transparency: Policies can promote transparency by providing a clear understanding of an organization's intentions, values, and objectives [48], [49], [50].

It is important to note that the policy formulation process is iterative and may involve multiple revisions before the final policy is agreed upon and implemented. Additionally, the process of formulating a policy should involve a transparent and inclusive process, taking into consideration the perspectives and needs of all relevant stakeholders, as shown in Figure 5 [48], [49], [50].

Policies play a critical role in guiding decision-making and ensuring that organizations and governments act in a consistent and transparent manner, aligned with their objectives and values [48], [49], [50].

C. EXISTING POLICIES IN SOLAR AND FSPV SYSTEMS

Formulating a policy involves several steps as shown in Figure 5, including: (a) identifying the need for a policy:

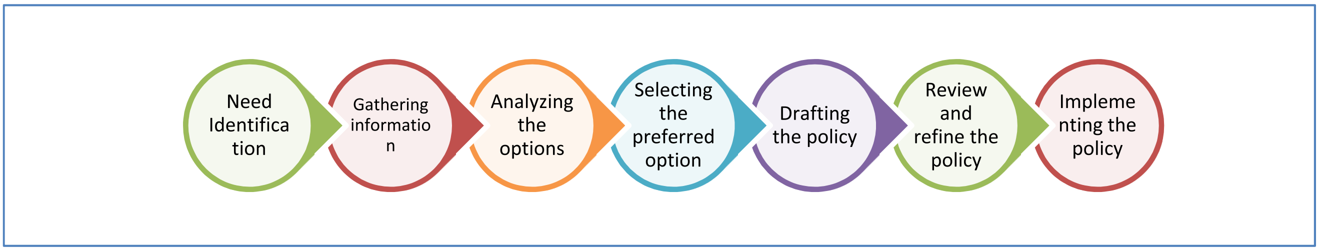

FIGURE 5. Steps in policy formulation [48], [49], [50].

this involves determining the reason for the policy and what problem it is intended to solve; (b) gathering information: this includes researching the issue and gathering data to support the policy, as well as consulting with stakeholders who may be affected by the policy; (c) developing policy options: this step involves generating different potential policy solutions to address the problem; (d) analyzing the options: this involves evaluating the strengths and weaknesses of each option, including the potential impact on stakeholders and the feasibility of implementation; (e) selecting the preferred option: based on the analysis, select the option that is most likely to achieve the desired goals and that is feasible to implement; (f) drafting the policy: the preferred option is then written as a policy, including clear and concise language that outlines the objectives, principles, and guidelines; (g) reviewing and refining the policy: The draft policy is then reviewed and refined, taking into consideration feedback from stakeholders and other relevant parties; and (h) implementing the policy: this involves communicating the policy to relevant parties and ensuring that it is put into practice, as well as monitoring and evaluating the policy to determine its effectiveness [48], [49], [50].

It is important to note that the policy formulation process is iterative and may involve multiple revisions before the final policy is agreed on and implemented. Policy formulation should involve a transparent and inclusive process that considers the perspectives and needs of all relevant stakeholders [48], [49], [50]. Policies play a critical role in guiding decision making and ensuring that organizations and governments act in a consistent and transparent manner, aligned with their objectives and values [48], [49], [50].

Specific policies related to solar PV systems vary by country and region, but some common policy frameworks include renewable energy targets, feed-in tariff (FiT) programs, net metering, tax credits and subsidies, permission and zoning regulations, environmental regulations, and grid connection standards [51], [52], [53], [54], [55], [56].

The policies related to floating solar photovoltaics (FSPV) in the United States and Europe vary by state and country, respectively. In the United States, FSPV policies are primarily driven by state-level regulations and incentives. Examples of state-level policies include (a) Renewable Portfolio Standards (RPS), (b) Net Metering, and (c) Tax Credits and Subsidies. Many states in the US have established RPS targets, which require a certain percentage of electricity to be generated from renewable sources. Thus, the FSPV systems can satisfy these requirements. Some states have implemented net metering policies that allow FSPV owners to sell excess electricity to the grid. States may offer tax credits or subsidies for the installation of FSPV systems to encourage investments in technology [55], [57], [58], [59].

In Europe, policies related to FSPV are primarily driven by European Union (EU) regulations and incentives. Examples of EU policies include (a) renewable energy targets, (b) the Feed-in Tariff (FiT) program, (c) Environmental Regulations, and (d) Grid Connection Standards. The EU has established a target of 32% of energy consumption to come from renewable sources by 2030. FSPV systems can help to meet this target. The EU has implemented FiT programs in many countries that provide financial incentives for the generation of renewable energy, including FSPV. The EU has established environmental regulations related to water quality and wildlife protection with which FSPV systems must comply. The EU has established standards for connecting FSPV systems to the grid, which affects the development of FSPV projects [60], [61], [62], [63].

Some common policy frameworks for solar PV can also be found in Asia and are somewhat similar to those of the US and the European Union, but wider: (a) Renewable Energy Target; (b) Feed-in Tariff (FiT) Program; (c) Environmental Regulations; (d) Grid Connection Standards; (e) Tax Credits and Subsidies; (f) Net Metering; (g) Permitting and Zoning Regulations; and (h) Grid Connection Standards [64], [65], [66].

Many Asian countries have established targets for the generation of renewable energy, including floating solar photovoltaics. This study provided a policy framework for the growth and development of FSPV. FiT programs provide financial incentives for the generation of renewable energy, including FSPV. These programs are designed to encourage investment in renewable energy and support industrial development. In Net Metering, this policy allows FSPV owners to sell excess electricity back to the grid, thereby providing financial incentives for the installation of FSPV systems. Tax Credits and Subsidies: Governments may provide tax credits or subsidies for the installation of FSPV systems to help reduce costs and encourage investment in technology. Local and national governments may have specific regulations related to permitting and zoning FSPV systems that can affect the development of FSPV projects. FSPV systems must comply with environmental regulations such as those related to water quality and wildlife protection [67], [68], [69].

Some examples of specific policies related to FSPV in Asia include Japan, China, and India. By 2030, Japan aims to have 50 GW of installed renewable energy capacity, which will include floating solar photovoltaics [70]. Japan has also implemented FiT programs and tax credits to encourage investment in renewable energy [71]. China has established a target of 15 GW of installed floating solar photovoltaics by 2020 and has implemented FiT programs and subsidies to encourage investment in technology [72].

In contrast, India has set a target of achieving 175 GW of installed renewable energy capacity, which encompasses floating solar photovoltaics, by 2022. Additionally, the country has introduced net metering policies and tax credits to stimulate investment in renewable energy [70], [71], [72].

The Philippines implemented policies to promote the development of renewable energy, including (a) the Renewable Energy Act of 2008, which established a framework for the development and promotion of renewable energy in the Philippines. The act provides for the implementation of feed-in tariff (FiT) programs and other financial incentives to encourage investment in renewable energy; (b) Renewable Energy Target: The Philippines has established a target of 1,000 MW of installed renewable energy capacity by 2040; (c) Feed-in Tariff (FiT) Program: The Philippines has implemented a FiT program, which provides financial incentives for the generation of renewable energy, including wind, solar, and hydropower; (d) Net Metering: The Philippines has implemented net metering policies, which allow renewable energy generators to sell excess electricity back to the grid; (e) Tax Credits and Subsidies: The Philippines may offer tax credits or subsidies for the installation of renewable energy systems to encourage investment in the technology; (f) Environmental Regulations: The Philippines has established environmental regulations related to water quality and wildlife protection that renewable energy systems must comply with; (g) Grid Connection Standards: The Philippines has established standards for connecting renewable energy systems to the grid, which impact the development of renewable energy projects.

These policies were designed to support the growth and development of renewable energy in the Philippines and to encourage investment in the sector. However, in the law and implementing rules and regulations (IRR) of the Renewable Energy Act of 2008, FSPV systems have not yet been provided or mentioned [73], [74].

III. METHOD

This risk assessment and policy development case study revisited the discussions on the FSPV, including its risks, barriers, and challenges. Furthermore, this case study explored the current policy and regulatory framework.

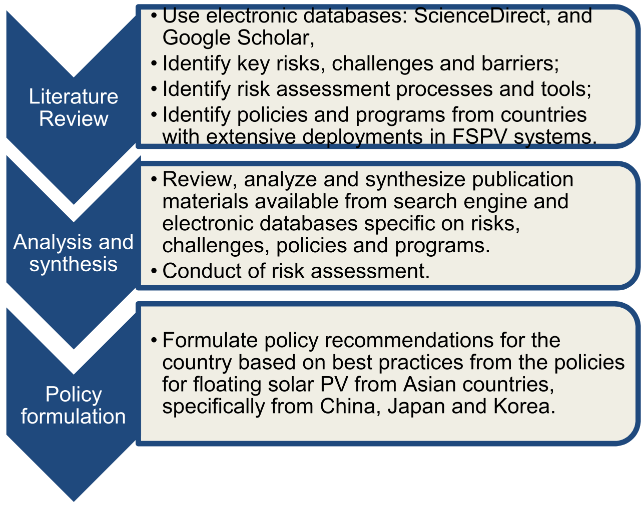

FIGURE 6. Methodological framework for the risk assessment and policy recommendations formulation [73].

A literature review was conducted using major electronic databases, including IEEE, Science Direct (journals in Elsevier), and Google Scholar, using selected keywords or phrases relevant to this study for the period 2012–2022 [73]. ScienceDirect is Elsevier's website, which offers entry into a huge bibliographic database of scientific and medical publications, as shown in Figure 6. The type of review conducted for this study is narrative or traditional literature reviews. These reviews synthesize findings from various studies to provide an overview of a topic. Their focus is on summarizing and interpreting research findings rather than on a detailed meta-analysis.

The following are the significant phrases in consideration to the literature review:

- Risk assessment in solar photovoltaics;
- Risks, challenges, and barriers and their management associated with FSPV systems;
- Risk assessment processes and tools; and
- Policies and/or regulations on FSPV.

Figures 7 and 8 show the framework and steps, respectively, for the risk assessment methodology from the identification of the hazards to its monitoring, which includes the conduct of risk assessments, known as the Hazard Identification and Risk

Assessment (HIRA) methodology. The HIRA methodology was applied in a study by [21], as published in the Journal of Risk Management and Healthcare Policy [21]. In addition, [21] discussed the potential occupational safety and health (OSH) risks associated with the installation and maintenance of floating solar photovoltaic (PV) projects, which are becoming increasingly popular as renewable energy sources [21]. The authors identified several potential hazards including electrical shocks, drowning, and falls from heights. The authors highlight the importance of addressing these risks to ensure that the growth of floating solar PV projects is

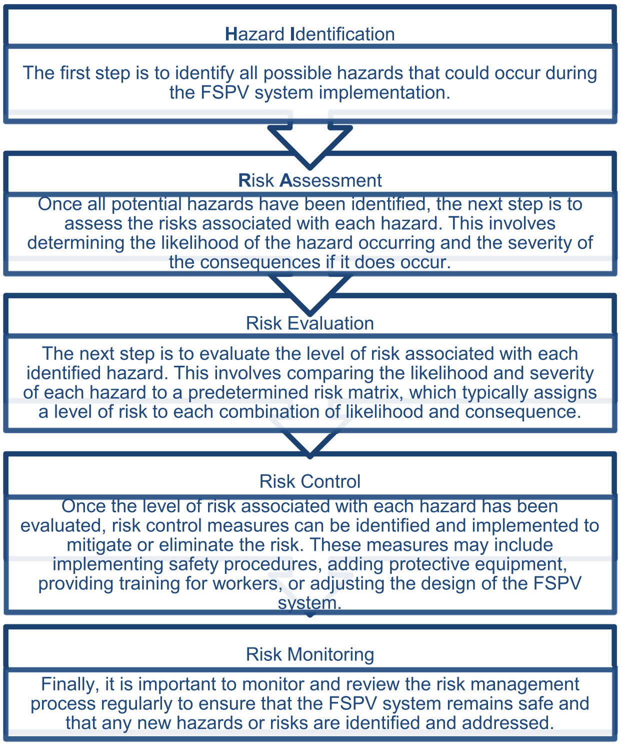

FIGURE 7. Risk assessment process main elements [73].

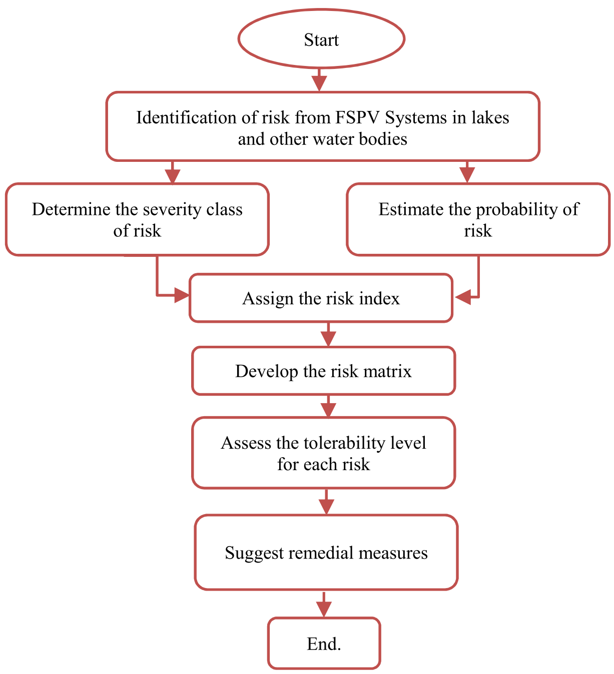

FIGURE 8. Risk assessment process' main elements [33].

sustainable and does not occur at the expense of worker safety or environmental protection.

IV. RESULTS AND DISCUSSIONS

This section presents the results of the systematic review, risk assessment, and analysis, including an evaluation of

TABLE 1. Summary of findings from the literature search on the risk assessments conducted in solar photovoltaics [73].

Database	Search	Boolean operator	Keywords or Search strings	Search Results (Number of documents
Science Direct	Basic search: "Find articles with these terms"	"or"	(risk assessment) or (solar photovoltaic)	13278
Science Direct	Advance Search: Title, abstract or author-specified keywords	"and"	(risk assessment) and (solar photovoltaic)	11
IEEE	Advanced Search	"and"	(risk assessment) and (floating solar)	3
Google Scholar	Advance Search: "floating solar" and "risks"	"and"	(Floating solar photovoltaics) and (Risks)	1,040
Google Scholar	Advance Search: "floating solar" and "risks and challenges"	"and"	(Floating solar photovoltaics) and (Risks and challenges)	11

the existing policies and best practices. This chapter also examines the policy and regulatory frameworks currently in place in other countries, including the incentives and subsidies available for FSPV systems, and evaluates the opportunities and barriers for scaling up the deployment of this technology. Additionally, the impact of FSPV systems on the environment, economy, and communities, and the potential for this technology to contribute to the transition to a low-carbon, sustainable future will be explored.

A. LITERATURE SEARCH

A comprehensive search was performed using the electronic databases IEEE, Science Direct and Google Scholar with keywords and Boolean algebra, as shown in Table 1 [73].

There are a few relevant publications that provide information and guidance on conducting risk assessments for floating solar photovoltaic (PV) systems, as shown in Table 2 [2], [74], [75], [76], [77].

These publications provide useful information and guidance for conducting a risk assessment for FSPV systems, and can serve as a useful resource for those looking to implement these systems. It is important to note that while these references provide a good starting point, it is important to also consult local regulations, guidelines, and best practices when conducting a risk assessment for FSPV systems.

TABLE 2. Relevant documents with risk assessments conducted in solar PV or in FSPV [2], [75], [76], [77], [78].

Database	Document Title	References
Science Direct	Solar photovoltaics in airport: Risk assessment and mitigation strategies.	[75]
Science Direct	Risk assessment in planning high penetrations of solar photovoltaic installations in distribution systems.	[76]
Google Scholar	Risk Assessment of Offshore Floating Photovoltaic Systems	[77]
Google Scholar	Assessment of floating solar photovoltaics potential in existing hydropower reservoirs in Africa.	[78]
IEEE	Risk Analysis Development of Solar Floating Power Plant in The Sea with Monte Carlo Method	[78]

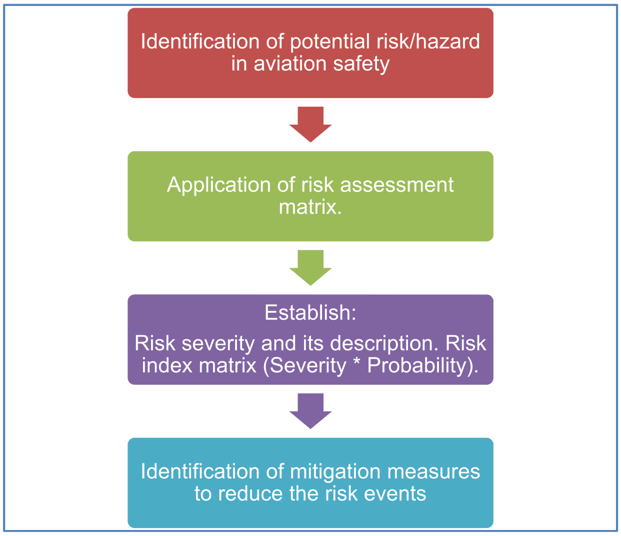

FIGURE 9. Methodology of the risk assessment conducted for a solar PV installation using the risk assessment matrix – "hazard identification and risk assessment (HIRA) method" [21].

TABLE 3. Types of risk probability [74].

Name of Probability	Descriptions	Probability ranking
Certain	Expected to occur in most situations	5
Likely	Probably occur at sometime	4
Possible	Might occur at sometime	3
Unlikely	Could occur at sometime	2
Exceptional	May occur in exceptional circumstances	1

B. RISK ASSESSMENTS IN SOLAR AND FSPV SYSTEMS

1) RISK ASSESSMENT IN AN AIRPORT

[74] conducted a risk assessment of the implementation of a solar PV land-based project in one of the airports in Malaysia [74]. They assessed potential risks and hazards that pose threats to aviation safety using the methodology in Figure 9 and references in Figure 10 on the risk probabilities and severity table and the types of risk probability in Table 3.

Risk probabilities	Risk Severity				
	Catastrophic (A)	Major (B)	Moderate (C)	Minor (D)	Insignificant (E)
Certain (5)	5A	5B	5C	5D	5E
Likely (4)	4A	4B	4C	4D	4E
Possible (3)	3A	3B	3C	3D	3E
Unlikely (2)	2A	2B	2C	2D	2E
Exceptional (1)	1A	1B	1C	1D	1E

FIGURE 10. Risk probabilities and severity table [74].

TABLE 4. Risk severity and its description [74].

Type of severity	Description Severity	ranking
Catastrophic	Total damage to aircraft leading to more than one fatality and colossal loss to airport assets.	A
Major	Main aircraft systems do not work resulting in the emergency procedure of flight, possible injuries to passengers and crew	B
Moderate	Partial failure of aircraft system and may result in the abnormal application of flight operation procedures	C
Minor	Affect the routine airport operational procedures	D
Insignificant	No implication to aircraft-related operation and safety	E

TABLE 5. Risk acceptability table [74].

Color Code	Risk Index	Decision on acceptance
Red	5A, 5B, 5C, 4A, 4B, 3A	Unacceptable under existing circumstances
Yellow	5D, 5E,4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	Acceptable after review
Green	3E, 2D, 2E, 1B, 1C, 1D, 1E	Acceptable as it is

Based on their study, seven (7) types of risks from the solar PV system at the airport were identified: (1) glare occurrence from PV modules, (2) interference with communication systems, (3) PV array penetration into restricted airspace, (4) accidental incursion into the PV array, (5) detachment of the solar PV system, (6) strikes from birds at PV sites, and (7) electric hazards from the PV system.

These publications provide useful information and guidance for conducting a risk assessment for FSPV systems, and can serve as a guide. According to Tables 4 and 5, which were used as a reference for risk assessment using the HIRA methodology, the highest risk index was associated with three factors: glare occurrence from PV modules (4 B), strikes from birds at the PV site (4 B), and interference with communication systems (3 B).

TABLE 6. Types and description of risks as found in the literature [11], [13], [21], [37], [78], [79], [80], [81], [81], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [92], [93].

Type of Risks	Risks	Description of risks	Source
Environmental Risks	Ecological disruption	FSPV systems can possibly disrupt aquatic ecosystems by blocking sunlight from reaching the water surface and altering water temperature and flow patterns. This can affect the growth and survival of aquatic plants and animals, as well as alter the nutrient cycling and other ecosystem processes.	[11],[13],[21] [37],[78],[79] [80],[81],[82]
	Water quality degradation	FSPV systems can also affect water quality by creating shading and reducing the exchange of gases between the water and atmosphere. This can lead to the buildup of organic matter and nutrients, which can contribute to the growth of harmful algae and other microorganisms. A study identified the potential for water quality degradation due to the accumulation of pollutants on the surface of the FSPV panels.	[83]
	Land use impacts	While FSPV systems can help to reduce land use, they also require the use of water bodies, which can have its own environmental impacts. For example, using water from rivers or lakes can affect aquatic ecosystems and downstream water users.	[83],[84]
	End-of-life management	Like all electronic equipment, FSPV systems have a limited lifespan and must be properly disposed of at the end of their useful life. The disposal of solar PV panels can potentially create hazardous waste, and there is a need to develop sustainable end-of-life management strategies for this technology.	[84]
	Marine environment risk	Typhoons, tsunamis and tidal waves can cause disastrous damage to offshore PV power plant.	[11],[85]
Regulatory	Uncertainty in regulations	As FSPV technology is relatively new, there may be regulatory uncertainty or a lack of regulations specifically designed for FSPV systems. This can lead to delays in obtaining permits and approvals, which can impact project timelines and increase costs.	[86]
	Permitting and licensing	Permitting and licensing requirements for FSPV systems may be complex and vary between jurisdictions, making it difficult for project developers to navigate the process.	[86]
	Tariff and incentive policies	Tariff and incentive policies can impact the economic viability of FSPV systems. Changes in policies or the expiration of incentives can result in a significant reduction in revenue, making the project less economically viable.	[86]
	Land use and zoning regulations	FSPV systems may be subject to land use and zoning regulations, which can impact the location and size of the project. Failure to comply with these regulations can result in fines, penalties, and project delays.	[86]
Technical	Stability	FSPV systems are exposed to different environmental conditions, such as wind, waves, and currents. As a result, they can experience higher levels of stress compared to ground-mounted solar PV systems. Ensuring the stability of the floating structures is crucial to prevent damage or loss of the system.	[86]
	Corrosion	FSPV systems are exposed to water, which can cause corrosion of the metal components, such as frames and mounting systems. Corrosion can lead to structural damage, electrical failures, and reduced system performance.	[87]
	Interconnection and integration	FSPV systems must be properly integrated with the power grid to ensure stable and reliable power generation. This includes interconnection with the grid, power management, and control systems. Integration challenges can arise due to the remote location of some FSPV systems and the need for advanced control and communication systems.	[11],[85]
	Maintenance and repair	Maintenance and repair can be challenging due to the location of the systems, which may require specialized equipment and personnel.	[11],[88]
	Site selection	The completion of the project may be delayed and the power generation of the project may fall short of expectations	[11],[89]
	PV array design	Insufficient utilization of solar radiation due to irrational PV array design results in lesser power production.	[11]
	Equipment selection	Failure of PV modules and inverter can result in loss of entire power output.	[11],[88],[89]
Economic	Financial and initial investment	FSPV systems require significant upfront investment, which can create financial risks for project developers and investors. These risks include changes in government policies, fluctuating energy prices, and the availability of financing.	[11],[85]
	Market	As FSPV technology is relatively new, there is still uncertainty around the future market for these systems. Market risks include changes in demand, competition from other renewable energy technologies, and regulatory changes that could impact the economic viability of the technology.	[11],[85]
	Installation and maintenance costs	The installation and maintenance costs of a FSPV system can be higher than those of a traditional ground-mounted system. These costs are largely due to the specialized equipment and expertise needed to install and maintain a floating system.	[11],[85]
Social	Displacement of local communities	FSPV systems may require the use of large bodies of water, which can displace local communities, particularly those who rely on the water for their livelihoods, such as fishermen.	[86]
	Changes to local landscapes	The installation of FSPV systems can change the appearance of local landscapes, which may impact the aesthetic value of the area and potentially harm tourism.	[86],[90],[91]
	Community engagement	Community engagement is crucial to the success of FSPV projects. Failure to involve local communities in the planning, development, and operation of the project may result in resistance, which can lead to delays, increased costs, and even project cancellation.	[86],[92]
	Health and safety risks	FSPV systems pose health and safety risks to workers and local communities. These risks include accidents during the installation and maintenance of the system, exposure to electrical hazards, and exposure to toxic chemicals.	[88]
	Land use conflicts	In some cases, there may be conflicts over the use of land, particularly in areas where there is high competition for land use. For example, there may be conflicts over the use of water bodies for FSPV systems versus for irrigation or drinking water.	[13],[93]

TABLE 7. Proposed risk severity rankings for the FSPV system [74].

Type of severity	Description Severity	Ranking
Catastrophic	Total damage of the FSPV system leading to more than one fatality and colossal loss to FSPV assets	A
Major	Main FSPV systems do not work resulting to possible injuries to stakeholders	B
Moderate	Partial failure of FSPV system and may result in the abnormal application of FSPV System operations	C
Minor	May affect the routine FSPV system operational procedures	D
Insignificant	No implication to FSPV system-related operation and safety	E

TABLE 8. Probability of occurrence [74].

Name of Probability	Descriptions	Probability ranking
Certain	Expected to occur in most situations	5
Likely	Probably occur at sometime	4
Possible	Might occur at sometime	3
Unlikely	Could occur at sometime	2
Exceptional	May occur in exceptional circumstances	1

TABLE 9. Risk index and decision basis for acceptance [74].

Color Code	Risk Index	Decision on acceptance
Red	5A, 5B, 5C, 4A, 4B, 3A	Unacceptable under existing circumstances
Yellow	5D, 5E,4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	Acceptable after review
Green	3E, 2D, 2E, 1B, 1C, 1D, 1E	Acceptable as it is

The HIRA methodology for this risk assessment was adopted from the Safety Management Manual of the International Civil Aviation Organization (ICAO). The same methodology was used in their paper entitled "Risk assessment and possible mitigation solutions for using solar photovoltaic at airports."

2) RISKS SUMMARY BASED ON THE AVAILABLE LITERATURE

Although floating solar photovoltaic (PV) systems offer numerous advantages, there are potential environmental risks associated with this technology. The types of risks identified in the literature are summarized in Tables 6 [11], [13], [21], [37], [78], [79], [80], [81], [81], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [92], [93].

C. RISK ASSESSMENT OF A SMALL-SCALE FSPV SYSTEM IN LAKE MAINIT, PHILIPPINES

Assessing the risks of implementing a 2.4 kWp small-scale FSPV system at Lake Mainit, Jabonga, in the province of Agusan del Norte in the Philippines (with coordinates: 9.375146, 125.555853) using Hazard Identification, Risk Assessment (HIRA) methodology involves a process that identifies potential hazards and evaluates their likelihood and consequences. Using the HIRA methodology, we adopted and proposed probability and severity rankings but tailored them to FSPV systems.

Using the HIRA methodology, the following tables were used to evaluate the risks of the FSPV system: Table 7 provides the risk severity rankings for the FSPV system and Table 8 shows the probability of occurrence. Table 9 presents the risk indices and acceptance. Table 10 presents the risk assessment and evaluation with the proposed recommendations in Table 11 for the FSPV system to be implemented in a local setting in Lake Mainit, Jabonga, and Agusan del Norte.

D. MINIMIZING SOCIAL RISKS, THE CASE IN OOST-VOORNSE LAKE, NETHERLANDS

While technical, environmental, and economic risks have expanded in the recent literature, the social aspect of FSPV deployment has seldom been studied. [81] conducted a social study in an FSPV pilot project in Oost-Voornse Lake in the Netherlands [81]. The authors consulted stakeholders to determine how the local community perceives the project. Some of the key findings of this social experiment are as follows.

- Public perception: The local community had a positive perception of the FSPV project, with many seeing it as a sustainable energy solution. However, there were concerns regarding the impact of the project on the visual landscape and recreational activities of the lake.
- Stakeholder engagement: The study found that stakeholders were involved in the planning and development of the project, and that their concerns were considered during the design and construction phases. This leads to a high level of trust between the stakeholders and project developers.
- Economic impact: The study found that the FSPV project had a positive economic impact on the local area, creating jobs and generating revenue for local businesses.
- Social impact: This study found that the FSPV project had a positive social impact, contributing to the sustainability and resilience of the local community.
- Environmental impact: This study found that the FSPV project had a positive environmental impact, reducing the carbon footprint of the local area and improving the water quality of the lake.

The social study found that the project had a positive social impact on the local community as well as positive economic and environmental impacts. This highlights the importance of considering the social aspects of FSPV deployment to ensure that projects are socially sustainable and accepted by local communities. This is a "living proof" that an FSPV system can be successfully adopted, deployed, or implemented for community-based use.

TABLE 10. Risk assessment of an off-grid 2.4 kWp FSPV system in Lake Mainit, Jabonga, Agusan del Norte [74].

Identify and List Hazards	Risks	Risk Prob.	Risk Severity	Risk Index	Decision (Accept or Not)	Remarks/Justifications for rating and Possible Mitigations
Environmental Risks	Ecological disruption	2	D	2D	Acceptable as it is	The "footprint" or size of the system is too small compared to the overall size of Lake Mainit.
	Water quality degradation	2	E	2E	Acceptable as it is	The FSPV system size is small to affect water quality.
	Land use impacts	1	E	1E	Acceptable as it is	For example, using water from rivers or lakes can affect aquatic ecosystems and downstream water users.
	End-of-life management	2	D	2D	Acceptable as it is	Proper monitoring and maintenance are necessary in the later years of the operation.
	Marine environment risk	3	D	3D	Acceptable as it is	FSPV system in lakes are not like those in offshore deployments where tsunamis and tidal waves can cause disastrous damage.
Regulatory	Uncertainty in policies or regulations	3	D	3D	Acceptable as it is	There are no present regulations for FSPV in the Philippines. This R&D project will help define for the development of a policy brief.
	Permitting and licensing	2	D	2D	Acceptable as it is	There is an existing MOA with LGU Jabonga for the FSPV system deployment in Lake Mainit.
	Tariff and incentive policies	1	E	1E	Acceptable as it is	For an off-grid FSPV application, this risk is not applicable.
	Land use and zoning regulations	1	E	1E	Acceptable as it is	There is an existing MOA with LGU Jabonga for the FSPV system deployment in Lake Mainit.
Technical	Stability	4	B	4B	Unacceptable under existing circumstances	The 2.4kWp system's stability of the floating structures (high wind tolerances of over 100kph) and anchoring should be ensured to prevent damage or loss of the system.
	Corrosion	3	D	3D	Acceptable after review	Unlike at sea, the Lake Mainit's water profile is not salty or corrosive.
	Interconnection and integration	1	E	1E	Acceptable as it is	For an off-grid FSPV application, this risk is not applicable.
	Maintenance and repair	2	D	2D	Acceptable as it is	The location of this FSPV system is right close to shore, hence maintenance and repair is expected to be manageable.
	Site selection	1	D	1D	Acceptable as it is	The risk is minimized with the identified location near the shore and is in inner portion of the lake.
	PV array design	2	D	2D	Acceptable as it is.	Prior to the implementation, the 2.4kWp system was carefully analyzed and control systems were developed to monitor the output and all with proper insulations.
	Equipment selection	2	D	2D	Acceptable as it is.	The selected PV modules are Selected to work in a lake environment with proper insulations.
Economic	Financial and initial investment	1	D	1D	Acceptable as it is.	For this particular project with the 2.4kWp system size, the upfront cost is manageable. However, this could be a challenge for bigger system size. For future R&D work, DOST can provide funding.
	Market	1	E	1E	Acceptable as it is.	As this is an R&D work, market analysis will not have an impact to the deployment of this small-scale system.
	Installation and maintenance costs	4	D	4D	Acceptable after review	The maintenance cost in the future is necessary for the continued operation. With the signed

TABLE 10. *(Continued.)* **Risk assessment of an off-grid 2.4 kWp FSPV system in Lake Mainit, Jabonga, Agusan del Norte [74].**

						partnership of the LGU, the maintenance cost should be covered.
Social	Displacement of local communities	1	E	1E	Acceptable as it is.	With a small-scale system, no displacement will be made in the local area.
	Changes to local landscapes	1	E	1E	Acceptable as it is.	The FSPV systems can actually provide aesthetic value of the area and potentially can be a tourism area.
	Community engagement	2	D	2D	Acceptable as it is.	Community engagement is crucial to the success of FSPV projects. With the signed MOA with the LGU, this is acceptable with them already.
	Health and safety risks	4	A	4A	Unacceptable under existing circumstances.	Exposure to health and safety risks to workers and members of the local communities. These risks include accidents, and exposure to electrical hazards if there are no protocols in placed.
	Land use conflicts	1	E	1E	Acceptable as it is.	There is an existing MOA with LGU Jabonga for the FSPV system deployment in Lake Mainit.

E. POLICIES FOR DEPLOYMENTS IN TOP FSPV COUNTRIES

Over the years, various countries have developed methods to increase the capacity of solar photovoltaic (PV) systems. Prior to the FSPV system deployment, land-based systems were the most popular form of deployment. Feed-in tariffs for large-scale solar PV systems and net metering for residential and smaller-capacity rooftop installations have become popular policy incentives for power generators and homeowners to capitalize [94].

The emergence of the FSPV system has enabled a revisit of the existing policies of countries that are active in their FSPV deployment, led mostly by Asian countries. Over the years, China and Japan are two of the Asian countries dominated the FSPV deployments comprising of more than 89% of the projects in the world with a total capacity of over one (1) TWp capacity as of Dec. 2018 with government policies highlighting the incentives of FSPV [95].

1) POLICIES IN CHINA

China is a global leader in the deployment of FSPVs. The majority of FSPV have been based on three solar photovoltaic policies [10]:

- The standard Feed-In-Tariff "Build Plan;"
- The Poverty Alleviation program; and
- Top Runner Program

The Top Runner Program was influential in the FSPV system deployments [96], [97], [98]. The government is moving to competitive auctions and gradually eliminating the FITs and other subsidies, however the FITs initially played a significant role in encouraging new investment in PV systems [96], [97], [98].

The Poverty Alleviation program provides financial assistance to facilitate the deployment of FSPV at the village and utility levels. This program was essential for enabling the use of FSPV in coal mines that had been unused and extremely polluted and were therefore unsuitable for many other uses [98].

The Top Runner Program, which offered financial incentives to FSPV systems and other cutting-edge PV technologies, was crucial to the development of FSPV in the country. The initiative established minimal performance standards for the participating technologies before establishing exclusive bids for those that met the requirements. The installation of approximately one (1) TWp of the FSPV was made possible by both initiatives, which have now been phased out. The country has since risen to become the largest FSPV system deployer globally [98].

In general, China offers guidance on promoting FSPV deployment:

- Encourage renewable energy deployment through national and regional targets and standards;
- Encourage deployment on bodies of water and otherwise useless land as opposed to natural water bodies, which could necessitate a more thorough environmental approval process.

2) POLICIES IN JAPAN

With over 200 MW of FSPV deployed and the development of a local FSPV industry that generates jobs, Japan has also emerged as a global leader in FSPV technology [98]. Japan's specific power system requirements, hilly terrain, and land constraints have contributed to the interest in FSPV systems. Following the Fukushima nuclear accident, the nation was determined to increase the deployment of renewable energy (RE). Consequently, through significant FITs, research and development funding, home solar subsidies, and renewable portfolio standards, the government has strengthened its support for renewable energy technologies (RETs), particularly solar energy. FITs were initially the primary incentive mechanism used to promote the deployment of solar PV; however,

TABLE 11. Risk identification, risk rating and proposed recommendations for mitigations [74].

Type of Risks	Risk	Risk Rating	Proposed Recommendations: Possible Actions and Mitigations
Social Risk:	Health and safety	4A	1. Stakeholder engagement: Engaging with stakeholders, such as local communities, authorities, and users of the water body, can help to identify concerns and address them in the design and operation of the floating solar PV system. Communication should be ongoing to keep stakeholders informed about the project and to address any concerns that may arise. 2. Safety measures: Appropriate safety measures should be implemented to ensure the safety of personnel involved in the installation and operation of the floating solar PV system. Safety equipment, such as life jackets, helmets, and safety ropes, should be provided and used as necessary. 3. Navigation aids: Navigation aids, such as buoys and markers, should be installed around the floating solar PV system to alert boat operators and other water users of its presence. This can help to prevent collisions and other accidents. 4. Access control: Access to the floating solar PV system should be controlled to prevent unauthorized access and ensure the safety of personnel and the integrity of the system. Security measures, such as fencing or barriers, should be installed as necessary. 5. Environmental impact assessment (EIA): Conducting a full-blown EIA can help to identify potential environmental and social risks and develop appropriate mitigation measures. The EIA should consider the potential impacts of the floating solar PV system on the water body, wildlife, and other natural resources. 6. Water quality monitoring: Monitoring the water quality around the floating solar PV system can help to identify any potential impacts on the water body and aquatic life. The monitoring should be conducted regularly to ensure that any adverse impacts are identified and addressed promptly.
Technical	Stability	4B	1. Design and engineering: The floating solar PV system design and engineering should be carefully planned and executed to ensure that it is stable and able to withstand various weather conditions, such as high winds, waves, and currents. The system should also be designed to minimize shading of the solar panels, which can reduce energy output. 2. Anchor and mooring systems: The anchor and mooring systems used to secure the floating solar PV system should be robust and designed to withstand the forces of wind, waves, and currents. The anchor and mooring systems should also be regularly inspected and maintained to ensure that they are functioning properly. 3. Electrical system: The electrical system of the floating solar PV system should be designed and installed to prevent short circuits, electrical shocks, and other hazards. Ground fault protection devices should be installed to protect the system from electrical faults. 4. Monitoring and maintenance: Regular monitoring and maintenance of the floating solar PV system can help to identify potential issues before they become major problems. The system should be inspected regularly for signs of wear and tear, corrosion, or damage. Maintenance activities should be carried out by trained personnel using appropriate tools and equipment. 5. Emergency response plan: An emergency response plan should be developed and communicated to all personnel involved in the installation and operation of the floating solar PV system. The plan should include procedures for responding to various types of emergencies, such as severe weather, equipment failure, or other incidents that could compromise the stability of the system
Economic	Installation and maintenance costs	4D	1. Cost-benefit analysis: Conducting a cost-benefit analysis can help to identify the economic benefits of the floating solar PV system and determine whether it is a financially viable investment. The analysis should consider the installation costs, maintenance costs, and the potential revenue from energy sales. 2. Project financing: Securing project financing can help to manage the economic risks of the floating solar PV system. Financing options may include debt or equity financing, grants or subsidies, and power purchase agreements (PPAs). 3. Maintenance planning: Developing a maintenance plan can help to reduce the long-term costs of the floating solar PV system. The plan should include regular inspections and maintenance activities, such as cleaning the solar panels, checking the mooring systems, and replacing damaged equipment. 4. Remote monitoring: Implementing a remote monitoring system can help to reduce the maintenance costs of the floating solar PV system. The system can provide real-time data on the performance of the system, allowing for proactive maintenance and reducing the need for on-site inspections. 5. Equipment selection: Selecting high-quality equipment can help to reduce the maintenance costs of the floating solar PV system. High-quality equipment may be more expensive upfront, but it can reduce the frequency and cost of repairs and replacements over the life of the system. 6. Long-term contracts: Entering long-term contracts with suppliers and contractors can help to manage the economic risks of the floating solar PV system. Long-term contracts can provide cost stability and reduce the risk of price volatility for equipment and services.

TABLE 11. ***(Continued.)*** **Risk identification, risk rating and proposed recommendations for mitigations [74].**

Technical	Corrosion	3D	1. Use corrosion-resistant materials: The use of corrosion-resistant materials in the design and construction of the floating solar PV system can help to mitigate the risk of corrosion. Materials such as stainless steel, aluminium, and coated steel can be used to prevent rust and corrosion. 2. Coatings and paints: Coatings and paints can be used to provide an additional layer of protection against corrosion. Specialized coatings and paints are available for use in marine environments that can help to mitigate corrosion risks. 3. Regular maintenance: Regular maintenance of the floating solar PV system can help to prevent and detect corrosion. Inspections and maintenance should be conducted regularly to identify any signs of corrosion and address them promptly. 4. Grounding and bonding: Proper grounding and bonding can help to prevent galvanic corrosion, which occurs when two dissimilar metals come into contact in the presence of an electrolyte.

these FITs are presently being phased out to stimulate the development of cost-effective technologies. In addition, the Asian Development Bank (ADB) and Japan International Cooperation Agency (JICA) have provided technical assistance and project funding to boost the implementation of solar PV in and outside Japan. Summary of lessons learned from Japan regarding FSPV deployment [98].

- The adoption of floating photovoltaic (FSPV) technology could be facilitated by offering clearly defined and mutually reinforcing incentives and constraints for energy advancement, land use, farming, and water resource administration, while considering the societal values associated with these systems and minimizing any associated obstacles or uncertainties.
- Encouraging the installation of FSPV systems in countries where land is limited and there is competition between agricultural use and human settlements could alleviate land-use challenges. In addition, such initiatives should comply with policies aimed at providing low-cost, sustainable electricity.
- There are various strategies to promote the adoption of FSPV technology, such as providing research and development assistance, financing pilot and demonstration projects, and advancing renewable energy (RE) targets. However, it is important to note that, as technology becomes more widely used, there may be increased resistance to ongoing government funding.
- Additionally, setting ambitious RE targets can encourage investment in emerging renewable energy technologies.
- A practical way to diversify the energy mix is to support the expansion of the emerging renewable energy technologies.

3) POLICIES IN SOUTH KOREA

South Korea uses solar PV deployment as part of its plan to decarbonize the power sector. Owing to the public opposition to the use of forests and agricultural land for solar development, the government is focusing on FSPV systems, which have become attractive alternatives to land-based PV systems. This emphasis on FSPV systems has made South Korea a frontrunner with at least 100 MW of installed FSPVs [98].

Recently, the country announced a $3.96 billion investment in offshore FSPV projects with a capacity of 2,100 MW. The government has been supporting FSPV through financial support for research and development, national renewable energy targets favorable to FSPV, and other emerging renewable energy technologies (RETs) [98].

In 2009, the government initiated its backing for FSPV by providing financial support for preliminary research, development, and demonstration (RD&D) endeavors. Subsequently, in 2011, the government joined forces with independent power producers to sponsor the experimental projects. Then, in 2013, the government revised its Renewable Portfolio Standards (RPS) by giving the greatest Renewable Energy Credit importance to FSPV systems and rooftop PV systems under the solar category [98], [99].

South Korea provides valuable insights into promoting the adoption of FSPV systems, including:

- Encouraging the adoption of FSPV systems can lead to the establishment of a local FSPV industry, generating job opportunities and avoiding conflicts caused by land-based PV systems competing with other land use needs.
- Encouraging the adoption of FSPV technology requires a multifaceted approach that involves both research and development (R&D) and deployment support.

F. POLICY RECOMMENDATIONS FOR FSPV IN THE PHILIPPINES

The policy recommendation for wider adoption of the FSPV system is a suggestion or proposal for a course of action that could be taken by policymakers, government officials, or organizations. Based on this descriptive study based on the literature available for FSPV systems, the following are the strategic recommendations provided in Table 12 aimed at providing guidance on the best way to achieve a desired outcome or objective a much wider adoption of the FSPV system in the country, and Table 13 provides for the implementation plan and the involvement of the government in

TABLE 12. Policy recommendations for FSPV systems [74].

Area	Item	Recommendations
Economic or Financial	1	Provide financial support for research and development (R&D) of FSPV technology to help reduce costs and improve efficiency. Research and development will be supported to improve the performance and cost-effectiveness of floating solar photovoltaic systems.
	2	Provide incentives and subsidies for the adoption of FSPV systems, such as tax credits, subsidies, and feed-in-tariffs, to encourage investment and reduce the payback period for investors.
	3	Develop clear, consistent, and mutually reinforcing incentives for energy development can mitigate uncertainties in FSPV projects and decrease the cost of project development.
	4	By investing in education and training programs for students and professionals, local communities can establish an FSPV workforce, equip industry experts with the necessary skills to support the growing FSPV sector, and potentially reduce project development costs.
	5	To promote equal opportunity in the FSPV and other renewable energy technology industries, gender mainstreaming could be included as part of workforce development initiatives.
	6	A national skills assessment could be conducted to achieve three objectives: (1) assess the current state of the FSPV workforce, (2) evaluate the transferability of skills from related industries, such as offshore, hydropower, water production, and land-based solar industries, and (3) determine the skills or certifications required in the FSPV industry that would strengthen and expand the FSPV workforce.
Technical	7	Develop and implement standards for the design, construction, material selection, operation, and maintenance of FSPV systems to ensure safe and efficient operation: ▪ Design and engineering: The floating solar PV system design and engineering should be carefully planned and executed to ensure that it is stable and able to withstand various weather conditions, such as high winds, waves, and currents. The system should also be designed to minimize shading of the solar panels, which can reduce energy output. ▪ Anchor and mooring systems: The anchor and mooring systems used to secure the floating solar PV system should be robust and designed to withstand the forces of wind, waves, and currents. The anchor and mooring systems should also be regularly inspected and maintained to ensure that they are functioning properly. ▪ Electrical Safety: FSPV systems must comply with electrical safety regulations, including grounding, isolation, and protection against electrical faults; ▪ Navigation Safety: Floating solar PV systems must not interfere with navigation or pose a hazard to boaters or another watercraft. There may be regulations related to the location of the system and the placement of warning markers. ▪ Maintenance and Decommissioning: Floating solar PV systems must be regularly maintained and eventually decommissioned in an environmentally responsible manner. There may be regulations related to the maintenance and decommissioning processes, including the disposal of materials and the restoration of the water body. ▪ Marine Life Protection: Floating solar PV systems must not cause harm to marine life. There may be regulations related to the design of the system, such as the distance between floats, the height of the system above the water, and the use of anti-reflective coatings on the panels. ▪ Water Quality: Floating solar PV systems must not have negative impacts on water quality. There may be regulations related to the type of materials used in the system, such as the type of panels, floats, anchors, and mooring systems.
	8	The establishment of reliable certifications and consistent standards can help reduce policy uncertainty, provide guidelines for operation and maintenance of FSPV systems, and ensure the installation of high-quality FSPV systems.
	9	Conduct research and development on the resilience of FSPV installations to natural disasters may enhance confidence in the performance of FSPV systems during extreme weather events.
	10	Grid integration planning approaches that are enhanced can simplify the process of integrating FSPV systems onto the grid.
Regulatory	11	Develop a regulatory framework that supports the development of FSPV systems and ensures the sustainable use of water resources.
	12	Setting clear and ambitious targets for FSPV deployment to create a sense of urgency and provide a clear direction for investors and industry stakeholders.
	13	Increased engagement with policymakers and financial institutions can raise awareness of FPV systems, resulting in greater support for investing in R&D and deployment projects. Policymakers lacking sufficient knowledge of renewable energy, including FSPV, may struggle to design effective policies and regulations.
	14	Simplifying FPV-permitting guidelines can lower permit fees and minimize discrepancies, thereby making project development more accessible.
	15	Promoting public-private partnerships to foster collaboration and knowledge sharing between government agencies, research institutions, and industry stakeholders.
	16	Integration of FSPV into the overall energy mix for larger capacities to support the grid during periods of peak demand
	17	Encouraging international cooperation and knowledge exchange to promote the development of a global FSPV industry and accelerate the deployment of this technology.

TABLE 12. *(Continued.)* **Policy recommendations for FSPV systems [74].**

Social	18	To avoid delays in the development process of the FSPV project, it is crucial to prioritize obtaining public support and buy-in through public outreach and engagement.
	19	To garner public support and buy-in for floating solar, it can be helpful to create educational initiatives aimed at informing people about the advantages of FSPV systems. Additionally, it is important to implement intentional analysis and tracking of public acceptance for floating solar as a means of monitoring progress.
	20	Access to the floating solar PV system should be controlled to prevent unauthorized access and ensure the safety of personnel and the integrity of the system. Security measures, such as fencing or barriers, should be installed as necessary.
Environmental	21	Evaluation of the environmental impact of FSPV to ensure that they do not cause harm to aquatic ecosystems or wildlife.
	22	Governmental 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 FSPV systems. This could shorten the environmental review process and reduce project development costs.
	23	Monitoring and assessment of FSPV to identify any opportunities for improvement;

TABLE 13. **Proposed implementation plan for FSPV policy recommendations [74].**

1	The implementation of this policy recommendations will be coordinated with the Department of Energy (DOE), Department of Science and Technology (DOST), Local Government Units in collaboration with other relevant government agencies, industry associations, and stakeholders.
2	The performance of floating solar photovoltaic systems will be regularly evaluated and the policy will be reviewed and updated as necessary to ensure its continued effectiveness.
3	The implementation plan will include the development of guidelines, regulations, and best practices for the design, construction, and operation of floating solar photovoltaic systems.
4	The implementation plan will also include the establishment of programs and incentives to support the deployment of floating solar photovoltaic systems.

the country. The goal of this policy recommendation is to influence decision makers and promote positive changes in policy, practice, or behavior.

V. CONCLUSION

In conclusion, FSPV systems represent a promising solution to the growing global energy demand, and the potential of this technology to play a significant role in the transition to a low-carbon, sustainable future cannot be ignored. Overall, floating solar PV systems can provide reliable and efficient renewable energy sources, particularly in locations in which land-based systems are impractical or unavailable.

Risks and barriers associated with FSPV systems were identified in this study and categorized as environmental, technical, regulatory, economic, and social based on the risk assessment conducted using the HIRA methodology. Based on the risk assessment, the risks with a higher probability of occurrence and severity were (1) social risk (health and safety), (3) technical risk (stability), (4) economic risk (installation and maintenance costs), and (5) technical risk (corrosion). To mitigate these risks, the proposed recommendations - actions and mitigation–are outlined. Overall, with community engagement or buy-in, proper planning, installation, and maintenance, the risks associated with FSPV systems can be managed effectively, and the benefits of this technology can be realized.

This case study provides a comprehensive overview of the risks and challenges associated with FSPV systems and helps to identify the best ways to promote the growth and success of this promising technology by identifying policies highlighting the programs and incentives from various countries ahead in FSPV deployments, such as China, Japan, and South Korea, which currently comprise over 90% of FSPV deployments. In China, the three programs that accelerated the FSPV deployments in the late 2010s were: (1) standard FIT "Build Plan"; (2) the poverty alleviation program; and (3) the top runner program.

Japan has also emerged as a global leader in FSPV technology through significant FITs, which is the primary incentive mechanism used to promote the deployment of solar PV. Research and development assistance, financing pilot and demonstration projects, and advancing renewable energy (RE) targets were implemented to promote the adoption of FSPV technology.

The Korean government collaborated with independent power producers to finance pilot projects and revised its Renewable Portfolio Standards (RPS) by assigning the highest Renewable Energy Credit weighting within the solar class to FSPV and rooftop PV systems. With these programs, a local FSPV industry was established to generate job opportunities and avoid conflict. The Korean government has pursued research and development (R&D) and deployment support to encourage the adoption of FSPV technology.

The findings of this study contribute to the ongoing discussions surrounding the development and deployment of FSPV systems and provide valuable insights for policymakers, industry stakeholders, and other interested parties.

REFERENCES

[1] A. Qazi, F. Hussain, N. A. B. Rahim, G. Hardaker, D. Alghazzawi, K. Shaban, and K. Haruna, ''Towards sustainable energy: A systematic review of renewable energy sources, technologies, and public opinions,'' *IEEE Access*, vol. 7, pp. 63837–63851, 2019, doi: 10.1109/ACCESS.2019.2906402.

[2] J. A. B. Wirawan and I. Garniwa, ''Risk analysis development of solar floating power plant in the sea with Monte Carlo method,'' in *Proc. 3rd Int. Conf. Inf. Technol., Inf. Syst. Elect. Eng.*, Yogyakarta, Indonesia, Nov. 2018, pp. 396–401, doi: 10.1109/ICITISEE.2018.8720956.

[3] A. Banik and A. Sengupta, ''Scope, challenges, opportunities and future goal assessment of floating solar park,'' in *Proc. Innov. Energy Manage. Renew. Resour.* Kolkata, India: IEEE, Feb. 2021, pp. 1–5, doi: 10.1109/IEMRE52042.2021.9386735.

[4] R. Kanotra and R. Shankar, ''Floating solar photovoltaic mooring system design and analysis,'' in *Proc. OCEANS*, Chennai, India, Feb. 2022, pp. 1–9, doi: 10.1109/OCEANSChennai45887.2022.9775352.

[5] V. Kosorić, S.-K. Lau, A. Tablada, M. Bieri, and A. M. Nobre, ''A holistic strategy for successful photovoltaic (PV) implementation into Singapore's built environment,'' *Sustainability*, vol. 13, no. 11, p. 6452, Jun. 2021, doi: 10.3390/su13116452.

[6] M. M. Farag, F. F. Ahmad, A. K. Hamid, C. Ghenai, M. Bettayeb, and M. Alchadirchy, ''Performance assessment of a hybrid PV/T system during winter season under Sharjah climate,'' in *Proc. Int. Conf. Electr., Comput., Commun. Mechatronics Eng. (ICECCME)*, Oct. 2021, pp. 1–5.

[7] N. K. Almarzooqi, F. F. Ahmad, A. K. Hamid, C. Ghenai, M. M. Farag, and T. Salameh, ''Experimental investigation of the effect of optical filters on the performance of the solar photovoltaic system,'' *Energy Rep.*, vol. 9, pp. 336–344, May 2023.

[8] M. M. Farag and A. K. Hamid, ''Performance assessment of rooftop PV/T systems based on adaptive and smart cooling facility scheme—A case in hot climatic conditions of Sharjah, UAE,'' in *Proc. 3rd Int. Conf. Distrib. Sens. Intell. Syst. (ICDSIS)*, vol. 2022, Oct. 2022, pp. 198–207.

[9] S. Mahmood, S. Deilami, and S. Taghizadeh, ''Floating solar PV and hydropower in Australia: Feasibility, future investigations and challenges,'' in *Proc. 31st Australas. Universities Power Eng. Conf. (AUPEC)*, Sep. 2021, pp. 1–5, doi: 10.1109/AUPEC52110.2021.9597714.

[10] S. Gadzanku, L. Beshilas, and U. Grunwald. (Jun. 1, 2021). *Enabling Floating Solar Photovoltaic (FPV) Deployment: Review of Barriers to FPV Deployment in Southeast Asia*. Accessed: Feb. 25, 2023. [Online]. Available: https://www.osti.gov/biblio/1787553

[11] J. C. R. Kumar and M. Majid, ''Floating solar photovoltaic plants in India—A rapid transition to a green energy market and sustainable future,'' *Energy Environ.*, vol. 34, no. 2, pp. 304–358, Nov. 2021, doi: 10.1177/0958305x211057185.

[12] M. Vujanović, Q. Wang, M. Mohsen, N. Duić, and J. Yan, ''Recent progress in sustainable energy-efficient technologies and environmental impacts on energy systems,'' *Appl. Energy*, vol. 283, Feb. 2021, Art. no. 116280, doi: 10.1016/j.apenergy.2020.116280.

[13] M. Fereshtehpour, R. J. Sabbaghian, A. Farrokhi, E. B. Jovein, and E. E. Sarindizaj, ''Evaluation of factors governing the use of floating solar system: A study on Iran's important water infrastructures,'' *Renew. Energy*, vol. 171, pp. 1171–1187, Jun. 2021, doi: 10.1016/j.renene.2020.12.005.

[14] A. C. Santos-Borja, ''Dealing with uncertainties: Floating solar farm in natural lakes,'' *IOP Conf. Ser., Earth Environ. Sci.*, vol. 789, no. 1, Jun. 2021, Art. no. 012036, doi: 10.1088/1755-1315/789/1/012036.

[15] S. Oliveira-Pinto and J. Stokkermans, ''Assessment of the potential of different floating solar technologies—Overview and analysis of different case studies,'' *Energy Convers. Manage.*, vol. 211, May 2020, Art. no. 112747, doi: 10.1016/j.enconman.2020.112747.

[16] N. Lee, U. Grunwald, E. Rosenlieb, H. Mirletz, A. Aznar, R. Spencer, and S. Cox, ''Hybrid floating solar photovoltaics-hydropower systems: Benefits and global assessment of technical potential,'' *Renew. Energy*, vol. 162, pp. 1415–1427, Dec. 2020, doi: 10.1016/j.renene.2020.08.080.

[17] S. Gadzanku, L. Beshilas, and U. Grunwald. (Jun. 1, 2021). *Enabling Floating Solar Photovoltaic (FPV) Deployment: Review of Barriers to FPV Deployment in Southeast Asia*. [Online]. Available: https://www.osti.gov

[18] J. Aleluia, P. Tharakan, A. P. Chikkatur, G. Shrimali, and X. Chen, ''Accelerating a clean energy transition in Southeast Asia: Role of governments and public policy,'' *Renew. Sustain. Energy Rev.*, vol. 159, May 2022, Art. no. 112226, doi: 10.1016/j.rser.2022.112226.

[19] N. J. Martin and J. L. Rice, ''Developing renewable energy supply in Queensland, Australia: A study of the barriers, targets, policies and actions,'' *Renew. Energy*, vol. 44, pp. 119–127, Aug. 2012, doi: 10.1016/j.renene.2012.01.006.

[20] C. R. Kumar. J and M. A. Majid, ''Renewable energy for sustainable development in india: Current status, future prospects, challenges, employment, and investment opportunities,'' *Energy, Sustainability Soc.*, vol. 10, no. 1, pp. 1–36, Jan. 2020. [Online]. Available: https://link.springer.com/content/pdf/10.1186/s13705-019-0232-1.pdf, doi: 10.1186/s13705-019-0232-1.

[21] A. Sen, A. S. Mohankar, A. Khamaj, and S. Karmakar, ''Emerging OSH issues in installation and maintenance of floating solar photovoltaic projects and their link with sustainable development goals,'' *Risk Manage. Healthcare Policy*, vol. 14, pp. 1939–1957, May 2021, doi: 10.2147/rmhp.s304732.

[22] R. Thabet, D. Bork, A. Boufaied, E. Lamine, O. Korbaa, and H. Pingaud, ''Risk-aware business process management using multi-view modeling: Method and tool,'' *Requirements Eng.*, vol. 26, no. 3, pp. 371–397, Mar. 2021, doi: 10.1007/s00766-021-00348-2.

[23] A. M. Radhi, ''Risk assessment optimization for decision support using intelligent model based on fuzzy inference renewable rules,'' *Indonesian J. Electr. Eng. Comput. Sci.*, vol. 19, no. 2, p. 1028, Aug. 2020, doi: 10.11591/ijeecs.v19.i2.pp1028-1035.

[24] M. Leimeister and A. Kolios, ''Reliability-based design optimization of a spar-type floating offshore wind turbine support structure,'' *Rel. Eng. Syst. Saf.*, vol. 213, Sep. 2021, Art. no. 107666, doi: 10.1016/j.ress.2021.107666.

[25] P. Raj Sinha, L. E. Whitman, and D. Malzahn, ''Methodology to mitigate supplier risk in an aerospace supply chain,'' *Supply Chain Manag., Int. J.*, vol. 9, no. 2, pp. 154–168, Apr. 2004, doi: 10.1108/13598540410527051.

[26] R. Kaplan and A. Mikes. (2012). *Managing Risks: A New Framework*. [Online]. Available: https://www.nsf.gov/oirm/bocomm/meetings/spring_2018/Managing_Risks_A_New_Framework.pdf

[27] T. Aven, ''Risk assessment and risk management: Review of recent advances on their foundation,'' *Eur. J. Oper. Res.*, vol. 253, no. 1, pp. 1–13, Aug. 2016.

[28] C. Foussard and C. D. Remis, ''Risk assessment: Methods on purpose?'' *Int. J. Process Syst. Eng.*, vol. 2, no. 4, p. 337, 2014, doi: 10.1504/ijpse.2014.070090.

[29] M. H. A. Abdullah, M. Othman, S. Kasim, and S. A. Mohamed, ''Evolving spiking neural networks methods for classification problem: A case study in flood events risk assessment,'' *Indonesian J. Electr. Eng. Comput. Sci.*, vol. 16, no. 1, p. 222, Oct. 2019, doi: 10.11591/ijeecs.v16.i1.pp222-229.

[30] S. Aminbakhsh, M. Gunduz, and R. Sonmez, ''Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects,'' *J. Saf. Res.*, vol. 46, pp. 99–105, Sep. 2013, doi: 10.1016/j.jsr.2013.05.003.

[31] R. Holzmann, L. Sherburne-Benz, and E. Tesliuc. (2003). *Social Risk Management: The World Bank's Approach to Social Protection in a Globalizing World*. [Online]. Available: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=2952a0ecddd0dd2e4a4a228d6a7573ea58e0a3df

[32] B. Baharuddin and M. M. Yusof, ''Evaluation of risk management practices in information systems project in the public sector,'' *Jurnal Pengurusan*, vol. 2, pp. 23–36, Jun. 2018, doi: 10.17576/pengurusan-2018-53-03.

[33] I. Daroen. (2021). *Risk Assessment of Offshore Floating Photovoltaic Systems: Methodology for Technological Risks*. Accessed: Feb. 25, 2023. [Online]. Available: https://repository.tudelft.nl/islandora/object/uuid:d66919f1-9d88-4992-8130-9d9a07ab4f02

[34] H.-P. Berg, ''Risk management: Procedures, methods and experiences,'' *Rel., Theory Appl.*, vol. 5, no. 2, p. 17, 2010. [Online]. Available: https://cyberleninka.ru/article/n/risk-management-procedures-methods-and-experiences

[35] Z. Jin, J. Gambatese, D. Liu, and V. Dharmapalan, ''Using 4D BIM to assess construction risks during the design phase,'' *Eng., Construct. Architectural Manage.*, vol. 26, no. 11, pp. 2637–2654, Nov. 2019, doi: 10.1108/ecam-09-2018-0379.

[36] S. Ayber and N. Erginel, ''Developing the neutrosophic fuzzy FMEA method as evaluating risk assessment tool,'' in *Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making*, Jul. 2019, pp. 1130–1137, doi: 10.1007/978-3-030-23756-1_133.

[37] J. Gao, F. Guo, X. Li, X. Huang, and H. Men, ''Risk assessment of offshore photovoltaic projects under probabilistic linguistic environment,'' *Renew. Energy*, vol. 163, pp. 172–187, Jan. 2021, doi: 10.1016/j.renene.2020.08.110.

[38] E. Akyuz, O. Arslan, and O. Turan, ''Application of fuzzy logic to fault tree and event tree analysis of the risk for cargo liquefaction on board ship,'' *Appl. Ocean Res.*, vol. 101, Aug. 2020, Art. no. 102238, doi: 10.1016/j.apor.2020.102238.

[39] A. Mascia, A. M. Cirafici, A. Bongiovanni, G. Colotti, G. Lacerra, M. Di Carlo, F. A. Digilio, G. L. Liguori, A. Lanati, and A. Kisslinger, ''A failure mode and effect analysis (FMEA)-based approach for risk assessment of scientific processes in non-regulated research laboratories,'' *Accreditation Quality Assurance*, vol. 25, nos. 5–6, pp. 311–321, Aug. 2020, doi: 10.1007/s00769-020-01441-9.

[40] C. Starr and C. Whipple, ''Risks of risk decisions,'' *Science*, vol. 208, no. 4448, pp. 1114–1119, Jun. 1980. Accessed: Feb. 25, 2023. [Online]. Available: https://www.jstor.org/stable/1683701

[41] K. Lane, M. Fuller, and G. Gagnon, ''Operator-informed risk assessment tool: Opportunities and barriers to support risk management practices,'' *AWWA Water Sci.*, vol. 4, no. 5, pp. 1–17, Sep. 2022. [Online]. Available: https://awwa.onlinelibrary.wiley.com/doi/pdfdirect/10.1002/aws2.1307?casa_token=5Q5iFNsMbmgAAAAA:tA1yhgNZjRRruhshTVHk4wn1v4BCooBt1ozVIA1VQZcDQWlf7edLKBwugs6XC5ZZNoTDItkJNprDSW5h, doi: 10.1002/aws2.1307.

[42] K. Sporleder, V. Naumann, J. Bauer, S. Richter, A. Hähnel, S. Großer, M. Turek, and C. Hagendorf, ''Root cause analysis on corrosive potential-induced degradation effects at the rear side of bifacial silicon PERC solar cells,'' *Sol. Energy Mater. Sol. Cells*, vol. 201, Oct. 2019, Art. no. 110062, doi: 10.1016/j.solmat.2019.110062.

[43] CDC. (Aug. 31, 2022). *CDC Policy Process | AD for Policy and Strategy | CDC*. [Online]. Available: https://www.cdc.gov/policy/opaph/process/index.html

[44] C. W. Anderson, ''The place of principles in policy analysis,'' *Amer. Political Sci. Rev.*, vol. 73, no. 3, pp. 711–723, Sep. 1979, doi: 10.2307/1955399.

[45] J. Zietlow, J. A. Hankin, A. Seidner, and T. O'Brien, *Financial Management for Nonprofit Organizations: Policies and Practices*. Hoboken, NJ, USA: Wiley, 2018. Feb. 25, 2023. [Online]. Available: https://books.google.com.ph/books?hl=en&lr=&id=T0VRDwAAQBAJ&oi=fnd&pg=PR23&dq=%5B50%5D%09Zietlow

[46] N. Wilton, *An Introduction to Human Resource Management*. Thousand Oaks, CA, USA: SAGE, 2019, pp. 1–632. [Online]. Available: https://www.torrossa.com/en/resources/an/5017769

[47] L. Lewis and T. H. Tietenberg, *Environmental Economics and Policy*. Evanston, IL, USA: Routledge, 2019. Accessed: Feb. 25, 2023. [Online]. Available: https://books.google.com.ph/books?hl=en&lr=&id=zzr3DwAAQBAJ&oi=fnd&pg=PP1&dq=%5B50%5D%09Lewis

[48] C. Althaus, S. Ball, P. Bridgman, G. Davis, and D. Threlfall, *The Australian Policy Handbook: A Practical Guide to the Policymaking Process*. New York, NY, USA: Taylor & Francis, 2022. Accessed: Feb. 5, 2023. [Online]. Available: https://books.google.com.ph/books?hl=en&lr=&id=85uaEAAAQBAJ&oi=fnd&pg=PT195&dq=%5B50%5D%09Althaus

[49] M. S. Sidney, ''Policy formulation: Design and tools,'' in *Handbook of Public Policy Analysis: Theory, Politics, and Methods*, Jan. 2017, pp. 79–88, doi: 10.4324/9781315093192-13.

[50] C. Knill and J. Tosun, *Public Policy: A New Introduction*. London, U.K.: Bloomsbury Publishing, 2020. Accessed: Feb. 25, 2023. [Online]. Available: https://books.google.com.ph/books?hl=en&lr=&id=KxxHEAAAQBAJ&oi=fnd&pg=PR12&dq=%5B53%5D%09Knill

[51] S. W. Ndiritu and M. K. Engola, ''The effectiveness of feed-in-tariff policy in promoting power generation from renewable energy in Kenya,'' *Renew. Energy*, vol. 161, pp. 593–605, Dec. 2020, doi: 10.1016/j.renene.2020.07.082.

[52] F. J. Ramírez, A. Honrubia-Escribano, E. Gómez-Lázaro, and D. T. Pham, ''Combining feed-in tariffs and net-metering schemes to balance development in adoption of photovoltaic energy: Comparative economic assessment and policy implications for European countries,'' *Energy Policy*, vol. 102, pp. 440–452, Mar. 2017, doi: 10.1016/j.enpol.2016.12.040.

[53] A. Queiroz, F. T. Najafi, and P. Hanrahan, ''Implementation and results of solar feed-in-tariff in Gainesville, Florida,'' *J. Energy Eng.*, vol. 143, no. 1, pp. 1–8, Feb. 2017. [Online]. Available: https://ascelibrary.org/doi/full/10.1061/%28ASCE%29EY.1943-7897.0000373?casa_token=WXP5CyECViMAAAAA%3APgI9qGH1TwDY_w5jw9Nr1iYU2CMXcizYeOpR-mGLH8LXuRfK8s_OE8LiJBrZ7niJv394Crx-dHRR, doi: 10.1061/(ASCE)EY.1943-7897.0000373.

[54] M. Castaneda, S. Zapata, J. Cherni, A. J. Aristizabal, and I. Dyner, ''The long-term effects of cautious feed-in tariff reductions on photovoltaic generation in the UK residential sector,'' *Renew. Energy*, vol. 155, pp. 1432–1443, Aug. 2020, doi: 10.1016/j.renene.2020.04.051.

[55] A. S. Pascaris, ''Examining existing policy to inform a comprehensive legal framework for agrivoltaics in the US,'' *Energy Policy*, vol. 159, Dec. 2021, Art. no. 112620, doi: 10.1016/j.enpol.2021.112620.

[56] C. Reid. *The Costs of Affordable Housing Production: Insights From California's 9% Low-Income Housing Tax Credit Program*. Accessed: Jan. 15, 2023. [Online]. Available: https://ternercenter.berkeley.edu/wp-content/uploads/pdfs/LIHTC_Construction_Costs_March_2020.pdf

[57] A. Ali, W. Li, R. Hussain, X. He, B. Williams, and A. Memon, ''Overview of current microgrid policies, incentives and barriers in the European Union, United States and China,'' *Sustainability*, vol. 9, no. 7, p. 1146, Jun. 2017, doi: 10.3390/su9071146.

[58] M. M. M. Hanifah, H. Zainuddin, and M. Z. Hussin, ''Establishment of standard reference environment for photovoltaic nominal operating cell temperature testing with dedicated approach for tropical region,'' *Indonesian J. Electr. Eng. Comput. Sci.*, vol. 12, no. 1, p. 433, Oct. 2018, doi: 10.11591/ijeecs.v12.i1.pp433-440.

[59] C. Marcantonini and A. D. Ellerman, ''The cost of abating CO_2 emissions by renewable energy incentives in Germany,'' in *Proc. 10th Int. Conf. Eur. Energy Market (EEM)*, Stockholm, Sweden, May 2013, pp. 1–8, doi: 10.1109/EEM.2013.6607312.

[60] J. H. Yzquierdo and A. Sánchez-Bayón, ''The European transition to a green energy production model: Italian feed-in tariffs scheme & Trentino alto adige mini wind farms case study,'' *Small Bus. Int. Rev.*, vol. 4, no. 2, pp. 39–52, Jul. 2020, doi: 10.26784/sbir.v4i2.246.

[61] N. J. Martin and J. L. Rice, ''Examining the use of concept analysis and mapping software for renewable energy feed-in tariff design,'' *Renew. Energy*, vol. 113, pp. 211–220, Dec. 2017, doi: 10.1016/j.renene.2017.05.068.

[62] P. Rövekamp, M. Schöpf, F. Wagon, M. Weibelzahl, and G. Fridgen, ''Renewable electricity business models in a post feed-in tariff era,'' *Energy*, vol. 216, Feb. 2021, Art. no. 119228, doi: 10.1016/j.energy.2020.119228.

[63] C. Inês, P. L. Guilherme, M.-G. Esther, G. Swantje, H. Stephen, and H. Lars, ''Regulatory challenges and opportunities for collective renewable energy prosumers in the EU,'' *Energy Policy*, vol. 138, Mar. 2020, Art. no. 111212, doi: 10.1016/j.enpol.2019.111212.

[64] T. N. Do, P. J. Burke, K. G. H. Baldwin, and C. T. Nguyen, ''Underlying drivers and barriers for solar photovoltaics diffusion: The case of Vietnam,'' *Energy Policy*, vol. 144, Sep. 2020, Art. no. 111561, doi: 10.1016/j.enpol.2020.111561.

[65] N. Ahmad Ludin, N. A. A. Affandi, K. Purvis-Roberts, A. Ahmad, M. A. Ibrahim, K. Sopian, and S. Jusoh, ''Environmental impact and levelised cost of energy analysis of solar photovoltaic systems in selected Asia Pacific region: A cradle-to-grave approach,'' *Sustainability*, vol. 13, no. 1, p. 396, Jan. 2021, doi: 10.3390/su13010396.

[66] A. K. Shukla, K. Sudhakar, and P. Baredar, ''Renewable energy resources in South Asian countries: Challenges, policy and recommendations,'' *Resource-Efficient Technol.*, vol. 3, no. 3, pp. 342–346, Sep. 2017, doi: 10.1016/j.reffit.2016.12.003.

[67] A. Banik and A. Sengupta. (Feb. 1, 2021). *Scope, Challenges, Opportunities and Future Goal Assessment of Floating Solar Park*. EEE Xplore. Accessed: Aug. 12, 2022. [Online]. Available: https://ieeexplore.ieee.org/iel7/9386328/9386519/09386735.pdf

[68] S. Gadzanku. (Jul. 1, 2022). *Enabling Floating Solar (FPV) Deployment: Policy and Operational Considerations*. Accessed: Feb. 25, 2023. [Online]. Available: https://www.osti.gov/biblio/1875536

[69] M. Abid, Z. Abid, J. Sagin, R. Murtaza, D. Sarbassov, and M. Shabbir, ''Prospects of floating photovoltaic technology and its implementation in central and South Asian countries,'' *Int. J. Environ. Sci. Technol.*, vol. 16, no. 3, pp. 1755–1762, Oct. 2018, doi: 10.1007/s13762-018-2080-5.

[70] C. Cheng, A. Blakers, M. Stocks, and B. Lu, ''100% renewable energy in Japan,'' *Energy Convers. Manage.*, vol. 255, Mar. 2022, Art. no. 115299, doi: 10.1016/j.enconman.2022.115299.

[71] D. Wen, W. Gao, F. Qian, Q. Gu, and J. Ren, "Development of solar photovoltaic industry and market in China, Germany, Japan and the United States of America using incentive policies," *Energy Exploration Exploitation*, vol. 39, no. 5, pp. 1429–1456, Dec. 2020, doi: 10.1177/0144598720979256.
[72] M. deCastro, S. Salvador, M. Gómez-Gesteira, X. Costoya, D. Carvalho, F. J. Sanz-Larruga, and L. Gimeno, "Europe, China and the United States: Three different approaches to the development of offshore wind energy," *Renew. Sustain. Energy Rev.*, vol. 109, pp. 55–70, Jul. 2019, doi: 10.1016/j.rser.2019.04.025.
[73] F. M. A. Lorilla and R. Barroca, "Challenges and recent developments in solar tracking strategies for concentrated solar parabolic dish," *Indonesian J. Electr. Eng. Comput. Sci.*, vol. 26, no. 3, p. 1368, Jun. 2022, doi: 10.11591/ijeecs.v26.i3.pp1368-1378.
[74] S. Sreenath, K. Sudhakar, and A. F. Yusop, "Solar photovoltaics in airport: Risk assessment and mitigation strategies," *Environ. Impact Assessment Rev.*, vol. 84, Sep. 2020, Art. no. 106418, doi: 10.1016/j.eiar.2020.106418.
[75] M. E. Samper, F. A. Eldali, and S. Suryanarayanan, "Risk assessment in planning high penetrations of solar photovoltaic installations in distribution systems," *Int. J. Electr. Power Energy Syst.*, vol. 104, pp. 724–733, Jan. 2019, doi: 10.1016/j.ijepes.2018.07.052.
[76] I. Daroen, "Risk assessment of offshore floating photovoltaic systems: Methodology for technological risks," M.S. thesis, Dept. Mech., Maritime Mater. Eng., Delft Univ. Technol., Delft, The Netherlands, 2021. [Online]. Available: https://repository.tudelft.nl/islandora/object/uuid:d66919f1-9d88-4992-8130-9d9a07ab4f02
[77] R. G. Sanchez, I. Kougias, M. Moner-Girona, F. Fahl, and A. Jäger-Waldau, "Assessment of floating solar photovoltaics potential in existing hydropower reservoirs in Africa," *Renew. Energy*, vol. 169, pp. 687–699, May 2021, doi: 10.1016/j.renene.2021.01.041.
[78] M. Kumar, H. M. Niyaz, and R. Gupta, "Challenges and opportunities towards the development of floating photovoltaic systems," *Sol. Energy Mater. Sol. Cells*, vol. 233, Dec. 2021, Art. no. 111408, doi: 10.1016/j.solmat.2021.111408.
[79] A. M. Pringle, R. M. Handler, and J. M. Pearce, "Aquavoltaics: Synergies for dual use of water area for solar photovoltaic electricity generation and aquaculture," *Renew. Sustain. Energy Rev.*, vol. 80, pp. 572–584, Dec. 2017, doi: 10.1016/j.rser.2017.05.191.
[80] A. Rahman, O. Farrok, and M. M. Haque, "Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic," *Renew. Sustain. Energy Rev.*, vol. 161, Jun. 2022, Art. no. 112279, doi: 10.1016/j.rser.2022.112279.
[81] V. Bax, W. I. van de Lageweg, B. van den Berg, R. Hoosemans, and T. Terpstra, "Will it float? Exploring the social feasibility of floating solar energy infrastructure in The Netherlands," *Energy Res. Social Sci.*, vol. 89, Jul. 2022, Art. no. 102569, doi: 10.1016/j.erss.2022.102569.
[82] J. Mayer, W. van der Gaast, G. Bachner, and E. Spijker, "Qualitative and quantitative risk assessment of expanding photovoltaics in The Netherlands," *Environ. Innov. Societal Transitions*, vol. 35, pp. 357–368, Jun. 2020, doi: 10.1016/j.eist.2019.10.010.
[83] J. E. Worren. (2012). *Assessing the Risks in Solar Project Development, Renewable Energy World*. Accessed: Apr. 30, 2021. [Online]. Available: https://www.renewableenergyworld.com/om/assessing-the-risks-in-solar-project-development/#gref
[84] Y. Wu and T. Zhang, "Risk assessment of offshore wave-wind-solar-compressed air energy storage power plant through fuzzy comprehensive evaluation model," *Energy*, vol. 223, May 2021, Art. no. 120057, doi: 10.1016/j.energy.2021.120057.
[85] J. Haas, J. Khalighi, A. de la Fuente, S. U. Gerbersdorf, W. Nowak, and P.-J. Chen, "Floating photovoltaic plants: Ecological impacts versus hydropower operation flexibility," *Energy Convers. Manage.*, vol. 206, Feb. 2020, Art. no. 112414, doi: 10.1016/j.enconman.2019.112414.
[86] S. Jain, T. Sharma, and A. K. Gupta, "End-of-life management of solar PV waste in India: Situation analysis and proposed policy framework," *Renew. Sustain. Energy Rev.*, vol. 153, Jan. 2022, Art. no. 111774, doi: 10.1016/j.rser.2021.111774.
[87] S. Gadzanku, L. Beshilas, and B. Grunwald. (2021). *Enabling Floating Solar Photovoltaic (FPV) Deployment Review of Barriers To FPV Deployment in Southeast Asia*. [Online]. Available: https://www.nrel.gov/docs/fy21osti/76867.pdf
[88] S. Oliveira-Pinto and J. Stokkermans, "Marine floating solar plants: An overview of potential, challenges and feasibility," *Proc. Inst. Civil Engineers Maritime Eng.*, vol. 173, no. 4, pp. 120–135, Dec. 2020, doi: 10.1680/jmaen.2020.10.
[89] A. Sahu, N. Yadav, and K. Sudhakar, "Floating photovoltaic power plant: A review," *Renew. Sustain. Energy Rev.*, vol. 66, pp. 815–824, Dec. 2016, doi: 10.1016/j.rser.2016.08.051.
[90] S. Gorjian, H. Sharon, H. Ebadi, K. Kant, F. B. Scavo, and G. M. Tina, "Recent technical advancements, economics and environmental impacts of floating photovoltaic solar energy conversion systems," *J. Cleaner Prod.*, vol. 278, Jan. 2021, Art. no. 124285, doi: 10.1016/j.jclepro.2020.124285.
[91] M. Jelić, M. Batić, N. Tomašević, A. Barney, H. Polatidis, T. Crosbie, D. Abi Ghanem, M. Short, and G. Pillai, "Towards self-sustainable island grids through optimal utilization of renewable energy potential and community engagement," *Energies*, vol. 13, no. 13, p. 3386, Jul. 2020, doi: 10.3390/en13133386.
[92] N. M. Kumar, S. Chakraborty, S. K. Yadav, J. Singh, and S. S. Chopra, "Advancing simulation tools specific to floating solar photovoltaic systems—Comparative analysis of field-measured and simulated energy performance," *Sustain. Energy Technol. Assessments*, vol. 52, Aug. 2022, Art. no. 102168, doi: 10.1016/j.seta.2022.102168.
[93] J. Ellis, L. L. Re, and F. D. Lorenzo. (May 2022). *How National Governments Can Facilitate Increased Mitigation Action From Non-Party Stakeholders: Insights From Urban Renewable Electricity and REDD+*. Accessed: Feb. 25, 2023. [Online]. Available: https://ideas.repec.org/p/oec/envaab/2022-02-en.html
[94] *Where Sun Meets Water*, World Bank, Washington, DC, USA, 2019, doi: 10.1596/32804.
[95] P.-Y. Nie, C. Wang, and Y.-H. Chen, "Top runner program in China: A theoretical analysis for potential subsidies," *Energy Strategy Rev.*, vol. 21, pp. 157–162, Aug. 2018, doi: 10.1016/j.esr.2018.06.006.
[96] D. Chang, D. Gao, X. Xu, X. Wang, Y. Ju, and X. Shen, "Top-runner incentive scheme in China: A theoretical and empirical study for industrial pollution control," *Environ. Sci. Pollut. Res.*, vol. 28, no. 23, pp. 29344–29356, Feb. 2021, doi: 10.1007/s11356-021-12561-1.
[97] S. Gadzanku, L. Beshilas, and U. Grunwald. (Jul. 1, 2021). *Enabling Floating Solar Photovoltaic (FPV) Deployment: Review of Barriers to FPV Deployment in Southeast Asia*. [Online]. Available: https://www.osti.gov
[98] S. Gadzanku, N. Lee, and A. Dyreson. (Jun. 16, 2022). *Enabling Floating Solar Photovoltaic (FPV) Deployment: Exploring the Operational Benefits of Floating Solar-Hydropower Hybrids*. Accessed: Feb. 25, 2023. [Online]. Available: https://www.osti.gov/biblio/1873503
[99] Y. Lee and K. Kim, "Analytical strategies for floating solar PV policy development in South Korea," *Membrane Water Treatment*, vol. 13, no. 1, pp. 7–14, 2022, doi: 10.12989/mwt.2022.13.1.007.

JEFFREY T. DELLOSA (Member, IEEE) received the B.Sc. degree in electronics and communications engineering from Mindanao State University–Iligan Institute of Technology (MSU-IIT), Iligan, Philippines, in March 2000, and the M.Eng. and D.Eng. degrees from Ateneo de Davao University, Davao, Philippines.

From 2000 to 2007, he was a New Product Introduction and Assembly Development Engineering with Philips Semiconductors Philippines Inc. (PSPI) and NXP Semiconductors, Philippines Inc., Cabuyao, Laguna, Philippines. In June 2007, he joined Caraga State University (CSU), Butuan, Philippines. He is currently a Faculty Member with the Department of Electronics Engineering (DECE), College of Engineering and Geosciences (CEGS), CSU. He is also the Vice President for Research, Innovation and Extension and an Alumnus of the Royal Academy of Engineering, London, U.K., and the Asian Institute of Management (AIM), Manila, Philippines, under the Leaders in Innovation Fellowship (LIF) Program. He was the Manager of the Innovation and Technology Support Office and the Director of the Technology Transfer and Licensing Office for over seven years. He is the author of technical papers presented in various IEEE conferences.

Dr. Dellosa has served as the session chair and a reviewer of the IEEE conferences. He was a three-term Governor of the Institute of Electronics Engineers of the Philippines Inc. (IECEP), Caraga Chapter, from 2017 to 2019.

ELEONOR V. PALCONIT received the D.Eng. degree in energy engineering from the University of San Carlos (USC), Cebu, Philippines.

She is currently an Associate Professor and the Department Chair of Computer Engineering with the School of Engineering and Architecture (SEA), Ateneo de Davao University, Davao, Philippines. She is actively promoting renewable energy specially in the marine sector. She is the Project Leader of the ongoing Ocean Renewable Energy project funded by the DOST-PCIEERD. She was also involved in the collaborative project in titled "Integrated Energy System Site Selection Assessment (IESSLA)" for Accelerated Business and Project Development in Off-Grid Island funded by U.K. She is involved in the ongoing project in the Newton Fund Marine Resource Assessment. Her research interests include clean energy in marine transportation, ocean renewable energy, system engineering design, and renewable energy.

NELSON H. ENANO JR. received the D.Eng. degree from Ateneo de Davao University, Davao, Philippines.

From 2004 to 2006, he was a University Lecturer with the University of the Philippines, Davao. From May 2007 to August 2007, he was an Intern with the International Telecommunication Union (ITU). From August 2007 to July 2008, he was the Managing Editor with ETH Zürich–Technische Universiteit Delft (TU Delft) TPM Network Industries. From August 2008 to March 2009, he was a Junior Researcher with the TU Delft Technology, Policy, and Management. From July 2013 to June 2015, he was an Associate Researcher with the International Energy Policy Institute, University College of London (UCL), Adelaide, South Australia. From July 2015 to November 2017, he was an Associate Researcher with the Centre for Energy and Environmental Markets, University of New South Wales (UNSW), Sydney, NSW, Australia. He is currently the Director for the Center for Renewable Energy and Appropriate Technologies (CREATE), Ateneo de Davao University, and the Consortium Chair with the Mindanao Renewable Energy Research and Development Center (MREC), Davao. The MREC is a consortium established by the Department of Science and Technology (DOST), Philippines.