WORLD BANK GROUP

SAWI SOUTH ASIA WATER INITIATIVE

UNLOCKING THE POTENTIAL OF FLOATING SOLAR PHOTOVOLTAICS IN INDIA

VOLUME 1: MAIN REPORT

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OCTOBER 2023

Disclaimer

The study focuses on Floating Solar Photovoltaics (FSPV) based power plants on inland waterbodies and details of applicable standards are included in the Volume 2: Guidance Document.

The study reflects the view of the World Bank and does not necessarily reflect the view of the Government of India (GoI) and the findings of the study are not binding on the GoI.

FOREWORD
by Country Director, India

Ramping up renewable energy is an integral part of India's plans to reduce greenhouse gas emissions to meet its Nationally Determined Contributions (NDC) under the Paris Agreement. In this context, India is taking rapid steps to incorporate abundantly available and affordable renewable resources into its energy mix. Yet while India's renewable energy resources are widely available, they often cannot be fully utilized due to a variety of factors, such as the paucity of large tracts of suitable land, or the high opportunity cost of land, among others.

This report builds a compelling case for India to look beyond land and institute an ecosystem that supports the installation and operationalization of floating solar photovoltaics (FSPV) power plants. Since these plants are installed on the underutilized surfaces of large water bodies, no land needs to be diverted from other uses. The installation of FSPVs also spurs job creation and catalyzes the development of a domestic value chain as some of the components, such as floaters, need to be manufactured close to installation sites. They also provide a range of other benefits as they generate relatively more power than ground-mounted solar plants (due to the cooling effect of water) and better utilize shared infrastructure such as transmission systems, wherever available.

India has an estimated potential of about 300 gigawatts of FSPV but less than 350 megawatts has been realized to date. The report analyses the constraints leading to the moderate pace of FSPV installation in the country and draws from global experience to suggest measures that can unlock the FSPV potential in India and other South Asian countries. The report also provides insights on the technical standards to be adopted in the use of floating solar technology.

I hope this study contributes towards deepening the understanding of policymakers and developers and facilitates the deployment of floating solar power plants, contributing to the achievement of India's NDC objectives, promoting energy independence and creating jobs for the people.

Auguste Tano Kouame
Country Director, India
The World Bank

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* The South Asia Water Initiative (SAWI) was a multi-donor Trust Fund supported by the UK, Australia and Norway and managed by the World Bank. SAWI supported a rich portfolio of activities designed to increase regional cooperation in the management of the major Himalayan river systems in South Asia to deliver sustainable, fair and inclusive development and climate resilience. It did this through four complementary outcome areas: strengthening awareness and knowledge on regional water issues; enhancing technical and policy capacity across the region; dialogue and participatory decision processes to build trust and confidence; and scoping and informing investment designs. Its work, structured across three river basins (Indus, Ganges and Brahmaputra) and the Sundarbans Landscape, spanned seven countries: Afghanistan, Bangladesh, Bhutan, China, India, Nepal and Pakistan.

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ABBREVIATIONS

AC	Alternating Current
ADB	Asian Development Bank
Asia EDGE	Asia Enhancing Development and Growth through Energy
ASTM	ASTM International
BHEL	Bharat Heavy Electricals Limited
BIS	Bureau of Indian Standards
BoS	Balance of System
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CEB	Ceylon Electricity Board
CEIG	Chief Electrical Inspector to Government
CERC	Central Electricity Regulatory Commission
COD	Commercial Operation Date/Chemical Oxygen Demand
CPPIB	Canada Pension Plan Investment Board
CTU	Central Transmission Utility
CUF	Capacity Utilization Factor
CWC	Central Water Commission
DC	Direct Current
DHD	Da Mi Hydropower Joint Stock Company
DISCOMs	Distribution Companies
DNV	Det Norske Veritas
DPPA	Direct Power Purchase Agreement
DVC	Damodar Valley Corporation
EGAT	Electricity Generating Authority of Thailand
EPC	Engineering, procurement, and construction
E&S	Environment and Social
ESCAP	Economic and Social Commission for Asia and the Pacific
ESIA	Environmental and Social Impact Assessment
ESMF	Environment and Social Management Framework
ESS	Environmental and Social Standards
EVN	Vietnam Electricity
FAT	Factory Acceptance Test
FI	Financial Intermediaries

FiP	Feed in Premium
FiT	Feed in Tariff
FoS	Factor of Safety
FSPV	Floating Solar Photovoltaics
FY	Financial Year
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIS	Geographic Information System
GoI	Government of India
GPS	Global Positioning System
GVMC	Greater Visakhapatnam Municipal Corporation
GW	Giga Watt
HDPE	High Density Polyethylene
HPP	Hydropower plants
HSE	Health, Safety and Environment
IBA	Important Bird Areas
ICMBA	Important Coastal and Marine Biodiversity Areas
IEC	International Electrotechnical Commission
IFI	International Financial Institution
IIT	Indian Institute of Technology
IP	Ingress Protection
IPP	Independent Power Producer
IREDA	Indian Renewable Energy Development Agency Limited
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
IUCN	International Union for Conservation of Nature
IVN	Institute for Nature Education and Sustainability
JRI	Japan Research Institute
KSEB	Kerala State Electricity Board
LCOE	Levelized cost of energy
LNG	Liquefied Natural Gas
METI	Ministry of Economy, Trade and Industry
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest & Climate Change
MOIT	Ministry of Industry and Trade
MoP	Ministry of Power
MoU	Memorandum of Understanding
MPWRD	Madhya Pradesh Water Resources Department
NDA	Non-disclosure agreement
NETRA	NTPC Energy Technology Research Alliance
NGT	National Green Tribunal
NHPC	National Hydro Power Corporation

NISE	National Institute of Solar Energy
NREL	National Renewable Energy Laboratory
NSM	National Solar Mission
O&M	Operation & Maintenance
OMPL	ONGC Mangalore Petrochemicals Limited
ONGC	Oil and Natural Gas Corporation
OPEX	Operating Expense
PGCIL	Power Grid Corporation of India Limited
pH	power of Hydrogen
PPA	Power Purchase Agreement
PPE	Personal Protective Equipment
PMC	Project Management Consultancy
PSA	Power Sale Agreement
PV	Photovoltaic
QA/QC	Quality Assurance/Quality Control
QAP	Quality Assurance Plan
R&D	Research & Development
RE	Renewable Energy
RESCO	Renewable Energy Service Company
RGCCPP	Rajiv Gandhi Combined Cycle Power Plant
RoW	Right of Way
RUMSL	Rewa Ultra Mega Solar Limited
SAARC	South Asian Association for Regional Cooperation
SAREH	South Asia Regional Energy Hub
SBI	State Bank of India
SCADA	Supervisory Control and Data Acquisition
SCG	Siam Cement Group
SDE++	Stimulation of Sustainable Energy Production and Climate Transition
SEAC	Solar Energy Application Centre
SEB	State Electricity Board
SECI	Solar Energy Corporation of India Limited
SERC	State Electricity Regulatory Commission
SOP	Standard Operating Procedure
STU	State Transmission Utility
TERI	The Energy and Resources Institute
TPP	Thermal Power Plant
TW	Tera Watt
USAID	United States Agency for International Development
UV	Ultraviolet
VGF	Viability Gap Funding
WAPDA	Water & Power Development Authority
WB/WBG	World Bank/World Bank Group

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Developing countries, in order to avoid the worst consequences of a changing climate are identifying, assessing, and deploying renewable energy solutions at scale that can facilitate in fulfilling their climate and development objectives. This is transformative for countries that are dependent on costly energy imports and are exposed to both price volatility and energy security risk if the fuel supply is partially or fully disrupted[1]. Within this frame of reference, the developing economies are incorporating available, reliable and affordable resources to power their economic activities and meet their national development objectives[2]. Although renewable energy resources are widely available in many developing countries, they often cannot be fully developed and utilized due to a variety of factors that include, amongst others, availability of suitable land parcels (large tracts with little or no undulations) for establishing utility scale solar plants which have large spatial footprints, alternate uses of available land that may lead to unwarranted land-energy conflicts, or, absence of technical know-how and value chains.

These impediments to establishing large scale renewable energy projects, though significant, make the most compelling case for developing countries towards instituting an ecosystem that supports the installation and operationalization of floating solar photovoltaic (PV) plants (FSPV). An FSPV, apart from avoiding land-energy conflicts and providing fillip to development of a domestic value chain can also provide a multitude of benefits such as (a) lowering land acquisition and site preparation costs; (b) gaining potential system efficiency and production due to temperature-regulating effect of water; (c) improving solar PV performance due to reduced shading effects; (d) increasing panel density for a given area; (e) power system benefits and reduction of costs when co-located with power plants; (f) reducing costs of waterbody maintenance due to decreased algae growth; (g) potentially reduced rates of water evaporation and thereby increasing availability of water for other uses such as irrigation; and (h) converting potentially underused space into areas that allow for revenue-generating use (Booth, Aznar and Lee 2019).

An FSPV, installed over an underutilized water body, in addition to providing additionality in energy generation[3] (Liu, et al. 2018) also overcomes some of the limitations of

1 These fuel supply disruptions could be caused by regional conflicts, geopolitical tensions or the financial situation of local utilities – all of which undermine economic growth and development objectives.

2 For example, India's envision to achieve net zero by 2070. The net zero commitment is buttressed by enterprising but ambitious near-term targets such as 500 GW of renewables capacity, 50 percent of requirements to be met with renewables, one billion tonne reduction in cumulative emissions and 45 percent lower emissions intensity of gross domestic product (GDP) by 2030.

3. PV modules, by virtue of being in close proximity with water stay relatively cooler due to the effect of evaporative cooling. Based on the temperature coefficient of the specific PV module used, this can translate into energy gains vis-à-vis a conventional ground mounted or rooftop solar PV power plant. The gains due to evaporative cooling can however be offset by the lower tilt angle of a FSPV. Hence, a combination of factors – [a] evaporative cooling; and [b] inclination angle of solar PV module determines the net benefit.

conventional ground mounted solar PV power plants[4] (Rosa-Clot and Tina 2018). FSPV technology, based on learnings from installed projects and supported by a combination of standardization, innovation, and reduction in costs, is rapidly approaching maturity.

The summary of the three volumes (Volume 1: Main Report, Volume 2: Guidance Document, and Volume 3: Green Jobs) of the report is presented below.

Mapping of Value Chain and Identification of Barriers

A comprehensive assessment of the value chain was undertaken to broaden the understanding of roles, responsibilities and preparedness of the involved stakeholders. This was based on desk review and consultative meetings. During the mapping, an emphasis had been laid on stakeholders' engagement and collection of important data and information thereby facilitating an analysis of the barriers to implementation and help design the path forward. The FSPV segment has a multitude of stakeholders who influence business models, access to capital, energy off-take, and technology maturity. When mapping stakeholders, the role of parallel industries including prospective players from sectors like automobile, plastics, maritime, oil and gas has been highlighted as such category could potentially have a lower entry cost into the FSPV manufacturing arena.

In summary, the following drivers were identified to address gaps and increase adoption rate:

- Visibility of scale of deployment for the short and medium terms;
- Prioritisation of less complex waterbodies for building scale and experience;
- Cost and design optimization;
- Standardization;
- Comprehensive data bank ensuring availability of requisite technical and non-technical information;
- Continued focus on research and development; and
- Training/re-training of workforce.

Based on the analysis of these barriers and their impacts on various risk parameters, several mitigation measures are recommended:

- Set FSPV targets, facilitate roadmap studies, resource characterization and prioritization for FSPV;
- Create a plug-and-play model for large-scale projects under Solar Park Scheme of the Government of India (GoI) with a minimum 1-year tender-calendar[5];
- Upscale manufacturing of floaters, solar panels, and balance of plant;
- Build skills and capacity with a focus on gender and diversity inclusion;
- Develop standards and guidelines, certification of components, and testing infrastructure;
- Research & Development (R&D), single & reliable source of information & its dissemination through regular workshops and other outreach programs such as newspapers;
- Facilitate development of different business models (for example, the Renewable Energy Service Company [RESCO] model[6]) for FSPV projects; and,
- Create a separate credit line for FSPV, similar to the one created for rooftop solar.

4 The benefits include reduced land usage, less shading, less soiling due to dust, reduction of evaporation loss and large potential.
5 MNRE has granted approval to at least six floating solar parks with a cumulative capacity of 1,805 MW.
6 RESCO is a company that provides energy to the consumers from renewable energy resources. In this model, offtaker utilizes the services of a developer who owns and operates the project, and the off taker pays only for the electricity generated.

Benchmarking the FSPV Ecosystem in India Against International Practices

The benchmarking covered three countries - Japan, Netherlands, and Vietnam, post analysis of all countries active in the domain. The three selected countries have a good solar potential but have challenges with respect to making appropriate land available for large scale solar projects. This emerged as common driver for floating solar in the shortlisted countries. The countries, post shortlisting, have been analyzed from the aspects of policy and regulatory landscapes, technical capabilities, make versus buy strategy of components, and research activities. Further, select global practices related to incentives offered, business models adopted, innovation in components manufactured, and R&D activities have been discussed for a few other prominent countries in FSPV as well. Key learnings from the study for India include:

- Although the existence of mandatory targets for floating solar generation has provided a major push in some other countries, technology agnostic targets would work better in India's developing market, particularly for emerging technologies including floating solar. Innovation and scale-up of such technologies is best left to open market forces.
- Successful pilots create confidence among players and can spur investments in scalable FSPV plants. Floating solar projects could be promoted through government agencies such as under Solar Park Scheme.
- The government should focus on creating a conducive environment while allowing market forces to run competitive price discovery.
- In the short term, components can be imported but, over time, it is important to develop manufacturing capability within the country.
- Government support is required to create standards that are robust but also flexible enough to allow for innovative solutions.
- While private players are expected to set up the projects, the government can collaborate by providing incentives.

Review of Technical Standards and Tenders

FSPV plants worldwide have similar technical challenges including the absence of specific design codes or guidelines to determine design loads, factor of safety, complex and computationally intensive structural system simulations, and the lack of a unified approach for solar PV and float testing. For sustainable growth, it is important that the technical standards remain flexible to encourage innovation, while ensuring quality and reliability. Considering the nascency of the FSPV technology, the following approach was adopted for the assessment with specific focus on inland and nearshore waterbodies:

- Review and evaluate the gaps in the relevant technical standards for design, material, installation, operation and maintenance of various specialised equipment while adopting it for floating solar applications.
- Formulate a Guidance Document (refer to **Volume 2: Guidance Document**) based on the above review, current knowledge of the FSPV system and the standardization efforts already undertaken.
- Review the technical requirements included in some of the tenders issued in India and provide recommendations for improvement/optimization.

The Volume 2: Guidance Document (as referred above) provides a review of the technology, deliberations for technology selection for FSPV plants, challenges/issues which may arise during design, installation and operation & maintenance (O&M) of FSPV equipment, mitigation to address the challenges and, finally, a review of the technical standards (and gaps in these standards) for FSPV applications. This guidance document is intended to make the reader acquainted with the broad requirements of components deployed in a FSPV system and is not envisioned to be a detailed document in itself. Further, Det Norske Veritas' (DNV) *Recommended Practice DNV-RP-0584 (Design, development and operation of FSPV projects)* can be referred to for more information on requirements, recommendations and guidelines for design, development, operation and decommissioning of FSPV systems. The recommended practice focuses on the lifecycle of FSPV systems and has been developed based on the recognized and agreed best practices and relevant requirements from existing standards, codes and guidelines. The World Bank's publication *Where Sun Meets Water: Floating Solar Handbook for Practitioners* is also a good reference for practical guidelines on FSPV projects, evolved from lessons learned from early projects.

Green Jobs potential across FSPV value chain

While India has achieved good progress in the field of solar technology, building its floating solar capacity in the years to come will require personnel with the capabilities and skills to drive success.

A detailed analysis of the roles, skills and experience required across the FSPV value chain, covering Feasibility, Design and Development, Manufacturing & Procurement, Construction, Operations & Maintenance, and Decommissioning was conducted (refer to the Volume 3: Green Jobs). Further, an attempt has been made to identify the emerging skills in the solar landscape based on an understanding of the current scenario and a study of leading practices.

While there is large employment potential for FSPV in India, a significant proportion of the Indian workforce would need to be trained with the necessary skills. Hence, building skills to bridge this gap is of paramount importance and must be addressed. There is considerable overlap with the solar sector in terms of skill requirements. However, there is a need to build expertise in the fields such as geology, geophysics, oceanography, hydrography engineering, marine biology, environmental monitoring, and marine architecture. FSPV requires an advanced level of specialization in areas such as design, construction, O&M of under and over water civil structures, electrical and mechanical works. A high level of knowledge and proficiency in offshore first aid, fire-fighting and prevention and personal survival techniques have emerged as critical skills across levels.

Key challenges pertaining to availability of the right skills are:

- Limited government impetus on building skills for FSPV;
- Limited upskilling and re-training opportunities for existing manpower; and
- Lack of specialized course, curriculum and institutions for knowledge building.

Some of these challenges and a mitigation plan to overcome them have been discussed in detail in the Volume 3: Green Jobs.

Regional Co-Operation and Status of FSPV in South Asian Countries

Many South Asian countries are characterized by similar key features such as high population, high incidence of poverty, low per capita electricity consumption, and high dependence on imported crude oil and petroleum products. While each country faces a unique set of challenges, regional co-operation will help to accelerate the energy transition through knowledge sharing and integrated market approach. As other countries in South Asia are relatively at an earlier stage than India for FSPV development, India can play a bigger role in the whole value chain of floating solar for these countries, drawing on its early learnings and mitigation strategies for challenges. The summary of recommendations from this assessment would apply to South Asian countries, with different degrees of importance.

India can facilitate regional knowledge transfer through:

1. Regional forums (including but not limited to)
    - International Solar Alliance (ISA)
    - South Asia Regional Energy Hub (SAREH) under the United States Agency for International Development (USAID)
    - International Renewable Energy Agency (IRENA): Investment forums in South Asia
    - South Asian Association for Regional Cooperation (SAARC) Expert Group on Renewable Energy
    - United Nations; Economic and Social Commission for Asia and the Pacific (ESCAP)
2. Bilateral relations
3. Joint conferences and initiatives

1. INTRODUCTION

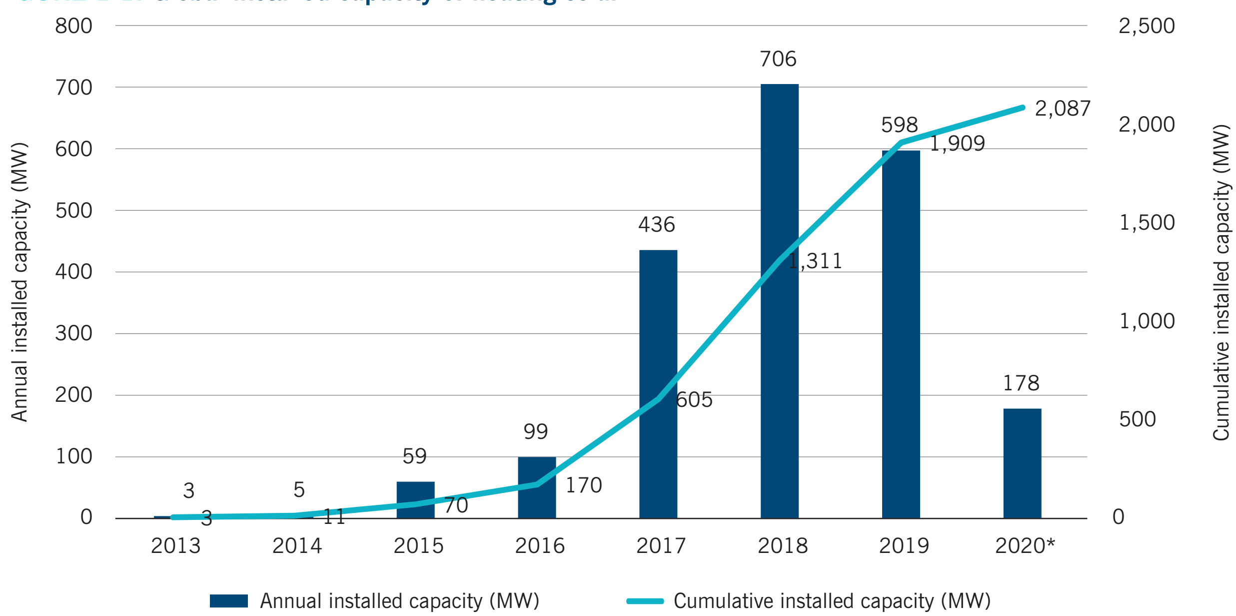
1 INTRODUCTION

The world's waterbodies have great potential for power generation. It is estimated that man-made inland waters alone have the potential to support up to 4 Tera Watt (TW) of new power capacity globally[7]. Furthermore, a study[8] by the US Department of Energy's National Renewable Energy Laboratory (NREL) states that deploying floating solar plants on existing hydropower reservoirs around the world would meet around 50 percent of total electricity demand.

Realising the huge potential of FSPV, several countries such as China, India, Japan, Vietnam, Republic of Korea, Netherlands, Taiwan, and the United Kingdom have been developing such projects. As of September 2020, the global FSPV installed capacity was around 2.1 giga watt (GW)[9].

The country-wise FSPV installed capacities of the world are shown in **Figure 1.2**. Asia is

FIGURE 1.1: Global installed capacity of floating solar



*Until September 2020

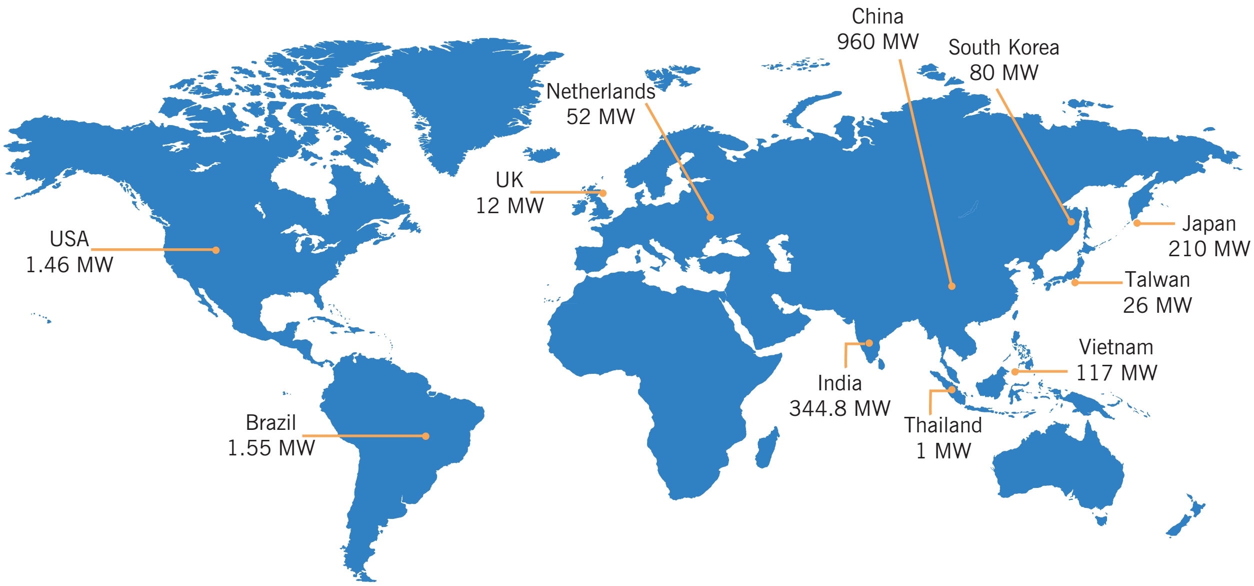
Source: World Bank analysis based on market research

7 Hopson, C. (2020, October 15). *Floating solar going global with 10GW more by 2025: Fitch | Recharge | Latest Renewable Energy News.* https://www.rechargenews.com/transition/floating-solar-going-global-with-10gw-more-by-2025-fitch/2-1-894336

8 Lee, N. (2020, September 29). *Untapped Potential Exists for Blending Hydropower, Floating PV.* https://www.nrel.gov/news/press/2020/untapped-potential-exists-for-blending-hydropower-floating-pv.html

9 SolarPlaza. (2021, February). Top 50 Operational Floating Solar Projects 2021.

FIGURE 1.2: Country-wise FSPV installed capacities[10]



Source: World Bank analysis based on market research

expected to lead the future growth, mostly driven by China, India, Republic of Korea, Taiwan, Thailand, and Vietnam. China, the largest market for FSPV, deploys systems with Feed in Tariff (FiT) or without subsidy support. Korea selected a preferred bidder to implement the world's largest FSPV installation of 2.1 GW in the tidal flats of the southwest coast, in addition to an estimated onshore FSPV market potential of around 9.7 GW. Taiwan and Vietnam have been following a FiT system for FSPV systems from 2017 and 2020, respectively. Thailand has announced plans to build 2.7 GW by 2037 (total of 16 FSPV systems on dams).

Some studies[11] have indicated the potential for about **280-300 GW** of floating solar in India, considering only grid connected projects on still water. Given the potential and benefits, India could mainstream floating solar and ramp-up its annual installation in the range of that witnessed for ground mounted solar. This will be possible only when the value chain is ready to support such expansion and growth. Regarding major FSPV projects in India, NTPC developed a 100 kilowatt-peak (kWp) FSPV plant in 2017, at their Rajiv Gandhi Combined Cycle Power Plant (RGCCPP) in Kayamkulam, Kerala, which has now been expanded to 92 megawatt (MW). NTPC Energy Technology Research Alliance (NETRA), the R&D arm of NTPC, developed the floating platform for the pilot 100 kWp plant, while the latter was installed and commissioned by Tata Power. NTPC Limited has also developed a 25 MW unit at Simhadri power plant, a 20 MW unit at Auraiya, Uttar Pradesh and a 100 MW at Ramagundam, Telengana. A number of FSPV tenders have been floated by various agencies, including a 600 MW capacity plant in Omkareshwar dam in Madhya Pradesh by Rewa Ultra Mega Solar Limited (RUMSL), of which the first phase of 280 MW is currently under construction.

The scenarios in **Table 1.1** are proposed as part of this study for upscaling and

10 The list of FSPV plants in Japan, Netherlands & Vietnam and in India are listed in Appendix C and Appendix D, respectively.
11 Acharya, M. & Devraj, S. (2019). Floating Solar Photovoltaic (FSPV): A Third Pillar to Solar PV Sector? | *TERI Discussion Paper: Output of the ETC India Project* | New Delhi: The Energy and Resources Institute (TERI).

TABLE 1.1: Scenarios for Upscaling of FSPV

Short term (3 years) Institutionalize (Inland/nearshore waterbodies)	Medium term (7 years) Mainstream (Inland/nearshore waterbodies)	Long term (10 years) Expand (Inland/nearshore waterbodies and Offshore)
• Policy support • Standardization • Deployment strategies • Skilling • Build local capacity for 2-3 GW annual installations	• Economies of scale • Product & service optimization • Capacity enhancement to 6-8 GW of annual installations	• Next round of growth fuelled by innovation • Floating solar to go offshore • Integration with offshore wind • Part of larger picture (support to green hydrogen)

mainstreaming FSPV in India. The short- and medium-term targets can have specific focus on inland and nearshore waterbodies, while the expansion phase in the long term could include offshore installations. Further, based on the analysis of current market readiness carried out in Section 2.2.1, it is anticipated that the value chain needs to be upscaled by more than five times to achieve 2-3 GW of annual installations in the next three years and more than 10 times to achieve 6-8 GW of annual installations.

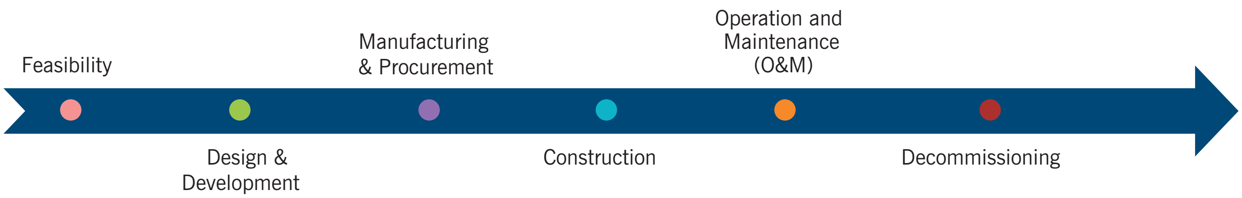
2. MAPPING OF THE VALUE CHAIN AND IDENTIFICATION OF BARRIERS

2 MAPPING OF THE VALUE CHAIN AND IDENTIFICATION OF BARRIERS

2.1. Value Chain Mapping

The value chain of FSPV projects include the primary activities depicted in **Figure 2.1** below:

FIGURE 2.1: Value chain of FSPV projects



To enable large-scale deployment in the FSPV sector, key stakeholders across the value chain have been identified to address the following key topics:

- Current and prospective players in the segment
- Level of indigenization of supply chain and services
- Drivers to establish economies of scale in the value chain and enable cost competitiveness
- Reliability of system and equipment
- Leveraging knowledge from other related sectors
- Competence development across the value chain

2.1.1. Equipment, Services & Skills

As a first step, the major equipment, services, and skill sets relevant to the different value chain phases of a FSPV plant were mapped.

Tables 2.1, 2.2 and **2.3** present the outcome of the mapping. Access to equipment, services, and skills is not difficult to come by in India, owing to the presence of large- and small-scale players from parallel industries, experienced freelancers, and float manufacturers, with some players offering turnkey solutions.

TABLE 2.1: List of major equipment applicable for the different value chain phases

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
Major Equipment	▪ **Bathymetry** ♦ Survey platform/vessel/ anchored barge to mount all equipment/sensors, ♦ Single or multi beam echo sounders	▪ Photovoltaic (PV) Modules ▪ Floaters ▪ Mooring & anchoring devices	▪ Boats ▪ Tools and tackles ▪ Diving equipment ▪ High precision GPS	▪ Boats ▪ Tools and tackles ▪ Diving equipment ▪ Cranes

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
	♦ LiDAR airborne acquisition ♦ Direct measurements with hand-lead line and graduated pole ♦ High precision Global Positioning System (GPS) ♦ Magnetometer ♦ Gyrocompass ♦ Motion sensor ♦ Sound Velocity Profiler ♦ Bar Check Equipment ♦ Auto Level/Total Station with accessories ♦ Navigation and Processing Software ▪ **Geotechnical investigation** ♦ Van Veen grab sampler ♦ Niskin water sampler ♦ Geo-electrical resistivity meter ♦ Thermal conductivity meter ♦ Seismograph ♦ Cable percussion or rotary drilling machine ♦ Loading device ♦ Stiff frame for compression tests ♦ Digital or analogue dynamometer ♦ Digital or analogue micrometre ♦ Auxiliary tools (shovel, magnetic tripod, slings, hydraulic jack, hooks, pile load cap, etc.)	▪ Inverters ▪ Balance of System: combiner boxes, transformers, cables, weather station, cleaning robots, Supervisory Control and Data Acquisition (SCADA) and monitoring system[12] ▪ Blow moulding/ injection moulding machines ▪ Test equipment for materials and finished products ▪ Health, Safety and Environment (HSE) equipment	▪ Drones (infrared thermography, underwater inspection) ▪ Cranes ▪ Ambulance ▪ Personal Protective Equipment (PPE) against drowning, slips, electric shock etc.	▪ Ambulance ▪ PPE against drowning, slips, electric shock etc. ▪ Machines for recycling

12 With respect to digitalization i.e., Internet of Things (IoT), control system, measurement, and other components, it is imperative that interoperability of components is ensured.

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
	▪ **Geophysical Survey** ♦ Differential GPS ♦ Side scan Sonar ♦ Sub Bottom Profilers ♦ Magnetometer ♦ Ultra-Short Baseline with beacons ▪ **Metocean survey equipment** ▪ **Meteo sensors** ♦ Weather stations • Pyranometers • Wind speed and direction • Temperature (ambient and water) • Humidity • Rainfall ♦ Wave and water current sensors (Moored weather buoy, Acoustic Doppler Current Profilers, Drifter (for open oceans)) ♦ Wave Rider Buoys ▪ **Diving equipment** ▪ **Boats/ships**			

TABLE 2.2: Services applicable for the different value chain phases

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
Services	▪ Bathymetry and geotechnical surveys ▪ Geophysical surveys ▪ Metocean studies ▪ Topography surveys ▪ Satellite service providers ▪ Structural design consultancy – Computational Fluid Dynamics analysis	▪ Manufacturing consultancy ▪ Polymers and plastics consultancy ▪ O&M services ▪ Testing and certification agencies ▪ Logistics service providers	▪ Installation and commissioning services ▪ Project management consultancy services ▪ O&M services ▪ Testing and certification services	▪ Waste recycling services ▪ Logistics service providers

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
	▪ Technical consultancy – grid integration, feasibility, etc. ▪ Environmental and Social Impact Assessment (ESIA) consultancy ▪ Auditing services ▪ Testing agencies for soil, water etc. ▪ Structural testing – wind tunnel, wave pool ▪ Testing and certification of components ▪ Software licenses ▪ Boat operators ▪ Diving services ▪ Financial and Legal advisory services ▪ Government departments – ownership data, topography maps, green belt, reserve areas etc.	▪ Inspection and Auditing services	▪ Diving services ▪ Boat operators ▪ Emergency rescue services ▪ ESIA consultancy ▪ Testing agencies for soil, water etc. ▪ Logistics service providers	

TABLE 2.3: Skill sets applicable for the different value chain phases

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
Skills required	▪ Surveyors ▪ Geographic Information System (GIS) analysts ▪ Marine Engineers ▪ Solar and Electrical Engineers ▪ Power System Engineers ▪ Communication and Instrumentation Engineers	▪ Material experts – plastics ▪ Technology experts – modules, inverters, etc. ▪ Finance professional ▪ Manufacturing Process experts ▪ Lab Technicians ▪ Production managers ▪ Machine operators	▪ Project Managers ▪ Finance professional ▪ Construction Engineers ▪ Divers ▪ Solar and Electrical Engineers ▪ Communication and Instrumentation Engineers ▪ Civil Engineers ▪ Quality personnel	▪ Researchers ▪ Factory workers ▪ Labourers ▪ Divers ▪ Drivers

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
	▪ Lab Technicians ▪ Structural & Civil Engineers ▪ Draftsperson ▪ Divers ▪ Trainers ▪ Environmental Engineers ▪ Sociology experts ▪ Finance professional ▪ HSE professionals ▪ Boat operators	▪ Manufacturing technicians ▪ Process Engineers ▪ Quality Engineers ▪ Design Engineers ▪ Maintenance Engineers ▪ Industrial Engineers ▪ Supervisors ▪ Procurement executives ▪ Accounts personnel ▪ Material inspectors ▪ Auditors ▪ Security personnel ▪ Drivers	▪ HSE personnel ▪ Sustainability personnel ▪ Environmental Engineers ▪ Site Managers ▪ Technicians ▪ Trainers ▪ Site supervisors ▪ Boat operators ▪ Labourers ▪ Security personnel ▪ Emergency personnel – doctors, rescue etc ▪ Drivers	

2.1.2. Stakeholders

The analysis places an emphasis on stakeholders' engagement and collection of important data and information, as understanding the roles, responsibilities and preparedness of the stakeholders would facilitate an analysis of the barriers to implementation and help design the path forward. The desk review and consultative meetings show that the FSPV segment has a multitude of stakeholders influencing the business models, access to capital, energy off-take, and technology maturity.

The key stakeholders as shown in **Figure 2.2** below have been classified based on the function they perform in the FSPV value chain:

- Policy & Regulatory bodies, responsible for formulation of policies & framing regulations.
- Enablers from industry and academia.
- Implementers, responsible for development of FSPV projects for the end user.

In the spectrum of stakeholders listed above, parallel industries include prospective players from sectors like automobile, plastics, maritime, oil and gas etc. who might be interested and may have lower entry cost to foray into FSPV manufacturing arena. **Tables 2.4** and **2.5** identify the stakeholders directly involved in the value chain of FSPV and those from the relevant parallel sectors, respectively.

FIGURE 2.2: Key stakeholders in the value chain

Policy and Regulatory Bodies

- Ministry of New and Renewable Energy (MNRE) and Ministry of Power (MoP)
- Central Electricity Regulatory Commission (CERC)
- State Electricity Boards (SEBs)
- Waterbody Owners
- Fisheries Boards
- Ministry of Environment, Forest and Climate Change (MoEFCC)
- Central Water Commission (CWC)
- National Green Tribunal (NGT)

Enablers

- National Institute of Solar Energy (NISE)
- Surveyors
- Testing agencies
- Design consultancies
- Certification agencies
- Bureau of Indian Standards (BIS)
- Skill development agency
- Research organisations

Implementers

- Lenders & Investors
- Solar Energy Corporation of India (SECI)
- State renewable agencies
- Developers/ Independent Power Producers (IPPs)
- Water body owners
- Insurance
- Transmission and Distribution utilities

- Engineering, procurement, and construction (EPC)/ O&M Contractors
- Manufacturers *(including Parallel Industries)*
  - Balance of System (BoS)
  - Inverter
  - Modules
  - Anchoring & Mooring
  - Floats

TABLE 2.4: Stakeholders directly involved in the FSPV value chain

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
Direct Stakeholders	▪ Lenders & Investors ▪ Research organisations ▪ Surveyors ▪ Developers/IPP ▪ Skill Development Agency ▪ Waterbody Owners ▪ Design consultancies ▪ Policy and regulatory bodies ▪ Testing and certification agencies ▪ Transmission and Distribution utilities	▪ Floater manufacturers ▪ Module manufacturers ▪ BoS manufacturers ▪ Inverter manufacturers ▪ Anchoring/Mooring manufacturers ▪ Testing and certification agencies ▪ Policy and regulatory bodies ▪ Skill Development Agency ▪ Research organisations	▪ Engineering, Procurement and Construction (EPC) Company/ O&M contractors ▪ Project Management consultancies ▪ Testing and certification agencies ▪ Insurance ▪ Regulatory bodies ▪ Skill Development Agency ▪ Transmission and Distribution utilities	▪ Plastic Recyclers ▪ Regulatory bodies

TABLE 2.5: Stakeholders from relevant parallel sectors

	Feasibility, Design and Development	Manufacturing & procurement	Construction and O&M	Decommissioning
Stakeholders from Parallel Sectors	▪ Fisheries Boards ▪ CWC ▪ National Green Tribunal (NGT) (Environment and Social [E&S]) ▪ Maritime & offshore ▪ Plastic industries	▪ Plastic industries ▪ Oil & Gas (engineering plastics) ▪ Automotive sector	▪ Maritime and offshore ▪ NGT (E&S)	-

The detailed list of various stakeholders is included in **Appendix A** along with the categorization of "well established" and "prospective" players and the rationale for selection. However, it is to be noted that this is not an exhaustive list. A total of **44** stakeholders were consulted from this list. The distribution of various stakeholders consulted is also available in **Appendix A**.

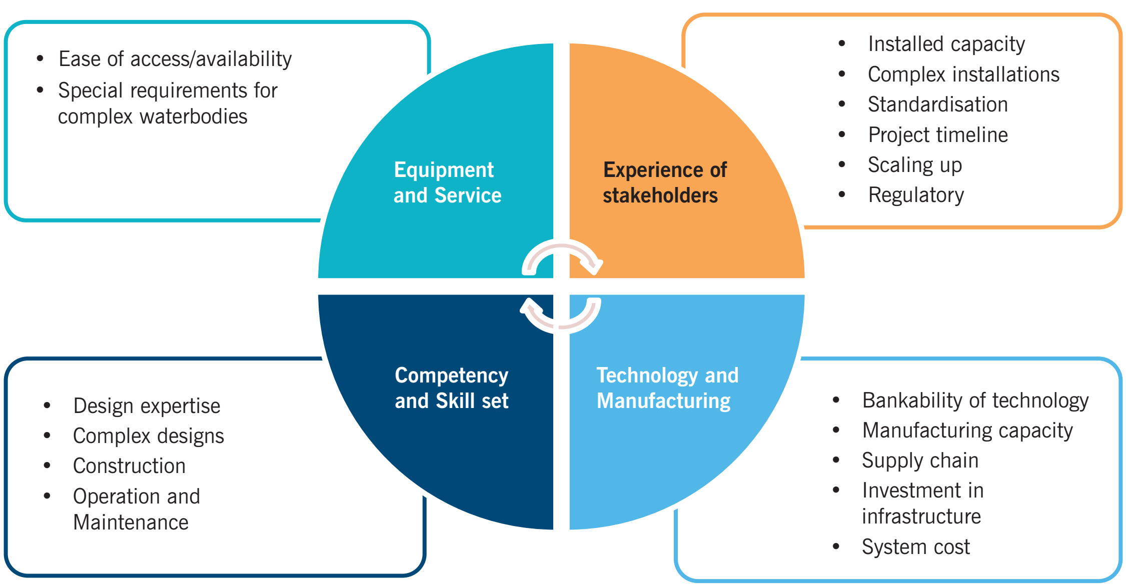
As described in the Section 2.2 below, float manufacturing has been identified as one of the major bottlenecks in FSPV value chain and hence emphasis has been given to this segment. Further details of the float and anchoring system manufacturers consulted are also presented in **Appendix A.**

2.2. Value Chain Assessment

2.2.1. Market Readiness of the Value Chain

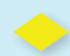
The market readiness of the value chain was assessed based on the four elements depicted in **Figure 2.3**, with inputs from the responses of stakeholders and further internal analysis.

FIGURE 2.3: Market readiness of value chain – assessment elements



- Green status indicates a conducive situation for scaling up.
- Yellow status indicates that some efforts are needed to create the initial momentum for scaling up.
- Red status indicates that significant efforts are needed for scaling up.

TABLE 2.6: Market readiness of value chain

Value chain elements	Description	Status
Equipment	▪ The equipment identified in Section 2.1.1 for site investigations and construction is typically used for surveys or work on waterbodies depending on its characteristics. Although FSPV is relatively new, this equipment is being utilized in parallel industries like maritime, offshore, etc. Specialised survey or construction vessels might be necessary for complex and deep waterbodies. ▪ The components of a solar PV plant, like modules, inverters and other BoS, are no different from those of land-based plants but need to have additional specifications for continuous use in a water environment. ▪ The floatation devices are varied in design, with High Density Polyethylene (HDPE) based floats seeing wider commercial deployment in fresh water so far. ▪ The mooring and anchoring devices are also varied in design and can be designed to suit the specific requirements of the project.	
Service	▪ The services identified in Section 3.1.1 for site investigations and construction are typical and a number of service providers are already present in the marine and offshore industry, which is valuable to address the current and projected scale of ambition in the FSPV segment. However, big players might find the scale of FSPV unattractive to begin with. ▪ Certain services like electrical design, grid integration, soil and water testing, logistics etc are no different from ground mounted plants. ▪ The testing infrastructure for floating structures is currently limited. ▪ Recycling is well established for plastic and other components (except PV modules) of the plant.	
Experience of stakeholders	▪ The experience of the stakeholders in ground mounted PV plants is relevant for FSPV installations. However, the added expertise needed for work on water is still low, owing to the handful of relatively small sized installations in India. ▪ As scale of deployment increases, complexity of waterbodies is also expected to increase, which calls for a higher level of expertise in technical, commercial, construction and O&M aspects. ▪ Some stakeholders are integrated into the value chain and are equipped to provide multiple services including supply of floats and anchoring system, inverters, BoS components, and installation.	

Value chain elements	Description	Status
	▪ When it comes to floats, anchoring and mooring, the required expertise can be drawn from parallel sectors including plastics, maritime, and offshore. ▪ Scaling up prospects depend on efficient project management to manage timelines and standardization of processes by the Developers/IPP and EPC/O&M contractors. ▪ The regulatory process for leasing a waterbody, approvals for safety of installations and monitoring of E&S impacts need to be revisited by regulators for applicability to FSPV projects.	
Technology	▪ Although the technology of floaters is still evolving, utility scale installations worldwide and in India have proven their feasibility. ▪ Some early accidents, globally, have highlighted the need for specific standards for the development and design of the floatation devices. However, this is true of any nascent technology. ▪ Reliability of the materials used for the floats for the expected plant life of 25 years is still to be proven and continuous investment into research and testing is needed. ▪ For complex waterbodies like hydropower plant (HPP) reservoirs, pilot projects will help to address design challenges and establish the fitness of the design concept.	
Manufacturing	▪ Manufacturing plastic floats is not a challenging task given the established plastics industry in India. Blow and injection moulding facilities are also easily available in India and can be adapted for the manufacture of floats. However, limitations should be anticipated for designs requiring a precision manufacturing process and a specialized supply chain for raw materials. ▪ The current FSPV specific manufacturing in India has an annual capacity of <550 MW (see **Table 2.8** in Section 2.2.2.4), which is insufficient to cater to the scale of ambition. However, the infrastructure is capable of a fast scale up. ▪ Given the universal use of plastics, no issues are anticipated with the supply chain of plastics for floats. However, competing use in parallel sectors could impact availability of virgin HDPE. ▪ It is crucial to achieve a reliable blend of the raw material for floaters to ensure a 25-year lifetime expectancy for an FSPV plant; the raw material blend needs to be optimized through tests and learnings from the field.	
Competency and Skillset	▪ Significantly inadequate competencies in designing of anchoring and mooring system in the FSPV industry. ▪ While expertise is obtainable from parallel industries, it is fragmented, and synergies have not yet been tapped into. ▪ Re-skilling of existing workforce would be a fast way for rapid scale up.	

In summary, these drivers are identified to address gaps and increase adoption rate:

- Visibility of scale of deployment for the short and medium terms.
- Prioritization of less complex waterbodies for building scale and experience.
- Cost and design optimization.
- Standardization.
- Comprehensive data bank ensuring availability of requisite technical and non-technical information.
- Continued focus on research and development.
- Training/re-training of workforce.

2.2.2. Barriers

The barriers identified through consultations with stakeholders were assessed for potential impacts on 10 risk parameters (see **Table 2.9** in Section 2.2.2.11) which have an influence across the value chain phases. **Table 2.7** gives a summary of the 10 risk parameters with their explanations. These parameters have overlapping impacts and categorization has been done mainly to devise recommendations (presented in Section 2.3) for mitigation. Further discussion on the risk parameters and drivers to address barriers are presented in the sections following **Table 2.7**.

TABLE 2.7: Definition of risk parameters

Sl. No.	Risk Parameter	Explanation
1.	Technical	Aspects which limit the optimization or reliability of the technical design of the projects like inadequate design considerations, safety factors, testing infrastructure, lack of standardization, inadequate experience, and unavailability of relevant input design data.
2.	Commercial	Factors affecting Capital Expenditure (CAPEX) such as scale, unoptimized designs, design validation, supply chain inefficiencies and bottlenecks, challenging site conditions, inexperience resulting in delays and project cost escalations, and cost of logistics. Factors affecting Operating Expense (OPEX) such as quality of plant and construction, reliability of components, site complexity, system degradation, inadequate design resulting in damages, climate change impacts, and lack of consideration of O&M in design.
3.	Policy and Regulatory	Timeline for securing approvals for project development and setting up of manufacturing units, policy and regulatory changes impacting project cost, budgets, approvals, unclear regulatory authority for HSE topics on waterborne power plant, lack of regulations, for example, for recycling.
4.	Manufacturing and Scale up	Limitations of manufacturing capacity, product development time, technological patents owned by overseas suppliers, inflexibility of float designs to customization, investment cost for manufacturing infrastructure, raw material supply chain issues and price fluctuations, new factories established near the sites without stabilized processes and necessary quality standards, process excursions resulting in delays, access to working capital, regulatory uncertainties, lack of roadmap and clarity among stakeholders, pitfalls on account of design adequacy, quality, incorrect data, incompetence all of which will limit fast scaling up.
5.	Site related and Timeline	Factors which result in extended development timeframe of projects like challenging site conditions, lack of planning, supply chain issues, prolonged time for statutory permits and compliances, long term data acquisition, unplanned construction issues, and difficulties with operation and maintenance.

Sl. No.	Risk Parameter	Explanation
6.	Quality, Safety and Reliability	Factors which impact the quality, safety and reliability of the project and its components like cost pressure, lack of standards and regulations, manufacturing process control and repeatability, material degradation, lack of experience, inadequate design and testing, substandard quality of material or services, and inadequate planning.
7.	Indigenization	Dependence on imports, perception of stakeholders, small volume, and lack of R&D initiatives.
8.	Investment	Risk or lack of motivation to invest in FSPV projects attributed to insufficient data to prove quality and reliability, lack of competence, lack of awareness, unfavourable regulatory environment, and uncertainties around environmental and social impacts.
9.	Environmental and Social	Uncertainties around impacts on environment or social aspects attributed to insufficient data, inadequate methods of impact assessment, lack of research studies, and climate change.
10.	Skill	Lack of skilled personnel for design, testing, manufacturing, construction, and maintenance for the scale of growth.

2.2.2.1. Technical

Technical risk encompasses all aspects which limit the optimization or reliability of the projects.

Lack of specific standards: The most notable risk is the absence of specific standards which has manifold implications across the value chain of FSPV, from initial feasibility studies to design, testing, construction and operation. A major challenge in standardization is finding the right balance to make it efficient and useful. Blind adoption of offshore standards will set the bar too high (overdesigned), while use of existing standards of ground mounted installations would invariably lead to inadequate design (under designed), both resulting in an unviable business case for floating PV. The absence of floating specific standards can also result in situations where quality conscious manufacturers do not get a level playing field in competitive bids.

Drivers: Standards defined based on test results, theoretical and empirical studies to ensure the desired quality and reliability of material and components in a water environment.

Global efforts to ensure standardization include:

- The World Bank's *When Sun Meets Water* series, including the *Handbook for FSPV practitioners.*
- STOWA (Netherlands) *Guide for licensing of floating solar parks on water.*
- International Electrotechnical Commission (IEC) TC 82, established to prepare international standards for PV systems, has included FSPV in its agenda.
- Working Group for Singapore-based technical reference (building on IEC TS 62738).
- Korea and China (NB/T 10187-2019) have national requirements for floating solar HDPE structures.
- Pilot testbeds and scientific research in Netherlands, Singapore, Germany, Italy, Norway, Spain, Portugal and Korea.
- Dedicated conferences organized in a few markets for dissemination and sharing of experiences.
- DNV's Joint Industry Project that resulted in the development of a Floating Solar PV Recommended Practice (DNV-RP-0584).[13]

13 DNV, (2021, October), Recommended practice | https://rules.dnv.com/docs/pdf/DNV/RP/2021-10/DNV-RP-0584.pdf

- DNV has developed project certification of PV power plants (DNVGL-SE-0078) and has certified ground mounted solar projects. A similar document can be developed for FSPV.

Testing infrastructure: The current infrastructure in India for structural testing is not geared to the needs of floating structures which are subjected to complex mechanical motions. Some organizations have the capability to do material testing but this knowledge is not widely disseminated. Given the variability in the float designs and site conditions, testing to customized requirements is key to optimize and validate product designs. Equally important is the design of tests to adequately cover all known and foreseen situations that the system could be subjected to during its lifetime.

Commonly used polymer blends such as HDPE, blended with other co-polymers or monomers and additives, require development specific to FSPV application. Hence, the results of material testing of plastics used for floats is an important input to the design of systems, especially in the absence of specific standards and adequate experience. The cost and time for testing, however, can be a possible hindrance to adoption by the industry.

Drivers: The need of the hour is a commercial R&D centre and possible grants or support for technological innovation with probable participation from the government, industry and research organizations. Facilitating collaboration between think tanks will ensure that learnings feed into faster formulation of standards and testing guidelines.

A clear projection of scale of growth of FSPV (see **Table 1.1** for scenarios) along with testing mandates can create a profitable business case for establishing new laboratories and drive reduction in the cost of testing. A system should be devised to enrol certifying bodies which are authorized to test float materials and formulate specific standards.

Input data for design: Several stakeholders identified the unavailability of reliable historical data (wave height, water current, water depth, bathymetry, wind speed, soil type, frequency of waves etc.) as a barrier for optimization of designs of floater platforms, anchoring and mooring systems. Data sharing is generally not done publicly by owners due to confidentiality reasons. Another hindrance is the lack of digitisation of available historical data. Site-specific investigations done for a short period of time (based on the project development timelines and cost), cannot be a substitute for long-term historical data. If data is inadequate, six months to one-year surveys could be carried out. Absence of proper design inputs can result in over/under designing of the system, higher cost, and long-term risk to the project.

Drivers: Inclusion of base data such as historical data of waterbody, feasibility surveys, location identified for installation, and evacuation point in bid documents will drive competitiveness of bids and avoid time delays in project development. Developing detailed atlases for mapping of waterbodies (a recent initiative is the Global Solar Atlas[14]) and making historical data, waterbody characteristics, and other relevant data available through a single window will aid the stakeholders. Further, the development of standard requirements for conducting technical and E&S studies as well as procurement specifications will contribute towards the uptake of FSPV.

Inadequate experience: Some players struggle with lack of design competency and inadequate focus on innovation. Lack of experience can result in incorrect budgeting of cost and underestimation of timelines, both of which are imperative for installations in complex near shore and inland waterbodies.

14 The World Bank Group. Hydro-connected sites. https://globalsolaratlas.info/map

Drivers: Experience builds with scale, but it is important to avoid early mistakes in the process. Formulation of FSPV specific standards and drawing on expertise from parallel industries or design consultants can help streamline the design process. Pilot projects on complex waterbodies like HPP reservoirs, will help to establish fitness for purpose of the design concept. Existing capacity-building programs may be extended to include the design process and applicable technical standards. Experience-sharing sessions with forerunners in the sector can provide valuable insights to all stakeholders.

2.2.2.2. Commercial

Barriers with commercial implications are highlighted throughout the value chain; the most important is the constraint of manufacturing capacity.

CAPEX: The current fragmented approach to conducting initial feasibility surveys and developing projects has not yet resulted in a scale attractive enough to optimize cost. Supply chain bottlenecks and inexperience can add to delays and project cost escalations apart from the high investment cost for complex waterbodies. Establishing manufacturing facilities near the project site is required to offset the high cost of logistics. Further, the common methods of blow moulding and pressure injection moulding, machinery, land, and associated infrastructure require substantial investment. International players desirous of entering the market face hurdles with pricing, policies, identification of right partners, and visibility of volumes.

Drivers: Clearly articulated targets for FSPV in the Government of India's National Solar Mission (NSM), with timelines for tendering and implementation, will give the much-needed visibility of volume for the industry to make commitments on infrastructure and investment, resulting in cost optimization. The tender specifications could also be finalized in discussion with the stakeholders to promote design optimisation and engagement. Government support like Viability Gap Funding (VGF), reduction of Goods and Services Tax for floaters, and removal of import duties (currently 15 percent) on floater raw material for an initial embryonic period could be explored. Further, a method to factor the benefit of avoided evaporation loss in the calculation of tariff could be considered.

OPEX: The quality of design, construction and reliability of components have a strong influence on the operational expenses of the plant. Equally important are the potential risks due to climate change. Compared to their ground mounted counterparts, FSPV installations have additional operation and maintenance challenges due to limited accessibility to the modules (depending on the type of float). Original Equipment Manufacturers do not currently offer any long-term warranty[15] for the float system (as back-to-back warranties for lifetime performance of floaters is not received from raw material suppliers), leading to contractors bearing a high-risk exposure disproportionate to rewards. Given the lack of confidence in a 25-year design life and limited warranty on floaters, close monitoring of the vulnerable components and a proactive inspection plan is needed, which adds to O&M costs. An increased maintenance reserve account for key components like floaters is also likely to be needed.

Drivers: Building a plant to last longer comes with a marginally higher initial investment but the benefits are reaped during the operational phase. A focus on quality, innovation, research, and testing to prove reliability of components can achieve the desired outcome.

15 Typically, 10 years for floatation devices.

2.2.2.3. Policy and Regulatory

The following policy and regulatory barriers are identified, with impacts on aspects such as project timelines, cost budgets, and approvals.

Delays and an increase in cost of FSPV deployment due to uncertainty about water rights. The uncertain ecological impacts of FSPV systems on natural waterbodies and related uncertain enacting of laws and rights can cause delays. Furthermore, there is uncertainty on whether various water right doctrines apply to FSPV systems developed on artificial reservoirs. This can increase FSPV deployment costs as developers may have to invest significant time and money to gain clarity before formally applying for the rights and permission to site FSPV systems on a given waterbody. The lack of clarity in licensing and permitting can also present major barriers to FSPV deployment.

Lack of cooperation and coordination among different stakeholders may stall FSPV deployment. Deployment of FSPV plants may require reviews, approvals, and permits[16] from multiple government entities. Lack of coordination between these agencies and non-governmental agencies can lead to delays in installation of the plant. Such agencies may include:

- Energy agencies, such as the MNRE, MoP, and distribution companies (DISCOMs).
- Water management agencies, such as the CWC, Ministry of Jal Shakti, and hydropower or thermal plant owners.
- Land management agencies, such as the Department of Land Resources.
- Environmental protection agencies, such as MoEFCC.

Lack of experience in the process of FSPV systems can make projects less financially appealing to banks and other financial institutions. Given the lack of experience that banks, insurers, and other financial institutions currently have with FSPV projects, financial closing is likely to take longer than it may for more familiar, ground-mounted solar PV projects.

Lack of clarity on the rules on the ownership, market participation and operation of hybrid hydropower-FSPV or thermal-FSPV plants. If an FSPV system is hybridized with a hydropower, thermal or other system, there are multiple stakeholders involved (such as the owners and operators of the reservoirs, hydropower dams, and FSPV systems) who may have conflicting interests. Project approval may face various barriers depending on the ownership model and market participation model. Clear regulatory processes on the ownership and market participation models and operation methods for such hybrid systems is required to provide clarity to all stakeholders and support an informed decision-making process.

Unclear and non-existent standards for FSPV installation, O&M and its equipment may result in deficient policies and regulations. The regulatory landscape is more pertinent for the waterborne power plant on the topics of electrical safety and fire safety. A lack of consistent FSPV installation and equipment standards may lead to poor quality FSPV products, installations, and system performance. Standards (and their enforcement) are a vital part of policies and regulations as they provide manufacturers with a benchmark of performance requirements for their products, guide users during product selection, and help government agencies to incorporate them into workplace safety and health regulations.

16 A collection of applicable policies, permits and approvals are included in Appendix F. However, this list could be dynamic, and a project specific due diligence is recommended.

Economic policy uncertainty may stall private sector interest in FSPV systems. Policies and support pricing specific to FSPV are currently not in force in India. Private sector players, especially in emerging industries, rely on a stable, transparent, and favourable policy environment that supports reliable and long-term energy markets. If a policy environment is uncertain, especially at the state level, private sector actors are less likely to pursue projects. An uncertain policy and regulatory environment can stall deployment of new technologies, such as FSPV, because developers prefer regulatory certainty in their investment choices.

Uncertainty about FSPV's ecological impacts may cause delays in development of policies. The potential ecological impacts of FSPV systems, especially their effect on the aquatic ecosystem, are not yet fully understood, and there is limited publicly available research on the impacts. This uncertainty may impede FSPV policy development because this could complicate environmental review processes and raise public concerns about the unknown impacts of FSPV deployment.

Policy for FSPV needs to address the barriers of lack of public buy-in of FSPV technology due to visual impacts and competing uses of waterbodies. Public opposition to development of new technologies such as FSPV could hamper implementation. Therefore, while drafting the policies, it is important to understand and incorporate the following elements:

- How FSPV projects will factor in the values of community (for example, concerns about climate change, job creation, etc.);
- Overall evaluation of costs, risks, and benefits of the technology and project;
- Clarity on the project development decision-making process; and
- Overall engagement approach that fosters trust in decision makers and other stakeholders.

Policy must address the barriers related to resettlement and rehabilitation, compensation practices. Unfairly applied resettlement and compensation practices can create a negative perception of FSPV projects. FSPV systems may thus face public opposition due to negative public perceptions stemming from previous conflicts.

Open ended market rules may lead to multiple interpretations. A lot of market rules such as prioritization of power despatch, must-run status, and energy banking are not currently robust enough to manage hybrid as well as stand-alone FSPV plants. Complexities further arise due to multiple end uses of the water in the reservoir such as irrigation or peak power generation. As two or more different stakeholders come into the play, there is a need for clear rules and regulations for operating the FSPVs as well as water reservoirs.

Drivers: Given the above, it is noted that the formulation of specific guidelines and regulatory process for deployment of FSPV projects can ease the timelines and uncertainties in setting up of such plants. Including targets and timelines for FSPV in the NSM can further give the visibility of the volume to the industry to drive investment in infrastructure and hence cost optimization.

2.2.2.4. Manufacturing and Scale Up

Among the varied solutions for floaters[17] available in the market currently, the HDPE pure float version has typically been adopted for the large-scale installations commissioned till date, primarily attributed to desirable material properties of HDPE for the

17 Pure floats (characterised by direct mounting of PV modules onto the floats), module rafts (characterised by structural frameworks supported by floats), membranes (characterised by PV modules attached to a reinforced membrane which is supported by additional structures, such as tubular rings to provide buoyancy support).

application, ease of manufacturing, and cost effectiveness. These floats, by virtue of their blow moulded construction, are bulky and incur significant transportation costs. Hence, moving the factories closer to project sites has been recommended as a viable option by the industry. However, a project capacity of 20-50 MWp was indicated by different stakeholders as a minimum scale to justify the cost and effort for setting up such temporary facilities. This, however, poses new challenges in terms of time-consuming regulatory approvals for setting up of the factory and ensuring quality and repeatability of processes. Process stabilization and control in a temporary manufacturing set up can be a challenging task, with impact on the long-term reliability of the end product.

For injection moulded components, the preference is to have centralized facilities as these components require heavy moulds, complex machinery, and stable power supply to ensure quality. Excess capacity, available in India with other industries like automobiles, can easily be tapped into if customized moulds for floaters are provided. However, the benefit of injection moulded components is that, unlike blow moulded components, their shipping can be done with nesting of components, which reduces the volume.

India does not have many established suppliers of floats and the availability and cost of working capital is a major deterrent to investment and scaling up of manufacturing capacity. Moulds, especially for large parts, are imported by some float manufacturers and the cost is significant (INR 30 lakhs to INR 1 crore per mould). Hence, some manufacturers prefer to subcontract manufacturing to meet additional demand rather than making capital investment themselves. Petroleum prices also add the risk of price fluctuation for raw materials. Major suppliers of raw materials like HDPE pellets, fillers, and additives are mostly loaded with orders from parallel sectors, and the current low demand from the FSPV segment makes availability throughout the year difficult. The current manufacturing capacities of some prominent suppliers in India are given in **Table 2.8.**

Drivers: A visible scale of deployment through a project pipeline/tendering timeline would entice interest in scaling up of manufacturing facilities. A series of tenders released by the government between 2018 and 2019 did not result in upscaling of manufacturing as expected, probably due to a wait and watch approach by the stakeholders involved. The recent 600 MW tender from RUMSL for Omkareshwar reservoir, along with others in the pipeline, could trigger a renewed interest from the industry. Establishment of manufacturing facilities near project sites can be facilitated through creation of specific infrastructure and single window clearance mechanisms under the purview of the "Aatma Nirbhar Bharat" and "Make in India" initiatives of the Government of India. The use of recycled plastic in manufacturing could be explored; however, it is not the most preferred option of manufacturers owing to challenges in meeting the required technical specifications, reliability, and possible environmental concerns. Facilitation of working capital for small-scale manufacturers can be provided by extending debt for longer tenure.

TABLE 2.8: Annual manufacturing capacity (2023) of floats in India[18]

Supplier	Annual Manufacturing Capacity, MW
Quant Solar	50
Ciel et Terre	300
Adtech Systems	100
Bloomseal	100
Flotex	300
Total	**850**

18 This is not an exhaustive list and covers only few technology providers.

2.2.2.5. Site Related and Timeline

Identification of favourable sites is important for the early projects. Waterbodies with issues such as greater depths and high-water level variations pose technical challenges for design and installation and drive up the development cost of projects. A lack of reliable historical data for the waterbody increases the uncertainties in the design boundary conditions which results in increased expenditure and time for site specific investigations.

Restricted access to the waterbody and local environment (such as water level changes, seasonal delays, rain, high wind, seasonal wildlife movement, floating debris during monsoon, and sedimentation,) can also impact the implementation timelines.

Drivers: Prioritizing waterbodies with less complexities (such as those with lesser depth and water level variations, captive reservoirs) for deployment of initial plants will help in building confidence and aid faster scaling up of the value chain. Learnings can be translated into best practices and necessary data can be collected for making the sector more bankable to attract investments.

A centralized approach to conduct pre-feasibility studies and surveys for identification of waterbodies would improve quality of assessments and reduce cost. For instance, the Global Solar Atlas[19], hosts a database of 2,173 reservoirs across India. Further streamlining can be done with standardization of technical requirements of surveys and identification of approved service providers.

More meticulous project planning is needed for FSPV installations in view of the hurried timelines typical of ground mounted PV plants, to avoid incidental construction quality issues.

2.2.2.6. Quality, Safety and Reliability

Considering the limited knowledge available in the field, the risks to design, execution and operation are manifold. Apart from the possible compromise on quality and over optimization of design driven by cost pressure and lack of specific standards, the unseen risks of safety, long term reliability of components, challenges of carrying out routine maintenance, and impact of future changes to the waterbody (presence of pollutants from industrial activity, physical risks due to climate change and the like) are other factors that need to be addressed to maintain confidence in the investment.

Currently, the workers employed in ground mounted plants are not trained to do work in a marine environment. Additionally, process control and repeatability of manufacturing process is important for the long-term reliability of product and system.

Drivers: Formulation of specific standards for product, structural design, and testing, and leveraging the expertise from parallel industries are important steps toward ensuring quality and reliability (please see Section 4 for more details). A continued focus on research and innovation is also needed to realise the scale of deployment. Project developers could be mandated to maintain and share records of specific parameters of interest with regard to FSPV like energy generation and impact on biodiversity. Knowledge sharing can be facilitated through means such as formation of expert committees and conferences. Training or re-training of the workforce is paramount to ensuring safety and quality of construction.

2.2.2.7. Indigenization

Barring floats, the components of a FSPV plant are sourced similarly to those of a ground mounted plant. Major components

19 The World Bank Group. Hydro-connected sites. https://globalsolaratlas.info/map

like modules are largely imported, while inverters are imported or locally sourced. The interactions with stakeholders made it clear that the dependence of supply chain on imports is not significant in the manufacturing of floats (import option is typically explored by float manufacturers for machinery and raw materials). The relevant experience is already present in parallel industries which, if used to advantage, can contribute to the upscaling of the sector. However, more emphasis needs to be laid on R&D. Multiple indigenous manufacturers are known to license patented technology from international players and then focus on manufacturing and implementation, which would limit their capability to optimize the product, system design and cost. On the other hand, there are home-grown start-up companies that are small in scale currently but have the flexibility and knowledge of local conditions to continually improve and innovate their designs. Innovation is the key to sustain the segment.

As local manufacturing (closer to the project location) should be mandatory for cost effectiveness and faster turnaround times in FSPV plants. Significant investment in manufacturing infrastructure across feasible locations in the country is necessary.

Drivers: Funding of the following activities can provide the much-needed impetus to the FSPV segment:

- research on materials, product design and impact on biodiversity;
- specific infrastructure and single window clearance mechanisms for establishing manufacturing facilities near proposed project sites; and
- support to small scale companies for raising debt and working capital.

Development of mobile platforms for blow moulding (a containerized solution which can be moved to different locations) with established plant machinery manufacturers could also be explored. As mentioned earlier, a clear visibility of volume for the industry to make commitments on infrastructure and investment is vital.

2.2.2.8. Investment

While FSPV is attractive in many aspects, the higher tariff ensuing from a higher project cost compared to ground mounted installations is a matter of concern for offtakers. Since the ecological impacts of FSPV system on a natural reservoir have not been sufficiently studied, investors and other stakeholders with a strong focus on sustainable investing would prefer captive waterbodies to natural ones. Further, insurance of floating PV assets is neither easy nor affordable as the scale is small and scant field data is available on the long-term status of installations.

Drivers: From the perspective of gaining confidence and experience, it is preferable to have initial installations on less complex waterbodies with low depth and less water level variations (the so-called low hanging fruits) before considering large reservoirs (and offshore developments in the future) to step up the scale. Maintenance of data like energy generation, material and equipment degradation etc. can help in reinforcing the quality and reliability of the project and thereby, trust in the technology. DNV, Quant Solar and ONGC Mangalore Petrochemicals Limited (OMPL) are in an agreement for a research and monitoring project on an operational MW scale floating solar to quantify the benefits of FSPV.

2.2.2.9. Environmental and Social (E&S)

The short- and long-term impacts of FSPV plants on biodiversity of the waterbody are not sufficiently known. Potential impacts could include changes in dissolved oxygen levels, temperature stratification, exposure to electromagnetic field associated with underwater electrical cables, and leaching of detergents, oil and chemicals. The methods to measure impacts during the operational period could also be ineffective. The social impacts could include restricted access to the waterbody for general public and an impact on livelihoods. This can be a deterrent to investors who are committed to sustainable investments.

Drivers: Creation of a baseline is important for measuring impacts on the environment and society. Although solar plants are currently exempted from environmental impact assessment, the same should be mandated for FSPV installations depending on the nature of waterbody (captive/natural reservoirs) and extent of coverage of water surface, to identify and limit any long-term impacts. The *Final Environmental and Social Management Framework* document of SECI[20] can provide guidance for undertaking ESIA, formulating an Environmental and Social Management Plan, conducting social assessments, stakeholder consultations, and monitoring and evaluation of projects.

Research funding can be allocated to assess the long-term impacts of the floating PV installation on the biodiversity of the waterbody. A periodical measurement of the impacts during the lifetime of the project can also be mandated to factually establish the assumptions.

2.2.2.10. Skill

The skill requirements of FSPV systems across the value chain find substantial overlap with ground mounted solar plants (please see **Section 1** for more details). However, owing to its nascency and situation in a water environment, lack of experience is evident in specific aspects of design of the floaters and anchoring and mooring systems, material engineering and safe and efficient working on waterbodies during construction and operational phases. The knowledge and experience from parallel sectors like maritime, automotive, offshore, and oil and gas are still untapped.

Drivers: Extracting synergies from the knowhow and experience in the parallel industries is vital for preventing early mistakes that could prove a deterrent for the scaling up of the segment. Structural design expertise from maritime and offshore industries, creation of material blends for engineering plastics from oil and gas industry, manufacturing optimization from automotive and other consumer segments are some instances of such opportunities. Specialists in the fields relevant for FSPV integration need to be developed. Reskilling of existing certified installers of ground mounted plants could be looked at as a faster option in comparison to the creation of a new FSPV-specific resource pool. Ensuring participation of women by guaranteeing their safety and a gender-neutral working environment

PROTECTING BIODIVERSITY

BayWa.re, installed “biohuts” from a French company Ecocean in its floating PV plant in Netherlands (Bomhofsplas) in an effort to monitor biodiversity and water quality. Biohuts are “fish hotels” that provide food, shelter and protection to young and small fish to protect them from predators. This increases the survival rate of small fish and ensures biodiversity of the waterbody. BayWa.re is monitoring these biohuts, while taking regular measurements of water quality, oxygen levels inter alia in a multi-year study to assess their effectiveness.

Source: BayWa.re

20 SOLAR ENERGY CORPORATION OF INDIA LIMITED (SECI). (2018, October). Final Environmental and Social Management Framework. https://www.seci.co.in/web-data/docs/ESMF_final.pdf

and formulate specific training courses for technicians, installers, and designers through a joint effort between industry and academia.

2.2.2.11. Assessment Summary

Stakeholder consultations helped identify 38 barriers. As shown in **Table 2.9**, each barrier was assessed for its potential direct impact on 10 risk parameters (elaborated in **Table 2.7**, Section 2.2.2). For instance, the barrier "absence of specific standards" has direct impact on the following risk parameters:

- **Technical:** Lack of standards can result in inadequate or sub-optimal design considerations impacting reliability of the equipment.
- **Commercial:** Unoptimized designs will have impact on upfront CAPEX and OPEX in the event of failures attributed to design deficiencies.
- **Regulatory:** No direct impact.
- **Manufacturing and scale up:** Lack of quality standards will have an impact on product quality.
- **Site related and timeline:** Inadequate or inaccurate collection of site data owing to absence of standardized specifications for surveys, can impact CAPEX or introduce delays in project execution timelines.
- **Quality, safety, and reliability:** Lack of standards can impact the quality, safety and reliability of the project and equipment.
- **Indigenisation:** No direct impact.
- **Investment:** Cost, quality and reliability are pertinent to secure investment in FSPV projects, which are dependent on development of specific standards for the application.
- **E&S:** No direct impact.
- **Skill:** No direct impact.

TABLE 2.9: Impact of Barriers on the Risk Parameters

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
1.	**Testing infrastructure:** 1. Insufficient testing infrastructure. 2. Low volume to justify investment in additional testing infrastructure. 3. Repetition of tests to local standards is an added cost for overseas manufacturers trying to enter the market.	Yes	Yes		Yes		Yes				
2.	**Standards:** 1. Lack of specific standards governing the requirements of a floating plant. 2. Absence of standards for design and testing, factor of safety (FoS). 3. Standards and requirement specifications of surveys. 4. Standardization of survey method.	Yes	Yes		Yes	Yes	Yes		Yes		
3.	Lack of rules on fire protection for plastic components.	Yes	Yes	Yes			Yes				
4.	**Experience:** 1. Low experience and expertise of suppliers and subcontractors. 2. Inadequate skills for installation and maintenance on water.	Yes	Yes		Yes	Yes	Yes				Yes

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
5.	**Installation:** 1. Requirement of sophisticated equipment depending on characteristics of waterbody. 2. Local environment impacting activities and timelines—water level changes, seasonal delays (rain, high wind etc.), restrictions to site access, seasonal wildlife movement, floating debris during monsoon, sedimentation etc. 3. Time needed for surveys—some inputs might have to be collected over a long term. 4. High cost of hiring available workmen for marine work. Need for expert diver companies for accurate positioning of anchors and mooring lines.	Yes	Yes		Yes	Yes	Yes				Yes
6.	**Technical:** 1. Unavailability of specific design standards. 2. Lack of experience to estimate the design boundary conditions, challenges with design of anchoring and mooring. 3. Lack of expertise with developer to specify required properties and testing standards of plastic floaters.	Yes	Yes		Yes		Yes				Yes

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
	4. Need to identify, specify and hire expensive consultants to do design calculations, conduct wave pool and wind tunnel experiments to improve confidence on design of floater assembly.										
7.	**Operation:** Unavailability of trained fire servicemen at reasonable distance [in case of remote locations].		yes			Yes	Yes				Yes
8.	**CAPEX:** 1. Unfavourable conditions at the waterbody (e.g., high depths, water level variation, waves, high salinity) etc leading to high costs of investment and infeasibility of projects. 2. Higher CAPEX resulting in high tariff which would be unfeasible for offtakers.	Yes	Yes		Yes	Yes			Yes		
9.	**Data availability:** 1. Unavailability of historical data of waterbody leading to incorrect preliminary design and cost estimation. 2. Data sharing is not done publicly by owners due to confidentiality reasons. 3. Digitisation of available historical data is needed to facilitate fast information sharing.	Yes	Yes		Yes	Yes	Yes		Yes		

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
10.	**Permits & regulatory:** 1. No clarity on ownership of waterbody. 2. Regulatory issues and securing approvals, especially with setting up of manufacturing unit near to the sites. 3. Policy and regulatory changes impacting project cost, budgets, approvals etc.		Yes	Yes	Yes	Yes			Yes		
11.	Regulatory requirements on ESIA – e.g., extent of coverage of waterbody.			Yes	Yes	Yes			Yes	Yes	
12.	Unclear regulatory authority for HSE topics on waterborne power plant.			Yes		Yes	Yes		Yes	Yes	
13.	**Raw material:** 1. Raw material supply chain issues and price fluctuations. 2. Cost of raw material being controlled by major players in the market and also linked to petroleum prices.		Yes		Yes		Yes	Yes	Yes		
14.	**Manufacturing:** 1. New factories near the sites without stabilised processes and necessary quality standards, process excursions resulting in delays.										

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
	2. Need to identify manufacturers of plastic floaters close to the sites or move the factories closer to site so that sum of cost of manufacture and cost of transportation is kept competitive. 3. Foreign players preferring to keep manufacturing centralised with overseas facilities, owing to requirements of precision and quality. 4. Moulds for manufacturing are imported as original manufacturer does not want to part with Ingress Protection (IP). 5. Technological patents (or IP) owned by overseas suppliers (parents) and associated costs of acquisition. 6. Need for scale of orders for economic development and manufacture of floaters.		Yes		Yes	Yes	Yes	Yes	Yes		Yes
15.	Manufacturing tolerances - less control on processes, impact on design calculations.	Yes	Yes				Yes				Yes
16.	Local availability and cost of flexible connectors in mooring lines for accommodating high water level variations.	Yes	Yes		Yes	Yes		Yes	Yes		Yes
17.	Limited manufacturing capacity.		Yes		Yes	Yes			Yes		

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
18.	Funding for setting up of manufacturing unit and access to working capital.		Yes		Yes	Yes		Yes	Yes		
19.	Float design and manufacturing for accommodating higher capacity panels >500 Wp with bigger sizes is a challenge.	Yes	Yes		Yes				Yes		Yes
20.	**O&M:** 1. Insufficient field experience to formulate a spare parts strategy and estimate lifetime. 2. Reliability issues of components leading to increased replacements and maintenance costs.	Yes	Yes				Yes				
21.	**Investment:** Lack of field data to support reliability of system to maintain confidence in the investment.	Yes					Yes		Yes		
22.	1. Safety aspects of working on water - drowning, water animals, floating objects, slips and falls, electric shock etc. 2. Work on waterborne plant requiring special skills on Health & Safety.					Yes	Yes				Yes
23.	Corrosion and degradation rates accelerated by water, presence of pollutants in water due to future industrial activity, etc.		Yes				Yes				
24.	Electrical design safety.	Yes		Yes			Yes				

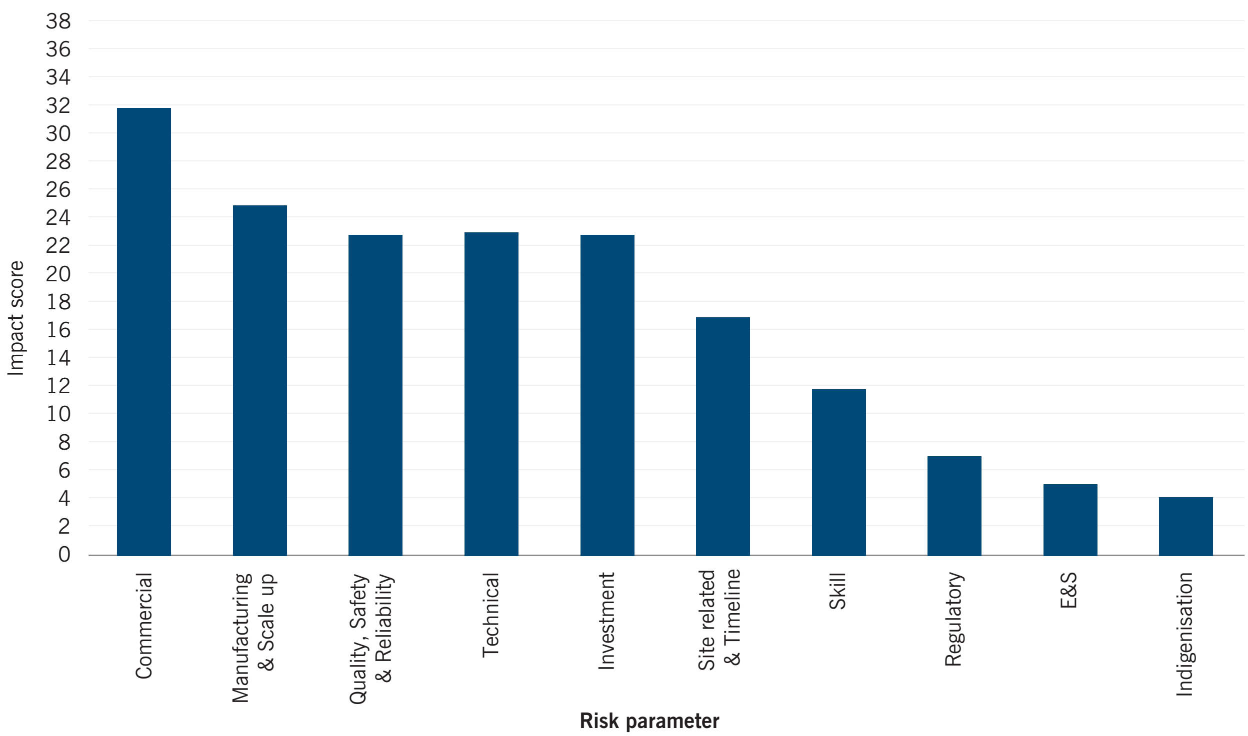
Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
25.	1. Price pressure leading to compromise on quality and specifications. Cost vs technology distinction is a deterrent to foreign players. 2. Specifications of floats not matured to suit the project and are copied. Optimizations happen after order.	Yes	Yes		Yes		Yes		Yes		
26.	Difficult maintenance due to low clearance of modules from water.		Yes			Yes					Yes
27.	Transition and physical risks attributed to climate change—typhoons/cyclones, flooding, high temperature or humidity leading to underperformance of PV plants.	Yes	Yes						Yes	Yes	
28	**Environment:** 1. Insufficient information on short- and long-term impacts on biodiversity and a baseline. 2. Insufficient methods to measure impacts due to construction and operation. 3. Standardize method for ESIA surveys. 4. Negative impact on tourism, water sports, fishing (livelihood of local villagers).			Yes					Yes	Yes	

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
29.	**Recycling:** 1. Recycling technology (adoption of high value recycling). 2. Economies of scale of recycling. Recycling plastic waste is a challenge due to contamination and inconsistency of materials. 3. Recycling industry is largely unorganized. 4. Lack of recycling regulations, awareness creation.	Yes	Yes	Yes	Yes		Yes			Yes	
30.	Developer having to bear the risks of deviation in environmental conditions and lack of support and risk sharing by Owner.	Yes	Yes		Yes				Yes		
31.	Inaccurate energy yield estimations and financial analysis - unavailability of site meteo data, validation of design assumptions, system degradation etc from site data.	Yes	Yes		Yes				Yes		
32.	Lack of understanding of the scope of work leading to incorrect estimation of cost.		Yes		Yes		Yes				Yes
33.	**Surveys:** 1. Cost of surveys. 2. Cost of mobilization and demobilization could be more than the cost of actual survey depending on the nature and location of the waterbody. 3. Survey scale of FSPV is not attractive for established large players.	Yes	Yes		Yes	Yes					Yes

Sl. No.	Identified Barriers	Impact on Risk Parameters									
		Technical	Commercial	Regulatory	Manufacturing & Scale up	Site related & Timeline	Quality, Safety & Reliability	Indigenisation	Investment	Environmental & Social	Skill
34.	**Warranties:** 1. Material reliability. 2. The terms of PBG upto 10 years with LD clauses is not viable for float manufacturers. 3. Lack of back-to-back warranties for lifetime performance of floaters from raw material or finished product manufacturers, leading to contractor having high risk exposure disproportionate to rewards. 4. Warranty is one of the biggest barriers for the manufacturer. 5. Manufacturers will not get warranty for the raw material from the master batcher.		Yes		Yes		Yes		Yes		
35.	Cost of transportation.		Yes		Yes	Yes			Yes		
36.	Tender requirements limiting flexibility to developers.	Yes	Yes		Yes				Yes		
37.	1. Reliability of existing wind data due to quality and maintenance issues of meteorology equipment used. 2. Available data (15 years probably) is not sufficient to predict 50-year return period.	Yes	Yes				Yes		Yes		
38.	Lack of funding for research on materials, recycling etc.	Yes	Yes		Yes		Yes		Yes		
	Impact Score of each Risk Parameter	23	32	7	25	17	23	4	23	5	12

The "impact score" of each risk parameter was then calculated. For instance, the risk parameter "Commercial" had an impact score of 32, indicating that 32 out of the 38 identified barriers were susceptible to this risk. The result of the assessment is presented in **Figure 2.4**. As can be discerned, "commercial," "manufacturing and scale up," "quality, safety and reliability", "technical" and "investment" risks have a wider impact across the value chain. These barriers are also the main influencers on the cost of FSPV projects.

FIGURE 2.4: Result of assessment



2.3. Recommendations

Based on the analysis of barriers and their impacts on various risk parameters, various recommendations are provided for mitigation. **Table 2.10** presents a summary of the recommendations to be implemented in the short term (1-3 years) along with the expected positive impacts, stakeholders responsible for implementation and the quantification of impact on levelized cost of energy (LCOE) wherever possible. The quantification of LCOE is mainly indicative to highlight the importance of each recommendation; however, the impacts of recommendations are not mutually exclusive. The assumptions indicated in **Table 2.11** were considered for the LCOE calculations.

TABLE 2.10: Summary of recommendations

Recommendation	Barriers addressed	Responsibility	Drivers	Expected Positive Impacts	Likely impact on LCOE
Setting of targets with at least 1-year tender-calendar	Technical/Commercial/ Policy and Regulatory/ Manufacturing and scale up/Indigenization/ Investment	MNRE/State Nodal agencies/ SECI/MoEFCC	▪ Clearly articulated targets for FSPV in the NSM with timelines for tendering and implementation ▪ Formulation of specific guidelines and regulatory process for deployment of FSPV projects, including ESIA	▪ Commitments on manufacturing infrastructure and investment from industry ▪ Cost optimization and lower tariff due to likely economies of scale ▪ Establish new test laboratories for structural and material testing.	Up to 21 percent (Construction time: ~3 percent, CAPEX: ~14 percent, OPEX: ~4 percent)
Roadmap studies & resource characterization and prioritization for FSPV	Technical/Commercial/ Manufacturing and scale up/Site related and timeline/Indigenization/ Investment	MNRE/SECI/State nodal agencies/ National Institute of Solar Energy (NISE)	▪ To identify long term commercial potential of FSPV ▪ To conduct pre-feasibilities and survey of most suitable & less complex 7-10 GW of sites (prioritization of waterbodies) to be developed in next 3 years ▪ Standardization of technical requirements of surveys and identification of approved service providers	▪ Long term investment ▪ Research and innovation ▪ Lower discovered tariff ▪ Streamlined and planned development ▪ Enable more players and positive competitive tension ▪ Enabling quality and uniformity of studies	Up to 18 percent (CAPEX: ~14 percent, OPEX: ~4 percent)

Recommendation	Barriers addressed	Responsibility	Drivers	Expected Positive Impacts	Likely impact on LCOE
			▪ To include different types of waterbodies to enable different business models and provide space to small players		
Plug and play model for large scale projects in the line of solar park[21] with at least 1-year tender-calendar	Technical/Commercial/ Policy and Regulatory/ Manufacturing and scale up/Indigenization/ Investment	SECI/State nodal agencies	▪ Development risks of approvals, clearances, interconnection etc. are mitigated (equitable distribution of risks to the most suited actors) ▪ More attractive to players resulting in CAPEX and OPEX optimization. ▪ Size favourable for large scale investment in manufacturing, new test laboratories and risk mitigation	▪ Scale-up and ramping up of local capacities ▪ Minimum critical scale for viability of the ecosystem ▪ Supports certification and standardization ▪ Enable infusion of large-scale investments	Up to 21 percent (Construction time: ~3 percent, CAPEX: ~14 percent, OPEX: ~4 percent)
Development of standards and guidelines Certification of components and system	Technical/Commercial/ Quality, Safety and Reliability/Investment	NISE/Bureau of Indian Standards (BIS)/MNRE	▪ To form a committee consisting of key stakeholders for necessary customization, adoption and regular updating of standards and guidelines developed by DNV and other agencies	▪ Optimized design and procedures ▪ Assurance of controlled risks to investors, insurers and other stakeholders and hence more accessibility to capital	Up to 18 percent (CAPEX: ~14 percent, OPEX: ~4 percent)

21 MNRE has granted approval to 6 floating solar parks of cumulative capacity 1805 MW.

Recommendation	Barriers addressed	Responsibility	Drivers	Expected Positive Impacts	Likely impact on LCOE
Single & Reliable Source of Information & its dissemination through regular workshops and other outreach programs such as newspapers	Technical/Commercial/ Quality, Safety and Reliability/Indigenisation	NISE/BIS/MNRE/ SECI	▪ To have a dedicated webpage for FSPV to provide all the necessary information to parallel sectors ▪ To provide guidance documents to key stake-holders	▪ Scale-up ▪ Entry of more players (parallel industries) for innovation ▪ To develop competitive landscape	Up to 18 percent (CAPEX: ~14 percent, OPEX: ~4 percent)
Facilitate development of FSPV projects through different business models (e.g., RESCO model).	Commercial/Policy and Regulatory/ Indigenisation/ Investment	SECI/MNRE/ Central Electricity Regulatory Commission (CERC)/State Electricity Regulatory Commission (SERC)	▪ To develop guidelines and regulatory process for deployment on small waterbodies where the water surface can be leased to the developer	▪ Democratisation of sector ▪ Solarisation of rural areas ▪ Conservation of water, waterbodies and water table	Up to 14 percent on CAPEX
Separate credit line for FSPV in the line of rooftop solar	Commercial/ Manufacturing and scale up/Indigenisation/ Investment	IREDA and Banks	▪ To provide exclusive credit line for FSPV with clear guidelines and simple procedures (easy access) ▪ To provide debt and working capital to float manufacturers	▪ Working capital for scale-up and innovation ▪ Promotion of local start-up, innovation, and customization	Up to 14 percent on CAPEX
Development of Testing infrastructure	Technical/Commercial/ Quality, Safety and Reliability/Investment	NISE/BIS/MNRE	▪ To provide basic guidelines for testing ▪ To enrol certifying bodies authorized for testing of materials of floats and formulation of specific standards	▪ Standardization of testing ▪ Enhanced reliability ▪ Possibility of more investment	Up to 4 percent on OPEX

Recommendation	Barriers addressed	Responsibility	Drivers	Expected Positive Impacts	Likely impact on LCOE
Skilling and Capacity Building	Skill	Skill Council for Green Jobs/ Ministry of Skill Development	▪ To constitute a committee of key stakeholders (key industry players) to frame necessary training curriculum and certificates ▪ To regularly update the curriculum to ensure relevance	▪ Availability of key skilled workforce ▪ Scale-up ▪ Industry participation and commitment	Up to 21 percent (Construction time: ~3 percent, CAPEX: ~14 percent, OPEX: ~4 percent)
Gender and Diversity Inclusion	Skill	NISE, BIS, Skill Council for Green Jobs	▪ To undertake an audit of guideline, training curriculum and guidance documents to ensure gender & diversity inclusion & neutrality (female workforce, rural workforce etc) ▪ To modify and exclude any inherent & subtle bias (e.g., pictures of only men with safety harness in the instruction sheet) ▪ To provide positive incentive for wider participation (e.g., less fees for training)	▪ Access to large potential workforce ▪ Access to localized and diverse resources ▪ Innovation due to diverse experience in the workforce ▪ Localization and customization	Nil.

Recommendation	Barriers addressed	Responsibility	Drivers	Expected Positive Impacts	Likely impact on LCOE
R&D	Technical/Commercial/ Quality, Safety and Reliability/Investment/ E&S	MNRE, NISE, Department of Science and Technology	▪ Research funding to assess the long-term impacts of the floating PV installation on the biodiversity of the waterbody ▪ Research funding to promote innovation and customization ▪ Funding for research on reliability of engineering plastics used for floats	▪ Risk mitigation for long term green investment ▪ Cost reduction due to innovation and customization	Up to 18 percent (CAPEX: ~14 percent, OPEX: ~4 percent)
Upscaling of Manufacturing	Technical/Commercial/ Policy and Regulatory/ Manufacturing and scale up/Indigenization/ Investment	Ministry of Finance, Nodal agencies	▪ Removal of Basic Custom Duty (7.5 percent) on import of Blow Moulding Machines for float manufacturing ▪ Establishment of manufacturing facility near project sites can be facilitated through creation of specific infrastructure and single window clearance mechanisms.	▪ Rapid ramp up of manufacturing capacity ▪ Optimization of transportation cost and timelines ▪ Local employment generation	Up to 21 percent (Construction time: ~3 percent, CAPEX: ~14 percent, Savings in transportation: ~1-4 percent)

TABLE 2.11: Fixed assumptions for LCOE calculations[22]

Assumption Head	Sub-head	Unit	Parameter
Power Generation	Installed Power Generation Capacity	MWp	100
	Useful Life	Years	25
	Annual system degradation rate	Percent	0.64
Financial Assumption	Tariff Period	Years	25
	Debt	Percent	70
	Equity	Percent	30
	Debt Term	Years	15
	Interest rate	Percent	10
	Discount rate/Weighted Average Cost of Capital	Percent	7.5
	Depreciation rate for 1st 15 years[23]	Percent	4.67%
	Depreciation rate 16th year onwards[24]	Percent	2%
	Total depreciation over 25 years	Percent	90%
	Corporate Tax	Percent	30
	Plant Residual value	Percent	10
O&M Expenses	Normative O&M expense per annum	INR Lakh/MWp	4
	Waterbody leasing per annum	INR Lakh/MWp	0.7
	Escalation Factor	Percent per annum	3.84

22 All assumptions are for the purpose of illustration only and may be revised based on the contemporary market scenario. For the purpose calculation, the assumptions are based on best available data at the time of compilation.
23 Assumption as per CERC RE Tariff Order for FY 2021-22.
24 Assumption as per CERC RE Tariff Order for FY 2021-22.

TABLE 2.12: Variable assumptions for LCOE calculations

Sl. No.	Sub-head	Drivers for the target	Unit	Base	Target	LCOE impact
1.	Alternating Current (AC) Capacity Utilization Factor (CUF)	Learnings from field data input into simulation process	Percent	23	25	8%
2.	Construction time	Visibility of volume, innovation, standardisation, enhanced manufacturing capacity, manufacturing close to site etc	Months	24	12	3%
3.	Capital cost[25]	Visibility of volume, innovation, standardisation, enhanced manufacturing capacity etc	INR Rs/Wp	42	35	14%
4.	Savings in transportation (base case of >1000km)[26]	Manufacturing facility <250 km from project location	INR Rs/Wp	42	40.2	4%
		Manufacturing facility 250-500 km from project location		42	40.7	3%
		Manufacturing facility 500-1000 km from project location		42	41.4	1%
5.	OPEX[27]	Visibility of volume, design optimisation and reliability testing	INR Lakh/ MWp	4	2.5	4%

25 Base capital cost derived from stakeholder consultations and publicly available information, primarily for controlled waterbodies (e.g., small ponds and reservoirs of thermal power plants) with water depth <10 m and water level variation within 5 m. Target is the current CAPEX level of ground mounted installations.

26 The base indicated is the system CAPEX considering >1000 km distance to manufacturing plant. Target is the expected system CAPEX with savings in transportation cost as the manufacturing facility is moved closer to the project location.

27 Base OPEX derived from stakeholder consultations, primarily for controlled waterbodies (e.g., small ponds and reservoirs of thermal power plants) with water depth <10 m and water level variation within 5 m. Target is the current OPEX level of ground mounted installations.

3. BENCHMARKING THE FSPV ECOSYSTEM IN INDIA AGAINST INTERNATIONAL PRACTICES

3 BENCHMARKING THE FSPV ECOSYSTEM IN INDIA AGAINST INTERNATIONAL PRACTICES

An FSPV, installed over an underutilized water body, apart from providing additionality in energy generation[28] (Liu, Krishna, Leung, Reindl, & Zhao, 2018) also overcomes some of the limitations of conventional ground mounted solar PV power plants[29] (Rosa-Clot & Tina, 2018). FSPVP technology, based on learnings from installed projects and buttressed by a combination of standardization, innovation, and reduction in costs, is rapidly approaching maturity. As a result, there has been an increase in the number of installed projects world over dominated by projects in developing countries (~ 90% of the top 50 FSPV, are in Asia). This has been driven by [a] availability of under-utilized water bodies[30]; [b] high opportunity cost of equivalent land; and [c] avoidance of land acquisition.

The genesis of FSPVP was based on the idea of avoiding the use of land, which has a high opportunity cost, for setting up a solar PV plant.[31] This, on one hand opened new avenues where underutilized surface area of water bodies that could be tapped to generate power such as HPP reservoirs, thermal power plant (TPP) reservoirs and natural and human-made lakes. The availability of water bodies defines the various business models that can be adopted, and a few initial plants have been summarised in **Table 3.1.**

- FSPV on hydropower plant reservoirs can enhance utilization of existing infrastructure, provide additional revenue, prevent water evaporation.
- FSPV on TPP reservoirs can enhance revenue stream, fulfil auxiliary power demand, and reduce evaporation losses.
- FSPV on lakes can provide revenue stream to local bodies and ensure upkeep of lakes. It can also support remote rural areas with a possibility of off-grid or mini grid solutions.

28 PV modules, by virtue of being in close proximity with water stay relatively cooler due to the effect of evaporative cooling. Based on the temperature coefficient of the specific PV module used, this can translate into energy gains vis-à-vis a conventional ground mounted or rooftop solar PV power plant. The gains due to evaporative cooling can however be offset by the lower tilt angle of a FSPV. Hence, a combination of factors – [a] evaporative cooling; and [b] inclination angle of solar PV module determines the net benefit.

29 The benefits include reduced land usage, less shading, less soiling due to dust, reduction of evaporation loss and large potential.

30 Such as regular in-land water bodies, sand extraction lakes, hydropower dams, water reservoirs, flooded mining subsidence, fishery lakes and near-shore waters.

31 With time, in addition to reduced land usage, multiple co-benefits have been identified, which include reduction in temperature loss, relatively lower near shading losses, lower soiling due to dust, access to grid, reduction in algae growth, application along with aquaculture and fish farming, inter alia (Liu, Krishna, Leung, Reindl, & Zhao, 2018).

TABLE 3.1: Summary of Business Models in Initial Projects

Country	Status	Solutions offered by integrating FSPV with available water bodies	Background
Brazil	Planned	The deployment of floating solar plant in the dam of a reservoir compensates the unstable generation of these systems by adjusting hydropower output. FSPV systems can compensate for the hydropower energy deficiency in mid to long term.	Capacity to store water in reservoirs of HPPs has declined, due to the increased Brazilian electricity consumption and more stringent environmental conditions for flooding areas leading to increased risk of power deficit in case of prolonged water shortage. A co-located solar component of generation can increase the dispatchable energy production, making better usage of the HPP's electrical grid connection. Installing 34 GW of FSPV on roughly 2.2 percent of total water surface of hydropower reservoirs can increase energy production by 53.3 TWh per year which is approximately 14 percent of Brazil's generation from hydropower.
Portugal	Operational	With 840 solar panels occupying an area of 2,500 square metre, the plant has installed capacity of approximately 220 kWp and estimated annual output of around 300 MWh. The platform generated net output 5 percent higher than forecast, an increase of 15 MWh. Alto Rabagão reservoir was chosen for FSPV deployment because of the availability of space and the adverse climatic conditions that enabled the technology to be tested in extreme conditions. It also has a deep valley with rocky soil and significant height variations which meant that the mooring solutions could be tested, with positive performance when the water level dropped. The FSPV plant was also able to withstand a harsh winter, with swell of about one metre, low temperatures and snowfall.	HPPs located in the vicinity of reservoirs have a connection to the power grid that is underutilized as the seasonality of rainfall means that the installed capacity cannot be occupied continuously. This technology offers many environmental advantages related to the protection of the underwater environment from solar radiation, with less proliferation of algae and, therefore, a lower eutrophic effect and fewer emissions of greenhouse gases.

Country	Status	Solutions offered by integrating FSPV with available water bodies	Background
Pakistan	Planned	The University of Lahore scientists modelled the implementation of FSPV at the 1.45 GW Ghazi Barotha Dam, which features five generating units with around 290 MW of capacity each. To cover daytime peak loads, installing a 200 MW floating system on the dam's reservoir could replace one of the five generating units if water levels are low. The researchers noted that Pakistan suffers frequent outages due to peak load hours during the day. Therefore, FSPV was adopted to work like a peaker plant.	It was observed that the cost of connecting FSPV to the grid accounts for about 25 percent of total project cost. However, that shrinks considerably when such projects use the existing infrastructure of hydroelectric dams.
China	Operational	The 40 MW FSPV is located in Huainan city in Anhui province of China. The array of solar PV modules floats on an artificial lake, created on the site of a former coal mine.	The plant was built by Sungrow Power, who converted abandoned flooded opencast mine in Anhui province. Establishing FSPV over abandoned coal mines allows for productively utilizing an otherwise unsuitable site. While providing clean energy, it also offers employment to the local population, which would otherwise be completely dependent on coal mining.
Germany	-	According to an assessment by the Fraunhofer Institute for Solar Energy Systems ISE, Germany's exploitable FSPV potential at opencast mines is set at 2.74 GWp70.	

3.1. Approach & Methodology

To benchmark the floating solar ecosystem in India, certain international markets were shortlisted. The shortlisted markets were then studied for these specific areas:

- **Policy & Regulatory Ecosystem analysis:** How attractive does the government make FSPV projects—incentives offered by the government, government intervention to create efficient value chain and key practices being followed.
- **Risk mitigation:** Steps taken by the government of that country to mitigate merchant risk/offtake risk.
- **Driver identification:** Key drivers that promote installation of FSPV in those countries were identified.
- **Evaluation of technical capabilities:** Some countries have more success than others with certain technology and therefore have superiority in areas of the value chain that use that technology. Hence, the technical capabilities of shortlisted countries were evaluated.
- **Evaluation of major projects:** Countries are following diverse market mechanisms to promote FSPV. Different projects were evaluated to identify key takeaways.

- **Make vs buy strategy for components:** Countries are growing in terms of manufacturing capacity of solar panels as well as floaters. The manufacturing capability and amount invested in the import of components was studied for each country.
- **R&D activities:** Countries across the globe are actively involved in R&D activities. The key breakthroughs in the R&D sector for floating solar was studied for the shortlisted countries.

Apart from countries shortlisted for study, best practices followed under different parameters by different countries were also investigated. For example, while China and Singapore are not on the shortlist, they are relatively focusing more on certain parameters such as R&D or technical standards.

3.2. Benchmarking

Benchmarking has been done against three countries—Japan, Netherlands and Vietnam. The rationale for selecting these three countries is given in Appendix C. This section delves into the practices in each of these countries with respect to the areas specified in Section 3.1.

3.2.1. Introduction to the Shortlisted Countries

The three shortlisted countries (from a list of nine countries presented in Appendix C) have great solar potential and the common driver of land scarcity. Furthermore, if the top 50 FSPV projects (by capacity) are considered at a global level, these three countries have the highest installed capacity[32] after China. The shares of global installed capacity (excluding China) are 31.8 percent in Vietnam, 21.5 percent in Netherlands and 12.8 percent in Japan[33]. The following sub-sections delve into each of the three countries.

3.2.2. Japan

In Japan, 210 MW of floating solar projects have been installed and another 52 MW is in the pipeline. The key drivers for adoption of floating solar in the country are:

1. **Policy driver for Renewable Energy (RE):** In Japan, the Ministry of Economy, Trade and Industry (METI) has jurisdiction over a broad policy area concerning Japan's industrial/ trade policies, energy security, control of arms exports and the like. It is responsible for securing stable and efficient supplies of energy and mineral resources. Furthermore, METI shapes policies for international trade and investment, Abenomics structural reforms, and energy. It drafts and amends legislation while enforcing and administering existing laws and regulations. METI and its affiliated agency, the Agency for Natural Resources and Energy, establish RE policies and incentives, including the FiT programme, at the national level. In Japan, by 2019, around 97.5 GW of RE capacity was achieved[34] (Solar – 78.5 GW; hydro – 28 GW; wind - 3.8 GW; bioenergy – 3.2 GW; geothermal – 0.5 GW).
2. **High potential for RE:** Owing to the high potential of RE, in 2030, METI expects renewable energy to account for 36%-38% of the country's energy mix for power generation in Financial Year (FY) 2030-31 - with the 1% introduction of green hydrogen/ ammonia and 20%-22% of nuclear power – totalling 57%-61% of the non-fossil fuel power supply (S&P Global, 2023).
3. **Land resource constraints:** Japan faces the constraint of limited ground space, a key driver for the country to switch from large-scale ground PV systems toward

32 SolarPlaza. (2021, February). Top 50 Operational Floating Solar Projects 2021.
33 SolarPlaza. (2021, February). Top 50 Operational Floating Solar Projects 2021.
34 IRENA. Energy Profile Japan. www.irena.org. https://www.irena.org/IRENADocuments/Statistical_Profiles/Asia/Japan_Asia_RE_SP.pdf

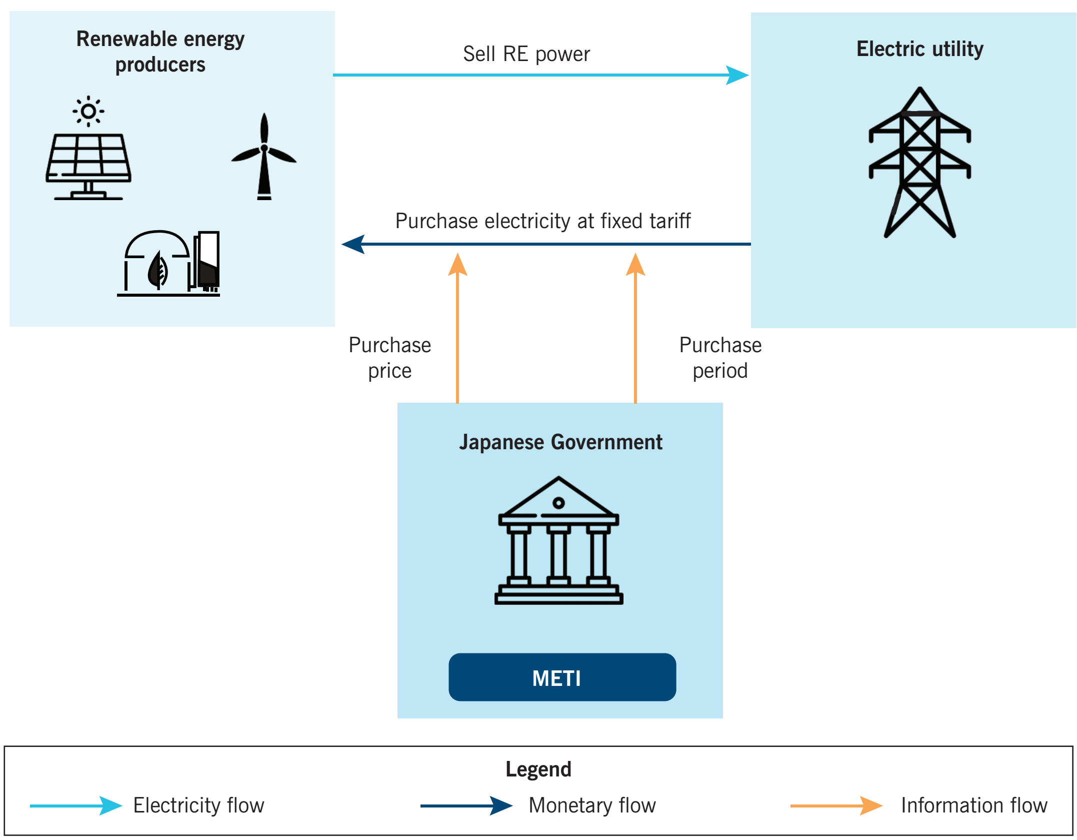
floating solar. Furthermore, installation of solar panels on water can mitigate land cost and the need for excavation. However, these costs are replaced by waterbody lease charges and the cost of dredging.

3.2.2.1. Policy and Regulatory Ecosystem

For installation of FSPV plants in Japan, construction plans must be filed in advance with METI. In addition, apart from METI, authorization is required from local power utility for FSPV projects to enter into a power purchase agreement (PPA) under the Feed-in Tariff (FiT) programme. A renewable power producer must fulfil certain requirements in relation to grid connection, such as consent to the output curtailment rule. FSPV projects built on irrigation reservoirs must also comply with the Basic Law on Food, Agriculture, and Rural Areas. In addition, environmental approvals are also required. Furthermore, as illustrated in **Figure 3.1**, for procurement by electricity retailers, the purchase price and purchase period are set by the METI annually or, at the discretion of the METI, semi-annually, for each category, depending on the configuration of installation and scale of RE generation facilities.

In Japan, FiT was introduced in 2012, under the Act on Special Measures Concerning the Procurement of RE by Operators of Electric Utilities[35,36]. Japan's percentage of electricity generated by renewables in total power generation increased from 10% in

FIGURE 3.1: Mechanism of power procurement by electricity retailers in Japan



35 Government of Japan. (2011). Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities (Act No. 108 of 2011) (2016 Ed.) | ESCAP Policy Documents Management. https://policy.thinkbluedata.com/node/1316

36 METI. (2016). Promulgation of the Partial Revision of the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities (METI). https://www.meti.go.jp/english/press/2020/0225_001.html

FY2011 to 18% in FY2019 thanks to the FiT scheme that was introduced in July 2012. With the reduction of capital cost, the cost of generation decreased and hence FiT decreased as well. The price difference between the expenditure for renewable electricity under FiT and the procurement cost for conventional electricity (avoided costs) is filled using the surcharge collected from electricity consumers (FiT surcharge) (Refer **Figure 3.2**). Due to this increased burden on consumers, Japan has decided to introduce the Feed in Premium (FiP) program.

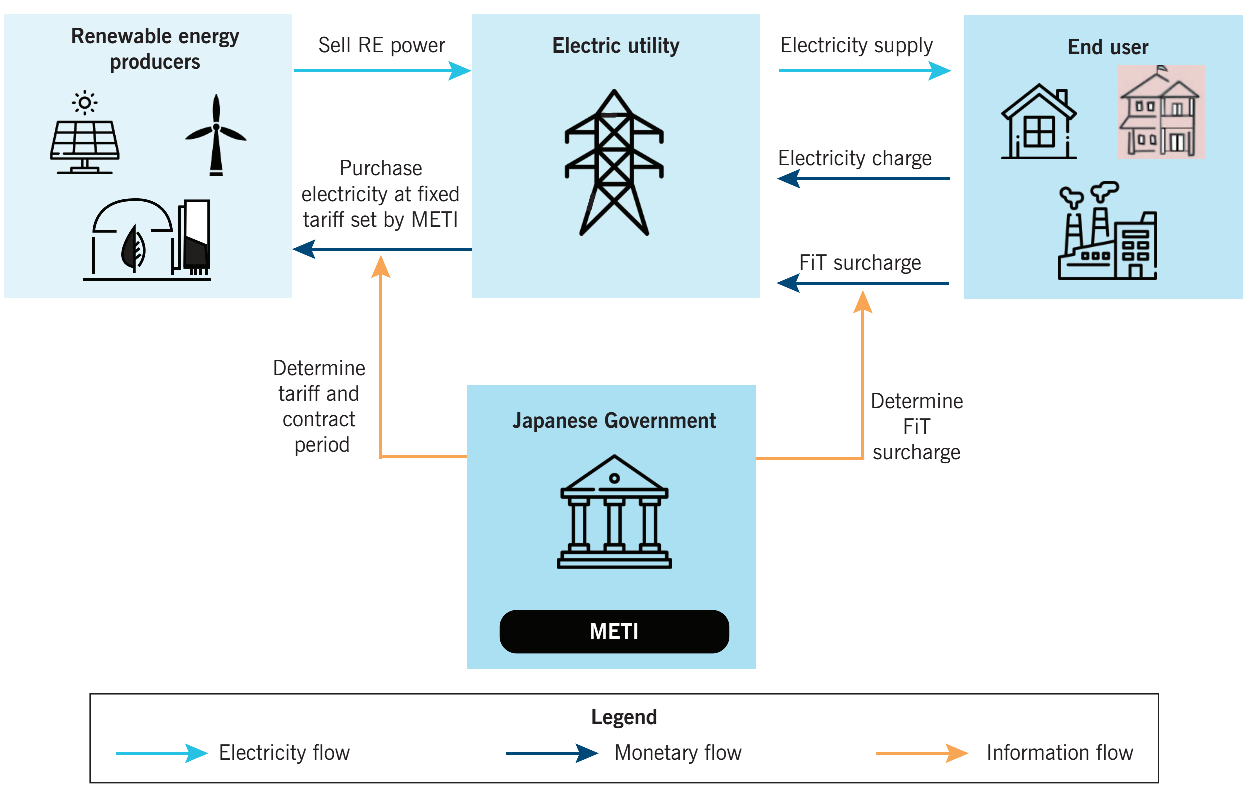
Under the amended RE Act of 2020, the FiP mechanism will be introduced for certain types and sizes of RE generation in 2022. Although the details of the applicable technologies and capacities have not been announced, FiP is expected to be applicable to large-scale solar power and wind power projects.

The FiP program will allow power producers to freely sell generated electricity to wholesale electricity trading markets or through direct negotiation. This will guarantee such power producers investment incentives by enabling them to receive a certain premium on top of the market price for the electricity that they generate. The premium will be equivalent to the price difference between the FiP price and the electricity market reference price. METI will be responsible for determining the method for calculating the premium and the period for which it will be granted.

Incentives

For FSPV systems under 2 MW, Japan provides incentives in the form of FiT. The FiTs for solar PV (including rooftop, ground mounted and floating solar projects), for the 2020 Japanese Financial Year (JFY2022) are given below[37]:

FIGURE 3.2: FiT mechanism in Japan



37 Colthorpe, A. (2020, February 6). Japan sets feed-in tariffs for the 2020 Japanese FY. PV Tech. https://www.pv-tech.org/japan-sets-feed-in-tariffs-for-the-2020-japanese-financial-year/

TABLE 3.2: FiT per kWh for solar projects in Japan

System size	Feed-in tariff per kilowatt-hour
Below 10 kW	17 yen (US$ Ct 14.7)
Between 10 kW and 50 kW	11 yen (US$ Ct 9.6)
Between 50 kW and 250 kW	10 yen (US$ Ct 8.7)

For FSPV projects above 250 kW and up to 2 MW, the winning bid receives FiT certification, and the bid's pricing becomes the official FiT (or purchasing price).

3.2.2.2. Key Projects Deployed and Major Developers

Most areas in Japan that are suitable for large-scale solar power plants are already being utilized or being planned for use. This section discusses the mechanism of public procurement adopted for FSPV projects, key projects deployed, and major developers in Japan.

Mechanism of public procurement

In Japan, the public procurement is generally through auction. The framework for auctions in Japan is given in **Figure 3.3.**

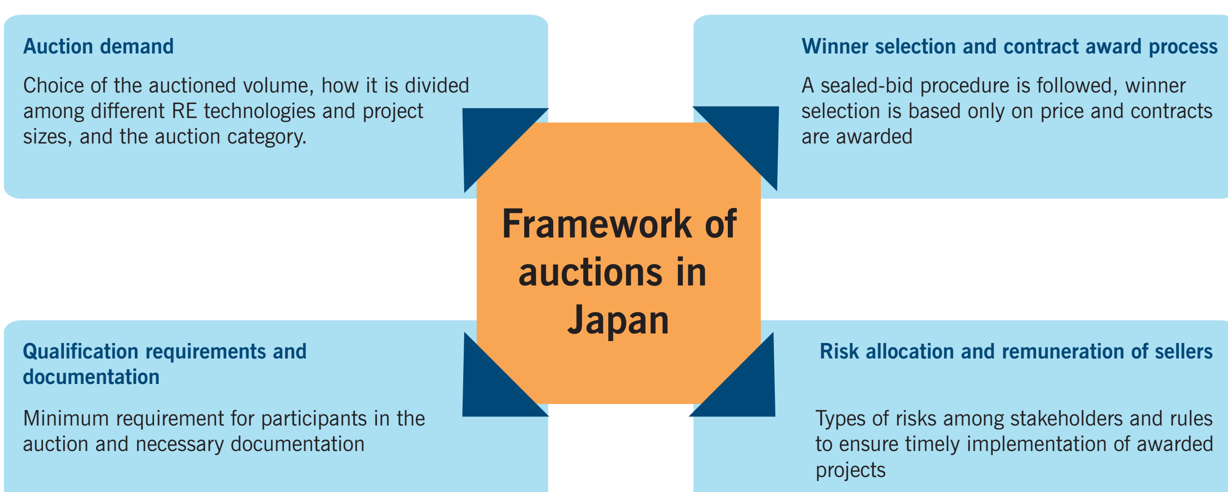
Several risks were identified:

Mandate of signing completion bond: In Japan, there are two types of commitment bonds: a bid bond to ensure contract signing, and a completion bond to ensure project implementation. The bid bond requirement in Japan is 500 yen/kW ($4.5/kW) and the main criteria for its confiscation include failure to sign the contract and/or evidence of bid-rigging. The bid bond is usually counted toward the completion bond or returned if the project is not awarded. However, the completion bond, is 10 times higher than the bid bond at 5,000 yen/kW ($45.3/kW).

Investor's revenue loss due to curtailment of power generation: The Electricity Power Companies can curtail power generation from renewable power plants without compensation, for up to 360 hours a year for PV plants. This potential risk of losing revenues for investors can translate to the total cost of the projects, which may lead to increase in the bid prices.

Risks associated with currency exchange rates and inflation: Exchange rates and inflation can have a considerable impact on

FIGURE 3.3: Framework for RE project auctions in Japan[38]



38 IRENA. (2021). Renewable Energy Auction in Japan: Context, design and results. https://www.irena.org/publications/2021/Jan/Renewable-energy-auctions-in-Japan

the viability of a project which is supposed to operate for a long time.

Key FSPV projects in Japan

In 2007, the world's first floating solar plant was built in Japan, in Aichi Prefecture in central Honshu. Furthermore, till early 2019, 73 of the 100 largest floating projects were based in Japan. As per SolarPlaza's report *Top 50 Operational Floating Solar Projects 2021*[39], the 10 largest operational FSPV plants in Japan have capacities in the range of 2 MW to 14 MW with an average capacity of 5 MW.

Most of Japan's FSPV plants are primarily located in the western part of the country because installers can take advantage of the area's many reservoirs and accessible grid connections. The north part of the country receives heavy snow in winter.

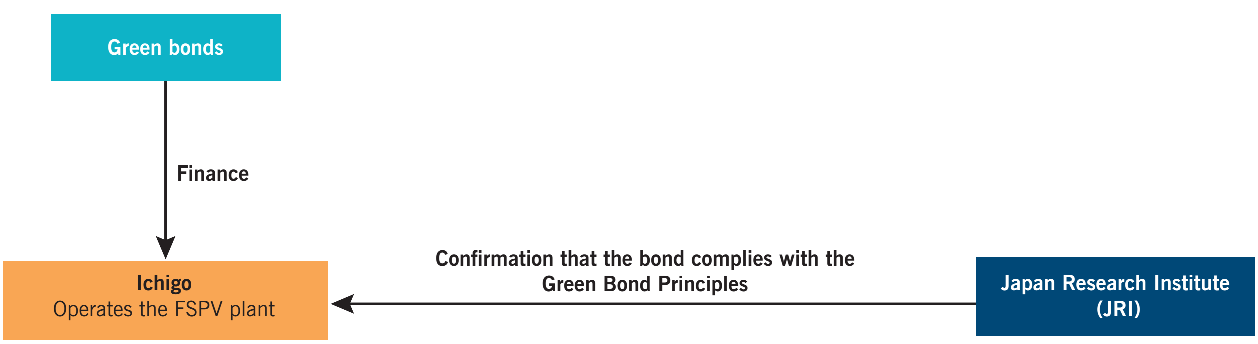
Different modes of financing were evaluated, and a project identified to be financed via green bonds. In April 2020, the Ichigo Kasaoka Osakaike ECO Power Plant began operation as a floating power plant on an agricultural reservoir in Okayama Prefecture. The 2.66 MW plant consists of 7,000 panels, covers an area of 122,000 square meters, and is estimated to provide enough power for 1,110 households.

Ichigo obtained independent confirmation from the Japan Research Institute (JRI) that the bond complies with the Green Bond Principles[40] issued by the International Capital Market Association and the Green Bond Guidelines 2017[41] issued by Ministry of the Environment, Japan. JRI is a company which performs three key functions - information systems, consulting, and think-tank. The certification from JRI enabled smooth approval process for the project.

In Japan, FSPV projects are generally developed by private players on government waterbodies and the power is sold to local utilities. This study identified two projects that differ by type of waterbody.

FSPV plant on a dam reservoir (public waterbody): Kyocera TCL Solar (a private company) started operation of the company's largest 13.7 MW floating solar plant, located on the Yamakura Dam reservoir in Ichihara, Chiba Prefecture. The plant was constructed over the surface of the reservoir, which is managed by the government water utility, Waterworks Bureau of Chiba Prefecture, for its industrial use. The project used Hydrelio technology by Ciel & Terre. All power generated is sold to Tokyo Electric Power Company (public electric utility).

FIGURE 3.4: Green bond financed FSPV plant in Japan



39 Solarplaza. 2021. Solarplaza | Top 50 - Operational Floating Solar Projects.
40 For more details: Green Bond.
41 Green Bond Guidelines, 2017 | Environmental Policy | Ministry of the Environment, Government of Japan.

RATIONALE FOR GREEN BOND ISSUANCE BY ICHIGO ECO

On July 25, 2019, Ichigo decided to issue a green bond to grow its clean energy business and further contribute to the company's goal of building a more sustainable society. The green bond issued by Ichigo ECO Energy ("Ichigo ECO") funded six Ichigo solar power plants. The proceeds from the green bond were used to pay for the refinancing and construction of the six solar power plants, five of which were already in operation, and one was under development.

GREEN BOND MARKET IN INDIA

In India, the first green bond was issued by Yes Bank in 2015. Further, the Indian green bond market observed these key milestones:

- In 2018, SBI entered the Green Bond market with a $ 650 million certified climate bond.
- In the first half of 2019, India became the second-largest Green Bond market globally after China with $10.3 billion worth of transactions.
- In October 2019, India joined the International Platform on Sustainable Finance to scale up environment-friendly investments.

However, despite achieving these goals, the Indian Green Bond market hasn't been able to diversify regarding assets, which remain focused on renewable energy projects. Since 2018, green bonds have constituted only 0.7 percent of all the bonds issued in India. Further, as of March 2020, bank lending to non-conventional energy projects constituted about 7.9 percent of outstanding bank credit to the power sector.

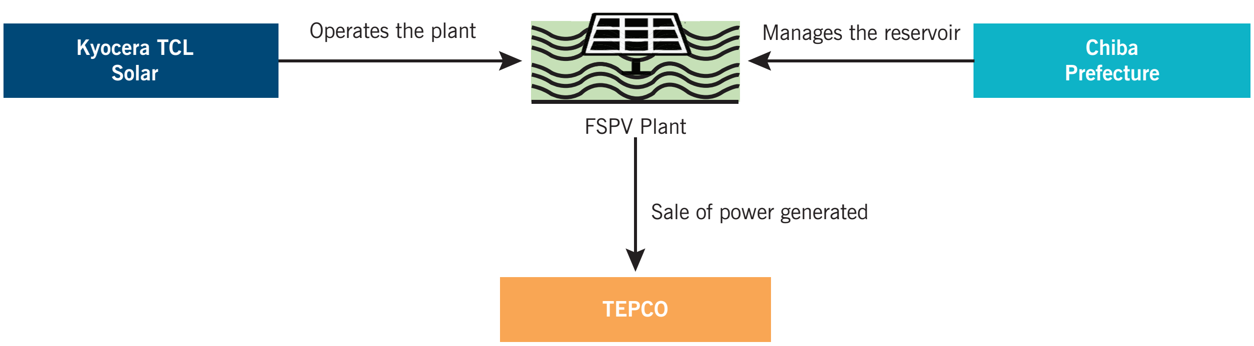
In November 2022, the Government of India launched the framework for Sovereign Green Bonds. It successfully raised INR 8000 crore ($980 million) in the first issue of the sovereign green bonds in January 2023.

Sources:

Verma, I. (2021, May 13). Sustainable Finance Through Green Bonds. Outlook Money. https://www.outlookindia.com/outlookmoney/opinions-and-blogs/sustainable-finance-through-green-bonds-7221

Javaid, A. (2021, January 29). What are Green Bonds? Jagranjosh. https://www.jagranjosh.com/general-knowledge/green-bonds-1611908611-1

FIGURE 3.5: Kyocera's 13.7 MW FSPV plant on a dam reservoir



FSPV plant on an irrigation pond: JFE Plant Engineering, a Japan-based EPC provider, constructed the Hyoshiga Ike FSPV plant with 2.7 MW capacity, on an irrigation pond. The plant is owned by Energy Bank Japan and Ciel & Terre provided its patented floats **(Figure 3.6)**. The plant provides electricity for utility use. Hyoshiga

TYPHOON FAXAI CAUSED THE 2019 FIRE AT THE FSPV PLANT ON YAMAKURA DAM, JAPAN

On September 9, 2019, the FSPV plant caught fire after Typhoon Faxai's impact. METI investigated and discovered the reasons behind the fire:

- **Aquatic level and mooring wire tension:** It rained heavily on the day of the typhoon, which caused the water level in the lake to reach around its maximum level of 37.5 m. The installed mooring lines were under tension due to the high water level. The tension on the lines allowed the forces from the oscillating movement caused by wind and waves to dissipate to the anchors more directly.
- **Shape of the plant:** Anchors were attached around the perimeter of the island, with mooring wires connected only to the outermost floats. The floats behind the fixed row were attached with resin bolts. Each row picked up wind forces, which accumulated into the first bolt.
- **Anchor failure:** The Yamakura Dam array had 112 anchors on the northern end, 107 on the western side, and 133 on the eastern edge, but only 68 anchors on the southern perimeter, where the anchors failed. The typhoon exceeded the standard technical assumptions set out when the site was designed.
- **Bolts and uplift:** After the anchors failed, the resin bolts started to collapse, because the wind loads were now dissipated more unevenly. After each collapsed bolt, the loads on the adjacent ones increased, causing a chain reaction. In this way, the array was ripped into three parts.
- **Fire:** The outermost floaters of floating PV installations are usually ballasted with water, to prevent uplift in windy conditions—a phenomenon that has been observed in the past. When the array was ripped apart, the wind-facing edge did not have any ballasted floats anymore. The installation then began to curl up, and mangled modules and other equipment started to short circuit, causing the electrical fire.

The findings of the investigations can be useful in designing floating solar systems which can withstand such storms or typhoons.

Source: Willuhn, M. (2020, February 22). The weekend read: Don't throw caution to the wind. pv magazine International. https://www.pv-magazine.com/2020/02/22/the-weekend-read-dont-throw-caution-to-the-wind/

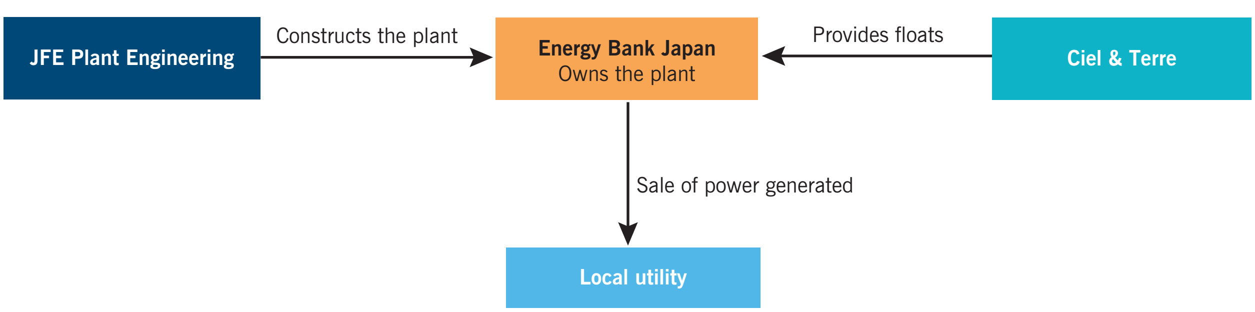
Ike can generate 3.14 MWh, equivalent to around 872 residential electricity annual consumption.

In countries, such as India, with abundant presence of irrigation ponds, FSPV projects can be developed over such waterbodies.

Major developers in Japan

Ciel & Terre is the biggest installer in the Japanese FSPV market. Its projects are mainly located in the western part of Japan due to availability of many reservoirs in that area. Another major developer is Mitsui

FIGURE 3.6: FSPV plant located on an irrigation pond in Japan



Sumitomo Corporation, which provides floating structures for 60 and 72 solar cells panels for the domestic market and is also working on overseas expansion to other Asian countries.

3.2.2.3. Research and Development (R&D) Activities

In a study in Hyogo Prefecture, local authorities concluded that solar panels on water generated 14 percent more power than those placed on the rooftop of an office building due to the cooling effect that the water has on the panels that makes them work closer to their ideal temperature.

The largest Japanese companies, such as Kyocera, Panasonic, Solar Frontier, Sharp, and Kaneka are developing high efficiency solar modules, with higher outputs at higher temperatures (lower temperature coefficient), better tolerance for shadows, and higher guaranteed performance during longer periods. Some examples are Panasonic's HIT technology (heterojunction solar cell with a bifacial structure), Solar Frontier's Copper Indium Selenium technology, and Sharp's black solar modules.

3.2.2.4. Make vs Buy Strategy for Components

The major module and float manufacturers or suppliers in Japan are given in **Table 3.3**.

For FSPV projects, Kyocera leads the solar PV module suppliers in Japan, followed by the Chinese Yingli Green Energy. Other prominent players include Jinko Solar, Sharp, and Trina Solar.

TABLE 3.3: Component manufacturers or suppliers in Japan

Component	Home Country	Company
Solar modules	**Japan**	Kyocera
		Panasonic
		Toshiba
		Sharp
		Kaneka
		Solar Frontier
		XSOL
	China	Yingli Green Energy
		Jinko Solar
		Trina Solar
		JA Solar
		Risen Energy
	South Korea	Hanwha Q-CELLS
	Canada	Canadian Solar
Floats	**Japan**	Sumitomo Mitsui Construction
		Kyoraku
	France	Ciel & Terre
	China	Mibet Energy
		Sungrow

Foreign companies such as Hanwha Q-CELLS, Jinko Solar, Canadian Solar, JA Solar, Yingli Green Energy, Trina Solar, and Risen Energy also operate in the country.

About 60 percent of the PV modules used in the country are produced by Japanese companies. However, these companies (e.g., Kyocera, Panasonic, Sharp and Kaneka) produce only 55 percent of their products within the country with the remaining 45 percent produced overseas. The balance 40 percent of the modules used in Japan are produced by foreign companies in overseas countries. The South Korean Hanwha Q CELLS leads Japan's imported solar panel market.

The import figures for PV cells (whether assembled in modules or made up into panels) stood at $3.03 billion in 2018, $2.88 billion in 2019 and $2.50 billion in 2020.[42,43]

Ciel and Terre has a manufacturing facility in Japan, and it has provided floats for FSPV projects with a cumulative capacity of around 100 MW—approximately 50 percent of the FSPV installed capacity in Japan. Other float manufacturers in Japan are Sumitomo Mitsui Construction (which has provided floats for a cumulative FSPV capacity of 6 MW) and Kyoraku (which has provided floats for a cumulative FSPV capacity of 5 MW). China-based manufacturers of floats, such as Mibet Energy and Sungrow, also supply their products in Japan.

3.2.3. Netherlands

In Netherlands, 52 MW of floating solar projects have been installed and another 500 MW is in the pipeline. The key drivers for adoption of floating solar in the country are:

1. **High potential for solar energy:** Netherlands is a country with a huge potential for solar PV. In 2021, the installed capacity of solar energy was 14.30 GW, which accounted for around 60 percent of the country's renewable installed capacity[44,45]. In addition, as per the Netherlands Environmental Assessment Agency, by 2030, the country is expected to witness another 12 GW, bringing the total capacity to approximately 27 GW[46].
2. **Easy availability of waterbodies:** To achieve the expected solar capacity, the Government of Netherlands considers that floating solar has an important role to play. With plenty of inland water in the form of lakes, canals and old sand pits, the Dutch geography is suitable for floating solar.
3. **Policy driver:** A consortium of national and local governments, Dutch companies, knowledge institutes, and water authorities have announced a target to achieve 2,000 hectares of floating solar farms by 2023[47].

3.2.3.1. Policy and Regulatory Ecosystem

The permission and approval process for FSPV projects consists of identification of type of ownership of water surface, permits (such as environmental and water permits), adherence to building code requirements and several other permits (such as license to generate, license to operate, and license to

42 (2020, October 1). www.customs.go.jp. https://www.customs.go.jp/english/tariff/2020_10/data/e_85.htm
43 Trade Statistics Data for Japan Values by Commodity Import. (2021). https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00350300&tstat=000001013141&cycle=1&tclass1=000001013183&tclass2=000001013185&tclass3val=0
44 Statista. (2021). Renewable capacity in the Netherlands 2008–2020. https://www.statista.com/statistics/1189567/total-renewable-capacity-in-the-netherlands/
45 Bhambhani, A. (2021, January 21). 2.9 GW New Solar Installed In Netherlands In 2020. Taiyang News. http://taiyangnews.info/markets/2-9-gw-new-solar-installed-in-netherlands-in-2020/
46 Bellini, E. (2019, November 4). Netherlands to reach 27 GW of solar by 2030. PV Magazine International. https://www.pv-magazine.com/2019/11/04/netherlands-to-reach-27-gw-of-solar-by-2030/
47 DutchNews.nl. (2019, June 12). Floating solar farm group targets 2,000 hectares of water. https://www.dutchnews.nl/news/2019/06/floating-solar-farm-group-targets-2000-hectares-of-water/

connect to the grid). These processes were recommended by the National Consortium Zon op Water (a partnership of more than 35 parties, consisting of private companies, knowledge institutions and governments, in the Netherlands, with a focus on floating solar), and Deltares (an independent institute for applied research in the field of water and subsurface).

If the waterbody is owned by a private party, then the civil laws apply, and the mechanisms of agreements or lease contracts are used. For public waterbodies, additional permission may be required from the Water Authority or state water works agency.

In 2017, a national consortium called Zon op Water (Sun on Water), was created by the Ministry of Infrastructure and Water Management and led by the Solar Energy Application Center (SEAC). SEAC is a non-profit organisation which is focussed on research in innovative solar energy products and services. The national consortium Zon op Water commissioned studies to understand the licensing and permitting processes applicable for FSPV systems in the Netherlands. These studies concluded that FSPV systems should be considered building structures, installed for a long period of time and connected to the ground via cables. In this sense, they could be compared to houseboats, common in the Netherlands, which require environmental permits.

Further, according to Deltares, when evaluating the FSPV permitting process, developers must first evaluate who controls the waterbody. A different set of rules apply for each of these scenarios. Three types of waterbody ownerships were identified:

- **National:** Works to be undertaken are in or close to a waterbody under the jurisdiction of the Ministry of Infrastructure and Water Management (Rijkswaterstaat) or on a national dam (typically large rivers, lakes and canals).
- **Regional:** Works to be undertaken are in regional waters (under the jurisdiction of a water utility) or on provincial waterways, which are smaller waterbodies.
- **Private:** The waterbody is owned by an individual or private company.

The key permits required for setting up a FSPV project are:

- **Environmental permit:** Environmental impact assessment is required, along with a landscape design plan, showing visual landscape impact.
- **Water permit:** If any project, such as FSPV, is developed on a water surface, permission is required.
- **Building code requirements:** Since Zon op Water has recommended that FSPV systems be considered as building structures, building codes similar to national standards for ‘construction in a marina,’ or ‘construction of house boats,’ including worker safety standards for ‘working near water’, ‘diving workers’, ‘working in electricity environments’, are required.

Some other permits, such as license to generate, license to operate, and license to connect to the grid are expected to follow. After going through this approval process, technical studies are conducted before construction of floating solar projects.

Incentives

The Netherlands has an operating subsidy (subsidy provided during the operating period of project) scheme, called Stimulation of Sustainable Energy Production and Climate Transition (SDE++). The scheme is a follow up to the SDE+ scheme. The SDE++ focuses on the large-scale rollout of technologies for RE production and other technologies that reduce greenhouse gas (CO_2) emissions. It compensates the difference between the cost price of the sustainable energy or the reduction in CO_2 emissions and the revenue. The subsidy is calculated over 12 to 15 years. The duration and amount of subsidy depends on the technology used and the level of CO_2 reduced. Under SDE++, for floating solar, a subsidy intensity of €175 per tCO_2 (\$210 per tCO_2) and incentive of €0.08 per kWh (\$0.10 per kWh) has been announced[48]. By the end of 2020, 4,112 applications were received (5,776 MW) under the scheme which accounted for a total budget claim of €6,397 million. Out of these total applications, solar energy contributed to 3,989 applications (4,195 MW) with a budget claim of €2,360 million[49].

Higher incentives are offered for projects with sun tracking.

3.2.3.2. Key Projects Deployed and Major Developers

Driven by space scarcity in the Netherlands, floating solar farms with good yields have already been built at a variety of locations, including sand extraction lakes, water treatment plants, water reservoirs and ponds. SolarPlaza's *Top 50 Operational Floating Solar Projects 2021* reports that the four largest operational FSPV plants in Netherlands have capacities in the range of 8 MW to 28 MW with an average capacity of 16 MW.

Key FSPV projects in Netherlands

In the Netherlands, a 100 MW project named Zon op de Slufter was developed with a goal to study how national sites could be optimized for the generation of power from renewable sources. The Zon op Water consortium installed FSPV systems on De Slufter, a contaminated dredging depot in the Port of Rotterdam, to function as a pilot testbed. The dredging depot is a contaminated water basin at the Maasvlakte, an artificial extension of the Europoort industrial facility at the Port of Rotterdam. The goals of the program are to:

- demonstrate the feasibility of floating solar farms at a wave category 2 location;
- determine the revenue model for the concepts, also compared to the yield on land;
- map the dynamic forces on the systems; and
- optimize the concepts

Bay.Wa.re. GmbH developed the 27.4 MWp Bomhofsplas floating solar farm in the Netherlands. The installation featured around 73,000 solar modules, 13 floating transformers and 338 inverters. Financing for the project was provided by ASN Groenprojectenfonds, a Netherlands-based sustainable bank[50]. The company recently sold the plant to a tie-up of Dutch energy players. The consortium of new owners consists of provincial fund Energiefonds Overijssel, local cooperative Blauwvinger Energie and an unnamed private investor.

Furthermore, BayWa r.e. developed several other major projects in the country. In 2019, it developed a floating solar plant, with a total capacity of 14.5 MWp. The project consists of 40,000 solar panels and can power around 4,000 homes. In addition, BayWa r.e. and its Dutch subsidiary GroenLeven recently energised two floating solar projects in the Netherlands with a combined capacity of 29.2 MWp (13.5 MWp Nij Beets park with 33,648 modules and 15.7 MWp Kloosterhaar plant with 39,256 modules).

48 Martín, J. R. (2020, February 18). The Netherlands moves to CO_2-based green energy subsidies in €5bn new push. PV Tech. https://www.pv-tech.org/the-netherlands-moves-to-co2-based-green-energy-subsidies-in-5bn-new-push/

49 Weijden, C., Rietvelt, M., & Rabbie, M. (2021, January 19). Update SDE++ 2020 round. Lexology. https://www.lexology.com/library/detail.aspx?g=3bc2c87a-337f-45a5-b704-3e5d8fabaedf

50 A sustainable bank is a bank which focuses on socially responsible and sustainable investments. It can be viewed as a source of financing for RE projects, including FSPV.

FIGURE 3.7: Sustainable bank financed FSPV project in Netherlands

In 2020, Evides Waterbedrijf, a water utility company, installed a 1.6 MW floating solar farm at Rotterdam. The plant has been developed by the Dutch-based developer, Floating Solar. The system consists of 4,787 solar panels and is expected to generate around 1.7 million kWh of clean power annually. The project has been set up partly on land and partly on a reservoir in Kralingen where Evides runs its operations.

Some observations have been made related to technical standards or practices in FSPV projects in the country:

- In FSPV projects, limited sensors are seen to be applied, for example, only one pyranometer and one reference cell for a 14 MWp plant.
- The major projects are built by BayWa r.e. and they build initially on full equity before opting for bank finance. This ensures a high-quality standard from an electrical design perspective.

Major developers in Netherlands

In the Netherlands, the floating solar space is being led by a German RE developer, BayWa r.e. Another major developer is the Dutch-based, Floating Solar. Furthermore, several global developers are trying to enter the Netherland's FSPV industry. For example, in September 2020, Sweden's Vattenfall completed its first floating solar farm in the Netherlands. The project has a capacity of 1.2 MW and has been developed to power sand and gravel extraction company Netterden's onsite operations in Gendringen on the latter's gravel quarry.

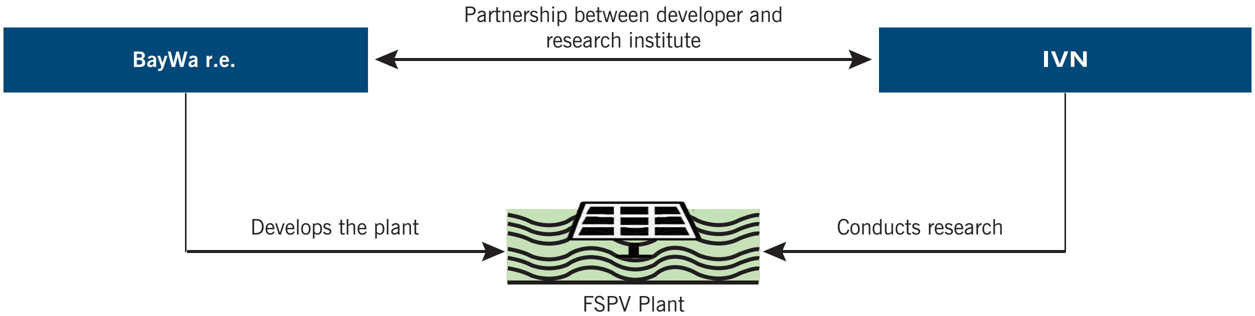
3.2.3.3. Research and Development (R&D) Activities

As mentioned earlier, the Zon op Water consortium installed four FSPV systems of 50 kWp each on De Slufter, a contaminated dredging depot in the Port of Rotterdam, to function as a pilot testbed.

Floating Solar has developed the world's largest solar-tracking PV system in Andijk in a drinking water treatment plant owned by Netherlands-based water utility PWN (Waterleidingbedrijf Noord-Holland). The system is based on an algorithm which can gradually adjust panel position and increase system yield by approximately 30 percent. To minimise ecological impact, the 73,500 solar panels will be arranged to form 15 individual islands. The islands' design and construction have a transparency factor of 80 percent to ensure that plenty of light reaches the water's surface. Special Weather Risk Management technology will minimise the risk of damage by automatically repositioning solar panels during storms.

BayWa r.e. and the Institute for Nature Education and Sustainability (IVN) collaborated in January 2021 on a study on the impact of floating solar on aquatic plants and

FIGURE 3.8: Partnership between a developer and a research institute



animals. BayWa r.e. and its Dutch subsidiary, GroenLeven BV, developed two FSPV projects with a combined capacity of 29.2 MWp. Both the sites, Nij Beets and Kloosterhaar, use minimal water surface for solar panels to ensure that enough sunlight can penetrate the water surface. Only 23 percent of available water space at Nij Beets has been used, leaving space near the banks to protect flora and fauna. The plants will be monitored over the next five years.

Zon op Water, which includes the Netherlands Organisation for Applied Scientific Research, is aiming, through the floating solar pilot projects that it oversees, to demonstrate the feasibility of floating solar in rough water conditions. The research is being conducted at a special testing facility at Oostvoornse, a lake that is located near Maasvlakte, an artificial extension of the Europoort industrial facility at the Port of Rotterdam.

Solar Duck, a Dutch start-up, has developed a triangular structure for floating PV that resembles an offshore oil platform. The triangular structure measures 16 x 16 x 16 meters. The solar panels are placed on the platforms which are raised using floating pillars. These platforms allow PV modules to be placed more than three meters above the water surface, allowing the structure to handle waves and dynamic loads. In addition, the distance from the water surface ensures that the modules and other components stay dry.

This arrangement is planned to be used in a pilot project.

Solar Duck and Voyex (a private hydrogen producer) are planning to set up a prototype of a solar island on the Waal near IJzendoorn, which can power ships with hydrogen that can be refuelled at offshore floating solar islands. The two Dutch companies have secured €350,000 in subsidies from the Province of Gelderland for the project that will also be supported by Dekker Group which will provide space for testing. Solar Duck will supply the solar island consisting of four linked platforms, each containing 39 solar panels. The floating solar island, which produces 65 kWp power, will be connected to a 10 kW electrolyser that produces hydrogen. The hydrogen will be bonded to a 'Liquid Organic Hydrogen Carrier', an oil-like liquid which will serve as a binding agent, or carrier, for the produced hydrogen.

3.2.3.4. Make Versus Buy Strategy for Components

The Netherlands is a major solar panel import and trading centre. In 2015, more than 50 percent of the imported panels came from China. In 2017, traders imported panels worth €1.7 billion of which 40 percent were built in Vietnam and only 13 percent in China; this was because several Chinese solar panel manufacturers moved production to Vietnam[51]. In 2020, the Netherlands imported around $2.31 billion worth of photosensitive semiconductor devices, including PV cells (whether assembled in modules or made up into panels) and light emitting diodes. The imports of photosensitive material accounted for 0.48 percent of total imports to Netherlands. In the same year, the export figures stood at, $1.46 billion[52], which accounted for around 0.26 percent of total exports from Netherlands.

By the end of 2017, the solar panel industry in the Netherlands had a workforce of 9,000 and estimated annual turnover of €3 billion[53]. Some of the solar panel manufacturers in the country are Hyet Solar, Girasolar, CCL Solar, etc. Eurotron is a Netherlands based company, established in 2005, which develops equipment for solar panel manufacturing. Zimmermann, a Germany-based company, is a major provider of a floating system called ZimFloat. The float system for the entire 80 MW of FSPV which is operational in the Netherlands, has been provided by Zimmermann.

Pro Floating manufactures floats in the Netherlands and has provided its product for a cumulative FSPV capacity of over 3 MW. Ciel & Terre has supplied floats for a cumulative FSPV capacity of ~2 MW. Other major suppliers of floats include Isifloating, Solarisfloat, and Sungrow.

3.2.4. Vietnam

In Vietnam, 117 MW of floating solar projects have been installed and another 400 MW is in the pipeline. In March 2022, the local authorities of the Nghe An province (Vietnam) have authorised the construction of two floating solar projects on the Vuc Mau and Khe Go lakes in Quynh Luu district, totalling 450 MW of capacity. The Vuc Mau project, developed by Vuc Mau Solar Power Investment at a cost of VND3,700 billion (US$160 million) will have an installed capacity of 200 MW, while the Khe Go project proposed by Khe Go MK Solar Power at a cost of VND4,100 billion (US$180 million) will be rated 250 MW. Both are targeted to be commissioned by December 2023. Power generation will be sold to the national power utility Electricity of Vietnam (EVN). The key drivers for adoption of floating solar in the country are:

1. **Policy driver for RE:** The National Power Development Plan for the 2011-2020 Period with the Vision to 2030 set out a strategy to ensure Vietnam's energy security, improve rural electrification, and increase RE capacity. In March 2016, a Revised Power Development Master Plan VII revised the percentage of RE required. It was determined that RE (excluding large and medium scale hydropower) should make up 10 percent of total generation by 2030. This was accompanied by a mandated reduction in coal-fired generation. Solar is seen as key to the proposed increase in renewable generation capacity, with a goal of 12 GW installed by 2030[54].
2. **Land resource constraints:** With limited land resources, solar power competes with agriculture for land. With abundant water surfaces available, the rise of

51 DutchNews.nl. (2018, January 24). The sky's the limit - solar panels soar in popularity in the Netherlands. https://www.dutchnews.nl/news/2018/01/the-skys-the-limit-solar-panels-soar-in-popularity-in-the-netherlands/

52 Netherlands | Imports and Exports | World | Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezo-electric crystals | Value (USD) and Value Growth, YoY (%) | 2009 - 2020. (2021). TrendEconomy.

53 DutchNews.nl. (2018, January 24). The sky's the limit - solar panels soar in popularity in the Netherlands. https://www.dutchnews.nl/news/2018/01/the-skys-the-limit-solar-panels-soar-in-popularity-in-the-netherlands/

54 Volkwyn, C. (2020, August 27). The transitioning of Vietnam's energy sector. Smart Energy International. https://www.smart-energy.com/industry-sectors/policy-regulation/the-transitioning-of-vietnams-energy-sector/#:%7E:text=The%20National%20Power%20Development%20Plan,and%20increase%20renewable%20energy%20capacity.&text=This%20initially%20prioritised%20the%20development%20of%20solar%20energy%20over%20other%20energy%20sources.

floating solar along with the still mostly untapped solar rooftop potential offer suitable future applications for solar power in Vietnam.

3.2.4.1. Policy and Regulatory Ecosystem

In Vietnam, the policies and regulations for RE are led by the Ministry of Industry and Trade (MOIT), which acts as the market supervisor, and the national electric utility EVN.

Till the end of last year, the country followed FiT programs. These programs were divided into two phases:

- **FiT Phase 1:** In 2016, a program for 850 MW overall solar capacity was announced with feed-in tariff of 2,086 VND/kWh (USD 0.0935 per kWh) for over 20 years. The tariff was applicable to all solar projects, including FSPV. The phase 1 ended in June 2019.
- **FiT Phase 2:** In April 2020, Phase 2 of the FiT program came into effect. In this phase, separate tariff for floating solar was defined, which was 1,758 VND/kWh (USD 0.0769 per kWh) for a duration of over 20 years. Criteria for eligibility included grid-connected solar power plants, reaching COD between June 1, 2019 and December 31, 2020.

In 2021, Vietnam implemented an auction mechanism for all RE projects. For the projects to be eligible, they must be in the relevant master plans, not eligible for FiT Phase 1 or FiT Phase 2. Such FSPV projects are eligible to bid for the upcoming auctions post a pilot auction scheme, and to participate in the synthetic direct power purchase agreement (DPPA) scheme. Under the DPPA mechanism, the power purchasers (offtakers) are private power consumers, who purchase electricity directly from independent power developers under long-term contracts, instead of buying electricity from the utility. Further, in synthetic (or financial or virtual) DPPA, renewable power is not directly physically delivered to the offtaker. Instead, the generator sells the renewable power to the grid and receives the open market price. The power generator and the offtaker enter into a DPPA in the form of Contract for Differences. The project developer pays the difference to the offtaker when the agreed-upon PPA price is below the market price. However, when the PPA price is more than the market price, then the difference is paid by the offtaker to the project developer. Therefore, the amount received by the developer is fixed, irrespective of the difference between PPA price and market price.

Incentives

The incentives provided under FiT were $0.0935 per kWh in phase 1 and $0.0769 per kWh in Phase 2. Another incentive is the provision of DPPA. It allows energy producers to sell and deliver electricity to corporate consumers instead of going through a state-owned electric utility company.

3.2.4.2. Key Projects Deployed and Major Developers

As discussed earlier, Vietnam has the third highest installed capacity of floating solar projects. As per SolarPlaza's report *Top 50 Operational Floating Solar Projects 2021*, the three largest operational FSPV plants in Vietnam have capacities in the range of 35 MW to 47.5 MW with an average capacity of 40 MW.

FIGURE 3.9: Evolution of FiT program in Vietnam

Mechanism of public procurement

For initial years, the public procurement was through FiT programs. As discussed in the earlier section, the FiT program was divided into two phases: FiT Phase 1 and FiT Phase 2.

In 2021, Vietnam implemented an auction mechanism for all RE projects. The transition to auction mechanism consists of two pilot programs:

- **Auction for floating solar:** In February 2020, a pilot auction scheme for floating solar on hydropower plant dams of around 400 MW was announced. The first EPC auction was to be held for over 50-100 MW, a second EPC procurement round for over 300 MW was planned for 2021. The projects will be located at hydro facilities belonging to the Da Mi Hydropower Joint Stock Company (DHD), the owner of the FSPV plant. DHD is a division of EVN, which is a government-owned power company in Vietnam.
- **DPPA:** In January 2020, the government outlined a pilot program on DPPA mechanism (discussed in the previous section).

Key FSPV projects in Vietnam

A major project in Vietnam has been financed by Asian Development Bank (ADB), which is an International Financial Institution (IFI). It has provided a US$37 million loan to the DHD. The capacity of the plant is 47 MW. The project is being developed on a man-made reservoir at the company's 175 MW Da Mi hydropower plant in Binh Thuan province, on Vietnam's south-eastern coast.

In terms of the role of stakeholders involved, several projects were based on collaboration between private organisations and the government. In such projects, private players have mostly played the role of the developer and owner of the plant, while the government acts as a waterbody provider. For example, two large-scale floating solar projects, with a total capacity of 70 MW, have been commissioned in Vietnam. They are the 35 MWp Ho Tam Bo floating solar power plant and the 35 MWp Ho Gia Hoet 1 floating PV plant. The two projects have been set up on irrigation lakes, in Quang Thanh commune, Chau Duc district. LONGi supplied high efficiency PV modules for both projects. Both projects were developed by Vietnam's TOJI Group.

Major developers

As discussed in the key projects, the major FSPV developers in Vietnam include DHD and the Vietnam-based TOJI Group.

Several major global players have been planning to enter the Vietnam's FSPV market. For example, in 2018, California-based clean energy developer Vasari Energy Inc announced a deployment of between 180 MW and 200 MW of solar capacity in

FIGURE 3.10: IFI (ADB) financed FSPV plant in Vietnam

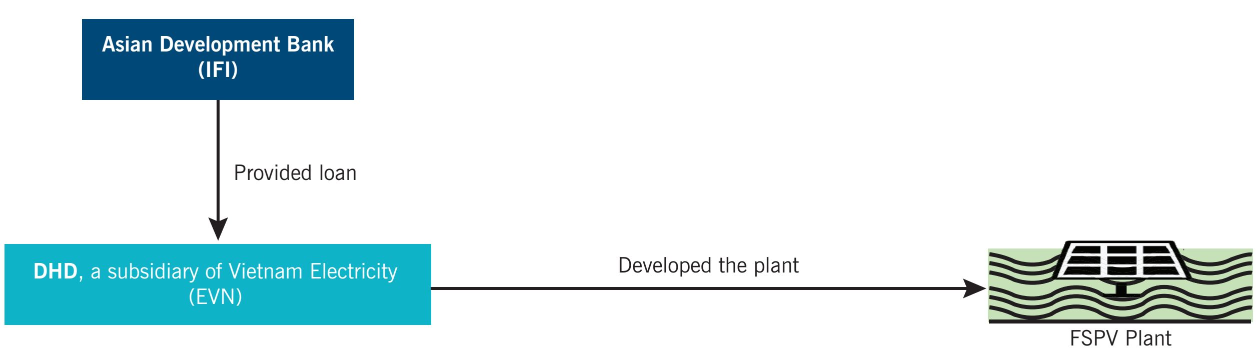


FIGURE 3.11: FSPV project involving collaboration between private organisations and government in Vietnam

Vietnam, both through land-based and floating installations. The company intended to build and operate two land-based and two floating solar power plants, each with a capacity of 40 MW-50 MW.[55]

3.2.4.3. Research and Development (R&D) Activities

Information on R&D activities in floating solar technology in Vietnam is not available.

3.2.4.4. Make vs Buy Strategy for Components

The major module and float manufacturers or suppliers in Vietnam are given in **Table 3.4.**

In 2022, Vietnam's cumulative solar module manufacturing capacity was 3,500 MW[56] (VIR, 2023). Furthermore, several manufacturers, both domestic and global, are trying to enter the country or expand their manufacturing

TABLE 3.4: Component manufacturers or suppliers in Vietnam

Component	Home Country	Company
Solar module	**Vietnam**	Solar Power Vietnam Technology
		Boviet Solar Technology
		Dehui Solar Power
		Green Wing Solar Technology
		IREX Energy
		Red Sun Energy
		Venergy Solar Industry
		Vietnam Green Energy Technology
		VSUN Solar
		Vina Solar Technology
	China	Jiangsu Seraphim Solar System Co. Ltd
		JA Solar
	USA	Allesun New Energy
Float	**France**	Ciel & Terre

55 Shumkov, A. I. (2018, January 18). Vasari plans 200 MW of land-based and floating solar in Vietnam. Renewables Now. https://renewablesnow.com/news/vasari-plans-200-mw-of-land-based-and-floating-solar-in-vietnam-598664/

56 At present, its annual production capacity in Vietnam stands at 1.5GW of silicon wafer and 3.5GW of solar modules.

capacity in the country. For example, a solar panel maker Vsun, a subsidiary of Japan-based Fuji Solar, is planning to set up a solar cell and module manufacturing facility in the Hoà Phú Industrial Zone in the Bắc Giang province, in the northeast part of Vietnam. The factory is expected to be operational soon with an annual solar module production capacity of 4 GW and a cell capacity of 2 GW. Vsun invested US$300 million in the project. Furthermore, China's Jiangsu Seraphim Solar System Co Ltd plans to build a 750 MW solar module assembly factory in Vietnam.

JA Solar is planning to set up 3.5 GW capacity of new high-power modules in Vietnam through JA Solar Viet Nam Company Limited. It will be set up in Gwangju Industrial Zone of Bac Giang province by using existing land to build this new production line and supporting facilities. It estimates an investment of RMB 700 million (US$103 million) on this project.

In Vietnam, Ciel and Terre has a manufacturing facility, which has a patented water-based PV concept, Hydrelio technology, consisting of modular 'Lego-esque' (building block type) floaters assembling into rows.

3.3. Key Observations from Other Countries

In this section, select global practices related to incentives offered, business models adopted, innovation in components manufactured and R&D activities are discussed.

3.3.1. Incentives Offered

As part of its Green New Deal Policy, **Korea** invested a total of 73.4 trillion South Korean won ($64.8 billion), which accounts for around 4 percent of the country's Gross Domestic Product (GDP) in 2019, to create 3,19,000 jobs by 2022 and 6,59,000 jobs by 2025 to boost the green energy sector[57,58]. The amount of 73.4 trillion South Korean won comprises private investment of 30.7 trillion South Korean won and public investment of 42.7 trillion South Korean won. The investment will be made on eight projects which are listed under the Green New Deal Policy.

In **Taiwan**, the FiT scheme follows a multi-phase bidding process within a year to determine the suitable tariff level payable. For instance, in 2021, the FiT for floating solar is 4.1957 New Taiwan dollars per kWh under phase 1 and 4.1204 New Taiwan dollars per kWh under phase 2. The factors which determine the applicable FiT rate (among phase 1 and phase 2) include the type of facility categorized under the Rules for Management of Renewable Energy Generation Facility Installation (Rules), its expected installed capacity, and the commercial operation date. The key reason behind following the multi-phase approach is that the cost of PV varies frequently even within a year, and so the constant yearly FiT rate becomes inappropriate. Further, within the FiT scheme, the FiT provided for FSPV are higher than those for ground-mounted PV. The 2022 tariffs for solar PV that would remain unchanged for 2023 are shown in **Table 3.5.** Given such conducive incentives, Chena Energy, a local developer in Taiwan, has built the world's largest floating solar PV with a capacity of 180 MW (Grid Connected). Such projects help to explore and capitalize on offshore capacities in the coastal areas of Taiwan.

57 Joon, P. S. (2021, April 8). Strengths and Limitations of the Korean Green New Deal | Heinrich Böll Stiftung Hong Kong | Asia Global Dialogue. Heinrich-Böll-Stiftung. https://hk.boell.org/en/2021/04/08/strengths-and-limitations-korean-green-new-deal

58 The World Bank. (2021). GDP (current USD) - Korea, Rep. | Data. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KR

TABLE 3.5: FiT rates in Taiwan for solar systems[59]

Type of solar PV system	Installed Capacity	2021 Feed-in-Tariff (NT$/kWh)	
		Phase 1	Phase 2
Rooftop	1 kW or more but less than 20 kW	5.8952	5.7848
	20 kW or more but less than 100 kW (without grid connection fee)	4.5549	4.4538
	20 kW or more but less than 100 kW (with grid connection fee)	4.4861	4.3864
	100 kW or more but less than 500 kW	4.0970	3.9666
	500 kW or more	4.1122	3.9727
Ground-mounted	1 kW or more	4.0031	3.8680
Floating	1 kW or more	4.3960	4.2612

3.3.2. Research and Development

Several research activities in the FSPV sector are being undertaken in **Korea**. In December 2020, the Ministry of Trade, Industry and Energy announced that the government would invest 50 billion South Korean won ($45.1 million) to build a joint solar energy R&D centre to focus on the development of solar technology and business models. In addition, the Korea Institute of Energy Research, a public sector research organization, leads the development in PVs in Korea.

In **Thailand**, the Siam Cement Group (SCG), a Thailand-based public holding company, has signed a Memorandum of Understanding (MoU) with the Electricity Generating Authority of Thailand (EGAT). EGAT is a government-owned company, responsible for electric power generation and transmission as well as bulk electric energy sales in Thailand. As part of the MoU, the two organisations will work collaboratively in research and development on a mooring system for a floating solar farm in EGAT's reservoirs and dams. SCG provides floating pontoons that are made of high-quality polyethylene resin which employs strength and durability and is eco-friendly. The pontoons can last up to 25 years which is equivalent to the solar panel's lifecycle. Furthermore, SCG provides a 25 year warranty on the pontoons. The long-lasting benefit helps reduce the costs associated with float maintenance.

3.4. Key Takeaways, Observations from Global Practices and Associated Risks of FSPV

Based on the benchmarking study of the three countries in Section 3.2, some key observations were made in the areas of drivers of FSPV, policy and regulations, FSPV component manufacturing and R&D, which are presented in **Table 3.6.**

3.4.1. Key Observations from Japan, Netherlands and Vietnam

3.4.1.1. Need for FSPV

The countries under consideration are majorly dependent on imports of conventional sources—Liquefied Natural Gas (LNG) and

59 The Ministry of Economic Affairs of Taiwan announced the feed-in-tariff for renewable energy projects for 2022. https://www.moeaboe.gov.tw/ECW/English/news/News.aspx?kind=6&menu_id=958&news_id=25032

TABLE 3.6: Summary of observations in key areas

Key areas		Countries		
		Japan	Netherlands	Vietnam
Drivers of FSPV	RE or Solar targets	✓	✓	✓
	Limited land availability	✓	-	✓
	Availability of waterbodies	✓	✓	✓
Policy and regulations	Competitive bidding	-	-	✓
	FiT	✓	✓	-
	DPPA	-	-	✓
Component manufacturing	Solar panels	✓	✓	✓
	Floats	✓	✓	✓
R&D	Efficiency of FSPV as compared to other technologies	✓	✓	Data not available
	Solar panels	✓	✓	
	Solar tracking	-	✓	
	Aquatic flora and fauna under solar PV panels	-	✓	
	Other areas	-	✓	

coal imports in Japan, natural gas imports in Netherlands, and coal imports in Vietnam—for electricity generation. However, the cost of coal and gas imports have increased over time and these country governments have committed to reducing their carbon footprint. Therefore, these countries are looking to transition to RE and have set defined RE targets.

Although, each of these countries has good potential for RE and the cost of renewable power has decreased over time, there are several barriers to its large-scale adoption. With the exception of Netherlands, one of the key barriers is low availability of land for deployment of RE projects like ground mounted solar. To address this barrier, these countries are switching to floating solar projects. In addition, the abundance of waterbodies makes FSPV plants suitable for all the three countries.

3.4.1.2. Key Learnings for India

Target level inclusion

In all three countries, the governments have set targets for reduction of emissions and generation from RE sources. Netherlands, in particular, has specified technology-specific targets for floating solar while others have set broader, technology-agnostic targets.

TABLE 3.7: Targets for RE in the three shortlisted countries

Country	Target
Japan	▪ Reduce GHG emissions by 26 percent by 2030 from the 2013 level ▪ Increase the share of RE and nuclear power to 44 percent by 2030 ▪ 22 percent-24 percent of the generation mix to be attributed to renewables by 2030
Vietnam	▪ RE target of 10 percent of total generation by 2030 ▪ 12 GW of solar energy by 2030
Netherlands	▪ Achieve 2,000 hectares of floating solar farms by 2023

LEARNINGS FOR INDIA: SET TECHNOLOGY-AGNOSTIC TARGETS

Developing countries, as borne out by case examples, typically institute technology-agnostic RE generation targets and leave it to market players to choose scalable technologies to achieve the same. For an emergent technology like FSPV, that is behind the maturity curve of ground-mounted solar PV in India, it could help to not have a specific target. It is anticipated that solar market players in India, having tasted success and scale with ground-mounted PV, will automatically expand into floating solar, given India's abundant water resources and the country's push for innovation and growth in clean technologies. This process would be further catalyzed by demonstration effects if the government were to take up a few pilot floating solar installations in the short term.

Technology maturity development strategies

Several studies and pilot projects helped Japan, Netherlands and Vietnam realize the on-ground requirements and key issues faced in the deployment of floating solar plants. This learning helped these countries gain confidence in deployment of large-scale FSPV projects.

When faced with a lack of data regarding the feasibility of FSPV, Netherlands developed a pilot testbed to assess whether national sites could be optimally utilized for the generation of power from FSPV plants. Furthermore, to fathom the impact of floating panels on aquatic flora and fauna, a private developer and an educational/research institute collaborated to undertake a study via a pilot project. In addition, a study was undertaken to demonstrate the feasibility of floating solar in rough water conditions.

In Japan, a study to assess the efficiency of FSPV plants concluded that solar panels on water generated 14 percent more power than those placed on the rooftop of a building. That water has a cooling effect on the panels that makes them work closer to their ideal temperature. The 2019 fire at the FSPV plant on Yamakura Dam triggered by Typhoon Faxai resulted in several key learnings to ensure reliability of FSPV plants.

For large scale deployment of floating solar plants, the following assessments are required to be undertaken:

- Identification of areas with a large number of reservoirs and other favourable conditions.
- Feasibility of installing floating solar projects in different types of waterbodies such as lakes, and reservoirs.
- Requirements to ensure optimum utilization of waterbodies and existing infrastructure.
- Efficiency of FSPV plants as compared to other technologies such as ground mounted solar.
- Impact of FSPV projects on the environment.
- Designing of the plant must ensure that it can withstand rough water conditions. For instance, assessments may be required for technical standards for mooring lines, anchors, connection bolts, and the like.

LEARNINGS FOR INDIA: PROMOTE PILOTS

The Indian FSPV market is at a nascent stage and there is a need to establish the proof of concept. Government agencies such as Solar Power Park Developers could promote floating solar projects. Successful pilots will create confidence among private players which in turn will spur investment in scalable FSPV plants. An example of the government taking the initiative is the 600 MW Omkareshwar Floating Solar Park being developed by RUMSL in Madhya Pradesh.

Market mechanisms

While all three countries followed FiT approach, they varied by strategy.

In Japan, the FiT policy for RE was enacted at the beginning of July 2012 with FiT of 40 Japanese yen per kWh. By 2020, the tariff decreased by 70 percent to reach 12 Japanese yen per kWh. The cost differential which arises due to FiT is borne by the consumer in the form of a surcharge. The tariffs for the period of 2017-2020 are given in **Figure 3.12.**

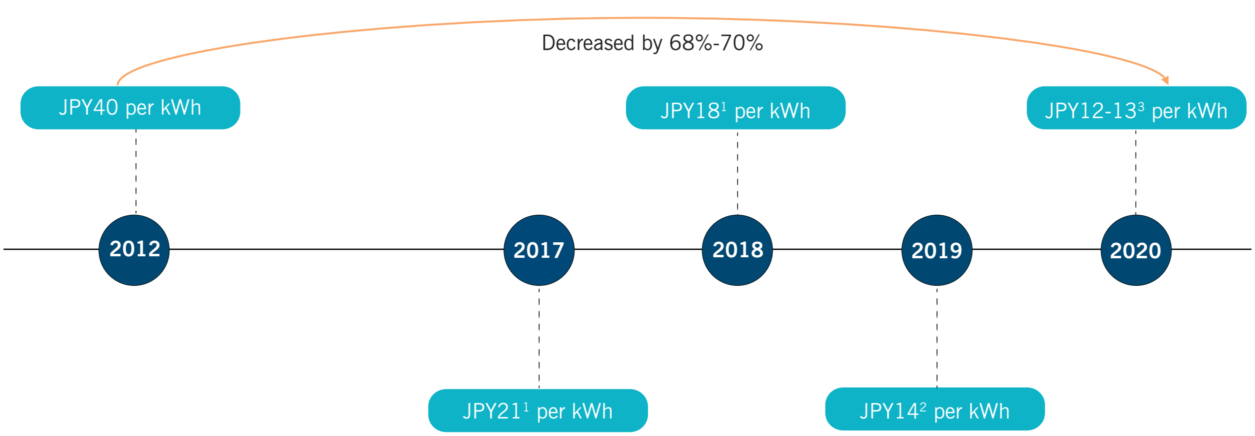
In Netherlands, as already discussed, SDE++ is a subsidy that compensates for the difference between the cost price of the sustainable energy or the reduction in CO_2 emissions and the revenue. The subsidy is calculated over 12-15 years. The subsidy intensity of €175/tCO_2 ($210 per tCO_2) and incentive of €0.08/kWh ($0.10 per kWh) has been announced for FSPV.

In Vietnam, between June 1, 2017, and June 30, 2019, FiT rates offered were $.0935/kWh in Phase 1 which was available for all solar technologies, including floating solar projects under the FiT program. The second phase offered variable FiT considering solar irradiation of the location and the solar technology used, including FSPV. Higher tariffs were proposed for regions with lower solar irradiation and potential. New proposed tariffs varied from $0.0667/kWh to $0.1087/kWh.

The key observations derived from each of these strategies are:

- When floating solar technology was at a nascent stage, FiT helped in lowering investment risks and financing costs which led to rapid increase in its adoption.
- The decrease in FiT in Japan is primarily driven by decrease in CAPEX of solar PV system, which has decreased by almost 80 percent from 2010 to 2020.
- The amount of the subsidy in Netherlands depends on the technology used and the level of CO_2 reduction that can be achieved. Hence, the developers' focus is on FSPV that offers high CUF. Higher incentives are offered on projects with sun tracking.
- In Vietnam, higher tariffs for floating solar projects are offered which compensate for the higher cost of technology.

FIGURE 3.12: Trend of FiT rates in Japan



Note: [1]FIT for >2 MW non-residential solar power production determined via auction process; [2]FIT for >0.5 MW non-residential solar power production determined via auction process from 2019; [3]FIT for >0.25 MW non-residential solar power production determined via auction process from 2020.

LEARNINGS FOR INDIA: ALLOW COMPETITIVE BIDDING

Although the FiT approach ensures upfront security, the Indian market, along with the global experiences, seems mature enough to allow competitive bidding for tariff discovery. The requirements for successful competitive tariff discovery payment security mechanism, standardization of contracts, offtake assurance and recourse to payments will need to be in place. The government should focus on creating a conducive environment using such mechanisms while allowing the market forces to enable competitive price discovery.

Value chain evaluations

Manufacturing of solar modules

In terms of solar module manufacturing, various manufacturers, both domestic as well as foreign, are already present in the three countries. Furthermore, existing as well as new players are trying to expand their manufacturing base in these countries. For example, in Vietnam, solar panel makers such as Vsun, JA Solar, and Jiangsu Seraphim Solar System are planning to set up large-scale solar cell and module manufacturing facilities. Apart from producing the solar panels for domestic use, manufacturers also export their products. For instance, manufacturers in Netherlands exported US$1.46 billion worth of photosensitive semiconductor devices, including PV cells, in 2020.

In Japan, about 60 percent of the PV modules are produced by Japanese companies. However, these companies produce only 55 percent of their products in Japan. The remaining 45 percent is produced overseas and imported to Japan. Similarly, in Netherlands, a large proportion of solar panels is imported.

Manufacturing of floats

The countries under consideration have achieved some level of maturity in float manufacturing capabilities. The France-based manufacturer, Ciel and Terre, has manufacturing facilities in all the three countries. Furthermore, several other foreign companies (such as the China-based Mibet Energy and Sungrow, and the Germany-based Zimmermann) are present in these countries. Apart from foreign manufacturers, there are domestic manufacturers such as Sumitomo Mitsui Construction and Kyoraku in Japan, and Pro Floating in the Netherlands.

International experience with FSPV

Globally, several FSPV projects have been developed by deploying solar panels on waterbodies which are already in use as hydropower stations. Such FSPV plants are also present in the countries under consideration.

LEARNINGS FOR INDIA: BOOST DOMESTIC MANUFACTURING

Initially, components required for construction of a floating solar plant may be imported. However, to help the floating solar sector grow, easy availability of solar panels, floats, and other components is a must. Domestic manufacturing capabilities need to grow over time. It is important that both domestic as well as foreign players expand their manufacturing base in a country. Further, once the manufacturing capability reaches a certain level of maturity, the manufacturers could focus on exporting their products. Domestic manufacturing capacity for floats and solar panels needs to increase. During stakeholder consultations, manufacturers highlighted the need for a clear project pipeline to put additional capital expenditure for increasing floater manufacturing capacity. Solar cell manufacturing can be promoted via benefits such as safeguard duties and government-driven R&D initiatives.

Further, the government must define quality standards and technical specifications to ensure that components can withstand high moisture content, salinity of water, high wind speeds, and other harsh conditions.

LEARNINGS FOR INDIA: DEVELOP ROBUST REGULATIONS

The 2019 FSPV plant fire in Japan presents a convincing case for governments to develop robust standards and quality controls; it also requires developers to meet these standards to avoid environmental damages to the assets.

Innovative deal structuring, and low-cost financing also plays an important role in adoption of the technology. While government support is required to provide an initial push to the market and reduce the fear of new technology, the regulations should be flexible enough to allow market players to design innovative solutions.

In Japan, the fire at the FSPV plant on Yamakura Dam highlighted the importance of ensuring the reliability of a plant under harsh conditions. Thorough analysis of designs is required to ensure that the plants can withstand the worst possible environmental conditions and external actions (loads).

In the Netherlands, a 27.4 MW FSPV project was developed by BayWa r.e. on the Bomhofsplas lake in Zwolle. The plant was then sold to a tie-up of Dutch energy players. This is an example of asset recycling which may be adopted to absorb the construction risks.

In Vietnam, Da Mi Hydropower Joint Stock Co. unit of Vietnamese power company Electricity of Vietnam, which is a government-owned electricity provider, constructed a 47 MW FSPV plant on a man-made reservoir at the company's 175 MW Da Mi hydropower plant.

Some of these countries have opted to integrate hydropower and floating solar PV due to several advantages:

- The combination can provide a balance of electricity generation from RE and conventional sources, with solar power generating significant power during the dry seasons and hydropower generating electricity during rainy seasons.
- By linking to a common substation, a combined system of floating solar and hydropower plant can reduce transmission costs.
- Floating solar reduces water evaporation from the reservoir, thus increasing hydropower generation.
- Deployment of FSPV power plant on the reservoir of a dam compensates the unstable generation of these systems by adjusting hydropower output, whereas PV systems can compensate for the hydro energy deficiency in the mid- to long-term.

3.4.1.3. Proliferation Strategies

Key deployment strategies and targets

In Japan, Netherlands and Vietnam, the key drivers of proliferation of floating solar were the RE targets and land availability constraints. In India, acquisition of land is accompanied with regulatory roadblocks and high cost. Further, similar to the three countries, India is endowed with a large number of waterbodies, unlocking a huge potential for FSPV. Therefore, to accomplish its RE targets, India can adopt floating solar for electricity generation.

For instance, NTPC Limited is leading the floating solar segment in the country by constructing FSPV plants at their TPPs. In this way, they are trying to utilise the waterbodies available to them, which have an estimated potential of at least 800 MW[60].

60 NTPC. (2017, March 10). NTPC installs India's largest Floating Solar PV Plant at RGCCPP Kayamkulam, Kerala | NTPC. www.ntpc.co.in. https://www.ntpc.co.in/en/ntpc-installs-india%E2%80%99s-largest-floating-solar-pv-plant-rgccpp-kayamkulam-kerala

Deployment Strategy

The key components in business models of floating solar projects consist of waterbody type, waterbody provider, project developer, plant owner, and source of financing. The findings on the business models adopted in the three countries are summarized in **Table 3.8.**

In India, waterbodies are available in the form of agricultural reservoirs, dam reservoirs, irrigation ponds, lakes and man-made reservoirs, and all these may be considered for deployment of FSPV projects. Furthermore, since most of these waterbodies are owned by the government, they may provide access for development of the FSPV plants. The FSPV plant can be owned by the government or its departments (such as the power and water utilities) as well as private players (such as a private company, plant developer, or private power utility). In addition, the financing for the construction of the plant may be obtained through bank loans, green bonds, IFIs, etc.

Commercial competitiveness

In the countries under consideration, several factors have led to the decrease in cost difference between RE power and electricity from conventional sources.

In Japan, the nuclear phase-out after Fukushima resulted in costly LNG and coal imports. This increased its energy import dependencies and related supply insecurities. Therefore, to decrease dependency on costly imports, Japan started focussing on RE. In Netherlands, over the period of 2010-2018, the province of Groningen, from where a major proportion of gas was extracted, faced several earthquakes. In March 2018, the Dutch Cabinet decided to scale back extractions in the Groningen gas fields, resulting in increased dependence on import of natural gas from Norway. Similarly, Vietnam is highly dependent on costly imported coal and hydropower (primarily dependent on a single river shared by multiple countries).

TABLE 3.8: Key observations on business models

Country	Observations
Japan	▪ FSPV projects are generally developed by private players on government waterbodies and the power is sold to local utilities. ▪ Major waterbodies include agricultural reservoirs, dam reservoirs and irrigation ponds such as Shinano, Tone, Ishikari, and Teshio. ▪ Some projects were financed via green bonds.
Netherlands	▪ Private developers constructed plants on waterbodies such as reservoirs and lakes. ▪ Waterbodies are mostly provided by the government. However, a water utility company also provided its waterbody for an FSPV project. ▪ Apart from key financial sources such as banks, financing for some projects was via a sustainable bank (a bank which focuses on socially responsible and sustainable investments). ▪ Major waterbodies include rivers such as Rhine, Meuse, and Eems.
Vietnam	▪ Majority of projects are based on collaboration between private organisations and the government. Private players mostly play the role of the developer and owner of the plant, while the government acts as a waterbody provider. ▪ Several projects were developed on man-made reservoirs. ▪ An IFI provided funding for a key project in Vietnam which is owned by a power utility. ▪ Major waterbodies include rivers such as Dong Nai, Gianh, and Vam Co Dong river.

Therefore, these countries considered switching to RE power as an alternative to the expensive power from conventional sources. However, with RE power, other barriers started appearing which led to increased focus on FSPV. For instance, Japan and Vietnam, faced with limited ground space, decided to switch from large-scale ground PV solar systems to floating solar. In Vietnam, solar power plants have to compete with agriculture for land. Therefore, high untapped potential for solar energy and abundant availability of waterbodies function as a key driver of FSPV plants.

Netherlands also has plenty of inland water in the form of lakes, canals and old sand pits, making the Dutch geography suitable for floating solar. In addition, it has been focusing on R&D activities in the FSPV segment which has resulted in development of advanced technologies with higher efficiencies. Such developments have resulted in making floating solar competitive with other technologies. Furthermore, in the Netherlands, the RE prices are decreasing steadily. As the prices fall further, RE is expected to sustain without subsidies.

In summary, high import prices of oil and gas, combined with decrease in prices of renewable power, competitive land use, easy availability of waterbodies and R&D breakthroughs in floating solar technology have helped in making FSPV commercially competitive with other technologies.

Market ecosystem development strategies

The market in India is at a nascent stage with about 345 MW of floating solar plants already commissioned. Another 2,300 MW (approx.) are under different phases of implementation and are majorly planned in the states of Maharashtra, Uttar Pradesh, Jharkhand, Telangana, Tamil Nadu, and Andhra Pradesh. Active players participating in these tenders are ReNew Power, AMP power, NTPC Limited, NHDC Limited, SJVN Limited, Shapoorji & Pallonji, Sterling & Wilson Solar Limited, Mahindra, Waaree, Bharat Heavy Electricals Limited (BHEL) inter alia. Although there are no targets for FSPV at the national level, many states are supporting FSPV under their state specific RE policies, such as, Kerala. The ecosystem development strategies followed by the countries under consideration are a combination of two approaches:

- Focus on promotion of local manufacturing of existing technologies
- Focus on R&D activities to develop advanced technologies

In Japan and Vietnam, there is a major focus is on promoting floating solar component manufacturers to expand their manufacturing capacity in the countries and help in reduction of imports. Furthermore, their goal is to enable new manufacturers, both domestic and foreign, to enter the floating solar manufacturing industry. However, these countries are not focused on undertaking R&D initiatives.

In the Netherlands, several manufacturers of floating solar components are already present. They are mainly focused on undertaking R&D initiatives which can help them in developing new and innovative technologies and hence become global leaders in the floating solar industry.

3.5. Associated Risks and Mitigation Strategies for India

The risks associated with floating solar along with the mitigation strategies are summarized in **Table 3.9.**

TABLE 3.9: Risks and mitigation strategies for India

Risk	Description	Mitigation strategy
Absence of FSPV-specific standards	Being a new technology, no specific standards are currently available for floating solar.	The government needs to work with multiple stakeholders such as research institutes, certification agencies and private developers to develop robust standards and quality control mechanisms. This would require a cross-functional task force to develop the standards. The team must comprise experts with experience in the fields of Floating PV, Grid Scale PVs, Marine Anchoring, Materials, Environment and Ecological and Financing. A guidance document including review of the technology, considerations for technology selection, review of the technical standards and gaps in these standards for each of the main equipment that comprise a floating solar project is being issued separately.
Absence of waterbody data	There is no data available related to the ownership, water surface area, water level, etc. for most of the waterbodies in the country.	Existing bodies, such as CWC already gathers data for all the waterbodies in the country. However, CWC may be mandated to collect data for other aspects which may be required for FSPV project development and share it with the project developers.
Risks related to safety from harsh environment conditions	FSPV plants regularly face harsh environmental conditions such as high humidity and salinity of water. They may also be exposed to natural calamities such as storms and cyclones.	Research is needed on ways to improve long-term reliability of the components. For example, in 2020, Floating Solar (a Dutch company) revealed the results of three years of testing of its pilot PV system at the Slufter, and said that its FSPV plants were storm resistant[61]. Furthermore, innovative components that are proven to last for long periods should be adopted. For example, in Thailand, SCG provides floating pontoons that are made of high-quality polyethylene resin which can last up to 25 years (equivalent to the solar panel's lifecycle). Data sharing and regional cooperation on technical aspects of the technology can accelerate deployment as well as reduce the risks by following the best practices.
Lack of domestic manufacturing capabilities	The manufacturing capabilities of FSPV components, which majorly include solar panels and floats, is low.	Policy support is required from the government to help the domestic manufacturing market to scale up.
Floating solar is a nascent technology	Since the technology is still at a nascent stage, there is not much information available on the impacts and reliability of the technology.	The government can promote collaboration between public sector, private developers and research institutes to set up pilot projects aimed at studying the reliability of the technology.

61 Garanovic, A. (2020, November 5). Trial demonstrates floating solar islands as storm-proof. Offshore Energy. https://www.offshore-energy.biz/trial-demonstrates-floating-solar-islands-as-storm-proof/

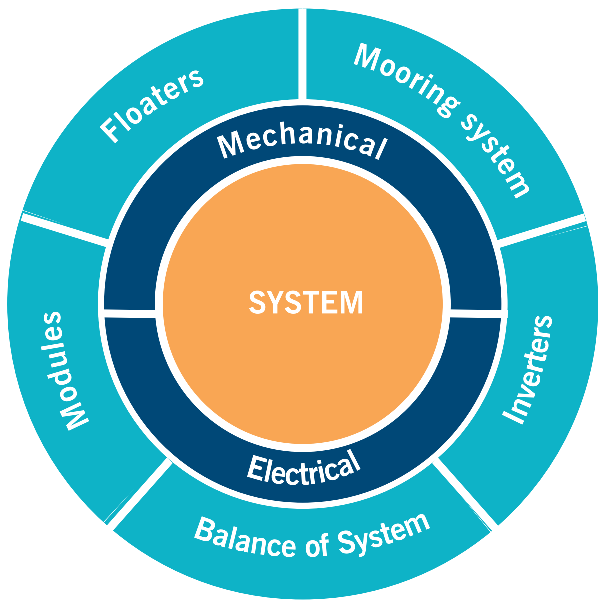
Risk	Description	Mitigation strategy
Higher electricity tariffs as compared to other RE plants	The cost of setting up a FSPV plant is higher than the cost of a ground mounted or rooftop solar plant. Therefore, the tariffs for electricity generated are expected to be higher.	To bring the tariffs at par with other RE technologies, incentives can be provided to project developers for some years, until the technology matures.
Possibility of adverse environmental impacts	The impact of long-term deployment of FSPV to the aquatic flora and fauna is not known.	Project developers can partner with research institutes to undertake such studies. For example, in the Netherlands, BayWa r.e. partnered with IVN to ensure and study how local flora and fauna thrive together with the floating PV panels.
Availability of data eventually	Lack of standardized data to understand the technical and environmental hurdles.	Sensors may be deployed on the FSPV plants to capture data in real time over the years to produce evidence.
Investment Risk	Lack of projects that have reached end of life creates risk for the investor which in turn can lead to increased financing costs.	Governments need to focus on developing cheaper financing options by introducing mechanisms such as issuing government bonds, designing credit guarantee schemes. Global experience and fund availability for IFI can be leveraged to reduce the investment related risks.

4. REVIEW OF TECHNICAL STANDARDS AND TENDERS

4 REVIEW OF TECHNICAL STANDARDS AND TENDERS

An overview of the components of a floating PV installation is presented in **Figure 4.1**:

FIGURE 4.1: FSPV System Components



Compared to the conventional ground mounted solar installations, the equipment installed in a floating solar plant has to endure harsh environmental stress like increased ultraviolet (UV) exposure, corrosion, high humidity, and damp heat, and increased mechanical stress due to constant wave motion. **Figure 4.2** summarizes the points to be considered for floating solar applications.

FSPV plants worldwide have similar challenges regarding technical aspects. These challenges pertain to absence of specific design codes or guidelines to determine design loads, FoS, complex and computationally intensive structural system simulations, and lack of unified approach for PV and float testing. For sustainable growth, it is important that the technical standards remain flexible to encourage innovation, while ensuring quality and reliability. Most of the floating solar projects have been developed on a tendering basis in India and an inadequate set of technical requirements was included in some of these tenders. This could have been a contributing factor to the mediocre response from the industry.

With this context, this approach was adopted for the assessment presented in this section:

- Review and evaluate gaps in the relevant technical standards while adopting it for floating solar applications.

FIGURE 4.2: Points of attention in an FSPV system

SITE CONDITIONS

- Assessment of waves and winds at relevant heights
- Defining appropriate return periods
- Water depth and water level variations

ENERGY YIELD ASSESSMENT

- FPV-specific phenomena: soiling, mismatch losses, cooling effect
- Applicability of satellite data
- Defining a methodology for accurate and realistic EYA

DESIGN PHILOSOPHY

- Site conditions as vital starting point
- Safety philosophy from offshore standards
- Tuning safety factors

ANCHORING AND MOORING

- Dynamic load modelling (combined loads)
- Load distribution
- Water level variation
- Testing

FLOATS

- Functional requirements for different technologies
- Interconnections
- Buoyancy
- Durability
- Additional tests for PV modules

ELECTRIC LAYOUT

- Building on existing solar standards and norms
- Increased requirements for water protection
- Fail-safe design

INSTALLATION AND O&M

- Increased focus on safety and access during O&M
- Preventive maintenance and monitoring
- Lessons learnt from past projects

ENVIRONMENTAL IMPACT

- Ongoing research
- Water quality and water composition
- Impact on flora and fauna in and near the water body
- Permitting procedures

- Formulate a guidance document (issued separately) based on the above review, current knowledge of the FSPV system, and the standardization efforts already undertaken.
- Review the technical requirements included in some of the tenders issued in India and provide recommendations for improvement/optimization.

The review of technical standards and technical requirements of some of the tenders[62] floated in India for floating solar projects in reservoirs and water storage areas of coal power plants resulted in the summary in **Table 4.1.** During the consultations, stakeholders expressed concerns about:

- lack of clarity on the boundary conditions of the installation, for example, the installation area identified on the waterbody, evacuation point, ownership of waterbody, and permits;
- missing or low quality of historical data of the waterbody and results of feasibility surveys;
- technical criteria with no relevant logical backing, leading to over-design and cost over-run; and
- prescriptive technical requirements that lack the flexibility to accommodate different float technologies and room for innovation.

A detailed analysis of the tender specifications along with recommendations are provided in the subsequent sections.

4.1. Manufacturing

The tenders specify compliances to various International Electrotechnical Commission (IEC) and ASTM standards to meet the requirements of UV rating, corrosion protection and mechanical impact rating. **Table 4.2** tabulates the reference standards for major equipment included in the tenders.

62 NTPC. (2018, October). Invitation for Bids for Development of 70 MW Floating Solar PV Project At Rajiv Gandhi Combined Cycle Power Project Kayamkulam in Kerala.
SECI. (2018, August). SECI Expression of Interest for Empanelment of Consultants for Bathymetric Survey and Hydrographic Survey for SECI's Floating Solar PV Projects.
SECI. (2018, April & September). Request for Selection (RfS) Document for Selection of Solar Power Developers for Setting up of 150 MW (50 MW x 3) Grid Connected Floating Solar Power Projects to be installed at Rihand Dam, Sonbhadra District, Uttar Pradesh under Global Competitive Bidding.
Greater Visakhapatnam Smart City Corporation Ltd. (2017, August). RfP for 2MWp grid connected Floating Type Solar PV Power Project on Mudasarlova Reservoir.

TABLE 4.1: Limitations of existing standards and technical requirements of tenders

Category	Identified Gaps
Manufacturing	▪ Deriving desired properties of raw materials of floats and acceptance criteria
Equipment	▪ Technical specifications for reliability and minimum environment impact ▪ Requirements of ingress protection
Design	▪ Establishing design boundary conditions ▪ Considerations for determination of design loads ▪ Requirements of design FoS ▪ Requirements of electrical safety
Testing	▪ Test procedure and duration for reliability testing ▪ Test acceptance criteria ▪ Extrapolation of test results to expected design life
Meteorological measurements	▪ Measurement parameters ▪ Specification of measurement instrumentation
Services	▪ FSPV specific requirements for equipment for surveys and installation ▪ Standardised specifications for bathymetry surveys for FSPV
Energy assessments	▪ Guidelines for resource assessment ▪ Guidelines for system modelling
Installation and O&M	▪ Guidelines for preventive and breakdown maintenance ▪ Requirements for data collection and documentation
HSE	▪ Guidelines for measurement of impact on biodiversity ▪ Requirements for work safety ▪ Standards for recycling ▪ Guidelines for waste disposal ▪ Guidelines for risk assessment
Logistics	▪ Requirements for transportation ▪ Specifications for storage

TABLE 4.2: Reference standards in tenders for major equipment in FSPV plant

Test	Component	Standard
UV Test	PV Modules	IEC 61215
	Inverters	IEC 62093
	Combiner Boxes	IEC 62093
	Cables	TUV 2pfg 1169/08/07
	Floats	ASTM D2565, ASTM D4329
Corrosion Protection	PV Modules	IEC 61701, IEC 62716
	Floats	ASTM D1693
Mechanical Impact	PV modules	IEC 61215
	Inverters and Combiner Boxes	IEC 62262
	Floats	International Organization for Standardization 16770. ASTM D638

Identified Gaps

- Manufacturing-related aspects for the key components are not clearly covered in any of the reviewed tenders.
- The mechanical and chemical properties of the key equipment to endure the challenges as listed in the **Figure 4.2** are not completely covered.

Recommendations

- Evolve tender technical specifications to meet the key challenges of FSPV and to ensure material longevity for an anticipated 25-year lifetime.
- Make tender specifications more technology agnostic to cover a wider range of technologies and types of floater structures, anchoring and mooring. For example, the tenders are currently more focused on HDPE floats, which will limit participation from other technology providers. A wider required definition for performance in tenders will facilitate innovation and allow the industry to learn, develop and mature the technologies.
- Include a indicative manufacturing quality assurance plan (QAP) for key equipment, especially for the floats and anchoring and mooring system. However, it is noted that owing to the large-scale deployment and experience of the solar industry, manufacturing QAP is standardized for the equipment like PV modules, inverters, transformers, combiner boxes, electrical switchgears, and cables.
- Include requirements for owners/ developers regarding witnessing factory acceptance test (FAT) and issuing material dispatch clearance certificate for all main equipment like floats, anchoring and mooring system, PV modules, inverters, transformers, combiner boxes, electrical switchgears, and cables.
- Include a field quality plan during construction and O&M phase for testing and recording the details of various equipment/floats dimensions, visual inspections, and for undertaking mechanical strength tests of floaters.

4.2. Equipment and Technical Specifications

The basic specification and IEC compliance for key equipment with respect to corrosion, UV resistance, high humid conditions, chemical resistance, and environmental compliance are covered. While PV modules and inverter technology selection may be made by applying the experience gained from the ground mounted systems, floats, systems for anchoring and mooring, earthing and lightning protection shall be specific to the site conditions.

Identified Gaps

- The bidder is made responsible for collection of key site data. This not only increases the time for responding to bids, but also leads to different assumptions being taken by the different bidders, which could limit discovery of commercially optimized bids.
- Many references for national and international standards for each major component are included. However, the technical specification on a component level does not adequately reflect the requirements of the floating solar environment.

Recommendations

- Have the bidding authority carry out the preliminary site investigations and make the data available to the bidders. This effort can also be centralized for a cluster of waterbodies to optimize cost of surveys and drive standardisation.

- Make historical data on the reservoir and waterbody owners available to the bidders.
- Include desired UV (rated for minimum of 2000 hours exposure) and IP rating for BoS items like connectors (minimum IP68), inverters (minimum IP55), combiner boxes (minimum IP65), electrical panels (minimum IP55), SCADA & communication panels (minimum IP 65) and cable accessories which are installed on water.
- Specify requirements of corrosion protection for BoS items, floats and PV modules.
- Specify restriction of hazardous substances and environmental impact for PV modules and other BoS components like usage of ester oil in transformer, halogen free cables etc. At present, they are specified for HDPE floaters only.
- Include specific construction and testing requirements of components to suit the high humidity and possible immersion in water.
- Evolve the Guidance document is being issued separately (which provides useful insights for floating solar applications) and the technical specifications based on recommendations in the document. DNV's *Recommended practice for design, development and operation of floating solar photovoltaic systems* (DNV-RP-0584) can also guide reliability in a marine environment.

4.3. Design

The tenders reviewed do not provide base data about the sites and the bidder is made responsible for collection of key site data, as indicated in **Table 4.3.**

The tenders specify the high-level design requirements for HDPE floats and anchoring and mooring system.

Floats

- Minimum 1.15 safety factor at extreme conditions.
- Temperature extremities of +50°C to -10°C.
- PV fixation system shall be of proven design and subjected to mechanical test to withstand unit failure conditions under static and fatigue conditions for wind speeds to withstand the maximum wind speed of the area.

TABLE 4.3: Data available from tender and data to be collected by bidder

Data	Description
Data provided in tender	▪ Max and min water depth level
Data to be collected by bidder	▪ Historical water level variation ▪ Depth of reservoir ▪ Bathymetry, Geophysical surveys, Geotechnical investigations ▪ Water discharge rate ▪ Wind speed, wave and water current details ▪ Water resistivity at surface and its variation with depth ▪ Historical water temperature and its variation with depth ▪ Total dissolved solids, power of Hydrogen (pH), Biochemical Oxygen Demand & Chemical Oxygen Demand of water

- Float system should be designed to withstand the maximum wind speed of the location and shall be able to withstand the weight of O&M personnel carrying tools, the forces of nature such as wind/water flow etc.
- Buoyancy to support weight of one solar panel and one person per solar panel.
- Design of floating system shall be certified by a third-party agency for safety and strength.

Anchoring and Mooring

- Withstand maximum wind speed, water level variation, waves etc.
- Design of anchoring system to be certified by accredited national or international laboratory.

Identified Gaps

- The minimum FoS specified is significantly less than what is followed for onshore and offshore construction.
- The requirement stated for buoyancy will result in overdesign if followed for the entire system.

Recommendations

- Adopt a safe FoS value. The effective minimum FoS for steel as per IS 800 corresponds to approximately 1.65. In the absence of specific standards, a similar value can be adopted for the design of FSPV projects, particularly considering the significant uncertainty in both loads and material strengths.
- Include a safety margin in the mechanical load or cable pull test for cable terminations. Since the installation on a floating platform is subject to constant up and down and lateral motions, it may add additional stress on the cable terminations. The present practice is to leave additional cable to account for this movement. Added safety margin on these mechanical properties can be examined to further optimize the cable length and to decrease the associated ohmic loss.
- Include a stability requirement for the floaters.
- Require buoyancy to support weight of personnel only for those areas where the movement of personnel is anticipated during construction and O&M phases. The requirement may not apply to other areas of the system.
- Set requirements for earthing and lightning protection.
- Design boundary conditions and considerations for determination of design loads.

Refer to DNV's *Recommended practice for design, development and operation of floating solar photovoltaic systems* (DNV-RP-0584).

4.4. Testing

Presently, the tender specifies testing of only the critical components:

- PV modules and inverters deployed for the project shall have a valid test certificate from any National Accreditation Board for Testing and Calibration Laboratories accredited labs or International Laboratory Accreditation Cooperation accredited labs from India/outside India.
- Testing requirements specified in the tender for the PV modules and inverters cover type test, environmental stress tests, reliability and durability tests.
- The aerodynamic design of HDPE floaters shall be tested by subjecting them to a wind tunnel test by imposing wind from all directions on real scale and real angle.

Identified Gaps

- Although broad requirements for testing are defined, specific tests to probe reliability of equipment in a FSPV installation are not included.

Recommendations

- Specify tests related to corrosion for all the BoS components, for example, IEC 61701—Salt Mist Corrosion Severity 7 for modules installed in saline water.
- Include accelerated tests for all critical components including PV modules, HDPE floats and inverters.
- Specify a study for marine growth for floats.
- Include a minimum requirement of sampling for HDPE floats for testing. Additionally, the float manufacturers can also offer the product for FAT and facilitate in-process inspection.
- Evolve a minimum threshold value for various mechanical properties based on the experiences gained and industry participation. At present, most of the standards for determining mechanical properties of floats provide test criteria for measurement of a particular property, but do not define acceptance criteria.
- Include vibration tests for PV modules, inverters, electrical panels, low, high and medium voltage switchgear and cable accessories. The vibration test procedure in the standards simulate the conditions when the equipment is not energized. Since in FSPV plants the equipment is subjected to mechanical stress and cyclic motion during its operation, the vibration tests can be evolved to simulate actual operating conditions and testing carried out in energized condition.

4.5. Meteorological Measurements

The tenders specify requirement for measuring:

- Solar radiation on module plane
- Ambient temperature
- Wind speed
- Other weather parameters
- Generated Direct Current (DC) & AC Power

Identified Gaps

- There is no reference to applicable standards for meteorological measurements.
- Specific measurements of interest for FSPV installations are not included, for instance, module temperature, wave, current and so on.

Recommendations

- Monitor parameters related to wind, wave, current and water temperature for floating solar applications, in addition to the requirements of IEC 61724-1 (Photovoltaic system performance - Part 1: Monitoring).
- Record (periodically) other parameters like water quality, fire protection system for transformers and electrical resistivity/conductivity of water at various depths.
- Install a test HDPE floater near the project area conduct periodical tests to study changes in mechanical and chemical properties. This data will help in further evolving or developing the product.
- Mandate logging of transformer operational parameters like winding temperature indicator, Oil temperature indicator, oil level and control and relay protection signals of transformers.

- Include desired technical specifications of the sensors for standardization of requirements along with the number of sensors.

4.6. Material Storage at Site

Material storage-related aspects are not covered in detail in any of the SECI tenders[63]. However, the tender of Vizag[64] floating solar project, indicates material storage yards along with the categorization for the following:

- Special storage - air conditioned
- Closed storage
- Semi closed storage
- Open storage

The material storage related aspects are adequately covered in this tender encompassing security, demarcation of stored items, housekeeping, mitigation of water logging, lighting, precautions to avoid fire like declaring no smoking area, placing fire extinguishers etc.

Identified Gaps

Material storage related aspects are not covered in detail in most of the tenders.

Recommendations

Request bidders to indicate the material preparation area requirement in the bid submission.

4.7. Other Requirements

Identified Gaps

- There is inadequate coverage of the requirements related to transport and logistics, energy assessment, O&M and HSE to be followed during installation and the commissioning and operational phases.

Recommendations

- Submit the methodology for assessments adopted by the Bidder for Energy along with bid. Compared to ground mounted installations, the two most important parameters which need attention are wave induced mismatch losses and cooling effect.
- Request submission of risk assessment and mitigation plan during installation and commissioning and O&M phases.
- Mandate that bidders submit indicative makes of the floats, inverter, PV module and other BoS items along with their respective conformance to the requisite standards.
- Include close monitoring of the vulnerable components and proactive inspection plan in the O&M requirements.
- Include relevant guidelines shall be included for HSE practices.

63 SECI. (2018, August). SECI Expression of Interest for Empanelment of Consultants for Bathymetric Survey and Hydrographic Survey for SECI's Floating Solar PV Projects.
SECI. (2018, April & September). Request for Selection (RfS) Document for Selection of Solar Power Developers for Setting up of 150 MW (50 MW x 3) Grid Connected Floating Solar Power Projects to be installed at Rihand Dam, Sonbhadra District, Uttar Pradesh under Global Competitive Bidding.

64 Greater Visakhapatnam Smart City Corporation Ltd. (2017, August). RfP for 2MWp grid connected Floating Type Solar PV Power Project on Mudasarlova Reservoir.

5. REGIONAL CO-OPERATION AND STATUS OF FSPV IN SOUTH ASIAN COUNTRIES

5 REGIONAL CO-OPERATION AND STATUS OF FSPV IN SOUTH ASIAN COUNTRIES

Various South Asian countries are characterized by similar key features—high population, high incidence of poverty, low per capita electricity consumption and high dependence on imported crude oil and petroleum products. Despite each country facing its unique set of challenges, regional co-operation will help in accelerating the energy transition through knowledge sharing and an integrated market approach. The following sections provide the background of each country regarding power sector, renewable target, current status followed by lessons learned from Sections 2 to 7 and various modes of knowledge transfer at the regional level.

5.1. Countries

5.1.1. Sri Lanka

5.1.1.1. Background

Sri Lanka has almost universal electrification, but per capita electricity consumption is only around one-fifth of the world's average. As on 2019, it has total electricity installed capacity of 4,217 MW, of which over 50 percent is thermal-based capacity as shown in **Table 5.1**.

The electricity demand peaks in the evening and is around 2,669 MW. The average realized tariff of Ceylon Electricity Board (CEB), the government-owned largest electricity company in Sri Lanka with major functions of electricity generation, transmission, distribution and retailing, is significantly lower than its average cost of supply (16.63 Sri Lankan rupees and 23.29 Sri Lankan rupees[66] per unit respectively in 2019) and hence it has led to accumulated losses over the years.

Table 5.1 shows that around 30 percent of installed capacity is hydropower and hence electricity generation from the same is susceptible to variations during monsoon rainfall. The utility compensates for the shortfall by procuring expensive fuel-oil based generation. The deployment of wind and solar provides an opportunity to lower the country's dependence on expensive and import led fuel-oil based generation and to ensure energy

TABLE 5.1: Total electricity installed capacity in Sri Lanka as of 2021[65]

Source/Parameters	Thermal (Coal & Fuel Oil)	Hydropower (including mini hydro)	Other RE power (wind, solar, biomass)	Total
Installed Capacity in MW	1,967	1,399	811	4,177
Generation percent	47	33.5	19.5	100

65 CEB. (2019). *Statistical Digest 2019*. https://ceb.lk/front_img/img_reports/1601877736Statistical_Digest_2019_Web_Version.pdf
66 16.63 LKR=8.4 cents USD and 23.29 LKR=12 cents USD with conversion rate of 198.95 LKR per USD

security. Also, it will fulfil climate change mitigation commitments.

The government's policy states that 70 percent of power generation is to come through renewables by 2030. A significant part of that would come from wind and solar as Sri Lanka has already exhausted most of its large hydro potential. Also, it is expected that the current demand peak in the evening would shift to daytime due to steady economic growth resulting in higher commercial and industrial demand of electricity during the day. Solar power can cater to the shifting of such electricity demand patterns.

While Sri Lanka has more than 15,000 MW of potential each for wind and solar, only 226 MW of other RE power has been installed. There are significant barriers for realization of the potential. For example, limited availability of land and fragmented nature of public land holdings pose significant barriers and delay in securing the permits for large utility-scale projects. Also, due to the poor financial health of the utility, the capacity to build new capital-intensive transmission infrastructure is limited.

FSPV offers a solution that can address multiple challenges. While it is relatively much cheaper than fuel-based sources, it can utilize the existing infrastructure of hydropower thereby avoiding land acquisition and building of new transmission lines. If 10 percent area of 25 largest reservoirs is considered for FSPV, it would constitute around 9 GW, which is more than what is needed to meet the 2030 RE target[67] of 4.5 GW to meet 70 percent of electricity demand. Even 2.5 percent coverage area, as per criteria mentioned in Section 6, would provide a capacity of more than 2 GW to meet a large proportion of the RE target.

5.1.1.2. FSPV in Sri Lanka

The first ever floating solar power plant of Sri Lanka with 42 kW capacity was commissioned in Jaffna University with Norwegian support in January 2020. This demonstration project was the result of collaboration between the University of Jaffna and the Western Norway University of Applied Sciences. Since then, no other floating solar projects have been commissioned, though a few such efforts are at various stages.

In April 2019, the Governments of Sri Lanka and Canada signed a co-operation agreement for the construction of a 100 MW floating solar park in Sri Lanka's Maduru Oya Reservoir. This was envisaged to be developed as part of the Soorya Bala Sangramaya Phase IV program, under which the country aims to add 400 MW of solar. In September 2020, India offered a line of credit worth $100 million for three solar projects including one FSPV project.

A tender for a feasibility study of two 100 MW FSPV projects at Kalawewa tank and Udawalawe reservoir has been floated in April 2021 by the Sri Lanka Sustainable Energy Authority. An effort has been initiated by The World Bank to conduct preliminary assessment of potential ground-mounted or floating solar PV connected to existing HPP.

5.1.1.3. Way Forward

FSPV has not been considered for major government programs like rooftop solar under Soorya Bala Sangramaya. FSPV in Sri Lanka faces similar barriers and challenges to those of India as mentioned in Section 2.2.2. Most of the recommendations mentioned in **Table 2.10** for development of FSPV in India would apply to Sri Lanka too. Given the physical proximity, Sri Lanka and India can share the supply chain

67 Ralapanawe, V. (2020, January 17). *Powering Sri Lanka through renewables: The floating solar opportunity*. https://www.ft.lk/columns/Powering-Sri-Lanka-through-renewables-The-floating-solar-opportunity/4-693740

and benefit from each other's learning in the areas of FSPV. A proposed transmission grid interconnection between India and Sri Lanka would further help Sri Lanka to absorb more renewable power as well as export power to India and vice versa.

FSPV, especially small ones of 5-10 MW size set up in the existing hydro projects of CEB can increase investor confidence and the government's understanding of the technological and project development risks. For more than 10 MW projects, detailed GIS-based mapping needs to be conducted with water surface coverage data to reduce damage to assets due to total evaporation of water. Given that 30 percent of electricity generation is from hydropower which is susceptible to variations in monsoon rainfall, a virtual battery configuration by integrating FSPV with hydropower would alleviate the issue significantly, as described in Section 6.1.2.1.

5.1.2. Bangladesh

5.1.2.1. Background

Bangladesh is one of the world's most rapidly growing developing economies and the vision of the country is to become a high-income country by 2041. As per this vision, the electricity demand forecasted by 2041 with base growth scenario is 62 GW, of which 40 percent of total electricity generation will come from renewable sources.

As on May 2021, Bangladesh has total installed electricity capacity of 22 GW (excluding captive power and off grid renewables) out of which, natural gas is around 52 percent, coal and oil is 41 percent, hydro is 1 percent, and renewable is 0.6 percent[68]. More than 95 percent of population has access to electricity and per capita electricity consumption is slightly above 500 units.

Solar has been recognized as the primary renewable source in Bangladesh as the potential for wind and its ensuing challenges have not been encouraging. Under Bangladesh's new Five-Year Plan, the government's draft National Solar Energy Roadmap presents three scenarios for the future of solar energy. Until 2041, in the business-as-usual case, solar capacity is estimated to be 6 GW; for the mid- and high-deployment cases, the estimations are 20 GW and 30 GW, respectively. The estimation includes largely grid connected utility and rooftop solar projects. A floating solar of 500 MW capacity on Kaptai lake is also included in this roadmap.

5.1.2.2. FSPV in Bangladesh

Bangladesh has one floating solar plant of 10 kW capacity in a pond of Mongla Municipality, established by a private developer, Solar EPC Development Limited. A few projects are under development. For example, a 10 MW floating solar plant is being planned in the same Mongla pond; Mongla Municipality will be an equity partner as owner of the waterbody, while two companies will set up the project as an IPP.

In May 2021, a feasibility study was conducted to identify 50 MW floating solar capacity in a

TABLE 5.2: Total electricity installed capacity in Bangladesh as of Jan 2023

Source	Natural Gas	Coal & Oil	Hydro	Renewable (Solar PV)	Import	Total
Installed Capacity in MW	11,522	10,311	230	259	1,160	23,482
Installed capacity in percent	49	43	1	1	5	100

68 Bangladesh Power Development Board. (2021, May 17). *Present Installed Generation Capacity (MW) as on 17 May 2021.* https://www.bpdb.gov.bd/bpdb_new/index.php/site/page/13e9-2cc0-ce41-9c09-088d-94d5-f546-04a6-b4fa-1d18

waterbody created after the extraction of coal from Barapukuria coal mine in Dinajpur. There is also a plan to develop floating solar on Kaptai lake with the support of ADB.

5.1.2.3. Way Forward

Bangladesh is a highly populated and agriculture-dominated economy and hence the competition for land is fierce. As ground-mounted solar requires a large tranche of land, this will always pose a challenge. Further, land acquisition is a complicated and long process. For energy security, Bangladesh has traditionally relied on fossil fuel-based power plants; it had more than 25 coal-based power plants in the pipeline by end of 2019. However, due to environmental concerns, difficulty in financing, and renewables getting cheaper, many previously approved coal-based power projects are being closed.

FSPV can circumvent the issue of land availability and higher electricity prices due to expensive imported fossil fuels. Bangladesh is a riverine country, and it has a vast multitude of irrigation canals, low-lying lands, haors, baors (wetlands); FSPV can be developed in these waterbodies. Water levels may drop during low-rainfall months—in these cases, a hybrid model of FSPV with a bed-like structure at the bottom can be considered. If 10 percent area of shallow waterbodies of 250,000 hectares is considered, 25 GW of floating solar can be developed. There would be more than 20 GW of additional potential from Kaptai lake, Padma river, and 150,000 hectares of pond. Collectively, this is enough to meet the 30 GW of high deployment case of solar by 2041.

To date, no nationwide consolidated study has been conducted on the feasibility of developing floating solar PV systems. A study would help identify potential sites for floating solar and set targets for RE. The recommendations mentioned in **Table 2.10** would apply well to Bangladesh too. Also, integration of FSPV with TPPs, as explained in Section 6.2, can be explored. Given the physical proximity with India, both India and Bangladesh can share the same supply chain of FSPV and complement each other wherever possible.

5.1.3. Pakistan

5.1.3.1. Background

The installed power generation capacity of Pakistan as on June 30, 2020, stands at 38,719 MW; 24,817 MW is thermal, 9,861 MW hydroelectric, 1,248 MW wind, and 530 MW solar. In FY 2019-20, Pakistan generated 134,745.70 GWh where 31 percent was generated by natural gas, 14 percent by furnace oil, 16 percent by coal, 29 percent by hydropower and 5 percent by renewable. The high cost of electricity is a major challenge for Pakistan which is endeavoring to shift to green and affordable sources of power.

As per the Alternative and Renewable Energy Policy 2019, the RE generation capacity will be increased from current 5 percent to 20 percent by 2025 and to 30 percent by 2030. This will require Pakistan to install around 24,000 MW of solar and wind by 2030.

TABLE 5.3: Total electricity installed capacity in Pakistan as of June 2022

Source	Thermal	Hydro	Renewable (Wind, Solar, Bagasse)	Nuclear & small captive power plant	Total
Installed Capacity in MW	26,683	10,635	2,837	3,620	43,775
Generation in percent in FY 2019-20	61	24	6.5	8	100

Pakistan has good wind and solar resources but harnessing of this potential has been slow. According to the World Bank[69], utilizing just 0.071 percent of the country's area for solar PV (solar PV) power generation would meet Pakistan's current electricity demand. Pakistan has several well-known wind corridors but less than 10 percent potential is utilized.

5.1.3.2. FSPV in Pakistan

There is no floating solar project in operation as yet in Pakistan, though significant progress is underway towards realization of the same. As mentioned in Section 6.1.2.2, the University of Lahore scientists modelled the implementation of FSPV at the 1.45 GW Ghazi Barotha Dam, which features five generating units with about 290 MW of capacity each. In 2019, the Floating Solar Project was initiated by the World Bank and the Water & Power Development Authority (WAPDA) of Pakistan. The plan is to install floating solar projects of 150 MW each on Barotha & Ghazi Lakes and 25 MW on Tarbela reservoir. In this regard, a feasibility study on the 150 MW Floating Solar Project on Barotha lake has been completed and further progress is underway.

5.1.3.3. Way Forward

Pakistan faces issues and challenges similar to those of India. Pakistan should start with a country-wide GIS mapping of all its waterbodies, taking a cue from the work done by TERI in India. Once the long-list is prepared, it can be reduced to 50 best possible locations where FSPV plants can be set up immediately. Such a mapping exercise, funded by multilateral agencies, would increase investors' confidence, reduce the basic uncertainties and data gap, and kick-start the process for detailed techno-commercial analysis and project implementation.

Pakistan can suitably utilize the reservoirs available at thermal and hydropower plants. Also, learnings from Section 5.3 can be used for the development of FSPV on lakes.

5.1.4. Afghanistan

5.1.4.1. Background

Afghanistan is one of the least developed countries in the world with less than 40 percent of the population having access to electricity. It has about 600 MW of electricity installed capacity, of which 49 percent is hydropower, 3 percent is solar and rest is thermal and diesel generator. Afghanistan relies heavily on electricity imports and about 70 percent of the power supply is from neighbouring countries.

The Afghanistan National Renewable Energy Policy 2015 sets a target of deployment of 4,500-5,000 MW of renewable capacity by 2032. Afghanistan has huge potential for renewables—222 GW of solar, 66 GW of wind and 23 GW of hydropower. However, most of the RE projects are grant-funded projects which while providing an impetus, cannot match the requirements. Hence, realization of the potential is limited. The Renewable Energy Policy envisions a transition to a fully private sector-led industry by 2032.

5.1.4.2. FSPV in Afghanistan

Afghanistan does not yet have a floating solar plant but it does have three operational ground-mounted solar power plants currently in Kandahar, Bamiyan and Herat provinces. However, few efforts are on for realization of FSPV.

In September 2018, ADB approved technical assistance for floating solar project at the Qargha reservoir. In September 2020,

69 The World Bank. (2020, November 10). *Expanding Renewable Energy in Pakistan's Electricity Mix* https://www.worldbank.org/en/news/feature/2020/11/09/a-renewable-energy-future-for-pakistans-power-system

Phelan Energy Group Limited announced that it would develop, in collaboration with a local partner and VGF from the USAID, a 24 MW floating solar project on a dam in Kabul province. The project is currently in the procurement stage.

5.1.4.3. Way Forward

As 50 percent of installed capacity is hydropower (with the issue of water scarcity), FSPV can be integrated with hydropower as described in Section 5.1. However, with available land resources and good potential for wind and solar, a preference for ground mounted solar would dominate the RE penetration in the country and hence a large-scale FSPV installation in the near future is not envisaged.

5.1.5. Maldives

5.1.5.1. Background

Maldives comprises 1,192 small islands grouped into 26 atolls in the central Indian Ocean with a population estimated at 533,941 people in 2019. Along with 187 islands inhabited by the Maldivian population, 123 islands are self-contained tourist resorts, and 128 are primarily used for industry and commerce. Each region needs its own power generation and distribution system and relies heavily on imported diesel for electricity.

Overall, Maldives is highly dependent on imported oil and diesel which remains the main source of power generation with 80 percent contribution in the energy mix; petrol, aviation gas, and Liquefied Petroleum Gas constitute 12 percent, 6 percent and 2 percent, respectively. By 2020, a total of about 354 MW capacity diesel generators were installed in inhabited islands, resort islands and industrial islands. A total of 21.5 MW of RE systems are installed across the country.

The dispersed nature of the islands and high reliance on imported diesel for electricity production has posed challenges in delivering secure electricity at an affordable rate. Increasing the amount of government spending on subsidies to the electricity sector has caused a significant strain to the government's budget. Large-scale adaptation of RE technologies such as solar PV is an effective approach to address these challenges.

Considering these challenges, the National Strategic Action Plan (2019-2023) set targets to increase the share of RE by 20 percent by 2023, compared to 2018 levels, and ramp it up to 70 percent by 2030.

5.1.5.2. Offshore Solar in Maldives

Maldives, being an island country, offshore solar (and not floating solar) has a great potential to scale up and fulfil the renewable target. However, offshore solar poses far more challenges than floating solar due to its harsh operating environment of humidity, salinity and wind and wave loads. Globally, offshore solar is at an early stage of development and there is insufficient experience in this area. However, this presents an opportunity to invest in technology development in cooperation with countries such as Netherlands that have already begun R&D for offshore conditions.

Areas near shore, such as harbours, jetty areas and docks, are being explored as sites for the establishment of offshore solar as they are not exposed to high wind and wave loads. Given the benign conditions in these nearshore areas, many of the experiences and technology from FSPV can be applied and such areas provide a huge opportunity in itself.

5.1.5.3. Way Forward

FSPV with suitable customization for nearshore can be explored. To harness such opportunities, it is important to have surveys done for such regions to understand and quantify the environmental conditions. Guidelines and best practices for FSPV as included in Section 4 and the Guidance Document (issued separately) can be suitably customized for such conditions. Surveys would provide a list of best regions along with the suitable guidelines to develop FSPV at scale.

5.1.6. Nepal

5.1.6.1. Background

Nepal is a landlocked country in South Asia and contains 8 of the world's 10 highest peaks including Mount Everest. It has a population of 29.6 million with electricity per capita consumption of less than 300 units. Nepal has around 1,320 MW of hydropower as of 2020 out of the huge potential of 40 GW. Other electricity sources include diesel generator (53.4 MW), while 340 MW was imported from India in 2020. Nepal's currently installed solar capacity is ~60 MW and much of this is in the form of more than one million small home systems that are not grid-connected.

Nepal's ambition is to increase clean and RE production tenfold to 15,000 MW by 2030. As Nepal has low potential for the large-scale utilization of wind energy, a large part of new RE would come from hydropower and solar. However, relying alone on hydropower has limitations as, during the dry season, a decrease in the river flow adversely impacts electricity generation. Solar seems to be the other cheaper and greener source, but due to the rugged terrain and 70 percent of the region being hilly, ground mounted solar projects are challenging. This is where floating solar has good prospects as it could be used in conjunction with irrigation reservoirs to prevent the evaporation of water and also in conjunction with hydropower reservoirs to provide an auxiliary means of power generation.

5.1.6.2. FSPV in Nepal

As of now, no floating solar project is being developed or planned in Nepal.

5.1.6.3. Way Forward

FSPV can be integrated to hydropower and irrigation reservoirs and learnings from Section 6.1 can be suitably utilized. India can take initiative as it has traditionally collaborated in construction of hydropower projects in Nepal and FSPV can be integrated with these projects. Given that there are challenges for development of ground mounted solar and wind at large scale due to rugged terrain, FSPV can be the major avenue for energy transition.

5.1.7. Bhutan

5.1.7.1. Background

Bhutan is a landlocked country in South Asia located in the Eastern Himalayas. The country's landscape ranges from sub-alpine mountains in the North to subtropical plains in the South. The supply of electricity is dominated by hydropower. The country generates surplus power during the monsoon season from its run-of-river hydropower infrastructure and the surplus power is exported. A significant portion of total electricity generation is exported to India, which has increased steadily from 2000 to 2017 when 74 percent of total generation was reported to be exported.

Bhutan has total installed generating capacity of 2,326 MW from hydropower as on 2019 out of the total hydropower potential of 30 GW. By 2025, it is estimated that the country's hydro capacity will be 5,264 MW owing to under-construction and pipeline projects with additional capacity of 589 MW[70].

With regard to floating solar, there is no project in Bhutan as yet, but waterbodies and hydropower reservoirs could be potential

70 Royal Government of Bhutan. (2018, June). *National Transmission Grid Master Plan (NTGMP) of Bhutan-2018*. https://www.moea.gov.bt/wp-content/uploads/2018/11/National-Transmission-Grid-Master-Plan-2018.pdf

sources. Detailed feasibility studies would be essential to assess the viability of such projects.

5.1.7.2. FSPV in Bhutan

As of now, no floating solar project is developed or planned in Bhutan.

5.1.7.3. Way Forward

A detailed feasibility study to integrate FSPV into hydropower should be conducted to assess the benefit. Learnings from Section 5.1 can be suitably utilized. As in the case of Nepal, India can take initiative as it has cooperation with Bhutan for the construction of hydropower projects, as mentioned in Section 5.4.2.

5.2. Lessons Learned

It is important to recognize that the development of floating solar worldwide is gaining importance.

- India has made significant progress compared to other countries in South Asia.
- Sri Lanka and Bangladesh have demonstration projects in operation, while feasibility studies for a few MW size projects are being conducted.
- Pakistan and Afghanistan have plans for MW size floating solar projects.
- Nepal and Bhutan have no plans for FSPV.
- Maldives will have offshore solar which is more challenging than floating solar due to the operating conditions in the sea. However, nearshore areas with benign conditions in Maldives can have FSPV with suitable customization.

The key drivers for floating solar would be different for different South Asian countries as shown in **Table 5.4**.

TABLE 5.4: Key drivers for floating solar in South Asian countries

Country	Key Drivers	Challenges/Comments
Sri Lanka	Competing use of land, predominance of hydropower (30 percent), large FSPV potential to complement hydropower.	No exclusive focus on FSPV, challenge to collect information across various agencies.
Bangladesh	High population density, scarcity of land, unsuitable wind resource, FSPV primary avenue for energy transition.	No prioritized focus on FSPV, challenge of data collection from several agencies, requirement of roadmap study. Possibility of setting up near-shore systems on the atoll-side can be examined in detail.
Afghanistan	Lowest per capita electricity consumption, 49 percent hydro, donor driven development, possibility of hydropower optimization.	Security issue, support from India and Middle East can help develop FSPV, but ground mounted solar would be preferred due to large availability of land.
Maldives	More than 1,000 islands, largely fuel based, potential of offshore solar.	Concerted efforts by the World Bank, offshore solar could be more challenging, FSPV with customization can be explored in nearshore areas.
Pakistan	29 percent Hydropower, 164 dams, hydropower optimisation, water conservation and energy affordability.	Early efforts by WAPDA. Big scope for using the large dams to generate solar power. In Sindh region, the long canals can have some amount of FSPV to check evaporation losses and also generate power at the tail-end of the grid.
Nepal & Bhutan	Rugged land, largely hydropower, collaboration with India.	No efforts so far. India can take the initiative and include FSPV in already ongoing engagement on hydropower.

As other countries in South Asia are at an earlier stage than India for FSPV development, the set of challenges faced by India would also be faced by other countries in due course of development. Hence, the learnings from the current assessment could be applied to most of the countries at different stages of market development.

It is important that a survey is conducted to assess the full realisable potential and quantify the importance of the same to be included in the national planning. The summary of recommendations as mentioned in **Table 2.10** of Section 2.3 would apply to the countries listed with different degrees of importance, except for Maldives where offshore solar requires more rigorous design criteria though many of he technical practices from FSPV would be applicable.

It should be noted that India can play a bigger role in the whole value chain of floating solar for all the South Asian countries. Given the issues associated with transportation of floaters and to achieve economies of scale, it is important that a reasonably large size (20 MW and above or small sizes in cluster to utilize the same manufacturing base) project is developed to allow the manufacturing of floaters near the project site.

All countries in South Asia will encounter the issue of guidelines and standardization. The Guidance Document (issued separately) can be used after suitably customizing it for local conditions. Similarly, training and capacity building would be required and recommendations from Section 1 can be customized to suit the local size of the market and level of upskilling, depending on the maturity of other parallel industries.

5.3. Deployment Model

Deployment models for integration of floating solar with HPP can be utilized for countries like Nepal, Bhutan, Afghanistan and Sri Lanka, where hydropower is the major source of power. Similarly, business models for deployment of floating solar on lakes can be used for Bangladesh and Pakistan.

5.4. Knowledge Transfer

As mentioned before, India has made significant progress in FSPV in comparison to other countries in South Asia and can facilitate the knowledge transfer at a regional level through the following ways:

1. Regional forums
    - ISA
    - SAREH under USAID
    - IRENA: Investment forums in South Asia
    - SAARC Expert Group on Renewable Energy
    - United Nations; ESCAP
2. Bilateral relations
3. Joint conferences and initiatives

A short description of the above-mentioned modes of knowledge transfer is provided below.

5.4.1. Regional Forums

There are several regional forums which are working in South Asia in the areas of energy security and energy transition. None of these forums have included floating solar in their program yet. Hence, it is important to raise awareness about the importance of floating solar so that these forums can recognize this and include FSPV in their programs. Such awareness can be generated through workshops, dissemination programs and meeting with key personnel from the forum. Below are some the of the important forums working in the area of energy in South Asia.

5.4.1.1. ISA

ISA was conceived as a coalition of solar-resource-rich countries to address their special energy needs. ISA aims to provide a dedicated platform for cooperation among such countries, through which the global community (governments, bilateral and multilateral organizations, corporates, industry, and other stakeholders) can contribute to help achieve the common goal of increasing the use and quality of solar energy in meeting energy needs of ISA member countries.

As guided by the Framework Agreement of ISA, the interests and objectives of ISA are as follows:

- Collectively address key common challenges to scale up solar energy applications in line with their needs.
- Mobilize investments of more than $1000 billion by 2030.
- Take coordinated action through program and activities launched on a voluntary basis, aimed at better harmonization, aggregation of demand, risk and resources, for promoting solar finance, solar technologies, innovation, R&D, and capacity building.
- Reduce the cost of finance to increase investments in solar energy in member countries by promoting innovative financial mechanisms and mobilizing finance from institutions.
- Scale up applications of solar technologies in member countries.
- Facilitate collaborative R&D activities in solar energy technologies among member countries.
- Promote a common cyber platform for networking, co-operation and exchange of ideas among member countries.

Currently, ISA has 76 member countries including India, Sri Lanka, Bangladesh and Maldives. There are several projects and activities related to ground-mounted and rooftop solar, solar mini-grids and solar E-mobility and storage and due focus is also on the capacity building as well as maintenance of an online platform (Infopedia) dedicated to the dissemination of information, best practices and knowledge. However, floating solar is not yet included in any of the programs and activities. Hence, ISA would be an appropriate forum where floating solar can be included in capacity building, online platform creation and a few projects for demonstration and knowledge transfer. India, being the President of ISA, should be able to use ISA for the knowledge transfer of floating solar.

5.4.1.2. SAREH under USAID

In 2018, the U.S. launched the Asia Enhancing Development and Growth through Energy (Asia EDGE) initiative to support the growth of sustainable and secure energy markets in the Indo-Pacific region. To support the implementation of Asia EDGE in South Asia, USAID/India established the SAREH. USAID/India coordinates and communicates all Asia EDGE activities within South Asia through the SAREH platform. The United States Energy Association is SAREH's implementing partner.

SAREH's overarching objective is to support USAID to achieve enhanced development and growth throughout the energy sector, specifically focusing on the following:

- Strengthening the energy security of South Asia partner countries
- Creating open, efficient, rule-based and transparent energy markets
- Improving free, fair, and reciprocal energy relations
- Expanding access to affordable and reliable energy

SAREH aids Asia EDGE interventions in Bangladesh, Bhutan, India, Nepal, Sri Lanka, and the Maldives, and facilitates coordination and collaboration between them, while creating new avenues for private sector participation. SAREH focuses on three interventions: coordination, communication, and technical support. Floating solar could be among the interventions that SAREH considers for South Asia.

5.4.1.3. IRENA: Investment Forums in South Asia

The South Asia Investment Forum aims to scale up RE investments in the region, support project development and implementation, and contribute to the creation of policy and regulatory frameworks conducive to RE investments.

The regional forum is part of IRENA's contribution to the Climate Investment Platform, which aims to advance sustainable energy projects to investment maturity and facilitate their access to finance.

Key forum activities include matchmaking between projects, project developers, and potential financiers, and investors. RE projects, along with renewable-based electricity grid and energy efficiency projects, are considered for support. The South Asia Investment Forum can be requested to fund the early floating solar projects in South Asia.

5.4.1.4. SAARC Expert Group on RE

SAARC was established with the signing of the SAARC Charter in 1985. SAARC has eight member states: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.

SAARC's objectives, as outlined in the Charter, are to promote the welfare of the people of South Asia and to improve their quality of life; to accelerate economic growth; to promote active collaboration and mutual assistance in the economic, social, cultural, technical and scientific fields; to strengthen co-operation among themselves in international forums on matters of common interests; and to cooperate with international and regional organizations with similar aims and purposes.

The process of regional cooperation in the energy sector began in 2000 with the establishment of a Technical Committee on Energy. The Council of Ministers, while recognizing the importance of focused attention for this vital area, approved creation of a specialized Working Group on Energy in 2004. Within Energy, there is an Expert Group on Renewable Energy (Lead Country Pakistan) that can be suitably used for knowledge transfer of floating solar.

5.4.1.5. United Nations; ESCAP

ESCAP serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 member states and 9 associate members, ESCAP has emerged as a strong regional think-tank, offering countries sound analytical products that shed insight into the evolving economic, social, and environmental dynamics of the region.

The overall objective of ESCAP is to promote inclusive and sustainable economic and social development in the Asia-Pacific region, with priority accorded to the implementation of the 2030 Agenda for Sustainable Development and the achievement of the Sustainable Development Goals. ESCAP pursues this objective by carrying out work, in close cooperation with other United Nations entities and intergovernmental organizations in the region, in many areas including Energy. The forum of ESCAP can be suitably utilized for integration of floating solar in the UN's development programs in South Asia and for overall knowledge transfer of the same.

5.4.2. Bilateral Relations

Being ahead in the development of floating solar, India can undertake capacity building and knowledge transfer related to floating solar for other South Asian countries. India is engaged with many of the countries bilaterally for energy cooperation, and development of floating solar could be part of this bilateral agreement and commitment. For example, the hydropower projects are an example of win-win cooperation between India and Bhutan. India has so far constructed four hydroelectric projects in Bhutan and three more hydroelectric projects are under construction. India can consider floating solar to be integrated with hydropower while developing projects in Bhutan. Similar collaboration through integrated hydropower with floating solar can be forged with Nepal too.

India and Sri Lanka are already working on a $100 million credit line by India in the solar power sector of Sri Lanka. This multi-pronged project envisages enhancement of solar power usage through the installation of rooftop units and commissioning of floating solar power plants in Sri Lanka.

Similarly, various projects including the implementation of India-Bangladesh Friendship Pipeline, and Maitree Super Thermal Power Project are underway in Bangladesh and India can include floating solar too in the bilateral cooperation agenda.

5.4.3. Joint Conferences and Initiatives

It is in the interest of India to take the initiative to integrate the market ecosystem for FSPV at the South Asia level. Cooperation at South Asia level would provide the economies of scale and exchange of experiences which would bring down the prices. It would help many Indian companies active in FSPV play a leading role in other South Asian countries as well. Hence, India should proactively work to organize joint conferences and capacity-building programs and help to conduct feasibility studies in other countries.

APPENDIX

APPENDIX A: DETAILS OF STAKEHOLDERS

The details of stakeholders selected for consultations are presented in **Table A.1** below, along with categorization into 'Well established' and 'Prospective'. The 'Well established' category includes those players who have already had a role to play in the Indian solar industry (ground mounted or the initial FSPV plants) or those from parallel industries with expertise relevant to FSPV projects - on plastic materials, manufacturing, maritime projects etc. The 'Prospective' category includes those stakeholders who can contribute to the upscaling of FSPV industry in India.

TABLE A.1

Category	Stakeholder	Category	Rationale for selection
Government	National Hydro Power Corporation (NHPC)	Well established	Largest organisation for hydropower in India, early initiatives taken
	NTPC	Well established	Largest power utility in India, early initiatives taken
	SECI	Well established	Facilitator for implementation of NSM
	MNRE	Well established	Policy driver
	CWC	Prospective	Premier technical organization of India in the field of Water Resources, provide inputs on feasibility and input data
	MoEFCC	Well established	Nodal agency for environmental and forestry policies and programmes, inputs on regulations and ESIA impacts of floating plants
	NGT	Well established	Dedicated jurisdiction on environmental matters, inputs on regulations and ESIA impacts of floating plants
	Fisheries department	Prospective	Stakeholder for alternate livelihood which might be impacted by FSPV projects
	Oil and Natural Gas Corporation (ONGC)	Well established	Largest crude oil and natural gas Company in India, early initiatives taken in line with the vision to enter solar development
State Governments	Maharashtra	Prospective	Policy driver, early initiatives taken in floating installations
	Kerala	Prospective	Policy driver, early initiatives taken in floating installations
	Odisha	Prospective	Policy driver, early initiatives taken in floating installations
	Madhya Pradesh	Prospective	Policy driver, early initiatives taken in floating installations
	Uttar Pradesh	Prospective	Policy driver, early initiatives taken in floating installations
	Telangana	Prospective	Policy driver, early initiatives taken in floating installations

Category	Stakeholder	Category	Rationale for selection
	Andhra Pradesh	Prospective	Policy driver, early initiatives taken in floating installations
Utilities	Power Grid Corporation of India Limited (PGCIL)	Well established	Owner of evacuation infrastructure
	Kerala State Electricity Board (KSEB)	Well established	Owner of floating plant
Regulatory Body	Central Electricity Authority (CEA)	Well established	
	CERC	Well established	
Municipal corporation	Vizag	Prospective	Early initiatives taken in floating installations
	Greater Mumbai	Prospective	Early initiatives taken in floating installations
	Indore	Prospective	Early initiatives taken in floating installations
	Kakinada	Prospective	Early initiatives taken in floating installations
	Kolkata	Prospective	Early initiatives taken in floating installations
Owners of waterbodies	Bhakra Beas Management Board	Prospective	Third largest installed hydropower capacity in India and also operates 98 km long water conductor system including channels & tunnels
	State Irrigation departments	Prospective	
	Damodar Valley Corporation (DVC)	Prospective	Owner of thermal and hydel power stations in West Bengal and Jharkhand
	Bihar Directorate of Fisheries	Prospective	Bihar Govt organisation owing waterbodies and developing FSPV
	Karnataka Urban Water Supply and Drainage Board	Prospective	Floated tender for FSPV on Build, Own, Operate model
	Central Mine Planning & Design Institute Limited	Prospective	State owned coal mining corporate
Lenders	IREDA	Well established	Non-Banking Financial Institution promoting new and renewable sources of energy and energy efficiency and conservation
	L&T Finance, L&T IDF	Well established	Active in financing of renewable projects
	State Bank of India (SBI)	Well established	Active in financing of renewable projects
	Tata Capital	Well established	Active in financing of renewable projects
Investors	Actis	Well established	Active in investments in the Indian market
	Canada Pension Plan Investment Board	Well established	Active in investments in the Indian market

Category	Stakeholder	Category	Rationale for selection
	National Investment and Infrastructure Fund	Well established	India's first infrastructure specific investment fund set up by the GoI, collaborative investment platform for international and Indian investors
	Caisse de dépôt et placement du Québec	Well established	Active in investments in the Indian market
	JP Morgan	Well established	Active in investments in the Indian market
	Abu Dhabi Investment Authority	Well established	Active in investments in the Indian market
Potential movers/ Prospective players/Parallel industries/ Master batchers	Jaypee	Prospective	Diversified Indian infrastructural industrial conglomerate
	JSW	Prospective	Diversified Indian multinational conglomerate
	Reliance Industries	Well established	Integrated player across energy, materials (petrochemicals)
	Indian Oil Corporation Limited	Well established	Diversified energy major in oil, gas, petrochemicals and alternative energy sources
	Sintex Plastics Technology Limited	Prospective	Parallel industry
	Vectus Industries Ltd	Prospective	Parallel industry
	Alok Masterbatches	Well established	Master batcher
	Polyblend Masterbatch Technik	Well established	Master batcher
	AVH Polychem Ltd	Well established	Plastic manufacturer
	ONGC Petro Additions Ltd	Well established	Plastic manufacturer, downstream integration for ONGC
	MEHR Petrochemical Company	Well established	Plastic manufacturer
	The DOW Chemical Company	Well established	Plastic manufacturer
	JAM Petrochemical company	Well established	Plastic manufacturer
	Saudi Arabia's Basic Industries Corporation	Well established	Plastic manufacturer
	Mitsubishi Engineering Plastics	Well established	Plastic manufacturer
	LG Chem	Well established	Plastic manufacturer
	Kamal Polyplast	Well established	Plastic manufacturer
	Milacron India Private Limited	Prospective	Injection & Blow Moulding Machines Manufacturer
	Toshiba Machine (Chennai) Private Limited	Prospective	Injection Moulding Machines

Category	Stakeholder	Category	Rationale for selection
	Neoplast Engineering Pvt. Ltd.	Prospective	Machine manufacturer
	Fixopan Machines Pvt. Ltd.	Prospective	Rotomolding Machine manufacturer
	N. A. Roto Machine & Moulds India	Prospective	Rotomolding, Blow moulding Machine manufacturer
	Shyam Plastic Industries	Prospective	Blow Moulding Machines
	Shree Momai Rotocast Containers Private Limited	Prospective	Rotomolding Machine manufacturer
	Polymechplast Machines Ltd.	Prospective	Injection & Blow Moulding Machines Manufacturer
	Deesha Impex	Prospective	Manufacturer of test equipment, injection moulding machines
	Esemplast	Prospective	Injection Moulding Machines
	Prikan Machinery Private Limited	Prospective	Injection Moulding Machines
	Jagmohan Pla Mach Pvt Ltd	Prospective	Blow Moulding Machines
	G S Machinery	Prospective	Injection and Blow Moulding Machines
	ACME Drinktec Solutions LLP	Prospective	Moulds and dies
	Blow Engineering	Prospective	Blow Moulding Machines
	Torrenza Mould Craft Pvt Ltd	Prospective	Plastic Injection Moulds & Dies
	Bloomseal	Prospective	Manufacturers of Plastic containers in India
	GLS Polymers Pvt Ltd, Bengaluru	Prospective	To bring in industry challenges on design, manufacturing, scalability, cost
	PlastIndia Foundation	Prospective	Knowledge transfer, manufacturing capacity identification, identifying growth drivers, recycling
	Indian Plastics Institute, Mumbai	Prospective	Industry association for locally available manufacturing & testing facilities
	Polyene Group	Prospective	Blow moulded products
	All India Plastic Manufacturers association of India	Prospective	Largest and the oldest apex body of plastic machine manufacturers in India - knowledge transfer, manufacturing capacity identification, identifying growth drivers, recycling
Float manufacturers	Ciel & Terre	Well established	International experience and installed capacity
	Sungrow	Well established	Installed capacity
	Adtech	Well established	Indigenous supplier, early installations
	Quant Solar	Well established	Indigenous supplier, early installations

Category	Stakeholder	Category	Rationale for selection
	Sheetal/Prabh Dayal/ Ram Setu	Well established	Indigenous supplier, early installations
	Oceansun	Well established	Offshore/Nearshore expertise
	Oceans of Energy	Prospective	Experience in the industry
	ISI genere	Well established	Experience in the industry
	Sumitomo Mitsui	Well established	Experience in the industry, Japanese manufacturer
	LG CNS	Well established	Experience in the industry, South Korean manufacturer
	NRG Energia	Well established	Experience in the industry
	ZIM float	Well established	Experience in the industry
	Moss Maritime	Well established	Experience in the industry
	Scotra	Well established	Experience in the industry
	NemoEng	Prospective	Experience in the industry, Korean manufacturer
	Profloating B.V	Prospective	Experience in the industry, Dutch manufacturer
	Floating Solar B.V	Prospective	Experience in the industry, Dutch manufacturer
	Texel4Trading	Prospective	Experience in the industry, Dutch manufacturer
	Swimsol	Prospective	Experience in the industry, Dutch manufacturer
	HydroPV	Prospective	Experience in the industry, Dutch manufacturer
	SunFloat	Prospective	Experience in the industry, Dutch manufacturer
	Sun Rise E&T Corporation	Prospective	Experience in the industry, Taiwanese manufacturer
	Bosch Xiamen new Energy	Prospective	Experience in the industry, Chinese manufacturer
	Kyoraku Co. Ltd	Prospective	Experience in the industry, Japanese manufacturer
	Xiamen Mibet New Energy Co. Ltd	Prospective	Experience in the industry, Chinese manufacturer
	SolarisFloat	Prospective	Experience in the industry, Potuguese manufacturer
	Vari Pontoons Pvt Ltd.	Prospective	Indigenous player and presence in floating technology for various industrial applications
	Jain Tarang Irrigation Systems	Prospective	Indigenous manufacturer and presence in ground mounting solutions

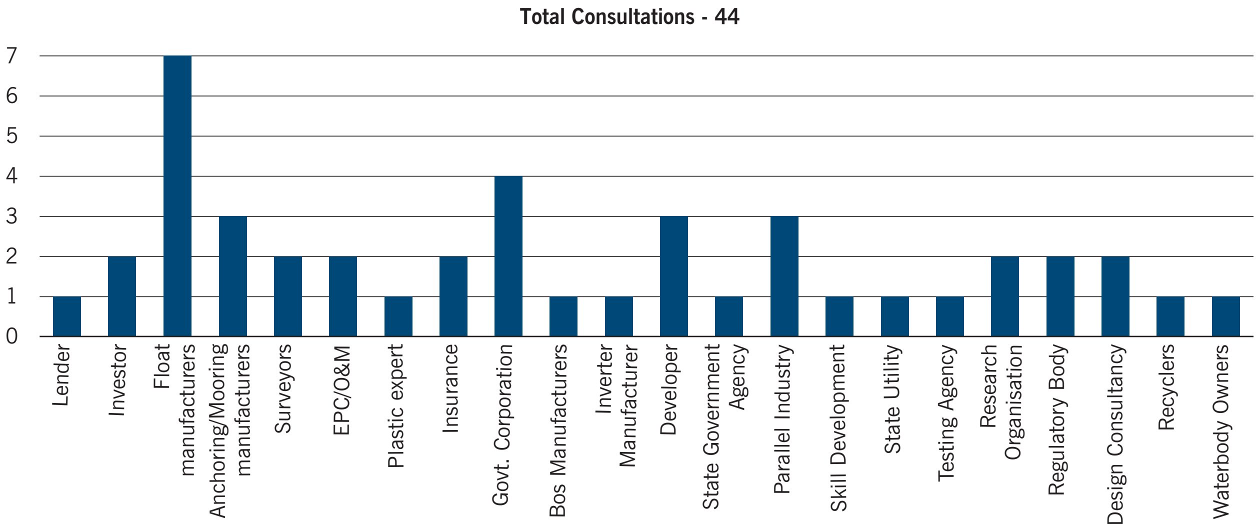
Category	Stakeholder	Category	Rationale for selection
Anchoring manufacturers/ anchoring service providers/Diver organisations	Seaflex	Well established	Experience in the industry
	Hazelett Marine	Well established	Experience in the industry
	HCM Marine Constructions	Well established	Experience in the industry
	Rock & Reef Pvt Ltd	Prospective	Experience in the industry
	Bluefin marine	Prospective	Experience in the industry
	Mooreast Asia Pte. Ltd.	Prospective	Mooring solutions
	Mech Marine	Prospective	Mooring solutions
	Duke offshore	Prospective	Experience in the industry
Module manufacturers (selected players)	Trina Solar	Well established	One of the top module suppliers globally
	Adani	Well established	Indigenous manufacturer
	Renewsys	Well established	Indigenous manufacturer
	Jinko Solar	Well established	Top module supplier to India
	JA Solar	Well established	Top module supplier to India
	LONGi Solar	Well established	Top module supplier to India
	Risen Energy	Well established	Top module supplier to India
	TATA Power Solar	Well established	Indigenous manufacturer
Inverter manufacturer (selected players)	Sungrow	Well established	One of the top inverter suppliers to India
	Huawei	Well established	Top string inverter supplier
	Fimer	Well established	Local manufacturing, one of the top suppliers
BoS manufacturers (selected players)	Polycab	Well established	Leading indigenous cable manufacturer
	Trinity Touch	Well established	Leading Indigenous SCB manufacturer
	ABB	Well established	MV equipment manufacturer
	Raychem RPG Pvt Ltd	Well established	Diversified manufacturer (cable and transformer)
Testing agencies	RWDI	Well established	Structural testing
	Central Institute of Plastics Engineering & Technology (CIPET)	Well established	Research, knowledge transfer
	NAL	Prospective	Structural testing
	National Wind Tunnel Facility, Indian Institute of Technology (IIT) Kanpur	Well established	Structural testing
	Department of Ocean Engineering, IIT Chennai	Well established	Structural testing
	IIT, Kharagpur	Well established	Structural testing

Category	Stakeholder	Category	Rationale for selection
	National Institute of Ocean Technology	Well established	Structural testing
	Intertek	Well established	Material testing
	BIS	Well established	Testing
	CPP	Well established	Structural testing
Surveyors	Fugro	Well established	World's leading provider of geo-intelligence and asset integrity solutions for large constructions, infrastructure and natural resources
	Shankar Surveys	Well established	Indigenous surveyor
	Idax Consulting and Research Pvt Ltd	Prospective	Indigenous surveyor
	New Horizon Surveys	Prospective	Indigenous surveyor
	Comacoe Engineering	Prospective	Indigenous surveyor
	Geo Marine Solutions Pvt Ltd	Well established	Indigenous surveyor
	Deekay Marine Services Pvt Ltd	Well established	Indigenous surveyor
	Ocean science and surveying Pvt Ltd	Well established	Indigenous surveyor
	Yolax Infranergy Private Limited	Prospective	Indigenous surveyor
	Geostar surveys	Well established	Indigenous surveyor
Design consultancies	Tractabel	Well established	
	The Energy and Resources Institute	Well established	
	Aryatech Marine & Offshore Services Pvt. Ltd	Prospective	Marine and Offshore Engineering and Consultancy Company
	WAPCOS	Prospective	
	Oceanergy	Prospective	
	Oiltech Engineering	Prospective	
	Tata Consulting Engineers	Well established	
Developers/IPP	Sungrow	Well established	Experience in the industry, presence across value chain
	Adani	Well established	Large IPP
	Lightsource Renewable	Well established	Experience in UK
	Renew Power	Well established	Large IPP
	Bay Wa r.e.	Well established	Experience in the industry
	O_2 Power	Well established	Experience in the industry

Category	Stakeholder	Category	Rationale for selection
	SunSource Energy	Well established	Experience in the industry
	Ayana	Well established	Experience in the industry
	Masdar	Well established	Initiative in SE Asia
EPC contractors	TATA Power solar	Well established	Experience in the industry
	Kyocera	Well established	Experience in the industry, module manufacturer
	L&T ECC	Well established	Experience in the industry
	Mahindra Susten	Well established	Experience in the industry
	BHEL	Well established	Experience in the industry
	Sterling & Wilson	Well established	Experience in the industry
O&M contractors	Sterling & Wilson	Well established	Experience in the industry
	Mahindra Susten/ Teqo	Well established	Experience in the industry
Research organisations/ academic institutions	National Institute of Oceanography, Goa	Prospective	Research and knowledge transfer
	Solar Energy Research Institute of Singapore	Well established	Early research
	Department of Hydro and Renewable Energy (formerly Alternate Hydro Energy Centre) IIT Roorkee	Prospective	Research and knowledge transfer
	IIT, Chennai	Prospective	General information on types of plastics and their applications relevant to floating solar plants
	IIT, Mumbai	Prospective	Research, testing and knowledge transfer
Industry experts in plastic manufacturing	Dr Nanda Kumar, Technical Director	-	Information on additive manufacturing in plastics
	S.R. Anujan, Freelance Consultant, Plastics Manufacturing	-	Knowledge on manufacturing processes and advantages/disadvantages
Recyclers (preliminary list)	Shakti Plastics	Well established	
	AP Chemi	Well established	
	Gravita India	Well established	
	Global PlastChem	Well established	
	Thermowaste solutions	Well established	
Skill development	Skill council of Green jobs	Well established	Nodal agency for skill development in India
Insurance	Marsh	Well established	Insurance provider for renewable industry
	Chubb	Well established	Insurance provider for renewable industry
	Bajaj Allianz	Well established	Insurance provider for renewable industry
	Willis Towers Watson	Well established	Insurance provider for renewable industry

The distribution of the various stakeholders consulted is depicted in **Figure A.1.**

FIGURE A.1



The details of float and anchoring system manufacturers consulted is given in the **Table A.2**.

TABLE A.2

Service	Stakeholder Name	Country	Years of existence (As on Mar'21)	International Presence	Installed Capacity (FSPV)
Float Manufacturer	Ciel & Terre	France	15	Japan, the US, UK, China, Taiwan, Malaysia, Thailand, India and France, South Korea and Brazil	490 MWp
	Quant Solar	India	6	India	2.5 MW
	Ocean Sun	Norway	5	Norway, Singapore, Philippines, Albania	3 MWp
	ISI Genere	Spain *(partnership with Autonics in India)*	13	Chile, Netherlands, India	4 MW
	Sungrow	China	24	China, Japan, Taiwan, Thailand, Israel, Abu Dhabi	1.1 GW
	Zimmermannn	Germany	12	UK, Netherlands, Brazil, Spain, Mauritania, Australia	70 MW
Anchoring & Mooring	Seaflex	Sweden	46	India, South Korea, USA	-
	Mooreast Asia	Singapore	28	SE Asia, India, Europe, UK	-
Surveyor	Fugro	Netherlands	59	61 countries across continents	-
	Shankar Surveys	India	20	India	-

APPENDIX B: METHODOLOGY FOR SHORTLISTING OF THE COUNTRIES FOR BENCHMARKING STUDY

Floating solar is at different stages of maturity trajectory in various markets and each market provides a different set of initial learning. Hence, the team first gathered information about the major initiatives in each key market. A summary of the information gathered is given in **Table B.1**.

TABLE B.1: Major initiatives in various markets

Country	FSPV Installed Capacity (MWp)	Brief Summary
China	960.0	In China, FSPV systems are either deployed as a result of a bidding scheme and are therefore eligible for a FiT granted over 20 years, or as a grid-parity project without any form of subsidy support. In June 2020, China's Datang Power released a tender seeking several bids for a total capacity of 820 MW of FSPV to be installed across China by December 2021.
Japan	210.0	With more than 210 MWp of installed capacity, Japan is a leading country in terms of total numbers of installation and home to 73 of the world's 100 largest FSPV plants. The majority of these plants are installed on man-made waterbodies created to retain rainwater or irrigation.
Vietnam	117.0	In April 2020, the government of Vietnam announced its plan to hold two auctions—one aimed at a 50-100 MW capacity and the second for a 300 MW FSPV project in 2021. In May 2020, the government announced a FiT for FSPVs. Accordingly, a tariff of VND 1,783/kWh, equivalent to EUR cents 0.65/kWh will be applied from the commercial operation date onwards for 20 years.
Korea	80.0	Located on Korea's southwest coast, the tidal flats of Saemangeum have been identified as the site for the world's largest FSPV installation of 2.1 GW by 2025, requiring an investment of approximately $ 4 billion. Korea's estimated onshore FSPV market potential is around 9.7 GW, which depending on the body of water (reservoirs, freshwater lakes, dams, irrigation and drain channels), would see between 2–20 percent of the water surface covered by FSPV.
Netherlands	52.0	Netherlands is a country with a huge potential for solar PV. In 2019, the solar energy accounted for around 60 percent of the country's renewable installed capacity[71,72]. Furthermore, in 2020, the solar capacity increased by 41 percent, reaching 10 GW[73]. In addition, as per the Netherlands Environmental Assessment Agency, by 2023, the Netherlands will have 15 GW of solar installed and by 2030 the country is expected to witness another 12 GW, bringing total capacity to approximately 27 GW[74].

71 Statista. (2021). Renewable capacity in the Netherlands 2008–2020. https://www.statista.com/statistics/1189567/total-renewable-capacity-in-the-netherlands/

72 Bhambhani, A. (2021, January 21). 2.9 GW New Solar Installed In Netherlands In 2020. Taiyang News. http://taiyangnews.info/markets/2-9-gw-new-solar-installed-in-netherlands-in-2020/

73 Bhambhani, A. (2021, January 21). 2.9 GW New Solar Installed In Netherlands In 2020. Taiyang News. http://taiyangnews.info/markets/2-9-gw-new-solar-installed-in-netherlands-in-2020/

74 Bellini, E. (2019, November 4). Netherlands to reach 27 GW of solar by 2030. PV Magazine International. https://www.pv-magazine.com/2019/11/04/netherlands-to-reach-27-gw-of-solar-by-2030/

Country	FSPV Installed Capacity (MWp)	Brief Summary
Taiwan	26.0	The Taiwanese government has offered FITs specifically for FSPV systems since 2017. Accordingly, FSPV systems coming online in the second half of 2020 were eligible to receive a FiT of NTD 4.2709–4.7067/kWh (EUR cents 12–14/kWh) for 20 years.
United Kingdom	12.0	Like many other Asian countries, lack of space for land-mounted PV is why the country is moving toward FSPV plants. The majority of the plants in the UK are installed on irrigation and water treatment ponds.
United States	1.5	Department of Energy's NREL released a report in 2019 outlining the potential of the technology to reach 9.6 percent of current electricity generation of US. This estimation is equivalent to 2100 GW.
Thailand	1.0	A national FSPV target is set by EGAT, which announced in March 2019 that it aims to build a total of 16 FSPV systems on dams with a combined capacity of 2.7 GW by 2037. Individual capacities of the envisaged FSPV systems range from 24 MW up to 325 MW.

After gathering the required data, a methodology was developed for ranking the countries based on multiple parameters.

In the methodology, distance to the frontier method was used for shortlisting the countries. The method is described below:

- Distance to the frontier measures the relative position of a given indicator viz.-a-viz. a reference point.
- The score illustrates the distance of a country to the "frontier", which represents the best performance observed on each scoring indicator.
- A country's distance to frontier is indicated on a scale from 0 to 100, where 0 represents the lowest performance and 100 the frontier.
- It can show how much the country has changed over time in absolute terms with respect to the scoring indicators. Calculating the distance to frontier score involves normalization of individual component (y) using the linear transformation (worst – y)/(worst – frontier).

Furthermore, during the calculation process, frontier and worst values were identified, depending on the scoring criteria of 'higher is better', which means that higher the value, better the performance (say installed capacity).

Illustration

The values for installed capacity range from the 960 MW (for China) to 0 MW (for UK). The higher the value on this scoring indicator, more is the attractiveness of a country for FSPV. As per this calculation, China is likely to get a score of 100 while it is likely to be 0 for UK.

The other countries will lie in between which represents the distance to the best value. This method of transformation warrants that each data point has a unique score. Hence, this method effectively captures the difference among the countries against their scoring indicators.

The parameters used and methodology adopted for ranking of the countries is given below.

- **Target/Potential:** Score of 100 is provided if FSPV target is in place, 50 if Overall RE/Solar target is defined, 0 if no target is in place.

- **Policy & Regulatory Analysis:** Score of 100 is provided if at least some policy and regulations are in place, score of 0 is provided if no policy and regulation is in place.
- **Incentives offered:** Score of 100 is provided if FiTs are being offered, score of 50 is provided if at least some subsidies, investment plan is in place for RE/FSPV, score of 0 is provided if no incentive is in place.
- **Business models:** Score of 100 is provided if some business models have been deployed commercially (for eg. Green Bond financing), score of 50 is provided if some pilot testings have been done on probable business models, score of 0 is provided in case of absence of business models.
- **R&D Activities:** Score of 100 is provided if R&D centre/specific R&D related to FSPV exist or has been conducted, score of 50 is provided if R&D activities are in progress, score of 0 is provided in case of absence of R&D activities.

The scores obtained by the countries along with their ranks are given in **Table B.2**.

Based on the ranks obtained by the different countries and discussions with the World Bank, three countries—Japan, Netherlands and Vietnam—were shortlisted for the benchmarking study.

TABLE B.2: Countries with scores and ranks

Country Name	Score under different parameters							Total Score	Rank
	Installed Capacity	Pipeline	Target/ Potential	Policy & Regulatory Analysis	Incentives offered	Business models	R&D Activities		
Japan	21.88	0.00	50	100	100	100	100	471.88	**1**
South Korea	8.33	100.00	100	100	50	0	100	458.33	**2**
Netherlands	5.42	21.45	100	100	50	50	100	426.86	**3**
Vietnam	12.19	16.66	100	100	50	100	0	378.85	**4**
Taiwan	2.71	6.18	50	100	100	0	0	258.88	**5**
China	100.00	36.76	0	0	50	50	0	236.76	**6**
Thailand	0.10	0.14	100	0	0	0	100	200.25	**7**
United Kingdom	1.25	2.49	50	0	0	50	0	103.74	**8**
Singapore	0.00	0.38	0	0	0	0	50	50.38	**9**

APPENDIX C: FLOATING SOLAR PLANTS IN JAPAN, NETHERLANDS AND VIETNAM

Below is a non-exhaustive list of the FSPV projects in Japan, Netherlands and Vietnam. These plants have been listed in the SolarPlaza's report *Top 50 Operational Floating Solar Projects 2021*.

Country	Plant name	Size (MW)	Operational year	Floating system provider
Japan	Yamakura solar power plant	13.7	2018	Ciel & Terre
	Umenoki	7.6	2015	Ciel & Terre
	Hirotani Ike Floating Solar Plant	6.8	2018	Takiron Engineering
	Oda ike	2.9	2018	Ciel & Terre
	Kato Shi (2 plants in total)	2.9	2015	Ciel & Terre
	Narasu Ike	2.8	2018	Ciel & Terre
	Hyoshiga Ike	2.7	2019	Ciel & Terre
	Katakami Oike	2.6	2019	Ciel & Terre
	Hiragio Ike Floating Solar Plant	2.6	2017	Sumitomo Mitsui Construction
	Ichigo Kasaoka Iwano Ike ECO Plant	2.6	2018	Ciel & Terre
Netherlands	Bomhofsplas	27.4	2020	PV-Floating/ Zimmermannn
	Kloosterhaar	15.7	2020	PV-Floating/ Zimmermannn
	Sekdoorn	14.5	2019	PV-Floating/ Zimmermannn
	Nij Beets	13.5	2020	PV-Floating/ Zimmermannn
	Tynaarlo	8.4	2019	PV-Floating/ Zimmermannn
Vietnam	Da Mi hydropower reservoir	47.5	2019	Narime-Qihua
	Gia Hoet 1	35.0	2020	NA
	Tam Bo	35.0	2020	NA

APPENDIX D: FLOATING SOLAR PLANTS IN INDIA

Table D.1 lists some of the currently operational FSPV plants in India.

TABLE D.1: Operational plants in India

Sl. No.	Agency/Project name	Capacity (MW)
1	National Thermal Power Corporation (NTPC)	100.0
2	National Thermal Power Corporation (NTPC)	92.0
3	National Thermal Power Corporation (NTPC)	25.0
4	National Thermal Power Corporation (NTPC)	23.0
5	National Thermal Power Corporation (NTPC)	20.0
6	Greater Visakhapatnam Smart City Corporation Limited (GVSCCL)	4.4
7	Bihar Renewable Energy Development Agency (BREDA)	1.6
8	Bihar Renewable Energy Development Agency (BREDA)	0.5
9	Kreala State Electricity Board (KSEB)	0.5
10	Chandigarh Renewable Energy and Science & Technology Promotion Society (CREST)	0.5
11	West Bengal Power Development Corporation Limited (WBPDCL)	5.0
12	Cochin Port Trust	1.5
13	Greater Visakhapatnam Smart City Corporation Limited (GVSCCL)	2.0
14	Assam Energy Development Agency (AEDA)	0.0
15	Indian Oil Corporation Limited (IOCL)	0.1
16	Cochin International Airport (CIAL)	0.5
17	Kreala State Electricity Board (KSEB)	0.5
18	Vizag Smart City	2.0
19	Oil & Natural Gas Corporation (ONGC)	2.0
20	Tirupati Smart City	4.0
21	Solar Energy Corporation India (SECI)	4.0
22	Southern Pertochemical Industries Corporation (SPIC)	14.7
23	National Thermal Power Corporation (NTPC)	36.0
24	Kreala State Electricity Board (KSEB)	0.0
25	The Singareni Collieries Company Limited	5.0
Total		**344.8**

Table D.2 lists some of the planned/under construction FSPV plants in India.

TABLE D.2: Planned/under construction FSPV in India

Project developer/Procurement authority	Location	Capacity (MW)
Government of Madhya Pradesh	Omkareshwar Dam	600
JSW Energy	Across India	250
NHPC	Rengali, Odisha	100
NHPC	West Kallada, Kerala	50
SECI	Getalsud Reservoir, Jharklhand	100
DVC Floating solar Park, Ph 1	Jharkhand	755
DVC Floating solar Park, Ph 2	Jharkhand	234
NHPC Floating solar Park, Ph 2	Odisha	200
Total		**2,289**

APPENDIX E: LIST OF POLICIES, PERMITS AND APPROVALS

While every attempt has been made to collate a comprehensive list of applicable policies, permits and approvals, please note that the list could be dynamic, and project-specific due diligence is recommended.

List of Policies

International Agreements and Conventions	Applicability of policy/regulation to FSPV projects
The Government of India being signatory to several international agreements and conventions, the States of India are also under obligation to adhere to the agreements and convention directions. Some critical international agreements and conventions and their relevance to the project are as follows:	
Ramsar Convention on Wetlands	The Convention on Wetlands is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The convention entered into force in India on February 1, 1982. India currently has 42 sites designated as Wetlands of International Importance (Ramsar sites), with a surface area of 1,081,438 hectares.
International Union for Conservation of Nature (IUCN)	IUCN is a democratic union that brings together the world's most influential organisations and top experts in a combined effort to conserve nature and accelerate the transition to sustainable development. India became a State Member of IUCN in 1969, through the MoEFCC. IUCN in India operates under four projects: marine & coastal, inland waters, business and biodiversity and species conservation.
Convention on Biological Diversity	Signed by 150 world government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity is dedicated to promoting sustainable development. Conceived as a practical tool for translating the principles of Agenda 21 into reality, the Convention recognizes that biological diversity is about more than plants, animals and microorganisms and their ecosystems – it is about people and their need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live.
Aarhus Convention	The Aarhus Convention establishes a number of rights to the individuals and civil society organizations with regard to the environment. The Parties to the Convention are required to make the necessary provisions that public authorities, at a national, regional or local level will contribute to these rights to become effective.
Paris agreement on Climate Action	India pledged to reduce the emission of GHGs and become carbon neutral by 2030 under the Paris agreement act.
SDG Goal 7	Sustainable development goal 7 aims to ensure universal access to affordable, reliable and modern energy services by the year 2030.
National level policies	**Applicability of policy/regulation to FSPV projects**
The Electricity Act 2003	CEA is a statutory institution as per provision of the Electricity Act 2003. The main responsibility of the organization is to advise the government on matters relating to national electricity policy and to coordinate activities of the various planning agencies for the optimal utilization of resources. It is also responsible for laying down technical standards for construction of power plants, power evacuation lines and grid connectivity.The Electricity Act 2003 requires projects to obtain licenses and comply with the required safety regulations as stipulated in the Act.

National level policies	Applicability of policy/regulation to FSPV projects
NSM	Aimed at achieving a national solar capacity of 175 GW by 2022, FSPV has a large potential in contributing to achieving this target.
Environmental Clearance under EIA notification 2006	MoEFCC is the nodal agency responsible for the environmental management of the country at the national level. The responsibilities include environmental policy planning, environmental legislation, regulation for environmental protection, environmental clearance of projects, monitoring of environmental conditions imposed in the EC process, conservation and management of biological diversity, protection of waterbodies and coastal areas. MOEFCC office vide office memorandum J-11013/41/2006-IA.II (I) dated 7 July 2017 has clarified that solar PV projects, solar TPPs and development of solar power parks are exempted from provisions of the EIA notification 2006, subject to the project following the environmental and statutory provisions made in office memorandum dated June 30, 2011.
Tiger Reserve Area	In India, approximately 50 tiger reserves are created to prohibit human activities in these protected areas.
Elephant reserves	Being an endangered species, the Indian elephant is a part of the Wildlife Protection Act, 1972.
Biosphere reserves	Biosphere reserves are typically large areas that serve as testbeds for understanding and managing interactions between social and ecological systems.
World Heritage sites Ancient Monuments and Archaeological Sites and Remains Act	Conservation of cultural and historical remains found in India. There are seven natural heritage sites and 30 cultural heritage sites in India as of 2020. These sites are considered to possess special cultural, physical or ecological significance. For a project located within 300m of such features (first 100 meters as prohibited area followed by 200 meters to be regulated area), approval from Archaeological Dept. the central government, Indian Heritage Society and Indian National Trust for Art and Culture Heritage is required.
Important Coastal and Marine Biodiversity Areas (ICMBAs)	There are 106 coastal and marine areas under the ICMBAs in India as of 2021.
Important Bird Areas (IBAs)	IBAs are areas identified using an internationally agreed set of criteria as being globally important for the conservation of bird populations.
Right to Fair Compensation and Transparency in Land Acquisition and Resettlement Act 2013	Revenue Department through office of District Collector is responsible for implementation of this Act to ensure that land acquired is for public purpose and to provide fair compensation to the affected owners when private land is acquired for the project.
Guidelines issued by MoP for payment of compensation towards damages caused by tower and Right of Way (RoW) for transmission lines.	Tower base area impacted due to installation of tower/pylon structure and compensation towards diminution of land value in the width of RoW corridor due to laying of transmission line and imposing certain restrictions.
The Forest (Conservation) Act 1980	State Forest Department MoEFCC's permission is required to divert forests for non-forestry use. Need to undertake compensatory afforestation if forestland is acquired.

Environmental Protection Act 1986	To protect and improve the overall environment. The Department of Environment at the State level is the apex body for all environmental related issues including implementation of certain delegated responsibility under the Environment Protection Act 1986. It also has administrative responsibility for managing the State Pollution Control Board.
State level policies	**Applicability of policy/regulation to FSPV projects**
Each state in India has departments that enforce policies and standards on energy, E&S issues pertaining to projects related to energy generation, including FSPV projects. FSPV project developers must comply with the state policies and standards. Some of the applicable policies are mentioned below:	
The Water (Prevention & Control) Act 1974	State Pollution Control Boards function under the administrative control of the State Departments of Environment. They are responsible for enforcing various provisions of environmental legislation like the Water (prevention & control) Act, 1974, Air (prevention & control) Act 1981 and all these Acts are under the umbrella of the Environmental Protection Act 1986.
The Air (Prevention & Control) Act 1981	
The Noise (Regulation & Control) Rules 2000	
The Batteries (Management & Handling) Rules 2001 as amended	
Solid Waste Management Rules 2016	
E-Waste Rules 2016	
Hazardous and Other wastes (Management & Transboundary movement) Rules 2016	
Labour Department	This department is responsible for formulation and enforcement of labor laws in the State. Prevention and settlement of industrial disputes, industrial safety & health of workers, and welfare of workers is also its responsibility.
Constitution (73rd Amendment) Act, 1992	The local Panchayats are an important institution in the decentralized administrative system of the country. They are empowered with management of local natural resources like forests, water, common property resources and for various infrastructure facilities like roads and buildings. A license from the local Panchayat is essential for construction-related activities.
Reservoir Fishery Policy	The State Government (Department of Fisheries is the main agency for implementation of the Reservoir Fisheries Development Programme. It is responsible for selection of the reservoirs, leasing of the waterbody to the beneficiary i.e., the lessee, monitoring and evaluation of the stocking and harvesting activities, assisting the beneficiaries in establishing sound forward and backward linkages, providing technical support and in capacity building of the beneficiaries from time to time.
Wildlife (Protection) Act 1971	Projects located inside the boundary of Wildlife Sanctuary or National Park, Wildlife reserves or bio-reserves or National biodiversity reserves, have to comply with the Act.
The Factories Act 1948 & State Rules	Chief Inspectorate of Factory & Boilers

State level policies	Applicability of policy/regulation to FSPV projects
Building & Other Construction Workers Act 1996	All the Acts are to ensure welfare of workers.
Contract Labour (Regulations & Abolishment) Act 1970	
Payment of Wages Act 1936	
Minimum Wages Act 1948	
Employer's Liability Act 1938	
Equal Remuneration Act & Rules 1976	
Industrial Dispute Act 1947	
Maturity Benefit Act 1961	
Employees State Insurance Act 1948	
Workmen's Compensation Act 1923	
Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act of 2013	
World Bank E&S Framework	**Applicability of policy/regulation to FSPV projects**
The Environmental and Social Framework effective from October 1, 2018, enhances the World Bank's commitment to sustainable development through 10 Environmental and Social Standards (ESS) that are designed to support Borrowers' E&S risk management.	
ESS1: Assessment and Management of Environmental and Social Risks and Impacts	For assessing, managing and monitoring environmental and social risks and impacts associated with each stage of a project.
ESS2: Labour and Working Conditions	Recognising the importance of employment creation and income generation in the pursuit of poverty reduction and inclusive economic growth.
ESS3: Resource Efficiency and Pollution Prevention and Management	Requirements to address resource efficiency and pollution prevention and management throughout the project life-cycle.
ESS4: Community Health and Safety	Health, safety, and security risks and impacts on project-affected communities and the corresponding responsibility of Borrowers to avoid or minimize such risks and impacts, with particular attention to people who, because of their particular circumstances, may be vulnerable.

ESS5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement	Avoid or minimize involuntary resettlement through appropriate measures to mitigate adverse impacts on displaced persons.
ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	Protecting and conserving biodiversity and sustainably managing living natural resources are fundamental to sustainable development and recognizing the importance of maintaining core ecological functions of habitats, including forests, and the biodiversity they support.
ESS7: Indigenous Peoples/ Sub-Saharan African Historically Underserved Traditional Local Communities	To ensure that the development process fosters full respect for the human rights, dignity, aspirations, identity, culture, and natural resource-based livelihoods of Indigenous Peoples/Sub-Saharan African Historically Underserved Traditional Local Communities.
ESS8: Cultural Heritage	Sets out measures designed to protect cultural heritage throughout the project life-cycle.
ESS9: Financial Intermediaries (FI)	Strong domestic capital and financial markets and access to finance are important for economic development, growth and poverty reduction. FIs are required to monitor and manage the environmental and social risks and impacts of their portfolio and FI subprojects, and monitor portfolio risk, as appropriate to the nature of intermediated financing.
ESS10: Stakeholder Engagement and Information Disclosure	Effective stakeholder engagement can improve the environmental and social sustainability of projects, enhance project acceptance, and make a significant contribution to successful project design and implementation.

List of Permits and Approvals

Sl. No.	Permit/Approval	Issuing Entity
1.	Letter of award/allotment of the project	Entity allocating the project (SECI, NTPC or state authorities).
2.	Project registration	State nodal agency
3.	PPA	Entity allocating the project (SECI, NTPC or state authorities).
4.	Power Sale Agreement (PSA)	Discoms
5.	Tariff adoption order	SERC of the DISCOM entering into PSA
6.	Connectivity	PGCIL/central transmission utility (CTU)/state transmission utility (STU)
7.	Approval under Section 68 and Section 164 for transmission scheme of connectivity system	CEA
8.	Transmission agreement for transmission of power in Inter-State Transmission System mode	CTU
9.	Long term access or Long term open access agreement (as applicable)	CTU/STU
10.	No Objection Certificate (NOC) for Long term open access (as applicable)	State DISCOM
11.	Wheeling and Banking agreement (as applicable)	DISCOM
12.	Chief Electrical Inspector to Government (CEIG)/ CEA approval	CEIG/CEA
13.	Telemetry and communication approval (for getting clearance from Power, Telecommunication, Railway and Defence Communication)	Bharat Sanchar Nigam Limited/Power and Telecommunication Co-ordination Committee depending on evacuation voltage level.
14.	Synchronization approval	DISCOM
15.	Commissioning certificate	Nodal agency/Local agency
16.	Implementation Agreement	Solar Power Park Developer
17.	Overhead line approval	DISCOM/PGCIL
18.	Bay allocation approval	DISCOM/PGCIL
19.	Commercial Operation Date Certificate	Commissioning committee/DISCOM/State nodal agency/STU
20.	Load dispatch centre approval for connecting load	
21.	Metering approval	Committee constituted for verification of commissioning of the plant or by the local DISCOM authorities.
22.	Factory License	Labour Department
23.	Factory plan approval	Labour Department
24.	Consent to Establishment and consent to operate	Central/State pollution control board

Sl. No.	Permit/Approval	Issuing Entity
25.	Fire safety permit	Fire Department
26.	Forest NOC	Forest Department
27.	Mining NOC	Mining Department
28.	Water Department NOC	Water Department
29.	Village panchayat NOC	Gram panchayat
30.	Building and other construction worker	Labour Department
31.	Contract labour regulation and abolition	Labour Department
32.	Land Use Permission Agreement: All land allotment approvals and documents (if allocated by Government) or complete documentation of land if acquired from private owners.	Revenue department/Collector/Tahsildar/District magistrate/Concerned commission
33.	Conversion of agricultural land to non-agricultural land, if applicable	Revenue Department/Collector/Tahsildar/ District Magistrate/Concerned Commission
34.	RoW if passing through lands of multiple owners, in case those lands are not acquired by developers	
35.	NOC/approval from port trust, coastal regulation zone, naval authorities or any other concerned authority	
36.	Clearance for surface water and extraction of ground water for solar PV panel cleaning and other activities.	Central Ground Water Authority
37.	Water Use Permission Agreement	Owner of waterbody

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