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FINAL REPORT

MAPPING AND PROSPECT ANALYSIS OF FLOATING SOLAR IN BANGLADESH

Policy Advisory for Promoting Energy Efficiency and Renewable Energy (PAP) Project

GIZ Bangladesh

November 2024

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

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List of Acronyms

Abbreviation		Meaning
ADB	:	Asian Development Bank
AFD	:	Agence Française de Développement
BPDB	:	Bangladesh Power development Board
BREB	:	Bangladesh Rural Electrification Board
DESCO	:	Dhaka Electric Supply Company
DPDC	:	Dhaka Power Distribution Company Limited
FIT	:	Feed In Tarif
FPV	:	Floating Photovoltaic
FRP	:	Fibre Reinforced Plastic
GIZ	:	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoB	:	Government of Bangladesh
ICB	:	International Competitive Bidding
IPRS	:	In-Pond Raceway System
IEE	:	Initial Environmental Examination
HMPE	:	High Modulus Poly Ethylene
JPL	:	Joules Power Limited
IPRS	:	In-Pond Raceway System
MDPE	:	Medium Density Poly Ethelyne
MPEMR	:	Ministry of Power, Energy and Mineral Resources
NESCO	:	Northern Electricity Supply PLC
O&M	:	Operation and Maintenance
OPEX	:	Operating Expenses
PAP	:	Policy Advisory for Promoting Energy Efficiency and Renewable Energy
PD	:	Power Division
PPP	:	Public-Private Partnerships
RE	:	Renewable Energy
SIA	:	Social Impact Assessment
SREDA	:	Sustainable & Renewable Energy Development Authority
EU	:	European Union
TC	:	Technical Cooperation
WB	:	World bank
WZPDCL	:	West Zone Power Distribution Company Limited

Executive Summary

Introduction

Floating Photovoltaic, a novel technology that harnesses solar energy on water bodies, offers a promising solution for countries like Bangladesh with limited land resources and abundant water bodies. Since land has multiple uses, this can overcome the land scarcity being faced to establish land based solar power plants. The objective of this study is to showcase the benefits and challenges of Floating Photovoltaic (FPV) in Bangladesh, evaluate existing policies and regulations, assess potential technologies, examine environmental aspects, identify stakeholder barriers, and analyze the financial viability of FPV projects and how to make it popular in Bangladesh.

Through the review of literature, it is evident that FPV is still in an early stage of development. It is progressing fast for the reason that land is becoming scarce all over the world due to multiple use of land. Simultaneously, they are also carrying out research to study the environmental impact on the aquatic life, flora and fauna of the surrounding areas. Till now whatever research has been done proves that there is minimal environmental impact. Most of the FPV has been installed in lakes, ponds, dams, subsided mines areas and calm water bodies.

Current Status of Floating Solar in Bangladesh

While Bangladesh possesses significant potential for floating solar, its deployment remains at a very nascent stage. A few pilot projects were initiated to demonstrate the technical feasibility of the technology but practically only one significant FPV project is effectively working. A 784 kW floating solar plant has been installed at Nawab Auto Rice & Feed Mills Pvt. Ltd. at Chapainawabganj under OPEX model and Net Metering System. The plant has been installed by Joules Power Ltd. (JPL) with their own finance and will be maintained by JPL for the next 12 years. At the end of the period, the plant will be handed over to Nawab Auto Rice Mills Ltd. JPL is selling the generated electricity to Nawab Auto Rice Mills at a rate of Tk. 8.10 per kWh. Rice Mill authority has contract with Northern Electricity Supply PLC (NESCO) to sell the excess electricity after own consumption under Net Metering Guidelines. However, a comprehensive policy framework specifically addressing floating solar is still lacking.

Merits of Floating Photovoltaic

(i) **Space Utilization:** One of the major benefits of installing FPV is that there is no need to use the costly land. FPV can be installed in any unutilized water bodies such as lakes, ponds, dams or reservoirs. Thus, saving valuable land for other priority uses.

(ii) **Increased Efficiency:** It has been proved through different experiments that water's natural cooling effect leads to higher solar panel efficiency for FPV. This increase is found to be up to 15%. The increased efficiency leads to higher energy generation, thus getting a better return on investment.

(iii) **Water Conservation:** FPV also helps to reduce water evaporation from water bodies. By restricting sunlight to enter the water body, it helps to control the growth of harmful algae, thus contributing to better water quality.

(iv) **Reduced Infrastructure Cost:** Costly land development of the site for land based solar PV is not required in FPV. Moreover, FPV are generally chosen near grid sub-station. It has been found through review of development of FPV that till now most of the FPV has been installed in manmade water bodies such as reservoirs, waste water storage ponds or agriculture irrigation ponds, quarries, mining sites and dams. One of the advantages of setting up the FPV plant in these man-made water body areas are that it comes with pre-existing infrastructure and access roads and other infrastructure. Thus, reducing installation costs significantly. As a result, there is a cost savings for infrastructure development.

(v) **Low Impact on Aquatic Life:** Studies have shown that there is no significant impact on aquatic life due to installation of FPV.

(vi) **Scalability and Flexibility:** Another major advantage of FPV is its ability to increase the size of the plant by adding additional modules due to its modular nature. Starting from a small plant it can be expanded as needed.

(vii) **Combining FPV with Other Generating System:** It has been found that FPV can be combined with other energy generating system like hydro power station and wind power station. The main advantage of setting up an FPV at a hydro power plant is that it could lead to sharing the existing infrastructure for transmission, thereby reducing cost associated with infrastructure development. FPV panel in the dam area give shading which can minimize water evaporation, thereby increasing the hydropower efficiency.

(viii) **Combining with Storage:** FPV can also be co-located with storage giving the benefit of peak shaving, time shifting and reduced strain on grid connection capacities.

Demerits of FPV

(i) **Increased Initial Investment:** FPV needs more careful design with their platforms, anchors, cables, panel placement etc. compared to the traditional solar PV. It also requires specialized knowledge to install the FPV. As a result, it leads to higher initial cost.

(ii) **Unproven Durability:** Since FPV is a comparatively new innovation compared to the ground mounted solar PV, it has not proved its durability during the total life span of the project like the effect of water on the structure or floating platform, durability of panel, water induced wear and tear etc. till now.

(iii) **Limited Application:** FPV technology is not universally applicable. Most of the FPV are large projects providing power to large commercial or utility companies. For small individual uses, rooftop solar is the solution.

(iv) Disruption to Aquatic Life: Setting up FPV obstructs sunlight from entering the water bodies. This could have effect on the aquatic life. The floating structure could also harm the water-based species. Further detailed studies are required in this field.

(v) **Social Acceptance:** There is a misconception among the general people that FPV is harmful for the environment and aquatic life. So, it is important to take into consideration public opposition which can sometimes lead to delay or termination of projects. Here are some ways to improve social acceptance of floating solar power plants:

(aa) **Share facts with Residents:** Share objective facts with local residents to help resolve doubts about environmental impact.

(bb) **Build Trust:** Build trust with local residents by sharing the benefits of the project and communicating with them continuously.

(cc) **Share Profits:** Share the profits generated by the project with the business operator and local residents.

Potential Opportunities

Abundant Water Bodies: Bangladesh boasts a vast network of rivers, lakes, and ponds, providing ample opportunities for floating solar installations.

Land Scarcity Alleviation: Floating solar can mitigate land constraints associated with traditional ground-mounted solar projects, optimizing land use.

Water Conservation: Floating solar panels can reduce water evaporation from reservoirs, contributing to water conservation efforts. Floating solar installations can create shade, providing a conducive environment for aquatic ecosystems and improving water quality.

Challenges and Barriers

High Initial Investment: The initial investment for floating solar projects can be significant.

Technical Complexity: The technology requires specialized engineering and construction expertise.

Regulatory Hurdles: A clear regulatory framework is essential to streamline project approvals and grid integration.

Financing Constraints: Access to affordable financing options can be challenging for large-scale projects.

Environmental Challenge: There is a popular conception that FPV leads to environmental degradation for the aquatic life. This misconception should be proven.

Recommendations

- **Dedicated Policy Framework:** Develop a comprehensive policy framework specifically addressing floating solar, including guidelines, standards, and incentives.
- **Financial Incentives:** Provide attractive financial incentives, such as Feed-in-Tariffs (FIT), tax breaks, and subsidies, to encourage private sector investment.
- **Technical Support:** Establish a dedicated technical support centre to assist developers and investors in project planning, design, and implementation.
- **Pilot Project Support:** Provide support for pilot projects to demonstrate the technology's viability and gather valuable data.
- **Public-Private Partnerships (PPP):** Promote public-private partnerships to leverage the expertise and resources of both sectors.
- **Prepare Guideline:** A Floating Photovoltaic Implementation Guideline like the Solar Implementation Guideline needs to be developed.

- **Site Study:** Site suitability study should be carried out to identify a few potential sites with Initial Environmental Examination (IEE) Assessment and Social Impact Assessment (SIA) involving all the stakeholders especially the Department of Environment and water body owners. This will help the Government to move quickly to the next step of carrying out a detailed feasibility study at the site or offer the site for tendering process.
- **Environmental Study:** Carry out a detailed environmental impact assessment at Nawab Auto Rice Mills and widely decimate the information for all.
- **Feed in Tariff:** To encourage investors for open tender competition, a benchmark or Feed In Tariff (FIT) can be set by the Government.
- **Demonstration Project:** Hatirhjeel is an ideal site for the development of FPV. It has calm water and the waterway is only used for water taxi and fishing. A pilot project at Hatirjheel could be taken up to showcase the benefits of installing FPV and attract other investors to set up FPV in the country. Alternatively, Gulshan Lake and Uttara Lake can also be considered for the development of FPV.
- **Capacity Building:** Organize training programs and workshops to build the capacity of local engineers and technicians in floating solar technologies.

Conclusion

Floating solar technology presents a significant opportunity for Bangladesh to enhance its renewable energy mix and address its energy security challenges. By implementing the recommended measures, the country can unlock the full potential of this innovative technology and contribute to a sustainable energy future.

Brief Study on the Status of Floating Solar in Bangladesh

1.0 Introduction

The *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* is an international enterprise owned by the German Federal Government. It operates in many fields across 120 countries. GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development. GIZ provides effective, demand-driven, and customized services for sustainable development. GIZ is active in a variety of sectors, including food security, health and basic education, environmental protection, resource conservation, democracy and governance, reconstruction, peace-building, and the transformation of civil conflicts. GIZ is working with the Government of Bangladesh (GoB) and other players for the last 50-year in business and society in Bangladesh. One of the priority areas of German Development Cooperation in Bangladesh is renewable energy and energy efficiency.

The "Policy Advisory for Promoting Energy Efficiency and Renewable Energy" (PAP) Technical Cooperation (TC) project is being implemented within this priority area from August 2021 to November 2024. The TC project's goal is to create better circumstances in Bangladesh for implementing the switch to green energy. Followings are the thematic areas of the project, in a mutual implementation strategy with the Bangladesh Ministry of Power, Energy and Mineral Resources (MPEMR):

(i) Improve the policy and regulatory framework to increase the share of Renewable Energy and Energy Efficiency in the power sector.
(ii) Improve the conditions for the dissemination of innovative Renewable Energy and Energy Efficiency technologies.

1.1 Project Background

Bangladesh electricity generation was dependent on indigenous Natural Gas in the past. With the depletion of the Natural Gas reserve and to ensure energy security, Bangladesh has diversified its primary fuel requirement for electricity generation to include Diesel, Furnace Oil, Coal, LNG, Nuclear and Renewable Energy. In line with Government of Bangladesh unwavering commitment to the effects of climate change, due importance is also being given by Government to develop renewable energy in Bangladesh. Government had adopted ‘Renewable Energy Policy of Bangladesh’ in 2008. A nodal agency named Sustainable and Renewable Energy Development Authority (SREDA) had been established with the mandate to promote Renewable Energy and Energy Efficiency & Energy Conservation activities in the country. The generation from Renewable Energy (RE) sources has reached 1447 MWp. At present, the majority share of RE is from solar 1154 MWp (79%) (grid and off-grid) with share from other sources such as 230 MW from Hydro, 63 MW from Wind, 1 MW from Biomass and Biogas. Among the Renewable Energy prospects in Bangladesh, solar based solution has the highest potential. As a result, Bangladesh has been aggressively promoting solar PV solutions. But with an estimated

population of 17 million[1] in a small land area of only 147,570 sq. km and a population density of 1119 per sq.km. in 2022[1], it is very difficult to find land for solar based PV power plants. Thus, all avenues to promote Renewable Energy has been taken up by the Government of Bangladesh such as grid tied solar PV power plant, Roof top solar power generation, Roof top with Net Metering solution, Solar Irrigation, Solar Charging Station, Wind based Grid tied power plant etc.

Land being scare for the establishment of land based solar power plant and Bangladesh being a country of rivers and ponds, floating solar can be a viable option to increase RE generation. To further increase the electricity generation from RE, GIZ would like to explore avenues of Floating Solar Photovoltaic (FPV) prospect in Bangladesh. To this end, GIZ has hired a National Consultant to carry out this study on the Status of Floating Solar in Bangladesh.

1.2 Objective of the Study

The objective of this study is to showcase the benefits and challenges of FPV in Bangladesh. Evaluate existing policies and regulations, assess potential technologies, examine environmental aspects, identify stakeholder barriers, and analyze the financial viability of Floating Solar (FPV) projects and how to make it popular in Bangladesh. Furthermore, pay attention to particular obstacles that have impeded the expansion of floating solar in Bangladesh in addition to general issues. This could involve problems with financing, grid connectivity, land issues, or regulatory obstacles. Also study the views and opinions of potential consumers of floating solar technology, including industries, homes, and farmers. This will assist in determining obstacles to adoption and possible tactics to boost acceptance.

2.0 Scope of Services

The following activities need to be carried out under this study but are not limited to:

I) Conduct interviews with stakeholders, including representatives from the Ministry of Power, Energy and Mineral Resources including Power Division and Energy Division, Ministry of Fisheries and Livestock, Ministry of Water Resources, Department of Environment, Bangladesh Energy Regulatory Commission, EPC companies, Development Partners e.g. World Bank, Asian Development Bank, French Development Bank (AFD), European Union (EU) and 6 Utilities, to gather their perspectives on Multipurpose uses of land (Agri-PV, Floating Solar, etc.) in Bangladesh;

II) Visit existing Floating Solar (FPV) project in Bangladesh to gather key insights for replicating similar projects in the country and also collect information (virtually) other non-structured FPV projects if any.

III) Review policies and regulations related to the permitting and licensing of multipurpose use of land projects (Agri PV, Floating Solar etc.) in Bangladesh.

IV) Identify the institutions/stakeholders who can play key roles for FPV market development and remove barriers for market development.

1 Bangladesh Bureau of Statistics Yearbook 2023

V) Assess the need for financial incentives or favorable government policies to encourage the development of multipurpose land uses (Agri-PV or FPV) projects in Bangladesh.

VI) Identify key opportunities for scaling up FPV in Bangladesh and highlight potential challenges, including environmental impacts and logistical issues and how to overcome the challenges.

VII) Analyze the cost structure and financial viability of FPV projects in Bangladesh and compare them with ground mounted solar PV projects in Bangladesh.

VIII) Review international best practices and case studies, particularly from South Asian countries, for implementing technically and financially viable FPV projects in Bangladesh.

IX) Compile a comprehensive report integrating findings from site visits, interviews, and desk study on Floating Solar.

3.0 Approach and Methodology

The main activities which need to be undertaken are:

a) **Specify the Goals of the Study:**

Clearly state the objectives of this study in relation to Bangladesh. Evaluate the present potential of floating solar systems, pinpoint obstacles, investigate why there is little progress in spite of support from several stakeholders, examine user mindset, and explore opportunities.

b) **Interview with Stakeholders**

Carry out interview with the relevant stakeholders representatives from the Ministry of Power, Energy and Mineral Resources including Power Division and Energy Division, Ministry of Fisheries and Livestock, Ministry of Water Resources, Department of Environment, Bangladesh Energy Regulatory Commission, EPC companies, Development Partners e.g. World Bank, Asian Development Bank, French Development Bank (AFD), European Union (EU) and 6 Utilities and discuss the prospect of FPV in Bangladesh and get their overall views on FPV.

c) **Field Visit**

Visit currently operating floating solar installation in Bulanpur, Chapainawabganj, Bangladesh and discuss with the developer to learn firsthand details about their layout, functionality, efficiency, challenges faced during the establishment of the FPV and what measures could be taken to encourage large scale expansion of floating solar;

d) **Review of Policies and Past Studies**

Review related policies and regulations relating to FPV and recommend financial incentives to be incorporated in the policy/regulation to promote FPV.

e) **Identify Other Stakeholders**

Identify other key stakeholders who can contribute towards popularization/establishment of FPV and obtain their views on FPV.

f) **Cost Estimatenof FPV and its Comparison with Ground Mounted PV system**

We'll also try to do financial analysis and shed light on how it affects the economy.

g) **Study Best Practices**

Study best practices and literature review in the region on FPV and progress on floating solar projects in South Asia region and other countries which have advanced in Floating Solar technologies and implementation. This offers insightful information on the technology, its uses, possible problems, and solutions for those problems.

h) **Final Report**

The final report on the study will highlight:

- ✓ Water Body Types: Appropriate Water Sources for Floating Solar such as (i) Lakes: which can provide sufficient room for floating solar arrays; (ii) Rivers: Despite having moving water, some river portions with broader channels or slower currents may be appropriate for floating solar projects; (iii) Reservoirs: Man-made lakes made by damming rivers are frequently employed for floating solar energy installations in addition to serving as water storage; (iv) Ponds: These smaller, mostly rural bodies of standing water can be used for more modest-scale floating solar installations.
- ✓ Project Size: The average and maximum sizes of Bangladeshi-feasible floating solar projects that considers grid connectivity.
- ✓ Review Technology: Available technologies for the establishment of FPV will be highlighted in the report.
- ✓ Environmental Aspects: Study about positive impacts like reduced Greenhouse Gas Emissions, land preservation, shade and cooling etc. will be discussed in the report. The report will also study negative impacts relating to biodiversity, water quality, visual impact etc.

4.0 Bangladesh Power Sector Overview

Since independence, Bangladesh has been steadily progressing to increase the electricity generation capacity of the country to meet the demand of the country. Today it stands at 31,094 MW (including captive and RE). There are plans to reach the generation capacity to 40,000 MW by 2030 and 60,000 MW by 2040 MW. Previously the majority of generation capacity was based on indigenous natural gas. With the depletion of natural gas steps were taken for fuel diversification to include liquid fuel (such as diesel, furnace oil) coal, and LNG. Bangladesh being a signatory to the Paris Agreement on Climate Change and one of the most affected country of climate change on environment due to the increased industrial activities further steps were taken to shift towards clean energy such as renewable energy and nuclear. Presently steps are being taken to increase the share of RE in the generation mix and reduce consumption of fossil fuel for power generation. The table below lists the share of different fuels in the generation mix.

Table-1
Share of Different Fuels in the Generation Mix[2]

Sl. No.	Fuel Type	Share in Generation Mix (%)
1.	Natural Gas	43%
2.	Furnace Oil	21%
3.	Coal	21%
4.	Diesel	2%
5.	On Grid Solar and Wind	2%
6.	Hydro	1%
7.	Electricity Import	10%
	Total	**100%**

Among the different renewable energy resources, Bangladesh has reasonably good solar resources and potential. Next RE potential resource is wind. Apart from these two resources other resources have minor contribution towards increasing RE in the country. Solar being more potential, more emphasis has been given to utilizing the solar resource. Wind has moderate potential. Moreover, utilizing the wind resource is more costly compared to solar.

Renewable Energy Policy 2008 was adopted to increase the use of RE in the country. Bangladesh has taken steps to implement all kinds of RE technology available for use in the country. Both on-grid and off-grid use of RE are being encouraged. The table below list the present status of RE technology in the country.

Table-2

Different Technology Based RE Capacity[3]

Sl. No.	Technology	Off-Grid (MW)	On-Grid (MW)	Total (MW)	Percentage Share (%)
1.	Solar	377.09	776.37	1153.46	79.75
2.	Wind	2.00	60.90	62.90	4.34
3.	Hydro	0.00	230.00	230.00	15.89
4.	Biogas to Electricity	0.69	0	0.69	0.04
5.	Biomass to Electricity	0.40	0	0.40	0.02
	Total	**380.18**	**1067.27**	**1447.45**	**100.00**

The solar technology includes grid connected solar parks, roof top solar without NEM, Net Metering Rooftop solar, solar irrigation and solar charging station. Efforts are continuously being made to increase the share of all these technologies. Floating Solar Photovoltaic technology is missing from this portfolio. Till now adoption of this technology in the country is lagging behind.

[2] Bangladesh Power Development Board Monthly Report – October 2024
[3] SREDA Website

5.0 What is Floating Solar (FPV)

Floating solar also known as photovoltaics or floating PV system consist of a solar panel array installed on top of a bouyant structure which floats on water. Generally these floating solar structure are set up on lakes, dams, ponds or other man made water bodies. The electricity generated from this system is transmitted through underwater cable to the designated sub-station.

5.1 Floating Solar Components

The floating solar consists of a few key components. They are:

5.1.1 Floating Structure or Platform: The floating structure is the most important component of the FPV. It keeps the whole system afloat by providing bouyancy. It also contains all the other components to generate and transport electricity. The floating structure are laid out in different layouts. The common material used for the floating structure are pure High Density Polyethylene (HDPE) floating system or rafted HDPE in combination with steel systems. Other materials used are Fibre Reinforced Plastic (FRP), Medium Density Polyethelyne (MDPE) or ferro cement. Some of the design for floating structure are:

(i) Pure float design: In this design the PV panels are placed directly on the float. In this design, the system is made in modular form joined with pins and bolts to make a larger platform.

(ii) Pontoon plus metal structure design: This design is similar to ground mounted structure made of metal and pontoons are placed below to provide buoyancy.

Aluminium alloy frame structures are used on which the solar panel are placed to increase stabilty and provide a strong mounting structure for the panels. The frames are then attached to the floating structure.

5.1.2 **Anchoring and Mooring System:** The anchoring and mooring system is used to keep the whole structure in place in the water body. Generally three type of anchors are used:

(i) **Bank Anchoring**: The structure are held in place with steel wire ropes which are fixed to the banks/shores of the water body. This kind of anchor is suitable for shallow or small water bodies;

(ii) **Bottom Anchoring**: Bottom anchoring are of two type, one in which anchors are fixed directly to the bottom of the water body and other is through placing of concrete blocks at the bottom of the water body to which the floating platform are fixed through mooring cables or wires.

(iii) Piles: It is the third option which can also be used by driving piles into the bed of the water body and the floating platform is moored to the piles.

5.1.3 **PV Modules:** PV modules are the componets that generate electricity from the irridance received from the sun. They are similar to the PV modules used in ground mounted solar PV.

5.1.4 **Electrical Components:** These are the componets such as DC cables, AC cables, inverters, tranformers as well as other auxillary components to generate and transmit electricity.

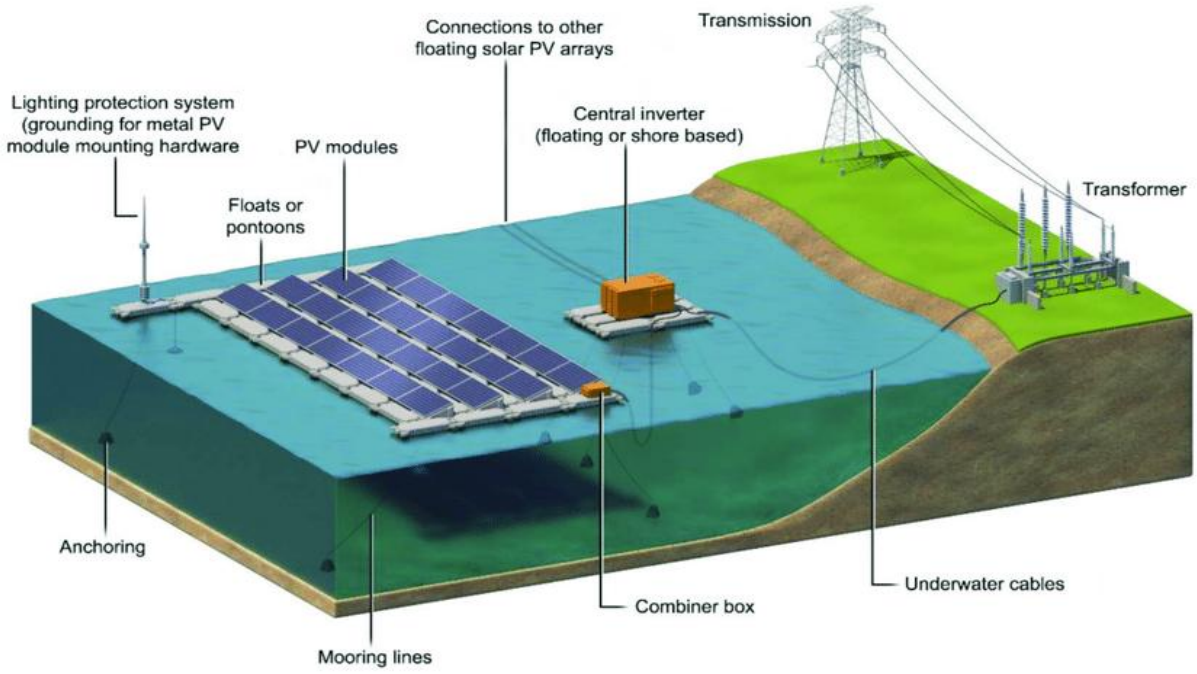


Figure-1

Schematic Diagram of Floating Photovoltaic

5.2 Merits of FPV

(i) **Space Utilization:** One of the major benefits of installing FPV is that there is no need to use the costly land. FPV can be installed in any unutilized water bodies such as lakes, ponds, dams or reservoirs. Thus, saving valuable land for other priority uses.

(ii) **Increased Efficiency:** It has been proved through different experiments that water's natural cooling effect leads to higher solar panel efficiency for FPV. The increase is found to be up to 15%. The increased efficiency leads to higher energy generation, thus getting a better return on investment. It also reduces the common overheating issues associated with land based solar PV.

(iii) **Water Conservation:** FPV also helps to reduce water evaporation from water bodies. This is particularly beneficial for arid or semi-arid regions. By restricting sunlight to enter the water body, it helps to control the growth of harmful algae, thus contributing to better water quality.

(iv) **Reduced Infrastructure Cost:** Costly land development of the site for land based solar PV is not required in FPV. Also, FPV are generally chosen near grid sub-station. Moreover, it has been found through review of development of FPV that till now most of the FPV has been installed in manmade water bodies such as reservoirs, wastewater storage ponds or agriculture irrigation ponds, quarries, mining sites and dams. One of the advantages of setting up the FPV plant in these man-made water body areas are that it comes with pre-existing infrastructure and access roads and other infrastructure. Thus, reducing installation costs significantly. As a result, there is a huge cost savings for infrastructure development.

(v) **Low Impact on Aquatic Life:** Studies have shown that there is no significant impact on aquatic life due to installation of FPV.

(vi) **Scalability and Flexibility:** Another major advantage of FPV is its ability to increase the size of the plant by adding additional modules due to its modular nature. Starting from a small plant it can be expanded as needed. Each module can be designed according to the dimension of the water body.

(vii) **Combining FPV with Other Generating System:** It has been found that FPV can be combined with other energy generating system like hydro power station and wind power station. The main advantage of setting up a FPV at a hydro power plant is that it could lead to sharing the existing infrastructure for transmission, thereby reducing cost associated with infrastructure development. FPV panels in the dam area give shading which can minimize water evaporation, thereby increasing the hydropower efficiency.

The solar and wind have complementary generation profile. So, FPV can also be set up in combination with wind power plants. In Europe it has been seen that solar power has more producing capacity in summer and wind in winter, thus complementing each other round the year. Also, there are short periods where no power is produced. This can lead to better returns on investment.

(viii) **Combining with Storage:** FPV can also be co-located with storage giving the benefit of peak shaving, time shifting and reduced strain on grid connection capacities.

5.3 Demerits of FPV

(i) **Increased Initial Investment:** FPV needs more careful design with their platforms, anchors, cables, panel placement etc. compared to the traditional solar PV. It also requires specialized knowledge to install the FPV. As a result, it leads to higher initial cost.

(ii) **Unproven Durability:** Since FPV is a comparatively new innovation compared to the ground mounted solar PV, it has not proved its durability during the total life span of the project like the effect of water on the structure or floating platform, durability of panel, water induced wear and tear etc. till now.

(iii) **Limited Application:** FPV technology is not universally applicable. Most of the FPV projects are large providing power to large commercial or utility companies. For small individuals, rooftop solar is the solution.

(iv) **Disruption to Aquatic Life:** Setting up FPV obstructs sunlight from entering the water bodies. This could have effect on the aquatic life. The floating structure could also harm the water-based species. Further detailed studies are required in this field.

(v) **Social Acceptance:** There is a misconception among the general people that FPV is harmful for the environment and aquatic life. So, it is important to take into consideration public opposition which can sometimes lead to delay or terminate projects. Here are some ways to improve social acceptance of floating solar power plants:

(a) Share Facts with Residents: Share objective facts with local residents to help resolve doubts about environmental impact.

(b) Build Trust: Build trust with local residents by sharing the benefits of the project and communicating with them continuously.

(c) Share Profits: Share the profits generated by the project with the business operator and local residents.

5.4 Cost Analysis

A very rough estimate of cost comparison between land based solar power plants and FPV for 1 MW (1000 kW) FPV is given below in USD ($) and actual costs may vary significantly based on specific project conditions, location, local regulations, and market prices.

Itemized Cost Estimate for a 1000 kWp Floating Solar Plant (in USD - $)

Sl. No.	Item	Unit Price in USD ($)	Total Cost For FPV in USD ($)	Total Cost for SPV on land in USD ($)
1.	**Solar Photovoltaic (PV) Modules:**			
	Quantity: Approximately 3,333 modules (assuming 300W per module)	Cost per module: 300-400 (varies based on brand and efficiency)	1,000,000-1,333,333	1,000,000-1,333,333
2.	**Platform/Mounting Structure**			
	Quantity: Depends on pond size and module layout for FPV (Estimate varies based on material and design)	Cost per square meter: 100-150	500,000-750,000	
	Mounting Structures: Cost depends on the type of structure (fixed-tilt or tracking). Local material (Estimated).			150,000 - 200,000
3.	**Inverters:** Quantity: Depends on system design and inverter capacity (Estimated. Varies based on capacity and brand)	Cost per inverter: 10,000-20,000	100,000-200,000	100,000-200,000
4.	**Cables and Connectors:** (Estimated)		50,000-100,000	50,000-100,000
	Installation and Labor: Expert will be required from other countries specialized in such FPV work.		150,000-200,000	150,000-200,000
5.	**Electrical Infrastructure:** (Estimated)		80,000-150,000	80,000-150,000
6.	**Grid Connection:**			
	Varies based on grid connection requirements and local regulations.		50,000 - 150,000	50,000 - 150,000

Sl. No.	Item	Unit Price in USD ($)	Total Cost For FPV in USD ($)	Total Cost for SPV on land in USD ($)
7.	**Permits, Licenses, Approval fees etc.:** Varies based on local regulations and permitting fees (Estimated)		20,000 - 50,000	20,000 - 50,000
8.	**Contingency**: (Estimated)	10 % of total project cost	195,000 - 293,000	168,000 – 238000
	Total Estimated Cost for 1 MWp Solar Power Plant:		**2,145000 - 3,226000.**	**1,760,000- 2,620,000**

Additional Considerations:
Pond Suitability: The pond's depth, water quality, and environmental impact should be assessed.

Site Preparation: Costs for site preparation, including clearing vegetation and leveling the pond's surface, may be significant.

Maintenance and Operation: Ongoing maintenance costs, including cleaning PV modules, repairing components, and monitoring system performance, should be factored in.

Financing: Explore financing options like loans, grants, or partnerships to reduce upfront costs.

Local Regulations and Incentives: Local regulations and incentives that may impact project costs and timelines.

Currency Exchange Rates: Exchange rate between the US dollar and the Bangladeshi Taka can impact the overall cost.

Local Market Conditions: Local market conditions for fluctuations in material and labor costs.

Long-Term Maintenance: Develop a comprehensive O&M plan to ensure the plant's long-term performance and minimize operational costs.

Insurance: Obtain adequate insurance coverage to protect against risks such as natural disasters, theft, and equipment failure.

It is important to note that these are rough estimates, and actual costs may vary significantly based on specific project requirements and local market conditions.

6.0 Challenges

Every project has its own challenges. FPV is new for Bangladesh. It has its own challenges, which are summarized below.

6.1. Technology Challenges

a. **Unavailability of FPV specific standards/technical guidelines**

FPV technology is still evolving and it has not matured as yet. No specific standards or guidelines has been prepared for FPV. A standard FPV standards and guideline needs to

be developed incorporating quality assurance of the different components of FPV to withstand climatic conditions throughout the lifetime of the project estimated to be 25 years without affecting the biodiversity of the water body.

b. **Unavailability of Water Body Data**
There is no specific data available on water surface areas, water level variation, historical change in water surface and on local biodiversity etc. on the different water bodies. Detailed water body data need to be collected through continuous monitoring in the designated water bodies where there is planning to set up FPV.

c. **Absence of Local Manufacturing Industries**
Apart from the solar panels, inverters and cables, some specific components such as floating platform, anchoring and mooring system are required to build FPV. The floating components are not manufactured locally and are required to be imported from abroad. The floaters and the alloy structure on which the solar panels are installed are not very complicated components and can easily be manufactured in the country. Initiative can be taken to manufacture it locally thereby reducing the installation cost of the FPV considerably.

d. **Unavailability of Bathymetry and Other Studies on Water**
In order to set up FPV in a water body, bathymetric and hydrographic survey is very important to understand the topography of the waterbed. A standard guideline should be developed to outline the procedures to carry out such study.

e. Environmental and Social Impact Assessment
Before setting up an FPV it is important to know the environmental and social aspect of the water body. Therefore, a detailed environmental and social impact assessment must be carried out at the designated site.

6.2 Installation Challenges:

i) **Permission for FPV**
Procedures are in place to get the required permission to set up a utility scale solar PV. Since no utility scale FPV has been set up in the country in open or government owned water bodies till now, therefore no procedure have been developed for what additional approvals are required to set up FPV. The approval procedure for FPV needs to be developed.

ii) **Ownership of Waterbody**
On many occasions, it has been found that the open government water bodies have multiple government departments who are owners. These different departments have their specific requirements from the water bodies. To set up a FPV plant in such a water body procedure should be outlined to get the required permission from each department easily like a one stop service.

iii) **Transportation of Floating Platform**
It has been reported that though light but being voluminous, the plastic floater occupies a lot of space to transport it to the site. If it can be manufactured locally it will reduce the cost of transportation significantly.

iv) **Operation and Maintenance Challenges**

Operation and maintenance of the FPV is a challenge. Generally, anchors and mooring are under water. Periodic inspection of the anchor and mooring requires divers to go underwater to check the condition. This entails additional costs for specialized divers. Again, replacement of electrical parts and maintenance of cables, wires etc. and working on floating platforms also require specialized trained personnel. As a result, a team of trained maintenance crew needs to be developed.

7.0 Environmental Impact of FPV

FPV is still in the early stage of development. Research is being carried out to study the impact of FPV on the environment and aquatic life. Further study is still required to arrive at a definite conclusion. Research has shown that deploying FPV on water surface could reduce evaporation and increase efficiency. This is because irradiance is blocked from reaching the water due to panel shading resulting in lower energy and heat is stored in the water. Thus, reducing evaporation of water. Another reason is that the panels physically occupy the surface of the water and impede the water from evaporation.

It has been seen through study that the solar panels create a sheltering and shading area for the aquatic species close to the surface of the water to spawn. Thus, helping in growth of some species.

Another result of the study has shown that FPV can inhibit the growth of algae in the water. Algae grow in warm climate and direct sunlight that increase the process of photosynthesis in water bodies. FPV system installed in reservoirs can help reduce the growth of algae by decreasing the sunlight infiltration on water surfaces and reducing the overall temperature of the water. This also leads to better water quality of the reservoir.

Visual impact is another social aspect of the FPV to integrate with the surrounding. FPV do not have high visual impact as they merge into the water surface and reduce the overall visual impact. However, before installation of FPV, it is important to assess the integration of FPV into the landscape on both aesthetic and practical level.

Apart from the studies carried out on the above-mentioned subject further study is required in the following fields:

(i) Impact on fishing patterns.

(ii) Impact due to leaching from materials.

(iii) Impact due to exposure to electromagnetic fields associated with underwater electrical cables.

(iv) Impact on hunting grounds of surface diving birds.

(v) Impact on migratory birds' habitats.

It is important to note that since waterbody characteristics vary widely, the scale of impact is site specific in nature and hence it is vital to take all factors into consideration before deploying FPV plants at large scale for each site.

8.0 Review of FPV Development Around the Globe

With a move towards clean energy to reduce the effect of climate change on the environment due to burning of fossil fuel gaining steam and land has other economic uses, the FPV technology is gradually maturing around the globe. The use of water bodies for solar power generation reduces the demand on land. The world's first FPV was built in Aichi, Japan in 2007. The capacity of the plant was 20 kWp. Later in 2008, the first commercial scale FPV was built in Far Niente Winery, California, USA with a capacity of 175 kWp. These were small scale projects developed for research and demonstration. From 2013, megawatt scale FPV projects started to be developed in Japan and South Korea. Presently majority of the projects are being built in Asia particularly in China, Japan, South Korea and India. Majority of the projects are being built in man-made waterbodies such as irrigation dams, industrial basins, water treatment plants and unused mining ponds or in hydro power plants.

World's Major Floating Solar Power Plants and Bangladesh Comparison

Sl. No.	Location	Scale (kW)	Country
1	Coal mining subsidence area of Huainan City	40,000.00	China
2	Coal mining subsidence area of Huainan City	20,000.00	China
3	Yamakura Solar Power Plant	13,700.00	Japan
4	Pei County	9982.00	China
5	Umenoki	7550.00	Japan
6	Hirotani Ike Floating Solar Power Plant	6800.00	Japan
7	Jining GCL	6776.00	China
8	Queen Elizabeth II Reservoir	6338.00	UK
9	Cheongpung Lake	3000.00	South Korea
10	Otae Province	3000.00	South Korea
11	Bulonpur, Amnura Road, Chapainawabganj	784.00	Bangladesh

Solarplaza.com

8.1 China

China is leading the country in installation of FPV. Starting from 2007 to 2018, China has reached 960 MWp. As reported China has also built the world's biggest FPV plant till 2018 with a capacity of 150 MW in Huainan, South Anhui province, China. Details of some projects in China is given below:

Three Gorges New Energy Floating Solar Farm, China - 150 MW

A 150 MW floating solar project from Three Gorges New Energy is located in Huainan City, in the eastern province of Anhui, and began feeding energy into the grid in December 2017. The project is located on a lake which came into being following the collapse of a former coal mine. The plant, which was constructed with solar modules from LONGi Solar, generates enough electricity to power 94,000 households.

Three Gorges New Energy Floating Solar Farm, China

CECEP Floating Solar Farm, China - 70 MW

Construction of the 70 MW CECEP Floating Solar Farm began in 2017 and was finally connected to the power grid in March 2019**.** The floating solar farm is owned by the China Energy Conservation and Environmental Protection Group (CECEP) and was installed using Hydrelio technology from French floating solar specialist Ciel & Terre, who also supervised design, supply, and installation. The project covers more than 60 hectares and includes 194,731 solar panels.

CECEP Floating Solar Farm, China

Dezhou Dingzhuang Floating Solar Farm, China - 320 MW

The largest solar farm in the world in 2022 was the Dezhou Dingzhuang Floating Solar Farm in Dezhou, China. With a capacity of 320 MW, it is the biggest floating PV project brought online to date. The floating solar farm project was constructed in two phases, with capacities of 200 MW and 120 MW respectively making up the 320 MW total. The plant constructed by Beijing Electric Company Huaneng Power International (HPI), is located in a reservoir in Shandong—an eastern province of China on the Yellow Sea.

The Dezhou Dingzhuang Floating Solar Farm is also connected to 8 MWh of battery storage and a 100 MW wind farm, with all components working together to make up the Huaneng Dezhou Dingzhuang Integrated Wind and Solar Energy Storage project. The 8 MWh of energy storage capacity was also deployed during the first phase of construction. According to HPI, the facility will generate around 550 million kWh of electricity per year.

Dezhou Dingzhuang Floating Solar Farm, China

8.2 Japan

The world's first floating solar plant was built in Japan, in Aichi Prefecture in central Honshu. The country's many inland lakes and reservoirs are now home to 73 of the world's 100 largest floating solar plants and account for half of those plants' 246 megawatts of solar capacity.

Japan is a world leader in floating solar power, with a significant number of large-scale installations across the country. These floating solar power plants offer several advantages, especially for Japan including:

- **Land Conservation:** Japan is a densely populated country with limited land available for traditional ground-mounted solar power plants. Floating solar plants utilize water bodies like reservoirs, lakes, and coastal areas, freeing up valuable land for other purposes.

- **Reduced Evaporation:** The floating panels create a shading effect on the water surface, reducing evaporation and helping to conserve water resources.
- **Cooler Panels:** The water below the panels helps to cool them, improving their efficiency and lifespan.
- **Reduced Risk of Damage:** Floating solar plants are less susceptible to damage from natural disasters like earthquakes and tsunamis.

Some of the notable floating solar power plants in Japan include:

- **Yamakura Dam Floating Solar Plant:** Located in Chiba Prefecture, this is a floating solar plant in Japan, with a capacity of nearly 14 MW.

Yamakura Dam Floating Solar Plant, Japan

- **Chikugo River Floating Solar Plant:** Located in Fukuoka Prefecture with a capacity of over 13 MW.

Chikugo River Floating Solar Plant, Japan

Lake Biwa Floating Solar Plant: Located in Shiga Prefecture, this plant is on a natural lake with a capacity of over 1.7 MW.

Lake Biwa Floating Solar Plant, Japan

In addition to these projects, Japan also has many smaller floating solar power plants installed on rooftops of buildings and other structures. The country's commitment to renewable energy and innovative technologies has made it a pioneer in the field of floating solar power.

8.3 India

Development of floating solar technology is still in early stage in India also. The first FPV was constructed in a pond in Rajarhat, Kolkata with a capacity of 10 kW in 2015. The next 100 kW FPV plant was constructed on a reservoir of a combined cycle power plant situated in Kayamkulam district, Kerala in 2016 by NTPC. Another 500 kW FPV was set up at Banasura Sagar reservoir in Wayanad district by Kerala State Electricity Board in 2016. Another 2 MW project was commissioned in 2018 at Visakhapatnam, Andhra Pradesh. Till October 2019 1700 MW worth of projects were in various stages of development. Below is description of some of the big FPV projects in India:

Omkareshwar Floating Solar Power Project

Omkareshwar Floating Solar Power Project is designed for 600 MW and is being constructed at a cost of Rs. 3000 crore on the Narmada river in Khandwa district, Madhya Pradesh. It has not yet been commissioned. The Omkareshwar Floating Solar Project will be the world's largest floating solar power plant upon completion. The project spans 1631 acres.

Omkareshwar Floating Solar Power Project, India

Ramagundam Floating Solar Project

The Ramagundam Floating Solar Project of 100 MW is one of India's largest floating solar power plants built over 500 acres by Bharat Heavy Electricals Limited (BHEL). It was commissioned in 2022 and situated in Telangana. The cost of construction was Rs. 423 crores. It is divided into 40 blocks of 2.5 MW, each block having 1 floating platform and 11,200 solar modules. Its floating mounting structure is made of High-Density Polyethylene (HDPE). The floating structure also has inverters, transformers, and a high-tension circuit breaker. The floating structure is anchored through High Modulus Polyethylene (HMPE) rope to dead-weight concrete blocks placed in the reservoir bed. 33 kV underground cables are used to transmit the electricity. All components including inverter, transformer, HT panel and SCADA (supervisory control and data acquisition) are on floating ferro-cement platforms. The plant will prevent evaporation of 32.5 lakh cubic

meters of water annually. It will help avoid coal usage of 1,65,000 tons and CO_2 emissions of 2,10,000 tons annually.

Ramagundam Floating Solar Project, India

Kayamkulam Floating Solar Power Plant

Kayamkulam Floating Solar Power Plant was built with a capacity of 92 MW at a cost of Rs. 465 crores. It was commissioned in 2022. It is situated in Kerala. Tata Power Solar has installed 70 MW and Bharat Heavy Electricals Limited installed 22 MW solar panels.

Kayamkulam Floating Solar Power Plant, India

Simhadri Floating Solar Power Project

The installed capacity of Simhadri Floating Solar Power Project is 25 MW. The cost of construction was Rs. 110 crores. It was commissioned in 2021. It is situated in Andhra

Pradesh. It is situated on the reservoir of Simhadri Thermal Station in Visakhapatnam. It was the first project to be set up under the Government of India's flexibilization scheme. It is spread over 75 acres and has over 1 lakh solar modules. The project can power about 7,000 households and prevent a minimum of 46,000 tons of CO_2 emissions annually.

Simhadri Floating Solar Power Project, India

Rihand Dam Floating Solar Power Plant

Rihand Dam Floating Solar Power Plant is being constructed with a capacity of 150 MW at a cost of Rs. 750 crores. It is situated in Uttar Pradesh's 1st floating solar park. Power from the project will be sold to UP Power Corporation Limited at Rs 3.36 per unit for 25 years. It is reported that Renew Solar Power Private Limited will develop 100 MW and Shapoorji Pallonji Infrastructure Private Limited will develop another 50 MW at the park.

Rihand Dam Floating Solar Power Plant, India

Chandigarh Floating Solar Power Plant

Chandigarh Floating Solar Power Plant with a capacity of 2 MW was commissioned in 2023. The cost of construction was Rs. 11.70 crore. It is situated in Chandigarh. Hartek Solar built this project under a contract from the Chandigarh Renewal Energy and Science and Technology Promotion Society (CREST). It prevents the emission of 80,000 tonnes of CO_2 annually.

Chandigarh Floating Solar Power Plant, India

Mudasarlova Reservoir Floating Solar Power Plant

Mudasarlova Reservoir Floating Solar Power Plant was commissioned in 2018 with a capacity of 2 MW. The cost of construction was Rs. 11.34 crore. It is located in Andhra Pradesh. The plant has prevented the burning of 1,540 tonnes of coal and 300 tonnes of CO_2 emissions annually. It spans 20 acres.

Mudasarlova Reservoir Floating Solar Power Plant, India

8.4 Singapore

Sembcorp Floating Solar Farm

Sembcorp Floating Solar Farm with a capacity of 60 MW was officially opened in 2021. This floating solar farm on the Tengeh Reservoir in Singapore consists of 122,000 solar panel covering 45 hectares or one-third of the reservoir's surface roughly the size of 45 football fields**.** At 60 MW of capacity, it was one of the largest floating solar farms in the

world in 2022. The project, which was developed to contribute to Singapore's goal of quadrupling its solar energy capacity by 2025, was installed by Sembcorp Industries.

Sembcorp Floating Solar Farm, Singapore

8.5 Thailand

Thailand currently produces around 12 percent of its energy from renewable sources. But it plans to increase that to 37 percent, more than a third of its total capacity, within 20 years with floating solar making a substantial contribution. Thailand's state utility, the Electricity Generating Authority of Thailand, has drawn up ambitious plans to construct 16 floating solar farms at nine hydropower reservoirs across the country – making a major contribution to future power needs.

A Memorandum of Understanding has been signed with a private Thai company, SCG Chemicals, to undertake research and development into the idea at its factory at Rayong, Bangkok.

Sirindhorn Dam Floating Solar Farm, Thailand

Sirindhorn Dam Floating Solar Farm on the Lam Dom Noi River in Thailand began operation in 2021. With a capacity of 45 MW, the project consists of 145,000 panels. The surface area of the panels roughly covers the size of 70 soccer fields, actually occupying just 1% of the reservoir's surface area.

Thailand has recently renewed its commitment to renewable energy by bringing forward its carbon-neutral target date to 2050—a big jump from the previous aim of carbon neutrality by 2065. The deployment of this project will play a significant role in achieving this aim. There are also plans to open up this floating solar farm for public viewing in order to generate further interest in renewables and create sustainable jobs in the area.

Sirindhorn Dam Floating Solar Farm, Thailand

The Electricity Generating Authority of Thailand (Egat) has announced plans to outsource engineering, procurement and construction firms for the development of a third solar floating project on the Srinagarind Dam reservoir. The project is expected to generate 140 MW and it will be Egat's third solar floating project. The Srinagarind Dam project will integrate with the existing hydroelectric power system, creating a hybrid power generation model.

Hydroelectric plants in Thailand normally operate during off-peak hours to support agricultural activities. The addition of floating solar panels will improve the stability and reliability of the power supply. The project is part of a larger initiative approved by the government, aiming to install a total of 2,725MW of floating solar power by 2037. This contributes to Thailand's broader goal of achieving 20 gigawatts of renewable energy generation from both Egat and private investors, as outlined in the revised National Power Development Plan for 2024 to 2037.

8.6 Malaysia

Solar power in Malaysia is still in its nascent stages, contributing less than 1% of the country's total energy consumption. However, the government's goal is to increase the country's share of renewable energy to 31% by 2025 placing a significant emphasis on solar.

Malaysia is constructing the first largest Sarawak Energy's Batang Ai Floating Solar Farm for the country in Sarawak region. The capacity of the plant is 50 MW. It is a hybrid

generation facility with hydro. The project is expected to be commissioned by the end of October, 2024. It will offset 52 kilotons of emission annually.

Sarawak Energy's Batang Ai Floating Solar Farm, Malaysia

8.7 The Republic of Korea

Republic of Korea has developed a total of 79 MWp FPV in the country and more than 2300 MWp are in the pipeline. Korea is the first country to install tracker based FPV with a capacity of 465 kW in 2014. Hapcheon Dam Floating Solar Power Project is a 40.32 MW solar PV power project. It is located in South Gyeongsang, South Korea. It was developed in a single phase. The project construction commenced in 2020 and subsequently entered into commercial operation in December 2021. It has 92,000 solar panels installed. This project is unique for the community investment in the project.1400 residents contributed equal to $2.6 billion. This investment covered 4% of the total cost of the project with a 10% annual return over 20 years. Korea is developing a big FPV project at Saemangeum Seawall Dyke, North Jeolla, South Korea with a capacity of 1200 MW. Currently it is in permitting stage. The construction of the project is expected to commence in 2025 and go into commercial operation in 2026. It is being developed by Hanwha Solutions.

8.8 Sri Lanka

Sri Lanka's first floating solar plant (46 kW) was declared open on January 2024, at the Kilinochchi premises of the University of Jaffna. Current Solar AS, the Norwegian developer of floating PV solutions, designed the system based on the experience from their test site in Singapore. The plant is established as an experimental plant in the pond with a depth of about 2 m. Floating pipes used in the design are made of HDPE in order to lift the solar panel sets upon the water surface. The floating pilot power plant system is connected through a net metering connection to the utility.

Sri Lanka's first FPV (46 kW) at Kilinochchi premises of the University of Jaffna

Sri Lanka is building a 100 MW Samanalawewa Reservoir Floating Solar PV Park in Sabaragamuwa, Sri Lanka. The project is currently at the announced stage. It will be developed in a single phase. The project construction is likely to commence in 2026 and is expected to enter into commercial operation in 2028. The project is owned by Ceylon Electricity Board with a stake of 100%.

Sri Lanka plans to allocate 0.99 hectares of water surface area and 0.1 hectares of land area from the Chandrika Wewa and Kiriibban Wewa reservoirs for two floating solar power generation pilot projects with a capacity of 1 MW each. In addition, the government has identified locations in 31 reservoirs which can be used to build 3,077 MW of floating solar plants. There is potential of Floating solar plants totaling 2,534 MW on 14 reservoirs belonging to Sri Lanka Mahaweli Authority. Another 553 MW of solar plants are planned on 17 reservoirs belonging to the Department of Irrigation. Sri Lanka's state-run Ceylon Electricity Board (CEB) is expected to allow private developers to build floating solar plants on reservoir owned by the utility.

8.9 Maldives

The Maldives, with its over 150 resort islands, presents an ideal setting for renewable energy projects. Globally, the demand for similar floating solar solutions is rising, offering a significant market opportunity. Ocean Sun and Canopy Power have teamed up to launch an innovative 2MWp floating solar power system at Soneva Secret, a luxurious resort in the Maldives. Announced on June 24, 2024, this ambitious project aims to significantly reduce the resort's dependence on diesel generators by providing clean, sustainable energy through three 74-meter diameter solar rings. It is scheduled for completion in the first quarter of 2025. The floating solar installation promises to revolutionize the resort's energy infrastructure. By integrating solar energy and battery storage, Soneva Secret will cut its diesel-generated electricity needs, thereby lowering its carbon footprint and operational costs. This eco-friendly initiative aligns with the commitment to promote sustainable tourism.

Maldives is seeking investors/developers for the development of a 10MWp grid-tied Floating Solar PV System under a private investment model based on a Power Purchase Agreement (PPA) framework. This is offered under an International Competitive Bidding (ICB) approach through the National Tender. It is the first public tender of this scale in the country.

8.10 Pakistan

Pakistan has launched the construction of the first 500 MW Kanjhar Lake Solar PV Floating Park FPV in Sindh. Construction of the project is expected to start in 2026 and go into operation in 2028. The cost of electricity generated from this floating plant will be Rs.15 per unit.

8.11 Netherlands

Sellingen Floating Solar PV Park

The Sellingen Floating Solar PV Park in Sellingerbeetse, Netherlands was commissioned in 2021with an installed capacity of 41.4 MWp. The number of solar modules is 76,616 (with 535 and 540 W). Recently eight battery packs having a total capacity of 30 MWh has been added to the FPV. The batteries are used to store energy during off-peak hours as well as stabilizing the grid and providing continuous and reliable power supply.

Sellingen Floating Solar PV Park with battery storage Netherlands

Sekdoorn FPV Park

Sekdoorn FPV park has been developed in Zwolle, Netherlands with a capacity of 14.5 MWp. It covers 28% of the lake surface area. To minimize the emission of CO_2 from the site during construction electric vehicles, tools and appliances were used. To avoid use of fossil fuels for generators or input from the grid, solar batteries were temporarily installed to provide power.

Sekdoorn FPV Park, Netherlands

Bomhofsplas Floating PV Project

Bomhofsplas Floating PV Project is built on a sandpit near Zwolle, Netherlands. The project was commissioned in 2020. Its capacity is 27.4 MWp and covers 25% of the lake's surface area. 20 bio huts were installed in the project area to evaluate the influence of FPV on the water ecosystem. The observation shows that Bio hut ecosystem successfully adapted and the new species also integrated well into the habitat under the floating PV.

Bomhofsplas Floating PV Project, Netherlands

9.0 FPV Status of Bangladesh

Bangladesh has progress in solar technology based on land. But FPV technology has not progressed at all to say the least. Though Bangladesh has constraint due to land availability, but still the country could not utilize the vast water bodies available for FPV due to various reasons. It is hoped that concerted efforts of all stakeholders will be able to make progress in this new technology. Till now only one FPV plant has been installed in the country under private initiative. Details of the project is given below.

9.1 Floating Solar Photovoltaic at Nawab Auto Rice & Feed Mills (Pvt) Ltd. Bulonpur, Amnura Road, Chapainawabganj

Bangladesh has installed a FPV at Nawab Auto Rice & Feed Mills (Pvt.) Ltd. at Chapainawabganj under private initiative. A visit to the site was held on 5th October and 22nd October 2024. The main business of the factory is processing rice. There are huge land and 52 ponds available inside the factory premises. To utilize the space in the factory and to contribute towards the promotion of climate change, the management has installed Renewable Energy technology inside the factory. The management in consultation with Joules Power Ltd. has installed a 2.3 MW solar plant in the factory. The solar plant is divided into 2 parts (i) solar roof top of 1231 kW installed on the roofs of the factory and (ii) 784 kW floating solar installed in the 2 ponds of the premises.

Under the OPEX model, Joules Power Ltd. has invested in setting up the whole solar plant. They will operate and maintain the power plant for the next 12 years. The generated electricity is sold to the factory at a fixed rate (Tk. 8.10/kWh) and the excess electricity after self-consumption is sold to the grid by the Mill Management under the Net Metering system to the local distribution utility company NESCO. After 12 years of operation by Joules Power Ltd. the whole system will be transferred to the factory management.

Technical Information:

Each panel capacity	:545 watts
Total panel	:1440
Wt. of each panel	:31.6 kg
Area covered	:44,640 sft.
Tilt angle	:100
Panel type	: Bi-facial panel
Operation start date	: June, 2023
Coverage area of the pond	:50%

Floating Solar Installation at Nabab Auto Rice Mills Ltd., Bangladesh

The Mill Management informed us that they are happy with the performance of the plant. They did not find any major environment issues in running the plant. But the dust from the rice milling process from the factory and surrounding areas is a big problem. It requires regular cleaning. The panel is cleaned using the water from the pond. The panels are water cleaned every 3 days, and brushing is done every 5 days.

The management informed that their main business is rice processing and fish cultivation in ponds. They follow the In-Pond Raceway System (IPRS) of fish farming and is one of the biggest farms in the country under this system of fish cultivation. After the fish reach a designated weight, they are released in the ponds containing the FPV system. Till now their study has shown no negative impact on the fish due to the presence of FPV in the ponds.

It was also informed that through the BADGE project of USAID, they are collecting data and carrying out investigations to identify the environmental impact of FPV on aquatic life. They have collected one year data and BADGE project informed us that they are finalizing the report and it will be published in a few months' time.

As part of the discussion with the Mills management, they informed us that they want to utilize the remaining 50 ponds inside the mills premises for RE generation. They now want to build utility scale power plant instead of net metering system with soft loans if available.

9.2 Related Studies in Bangladesh

Asian Development Bank had carried out study at Kaptai Lake, Kaptai, Barapukuria lake, Dinajpur, Bukbhara Baor, Jashore, Joydia Baor, Jhenaidah and Mahamaya Lake, Chittagong.

9.3 Kaptai Lake

The study suggested to set up 24 MW FPV at Kaptai Lake. Bangladesh Power Development Board took steps to implement the project. But there were negative reports from different departments. As a result, the project could not be implemented.

9.4 Barapukuria Lake

A floating solar power plant is planned for Barapukuria Lake in the Barapukuria coal mine area of Dinajpur, Bangladesh. The plant will be built on a body of water created after coal was extracted from the Barapukuria coal mine. The capacity of the plant is expected to be 40–50 MW. The plant will be built by a consortium of Sumitomo Corporation and Parker Bangladesh. The plant will have two reservoirs for the floating unit, covering 109 and 95 acres.

Other sites like Bukbhara Baor have prospect of 6 MWp, Joydia 9 MWp and Mahamaya 4.8 MWp. These potential sites need to be further investigated for implementation of FPV.

9.5 Hatirjheel Lake

Hatirjheel lake is another ideal site for development of FPV. A study by Green University has shown that it can host 6.7 MW plant.

10.0 Review of Policy for the Promotion of FPV

Bangladesh has adopted the "Renewable Energy Policy of Bangladesh" in 2008 to promote RE in the country. This policy is the guiding policy under which RE projects are promoted in the country. The target set in the policy is to achieve 10% RE generation capacity. To

promote Re in the country some investment and fiscal incentives are described in the policy.

With the adoption of RE Policy-2008, a "Guideline for the Implementation of Solar Power Development Program" was prepared in 2013. This guideline described the procedures and fiscal incentives for the establishment of solar based projects such as solar parks, solar Mini grids, roof top solar, solar irrigation, social solar projects. It is mentioned in the guideline that the developer has to follow existing laws, policies, guidelines like environment law, private sector power generation policy and renewable energy policy.

To establish any projects of any kind it has to get approval from Department of Environment (DOE). The guiding rule is the Environmental Conservation Rule 2023. In this rule the requirement for establishment of solar power plants is given.

Nowhere floating solar photovoltaic has been specifically mentioned in Renewable Energy Policy of Bangladesh or Guideline for the Implementation of Solar Power Development Program or Environmental Conservation Rule 2023. It is assumed that they will fall under solar power plant category.

FPV technology is still in the early stage of market penetration. To promote FPV in the country and to achieve 10% target of RE generation capacity, it is imperative to set specific standards or guideline for FPV. Since the cost of establishment of FPV incurs higher investment than land based solar parks, additional fiscal incentives should be provided for such projects compared to land based solar projects. The authority of the water bodies should also be relaxed in providing permission or ask developers of the project to mitigate the environmental issues when developing FPV without compromising the environmental issue.

11.0 Insight from Stakeholders

Detailed discussion with the representatives of following stakeholders were held to get their insight on FPV and its status in Bangladesh: Bangladesh Energy Regulatory Commission (BERC), Power Division, Ministry of Power, Energy & Mineral Resources, Bangladesh Power Development Board (BPDB), Bangladesh Rural Electrification Board (BREB), Dhaka Power Distribution Co. Ltd. (DPDC), Dhaka Electric Supply Company Ltd. (DESCO), West Zone Power Distribution Co. Ltd. (WZPDCL), Northern Electricity Supply PLC (NESCO), Department of Environment (DOE), Bangladesh Water Development Board (BWDB), Center for Environmental and Geographic Information Services (CEGIS), Joules Power Ltd., TotalEnergies SE, France, Asian Development Bank (ADB), The World Bank (WB), European Union (EU) and Sher-e-Bangla Agriculture University.

During the discussion everybody appreciated the initiative taken by GIZ to carry out a FPV situation report for Bangladesh. They stated that Bangladesh has progressed very little in this sector of RE. They would also like to know the barriers and challenges in setting up FPV plants in the country. Each organization from their stand point said they are ready to help in promoting FPV in the country. One of the major concerns raised during the discussion was the environmental concern. If a pilot project is undertaken incorporation all aspects of environment and the study result is circulated widely then it will be easier to move forward with FPV projects. Some suggested they are ready to

provide policy support as well as assist in different studies relating to FPV. Others were of the opinion that experience of neighboring countries will help in implementation of FPV in the country. EPC are interested to implement projects like the one taken in Nawab Rice Mills. A pilot project can also be taken up at Hatirjeel, Gulshan Lake or Uttara Lake. This can showcase the results of the project to everyone.

12.0 Off Shore Floating PV Technology

Due to the increase in global warming and limiting the temperature rise to 1.5^0 is putting the demand to move away from fossil fuel-based energy needs. As a result, solutions are being explored in renewable energy. Among the renewable energy, solar and wind has been found to be the most prospective solutions till now. Again, between the solar and wind, solar has more prospect than wind. As a consequence, different technologies have been found to utilize the solar resources. One of the disadvantages of the use of solar resources on land is that it requires substantial quantity of land to harness its energy. But land is limited and as the population increases the pressure on land increases for urbanization and for other economic activities. There are vast oceans where only limited area is being used for offshore wind projects where favorable wind condition exists. Other areas of the ocean remain unutilized. Thus, apart from the established technologies for use of solar resources, a new technology- offshore floating PV is emerging. The near shore areas of the vast ocean can be utilized for offshore FPV.

Offshore floating PV systems harness solar energy by deploying photovoltaic (PV) panels on floating structures in water bodies. This innovative technology offers several advantages over traditional land-based solar installations:

12.1 Key Components

The key components of FPV may be grouped as under:

(i) Floating Structures: These structures, typically made of high-density polyethylene (HDPE) or other buoyant materials, support the PV modules. They are designed to withstand harsh marine environments, including waves, currents, and storms.

(ii) PV Modules: Standard crystalline silicon or thin-film PV modules are used, similar to those in land-based systems.

(iii) Mooring System: Anchors and chains or ropes secure the floating structures to the seabed, ensuring stability.

(iv) Power Conditioning System (PCS): This system converts the direct current (DC) electricity generated by the PV modules into alternating current (AC) for grid integration.

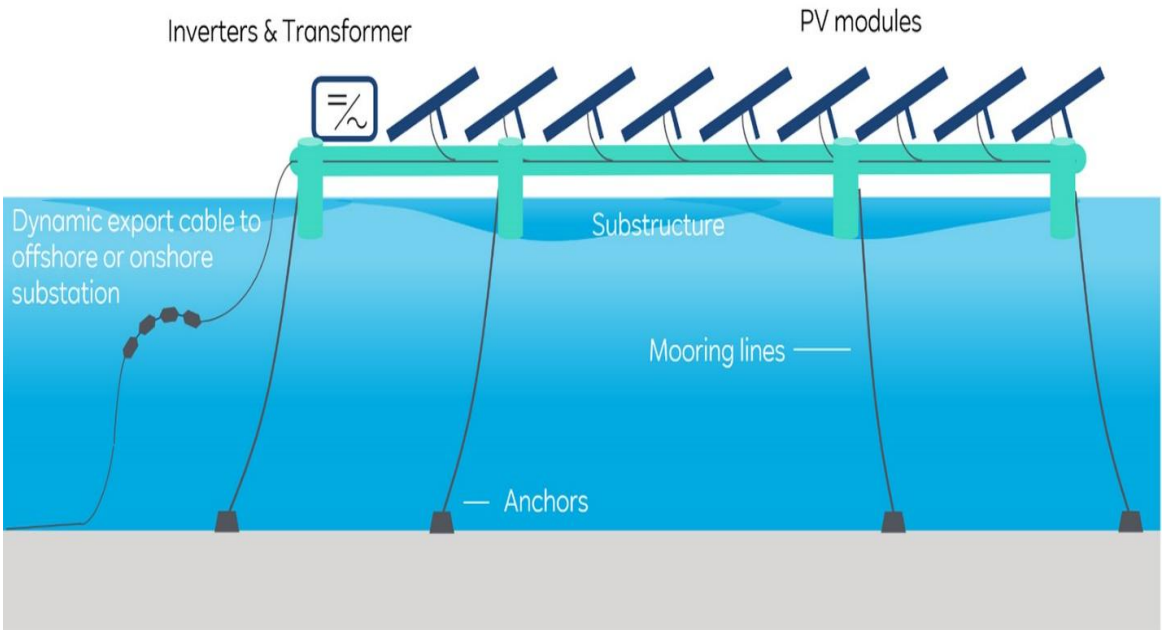
(v) Submarine Cables: These cables connect the floating structures to the onshore grid, transmitting the generated electricity.

.12.2 Working Principle of offshore solar

Offshore solar uses similar technology to land-based solar but the modules and inverters are mounted on floating substructures and floating structure are secured to the seabed with mooring lines and anchors. The generated electricity is transmitted to shore via subsea cables.

Deploying photovoltaics at sea requires a structure which can withstand high waves, strong winds and the stresses caused by salt water. Therefore, the structure design and material selection differ significantly from lake- based floating photovoltaics systems.

If this technology can be implemented at sea, then stand-alone offshore solar projects can be established where offshore wind resource is limited and solar irradiance is high. It can also be a hybrid project where land is a constrained and where both wind and solar resource are good. Below is a schematic diagram of offshore solar FPV.



Schematic Diagram of Offshore Solar FPV

Mainly three main technologies have emerged for the offshore FPV. They are:

Flat Pontoon Concept:
It has a floating pontoon with PV panels mounted on top that are coupled into a modular floating array that is moored to the seabed. The technology is designed to use buoyancy for maintaining the systems very close to the sea surface, thus enabling self-cleaning capabilities and additional cooling from sea temperature whilst preventing exposure to wind forces.

Elevated Truss Concept:
The platform with solar panels is placed on a truss structure supported by semi-submersible buoyancy elements and moored to the seabed. Waves can move underneath the structure due to elevated design. The system is designed to keep PV panels and other electrical elements beyond the reach of water.

Foil or Membrane Concept:
It is a very flexible structure following the movements of the waves. Solar panels are mounted on a floating body and must be able to follow the deformation of the floater. During the higher waves' conditions, part of the structure may directly be washed over by waves.

Merganser is an offshore solar project. It consists of six interconnected platforms that can withstand extreme offshore conditions such as high waves, strong winds and a corrosive environment. The project was installed off the coast of Scheveningen in the Dutch North Sea in July 2024.

12.3 Benefits of Offshore Solar

1) The solar resource at water site is better than at land due to less cloud over and no shading issues resulting in an extremely abundant resource. Utilizes vast water bodies, freeing up valuable land for other purposes.

2) Offshore floating PV could open up locations where other renewable energy solutions are simply not feasible or economical.

3) Offshore floating PV has a very high energy density, in other words much more capacity in MW terms can be deployed per unit of area (km^2).

4) Onshore solar PV has demonstrated its potential to be the renewable energy with the most explosive growth. Offshore floating solar can also present the scalable potential with less of some of the barriers that land based PV has had to deal with.

5) Offshore FPV has a very low visual impact in comparison to offshore wind turbine generators which has in some places raised resistance from communities. Offshore solar can also help in mitigating tensions or conflicts regarding the use of land for renewable energy generation.

6) When regulatory frameworks are in place it is likely that development timelines can be significantly shorten than other technologies.

7) Higher Solar Irradiance: Offshore environments often have higher solar irradiance compared to land, leading to increased energy generation.

8) Cooling Effect: Water acts as a natural coolant, improving PV module efficiency.

9) Reduced Land-Use Conflicts: Minimizes conflicts with agriculture, urban development, and other land-based activities.

12.4 Challenges of Offshore solar

1) Study has to be carried out to test the durability and performance of the equipment under real conditions at sea to prove survivability in harsh conditions and over plant life (extreme loads, fatigue and corrosion).

2) Design of the substructure needs to be optimized for cost efficiency and simple manufacturing without comprising durability.

3) Cost-effective electrical interconnection of stand-alone and hybrid farms needs to be developed within the farm as well as integration to the grid.

4) Operation and maintenance of the plant will require trained personnel with special safety gears to operate at sea.

5) The impact of marine life on offshore PV systems is a much larger challenge than in freshwater habitats.

6) Evidence on the potential impacts of large scale offshore floating PV on ecosystems requires more research especially regarding potential impacts on ecosystems from blocked or reduced sunlight.

7) Adequate policy frameworks need to be developed and promoted when tenders are launched to firstly support the development of initial projects followed by commercial scale capacities. To popularize the technology, characteristic costs of innovative technologies must be considered and financial incentives like specific feed-in-tariffs or other mechanisms should be in place.

8) Marine Environment: Requires robust design and materials to withstand harsh conditions.

9) Installation and Maintenance: Complex installation and maintenance procedures, often requiring specialized equipment.

10) Cost: Higher initial costs compared to land-based systems, but potential for long-term cost reduction through economies of scale.

11) Grid Connection: Requires careful planning and infrastructure development for efficient grid integration.

Offshore solar can open up a new frontier for solar energy with potential to provide a crucial answer to increasing land scarcity by allowing gigawatt scale solar development. The emergence of offshore solar presents the introduction of new technologies which are distinct from its inland predecessors to withstand the harsh offshore conditions.

There is a large opportunity for offshore solar either as a stand-alone or a hybrid in combination with other forms of renewable energy. Currently pilot projects are predominantly located in Europe where there is emerging supportive policy framework but there is also emerging activity in Asia Pacific. Offshore solar technology has several benefits including high scalability and supporting decarbonization but there are several challenges that the technology must overcome to accelerate commercialization.

12.5 Off Shore Future Potential:

Offshore floating PV technology has the potential to significantly contribute to global renewable energy goals. As the technology continues to mature and costs decrease, it is expected to play an increasingly important role in the energy landscape.

13.0 Way Forward

Review of literature on FPV and global implementation strategy, it is evident that it is more preferable to install FPV in calm water ponds, lakes, enclosed water bodies and hydro dam areas rather than in flowing water like rivers. Rivers produce more challenges for FPV.

Bangladesh has many inland water bodies like haors, baors, beels, lakes, ponds etc. It is reported that rivers cover approximately 7.5 million ha, beels and haors cover another 1million ha, other estuaries and mangrove swamps 6 million ha and numerous small and large ponds in the country. If a small percentage of suitable water areas can be utilized for FPV, it will lead the country towards reaching the country's renewable target. To achieve the target following measures need to be taken.

1) There is no policy framework for FPV. A policy framework is essential to develop FPV in the country;

2) A Floating Photovoltaic Implementation Guideline like the solar implementation Guideline needs to be developed.

3) Site suitability study should be carried out to identify a few potential sites with Initial Environmental Examination (IEE) Assessment and Social Impact Assessment (SIA) involving all the stakeholders especially the Department of Environment and water body owners. This will help the Government to move quickly to the next step of carrying out a detailed feasibility study at the site or offer the site for tendering process.

4) Carry out a detailed environmental impact assessment at Nawab Auto Rice Mills and widely decimate the information for all.

5) To encourage investors for open tender competition, a benchmark or Feed In Tariff (FIT) can be set by the Government.

6) Hatirhjeel is an ideal site for the development of FPV. It has calm water and the waterway is only used for water taxis and fishing. A pilot project at Hatirjheel could be taken up to showcase the benefits of installing FPV and attract other investors to set up FPV in the country. Alternatively, Gulshan Lake and Uttara Lake can also be considered for the development of FPV.

14. Conclusion

The burgeoning landscape of renewable energy technologies presents a promising avenue for Bangladesh to address its growing energy demand while mitigating climate change impacts. Floating solar power, a relatively nascent technology, offers a unique solution to harness solar energy efficiently, particularly in a country with abundant water bodies and limited land resources.

Despite its immense potential, the adoption of floating solar in Bangladesh is still in its early stages. Several challenges, including high initial investment costs, technical

complexities, regulatory hurdles, and financing constraints, hinder its widespread deployment. To overcome these barriers, a comprehensive and supportive policy framework is essential.

This study underscores the need for a dedicated policy framework that addresses specific concerns related to floating solar projects. Financial incentives, such as feed-in tariffs, tax breaks and subsidies, can stimulate private sector investment. Technical support and capacity building programs can enhance the local expertise and facilitate project implementation.

Additionally, promoting public-private partnerships can leverage the strengths of both sectors to accelerate project development. Pilot projects can serve as valuable learning experiences and help refine future projects. By addressing these key recommendations, Bangladesh can unlock the full potential of floating solar power and contribute to a sustainable energy future.

The successful integration of floating solar technology into the country's energy mix can not only help meet the growing energy demand but also contribute to environmental sustainability, water conservation, and climate change mitigation.

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