

Dealing with uncertainties: floating solar farm in natural lakes

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Abstract. Floating solar farm has been demonstrated as technically and commercially viable in man-made lakes, ponds and in coal-mining subsidence areas. Studies on its environmental impacts are limited and some are still being conducted globally. The use of natural lakes for this kind of renewable energy generation is being explored for the first time in the Philippines, particularly in Laguna de Bay. It is considered as a potential development project, but there were concerns on the environmental and social impacts on a multiple-use lake. As an initial step to deal with uncertainties, the Laguna Lake Development Authority allowed the operation of floating solar farms on a pilot scale for one year subject to certain requirements including the monitoring of essential water quality parameters in the pilot sites to determine the impacts. The data together with the inputs from the operators of the pilot projects were used in the assessment of the environmental, technical and commercial viability of floating solar farm and was used by the Laguna Lake Development Authority in formulating a policy on this emerging use of the lake and in crafting the implementing rules and regulations.

I. Introduction

Renewable energy generation through floating solar farm (FSF), also referred to as floating solar photovoltaics (FPV) or floatovoltaics is gaining world-wide interest in the last decade. Among the benefits associated with this renewable energy production are reduction in GHG emissions, reduced water evaporation, prevention of harmful algal blooms. However, covering the water surface with floating solar panels can affect sunlight penetration to the water body and is perceived to increase water temperature, affect the rate of photosynthesis and the concentration of dissolved oxygen, and the distribution of nutrients.

The first comprehensive report about FPV was published in 2018 by the World Bank, ESMAP and SERIS [1]. According to the report, the use of floating solar photovoltaic panels on the surface of bodies of water has grown more than a hundred-fold in less than four years, from a worldwide installed capacity of 10 megawatts at the end of 2014 to 1.1 gigawatts by September 2018. The first FPV system was built in a reservoir at Aichi Prefecture, Japan in 2017 and the first commercially operated installation was built on an irrigation pond at Far Niente Winery in Napa County, California. The same report states that after an initial wave of deployment concentrated in Japan, Korea, and the United States, the FPV market spread to China, Australia, Brazil, Canada, France, India, Indonesia, Israel, Italy, Malaysia, Maldives, the Netherlands, Norway, Panama, Portugal, Singapore, Spain, Sweden, Sri Lanka, Switzerland, Thailand, Tunisia, Turkey, the United Kingdom, and Vietnam,



among others. Further, there are on-going developments in other countries such as Afghanistan, Azerbaijan, Colombia, Ghana, the Kyrgyz Republic, Myanmar, and Pakistan. None of them are located in natural lakes.

The topics covered in the said report are the benefits and challenges of floating solar farm, technology development, global potential to reduce greenhouse gas emissions and as a viable business venture, as well as policy considerations among others, with brief discussion on possible effects on water bodies.

The following year, in 2019, the World Bank published the Floating Solar Handbook for Practitioners [2] to promote an active dialogue among all stakeholders, both in the public and private sector. Incorporated in the handbook are the lessons learned from early FPV projects, the global understanding of FPV technologies and the development of well-designed projects while minimizing possible negative environmental and social impacts. All aspects of the FPV technology and business were discussed as well as the environmental and social considerations and the methodology to adopt.

At present, the world's largest testing center for FPV is located at the Tengeh Reservoir in Singapore. It covers a one-hectare area where the type of solar cell technology most suited for use in Singapore is examined as well as the effect of FPV on the reservoir's water quality, biodiversity and other physical factors. The project is a collaboration among Singapore's Economic Development Board, Public Utilities Board (PUB), and Solar Energy Research Institute of Singapore (SERIS) [<https://www.pub.gov.sg>]. There are also very limited publications on environmental assessment studies on floating solar farm in natural and man-made lakes. The results of the comprehensive studies in Tengeh Reservoir are not yet available online or in scientific journals and quite a number of reports on FPV in various parts of the world are found in magazines such as in www.pv-magazine.com and www.pv-tech.org.

2. Floating solar farm in natural lakes

To date, there are no existing reports on floating solar farms in natural lakes, except the pilot-scale projects in Laguna de Bay, Philippines. Since the size of the pilot project is small, the term FPV will be used since the term floating solar farm can connote a "farm" size operation. This paper aims to:

- a. Share the initiative undertaken by the Laguna Lake Development Authority (LLDA) in addressing the demand to use the lake for FPV, in collaboration with the FPV developers, all of whom have experience in operating land-based solar farms.
- b. Solicit the contribution of limnologists and experts from related disciplines on the most appropriate approach in determining the environmental impacts of this emerging use to lake ecology and to encourage research along this line. The data that can be generated will be very useful in providing the necessary information to guide both policy makers, FPV developers and operators and businessmen in crafting policies and rules on FPV in order to maximize its benefits and reduce negative environmental impact

3. LLDA's approach in addressing an emerging use of the lake

The FPV technology was introduced to the Laguna Lake Development Authority (LLDA) by renewable energy developers in 2016 through the author when she was the Department Manager of the Authority's Resource Management and Development Department (RMDD). All aspects dealing with this emerging use of the lake were handled by the RMDD, thus the succeeding information and discussion were based on direct experience and first-hand knowledge of the author with the assistance of the RMDD officers and staff. Primary data of the LLDA-RMDD were used.

3.1. Adoption of the Precautionary Principle

The first expression of interest to use the lake for FPV was in 2016. Thereafter, there were several developers who approached the Laguna Lake Development Authority to discuss their proposals on this emerging use of the lake as a platform for floating solar farms. These were received with caution for the following reasons:

- a. FPV is very new and there are no existing reports and publications from which the LLDA can base their initial evaluation on this emerging use of the lake.
- b. The lake is a multiple-use resource with fishery as the traditional and dominant use wherein most fishermen and aquaculture operators have closed ranks in recent times to maintain the dominant use of the lake for aquaculture.
- c. The impacts of the FPV in natural lakes are yet to be determined.
- d. Lack of experience and sufficient policy tools to address this emerging use of the lake.

The LLDA recognized the use of renewable energy for power generation and the benefits of reducing greenhouse gas emissions [3]. Likewise, it is a potential development project which is in line with the mandate of the LLDA, i.e., to lead and promote the development of the Laguna de Bay Region with due regard to environmental protection. With the uncertainties of using the lake for floating solar farm, the LLDA adopted an approach similar to what was undertaken when aquaculture was proposed in the late 1960's, i.e., through a pilot project to produce data that will be used for evaluating the development project [4]. Thus, in 2018, the LLDA allowed the operation of pilot projects based on the following conditions [5]:

- a. Maximum area to be occupied in the lake is one hectare.
- b. The pilot project must be located in the Central Bay, East Bay or South Bay of the lake. The West Bay is excluded because most of the aquaculture structures are located in this area.
- c. The location in the lake must be not within the 200-meter distance from the shoreline which is in line with the aquaculture regulation
- d. Only one pilot project can be allowed for each proponent (renewable energy developer).
- e. The duration of the pilot studies shall be for one year.
- f. Water quality monitoring shall be done by the LLDA and independently by the developers of the pilot projects in the area where the FPV is installed and in the open water near the pilot site.
- g. Minimum water quality parameters to be monitored are temperature, pH, chlorophyll *a*, phytoplankton count, dissolved oxygen, and biochemical oxygen demand.
- h. Consultation shall be done with the fishermen and the local officials and there must not be any objection to the pilot project
- i. The beneficiary of project in terms of electricity from the FPV shall be the public sector such as the lake shore town or city or barangay (village) and public schools
- j. The design and materials shall be the responsibility of the project developers and the location of facilities shall be approved by the LLDA upon the approval of the Mayor of the town or city where the pilot project will be installed off the shore.
- k. At the end of the pilot project, the installation must be removed from the lake and turned over to the LLDA
- l. A Memorandum of Understanding among the LLDA, the Mayor and the FPV developer must be signed prior to the start of the pilot project.

Also, in the same year, a Round Table Discussion on the Floating Solar Farming Initiative in Laguna de Bay was held through the collaboration of the LLDA and the Asian Development Bank with participants from the Department of Energy, project developers, technology providers, the LLDA and the ADB. In the spirit of transparency, the LLDA shared with the stakeholders the key considerations in coming up with the guidelines on pilot-scale operation of FPV.

3.2. The pilot projects

There were four developers that ventured into the pilot project, located in the Central Bay, South Bay and East Bay of the lake (figure 1). The typical floating solar farm installation is in figure 2

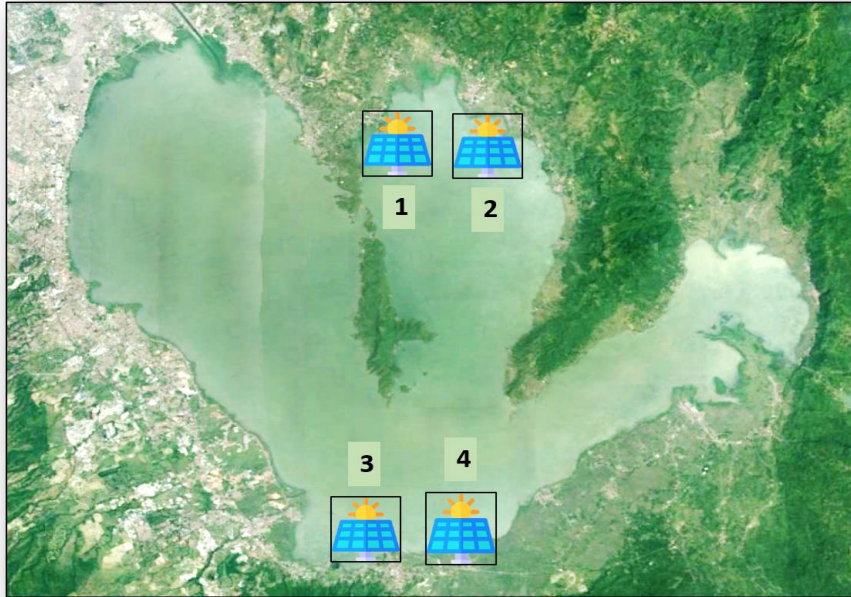


Figure 1. Location of FPV pilot projects in Laguna de Bay (LLDA-RMDD).



Figure 2. FPV installation in Laguna de Bay (LLDA-RMDD).

Table 1 shows some information about the four (4) pilot project projects and their beneficiaries. None of the project developers fully utilized the maximum one-hectare allocation. The FPV installations occupied an area ranging from 120 m² to 240 m². The savings in electricity cost were much appreciated by the beneficiaries, although they are not really net savings since the cost of the FPV system including manpower cost were shouldered by the project developers. Likewise, it served as a communication tool to introduce the technology to the communities around the lake and to demonstrate the benefits of using this type of renewable energy.

Table 1. Small-scale FPV Pilot Projects in Laguna de Bay

Proponent	Location, size of FPV	Observation Period	Beneficiary	Generated Energy (kWp)	Savings
1. Solar Philippines	Cardona Rizal 200 m ²	Mar. 2019 - Mar. 2020	Multi-purpose building and daycare center	16.25	PHP 1,500 per month
2. Winnergy Holdings Corp.	Baras Rizal 120 m ²	Sept. 2018 - Sept. 2019	Lake shore park	10	No data, first time for the park to be illuminated
3. Vena Energy	Los Baños Laguna 200 m ²	Dec. 2018 - Dec. 2019	Police Station and Museum	22	PHP 20,000 to 25,000 per month
4. Nortcsol III, Inc.	Bay Laguna 240 m ²	Mar. 2019 - Mar. 2020	Barangay (Village) Hall and covered basketball court	13.20	PHP 10,000 per month

3.2.1 Impacts on water quality. The water quality in each pilot site was monitored by the LLDA and the four (4) developers. Water samples were collected inside and outside the areas occupied by the floating solar installations. The parameters measured were chlorophyll *a*, phytoplankton, temperature, dissolved oxygen, biochemical oxygen demand and pH. Among the five sets of water quality data collected during the pilot-testing period, only two were relatively complete, i.e., Los Baños (Site 3) and Bay (Site 4). However, the number of observations was too small to make a good statistical evaluation. What was clearly evident was the big difference in the phytoplankton population inside and outside the floating solar installation (table 2a and table 2b). As expected, there were more phytoplankton outside the installation than inside the installation wherein the area was covered by the floating solar panels. The only exception was the data in Bay (site 4) on June 2019, wherein the phytoplankton population inside the installation was more than the population outside the installation. The DO levels didn't show distinct differences except in the installation site in Los Baños (site 3) where the DO level inside is around 50% less than outside (July and September 2019), but the reverse is true in the data collected in November 2019. In the same location, there was an unusual increase in the BOD, both inside and outside in July 19. There was also a distinct increase in BOD in Bay both inside and outside on September 2019. Except for the increase in BOD, all other values met the Water Quality Guidelines of the Philippines [6]. There is yet no existing guideline for phytoplankton and chlorophyll *a*. The water quality data in all the sites are just indicative in nature which showed that: a.) there was no distinct differences in the pH, BOD, DO in the area occupied by the floating solar test beds and in the area outside the installation and b.) the phytoplankton and chlorophyll *a* were generally lower in areas occupied by floating solar test beds.

Table 2. Results of Water Quality Monitoring

(a) Los Baños - Site 3

Water Quality Parameters	Sampling dates (2019)												WQG ^d
	Jun		Jul		Aug		Sept		Oct		Nov		
	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	
pH			6.9	7.1	7.1	7.3	7.1	7.3	7.5	7.7	7.3	7.1	6.6-9.0
BOD ₅ , mg/L	5	5	37	39	4.8	<2	5.5	10	3.5	4.4	<2	<2	<7 mg/L
DO, mg/L	6	5.1	2.4	6.9	4.4	3.9	2.6	4.1	4	4.5	4.4	2.5	min. of 5 mg/L
Phytoplankton, cells/mL (x10 ³)	49	117	18	26	32	38	13	18	9	10	ND ^c	ND ^c	NG ^e
Chl _a , mg/L	20	54	12	20	19	27	14	18	14	15	ND ^c	ND ^c	NG ^e
Temp., °C	34	ND	33	ND ^c	32	ND ^c	32	ND	33	ND ^c	33	ND ^c	NG ^e

(b) Bay - Site 4

Water Quality Parameters	Sampling dates (2019)												WQG ^d
	May		June		Jul		Aug		Sept		Nov		
	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	I ^a	O ^b	
pH	ND ^c	ND ^c	ND ^c	ND ^c	ND ^c	ND ^c	7.4	7.3	7.4	7.1	8.1	8.2	6.5-9.0
BOD ₅ , mg/L	ND ^c	4.3	3.2	3.2	1.8	2	2.6	30	45	49	3	5	<7 mg/L
DO, mg/L	6	6.5	7.4	7	5.8	6.1	7.9	7.8	4.2	5	4.4	4.6	min. of 5 mg/L
Phytoplankton, cells/mL (x10 ³)	ND ^c	ND ^c	202	186	89	173	69	92	69	129	ND ^c	ND ^c	NG ^e
Chl _a , mg/L	ND ^c	ND ^c	64	63	28	47	13	23	29	38	ND ^c	ND ^c	NG ^e
Temp., °C	36		35		34				30	ND ^c	ND ^c	ND ^c	<10% ^f

^ainside the FPV installation^boutside the FPV installation^cno data^dwater quality guidelines^eno guideline^fallowable exceedance from the background temperature

3.2.2 Community Benefits. The beneficiaries of the four pilot projects are the host local government unit (LGU) and the community (table 1). The electricity supplied by the floating solar farm are given free of charge by the developers in line with the Memorandum of Agreement and are used to meet the power requirements of LGU offices, a museum, a police station, a multi-purpose hall which includes a day care center and a park. The savings in electricity bills ranged from PHP 1,500 per month to PHP 25,000 per month (1 PHP is about USD 48). The park has never used electricity and is not illuminated at night until the pilot project came in the area. This was much appreciated by the community because they can do social and leisure activities during night time. The fishermen and other lakeshore residents were also hired by the project developers to provide their labor requirements.

In addition to the previously mentioned benefits, the community and the local officials became aware of the floating solar farm technology as well as their benefits as a clean technology for power generation. The presence of small floating solar farms in the host local government unit has also encouraged local tourism due to the interest and curiosity generated by the small-scale demonstration of this emerging use of the lake.

4. Policy Response

With the experience, information and feedback from the direct beneficiaries of the pilot project (local government officials and the community), from the developers and from the technical team of LLDA on the one-year pilot test run of FPV in the lake, the LLDA management, through its Resource Management and Development Department, presented to the LLDA Board of Directors the output of the FPV pilot projects with recommendation to allow the operation of floating solar farm, still on a pilot basis, but in a commercial scale [7]. The LLDA management's recommendation to continue with the pilot project were based mainly on the following:

- a. The data used to determine the effects on water quality are insufficient.
- b. The determined effects on the water quality during the operation of small-scale pilot projects with a size ranging from 120 m² to 240 m² are expected to be different in a commercial scale installation.
- c. Data gathering on the effects of the project on the lake ecology, its social acceptability and economic benefits should be done in a scientific and comprehensive manner to generate information that will lead to better environmental, social and economic impact assessments as well as in crafting science-based policies, rules and regulations.

The LLDA Board of Directors acted favorably on the recommendations of the LLDA Management Team, with additional instruction to create a Technical Working Group to develop the Implementing Rules and Regulations. The LLDA Board's decision was formalized in Board Resolution No. 576 dated January 29, 2020 [8].

5. Implementing Rules and Regulations

Laguna de Bay is a multiple use resource where capture fishery and aquaculture are the most dominant uses. Thus, one of the main considerations is the allocation of area for floating solar farm. The areas allocated for fisheries were already covered by LLDA Board Resolutions No. 561 which is the 2019 Laguna de Bay Fishery Zoning and Management Guidelines [9]. Another important consideration are the other uses and users of the lake. The following are the key considerations in preparing the Implementing Rules and Regulations.

- a. Area allocation and maximum allowable size of a floating solar farm, taking into account the distance between the installations to allow water movement and designation of access lanes;
- b. Eligibility criteria for renewable energy (RE) developers;
- c. Resource user fee, fines and penalties in case of violations;
- d. Environmental impact assessment and review process;
- e. Establishment of water quality monitoring stations, water quality parameters to be monitored, hydrometeorological data to be collected and frequency of monitoring;
- f. Duration of the data collection period;

- g. Terms and conditions of the Permit to operate a floating solar farm (FSF) or a contract to use a certain portion of the lake for Floating Solar Farm;
- h. Regulatory procedures and legal instruments in case of violations of the permit conditions.

In line with the conditions of the LLDA Board in allowing a commercial scale pilot-operation of floating solar farm, the RE developers, the LLDA and other regulatory agencies such as the Department of Environment and Natural Resources must conduct a scoping session on what water quality parameters and hydrometeorological data should be collected in order to generate sufficient data for a comprehensive environmental impact assessment. Likewise, the RE developer who will be allowed to operate a FSF can assess the most suitable materials such as solar panels, floaters and other materials in Laguna Lake.

6. Subsequent actions

To date, the LLDA is in the process of consultation with all the stakeholders with the aim of finalizing the Implementing Rules and Regulations for Floating Solar Farm Operation in Laguna de Bay, before it is finally submitted to the Board of Directors for their decision. The LLDA experience in dealing with uncertainties on the use of a natural lake as a platform for solar energy generation, such as the adoption of the precautionary principle by allowing pilot projects prior to making a decision if a full-scale implementation can be allowed and the applicable administrative and regulatory requirements for compliance by renewable energy developers, are deemed to be important contributions that can provide considerable basis for decision making on the use of natural lakes for this kind of renewable energy generation. It is also hoped that professionals from related disciplines will be able to contribute to the development of procedures to properly assess environmental, social and economic impacts of this emerging use of the lake, in addition to the on-going studies in reservoirs in various parts of the world. Equally important is the information on solar panels suited for inland waters, the life span of solar panels and the guidelines on recycling or reuse of the various materials used for floating solar photovoltaics.

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References

- [1] World Bank Group, ESMAP and SERIS 2018 *Where the Sun Meets Water: Floating Solar Market Report* (Washington EC:World Bank Group) pp1-122
- [2] World Bank Group, ESMAP and SERIS 2018 *Where Sun Meets Water: Floating Solar Handbook for Practitioners Report* (Washington DC: World Bank) pp 1-14
- [3] Santos-Borja L *The Regulatory Challenges for Floating Solar Projects in Laguna de Bay, Philippines*. 1st Philippine Floating Solar Forum. September 4, 2019 Manila, Philippines (powerpoint presentation)
- [4] Santos-Borja A C *Exploring the Potential of Laguna de Bay for Floating Solar PV*. Floating Solar ASEAN Conf. November 15, 2019 Muntinlupa City, Philippines. (powerpoint presentation)
- [5] Laguna Lake Development Authority 2018 *Memorandum of Agreement among the LLDA, Nortesol III Inc. and the Municipality of Bay, Laguna on the Implementation of a Pilot Floating Solar Project in Laguna de Bay*, Quezon City Philippines
- [6] Department of Environment and Natural Resources 2016 *Administrative Order No. 2016-08 Water Quality Guidelines and General Effluent Standards of 2016* (Quezon City,

- Philippines: Department of Environment and Natural Resources – Environmental Management Bureau) pp 1-25
- [7] Santos-Borja A C A *Report on the FPV Pilot Projects in Laguna de Bay to the LLDA Board of Directors*. January 29 2020 Laguna Lake Development Authority, Quezon City Philippines (powerpoint presentation).
- [8] LLDA Board Resolution No. 576 A *Resolution Allowing the Use of the Laguna Lake for Renewable Energy Generation by Means of Floating Solar Photovoltaics in Commercial Scale, Initially on Pilot Basis, for Data Gathering Purposes and the Creation of Technical Working Group to Develop its Implementing Rules and Regulations* January 29 2020 Laguna Lake Development Authority, Quezon City Philippines
- [9] LLDA Board Resolution No. 561 2019 *Laguna de Bay Fishery Zoning and Management Guidelines* Laguna Lake Development Authority, Quezon City Philippines