MINISTRY OF NATIONAL DEVELOPMENT PLANNING / NATIONAL DEVELOPMENT PLANNING AGENCY

BAPPENAS

STUDY IMPLEMENTATION OF FLOATING SOLAR PV INSTALLATION IN DOISP DAM

Final Report

December 2021

EXECUTIVE SUMMARY

This report presents the study related to the potential of the Floating Solar PV (FPV) installation in the Dam Operational Improvement and Safety Project (DOISP) Dam by considering three aspects, i.e., (1) technical, (2) environmental, (3) business, and financial aspects. In addition, legal aspects related to FPV are also discussed in this report. Generally, the main objective of this study is to provide recommendations for Bappenas, MPWPH, MERM, and other stakeholders for implementing the Solar PV Installation as an option to develop Sustainable Financing for the Dam's Operation and Maintenance. The methodology used in this study is as follows: conduct a literature study; perform an iterative process between proposing the draft report and considering input and suggestions by stakeholders; finally submit the final report.

Implementing a floating solar PV power plant at a dam reservoir requires reviewing Indonesia's laws and regulations regarding electricity provision. Therefore, two aspects related to renewable energy are discussed in this study, i.e., regarding the electricity provision in Indonesia and the service level agreement of electricity provision (e.g., regulation on electricity price).

It is essential to review the scheme of electricity provision as the floating solar PV is planned to involve private sectors with the Public and Private Partnership (PPP) scheme. Based on the regulations, at least three schemes that Solar PV power plant developers could pursue. First, an electricity provision could be awarded to the Independent Power Producer (IPP) as a Wilayah Usaha. The second scheme is Power Purchased Agreement (PPA) contract with PLN, and the third scheme is by Power Wheeling Scheme (PWS).

Wilayah Usaha might not be feasible due to the intermittency and the capacity of power production that might not be adequate to provide the electricity as needed in a particular area; moreover, most of the operational areas have been owned by PLN. PPA scheme is recently the most common scheme for an IPP. However, the problem with this scheme is relatively risky for a PPP scheme (KPBU) since PLN should do an open tender for an electricity quota in a particular grid system. The third scheme allows any independent power producer (IPP) to sell its electricity production using a business-to-business (B2B) contract scheme with their prospective buyer. However, this scheme has never been implemented since the regulation was issued.

The regulation regarding the electricity purchasing tariff is discussed in this report. The electricity generation cost, known as Biaya Pokok Pembangkitan (BPP), is different in each region and is usually used to benchmark the purchasing price. The MoEMR no 169, the year 2021, shows that the BPP is slightly lower than the BPP based on MoEMR no 50, the year 2021. The MoEMR no. 4, 2020, regulates that the BPP for the photovoltaic maximum is 85% from the BPP. Therefore, a Badan Usaha Pelaksana (BUP) must consider this condition.

The application of Floating Solar PV (FPV) is very suitable for areas with limited land availability, utilizing reservoirs or lakes. It also has several advantages in term of environmental aspects, such as: water conservation due to a decrease in the evaporation rate and inhibitions of algal growth by the reduction of sunlight intensity.

However, the environmental impact assessment (AMDAL/EIA) for the purpose of obtaining environmental permit shall be executed before the installation of FPV. The assessment is important to control the environmental effects that will be caused. Environmental monitoring of the installation must be carried out starting from planning, construction, operation, maintenance, and commissioning activities aimed at preventing risks and potential pollution. Especially if the water accommodated by the dam is used as raw water for drinking water which can affect the water treatment process.

Some critical points on the impact of FPV to the water environment are:

- the leaching of heavy metals from the solar modules;
- the decrease in evaporation rate and its effect on water quality, such as the decrease of oxygen levels due to FPV covering the water surface;
- oil droplets due to leaks from ship fuel tanks used for operation and maintenance of FPV;
- water quality changes due to the usage of detergent and other compounds during panel cleaning;
- the reduction of mixing process in the reservoir;
- water quality and ecosystems changes, especially the microorganism populations, due to the reduced intensity of the sunlight to the surface of the reservoir.

A series of mitigation measures should be addressed during the preparation, the construction and the operation of the FPV. With a proper anticipation of environmental impacts and mitigation measures, most of those impacts are considered to be minimal.

The local specified design criteria for FPV plants in Indonesia are still unavailable at this moment yet. Therefore, the proposed design criteria consider all the relevant local (national) and international standards while prioritizing local standards/rules. The guidelines in this report are non-binding. Thus, the complete methodology (design principles, safety factors, return periods, and analysis methods) from alternative sources may be applied as long as they are justified through a thorough and well-documented analysis or the safety level is not less than given herein.

Some aspects need to be considered in designing FPV on the Dam, i.e., the load cases and their respective safety factors, possible points of failure, redundancy to failure, and dam safety aspects. For loading and structural design considerations, the general recommendation is to prioritize direct measurement data when practically possible. Other acceptable data sources or design guideline alternatives were also discussed. Although recommended safety levels were provided in the guideline, a less conservative value may be used with proper calibration through proper analysis or by considering different relationships with the critical reservoir structures.

The design guidelines for floating PV in the DOISP reservoir were discussed, focusing on the support structure's design (floaters, mooring, anchor) and their relation to the dam safety requirements. Floating PV design criteria in the design guideline are site-specific, tied to the site's environmental condition, and acceptable safety level (nominal annual probability of failure). Based on this guideline, the site-specific loadings and design requirements mean that the use of fixed design parameters for all possible DOISP sites will be counterproductive since it will not give the most optimum design in terms of cost and safety level. These design guidelines may also be used as general guidance to determine the reservoirs' location, layout, configuration, and optimum utilization area in terms of structural safety aspects.

Two selected existing dams were used as study cases in this report, i.e., Cacaban and Pandanduri dams. Cacaban Dam is located in Central Java Province, while Pandanduri dam is located in West Nusa Tenggara Province. Based on the surveys and visual inspections of Cacaban and Pandanduri dams, several issues arise that may cause potential risks to the installation of floating PV. Generally, the issues related to the Dam's structures such as the Dam's stability, the leakage on the tunnel, the intake and spillway conditions. Therefore, it is recommended that the existing dam conditions and environmental issues have to be solved before further actions regarding the design and installation of floating PV.

In terms of the ecosystem changes and the population of microorganisms, a study conducted in the area with low E Coli level revealed that with a surface cover of not more than 30%, the bacteria removal targets can be achieved. Considering the E Coli levels in either Pandanduri or Cacaban Dams are higher, the surface cover for FPV installations in both dams should not exceed 30%.

In term of structural aspects, two options are introduced in this report to fulfill the Dam Safety requirements for installing floating PV in Cacaban and Pandanduri. The two options are:

1) Keep the floating PV probability of failure lower than the total probability of failure of the Dam during the floating PV design service life. Consequently, the design requirements for FPV will be higher and may increase CAPEX & OPEX of FPV.

2) Design preventive mitigation plans by using multiple safety barriers (physical and non-physical).

This report also introduces two or three hypothetical PV locations' advantages and disadvantages based on their practicality and dam safety aspects for Cacaban and Pandanduri.

Concerning the limit of the allowable area of FPV as a percentage of the reservoir area at Normal Water Level, there could be variations and not a single number after due consideration of several factors, such as:

a. the probability of dam failure as a result of risk analysis at a current stage prior to the introduction of potential FPV on its reservoir;
b. the location of the Dam: either it is on the offstream or the mainstream, especially if a cascade system is in place;
c. the technical data of the Dam in terms of its height, total reservoir area, operational conditions, and others.

In the structural design perspective, the loadings and environmental conditions are treated as anticipated variables, whereas other variables such as financial aspects and environmental sustainability aspects are treated as the limiting variables.

From the results of this study, it can generally be said that this project will be economically and financially viable if it meets several important variables, including: Engineering variables such as (1) the maximum limit of the percentage of inundation areas allowed; (2) calculation of the value of the investment required; (3) electricity produced and to be absorbed; And financial variables such as (1) risk-sharing between government and private sector by involving state-owned enterprises; (2) interest rates used to calculate for potential income; and (3) sources of project financing by finding financial partners who are able to provide the lowest interest rates.

In this study, we used 3 (three) scenarios to regulate the percentage of cooperation patterns between government and private or scenario, such as: (1) if the role of government is 51% and private 49%; (2) If the role of government is 40% and private 60%; and (3) if the role of government is 30% and private 70%. While the approach to the financial aspect, we use 3 (three) alternatives, such as: (1) if using tariffs in accordance with Ministry regulation of EMR no 169/2021 and conventional loan interest rates of 9.55%; (2) If using a market rate of 12 USD cents per KWh and a conventional loan interest rate of 9.55%; and (3) If using Ministry regulation of EMR no 169/2021 the appropriate tariff and the interest rate on "Green Bonds" loans 3.55%.

After several financial models as discussed above with using scenarios and alternatives, it can be concluded that the floating solar panel project in the reservoir area of the dam will be financially viable and attract the interest of potential investors, if:

(1) The government ensures the amount or maximum limit of the utilization of inundation areas in reservoirs above 5 percent;

(2) The government decides the selling price of renewable energy products from floating solar panels is higher than the current tariffs (Ministry regulation of EMR number 169/2021)

(3) The government helps investors so that the resulting of electricity production from solar panel project will be absorbed and distributed by PT PLN;

(4) The government will regulate the pattern of risk-sharing and forms of cooperation between the government, state-owned enterprises and private investors; and

(5) Ministry of Public Works and Housing as the owner of the majority dam in Indonesia, makes calculation patterns and loading mechanisms to investors for the use of areas in puddles in reservoirs as well as a form of responsibility to maintain safety and efforts to maintain a sustainable environment.

Here we submit the final report, the results of a review of the implementation of floating solar panels at the Cacaban and Pandanduri dam covering technical, environmental and financial aspects that have been conducted and discussed over the past 3 (three) months.

Prepared by:

Dr. Ir. Aries F. Firman	Senior Dam Structure Expert
Alia Tridarmawati S Si., MT	Senior Environmental Impact Assessment Expert
Djoko Rebowo SE., MM	Senior Business & Financial Expert
Azkaa Filardhi, ST	Junior Marine Engineering Expert

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FOREWORD

Study Implementation of Floating Solar PV Installation in DOISP Dam

This report presents the study related to the potential of the Floating Solar PV (FPV) installation in the Dam Operational Improvement and Safety Project (DOISP) Dam by considering three aspects, i.e., (1) technical, (2) environmental, (3) business, and financial aspects. In addition, legal aspects related to FPV are also discussed in this report. Generally, the main objective of this study is to provide recommendations for Bappenas, MPWPH, MERM, and other stakeholders for implementing the Solar PV Installation as an option to develop Sustainable Financing for the Dam's Operation and Maintenance. The methodology used in this study is as follows: conduct a literature study; perform an iterative process between proposing the draft report and considering input and suggestions by stakeholders; finally submit the final report.

This activity will be funded by IBRD loan No. 8711-ID and AIIB Loan No.000010 -1 IDN. The study was carried out for 3 (three) months, starting in 28 September 2021 and ends at 28 December 2021.

Executing officials of this study is Ministry of National Development Planning Republic of Indonesia / National Development Planning Agency (Bappenas) - Directorate of Water Resources and Irrigation

Jakarta, December 2021

Abdul Malik Sadat Idris, S.T., M.Eng.

Director of Water Resources and Irrigation - BAPPENAS

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GLOSSARY

ADB	Asian Development Bank
AMDAL	Analisis Mengenai Dampak Lingkungan (Environmental Impact Assessment)
ANDAL	Analisis Dampak Lingkungan Hidup (Environmental Impact Analysis)
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BIG	Badan Informasi Geospasial (Geospatial Information Agency)
BMKG	Badan Meteorologi, Klimatologi, Dan Geofisika (Indonesian Agency for Meteorology, Climatology and Geophysics)
BPS	Badan Pusat Statistik (Statistics Indonesia)
CSP	Concentrated Solar Power
DEM	Digital Elevation Model
DivEBT	Divisi Energi Baru Dan Terbarukan (New and Renewable Energy Division)
ESMAP	The Energy Sector Management Assistance Program
FC	Financial Closure
FiT	Feed-in-tariff
GADM	Global Administrative Areas
GEP	Geospatial Electrification Planning
GIS	Geographic Information System
GIZ	Gesellschaft Für Internationale Zusammenarbeit
GNS	Geonet Names Server
GPCP	Global Precipitation Climatology Project
GTOPO	Global Topography
IHC	Indonesia Hydro Consult
IMB	Izin Mendirikan Bangunan (Building Construction Permit)
IP	Inception Phase
IPP	Independent Power Producer
IT	Information Technology
IUCN	International Union for Conservation of Nature
IUPTL	Izin Usaha Penyediaan Tenaga Listrik (Electricity Business Permit)
JICA	Japan International Cooperation Agency
KA-ANDAL	Kerangka Acuan Analisis Dampak Lingkungan Hidup (Environmental Management Plan)
KEN	Kebijakan Energi Nasional (National Energy Policy)
LCOE	Levelized Cost of Electricity
LHP	Large Hydropower
METI	The Ministry of Economy, Trade, And Industry of Japan
MHP	Mini Hydropower

MoEMR	The Ministry of Energy and Mineral Resources of Indonesia
MoFo	The Ministry of Forestry of Indonesia
NASA	United States National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NGO	Non-Governmental Organization
NTB	Nusa Tenggara Barat
NTT	Nusa Tenggara Timur
OTEC	Ocean Thermal Energy Conservation
PEN	Pengelolaan Energi Nasional (Blueprint of National Energy Management)
PLN	Perusahaan Listrik Negara (State Electricity Company)
PLTD	Pusat Listrik Tenaga Diesel (Diesel Power Plant)
PLTM	Pusat Listrik Tenaga Mini (Mini Hydropower Plant)
PLTP	Pusat Listrik Tenaga Panas Bumi (Geothermal Power Plant)
PPA	Power Purchase Agreement
PS	Pump-Storage Hydropower
PV	Photo Voltaic
RE	Renewable Energy
RKL	Rencana Pengelolaan Lingkungan Hidup (Environmental Management Plan)
RPL	Rencana Pemantauan Lingkungan Hidup (Environmental Monitoring Plan)
RUKD	Rencana Umum Ketenagalistrikan Daerah (Regional General Plan of Electricity)
RUKN	Rencana Umum Ketenagalistrikan Nasional (Electricity Master plan)
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik (Power Supply Business Plan)
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik (Electrification Development Program)
SHP	Small Hydropower
SRTM	Shuttle Radar Topography Mission
TRMM	Tropical Rainfall Measuring Mission
UKL	Upaya Pengelolaan Lingkungan Hidup (Environmental Management Efforts)
UNEP	United Nations Environment Programme
UPL	Upaya Pemantauan Lingkungan Hidup (Environment Monitoring Efforts)
USAID	United States Agency for International Development
USGS	United States Geological Survey
VMAP	Vector Map
WB	World Bank
WCMC	World Conservation Monitoring Center
WCPA	World Commission on Protected Areas
WDPA	World Database Protected Areas
WMO	World Meteorological Organization

1 PREFACE

1.1. Background

Dam operations and maintenance activities are currently mostly sourced from the limited APBN and loan-funded programs, namely the Dam Safety Project (1994-2003, worth USD 63 million) and Dam Operational Improvement and Safety Project (DOISP) implemented in two stages (Stage 1: 2009-2017 worth USD 50 million, Phase 2: 2017- 2023 worth USD 250 million). The need for the burden of operating and maintaining dams will be highly dependent on the state budget, especially for single purpose dams because 42% of dams in Indonesia are single purpose dams. Therefore, innovation is needed in the mechanism of dam management that can encourage the operation and maintenance of dams that are independent and sustainable.

The reservoir is one of the areas in the dam that has the potential to be utilized. Currently what has been done is for tourism, fisheries, and sports activities. However, not all reservoirs are suitable and suitable for use through these three activities. Another alternative that is currently developed in several countries is by utilizing the reservoir area as a medium for installing solar panels using Floating Solar PV.

Indonesia currently has around 220 dams that are already in operation and most of them have not been optimized for the reservoir area. If it is simulated in a simple way, the existence of a dam currently has an electricity potential of 7,000-16,000 MW which can be generated from Floating Solar PV. This calculation was taken from 110 dam data with a total surface area around 224,000 ha. The surface area that can be used based on ICOLD rules is 1-5% and the ratio of electricity production from Floating Solar PV is 0.7-1.5 Ha/MW. Based on these considerations, Indonesia has the potential to utilize the reservoir area as a medium from floating solar PV.

Indonesia has a target of achieving the use of Renewable Energy (EBT) of 23% by 2025. From the amount of the EBT target, the target portion for solar PV is 6,500 MW, while currently solar PV is installed only about 100 MWp. Based on the 2019-2028 RUPTL, there is a total solar PV development plan of around 815 MW until 2028 (Power Balance Table), while the plan in the potential list is around 2,280 MW. So, the total plan and potential until 2028 is around 3000 MW, including the plan/potential for Floating Solar PV. The development of Floating Solar PV is potentially viable, considering that one aspect that often becomes an obstacle is land so that it can be overcome by the availability of inundation areas in water bodies.

The discourse to be able to utilize more than 5% of the body area/water reservoir has appeared before the issuance of the PUPR Ministerial Regulation No. 6 of 2020 concerning amendments to the Minister of Public Works and Public Housing Number 27/PRT/M/2015 concerning of Dams. In its development, these aspirations continue to grow and strengthen with increasing interest in the development of Floating Solar PV.

Photovoltaics (PV) are a rapidly growing technology as global energy sectors shift towards "greener" solutions. While enough large-scale projects have been implemented to permit floating solar technology to be considered commercially viable, there are remaining challenges to its deployment, among them the lack of a robust track record; uncertainty surrounding costs; uncertainty about predicting environmental impact; and the technical complexity of designing, building, and operating on and in water.

However, based on the discussion between Bappenas, Ministry of Public Works and Public Housing, Ministry of Energy and Mineral Resources, PT. PLN, INACOLD, and other stakeholders, it is necessary to provide more research or studies on the three aspects, i.e., Technical Aspect, Environmental

Aspect and Business and Financial Aspect. These studies currently not yet provided by ministries in Indonesia.

For this reason, under the work of the Dam Operational Improvement and Safety Project (DOISP) Phase II, further study will be carried out on STUDY IMPLEMENTATION OF THE FLOATING SOLAR PV INSTALLATION IN DOISP DAM. Furthermore, when floating solar PV has a technically feasible, environmentally feasible, and commercially viable business model, it can be a source of income that can contribute to the overall dam operation and maintenance costs.

1.2. Purpose and Objectives

The purpose of this implement study activity is to find out the potential of the Floating Solar PV installation in DOISP Dam with areas of interest in three aspects: 1) Technical Aspect; 2) Environmental Aspect; and 3) Business and Financial Aspect.

The objectives of the study:

1. To study the technical compliances and requirements regarding the installation of Solar PV in term of safety and operation of dam, especially in DOISP Dam, that can contribute to sustainability of dam operation and management.
2. To study the environmental compliances and requirements regarding the installation of environmental impact and social impact in the reservoir area and dam's surrounding area
3. To study the business and financial aspect regarding the installation of Solar PV in term of formulating the business model that can be implemented in reservoir water bodies that can contribute to sustainability of dam operation and management cost.
4. As a reference in the implementation of Floating Solar PV in dams/water bodies for sustainability of dam operation and maintenance in Indonesia, especially in DOISP Dam.

1.3. Targets

The activities of this implementation study are expected to be able to:

1. Provide a technical guideline for Solar PV installation in the reservoir which considers the safety and operation of the dam;
2. Provide environmental guidelines for Solar PV installation in the reservoir which comply with the good practice of environmental impact plan;
3. Provide a business model for Solar PV installation in the reservoir that can contribute to sustainable financing of Dam Operation and Maintenance.
4. Provide recommendations and strategy for the Bappenas, MPWPH, MERM, and other key stakeholders to implement the Solar PV Installation as an option to develop Sustainable Financing for the Dam's Operation and Maintenance.

1.4. Scope of Work

The activities of this implementation study are expected to be able to:

1. Collect all relevant data and information related to technical, environmental and financial, and business aspects;
2. Collect all relevant data and information from selected dams for assessment on existing dams in the DOISP Project;
3. Identify the main stakeholders of the dam operation, electricity sector, environmental sector, and their role in the process;

4. Collect and review existing policy documents on the dam sector, electricity sector, energy sector and potential utilization of floating solar PV;
5. Conduct research and analysis in technical aspect, environmental aspect and financial and business aspect of floating solar PV to become viable using proven frameworks;
6. Conducting Focus Group Discussions and Workshops on the results of studies with relevant stakeholders to present the data collected and the results of the analysis of implementation of the Floating Solar PV in reservoir water bodies.
7. Prepare presentation materials that summarize of the Study of Implementation of the Floating Solar PV Installation in DOISP Dam to present the design results of the analysis and gather input from stakeholders;
8. Presentation and discussion with Bappenas, World Bank, AIIB, and other stakeholders, and reflect the input received in Final Report;
9. Provide final recommendations to Bappenas and other key stakeholders regarding the policy required, regulation adjustment, and implementation.

1.5. Methodology

The methodology used in this study is comprised mainly of literature study, stakeholder approach, and review processes. The illustration of the methodology of the study can be found in Figure 1-1. The details of each component can be found below:

a) Literature study, the initiation, and further iteration of the proposed concept should consider the existing government regulation, technical guidelines/design codes from various relevant fields, and the state-of-the-art floating solar PV technology and knowledge. Details of the type of documents/articles to be reviewed, along with several additional considerations for each document/article described below:

   - Government Regulation (s)

     The government regulation review is necessary to overview whether there is any limitation of the dam reservoir utilization. The essential regulation is related to dam safety.

   - Relevant technical guideline(s) and design code(s):

     Relevant technical guidelines and design codes review is necessary to acquire and transfer the accumulated expertise in various fields and survey the existing guideline and code. Priorities would be given to one/several guidelines (s) and code(s) against the others by considering one or combinations of the following aspects: 1) Locality. Technical guidelines and design code from local entities would be prioritized against international guidelines and design code (i.e., SNI design code would be prioritized against the DNV design code), 2) Relevance. Technical guidelines and design codes from closely related industries would be prioritized (i.e., A mooring guideline for a floating solar PV would be prioritized against a mooring guideline for the oil & gas industry), 3) Safety and reliability. Guidelines and codes with the most stringent safety and reliability requirements would be prioritized

   - Scientific journal and conference proceeding article(s):

     Scientific journal and conference proceeding article reviews are necessary to keep up with the state-of-the-art technology and knowledge related to floating solar PV. Priorities would be given to one/several article(s) against the others by considering one or combinations of the following aspects: 1) Recency. The most recent scientific journal articles and conference proceedings would be prioritized. 2) Reputation. Reputable articles would be prioritized.

The reputability of an article would be determined through the amount of citation (citation index), impact factor and Q rating, amount of conference held and the associated organization's/institution's reputation (for proceeding), the reputation of the authors and their organization, etc. 3) Validity. The validity of the conclusion and methodology is assessed according to precedent, thoroughness, and scientific principles.

- Sources of Business information, Financial and Investment Financing related to article(s):

  Financial journal and conference proceeding article reviews are necessary to keep up with sources of financial aspect and investment financing. Priorities would be given to one/several article(s) against the others by considering one or combinations of the following aspects: 1) Recency. The most recent financial journal articles and conference proceedings would be prioritized. 2) Reputation. Reputable articles would be prioritized. The reputability of an article would be determined through the amount of citation (citation index), impact factor and Q rating, amount of conference held and the associated organization's/institution's reputation (for proceeding), the reputation of the authors and their organization, etc. 3) Validity. The validity of the conclusion and methodology is assessed according to precedent, thoroughness, financial and accounting principles.

b) Stakeholder feedback. The proposed concept should receive input from all stakeholders to ensure its reliability, thoroughness, and feasibility for implementation. The feedback can be obtained either through direct communication such as interviews, surveys, focus group discussions, or by other means of correspondence. The stakeholders may include but are not limited to governmental entities, owners, operators, contractors, and NGOs.

c) Review. Feedbacks from all stakeholders is internally reviewed to assess for its validity. Valuable feedbacks would be adopted in the next iteration of the concept. After several rounds of concept iteration are done, the final product would be determined from the latest concept. The objective of this review period is to develop multi-criteria analysis, incorporating findings from the technical (structural) team as well as the environmental and financial teams, to enable Bappenas and World Bank to justify the 'needs case' for floating solar PV plants potentials in being implemented as part of the DOISP Phase II project. The Consultant will select two existing DOISP dams proposed by Bappenas / World Bank for the multi-criteria analysis assessment. The results will be summarized in the final report.

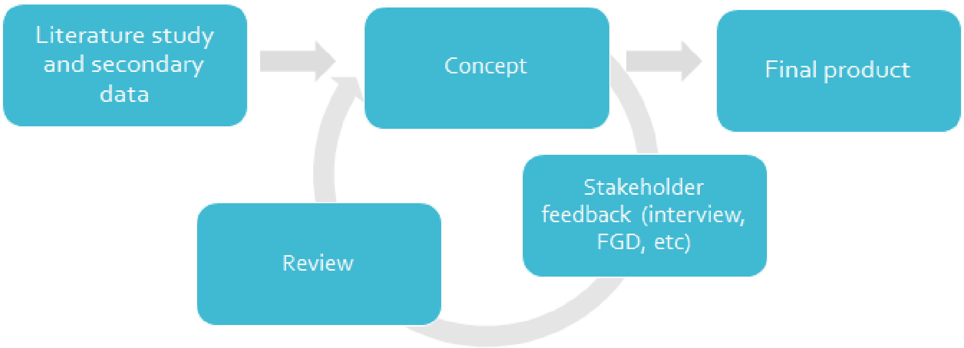


Figure 1-1 Technical aspect study methodology

2 LITERATURE STUDY

2.1 Legal Framework

2.1.1 Dam operation

The Ministry of Public Works & Housing Indonesia announced a new regulation on the use of dam reservoirs as amendments to the previous regulation number 27/2015 regarding the dam. Several issues need to be highlighted in the new regulation number 6/2020, such as:

a. dam safety.

b. reservoir functions

c. social, economic, and culturally specific issues, and

d. the destructive force of water

The regulation promotes several aspects that need to be implemented in designing the FPV plants, such as:

- FPV must be a safe distance from the water flow towards the intake of the dam.
- FPV grid must be a safe distance from the flow of water to the dam spillway.
- FPV does not obstruct the reservoir and dam inspection boat route.
- FPV does not obstruct the route of moving the crane bar towards the spillway and intake.
- FPV is safe from natural disturbances (strong winds, high waves, strong currents).
- A thorough evaluation of the interaction between the newly constructed solar panel and the existing informal fishery industry must be undertaken.
- A thorough evaluation of the impact of the floating panel on the environment, such as the water quality in the reservoir and the public safety around the dam location, must be undertaken.
- Ensure that the floating panel shall support water quality management in the reservoir.

2.1.2 Renewable Energy Policy

Implementing a floating solar PV power plant at a dam reservoir requires reviewing Indonesia's laws and regulations regarding electricity provision. As solar floating PV in this study is planned to be installed at the dam's reservoir, at least two stakeholders might need to consider. The dam reservoir is managed by the Ministry of Public Works and Public Housing (Kementerian *Pekerjaan Umum dan Perumahaan Rakyat*/PUPR), while the electricity provision is regulated under the Ministry of Energy and Mineral Resources (*Kementerian Energi dan Sumber Daya Mineral* - ESDM). This situation brings another challenge to making a floating solar PV is being materialized.

There are at least two aspects related to renewable energy that is required to review in this study. Firstly, regarding the electricity provision in Indonesia. Secondly, regarding the service level agreement of electricity provision, e.g., regulation on electricity price.

2.1.2.1 Electric Power Provision

Having a power plant means that we have to consider how to deliver it to the market. Electric power sales in Indonesia are regulated. Therefore, it is important to review the available regulation regarding electricity provision before such a project is undertaken. It is essential to review the scheme of electricity provision as the floating solar PV is planned to involve private sectors with the

Public and Private Partnership (PPP) scheme. Based on the regulations, at least three schemes that Solar PV power plant developers could pursue. First, an electricity provision could be awarded to the Independent Power Producer (IPP) as a ***Wilayah Usaha***. The second scheme is Power Purchased Agreement contract with PLN and the third scheme is by Power Wheeling Scheme.

1) Own an operational area (Wilayah Usaha)

The 2009 Electricity Law governs energy investments in a Wilayah Usaha. This law gives PLN priority rights over the electricity supply business throughout Indonesia, with exceptions for certain *Wilayah Usaha* given to private enterprises, cooperatives, and self-reliant community institutions involved in the electricity supply business. Although PLN has exclusive powers over the transmission, distribution, and supply of electricity to the public, the private sector's participation is allowed through independent power producer (IPP) or Public-Private Partnership (PPP) initiatives.

Peraturan Pemerintah no. 25 *tahun* 2021 (PP no. 25 / 2021) govern that a private sector is eligible to own a *Wilayah Usaha*. This *Wilayah Usaha* means that the private sector could manage the whole electricity business, from power generation to distribution. However, in terms of floating photovoltaic at dam reservoir, this scheme might not be feasible due to the intermittency and the capacity of power production that might not be adequate to provide the electricity needed in a particular area.

Furthermore, most of the operational areas have been owned by PLN. Although, based on PP no. 25 /2021, it is possible for an owner of a *Wilayah Usaha* to lose their right in an operational area. However, it is not recommended for an executing entity (*Badan Usaha Pelaksana*-BUP) in a photovoltaic power plant to pursue this path.

2) Power Purchased Agreement Contract with PLN

As a State Company, PLN technically monopolizes the current practice of electricity provision in Indonesia. Therefore, Indonesia's most common electric power sale is having a power purchased agreement (PPA) contract between the independent power producer (IPP) and PLN. This PPA scheme has given priority to renewable energy sources, including photovoltaic. The MoEMR regulation No. 4 2020 has also revoked the transfer obligation in the Build-Own-Operate-Transfer (BOOT) scheme.

Regarding the contract for a BUP in the floating photovoltaic, this scheme has a disadvantage, as the PPA contract should be given in open bidding. Moreover, the unsolicited mechanism, that as commonly found in the PPP scheme (KPBU), is unrecognized in the PPA scheme. Furthermore, there is no right-to-match scheme in the PPA bidding as well. Therefore, a BUP will face a great risk of losing to their competitor without any compensation even though they did all studies and project engineering design.

This PPA scheme is also problematic if a floating PV power plant is built in the dam's reservoir with a PPP scheme. Since the stakeholder of the PPP scheme for the dam's reservoir utilization is the directorate of water resources, the ministry of public work and people housing (Kementerian Pekerjaan Uumum dan Perumahaan Rakyat-KPUPR), while the PPA contract will be with PLN. Therefore, the BUP has to get both contracts for the Floating PV project at the dam's reservoir.

Therefore, if there is no political will that involves both KPUPR and KESDM, the utilization of the dam's reservoir with the PPP scheme is hardly materialized. However, there is an opportunity to avoid the circumstances of this scheme. The BUP could pursue a direct assignment by setting up a joint venture with one of PLN's subsidiary companies, such as Indonesia Power or PJB

3) Power Wheeling Scheme

MoEMR regulation no 1/2015 (Peraturan Menteri ESDM Nomor 1 Tahun 2015) allows any independent power producer (IPP) to use the existing grid and transmission system operated by PLN. This regulation allows the renewable energy source could have an opportunity to sell its electricity production using business to business (B2B) contract scheme with their prospective buyer. However, this power wheeling scheme has never been implemented since the regulation was issued.

2.1.2.2 General Plan Of Electric Power Provision (RUPTL)

The general plan of electric power provision or *Rencana Umum Penyediaan Tenaga Listrik* (RUPTL) regulates a ten-year electricity development plan for the operational areas, or *Wilayah Usaha*, of PLN. The RUPTL contains demand forecasts, future expansion plans, and electricity production forecasts. The RUPTL also indicates which projects are planned to be developed by PLN and private investors. Thus, RUPTL is important for the investment strategy in Indonesia. However, when an electricity provision project has been mentioned in the RUPTL, the energy sources and the commercial operation date (COD) for the individual powerplant usually have been decided.

The RUPTL is written based on the National Electricity General Plan (*Rencana Umum Ketenagalistrikan Nasional* – RUKN) and Regional Electricity General Plan (*Rencana Umum Ketenagalistrikan Daerah* – RUKD). The Ministry of Energy and Mineral Resources (MoEMR) is responsible for the RUKN, and the regional governments (Provincials and Regencies) are responsible for preparing the RUKD based on RUKN.

2.1.2.3 Electricity Generation Cost (Biaya Pokok Pembangkit - BPP)

The electricity purchasing tariff in Indonesia is determined by the electricity generation cost, known as *Biaya Pokok Pembangkitan* (BPP). The BPP is different in each region and is usually used to benchmark the purchasing price. The BPP usually increase or decrease following the fossil fuel market price at the time. The MoEMR no 169, the year 2021, show that the BPP is slightly lower than the BPP based on MoEMR no 50, the year 2021. Based on the latest BPP, Cacaban has significantly lowerBPP (with only 6.23 cents USD/kWh) than Pandan Duri (with 11.77 cents USD/kWh). The MoEMR no. 4, the year 2020, regulate that the BPP for the photovoltaic maximum is 85% from the BPP. This MoEMR regulation is problematic in terms of Indonesian commitment for the Net Zero Emission (NZE), since this regulation did not show Indonesian commitment to allowing renewable energy to be developed. However, the regulation is in the domain of MoEMR, and all floating solar PV should comply with this regulation. Therefore, it is necessary for a BUP to develop a floating solar PV in the dam's reservoir to consider this condition.

2.1.2.4 Prospect of Floating Solar PV in the de-dieselization programme

As Indonesia has pledged to set a unified net-zero target to be implemented across industrial sectors to realize its Paris Agreement commitments, the country has updated its nationally determined contribution (NDC) to the agreement. At COP 26, Indonesia targeted to reach net-zero emissions by 2060 or a decade earlier than the previous target. In addition, to boost renewable energy utility for achieving the target of 23% renewable energy mix by 2025, PT PLN (Persero) launches the diesel conversion to renewable energy program that well-known as Dedieselization program.

For the first stage, PLN plans to retire 5200 diesel power plants (or in approximate 255 MW installed capacity) across the country and replace them with renewable energy (see Figure 2-1). This program could be an opportunity for the floating PV program at DOISP dam. The DOISP dams could pursue to be part of the dedieselization program. Retiring 5200 diesel power is phase I of dedieselization program. There are in total of PLTD 4.698 MW (or 7% of the entire power plant system in Indonesia) across the country that might be in the next phases of dedieselization program.

Source: RUPTL 2021-2030

Figure 2-1 Location of 5200 diesel power plant in a part of Dedieselization Programme

2.2 Solar PV Resources Assessment and Reservoir Utilization

There are two major types of solar energy conversion, concentrated solar power (CSP) and Photovoltaic (PV). CSP electric power by converting the sun's energy into high-temperature heat using various mirror configurations; meanwhile, PV uses the sun's light to make energy. The way CSP technology works is that various reflectors concentrate the sun's energy, and this concentrated energy is then used to drive a heat engine and drive an electric generator. The CSP plants that utilize this system consists of two parts: one that collects solar energy and converts it to heat, and the other that converts the heat energy to electricity. Therefore, CSP is an indirect method that generates alternating current (AC), which will then be easy to distribute on the power network. Meanwhile, Solar PV, as explained previously, is the direct conversion of light into electricity. The way this Solar PV works is by absorbing the light, which will then knock electrons loose. Then once the loose electrons flow, a current is created, and this current is then captured and transferred into wires, thus generating a direct electric current (DC). After the direct electric current is generated, it is then converted into AC, usually using inverters, so that it will be distributed on the power network. This study only focuses on Solar PV technology. Therefore, this section only discusses the resource assessment on solar PV.

There are two important parameters in determining Solar PV potential resources, Global H

- Global Horizontal Irradiation (GHI) is used as a reference value for comparing solar potential related to PV electricity systems, as it eliminates the possible variations, given by choice of technical components and the PV system design.
- Direct Normal Irradiation (DNI) is one of the primary solar resource parameters needed for the computation of Global Tilted Irradiation (GTI).
- Global Tilted Irradiation (GTI) is the key source of energy for flat-plate photovoltaic (PV) technologies. The regional trend of GTI received by PV modules tilted at an optimum angle (GTI) is similar to DNI. PV modules tilted at optimum inclination show daily totals of GTI at about 5.6 kWh/m2 (annual totals about 2045 kWh/m2) and higher, especially in the Eastern Java and the Lesser Sunda Islands.

Electricity production in a potential PV power plant depends on the site position and follows a combined pattern of global tilted irradiation and air temperature. The resource calculation

In PV energy simulation procedure, there are several energy losses occurring in the individual steps of energy conversion:

1. Losses due to terrain shading caused by far horizon. Shading of local features such as nearby building, structures or vegetation is not considered in the calculation,

2. Energy conversion in PV modules is reduced by Losses due to angular reflectivity, which depends on relative position of the sun and plane of the module and Temperature Losses, caused by performance of PV modules working outside of STC conditions defined in datasheets,
3. DC output of PV array is further reduced by Losses due to dirt, soiling or snow depending mainly on the environmental factors and module cleaning, Losses by inter-row shading caused by preceding rows of modules and Mismatch and DC cabling losses, which are given by slight differences between nominal power of each module and small losses on cable connections,
4. DC to AC energy conversion is performed by inverter. Efficiency of this conversion step is reduced by Inverter losses, given by inverter efficiency function. Further factors, reducing AC energy output, are Losses in AC cabling and Transformer losses (apply only for large–scale open space systems),
5. Availability. This empirical parameter quantifies electricity losses incurred by shutdown of a PV power plant due to maintenance or failures, including issues in the power grid. Availability of well operated PV system is approximately 99%.

2.2.1 Resource Assessment

Solar resource assessment is necessary for this floating PV power plant design that allows assessing the feasibility of a floating PV plant in a given reservoir location. One of the ultimate objectives of the assessment is to calculate the electricity production from a floating solar PV power plant with typical PV technology that can be annually produced. Certain factors vary from place to place, and with time, hence it is important to gain knowledge of these factors before establishing. These factors include the solar irradiance at a horizontal plane, the irradiance at a tilted position of the PV module, and a sun path diagram. Solar resource assessment generally involves collecting meteorological data from the site, such as weather data, the amount of sunlight received in the location, wind speed, air temperature, etc.

There are many services that available that could be used for a solar PV resource assessment in the website format. However, most of them are paywalled access. One of the options that could be used for an assessment is the solar GIS website of the Energy Sector Management Assistance Program (ESMAP) study funded by the World Bank, a multi-donor trust fund administered by The World Bank and supported by 13 official bilateral donors. This website can be found from the following address https://globalsolaratlas.info/. This ESMAP initiative provides quick and easy access to solar resources and photovoltaic power potential data globally, including in Indonesia. This website is the most recommended site for an assessment study since this website is free.

The solar GIS website has shown the potential of every location in the world, including Indonesia. This information could be used for a preliminary study of Solar PV assessment in Indonesia. The PV report from the ESMAP solar GIS could be tailored by the area of interest in the assessment. The ESMAP Solar GIS mentioned in their website that this website has considered the technical and environmental prerequisites. This map also considers the potential area in terms of the feasibility of such area is developed for solar PV power plant. The constraints such as main roads, railways, and transmission line networks that help define the accessibility and feasibility of sites for the location of power plants is also included in this website. This website gives output in different map layers that can be selected: photovoltaic electricity output (PVOUT), global horizontal irradiation (GHI), direct normal irradiation (DNI), diffuse horizontal irradiation (DIF), global tilted irradiation for fixed systems at an optimum angle (GTI), optimum angle of PV modules (OPTA), temperature (TEMP), elevation (TERRAIN), satellite view (SATELLITE) and information on roads and streets (NORMAL).

However, this map has not included the available existing power transmission line in an area. As mentioned in the website, the World Bank Group is exploring opportunities to improve and disseminate data on power transmission lines.

As shown in the user guide of the website (https://globalsolaratlas.info/support/user-guide?c=-2.767478,118.125,5), the solar PV resources could be accessed by browsing the location of interest. This website also includes Solar PV technology, including floating solar PV.

ESMAP website categorizes solar PV resources into three stages, Theoretical, Practical and Economic.

1. Theoretical PV Potential

Theoretical potential is the resources based on the sun radiation parameter. This potential is calculated based on global horizontal irradiation (GHI, measured in kWh/m /day), the long-term amount of solar resource available on a horizontal surface on Earth.

2. Practical PV Potential

At this stage, the resources have already considered the technological constraints from the available Solar PV technology. This potential in the website is presented as the photovoltaic power output of a PV system (specific yield, measured in kWh/kWp/day); in this case, the long-term power output produced by a utility-scale installation with fixed-mounted, mono facial c-Si modules with optimum tilt. There are three levels of practical resources.

- Level 0 – Practical potential disregarding any land-use constraints
- Level 1 – Level 0 practical potential, excluding land with identifiable physical obstacles to utility-scale PV plants
- Level 2 – Level 1 practical potential, excluding land possibly under land use regulations due to nature and cropland protection

3. Economic PV Potential

This stage has already considered the Levelized cost of electricity (LCoE). The ESMAP uses the ICoE in USD/kWh. The LCoE is defined as the lifetime costs associated with the construction and operation of the power plant divided by the electricity produced during this lifetime (the lower the cost, the higher is the economic potential). In Indonesia, based on the MoEMR regulation no. 4, the year 2020 and its was adjusted with the MoEMR regulation no 4 the year 2021, the LCoE should be 85% lower than the BPP of the local system.

2.2.2 Indonesian Solar PV resources

Indonesia is categorised as a country with medium potential solar PV resources in terms solar PV resources. Figure 2-2 shows the Indonesian solar PV resources in the world solar PV practical resources map. Indonesia shows its potential at an average of 4.625 kWh/m^2 / 136. The highest GHI is identified in the southern islands of the Indonesian archipelago, where the average daily totals reach 5.6 kWh/m2 (average annual 2045 kWh/m2) and higher. Further north, the average daily totals of GHI values are between 3.8 kWh/m2 and 4.8 kWh/m2 (annual sums are between 1400 and 1750 kWh/m2). Minimum daily GHI values in the country are lower than 3.6 kWh/m2 (average annual value lower than 1300 kWh/m2), but the solar resource in these areas is still sufficiently high for small-scale PV. Indonesia is categorically a level 2 site for solar PV, which means there are locations that potentially fit for the solar PV development. Figure 2-3 shows PV out across Indonesia, showing the

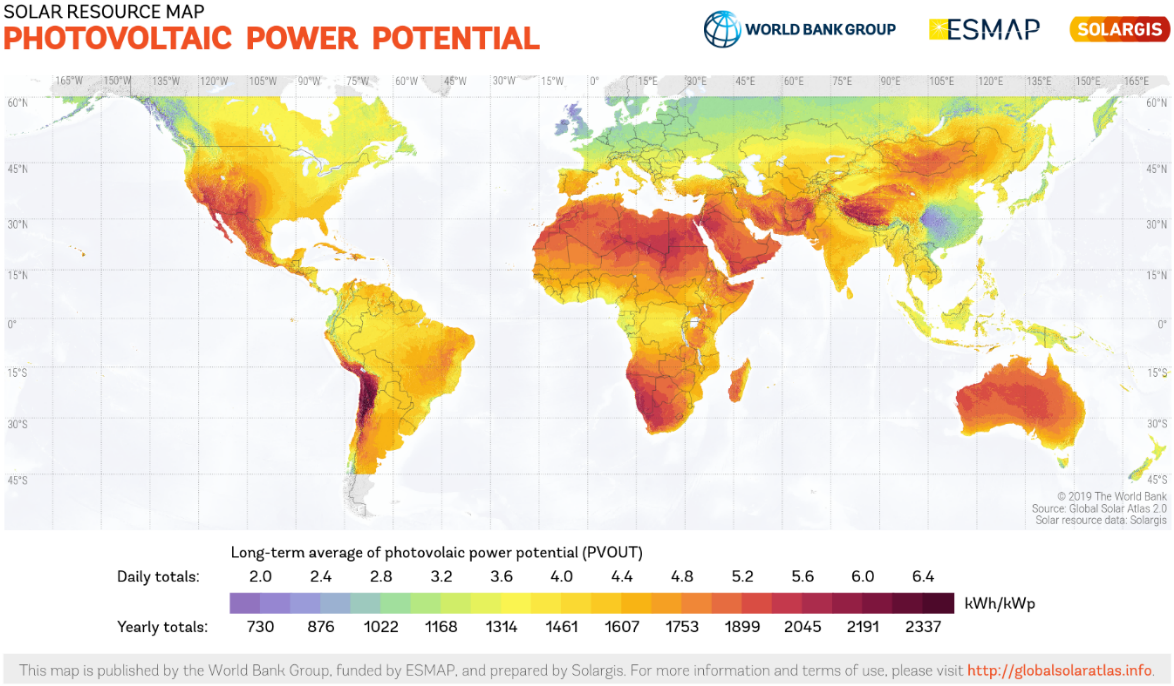


Figure 2-2 World Solar PV Practical Potential based on ESMAP solar GIS (https://globalsolaratlas.info/download/indonesia)

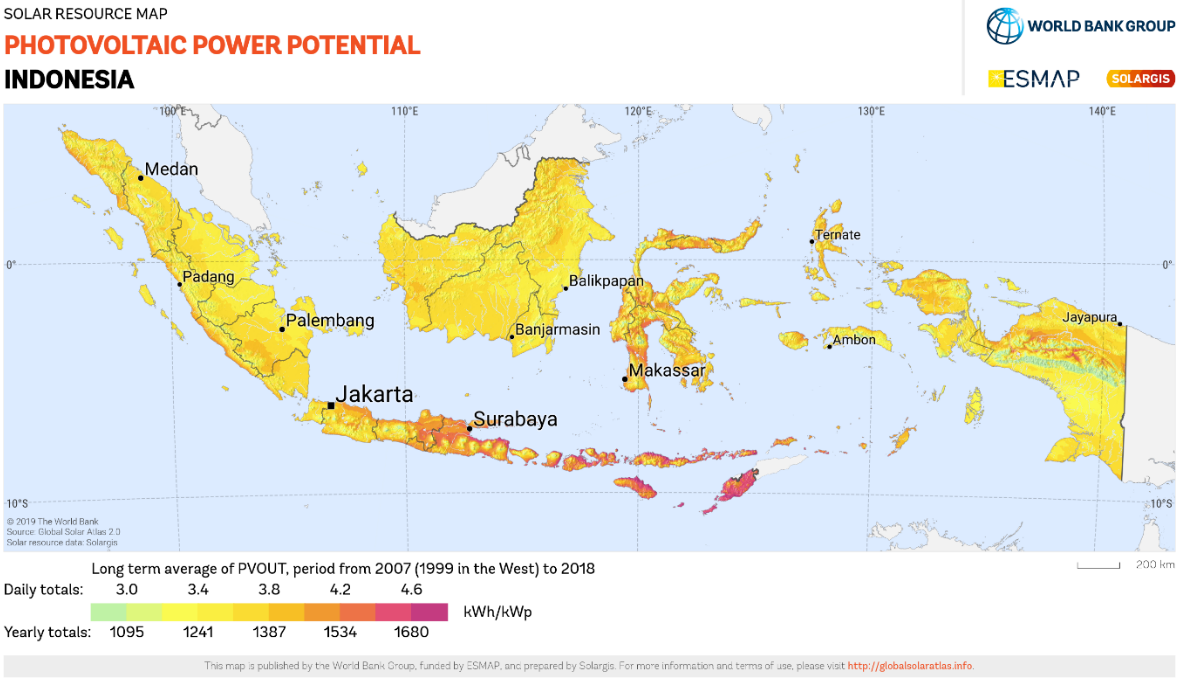


Figure 2-3 The solar PV practical resources across Indonesia based on ESMAP solar GIS (https://globalsolaratlas.info/download/indonesia)

ESMAP Solar GIS indicates that 23.8 % of the Indonesian area is level 2 of practical potential solar PV potential resources. This means the potential solar PV resources is great in Indonesia. As explained previously, level 2 means the area with consideration of the protected and agricultural areas (see). However, the Indonesian population density made the solar PV considered the populated area. Land acquisition in infrastructure projects usually plays a vital role in the project's outcomes. A floating PV in a water body, either in lakes or reservoirs, is a solution for this challenge.

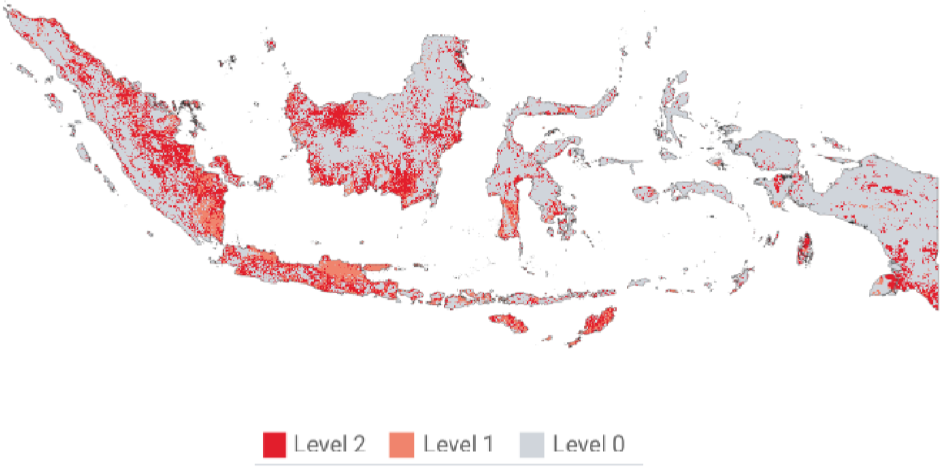


Figure 2-4 The potential practical area for Solar PV in Indonesia

2.2.3 Reservoir Utilization

As mentioned previously, solar PV systems in Indonesia need to overcome land space limitations. It is not always possible to secure enough space for the ground's photovoltaic power generation facilities in some areas with densely populated areas. In such cases, local land shortage issues can be a barrier for PV installations. Furthermore, public opposition to the land acquisition process is a significant obstacle to the economic scalability of the solar PV installed capacity. Not to mention, environmentally protected areas and natural and agricultural lands might pose additional limitations to solar PV-system installations. Therefore, it is sensible to seek the opportunity to use a dam’s reservoir to develop solar PV in this country.

However, the Ministry of Public Works & Housing number 6/2020 indicates only 5% of the reservoir area that could be utilized for the floating solar PV. This regulation has no scientific explanation for how this number was determined. Furthermore, this regulation has no reference in other countries as well. Table 2-1 shows a few floating PV examples that exceed 5% of the reservoir area.

Table 2-1 A few examples of Floating PV in reservoir areas in a few countries

Countries	**Installed Capacity (MW)**	**Annual Energy Production (GWh)**	**Area Reservoir (km^2)**	**Area Floating PV (km^2)**	**Area Floating PV/Area Res**
Burundi	18,0	31,0	1,5	0,22	14,56%
Gabon	228,4	393,3	27,7	2,83	10,21%
Mauritius	41,4	82,1	3,3	0,51	15,61%
Namibia	353,0	879,8	5,2	4,37	84,66%
Rwanda	28,0	50,3	3,3	0,35	10,63%
Sierra Leone	56,0	112,2	10,1	0,69	6,91%
Eswatini	40,8	81,0	6,5	0,50	7,83%

2.3 Current Floating PV Projects in Indonesia

2.3.1 Floating PV Cirata

The 145 MW Cirata Floating Photovoltaic (CFPV) Power Plant is located in the Cirata Hydroelectric Reservoir Area in Cipeundeuy District (Bandung Barat Regency) and Maniis & Tegalwaru Districts (Purwakarta Regency), as shown in Figure 2-5. With 6,500 hectares, the Cirata Reservoir is divided into two large zones: open area and restricted area (Figure 2-6).

The dam, a Concrete face Rockfill Dam (CFRD), has been operated since 1988. The dam in the normal water level condition is capable of holding ± 2,165 million m^3 water from the Citarum River. The top elevation of the dam is + 225 m, and the dam length is 451.5 m. The dam's function is primarily as a powerplant with a capacity of 1,080 MW. The dam operation and management are under PT. PJB-Badan Pengelola Waduk Cirata (BPWC). Based on the Dam Safety Inspection in 2020, generally, Cirata Dam can be classified as in good condition, and the dam is safe for operating on normal and higher conditions loads.

The location is selected for Floating PV (FPV) due to as follows:

- It is one of the largest reservoirs on the island of Java, so it has excellent potential for FPV
- It is an artificial reservoir, making it easier for environmental permits
- Located in an industrial location (West Java) where electricity consumption during the day is relatively high.

As the first project in the FPV plant, the Cirata is also one of the national strategic projects (PSN), as the government aims to boost the contribution of renewable energy sources in Indonesia. The purpose of the CFPV project are as follows:

1. To utilize the reservoir area of the Cirata hydropower plant for generating electricity outside the hydropower plant.
2. To meet the increasing demand for electricity coming from renewable energy.
3. To increase the national new and renewable energy mix to the target of at least 23% by 2025
4. To be a trendsetter for large-scale FPV in Indonesia, which has a competitive price with fossil energy.
5. To be a pilot for large-scale FPV projects in Indonesia and Southeast Asia.
6. To increase the role of local industry to the solar module industry and solar floater industry to achieve the National Capacity Building function.

Figure 2-5. Location of Cirata Dam

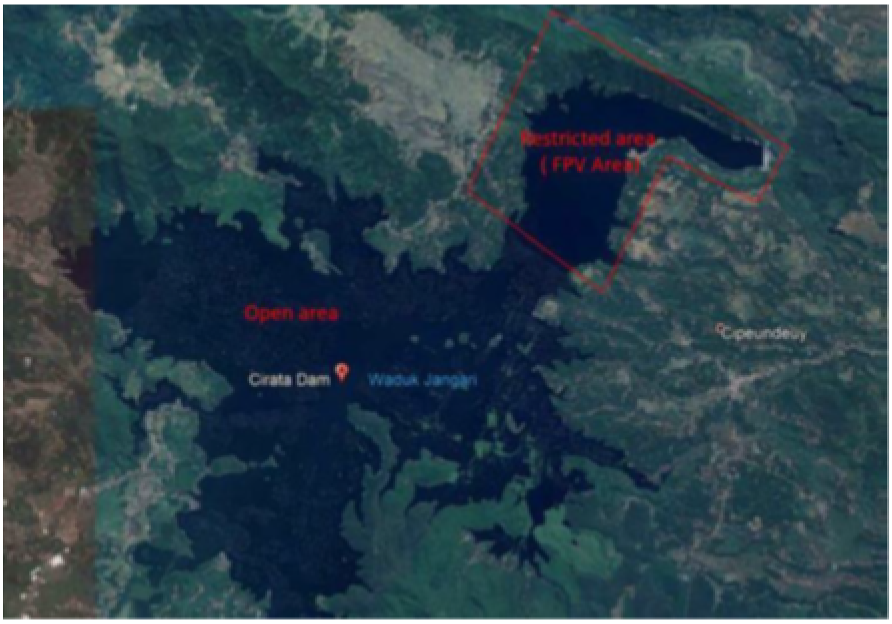


Figure 2-6. Area of Cirata Reservoir

The area of CFPV covers about 200 Ha or about only 3% of the total area of the Cirata reservoir. The energy of Floating Solar PV will be transmitted through about 150 KV, Grid for about 5 KM across Centayan Mountain to Cirata High Voltage Substation. Even though there is almost no current in the reservoir, the floating PV system must be designed for conditions without mechanical stress on the equipment. In addition, the depth of the Cirata Reservoir can vary from 3 m to 94 m which complicates the design process.

2.3.2 Floating PV Krenceng

The Krenceng Floating Photovoltaic (KFPV) Power Plant is located in Krenceng Reservoir Area in Cilegon City, Cangkil District, Banten Province, as shown in Figure 2-7. The Floating PV plant in the Krenceng (Cilegon) reservoir has different challenges. First, the relatively small reservoir area compared to CFPV causes obstacles to the maximum limit of 5% of the Floating PV area that can be planned compared to the reservoir area of around 130 hectares. Second, another differentiating factor is the Krenceng reservoir located outside the main river because this reservoir gets its water from a pump installed in a nearby river. Therefore, the shallower reservoir depth and limited reservoir area need to be considered.

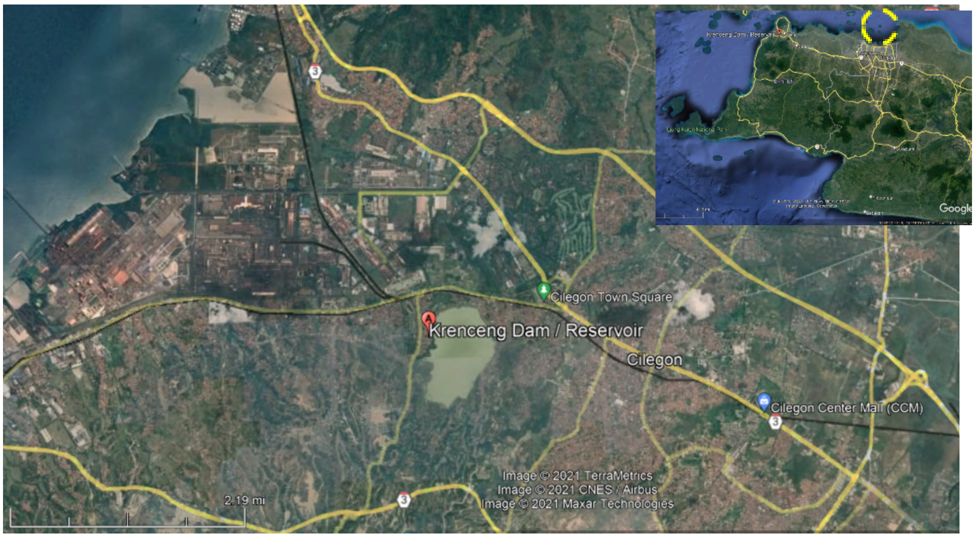


Figure 2-7. Location of Krenceng Dam

The construction of floating solar power plants is expected to provide environmentally friendly renewable energy, especially electricity. The goal is to reduce the cost of electricity consumption and contribute to environmental conservation. It is expected, the capacity produced by KFPV in the early stages is 16 MW, with a value of electricity cost savings of IDR 7.8 billion per year. The project is planned to be commercially operational by the end of 2022. The floating PV is expected to provide added value for the owner and could answer the challenges of future energy supply needs that depend on renewable energy.

3 ENVIRONMENTAL ASPECTS

The application of Floating Solar PV is very suitable for areas with limited land availability, utilizing reservoirs or lakes. There are some aspects where Floating Solar PV is said to have several advantages, in term of environmental aspects, such as:

- Space advantage

  The existence of Floating Solar PV will result in land savings and can be used for other needs such as for agriculture and other uses. This can happen because floating solar in general is placed at ground level which results in reduced empty land.

- Water conservation

  Floating solar PV placed on the surface of the water can result in a decrease in the rate of evaporation in the reservoir water. This can be beneficial because with reduced evaporation rates help water conservation by reducing loss through evaporation.

- Environmentally safe

  Solar panels on the surface of the reservoir water are considered safer for the environment because the effect caused by solar panels (leachate) is not too significant. This technology does not pose a danger or risk to the surrounding habitat for wildlife when applied.

- Economically friendly

  With a proper management and technical approaches, the placement of solar panels above the reservoir will result in a natural cooling effect from the water. This makes the maintenance of solar panels easier.

- Hinder evaporation and inhibit algal growth

  Algae that grow excessively on the surface of lake water can cause eutrophication. The closure of the reservoir water surface by solar panels will reduce the intensity of sunlight entering the reservoir thus minimizing the growth of aquatic organisms such as algae.

However, the placement and installation of Floating Solar PV needs to consider the environmental impact that will be caused, because the construction will cover some part of the water surface in the dam that will affect the quality of water.

Environmental monitoring of the installation must be carried out starting from planning, construction, operation, maintenance, and commissioning activities aimed at preventing risks and potential pollution. Especially if the water accommodated by the dam is used as raw water for drinking water which can affect the water treatment process.

Apart from the relevant standards for the construction, policy and regulation analysis related with Environmental Impact Assessment (EIA), environmental compliance, renewable energy policy, and other related data are as follows;

- Ministry of Energy and Mineral Resources (2020). Solar Power Plant Environmental Management Guide. Directorate General of Renewable Energy and Energy Conservation.
- Ministry of Energy and Mineral Resources (2021). Floating Solar Power Plant Planning Guide. Directorate General of Renewable Energy and Energy Conservation
- Government Regulation of the Republic of Indonesia No. 32/2009 About Environmental Protection and Management
- Government Regulation of the Republic of Indonesia No. 27/2020 About Management of Spesific Waste
- Ministry of Environment No. 5/2014 about Wastewater Quality Standards

- Ministry of Public Work and Public Housing No. 27/2015 About Dam
- Ministry of Public Work and Public Housing No. 6/2020 About changes the regulation of Ministry of Public Work and Public Housing No. 27/2015
- Government Regulation of the Republic of Indonesia No. 82/2001 About Water Quality Management and Water Pollution Control

3.1 Environmental Impact Assessment (AMDAL/EIA)

The environmental impact assessment (AMDAL/EIA) for the purpose of obtaining environmental permit shall be executed before the installation of Floating Solar PV. The assessment is important to control the environmental effects that will be caused. Therefore, environmental and social considerations are important in the selection of technology for the Project. The environmental and social conditions of the sites shall be reviewed based on existing data and visual inspections during the site visit.

It also compulsory to review any regulations or standards such as ambient air, noise, emission, water quality that may affect the technical design of the power plant. The expected local limits (if any), World Bank guidelines and Equator Principles (environmental guidelines followed by most of the international commercial banks) for the project shall be given.

Potential environmental and social impacts of the project shall also be discussed, including any emissions, solid and liquid wastes. In addition, preliminary identification of potential impact to the surrounding biodiversity will be briefly discussed to provide baseline information during the AMDAL/EIA studies.

In the preparation of the AMDAL study, the project initiator may request the services of a consultant to prepare the AMDAL. The AMDAL document compiler is expected to have a Competency certificate from the AMDAL Drafting Licensing Agency. In general, the process of preparing the AMDAL/EIA document is carried out in the following steps:

a) AMDAL mandatory screening process

AMDAL mandatory screening Process is a process to determine whether the FPV installation is required to prepare an AMDAL or not. The screening process is carried out using a one-step screening system. Provisions on whether an activity plan needs to prepare an AMDAL document or not can be seen in the Minister of Environment and Forestry Regulation No. 4/2021. (Permen KLHK RI No 4/2021) concerning Types of Business and/or Activity Plans that Must be accompanied by an AMDAL. The term Floating Solar PV is still not listed in all sectors of industries, and it shall be discussed under the categories of the ‘Floating Facility’ and ‘Solar Power Plant Construction’. The decision whether the FPV installation installation is required to prepare an AMDAL or not shall be issued at least by the Provincial Government.

b) Announcement process

When the decision of the needs to prepare AMDAL document is issued, the FPV installation project is required to announce its activity plan to the community before the proponent prepares the AMDAL. Announcements are made by the responsible agency and the initiator of the activity. The procedures and forms of announcements as well as procedures for submitting suggestions, opinions and responses are regulated in the Minister of Environment Regulation No. 17/2012 concerning Community Involvement and Information Disclosure in the AMDAL Process.

c) Scoping process

Scoping is an early process to determine the scope of the problem and identify significant impacts associated with the FPV installation activities. The purpose of scoping is to define the boundaries of the study area, identify significant impacts on the environment, determine the depth level of the study, determine the scope of the study, and examine other activities related to the planned activity being studied. The final result and scoping process is the KA-ANDAL document. Community suggestions and input must be taken into consideration in the scoping process

d) Preparation and assessment of KA-ANDAL

After the KA-ANDAL has been compiled, the proponent can submit documents to the AMDAL Assessment Commission for evaluation. Based on the regulations, the maximum length of time for the KA-ANDAL assessment is 75 days beyond the time required by the compiler to correct/refine the document.

e) Preparation and assessment of ANDAL, RKL and RPL

The preparation of ANDAL, RKL & RPL is carried out with reference to the agreed KA-ANDAL (the results of the AMDAL Commission assessment). After completion of preparation, the proponent can submit documents to the AMDAL Assessment Commission for evaluation. Based on the regulations, the maximum length of time for the assessment of ANDAL, RKL and RPL is 75 days beyond the time required by the compiler to correct/refine the document.

f) Environmental Eligibility Approval

Environmental Approval is a decision on environmental feasibility or a statement of ability to manage the environment that has obtained approval from the Central Government.

Based on the Ministry of Energy and Mineral Resources document entitled Floating Solar Power Plant Planning Guide 2021, several aspects considered when installing floating solar PV are:

1. Changes in environmental temperature and oxygen levels in water due to floating solar PV covering the water surface. It also can increase the heat generated by the floating solar PV if it covers more than 5% of total water surface. These changes will have an impact on aquatic ecosystem life and water quality. Such changes can have a negative or positive impact depending on the system implemented.
2. Water quality and ecosystems may also change due to the reduced intensity of the sunlight to the surface of the reservoir water, because it is blocked by floating solar PV.
3. Oil droplets due to leaks from ship fuel tanks used for operation and maintenance of floating solar PV. Also the possibility of the usage of detergent and other compounds during panel cleaning.

Other than the above-mentioned aspects advised by the Guide, several other concerns may still need to be considered. The nature of solar power plants typically have site-specific impacts on the environment and surrounding communities. The construction phase will involve site preparation (e.g. grading and levelling) and installation and commissioning of infrastructure (including the floats, Photovoltaic (PV) panels, inverters, transformers, access road and transmission lines). These activities are likely to generate air and noise emissions, impacts on aquatic habitats and occupational and community health and safety risks. However, these impacts are not expected to be significant, given the short duration of the construction phase (i.e. a year) and the proposed mitigation measures.

Key mitigation measures include the use of dust suppression techniques, traffic management, and use of personal protective equipment, fencing of the Project site, and continued engagement with stakeholders. The operation phase will also involve ongoing maintenance.

3.2 Impact of Floating Solar PV to the Environment

Application of floating solar panels on water storage reservoirs should preferably have no or negligible negative effects, or a net beneficial effect. Possible effects of covering a reservoir with floating solar panels include, but are not limited to: reduced mixing (by wind) of the reservoirs, changes related to flora and fauna and related organisms (birds, fish, water plants, mussels, insects, algae, bacteria, viruses, etc., which are all present in or around the reservoir; note that these could also be beneficial), leaching of heavy metals (or other compounds), other changes in physico-chemical parameters and reduced evaporation.

3.2.1 Leaching effect of heavy metals

Despite the clean energy benefits of solar power, photovoltaic panels and their structural support systems (e.g., cement) often contain several potentially toxic elements used in their construction. Determining whether these elements have the potential to leach into surrounding environments should be a research priority, as panels are already being implemented on a large scale.

Photovoltaic panels contain several components known to present health risks to both wildlife and human populations. Metals and metalloids commonly used in panels include cadmium (Cd) and selenium (Se) semiconductors, copper (Cu) wiring, nickel (Ni) and silver (Ag) contacts, tin (Sn) and lead (Pb) soldering, and strontium (Sr) and barium (Ba) doping used to increase panel efficiency. Furthermore, structural support components of the PV system, including cement foundations, may also leach hazardous elements into surrounding environments over time. Lead and Cd, in particular, are contaminants of concern in the solar panel industry due to both their abundance within panels as well as their highly toxic nature. Exposure to Pb can cause kidney and brain damage as well as mortality in humans. Lead is also well documented to reduce reproduction, increase behavior problems, and cause mortality in wildlife. Cadmium is toxic to the kidneys, blood, prostate, and respiratory system. Other metals found within PV materials that are also highly toxic include Ni and Cd, which are known carcinogens; copper (Cu), which can cause kidney and liver damage; Se, which can cause selenosis, a disease of the respiratory system, as well as hair loss and nail brittleness and Sr, which can have negative effects on bone development if consumed in large quantities (Robinson & Meindl, 2019).

However, based on study by Robinson & Meindl (2019), it is revealed that there were no significant differences in lead or cadmium levels near vs. far from the PV systems. Despite concentration differences for some elements near vs. far from the panel systems, no elements were, on average, present in concentrations that would pose a risk to nearby ecosystems. PV systems thus remain a cleaner alternative to traditional energy sources, such as coal, especially during the operation of these energy production systems.

The experiment was conducted on a solar panel installation that has a capacity of 750,000 watts at New York University. The results showed fluctuations in heavy metals at certain distances. The concentration of such heavy metals at a certain distance can be seen in Figure 3-1.

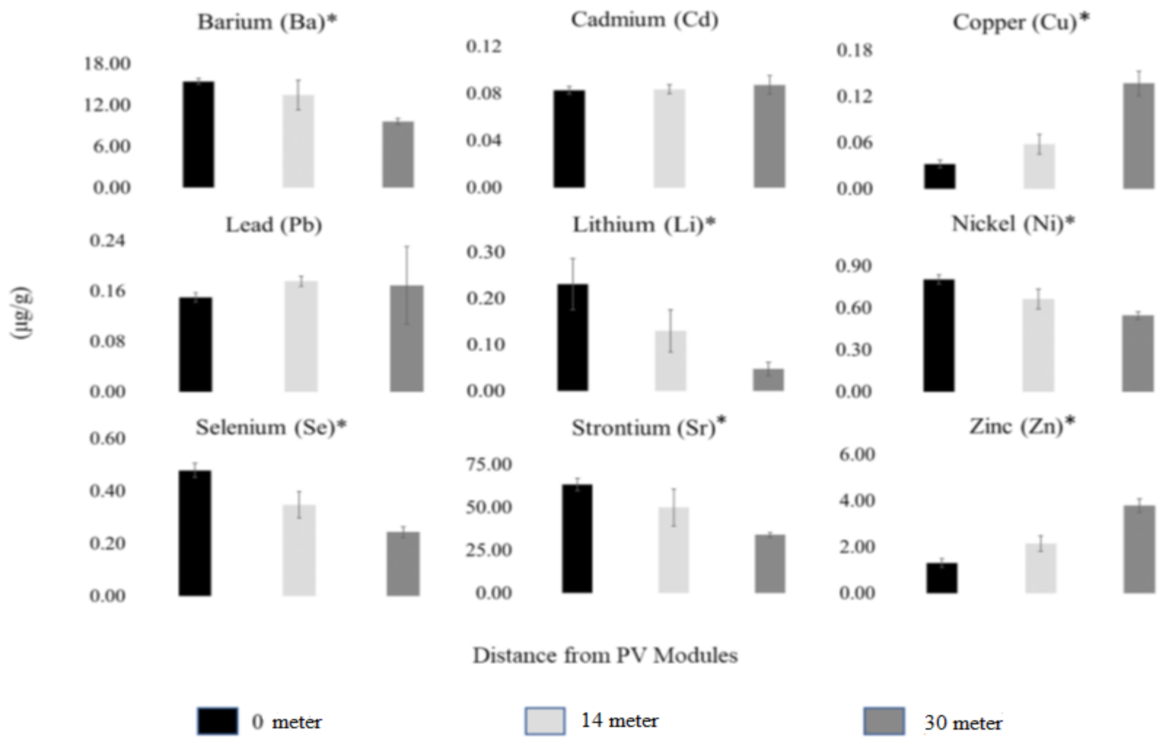


Figure 3-1. Heavy metal content in the soil around solar panels (Robinson & Meindl, 2019)

The conclusion from Robinson & Meindl (2019) for PV systems in general is inline with the result of the study specific for Floating Solar PV by Mathijssen et al (2020). The leaching tests performed in Evides were conducted at a relatively high water temperature of 20 °C, representing a worst-case scenario as leaching speed is expected to increase with temperature. Of the circa 200 compounds tested, only some heavy metals were found in higher concentrations than in the blank (Table 3-1).

Table 3-1. Results of the leaching experiments for heavy metals (Mathijssen et al., 2020).

Heavy Metal	Unit	IS	PE Tubing		Pe Caps		Sealant		Blank	
			2 weeks	24 h	2 weeks	24 h	2 weeks	24 h	2 weeks	24 h
Aluminium	µg/l	10	3,43	2,21	2,77	8,00	3,91	3,05	0,88	1,09
Arsenic	µg/l	2	1,76	1,58	1,69	1,67	1,79	1,60	1,69	1,60
Boron	µg/l	250	52,50	47,50	50,10	45,20	44,90	45,00	45,80	46,80
Cadmium	µg/l	0,1	0,02	0,03	0,02	0,03	0,03	0,02	0,02	0,02
Chromium	µg/l	1	0,04	0,38	0,37	0,33	0,36	0,46	0,38	0,33
Copper	µg/l	40	2,77	1,51	1,51	1,52	10,90	2,88	2,24	1,58
Mercury	µg/l	0,05	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,00
Lead	µg/l	1	0,06	0,07	0,08	0,04	0,19	0,09	0,11	0,04
Manganese	µg/l	40	0,56	0,59	0,44	0,49	3,91	0,53	0,63	0,50

Heavy Metal	Unit	IS	PE Tubing		Pe Caps		Sealant		Blank	
Nickel	µg/l	5	2,81	2,41	2,61	2,50	2,65	2,67	2,51	2,52
Selenium	µg/l	1	0,25	0,26	0,27	0,29	0,29	0,29	0,26	0,26
Zinc	µg/l	50	9,05	6,74	5,18	1,34	4,19	2,74	3,33	1,91

IS = Internal Standard for produced drinking water at Evides.

The PE tubing and caps release some aluminium and zinc. Some aluminium, copper, manganese and zinc leach from the sealant, but leaching appeared to take longer as most of these (excluding aluminium) were only found leaching after 2 weeks and not after 24 hrs. The concentrations are several times lower than the internal standard for produced drinking water.

The water body tested for the study is used as raw water for drinking water purposes. At most 4% of the raw water is taken from the reservoir, and that the water will still be coagulated as a first treatment step, it is highly unlikely that these heavy metals will cause any detectable increase of heavy metal concentrations in the finished drinking water. Of course, seasonal effects may also occur and it is possible that longer term leaching may give rise to other compounds being released (Mathijssen et al., 2020).

It is also worth noting that conditions in Indonesia as a tropical country may result in a more extensive leaching process. At temperatures that are likely to reach higher than 20 °C, it is possible that the metal content in the waters due to the leaching process is greater. However, except for alumunium and zinc which are detected to be considerably higher than the blanks, the concentration of metals due to leaching process are still very low.

3.2.2 Changes in microorganisms

There are two main concerns on the effects of the surface coverage by Floating Solar PV on water bodies.

1. Ultraviolet light from the sun has a function in the elimination of bacteria. In general, it is evident that with surface covering, the removal of bacteria in water bodies shall be reduced.
2. The impact of surface coverage to phytoplankton. Phytoplankton are the autotrophic components of the plankton community and a key part of ocean and freshwater ecosystems. Analysis of the sun radiation during the day in floating PV coverage may predict its effect on the phytoplankton density.

Mathijssen et al. (2020) studied the potential effects of floating solar on the decimal elimination capacity (DEC) of the reservoirs via Quantitative Microbial Risk Assessment (QMRA) in a worst-case scenario where the floating solar panels block all incoming light. It was found that the lower limits on the DEC for the application of floating solar panels on reservoirs at Evides for Cryptosporidium and Giardia are reached first, and not as was initially suspected for Campylobacter. Based on this study, Mathijssen et al. (2020) conclude that from the point of view of the QMRA, with a surface cover of not more than 30%, the majority of bacteria removal targets were still achieved (for a surface area between 3 – 96 hectares) (Table 3-2).

Table 3-2. Pathogen Elimination at 30% Water Body Closure (Mathijssen et al., 2020).

Index Pathogen	Required DEC 70% DEC BB		Total DEC reached		
	Average	Max	Site 1	Site 2	Site 3
Adenoviruses	≥ 4,6	≥ 5,4	6,0 - 8,2	> 7,2 - 9,4	> 6,6 - 8,8

Enteroviruses	4,2	5,0	7,2 - 9,4	8,6 - 10,8	8,9 - 11,1
Cryptosporidium	4,4	6	7,6	> 5,8	> 6,3
Giardia	4,8	6,7	7,7	> 6,7	> 6,4

The study by Mathijssen et al. (2020) was carried out in three water bodies: Kralingen, Baanhoek, and Berenplaat. Data regarding the condition of water quality in these three reservoirs need to be considered in order to compare them with conditions in Indonesia. The 30% surface cover is the result of water quality conditions in those three reservoirs. For example, Berenplaat reservoir has an E Coli number of 100 /100 ml. This figure may be important to note in order to determine the extent of FPV cover that may be applied in Indonesia, which may has a higher E Coli number.

On the other hand, there is also a concern where the closure of surface water body will endanger the phytoplankton communities. In an unpublished report by Akuo, it is reported that the phytoplankton density slightly decreases, indicates that the covering by the floating PV has minor effects on the phytoplankton community in the reservoir. Akuo studied many types of phytoplankton community with several characteristics and built a model to study the effect of Floating Solar PV to the ecosystem.

For Chlorophyceae, a type of phytoplankton that rely on photosynthesis, the restricted sunlight penetrating the water column will cause the decrease of its productivity. Other type of phytoplankton, Dinophyceae, where its productivity do not rely on photosynthesis, and as such the modeling shows an increase of Dinophyceae density. However, these changes (decrease and increase of phytoplankton communities) are very minor and do not affect the water quality of the reservoir.

The study also showed that the covering of the surface water by the floating PV brings only a slight decrease (1.98% to 3.20%) of the phytoplankton community in the reservoir. The decreasing 3-4% of total density its usually occurs during seasonal changes caused by nutrient intake entering water bodies.

Some other studies that states that the density of phytoplankton are positively correlated with clarity. In the application of floating solar PV, however, sunlight can still penetrate on the surface of the water covered by the panels. This may cause the phytoplankton do not to drop significantly.

3.2.3 Decrease in Evaporation Rate and Its Effect on Water Quality

The water level in the reservoir will evaporate if not blocked by anything, and with the closure by solar panels there will be a reduction in the rate of evaporation in the reservoir. Evaporation can occur due to an increase in air temperature around the reservoir. The closure of the water surface will affect the temperature on the surface of the water, which create a stable temperature all the time resulting in a decrease in the rate of evaporation.

When the air temperature drops, then the temperature in the water in the reservoir will also drop, and when the temperature on the air rises, then the temperature on the surface will rise as well. Study by Iqbal and Dwinandha (2017) shows that the most significant evaporation rate occurs between 07.00 and 08.00 when the temperature of the water rises sharply. Humidity also affects the rate of evaporation, where the low humidity and high temperature, will increase the evaporation rate.

Based on the regulation from Ministry of Energy and Mineral Resources document entitled Floating Solar Power Plant Planning Guide 2021, parameters that are used as a reference to identify water quality are temperature, acidity level, dissolved oxygen, and algae concentration. Evaporation that occurs in reservoir water allows for influence on chemical and physical parameters. These changes can occur due to a chemical reaction between water and air around the reservoir. The closure of the water surface with solar panels causes the air around the water surface to be limited, allowing changes in chemical and physical parameters.

Iqbal and Dwinandha (2017) studied the changes of physical and chemical parameters caused by evaporation. The parameter used as a reference to measure the changes is Electrical Conductivity (EC) and dissolved oxygen (DO). The study shows that there is no any significant changes in the water parameters. This shows that in general there is no direct effect of evaporation on oxygen content and conductivity. The installation of solar panels may only affect the evaporation rate without affecting water quality (Figure 3-2).

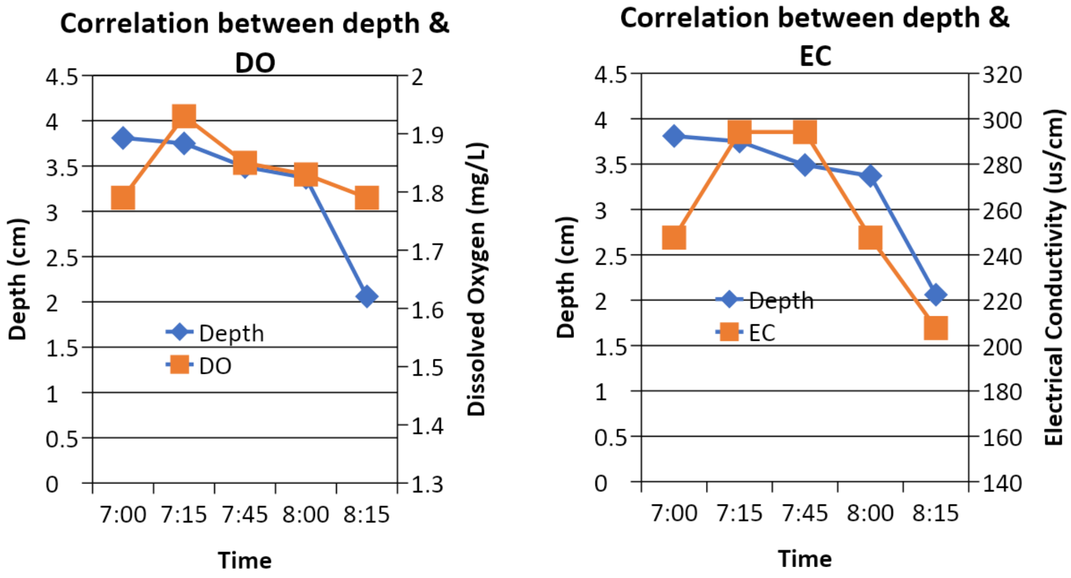


Figure 3-2. Effect of evaporation on oxygen content and conductivity Iqbal and Dwinandha (2017)

3.2.4 Water Pollution by Cleaning Agent

Detergents are used to clean solar panels. The use of such detergents in large can cause water pollution in the reservoir. The main component of the detergent is surface active agents or surfactants. The most commonly used surfactant contains linear alkylbenzen sulfonate (LAS). LAS is an anionic detergent that is classified as hard detergent and can be toxic. This may become an important issue only if the concentration of surfactants in detergents is high, affecting the life of the organism in the ocean waters.

In the application of Floating Solar PV, the conditions are more challenging, where the evaporated water created moist condition on the panels. This moist may create a condition suitable for bacterial growth, and may lead to corrosion and damage to the panels. In some area, the usage of cyanide is applied as the cleaning agent as well as to kill the bacteria. If the solar panels are large enough, the usage of the cyanide may also quite significant and may pose a danger to the aquatic ecosystems.

Zahedi et al (2021) studied many cleaning techniques (Table 3-3) and reported that there is no specified cleaning cycle for all Floating Solar PV systems, and the environmental conditions determine the frequency of the cleaning. For freshwater reservoirs, the manual cleaning (before sunshine and without using chemical materials) can be fine, as it requires no additional water or electrical source. Assuming high stability of the coated layer, the combination of the coating technique and manual cleaning is an ideal solution for FPV systems installed on the freshwater reservoirs.

Based on the study by Zahedi et al (2021) above, it may be concluded that plenty of techniques have been developed for cleaning PV systems. Furthermore, water-based techniques are typically considered the best solution for cleaning. The application of these techniques for FPV systems depends on water availability and reservoir water quality, which are always feasible. Therefore, the cleaning process for the PV panels do not need large amount of hazardous chemicals, and the effect of the cleaning agent to water pollution is considered minimal.

3.2.5 Reduced mixing process in lake by wind

The air temperature around the surface of the lake will affect the mixing process in the whole water body. This mixing process is caused by the distribution of heat by water and is controlled by stratification in reservoir. Existing stratification of lakes reduces vertical exchange and can encourage horizontal exchange. Air temperature also affects the formation of stratification in reservoir water which is the result of energy equilibrium. In addition to being caused by the increased water temperature the mixing process is also caused by the wind that causes a shear voltage on the surface water. Stratification of reservoir water can be seen in Figure 3-3.

Stratification has important implications for fisheries management, phytoplankton (algae) populations, and water supply quality. Floating Solar PV in water surface impacts the reduced oxygen in the water that can be caused by a lack of air circulation at the water surface by the panels. This condition can cause anoxic conditions, in the extreme condition cause death in fish. Anoxic conditions can also cause the formation of H_2S in water. H_2S compounds cause corrosive effects especially on Floating Solar PV that are on it. Phosphorus and Nitrogen: In anoxic conditions, the nutrients phosphorus and ammonia-nitrogen become more soluble (dissolvable) and are released from the bottom sediments into the hypolimnion. Some metals and other elements—notably iron, manganese, and sulfur (as hydrogen sulfide)—also become increasingly soluble and are released from anoxic bottom sediments. These compounds cause taste and odor problems potentially serious concern in drinking water supply reservoirs.

Table 3-3. Comparison of cleaning techniques. (Zahedi et al., 2021)

Technique	Approach	Merits	Demerits
Rainfall	Water-Based	• No cleaning cost • Doesn't need any reformation • No electrical power consumption • Cooling effect	• Low efficiency • Not accurately predictable • No specific falling pattern • Low access in arid and desert regions
Manual Cleaning	Water-Based	• Low cleaning cost • Simplicity • No electrical power consumption • Cooling effect	• The dependency of cleaning efficiency on human labor caution • High wastage of water • Restrictions of the floating structure are weight-bearing
Self-Cleaning	Water-Based and/or Water-Free	• Fully automated • Cooling effect (water-based approach)	• Low efficiency (water-based approach) • High wastage of water (water-based approach) • High initial cost (water-free approach) • Electrical power consumption
Robotic	Water-Based and/or Water-Free	• High efficiency • Low water wastage (water-based approach)	• High total cost • Possibility of falling into water or a not programmed position • Risks of PV panel damaging
Airflow	Water-Free	• No/Low cleaning cost • No electrical power consumption	• Low efficiency • Risks of PV panel damaging
Coating	Water-Free	• High efficiency in humid regions • No electrical power consumption • Availability of providing other features such as anti-icing, more stability, anti-reflecting, photocatalysis reaction, and anti-fogging	• Recoating requirement • Treats of realized chemical materials for the environment
EDS	Water-Free	• High efficiency for desert regions • Fast technique	• Low efficiency for wet, cemented, and small-sized particles • High total cost
Surface Vibration	Water-Free	• High efficiency • Low electrical power consumption	• Risks of PV panel damaging due to the vibrations • High maintenance cost

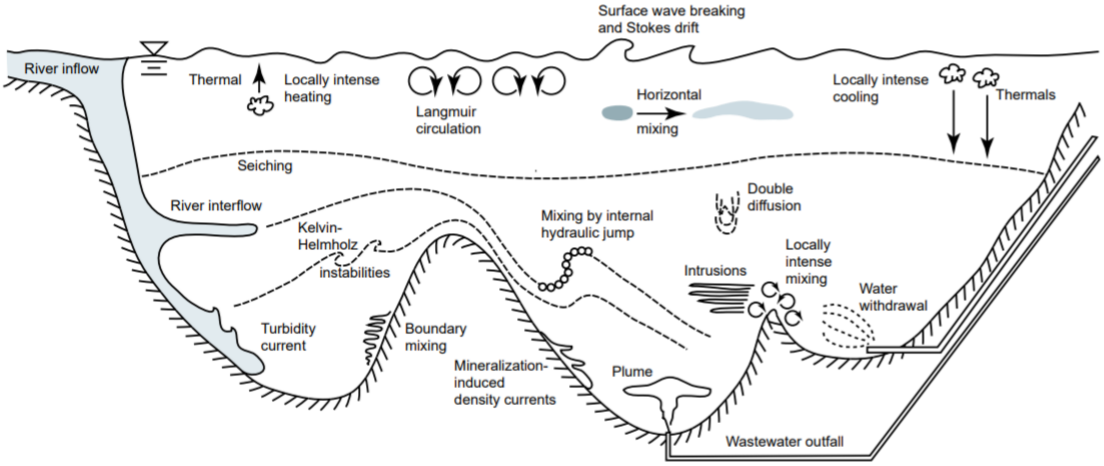


Figure 3-3. Stratification of Reservoir (Imboden,& Wuest, 1995)

3.3 Anticipated Environmental Impacts and Mitigation Measures

3.3.1 Impacts during Construction

During the construction phase, non-hazardous solid waste maybe generated mainly from activities including site clearance and preparation, land excavation. Notably, the Floating Solar PV project does not cause major excavation works, thus the solid waste will be minimal. Hazardous solid waste may also be generated during the construction. It includes oily waste, oily cleaning mops and grease generated from machinery maintenance. This amount of hazardous solid waste generated during the construction process of the project depends on the number of construction machines and transportation, the amount of lubricant discharged from the motor vehicle; lubrication and machinery maintenance plans. However, maintenance activities will be mainly carried out on the land, thus impacts from hazardous solid waste are considered minor.

Construction wastewater will be mainly generating from the concrete mixing process which will occur during construction. Volume of construction wastewater is not much. Therefore, the industrial wastewater cause minor impacts on the environment. Oily wastewater is released from repairing and maintaining construction vehicles. It contains a high level of suspended solids and grease which can lead to surface water pollution if it is not treated. However, the construction vehicles shall be maintained in the garages in the local area, so its impact from oily wastewater is also minor. Float manufacturing process will generate cooling water from the blow moulding step. However, the cooling water will be recirculated to reduce impacts on the surrounding surface water bodies. Therefore, impact from industrial wastewater is minor. During the construction period a number of civil works will be required, including land clearing, backfilling, levelling and grading. This will modify the landscape and change on-site drainage patterns. The result will likely be an increase in run-off to nearby properties, which may result in an increase in soil erosion and flooding. Soil erosion and flooding are of particular concern during periods of rain season.

During anchoring floating systems to the bottom of the reservoir, it will affect sediment and muddy layers in the reservoir. To reduce the impact, the construction contractor has to comply with the anchoring process requirements. In particular, the position of anchors at the ground is determined accurately and then the anchors will be slowly put down to the bottom by cranes so that the impact force of collision between the anchor system and the lakebed is reduced. Therefore the amount of sludge dispersed is small within a short penetration distance.

3.3.2 Impacts during Operation

The operating life of the PV panels is about 20 years and in operation phase, does not cause pollution. However, with damaged and replaced PV panels, they shall be temporarily stored in the hazardous waste storage. The operational manager shall also contract with licensed waste treatment agencies to collect and treat the panels as well as hazardous solid waste in compliance with national regulations. The estimated replacement ratio of the PV panels is 0.05% for whole 20 year Project lifecycle; thus the operation of the floating solar farm will produce negligible solid waste.

There will be an oil well constructed at the transformer station. The storage capacity of oil well will be larger than the amount of oil contained in the transformer. When any incident occurs at the transformer station, so oil leaks will be minimized. Therefore oily wastewater caused in the operation phase is manageable and limited, so its impact should not be significant.

Water to be used for PV modules cleaning shall be supplied from water in the reservoir. Waste water from the cleaning activities will be discharge directly to the reservoir because it is not hazardous to the water environment. Accidental leakage of transformer oil can occur during transmission line and substation operation. However, substation transformers will be located within secure and impervious areas with a storage capacity of 100% spare oil. The potential impact on surface water during the operation phase is negligible.

During the operation phase, the floating solar power system will be regularly checked and maintained. During operations the PV panels will already be installed and so will not cause any incidents related to dropping battery panels or wires into the reservoir or affect the water environment at the area.

At transformer station, oil might leak or spill into the environment. If there are no collection measures, the oil spills from the transformer will result in pollution of the local environment, especially soil and water environment. This might cause negative impacts to the habitat of species, the ecosystem and people living in the Project area. Therefore, the transformer station should be designed with an oil collection system and an oil trap. Therefore the penetration of oil spill will be minimized. Oil spill response measures are also expected to be put in place, so the impact shall not be significant.

During the operation phase, impacts on biodiversity may include i) loss of terrestrial habitat, ii) changes to aquatic habitat functionality; iii) barrier creation, degradation of habitat, fragmentation and edge effects, iv) mortality by vehicle strike, hunting, fishing and poaching, v) mortality by Avifauna Infrastructure Strike with Transmission Line; and vi) ecosystem services.

Based on the discussion in Chapter 3.2, all of these effects are actually minimal, and the main cause of the problems that may arise is from the reduced penetration of sunlight which will reduce the level of water mixing in the dam and eventually lead to anoxic conditions. In some Floating Solar PV installations, this anoxic condition is avoided by installing an aerator or mixer under the panel. The installation of this mixer ensures that the process of water mixing under the FPV still takes place, so that the concerns about changing conditions of microorganisms in the reservoir are eliminated. The installation of this aerator can be considered for certain conditions.

3.3.3 Mitigation Measures

Other than concerned environmental effects that may arise during and after FPV installation, project initiator and construction contractor need to assess a more general mitigation measures to ensure the sustainability of the project. The assessments, which should be incorporated in the Environmental Impact Assessment (AMDAL/EIA), shall include:

- Document of terms of reference for environmental impact analysis (KA-ANDAL) that has been assessed and approved by the AMDAL Assessment Commission
- Environmental impact analysis (ANDAL) document
- Environmental management plan (RKL) document
- Environmental monitoring plan (RPL) document,
- Executive summary
- Activity Report

Table 3-4 shows some actions for proposed mitigation measures for the FPV installation.

Table 3-4. Proposed Mitigation Measures for FPV Installation

Predicted impact issues	**Mitigation Measure(s)**	**Cost**	**Schedule**	**Responsibility**
Preparation				
Access restriction and fishing disturbance	Conducted a target survey to identify those households who lost more access for fishing activities and development of a livelihood program for these households based on engagement with them Appoint Project personnel to guard the area to remind people to not access the area for illegal activities including fishing and settlement and warn them with health and safety risks	Part of preparation cost	Before construction	Project sponsor
Construction				

Predicted impact issues	**Mitigation Measure(s)**	**Cost**	**Schedule**	**Responsibility**
Air quality management	Implement extra control measures, either excavation stopped if excessive dust generated or water applied in case of extremely dry weathers.	Part of construction cost	Through construction period	Project sponsor, Construction Contractor
Noise and vibration management	Optimize scheduling of vehicles and construction equipment to reduce noise, Reduction of the level of noise and vibration caused by float manufacturing process.	Part of construction cost	Through construction period	Project sponsor, Construction Contractor
Occupational health and safety	Establish HSE board before starting construction phase. This board will control safety aspects for the Project including training and raising safety awareness for workers, inspecting safety, and identifying safety issues.	Part of construction cost	Throughout construction	Project sponsor, Construction Contractor
Community health and safety and general disturbance due to construction activities	Implement the measures proposed for mitigation and management of environmental impacts to reduce the environmental disturbance to daily life including livelihood of the local people. Allocate Project personnel to in charge of security in the construction area and restrict unauthorized people to access to the area, especially the lake where the solar panels will be installed.	Part of construction cost	Prior to and during construction	Site Manager, Project Sponsor and Construction Contractor
Worker and local community relation	Issue a Work Site Regulation and a Worker's Code of Conduct, both to be approved by the Project Company, in order to reduce the potential for cultural related conflicts among the migrant and local workforce and the local population.	Part of construction cost	Prior to and during construction	Site Manager of the Project Sponsor and Construction Contractor
Operation				
Water management	Manage domestic wastewater by using septic tanks with an option to connect to public sewer line. Monitor water quality of Cacaban and Pandanduri reservoir regularly.	Part of operation cost	During operation	Project Sponsor
Waste management	Collect and store hazardous waste (e.g. PV panels) in hazardous waste storage and transfer to the certified hazardous waste contractors for transportation and disposal. Prepare and submit annual hazardous waste management report to the authority Store oily waste from transformer in proper area Ensure waste collection, storage and treatment in accordance with Government Regulation of the Republic of Indonesia No. 27/2020 About Management of Spesific Waste Engage a licensed waste disposal company to collect and handle the non- hazardous solid waste in accordance with the applicable laws and regulations.	Part of operation cost	Throughout operation	Project Sponsor
Occupational health and safety	Develop and implement occupational health and safety procedures for activities related to the Project's activities (e.g. working over water, working with electricity, etc.). Allocate HSE in charge persons during operation phase. Ensure safety when working related electric jobs. Prevent fire and deal with firefighting quickly and approximately via fire-fighting and prevention procedure.	Part of operation cost	Throughout operation	

Predicted impact issues	**Mitigation Measure(s)**	**Cost**	**Schedule**	**Responsibility**
Community health and safety	Implement the measures proposed for mitigation and management of environmental impacts to reduce the environmental disturbance to daily life including livelihood of the local people. Allocate Project personnel to in charge of security in the Project area and restrict unauthorized people to access to the area, especially the lake where the solar panels will be installed. Install and regularly inspect lightning protection systems. A RKL and UPL will be in implementation with a major focus on livelihood and skill development and promote the health and safety of local people. Local procurement should be promoted during operation of the Project. In particular, the Project should use local foods/products and local supply to enhance benefits to the local communities.	Part of operation cost	Throughout operation	Project Sponsor

Many of the mitigation measures in Table 3-4 are general to AMDAL documents, since the effects of many activities are somewhat similar to the environment, especially in terms of noise, vibration and air pollution during construction, as well as the generation of solid waste and waste water. However, we may point out some specific points in terms of FPV installation, such as:

- The needs to appoint personnel to guard the area to remind people to not access the area for illegal activities including fishing and settlement and warn them with health and safety risks
- The needs to monitor water quality of Cacaban and Pandanduri reservoir regularly for the possibility of:
  - ✔ leaching effects from the solar modules as well as the
  - ✔ changes in oxygen levels in water due to FPV covering the water surface.
  - ✔ water quality and ecosystems changes due to the reduced intensity of the sunlight to the surface of the reservoir water
  - ✔ oil droplets due to leaks from ship fuel tanks used for operation and maintenance of floating solar PV.
  - ✔ water quality changes due to the usage of detergent and other compounds during panel cleaning.
- The needs to prepare and submit annual hazardous waste management for the panel repairs and replacement and to report to the authority

The mitigation measures shall be implemented through monitoring plan than can assess the success criteria on mitigation effort. The parameters and methods for monitoring plan should be selected to help monitor the predicted impacts as well as implementation of the proposed management measures. The proposed monitoring plan is shown in Table 3-4.

Table 3-5. Proposed Monitoring Plan for Floating Solar PV Installation

Impact Issue	**Parameter**	**Location**	**Method of Monitoring**	**Frequency**
Preparation				
Access restriction and fishing disturbance	Complaints	Project site and line transition area	Checking complaint log book and stakeholder engagement records	Monthly

Impact Issue	Parameter	Location	Method of Monitoring	Frequency
Construction				
Emissions (dust)	Dust, CO2, NOx, SO2	Project site, access road and commune road	Sampling collection and analysis	Quarterly monitoring throughout construction
Emissions (noise)	Noise level (dB)	Projec site nearest residential areas	Sampling collection	Quarterly monitoring throughout construction
Water management	Government Regulation of the Republic of Indonesia No. 32/2009 About Environmental Protection and Management	Cacaban and Pandanduri Reservoir	Sampling collection and analysis	Quarterly monitoring throughout construction
Wastewater	Ministry of Environment No. 5/2014 about Wastewater Quality Standards	Project site	Sampling collection and analysis	Quarterly monitoring throughout construction
Waste (solid waste and hazardous waste)	Volume of waste generated, storage and transfer to the treatment vendors.	Project site	Site inspection and record keeping	Quarterly monitoring throughout construction
Occupational health and safety (accidents and injuries)	Health and safety incidents and Unsafe behaviours or practices	Project site	Site records detailing incidents Site inspection and observation of health and safety practices	Monthly monitoring throughout construction
Operation				
Waste (solid waste and hazardous waste)	Volume of waste generated, storage and transfer to the treatment vendors.	Project site	Measurement	Quarterly monitoring throughout operation
Water quality of Cacaban and Pandanduri reservoir	Government Regulation of the Republic of Indonesia No. 32/2009 About Environmental Protection & Management	Cacaban and Pandanduri reservoir	Site inspection and record keeping	Bi-annually or when received requests from authorities
Water demand	Volume of water used for PV panel cleaning	Project site	Flow meters	Monthly throughout operation
Occupational health and safety (accidents and injuries)	Health and safety incidents	Project site	Site records detailing incidents	Bi-annually throughout operation

All monitoring data shall be stored on site (such as site inspection and observation notes). The data generated through the monitoring plan will be used to evaluate the effectiveness of the management measures in mitigating the predicted impacts on an on-going basis during construction and annually during operation. Based on the monitoring results and the evaluation process, any issues of concern will be investigated and where required corrective actions will be implemented. Any required changes or modifications to the management measures will be reflected in the future monitoring plan.

4 STRUCTURAL ASPECTS

The FPV is relatively new in Indonesia; therefore, the local specified design criteria for FPV plants in Indonesia are still unavailable at this moment yet. All the relevant standards, both from local and international, are considered in the proposed design criteria such as:

- Ministry of Public Works & Housing No.6/2020
- SNI 1726:2019: The standard for Earthquake Resistance Planning for Building Structures
- SNI 8460:2017: Geotechnical and Seismic Design.
- SNI 1727: 2020: Minimum design loads and associated criteria for buildings and other structures.
- DNVGL-RP-0584 (2021): Design, development, and operation of floating solar photovoltaic systems
- DNVGL-OS-E301 (2018): Position Mooring
- DVGL-RP-C212 (2015): Design of offshore steel structures, general-LRFD method
- DNV-RP-C205 (2014): Environmental Conditions and Environmental Loads
- DNVGL-ST-0119 (2018): Floating Wind Turbine Structures
- API RP-2SK (2005): Design and Analysis of Station Keeping Systems for Floating Structures
- ABS Guide for Position Mooring Systems (2020)
- ABS Guidance Notes on Selecting Design Wave by Long Term Stochastic Method
- BV NI 605 (2014): Geotechnical and Foundation Design
- BV NR 493 (2015): Classification of Mooring Systems for Permanent and Mobile Offshore Units
- ISO 19901-1-2015: Metocean design and operating consideration
- ISO 19901-7-2013: Stationkeeping systems for floating offshore structures and mobile offshore units
- EN 1991-1-4:2005 Actions on Structures: General Actions-Wind Actions

4.1 Design Criteria: Environmental and Site Conditions

4.1.1 Wind

The factors and data included in the design of the FPV project and shall be considered when assessing wind conditions for an FPV project location are reference wind speed, wind profile, horizontal variation (turbulence, coherence), and transient effects. From those factors, the operationally relevant and extreme wind conditions shall be specified.

Only brief descriptions are provided here; a more detailed description of the relevant wind environmental data, modeling, and loading may be found in:

- DNVGL-RP-C205 Sec.2
- API-RP 2SK
- ISO 19901-1-2015

- EN 1991-1-4 sec 4
- SNI 1727 – 2020 Bab 26
- ABS – Guide for position mooring Systems -2020 Ch 8
- ISO 19901-1-2015
- BV 493-NR-2015 3.2

4.1.1.1 Wind model and data

4.1.1.1.1 Wind profile

Wind speed varies along time, vertical elevation, and horizontal position. To obtain these wind profile, long-term direct measurement data should be prioritized. However, noting that such data are rarely available, especially in the early design stage, a theoretical or empirical model of the wind profile may be used. The guidance for assessing the wind profile may be found in DNVGL-RP-C205 Sec.2 and API-RP 2SK Appendix B. The defining or characteristic model parameters for the wind models are:

- U10: 10-60 minutes mean wind speed at 10 m height above the ground or water surface.
- sigma10: standard deviation of wind speed about U10, obtained from the same measurement as U10
- Lu: Integral length scale of the wind speed process as defined in DNVGL-RP-C205 sec.2.3.5.5. At this length scale, the horizontal stochastic processes is assumed to be stationary.

Other models not provided in the DNVGL-RP-C205 Sec.2 and API-RP 2SK Appendix B may also be used if it can be justified by the site-specific data. Several known issues regarding the proposed wind modeling guideline are noted below:

- Most empirical and theoretical wind models are calibrated to wind data obtained over land; thus, extreme care should be exercised when applying these models to lakes or reservoirs.
- The true integral length scale of the wind speed process may deviate significantly from the proposed integral length scale of the model spectrum

4.1.1.1.2 Wind data and model parameters source

Wind data may be obtained either from measurement, hindcast, or secondary data source such as government records or national codes. Non direct measurement data should be justified and properly calibrated through direct site measurements sampling or other appropriate verification methods. This verification is needed to account for local effects and the most recent environmental conditions.

4.1.1.1.3 Wind spectra

Fluctuating wind is modeled by a steady component velocity Uo plus suitable time varying empirical or theoretical wind gust spectrum. The empirical or theoretical wind gust spectrum may be found in DNVGL-RP-C205 Sec.2 and API-RP 2SK Appendix B

4.1.1.1.4 Transient effect

When the wind speed changes or the direction of the wind changes, transient wind conditions may occur. Transient wind conditions are wind events which by nature fall outside what may be represented by stochastically stationary condition. These conditions should be considered when modelling for wind loads and therefore should be properly modeled and measured. Examples of transient wind conditions are:

- Gusts: defined as the peak of time series of wind speed, averaged over an interval of three seconds
- Squalls: intense winds characterized by a sudden onset, with a duration of the order of 10-60 minutes, followed by a sudden decrease in speed. It implies a change in the mean wind speed level. This condition significantly affects the vertical wind profile and lateral coherence, such that theoretical and empirical wind profile may not capture the phenomena properly.
- Strong wind shears
- Extremes of wind speed gradients and extreme changes in wind direction
- Simultaneous changes in wind speed and wind direction such as when wind front pass.

4.1.1.1.5 The vertical and lateral variation in wind speed

The vertical wind speed profile formula in DNV-RP-C205 sec 2.3.2 or EN 1991-1-4 sec 4.3.1 may be used. In both documents, the vertical profile is a function of terrain roughness parameter z_o and minimum vertical distance z_min. For lake or flat horizontal area with negligible vegetation and without obstacle, z_o = 0.01m and z_{min} = 1m should be used (EN 1991-1-4 Table 4.1).

Correlation between wind speed at separated lateral distances may be of importance for large PV systems and should be considered during the estimation of wind loads. Significant wind characteristics variation between two lateral points is indicated by small coherence spectrum amplitude or by a small integral length scale. In this case, separate measurement points or phase shifting of the wind spectra may be required. The integral length scale and the coherence spectrum formula can be found in DNVGL-RP-C205 sec.2.3.5.5

4.1.1.1.6 The extreme wind speed at a certain return period

The extreme speed at a certain return period may be obtained from the probability distribution function of wind speed at a certain height and relevant averaging period. The extreme wind speed shall reflect the presence of Hurricanes, Typhon, Cyclones, or other extreme phenomena.

4.1.1.1.7 Wind parameters requirements for wind loading calculations:

The following wind parameters should be determined based on sec 4.1.1.1.1 - 4.1.1.1.7

- Probability distribution of wind speed at a certain height and relevant averaging period
- Distribution of wind direction: wind rose or by other methods
- Vertical wind speed profile
- Wind spectra: may vary with lateral and vertical locations
- Lateral variation in wind speed: Lateral turbulence, wind shear, etc.
- Transient effect
- The extreme wind speed at a certain return period

4.1.1.2 Wind loading

4.1.1.2.1 Wind pressure

In general, wind pressure q shall be calculated by considering both the mean wind speed and wind speed variation as follow

$$q = \frac{1}{2}\rho_a C_p \left|\overline{U}_{T,z} + u - \dot{x}\right| \left(\overline{U}_{T,z} + u - \dot{x}\right)|$$

where

ρ_a = air density

u = Gust speed and direction variation,1 as defined in 4.1.1.1.3

$\overline{U}_{T,z}$ = mean wind speed at a given vertical position z and averaging period of T, as defined in 4.1.1.1.4

$\dot{x}$ = instantaneous velocity of the structural member

For structures where the structural velocity x_dot is negligible compared to the wind velocity, the equation can be linearized into

$$q = \frac{1}{2}\rho_a C_p \left\{ \left|\overline{U}_{T,z}\right| \overline{U}_{T,z} + \left|\overline{U}_{T,z}\right| u + |u| \overline{U}_{T,z} \right\}$$

Both frequency and time domain analysis methods may be used in the linearized form.

The turbulent intensity of the wind speed profile may be defined as the ratio sigma10/U10. A negligible turbulent intensity may indicate that approximation of wind load from U_{T,z} alone may be sufficient. On spectral analysis, negligible turbulent may be indicated by a very narrow band spectrum concentrated close to zero frequency.

4.1.1.2.2 Wind force

In general, the wind force on structures may be written as

$$F_w = C_w \, q \, S \sin sin \, (\alpha)$$

where

C_w = wind pressure and force coefficient

q = the basic wind pressure according to 4.1.1.1.8

S = projected area of the member normal to the direction of the force

α = angle between the wind direction and the axis of the exposed member or surface

Here, C_w is the general wind pressure and force coefficient. It may contain the shape coefficient, finite length effect, and solidity ratio. For PV farm that is arranged in arrays, the shielding effect play key factor and shall be included in C_w. Furthermore, in a typical PV configuration that is lifted from the ground by rigging with small blockage area, the lift force is typically significant. In this case, the lift force should be included in the wind loads calculation.

C_w and lift force may be defined through model test. The model test results can be expanded to cover wider range of cases than the one that was tested by using CFD (computational fluid dynamic) simulation, provided that the simulation is properly validated and verified.

When model test data is not available, C_w and lift force data from literature may be used on the condition that it gives more conservative value. In this regard, wind pressure and force coefficient Cw on floaters, PV, riggings, and other structural components may be obtained from **DNV-RP-C205 sec 5**, while the lift force may be obtained from **SNI-1727-2020** or **EN 1991-1-4.**

4.1.2 Waves

The factors and data included in the design of the FPV project and shall be considered when assessing wave conditions for an FPV project locations are: design wave height, period, and direction; short term stochastic value (Hs, Tp, Tz, etc); long term stochastic value (scatter diagram); wave frequency and low frequency loading; other wave loading such as land-slide generated tsunami and

Kelvin ship wave. From those factors, the operationally relevant and extreme wave conditions shall be specified.

Only brief descriptions are provided here, more detailed description of the relevant wave environmental data, modelling, and loading may be found in:

- DNVGL-RP-C205 Sec.3
- ABS – Guidance Notes on Selecting Design Wave by Long Term Stochastic Method
- Shore Protection Manual volume 1-1 (1984), chapter 3
- US Army Corps of Engineer - Coastal Engineering Manual - Part II (2015)
- ISO 19901-1-2015
- API-RP 2SK
- ABS – Guide for position mooring Syetems -2020 Ch 8
- BV 493-NR-2015

In this section, all waves refer to the a non-breaking wind generated surface gravity waves, unless stated otherwise.

4.1.2.1 Wave data and modeling

4.1.2.1.1 Wave data representation

Wave conditions which should be considered for structural and mooring design purposes, may be described either by deterministic design wave methods or by stochastic methods applying wave spectra.

- Deterministic: regular waves defined by wave height and wave period (H and T)
- Short term stochastic: irregular waves may be presented as a wave spectrum with the energy distributed over many wave frequency components or a short-term variation of water level elevation over time. The key parameters are significant wave height (Hs) and peak wave period (Tp). Directional wave spectrum may also be used in analysis, which allow for directionality information of the wave to be analyzed. This analysis requires that the phenomena be stochastically stationary over one irregular wave realization, which for wind generated wave typically assumed to be satisfied in 1 to 6 hours period.
- Long term stochastic: Typically shown as scatter diagram, which shows a long-term joint probability of occurrence for a certain Hs and Tp or Tz pair as described in short term stochastic method. The scatter diagram is analyzed in the order of years, typically longer than 10 years. This type of wave data is needed to analyze the fatigue life of the structure and for extreme design wave with a certain return period.

Definition of the key parameters described above are

- H: individual wave height, defined as the vertical difference between consecutive wave's through and wave's crest
- T: individual wave period, defined as the zero-crossing period in which H is measured. For surface gravity wave, Individual wave period are interchangeable with wave length \lambda through the dispersion relationship.
- Hs: significant wave height, defined as the mean of the top (highest) 33.3% individual wave height on the record. In a wave spectra description, Hs typically has direct relation with the area under the wave spectra mo

- Tp: peak wave period, defined as the wave period that corresponds to the peak wave energy in the wave spectra
- Tz: mean zero crossing period, defined as the mean of zero crossing period on the record

4.1.2.1.2 Regular and deterministic wave use case

Deterministic representation of wave may be used as an equivalent irregular wave loading in quasi-static analysis or non-wind generated waves (extreme waves caused by landslides, regular waves due to passing vessels, etc.).

In the quasi-static analysis, Wave Frequency (WF) response of structural elements are assessed by applying the expected maximum wave heigh / most probable maximum wave height for the duration of the irregular time series.

In the case with high intensity of human activity such as fishing and tourism, the ship induced waves shall be included in the wave loading analysis. The ship induced waves shall be calculated as a function of passing ship's displaced volume, mean annual travel frequency, and ship's speed.

4.1.2.1.3 Irregular Wave data and model

The most reliable wave data is obtained by direct site measurements. However, in the absence of a reliable measurement data, the wave data may be estimated through hindcast numerical modelling or estimation formulas. The wave data estimation should reflect the local environment as best as possible, which include fetch length effect, wind stress effect, and water depth effect. If estimation from wind speed is used, it shall be properly documented.

Two common hindcast models that typically used are the empirical formulas for fetch limited waves described in the Shore Protection Manual (1984) volume 1-1 ch.3 sec.V (SPM method) and the Breugem and Holthuijsen (2007) (B&H method). The B&H method is recommended, noting that it was based on a lake (closed water body) measurement and consider depth factor in the wave growth estimation. The B&H hindcast formula is provided below (all input are in SI units):

$$H_{S0} = \frac{H_s \times g}{U_{10}^2} = 0.24\left(\tanh tanh\,(A1)\ \tanh tanh\left(\frac{B1}{\tanh tanh\,(A1)}\right)\right)^{0.572}$$

$$T_{p0} = \frac{T_p \times g}{U_{10}} = 7.69\left(\tanh tanh\,(A2)\ \tanh tanh\left(\frac{B2}{\tanh tanh\,(A2)}\right)\right)^{0.187}$$

$$A1 = 0.343\left(\frac{gh}{U^2}\right)^{1.14}$$

$$B1 = 4.41\times10^{-4}\left(\frac{gF}{U^2}\right)^{0.79}$$

$$A2 = 0.1\left(\frac{gh}{U^2}\right)^{2.01}$$

$$B1 = 2.77\times10^{-7}\left(\frac{gF}{U^2}\right)^{1.45}$$

The fetch length F may be inferred from geometric estimation by measuring the distance from the location of observation to the upwind coast. h in the formula refers to the average up-wind water depth.

Empirical wave spectra formula may be used as an estimate for the short-term stochastic data, provided that no direct measurement data is available. The Texel-Marsen-Arsloe (TMA) spectrum is recommended as it adjust the JONSWAP spectrum to include the water depth effect for a developing sea state in a fetch limited situation. The peak enhancement factor, γ, described the bandwidth of the peak energy and may be estimated from Hs and Tp according to DNVGL-RP-C205 [3.5.5.5]. The TMA spectrum and its relation to its JONSWAP spectrum is provided below:

$$S_{TMA}(\omega) = A_{\gamma}\frac{5}{16}H_s^2\omega_p^4\omega^{-5}\,\exp exp\left[-\frac{5}{4}\left(\frac{\omega}{\omega_p}\right)^{-4}\right]\gamma^{\exp exp\left[-0.5\left(\frac{\omega-\omega_p}{\sigma\omega_p}\right)^2\right]}\frac{(kh)}{(kh)+kh\coth coth\,(kh)}$$

$$\omega_p = 2\pi/T_p$$

The spectral width parameter σ and normalizing factor A_{γ} values may be found in DNVGL-RP-C205 [3.5.5.2]

Note that both B&H hindcast formula and the TMA spectra formula indicate that the wave height diminishes with shallower depth and shorter fetch length, which also verified from field observation. Therefore, there are possibility of negligible wind generated waves in reservoir with shallow depth or small wind fetch area. On such condition, wave loading on structures may be neglected, if sufficient justification and proof is provided.

The use of other empirical formula or numerical simulation for wave hindcast is permissible, provided that it is properly justified and verified. If data is not indicating otherwise, strong correlation should be assumed between wind and waves and therefore taken at the same probability level, i.e., Hs for 50-years return period calculated from wind speed at the same return period.

4.1.2.2 Wave loading

4.1.2.2.1 Empirical formula (Morison & Maruo's Formula)

The Morison formula may assess wave frequency load on slender structures with small diameter (or other characteristic lengths) to wavelength ratio. The wave pattern is assumed undisturbed by the structure in the Morison formula. The Morison force should be applied to individual structural components (floaters, moorings, etc.)

The Morison formula may model both drag and inertia loads, including added mass effect, undisturbed wave's first order pressure force (Froude Krylov), pressure, and skin friction viscous drag. Morison formula may be represented as follow:

$$F_{wave} = \rho\forall\dot{U} + \rho\forall C_a\left(\dot{U} - \ddot{\xi}\right) + \frac{1}{2}\rho A_p C_d\left(U - \dot{\xi}\right)\left|U - \dot{\xi}\right|$$

Where:

F_{wave} = total Morison force acting on a body

ρ = density of water

$\dot{U}$ = water's acceleration due to unsteady wave action. For small wave slope, may be obtained from the first-order linear wave (airy wave)

U = water's velocity due to unsteady wave action. For small wave slope, may be obtained from the first-order linear wave (airy wave)

$\dot{\xi}$ = structure's velocity

$\ddot{\xi}$ = structure's acceleration

$\forall$ = wetted body volume subjected to the wave action

A_p = projected body area perpendicular to water's relative velocity vector

For structures with simple geometry, the added mass coefficient C_a and the Morison drag coefficient C_d may be found in DNVGL-RP-C205 App.D and DNVGL-RP-C205 App.E. Other methods, including other guidelines and codes, may be used in determining the hydrodynamic coefficients if sufficient justification is provided.

Steady mean drift force may be estimated by Maruo's formula, assuming full reflection of short waves, small diffraction, small convection, and limited relative body motion. Maruo's formula may be represented as follow:

$$F_{drift} = \frac{\rho g \zeta_A^2}{2} L \cdot sin(\theta)$$

Where:

L = length of the floating system subject to incoming waves of aplitude ζ_A.

θ =relative angle between the perimeter of length L at the incoming waves

The resulting wave drift force at each side acts normal to the perimeter, L, of the FPV system. Note that in its default form, both Morison and Maruos formula does not account for the multi-body interactions such as wake interaction effect, wave shielding effect, and wave energy absorption effects.

4.1.2.2.2 Boundary element method (BEM):

This method calculates the wave loading by direct integration of fluid pressure over panels representing the wetted surface of the structure. BEM is typically used for large volume structures, where the structure influences the wave pattern.

BEM can be used to refine the model when wave loads become dimensioning. Large wave transformation by the body (diffraction) and body motion's induced wave (radiated wave) is one of several indications that BEM analysis should be used. Note that BEM does not account for viscous effects such as wake interaction effect and viscous drag force, which may be negligible when wave height to structural characteristic length ratio (also called Keulegan Carpenter number) is small.

Hydrodynamic interaction between floats may also be studied by BEM using a multibody analysis. However, these analyses are relatively advanced and require sophisticated modeling. In addition, steady drift and higher-order wave loadings such as slowly varying wave load may also be estimated more accurately by the BEM method (compared to the empirical formula).

If frequency and wave direction-dependent drift coefficients, $C(\omega, \theta)$, are available from BEM-analysis, the mean drift load on one body should be calculated from the wave spectrum for irregular waves $S(\omega)$ by integration. With N bodies along the edge of the floating system subject to waves, the total load may be estimated as:

$$F_{drift} = N \cdot 2 \int C(\omega, \theta) S(\omega) d\omega$$

4.1.2.2.3 Computational fluid dynamics (CFD):

This method used to model the fluid motion and dynamic pressure around the structure in a more detailed manner. CFD is typically used to model various effects that was not properly captured by either BEM or the Morison Formula. These loadings include viscous effects on structures with complex geometry and nonlinear effects such as wave impact, wave overtopping, and breaking waves.

4.1.2.2.4 Model test:

It would normally not be required to carry out hydrodynamic model tests for wave loadings for a standard FPV system. However, it is recommended to do so for novel designs and for structures that will be exposed to large environmental forces. Furthermore, results from hydrodynamic model tests may be utilized later for designs/projects that are similar in shape and characteristics as the design that has been tested.

4.1.3 Current

The factors and data included in the design of the FPV project and shall be considered when assessing current conditions for an FPV project locations are: design current velocity (speed and direction) and vertical profile of the current. Only brief descriptions are provided here, more detailed description of the relevant current environmental data, modelling, and loading may be found in:

- DNVGL-RP-C205 Sec.3
- DNVGL-RP-C301 Sec.2
- ISO 19901-1-2015
- API-RP 2SK
- ABS – Guide for position mooring Syetems -2020 Ch 8
- BV 493-NR-2015 3.2

Just like wave, current phenomena are generally prevalent in water bodies with large area and high depths. Several preliminary studies on environmental condition for man made reservoir suggested that the current only

4.1.3.1 Current data and modeling

When long-term measured current profile data sets are available, design current profiles can be derived by parametrizing the data using so-called empirical orthogonal functions (EOF). This technique is used for representing a set of spatially distributed time series as a sum of orthogonal spatial functions $b_m(x)$ (EOFs) multiplied by their temporal amplitudes $w_m(t)$. A current profile at location x can then be expressed as:

$$V_c = \sum_{m=1}^{M} b_m(x) w_m(t)$$

4.1.3.1.1 Inlet and outlet flow generated current

In the case where site measurements is not available, the inflet and outlet flow generated current may be estimated by simple numerical modelling. The historical data of flow rate at the inlet and spillway may be used as boundary conditions that drives the flow. The flow should properly accounts for bathymethry effects and shows the spatial and temporal distribution of the currents

4.1.3.1.2 Wind generated current

In reservoirs with large surface area and deep water, current may be generated by wind stress at the water surface. If statistical or direct measurement data is not available, the wind generated velocities at the still water level may be approximated by the following formula

$$V_{c,wind}(0) = 0.015 \cdot \overline{U}_{w,1hr,10m}$$

When detailed field measurement are not available, the wind generated vertical profile may be calculated by

$$V_{c,wind}(z) = V_{c,wind}(0)\left(\frac{d_o+z}{d_o}\right) \qquad \text{for } -d_o \leq z \leq 0 \text{ (linear profile)}$$

Or

$$V_{c,wind}(z) = V_{c,wind}(0) \qquad \text{for } -d_o \leq z \leq 0 \text{ (slab profile)}$$

Where d_o is the reference depth for wind generated current in which the current is assumed to vanish. $d_o = 50m$ may be used as the default value.

4.1.3.2 Current load

For a site with presence of current, the effect of the current loads on the float and mooring system shall be assessed. The FPV system would typically have a large area of submerged parts potentially exposed to current forces with the main contribution from floats, however the mooring lines and power cables may also be relevant. Current would mainly give rise to static loading on the system. To assess the loads, it is important to determine the current force coefficients which describes the current load characteristics on a floating structure. They may be obtained by the following methods depending on the required level of accuracy:

- analytical formula
- wind tunnel tests
- water basin/towing tank
- CFD.
- Other approved methods

Analytical formulas may be sufficient for establishing current force coefficients for simple pontoon designs. Typical analytical formula for current loading follows the same form as the one in morison drag formula, which is proportional to the current velocity squared multiplied by drag coefficient C_d. The same drag coefficient C_d as the one used in hydrodynamic wave loadings shall be used (DNVGL-RP-C205 App.D and DNVGL-RP-C205 App.E).

For multi-body floating structures the shielding and wake interaction effect of current may also be important. Guidance about shielding effect of current is provided in DNVGL-RP-C205 [6.10].

4.1.4 Seismic / earthquake

Indonesia is located in the most active belts in the world, also well known as the Ring of Fire, i.e., the Circum-Pacific belt. This belt contributes about 90% of the world's (Kramer, 1996). Therefore, seismic activities need to be considered in designing structures or infrastructures in Indonesia.

The level of seismic activity of the area where the FPV system will be installed shall be assessed by local codes for seismic resistant design (such as SNI or other relevant International codes) on the basis of previous records of earthquake activity, especially if an identified active faults near the project location. The return period of the earthquake shall follow the Operating Basis Earthquake (OBE) and Safety Evaluation Earthquake (SEE) of the Dam. This information is required to assess reservoir slope stability with the current soil conditions and the earthquake loads based on SNI 8640 2017.

Suppose the area is determined to be seismically active (close to active faults). In that case, the regional and local geology shall be evaluated to determine the location and alignment of possible active faults. In addition, local soil conditions shall be considered to the extent that they may affect the ground motion. The seismic design, including the development of the seismic design criteria for the site, shall be following recognized industry practice.

Based on literature studies, consequences examples of earthquake actions have been identified as potential threats to floating PV:

1) Induced landslides on reservoir rims that might impact FPV anchors; and may induced tsunami like waves that add undue loading to the structures
2) Rocks falling from nearby slopes and potentially impacting FPV panels
3) Reduction in slope stability in sloping bathymetry which might impact FPV anchors and mooring tensions
4) Dynamic loading to the anchor and mooring in the case of structures with taut moorings

Therefore, in seismically active areas, analysis for all the above events plus other potential threats that were not included in this documents but deemed necessary based on engineering judgements, should be included in the design phase.

4.1.5 Other environmental effects

Some environmental phenomena set up boundary conditions for the FPV system in the load assessments. The value to be used depends on the type of environmental phenomena, it will either be a specified value or shall be selected conservatively as an associated value conditioned on the studied environmental parameter. Here are some examples:

- Water level:
  Structural analysis for full range of water level variation (flood level, normal level, and low water level) should be shown in the design phase
- Marine growth:
  The fully developed marine growth should be applied when necessary. This may increases the permanent load due to the additional mass and the dynamic load due to change of structure's geometry.
- Scouring and sedimentation:
  These conditions may change the mooring tension, stranded condition occurance, and other environmental condition due to the change of bathymetry. The presence of the FPV may also change the sedimentation and scouring characteristic of the reservoir. Both effect should be carefully studied in locations that shows significant scouring and sedimentation occurance. Sedimentation rate is also important due to its correlation to the service life of a dam, and consequently the design service life of the floating PV.

4.2 Design Criteria: Structural Design Basis

4.2.1 General structural model considerations and analysis method

The global model of an FPV system shall:

- represent the individual floating elements that constitutes the complete structure as realistically as possible. Aggregate modeling such as hydro-elasticity model which represents the complete structure as a whole may also be used, provided the dynamic characteristics of the individual floating elements are properly represented (i.e., mode shape, local loading, etc.)
- include realistic connections between floats
- capture all relevant loads
- include the mooring system.
- The model shall perform both static and dynamic load assessment with a realistic representation of the environmental actions in time domain.

The global model shall be used to assess the following, including but not limited to:

- the global motions
- the mooring tension

- the forces in connection between floats
- inputs (e.g. float accelerations) for detailed structural assessments.

4.2.2 Structural response to environmental loading

Three distinct structural response may occurs due to the applied loadings:

- Mean displacement / offset:
  defined as mean displacement due to mean dynamic environmental loads and static loadings. These loadings Include include mean wave loading (from non-linear drag, wave drift loading, etc), mean current loading, mean wind loading, mooring pretensions, etc.

- Low frequency (LF) response:
  defined as motion with typical natural period of 1-10 minutes, typically occurs in surge, sway, and yaw degree of freedom. This may comes from the wind loads and second-order wave loads. Along with the mean load, the low frequency motion are especially important in the determining the mooring tension and floater's offset. In this frequency region, the effect of additional mooring stiffness on the floaters become important.

- Wave frequency (WF) response:
  defined as motion that is excited by wave frequency cyclic loads with typical periods ranging from 5-30 seconds. This motion typically independent of mooring stiffness, unless for several cases such as:
  - small floating structures where first order loads are not large
  - moored floating body with natural frequency close to the wave frequency.

  Direct environmental loads and floaters motion in this frequency range is also typically in determining the mooring's fatigue life.

Three different loading-structures interaction analysis method may be used for different type of loadings and different design phase

- Dynamic analysis:
  Dynamic analysis in the frequency or the time domain is required to analyze complex structures under severe dynamic (time varying) loadings. The analysis should cover all dynamic effects, such as time variation, stochastic processes, relative motion effects, dynamic amplification factor, resonance, fluid acceleration (added mass), all critical degree of freedom, damping, stiffness, inertia, etc. This analysis method should always be prioritized, unless sufficient justification and verification is presented. In that case, the two alternative analysis method below may be used

- Quasi-Static analysis:
  For quasi-static analysis, the wave frequency (WF) response of structural elements to irregular wave's dynamic loadings is calculated as the structural response to the equivalent regular wave. The equivalent regular waves has a height that is equals to the expected maximum wave height (MPM) for the duration of the irregular time series, with period obtained from the wave's height-period correlation from the long-term irregular waves data (scatter diagram). Resonance load case should also be checked, in the case where the wave loading from the resonance frequency component generated larger loading than MPM wave case. This method is not applicable for mooring-related responses, e.g. line tension, which are influenced by low frequency dynamics LF dynamics. For these responses the complete dynamic analysis shall be applied.

- Static analysis:

A static load assessment may be sufficient to cover critical load scenarios for less severe environmental actions and insignificant structural dynamic response. Therefore, this calculation method is not suited to determine load distribution in a complex mooring line configuration or stress concentration between floats.

Simplified dynamic effects may be included by applying the maximum dynamic load above the mean load, multiplied by the dynamic amplification factors (DAF). A static assessment by load estimation, e.g. simple scripts or spreadsheet calculations may be useful for the following design considerations:

- Local wind pressure loads
- Global loads to establish main float dimensions and the number of mooring lines

4.2.3 Design principle and safety philosophy

The structure to be designed is assigned a consequence category based on the consequences of failure. The categorization is normally determined by the purpose of the structure. For each consequence category, a target safety level can be defined in terms of an annual probability of failure. These target safety levels are aimed at for systems whose failures are ductile and have some reserve capacity. These target safety levels apply to systems which are correctly planned and built, i.e. without systematic errors.

The target safety level is the safety level aimed at for the entire system and will in practice also be the safety level for individual failure modes, since one failure mode is usually dominating. It is intended for use both in case of local failures in hot spots and in case of failures with system effects, such as failure in the weakest link of a mooring line.

The recommended target safety levels for two different consequence of failure are defined as below:

Table 4-1. Target Safety Level Based on Consequence Category (DNVGL-RP-0584)

Consequence category	**Definition**	**Target safety level / nominal annual probability of failure**
1	Failure is unlikely to lead to unacceptable consequences such as loss of life, collision with an adjacent structure, and environmental impacts	10^{-4}
2	Failure may well lead to unacceptable consequences of these types	10^{-5}

The target safety level may be calibrated if dam safety is considered separately from the floating PV, or any other acceptable justification is shown and approved in the early design phase. Any increase and reduction of target safety level may be reflected on the change of return period of the loadings and/or change of the partial safety factor.

The target safety level is met as close as possible by applying the partial safety factor method as a design method. This shall be achieved by applying load and resistance factors to characteristic values of the governing variables and subsequently fulfilling a specified design criterion expressed in terms of these factors and these characteristic values. The characteristic values of loads and resistance, or of load effects and material strengths, are chosen as specific quantiles in their respective probability distributions. The safety level of a structure or a structural component is considered to be satisfactory when the design load effect Sd does not exceed the design resistance Rd:

$$S_d \leq R_d$$

$$S_c \bullet \gamma_s \leq \frac{R_c}{\gamma_m}$$

$$\left(G \bullet \gamma_{fG}\right) + \left(Q \bullet \gamma_{fQ}\right) + \left(E \bullet \gamma_{fE}\right) + \left(D \bullet \gamma_{fD}\right) + \left(P \bullet \gamma_{fP}\right) \leq \frac{R_c}{\gamma_m}$$

Where

S_c = characteristic load effects, related to the return period and other specified values depending on operational requirements. This corresponds to a certain annual probability of exceedance of the design loads.

γ_s = load factor. Account for uncertainty in characteristic load effects determination.

R_c = characteristic resistance. Obtained as a specific quantile in the distribution of the resistance. It may be obtained by testing, or it may be calculated from the characteristic values of the parameters that govern the resistance.

γ_m =material factor. Account for unfavourable deviation in the material resistance from its characteristic values and possible reduction of the material resistance

For fatigue limit state, both load factor γ_s and γ_m is taken as 1 (limited to metallic components)

The general basis for determining the characteristic loads (S_c) in the design limit states as a function of load categories are summarized at table below.

Table 4-2. Basis for characteristic load in design condition (DNVGL-RP-0584)

Load Category	Limit states – operating design conditions				
	ULS	FLS	ALS		SLS
			Intact Structure	Damage Structure	
Permanent (G)	Expected value				
Variable (Q)	Specified value				
Environmental (E)	50-year return period	Expected load history	500-year return period	1-year return period	Specified value
Accidental (A)	Specified value				
Deformation (D)	Expected extreme value				
Prestressing (P)	Specified value				

Where each categorization of loads are defined as follow:

- Permanent loads (G):
  These include mass of the structure and permanent ballast, mass of installed components including PV modules, cables, and other equipment, as well as pretension loads.

- Variable functional loads (Q):
  Variable functional loads are loads which may vary in magnitude, position, and direction during the period under consideration, and which are related to operation and normal use of the structure in question.

- Environmental loads (E):

Environmental loads are loads caused by environmental phenomena. Individual environmental actions (e.g. wind, waves, current) shall be assumed omnidirectional and collinear unless site data stating otherwise is available, which then allows for directional design. Wave's, current (wind generated only), and wind is assumed to be strongly correlated, thus their design return period shall always be the same.

For non-wind generated currents, two design return period combinations shall be used, the first is where the current has 1/10 of the probability of exceedance of wind and waves, the second is where the wave and waves has 1/10 of the probability of exceedance of current. For example: 1st case is for 50-year wave and wind return period + 5-year current return period, and the 2nd case is for 5-year wave and wind return period + 50-year current return period.

- Accidental loads (A):
  Accidental loads are loads related to accidental events, abnormal operations, or technical failures. Accidental loads that shall be considered include but are not limited to loss of mooring line(s), loss of buoyancy, and dropped objects.

- Deformation loads (D):
  Deformation loads are loads caused by inflicted deformations such as temperature loads, creep loads, and settlements of foundations.

- Prestressing loads (P):
  Prestressing loads are loads that are applied to different components, first, to induce desirable strains and stresses in the structure and second, to counterbalance undesirable strains and stresses.

Note that load γ_s and resistance factors γ_R recommended in this RP are not yet calibrated specifically for FPV systems, by means of structural reliability methods, to match target safety level in [4.2.1.3]. The load factors are consistent with DNVGL-ST-0119 (floating wind turbine design guideline), which applies the same safety philosophy as in this document, i.e. the load factors are intended to target a nominal annual probability of failure of 10E-4 in consequence category 1 and 10E-5 in consequence category 2.

The complete methodology (design principles, load factors, environmental return periods and analysis methods) from alternative standards or guidelines may be applied and it shall be justified that the overall level of safety is not less than given herein. In addition, any regional and national requirements shall be adhered to as applicable.

4.2.4 Limit sate definition

A limit state is a condition beyond which a structure or a structural component will no longer satisfy the design requirements. The following limit states are considered in this design:

- Ultimate limit state (ULS):
  corresponds to the maximum load-carrying resistance For ULS, the idealized system is analyzed, i.e., applying the as designed prestressing loads, anchor positions, line lengths, line tensions, etc.

- Accidental limit state (ALS):
  corresponds to the survival condition in a damaged condition or the presence of abnormal environmental conditions

- Fatigue limit states (FLS):

corresponds to failure because of cumulative damage of cyclic loading. All environmental loads with cyclic behaviour shall be taken into account to verify the float structure and components fatigue damage estimation.

The design cumulative fatigue damage may be expressed as

$$D_d = DFF \cdot D_c$$

Where D_c is the characteristic cumulative fatigue damage caused by the stress history in the mooring line over the design life, and DFF denotes the Design Fatigue Factor. The dynamic time- or frequency-domain analyses are required to calculate the cumulative fatigue damage Dc.

The design cumulative fatigue damage DD shall not exceed the design life of the structures. Detailed guidance on how to estimate the cumulative fatigue damage is given in DNVGL-OS-E301 Ch.2 Sec.2 [6], API-RP-2SK Ch.6 & 7, or ISO 19901-7-2013 Ch 9.

The DFF for metallic units with the low consequence of failure and where it is demonstrated that the structure satisfies the requirement to damaged condition according to the ALS with failure in the actual element as the defined damage is given in the table below.

Table 4-3. The DFF value for different metallic structural elements (DNVGL-RP-0584)

Metallic Structural element	DFF
Internal structure, accessible and not welded/attached directly to the submerged part	1
External structure, accessible for regular inspection and repair in dry and clean conditions, e.g., welds and bolted connection in PV mounting structure of modular rafts	1
Internal structure, accessible and welded/attached directly to the submerged part, e.g. any attachments to the floats	2
External structure not accessible for inspection and repair in dry and clean conditions e.g. anchors connection	2
Non-accessible areas, areas not planned to be accessible for inspection and repair during operation	3

The DFF for mooring line as a function of consequence category are given in table below

Table 4-4. The DFF for the mooring line

Structural element	DFF	
	Consequence Category 1	Consequence Category 2
Mooring systems and its components	5	10

DFF for polymer material of a given float may be obtained either by material testing or provided by the manufacture. The polymer fatigue test shall consider 80% material strength and at least 100,000 number of cycles. DFF for other materials such as ferrocement/aluminium should be assessed on a case-by-case basis. Other specific test requirements may follow the list of test standards accepted by the DNVGL-RP-0584 Ch.5.7.2 or If an equivalent SNI test standard exists or their equivalent.

- <u>Serviceability limit states (SLS):</u>
  corresponds to project-defined criteria applicable by intended use such as:
  - displacements or rotations that may change the distribution of loads between supported rigid objects and the supporting structure

- excessive vibrations and accelerations producing discomfort or affecting non-structural components
- deflections/stresses which may prevent the intended operation of equipment
- stresses, deflection and vibrations which may cause hindrance during maintenance.

During the SLS analysis, maintenance operation shall be foreseen and used as the design cases. The loads in SLS could be caused by the normal environmental condition and pre-specified maintenance operations

- Other limit states and design checks:

unless noted otherwise, a specific design check should be performed for stranded conditions (i.e., zero water level) when the floating PV is located in locations where a historical record shows a possibility for zero water level. The design check for the stranded condition is especially important in these conditions:

- The ground basin slope variation is relatively high (i.e., irregular basin) or is considered to be rocky. In this condition, the ground slope might introduce undue loading distribution on the floaters and other structural components
- The ground basin consists of soft soil, high sedimentation, or muds. In these conditions, floaters, moorings, and other support systems may partially sink or buried in stranded conditions, such that it will pose a problem when the water level rises.

Other special events with a low probability of occurrences, such as earthquakes, landslides, squalls, and accidental impact loading, shall be assessed as separate ALS cases.

4.2.5 Floaters

The floats supporting the mounting structure shall provide adequate buoyancy and stability to ensure that walkways and electrical components which are not designed to be submerged do not come into contact with the water body. The floats shall be able to transfer loads from the mounting structure without failure of joints or members of the mounting structure. The level of deformation of the floats caused by the loads shall not damage the mounting structure and shall not place excessive loads on the PV modules.

$$\left(G \bullet \gamma_{sG}\right) + \left(Q \bullet \gamma_{sQ}\right) + \left(E \bullet \gamma_{sE}\right) + \left(D \bullet \gamma_{sD}\right) + \left(P \bullet \gamma_{sP}\right) \le \frac{R_c}{\gamma_m}$$

γ_m =material factors of floaters and its supporting components. For ULS and ALS of metallic and composite materials may be found in different international and local standards or from physical testing of materials. Further guidance can be seen in EN1990-2002 Annex A1, DNVGL-OS-C101 Ch.2 for steel material, and DNVGL-ST-C501 App.E for composite material. Material factors for aluminum may be obtained from EN 1999-1-1.

The load factor γ_f based on load component combinations and design limit state to be considered in the overall strength analysis for the design of floating support structures and moorings for FPV systems are specified in the table below.

Table 4-5. Load factor γ_f for ULS and ALS (DNVGL-RP-0584)

Load factor set	***Limit state***	***Load categories***					
		G	***Q***	***E- with consequence category of***		***D***	***P***
				1	***2***		
(a)	ULS	1.25	1.25	0.7^1		1.0	$0.9/1.1^3$
(b)	ULS	1.0^2	1.0	1.35	1.55	1.0	$0.9/1.1^3$

(c)	ALS – intact	1.0[2]	1.0	1.0	1.15	1.0	$0.9/1.1$[3]
(d)	ALS – damaged	1.0[2]	1.0	1.0	1.15	1.0	$0.9/1.1$[3]

1) When environmental loads shall be combined with functional loads from boat impacts, the environmental load factor should be increased from 0.7 to 1.0 to reflect that boat impacts are correlated with the wave condition
2) It is assumed that tight weight control of the structure is performed for floats. If sensitivity studies show risk for excessive dynamic excitations, the load factors for permanent loads should be varied between 0.9 and 1.1
3) The most conservative value of 0.9 and 1.1 should be used as load factor design

The use case for each load factor set is defined as follow:

a) Used when the variable functional loads like design against pretension, lifting forces and hydrostatic pressures is governing. Also, load factor set 'a)' is of relevance for the design of secondary structures such as boat landings, fenders and lay down areas, for which variable functional loads from boat impacts are the dominating loads.
b) Used for ULS design when the environmental load is the dominating load, for instance, the high-speed wind during FPV array operation.
c) Used for ALS design in an accident situation. Accidents may include but are not limited to impact from unintended collision by drifting service vessel/debris, impact from a dropped object, failure of mooring line/anchor.
d) Used for ALS design in a post-accident situation

Where G, Q, E, D, and P are the characteristic loads as defined in sec. 4.2.3.

The characteristic load acting on floater systems would also be affected by their configurations. Examples of various floater systems configurations of floating PV for reservoir applications may be found in:

- R. Cazzaniga, “Floating PV structures,” in Floating PV Plants, Elsevier, 2020, pp. 33–45
- “Panduan Perencanaan PLTS Terapung,” Dirjen EBTKE-Kementrian ESDM, 2021, section 3.2.1

The characteristic resistance of the floaters (R_c) may be obtained from the allowable maximum load acting on the floater system components (materials, connections, floats, riggings, etc), and shall be estimated from mechanical testings. Several examples of the required mechanical testing for floater systems are shown in Table 4-6.

Table 4-6. Examples of required mechanical testing for floater systems and their components

Test type	**Component**	**Explanation**	**Example of related guidelines and standards**
Flexure	Subassembly of floats and interconnection	The bending strength of the material shall be tested according to the expected wave height	ASTM D790 & D695: Plastic ASTM E190&E290: Metallic ASTM D7264: Polymer Composite
Compression and tension test	Floaters	Tested for tensile strength before breakage and compressive strength before deformed	ASTM D638 & D695: Plastic ASTM D3039 & D6641: Polymer Composite ASTM E8 & E9: Metals
Durability	All components	Tested for long term	Fatigue:

		performance under load, typically against tensile, compressive, and flexural creep and fatigue	ASTM D7791: Plastics ASTM D3479: Polymer Composite ASTM E466: Metallic Creep: ASTM D2990: Plastics ASTM D7337: Polymer Composite ASTM E139-11: Metallic
Tension test	Subassembly of floats and interconnection	Shall be recorded when first breakage in any float/interconnection occurs.	ASTM D638: Plastic ASTM D3039: Polymer Composite ASTM E8: Metals
	Interconnecting elements (plates with fasteners, latch, pad eyes, etc.)	Shall be tested to identify the tensile strength	
Shear strength	Fasteners (if applicable)	Tested in accordance with relevant standards	ISO 3597 for reinforced plastic and ASTM D5379 for composite material
Puncture	Load carrying floaters that is susceptible to punctures (if applicable)	Susceptibility to puncture includes a lost of load carrying capabilities when punctured	ASTM F1306 and ASTM D3763
Impact	Components made of polymers	Tested in accordance with relevant standards	ISO 179-1, ISO 180, ASTM, D256. ASTM D6110.

The related guidelines and standards shall only be treated as examples. The standards that is used on the actual testing shall consider the properties, shape, and configuration of the examined components. In addition to the mechanical testings, other non-mechanical testings that may affect the floater design, along with the related test standard examples are:

- UV degradation: ISO 4892-3, ISO 4892-2, STM G154, ASTM G155 and EN16472:2014
- Thermal degradation: ASTM E794 – 06, ISO 11357-6
- Fire resistance: ASTM E119, ASTM E84, ASTM D635, ASTM D3801, ISO 9773, ISO 9772

4.2.6 Mooring

The table below provides a summary of the recommended load cases for mooring and anchor design analysis for ULS and ALS.

Table 4-7. The recommended load cases for mooring and anchor design analysis for ULS and ALS

ID	Limit State	System condition	Environmental return period (years)	Annual Prob. Of exceedance	Environmental direction
ULS – 1	ULS	As-designed	50	2%	0-360 deg
ULS – 2	ULS	Uneven load distribution	50	2%	Critical directions from ULS-1
ALS – 1	ALS	Critical area failure	1	100%	Critical directions from ULS-1
ALS – 2	ALS	Corner failure	1	100%	Corners
ALS – 3	ALS	Loss of buoys	1	100%	Critical directions from ULS-1

ID	Limit State	System condition	Environmental return period (years)	Annual Prob. Of exceedance	Environmental direction
ALS – 4	ALS	Transient line failure	1	100%	Corners
ALS – 5	ALS	Robustness	500	0.2%	Critical directions from ULS-1

In ALS, the mooring system in the damaged condition is assessed. Redundancy in the mooring system shall be demonstrated, i.e., that a single line failure will not lead to the progressive collapse of multiple lines. For systems with many mooring lines (above 30), failure in critical areas should be evaluated rather than single line failures. It is recommended to evaluate a 2-lines failure scenario in the critical areas.

Critical areas are defined as for the ULS. For systems with more than 30 mooring lines, it is recommended to define critical areas including about 10 lines adjacent to each of the most utilized lines. For corners, at least the 2 first lines on either side should be included in the critical area. For each critical area, failure of at least 2 mooring lines should be assessed. The utilization of the remaining lines are calculated.

Removal of corner lines shall always be included as load cases in the ALS analysis.

In addition, to analyze the non-linearity in the mooring system response characteristics, it is recommended to carry out an analysis applying a larger environment return period than for normal ULS conditions. A sensitivity check for uneven load distribution is not required for the robustness check.

$$T_d \leq R_d$$

$$T_{c,mean} \bullet \gamma_{s,mean} + T_{c,dyn} \bullet \gamma_{s,dyn} \leq \frac{R_c}{\gamma_m}$$

Where

R_c = characteristic resistance of mooring. May be obtained from the minimum breaking load of the component in the individual mooring line.

T_c = characteristic tension of mooring, obtained from maximum line tension as it is exposed to the characteristic environmental load S_c. Subscript mean and dyn represents mean and dynamic component, respectively.

γ_m = material factor of mooring, equals to 1 for ULS and ALS in mooring line analysis

γ_s = load factors, as given in table below

Table 4-8. Load factors for tension in mooring lines (DNVGL-RP-0584)

Limit states	Load factor	Consequence Category 1	Consequence Category 2
ULS	$\gamma_{s,mean}$	1.30	1.50
ULS	$\gamma_{s,dyn}$	1.75	2.20
ALS	$\gamma_{s,mean}$	1.00	1.00
ALS	$\gamma_{s,dyn}$	1.10	1.25

Applying a two-factor format reflects the fact that there are larger uncertainties related to the dynamic part of the line tension than the mean part of the line tension.

The characteristic tension of mooring would also be affected by their configurations. Examples of various mooring systems configurations of floating PV for reservoir applications may be found in:

- T. Whittaker, M. Folley, and J. Hancock, “Environmental loads, motions, and mooring systems,” in Floating PV Plants, Elsevier, 2020, pp. 47–66.
- “Panduan Perencanaan PLTS Terapung,” Dirjen EBTKE-Kementrian ESDM, 2021, section 3.3.1.
- This document, 6.1.6 and 6.2.6.

4.2.7 Anchor

ULS: ensure that the anchor with its geotechnical anchor resistance can withstand the loads arising in an intact station keeping system under extreme environmental conditions

ALS: ensure that the anchor can withstand the loads arising in an intact station keeping system under accidental load conditions, or to ensure that the damaged station keeping system retains adequate capacity if one mooring line or one anchor fails.

Both of these conditions may be accomplished by achieving the following condition in all design limit states:

$$T_d \leq \frac{R_c}{\gamma_m}$$

Where

R_c = characteristic geotechnical anchor resistance. Obtained from the mean anchor resistance as set up by the supporting soils or rock. It shall be estimated based on site-specific soil data. For additional guidance on the determination of characteristic soil properties, see DNVGL-RP-C212. The geotechnical anchor resistance should consider all possible foundation failure modes. Example of such failure modes are:

- Bearing failure
- Sliding
- Overturning
- Anchor pull-out
- Large settlements or displacements

T_d = design load factor, equals to the design tension of mooring T_d in sec 4.2.6. Loadings other than mooring tension should be considered, if they show to have a significant effect to overall design load factors.

γ_m = material factors. Details of material factors calculation for various type of anchors may be found in DNVGL-OS-C101 Ch.3-Ch5 Sec.10. More general material factors obtained by adopting more conservative values may be found in DNVGL-RP-0584 at Table 4-9 below.

Table 4-9. Anchor material factors, γ_m (DNVGL-RP-0584)

Limit states	Load factor	Consequence Category 1	Consequence Category 2
ULS	γ_m	1.30	1.30
ALS	γ_m	1.00	1.30

When the structure is located in a seismically active region, the effects of earthquakes on the slope stability shall be included in the analyses, as it may affect the design anchor resistance and the design load factor.

4.2.8 Floating PV Layout and Location

A simpler rectangular PV layout configuration should always be prioritized against a more complex layout. If the targeted floating PV area is too large, it should be broke down into smaller sizes. These recommendation is made base on the following considerations:

- Yamakura incident study (Fukuwatari & Ueda, “The accident at Yamakura, Japan”, Solar-Hydro, 2021) shows that the main reason of the floating PV failure is because of high stress variation and concentration across the floater, mooring connection points, and anchors, on the inner corners of floating PV. These stress variation and concentration is shown to be greatly decreased when a simpler rectangular floating PV layout is adopted.
- A more complex geometry where all floating PV is interconnected may minimize the cost of mooring line and anchor systems. However, any failure to the system will affect the structural stability as a whole. For a system where large floating PV area is broken down into smaller islands with simpler geometry, any failure to one sub-system is expected to be isolated to that particular sub-system.

Maximum offset of the floating PV should be assessed so that it will not go pass the permittable water circle or zoning area. When frequency domain approach is used for the simulation of vessel dynamics, the maximum offset is defined as follow (API-RP 2SK):

$$S_{max} = max(S_{max1}, S_{max2})$$

$$S_{max1} = S_{mean} + S_{lfmax} + S_{wfsig}$$

$$S_{max2} = S_{mean} + S_{wfmax} + S_{lfsig}$$

Where

S_{max} = maximum vessel offset

S_{mean} = mean vessel offset

S_{wfmax} = maximum wave frequency motion

S_{wfsig} = significant wave frequency motion

S_{lfmax} = maximum low frequency motion

S_{lfsig} = significant low frequency motion

Alternatively, time domain approach or combined time and frequency domain approach may be used. In the combined time and frequency domain approach the statistical peak of the wave frequency motion is obtained from the frequency domain and then superimposed to the time domain mean and low frequency motion.

Environmental conditions, motions and consequence of breakage of one anchor line during the operation shall also be considered in order to establish sufficient clearance. Detailed information is given in DNV-OS-H203.

The following criteria for choosing the floating PV location shall be used, unless appropriate justification and careful consideration is shown in the design process:

- floaters and anchors should be chosen in locations that avoid stranded condition on any water level.
- floaters should be chosen in locations where the static loading direction, causes the floaters to drift away from spillways and other critical dam structures in the case of mooring or anchor failures

In addition, the following criteria for choosing the floating PV location should always be complied:

- floaters, moorings, and anchor location should not interfere with operational requirement of the reservoir structures, i.e., they should not block intake flow, dam/reservoir inspection routes, and regular bathymetric survey route, nor cause significant backwater. These conditions should be complied in both installation and in-place condition.
- floaters, moorings, and anchor location should be outside the designated safety zones and does not interfere with critical function of the reservoir structures such as the intake and spillway structures and should avoid unnecessary risk to floating PV. This may be shown by the offset analysis shown above, multiplied by appropriate safety factor. The determination of the safety zones may also include the analysis of the following aspects:
    - Uncontrolled drift
      Example of such analysis is to analyze the probability of occurance of uncontrolled drift of floating PV in certain area to actually reach a critical reservoir structures. The analysis may also include the time taken for uncontrolled drift of floating PV to reach the critical reservoir structures. The safety zone therefore should be chosen such that the event has low probability of occurrence (i.e. due to the layout of reservoir and predominant wind direction) or the drifting time is acceptably long such that remedial action could be taken.
    - Potential hazard from existing activities such as aquaqulture and tourism
      Example of such analysis is the ship generated waves analysis and its effects to floating PV performance. The ship generated wave analysis may provide a good approximate for ship route, ship size, or speed restriction in certain area.
    - Land slide hazard from nearby reservoir slopes.
    - Other project and location specific factors that is deemed as potential hazard.

  If such analysis is not available, a conservative value of 500m from the outermost part of the structure may be used.

4.2.9 Dam safety

The objective of the Dam Safety requirements in its relation to the presence of the floating PV is to guaranty that a residual risk and safety factor for the dam is low enough to be acceptable. Three options may be chosen to obtain this goal:

1) Keep the floating PV probability of failure low. Preferably lower than the total probability of failure of the dam during the floating PV design service life. This will results in a high design requirement for the PV.

2) Disconnect the floating PV safety requirements from the dam safety requirements, where the probability of failure of the dam does not directly tied to the failure of PV.

3) Design the safety requirements of the dam with the presence of the floating PV in place.

Point 1) may be achieved by strengthening the design criteria, i.e., keeping the annual probability rate of failure of floating PV as low as practically possible), or by reducing the loads acting on the floating PV. Reduction of loads to the floating PV may be achieved by improving the structure shapes to reduce loads, installation of wave breakers, or installation of barriers to reduce the risk of accidental impact by boat or debris. This method, however, may result in CAPEX and/or OPEX increase of the floating PV.

Point 2) may be achieved by designing a preventive mitigation plan should critical floating PV failure occurs (e.g., uncontrolled drifting due to mooring line failures) and should the critical dam failure occur (e.g., dam break event). One example of this mitigation plan is to have multiple safety barriers (physical and non-physical). These safety barriers may take the form of the choice of floating PV location, an anti-drifting device such as log boom in the downstream direction, etc. With these multiple barriers, the probability of failure of the dam becomes detached from the floating PV probability of failure, but instead tied to the joint probability of failure of all the safety barriers mentioned earlier.

Point 3) may be achieved if the dam is still considered as greenfield, such that dam design and/or structural modification is still possible. In this option, dam structure may be designed in such way that its design takes into account of a possible PV failure. This method, however, may results in CAPEX and/or OPEX increase of the dam structures.

5 FINANCIAL AND BUSSINESS ASPECT

5.1 Policy and Regulation Analysis

5.1.1 Energy Tariff in Renewable Energy in Indonesia

Ministry of Energy and Mineral Resource (EMR) is responsible for power sector policy and regulation in Indonesia, which includes regulation of electricity tariffs, as well as procurement and contracting of renewable energy (RE) generation by the State Electricity Company (PLN).

EMR's overriding power sector policy objective since the start of 2017 has been to ensure affordability of electricity. Given that the Government of Indonesia also aims to reduce subsidies to PLN and simultaneously maintain PLN's financial health, the unwillingness to increase tariffs triggers a need to minimize PLN's costs. As part of this effort, in 2017, EMR's replaced existing regulations on the pricing of RE purchases by PLN with new regulations capping the price of most renewable technologies at some percentage of PLN's generation production cost (BPP).

BPP is calculated by PLN region (roughly corresponding to provinces) and small isolated systems based on PLN's accounting cost of generation for the previous year in that region or system. The key regulation governing RE pricing is PERMEN ESDM 50/2017 on Utilization of Renewable Energy Resources for Electricity Supply, as amended by 53/2018.2 RE power prices are negotiated between PLN and the developer, and subsequently approved by EMR (which may involve renegotiation). If the project is located in an area where the regional BPP is greater than national average BPP, then the negotiated price cannot exceed either 85% or 100% of the regional BPP depending on the technology.

The current pricing methodology raises three important concerns as regards RE development, some critical issues on BPP calculation such as:

- BPP and prices linked to it are below the cost of some, but not all new RE projects, meaning these projects are not financially viable for developers. Figure 5-1 compares current BPP and price caps derived from it with estimates of the costs of illustrative new RE projects. Geothermal and wind projects are generally unlikely to be viable at current price caps, but solar and minihydro projects will often be viable at prices below regional BPP, if other impediments to their development can be overcome.
- BPP relies on average depreciated book value together with a financing charge allocation to represent capital costs of PLN generation. It is very likely that new fossil fuel generation capacity of the same technology would cost significantly more;
- There is no margin applied to the BPP calculation. Consequently, BPP does not take into account the equity returns or profit that any developer (including PLN) requires to make new generation investments financially viable;
- BPP is based on average historical accounting costs rather than forward-looking marginal costs, which more accurately represent the capital, operating, and fuel costs PLN is likely to face in the future;
- BPP does not reflect the nonfinancial benefits of RE generation. For example, it takes no account of reductions in air pollution that result from substituting RE generation for coal-fired generation. As a result, the use of BPP as the benchmark for RE pricing undervalues the benefits of RE generation and results in levels of development below those that are socially optimal;

(Source : ADB, Renewable Energy Tariffs and Incentives in Indonesia, 2020)

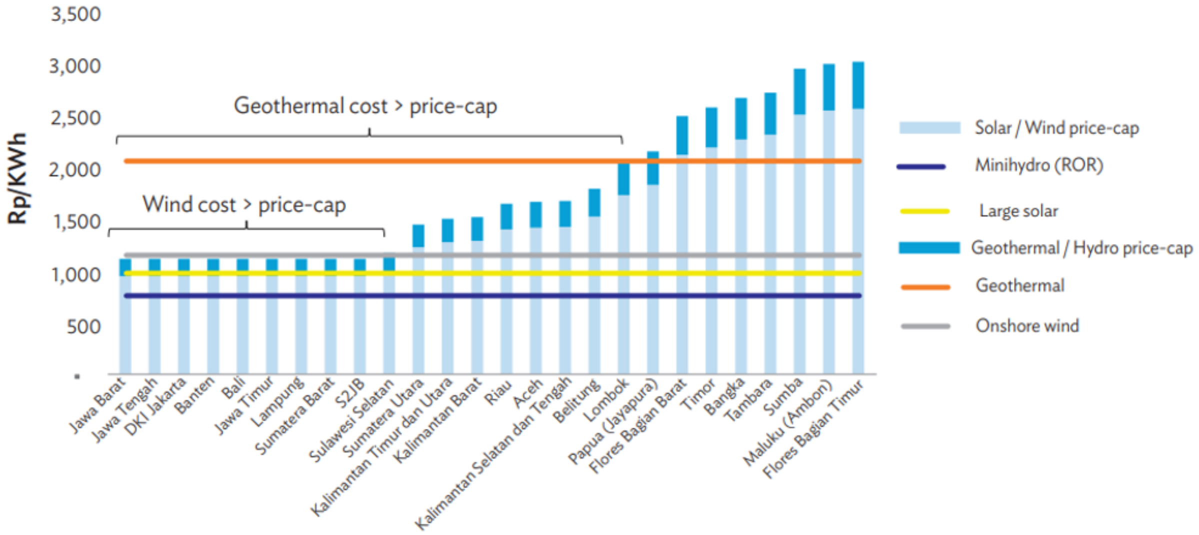


Figure 5-1 Price–Cost Gap for Selected Renewable Energy Technologies

BPP = biaya pokok produksi (production cost), PT SMI = PT Sarana Multi Infrastruktur, ROR = Run of river, Rp = Indonesian rupiah.
Notes: Renewable energy technology costs are estimated from Ea Energy Analysis. 2017. Technology Data for the Indonesian Power Sector. National Energy Council, with the exception of geothermal where estimates are derived from GT Management. 2019. Cost of Production from Geothermal Power Projects in Indonesia. PT SMI. Funded by New Zealand Foreign Affairs and Trade Aid Programme. Geothermal/hydro price cap is higher of 100% of national average BPP or regional BPP. Solar/wind price cap is higher of 85% of national average BPP or regional BPP.
Source: ADB.

5.1.2 Market Policy in Renewable Energy

5.1.2.1 Current Market

From World Bank research in 2018, the world market FPVproject has been surging over the past few years and, its capacities of individual projects are increasing installed year on year. Largest of the FPV systems was operated in China, they have two projects with capacities of 150 megawatt-peak (MWp) were developed by Sungrow Group and China Three Gorges New Energy Co., Ltd. They installed FPV project with capacity exceeded 1.3 GWp as of December 2018 and has been growing exponentially since 2017. Figure 5-2 illustrates total of largest FPV projects completed as of December 2018.

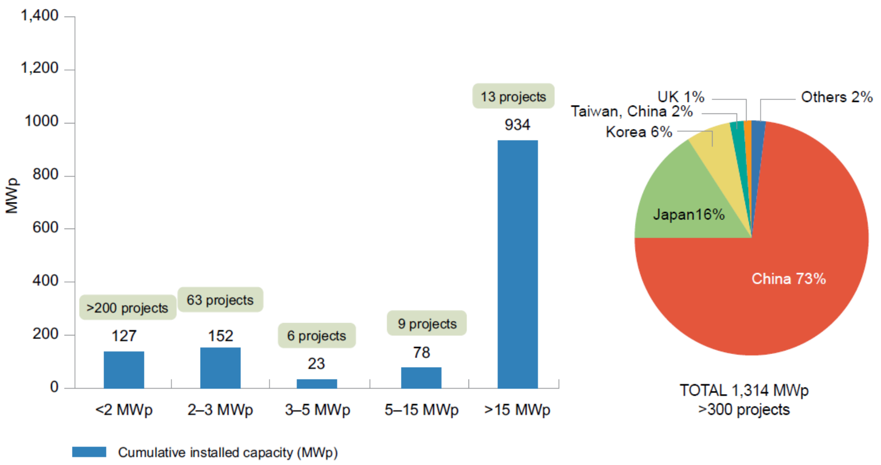


Figure 5-2 Distribution of FPV plants according to their size, as of December 2018

Note: MWp = megawatt-peak. List of projects attempts to be exhaustive, but omissions might have occurred
Source: Where Sun Meets Water, Floating Solar Market Report, WB – ESMAP, 2019

Market data suggests with the installation of a few large FPV project in the last two years, China has become the FPV market project leader with installed capacity more than 950 MWp, representing about 73 percent of the world's total.

The remainder of the installed capacity is mainly spread between Japan (about 16 percent), the Republic of Korea (about 6 percent), Taiwan, China (about 2 percent), the United Kingdom (about 1 percent) whilst the rest of the world accounts for only 2 percent. FPV plants totaling more than 180 MWp have been installed to date in Japan; most of them are below 3 MWp.

Plants were divided into five categories: (i) smaller than 2 MWp, (ii) between 2 and 3 MWp, (iii) between 3 and 5 MWp, (iv) between 5 and 15 MWp, and (v) larger than 15 MWp. Most of the installations to date are small systems with capacities below 3 MWp.

However, the number of large systems has been increasing significantly since 2017 and this trend is set to continue, with many FPV projects larger than 10 MWp under development. The world's 13 largest plants (>15 MWp) account for more than 70 percent of all FPV installed capacity. FPV offers significant advantages in countries where land is scarce or expensive, and suitable water bodies are present. Some economies, such as Taiwan, China, offer financial incentives for the use of water bodies for PV deployment. Several large FPV installations are integrated with hydropower plants. These arrangements increase the overall efficiency of both solar and hydropower production and allow the sharing of existing transmission infrastructure

5.1.2.2 Indonesia Market Policy

Indonesian market policy could be decreased to produce of fossil fuel, especially oil, its policy in line with the global gevernment commitment to reduce the greenhouse effect, so that its has sought to be increasing the role of new and renewable energy in the country's power sector. Blessed with rich natural resources, Indonesia has significant potential to expand its use of renewable energy.

With the President's Decree No. 79 of 2014 on National Energy Policy, Indonesia has set an ambitious target for the contribution of new and renewable energy to the energy mix to be at least 23% and 31% by 2025 and 2030 respectively. Indonesia has a very strong potential market in the renewable energy (as shown as table below) to achieve that target. It is predicted that Indonesia will need investment approximately US$66 billion for the renewable energy industry over the next six years and has staggering US$13 billion of investment annually.

Table 5-1 Indonesia Renewable Energy Market Potency

Energy Type	Potential
Hydro	94.3 GW
Geothermal	28.5 GW
Bioenergy	PLT Bio: 32.6 GW and BBN: 200k Bph
Solar	207.8 GWp
Wind	60.6 GW
Ocean	61 GW

Source: Indonesia Ministry of Energy – New and Renewable Directorate (EBTKE), 2019

The total potential renewable energy was equivalent of 442 GW utilized by power plants. Meanwhile for BBN (biofuel) and biogas as 200,000 Bph are used as fuel for transportation, households, commercial and industries. The utilization of renewable energy for the power plant in 2018 was 8.8 GW which was 14% of total capacity of Indonesia's fossil and non-fossil power plants. The total capacity now is 64.5 GW. Most of new and renewable energy sectors are used for producing power with rest is used for transportation, industries, commercial and other sectors.

The state owned electric company PT.PLN, will be added new power plants with total 75.9GW for the next 10 years throughout Indonesia as stated in Electricity Supply Business Plan or known as RUPTL 2017 – 2026. The development of renewable energy was rely on local's condition and on each region's potential. For Sumba, East Nusa Tenggara area for wind power and solar. Sukabumi, West Java for wind farm. The government has pushed to utilize solar power for street lights, rooftop photovoltaic, etc.

Solar energy has the potential in Indonesia to be contributed more than 200 GW with efficient photovoltaic technology. However, despite being a tropical country that is also located on the equator, the utilization of solar energy in Indonesia is currently less than 100 MW. Solar energy potential is well spread throughout Indonesia with the highest potential is in West Kalimantan (20GW), South Sumatera (17GW) and East Kalimantan (13GW) In 2017, an initiative taken by the Indonesian government, working with local renewable industries, to strengthen resiliency in through achievement of renewable energy contribution as mandated to achieve 23% by 2025 whereas approximately 7GW from solar, launched a national program toward a million of photovoltaic in Indonesia. This program launched to accelerate the solar photovoltaic rooftop of residential housings, commercial buildings, public/ government buildings and industrial facilities across the country for achieving 1 GW by 2020. Further information, there are 800 public buildings targeted to have solar rooftop pv as government plan. Through Ministry of Energy and Mineral Resources, government allocated US$13 million for installing panels on boarding schools, clinics, orphanages, government offices and police stations in 17 provinces. (source : Energy Resource Guide - Indonesia-Renewable Energy_trade.gov)

The research team analyzed model scenarios based on Indonesia's 2019–2028 national energy procurement plan (RUPTL) and initial demand forecasts and details regarding more than 1,050 existing and planned power stations representing some 90% of energy consumption on Java, Bali and Sumatra—about 70 percent of the nation's population. (Sourece: Liebman, How Renewable Energy Can Power Java-Bali and Sumatera, IESR, 2019)

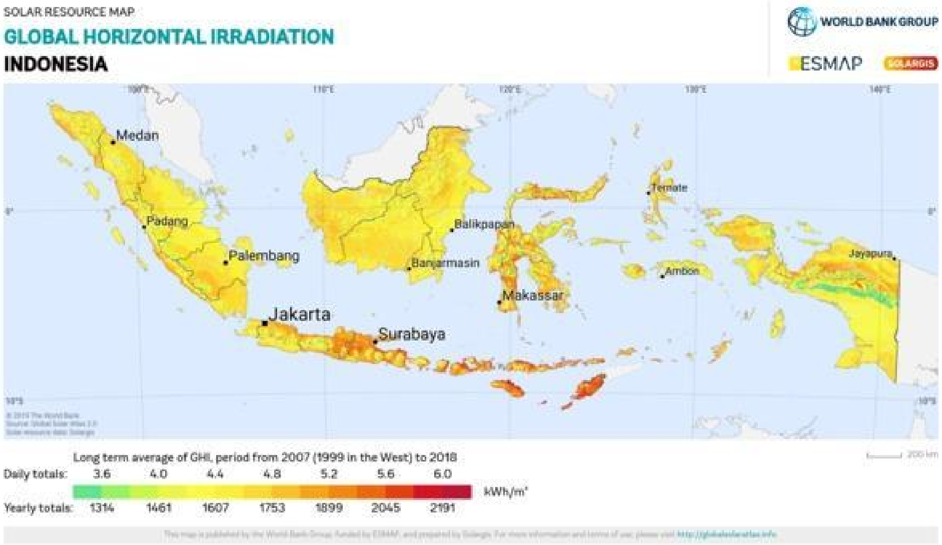


Figure 5-3 SolarGIS map of Indonesian Solar Resources

Source: A Roadmap for Indonesia's Power Sector report

Referring to the study of the floating solar panels which are planned to be built in the Cacaban reservoir, Tegal, Central Java and the Pandanduri reservoir in Lombok, West Nusa Tenggara, as well as information regarding the Ministry of EMR's 2021-2030 plan regarding electricity needs and the potential for developing a sheltered solar panel project,

Table 5-2 Sales Forecast, Production and Electricity Peak Load Projection, Central Java Province

ITEMS	UNIT	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	GROWTH
Economic growth	%	5,2	5,72	5,88	6,04	6,16	6,25	6,32	6,36	6,4	6,38	6,07
Sales forecast	GWh	25.954	26.778	27.979	29.414	30.759	32.213	33.730	35.262	36.869	38.672	4,42
Electricity Production	GWh	27.711	28.572	29.828	31.299	32.701	34.178	35.738	37.322	38.998	40.876	4,43
Electricity Peak Load	MW	4.252	4.372	4.552	4.764	4.964	5.175	5.396	5.621	5.858	6.124	4,60
Total Customer	Thousands	10.973	11.241	11.492	11.732	11.964	12.189	12.407	12.620	12.829	13.037	2,29

(Source: RUPTL 2021-2030, PT. PLN)

Based on the General Plan for electricity development 2021-2030, central Java province needs a electricity supply of 25,954 GWh in 2020 and raise to 38,672 GWh in 2030, with average growth approximately 4% in a year. Central Java province has the potential of primary energy source that can be utilized for the development of electricity consisting of hydropower potential estimated at 813 MW, geothermal 517 MW wind power and solar energy of 420 MW. This shows that the plan of floating solar panel project in Cacaban reservoir becomes one of the options for the government to be able to supply electricity power needs for household and industrial consumers in central Java. (Source: RUPTL 2020-2030, Ministry of EMR)

Figure 5-4 Electricity Maps of Central Java

Source : RUPTL, PT PLN 2021-2030

Electricity system in West Nusa Tenggara province consists of Lombok system 150 KV, Sumbawa-Bima system 150 KV as well as several small isolated systems. while medium and small systems are supplied from diesel-fueled power plants and as a electricity development of solar power.

Currently electricity power supply in west Nusa Tenggara is still dominated by electricity diesel power plants, so the cost of production of electricity plants is still high. Based on the General Plan for electricity development 2021 - 2030, central Java province needs a electricity supply of 2.346 GWh in 2021 and raise to 4,745 GWh in 2030 with average growth approximaly 8% in a year.

Table 5-3 Sales Forecast, Production and Electricity Peak Load Projection, Central Java Province

ITEMS	UNIT	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	GROWTH
Economic growth	%	4,5	5,0	5,2	5,3	5,4	5,5	5,6	5,6	5,7	5,6	5,3
Sales forecast	GWh	2.347	2.563	2.784	3.028	3.277	3.544	3.818	4.114	4.428	4.745	8,2%
Electricity Production	GWh	2.704	2.982	3.237	3.620	3.933	4.249	4.572	4.920	5.290	5.669	8,6%
Electricity Peak Load	MW	431	475	516	576	626	676	727	781	839	899	8,5%
Total Customer	Thousands	1.636	1.710	1.785	1.860	1.936	2.012	2.089	2.165	2.242	2.320	4,0%

(Source: RUPTL 2021-2030, PT. PLN)

The above project includes the needs of KEK Mandalika potential needs and the needs of large customers and other lindustries. Currently, the electricity demand in Nusa Tenggara is supplied by geothermal power plants with a small power of about 6 MW which are located in three locations. According to the general plan for the 2021-2030 power plant, in 2022-2024 PLN plans to build a solar power plant of around 25 MW in Lombok. (Source: RUPTL 2020-2030, Ministry of EMR)

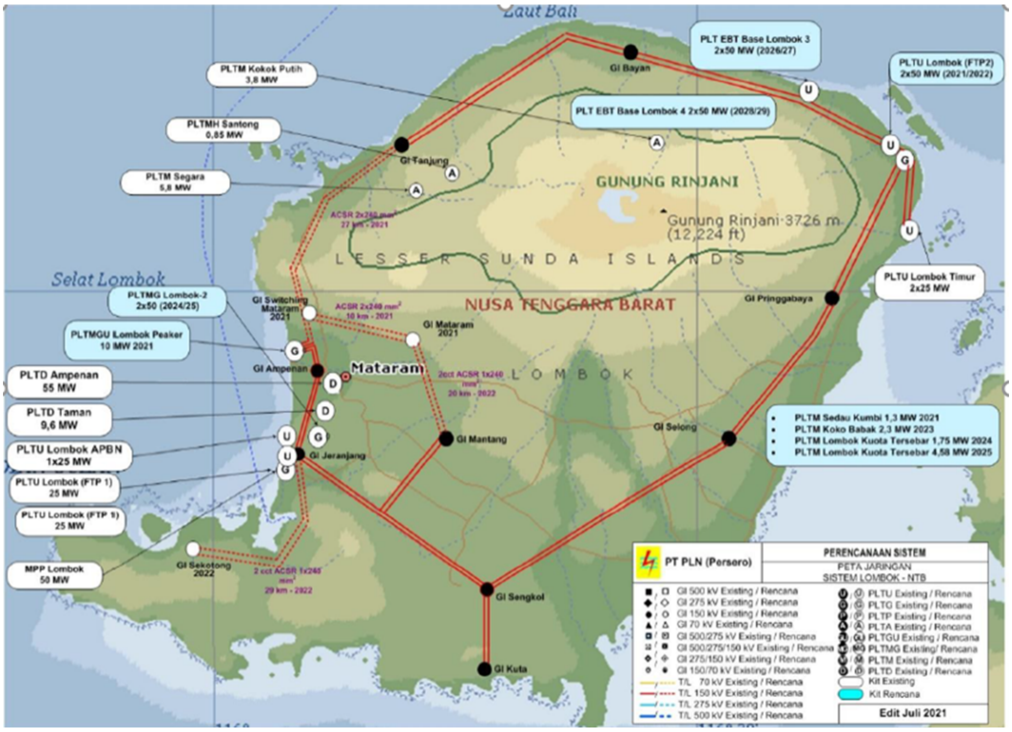


Figure 5-5 Electricity Maps of West Nusa Tenggara

Source : RUPTL, PT PLN 2021-2030

5.1.2.3 *Indonesian Big FPV Project*

Indonesia has significant FPV potential, and one of the major developers in the country, the Abu Dhabi–based Masdar Clean Energy, was looking ahead in that direction. Many forested areas across the islands of Indonesia are not suitable for solar deployment, and land prices are high. The company has identified more than 60 reservoirs that could be host FPV plants. The project was signed a project development on third party agreement with the local power utility PT Pembangkitan Jawa-Bali, Abu Dhabi Future Energy Company PJSC (Masdar) and Perusahaan Listrik Negara (PLN) . Its project plan to build a 200 MWp FPV plant covering 225 hectares of the surface area of the Cirata Hydroelectric Plant Reservoir in West Java Province.

Figure 5-6 Cirata FPV Solar Power Plan

Source: Cirata-reservoir-Masdar-indonesia-infographic-eng-nov-28-2017.jpg

The FPV Cirata project become is biggest floating solar power plant in the Southeast Asia region and one of the biggest of its kind in the world in 2019/2020. The project was developed by PT. Pembangkitan Jawa Bali Masdar Solar Energi (PMSE), a joint venture of Abu Dhabi Future Energy Company PJSC (Masdar) and Perusahaan Listrik Negara (PLN). Total investment cost was estimated approximately £95 million (or 129 million USD), the 145MW project will generate sufficient electricity to power up to 50,000 houses and reduce the carbon dioxide emissions by 214,000t a year upon completion. The project was inaugurated in December 2020 and is expected to create up to 800 jobs. The construction on the power plant is expected to start in the first half of 2021 with commissioning scheduled on 2022.

In accordance with World Bank statement, the Asian Development Bank also performed a preliminary opportunity assessment of FPV projects in Sulawesi and Kalimantan by identifying six sites with a cumulative capacity of 975 MWp. It estimates FPV potential projects to be in the range of several gigawatts at similar sites (e.g., hydropower reservoirs, estuaries, bays) across the country (Source: Where Sun Meets Water, Floating Solar Market Report, WB – ESMAP, 2019)

5.1.3 Business Model

The business model for infrastructure with Public Private Partnership (PPP) idea which one of them in the field of electricity in Indonesia has been regulated through the regulation of the minister of national planning and development number 1/2020 and the implementation of infrastructure development through PPP Project and technically by the regulation of the minister of Energy and Mineral Resources through the guidance book for planning floating “PLTS” solar power plants.

The other vital factor that enabled the Power Purchase Agreement (PPA) model to be developed was the financing technique known as ‘project finance’, which provides the high ratio of long-term debt financing required for such projects (Solar Panel or FPV project). This PPA contract is carried out with a built owned operate transfer (BOOT) mechanism. The particular project-finance structures used to finance PPA provided the basis for financing all types of PPPs.

In financing, the source of financing of an project infrastructure can be done alone by the government, done by cooperating with private parties, or through assignment to state-owned enterprises. It is very dependent on the location of project infrastructure and the results of economic and financial feasibility assessments. As an overview of the following figure 5.7 can illustrate the government's role or risk sharing for an infrastructure project financing system

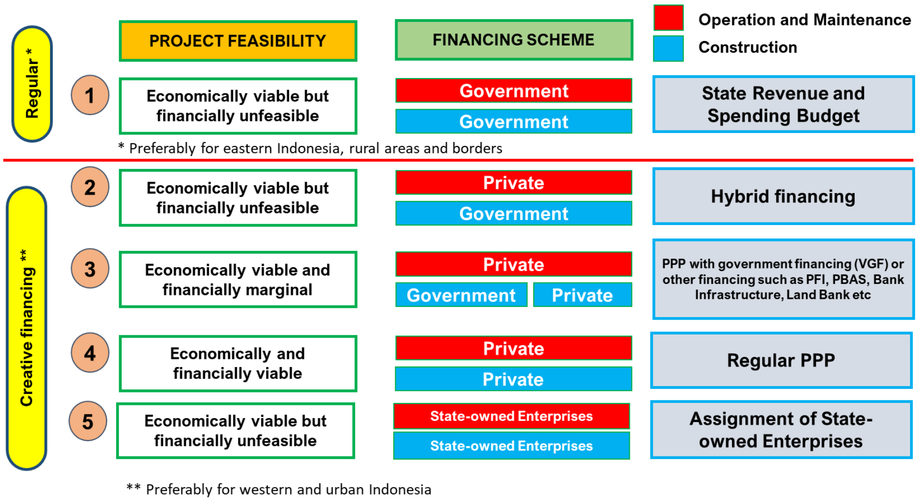
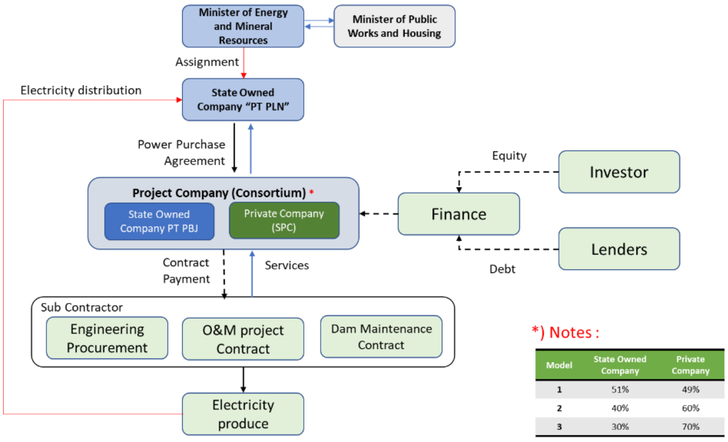


Figure 5-7 The Government's Role Infrastructure Project Financing System

Source: Directorate of Development of Government and Business Cooperation, Ministry of National Development Planning of the Republic of Indonesia / National Development Planning Agency, 2016

In the illustration above, the infrastructure development funding system is the most important on economic and financial feasibility. The potential investor or private parties will be interested if economic and financial qualifications are met, therefore some financial models must be tried so that eligibility can be fulfilled. In addition to risk sharing in the infrastructure development process between private and government, several creative steps need to be taken.

In Indonesia, one of the risk sharing patterns between the government and the private sector is to involve state-owned enterprises, so that it will reduce the burden on the private sector in relation to improving financial viability.



*) Notes :

Model	State Owned Company	Private Company
1	51%	49%
2	40%	60%
3	30%	70%

Figure 5-8 Project Finance for a Power-Purchase Agreement

Figure 5-8 above illustrated an important aspect of project finance is lack of recourse to the project sponsors (i.e. they do not usually guarantee the debt raised by the project company), as well as the transfer of the risks mentioned above from the project company to subcontractors. its shows how this risk transfer fits within the main building blocks for a power-generation on project FPV.

The arrows show the direction of cash flows—contract cash flows are shown with solid lines and financing cash flows with dotted lines. The main components in the structure are:

- a project company, owned by private-sector investors;
- a PPA without an electricity-distribution company (or private sector entity) and usage charges;
- financing for the project's capital costs ('capex') through shareholder equity investment and project-finance debt;
- an 'engineering, procurement and construction' (EPC) subcontract, under which the EPC subcontractor agrees to deliver a completed and fully-equipped power facility to the project company to the required specification, at a fixed price and schedule; this type of contract to provide a complete facility at a fixed price is known as a 'turnkey' contract;
- where relevant, a fuel-supply subcontract, under which, say, natural gas is provided to the project company to fuel the power facility's turbines;
- an operation and maintenance (O&M) subcontract, under which an O&M contractor agrees to operate and maintain the facility on behalf of the project company; and
- surplus cash flow after payment of operating and maintenance costs ('opex') is used, firstly, for payments of interest and repayments of loan principal ('debt service') to the lenders, and then to give a return on investment to the equity investors ('distributions').
- In this case risk sharing can also be done if the Project Leader or SPC shifts some of the risk through the division of business ownership between state-owned companies and private investors, such as 51%:49%, 40%:70% or 30%:70%.

The subcontractors have thus taken over many of the key risks that the contracting authority had passed to the project company, e.g. as to the outturn capital cost of the power station and its operating costs. (source: E.R. Yescombe and Edward Farquharson, Public Partnerships for Infrastructure, Principles of Policy and Finance, second edition, Elsevier Ltd, UK, 2018)

One of them is to find the cheapest source of financing, for example looking for sources of funding from financial institutions with low interest rates. This will reduce the investment burden and will lift the level of financial viability.

In theory when investor will decide on an new project, the investor has to consider whether the investment provides an adequate return. The baseline against which this is measured is normally the investor's own cost of capital. For a company, the 'weighted average cost of capital' (WACC) is used, i.e. the weighted average of the costs of its own equity and debt funding. A simplified WACC calculation would be (E.R. Yescombe, at all, 2018):

$$\mathrm{WACC} = \left(\frac{E}{E+D} \times \mathrm{Re}\right) + \left(\frac{D}{E+D} \times \mathrm{Rd} \times (1 - T\%)\right)$$

Where:

- E : market value of company's equity;
- D : company's outstanding debt;
- Re: return on equity, expressed as a rate of return;
- Rd: return on debt, i.e. the cost of borrowing expressed as a rate of interest; and

Notes:

Return on debt (Rd) depending where funding agency and how much the interest rate must be paid by the shareholders on the project.

5.2 Electricity Selling Price in Indonesia

From Government side, solar panel system was concerned for the rapid run-up fixed generating costs (PT PLN), its issued a new solar tariff regime in early 2017, which was updated again within the same year. This latest regulation for commercial on solar power generation is MEMR Regulation No. 50/2017. The regulation states that the solar tariff is now determined by benchmarking against the applicable Electricity Generation Cost or the “Biaya Pokok Pembangkitan” (BPP).

The BPP as a leverage to supported a policy framework and instead ties the solar tariff to the cost of prevailing conventional baseload power generation and forces new solar units to be compere with another PT PLN facilities as we know using domestic coal. Where the local BPP is higher than national BPP, a maximum 85% of the local BPP will be applied for solar, wind, biomass, biogas and tidal projects.

In addition, the government policy introduces a preference for other sources of renewable and alternative generation with a provision with maximum 100% from the local BPP. The renewable energy applied from hydro, municipal solid waste and geothermal projects. If the local BPP is equal to or lower than national BPP, then the tariff will be based on mutual agreement between the potential investor and PLN.

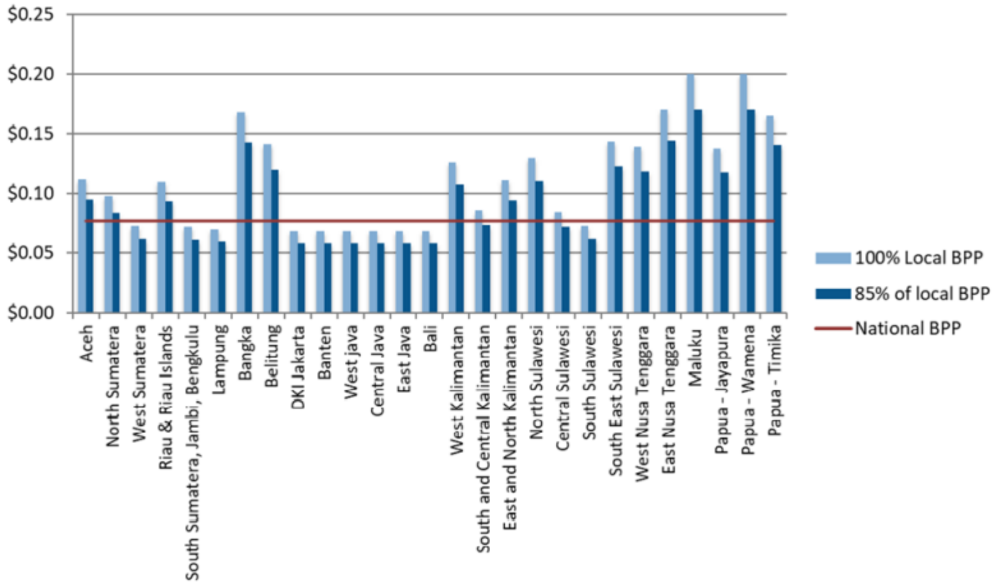


Figure 5-9 Electricity Feed-In Tariffs Capped per Region

Note: Locations where the local BPP is higher than national BPP receive tariffs up to 85% of local BPP. The graph shows that areas with more attractive prices are located mostly in the Eastern part of Indonesia, where infrastructure such as roads and ports are not as well developed as the ones on Java-Bali island which leads to higher project costs.

Source: Erlika Hamdi, Indonesia’s Solar Policies, IEEAFA.Org, 2019

Based on the results of the discussion (FGD) of the National Planning and Development Agency (Bappenas) “Meeting Marketing Issues” with the organizers of the Floating Solar Panel PLTS industry in November, it was found that the selling price of energy produced by the Floating Solar Panel PLTS is around 85% of the Cost of Electricity Generation PT PLN, where The BPP-PLN for the Province of Tegal, Central Java, is Rp. 907.77 per KWh, while in Lombok, NTB, it is Rp. 1,715.65.

This is in accordance with the Decree of the Minister of Energy and Mineral Resources (MEMR) No.: 169.K/HK.02/MEM.M/2021, regarding the Basic Cost of Providing PT PLN Generation in 2020. Thus, the unit selling price for electricity used in the financial simulation for the Cacaban reservoir , Tegal, Central Java and the Pandanduri reservoir, Lombok, NTB are as follows:

Table 5-4 Electricity Tarriff Usage on th Project Financial

Wilayah	BPP PLN		Tarif	
Jateng	Rp 907,77	per KWh	Rp 907,77	per KWh
NTB, Lombok	Rp 1.715,65	per KWh	Rp 1.458,30	per KWh

Source: BPP PT PLN for Central Java and West Nusa Tenggara,
Ministry EMR degree No. 169/2021 (processed)

Referring to the general tariff applicable to floating solar panel projects in America and several other countries, including in Asia, the electricity tariff generated from renewable energy (EBT) projects is an average of 22 cents USD per KWh.

Some types of electricity selling price tariffs in Indonesia depending on the type of resources used, such as electricity tariffs sourced from electricity plants, such as from Water, Steam or Diesel.

5.2.1 Indonesian Industrial Electricity Usage 2021

On new regulation of the Minister of EMR No. 26/2021 which is a revision of Article 6 of ESDM Candy No. 49 of 2018. The Ministry of Energy and Mineral Resources (ESDM) issued a new regulation requiring PLN to buy electricity from PLN customers who also have rooftop solar power plants (PLTS), amounting to 100 percent of electricity prices or Rp1,440 kWh.

Meanwhile, the selling price of electricity to the community and industry in Indonesia consists of three clusters. This is different from another country where electricity tariffs were distinguished between for consumer society (Household) and industrial consumers (Non-Household).

Small Industry: this first class of electricity applies to small industrial or low voltage households. Small industrial electricity tariff classes are charged by customers with power of 450 VA to 14 kVA (I-1/TR).

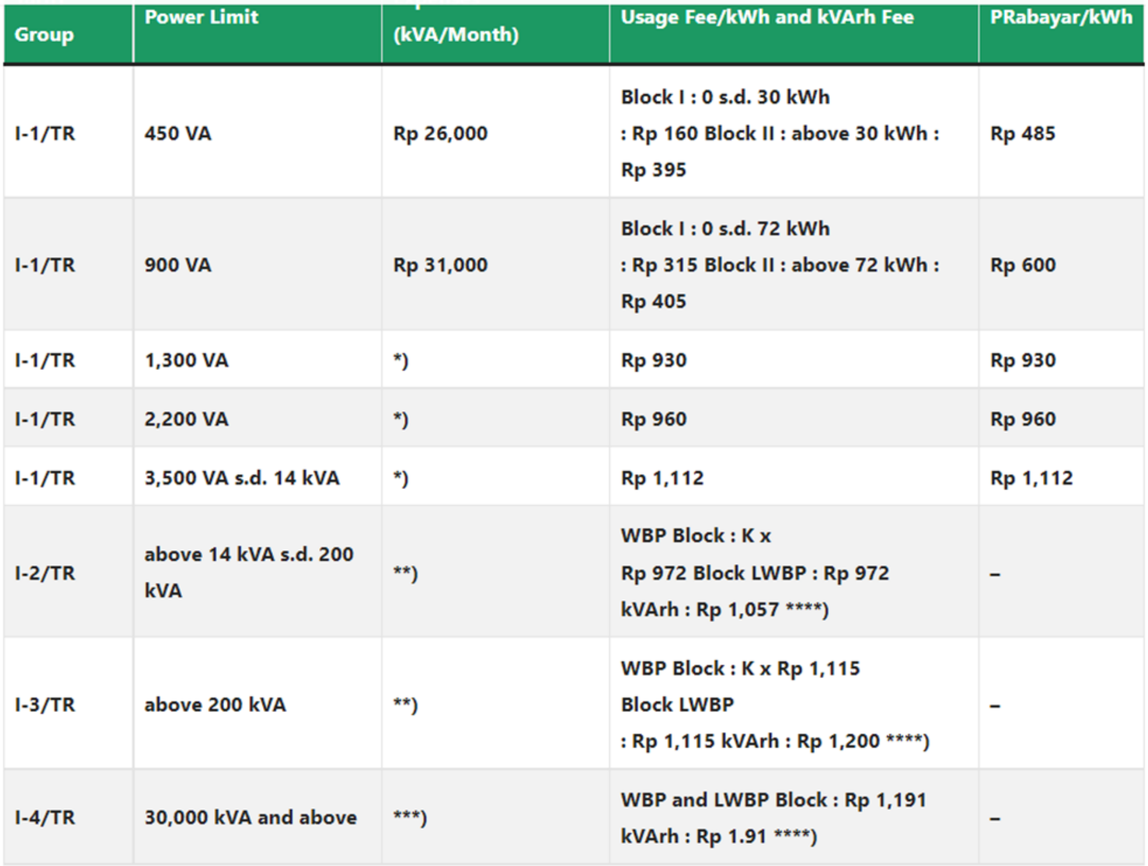
Medium Industry: next is that there is a moderate industrial electricity group that uses low voltage electricity. The moderate industry group consists of customers with power above 14 kVA to 200 kVA (I-2/TR).

Medium Industry: almost the same as the moderate industrial class, customers of this middle industrial class are certainly used for medium industrial needs at medium voltage. Customers who belong to the middle industrial class are customers with power above 200 kVA (I-3 / TR).

Big Industry: Finally, there is a large industry criterion. This large industrial tariff group is at a high voltage with power of 30,000 kVA and above (I-4/TR). Of the three groups above, big industry becomes the highest group.

This selling price also determines how much the maximum electricity production cost can be set by the government, because PT PLN as a state company must finance electricity both for the needs of society and industry.

Table 5-5 Electricity Tariff (PT PLN) for Consumer in Indonesia



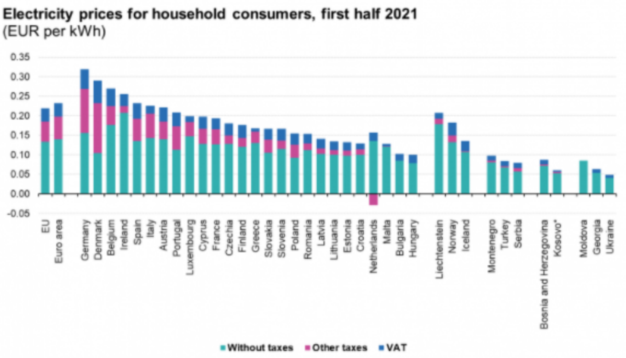
Group	Power Limit	(kVA/Month)	Usage Fee/kWh and kVArh Fee	PRabayar/kWh
I-1/TR	450 VA	Rp 26,000	Block I : 0 s.d. 30 kWh : Rp 160 Block II : above 30 kWh : Rp 395	Rp 485
I-1/TR	900 VA	Rp 31,000	Block I : 0 s.d. 72 kWh : Rp 315 Block II : above 72 kWh : Rp 405	Rp 600
I-1/TR	1,300 VA	*)	Rp 930	Rp 930
I-1/TR	2,200 VA	*)	Rp 960	Rp 960
I-1/TR	3,500 VA s.d. 14 kVA	*)	Rp 1,112	Rp 1,112
I-2/TR	above 14 kVA s.d. 200 kVA	**)	WBP Block : K x Rp 972 Block LWBP : Rp 972 kVArh : Rp 1,057 ****)	–
I-3/TR	above 200 kVA	**)	WBP Block : K x Rp 1,115 Block LWBP : Rp 1,115 kVArh : Rp 1,200 ****)	–
I-4/TR	30,000 kVA and above	***)	WBP and LWBP Block : Rp 1,191 kVArh : Rp 1.91 ****)	–

5.2.2 Electricity prices for household consumers benchmark

For household consumers in the EU (defined for the purpose of this article as medium-sized consumers with an annual consumption between 2 500 kWh and 5 000 kWh), electricity prices in the first half of 2021 were highest in Germany (EUR 0.3193 per kWh), Denmark (EUR 0.2900 per kWh), Belgium (EUR 0.2702 per kWh) and Ireland (EUR 0.2555 per kWh); see Figure 1. The lowest electricity prices were in Hungary (EUR 0.1003 per kWh), Bulgaria (EUR 0.1024 per kWh) and Malta (EUR 0.1279 per kWh). The price of electricity for household consumers in Germany was more than three times higher than the price in Hungary and 45.6 % higher than the EU average price.

Country	Tariff		1 Euro = Rph		Tariff (IDR)	
Germany	€	0,32	Rp	16.155	Rp	5.158
Denmark	€	0,29	Rp	16.155	Rp	4.685
Belgium	€	0,27	Rp	16.155	Rp	4.365
Ireland	€	0,26	Rp	16.155	Rp	4.128
Hungary	€	0,10	Rp	16.155	Rp	1.620
Bulgaria	€	0,10	Rp	16.155	Rp	1.654
Malta	€	0,13	Rp	16.155	Rp	2.066

Notes: annual consumption 2.500 - 5.000 KWh



The EU average price in the first semester of 2021 , a weighted average using the most recent (2021) data for electricity by household consumers — was EUR 0.2192 per kWh (source: Eurostat (nrg_pc_204)

Figure 5-10 The EU average price for Household, 2021

5.2.3 Electricity prices for non-household consumers benchmark

Non-household consumers are defined for the purpose of this article as medium-sized consumers with an annual consumption between 500 MWh and 2 000 MWh. As depicted in Figure 6, electricity prices in the first half of 2021 were highest in Germany (EUR 0.1813 per kWh) and Italy (EUR 0.1584 per kWh). We observe the lowest price in Finland (EUR 0.0676 per kWh) and Denmark (EUR 0.0797 per kWh). The EU average price in the first semester of 2021 was EUR 0.1283 per kWh. The aggregates are weighted averages taking into consideration the average consumption in each band.

Country	Tariff	1 Euro = Rph	Tariff (IDR)
Germany	€ 0,18	Rp 16.155	Rp 2.929
Italy	€ 0,16	Rp 16.155	Rp 2.559
Finland	€ 0,07	Rp 16.155	Rp 1.092
Denmark	€ 0,08	Rp 16.155	Rp 1.288
Average	€ 0,13	Rp 16.155	Rp 2.073

Notes: annual consumption 500 - 2.000 MWh

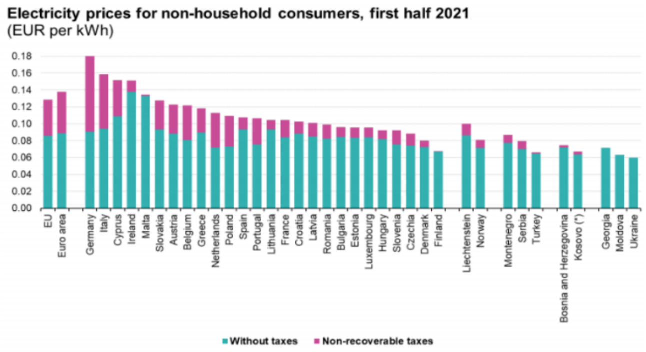


Figure 5-11 The EU average price for Non Household, 2021

Based on the explanation above, it can be concluded that actually industrial tariffs in a country are largely determined by the purchasing power of the people in the country itself. Because electricity prices or tariffs cannot be imposed on the community and are very dependent on the economic strength of a country. The government can provide subsidiaries, but in the end, PT PLN is a state company that must win profits or losses in the end in the long term.

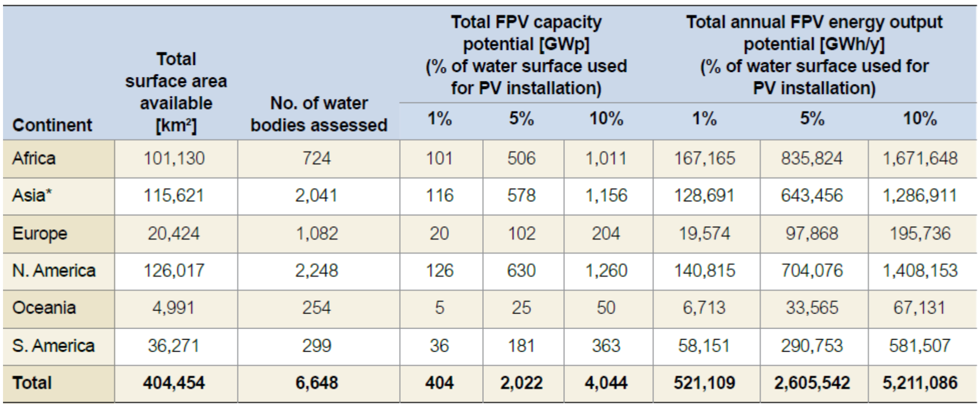
5.3 Research on the Market Analysis and Barrier Analysis

5.3.1 Market Potency

5.3.1.1 Global Market

The potency of capacity and energy generation of FPV projects on the continent with relatively high irradiation and high power demand in the global was studying woth NREL in cooperation with USAID (2021). On the Figure 5-6 we can see by percentage of reservoir surfaces used which is installed with all conventional solar PV Systems combined at the end of 2017. The FPV market would represent a terawatt (1.000 GW) scale market opportunity. That is before even tapping the resources potential of the world's natural landlocked water bodies or its oceans which receive the majority of solar energy received on earth. The Solar Penal or FPV project investigated include Yamakura Dam Reservoir in Japan, Umenoki in Japan, Agongdian reservoir in Taiwan, Godley reservoir in United Kingdom and Queen Elizabeth II in United Kingdom

Table 5-6 Peak Capacity and Energy Generation Potential of FPV on Freshwater Man-Made Reservoirs, by Continent



Continent	Total surface area available [km²]	No. of water bodies assessed	Total FPV capacity potential [GWp] (% of water surface used for PV installation)			Total annual FPV energy output potential [GWh/y] (% of water surface used for PV installation)		
			1%	5%	10%	1%	5%	10%
Africa	101,130	724	101	506	1,011	167,165	835,824	1,671,648
Asia*	115,621	2,041	116	578	1,156	128,691	643,456	1,286,911
Europe	20,424	1,082	20	102	204	19,574	97,868	195,736
N. America	126,017	2,248	126	630	1,260	140,815	704,076	1,408,153
Oceania	4,991	254	5	25	50	6,713	33,565	67,131
S. America	36,271	299	36	181	363	58,151	290,753	581,507
Total	**404,454**	**6,648**	**404**	**2,022**	**4,044**	**521,109**	**2,605,542**	**5,211,086**

Source: SERIS calculations based on the Global Solar Atlas © World Bank Group (2019) and the GRanD database, © Global Water System Project (2011).
Note: GWh = gigawatt-hour; GWp = gigawatt-peak; km2 = square kilometers; PV = photovoltaic.

5.3.1.2 ASEAN Market

Emerging opportunities in Asia - India, South Korea and Vietnam. IHS Markit expects Asia to account for over 70 percent of total floating PV installations in the next five years. The top-three markets are expected to be India, South Korea and Vietnam which will account for over half of total installations if development and completion continues as planned. IHS Markit is tracking over 300 floating PV projects globally in its 'Solar deal tracker' from early stage development to under construction that plan to be installed in the next five years, and of which are heavily concentrated in Asia. Tenders and auctions are expected to be the main drivers to help the adoption of floating PV in many of the Asian markets and the fallout from the impact from Covid-19 may dampen the rate of installation of floating PV in these markets.

Outside of Asia, key markets will be the Netherlands in Europe owing to its aggressive target for floating PV due to having an abundance of shallow inland water and its support via the SDE+ subsidy scheme. Brazil is expected to be the biggest market for floating PV in the Americas due to its siting of floating PV on hydropower plant sites. Sungrow and Ciel et Terre remain the top-two manufacturers of floating structures

Both Ciel et Terre and Sungrow continue to dominate the global market of floating PV mounting suppliers with both suppliers accounting for 70 percent of the total completed or under construction installations. Sungrow continues to have the largest installed base due to its large market share in China and in other Asian markets but Ciel et Terre has the widest global footprint of all floating PV mount suppliers globally. Many of the other floating PV mount suppliers are headquartered in early growth floating PV markets such as China, Japan and South Korea.

Floating PV outlook is upwards manageable. Disused mining sites, hydropower plants, shallow inland waterways, and man-made reservoirs, are among the many locations to be considered attractive, while offshore floating solar is tested and evaluated further. (source: Cormac Gilligan, HIS Markit, Asia region to drive floating solar installation growth in next five years, 2020)

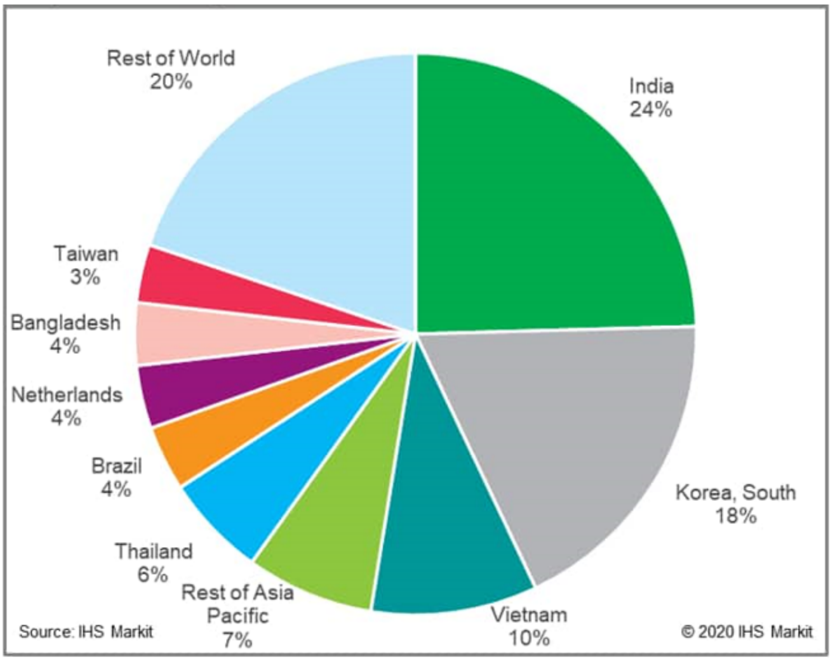


Figure 5-7 Top-ten floating PV markets from 2020-24

Source: Posted 28 May 2020 by Cormac Gilligan, Associate Director, Clean Energy Technology, IHS Markit

5.3.2 Economic Barriers to Implement of the FPV Project

Some of sections in general to breakdown economic, environmental, cultural, and regulatory barriers when investor could be impending in the commercialization dan deployment of FPF Project. On Table 5-7, there are some of the obstacles faced in the development of floating solar panel projects in general from NREL Study 2021 (USAID-NREL, Enabling Floating Solar Photovoltaic Deployment, Review of Barriers to FPV Development in Southeast Asia, June 2021)

Table 5-7 General Economic Barriers to Implement FPV Project

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

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

5.3.3 Some of Barriers to Implement FPV Project I Indonesia

Leibman from IESSR said the potential for Indonesia to transition to local, emissions-free energy resources is there. The lack of consistent, supportive renewable energy policy and regulations raises project development costs in Indonesia and makes for an unstable, uncertain business environment, however. The resulting lack of solar and renewable energy industrial ecosystems serves as another barrier to market and industry growth.

As it stands, aspiring independent solar and other renewable energy power producers need to go through a legal and bureaucratic process that entails obtaining approvals, licenses and permits at both the national and local government levels. They all need to contract with PLN, which has a monopoly on transmission and distribution nationwide, for the sale and purchase of all electricity produced. Furthermore, all project development by independent power producer is based on the BOOT model.

Modernizing the power grid to accommodate renewable energy generation, transmission and distribution poses another major challenge for solar and renewable energy growth in Indonesia more generally. PLN has begun addressing this issue, piloting implementation of advanced metering infrastructure (AMI) and smart grid technology. The state-owned utility also continues to implement required load frequency control and automatic generation control for the Java-Bali grid network

In addition, the lack of a solar and renewable energy industry base and supply chains constrain Indonesia’s capacity to realize the nation’s renewable energy potential. So does the lack of skilled, experienced people. (Source: Liebman, Barriers to solar and renewable energy growth, 2021)

5.4 Business and Financial Analysis of Floating Solar PV

5.4.1 Financial Assuming for Investment Cost

To calculate the value of the investment, we use the basic calculation figures from study conducted by NREL in 2021. The bottom-up NREL modeling method was used to calculate the capital costs associated with FPV applications for the characteristics of different projects and system design types. This approach involves mapping all the key steps in the installation process and determining the labor, materials, and equipment required for each stage.

In the benchmark the FPV system modeling with a central inverter placed on the ground. Electrical equipment selected for FPV installations must have a high Ingress Protection (IP) rating to avoid damage due to dust and water, as the system is usually subject to high humidity and wave motion. Data comes mostly from interviews with personnel from various FPV developers and installers: Floating Systems, Ciel et Terre, D3Energy, Seaflex, Multiconsult, Innosea, Baywa, and Energi Noria. interview data to supplement floating and anchor costs and costs from the standard construction cost guide (Gordian 2021). The FPV balance of system costs is based on simple averages of material, equipment, and labor costs across all US states and system-related metrics inferred from the FPV project data set provided by the system installer.

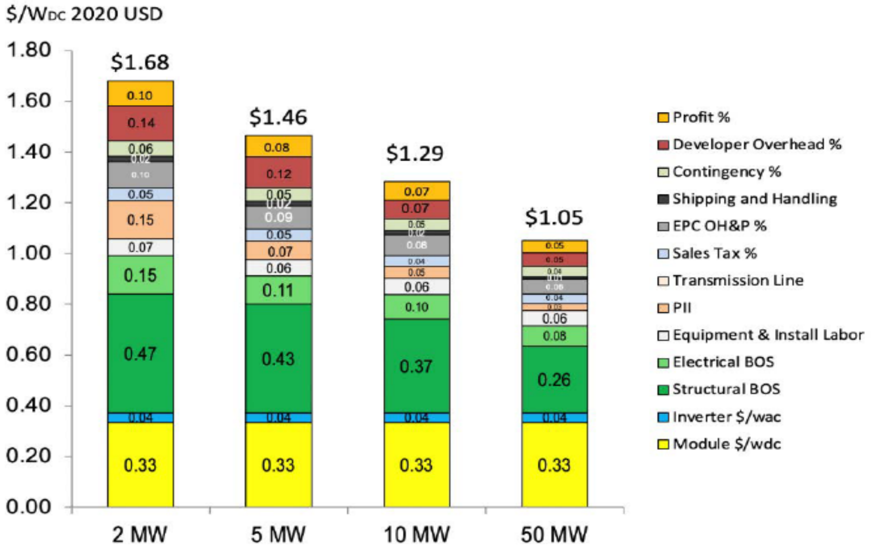
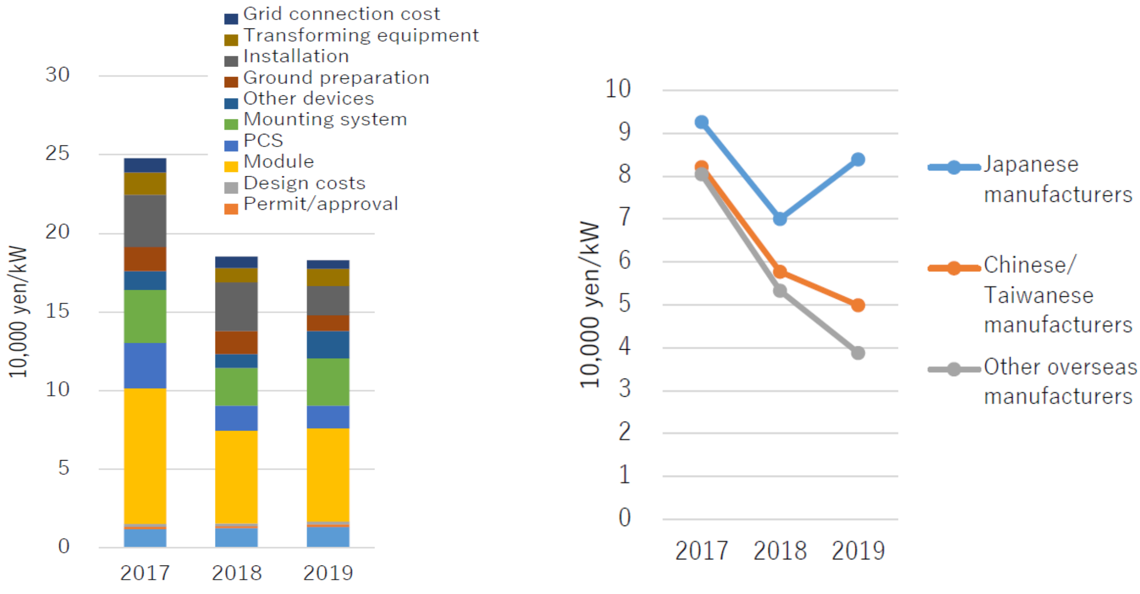


Figure 5-8 Unit Price per Installed MW Capacity

Source: Vignes Ramansamy dan Robert Margolis, NREL, Floating Photovoltaic System Cost Benchmark: Q1 2021 Installations on Artificial Water Bodies, October 2021.

In 2019 Japan conducted research on unit prices for investment in floating solar panel projects in several European countries, the Americas and including in Asia. The results showed that the unit price of solar panel devices with Asian brands (especially Taiwan) is much cheaper than the same product from European and American countries. In the following Figure it is seen that investment in floating solar panel projects in some countries that use products from Asia (especially Taiwan) is much lower in value. this causes the benchmark price while at tender time in some Asian countries is much lower than other countries. (Source : Renewable Energy Institute, Solar Powel Generation Cost in Japan, Current Status and Future Outlook, October 2019)



(a) (b)

Figure 5-14 Average Unit Price of solar module: (a) by cost item; (b) by region of manufacturer

(Source : Renewable Energy Institute, Solar Powel Generation Cost in Japan, Current Status and Future Outlook, October 2019)

The same study was conducted by WB Group and ESMAP with data on the procurement of floating solar panel projects between 2014-2018, obtained information that the unit price of investment in some Asian countries is much lower. The figure below shows that the comparison of unit values of investments during the procurement process during the period. Total capital expenditures for turnkey FPV installations in 2018 generally range between $0.8–1.2 per Wp, depending on the location of the project, the depth of the water body, variations in that depth, and the size of the system. China is the only country that has yet built installations of tens to hundreds of megawatt-peak in size. The costs of smaller systems in other regions could vary significantly. (Source: WB Group and ESMAP, Whre Sun Meets water, Floating Solar Market Report, 2019)

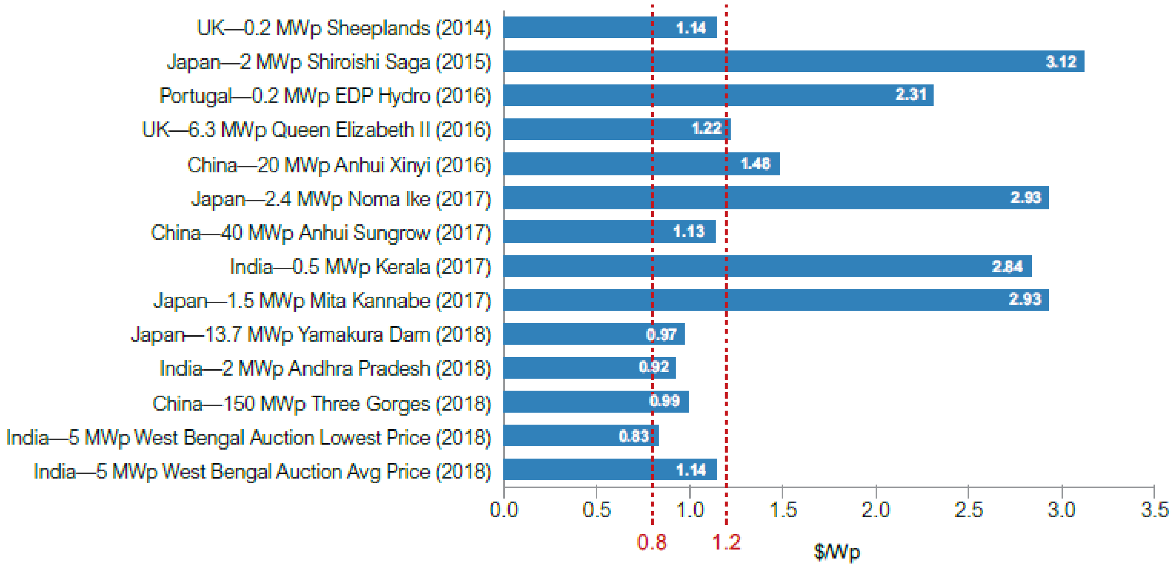


Figure 5-9 Investment costs of FPV in 2014–2018 (realized and auction results)

Source: Authors' compilation based on media releases and industry information.
Note: Using the 2017 $ annual exchange rates, as released by OECD. PV = photovoltaic; $/Wp = U.S. dollars per watt-peak.

5.4.1.1 Cacaban Investment Cost

Table 5-8 below describe of the investment cost for FPV Project on Cacaban Dam, with approached by the percentage of the reservoir allocation start from 5 percent, 8 percent, 10 percent, 15 percent, 20 percent and 25 percent.

After that we calculate the investment cost with electricity generates (KWh) multiplied by the conversion factor and unit cost. For example 5% reservoir allocated in Cacaban dam, described as follow:

Table 5-8 Investment Cost Calculated of Cacaban for 5% Reservoir Allocation

1	Module	22.947.157 KWh x $ 0,469	$ 10.764.052
2	Inverter	22.947.157 KWh x $ 0,052	$ 1.196.006
3	Equipment and Install Labor	22.947.157 KWh x $ 0,039	$ 897.004
4	Structural and Electrical BOS	22.947.157 KWh x $ 0,516	$ 11.840.458
5	E P C	22.947.157 KWh x $ 0,078	$ 1.794.009
6	Shipping and Handling	22.947.157 KWh x $ 0,013	$ 299.001
	Total Investment for 5% from reservoir allocated		$ 26.790.530

Source: PT Mettana 2021 (processed)

5.4.1.2 *Pandanduri Investment Cost*

After that we calculate the investment cost with electricity generates (KWh) multiplied by the convertion factor and unit cost. For example 5% reservoir allocated in Pandanduri dam, described as follow:

Table 5-9 Investment Cost Calaculated of Pandan Duri for 5% Reservoir Allocation

1	Module	8.752.859 KWh x $ 0,527	$ 4.610.569
2	Inverter	8.752.859 KWh x $ 0,060	$ 526.922
3	Equipment and Install Labor	8.752.859 KWh x $ 0,045	$ 395.192
4	Structural and Electrical BOS	8.752.859 KWh x $ 0,579	$ 5.071.626
5	E P C	8.752.859 KWh x $ 0,090	$ 790.383
6	Shipping and Handling	8.752.859 KWh x $ 0,060	$ 526.922
	Total Investment for 5% from reservoir allocated		$ 11.921.613

Source: PT Mettana 2021 (processed)

Note: for another percentage of reservoir allocation could be seen in the table below

The following graph compares the unit price of FPV project investment in Cacaban and Pandanduri dam:

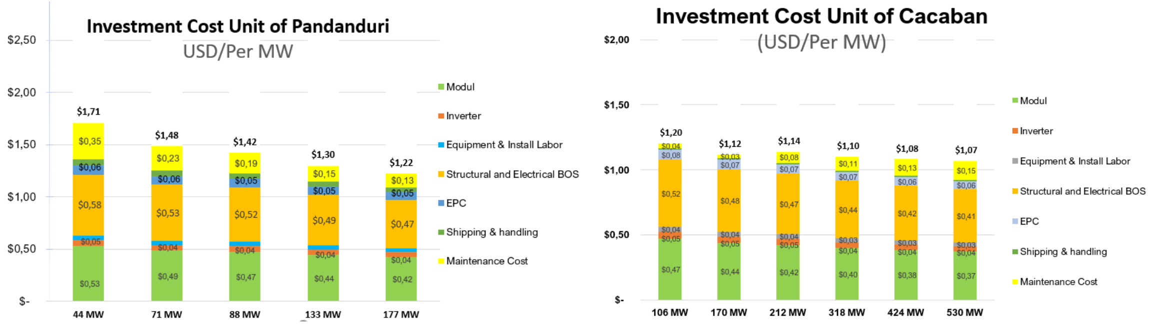
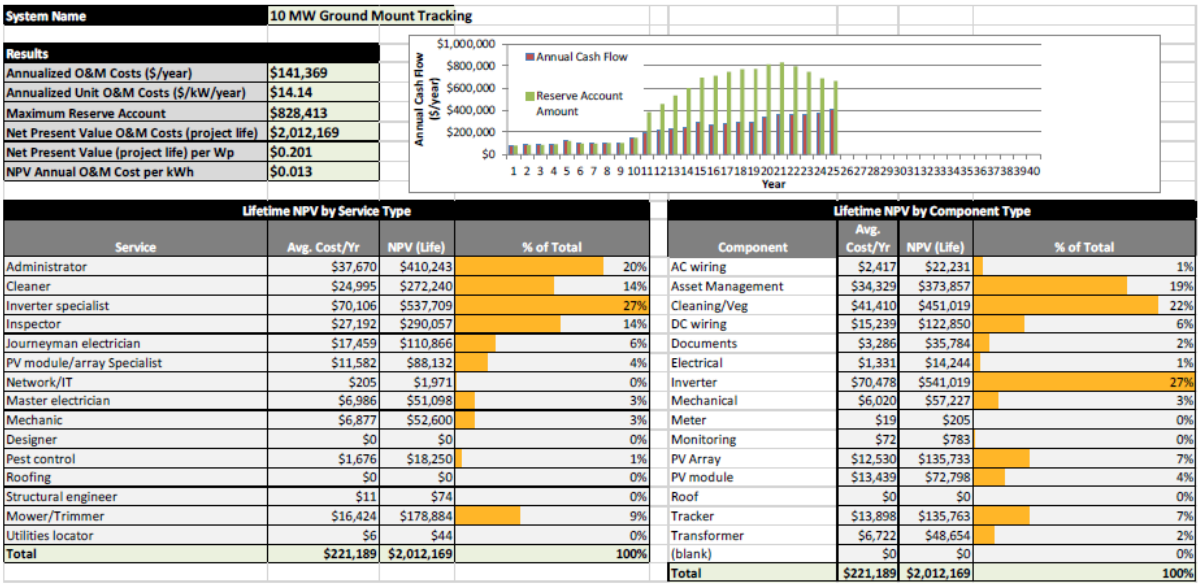


Figure 5-16 Unit Price per Installed MW Capacity Comparison

5.4.2 Operational and Maintenance Cost (O&M)

For operational and maintenance cost, we used and adopted with some adjustment the NREL study Model of Operation-and-Maintenance Costs for Photovoltaic Systems (2020). Describe its calculation as follow, in Figure 5-17: shows results from the prototype spreadsheet calculation. Results include annual cost for each year of the analysis period, life cycle cost, and key cost indicators, such as O&M costs per kW of installed capacity or per kWh of energy delivered. Results also include the amount of money that should be kept in a reserve account or line of credit, or spare parts inventory, to provide the desired level of certainty that the reserve account will be sufficient to cover unplanned costs for each year of the analysis period.

For the example considered (a 10-MW ground-mounted system with 10 inverters), annual costs vary from less than $100,000/year early in the analysis period to almost $400,000 late in the analysis period, with an annualized value of $143,581/year or $14.36/kW/year. The net present value is $2,044,656, or $0.013/kWh per unit of delivered energy. Assuming a desired probability shows results from the prototype spreadsheet calculation. Results include annual cost for each year of the analysis period, life cycle cost, and key cost indicators, such as O&M costs per kW of installed capacity or per kWh of energy delivered. Results also include the amount of money that should be kept in a reserve account or line of credit, or spare parts inventory, to provide the desired level of certainty that the reserve account will be sufficient to cover unplanned costs for each year of the analysis period. (source: NREL, Model of Operation-and-Maintenance Costs for Photovoltaic Systems, 2020)



System Name	10 MW Ground Mount Tracking

Results	
Annualized O&M Costs ($/year)	$141,369
Annualized Unit O&M Costs ($/kW/year)	$14.14
Maximum Reserve Account	$828,413
Net Present Value O&M Costs (project life)	$2,012,169
Net Present Value (project life) per Wp	$0.201
NPV Annual O&M Cost per kWh	$0.013

Lifetime NPV by Service Type

Service	Avg. Cost/Yr	NPV (Life)	% of Total
Administrator	$37,670	$410,243	20%
Cleaner	$24,995	$272,240	14%
Inverter specialist	$70,106	$537,709	27%
Inspector	$27,192	$290,057	14%
Journeyman electrician	$17,459	$110,866	6%
PV module/array Specialist	$11,582	$88,132	4%
Network/IT	$205	$1,971	0%
Master electrician	$6,986	$51,098	3%
Mechanic	$6,877	$52,600	3%
Designer	$0	$0	0%
Pest control	$1,676	$18,250	1%
Roofing	$0	$0	0%
Structural engineer	$11	$74	0%
Mower/Trimmer	$16,424	$178,884	9%
Utilities locator	$6	$44	0%
Total	**$221,189**	**$2,012,169**	**100%**

Lifetime NPV by Component Type

Component	Avg. Cost/Yr	NPV (Life)	% of Total
AC wiring	$2,417	$22,231	1%
Asset Management	$34,329	$373,857	19%
Cleaning/Veg	$41,410	$451,019	22%
DC wiring	$15,239	$122,850	6%
Documents	$3,286	$35,784	2%
Electrical	$1,331	$14,244	1%
Inverter	$70,478	$541,019	27%
Mechanical	$6,020	$57,227	3%
Meter	$19	$205	0%
Monitoring	$72	$783	0%
PV Array	$12,530	$135,733	7%
PV module	$13,439	$72,798	4%
Roof	$0	$0	0%
Tracker	$13,898	$135,763	7%
Transformer	$6,722	$48,654	2%
(blank)	$0	$0	0%
Total	**$221,189**	**$2,012,169**	**100%**

Figure 5-17 Example report from PV O&M cost model for 1-MW ground-mounted system

Research in Japan, team was conducted a survey of approximately 1.676 business that operate solar PV power plants . the number cost data case studies collected was 63, with high proportion of these 46, being medium size power plants. After analyze, they found that:

- Unit cost per kilowatt for hardware such solar PV modules decline significantly from 2017 to 2018;
- Investment cost and operation maintenance cost varied significantly among operators;
- With three scenarios, it was found that there was a large variance in generation costs even among power plants that commenced operation during the same period.

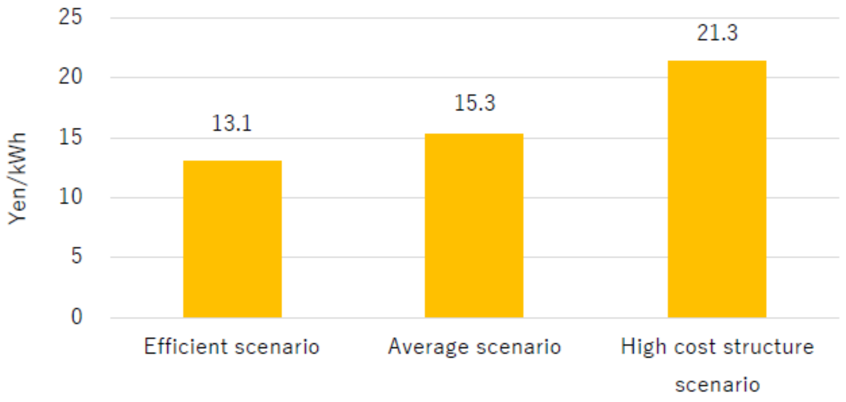


Figure 5-18 Estimated of Generation Cost in Each Scenario

That’s several factors behind estimation of the generation costs, such as :

- A decline in the cost of hardware, such as the unit cost of solar PV modules.

- A decline in mounting system costs, installation costs, and ground preparation costs due to an increase in the generation efficiency of solar PV modules, which will reduce the area of land requiring ground preparation and the number of installations required per kW of generation.
- Adoption of the ramming method of installation, which is the most cost-efficient among current installation methods.
- Regarding grid connection costs, convergence in the unit price for connection work due to use of cost efficient private lines.
- Appropriate and efficient monitoring systems to reduce operation and maintenance costs, and
- technological advances in weed removal methods a decline.

  (source: Renewable Energy Institute, Solar Power Generation Costs in Japan, Current Status and Future Outlook, 2019)

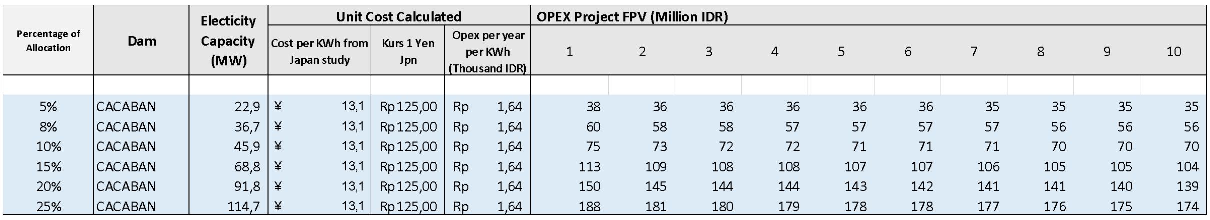
Implementation of this calculation are described in the following subchapter.

5.4.2.1 Operational and Maintenance Cost of Cacaban Dam

From NREL illustrated above and after adopted form Japanes research in FPV Projects, we are calculating of O&M Cost per year for the Cacaban Dam, as follow:

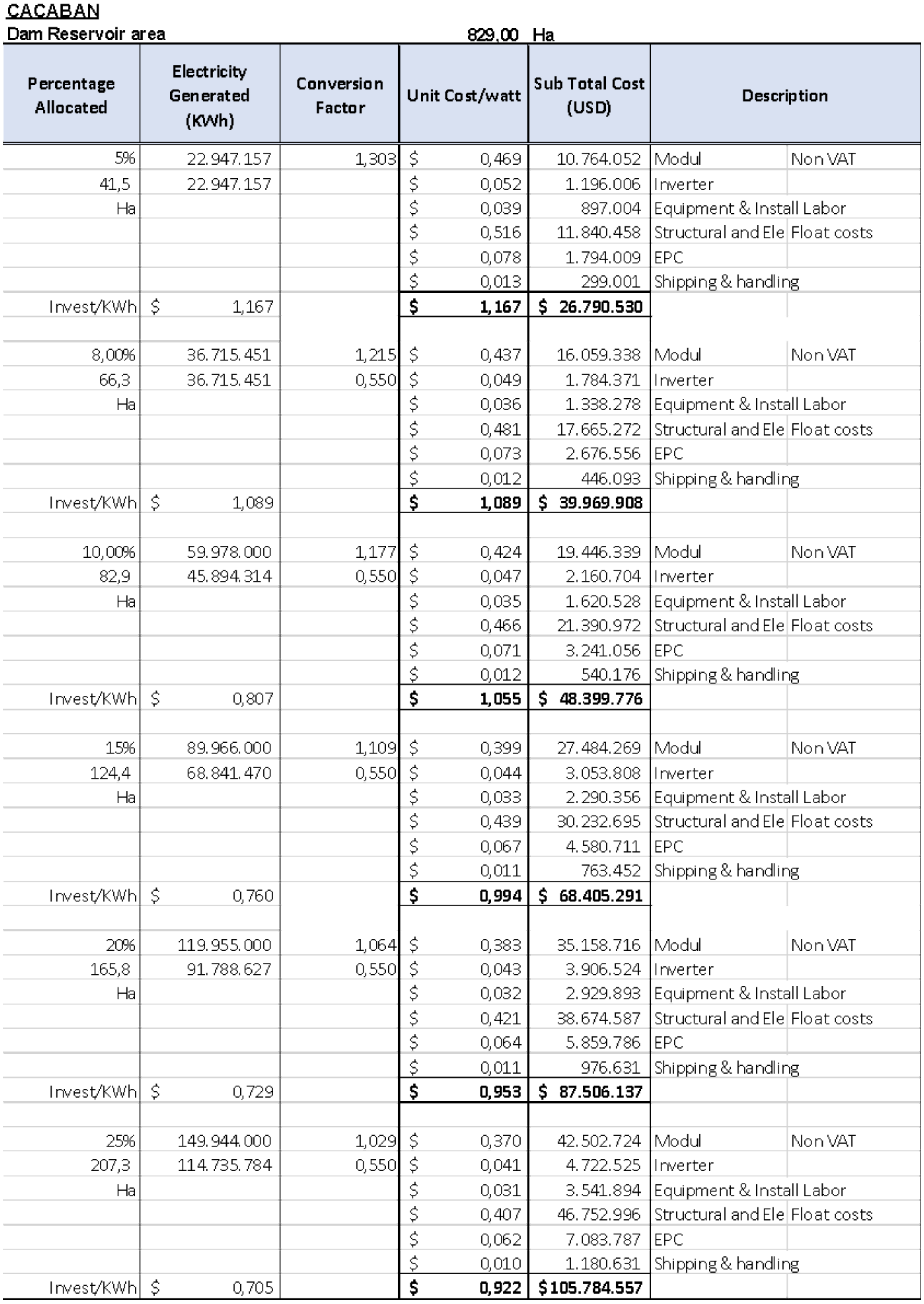
- Operx per year per MW = 13,1 Japanes Yen per KWh
- 1 Japanes Yen =Rp 125,00
- Opex per year per KWh = Rp. 1.640
- Opex Cacaban for 5% reservoir allocation = 22.947.157 KWh x Rp. 1.640 = Rp 38 milion

Table 5-10 Operational and Maintenance Cost Projection of the Cacaban FPV Project on 10 years



Percentage of Allocation	Dam	Electicity Capacity (MW)	Unit Cost Calculated			OPEX Project FPV (Million IDR)									
			Cost per KWh from Japan study	Kurs 1 Yen Jpn	Opex per year per KWh (Thousand IDR)	1	2	3	4	5	6	7	8	9	10
5%	CACABAN	22,9	¥ 13,1	Rp125,00	Rp 1,64	38	36	36	36	36	36	35	35	35	35
8%	CACABAN	36,7	¥ 13,1	Rp125,00	Rp 1,64	60	58	58	57	57	57	57	56	56	56
10%	CACABAN	45,9	¥ 13,1	Rp125,00	Rp 1,64	75	73	72	72	71	71	71	70	70	70
15%	CACABAN	68,8	¥ 13,1	Rp125,00	Rp 1,64	113	109	108	108	107	107	106	105	105	104
20%	CACABAN	91,8	¥ 13,1	Rp125,00	Rp 1,64	150	145	144	144	143	142	141	141	140	139
25%	CACABAN	114,7	¥ 13,1	Rp125,00	Rp 1,64	188	181	180	179	178	178	177	176	175	174

Table 5-11 Cacaban Dam Investment Cost



CACABAN

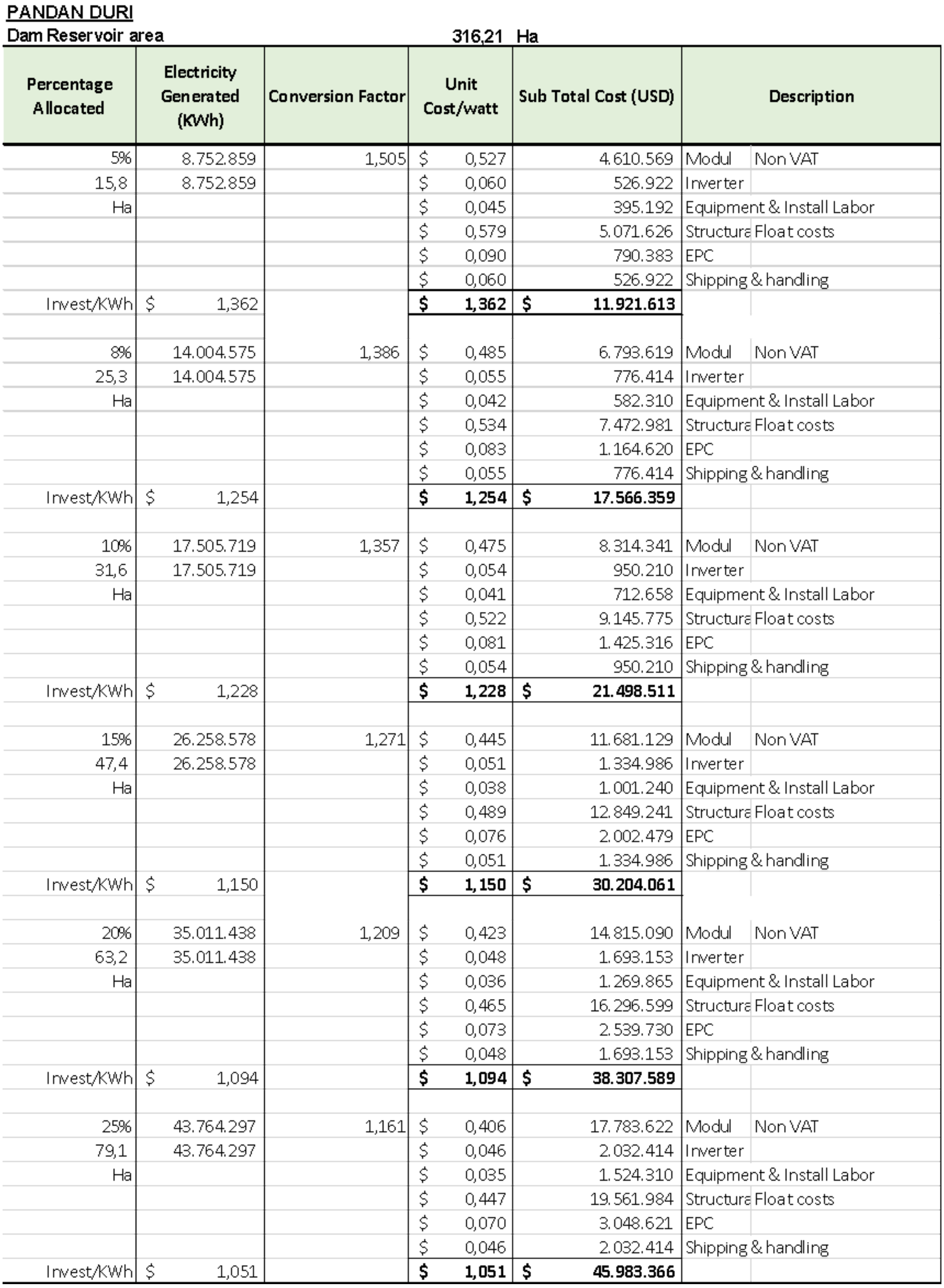
Dam Reservoir area 829,00 Ha

Percentage Allocated	Electricity Generated (KWh)	Conversion Factor	Unit Cost/watt	Sub Total Cost (USD)	Description	
5%	22.947.157	1,303	$ 0,469	10.764.052	Modul	Non VAT
41,5	22.947.157		$ 0,052	1.196.006	Inverter	
Ha			$ 0,039	897.004	Equipment & Install Labor	
			$ 0,516	11.840.458	Structural and Ele	Float costs
			$ 0,078	1.794.009	EPC	
			$ 0,013	299.001	Shipping & handling	
Invest/KWh	$ 1,167		**$ 1,167**	**$ 26.790.530**		
8,00%	36.715.451	1,215	$ 0,437	16.059.338	Modul	Non VAT
66,3	36.715.451	0,550	$ 0,049	1.784.371	Inverter	
Ha			$ 0,036	1.338.278	Equipment & Install Labor	
			$ 0,481	17.665.272	Structural and Ele	Float costs
			$ 0,073	2.676.556	EPC	
			$ 0,012	446.093	Shipping & handling	
Invest/KWh	$ 1,089		**$ 1,089**	**$ 39.969.908**		
10,00%	59.978.000	1,177	$ 0,424	19.446.339	Modul	Non VAT
82,9	45.894.314	0,550	$ 0,047	2.160.704	Inverter	
Ha			$ 0,035	1.620.528	Equipment & Install Labor	
			$ 0,466	21.390.972	Structural and Ele	Float costs
			$ 0,071	3.241.056	EPC	
			$ 0,012	540.176	Shipping & handling	
Invest/KWh	$ 0,807		**$ 1,055**	**$ 48.399.776**		
15%	89.966.000	1,109	$ 0,399	27.484.269	Modul	Non VAT
124,4	68.841.470	0,550	$ 0,044	3.053.808	Inverter	
Ha			$ 0,033	2.290.356	Equipment & Install Labor	
			$ 0,439	30.232.695	Structural and Ele	Float costs
			$ 0,067	4.580.711	EPC	
			$ 0,011	763.452	Shipping & handling	
Invest/KWh	$ 0,760		**$ 0,994**	**$ 68.405.291**		
20%	119.955.000	1,064	$ 0,383	35.158.716	Modul	Non VAT
165,8	91.788.627	0,550	$ 0,043	3.906.524	Inverter	
Ha			$ 0,032	2.929.893	Equipment & Install Labor	
			$ 0,421	38.674.587	Structural and Ele	Float costs
			$ 0,064	5.859.786	EPC	
			$ 0,011	976.631	Shipping & handling	
Invest/KWh	$ 0,729		**$ 0,953**	**$ 87.506.137**		
25%	149.944.000	1,029	$ 0,370	42.502.724	Modul	Non VAT
207,3	114.735.784	0,550	$ 0,041	4.722.525	Inverter	
Ha			$ 0,031	3.541.894	Equipment & Install Labor	
			$ 0,407	46.752.996	Structural and Ele	Float costs
			$ 0,062	7.083.787	EPC	
			$ 0,010	1.180.631	Shipping & handling	
Invest/KWh	$ 0,705		**$ 0,922**	**$105.784.557**		

Sources:

- PT Mettana, Cacaban and Pandanduri Dam Study, December 19, 2021 (processed)
- Vignesh Ramasamy and Robert Margolis, National Renewable Energy Laboratory, Floating Photovoltaic System Cost Benchmark: Q1 2021 Installation on Artificial Bodies, https://www.nrel.gov/docs/8095.pdf

Table 5-12 Pandanduri Dam Investment Cost



PANDAN DURI

Dam Reservoir area 316,21 Ha

Percentage Allocated	Electricity Generated (KWh)	Conversion Factor	Unit Cost/watt	Sub Total Cost (USD)	Description	
5%	8.752.859	1,505	$ 0,527	4.610.569	Modul	Non VAT
15,8	8.752.859		$ 0,060	526.922	Inverter	
Ha			$ 0,045	395.192	Equipment & Install Labor	
			$ 0,579	5.071.626	Structura	Float costs
			$ 0,090	790.383	EPC	
			$ 0,060	526.922	Shipping & handling	
Invest/KWh	$ 1,362		**$ 1,362**	**$ 11.921.613**		
8%	14.004.575	1,386	$ 0,485	6.793.619	Modul	Non VAT
25,3	14.004.575		$ 0,055	776.414	Inverter	
Ha			$ 0,042	582.310	Equipment & Install Labor	
			$ 0,534	7.472.981	Structura	Float costs
			$ 0,083	1.164.620	EPC	
			$ 0,055	776.414	Shipping & handling	
Invest/KWh	$ 1,254		**$ 1,254**	**$ 17.566.359**		
10%	17.505.719	1,357	$ 0,475	8.314.341	Modul	Non VAT
31,6	17.505.719		$ 0,054	950.210	Inverter	
Ha			$ 0,041	712.658	Equipment & Install Labor	
			$ 0,522	9.145.775	Structura	Float costs
			$ 0,081	1.425.316	EPC	
			$ 0,054	950.210	Shipping & handling	
Invest/KWh	$ 1,228		**$ 1,228**	**$ 21.498.511**		
15%	26.258.578	1,271	$ 0,445	11.681.129	Modul	Non VAT
47,4	26.258.578		$ 0,051	1.334.986	Inverter	
Ha			$ 0,038	1.001.240	Equipment & Install Labor	
			$ 0,489	12.849.241	Structura	Float costs
			$ 0,076	2.002.479	EPC	
			$ 0,051	1.334.986	Shipping & handling	
Invest/KWh	$ 1,150		**$ 1,150**	**$ 30.204.061**		
20%	35.011.438	1,209	$ 0,423	14.815.090	Modul	Non VAT
63,2	35.011.438		$ 0,048	1.693.153	Inverter	
Ha			$ 0,036	1.269.865	Equipment & Install Labor	
			$ 0,465	16.296.599	Structura	Float costs
			$ 0,073	2.539.730	EPC	
			$ 0,048	1.693.153	Shipping & handling	
Invest/KWh	$ 1,094		**$ 1,094**	**$ 38.307.589**		
25%	43.764.297	1,161	$ 0,406	17.783.622	Modul	Non VAT
79,1	43.764.297		$ 0,046	2.032.414	Inverter	
Ha			$ 0,035	1.524.310	Equipment & Install Labor	
			$ 0,447	19.561.984	Structura	Float costs
			$ 0,070	3.048.621	EPC	
			$ 0,046	2.032.414	Shipping & handling	
Invest/KWh	$ 1,051		**$ 1,051**	**$ 45.983.366**		

Sources:

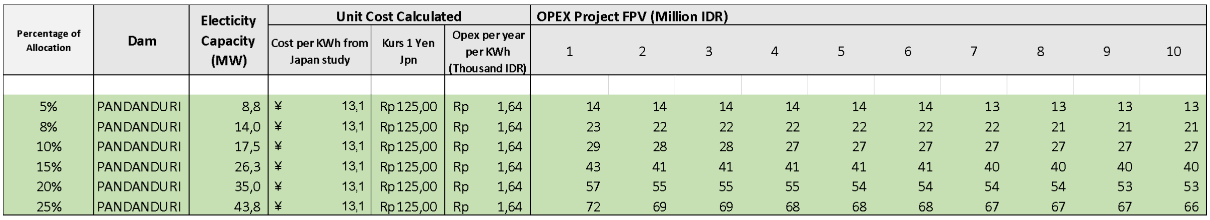
- PT Mettana, Cacaban and Pandan Duri Dam Study, December 17,r 2021 (processed);
- Vignesh Ramasamy and Robert Margolis, National Renewable Energy Laboratory, Floating Photovoltaic System Cost Benchmark: Q1 2021 Installation on Artificial Bodies, https://www.nrel.gov/docs/8095.pdf

5.4.2.2 Operational and Maintenance Cost of Pandanduri Dam

From NREL illustrated above and after adopted form Japanes research in FPV Projects, we are calculating of O&M Cost per year for the Pandanduri Dam, as follow:

- Opex per year per MW = 13,1 Japanes Yen per KWh
- 1 Japanes Yen =Rp 125,00
- Opex per year per KWh = Rp. 1.640
- Opex Cacaban for 5% reservoir allocation = 8.752.859 KWh x Rp. 1.640 = Rp 14 milion

Table 5-13 Operational and Maintenance Cost Projection for the Pandanduri FPV Project in 10 years



Percentage of Allocation	Dam	Electicity Capacity (MW)	Unit Cost Calculated			OPEX Project FPV (Million IDR)									
			Cost per KWh from Japan study	Kurs 1 Yen Jpn	Opex per year per KWh (Thousand IDR)	1	2	3	4	5	6	7	8	9	10
5%	PANDANDURI	8,8	¥ 13,1	Rp125,00	Rp 1,64	14	14	14	14	14	14	13	13	13	13
8%	PANDANDURI	14,0	¥ 13,1	Rp125,00	Rp 1,64	23	22	22	22	22	22	22	21	21	21
10%	PANDANDURI	17,5	¥ 13,1	Rp125,00	Rp 1,64	29	28	28	27	27	27	27	27	27	27
15%	PANDANDURI	26,3	¥ 13,1	Rp125,00	Rp 1,64	43	41	41	41	41	41	40	40	40	40
20%	PANDANDURI	35,0	¥ 13,1	Rp125,00	Rp 1,64	57	55	55	55	54	54	54	54	53	53
25%	PANDANDURI	43,8	¥ 13,1	Rp125,00	Rp 1,64	72	69	69	68	68	68	67	67	67	66

5.5 Benchmark and Government Policy

So far, a number of countries have taken different approaches to floating PV. Typical policies currently supporting floating solar installations can be grouped into two categories: Financial incentives:

- Feed-in tariffs that are higher than those for ground mounted PV (as in Taiwan, China)
- Extra bonuses for renewable energy certificates (as in the Republic of Korea)
- A high feed-in tariff for solar PV generally (as in Japan)
- Extra “adder” value for floating solar generation under the compensation rates of state incentives program (as in the U.S. state of Massachusetts).

Supportive governmental policies:

- Ambitious renewable energy targets (as in Korea and Taiwan)
- Realization of demonstrator plants (as in the Indian state of Kerala)

(source: WB. Where Sun Meets Water Floating Solar Market Report, ESMAP, 2018)

6 CASE STUDY FOR FPV INSTALLATION

This section briefly described two DOISP Dams used in this study, i.e., Cacaban and Pandanduri Dams.

6.1 Cacaban Dam

6.1.1 General

Cacaban Dam is administratively located in Penujah Village, Kedungbanteng District, Tegal Regency, Central Java Province, as shown in Figure 6-1. The dam, which is a homogeneous landfill dam, was constructed from 1952 to 1958. The dam on the normal water level condition is capable of holding ± 90,000,000m^3 water from the main Cacaban Wetan River. The top elevation of the dam is + 89.50 m, and the dam length is 168 m. The dam functions as a water reservoir in the rainy season and irrigates a 17,481 ha rice field. The dam operation and management are under the supervision of BBWS Pemali Juana.

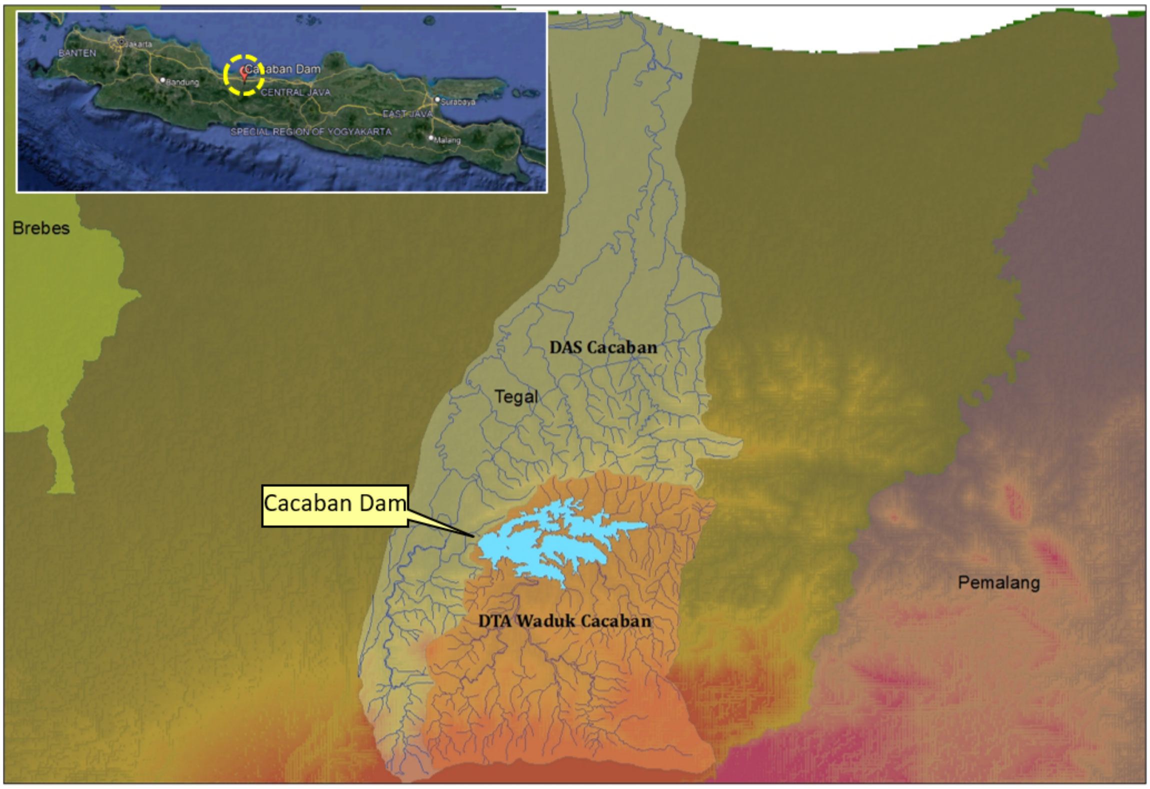


Figure 6-1. Location of Cacaban Dam

A major inspection of the Cacaban dam was carried out in 2017 by PT Mettana Engineering Consultant. The inspection consists of visual inspection and dam stability assessment. Based on the visual inspections, the geotechnical condition of the dam looks stable. However, it is necessary to continue monitoring and slope stability analysis based on field and laboratory investigations data. All appurtenance structures, such as intake and discharge channels, and spillway structures, are reasonably good. Unfortunately, severe damage occurred to the V-notch instrument, so that in recent years it has been unable to monitor seepage discharge (PT. MEC, 2017).

Based on a 1000-year rainfall analysis, the water level elevation is +78.74 m with freeboard about 1.26 m from crest elevation of +80.0m. As for the Probable Maximum Flood (PMF) results, the water level elevation is +79.52 m with freeboard about 0.48 m (PT. MEC, 2017).

6.1.2 Site Visit Report

Based on the site visit conducted on 12th November 2021, some conditions need to be considered, as follows:

1. Based on visual inspection, the stability of the slope on the upstream right abutment looks unstable. Therefore, the slope needs to be assessed carefully. According to the inspection report on 2017 by Mettana Engineering Consultant, generally, the stratigraphy consists of residual soil resulting from weathering of calcareous sandstones and claystone in the form of silty clay, a little sand and gravel, light yellowish-brown to dark brown, firm to rubbery, low to medium plastic in nature. The thickness of the residual soil covering the surface is relatively thin, which is about 1 m to 3 m (Figure 6-3). Based on the information, some slope locations were reinforced by anchors. Unfortunately, there is no detailed information regarding the safety factor of such slope protection.
2. Some slope locations were also protected by the newly replaced rock riprap in the scope of ongoing remedial works until the end of 2021, as shown in Figure 6-4.
3. The spillway was already repaired with a new layer of higher-quality concrete. But unfortunately, the report documentation regarding the quality control or quality assurance of the concrete repair was not found during the site visit.
4. This dam is also utilized as a recreation area, as shown in Figure 6-6. Unfortunately, presently the master plan of the zoning for tourism was not found. This zoning requires Public Safety information, especially if the floating PV will be built in this area.
5. Although there was already a major inspection in 2017 and remedial works started in 2020. However, it has not been reported yet to the Dam Safety Unit for the process of Certification in Dam Operation granted by the Minister of Public Works and Housing.

Figure 6-2. Photo Location

Figure 6-3. Condition Slope on the Upstream Right Abutment (Photo -1)

Figure 6-4. Riprap for Slope Protection on the Upstream Dam (Photo -2)

Figure 6-5. Condition of Spillway Left Bank Concreting Works (Photo -3)

Figure 6-6. Recreation facilities on the Left Bank of Reservoir (Photo -4)

6.1.3 Seismicity Conditions

Based on National Center for Earthquake Studies (PuSGeN), there is no active fault close to the Cacaban dam, as depicted in Figure 6-7. According to PUSGEN (2017), the peak ground acceleration (PGA) for 5000 years returns period ranges between 0.4g and 0.5g (Figure 6-8).

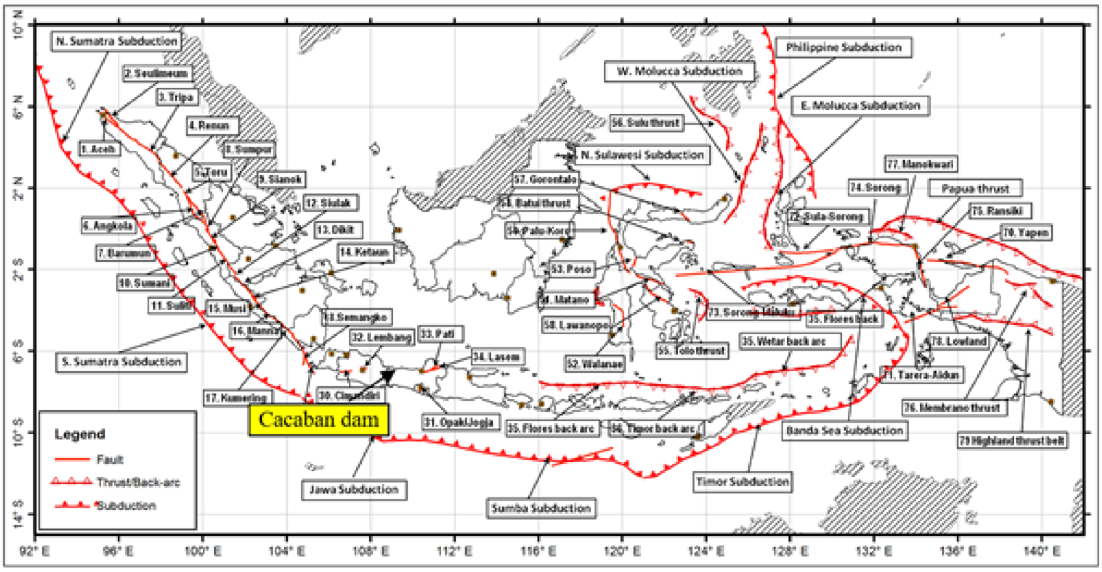


Figure 6-7. Seismic sources around Cacaban Dam

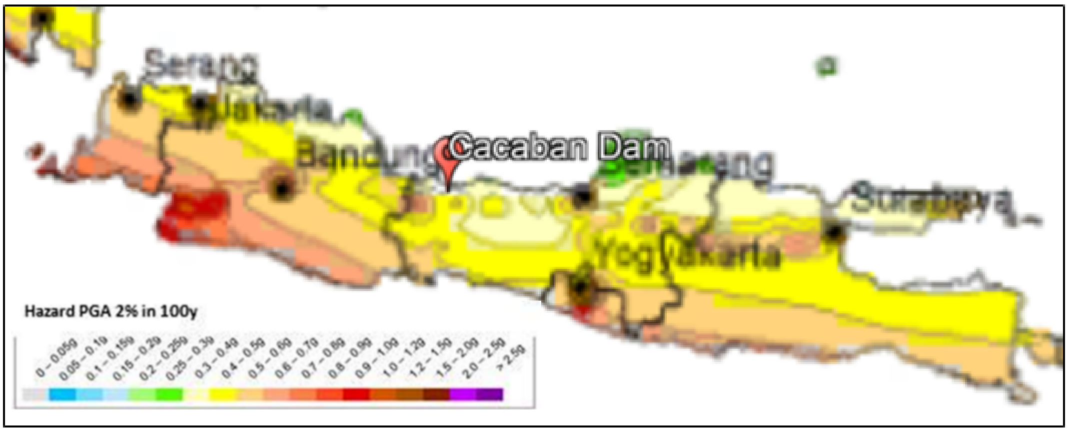


Figure 6-8. PGA for 5000 years return period (PUSGEN, 2017)

6.1.4 Floating PV Coverage Area, Layout, Location, And Zonation

The ratio of reservoir area between its minimum water level and the normal water level is roughly 1:8, or 12.5%. It means that 87.5% of the area may cause the PV to be stranded when the targeted PV coverage area is calculated from the normal water level (instead of the minimum water level). In this reservoir, the 5% PV coverage area in normal water level will translate to 40% coverage area in low water level, and that the availability of location that does not show any stranding risk is only 12.5% of total reservoir area in normal water level.

Based on the analysis above, the risk of stranding conditions is relatively high. If based on other analysis, if it is found to be impossible to avoid stranding conditions during the floating PV's lifetime, additional detailed analysis for stranded and re-floating conditions such as suggested in Section 4.2.4. In addition, other limit states and design

Although Cacaban dam has relatively low seismic activities (see 6.1.3), historical data shows a relatively high landslide risk on the upstream right abutment. Therefore, a consequence analysis (and its probability of occurrence, if needed) of landslides from the upstream right abutment should be conducted. According to the following guideline notes in Section 4.1.2.1.2, 4.1.4, and 4.2.4, the analysis should include the landslide's effect on floating PV's anchor stability and landslide induced-wave loading. In addition, a safe distance between the closest anchor point to the potential landslide location may be determined from this analysis.

Due to existing recreation activities, a clear zoning regulation should be enacted. Based on "4.2.8. Floating PV Layout and Location", a safety zone with clear warning signs and / or safety barriers such as safety buoys may be used to avoid accidental recreational boat impact and / or unwarranted human activities near the floating PV. The zoning regulation may include the permitted boat speed, passing frequency, and boat size within a particular restricted area. More detailed safety zone and restrictions implementation may be analyzed by the ship-induced wave analysis, accidental boat impact analysis, and risk-reliability analysis based on the existing recreational facilities. A conservative value of 500m from the outermost part of the structure may be used in the absence of a more detailed analysis.

The implementation example of the guideline Section 4.2.8 and 4.2.9 in the Cacaban dam may be illustrated in Figure 6-9 and Table 6-1 below. In these examples, three hypothetical PV locations' advantages and disadvantages are discussed based on their practicality and dam safety aspects.

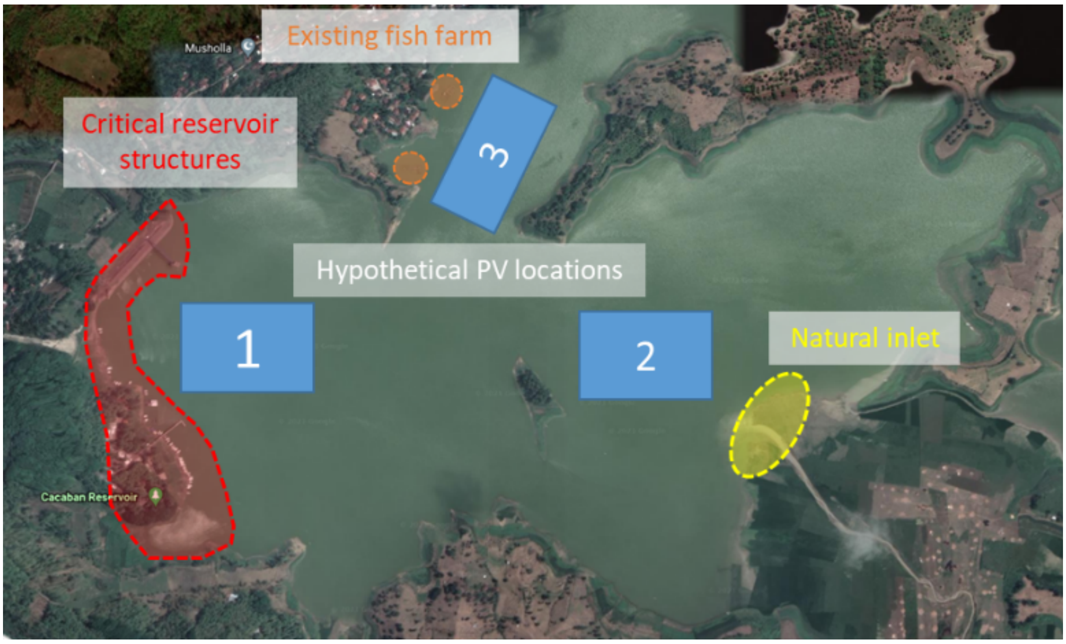


Figure 6-9. Critical reservoir structures and hypothetical floating PV locations in Cacaban reservoir (Source: Google Earth)

Table 6-1. Implementation Examples of Design Considerations of Three Hypothetical Floating PV Locations in Cacaban Reservoir

Hypothetical Location	Advantages	Disadvantages

Loc. 1	● Proximity to shore and critical reservoir structures may reduce the length of transmission lines and provide easier maintenance access ● Large available water body available for installation	● Proximity to an existing recreational area, may increase the risk from human activities ● If the dominant wind direction is blowing towards the west, there is no safety barrier between the floating PV and critical reservoir structures on its left in the case of an uncontrolled drift event ● Large wind fetch length on its right side
Loc. 2	● If the dominant wind direction is blowing towards the west, an island to the left of the floating PV provides a natural safety barrier between the PV and critical reservoir structures in the case of uncontrolled drift ● Large available water body available for installation ● Relatively small wind fetch length from all direction	● If the dominant wind direction is blowing towards the east or south, there is no safety barrier between the floating PV and critical reservoir structures on its bottom-right in the case of an uncontrolled drift event ● May be harder to access and require longer transmission lines due to its location that is relatively far from any existing structures or population center(1) ● Sedimentation may be highly affected by the structure since it is close to a natural inlet on its right side(1)
Loc. 3	● Any dominant wind direction will cause the floating PV to move away from any critical reservoir structure in the case of an uncontrolled drift event. ● Proximity to shore and population center may reduce the length of transmission lines and provide easier maintenance access ● Relatively small wind fetch length from all direction ● Located on reservoir dead storage area, thus stranding risk is minimized(2)	● Relatively close to existing fish farm area, may increase the risk from human activities(1) ● Limited available water body for installation. The floating PV may also affect the water flow and sedimentation since it is located in a constricted area.

(1)Based on secondary data from Google Earth Image

(2)Based on a topographical and bathymetric survey of PT.Mettana, 2017

6.1.5 Environmental Aspects In Structural Design

Based on secondary data obtained from ECMWF database from 1979 to 2020, the monthly-averaged wind speed around Cacaban reservoir ranges from **2.3m/sec – 10.5m/sec**. Note that this value is monthly averaged, thus sudden wind gust with a small period (in the order of minutes or hours) will not be reflected in the data.

Based on the topographical and bathymetric survey of PT.Mettana (2017), the water depth around the area illustrated in Figure 6-9is ranging from **0m-16m**. The longest wind fetch length for wave calculation is **1.8km**, based on hypothetical PV location 1. Note that this is the maximum possible fetch length, if the actual floating PV coverage area or different location is considered, the fetch length will be decreased. Based on the data above, the significant wave height based on the hindcast formula given in 4.1.2.1.3 can be seen in Figure 6-10.

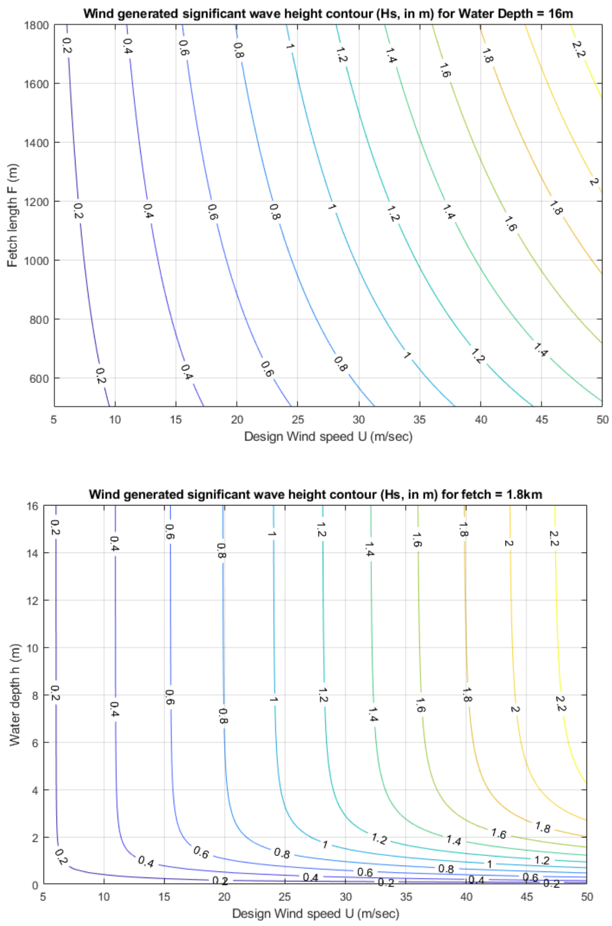


Figure 6-10 Significant wave height contour based on water depth, wind speed, and fetch length variability on Cacaban Dam

From Figure 6-10, we can see that at maximum fetch length (1.8 km), the wave's height is invariant to water depth larger than 4m. On the other hand, at a maximum water depth (16m), the wave's height is relatively unaffected by fetch length at a small wind speed (< 15m/sec). Note that the design wind speed used in the wave calculation should reflect the targeted return period of the wave. On a typical operational environment (non-extreme weather, typically used for fatigue calculation), generated waves may be roughly approximated from the maximum monthly averaged wind of 10.5m/sec. This corresponds to a small significant wave height value of 0.4m. Note that these conditions should not be used for a design basis. For actual design, the detailed analysis and data on bathymetry, soil type, current velocity (speed and direction) and occurrence, wind velocity and occurrence, design wind fetch length, wave hindcast, and verification based on the guideline in sub-section 4.1 are needed.

The sedimentation problem was qualitatively observed based on a site visit in 2021. The presence of PV may affect the sedimentation through the following process:

- Decrease in turbidity due to decrease in wind fetch area
- Change in fluid flow velocity close to the surface
- Change in overall water temperature and vertical temperature distribution

All of the above may change the sediment settling time, settling velocity, and sedimentation locations. Therefore, further sedimentation analyses are needed to ensure that it will not hinder the operability of reservoir (e.g., its service life and flow control) and floating PV (e.g., accidental mooring burial, increase in mooring-reservoir floor contact, or increase in stranding condition).

6.1.6 Floater, Anchor, And Mooring Design

The high water level variation means that the mooring systems need to be able to accommodate for the high change in water depth without sacrificing its station-keeping capability. Excessive variations on the bottom laying part of the moorings need to be avoided, since it may cause tangling and also bottom impact or friction loading which in overall may damage the mooring lines (see Figure 6-11).

Typical solutions are to utilize either buoy-mooring systems, S-tether mooring systems, or their variations (see Figure 6-12). These solutions aim to decouple the mooring parts into the high and low tension zones. A high tension zone is responsible for the overall station-keeping capability and for reducing the mooring reservoir's floor contact variation. On the other hand, the low tension zone is responsible to accommodate high water level variation.

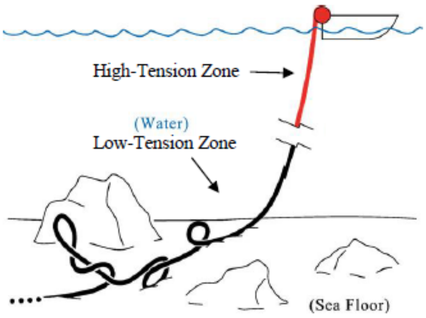


Figure 6-11 Potential tangling near the bottom, caused by high variation of mooring's catenary length (mooring's length between touch down point and top connection, Goyal & Perkins 2007)

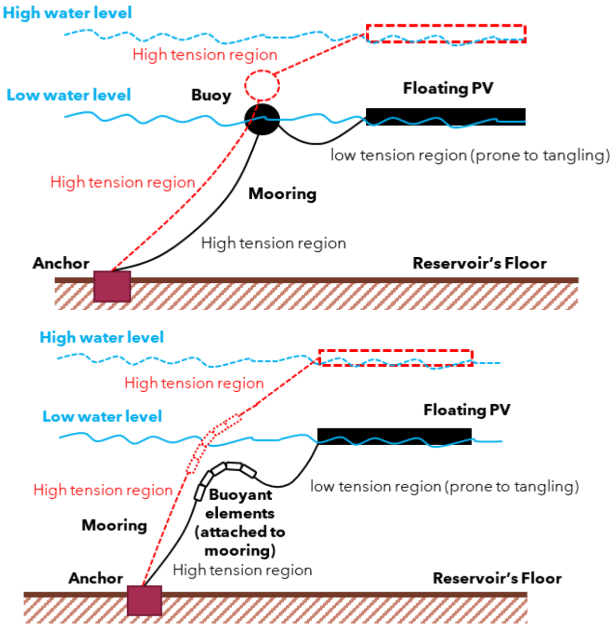


Figure 6-12 Illustration of buoy-mooring systems (left) and s-tether systems (right)

The following concern when designing buoy-mooring or s-tether mooring systems need to be addressed and analyzed:

- In general, tangling may still occur on the low tension part, which now moved closer to the mooring's top connection. However, the bottom friction and impact is minimized
- The water circle of the floaters will be increased during low water levels due to decrease in tension on the low tension zone.

- Different stress concentrations and cyclic loading between low and high water levels on anchors, mooring lines and connections, and floaters may occur.

Note that the mooring system configuration explained above should only serve as illustrations and examples and may not be taken as a design guideline. In a region where the sedimentation rate is high (as qualitatively observed in the Cacaban dam), the accidental burial of bottom-laying mooring lines needs to be anticipated in design considerations. More detailed design analysis for the floater, anchor, and mooring components should follow subsection 4.2.1 to 4.2.7.

6.1.7 Environmental Conditions

The water at Cacaban Dam has a total volume of 90 million m^3. The water is used as a provider of irrigation water for an area of 17,481 ha. Agricultural commodities in the region include palawija plants (corn, peanuts, soybeans), vegetables (onions, garlic, potatoes, cabbage, chili, tomatoes, carrots, long beans, chickpeas, cucumbers, etc.), and fruits (mango, rambutan, duku, cane, starfruit, durian, banana, salak, orange, pineapple, papaya, etc.). The use of water as a source of irrigation causes the water quality in the dam to be maintained. Poor water quality, especially if there is a heavy metal content, will be able to cause a significant impact on crop yields and can cause adverse effects on health if consumed.

The water quality at the Cacaban Dam that has been studied is shown in Table 6-2. The water quality is compared to Government Regulation of the Republic of Indonesia No. 82/2001, Class 2, water whose designation can be used for water recreation infrastructure/facilities, freshwater fish cultivation, animal husbandry, and water for irrigating crops.

Table 6-2 Cacaban Dam Water Quality

No	Parameter	Unit	Standard	Result	Reference Method
	Physical				
1	Total Dissolved Solids (TDS)	mg/L	1000	790	SNI 06-6989.27-2005
2	Total suspended solids (TSS)	mg/L	50	15	SNI 06-6989.3-2004
	Chemical				
1	pH	mg/L	6 - 9	7,28	SNI 06-6989.11-2004
2	BOD_5	mg/L	3	11,97	SNI 06-6989.27-2009
3	COD	mg/L	25	35,7207	SNI 06-6989.2-2009
4	DO	mg/L	> 4	6,14	APHA 4500 P-D-2012
5	Total Phosphate (P)	mg/L	0,2	0,0665	SNI 06-6989.79-2011
6	Nitrate (NO3-N)	mg/L	10	2,2718	APHA 3114-C-2012
7	Arsenic (As)	mg/L	1	<0,0021	US EPA Method No 200.7-2001
8	Cobalt (Co)	mg/L	0,2	0,01499	US EPA Method No 200.7-2001
9	Boron (B)	mg/L	1	0,10564	APHA 3114-C-2012
10	Selenium (Se)	mg/L	0,05	< 0,0013	US EPA Method No 200.7-2001
11	Cadmium (Cd)	mg/L	0,01	0,00993	US EPA Method No 200.7-2001
12	Chrome Hexavalent (Cr-VI)	mg/L	0,05	< 0,0083	SNI 06-6989.78-2011
13	Copper (Cu)	mg/L	0,02	< 0,00819	US EPA Method No 200.7-2001
14	Lead (Pb)	mg/L	0,03	< 0,01039	US EPA Method No 200.7-2001
15	Mercury (Hg)	mg/L	0,002	< 0,0004	SNI 6989.78-2011
16	Zinc (Zn)	mg/L	0,05	< 0,01894	US EPA Method No 200.7-2001
17	Cyanide (CN-)	mg/L	0,02	< 0,0050	SNI 6989.77-2011
18	Nitrite (N02-N)	mg/L	0,06	0,0431	SNI 06-6989.9-2004
19	Free Chlorine (Cl2)	mg/L	0,03	0,03	Colorimetry
20	Sulfur as H2S	mg/L	0,002	< 0,0013	SNI 6989.70-2009
21	Oil and Grease	mg/L	1	< 0,94	SNI 6989.10-2011
22	Detergent (MBAS)	mg/L	0,2	0,1362	SNI 06-6989.51-2005
23	Phenol	mg/L	0,001	< 0,0004	SNI 06-6989.21-2004
	Microbiology				
1	Fecal Coliform	TC/100 ml	1000	540	APHA 9221-E-2012
2	Coliform	TC/100 ml	5000	920	APHA 9221-B-2012

Source: PT. Mettana, 2016

From Table 6-2, it can be seen that the water quality in the dam can not fulfill the requirements for Class 2 waters, especially for BOD and COD parameters. The BOD of the waters is quite high, almost 12 ppm compared to the standard at 3 ppm, as well as the COD at 35 ppm compared to standard at 25 ppm.

Concerning the environmental aspect, despite the water quality presented in Table 6-2, Cacaban Dam water looks in good condition. The water surface in the reservoir is relatively clean and clear, not disrupted by eutrophic water plants such as water hyacinth and also there is no development of fish farming. There is a development of Cacaban Reservoir by the Tegal Regency Tourism Office with the presence of a pier and tourist boats on the left upstream. Several points on the edge of the upstream slope of the dam and at the left perimeter there is some garbage from the visitors.

The area around Cacaban Dam is also used as a settlement for the community. Judging from the BPS (Central Bureau of Statistics) Tegal Regency in 2021, the population density in Kedungbanteng sub-district is 511 people/km^2 with a population growth of 1.13% in 2020. The increase in the population causes more dense settlements in the Cacaban Dam area. The condition of the settlement near the Cacaban Dam can be seen in the upper-left corner in Figure 6-8.

Based on the discussion with the staff at the dam, we obtained information that the sedimentation at the bottom of the dam already is 9-10 meters thick (from a total depth of 19 meters during dry season). The largest sediment from the river that enters the dam is because the catchment area is not maintained, and this might be related to the dense population in the surrounding area.

6.2 Pandan Duri Dam

6.2.1 General

Pandanduri dam is located in Swangi Village, Sakra District, East Lombok Regency, West Nusa Tenggara Province, as shown in Figure 6-13. Pandanduri dam consists of the Main Dam and nine (9) Saddle Dams. The dam was constructed from 2011 to 2014. The main dam is a random earth-fill with a maximum height of 42.00 m from the base of the foundation. The dam in the normal water level condition is capable of holding ± 29,60,000m^3 water from the Palung River. The dam functions as flood control in the rainy season and irrigates 450 ha. The dam operation and management are under BWS Nusa Tenggara 1.

Figure 6-13. Location of Pandanduri Dam

6.2.2 Existing Condition

Based on the report from PT Indra Karya submitted by BBWS NT-1 to the Dam Safety Unit at the end of November 2021, the existing conditions of the Pandanduri dam are as follows:

1. Figure 6-14 shows a high reservoir water level variation from +277.5m during NWL in February 2020 to +270.92m during the dry condition in September 2020. This variation is already discussed in Section 6.2.4. The fluctuation of water levels is followed by the sedimentation process, as shown in Figure 6-14.

Figure 6-14 Variations of reservoir water level

2. Based on the inspection, several cracks are identified on the saddle dams, especially saddle dam #9, as shown in Figure 6-15. The dimensions of cracks are 20-70 mm wide, 18 cm deep, and 173 meters long. It is probably due to the existence of expansive clay identified on the dam's foundation.

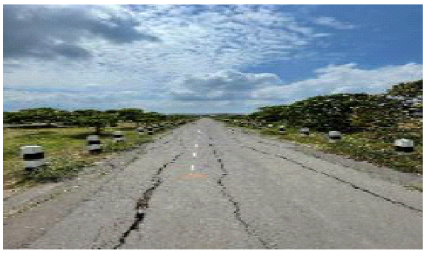


Figure 6-15. Cracks occur on saddle dam #9

3. Based on visual inspection, leakages are identified on the conduits in the tunnel, as shown in Figure 6-16. The leakages are probably due to the poor quality of construction in some locations of the tunnel.

Figure 6-16. Conduit

4. There is a potential for landslides on the left and right sides of the spillway, as shown in Figure 6-17. The landslide in the spillway area was initially reported on September 3, 2018. The landslide occurred on the right and left sides of the spillway wall. It is informed that the cause of landslides is probably caused by rainwater erosion due to no surface drainage around the

spillway embankment. Then rehabilitation was carried out using retaining walls with a depth of 10 m on both sides of the downstream spillway. There is a need to ensure the backfill materials are free drained, consisting of gravel instead of random clay.

Figure 6-17. Spillway conditions

5. There is no trash boom in the intake, as shown in Figure 6-18. The previous trash boom is probably damaged due to the large flow of the reservoir and the poor construction of the trash boom anchor.

Figure 6-18, Intake condition

6.2.3 Seismicity Conditions

Based on PUSGEN (2017), there is no active fault close to the Pandanduri dam, as depicted in Figure 6-19. The closest seismic sources from the site are the Sumbawa strait strike-slip. According to PUSGEN (2017), the peak ground acceleration (PGA) for 5000 years returns period ranges between 0.5g and 0.6g (Figure 6-20).

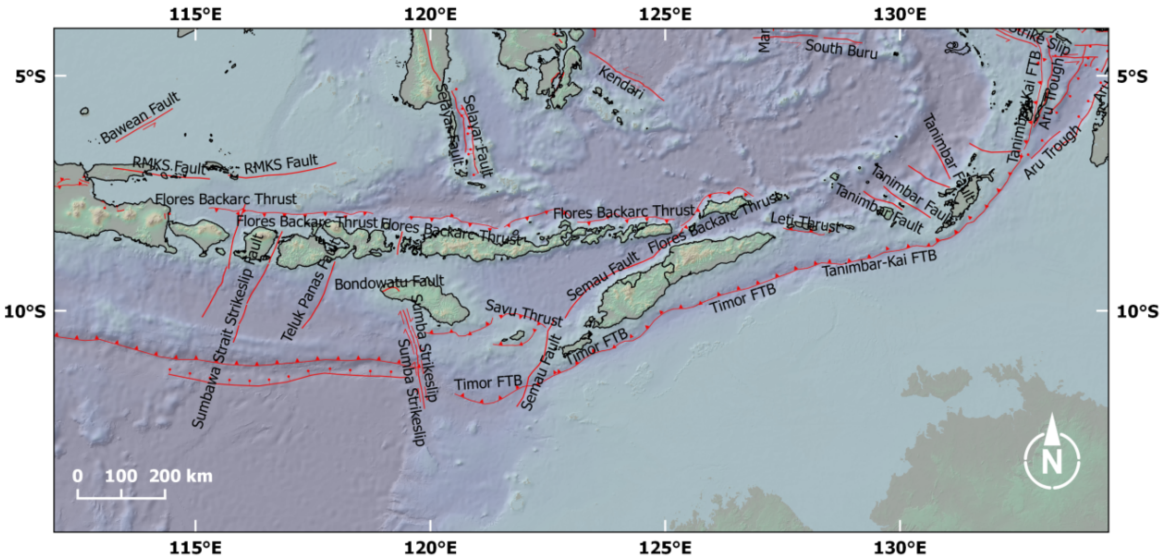


Figure 6-19. Seismic sources around Pandanduri Dam

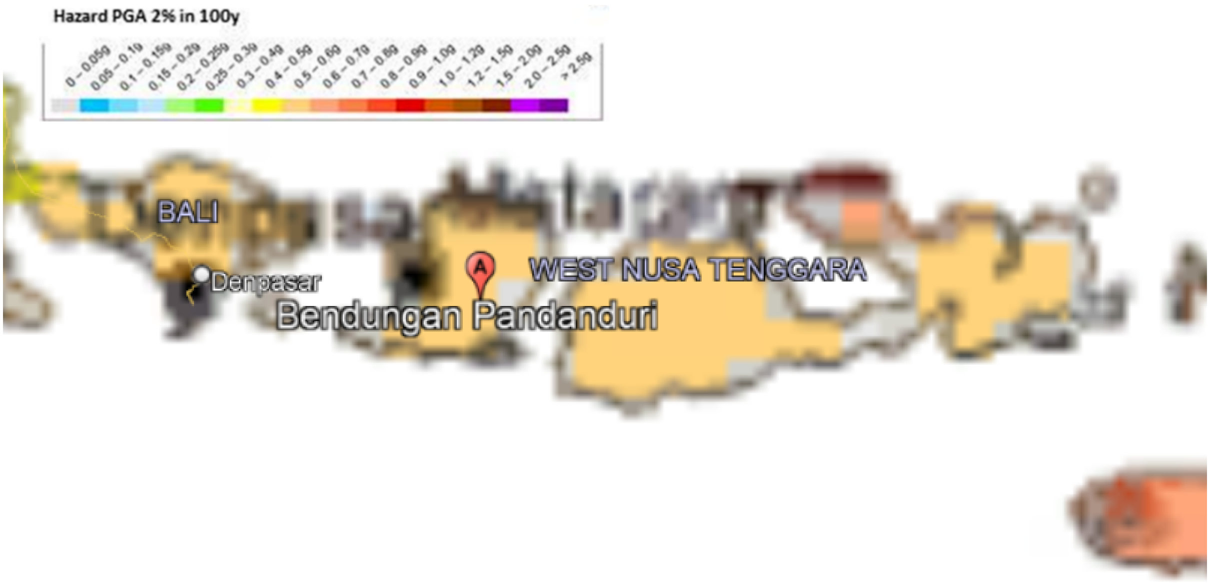


Figure 6-20. PGA for 5000 years return period (PUSGEN, 2017)

6.2.4 Floating PV Coverage Area, Layout, Location, And Zonation

Historical data shows high variation of reservoir water level and area. Ranging from +281.5m during normal water level (NWL) with 316ha reservoir area to +264m during low water level (LWL) with 28ha reservoir area. We can conclude that disparity between the NWL and LWL in Pandanduri dam is higher than the Cacaban dam.

The ratio of reservoir area between its LWL and NWL in Pandanduri dam is roughly 1:11, or 8.8%. This means 91.2% of the area may cause the PV to be stranded when the targeted PV coverage area is calculated from the normal water level (instead of the minimum water level). In this reservoir, the 5% PV coverage area in normal water level will translate to 56% coverage area in low water level. Therefore, the availability of a location that does not show any stranding risk is only 8.8% of the total reservoir area at normal water level.

Same as the Cacaban dam, the risk of stranding conditions in Pandanduri dam is relatively high. If based on other analysis, if it is found to be impossible to avoid stranding conditions during the floating PV's lifetime, additional detailed analysis for stranded and re-floating conditions such as suggested in 4.2.4 is required.

The implementation example of the guideline section "4.2.8 Floating PV Layout and Location" and "4.2.9. Dam Safety" in Pandanduri dam, may be illustrated in Figure 6-21 and Table 6-3 below. In these examples, two hypothetical PV locations' advantages and disadvantages are discussed based on their practicality and dam safety aspects.

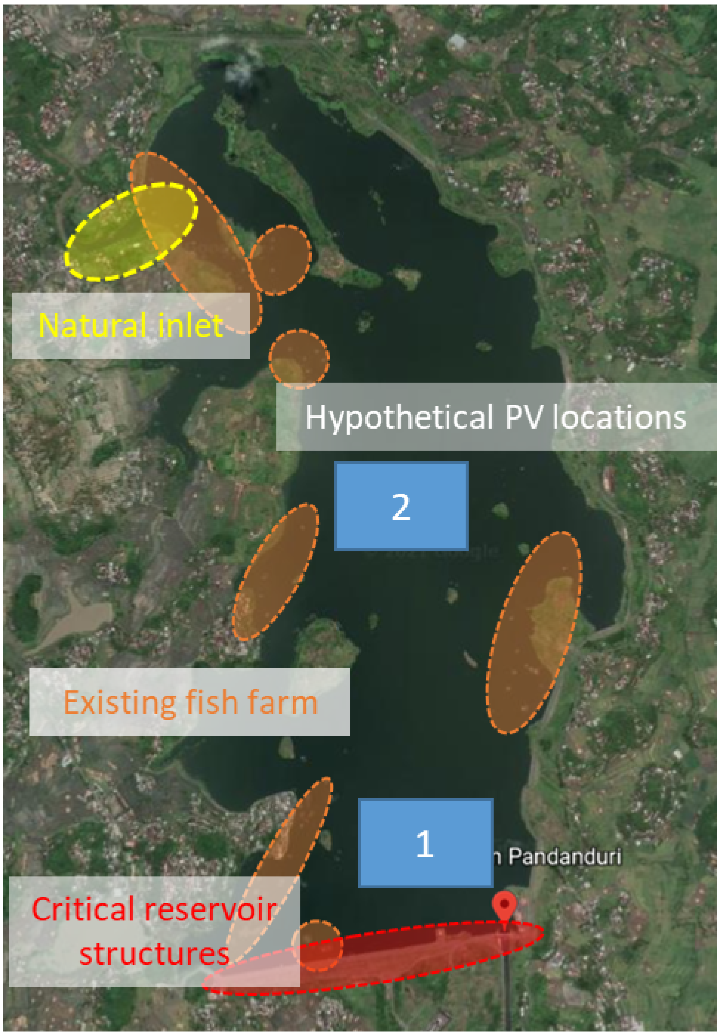


Figure 6-21 Critical reservoir structures and hypothetical floating PV locations in Pandanduri reservoir (source: Google Earth)

Table 6-3 Implementation examples of design considerations of three hypothetical floating PV locations in Pandanduri reservoir

Hypothetical Location	Advantages	Disadvantages
Loc. 1	• Proximity to shore and critical reservoir structures may reduce the length of transmission lines and provide easier maintenance access • Large available water body available for installation	• Proximity to an existing recreational area, may increase the risk from human activities • If the dominant wind direction is blowing towards the south, there is no safety barrier between the floating PV and critical reservoir structures on its left in the case of an uncontrolled drift event • Large wind fetch length on its north side
Loc. 2	• If the dominant wind direction is blowing towards the south, a large separation distance between the floating PV and critical dam structure would provide ample time for corrective measures in the case of an uncontrolled drift event • Large available water body available for installation • Relatively small wave fetch length from the north direction compared to location 1	• May be harder to access and require longer transmission lines due to its location that is relatively far from any existing structures or population center(1) • Relatively large wind fetch length from the south direction compared to location 1

(1)Based on secondary data from Google Earth Image

6.2.5 Environmental Aspects In Structural Design

Based on secondary data obtained from ECMWF database from 1979 to 2020, the monthly-averaged wind speed around Pandanduri reservoir is ranging from **2.7m/sec – 8.3m/sec**. Note that this value is monthly averaged, thus sudden wind gust with a relatively small periods (in the order of minutes or hours) will not be reflected in the data.

Based on the topographical and bathymetric survey of PT.Mettana (2021), the water depth around the area illustrated in Figure 6-21 is ranging from **0m-23m** (from LWL to flood condition). The longest wind fetch length for wave calculation is **2km**, based on hypothetical PV location 1. Note that this is the maximum possible fetch length, if the actual floating PV coverage area or different location is considered, the fetch length will be decreased. Based on all the data above, the significant wave height based on hindcast formula given in 4.1.2.1.3, can be seen in Figure 6-22.

From the Figure 6-22, we can see that at maximum fetch length (2 km), the wave's height is invariant to water depth larger than 5m. On the other hand, at a maximum water depth (23m), the wave's height is relatively unaffected by fetch length at small wind speed (< 10m/sec). Note that the design wind speed used in the wave calculation should reflect the targeted return period of the wave. On typical operational environment (non-extreme weather, typically used for fatigue calculation), generated waves may be roughly approximated from the maximum monthly averaged wind of 8.3m/sec. This corresponds to a small significant wave height value of 0.3m. Note that these conditions should not be used for design basis. For actual design, a detailed analysis and data on bathymetry & soil type, current velocity (speed + direction) and occurrence, wind velocity and occurrence, design wind fetch length, wave hindcast and verification, etc. based on the guideline subsection 4.1 of the is needed.

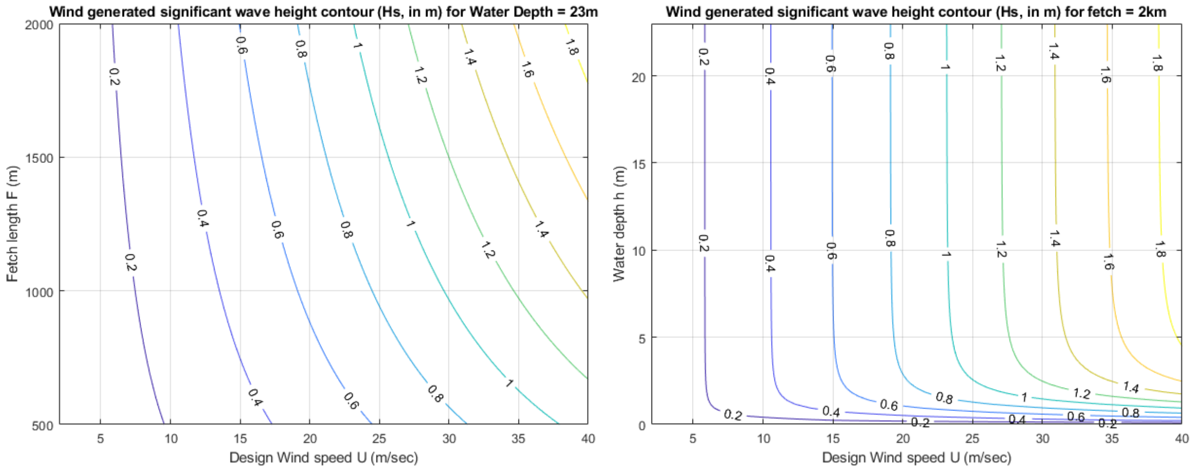


Figure 6-22 Significant wave height contour based on water depth, wind speed, and fetch length variability on Pandanduri Dam

6.2.6 Floater, Anchor, And Mooring Design

Similar environmental conditions and variation in water elevation and reservoir area with the one in Cacaban dam is observed in Pandanduri dam. Therefore, the same considerations with the one in Cacaban dam discussion also applied here.

6.2.7 Environmental Conditions

With a surface area of 328.84 ha of inundation, the water source of this dam comes from three rivers, namely the Sordang River, Treng Wilis River, and Gading River. Compared to Cacaban Dam, the water in Pandanduri Dam is visually dirty, where several locations are covered by garbage. The garbage gathering point is located in front of the door of the spilt, and is depicted in Figure 6-18. Garbage in the reservoir area is cleaned regularly to prevent the piles of garbage which will disturb the ecosystem. Weeds such as water hyacinth are also found in the reservoir as depicted in Figure 6-19.

Figure 6-23. Pile of Garbage in Front of the Overflow (Ministry of Public Work and Public Housing, 2020)

Figure 6-24. Water Hyacinth Plants Around the Reservoir (Ministry of Public Works and Public Housing, 2020)

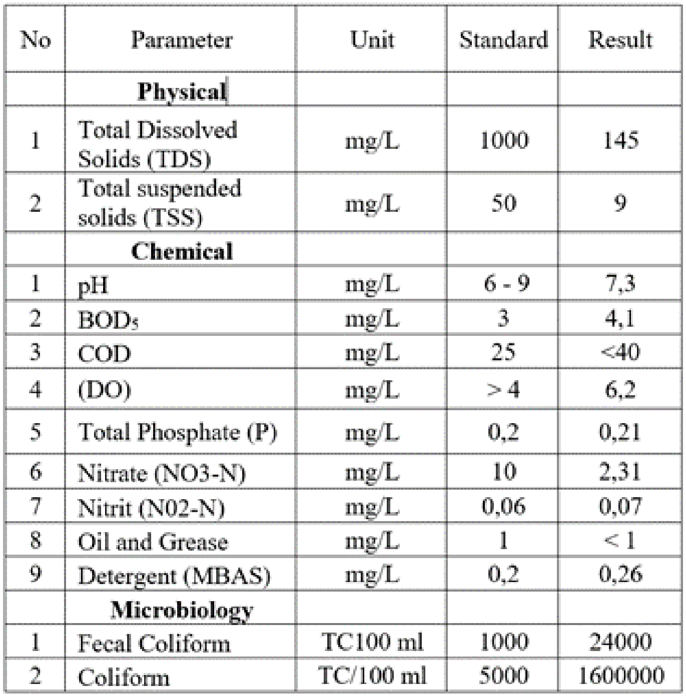
Utilization for residential land around Pandanduri Dam is less than 1%, with a total population density of 948 people/km^2. However, it is believed that the population will continue to increase annually and cause denser residential areas in the dam's vicinity. The condition of the settlements in the Pandanduri Dam area is depicted in Figure 2-20.

Figure 6-25. Settlement Conditions in Pandanduri Dam Area (Google Earth, 2021)

Generally, the waters are used as a source of irrigation for an area of about 5,168 ha downstream of the dam. Other than being the source for irrigation, the area of Pandanduri Dam is also used for planting during the dry season. The locals also use the reservoir area as land for fish cages, as shown in Figure 6-24.

As explained before that the water in Pandanduri is dirty. The water quality analysis shown in Table 6.4 confirmed the visual exploration. Even though the BOD and COD values are comparably lower than those at Cacaban Dam (4 and 40 ppm, consecutively), but the microbial parameters, i.e., Fecal and Total Coliform, are much higher than Class 2 standards. This may be due to the many activities of local fish cages, which usually cause a lot of fishery waste and led to the immense growth of bacteria.

Table 6-4 Pandanduri Dam Water Quality



No	Parameter	Unit	Standard	Result
	Physical			
1	Total Dissolved Solids (TDS)	mg/L	1000	145
2	Total suspended solids (TSS)	mg/L	50	9
	Chemical			
1	pH	mg/L	6 - 9	7,3
2	BOD_5	mg/L	3	4,1
3	COD	mg/L	25	<40
4	(DO)	mg/L	> 4	6,2
5	Total Phosphate (P)	mg/L	0,2	0,21
6	Nitrate (NO3-N)	mg/L	10	2,31
7	Nitrit (N02-N)	mg/L	0,06	0,07
8	Oil and Grease	mg/L	1	< 1
9	Detergent (MBAS)	mg/L	0,2	0,26
	Microbiology			
1	Fecal Coliform	TC100 ml	1000	24000
2	Coliform	TC/100 ml	5000	1600000

6.3 Financial and Business Aspects

Based on the results of the calculation of the electrical projection, when multiplied by the unit rate (according to the scenario), a projected annual income potential will be obtained, which in turn becomes a source of income for the dam owner to finance part of the cost of maintaining the dam which is currently a heavy burden for the dam owner. government.

The tariff unit used uses two scenarios, the first scenario is using the tariff according to the regulation of the Minister of Energy and Mineral Resources number 169 of 2021, and the second scenario is using the prevailing general rate of 15 cents USD per KWh.

For potential investors, the burden that must be borne in addition to the costs mentioned above, also has to bear interest costs and loan installments related to investments for floating solar panels. Installments and long-term loan installments for investors have many choices both in terms of the term and the amount of loan interest rates.

In calculating this floating solar panel project, the consultant uses two scenarios, the first scenario is if the general investment loan interest rate is based on the average infrastructure investment loan interest rate in Indonesia of 9.55 percent per year (Source: Bank Indonesia, on average). -average investment loan interest rates 2017-2021). The second scenario is to use the Green Bonds or Sukuk Wakalah loan interest rate of 3.55 percent per year with a 30-year tenor (source: Ministry of Finance, June 2021, and POJK no 60/POJK.04/2017, concerning Issuance and Requirements for Debt Securities Environmentally Friendly or Green Bonds).

However, to get the interest, certain requirements must be met, namely carrying out the principles of dam safety and protecting the dam environment through strict monitoring and evaluation as required in the Climate Bonds Initiative. This also means that it is in line with PT PLN's RUPTL 2021-2030 which requires Green RUPTL to meet the 23% EBT target in 2025 (source: Directorate of Various Energy and Renewable Energy, PLTU Substitution with EBT Generators through the FPV program, 23 Nov 2021).

In sub chapter 6.3.1, the steps for preparing financial reports for both the Cacaban and Pandanduri reservoirs will be explained. Meanwhile, the steps for preparing economic, financial and value for money analysis will be explained in sub-chapter 6.3.2.

6.3.1 Learning form Floating Solar Panel Project Financial

In accordance with the explanation in the sub-chapter above, the report on the economic, financial and value for money of the Floating Solar Panel project in PT Mettana (2021) if we used as basic model for this study, we can made with 3 (three) scenarios or approaches, according to Table 6.5 as follows:

Table 6-5 Financial Scenario FPV Project of Cacaban and Pandanduri Dam

DAM	SCENARIO	INTEREST RATE	TARIFF
CACABAN	1	Conventional 9,55%	Regulation of Minister Energy and Mineral Resources 169/2021 Rp. 907,77
PANDANDURI	1	Conventional 9,55%	Regulation of Minister Energy and Mineral Resources 169/2021 Rp.1.458,30
CACABAN	2	Conventional 9,55%	General market Rp.2.186,80 or 15 Cent USD
PANDANDURI	2	Conventional 9,55%	General market Rp.2.186,80 or 15 Cent USD
CACABAN	3	Green Bonds, Sukuk Wadalah 3,55%	Regulation of Minister Energy and Mineral Resources 169/2021 Rp. 907,77
PANDANDURI	3	Green Bonds, Sukuk Wadalah 3,55%	Regulation of Minister Energy and Mineral Resources 169/2021 Rp.1.458,30

After learning from Cirata FPV project in West Java, as we know its project funding from Intergovernmental cooperation among Indonesian government with United Emirates of Arab (UEA), and to be cooperated in special percentage of shareholders. The state owned company PT Pembangunan Listrik Jawa Bali (PT PJB) with PT Masdar as a private investor company, where project capital share among PT PJB and Masdar is 51% and 49%. That's why we made the same financial policy to implementing of the project funding alternatives in the case of Cacaban and Pandanduri with capital sharing among ownership of state-owned enterprises with private investors through the following alternatives

Table 6-6 Funding Alternative for FPV Project of Cacaban and Pandanduri Investment

Funding Aletrnative	% Share of State Owned Company (SOC) I.e. PT PJB	% Share of Private Investor (PI) or Special Purpose Company
1	**51%**	**49%**
2	**40%**	**60%**
3	**30%**	**70%**

Its report is of course made in a different form or format, but still in the same principle or approach. The results are presented in the form of a separate table, which is equipped with graphs and detailed explanations. The following is a summary of the report from the financial side for a period of 25 (twenty five years) in million rupiah for each reservoir according to the scenario above.

6.3.2 Comparison Result of Floating Solar Panel Project in Cacaban and Pandanduri

Financial, economic and value for money analysis is an integral part of the standardization of business and financial statements. in this review from PT Mettana study in 2021, all three parts of the report can be reported in the form of a composite overview table so that the overall picture of the full report can be seen.

Based on the results of the analysis of financial, economic and value for money projections above, a brief summary table of financial and business analysis can be obtained as follows:

Table 6-7 Summary of Business and Financial Aspect Analysis

Alternative-1, Cost Sharing of Project Investment, SOC 51% : PI 49%

SCEN	**DAM**	**TARIFF/KWh**	**INTEREST, P.A.**	**5%**	**8%**	**10%**	**15%**	**20%**	**25%**
1	CACABAN	Rp 908	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
1	PANDANDURI	Rp 1.458	9,55%	Not Feas	Feasible	Feasible	Feasible	Feasible	Feasible
2	CACABAN	Rp 1.704	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
2	PANDANDURI	Rp 1.704	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
3	CACABAN	Rp 908	3,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
3	PANDANDURI	Rp 1.458	3,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible

Alternative-2, Cost Sharing of Project Investment, SOC 40% : PI 50%

SCEN	**DAM**	**TARIFF/KWh**	**INTEREST, P.A.**	**5%**	**8%**	**10%**	**15%**	**20%**	**25%**
1	CACABAN	Rp 908	9,55%	Not Feas	Feasible	Feasible	Feasible	Feasible	Feasible
1	PANDANDURI	Rp 1.458	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
2	CACABAN	Rp 1.704	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
2	PANDANDURI	Rp 1.704	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
3	CACABAN	Rp 908	3,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
3	PANDANDURI	Rp 1.458	3,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible

Alternative-3, Cost Sharing of Project Investment, SOC 30% : PI 70%

SCEN	**DAM**	**TARIFF/KWh**	**INTEREST, P.A.**	**5%**	**8%**	**10%**	**15%**	**20%**	**25%**
1	CACABAN	Rp 908	9,55%	Not Feas	Not Feas	Not Feas	Not Feas	Not Feas	Feasible
1	PANDANDURI	Rp 1.458	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
2	CACABAN	Rp 1.704	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
2	PANDANDURI	Rp 1.704	9,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
3	CACABAN	Rp 908	3,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
3	PANDANDURI	Rp 1.458	3,55%	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible

Based on the overview on Table 6-7 above, it is seen differential that scenario one and two where the electricity that significant variables are selling price For example the comparison tariff implemented in alternative 1 and alternative 2, with Ministry EMR no. 169/2021 and with market tariff, with 8 percent reservoir area tha Cacaban was feasible, but for Pandanduri was viability on 5% reservoir allocated. But if we use alternative 3, where shareholders equity SOC 30% and PI 70%, the Cacaban must used 25% reservoir allocation and Cacaban only 5% reservoir allocation.

From this case, we have conclusion that the proportional of funding investment alternatives is one of key point concern to make its project success or not success, because equity risk sharing is very important for the financial investment calculation.

7 CONCLUSION AND RECOMMENDATION

7.1 Conclusions

7.1.1 Environmental Aspects

Based on the Ministry of Energy and Mineral Resources document entitled Floating Solar Power Plant Planning Guide 2021, the aspects to be considered are only mentioned as follows: changes in environmental temperature and oxygen levels in water due to floating solar PV covering the water surface, changes in water quality and ecosystems due to the reduced intensity of the sunlight, and oil droplets due to leaks from ship fuel tanks used for operation and maintenance and the usage of detergent and other compounds during panel cleaning.

Other than the considerations mentioned above, many studies have discussed the effect of Floating PV to the environment, i.e. the leaching of heavy metals, the changes in microorganism populations, the decrease in evaporation rate and its effect on water quality, water pollution by cleaning agent, and the reduction of mixing process in the reservoir. With a proper anticipation of environmental impacts and mitigation measures, most of those impacts are considered to be minimal.

Based on the discussions in Chapter 3.2, for reservoirs with surface areas between 3 – 96 hectares, by Quantitative Microbial Risk Assessment, it is concluded that with a surface cover of not more than 30%, the majority of bacteria removal targets were still achieved. We may add that this condition is supported by the fact that the water quality of the study area (in the Netherlands) is much better than what we have in Indonesia. The study was carried out in Berenplaat, which has E Coli number of 100/ 100 ml. In the case of Pandanduri Dam with poor water quality with E Coli number of 1,600,000 / 100 ml then we may argue that 30% of coverage area may not possible. Coupled with the condition that the compliance level in Indonesia is usually low, it is necessary to provide a higher safety factor. Considering this, we may suggest the coverage area of Floating Solar PV in Indonesia should be less than 30%.

Even though Cacaban Dam has lower E Coli number of 920 / 100 ml (still higher than that of Berenplaat), but the BOD and COD values are much higher. This condition will lead to further bacterial growth and it is possible that the microbial conditions will be higher in the future.

One option for mitigation effort to control the effect of Floating Solar PV is the installation of aerator or mixer under the panel. However, the condition of Cacaban Dam with a sediment height of 9 meters and water depth above the sediment of not more than 9 meters may lead to scouring, so installation of mixer is not recommended.

7.1.2 Structural Aspects

The design guidelines for floating PV in the DOISP reservoir were discussed, focusing on the support structure’s design (floaters, mooring, anchor) and their relation to the dam safety requirements. Floating PV design criteria in the design guideline are considered to be site-specific, tied to the site’s environmental condition, and acceptable safety level (nominal annual probability of failure). In the structural design perspective, the loadings and environmental conditions are treated as anticipated variables, whereas other variables such as financial aspects and environmental sustainability aspects are treated as the limiting variables.

For loading and structural design considerations, the general recommendation is to prioritize direct measurement data when practically possible. Other acceptable sources of data or design guideline alternatives were also discussed, provided that acceptable justifications were provided. Although recommended safety levels were provided in the guideline, a less conservative value may be used with proper calibration or with a different relationship with the critical reservoir structures, as discussed in 4.2.9.

Based on this guideline, the site-specific loadings and design requirements mean that the use of fixed design parameters for all possible DOISP sites will be counterproductive since it will not give the most optimum design in terms of cost and safety level. These design guidelines may also be used as general guidance to determine the reservoirs' location, layout, configuration, and optimum utilization area in terms of structural safety aspects.

Based on the surveys and visual inspections of Cacaban and Pandanduri dams, several issues arise that may cause potential risks to the installation of floating PV. Generally, the issues related to the dam’s structures such as the dam’s stability, the leakage on the tunnel, the intake and spillway conditions.

This report introduces two or three hypothetical PV locations' advantages and disadvantages based on their practicality and dam safety aspects for Cacaban and Pandanduri.

7.1.3 Financial and Business Aspects

The results of discussions through FGDs and internal discussion, qualitative result studies as two sample dam Cacaban and Pandanduri, we have some conclusion that its described as follows:

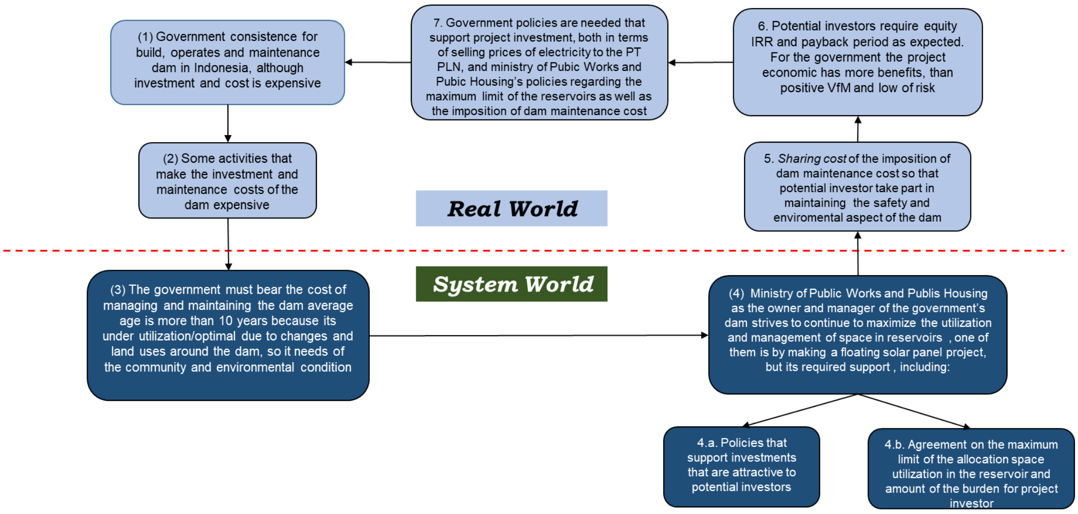


Figure 7-1 Result of Qualitative Research Cababan and Pandanduri Dam

Based on the results of other qualitative analysis:

A. Real World, it is seen that:

- The government must consistently be responsible for the development, operation and maintenance of government-owned dams that are safe and environmentally sound, even though the costs are expensive;
- How much dam maintenance costs can be charged to the floating solar panel project in an effort to maximize the utilization of the waterlogged area of the dam;

B. Systemically, the Government:

- Have to bear the cost of maintaining a dam which is quite expensive where the average age of government-owned dams is above ten years. Meanwhile the condition of the area (originally agriculture became industry and housing) and the community around the dam area has also changed (the influence of urban development), from the plan when the dam was built.

- The Ministry of PUPR as the owner of the largest dam in Indonesia, feels that the utilization of space in the reservoir is currently not optimal, therefore one solution is to create a Cooperation project with the private sector to produce renewable energy through the construction of floating solar panels, but requires support in the form of:
    - Policies that support private investment that are attractive to potential investors;
    - Cooperation Agreements that give flexibility to the use of space in the reservoir but are willing to be charged for the cost of maintaining the dam.

7.2 Recommendations

Based on the current information of Cacaban and Pandaduri dams, the issues related to the dam structures and environment need to be considered and solved before further actions regarding the design and installation of floating PV.

Two options are introduced in this report to fulfill the Dam Safety requirements for installing floating PV in Cacaban and Pandanduri, as discussed in section 4.2.9. The two options are:

3) Keep the floating PV probability of failure lower than the total probability of failure of the dam during the floating PV design service life. This will result in a high design requirement for the PV.

4) Design preventive mitigation plans by using multiple safety barriers (physical and non-physical).

In the case of FPV development on a dam reservoir, the dam owner or operator should examine thoroughly at the planning stage on how it would implement the FPV by taking into account the following:

a. To start the study of FPV during the early stage of dam development to allow the simultaneous construction and FPV installation activities. This approach could reduce the difficulties arising from the reservoir after it already reaches an operational level
b. The Term of References (TOR) from the dam owner or operator shall stipulate clearly the obligations of all potential investors to investigate overall site conditions in the effort of full compliance to the regulations, including universally accepted Norms, Standards, Guidelines, and Manuals
c. The dam owner or operator shall initially determine the master plan of reservoir use by establishing the Zoning for FPV in addition to tourism activities, fishing, and others., with prior discussions involving the local authorities and communities.

With regard to the limit of the allowable area of FPV as a percentage of the reservoir area at Normal Water Level, there could be variations and not a single number after due consideration of several factors, such as:

d. the probability of dam failure as a result of risk analysis at a current stage prior to the introduction of potential FPV on its reservoir;
e. the location of the dam: either it is on the offstream or the mainstream, especially if a cascade system is in place;
f. the technical data of the dam in terms of its height, total reservoir area, operational conditions, and others.

In terms of environmental aspects, to define the limit of the allowable area of FPV, water water quality of the dam should also be considered. Those parameters may include, but not limited to:

a. Water transparency, can be measured as Secchi depth. The lower the water transparency, the lower the allowable area.

b. Total counts of bacteria, can be measured as Total Coliform and Fecal Coliform. The higher numbers of bacteria, the lower the allowable area, since the needs of sunlight penetration is higher to remove the bacteria.
c. Other parameters such as BOD, COD and DO, where the lower the water quality of the dam, the allowable area should also be lower.

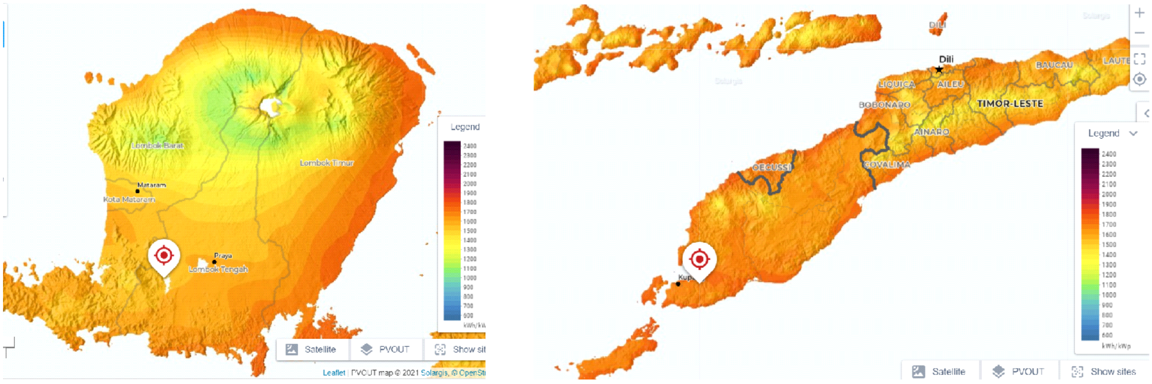
Mitigation measures to control the environmental effects may include the installation of FPV with high transparency to ensure sufficient intensity of sunlight that reaches the surface of the water body.

As per financial aspects, after studying the conclusion of the financial, economic and VfM study, recommendations is as follows:

a. Sharing the cost of dam maintenance costs is a fair measure for the government so that potential investors are responsible for the safety of the dam and help protect the environment around the dam;
b. However, for investors (private parties) there is hope that the equity IRR and return on investment must be in line with expectations, while for the government this floating solar panel project must provide benefits to the community and have positive value for money for the government and have low risk;
c. Several strategies must be developed to support the success of the floating solar panel project, including:
    (1) ensuring that the electricity generated by the project is absorbed by PT PLN at the agreed rate;
    (2) ensure the maximum limit (limitation) of the inundation area in the reservoir so that it is attractive to potential investors;
    (3) setting limits on cost sharing to potential investors so that they are also responsible for the sustainability of dam management;
    (4) cooperation between of Ministry Public Works and Housing with Ministry of Enery and Mineral Resource to decided the best of alternative financial investment model to win win solution for potential investor; and
    (5) proportion of risk sharing between government and private and involvement of state-owned enterprises to improve eligibility.

Regarding the future study for the floating PV at dam reservoirs, this study recommends conducting such a study for other dams. As shown in Figure 2-3, the Eastern Nusa Tenggara has the highest PV potential resources based on the irradiation index. Therefore, it is worth studying the potential resources in this *Balai Wilayah Sungai* (BWS).

There are two DOISP dams that are recommended for future study, Pengga Dam and Tilong Dam. The Pengga dam is located in Lombok island or in the area of BWS Nusa Tenggara I. A similar to the Pandan Duri Dam (see Figure 7-2 a). Meanwhile, the Tilong Dam is located in Timor Island, as shown in Figure 7-2 b. These two dams are located in the area with the most diesel power plant in the country. Therefore, this might be a complement to the PLN dediezelitation programme.



a. Pengga Dam at Lombok, West Nusa Tenggara

b. Tilong Dam at Kupang, East Nusa Tenggara

Figure 7-2 Location of Pengga and Tilong Dams

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