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NATIONAL POTENTIAL STUDY

RENEWABLE ENERGIES IN ARMENIA

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FLOATING PHOTOVOLTAIC OPPORTUNITIES

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ACRONYMS

AUA	Acopian Centre for the Environment
CAPEX	Capital Expenditure
ENA	Electric Network of Armenia
FPV	Floating Photovoltaics
FSL	Full Supply Level
HDPE	High-Density Polyethylene
HPP	Hydro Power Plant
MASL	Metres Above Sea Level
MOL	Minimum Operating Level (in MASL)
MWL	Maximum Water Level (in MASL)
PSRC	Public Services Regulatory Commission
PV	Photovoltaic
RA	Republic of Armenia
R2E2	Armenia Renewable Resources and Energy Efficiency Fund
SHPP	Small Hydro Power Plant
SPNA	Specially Protected Natural Areas

1 INTRODUCTION

1.1 ARMENIA RESOURCES AND OPPORTUNITIES

Armenia has no proven reserves of fossil fuels such as oil and gas. Hence, renewable energy and energy efficiency constitute a major element of the country's development and life quality. Construction of renewable energy plants such as solar, wind, geothermal or hydro is of strategic importance to ensure long-term energy self-sufficiency and security.

In particular, Armenia enjoys an enormous solar potential: the average annual amount of solar energy flow per square meter of a horizontal surface is about 1 720 kWh. Today, hydro resources are the most widely exploited among the renewable energy resources (almost 33% of total electricity production), which promises a brilliant future for PV technologies (less than 3% of total electricity production).

On top of this huge untapped potential, the Republic of Armenia (RA) has managed to create a liberalized market for renewable energy and is attracting private investors from all around the world to develop projects. Thus, to reassure them, the RA recently reorganized its electricity network infrastructures management.

Besides, the RA has created several mechanisms to promote the use of renewable energy sources. According to the article 59 of the Armenian "Law on Energy" (adopted on 7 March 2001), the purchase of the electricity generated by renewable energy sources is guaranteed 15 years for Small Hydro Power Plants (SHPP) and 20 years for solar, wind, biomass and geothermal plants, tariffs being reviewed annually. For 2021 and 2022, the solar PV tariff has been set at 26,204 AMD / kWh.

Armenia also proves to be very rich in hydro resources. The country possesses a extensive network of 41 large mountain rivers, 16 water reservoirs and a high mountain Lake Sevan. These considerable natural resources explain the historical and still ongoing massive development of Hydro Power Plants (HPP). Combining the hydro resources large potential, the hydropower wide development, the existing electricity grid infrastructures and the fantastic solar potential, floating PV power plants on HPPs reservoirs, and to some extent, on reservoirs close to the grid, constitute a promising and relevant solution for the country.

Such a combination has indeed several major assets. First, floating PV solutions add value to unused areas without conflicting with other activities such as agriculture or construction, but also permit the increase of both the yields of PV panels (natural cooling due to water proximity) and hydro potential (PV coverage reduces water reservoirs evaporation). Furthermore, this approach might lead to significant economies of scale and capital expenditure (CAPEX) optimization, the PV plant being directly connected to the existing HPP electrical network or any nearby grid substation, avoiding long-distance grid connections.

This solution may then constitute a real chance for the Republic of Armenia to optimize its electricity network infrastructure, its production sites and mix of renewable energy resources to attenuate intermittencies and grid stress.

This rich context constitutes a great opportunity to develop and carry out an innovative renewable energy project in Armenia within the specific French FASEP framework.

1.2 THE FASEP OPPORTUNITY

FASEP stands for Study and Private Sector Help Funds. It is a projects donation instrument managed by the French Ministry of Economic and Financial Affairs. FASEP may finance feasibility studies / technical assistance prior to project development but also innovative technology pilots dedicated to the environment and sustainable development. The aim of the latter is then to demonstrate to local actors and authorities the interest of such innovative technologies and the opportunity to widely develop them to achieve their green objectives. Co-financers are usually sought in order to strengthen the project, which must rely on French technologies.

The FASEP beneficiary is the Armenia Renewable Resources and Energy Efficiency Fund (R2E2). Established in 2005, R2E2 Fund is an autonomous state entity, that creates a favourable environment for the development of renewable energy and energy efficiency sectors by introducing the best practice of sustainable energy aimed at ensuring energy security, freedom, and economic growth in Armenia.

1.3 THE PROJECT AMBITION

This FASEP project is an ambitious attempt to draw up an inventory of the constraints and opportunities of the Armenian territory for the development of floating photovoltaic, in order to allow the emergence of the sector. The studies carried out will aim to present the Armenian context, to open the Armenian market to energy companies specialized in floating photovoltaics. They will thus attract investors to increase the renewable energy production capacity of the Republic of Armenia and will allow the structuring of projects around the French technology partners of the FASEP.

The project is therefore structured in 3 distinct parts, to quantify and qualify the Armenian potential for the development of the FPV sector and then implement a first pilot power plant.



1.4 NATIONAL POTENTIAL STUDY

The national potential study presented in this report first provides a regulatory overview of the Armenian development context for floating photovoltaic projects. An analysis of natural resources required for the development of floating photovoltaic projects, i.e., irradiation and water resources, is then carried out. The study then goes on to detail the constraints and opportunities of the Armenian territory impacting the development of such projects.

Finally, a cross-mapping analysis of the resources and constraints is carried out, making it possible to estimate a potential FPV capacity on the Armenian territory and an electric production.

In addition to estimating the role that the floating photovoltaic sector could take in the Armenian electricity mix, the study also makes it possible to characterize the potential, in order to identify technologies adapted to the local context.

1.5 PARTNERS OF THE STUDY

This study was carried out in partnership with the French companies introduced below.

NEPSEN TRANSENERGIE	Transénergie is an engineering and consultancy firm, specialized in renewable energies, in particular photovoltaic systems and territorial energy strategies. Transénergie develops a global offer from studies to projects execution, coordination, and monitoring. Its field of expertise includes technical, socio-economical, and financial engineering.
EDF	As a historic producer of electricity in France, EDF is expanding into the renewable energy market. EDF is the historic operator of all French hydroelectric dams and is now working on the development of its fleet with floating photovoltaic installations.
TRANSVALOR	Transvalor is a French company coming from the research sector whose activities are centred around numerical analysis. In 2009, Transvalor started the SODA web services portal and the HELIOCLIM solar radiation database, one of the world standards for providing solar radiation data.
RINA	RINA is an international company who provides a vast array of engineering and consultancy, testing, inspection, and certification services, dedicated to all players of the energy sector, helping operators to meet sustainability targets as well as ensuring compliance to the highest standards of engineering and construction.
PJN CONSULTING	PJN-Consulting is an environmental management consulting company. PJN-Consulting works on several major international projects to help structure government environmental policies.

Nota: *general paragraphs on floating photovoltaic technologies and the development of such projects in this report are generally inspired or adapted from the handbook "Where Sun Meets Water – Floating solar handbook for practitioners" – by the Solar Energy Research Institute of Singapore (SERIS), under contract from the World Bank.*

2 FLOATING SOLAR PV TECHNOLOGY

Floating solar photovoltaic (FPV) installations reached 2.6 gigawatt peak (GWp) of total installed global capacity at the end of 2020[1], and deployment appears likely to accelerate as the technologies mature, opening a new frontier in the global expansion of renewable energy. When combined with other demonstrated benefits—such as higher energy yield, reduced evaporation, and in certain cases improved water quality—FPV is likely to be an attractive option for many countries. With a global potential of 400 GWp under conservative assumptions, FPV is likely to become an important market segment for solar PV deployment.

The general layout of an FPV system is similar to that of a land-based PV system, except that the PV arrays, and often the inverters, are mounted on a floating platform. The floating platform is held in place by an anchoring and mooring system, the design of which depends on factors such as wind load, float type, water depth, and variability in the water level.

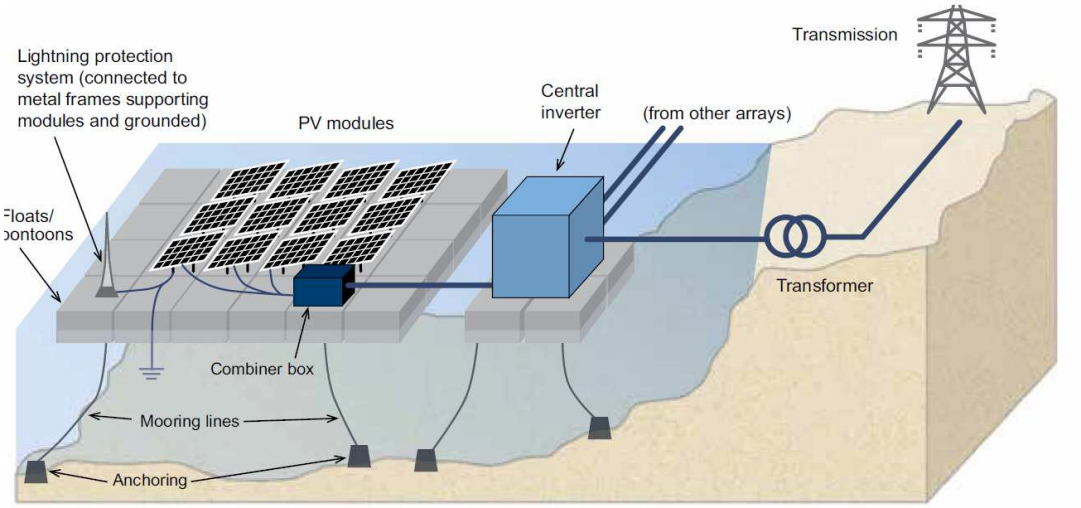


Figure 1 – Schematic representation of a FPV system with its key components.

Specific aspects of FPV components are explained below.

2.1 FLOATING STRUCTURES AND PLATFORMS

The floating platform comprises structures with enough buoyancy to support PV modules, electrical equipment on water, as well as personnel during construction and O&M. Floating platforms typically predominantly feature high density polyethylene (HDPE) components; different additives provide for UV resistance and other necessary physical properties. HDPE floats are used with metal frames or other mounting structures that can fix the PV modules at different tilt angles. Other materials used in floats include an expanding polystyrene foam filling to avoid

[1] PV Magazine, 22/09/20 : https://www.pv-magazine.com/2020/09/22/floating-solar-pv-gains-global-momentum/

loss of buoyancy due to perforation. Many of these composites aim to be recyclable, hard-wearing, UV-stable, and rot- and fire-resistant.

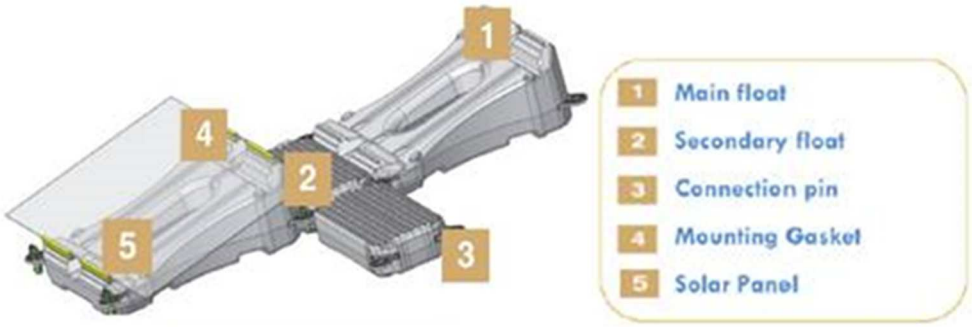


Figure 2 - Standard Ciel&Terre primary and secondary floats.

2.2 ANCHORING AND MOORING SYSTEMS

The anchoring and mooring system holds the floating platform in place and provides the mechanical stability that is required throughout the lifetime of its operation. Anchors and mooring lines are the key components of the system. The structures can range from simple shore anchoring, typical in smaller water bodies or very deep ones, to highly complex anchors suitable for reservoirs with great variations in water level, as can be the case in some hydropower reservoirs. The exact design will be site-specific and depend on the use of the water body, soil properties of the reservoir bed, wind loads, and other environmental constraints.

FPV platforms can be anchored either to the bottom of the water body or to the bank of the shore. Common types of anchors used in bottom anchoring are dead weights such as concrete blocks and helical anchors that are screwed and piled to the ground. Specialized barges or even divers are usually needed to deploy them. For bank anchoring, civil work is needed to pile the anchors firmly to the ground.

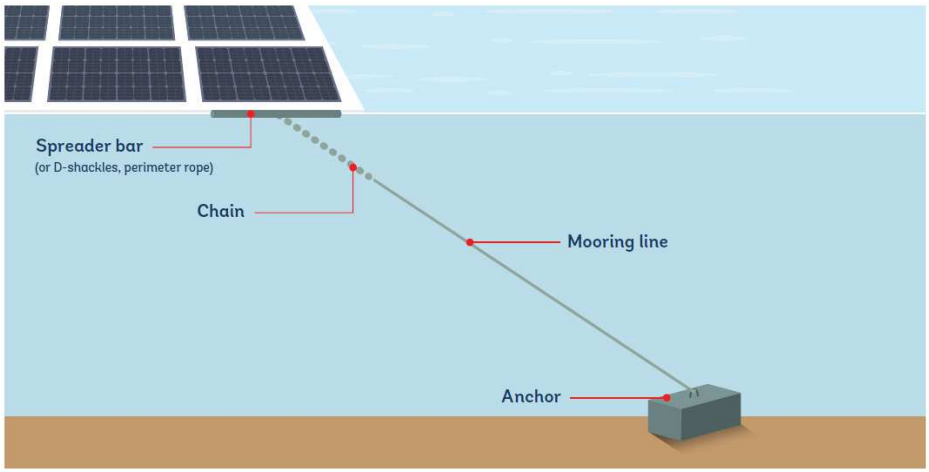


Figure 3 –Schematic anchoring to reservoir bottom (Source: World Bank, 2019).

Mooring lines are usually made of wire rope, galvanized steel wires, chains, synthetic-fibre rope, elastic rubber hawsers, or combinations thereof. Many possible combinations of line type, size, and configuration can be used to achieve the required mooring performance.

Overall, the system's layout design needs to feature a holistic consideration of all components and their interaction with the floating platform. Wind loads and water movements (currents) are particularly important parameters to consider ensuring the integrity of the entire floating platform and its anchors. Failure of the anchoring or mooring system could have severe impacts on the project as rectification might be difficult.

2.3 PHOTOVOLTAIC MODULES

PV modules are often exposed to various and extreme environmental conditions, including heat, cold, humidity, snow, and so forth. In general, the standard photovoltaic module has performed well under a variety of conditions and represents much of the installed base worldwide. This standard design features a 60, 72 or 144 poly- or mono-cell glass front or thin film. Given the robustness of existing module designs, modules suitable for actual ground-mounted installations are suitable for FPV applications with minimal or no modification.

FPV systems have a higher energy yield than ground-mounted PV systems under similar conditions since a cooling effect of the surrounding water improves the efficiency of the PV modules.

2.4 CABLE MANAGEMENT ON WATER

On small projects, inverters can be installed onshore. Most large-scale projects have inverters, and possibly even transformers, floating on the PV islands, with the cables routed to the onshore substation. Regardless of which design type is used, DC or AC cables can either be floating cables or submarine cables —although the cost of the latter option will be much higher.

Cable lengths and their routing need carefully calculated: sufficient slack must be included to accommodate both the movement of the floating islands and the variations in water levels. In addition, floating cables could obstruct boats, so careful planning is required at the project initiation stage. Submarine cables can be implemented on water bodies where boat traffic is important.



Source: © Ciel & Terre International.



Source: © Sungrow.

Figure 4 - Examples of cable management on water (Source: World Bank).

2.5 Construction

Before the construction begins, a suitable launching area to the water body is identified, with a gentle slope. The floating structure is assembled and launched on this shore area.

A launch ramp, built with metal or wooden scaffolding and slats, can be constructed on the bank's natural slope into the water body. Although not mandatory in all cases, a launch ramp can ease deployment efforts and reduce float damages.

Once the materials are delivered onsite, the assembly work of the floating structure can start onshore. Small blocks of single floating units are usually assembled by multiple teams of workers.

The following steps are carried out for the construction of a single block of floating units:

- The layup of floating components,
- Assembly of floats together,
- Assembly of module support structures (metal or HDPE plastic),
- Installation of modules on top of the floats.

Once assembled, the single units are linked together. After a few units are linked, the entire row is partially pushed into the water. Subsequent rows are built and launched until the floating island is completed.



Figure 5 – Assembling of the FPV island (Source: Isigenere).



Figure 6 – Floating system installation onshore (Source: Ciel&Terre).

Upon completion, the entire FPV island is towed to its final location by motorboat. The system is then ready for mooring and anchoring.

In case the floating island is anchored to the bottom of the water body, professional divers and/or specialized barges may be employed to moor and anchor them. Buoys can be used to keep the mooring connection point afloat, which would be later connected to the floating structure.

Mooring lines (such as ropes, chains, wires, elastic rubber hawsers, or a combination thereof) can be connected to the floating PV islands in various ways, depending on the floating platform design and recommended installation practices by the mooring supplier.

2.6 POTENTIAL IMPACTS ON WATER QUALITY

FPV is still a rather new technology, lacking long-term experience. Actual assertions on environmental impacts of floating solar panels are just assumptions which need verification/rejection by a long term and thorough study. There is currently little knowledge available on the environmental effects of floating solar panels. Several studies have revealed some impacts (e.g., Mathijssen et al., 2020; Härtwich, 2016) others have shown no effects (i.e., de Lima et al., 2015), therefore, the environmental effects of these constructions, in general, are not sufficiently known.

FPV projects may affect water quality to varying degrees, depending on their type, size, and design characteristics, but positive effects were also seen in several studies.

Potential impacts of FPV projects on water quality include the following:

- Reduced flow in the areas surrounding the arrays is possible and can contribute to increased sedimentation in these areas.
- FPV plants may cause large areas of uneven surface heating, reduced reservoir turnover efficiencies and degradation of littoral zone plant growth as a result of reduced sunlight.
- Positioning of PV arrays needs to be studied to understand their effects on the flow patterns of the reservoir/river, which can contribute to shoreline degradation, undesirable morphological changes, and eventually water quality.
- Changes to ambient temperature stratification and dissolved oxygen levels can result from the shading of water and/or increased heat generated from the FPV installations, with effects on aquatic life and water quality. These changes could be complementary or detrimental, depending on the FPV system type and size.
- Impacts on water quality and aquatic fauna could result from leaching from materials used as part of the FPV installation.

FPV systems often use high-density polyethene (HDPE) pontoons/floats to support the racking system for the solar. Project materials must be selected with a view to avoid or minimize breakdown into toxic materials or leaching. When relevant, FPV components that may be in contact with water should meet internationally recognized standards for drinking water systems.

2.7 BENEFITS OF FPV TECHNOLOGY

An FPV powerplant has several advantages, both for photovoltaic production and for the reservoir that supports it:

- Increased energy yield from the cooling effects of water on the power plant,
- Ease of deployment,
- No land requirement,
- Reducing evaporation of the water in the reservoir.

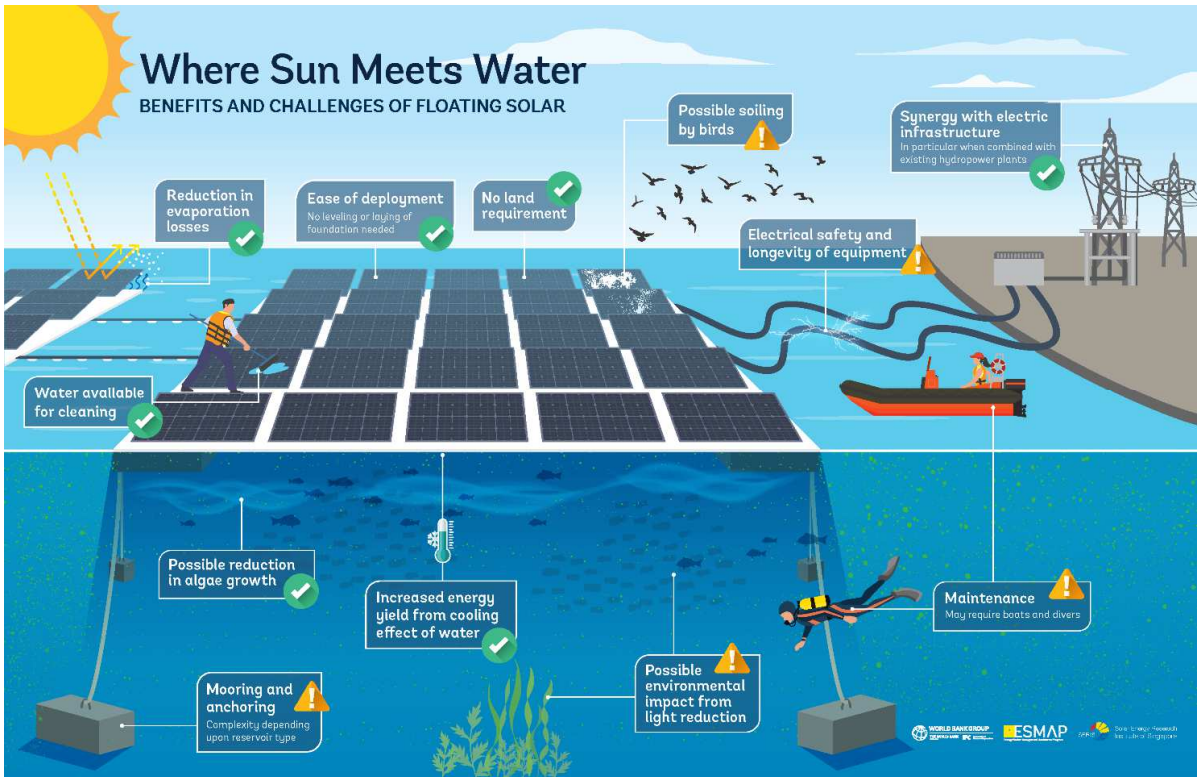


Figure 7 - Benefits and challenges of FPV (Source: World Bank).

Thus, floating PV is likely to be an attractive option for many countries to avoid using their scarce land-based resources for solar power generation. The coupling of floating solar PV to hydroelectric power plants also has many advantages. In some hydropower plants where operation can be flexible, solar capacity can help manage periods of low water availability by allowing the hydro plant to operate in 'peak' rather than 'base load' mode. And the benefits go both ways - by combining the dispatch of solar and hydropower, the variability of solar generation could be mitigated. Thus, this coupling makes it possible to optimize the use of these two energy generators while making better use of existing transmission facilities.

3 REGULATION FRAMEWORK

3.1 ARMENIAN ENERGY LAW

3.1.1 Legislative framework

The *Law on Energy* of the RA has been adopted in 2001 to provide a legal basis for producing and delivering energy. It regulates the relations between the consumers, the government bodies and the legal entities concerning electricity, thermal energy, and natural gas. Its basic principles are:

- Enhancement of competition and efficient operation in the energy sector and creation of essential conditions for the development of a competitive environment.
- Regulation of the energy sector operation.
- Separation of the economic activity, government management and regulation functions.
- Protection of the rights of the consumers and the economic entities in the energy sector, and the balancing of their interests.
- Efficient use of domestic energy resources and alternative sources of energy and implementation of economic and legal mechanisms for that purpose.
- Encouragement of investments in the energy sector, development of energy markets and scientific and technical progress.
- Ensuring transparency of the licensed operations, protection of the environment.
- Enhancement of the energy independence of the Republic of Armenia (RA).

In 2004, the *Law on Energy Saving and Renewable Energy* has then been published in order to define the principles of the state policy on the development of energy-efficiency and renewable energy. Its aims are:

- To strengthen the economic and energy independence of the Republic of Armenia.
- To establish and develop new industry infrastructures and organizations of services promoting energy-saving and renewable energy.
- To reduce the adverse techno-born impacts on the environment and human health.
- To encourage the voluntary participation of the parties.

RA *Law on Public Regulatory Authority* sets the rules and conditions for the activities of the Public Services Regulatory Commission (PSRC).

Since then, several amendments have been published to drive greater liberalization of the market and to introduce competition among electricity suppliers. The Electrical Network of Armenia (ENA) is no longer the sole buyer and seller of electricity, as the law also provided for new participants in the electric energy market, such as:

- Electricity suppliers,
- Guaranteed electricity providers,
- Wholesalers,
- Qualified consumers.

3.1.2 RA Energy Sector Development Strategic Programme to 2040

The maximum use of renewable energy potential, considering it as a part of the Least Cost Energy Development Plan, is one of the key priorities of the Energy Sector development programme. Considering the available domestic resources and development tendencies of this technology throughout the world, the construction of solar power plants is likely to prevail over other forms of energy, given the limitations of the system reliability and safety indicators. The aim for Armenia is to reach 15% of solar electricity generation in the electricity balance.

3.1.3 Electricity market

The current model of the Armenian electricity market was introduced in 2004. The market is fully regulated both in the wholesale and retail sectors. In many countries, the electricity markets are liberalizing and operating under competition. The liberalization of the electricity market requires the transition to a new model which will improve the efficiency of the wholesale and retail electricity markets. The transition to the new market model in Armenia will be carried out in the coming years with a long-term target of full market liberalization. The market's new model will be based on the current electricity trading rules and will operate on the basis of balancing demand and supply.

At the first stage of the market reforms, issues related to improving the efficiency of the tariff policy, in particular, the feasibility of future use of night-time and day-time tariffs and its alternatives, implementation of new tariff adjustment mechanisms for reactive energy, the necessity to fix monthly service fee, etc. will be considered.

Meanwhile, it is envisaged to initiate changes in the laws on "Energy" and "Energy Saving and Renewable Energy", as a result of which the renewable energy power plants will be entitled to sell electricity in the new electricity market exclusively under competitive terms without providing a power purchase guarantee and signing a Public-Private Partnership agreement, as well as to generate and consume energy at various metering points of the power system.

3.1.4 Relevant authorities

The key entities involved within the Armenian energy sector and their role are the following:

- **Ministry of Territorial Administration and Infrastructure**: it is one of the 12 Ministries of the Republic of Armenia. Its main task is to elaborate and implement the Government policy for ensuring safety in the sectors, among others, of energy, nuclear energy, renewable energy and energy consumption, development of energy independence, energy-saving, and energy efficiency in the Republic of Armenia.
- **Public Services Regulatory Commission**: the PSRC is a regulatory authority in the spheres of energy and many others. As a regulator, it sets tariffs, issues, suspends, and terminates licenses in the energy sector.
  For FPV projects, the PSRC is responsible for issuing the Electric Energy Production License, approving the form of PPA, and setting the tariff.

- **“Electric Power System Operator” CJSC**: it is the only company in the energy system of the Republic of Armenia, which is licensed with the exclusive right to carry out the functions of management for generating, transporting, and distributing electric energy both in the territory of the Republic of Armenia and during export and import.
  For FPV projects, the System Operator shall give consent on the Technical Specifications of connection to the grid and on the Connection Permit to the grid.
- **The "Settlement Centre" CJSC**: it has been granted an exclusive license of the market operator. Its purpose is to make power and energy calculations and perform financial calculations in the wholesale market of electric energy.
  For FPV projects, the Market Operator shall give consent to the connection design, in case of connection to the transmission grid, accept and register the Acceptance of the Project Company's accession to the electric energy wholesale market agreement.
- **“High Voltage Electric Networks” HVEN:** it is the only company with a license for electric energy transmission.
  For FPV projects, if the plant is to be connected to the transmission grid, the HVEN shall provide Technical Specifications for grid connection, sign a Connection Agreement, and grant a Grid Connection Permit.
- **“Electric Network of Armenia” ENA:** it was established in May of 2002, as a result of the merger of four state regional electricity distribution and supply companies. The company mainly deals with the distribution and supply of electricity. The electric energy distribution is carried out at tariffs approved by the Public Services Regulatory Commission of the Republic of Armenia. The company is privatized and belongs to the group of Tashir companies. It is the only company with licenses for electric energy distribution and guaranteed electricity supply.
  For FPV, the ENA shall provide Technical Specifications for grid connection, sign the PPA and grant a Grid Connection Permit.

3.1.5 Photovoltaics in Armenia

As of October 1st, 2021, 6077 autonomous solar power plants with a capacity up to 500 kW, with a total installed capacity of 115,2 MW are connected to the network, and a further 13.7 MW is under development[2].

RA Public Services Regulatory Commission (PSRC) set the tariff for July 2021 to July 2022 at 26 204 AMD/kWh (around 53,3 $/MWh). This tariff is reviewed annually.

3.2 WATER CODE

3.2.1 Definition

The Water Code consists of 121 articles of law made to manage the use and protection of water resources and water systems in the Republic of Armenia. Its main objectives are the following:

- Establishment of appropriate water resources management mechanisms.

[2] https://energyagency.am/en/category/infografiks/inqnavar-arevayin-kayanner-2021t--hoktemb

- Conservation and protection of water resources, including mitigation of pollution, maintenance and supervision of water standards and water level of the national water reserve.
- Prevention of harmful impact of watercourses.
- Ensuring water resources assessment.
- Ensuring water supply to population and economy in necessary quantity and quality by regulated tariffs.
- Safe and smooth functioning of water supply and wastewater systems and provision of normal conditions for their use and maintenance and supervision.
- Organization of the management, protection, and development of water systems.

The following documents are also parts of RA's water management strategic documents:

- **National Water Program:** this document draws up the perspectives of development, management and conservation of the water resources and water systems, by which the objectives of this Water Code shall be implemented. It also defines which Water Systems (dams, water storage facilities, etc.) are of state significance and shall not be subject to privatization.
- **State Water Cadastre:** a permanent operating system that keeps comprehensive records of quantitative and qualitative indices on water.

3.2.2 Organization and relevant authorities

The key entities involved within the Armenian water management are the following:

- **National Water Council:** it is the highest advisory body in water resources management. Through intersectoral participation, it discusses and makes recommendations on the National Water Policy, National Water Program, and other legal acts.
- **Dispute Resolution Commission:** acting in the structure of the National Water Council, its mission is to resolve disputes related to water use permits.
- **Water Resources Management and Protection Body:** authorized by the Government of the Republic of Armenia, this body is responsible for the management and protection of water resources.
- **Water Systems Management Body:** authorized by the Government of the Republic of Armenia, this body is responsible for the organization of water supply and wastewater services, water systems, and provision of their safety and protection.
- **Regulatory Commission:** this independent commission determines tariff policy in water relations and issues water systems use permits.

3.2.3 Water Use Permit

Water Use Permits are issued by the Water Resources Management and Protection Body. Such permit is mandatory, except if the Water Resources Management and Protection Body provides an exemption, and only if:

- The water use is negligible.
- The activity does not rise to a level that harms or potentially harms the water standards.

As an FPV project is only using the water body as a support, without water consumption, and with most of the floating technologies being certified for use on drinking water reservoirs, exemption of Water Use Permit can be expected.

If not, it takes between 3 and 4 months to get a water use permit, and Water Use Permit is limited in terms of period validity. If investment cost is important, the Water Resources Management and Protection Body may allocate a water use permit for a long duration, not exceeding 40 years.

The award criteria for Water Use Permit delivery are:

- Direct and cumulative impacts of the proposed water use to the national water reserve, water quality and quantity.
- Correspondence of the proposed water use with water allocation priorities and significance.
- The potential impact of pending water use permits on the water use rights of existing water use permit holders.
- Social, economic, and environmental impacts.
- Opinions resulting from the public notification process.
- Compliance with the international agreements of the Republic of Armenia.

3.2.4 Hydrotechnical systems (HTS)

The owner of the HTS, or at his request the operating organization thereof, makes a declaration of safety of HTS during its projecting, construction, operation, after its decommissioning, reconstruction, or capital repair as well as in case of temporary suspension. The declaration of safety of HTS is the main official document containing information about HTS compliance with safety norms. It is presented to the Water System Management Body for approval. The declaration of safety also serves as the basis for the registration of the HTS in the State Water Cadastre.

3.2.5 Transboundary water resources use

The norms defined by the Water Code are applied over the transboundary water resources originating within the territory of the Republic of Armenia before crossing the state frontier of the Republic of Armenia.

3.3 ENVIRONMENTAL LEGAL FRAMEWORK

3.3.1 Regulations and mechanisms for protected areas

Several legal acts on flora and fauna, forests and protected areas have been developed and adopted with the aim of ensuring biodiversity conservation and sustainable use in the country. From these legal acts, the central act is *Law on Specially Protected Natural*, which objective is to set forth the legal principles of state policy for the sustainable development, restoration, conservation and use of ecosystems, nature complexes and separate objects of specially protected natural areas of environmental, economic, social, scientific, historical-cultural, aesthetic, health, climate regulating, recreational or spiritual value.

Specially Protected Natural Areas (SNPA) in the RA are under state ownership. It is prohibited to transfer the state-owned lands of specially protected natural areas to private ownership (e.g. industrial activity). In Armenia, SPNA management is carried out by the Ministry of Environment of RA, the Environmental Impact Expertise Centre (SNCO) of the Ministry of Environment and the National scientific laboratory Yerevan Institute of Physics.

Economic activities are prohibited in the Specially Protected Natural Areas, they may threaten the stability of the ecosystems of those areas, the protection of flora and fauna, objects of scientific or historical value. For the establishment of Specially Protected Natural Area to the respective area, the Government of the Republic of Armenia, adopts a decree on its conservation, according to which the economic activity in the given area is restricted and if necessary is ceased from. The decree related to an SNPA, and statute is the legal basis for any potential activity.

The total area of nationally designated protected areas currently covers 12,9 % of the terrestrial territory and inland waters of Armenia. Protected areas in Armenia are categorized as follows: 4 national parks, 3 state reserves, 27 state sanctuaries National parks and 232 natural monuments.

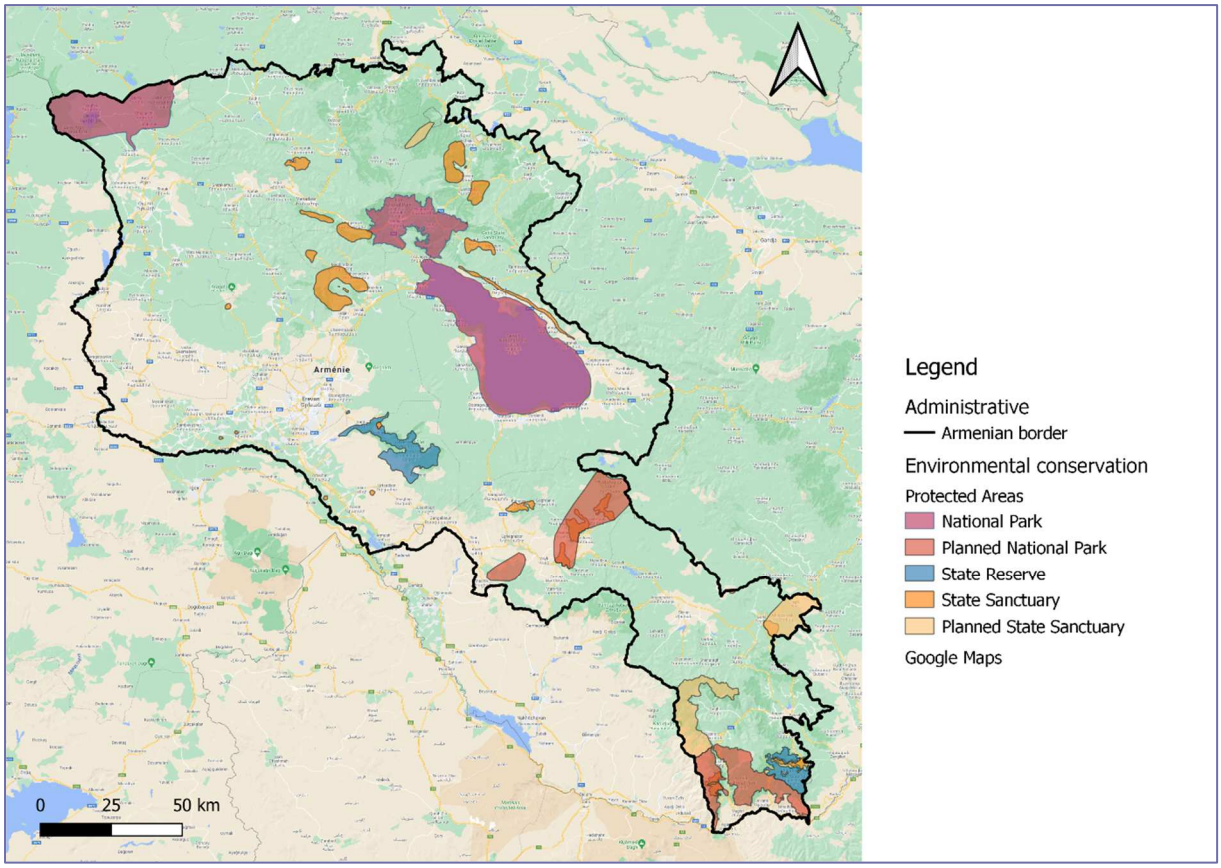


Figure 8 - SPNAs in Armenia.

3.3.2 Impact on permit for a solar project

The main purpose of the section is to evaluate the status of a project constructed in an SNPA with respect to the above-mentioned mechanisms and regulations: e.g., if the Project will be strictly forbidden; if potential administrative derogation or dispensation is possible; or if compensation may be allowed and authorized by special agreement with the protected area authority.

The general rule is the prohibition of economic activities that are strictly forbidden in SNPA, nevertheless, the proponent of a Project in a specific SNPA may obtain special permission delivered on a case-by-case basis with authorities, and relevant compensation will be evaluated with stakeholders depending on the magnitude of impacts.

3.3.3 Documents and authorizations needed

According to the *Law on Environmental Impact Assessment and Expert Examination*, a project of Solar Photovoltaics, as an activity within the energy sector that is subject to assessment and environmental impact expert examination (hereafter ESIA), can be either classified B or G according to the degree of impact on the environment.

An ESIA and a Public Consultation are requested for "solar power stations occupying 40 hectares of territory and more" and is classified as a category G. Under this classification, there are two rounds of public consultations.

Also, all proposed activities, not listed in the Law which will be carried out in specially protected areas of nature and in forested areas, within the territories of historical and cultural monuments, in green belts of common use, shall be subject to expert examination as well. In this case, the expert examination shall be carried out in accordance with the procedure for Category B.

According to the Law of Environmental Impact Assessment and Expert Examination, Article 18, the basic documents submitted for expert examination attached to the reports shall be the following:

- The design document for the proposed activity,
- Documents related to the participation of the participants of the process (the copy of the publication of the notification, the comments and suggestions received, the minutes of public hearings, audio, and video records),
- In the event of a legal person — the copies of its charter and inset, and in the case of an individual entrepreneur — the copy of the state registration certificate,
- In case it is prescribed by the legislation of the Republic of Armenia — the copy of the licence or permission to engage in the proposed activity,
- Payment receipt of the state duty (in the case of Projects Categories A and B — the proposed activity being subject to impact assessment in accordance with the terms of reference which may require other documents to be submitted).

Important note: a new *Environmental Law* is under preparation with potential modification of ESIA contents and permitting process. The draft version of the new environmental law is not available yet, and no date of enactment is known.

3.4 Development of solar project

In general, solar PV projects follow the flow outlined in Figure 9. This chart could be applicable in different markets.



Figure 9 - Steps of a PV project.

Performance of any electricity market activity requires a license from the PSRC. The licensing procedure is defined in the Energy Law and Energy Market Licensing Regulation. With recent developments, projects with a capacity below 500 kW are considered as autonomous power plants, they are not regulated and do not require licenses. As of 1st of October 2021, 6077 autonomous PV projects with a total capacity of 115.2 MW has been connected to ENA and a further 13.7 MW is under development[3].

According to the Armenian legislations (Regulatory Commission: By the decision N 88-N, 2015 April 22), projects with a capacity up to 5 MW (inclusive) can obtain a license for electricity generation from November 2, 2018, to December 31, 2020, inclusive. It is understood that the 5 MW limit is still valid. These plants will benefit from the tariffs for the sale of electricity for generating electricity using renewable energy resources in the territory of the Republic of Armenia. On October 24, 2018, the PSRC set the tariff for PV plants with a capacity of up to 5 MW at 23.864 AMD/kWh[4]. The total installed capacity can be up to 100 MW (as of November 2018, seven PV plants have received licences). At the end of each year, the tariff set for solar PV power plants is indexed, depending on the fluctuations of the Armenian dram against the dollar, in line with the consumer price index in Armenia. The tariffs are revised annually.

The procedure to develop a solar PV project is explained in the webpage[2] of the Ministry of Energy Infrastructures and Natural Resources of the Republic of Armenia (the 'Minenergy') as summarized below:

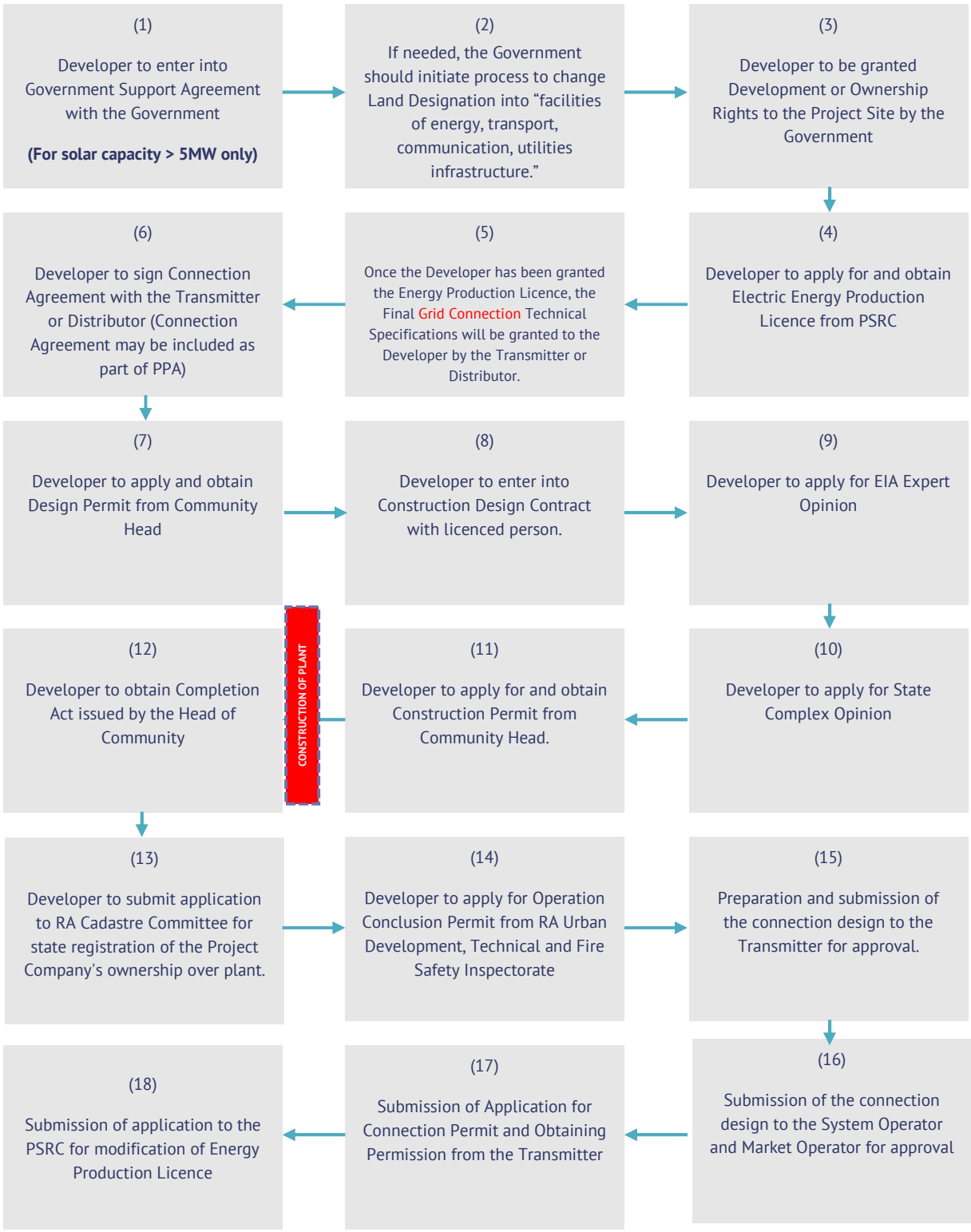
- Selection of suitable land (Solar Resource Map on the Minenergy webpage can be used).
- Obtaining land usage rights and changing the land use designation to "objects of energy, transport, communication and utility infrastructures" as needed.
- Application to PSRC to obtain electricity production license.
- Construction of the solar power plant in respect to the terms of the electricity production license.

It is understood that electricity generation licenses for projects exceeding 5 MW are issued within the framework of public-private partnership transactions and the license is attributed via tenders. There have been 2 main PV tenders in Armenia recently as detailed below.

- The lowest tariff for the international tender announced for the construction of the Masrik-1 55 MW solar PV was presented by a consortium of Dutch "Photovatio Renuable Ventures" and Spanish "FSL Solar" companies. It is 0.0419 USD /kWh per 1 kWh (about 20.11 AMD) without VAT.
- The international tender announced for the construction of the Aig-1 200 MW solar PV was won by Masdar, a subsidiary of UAE sovereign wealth fund, the Mubadala Investment Company. The tariff agreed with Masdar is 0.0290 USD /kWh.
- Tenders for construction of five more large-scale PV plants with capacities ranging from 5 MW to 19.4 MW are going to be undertaken.

The following chart details the implementation steps of a PV project via an auction.

[3] https://energyagency.am/en/category/infografiks/inqnavar-arevayin-kayanner-2021t--hoktemb
[4] http://minenergy.am/en/page/416


(1)
Developer to enter into Government Support Agreement with the Government
(For solar capacity > 5MW only)
(2)
If needed, the Government should initiate process to change Land Designation into "facilities of energy, transport, communication, utilities infrastructure."
(3)
Developer to be granted Development or Ownership Rights to the Project Site by the Government
(4)
Developer to apply for and obtain Electric Energy Production Licence from PSRC
(5)
Once the Developer has been granted the Energy Production Licence, the Final Grid Connection Technical Specifications will be granted to the Developer by the Transmitter or Distributor.
(6)
Developer to sign Connection Agreement with the Transmitter or Distributor (Connection Agreement may be included as part of PPA)
(7)
Developer to apply and obtain Design Permit from Community Head
(8)
Developer to enter into Construction Design Contract with licenced person.
(9)
Developer to apply for EIA Expert Opinion
(10)
Developer to apply for State Complex Opinion
(11)
Developer to apply for and obtain Construction Permit from Community Head.
CONSTRUCTION OF PLANT
(12)
Developer to obtain Completion Act issued by the Head of Community
(13)
Developer to submit application to RA Cadastre Committee for state registration of the Project Company's ownership over plant.
(14)
Developer to apply for Operation Conclusion Permit from RA Urban Development, Technical and Fire Safety Inspectorate
(15)
Preparation and submission of the connection design to the Transmitter for approval.
(16)
Submission of the connection design to the System Operator and Market Operator for approval
(17)
Submission of Application for Connection Permit and Obtaining Permission from the Transmitter
(18)
Submission of application to the PSRC for modification of Energy Production Licence

4 RESOURCES IN ARMENIA

4.1 SOLAR RESOURCE

4.1.1 Ground measured solar irradiance and meteorological data

In 2016-2017, the World Bank funded solar measurement stations in Armenia, in Yerevan, Talin, Hrazdan and Masrik as part of the preparation activities for the Armenia Utility-Scale Solar Project. For these four locations, 10 minutes measurement data for the period mid-May 2016 to early June 2017 were obtained. Several solar radiation components are available, the Global Horizontal Irradiance (GHI), the Diffuse Horizontal Irradiance (DHI), the Direct Normal Irradiance (DNI) and the Global Tilted Irradiance (GTI – irradiance received for a PV panel tilted at 34° and south oriented).

In addition to the solar irradiance data, the temperature at 2m height, humidity, wind speed and wind direction were also available in the measurement data files.

A very comprehensive quality check report on the measured data was performed by the company Effergy between May and June 2017. The main conclusion is that the quality of the measurement is good, and the Quality Check (QC) performed on the irradiance and meteorological data are following a standard commonly accepted by the experts.

Nevertheless, the QC procedure was passed out on the ground data, prior to comparing the measurements to the solar irradiation from database HelioClim-3v5 and the meteorological data (temperature, wind) to the MERRA-2 based meteorological database. The following figure represents, for the year of available data, the results of the QC. For irradiance, blue represents the night slots, yellow represents data that passed the QC and red represents data rejected by the QC. Meteorological data have only yellow and red colours, as there are measured at night also.

GHI and DNI data is of very good quality, with more than 98% of data available after QC. DHI is good with over 90% of data kept after QC. Temperature and relative humidity data are also very good with over 97% of data available after QC. Wind speed is fair, with 68% of data that pass the QC. The QC results for the three other sites are similar for irradiance, temperature, and humidity and better for the wind speed, with 87% of data kept after QC at the minimum.

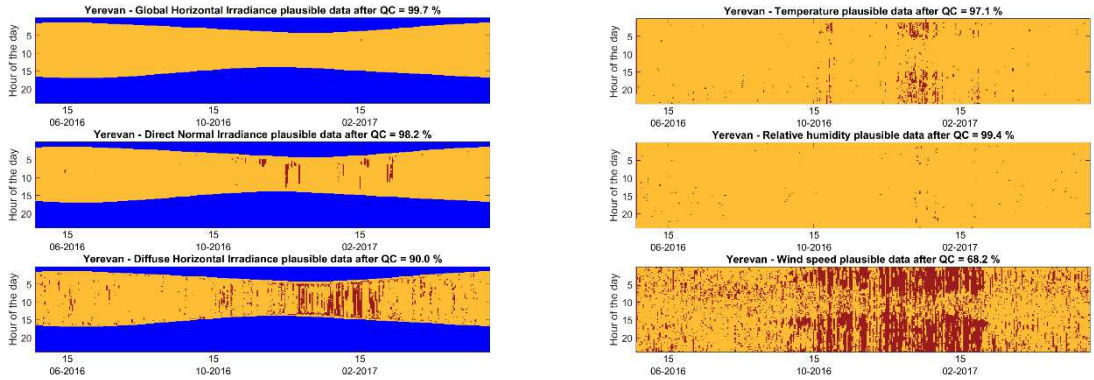


Figure 10 – Quality check of irradiance and meteorological data for Yerevan (Source: Transvalor).

4.1.2 Comparison with the HelioClim-3 satellite irradiance data

For each of the four sites, the measured irradiance was compared to the irradiance from the HelioClim-3v5 database from Transvalor. As shown in the below figure for Yerevan, the scatterplots of all 10-minutes data pairs comparison are good for all irradiation components.

Similar results were found for the three other sites. The main conclusion is that the HelioClim-3v5 data is generally reliable over Armenia and no calibration of the database is needed for the first phase of the solar potential analysis of the country.

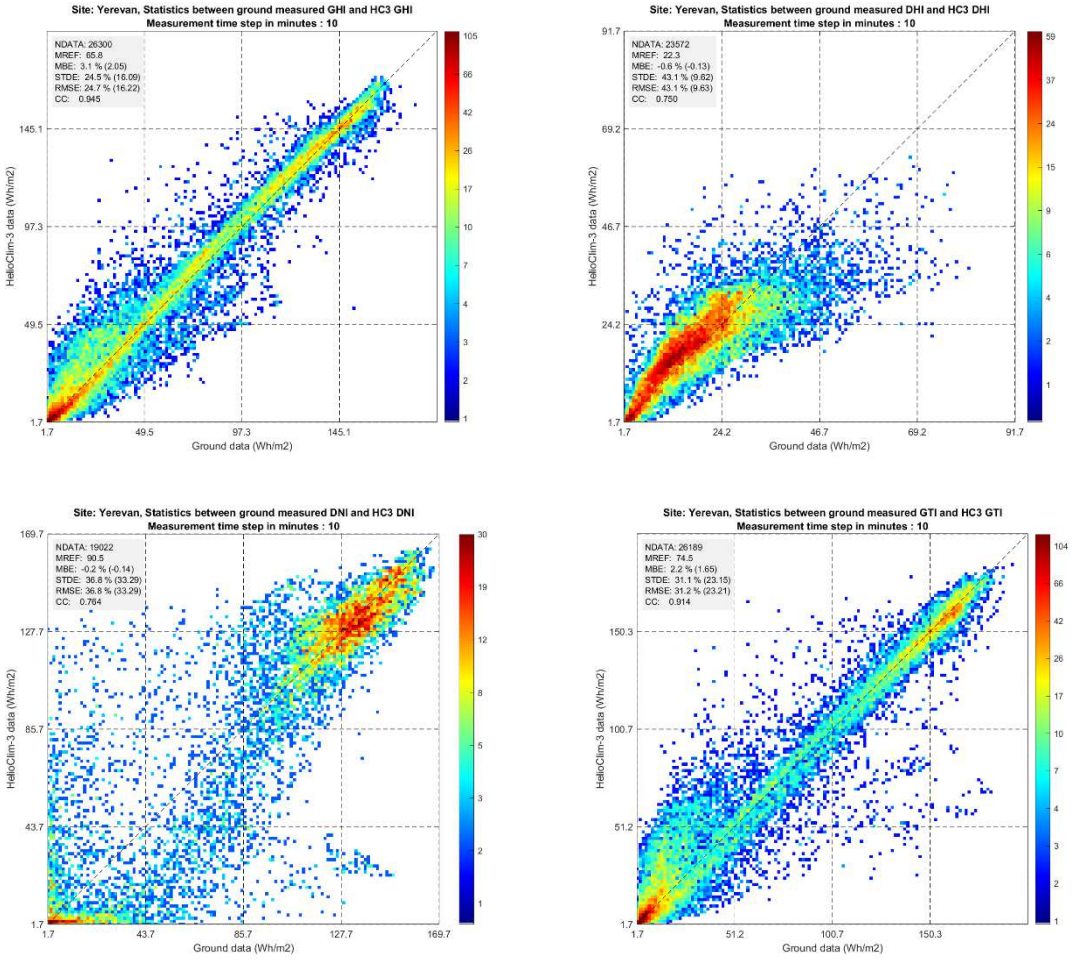


Figure 11 – Irradiance comparison between measurements and HelioClim-3v5 for Yerevan.

4.1.3 Comparison with the MERRA-2 Numerical Weather Model database

The most important meteorological parameter needed to estimate the electricity production of a photovoltaic solar plant is the air temperature. To create the solar and meteorological data files used in the electricity production simulation codes (PVSyst or SAM), Transvalor complements the irradiation from HelioClim-3v5 with the meteorological data from the MERRA-2 database.

The figure below represents the scatterplots of 10 minutes data pair comparison for the temperature at Yerevan between ground measurements and MERRA-2 data. Considering that the MERRA-2 Numerical Weather Model pixel resolution is about 50 km, and the time step is 1 hour, the two datasets are extremely similar, with a bias of less than 1 °C and a correlation coefficient above 95%. For the three other sites, the results are similar, with an extremely good correlation and a bias ranging from +2 °C for Masrik and Hrazdan and +0.5°C for Talin.

For any subsequent location to be analysed in Armenia, a simple constant shift for the temperature correction is therefore considered acceptable.

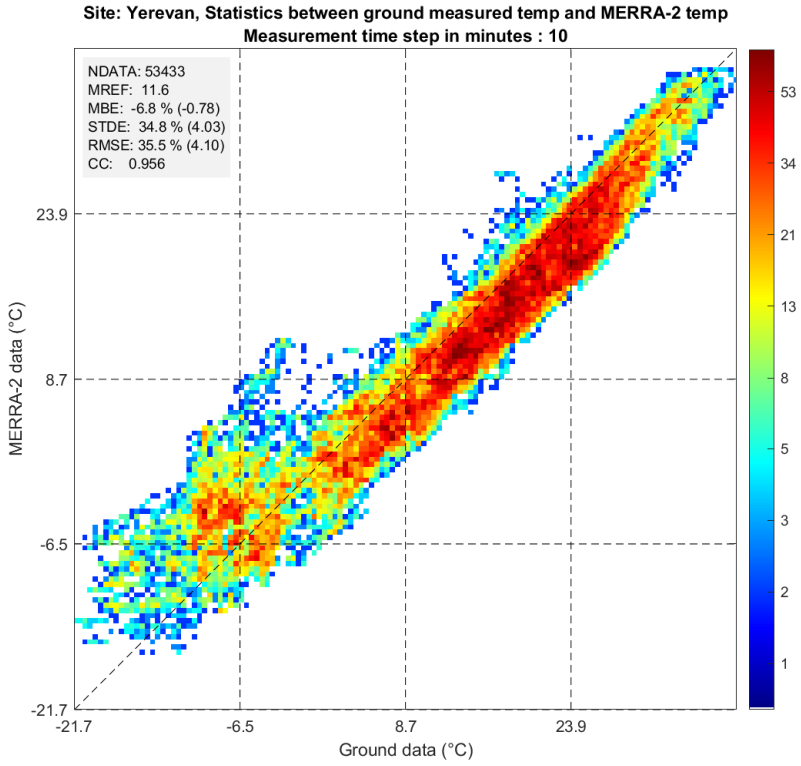


Figure 12 – Temperature comparison between measurements and Merra-2 for Yerevan.

4.1.4 Solar potential maps for Armenia

Transvalor has created several solar irradiation maps over Armenia from the HelioClim-3v5 irradiation database which will be used in the feasibility studies. These maps are at a 1 km resolution and consider the local horizon effect from the relief. Maps for each of the yearly and

monthly average irradiation components (GHI, DHI and DNI) for the period 2005-2020 were computed.

In addition, the monthly and yearly average maps for a tilted PV panel at the typical tilt angle for floating PV have been also computed at 12° tilt. The yearly GHI average over Armenia is illustrated in the following figure.

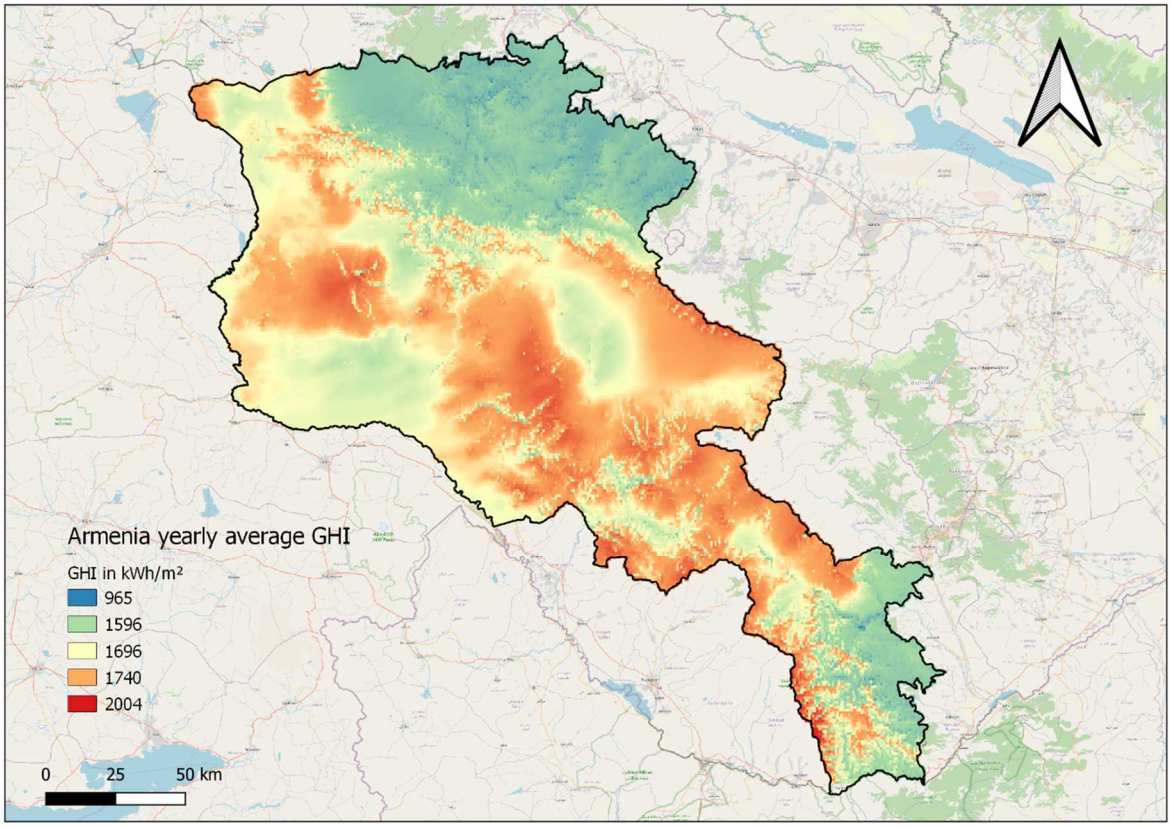


Figure 13 - Global Horizontal Irradiation average for the period 2005-2020 (Source: Transvalor).

4.2 HYDRO RESOURCES

4.2.1 Lakes and reservoirs

The Armenian territory has a large network of natural lakes and artificial reservoirs for hydroelectric production and irrigation: 561 lakes and 314 reservoirs have been identified. The Armenian surface cover by the lakes is 126 291 ha. Lake Sevan represents more than 99% of this water surface. Reservoir and their 15 834 ha only represent 11% of the Armenian water surface.

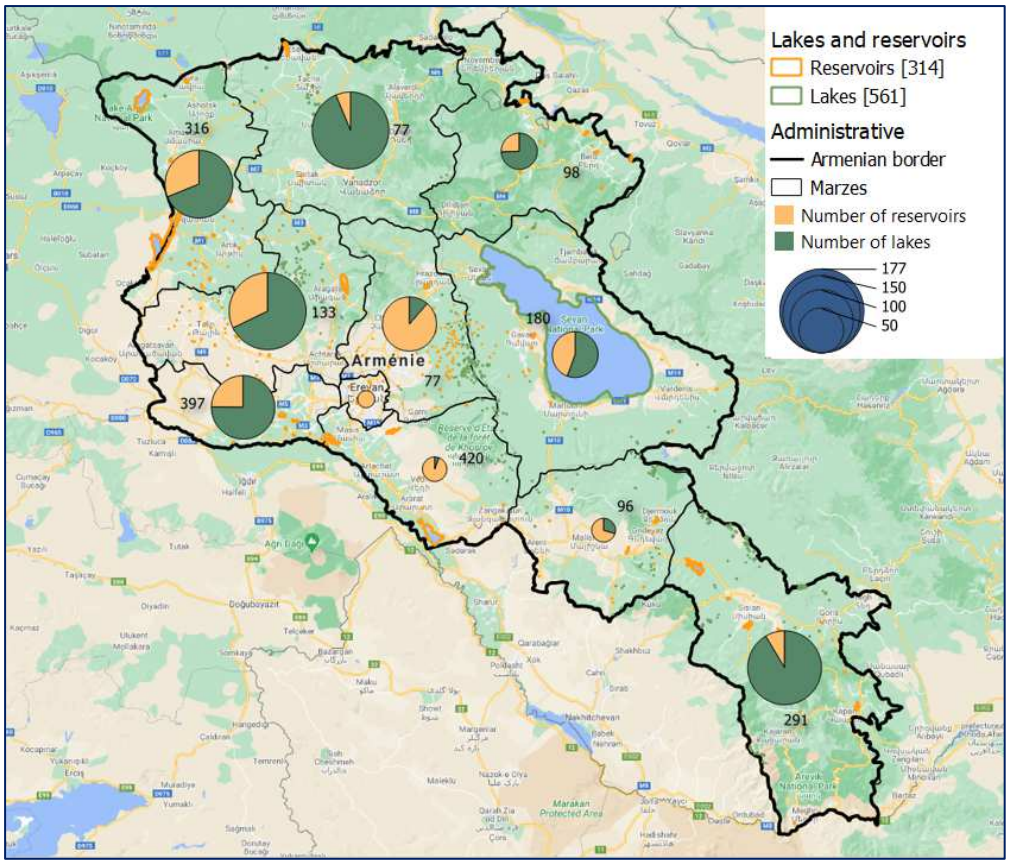


Figure 14 - Number of the lakes and reservoirs in Armenia.

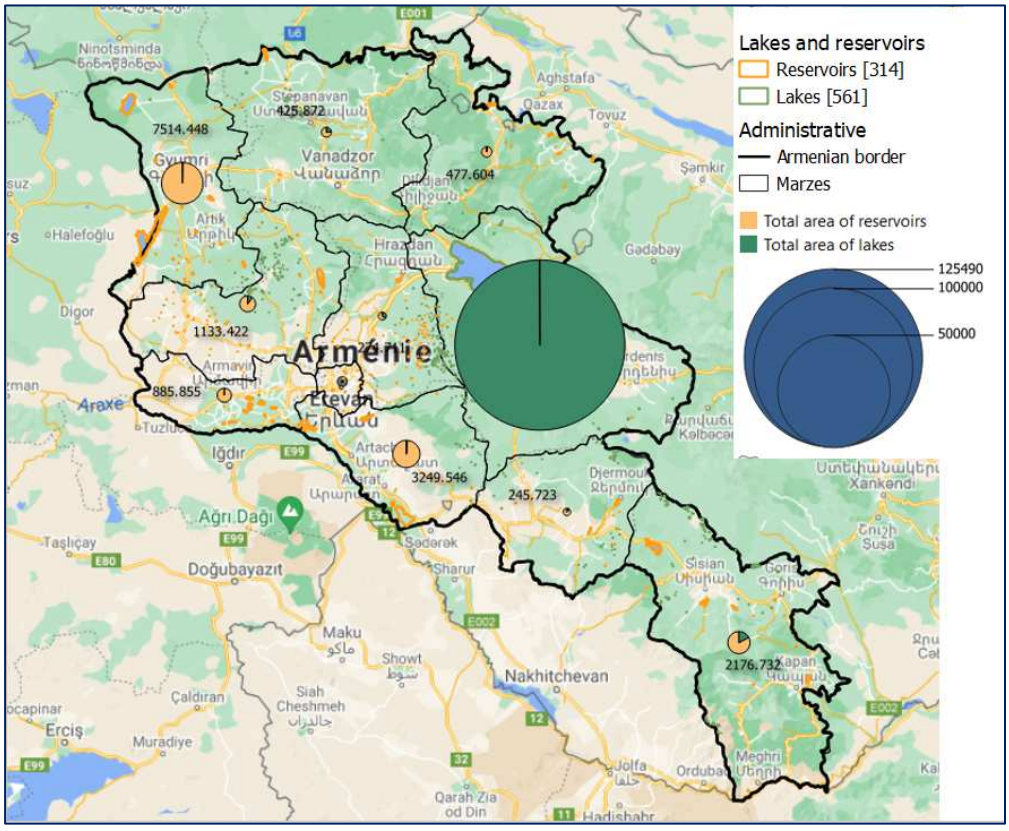


Figure 15 - Water surface of lakes and reservoirs in Armenia.

4.2.2 Water permanency

The water level is a crucial piece of information to gather, and this includes the depth at different points as well as the water-level changes over different seasons. Water-level variation due to reservoir operation, serving purposes like hydropower generation or irrigation, should also be taken into consideration. In general, FPV is best deployed at sites where water levels are 15 metres deep or less, with minimal variation. For sites with considerable water-level variation, the system will have to be designed for extreme water-level variations as well as short-term variations due to waves or tides. In the event where water completely dries out and the bottom is exposed, it is important to ensure that the bottom terrain and obstacles such as rocks and tree branches will not damage the floating structures. Greater depths and water-level variations will require more complex and costly anchoring and mooring solutions.

Many Armenian lakes and reservoirs are subjected to significant water level changes over the year. Many reasons can explain those variations: irrigation, evaporation, snowmelt. As a result, the characterization of the available water surface on a lake is two-fold: permanent surface and seasonal water surface.

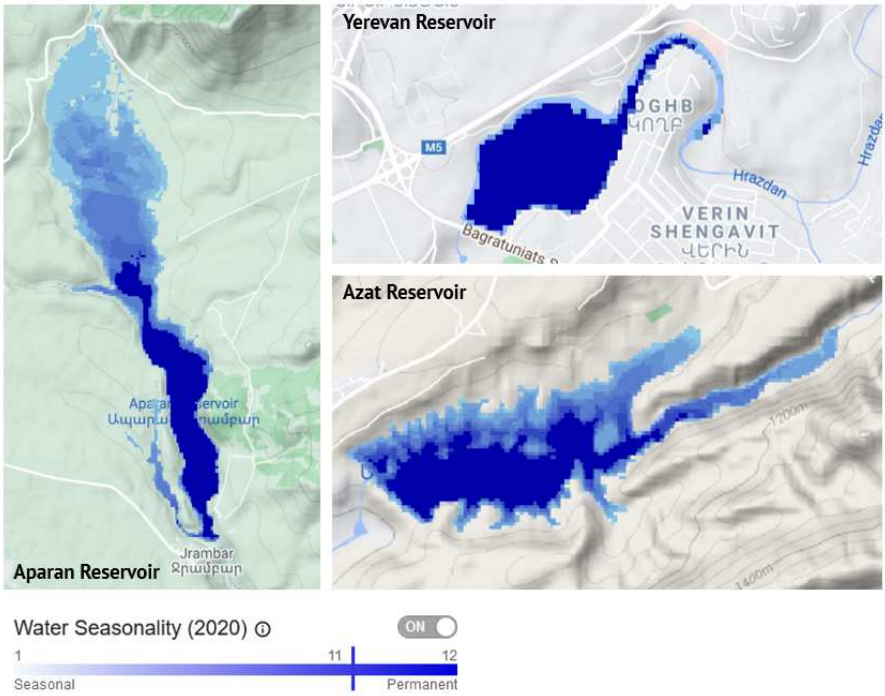


Figure 16 – Water seasonality of a few reservoirs (Source: Global Surface Water).

According to data available on the database of Acopian Center for Environment (AUA)[5], the total surface area of the Armenian reservoirs and lakes, apart from Lake Sevan, equals 11 075 ha. Among this total area, only 35% is permanent throughout the year. A significant number of lakes and reservoirs completely dry out by the end of the summer.

[5] https://ace.aua.am/

4.2.3 Hydropower plants (HPP)

These natural resources explain the historical and still ongoing massive development of Hydro Power Plants (HPP) in Armenia. The Armenian hydropower strategy, implemented by the Ministry of Energy Infrastructures and Natural Resources, is based on the existing two major HPPs cascades (Sevan-Hrazdan and Vorotan), the construction of three new middle-size HPPs and the large exploitation of Small Hydro Power Plants (188 existing SHPPs totalizing 369 MW, 33 additional SHPPs being under construction totalling 66 MW).

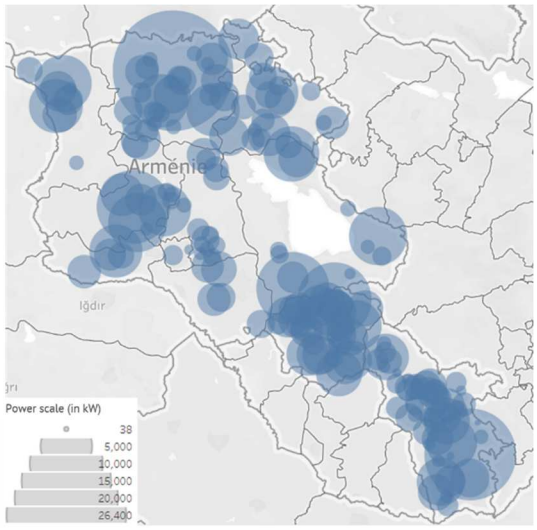


Figure 17 - Operational SHPPs

(source: https://public.tableau.com)

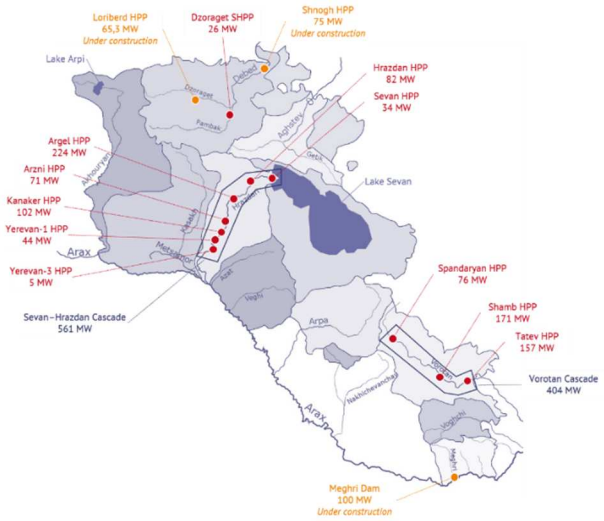


Figure 18 - Actual and future HPPs.

#	Site	Year	Ownership	Capacity (MW)	Annual energy prod. (MWh)	Load factor (h)	*Latitude*	*Longitude*	Type	Reservoir	Surface (m²)
	Sevan-Hrazdan Cascade										
1	Sevan HPP	1949	RusHydro	34	20 400	596	*40.554722*	*44.965556*	Run-of-the-river	Lake Sevan	1 236 000 000
2	Atarbekyan HPP (Hrazdan)	1959	RusHydro	82	54 800	672	*40.508111*	*44.760944*	Run-of-the-river	Hrazdan	676 000
3	Gyumush HPP (Argel)	1953	RusHydro	224	181 900	812	*40.378917*	*44.607917*	Run-of-the-river	Argel	46 300
4	Arzni HPP	1956	RusHydro	71	49 600	704	*40.296806*	*44.588583*	Run-of-the-river	-	-
5	Kanaker HPP	1936	RusHydro	102	66 700	654	*40.220556*	*44.518333*	Run-of-the-river	Kanaker	48 600
										Hrazdan 2	22 000
6	Yerevan 1 HPP	1961	RusHydro	44	36 200	823	*40.1895*	*44.49875*	Run-of-the-river	-	-
7	Yerevan 3 HPP	1960	RusHydro	5	2 500	500	*40.164194*	*44.500917*	Run-of-the-river	-	-
	Vorotan Cascade										
8	Spandaryan HPP	1984	CountourGlobal (US)	76	154 000	2 026	*39.65*	*45.85*	Dam	Spandaryan	6 410 000
9	Shamb HPP	1977	CountourGlobal (US)	171	272 000	1 591	*39.45716*	*46.16314*	Dam	Shamb	858 000
									Dam	Tolors	3 430 000
10	Tatev HPP	1970	CountourGlobal (US)	157	580 000	3 690	*39.4275*	*46.370833*	Dam	Tatev	11 900
	Others										
12	Dzoraget SHPP	1932	Dzoraget LTD	26,2	80 000	3 053	*40.94558*	*44.62966*	Run-of-the-river	-	-
	Under construction										
11	Loriberd HPP	-	-	65,3	-	-	*41.00759*	*44.4107*	Run-of-the-river	-	-
13	Shnogh HPP	-	-	75	-	-	*41.1505*	*44.83997*	Run-of-the-river	-	-
14	Meghri Dam	-	-	100	-	-	*39.091111*	*45.402222*	Dam	Aras	145 000 000
	Other large reservoirs										
										Artsvanik	2 110 000
										Azat	1 520 000
										Ketchut	1 140 000
										Herher	828 000
										Karkatchun	214 000
										Karnut	965 000

Figure 19 - Major HPPs and water reservoirs characteristics.

5 CONSTRAINTS AND OPPORTUNITIES

5.1 GRID INFRASTRUCTURES

Depending on the project location and its proximity and accessibility to the grid infrastructure, the grid connection cost may vary. Higher grid connection costs may even lead to the project being unfeasible or at least unfavourable compared to other projects. Thus, the distance to the nearby connection point is likely to be the determining factor. Even though very remote lakes and water reservoirs exist, one of the main advantages of the HPP connected FPV is its proximity to the grid connection point and very low grid connection costs in the case of common coupling. Depending on project capacity, such an advantage generally brings down the LCOE of FPV to a level lower than the LCOE of ground mounted plants (at proximity of the FPV site).

Another constraint regarding grid infrastructure is the renewable energy capacity of the grid. This mainly depends on the quality of the grid network, consumer profiles, etc. Not all power lines (in close proximity of the PV project) may have adequate capacity for a PV project. Even though further investments can solve the issue, the project may not then be feasible from an economical point of view. This, again, is one of the advantages of the HPP connected FPV projects since the available grid infrastructures generally have suitable capacities.

Estimation of project capacity vs distance to the grid is further detailed in Section 6.4.4.

5.2 ACCESSIBILITY

Proximity to the main road is beneficial as transportation costs of all required materials affect the overall cost of FPV projects. For a utility-scale project, the number of materials requiring transport from storage to the construction site is substantial. The site should be served by roads (ideally, gravel-chip finish or better) that allow truck access. The closer the site is to the main access road, the lower the cost of additional infrastructure and safe transportation of solar panels.

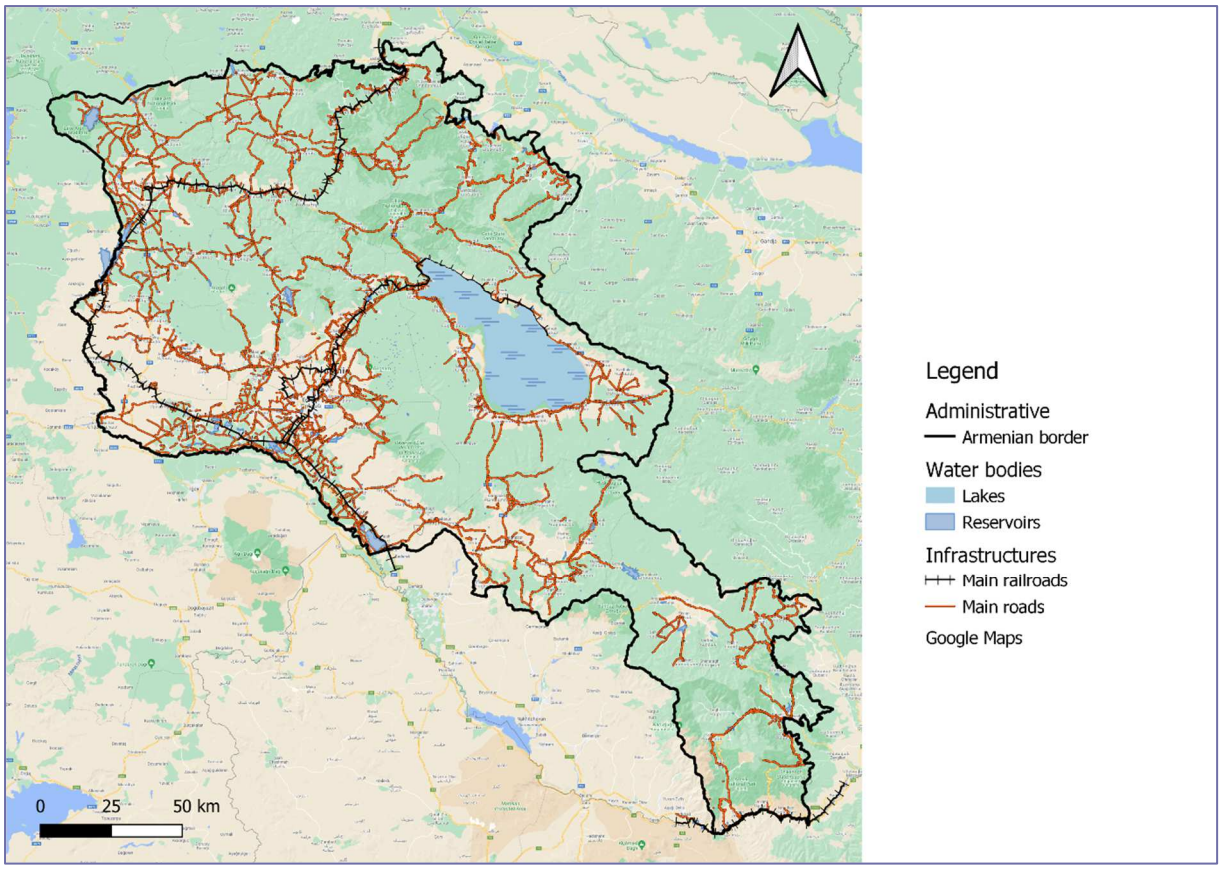


Figure 20 - Main transport infrastructures.

5.3 NATURAL CONSTRAINTS

If solar irradiance is one of the most important parameters when it comes to PV projects, climatic conditions also have significant implications for construction, foundations, system design and layout, as well as system reliability. Seasonal variations in weather—such as temperature range, precipitation, wind speed and direction, humidity, lightning occurrence, and storm statistics are key factors that require close study. In Armenia, winter conditions, flood occurrences and seismic risks are the major natural constraints for FPV development.

5.3.1 Ice and snow

Winter climatic conditions in Armenia are particularly tough, especially in the most mountainous regions. Lakes and reservoirs are often covered by a layer of ice that can reach tens of centimetres for several months. Snowfalls can also be significant, and the snow layer can be persistent.

These winter conditions impose strong constraints on the mechanical strength of the photovoltaic island and on the buoyancy of the floats under the weight of the snow. Most floating devices are designed for occasional snowfall, and this would need to be reinforced to ensure the buoyancy of the powerplant during the Armenian winter season.



Figure 21 - Ice layer on Aparan Lake on April 2021 (Source: PJN-Consulting).

The world's first high-altitude floating solar powerplants was realized in Switzerland in 2019 by Romande Energie, one of the main national electricity suppliers. It was built at an altitude of 1 810m. The installation consists of an aluminium frame, resistant to mechanical stress due to ice movements, supported by polyethylene floats. The installation rests on the bed of the empty lake when the water is drained out between November and March.

Technological solutions are being studied and tested to facilitate the development of FPV on high-altitude reservoirs. Armenia can benefit from those future improvements, but also position itself as an active player in this technical development.

5.3.2 Flood

The risk of floods plays a very important role in the sizing of the power plant's anchoring and on the risk of damage on the installation. Small reservoirs with strong currents on normal operation have larger flood flows and should therefore be avoided. The number of debris charged by the current in normal operation and during a flood is also an important parameter.

5.4 HUMAN USE OF WATERBODIES

The implementation of a floating photovoltaic power plant must consider the prior uses of the water body. Indeed, energy production must be compatible with the current economic and recreational uses of the reservoir and anticipate their evolution.

5.4.1 Use conflicts

In Armenia, lakes and reservoirs are often used for fishing, sometimes resulting in associated navigation activities. Tourist activities are sometimes developed on the shores of the lakes, especially on Lake Sevan. Water bodies also host recreational and sporting activities, such as canoeing, boating, rowing, etc.

These conflicts of uses must be anticipated to find solutions that allow understanding between users of the water body. The location or size of the photovoltaic island, the circulation of cables on or under water, the indication of the installation or its integration into the landscape are mitigation possibilities in order to preserve existing uses.

5.4.2 Safety

If located near ports, harbours, shipping lanes, or recreational areas, an FPV project may pose risks to shipping safety (for example, collision or the alteration of vessel traffic routes). Such risks are exacerbated during the construction phase when additional vessels are accessing the site. Collisions may result in damage to floating systems and/or vessels, as well as pollution from spilt oil. Planning the location of floating systems; cable routes; and other associated infrastructure (anchoring, mooring, and rigging) requires careful consideration of factors such as anchorage areas, seabed conditions, archaeology sites, existing cable or pipeline routes, and fishing grounds. Efforts must be taken to minimize any impacts where possible.

Safety issues may also arise where floating modules or substations may be accessed by the public. Any public rights of way located within or close to an FPV project site should be identified before construction and measures taken to ensure the safety of users. To manage public access, gates, fences, security barriers and clear information about safety hazards must be considered.

5.4.3 Social acceptability

Depending on the location, the floating modules of an FPV project may be visible from residential areas or tourist sites. Project operations may also change the character of the surrounding landscape. Impacts on legally protected and internationally recognized areas of importance to biodiversity and cultural heritage are important to consider before construction. It is recommended that wire-frame images and photomontages from key viewpoints be prepared to inform both assessment and consultation processes. Measures to avoid and minimize landscape, seascape, and visual impacts are largely associated with the siting and layout of floating modules and associated infrastructure. Consideration should be given to the floating modules layout, size, and scale in relation to the surrounding landscape (including, for example, residential properties and recreational areas/routes).

5.5 TECHNICAL CONSTRAINTS

5.5.1 Launching areas

A suitable launching area by the water body with a gentle slope is necessary to identify for the construction, where the floating structure is assembled and launched. In general, working on the land is easier than assembling the components directly on the water. The launching area always needs some preparation. A launch ramp can be constructed on the bank's natural slope into the water body. This temporary infrastructure could be built with metal or wooden scaffolding and slats at minimal investment. Although not mandatory in all cases, a launch ramp can ease deployment efforts and reduce float damages.

Workers can gently push the assembled floats into the water, so lifting machinery is generally not necessary. There are, however, other assembly and launch methods: assembling on land, then lifting and launching into the water. The system could also be assembled on water, depending on the floating structure design and ease of construction works.

5.5.2 Specificities of dam reservoirs

5.5.2.1 Reservoir safety management

Safety is a major topic in dam reservoirs management, especially for some reservoirs where protection of downstream population and infrastructure is a major concern. Indeed, the FPV project must not change the hydro scheme current safety level.

Specific site regulations and safety duties must be analysed. A risk analysis of the FPV project on dam safety and operation must be conducted. Based on technical data and project choices of design, a demonstration that the project does not modify the current safety level is required. This implies that the permitting process complexity can increase with the reservoir safety requirements.

For instance, in case of flood, the dam operator is entitled to manage the reservoir in a specific way (Flood control outlet management, overflow, anticipated low level …). The FPV project must be designed accordingly in order not to reduce flood evacuation capacities. It is possible that the dam flood operating process is not compatible with the installation of an FPV project.

5.5.2.2 Reservoir operation activities

To ensure FPV project acceptance by dam reservoir stakeholders (operator, local authorities), the FPV project must not:

- Prevent the operator from proceeding with current and exceptional operational activities on the reservoir,
- Prevent the dam operator to produce electricity “business as usual” during construction works and operation.

The activities that are usually occurring on or nearby the reservoir must be detailed. Besides, foreseen activities even with uncertainties in terms of timing and/or occurrence need to be identified and detailed. For instance, the fact that a reservoir could one day be emptied for specific civil works must be considered.

6 IDENTIFICATION AND CHARACTERIZATION OF SITES

6.1 METHODOLOGY

The methodology developed to estimate the floating photovoltaic potential is a method of selecting and characterizing the available water surfaces, based on a cartographic analysis of the data. Data related to water bodies, grid, climate and topology, accessibility and natural constraints have been crossed-analysed to characterize the sites and to highlight those that present favourable characteristics for the development of floating photovoltaic projects.

The selection and characterization steps are the following:



This study is not a preliminary feasibility study. Above all, its aim is to estimate a national potential, to identify predominant technical constraints at a national level, and to propose a list of sites that may justify feasibility studies at a later stage.

6.2 ASSUMPTION USED ON AVAILABLE AREAS

Only the sites allowing for a capacity greater than 1 MWp have been selected, considering that an area of 10,000 m² (1 ha) is required per MWp of floating photovoltaics.

For environmental reasons and to mitigate use-conflicts risks, it was considered that FPV can cover a maximum of 50% of the lake or reservoir. This assumption was generally observed in our literature review. This coverage ratio can then be revised during the pre-feasibility and design phase, depending on environmental issues and pre-existing uses on the water body.

Consequently, lakes and reservoirs with a surface below 2 ha (20 000 m^2) have been excluded, considering their incompatibility with the implementation of a 1 MWp capacity. This surface limit has an important impact on the number of sites : only 121 out of the 314 reservoirs and 67 out of the 561 natural lakes are larger than 2 ha.

This 1 MWp threshold is aiming for large-scale projects of major interest for investors, developers, and independent power producers. It was also considered that most of the national potential capacity would be covered by such projects.

Smaller projects, community projects for example, could be implemented on smaller water bodies and therefore add to the estimated potential.

Most of the reservoirs present important seasonal surface variation over the year, due to water use for irrigation, energy production, or evaporation. The permanent water surface of each lake

and reservoir, in normal operation conditions, has been measured using the data of the Global Surface Water Explorer[6] and satellite images.



Figure 22 - Example of the maximal (in red) and permanent (in blue) water level considered on a reservoir.

6.3 YIELD ANALYSIS

The electricity generated of an identified surface is calculated as follow:

$$E = Irradiation_{South,12°} \times DC\ Capacity \times Performance\ Ratio \times Corrective\ ratios$$

Where:

- The solar irradiation for a south orientation and an inclination of 12° was extracted for each site from the irradiation data provided and explained in Section 4.1.
  The tilt of 12° is the standard inclination for Ciel&Terre floats. Some other manufacturers may offer a different tilt.
- The DC capacity of the installation is calculated from the available surface.
- The performance ratio (PR) of an installation corresponds to the performance of an installation according to its technical characteristics and its environment. A PR equal to 86% was estimated for a standard FPV installation in Armenia, considering the water cooling of the modules, characteristic of the FPV, which improves the performance of the installation.
- Corrective ratios were then applied to theorical PR to account for the degradation of energy generation by other factors: snow, shading, etc. Those ratios are estimated at a regional scale.

[6] https://global-surface-water.appspot.com/map

Snowfall and the permanency of the snow cover in winter is the main factor of yield degradation that was applied in Armenia. This was estimated based on the number of average annual snow days for each climatic zone.

Tableau 1 – Number of days with snow cover and associated losses.

Zone	Number of days with snow cover	Ratio
1	25	96,7%
2	35	95,31%
3	50	93,2%
4	40	94,8%
5	45	94,10%
6	60	91,2%
7	70	89,5%
8	110	81,4%
9	135	78,8%
10	150	75,0%

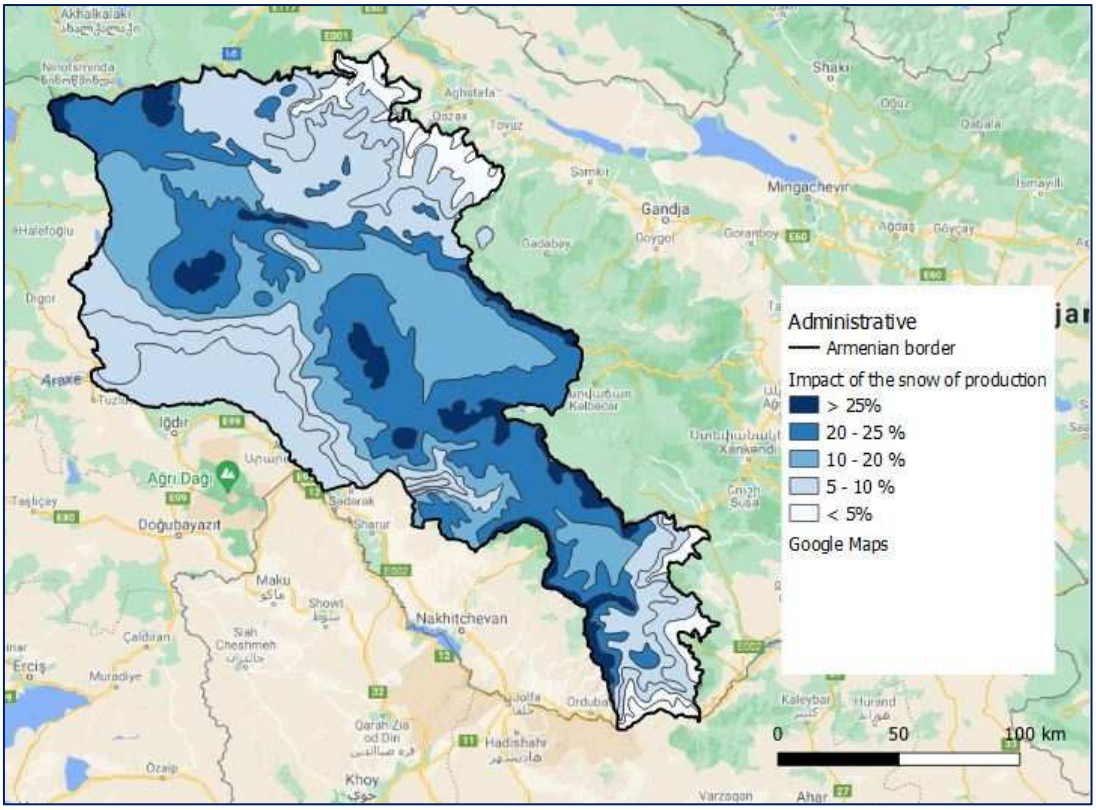


Figure 23 - Impact of the snow on energy production.

In some regions, snowfall, and the permanency of the snow cover over several months can result in significant production losses, well over 20%. This loss of production has a negative impact on the economic feasibility of the project.

For each site, an annual average irradiation value was extracted from the values provided by Transvalor, as described in 4.1.4, and the yield analysis methodology described above was used.

Theoretical electric generation of a standard FPV project is thus calculated for each site by using the local irradiation values and corrected by regional factors (such as snowfalls, temperature, etc).

6.4 ANALYTICAL GRID

A grading from level 1 to level 3 was associated to each parameter / constraint, the higher the number the less attractive:

- 1: the constraint should not impact the feasibility of an FPV project on this site,
- 2: some issues may impact the feasibility study, the impact of this constraint must be further analysed at feasibility stage
- 3: this constraint will likely prevent an FPV project on this site.

6.4.1 Water level variation

Water level variation has been estimated for reservoirs through measuring the maximum and minimum length of the reservoir, the altitude of the maximum water level, and altitude of the lowest point of the dam.

We consider that our estimation has a significant margin of error, due to measurements tolerances and uncertainty of satellite data.

However, our grading allows to identify sites for which this data must be collected or investigated in priority before any in-depth study, to assess the relevance of a project. Sites on which the water level variation exceeds 20 m are generally not feasible and are not recommended as a general approach in the industry.

Level	Water level variation
1	< 10 m
2	Between 10 and 20 m
3	> 20 m

With the development of more and more floating photovoltaic projects on dam reservoirs, we expect that the adaptation of anchorage to water level variations will likely benefit from technical progress. New anchoring technologies may expand the possibilities for PV island projects on these now heavily constrained sites.

6.4.2 Climate

As a mountainous country, many Armenian lakes and reservoirs are in high altitudes. To estimate the impact of the climate on the feasibility of an FPV project on a site, three parameters have been combined: climate zones, altitude, annual mean temperature.

Climate zones

Armenia is divided into 10 climatic zones. Climates with long and cold winters are less favourable for FPV projects, due to snow cover affecting electric generation, and ice mechanical forces on the floating structure.

Table 1 – Climatic zones in Armenia and level of constraints on FPV projects.

Level	Climate
1	Arid continental, with dry warm summers and moderate cold winters
1	Arid subtropical, with hot summers and calm winters
1	Arid, continental, with hot summers and cold winters
2	Moderate, relatively dry warm summers and cold winters
1	Moderate, relatively humid during all seasons
1	Moderate, warm arid summers and moderate cold winters
2	Moderate, with short cool summers and cold winters
1	Moderate, with warm summers, relatively humid calm winters
3	Mountain tundra climate
2	Warm summers and relatively calm winters

The mountain tundra climate, which concerns the highest Armenian peaks, was considered eliminatory for an FPV project.

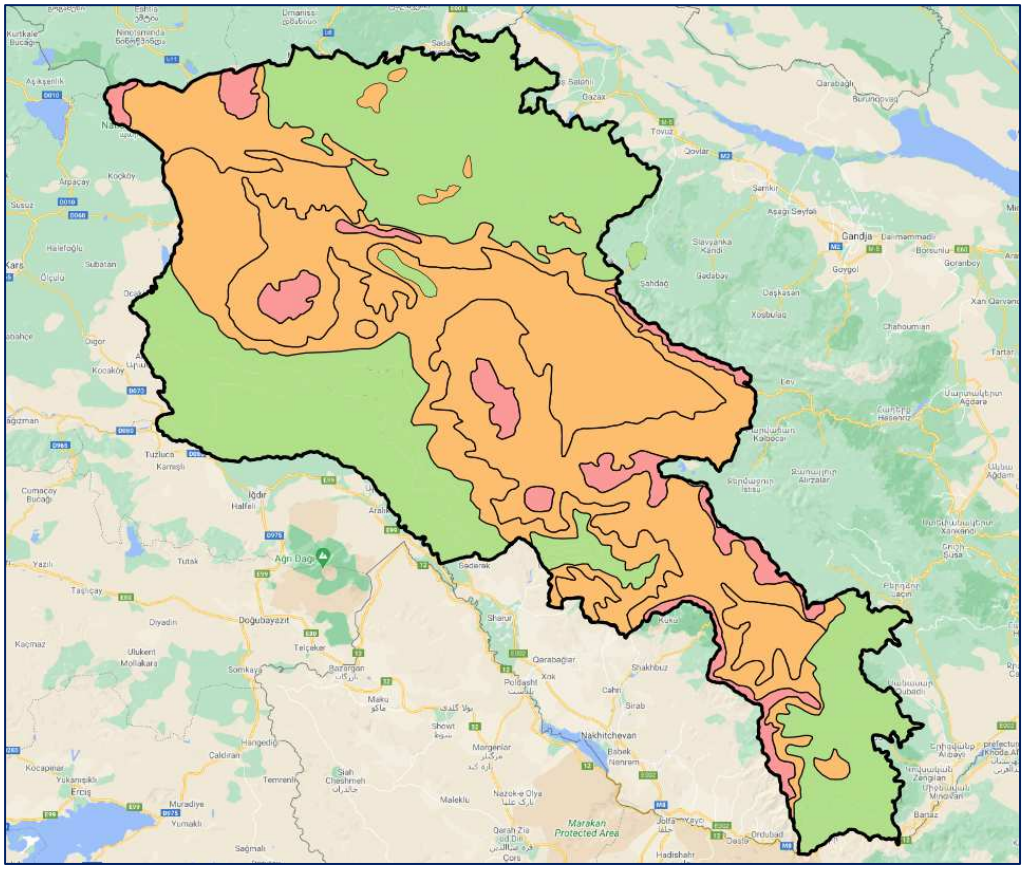


Figure 24 - Level of constraints on FPV projects due to climatic zones.

The mountainous diagonal that crosses Armenia from northwest to southeast, with harsh mountain climate and long, cold winters, is less favourable for FPV projects than the continental and subtropical plains in the north, south and east.

Altitude

The altitude of a lake obviously affects the climate that prevails there but also affects its accessibility.

Table 2 - Altitudes and level of constraints on FPV projects.

Level	Altitude
1	< 1 000 m
2	Between 1000 and 1 800 m
3	> 1 800 m

Areas with an altitude greater than 1800 m may either prevent easy access or heavy snow constraints.

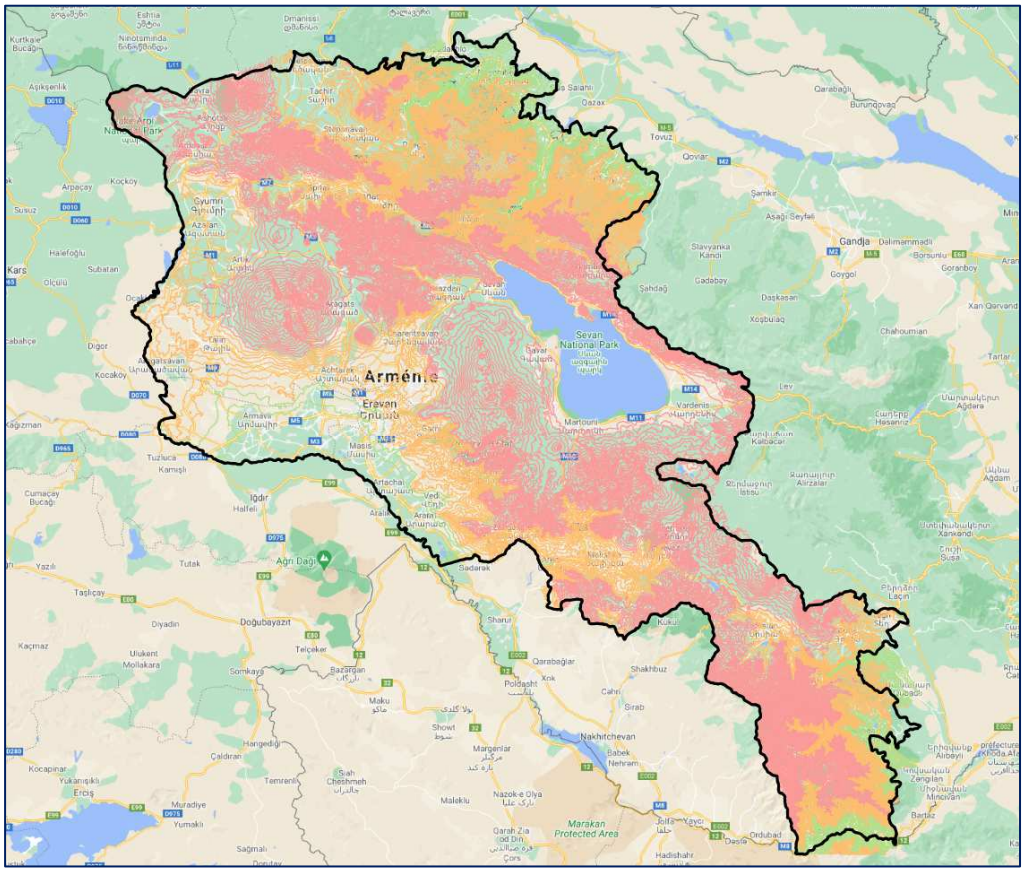


Figure 25 - Level of constraints on FPV projects due to altitude.

Annual mean temperature

The mean annual temperature was used as an indicator of the severity of the climate and the importance of ice constraints. Data on maximum and minimum temperatures would also have been relevant to use, but they were not available at the time of the study.

Table 3 – Mean annual temperature and level of constraints on FPV projects.

Level	Altitude
1	> 2°C

2	Between -2°C and 2°C
3	< - 2°C

The distribution of the constraints due to the temperature follows the distribution of the constraints of altitude and climate. It confirms the importance of these constraints throughout the Armenian mountain ridge.

6.4.3 Accessibility

The accessibility of a site is estimated from the distance to the nearest road. Altitude was also considered to estimate the difficulty of building a specific road access for the project.

Level	Distance to the road
1	< 1 000 m
2	Between 1 000 and 5 000 m and altitude > 1 500 m
3	Others

The estimation of accessibility constraints was limited to the availability and accuracy of cartographic data.

6.4.4 Grid connection

As explained in Section 5.1, distance to the nearby available grid infrastructure is a determinant factor on the project feasibility. A high-level study has been conducted to estimate grid connection costs based on project capacity and grid distance. The costs cover the floating MV cables, onshore grid lines (considered to be overhead lines), and transformers (from LV or MV to appropriate transformer step-up ratio 35kV, 110kV, 220kV). To better estimate the effect of project capacity and distance to the grid infrastructure, a cost function for each element is created, considering that there is a base cost and variable costs for the installation of overhead lines, transformer substations, etc. As an example, the 110 kV grid connection of a project with a capacity of less than 2 MWp is considered unfeasible due to the very high CAPEX of grid connection, which makes the LCOE of the FPV project higher than the available or average feed-in tariffs in Armenia.

However, this study is limited to the grid data available. A grid map was found through our literature review[7], and another set of data was obtained from an extraction of grid data contained on Open Street Map from Google. Those datasets only contain the information for 35kV, 110kV, and 220kV grid lines and it is not certain whether all grid lines at this voltage level are correctly implemented or not. Moreover, there are lower voltage levels available in Armenia. Thus, the grid connection study is not used at this stage as a definitive constraint due to the limitation of the available data.

Grid			
Project Capacity	**35 kV**	**110 kV**	**220 kV**
2 MWp and smaller	Up to 1 km	Not feasible	Not feasible

[7] http://www.geni.org/globalenergy/library/national_energy_grid/armenia/graphics/armegrid.jpg

From 2 to 5 MWp	Up to 2 km	Up to 1 km	Not feasible
From 5 to 10 MWp	Up to 5 km	Up to 2 km	Up to 500 m
From 10 to 30 MWp	Up to 10 km	Up to 5 km	Up to 2 km
	Up to 15 km	Up to 10 km	Up to 5 km
From 30 to 60 MWp	Up to 15 km	Up to 10 km	Up to 5 km
		Up to 13 km	Up to 10 km
From 60 to 100 MWp	Up to 15 km	Up to 15 km	Up to 15 km

6.4.5 SPNA

The general rule is the prohibition of economic activities that are strictly forbidden in Specially Protected Natural Areas.

Nevertheless, the proponent of a project in a specific SNPA shall obtain special permission delivered on a case-by-case basis with authorities. Therefore, level 3 of constraint has been associated with projects located in an SPNA. However, the potential on lakes and reservoirs in SPNA has been calculated.

6.5 Limitations

The FPV potential estimation was carried out considering the data available at the national level. A macroscopic approach has several limitations, which are detailed below:

- The water bodies considered are taken from the AUA databases. These databases may be incomplete or partially obsolete.
  Moreover, all waterbodies of artificial origin are called reservoirs: hydroelectric reservoirs but also irrigation basins, fish farming, gravel pits, etc.
- The climatic data were considered on a regional scale. The impact on the feasibility of a PV project and on energy yield was therefore generalized to a climatic zone.
- The data available on electrical infrastructure is limited. In particular, the location of medium voltage lines is not always specified in the datasets used. The location of the substations and their capacity to accommodate new electricity production capacities was not considered.
- Some data come from satellite sources or were measured from a satellite imagery. This leads to a margin of error on the measurements taken.
- Snow data was extrapolated to climatic regions proposed by the AUA. Consequently, the degradation of the electric generation by snow has probably been locally overestimated or underestimated.

In addition, the minimum and maximum capacity assumptions for a FPV project also significantly impact the potential :

- A minimum capacity of 1 MWp has been chosen to promote the emergence of industrial-scale projects that can attract investors. However, a number of sites may be favorable for small community projects.

Among the lakes and reservoirs with maximum water cover bigger than 2 ha, 33 sites are favorable for small installations from 100 kWp to 1 MWp on permanent water surface, for a total potential of 11.8 MWp.

Lakes and reservoirs smaller than 2 ha were not studied in this work, but local investigation could lead to the development of small FPV projects.

- A maximum capacity of 50 MWp has also been considered, in order not to overestimate the national potential from the few largest sites. The majority of FPV projects in service around the world have capacities below 50 MWp. However, with the growth of the FPV industry, several giant projects, more than 150 MWp, are being constructed around the world. Such opportunities should be investigated in the future and would increase the potential.

  6 sites are affected by the threshold of 50 MWp for FPV power plants on permanent water bodies, and 11 more sites for FPV power plants with seasonal ground landing.
- The assumptions on the capacity per ha (1MWp/ha) are based on the Ciel&Terre floats technology. Other technologies allow bigger capacity density, up to 1,6 MWp/ha. In addition, technical progress in modules and floats technologies may increase capacity densities in the future.

7 FPV NATIONAL POTENTIAL

The estimated energy generation potential, based on the assumptions presented in part 6 is detailed in this section. The objective of the potential cross-analysis is to identify the most important constraints on the water bodies that have been studied, to anticipate the future choices of technologies for future industrial-scale projects. It also highlights specific points of attention that should be checked in priority in the feasibility and design phases of future projects.

7.1 ESTIMATED ARMENIAN FPV POTENTIAL

The tables in this section show the estimated FPV capacity and corresponding energy generation potential in Armenia. Considering significant water level variations, the potential on permanent water bodies and all water bodies are provided in separate tables. Moreover, the potential on Protected Natural Areas vs non-protected areas is distinguished.

Table 4 only considers areas with permanent water cover and no ground landing required.

Table 4 – Permanent water bodies FPV potential capacity on permanent water coverage.

Initial potential	Sites	Capacity (MWp)	Annual energy generation (GWh/year)
In non-protected areas	36	520	691
In protected areas	9	201	276
Permanent water bodies	**45**	**721**	**967**

Even considering the most conservative potential, limited to FPV capacities on permanent water bodies in non-protected areas, the potential, 520 MW, equals 4 times the ground-mounted PV capacity installed and under construction in Armenia in October 2021. The electrical generation associated, 621 GWh/year, enable to cover 12% of the national electric consumption.[8] The Republic of Armenia government aims to increase the share of solar power generation at least to 15% or 1 800 GWh by 2030.[9] The FPV sector could contribute nearly 40% to these objectives, considering the most conservative potential described above.

Considering that several sites show important water lever variations, we also analysed the possibility to extend the initial potential to include FPV solar plants that stay afloat for a part of the year, and land on the ground when water retires during dryer seasons. The estimated capacity is calculated using a coverage rate of 50% of the maximum water surface. Depending on the water level variations, a part of this capacity will ground land.

Such assumption significantly increases the initial potential, with additional 1007 MWp capacity (+140%), on 79 sites. This is considered feasible with the implementation of specific technologies, subject to technical analysis at feasibility stage.

[8] World Bank Data from 2014 : https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?locations=AM.
[9] Republic of Armenia Energy Sector Development, Strategic Program to 2040 (2020).

Such specific technologies are expected to raise several difficulties:

- Only perfectly flat areas, without asperities and stranded objects, can be selected, to enable stable ground landing without damaging the floating structure. The choice of location and the available surface will thus be limited. Thus, some of the sites constituting the 1 007MWp additional capacity may not be feasible.
- An increase of the capital and operational costs, thus the LCOE of the project, is expected.
- Areas that are out of water for long periods can be seasonally used by locals, for shore fishing activities for example. In addition to usage conflicts of the land, a ground landed power plant is easily accessible to intruders, leading to security and safety issues.
- The transition period during which part of the installation is ground landed and part is floating, is a source of strong mechanical stresses on the floating structure which must be precisely studied during the design phase.

It is thus preferable to prioritize sites with permanent water cover. However, this technical possibility can be considered to extend the potential.

Table 5 – Extended FPV potential capacity including landing areas.

Extended potential	Sites	Capacity (MWp)	Annual energy generation (GWh/year)
In non-protected areas	109	1 429	1 969
In protected areas	15	299	404
Permanent water + landing areas	**124**	**1728**	**2 373**

Protected natural areas cover a 17% to 28% of the potential capacity. It is therefore possible and recommended to prioritize projects outside of the protected natural areas.

Ararat, Armavir, and Syunik provinces have the most important potential in Armenia, beyond 250 MWp for each of them. Syunik region has a particularly interesting potential because most of its potential is on permanent water bodies, easing project design and implementation and making the potential project more attractive.

Table 6 – Initial and extended FPV potential including natural protected areas, per province.

	On permanent water bodies : no landing required			On permanent and non-permanent water bodies : landing partially or fully required		
Province	Sites	Capacity (MWp)	Annual energy generation (GWh/year)	Sites	Capacity (MWp)	Annual energy generation (GWh/year)
Aragatsotn	5	66	85	22	126	164
Ararat	5	112	170	13	328	492
Armavir	4	25	38	25	322	478
Gegharkunik	6	78	102	11	163	211
Kotayk	3	34	40	14	86	102
Lori	2	39	52	5	61	82
Shirak	6	56	73	11	179	234
Syunik	6	171	218	11	258	333
Tavush	2	73	99	3	85	116
Vayotz Dzor	3	39	50	5	92	116
Yerevan	3	28	41	4	30	45
Permanent water bodies	**45**	**721**	**967**	**124**	**1 728**	**2 373**

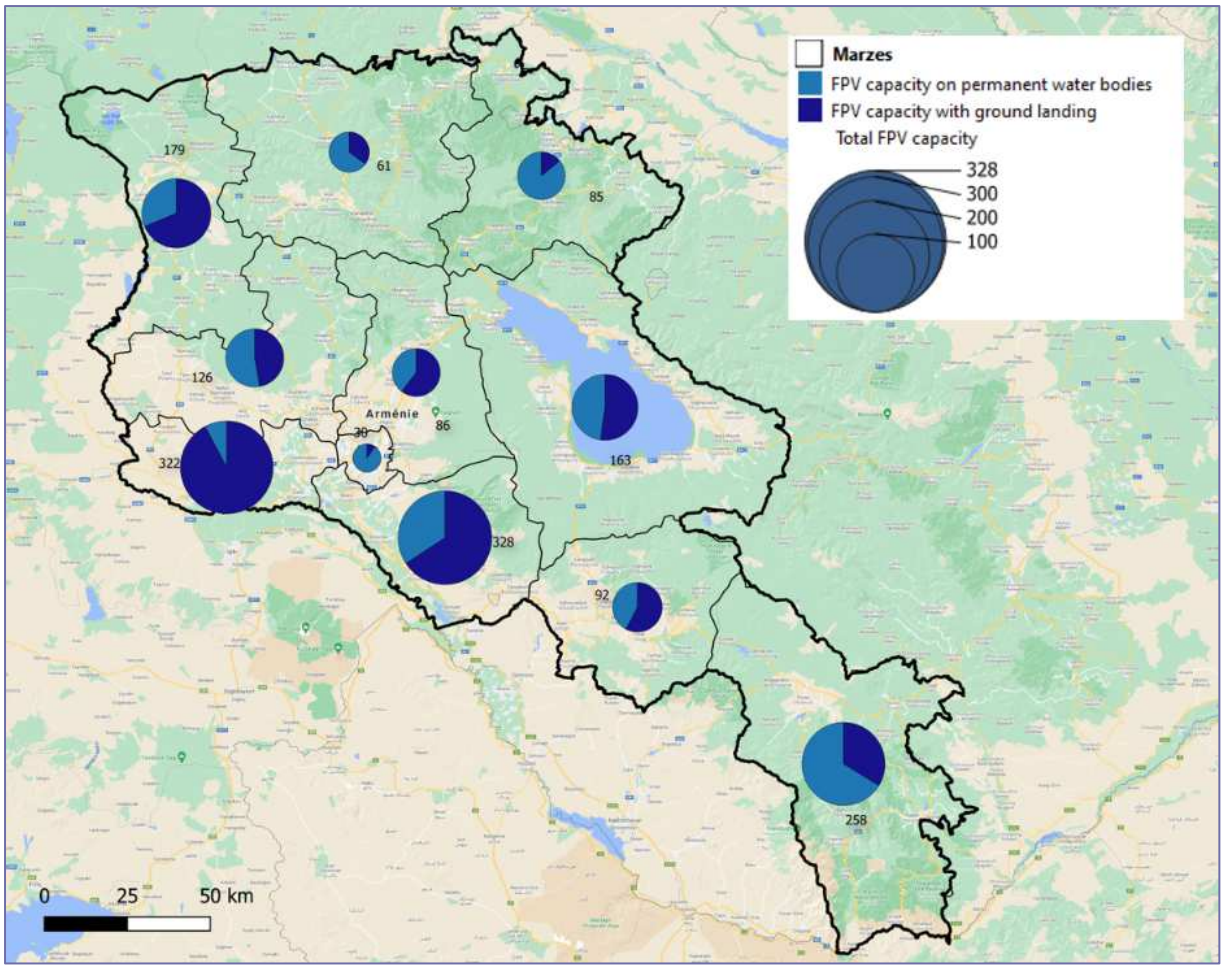


Figure 26 – FPV potential capacity.

The figure above summarizes the potential capacity identified by province. The extended potential capacity, including the potential on permanent waterbodies and with ground landing areas, is materialized by the size of the diagram. The colours in the diagram represent the part of the capacity provided by the initial potential, in light blue, and the part completed by the technology allowing ground landing, in navy blue.

7.2 IMPACTS OF LEVELS OF CONSTRAINTS

The number of sites affected by each constraints level presented in part 6.4 is detailed in Table 5.

Table 7 – Number of sites impacted by each constraint.

Level	Climate	Accessibility	Protected natural areas	Grid	Water Level Variation	General
Low	82	130	160	65	38	71
Medium	58	4	-	10	8	38
High	46	52	26	-	2	77
Unknown	-	-	-	111	NA	-

Each constraint was assessed throughout the analytical grid as described in section 6.4.

The "General" ranking for each site was assessed as the highest ranking from individual criterions. For example:

- any site with at least one high risk is graded as generally high,
- any site with no high risk, but at least one medium risk, is graded as generally medium
- any site with only low risks, is graded as generally low.

Finally, 77 out of the 186 lakes and reservoirs have a high level of constraints, corresponding to 41% of them. These sites are considered unfavorable to a PV project and excluded from the potential.

As previously explained, the available grid information data does not cover all the grid lines in the country. Thus, due to the limited level of precision, constraints of grid connection were not used as an evaluation parameter.

Reservoirs are considered to have more favourable profiles for developing FPV projects than lakes: 64% of the lakes were ranked with a generally high level of constraints, in comparison with only 33% of the reservoirs. Climate constraints are particularly important on natural lakes.

Table 8 - Comparison of the number of constraints on lakes and reservoirs.

Level	Number of lakes	Proportion of lakes	Number of reservoirs	Proportion of reservoirs
Low	12	26%	59	42%
Medium	5	11%	33	24%
High	30	64%	47	34%
Total	47	100%	139	100%

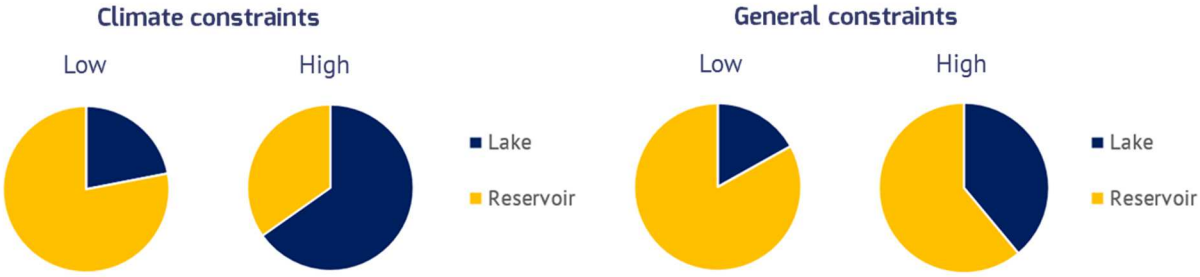


Figure 27 – Comparison of the level of constraint on lakes and reservoirs.

Climate and accessibility are the most limiting factors for the development of FPV projects in Armenia: climate is prohibitive for almost 25% of the sites, and accessibility for 28% of them. It should be noted that the sites, excluded due to unfavorable climate and accessibility conditions, are often the same. They concern reservoirs or lakes located in altitude, far from densely populated regions.

8 FPV SITES QUALIFICATION

Among the sites that have been studied, the reservoirs below were ranked with a generally low level of constraints (only low criterions). They could be part of the sites to be primarily studied during feasibility studies.

Grid connection facilities around the sites should be investigated in priority at feasibility stage.

Table 9 – Characterization of the most favourable sites identified.

Hakhum reservoir

	• FPV potential on permanent waterbody:
	  ○ Capacity: 20,5 MWp,
	  ○ Production: 26,65 GWh.
	• Description of the site:
	  ○ Altitude: 700 m,
	  ○ Climate: arid subtropical,
	  ○ Direct access to the road.
	
	Attention points: close to the border, water level variation.

Metsavan reservoir

	• FPV potential on permanent waterbody:
	  ○ Capacity: 30,0 MWp,
	  ○ Production: 35,82 GWh.
	• Description of the site:
	  ○ Altitude: 1 600 m,
	  ○ Climate: moderate, relatively humid during all seasons,
	  ○ Direct access to the road and close to the grid.
	
	Attention point: altitude.

Tavush reservoir

	• FPV potential on permanent waterbody:
	  ○ Capacity: 13,0 MWp,
	  ○ Production: 16,66 GWh.
	• Description of the site:
	  ○ Altitude: 800 m,
	  ○ Climate: arid subtropical,
	  ○ Direct access to the road and close to the grid.
	
	Attention point: close to the border, water level variation.

Aygezdor reservoir

	• FPV potential on permanent waterbody:
	  ○ Capacity: 5,7 MWp,
	  ○ Production: 6,55 GWh.
	• Description of the site:
	  ○ Altitude: 1000 m,
	  ○ Climate: arid subtropical,
	  ○ Direct access to the road.
	
	Attention point: close to the border.

Karahunj reservoir

	• FPV potential on permanent waterbody:
	  ○ Capacity: 4,7 MWp,
	  ○ Production: 6,48 GWh.
	• Description of the site:
	  ○ Altitude: 1 700 m,
	  ○ Climate: moderate, relatively humid during all seasons,
	  ○ Direct access to the road.
	
	Attention point: close to the border.

Vardavarri lake

	• FPV potential on permanent waterbody:
	  ○ Capacity: 4,3 MWp,
	  ○ Production: 6,5 GWh.
	• Description of the site:
	  ○ Altitude: 1 000 m,
	  ○ Climate: arid continental,
	  ○ Direct access to the road.

Lukasert reservoir (Argel)

	• FPV potential on permanent waterbody:
	  ○ Capacity: 2,1 MWp,
	  ○ Production: 3,11 GWh.
	• Description of the site:
	  ○ Altitude: 1 600 m,
	  ○ Climate: arid subtropical,
	  ○ Direct access to the road.
	
	Attention point: altitude.

Kanaker reservoir

	• FPV potential on permanent waterbody:
	  ○ Capacity: 20,5 MWp,
	  ○ Production: 26,65 GWh.
	• Description of the site:
	  ○ Altitude: 1 200 m,
	  ○ Climate: arid continental,
	  ○ Direct access to the road.

Yerevanian lake

	• FPV potential on permanent waterbody:
	  o Capacity: 22,1 MWp,
	  o Production: 32,97 GWh.
	• Description of the site:
	  o Altitude: 900 m,
	  o Climate: arid continental,
	  o Direct access to the road.

The sites discussed above are not those with the greatest potential capacity but have the fewest technical and environmental constraints. Among them, three sites (Yerevanian, Kanaker and Vardavarri) are located near Yerevan. Medium-sized installations could be considered on these urban reservoirs to supply the capital with renewable electricity.

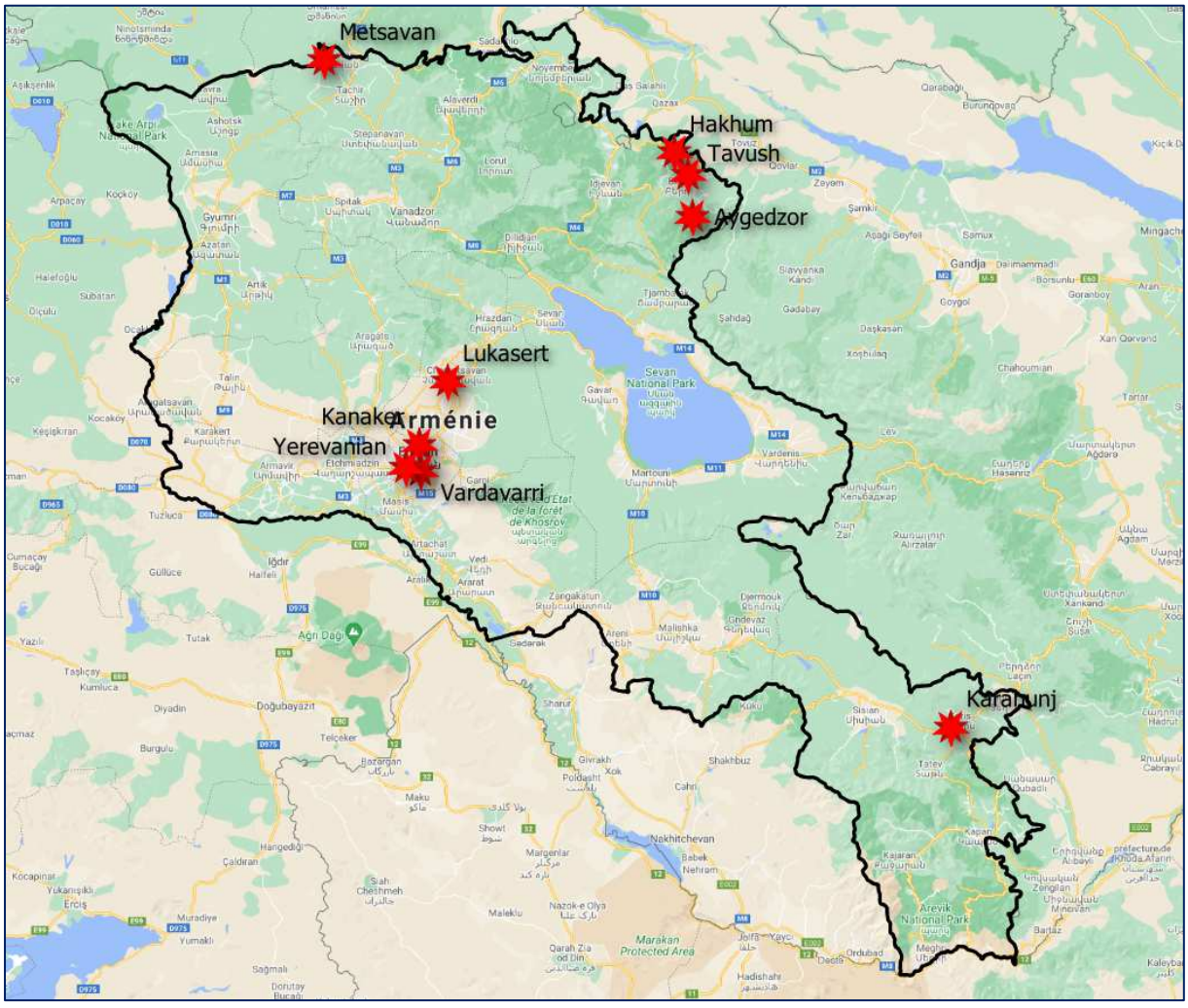


Figure 28 – Location of the nine most favourable FPV sites identified.

9 TOOLS

In addition to the results presented above, tools containing site characterization elements are provided as appendices to this report. The purpose of the tools is to:

- Enable key actors that will be working on the development of the floating photovoltaic sector in Armenia to appropriate the results and adapt the levels of constraints to the evolution of technologies and constraints observed.
- Identify the most favourable sites for starting in-depth feasibility studies, to supplement the GIS mapping data with field data.
- Communicate the results and promote their dissemination to energy actors in Armenian: national and local institutions, project leaders, etc.

The list of lakes and reservoirs studied as well as the parameters for describing each site (climate, distance to the network, permanent water surface, etc.) is made available. It is possible to play with the assumed thresholds of the level of constraints, to adapt the table to the future technical developments of the FPV sector and to the feedbacks observed on the first projects. It will then be possible to adjust the Armenian potential over time, and to evolve the characterization of the sites, to highlight the most favourable sites of the moment.

Site identification		Site description				Constraints								Ranking		Potential electric production per site	
Type	Name	Maximum Water Surface (ha)	Permanent Water Surface (ha)	Capacity on permanent water body (MWp - max 50 MWp)	Capacity on total body surface (MWp - max 50 MWp)	Level Variation Issue	Altitude (m)	Climate Description	General Snow/Ice issue (Altitude + Temperature + Climate)	Road Distance (m)	General Road Distance Issue Road Distance & Altitude	Grid Issue	SPNA	Synthesis of constraints	General ranking (except SPNA issue)	General ranking	Production on permanent water body (GWh/year)	Production on full body surface (GWh/year)
Reservoir	Metsavan	317,30	59,967	30,0	50,0	1	1 600	Moderate, relatively humid during all seasons	1	0	1	1		; ;	1	1	35,82	59,73
Reservoir		2 042,56	414,53	50,0	50,0	1	800	Arid, continental, with hot summers and cold winters	1	0	1	1		; ;	1	1	75,45	75,45
Reservoir		154,71	15,75	7,9	50,0	1	800	Arid, continental, with hot summers and cold winters	1	54	1	1		; ;	1	1	11,90	75,54
Reservoir		399,90	0,387	0,2	50,0	Frequently Dry	900	Arid, continental, with hot summers and cold winters	1	22	1	1		; ;	1	1	0,29	74,52
Reservoir		222,72	0,253	0,1	50,0	Frequently Dry	900	Arid, continental, with hot summers and cold winters	1	198	1	1		; ;	1	1	0,19	74,27
Reservoir		186,57	0,218	0,1	50,0	Frequently Dry	900	Arid, continental, with hot summers and cold winters	1	164	1	1		; ;	1	1	0,16	74,52
Reservoir		181,08	0,216	0,1	50,0	Frequently Dry	900	Arid, continental, with hot summers and cold winters	1	105	1	1		; ;	1	1	0,16	74,56
Reservoir		164,65	0,169	0,1	50,0	Frequently Dry	900	Moderate, with warm summers, relatively humid calm winters	1	290	1	1		; ;	1	1	0,11	65,12
Reservoir		128,60	0,076	0,0	50,0	Frequently Dry	900	Arid, continental, with hot summers and cold winters	1	0	1	4		; ;	1	1	0,06	73,82
Reservoir	Aghbyurak	114,29	74,084	37,0	50,0	1	1 700	Moderate, relatively dry warm summers and cold winters	2	0	1	1		; ;	2	2	48,62	65,63
Reservoir	Aparan	873,20	146,278	50,0	50,0	2	1 900	Moderate, relatively dry warm summers and cold winters	2	0	1	4		; ;	2	2	64,51	64,51
Reservoir	Kamut	164,32	62,744	31,4	50,0	1	1 600	Moderate, relatively dry warm summers and cold winters	2	84	1	1		; ;	2	2	41,09	65,49
Reservoir	Spanderyan	1 131,50	679,966	50,0	50,0	3	2 100	Moderate, relatively dry warm summers and cold winters	2	0	1	4		; ;	2	2	63,56	63,56
Reservoir	Tolors	292,00	155,126	50,0	50,0	2	1 700	Moderate, relatively dry warm summers and cold winters	2	0	1	1		; ;	2	2	64,40	64,40
Reservoir	Arpilich	2 059,18	1219,648	50,0	50,0		2 100	Moderate, with short cool summers and cold winters	3	30	1	4	National Park	Snow-Ice Issue ; ; SPNA Zone	3	3	61,23	61,23
Reservoir	Kechut	120,14	99,045	49,5	50,0	2	2 000	Moderate, with short cool summers and cold winters	2	0	1	4	Planned National Park	; ; SPNA Zone	2	3	64,74	65,36
Lake	Sevan	125 044,58	125 044,58	50,0	50,0	Humid Lake	1 900	Moderate, relatively dry warm summers and cold winters	2	0	1	4	National Park	; ; SPNA Zone	2	3	64,75	64,75
Reservoir	Zovashen (Azat)	261,34	133,061	50,0	50,0	3	1 100	Arid continental, with dry warm summersand moderate cold winters	1	120	1	4	State Reserve	; ; SPNA Zone	1	3	75,91	75,91
Reservoir		96,30	0,216	0,1	48,2	Frequently Dry	2 000	Moderate, relatively dry warm summers and cold winters	2	0	1	4	National Park	; ; SPNA Zone	2	3	0,14	61,58
Reservoir	Shamb	94,98	85,521	42,8	47,5	1	1 400	Moderate, relatively dry warm summers and cold winters	2	0	1	1		; ;	2	2	53,61	59,54
Reservoir	Mantash	94,25	37,085	18,5	47,1		2 600	Moderate, with short cool summers and cold winters	3	44	1	4		Snow-Ice Issue ; ;	3	3	23,81	60,52
Reservoir	Hakhum	81,76	41,027	20,5	40,9	2	700	Arid subtropical, with hot summers and calm winters	1	0	1	4		; ;	1	1	26,65	53,10
Reservoir		79,30	0,082	0,0	39,7	Frequently Dry	900	Arid, continental, with hot summers and cold winters	1	0	1	1		; ;	1	1	0,06	59,38

Figure 29 – Extract from the site characterization table.

The data tables used for the analysis with the specialized GIS software have been synthesized and exported in a format adapted to the Google Earth software. The user will thus have very easy access to the scopes of the sites studied and the associated constraints.

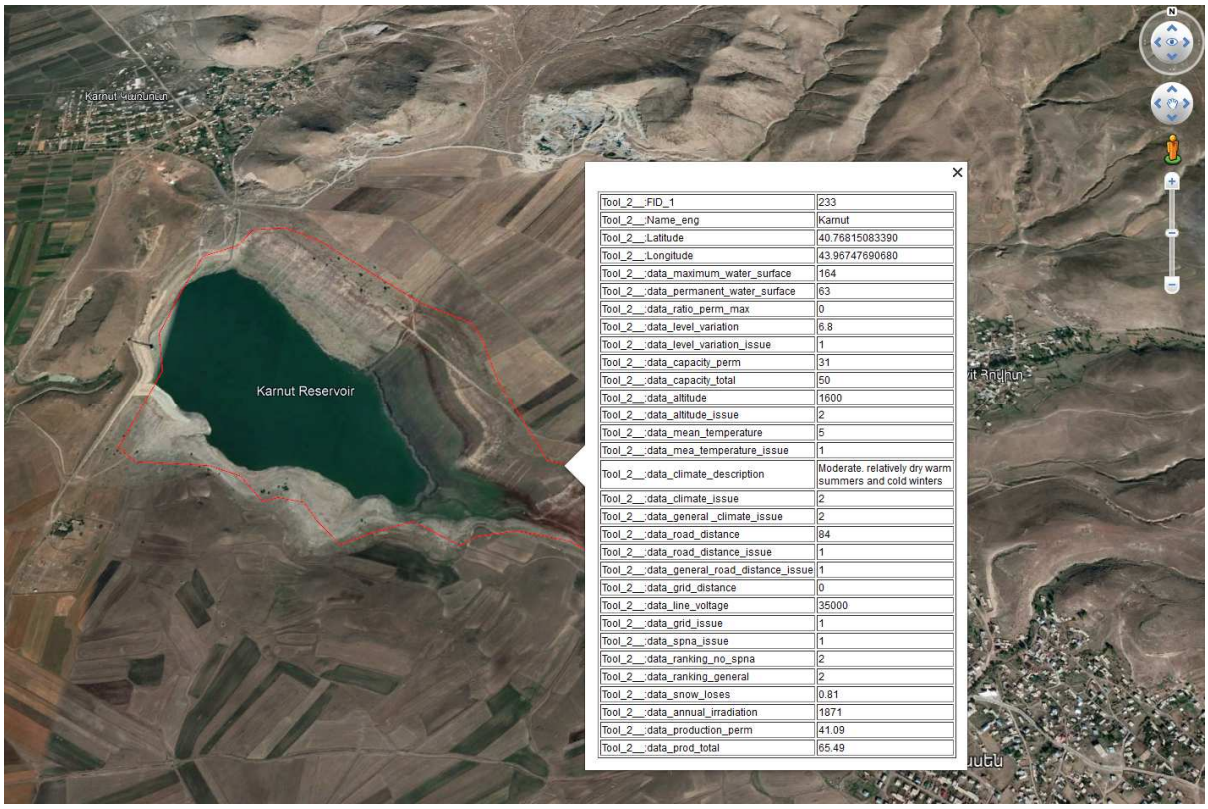


Figure 30 - Overview of one of the reservoirs and its characteristics, based on the proposed tool.

10 Conclusion

The Republic of Armenia puts the development of the photovoltaic sector as a priority for the development of production capacities of renewable energy. Floating photovoltaic enables taking advantage of the resources of the Armenian territory: an important network of reservoirs and lakes, combined with a very significant amount of sunshine.

Armenia is gradually adapting its legislation to allow autonomous producers of renewable electricity to inject their production onto the national grid. These developments create a favourable context to attract investors to consider large-scale floating photovoltaic projects.

If the large number of Armenian lakes and reservoirs suggests a significant floating photovoltaic potential, two specificities of the Armenian context might shade this observation. First, the Armenian context is characterized by a large mountainous ridge: most of the territory is located at altitudes exceeding 1500m. As a result, water bodies are often subjected to severe ice and snow constraints, over periods that can last for several months. Altitude reservoirs are also underserved by roads and the electrical grid; developing FPV projects therefore become more difficult by the lack of pre-existing infrastructure.

In addition, Armenian lakes and reservoirs show great water level variability. The water surface available on a lake, therefore, changes according to the seasons. As a result, the capacity of an FPV power plant will be limited by the lowest water level, except when using floats technologies that allow the structure to ground land at the bottom of the reservoir when needed. Only 35% of the total identified potential is in areas with permanent water cover. In addition, large variations in water level can also put stress on the anchoring of the PV island and increase project costs.

The implementation of an FPV power plant on a hydroelectric reservoir enables benefitting from the infrastructures nearby, especially the electrical connection. Nevertheless, good knowledge of the dam operation is necessary to best articulate the two activities, without compromising the management of the dam and its safety.

The study identifies a total generation potential of 2,773 GWh, located mainly on artificial reservoirs, and in the provinces of Ararat, Armavir, and Shirak. among the sites studied, around ten reservoirs present minimum level of stakes and have been identified as the most favourable for the development of first FPV projects, for a maximum power of 120 MWp. Some of these sites are located near Yerevan, making it possible to consider the development of urban projects to supply the capital with renewable energy.

This study will be followed by three more detailed feasibility studies and the construction of a 150 kWp demonstration power plant. However, to allow Armenian authorities to continue the pre-identification work carried out, two synthesis tools designed according to the study are provided in the appendix.

APPENDIXES

Appendix I	Tool 1 – Potential analysis per site
Appendix II	Tool 2 – GIS Data
Appendix III	FPV on dam reservoirs: Guide note for project development *EDF CIH*
Appendix IV	Irradiation data *Transvalor*

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