Energy and Economic Assessment of Floating PV in Spanish Reservoirs

Leonardo Micheli

Advances in Photovoltaic Technology (AdPVTech),
CEACTEMA, University of Jaén, Spain

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Agenda

• Background
• Methodology
• Results
• Conclusions
Floating PV: Why?

Spain’s Integrated National Energy and Climate Plan 2021-2030 targets to reach **39 GW of PV** installed nationwide by 2030, three times the current capacity (**12 GW**).

To achieve this, PV capacity has to increase by 3GW per year!

→ **We need ~60 km² of land every year.**
Floating PV: Why?

Recent letter from Spanish researchers to Science:
Spain should adopt a more cautious approach to prevent a scenario in which energy goals are met at the expense of biodiversity. […] Photovoltaic energy needs huge amounts of land and will mostly affect declining species of steppe birds, which are poorly represented in the Spanish Natura 2000 network.

Floating PV: Why?

Using land for PV is 10 times more profitable than for farming!


Floating PV: Definition

PV is installed on the surface of water bodies instead of land.

This work only considers water bodies in continental Spain.
Floating PV: Capacity

By August 2020, FPV had reached a global 2.6 GW capacity, distributed over 35 countries. This is twice the capacity reported at the end of 2018. Land based PV (LPV) capacity was 2.6 GW in 2003.
Floating PV: Pros & Cons

• The cost for renting land for PV is increasing. ➞ Lower rent installing on water!

• Use of existing electricity transmission infrastructure at hydropower sites. ➞ Lower costs for infrastructures!

• Expected to work at lower temperature thanks to the cooling effects of water. ➞ Better performance!

• No need for major site preparation, such as leveling or the laying of foundations. Easy installation and deployment. ➞ Lower installation costs!

• However, FPV modules have to be installed at lower tilt angles (~10°). ➞ Worse performance!
1) Which is the Floating PV potential in Spain?

2) Which **Capital Expenditure (CAPEX)** can be sustained by FPV systems to be economically competitive with inland PV (LPV)?
Capacity: Methodology

1) Which is the Floating PV potential in Spain?

Global Reservoir and Dam Database (GRanD)

The Global Reservoir and Dam Database (GRanD) v1.3 is a product of the Global Water System Project, which initiated a collaborative international effort to collate existing dam and reservoir datasets with the aim of providing a single, geographically explicit and reliable database for the scientific community.

I considered the reservoirs listed in the Global Reservoir and Dam Database (GRanD) v1.3.

It contains a large number of information on each dam. However, it might report only part of the total number of dams, leading to a conservative estimation of the FPV surface available.

1) Which is the Floating PV potential in Spain?

Each 1% of reservoir surface covered by PV can:

- increase the national PV capacity by **3 GW** (25% of current capacity)
- provide **1.7%** of the annual electricity demand.
1) Which is the Floating PV potential in Spain?

If hydro-capacity is matched:

- **10% surface** of the hydroelectric lakes;
- **20 GW of FPV**: 75% of the capacity currently missing to reach the 2030 target.
- **12% of the national electricity demand**.
2) Which are the maximum CAPEX allowed?


PVsyst SA. PVsyst. [https://www.pvsyst.com/](https://www.pvsyst.com/).

2) Which are the maximum CAPEX allowed?

PVsyst model:

\[ T_C = T_a + \frac{\alpha E (1 - \eta_m)}{U_c + U_v \times WS} \]

\[ T_C = T_a + \frac{\alpha E (1 - \eta_m)}{U} \]


Economics: Methodology

2) Which maximum CAPEX are allowed?

- Ambient Temperature
- Irradiance
- Copernicus Atmosphere Monitoring Service (CAMS)
- Referenced U-value

PV Syst Model
PV Watts Model
Yields
Economics: Methodology

2) Which are the maximum CAPEX allowed?

The Levelized Cost of Electricity (LCOE) quantifies the cost of producing a kWh of electricity. The lower, the better.

\[
LCOE = \frac{\text{Installation Costs} + \sum \text{Yearly O&M Costs} / \text{Discount}}{\sum \text{Yearly Energy Yield} / \text{Discount}}
\]

The Net Present Value (NPV) evaluates the profitability of an investment. The larger, the better.

\[
NPV = -\text{Installation Costs} + \sum \frac{\text{Yearly Revenues} - \text{Yearly O&M Costs}}{\text{Discount}}
\]
Economics: Methodology

2) Which are the maximum CAPEX allowed?

Finding the maximum allowed for FPV so that:

\[ LCOE_{FPV}(CAPEX_{FPV}) \leq LCOE_{LPV}(CAPEX_{LPV}) \]

\[ NPV_{FPV}(CAPEX_{FPV}) \geq NPV_{LPV}(CAPEX_{LPV}) \]

Comparing energy and economic performance of FPV and land based (LPV).

<table>
<thead>
<tr>
<th></th>
<th>FPV</th>
<th>LPV</th>
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</thead>
<tbody>
<tr>
<td>U-value</td>
<td>56 W/m2K</td>
<td>29 W/m2K</td>
</tr>
<tr>
<td>Tilt angle</td>
<td>10 degrees</td>
<td>Latitude</td>
</tr>
<tr>
<td>CAPEX</td>
<td>TBD</td>
<td>700 €/kW</td>
</tr>
</tbody>
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Monofacial Si module, at fixed tilt angle, south facing.
Economics: Results

2) Which are the maximum CAPEX allowed?

In some regions, FPV can already economically compete with LPV:

- **West**: lower PV potential
- **South**: higher temperature and irradiance
- **Northeast**: lowest ambient temperatures and intermediate irradiance values
Economics: Results

2) Which are the maximum CAPEX allowed?

If NPV is used, the same distribution is found.

However, the allowed CAPEX are lower.
Economics: Results

2) Which are the maximum CAPEX allowed?
Economics: Results

2) Which are the maximum CAPEX allowed?

FPV would match the LPV economics at tilt angles of 16 deg – 18 deg.

However, higher tilt angles might require additional CAPEX to strengthen the FPV foundations.
2) Which are the maximum CAPEX allowed?

The results vary depending on all the variable in input. FPV potential increases with:

- U-value
- Temperature dependence of the PV module
Economics: Results

2) Which are the maximum CAPEX allowed?

Additional factors were also tested:

A. Different OMEX
B. Potential gain in hydro
C. Different degradation
D. Low bifaciality for FPV
Conclusions and future works

Floating PV can be key for future of PV in Spain. In Spain, CAPEX of FPV should be 1 to 10% lower than CAPEX of land based PV (LPV).

Several factors can affect its competitiveness:

- **Module temperature coefficient** is a key factor in determining maximum allowed CAPEX of FPV.
- The higher the **future electricity prices**, the lower the CAPEX for FPV to match LPV.
Thanks for your attention!

Leonardo Micheli
lmicheli@ujaen.es


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