Operations and Maintenance (O&M) of Floating PV

Ioannis Tsanakas, R&D Project Manager CEA-INES (France)

Vienna, 24/09/2024

O&M scope

O&M encompasses a combination of: i) routine (preventive and reactive) maintenance tasks, ii) continuous monitoring, and iii) risk preparedness (or emergency-response) **plans**.

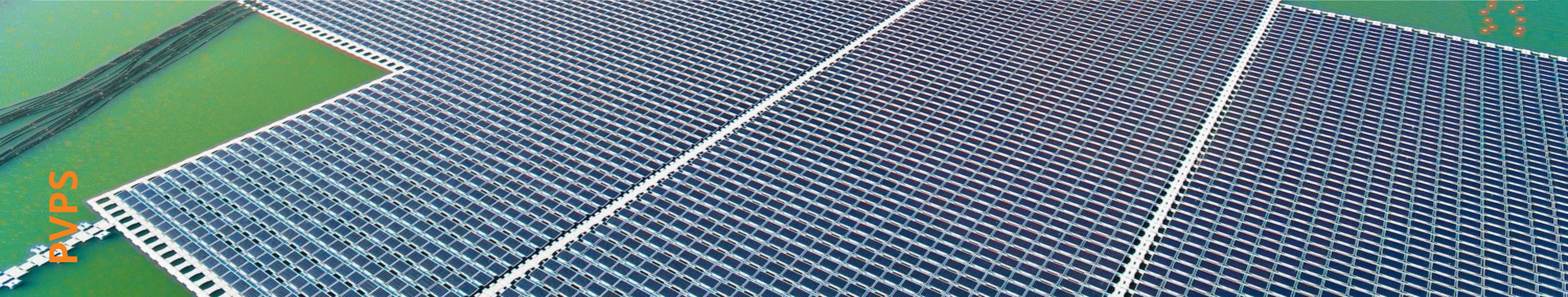
Twofold mission:

1. Efficient **mitigation** of potential **technical risks** (hence, downtime),
2. **Maximized** long-term PV **energy yield** ⇒ direct positive impact on LCOE and payback time.

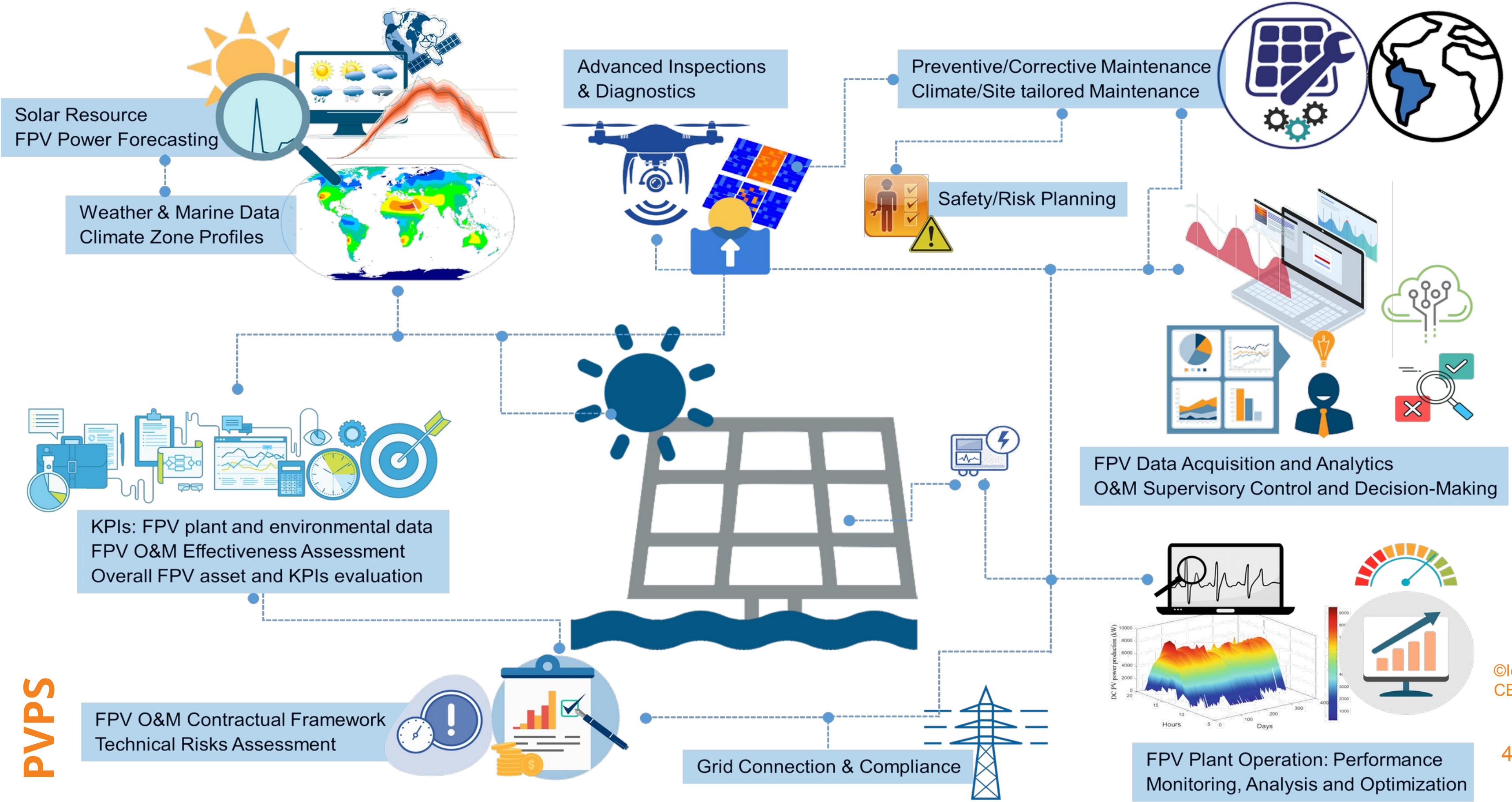
O&M scope and floating PV

Adding the **water/marine dimension** for the case of **FPV** O&M, implies additional considerations and requirements to ensure:

- Minimal impact from and to the environment
- Efficient mitigation of FPV-specific safety and technical risks related to key new components:
  - Floaters;
  - Anchors;
  - Mooring systems;
  - Electrical components.



O&M agenda : Overview



PVPS


O&M actions
importance & best practices

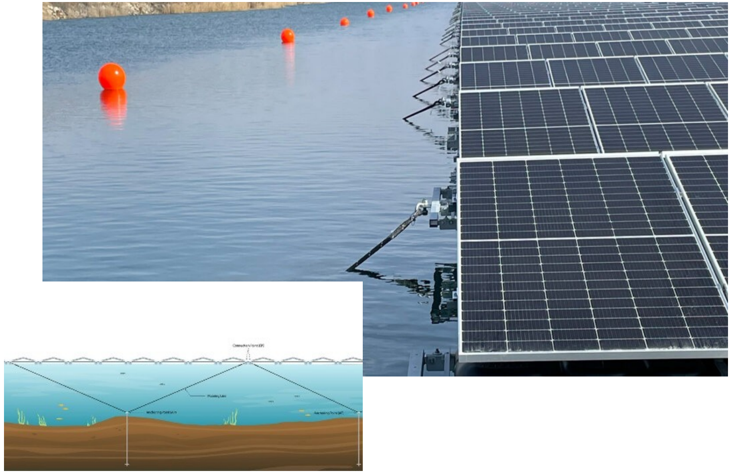
Inspection of mooring / anchoring systems

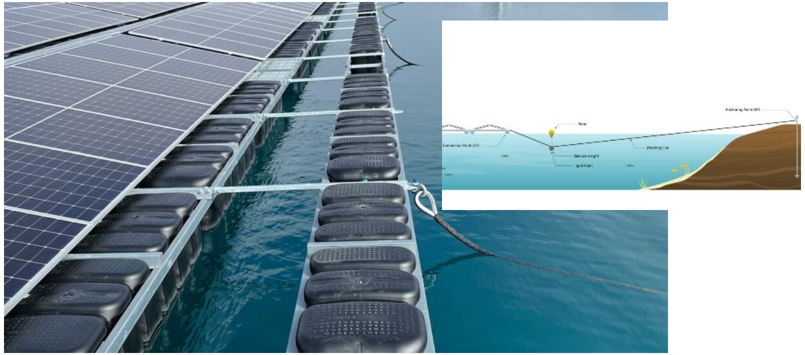
Why is critical? ↳ Maintain the stability of the FPV installation and limit mechanical stresses at design levels.

FPV-site specific risk assessments dictate the frequency and level of detail of inspections.

<u>Increased attention:</u>

- critical parts (receiving relatively higher stresses or having sustained previous failures)
- special cases e.g. following extreme weather events.





Inspections by trained specialized personnel (divers) or remotely operated vehicles (ROVs).

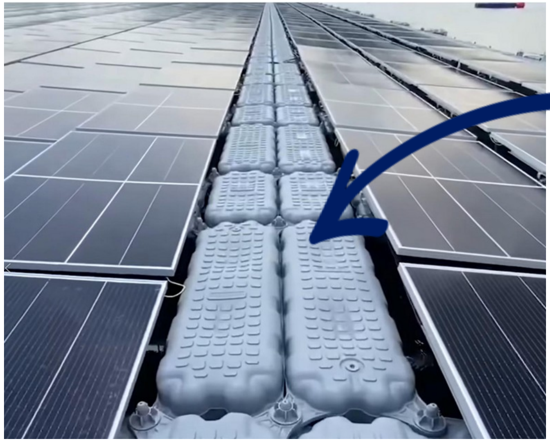
↳ wear, fatigue, corrosion, chafing, marine growth, bio-fouling

Key areas:

- mooring lines (continuous integrity checks and tension measurements).
- anchor pad eye (physical degradation).

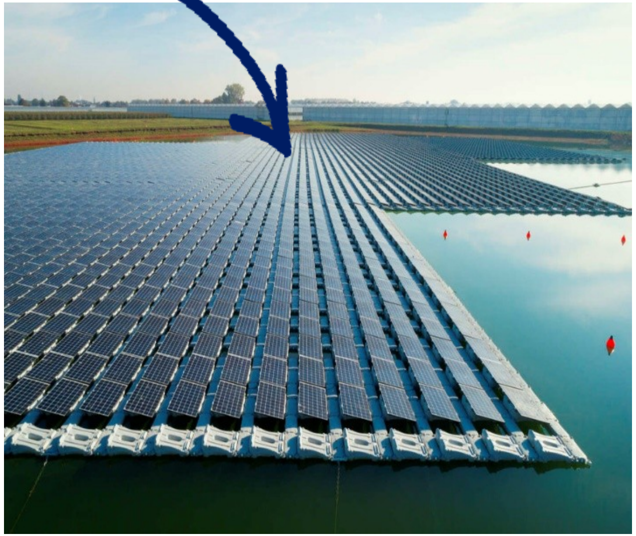
PVPS

Inspection of floaters and PV arrays



Why are critical?

- Identify leaks, wear, fatigue or failures in the floating platforms, to ensure their integrity stability, safety and longevity.
- Detect common PV failures, but also reveal and track degradation mechanisms dominant in marine environments, such as corrosion, moisture ingress and UV degradation.



Key areas and considerations:

- Highly stressed parts and cases following EWE → leaks due to punctures/cracks, buoyancy/stability loss; loosening of connection pins; corrosion of metallic components.
- PV array ends and in proximity to anchoring/mooring lines.
- Limited accessibility → favor sampling approaches, remote sensing and airborne equipment esp. for IR imagery.

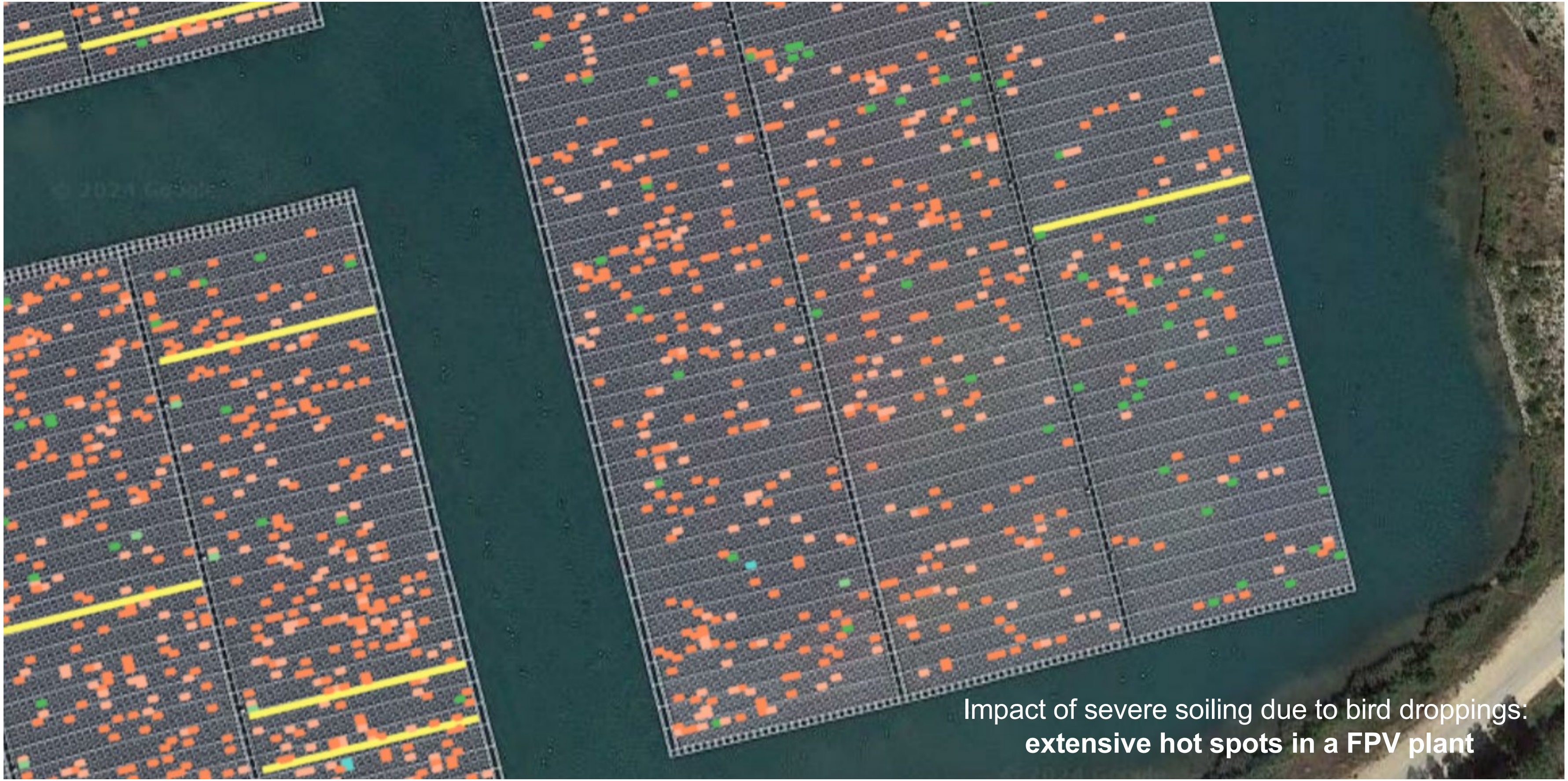
Soiling mitigation in FPV

- FPV-specific factors for soiling buildup: combined impact of humidity, water/salt spray, organic matter and seasonal effects (pollen, airborne sand), presence of migratory birds.
- For FPV in tropical areas or waters with high nutrients (irrigation ponds, runoffs from farmlands) → biofouling is a potential accelerator of soiling losses.
- For FPV in snow prone areas: significant soiling losses and mechanical stresses due to snow buildup.

Soiling mitigation in FPV remains a challenge

- Monitoring of bird population and historical records → “high soiling risk” periods → plan (or intensify) cleaning interventions.
- Aerial imagery (IR and RGB) can help assessing and mitigating hot spots due to soiling from bird droppings.

Soiling mitigation in FPV

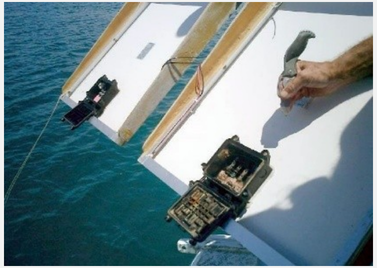


Impact of severe soiling due to bird droppings:
extensive hot spots in a FPV plant

PVPS

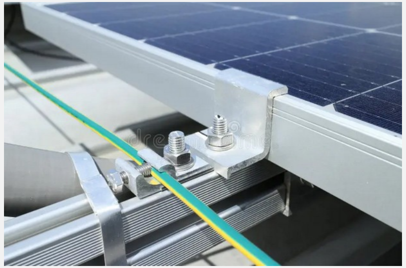
Other maintenance actions and points in FPV

Moisture & corrosion mitigation



Circuitry & cabling checks

Earthing and lightning protection system



Inverters maintenance

Monitoring & Upkeep of instrumentation

Water quality control

Other maintenance actions and points in FPV

Moisture & corrosion mitigation

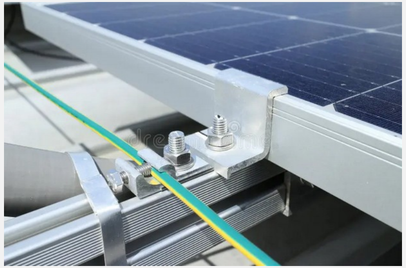
- Retrofit coatings
- Monitoring of humidity levels

Attention at :

- moisture ingress inside enclosures
- Components exposed to UV ▭ combined accelerated degradation

Circuitry & cabling checks

Earthing and lightning protection system



Inverters maintenance

Monitoring & Upkeep of instrumentation

Water quality control

Other maintenance actions and points in FPV

Moisture & corrosion mitigation

- Retrofit coatings
- Monitoring of humidity levels

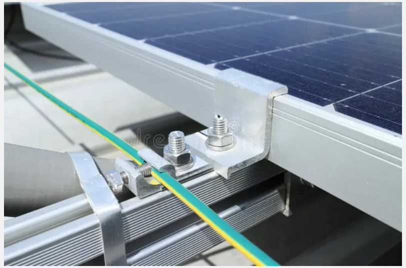
Attention at :

- moisture ingress inside enclosures
- Components exposed to UV ▭ combined accelerated degradation

Circuitry & cabling checks

- Cables & connectors accidentally in contact with water
- Areas with potential insulation faults
- Submerged cables (often subject to marine organisms and biofouling)
- Checks of appropriate slackness on cable runs, to prevent stress.

Earthing and lightning protection system



Inverters maintenance

Monitoring & Upkeep of instrumentation

Water quality control

Other maintenance actions and points in FPV

Moisture & corrosion mitigation

- Retrofit coatings
- Monitoring of humidity levels

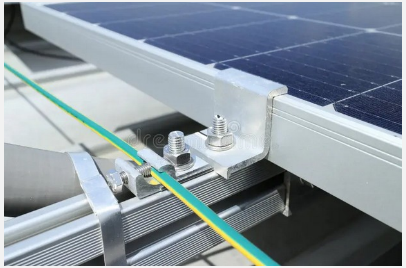
Attention at :

- moisture ingress inside enclosures
- Components exposed to UV ▭ combined accelerated degradation

Circuitry & cabling checks

- Cables & connectors accidentally in contact with water
- Areas with potential insulation faults
- Submerged cables (often subject to marine organisms and biofouling)
- Checks of appropriate slackness on cable runs, to prevent stress.

Earthing and lightning protection system



Inverters maintenance

Monitoring & Upkeep of instrumentation

- Advisable to invest upfront in equip-ment to monitor IV at string level.
   identify underperforming strings at high spatiotemporal granularity
   minimize needd for on-site interventions (being costly and complex specifically for FPV)

Water quality control

Other maintenance actions and points in FPV

Moisture & corrosion mitigation

- Retrofit coatings
- Monitoring of humidity levels

Attention at :

- moisture ingress inside enclosures
- Components exposed to UV → combined accelerated degradation.

Circuitry & cabling checks

- Cables & connectors accidentally in contact with water
- Areas with potential insulation faults
- Submerged cables (often subject to marine organisms and biofouling)
- Checks of appropriate slackness on cable runs, to prevent stress.

Earthing and lightning protection system

- Regular checking of earthing resistance value.
- For FPV systems earthed to water → periodic checks of the conductor (rod/tape) against degradation and corrosion risks.

Inverters maintenance

- As per technical specifications and guidelines of the OEM manuals
- Focus on follow-up checks and inspections after EWE.

Monitoring & Upkeep of instrumentation

- Advisable to invest upfront in equipment to monitor IV at string level.
  - → identify underperforming strings at high spatiotemporal granularity
  - → minimize needd for on-site interventions (being costly and complex specifically for FPV)

Water quality control

Monitoring water quality, contaminants and algae propagation:

→ Crucial measures in FPV to prevent fouling and degradation of the water environment

More details in our report


Assesing risks
and O&M costs

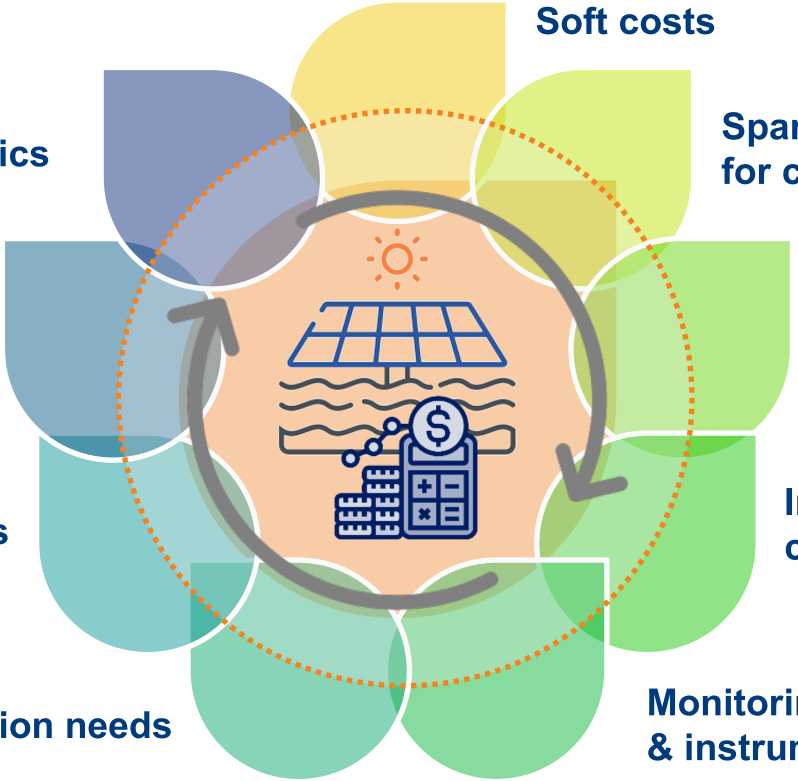
Failure modes & effects analysis (FMEA) in FPV

Failure mode	Indicative Occurrence (1-4)	Indicative severity (1-5)	Indicative RPN (1-10)	Mitigation measure
Early / mid-life failures at FPV module at array level). Power output loss and risk of follow-up failures.	2	3	8	Scheduled and/or data-driven inspections
Soiling/debris build-up. Soiling losses and potential hot spots.	2	2	5	Cleaning at site-specific intervals, manual or robotic solutions. Deployment of anti-soiling retrofits.

Failure mode	Indicative Occurrence (1-4)	Indicative severity (1-5)	Indicative RPN (1-10)	Mitigation measure
Inverter failure; Power losses at string(s) level.	2	2-3	5	OEM manual based inspections of inverters; repairs or replacement.
Water quality compromised; Follow-up degradation of the local ecosystem.	2	2	5	Water quality monitoring and management; materials against water contamination
Non-compliance to regulatory framework updates	2	3	7	Regular audits, follow-up of regulatory framework at local, national, international level.

FPV O&M budgeting – Cost aspects

Highly variable, depending (and affected by) multiple interrelated factors:



Soft costs

Site characteristics

Spare parts and reserve for contingency

Technology and design

Labor and training costs

Accessibility and logistics

Inspections of electrical components / BOS

Cleaning/soiling mitigation needs

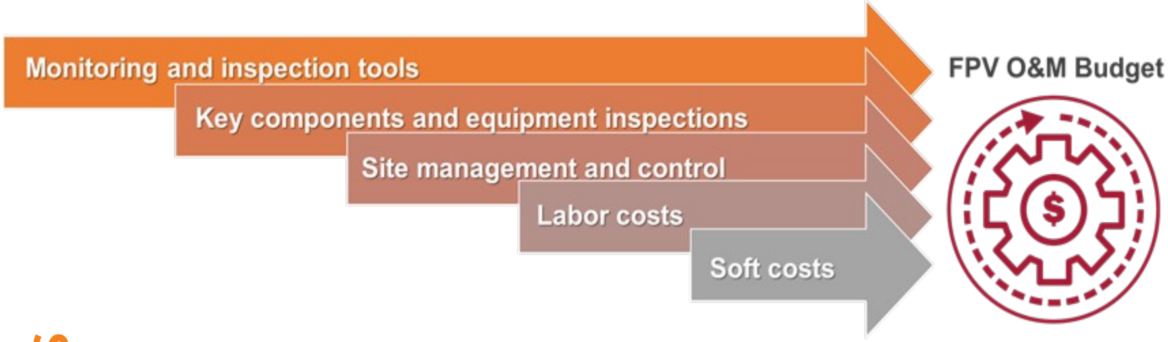
Monitoring/SCADA systems & instrumentation

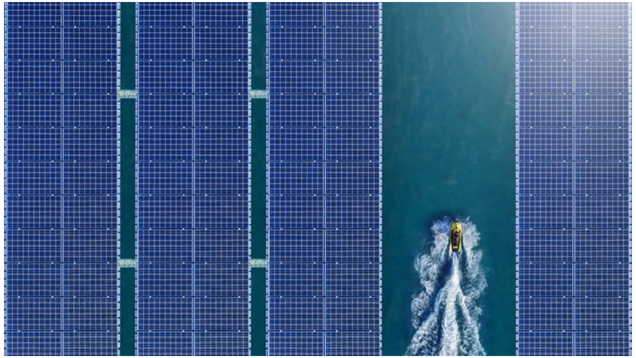
FPV O&M budgeting – Cost aspects

Specific, detailed real-case figures for FPV O&M budgeting not readily available, so far.

NREL's recent bottom-up analysis on installation costs for FPV systems deployed on artificial water bodies under average site conditions* :

- Estimated FPV installation cost premium of $0.26/WDC (25%) for 10-MWDC fixed-tilt FPV systems, compared with ground-mounted, fixed-tilt PV installed over bare ground,
- Largest contributors: Higher structural costs for floats and anchoring systems.





PVPS

* 40 m/s wind load, 20 psf snow load, 50 m water depth, 10 m water level variation and 1m swell height.


Outlook

O&M challenges and opportunities

Acknowledgements

Big thanks to all formal and "informal" contributors and reviewers from **IFE**, **SERIS** and **SERENDI-PV** project FPV partners (**Akuo** and **Compagnie Nationale du Rhône (CNR)**).

Part of this work has been supported in the framework of the H2020 SERENDI-PV project. SERENDI-PV project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 953016.
Part of this work was also supported by the French National Program "Programme d'Investissements d'Avenir - INES.2S" under Grant Agreement ANR ANR-10-IEED-0014 0014-01.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº

www.iea-pvps.org

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 953016.

Thank you

Ioannis Tsanakas, Task 13 expert, CEA-INES (France)
ioannis.tsanakas@cea.fr

Reach out to me