On the Status, Potential and Challenges of Floating Photovoltaics (FPV) Systems: A Worldwide and Australian Perspective

Dr Carlos Rodríguez, Head of Yield and Performance, RINA

Seminar at the School of Photovoltaic and Renewable Energy Engineering (SPREE), University of New South Wales (UNSW), 31 May 2024

RINA 2024

5600 colleagues

220 offices

70 countries

- **Energy**
- **Industry**
- **Marine**
- **Real Estate**
- **Certification**
- **Infrastructure and Mobility**

Our people

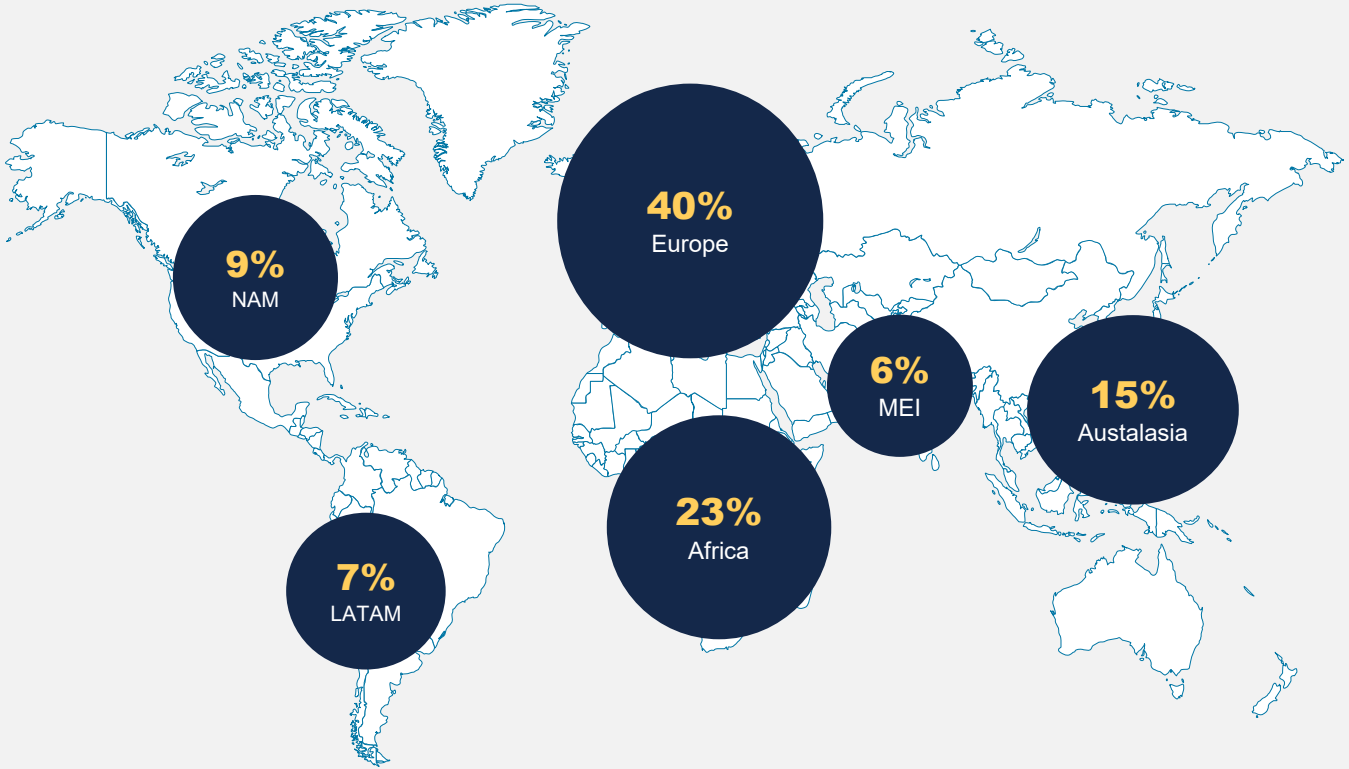
More than **90 nationalities**

80%+
educated to **degree level**

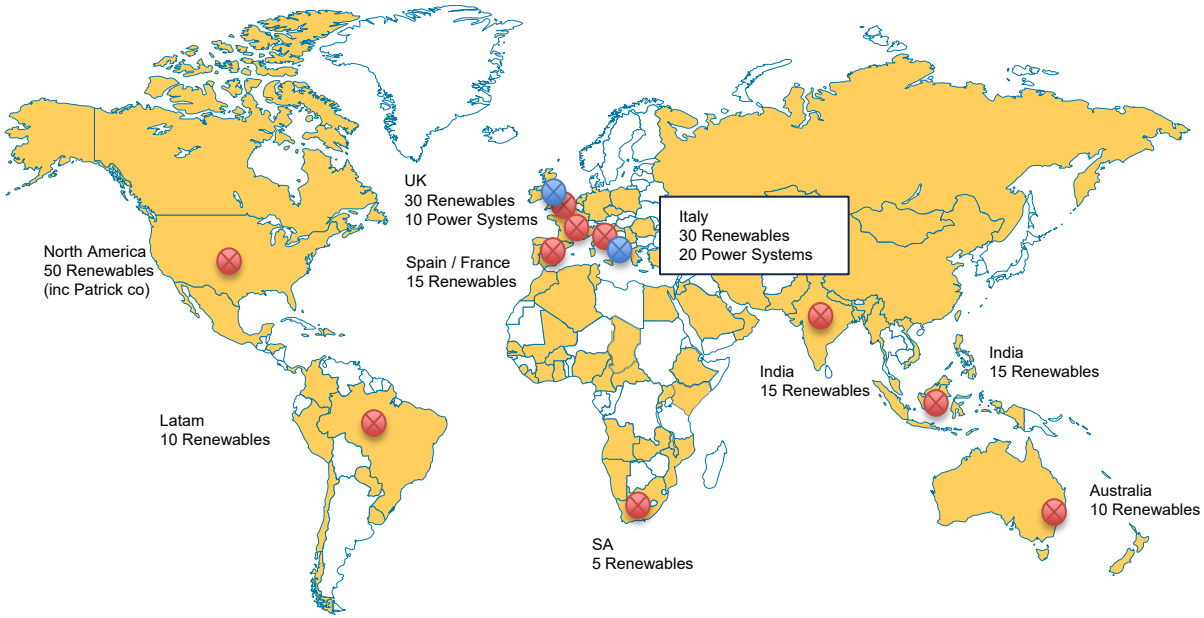
42
average **age**

Geographical Coverage

2022 Order Intake by client location



RINA Consulting – Green Energy Solutions Worldwide Presence



KEY:

Renewables Hub =

Power Systems Hub =

Projects Carrying out here =

~ 160 Renewables experts globally, supported by wider RINA consulting and RINA services to support our clients across the entire project lifecycle.

~ 30 Power Systems experts globally servicing grid, earthing and lightning protection disciplines.

Renewables team are global, supporting each-other when and where required.

Project Summary

- **BESS, Hydrogen, Wind, PV** supporting **developers, lenders, IPPs, banks, EPCs…**
- **120 GW** TA services for **Solar** Projects
- **50 GW** TA services for **Wind** Projects
- **~ 9.5+ GWh/ 7+GW** TA services for **Energy Storage** Projects
- Hydrogen is multidisciplinary, supported by industry, mobility and plant businesses (over 100+ engineers drawn on

Energy Solutions
Main Services

RINA is able to provide a full set of services during all project phases:

FID/M&A

- TECHNICAL DUE DILIGENCE
- COST TO BENEFIT ANALYSIS
- ENERGY YIELD ASSESSMENT

DESIGN & PERMITTING

- FEASIBILITY STUDIES
- OWNER'S ENGINEERING
- GRID CONNECTION STUDIES
- ENVIRONMENTAL, SOCIAL & BIODIVERSITY
- HEALTH & SAFETY
- PERMITTING SUPPORT

PROCUREMENT

- SHOP INSEPCTIONS AND EXPEDITING
- FAT
- PRE-SHIPMENT INSPECTIONS
- VENDOR'S AUDITS

CONSTRUCTION

- ON SITE QA/QC
- ON SITE HSE
- PLANNING & CONTRACT MANAGEMENT
- CONSTRUCTION SUPERVISION
- COMMISSIONING SUPERVISION

OPERATION & MAINTENANCE

- RINA GENIUM WIND BLADES
- CONDITION MONITORING
- FAILURE & RCA ANALYSIS
- REMAINING LIFE ASSESSMENT & DESIGN LIFE EXTENSION

PROJECT MANAGEMENT CONSULTANCY

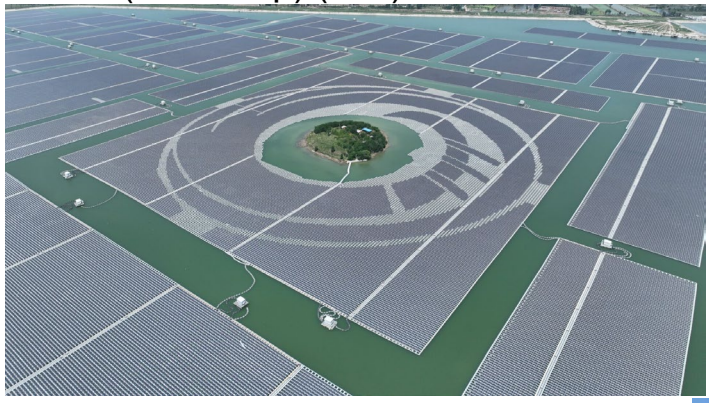
FPV: floating ≠ pile/stilt-based

Floating PV (FPV)

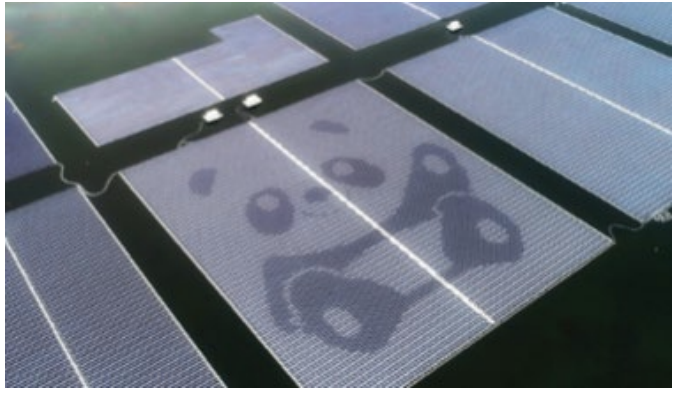
Pile/stilt-based PV

FPV: Utility Scale Deployment

China (320 MWp) (HPI)



China (100 MWp) (Sungrow)



Vietnam (70 MWp) (LONGi)

Singapore (60 MWp) (Sembcorp)

FPV: Types

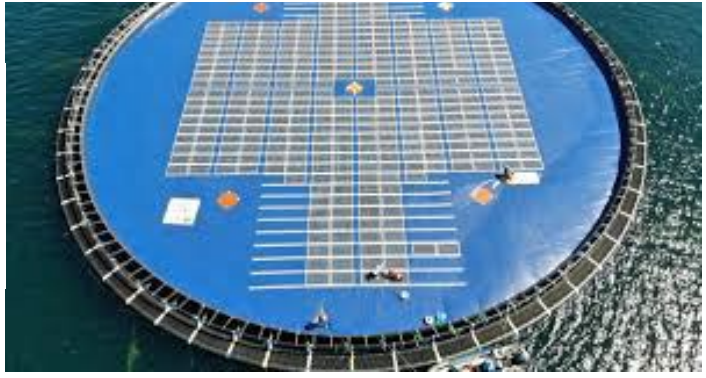
Pure floats

C&T

Metal or FRP structure + floats/pipes

Scotra

Membrane or mats



Ocean Sun

(Semi-) closed

Texel4trading

FPV: Advantages

- Limited (or none) land requirement
- Potential performance gain due to reduction in temperature loss
- Less shading: open area & flat environment
- Less soiling due to dusts
- Environmental benefit: potential algae reduction
- Water preservation

FPV: Challenges

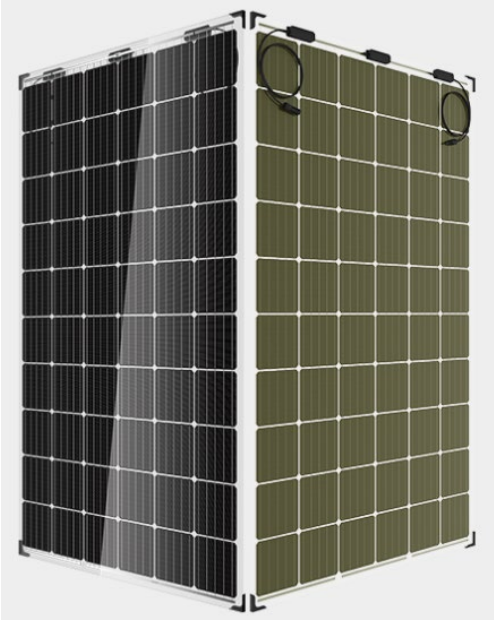
- Relative new technology in comparison to PV
- Higher costs
- PV tilt is typically limited (mechanical constraint)
- More guidelines and standards are required
- O&M and degradation concerns
- Warranty assurance

FPV: Monofacial vs Bifacial Panels

- Monofacial: light absorption from front side only
- Bifacial: light absorption from front and rear side

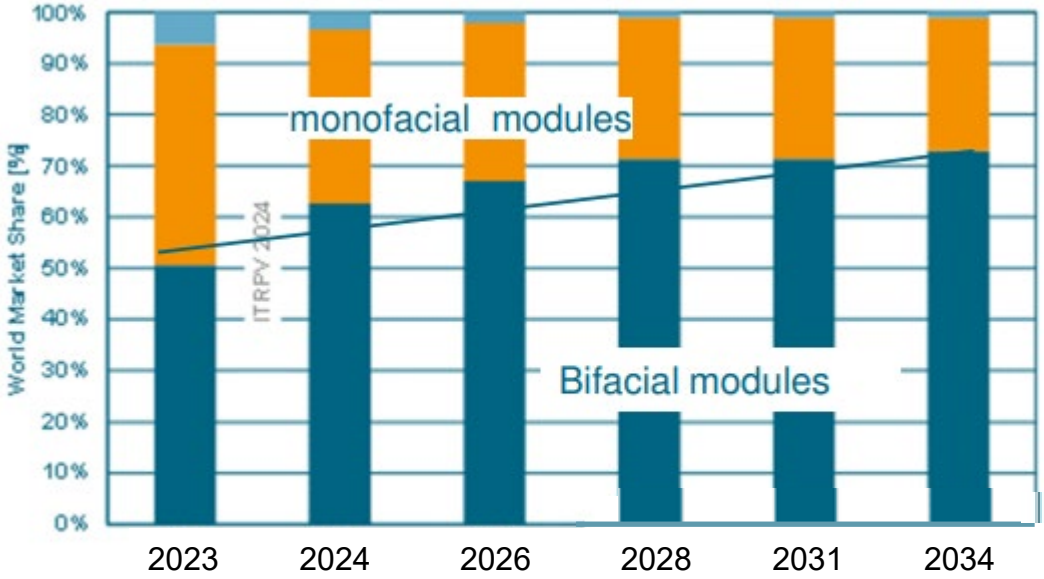
Monofacial

Bifacial



FPV: Monofacial vs Bifacial Panels

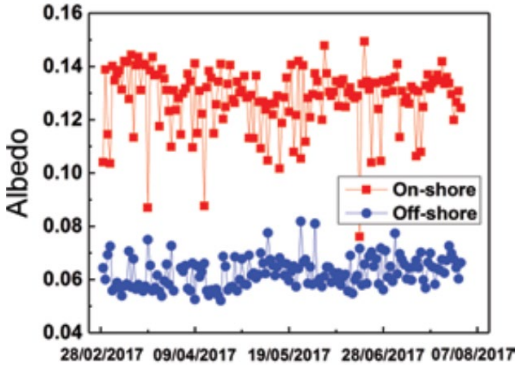
- **Monofacial: light absorption from front side only**
- **Bifacial: light absorption from front and rear side**



[1] International Technology Roadmap for Photovoltaics (ITRPV) 2024

FPV: Bifacial Panels

- Desired properties for bifacial installations:
  - High albedo values BUT Typically <10%
  - High tilt values BUT Typically <20°
  - High height from ground BUT Typically <50 cm

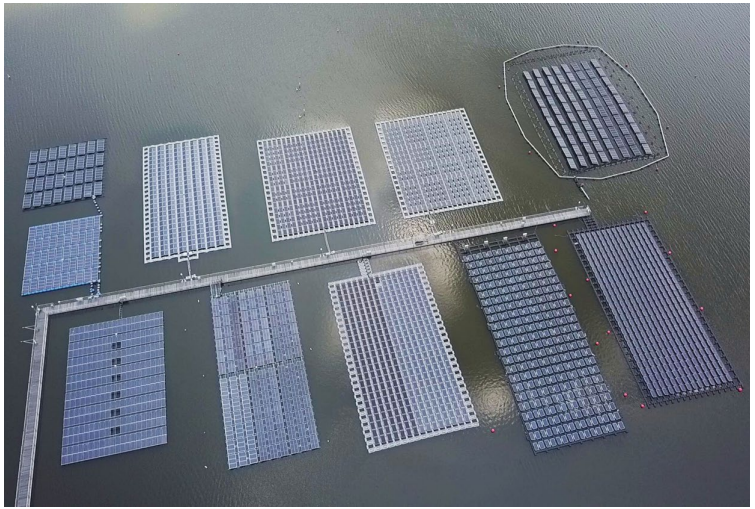


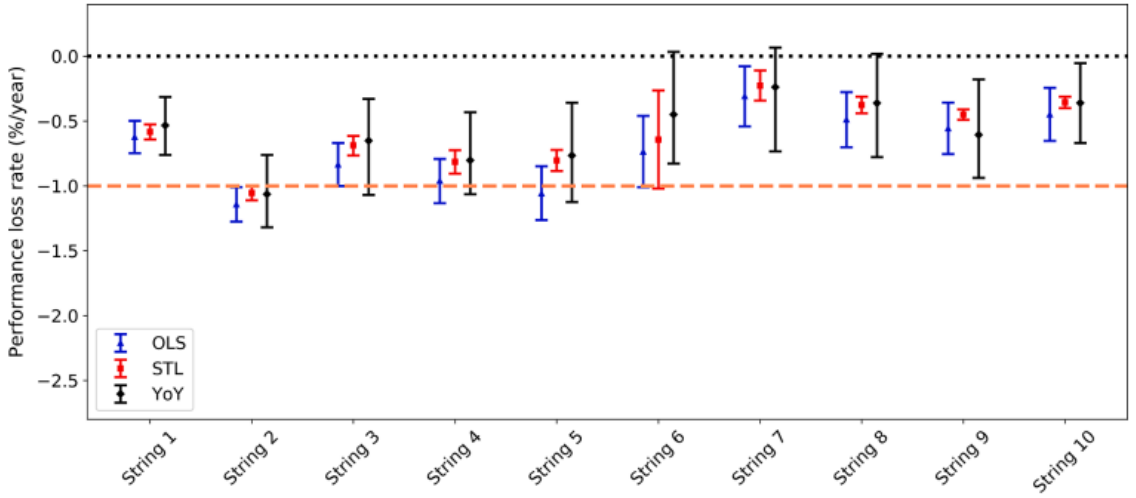
SERIS

- Bifacial panels do not add a considerable amount of extra energy. BUT…, they are still employed for FPV due to their competitive cost and expected low degradation.

FPV: Degradation (more studies still needed!)

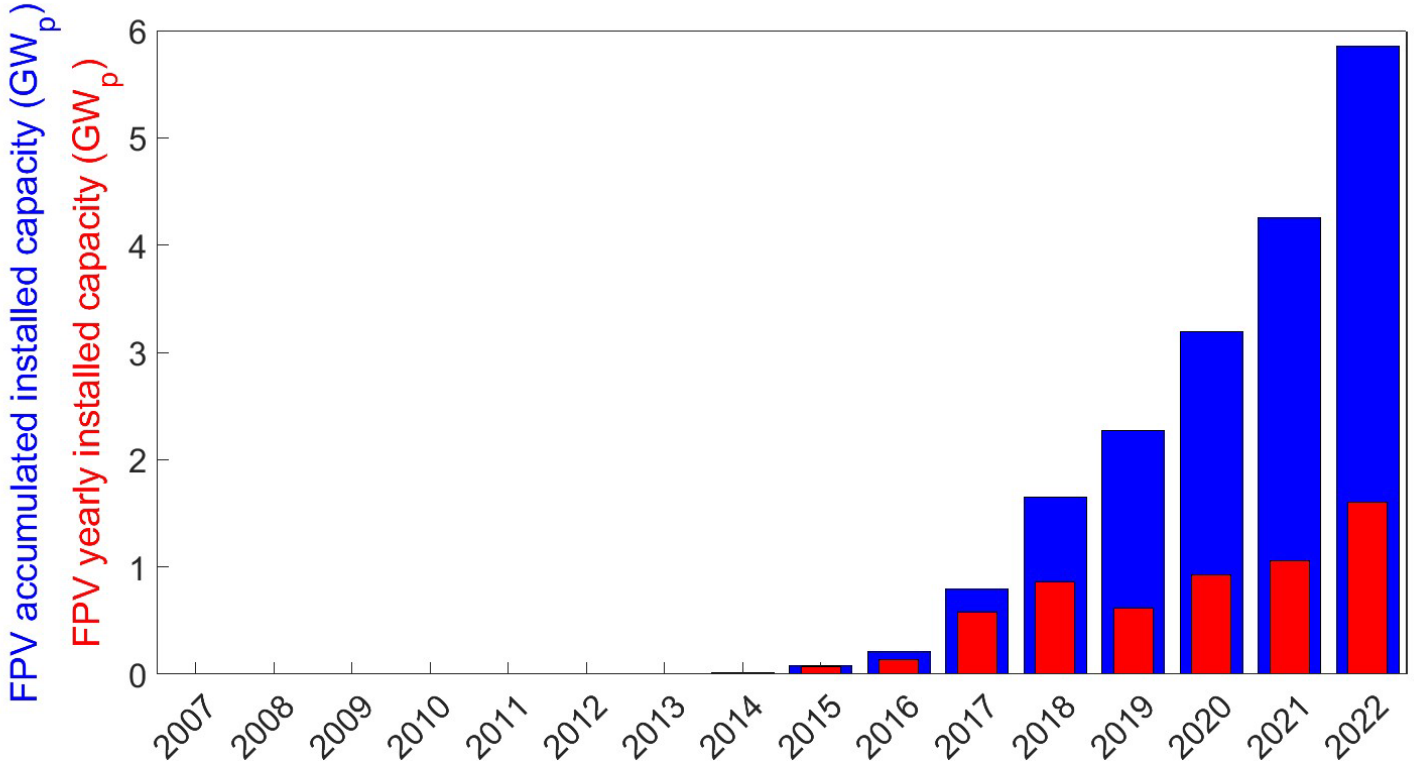
- Study performed by SERIS at their FPV testbed in Tengeh Reservoirs, Singapore
  - OLS: Ordinary least squares
  - STL: Seasonal and trend decomposition using locally weighted scatterplot smoothing
  - YoY: Year-on-year





Wei et al., Solar Energy, 2021

FPV Capacity Worldwide: 6 GWp till 2022

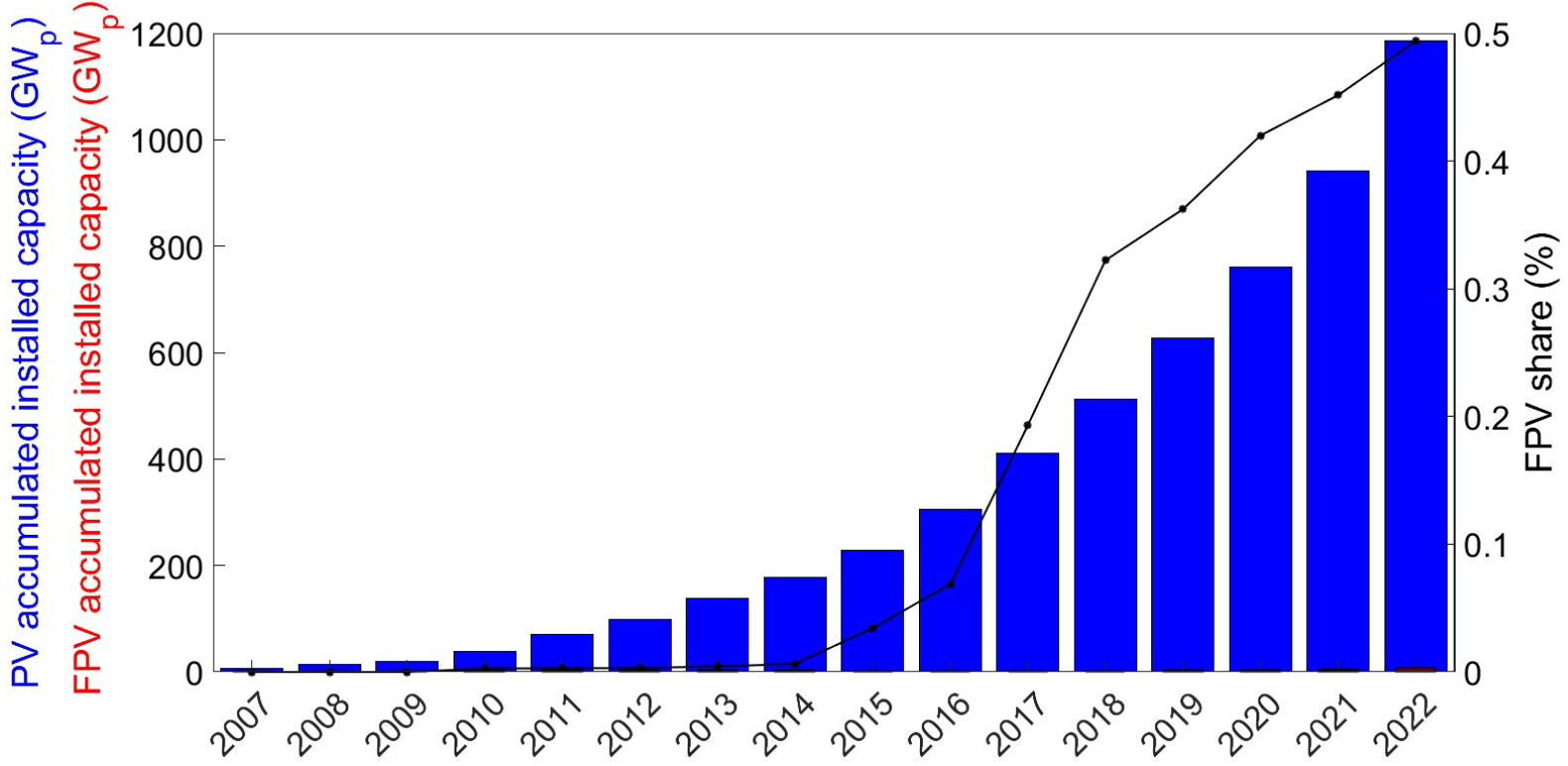


[1] SERIS Annual Report 2023. Digitization by RINA

PV Capacity Worldwide: 6 GWp till 2022

- **Watt peak (Wp) is a measure of PV power produced under Standard Testing Conditions (1000 W/m^2, 25°C, 1.5 AM)**

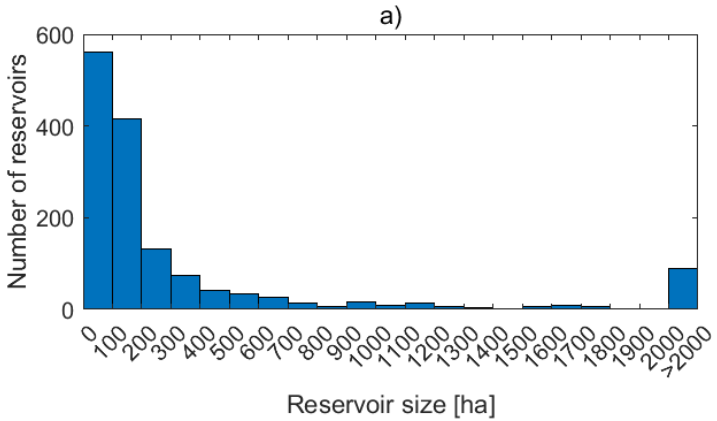
FPV vs PV Capacity Worldwide

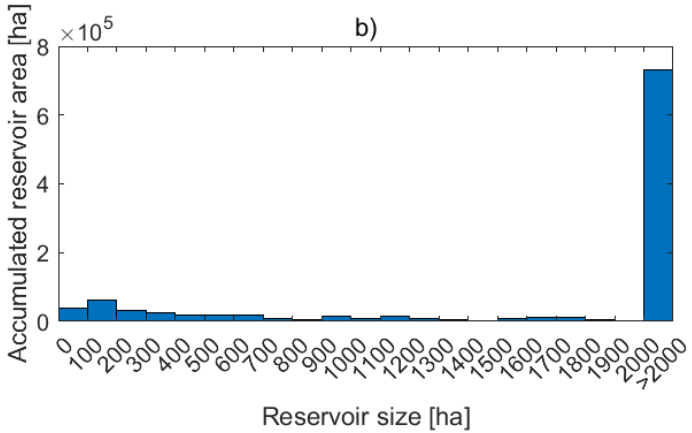


[1] SERIS Annual Report 2023 & International Energy Agency (IEA), Snapshot of Global PV Markets. Digitization by RINA

FPV inland potential: Australia

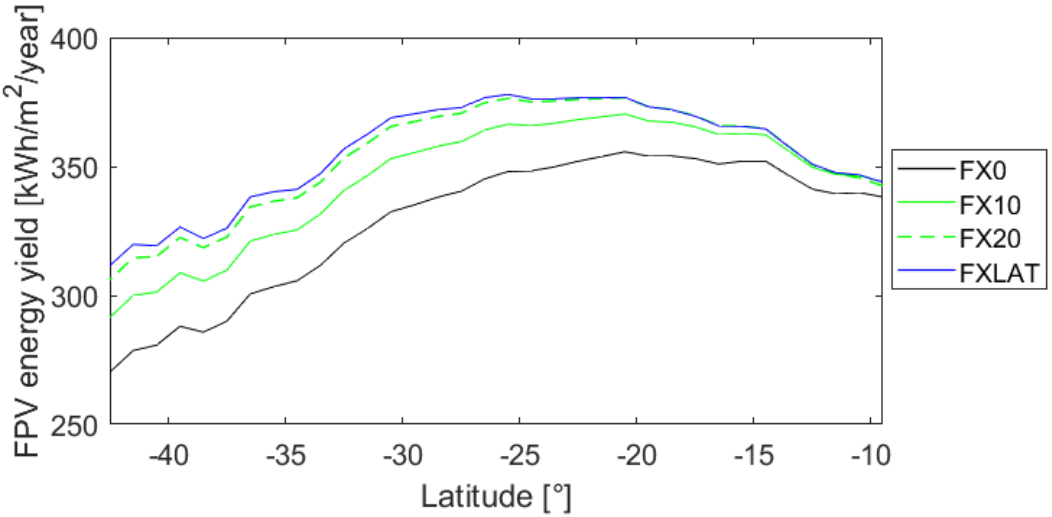
- **Analysis of multiple reservoirs in Australia (~1,500)**

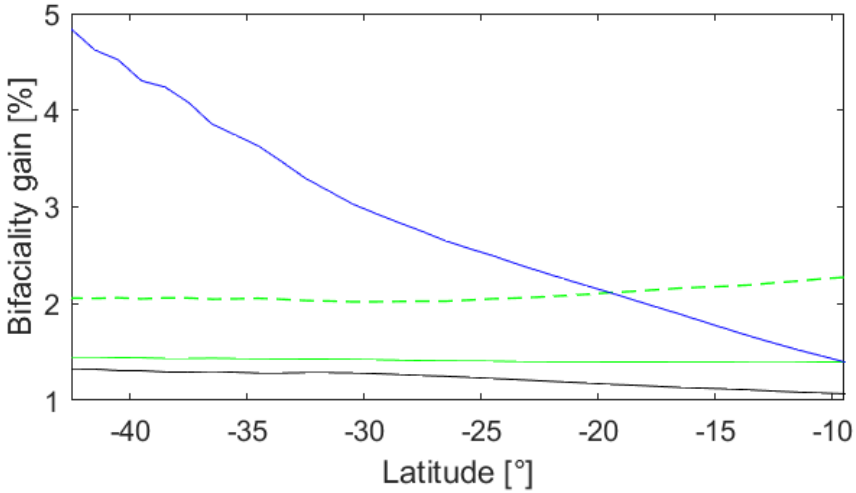




Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Global FPV Status and Potential', submitted to Joule

FPV inland potential: Australia





- **FX0: Horizontal**
- **FX10: 10° tilt facing equator**
- **FX20: 20° tilt facing equator**
- **FXLAT: tilt = latitude and facing equator**

Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Global FPV Status and Potential', submitted to Joule

FPV inland potential: Australia

- **FPV results for Australia considering 10% area of reservoirs**

	PV capacity	Energy production				Water savings
		Horizontal	10° tilt facing equator	20° tilt facing equator	Tilt=latitude, facing equator	
	105 GWp	167 TWh/year	177 TWh/year	183 TWh/year	184 TWh/year	1811 km^3/year
Countrywide influence		68%	72%	75%	75%	11%

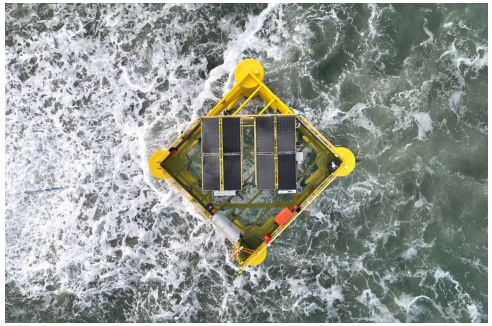
Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Global FPV Status and Potential', submitted to Joule

Offshore FPV: Still at Development Stage

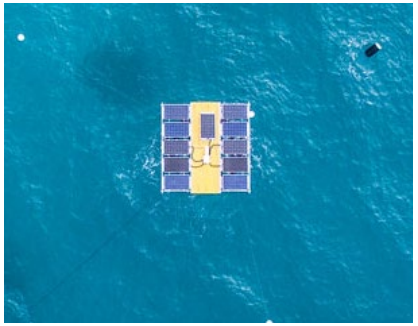
China, 500 kWp
Souce: Ocean Sun

Netherlands, 400 kWp
Souce: Oceans of Energy

China, 400 kWp
Souce: CIMC Raffles



Belgium, ~4 kWp
Souce: SeaVolt



Maldives, 3.3 kWp
Souce: Swimsol

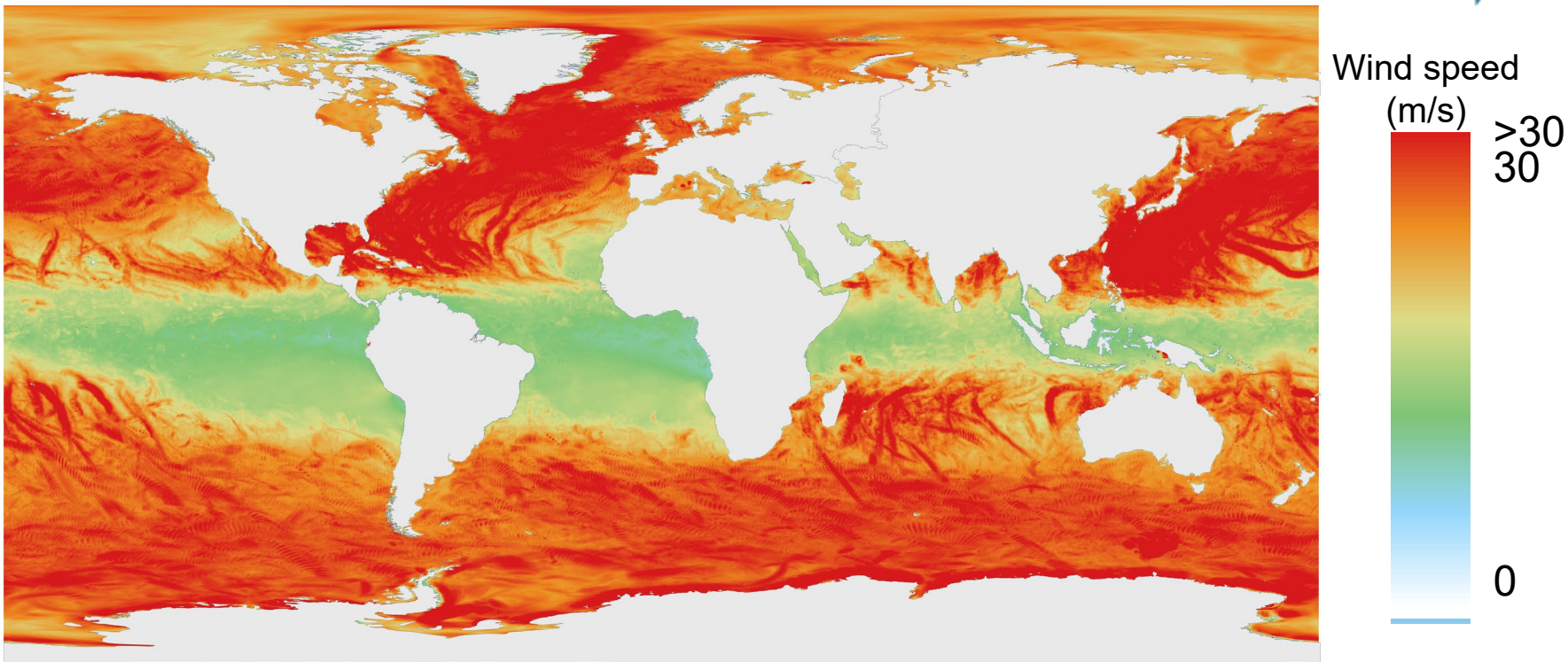
Offshore FPV: Challenges

- Mechanical complexities: wind and wave conditions
- Salinity: technology limitation
- Operation and maintenance: distance from shore
- Warranty: manufacturers concern
- Losses: mismatch losses

Offshore FPV: Advantages

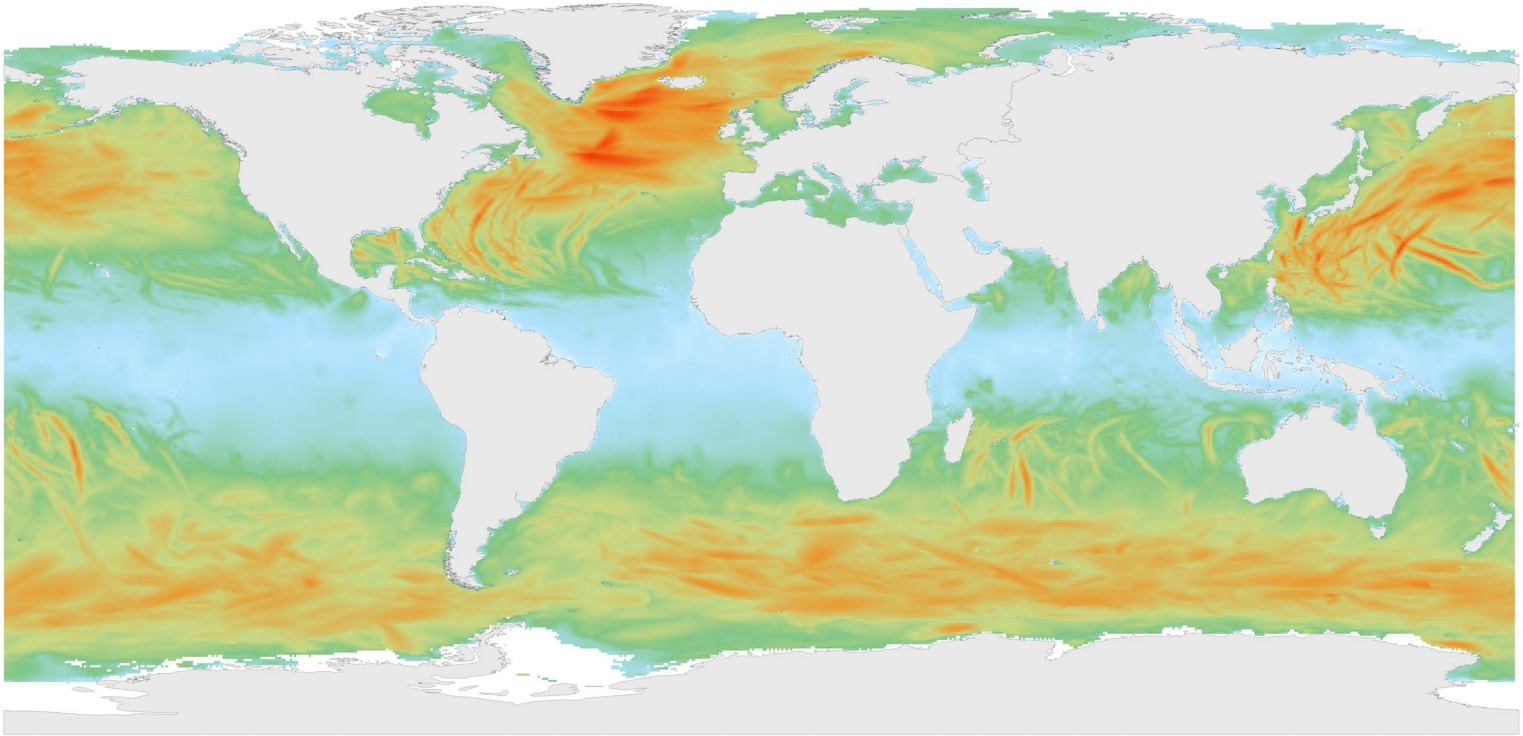
- Space…

Offshore FPV: Potential
Wind speed conditions



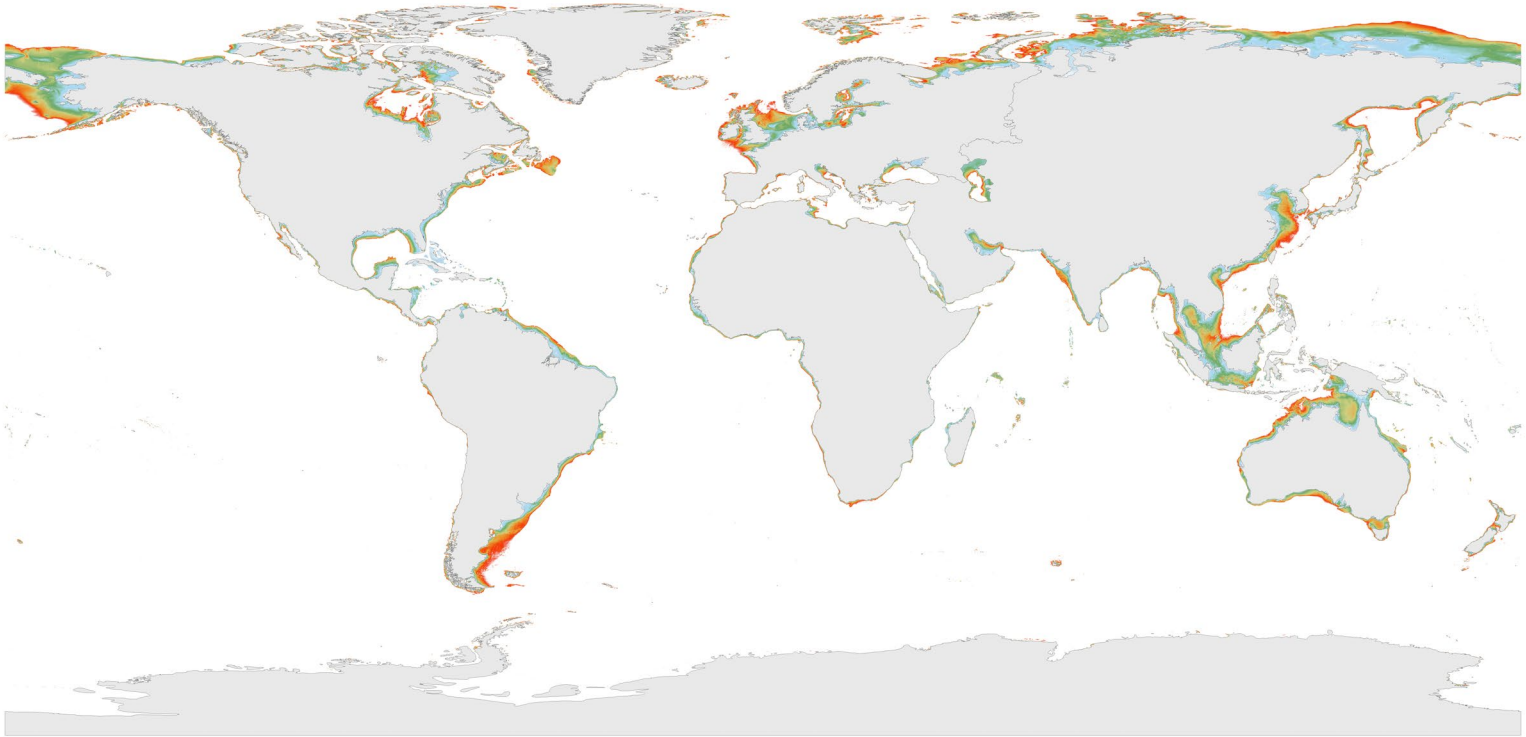
[1] ERA5 database. Digitization by Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential
Wave height conditions



[1] ERA5 database. Digitization by Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

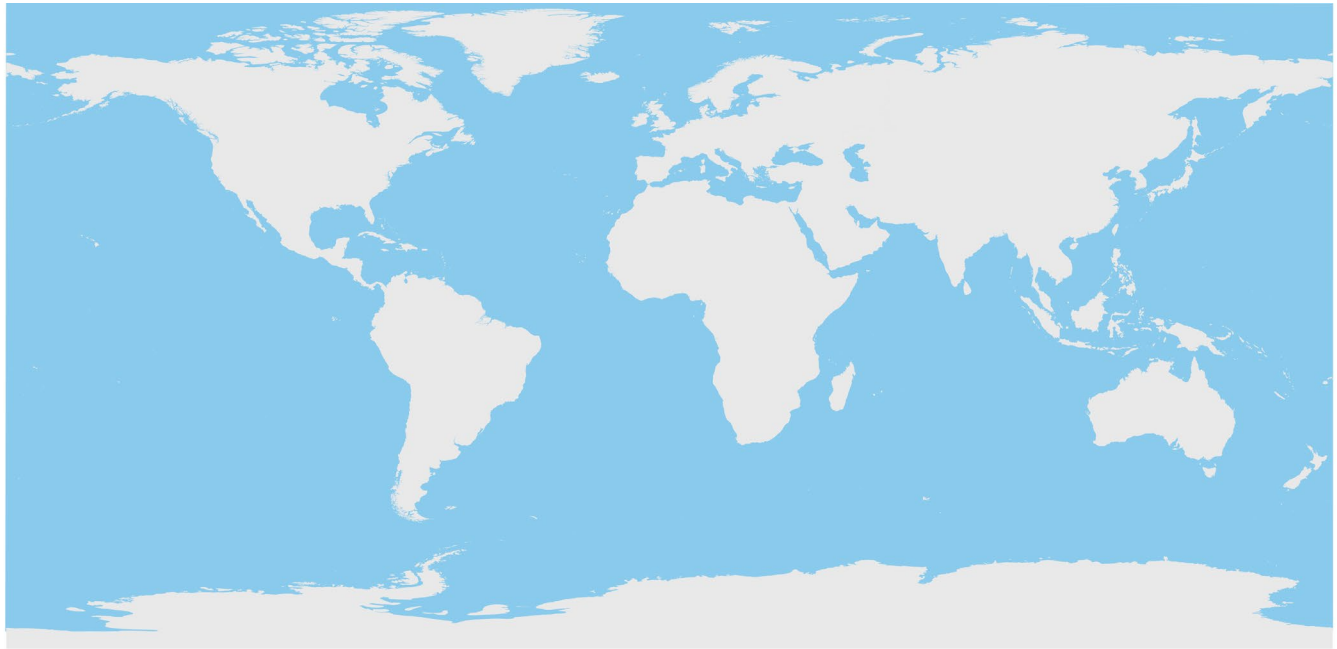
Offshore FPV: Potential Bathymetry conditions



[1] ERA5 database. Digitization by Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential Based on Constraints

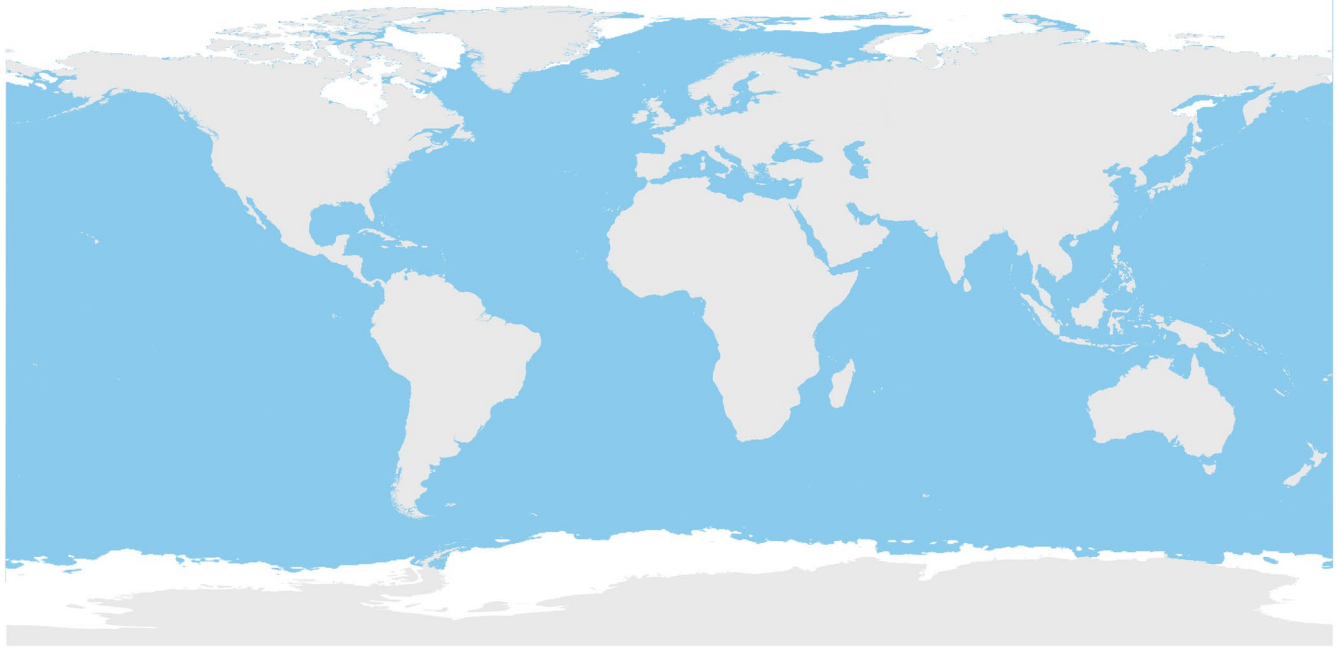
- **No constraints**



[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential Based on Constraints

- **No ice regions**

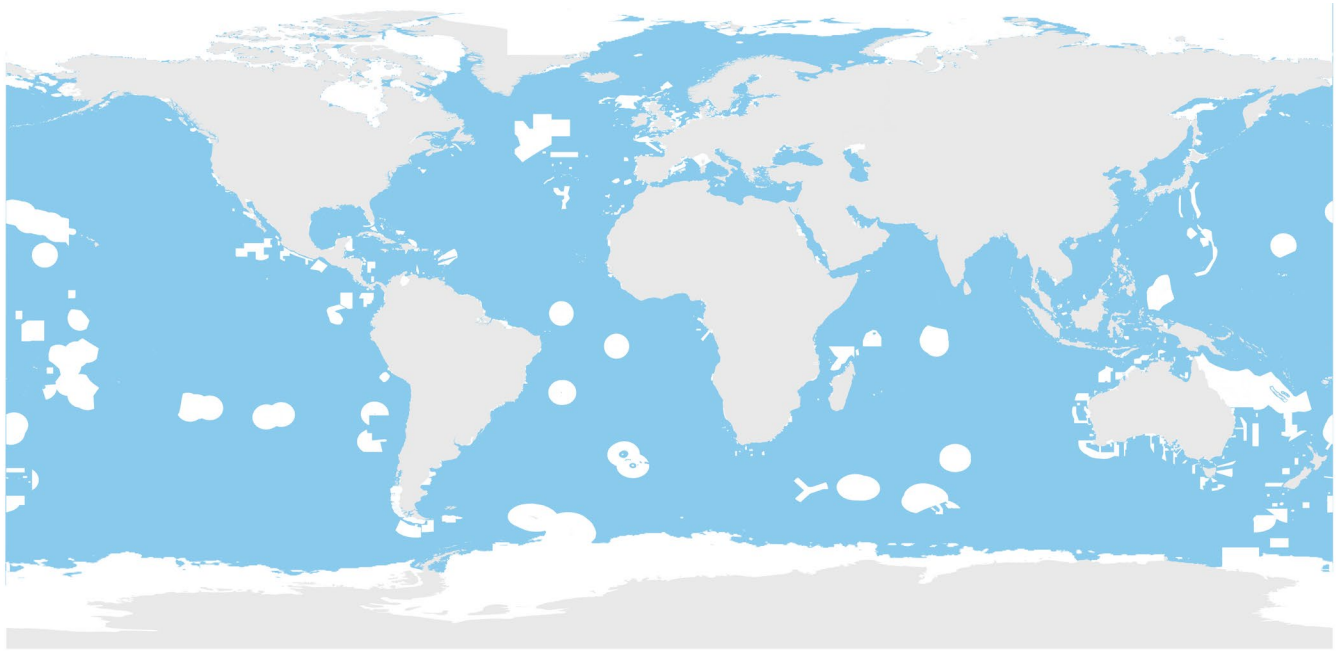


Note: Blue areas are within given constraints. White areas are not within given constraints

[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential Based on Constraints

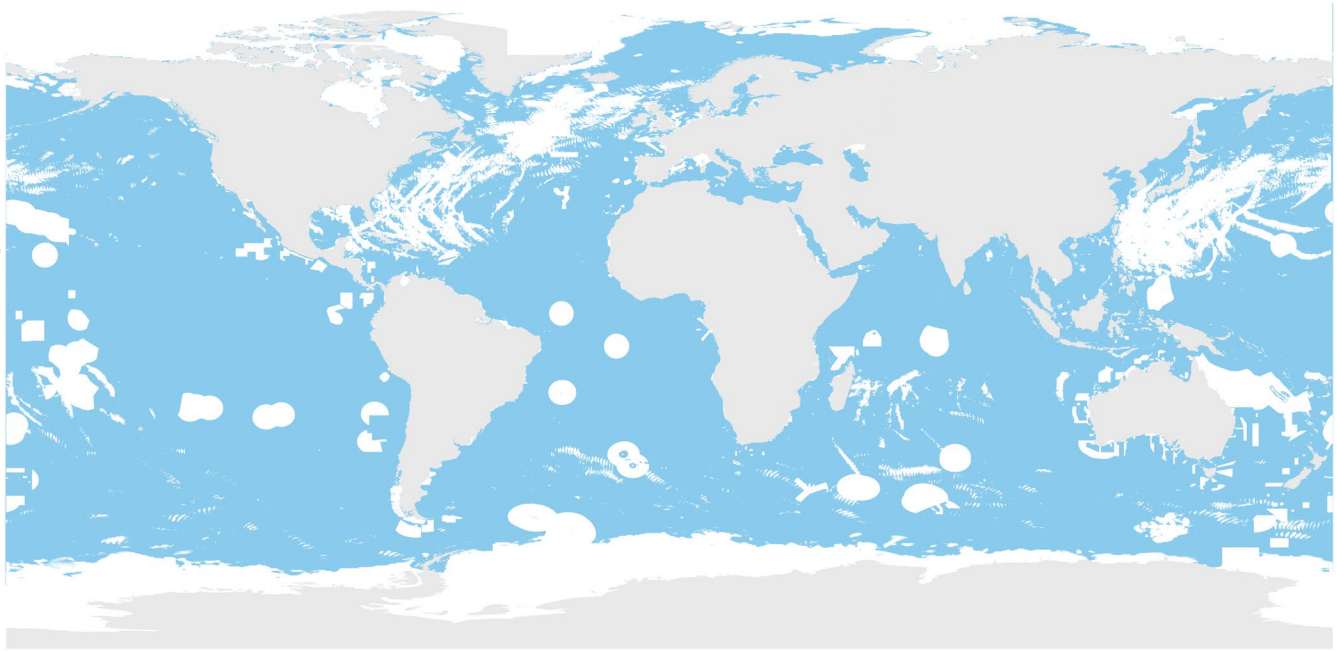
- No ice regions
- No protected areas



[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., ‘Offshore FPV Potential Worldwide ’, to be submitted

Offshore FPV: Potential Based on Constraints

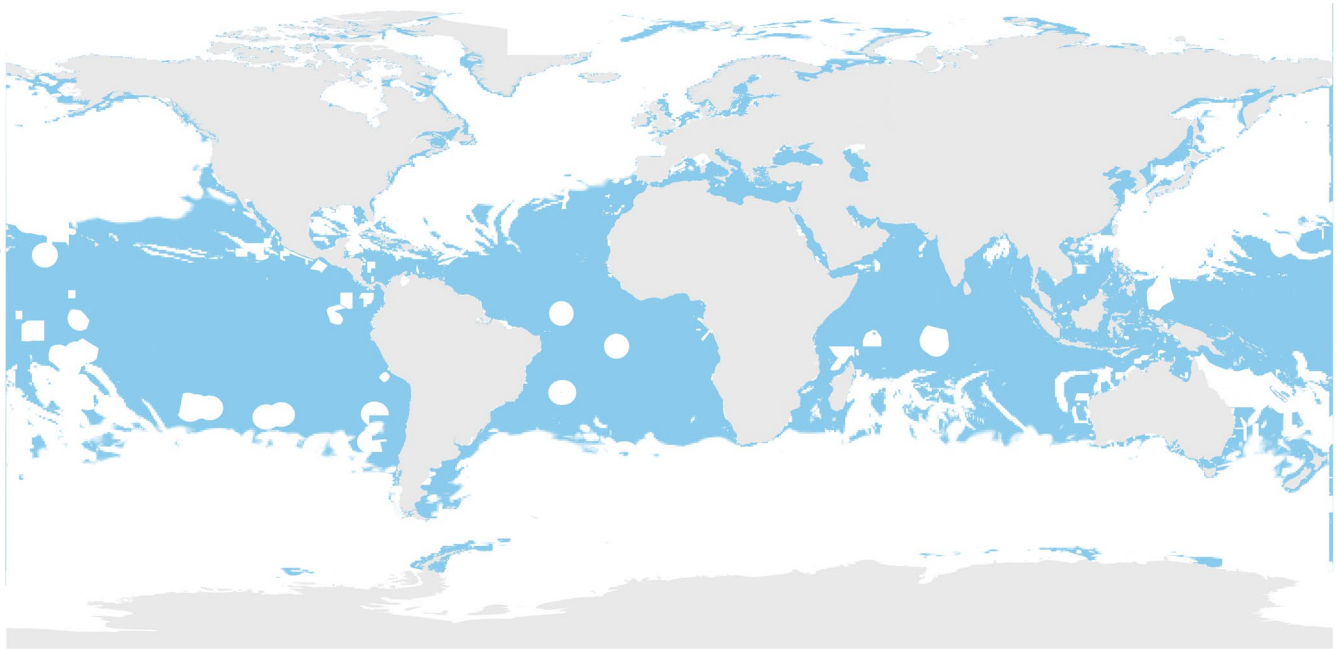
- No ice regions
- No protected areas
- Wind speed ≤ 30 m/s



[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential Based on Constraints

- No ice regions
- No protected areas
- Wind speed ≤ 30 m/s
- Wave height ≤ 10 m



[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

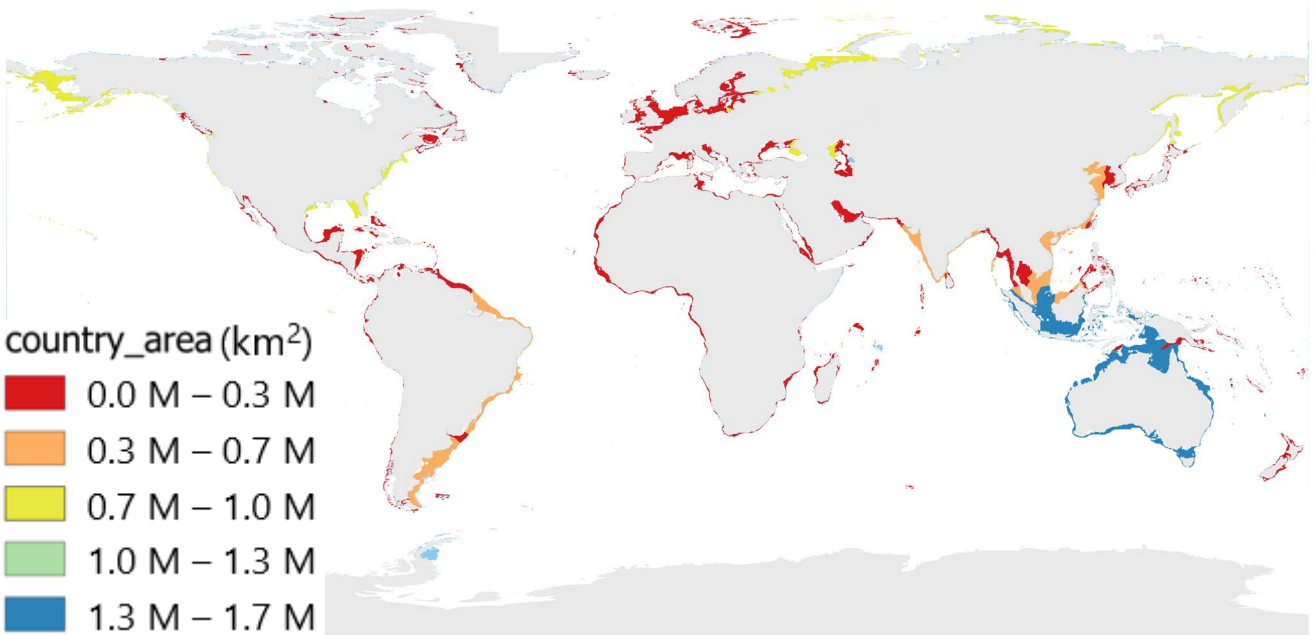
Offshore FPV: Potential Based on Constraints

- No ice regions
- No protected areas
- Wind speed ≤ 30 m/s
- Wave height ≤ 10 m
- Water depth ≤ 100 m

[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential Based on Constraints

- No ice regions
- No protected areas
- Wind speed ≤ 30 m/s
- Wave height ≤ 10 m
- Water depth ≤ 100 m
- Country's territory



[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., 'Offshore FPV Potential Worldwide ', to be submitted

Offshore FPV: Potential Based on Constraints

- **Table of results for top 10 countries considering FPV is deployed in only 10% of available area from previous slide**

Country	Available area ($x10^5$ km^2)
1. Indonesia	1.52
2. Australia	1.11
3. Russia	0.80
4. United States	0.68
5. China	0.53
6. Brazil	0.53
7. Argentina	0.48
8. India	0.35
9. Vietnam	0.33
10. Malaysia	0.32

[1] Rodriguez-Gallegos C.D., Gandhi O, Sun H., et al., 'Offshore FPV Potential Worldwide ', to be submitted

For more info:

Thank you for your attention

carlos.rodriguez@rina.org