Where Sun Meets Water – Floating Solar Growth Potential

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Ouarzazate, Morocco
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SERIS is a research institute at the National University of Singapore (NUS). SERIS is supported by the National University of Singapore (NUS), National Research Foundation Singapore (NRF) and the Singapore Economic Development Board (EDB).

Outline

- Who is SERIS
- Floating PV market trends
  - Rationale
  - Growth potential
  - Technologies and suppliers
  - Cost comparison
  - Hybrids with (existing) hydropower
- Conclusions

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SERIS

Solar Energy Research Institute of Singapore

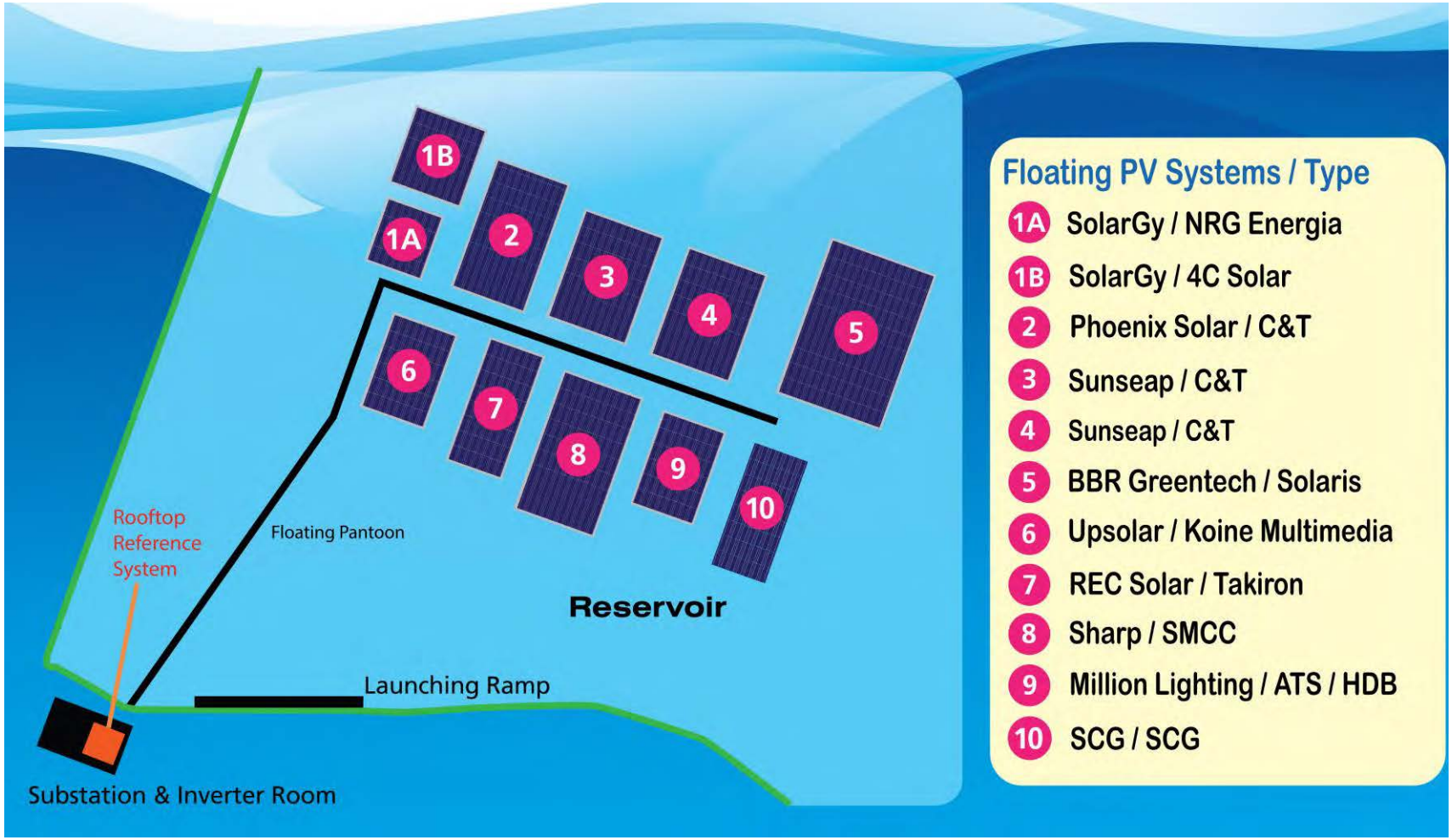
- Founded in 2008; focuses on applied solar energy research
- Part of the National University of Singapore (NUS)
- State-of-the-art laboratories
- R&D focus is on solar cells, PV modules and PV systems
- Specialised in professional services for the PV industry
- ISO 9001 & ISO 17025* certified
  (* PV Module Testing Lab)

SERIS lab's in Singapore

Pictures: SERIS

SERIS Floating PV Testbed

10 commercial Floating PV solutions



Source: SERIS

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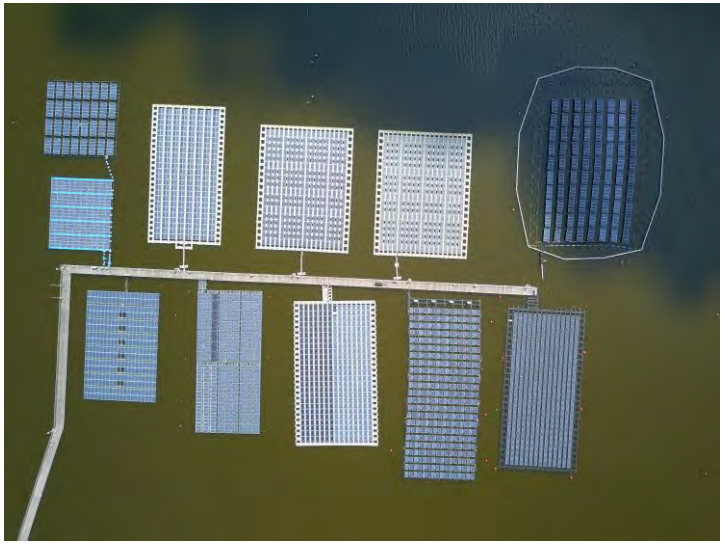
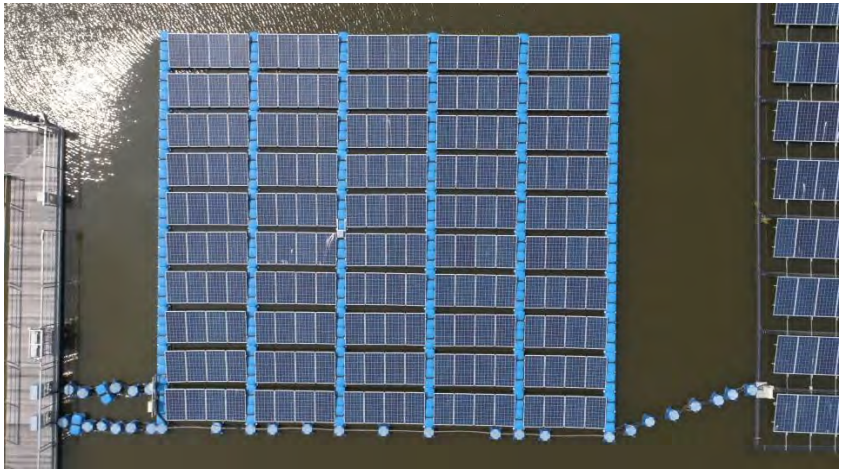
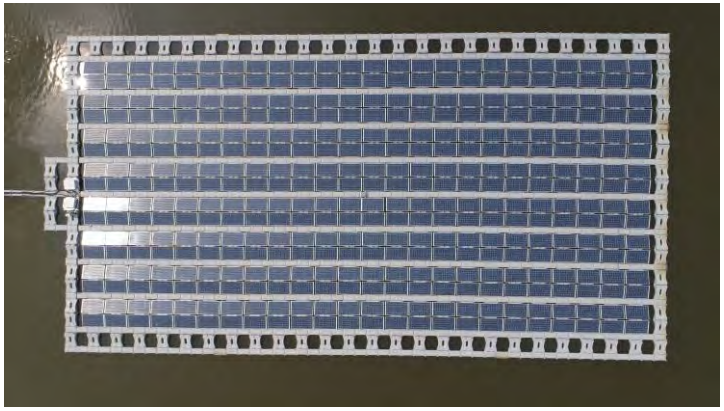
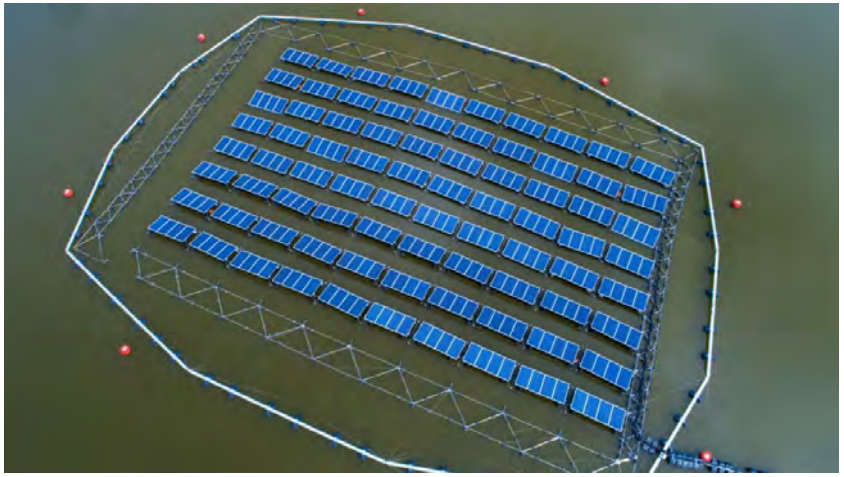
SERIS Floating PV Testbed

1 MWp on a drinking water reservoir



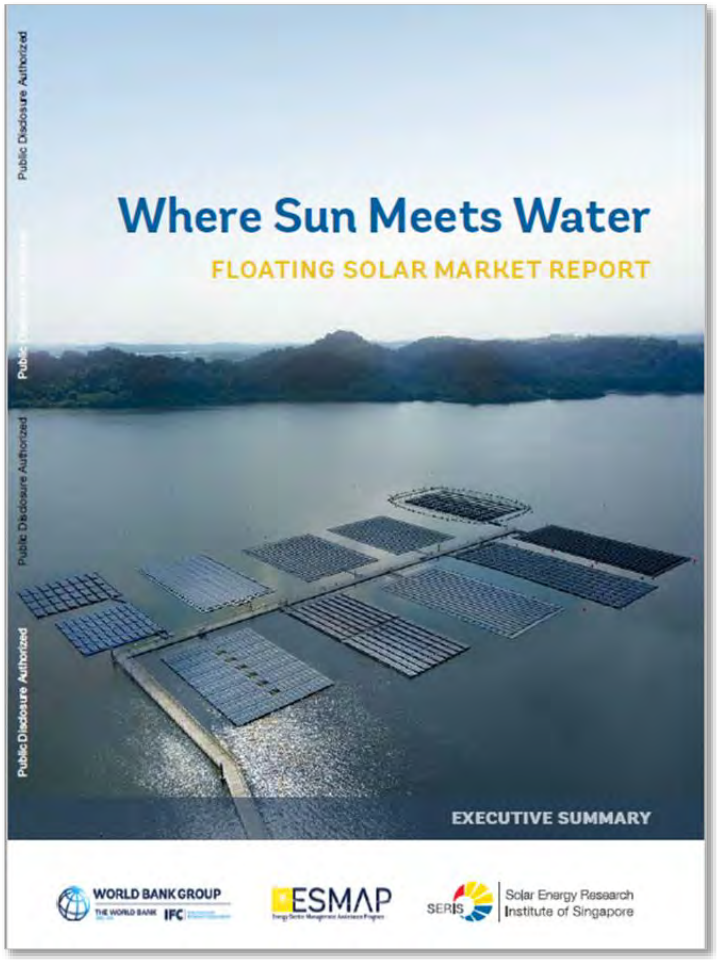






Pictures: SERIS

Collaboration with the WBG-ESMAP



- Floating Solar Market Report

  1. Rationale
  2. Technology overview
  3. Market potential and opportunities
  4. Economics
  5. Policy and regulatory framework
  6. Suppliers/EPCs

Publication: 1Q 2019

- Practitioner Handbook

  1. Project development phases
  2. Best practices and guidelines
  3. Environmental and social considerations

Publication: 2Q 2019

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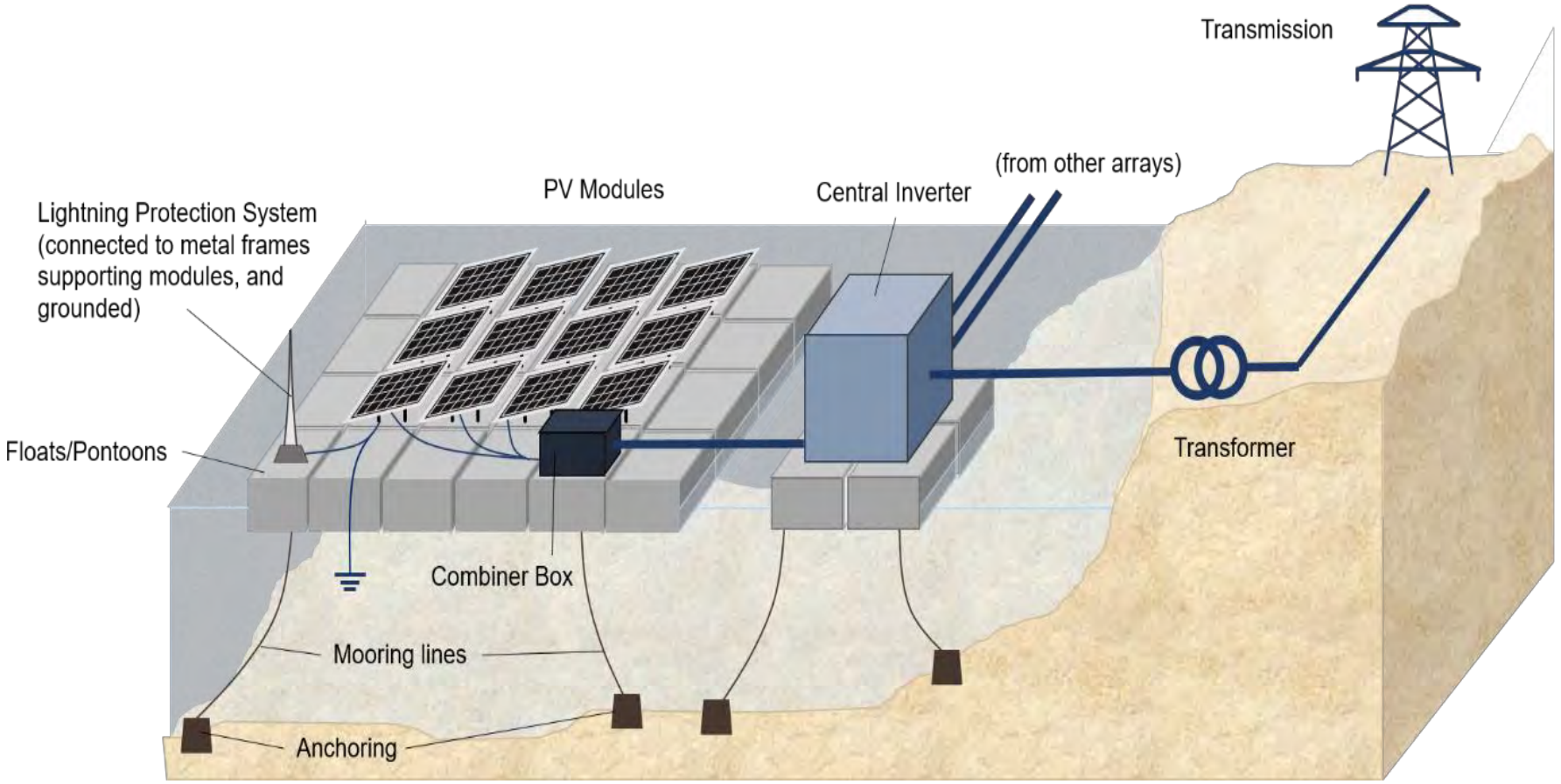
What is FPV?

- PV systems floating on water bodies such as lakes, drinking water reservoirs, hydroelectric dams, mining ponds, industrial ponds, water treatment ponds, etc.
- Third pillar for PV deployment after ground-mounted and rooftop
- First system built in 2007 in Japan
- Relevant where land is scarce and expensive, or needed for other purposes (agriculture, urban habitat, etc.)
- Typical benefits: (1) increased energy yield, (2) water evaporation reduction, (3) maximization of existing infrastructure usage

Picture: Lightsource BP

Typical large-scale FPV system

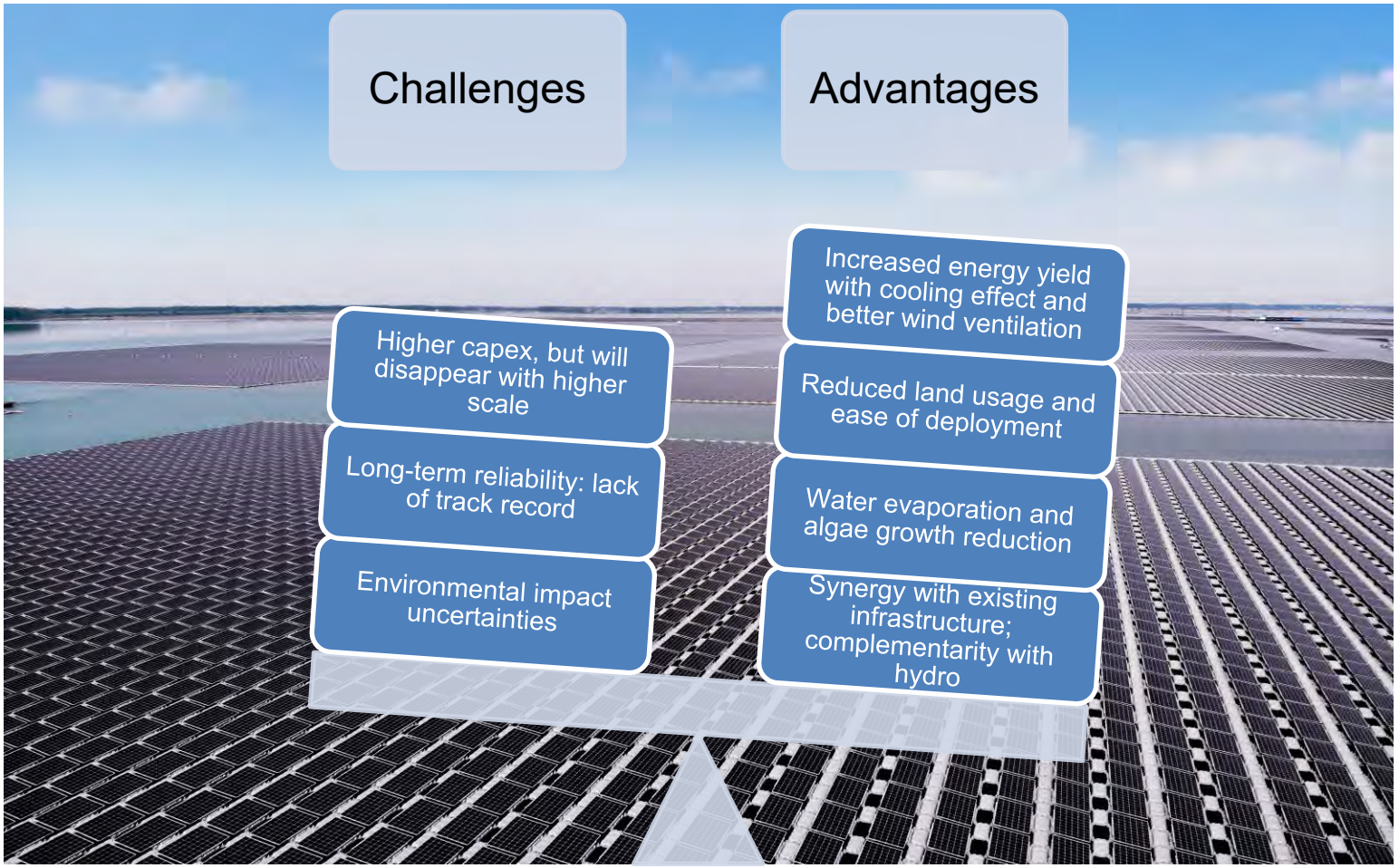
Using central inverter on a separate island (can also be placed on land)
Various anchoring and mooring systems are possible



Source: SERIS

Perceived challenges & advantages

Site-specific EIA* and experienced quality suppliers are paramount



* EIA = environmental impact assessment.

Picture: Sungrow

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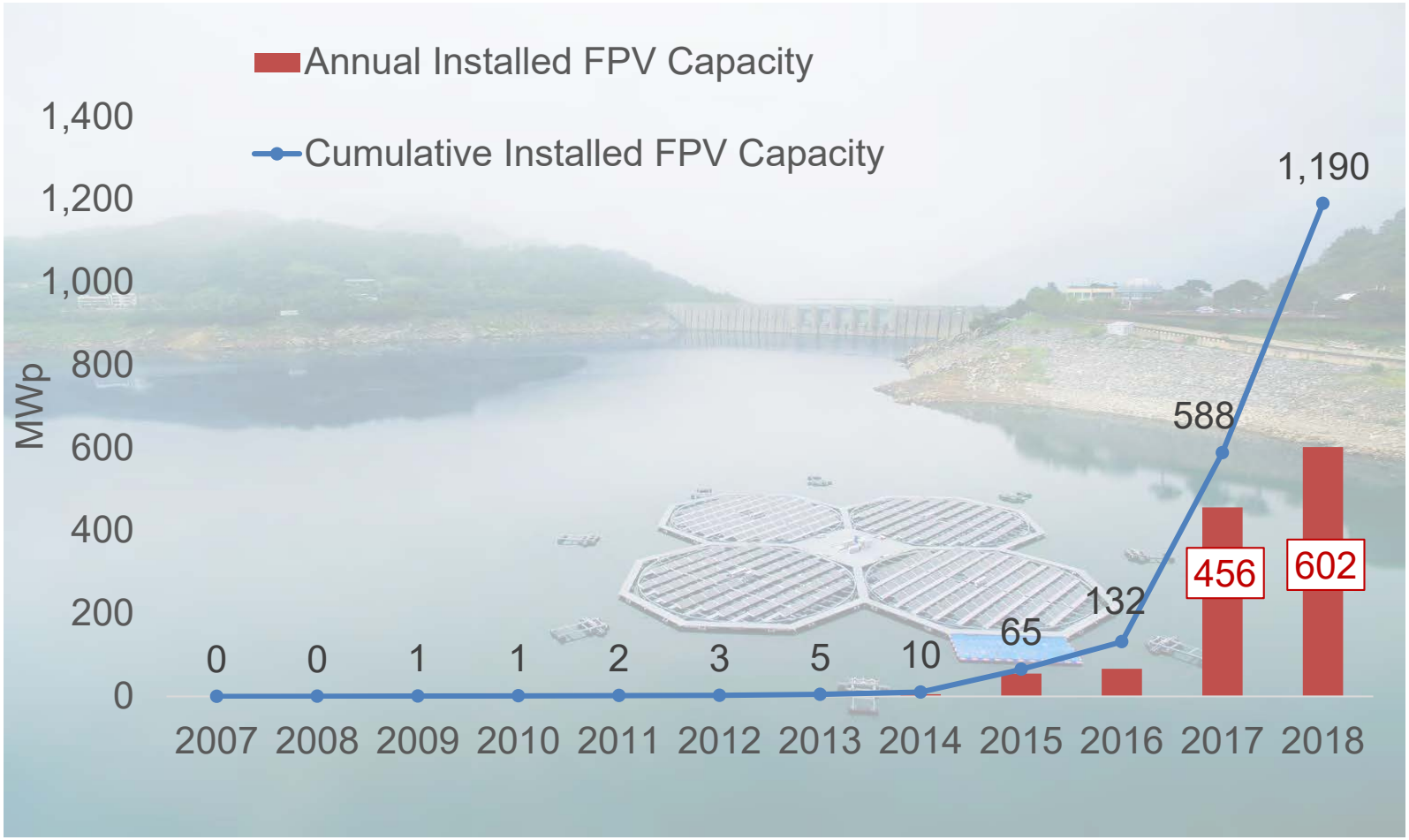
More than 1.2 GW FPV installed

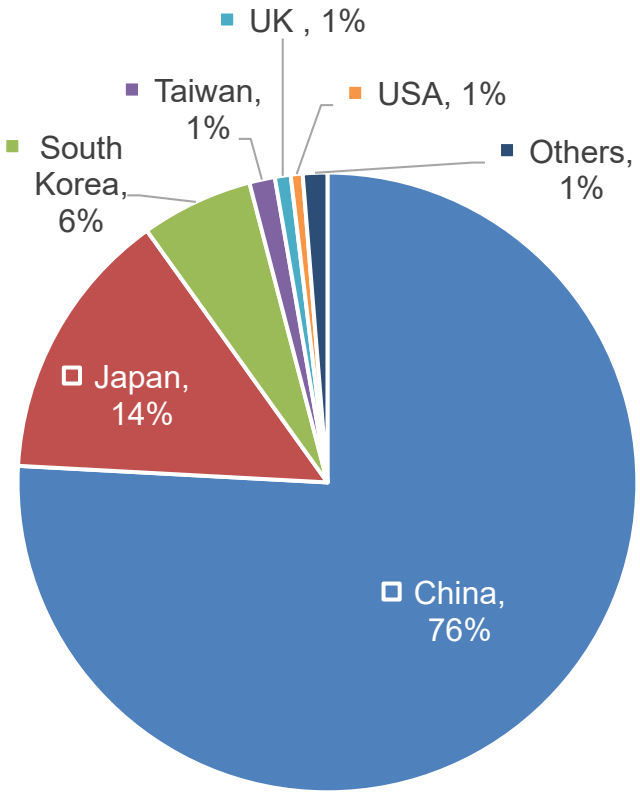
Below figures represent installed FPV projects of 2 MW+

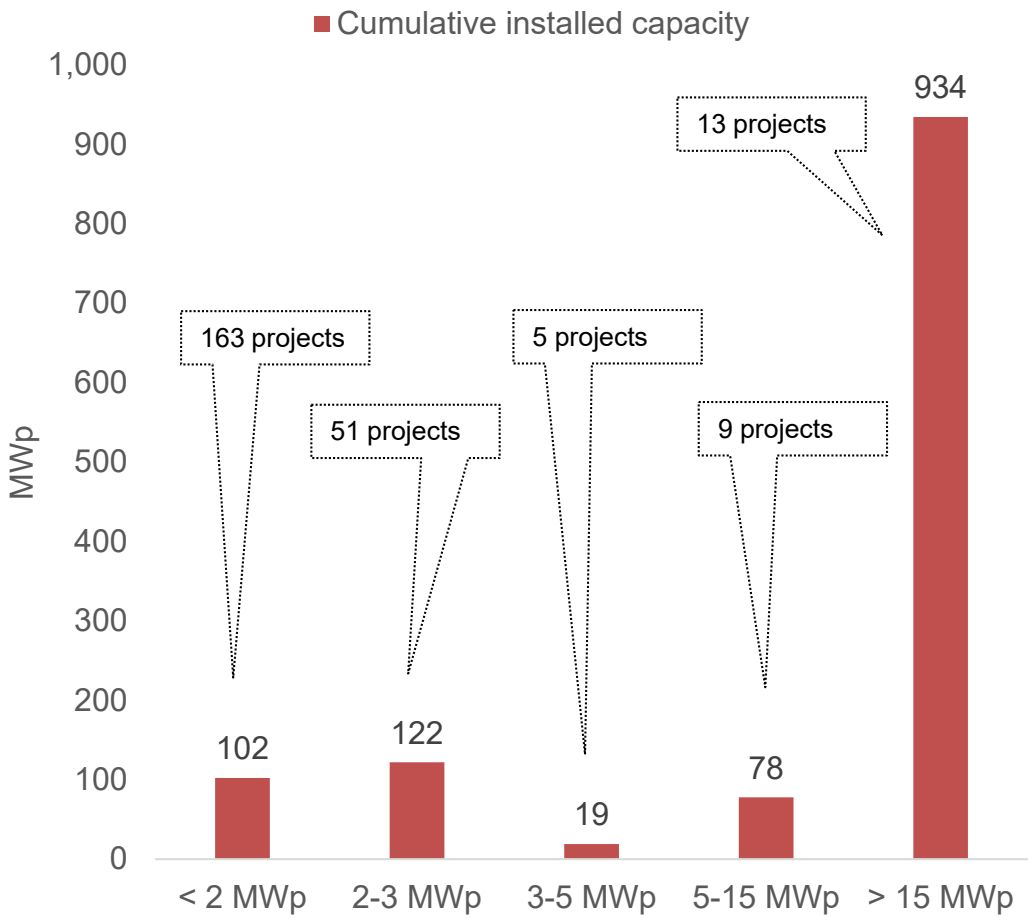


Source: SERIS. Picture: K-Water

China no. 1 with few large projects

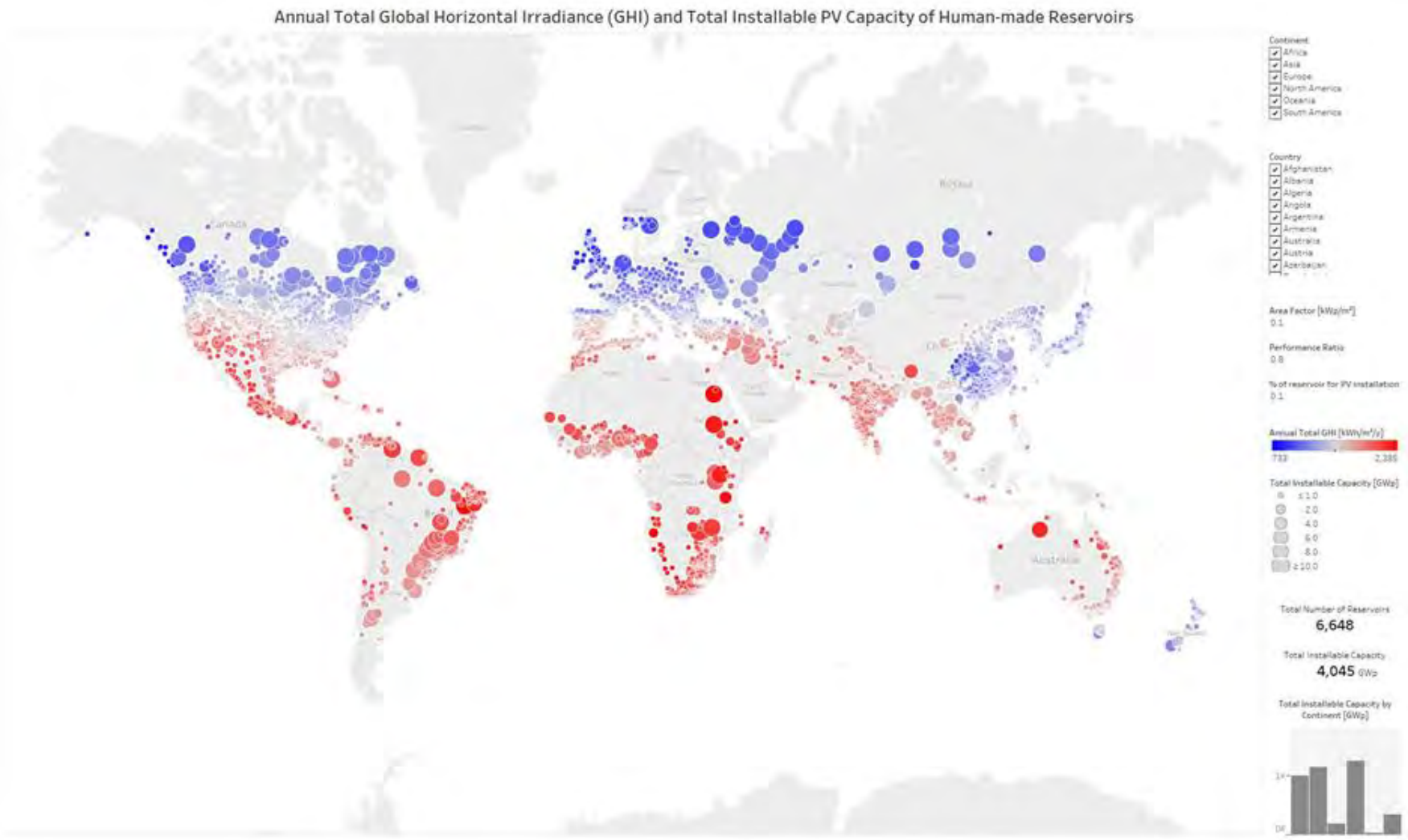
= ~ 952 MWp spread across 20 projects





Source: SERIS

World: ~4 TWp with 10% coverage



Source: SERIS based on the Global Solar Atlas and the GRanD database, © Global Water System Project (2011)

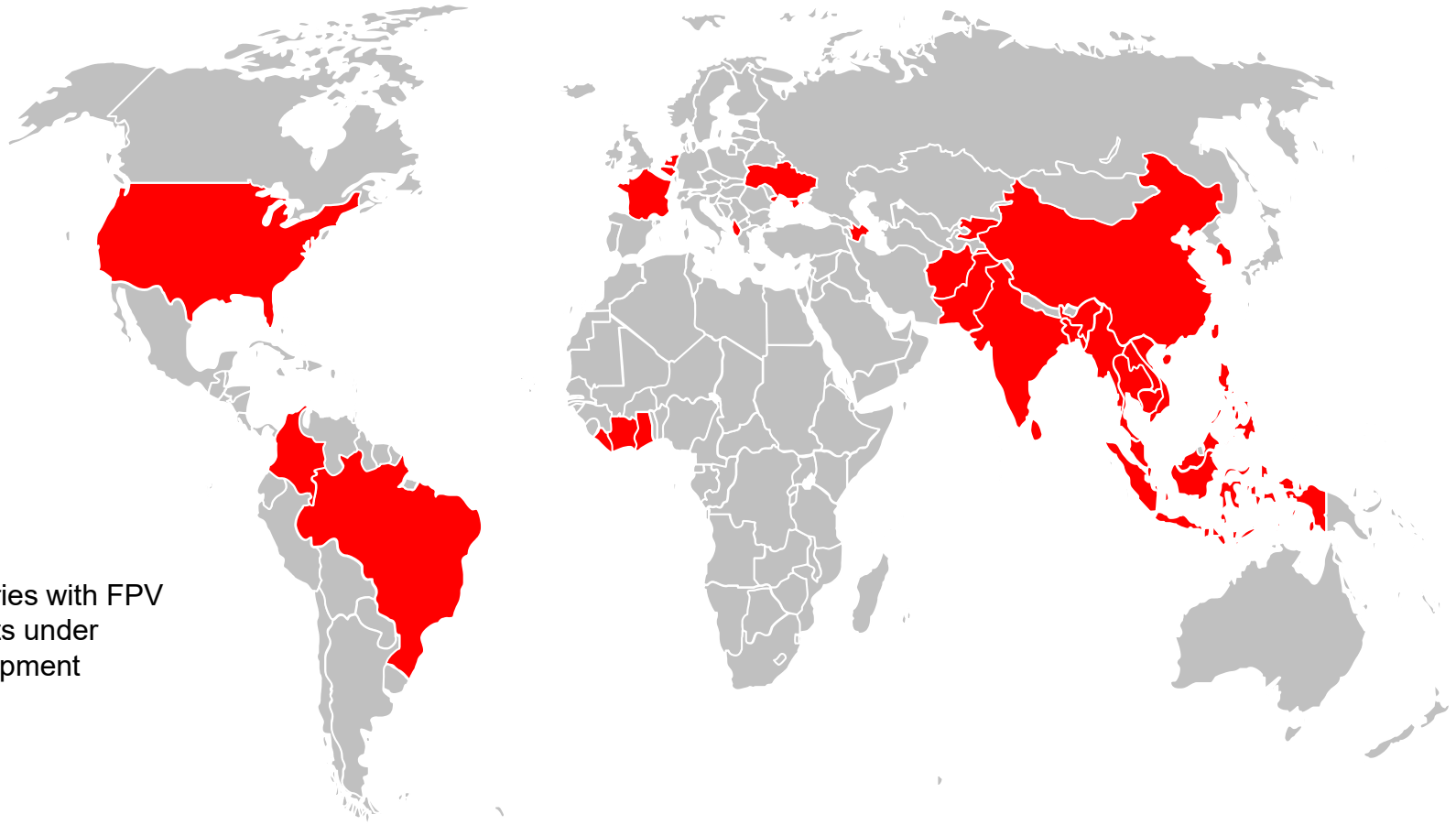
A Terawatt scale market potential

Huge potential with more than 400,000 km² man-made reservoirs

Continent	No. of Water Bodies Assessed	FPV Total Installable Capacity [GWp] (% of water surface for PV installation)		
		1%	5%	10%
Africa	724	101	506	1,011
Asia	2,041	116	578	1,156
Europe	1,082	20	102	204
N. America	2,248	126	630	1,260
Oceania	254	5	25	50
S. America	299	36	181	363
Total	6,648	404	2,022	4,044

Source: SERIS calculations based on data from GRanD database, © Global Water System Project (2011)
Available online at: http://sedac.ciesin.columbia.edu/pfs/grand.html

Current pipeline is growing fast



Countries with FPV projects under development

With more than 6 GW planned worldwide

Source: SERIS

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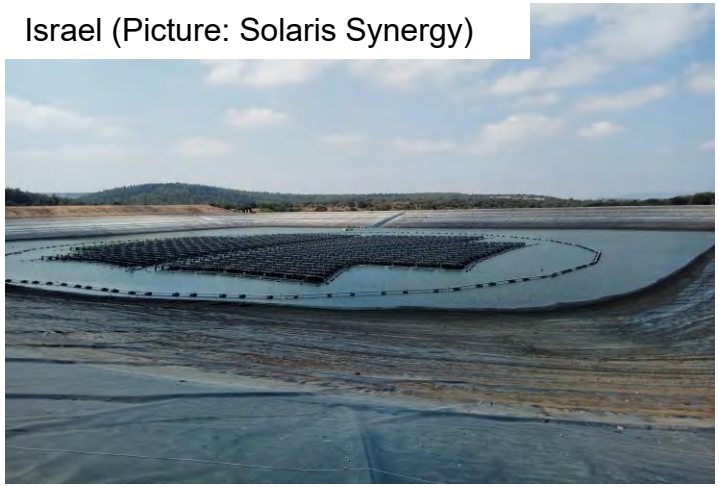
From experimental systems …

Canada (Picture: MIRACO)

Korea Rep. (Picture: K-Water)

Israel (Picture: Solaris Synergy)



Australia (Picture: Infratech Industries)

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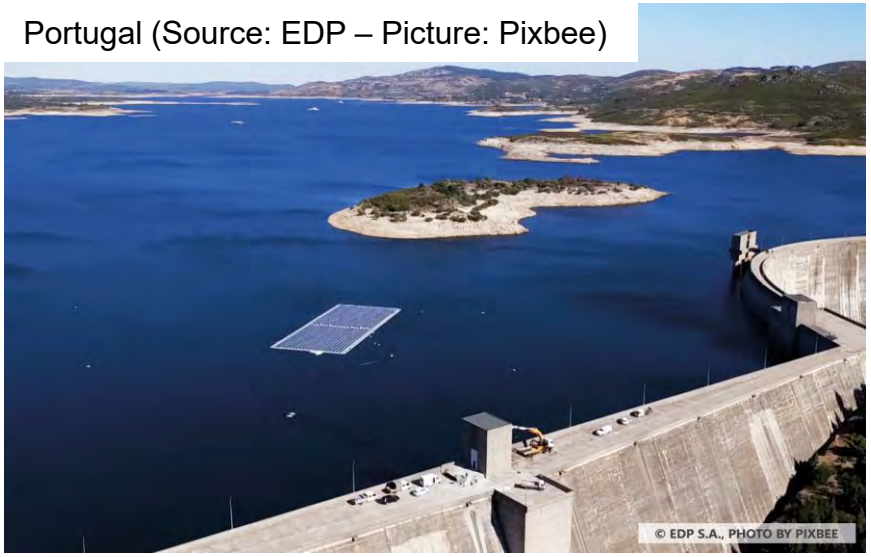
To small commercial installations …

Norway (offshore) (Picture: Ocean Sun)

Maldives (offshore) (Picture: Swimsol)

USA (Picture: Far Niente Winery)

Portugal (Source: EDP – Picture: Pixbee)



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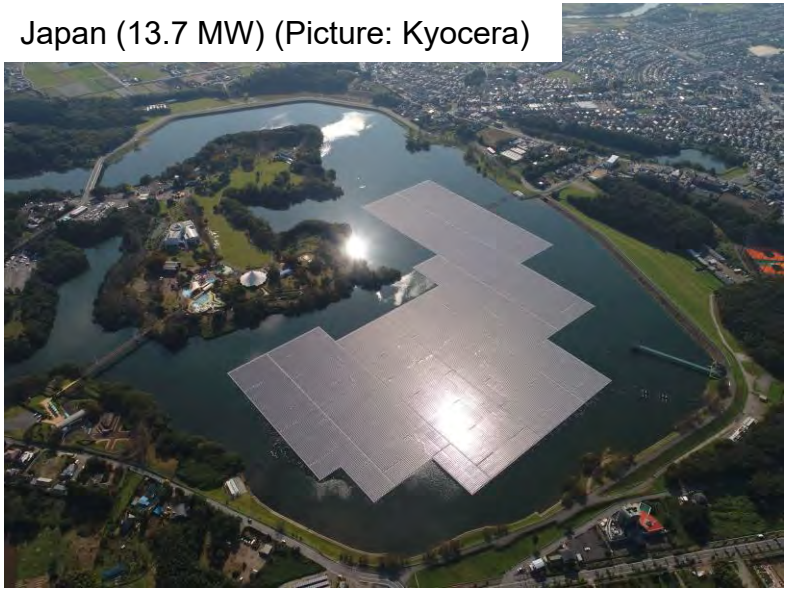
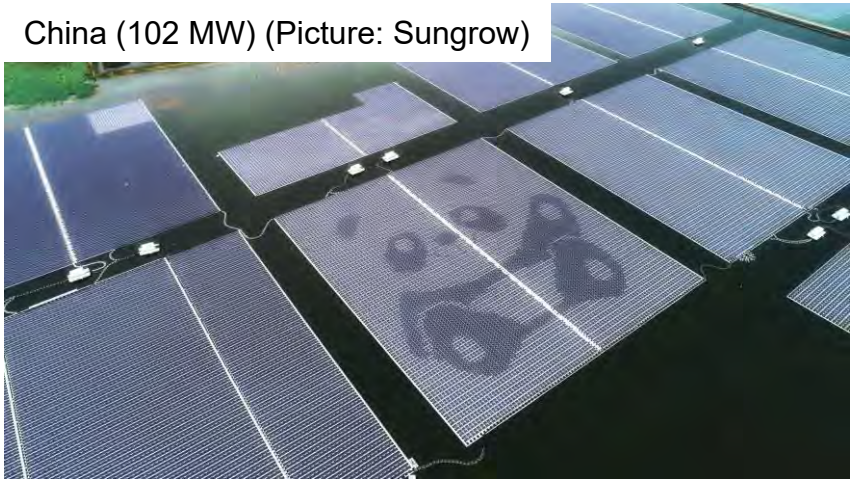
To large-scale implementation

Korea Rep. (3 MW) (Picture: LG CNS)

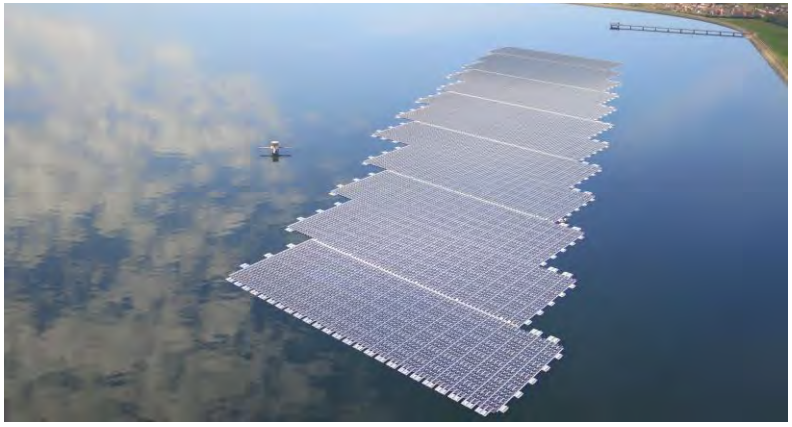
Japan (13.7 MW) (Picture: Kyocera)



China (102 MW) (Picture: Sungrow)



United Kingdom (6.3 MW) (Picture: Lightsource BP)



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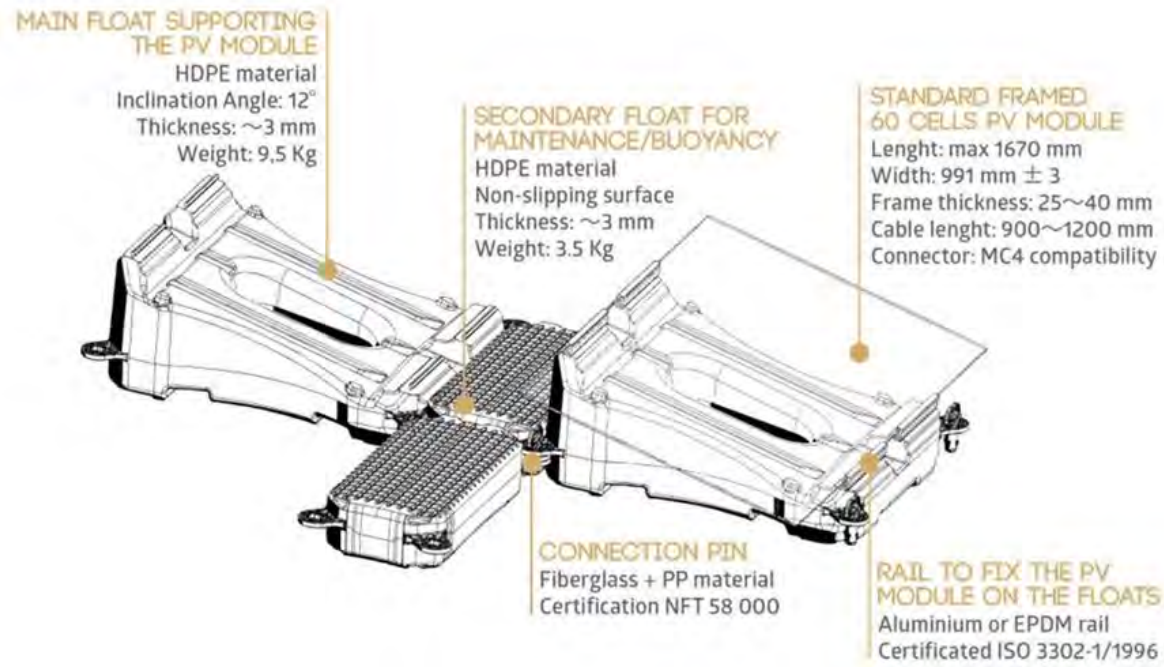
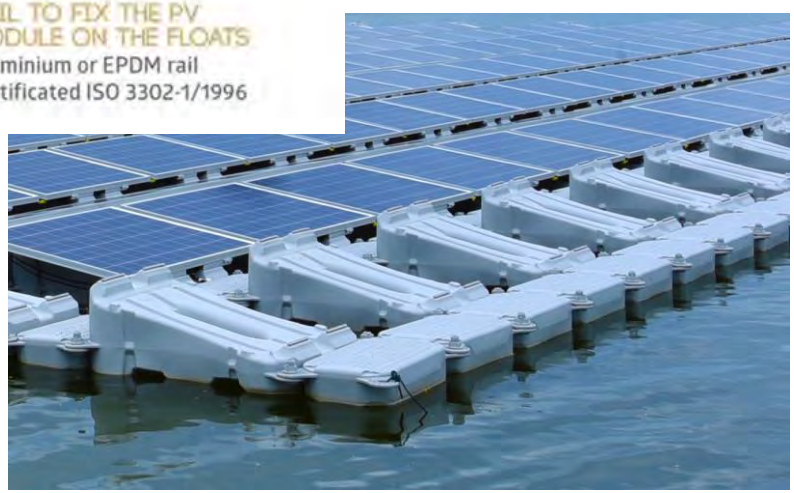
Mainstream technology: HDPE* floats



Source: Ciel & Terre



Source: SERIS

* High-density polyethylene.

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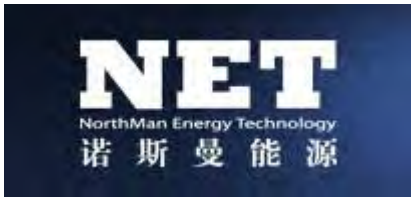
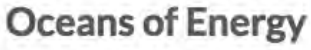
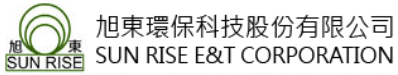
FPV supplier-base is growing







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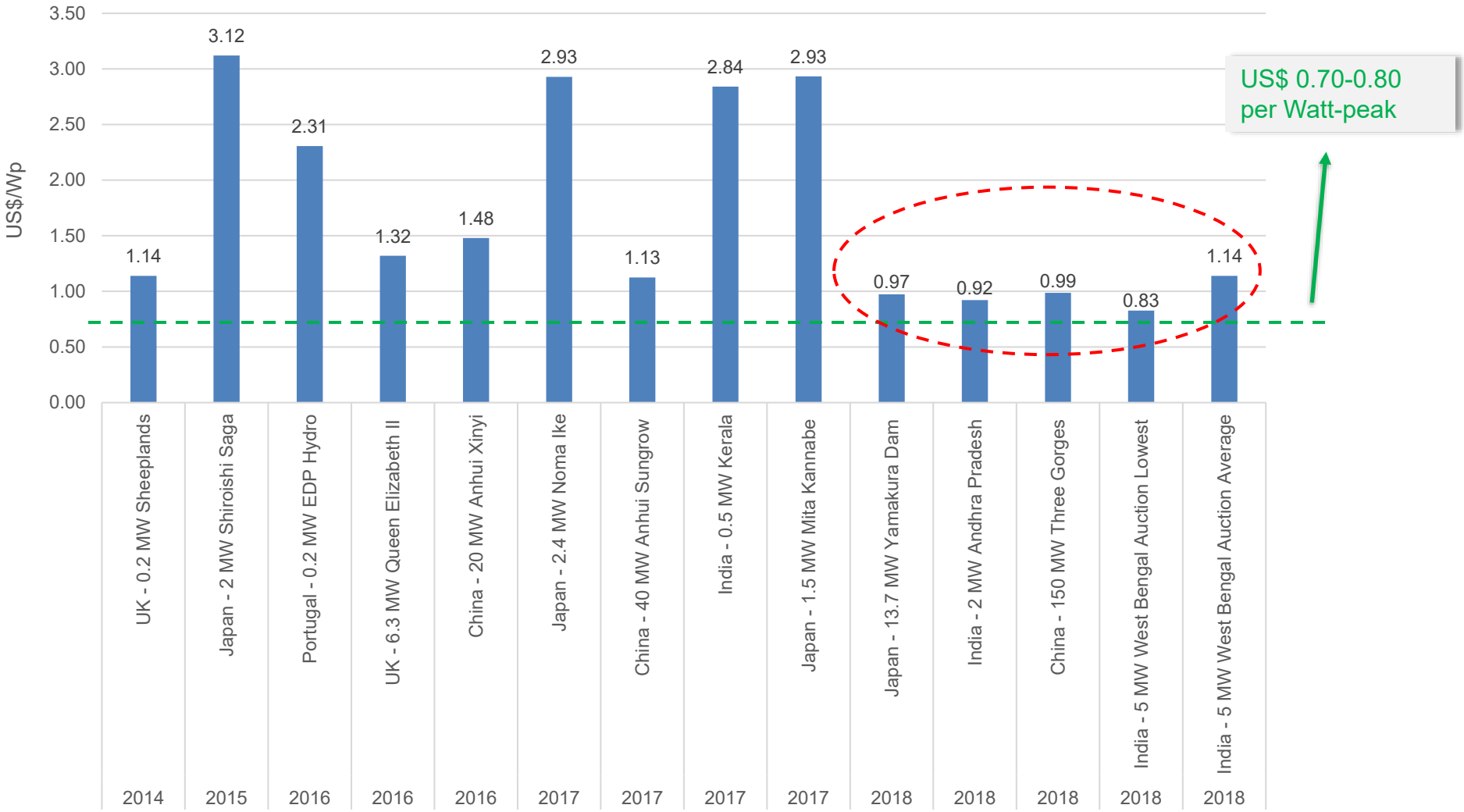
‘Realized’ capex developments



Source: SERIS

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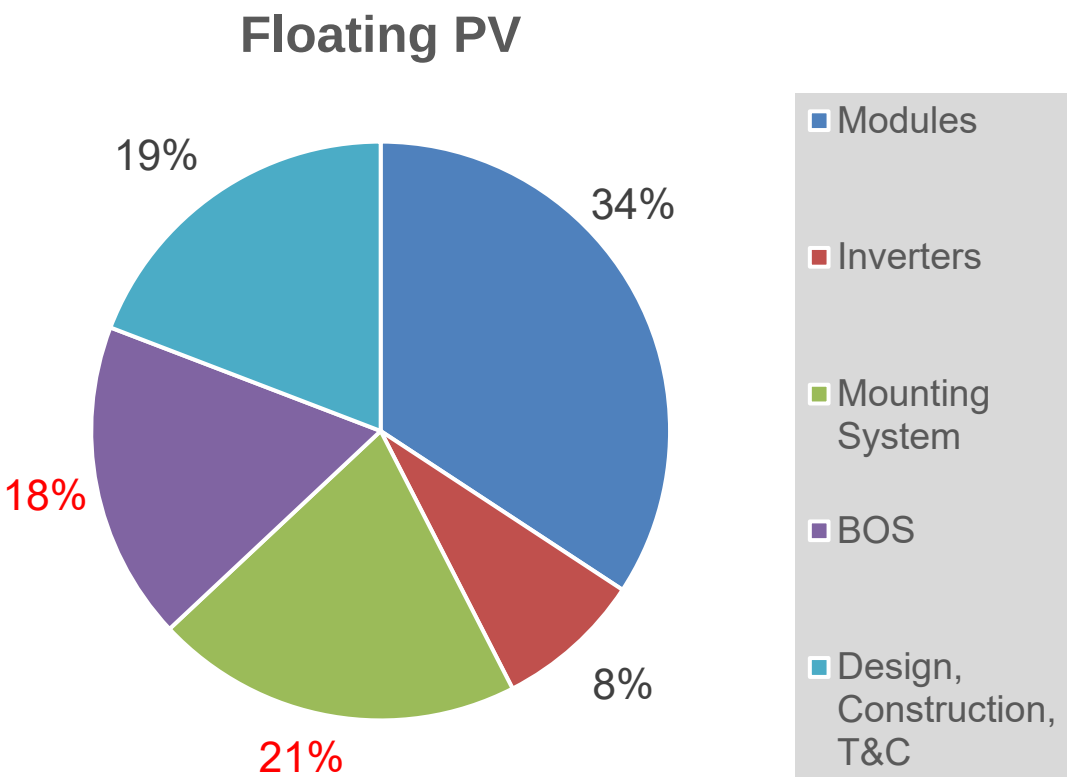
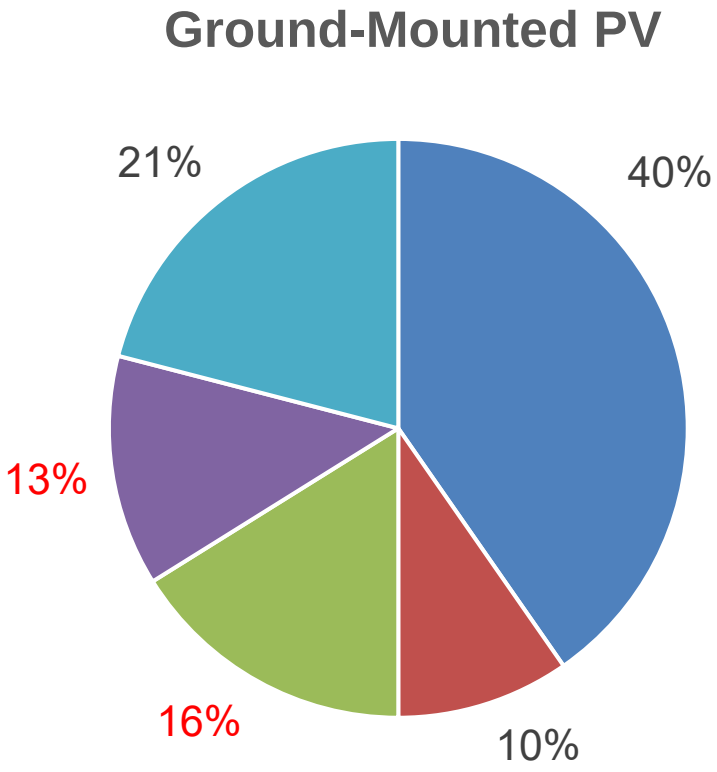
Capex breakdown comparison





For both: same module (US$ 0.25/Wp) and inverter costs

Source: SERIS

LCOE results in US$ cents/kWh

			Ground-Mounted PV 50 MWp	Floating PV 50 MWp	
				Conservative (+5% PR*)	Optimistic (+10% PR*)
Tropical	WACC	6%	6.25	6.77	6.47
		8%	6.85	7.45	7.11
		10%	7.59	8.28	7.91
Arid/Desert	WACC	6%	4.52	4.90	4.68
		8%	4.96	5.39	5.15
		10%	5.51	6.01	5.74
Temperate	WACC	6%	6.95	7.53	7.19
		8%	7.64	8.30	7.93
		10%	8.49	9.26	8.85

* The performance ratio (PR) is a measure of the quality of a PV plant. It is stated as a percentage and describes the relationship between the actual and theoretical energy outputs of the PV plant.

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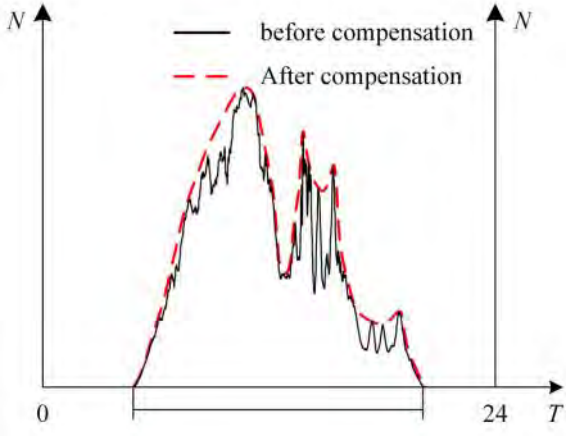
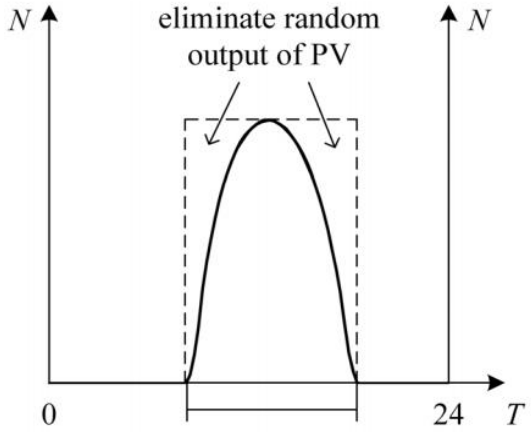
Complementary FPV and hydropower

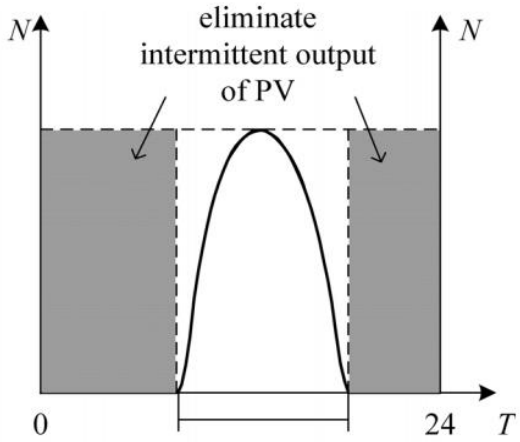
Joint operation of Floating PV and hydropower station

- ✓ Utilisation of available reservoir surface
- ✓ Existing power grid connection (often not fully utilized)
- ✓ Smoothing of PV variability (by adjusting turbines)
- ✓ Optimize day/night power generation
- ✓ Seasonal benefits (dry / wet seasons)

⇒ Use the reservoirs as “giant battery”







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Complementary FPV and hydropower

Longyangxia hydropower plant

- Commissioned in 1989
- Installed capacity: 1,280 MW (4x320 MW)
- Electricity production: 5,942 GWh/year
- Reservoir area: 380 km^2
- Major load peaking and frequency regulation power plant in Northwest power grid of China (quick-response turbines)

Complementary FPV and hydropower

Gonghe solar PV station (30 km away from Longyangxia Hydro)

- One of the largest PV power plants in the world
  - ✓ Phase I (2013): 320 MW, electricity production : 498 GWh/year
  - ✓ Phase II (2015): 530 MW, electricity production: 824 GWh/year
- Hybrid: the solar power plant is coupled to the existing hydropower substation through 330kV transmission line
- Solar power station is treated as an additional non-adjustable unit of hydro power plant

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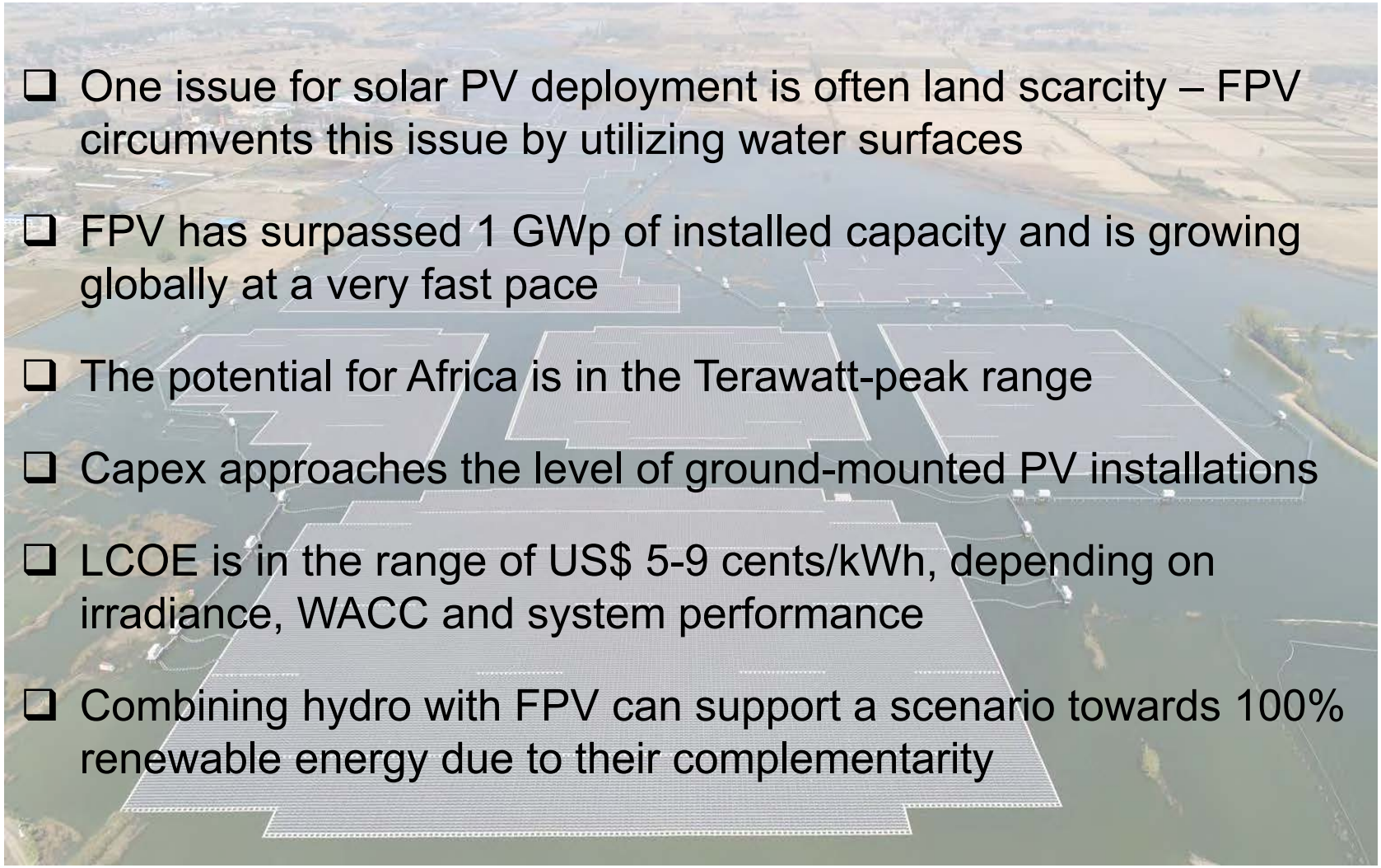

- One issue for solar PV deployment is often land scarcity – FPV circumvents this issue by utilizing water surfaces
- FPV has surpassed 1 GWp of installed capacity and is growing globally at a very fast pace
- The potential for Africa is in the Terawatt-peak range
- Capex approaches the level of ground-mounted PV installations
- LCOE is in the range of US$ 5-9 cents/kWh, depending on irradiance, WACC and system performance
- Combining hydro with FPV can support a scenario towards 100% renewable energy due to their complementarity

Picture: Ciel & Terre

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Thank you for your attention!

More information at
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We are also on:

ANNEXES

LCOE cost assumptions

	Ground-Mounted	Floating
System size (MWp)	50	50
System price (US$/Wp)	0.62	0.73
O&M costs (US$/Wp/year)	0.011	0.011
Yearly insurance (in % of system price)	0.3%	0.3%
Inverter Warranty Extension	Year 5: 20% of prevalent price Year 10: 45% of prevalent price Year 15: 60% of prevalent price ~US$ 0.004/Wp	Year 5: 20% of prevalent price Year 10: 45% of prevalent price Year 15: 60% of prevalent price ~US$ 0.004/Wp
D:E ratio	80:20	80:20
WACC	6% / 8% / 10%	6% / 8% / 10%
Debt premium (%)	4%	4%
Maturity of loan (years)	10	10
Surface lease cost (US$/year)	-	-
Inflation (%)	2%	2%
Years of operation	20	20

Source: SERIS

LCOE energy yield assumptions

Climate-related Assumptions	GHI (kWh/m2/year)	System Degradation Rate (%)	Ground-mounted PR (%)	Floating PR (%)	
				Conservative (+5%)	Optimistic (+10%)
Tropical	1,700	1.0	75.0	78.8	82.5
Arid/Desert	2,300	0.7	75.0	78.8	82.5
Temperate	1,300	0.5	85.0	89.3	93.5

Source: SERIS

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