Solar Energy Research Institute of Singapore

Smart Grid Floating Solar

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Solar Energy Research Institute of Singapore (SERIS)
National University of Singapore (NUS)

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National Research Foundation
Prime Minister's Office
Singapore

EDB singapore

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).

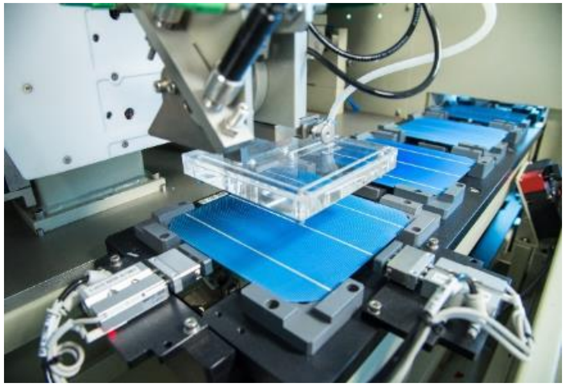
NUS National University of Singapore

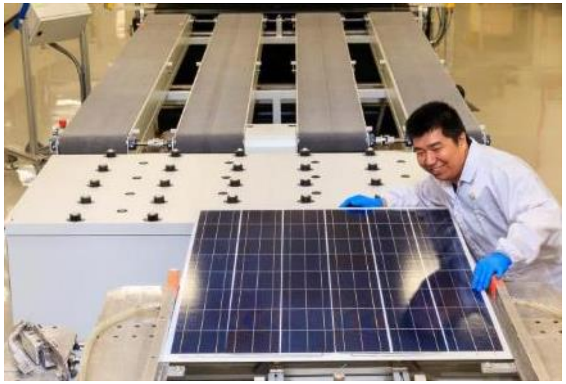
SERIS

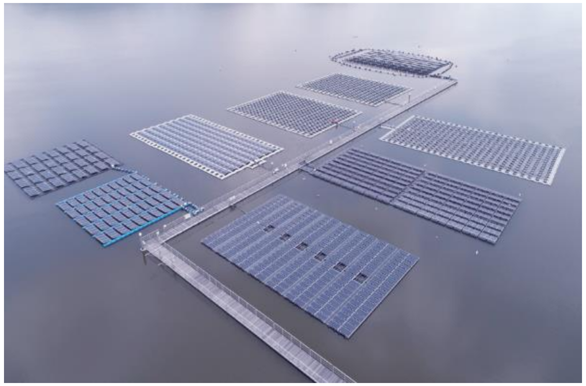
Solar Energy Research Institute of Singapore

- Founded in 2008; focuses on applied solar energy research
- Part of the National University of Singapore (NUS)
- Rapid growth (now > 200 people and > 6000 m^2 of space)
- 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)

Main R&D areas of SERIS







Solar cells:

- Silicon wafer solar cells (various cell architec-tures)
- Tandem solar cells on silicon (e.g. GaAs, perovskites)
- Characterisation & simulation

PV modules:

- Module development
- Module testing (indoor & outdoor)
- Module certification
- Characterisation & simulation

Solar systems:

- System technologies, incl. Floating PV
- PV grid integration
- Solar potential & energy meteorology
- Urban Solar, incl. BIPV
- Quality assurance of PV systems
- Solar thermal systems

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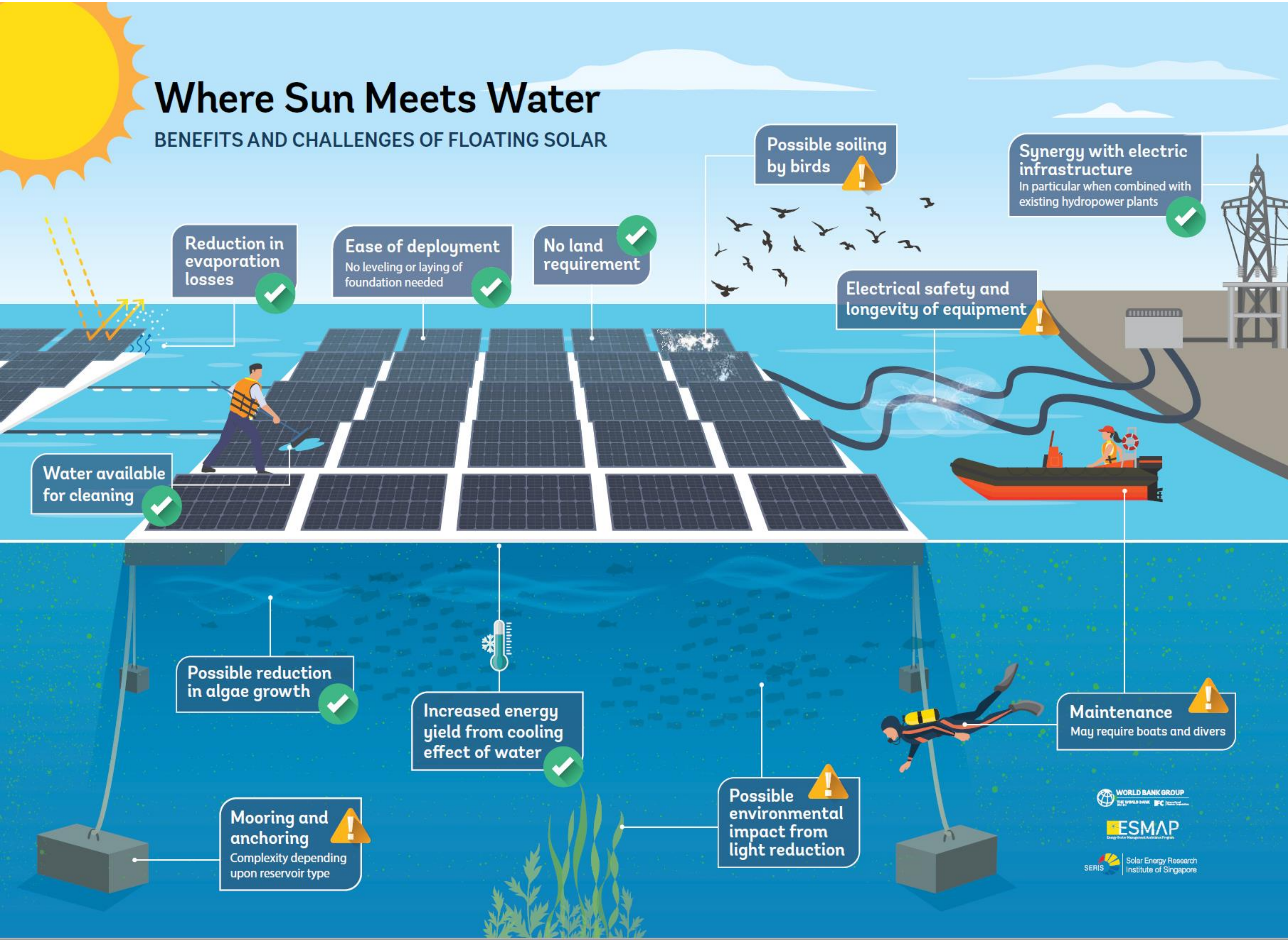

Where Sun Meets Water
BENEFITS AND CHALLENGES OF FLOATING SOLAR
Reduction in evaporation losses
Ease of deployment
No leveling or laying of foundation needed
No land requirement
Possible soiling by birds
Synergy with electric infrastructure
In particular when combined with existing hydropower plants
Electrical safety and longevity of equipment
Water available for cleaning
Possible reduction in algae growth
Increased energy yield from cooling effect of water
Mooring and anchoring
Complexity depending upon reservoir type
Possible environmental impact from light reduction
Maintenance
May require boats and divers
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The largest floating PV plants

40 MWp, Huainan, Anhui

150 MWp, Huainan, Anhui

18MWp, Gunsan Retarding Basin, South Korea

8.5MW, Sanshan, Wuhu, Anhui

Coal mining subsidence area, Huainan, Anhui

Image sources: Google Map, Scotra and Sungrow press release.

China's collapsed coal mines turned into a solar opportunity

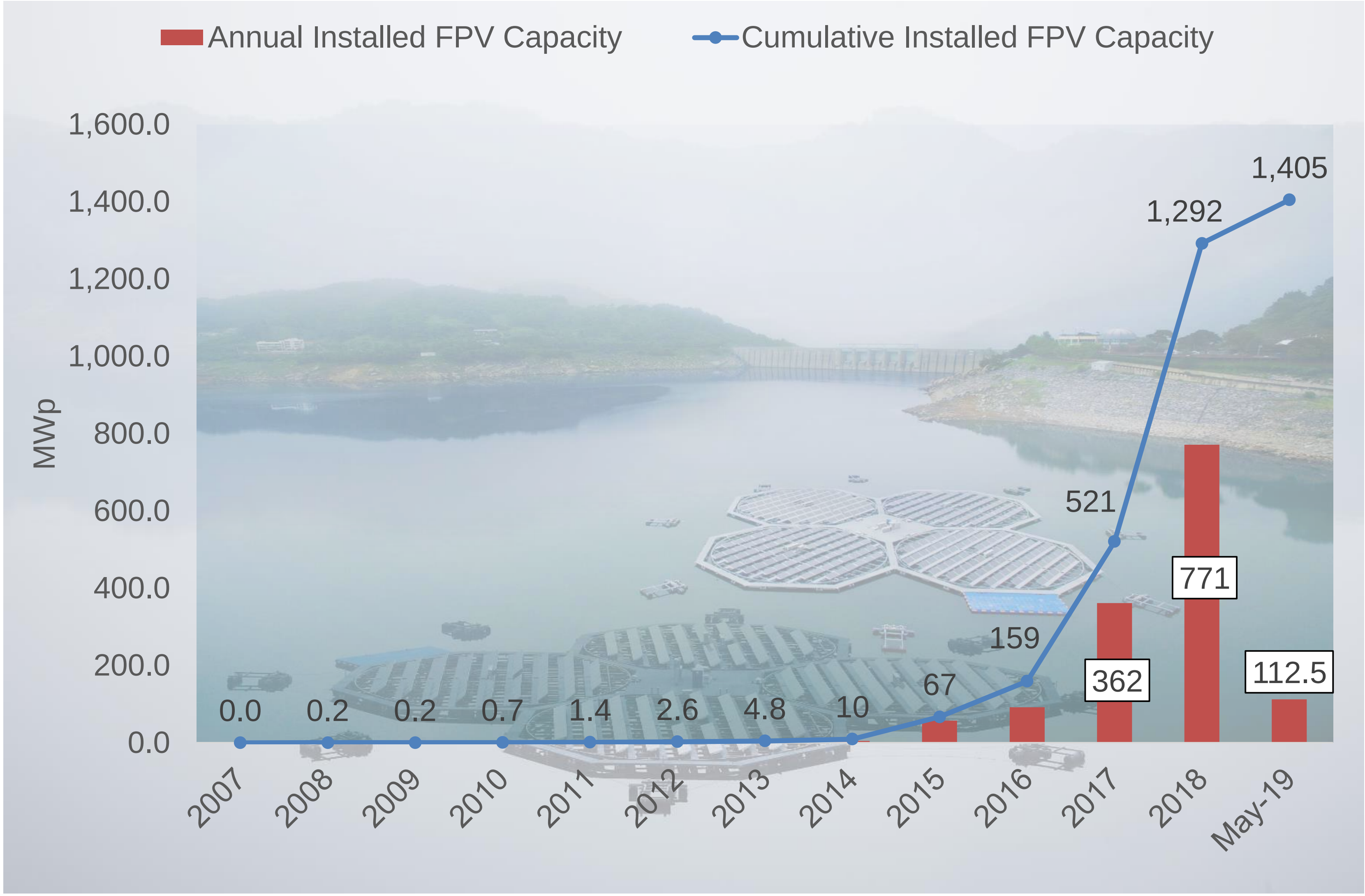
There are dozens of flooded coal mines in China. Spurred by China's "Top Runner" program, solar developers are turning these environmental and social disasters into an opportunity. Anhui Province is home to the world's largest floating solar installations to date, ranging from 20 megawatts (MW) to 150 MW per site.

Local people who just a few years ago worked underground as coal miners are now being retrained as solar panel assemblers and maintenance personnel. They are earning better wages and are no longer exposed to harmful mine conditions known to cause lung disease.

Producing solar power in mining regions while scaling back coal-based power production is one way to improve local air pollution issues in several regions of China.

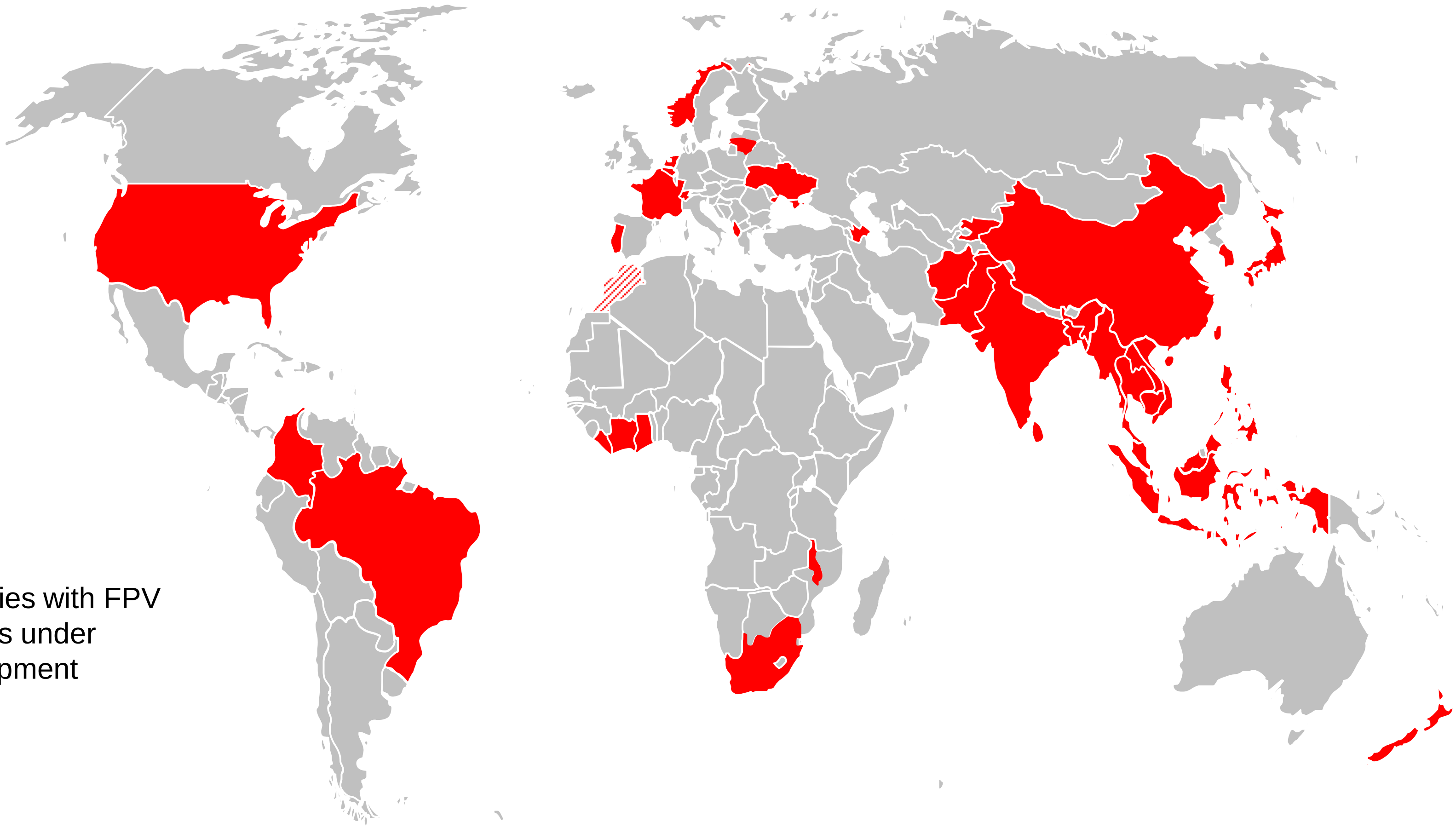
Source: Authors' compilation based on Mason (2018) and BBC (2018).

~1.4 GWp FPV installed worldwide



Source: SERIS. Picture: K-Water

Current pipeline is growing fast

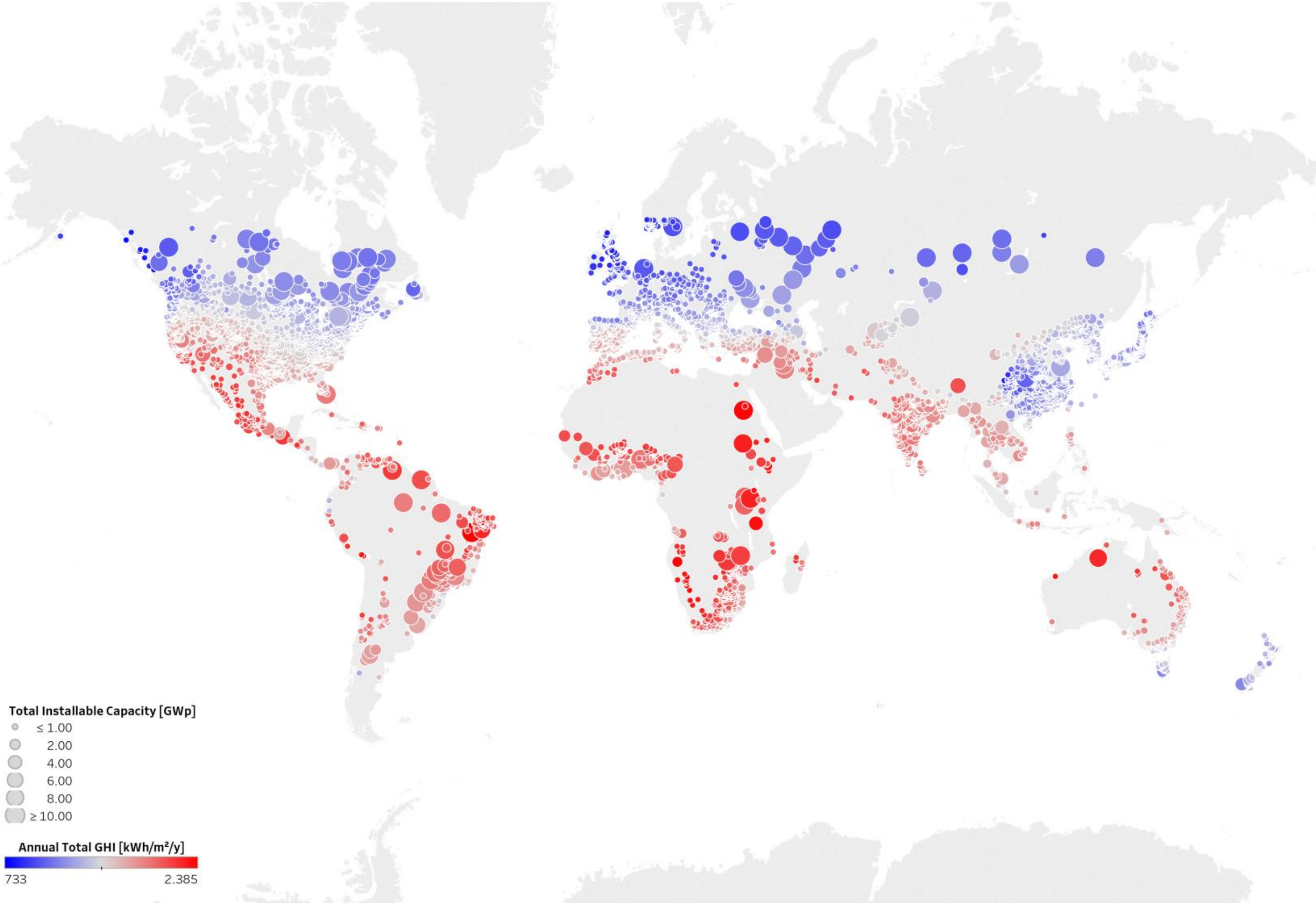


Countries with FPV projects under development

With more than 10 GW planned worldwide

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)

FPV hybrid with hydropower stations

Examples for Floating PV additions

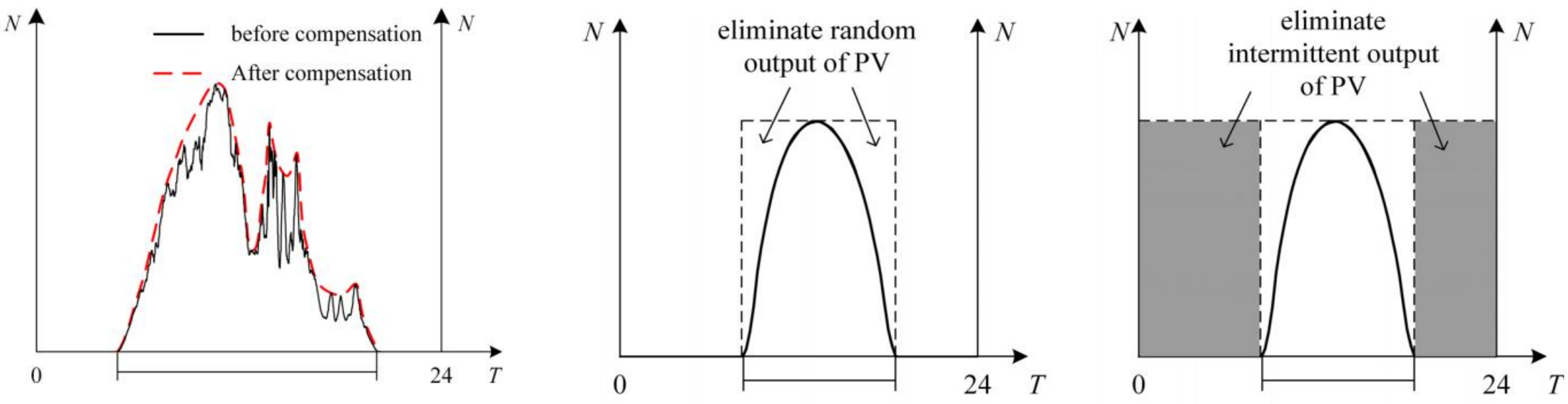
Example Dam/Reservoir	Region	Reservoir Size	Hydro Power	Area Fraction Required to add same Power of Floating Solar
Narmada Dam	**India**	**375 km^2**	**1.5 GW**	**4%**
Bakun Dam	**Malaysia**	**690 km^2**	**2.4 GW**	**3%**
Lake Volta	**Ghana**	**8500 km^2**	**1.0 GW**	**<1%**
Guri Dam	**Venezuela**	**4250 km^2**	**10.2 GW**	**2%**
Itaipu	**Brazil**	**1300 km^2**	**14.0 GW**	**11%**
Sobradinho "Lake"	**Brazil**	**4220 km^2**	**1.0 GW**	**<1%**
Xiluodu Dam	**China**	TBD **km^2**	**13.8 GW**	TBD
Three Gorges Dam	**China**	**1000 km^2**	**22.0 GW**	22%
Aswan Dam	**Egypt**	**5000 km^2**	**2.0 GW**	**<1%**
Attaturk Lake and Dam	**Turkey**	**820 km^2**	**2.4 GW**	**3%**

Complimentary FPV and hydropower

Joint operation of Floating PV and hydropower station

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

⇒ Use the reservoirs as "giant battery"



FPV supplier-base is growing fast

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Scotra
LS 산전
K2 systems
jntech
MIBET ENERGY
NET NorthMan Energy Technology 诺斯曼能源
SUMITOMO MITSUI CONSTRUCTION CO.,LTD.
LG CNS
isifloating FLOATING SOLAR SYSTEM by isigenere
KYORAKU
SUNGROW
Koinè MultiMedia
Upsolar
SOLARISFLOAT
Ciel & Terre
中能众诚 ZHONGNENG ZHONGCHENG
Ocean Sun
Oceans of Energy
AQUA-PV.COM
mossmaritime
SCG CHEMICALS
Swimsol
NRG ENERGIA
旭東環保科技股份有限公司 SUN RISE E&T CORPORATION
ZIMMERMANN PV-Stahlbau
ADTECH SYSTEMS LIMITED
PROFLOATING
C.I. TAKIRON
4C SOLAR, INC.
SUNENGY
Sunfloat®
SOLARIS SYNERGY
FLOATING SOLAR B.V.

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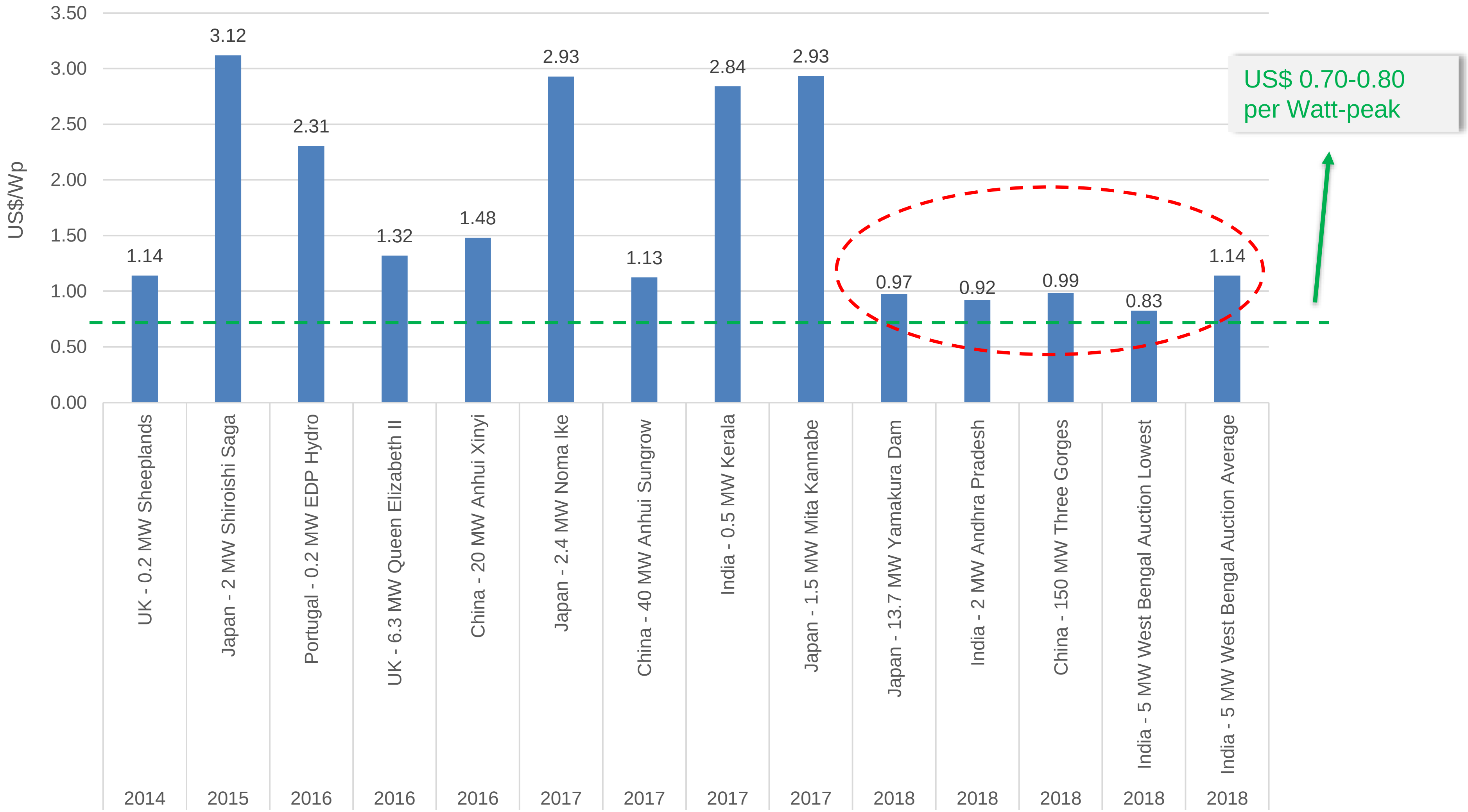
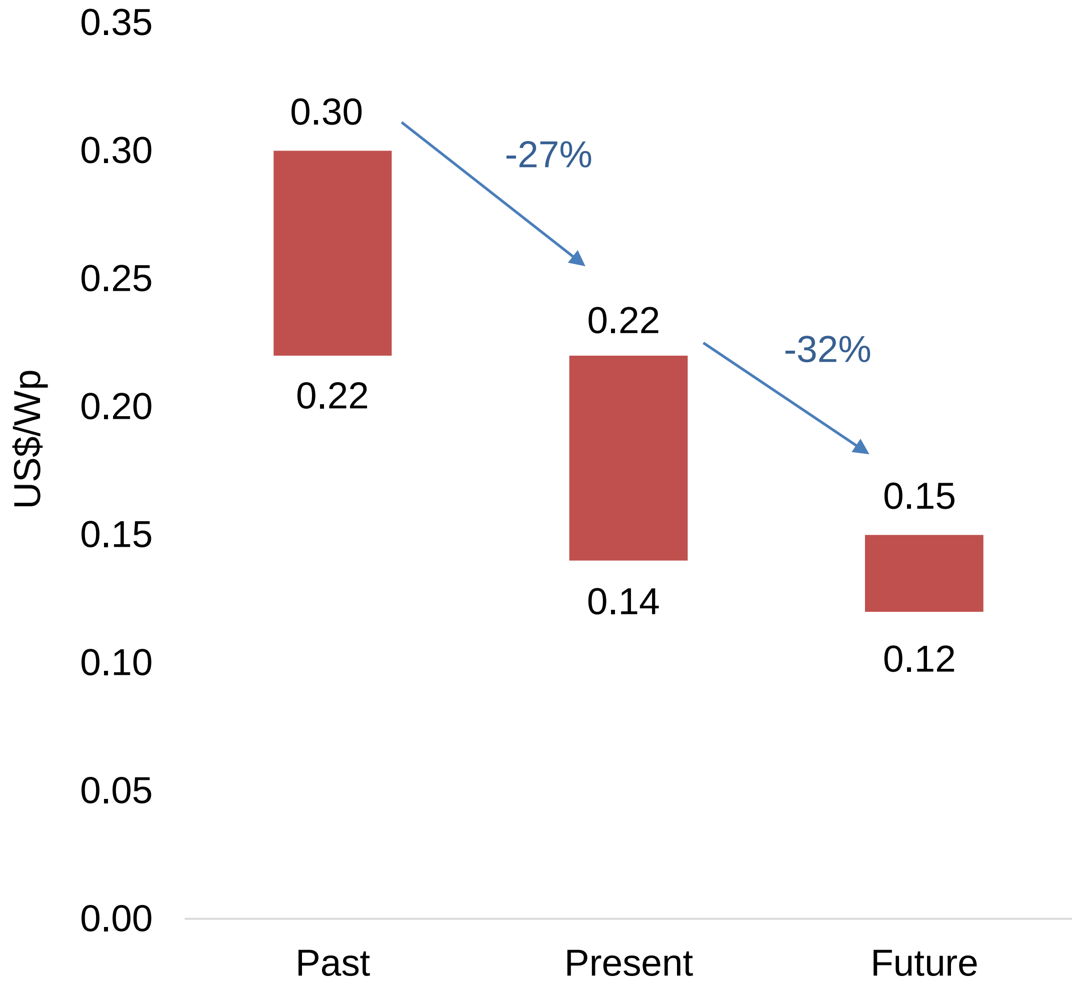
‘Realized’ capex developments



Source: SERIS

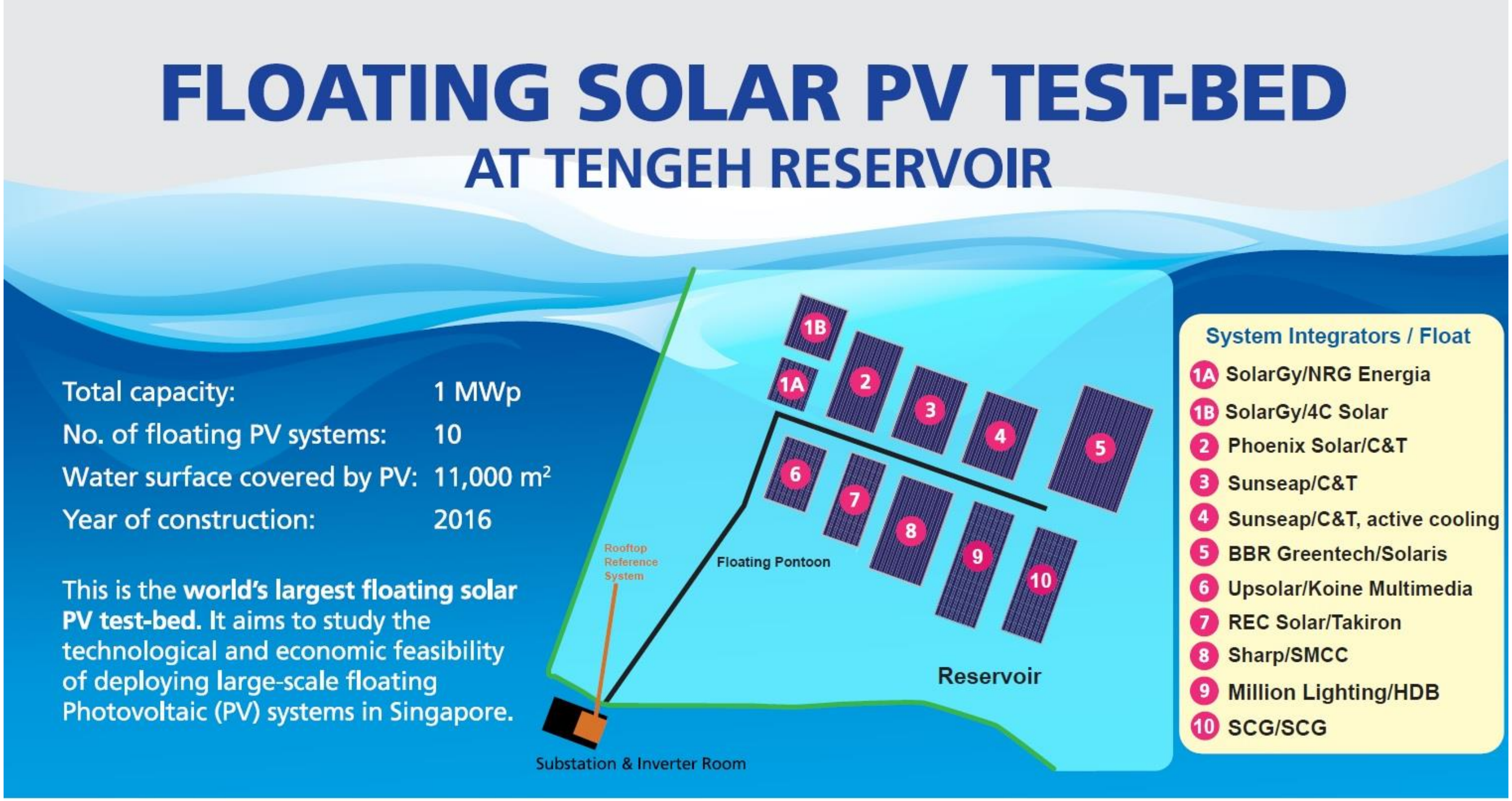
Floating structure costs decline in Asia



Source: SERIS

The Singapore floating PV Testbed

- Total capacity ~ 1 MWp



Project collaborators: PUB Singapore's National Water Agency; EDB Singapore; NUS National University of Singapore; SERIS Solar Energy Research Institute of Singapore

Testbed design and objectives

- ❑ Large scale FPV testbed
- ❑ Side-by-side comparison of major commercial FPV technologies
- ❑ Detailed monitoring
  - ➢ Environment
  - ➢ Energy yield
  - ➢ Module temperature
  - ➢ Bi-facial module
  - ➢ Active cooling
- ❑ Economics, LCOE

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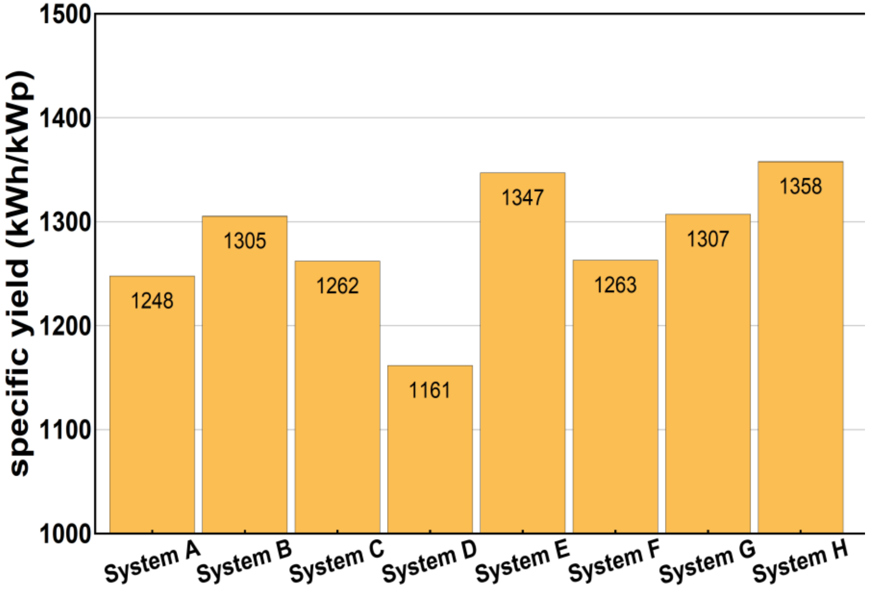
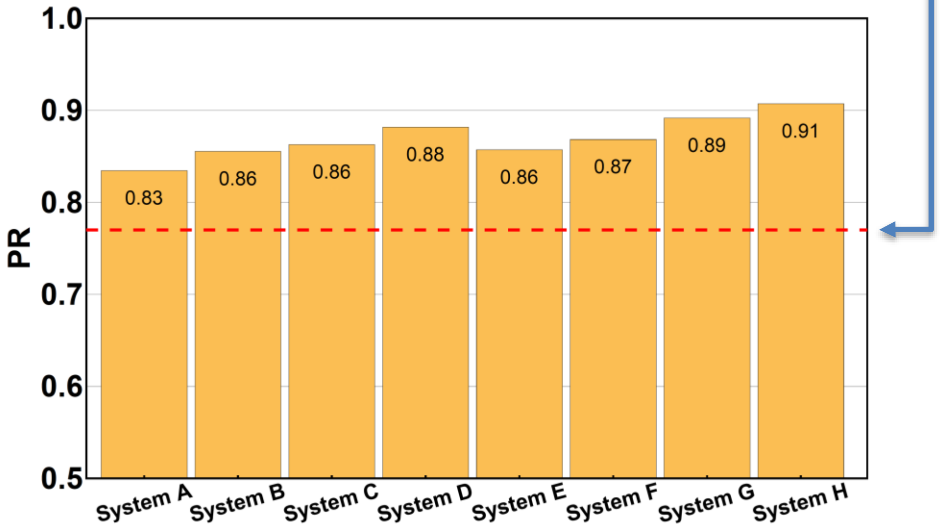
Specific yield and PR

For the first year

Yearly insolation=1601 kWh/m²



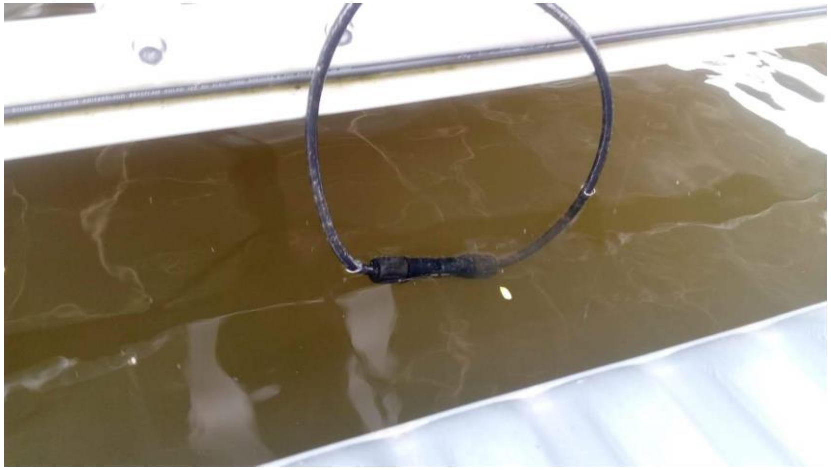
Average rooftop system in Singapore

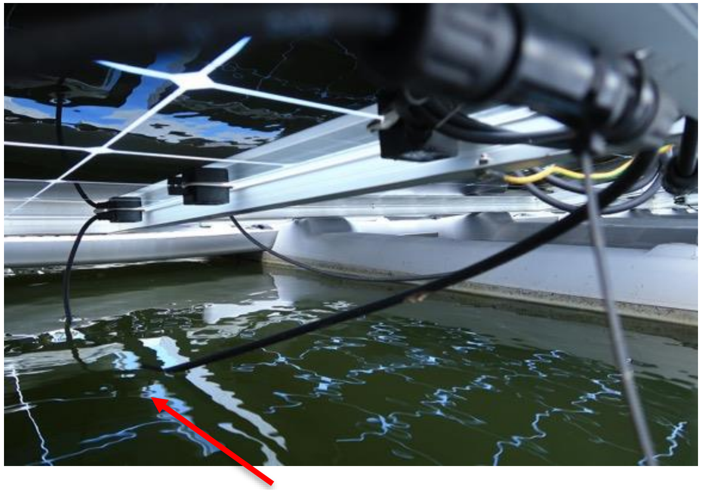


Excluding major downtime

Cables or connectors touching water

- Causes
  - Low clearance from water surface as well as mismatch in module cable length and floats dimension.
  - Waves due to wind or boat
- Consequences
  - Leakage and low insulation resistance
  - Degradation (corrosion) of cables

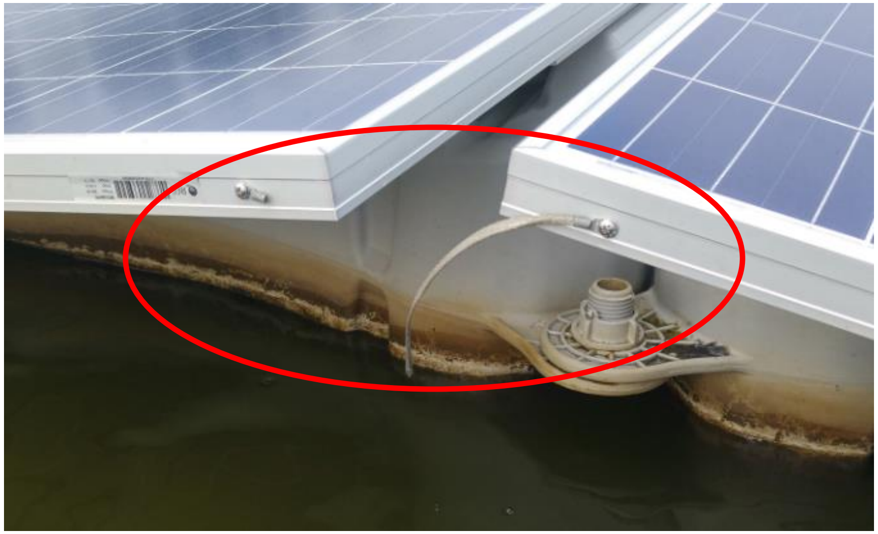


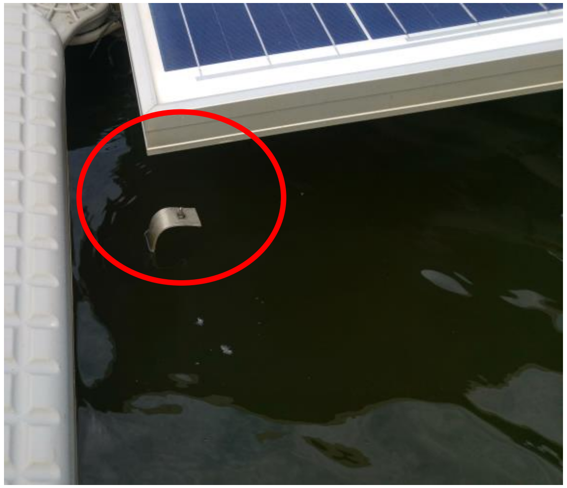


- Recommendation: better cable routing, matching module & float dimensions

Breakage of connecting parts

- Mechanical stress
  - At the joints of rigid structures
  - On equipotential bonding tape/wire
  - At the earthing tape connection for grounding

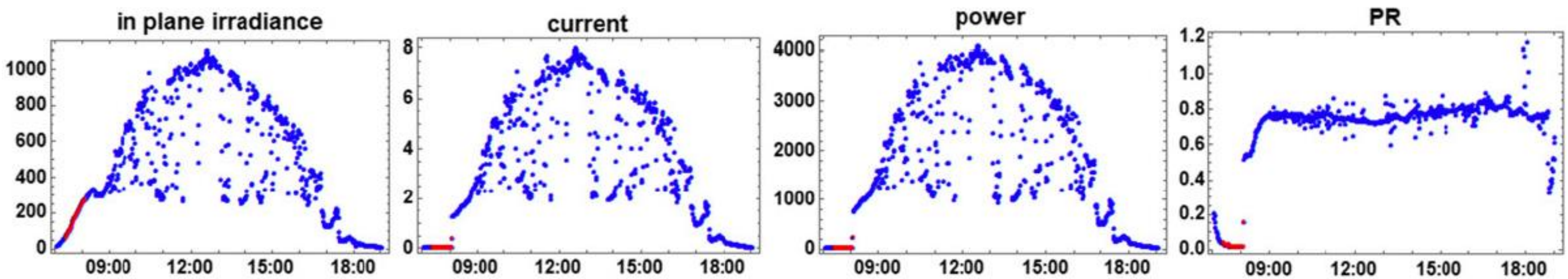




Insulation resistance issues

Inverters starting late

- Insulation faults observed for some systems
  - The insulation resistance (R_{iso}) is low for some floating PV strings.
  - Inverters measure R_{iso}. When R_{iso} does not meet the preset threshold, inverters do not start.
  - Result: inverters start late (till the R_{iso} limit is passed) and thus loss of energy.



Animal visits

Soiling – from bird droppings

- Bird droppings observed on floating PV modules
  - Partial shading
  - Reduced performance, less energy yield
  - Cell reserve biased, hot spots, => can lead to accelerated module degradation

Singapore floating PV Testbed

- Possible solutions
  - Part of the O&M routine (i.e. immediate actions / cleaning)
  - Barrier methods
  - Non-barrier methods
    - Ultrasonic, Sonic Repeller
    - Visual Scare Device

Queen Elizabeth II reservoir, UK

Other potential issues

Due to proximity to water, high humidity

- Potential Induced Degradation (PID)
  - Anti-PID modules preferred
- Corrosions (more aggravated for off-shore environments)
  - Combiner boxes
  - Inverters
  - Metal supporting structures
- Risk of solar cables submerged in water
  - Electrical safety, earth leakage
  - Performance drop, system downtime
- Structural
  - Anchoring / mooring needs to be carefully assessed during feasibility study

⇒ ***Highly valuable results from this testbed shall lead to new technical standards for Floating PV (via IEC TC 82)***

First off-shore FPV project in SGP

5 MWp capacity, directly connected to the Singapore power grid

- ❑ Likely world's largest off-shore floating PV system, size of 5 football fields
- ❑ Supported by the Singapore Economic Development Board (EDB)
- ❑ North of Woodlands Waterfront Park, along the Straits of Johor

Multiple uses for off-shore FPV

Example: Smart Floating Farms (SFF) with fish farming and crops

Source (picture): Smart Solar Farms

Collaboration with the WBG-ESMAP

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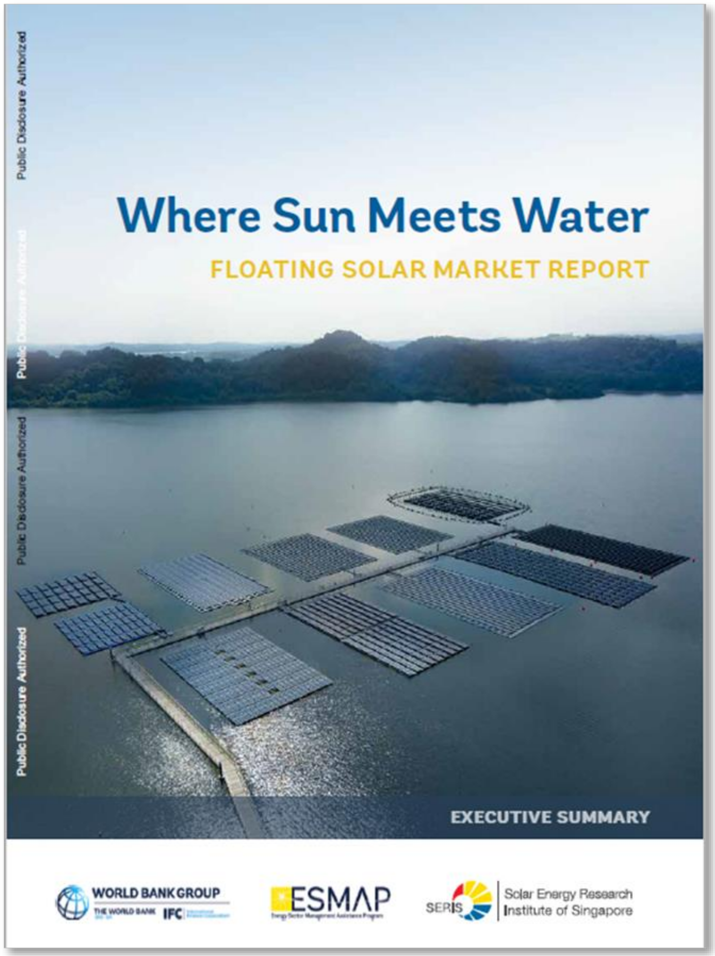

- ❑ Floating Solar Market Report

    1. Why floating solar?
    2. Technology overview
    3. Global market and potential
    4. Policy considerations and project structuring
    5. Costs of floating solar
    6. Suppliers of floating PV systems

Published: June 2019

- ❑ Practitioner Handbook

    1. Project development overview
    2. Initiation phase – Technical considerations
    3. Initiation phase – Financial and legal considerations
    4. Initiation phase – Environmental and social considerations
    5. Construction phase
    6. O&M phase

Published: October 2019

Collaboration with the WBG-ESMAP

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The newly released "Floating Solar" reports are freely available for download at the SERIS website:

Floating Solar "Market Report":
http://www.seris.sg/doc/publications/ESMAP_FloatingSolar_TEXT-A4-WEB.pdf

Floating Solar "Handbook for Practitioners":
http://www.seris.sg/doc/publications/ESMAP_FloatingSolar_Gde_A4%20WEBL-REV2.pdf

More info also under:
http://www.seris.sg/publications/scientific-publications.html

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More information at
www.seris.sg
www.solar-repository.sg

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