World's largest Floating Solar Testbed – Overview & Findings

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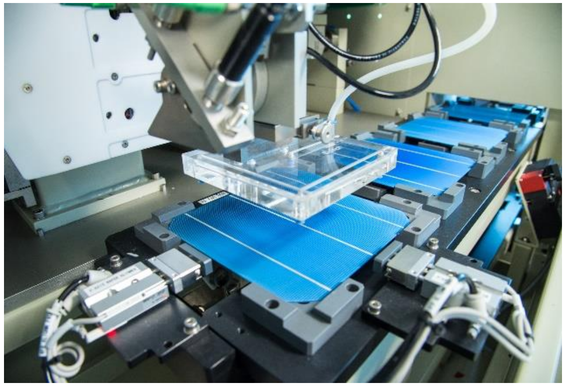
SERIS

Solar Energy Research Institute of Singapore

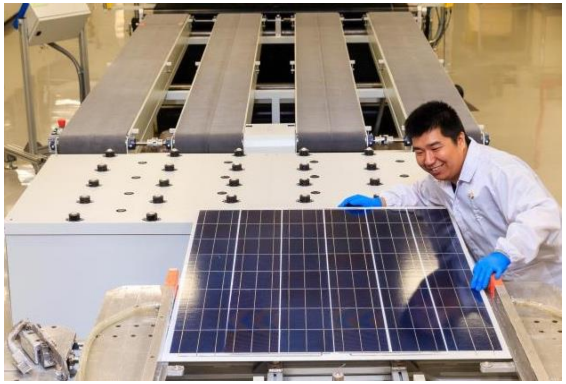
- Founded in 2008; focuses on applied solar energy research
- Part of the National University of Singapore (NUS)
- Rapid growth (now > 200 people and > 6000 m^2 of space)
- State-of-the-art laboratories
- R&D focus is on solar cells, PV modules and PV systems
- Specialised in professional services for 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 architectures)
- Tandem solar cells on silicon (e.g. GaAs, perovskites)
- Characterisation & simulation



PV modules:

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

PV 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

National Research Foundation
Prime Minister's Office
Singapore

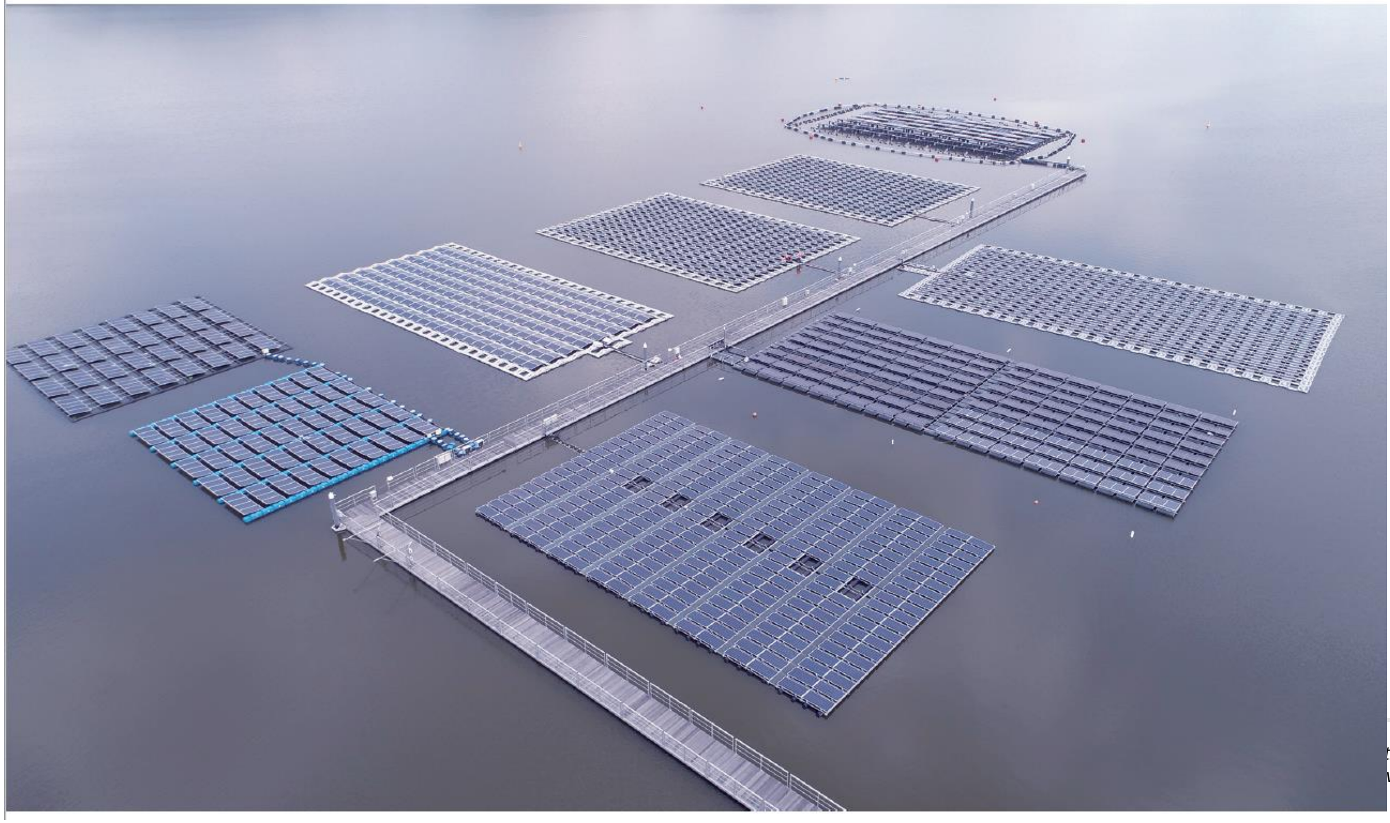
EDB singapore

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

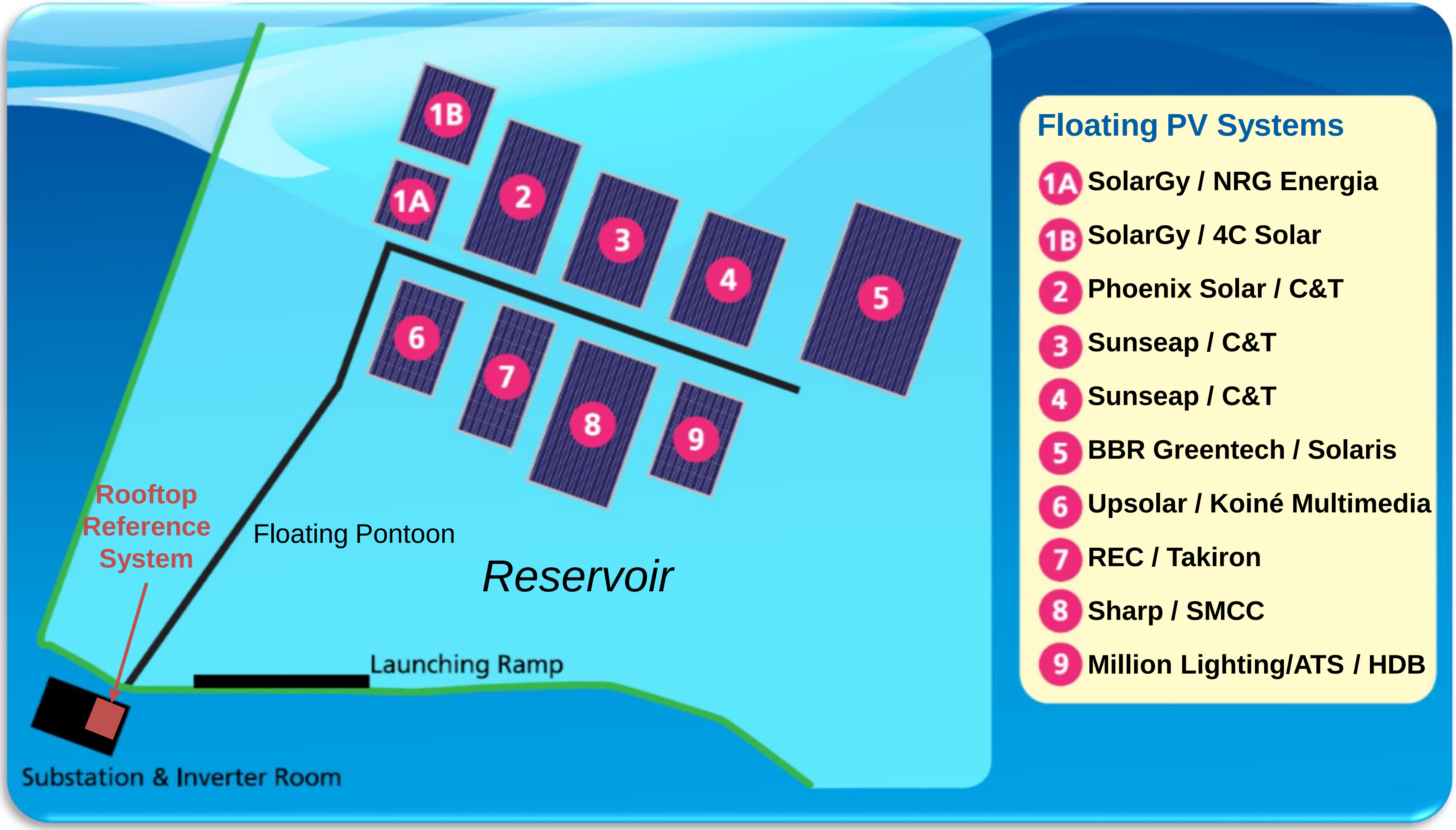
At the heart of floating solar: Singapore

Floating PV | Singapore operates the world's largest testbed for floating PV, comparatively testing and evaluating 10 different floating PV installations from around the world, and held the first floating solar conference globally in October 2017. Writing exclusively for *PV Tech Power*, Thomas Reindl of the Solar Energy Research Institute of Singapore (SERIS) reports on a form of solar power whose huge potential is starting to be realised



Floating PV Testbed

- Project Site Plan



Floating PV Testbed

- Large scale FPV test-bed
  - Side-by-side comparison of major commercial FPV technologies
  - Detailed monitoring of all FPV systems
    - Energy yield
    - Cooling effect
    - Bi-facial module
    - Active cooling
  - Economics, LCOE
  - Environmental impact
    - Water evap. losses
    - Water quality
    - Biodiversity

Floating PV Testbed

- Comprehensive monitoring infrastructure, with >500 parameters
  - Meteorological station (reservoir & rooftop)

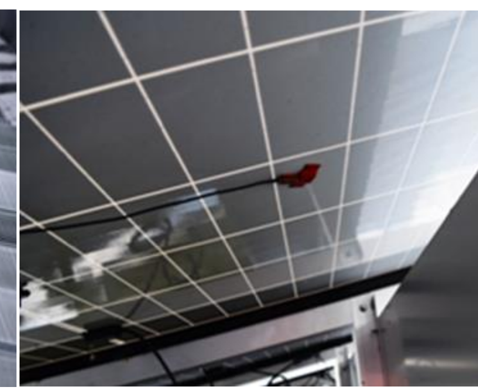



  - PV System performance monitoring

DC (PV String)

AC (PV array)

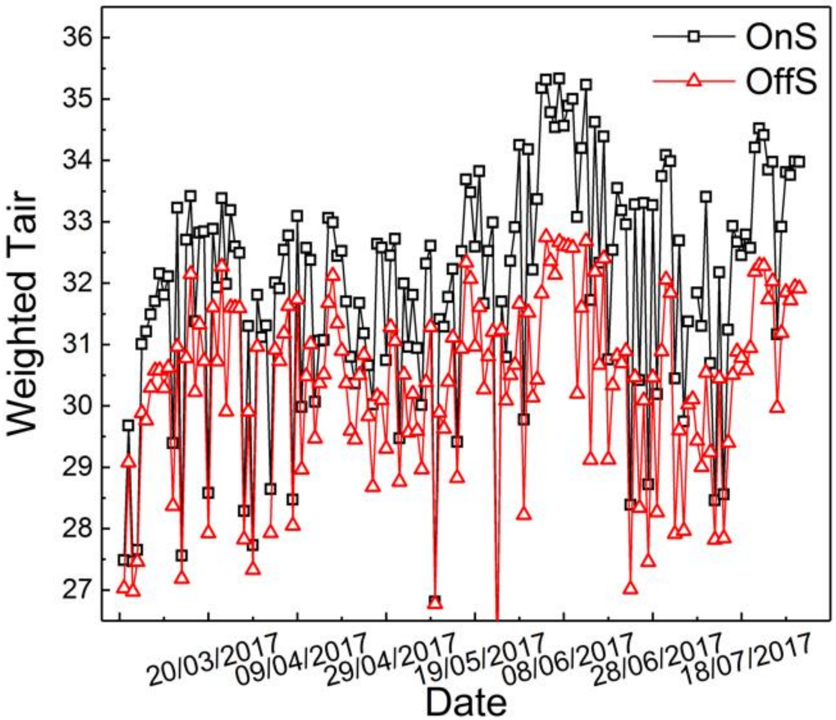
Motion sensor

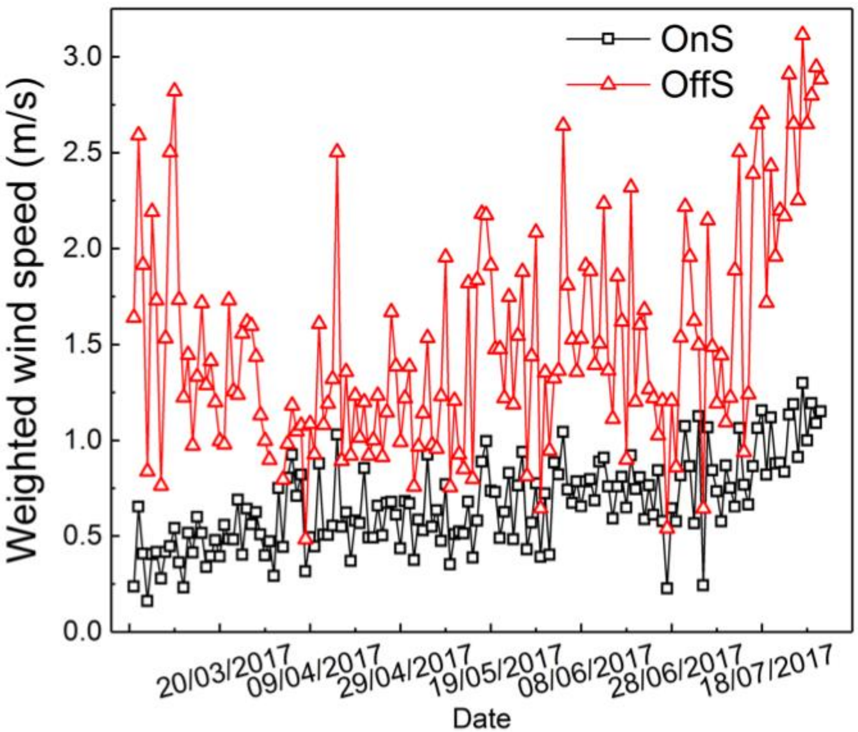


Module Temp.

Testbed operating conditions (1)

- ❑ Ambient temperatures
  - ➢ $T_{ambient}$ on water (vs. rooftop) is consistently lower
- ❑ Wind Speed
  - ➢ Wind speed on water (vs. rooftop) is generally higher

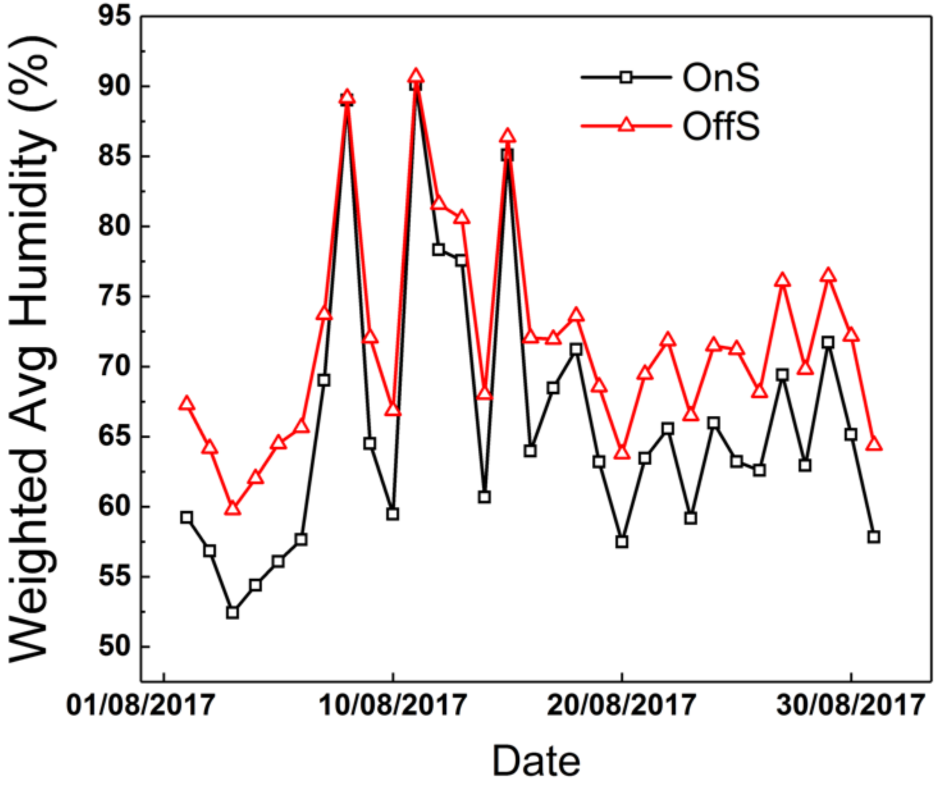




Testbed operating conditions (2)

❑ Humidity

- Humidity on water is generally higher

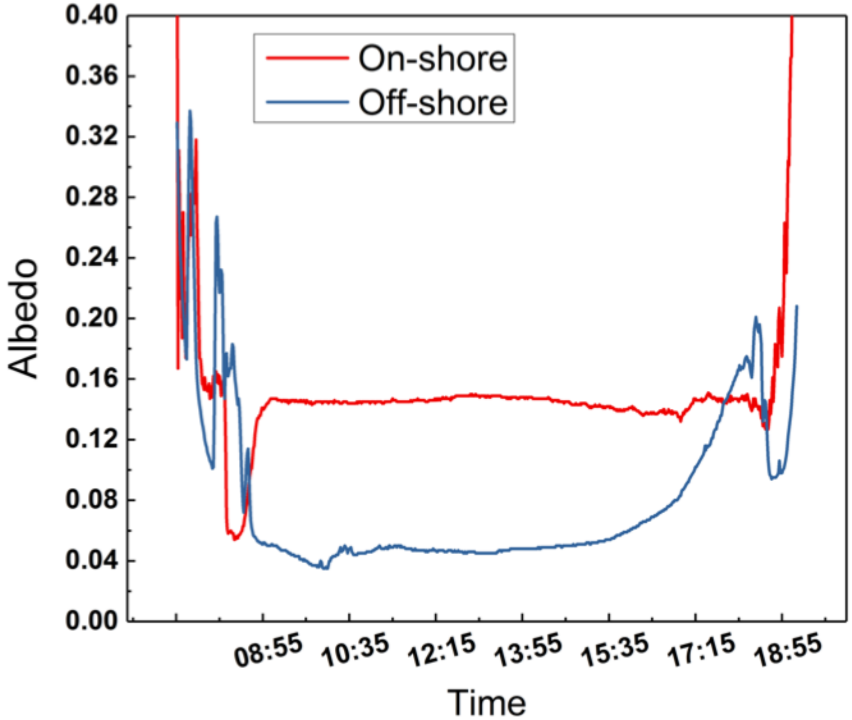


Testbed operating conditions (3)

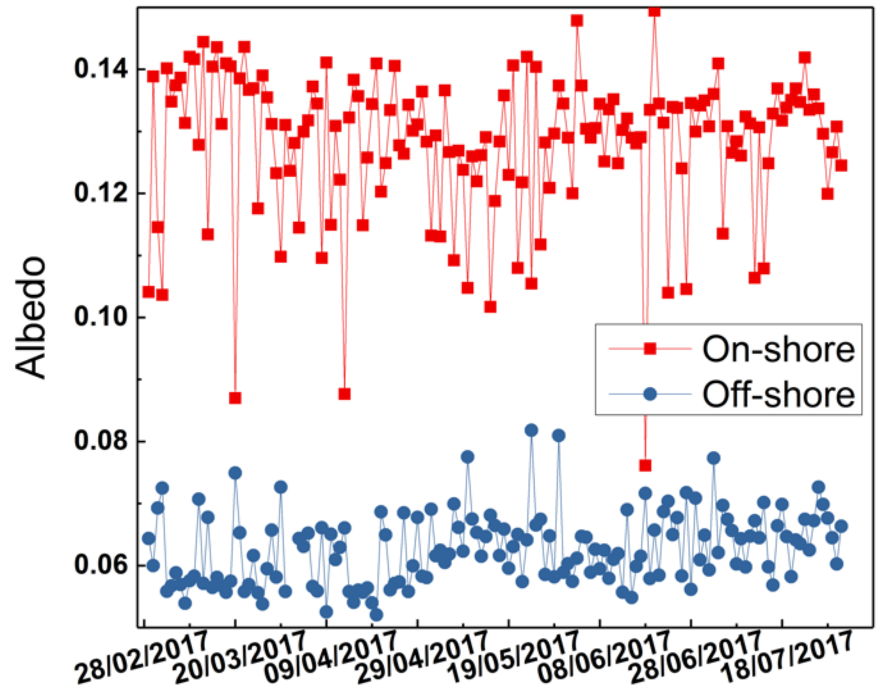
❑ Albedo

➢ Albedo of water surface is rather small, 5~6% measured

Albedo for 15 Mar 2017

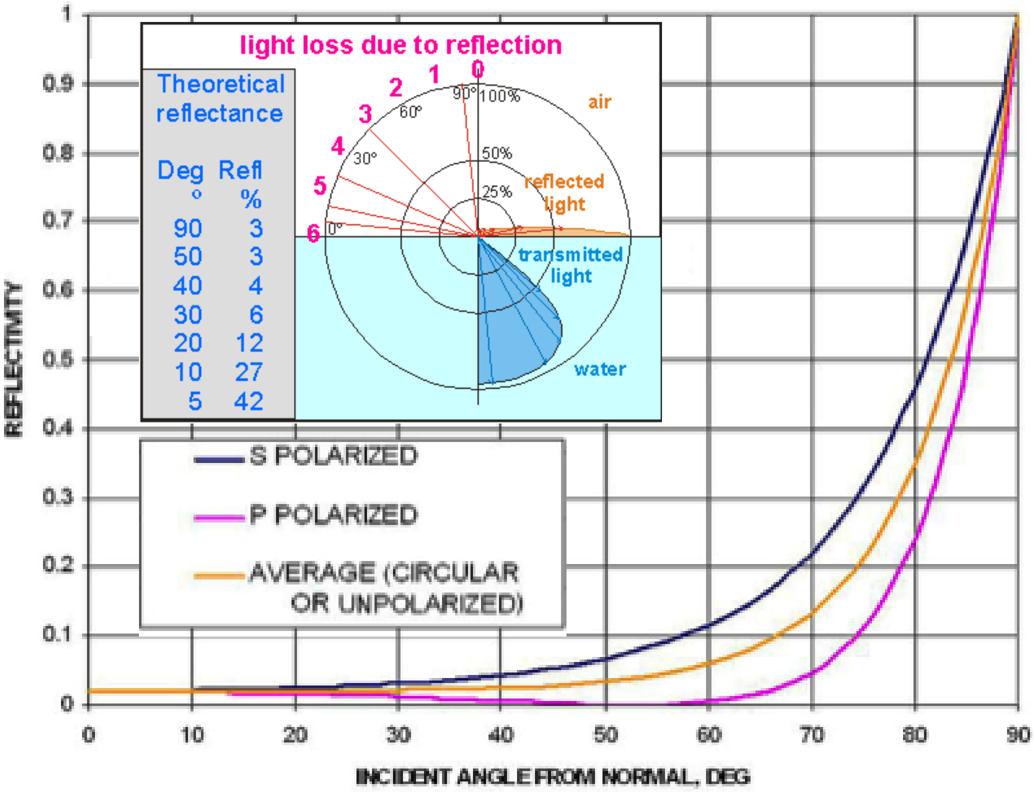


Daily average

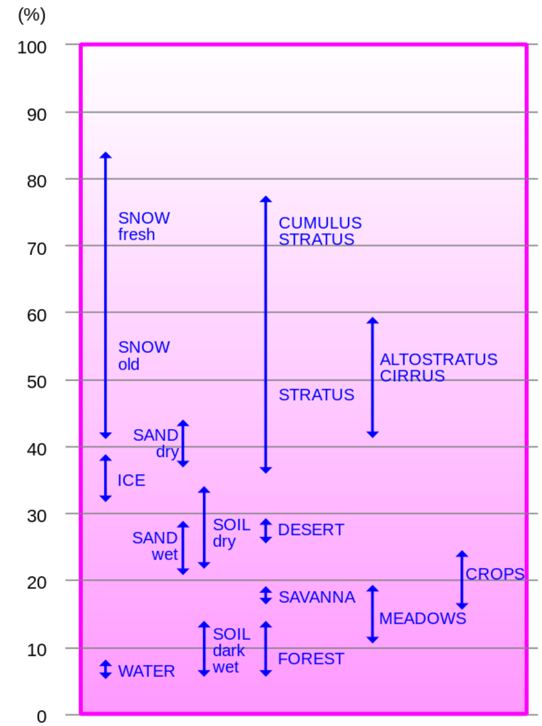


Testbed operating conditions (4)

- Albedo
  - Water surface reflectivity is usually less than 10% at high incident angles (around 3 ~ 6% according to most reported measurements).

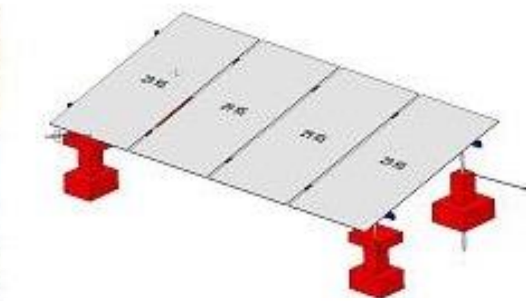


Reflectivity of smooth water at 20 °C (refractive index=1.333)



Source: Wikipedia

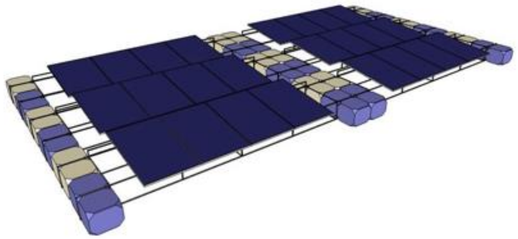
Cooling effect comparison



Free Standing

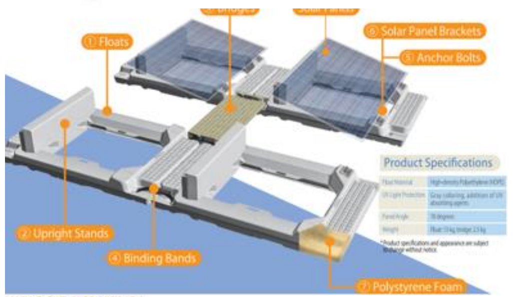
Minimized Footprint on water

Very Good convective cooling



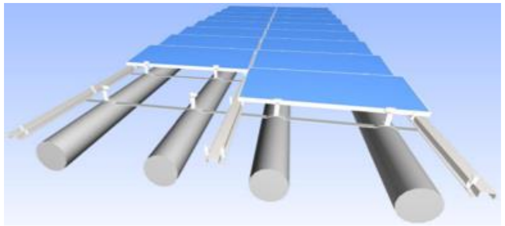
Small Footprint on water

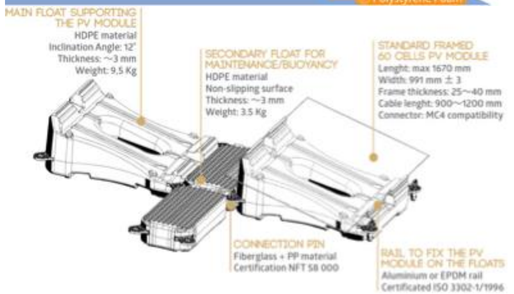
Good convective cooling



Large Footprint on water

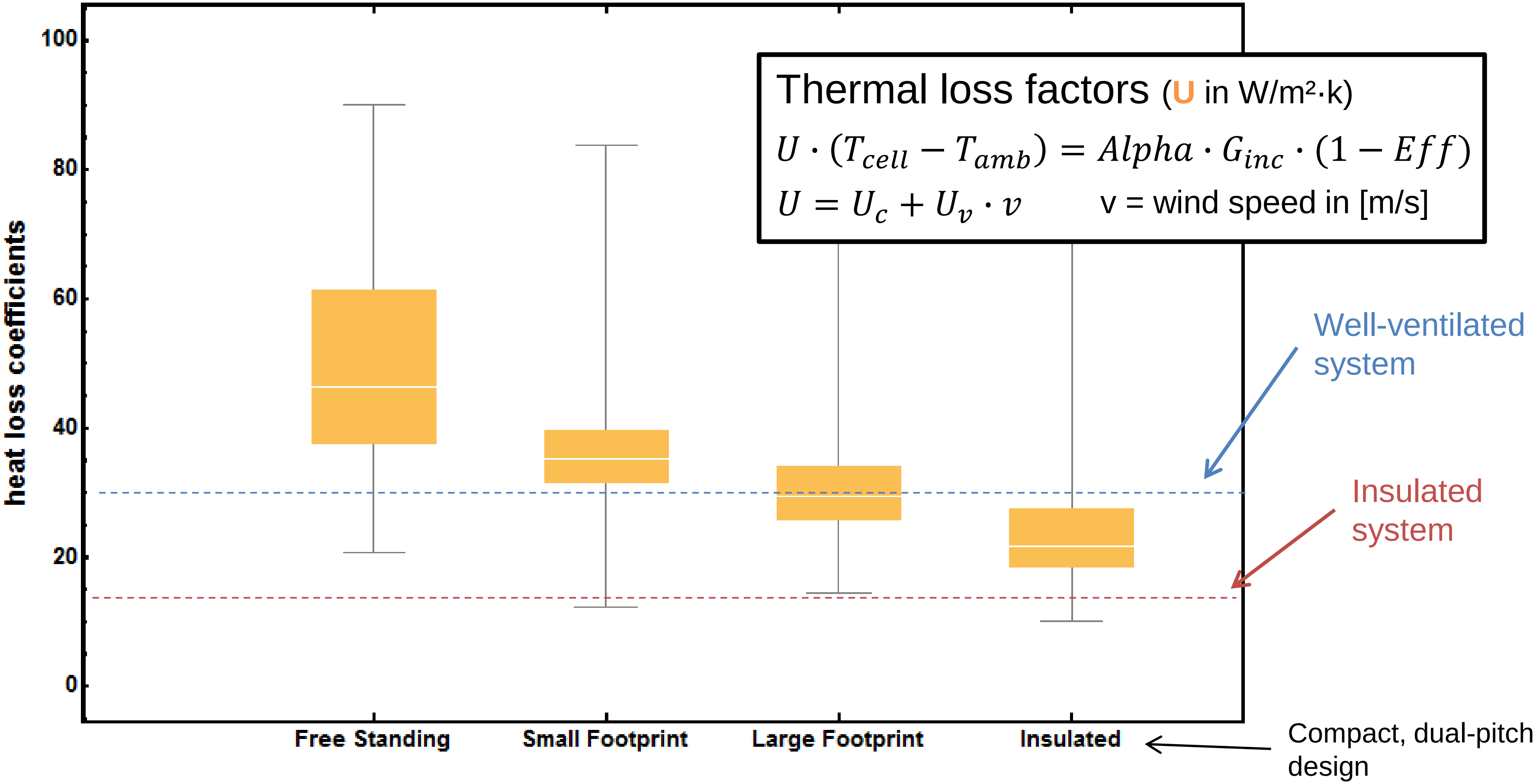
Water surface partially blocked





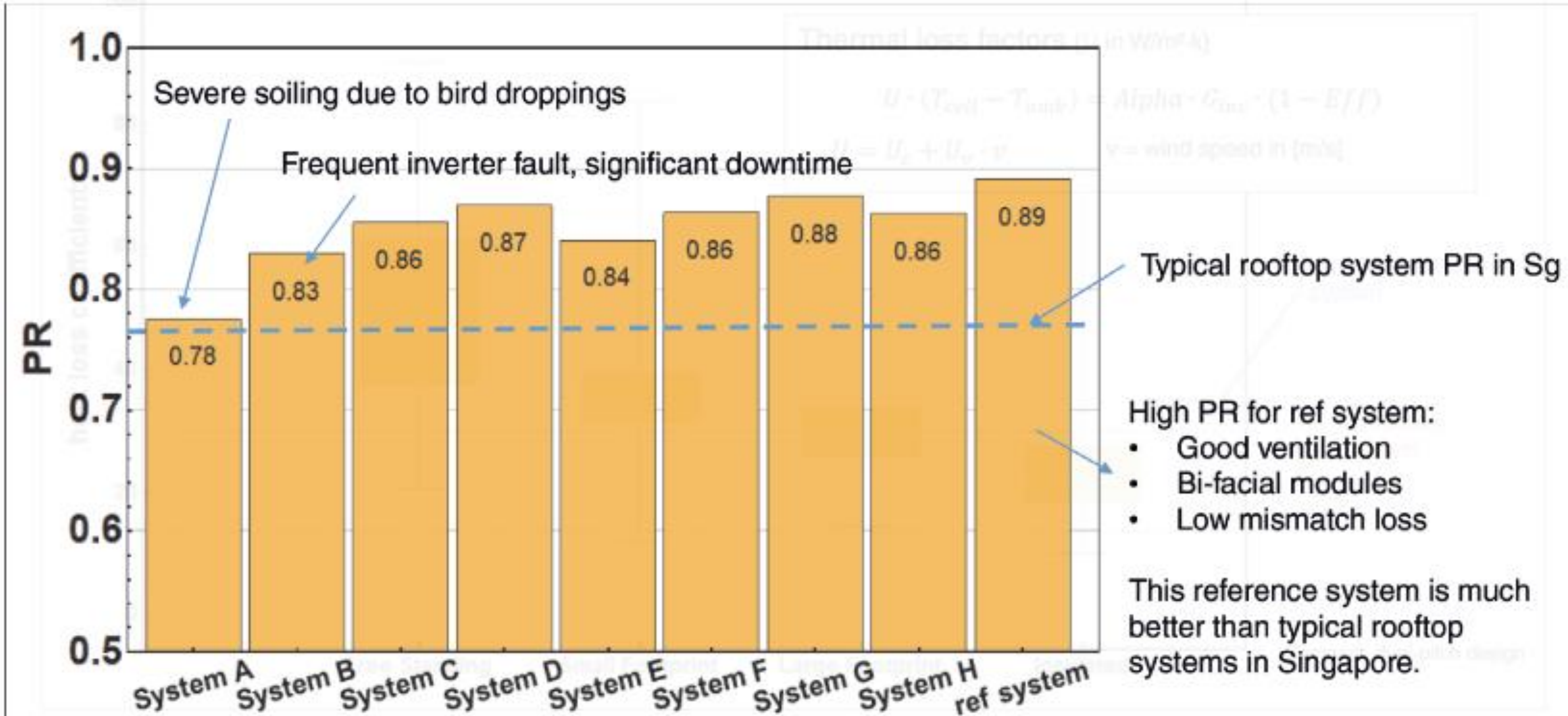
Module cooling

- Cooling effect (indicated by heat loss coefficient) is dependent on floating structure.



Testbed system performance (1)

- FPV system performance ratio (from Apr 2017 to Mar 2018)
  - Up to about 10-15% higher than typical rooftop PV systems in Singapore (with PR of 75 ~ 80%)

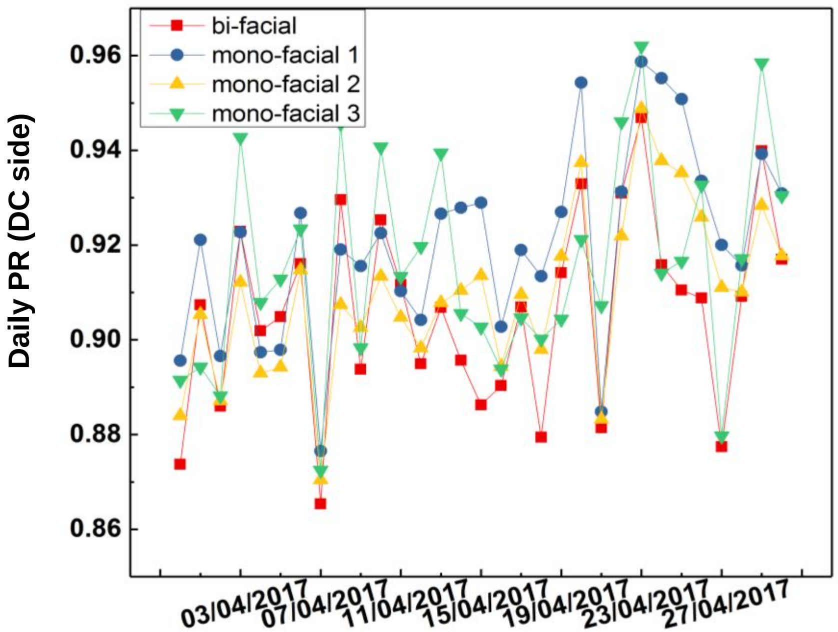


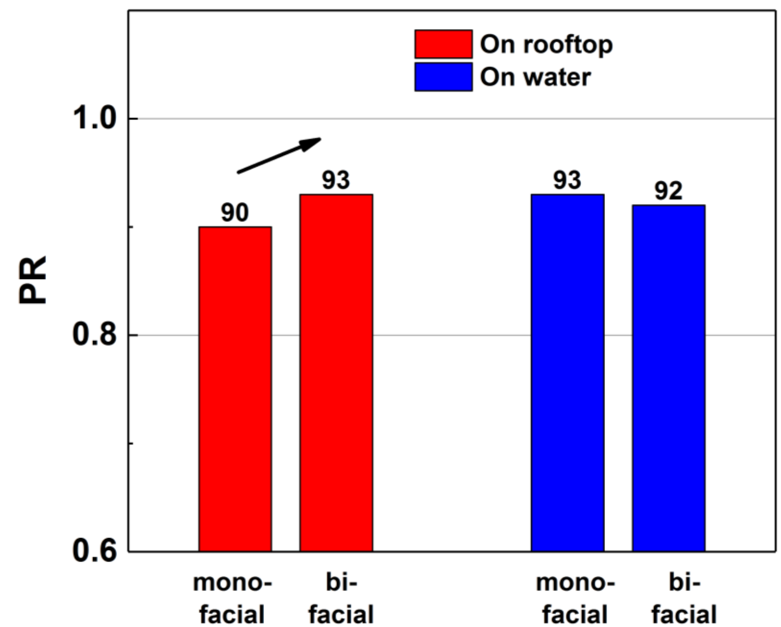
System numbering is reordered for anonymity

Testbed system performance (2)

- Bifacial modules
  - On rooftop, bi-facial string outperforms mono-facial strings
  - On water, bi-facial string does not seem to outperform mono-facial strings, due to low albedo on water
  - However, bi-facial might have benefit in the long term (dual glass, slower moisture ingress)

Bifacial string vs. mono-facial strings





Issues encountered (1)

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

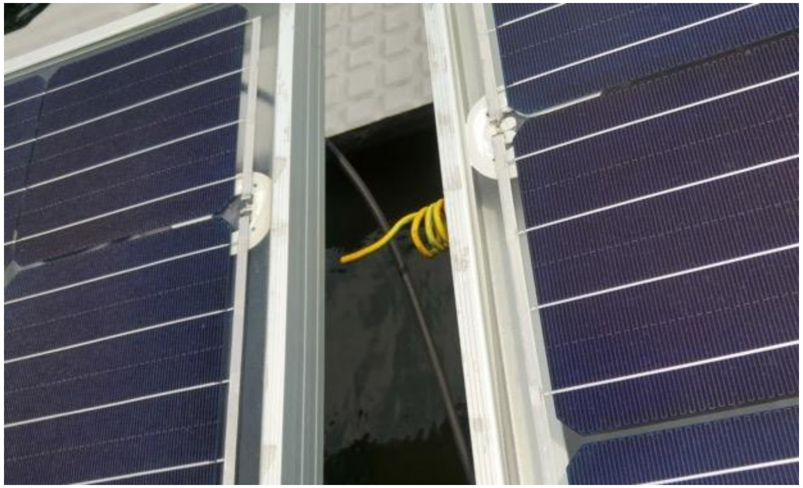
- Solutions
  - Part of the O&M routine (i.e. immediate actions / cleaning)
  - Barrier methods
  - Non-barrier methods
    - Ultrasonic, Sonic Repeller
    - Visual Scare Device

Queen Elizabeth II reservoir, UK

Issues encountered (2)

Constant movement of floating platform

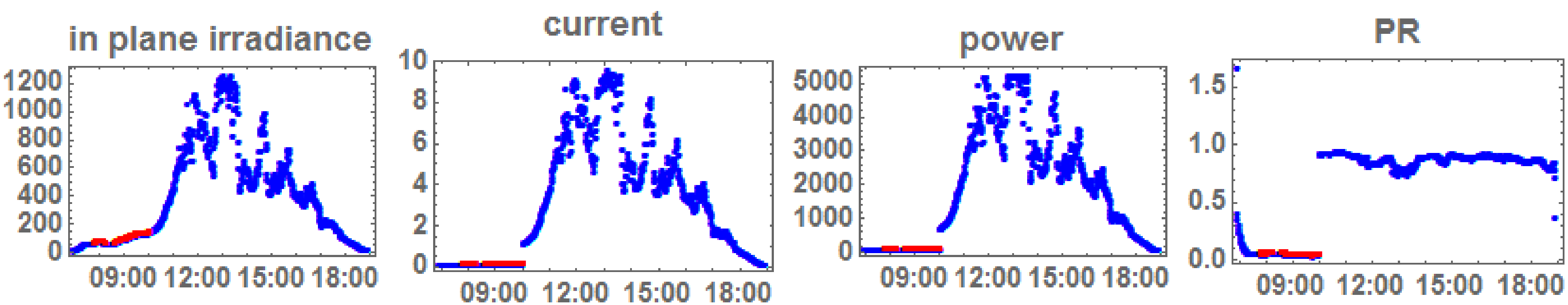
- Mechanical stress
  - At the joints of rigid structures
  - On equipotential bonding tape/wire
  - At the earthing tape connection for grounding



Issues encountered (3)

Insulation faults

- Insulation test failure for inverters
  - The insulation resistance (R_{iso}) dropped over time for floating PV strings
  - Inverters measure R_{iso}. When R_{iso} does not meet the preset threshold inverters do not start.
  - Common result: inverters start late (till the R_{iso} limit is passed).



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)***

THE SECOND

INTERNATIONAL FLOATING SOLAR SYMPOSIUM

SAVE THE DATE !

31 Oct 2018 – 1 Nov 2018

Marina Bay Sands Convention Centre, Singapore

2 Nov 2018

SERIS (Solar Energy Research Institute of Singapore)
Workshops, lab tour and visit to the world's largest Floating PV testbed

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More information at
www.seris.sg
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