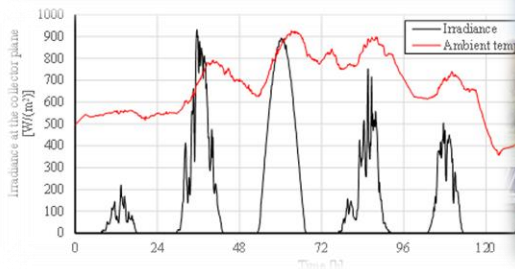
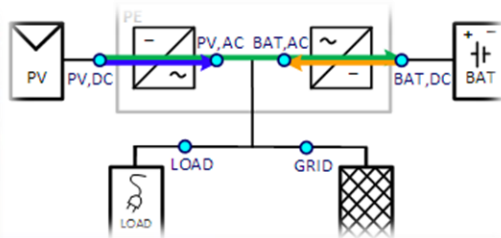
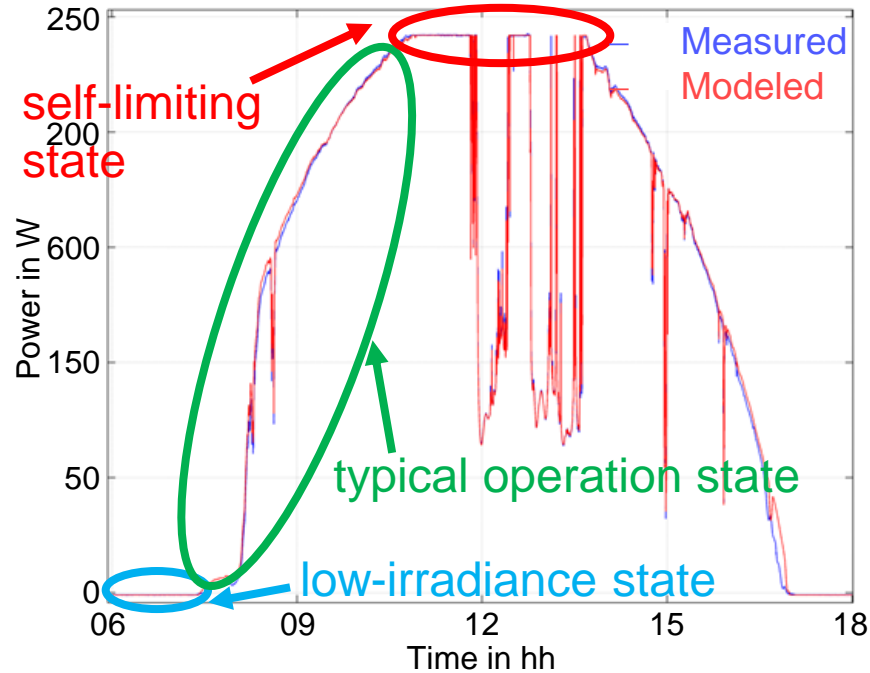


Performance of New Photovoltaic System Designs



- New performance indicators besides the PV yield are necessary to rate PV installations with multiple use and multiple benefits.
- Currently key performance indicators for multiple use benefits are defined for each technology separately.

PV AC Modules Performance Characterization



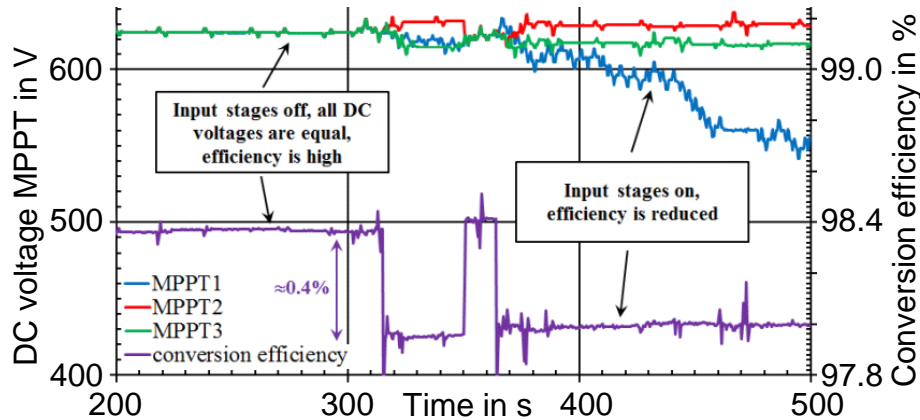
- Fully-integrated PV module with a micro inverter:
 - Characterization as a whole
 - No current standards

$$PR_{PV \text{ system, AC}} = \frac{Energy_{PV \text{ system, AC}}}{Energy_{PV \text{ modules, DC}}} \quad \begin{matrix} \checkmark \\ \times \end{matrix}$$

- Approach: model from operation data
- Three PV AC module operation states
- The PV AC module model allows for detailed simulations to rate its PR

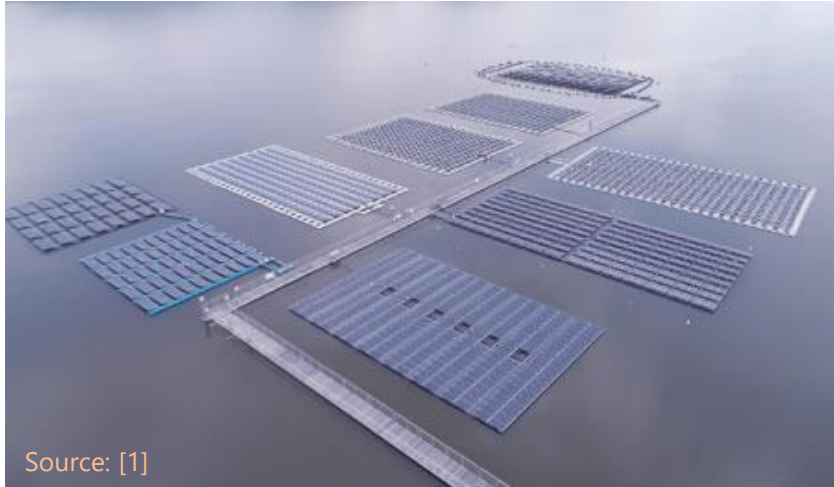
D. M. Riley *et al.*, "A Performance Model for Photovoltaic Modules with Integrated Microinverters," Albuquerque, New Mexico, 2015.

Multi-MPPT PV Inverter Performance Characterization



- Current standard for single MPPT inverters (EN 50530)
- New approach: Heterogeneous input conditions for each MPP tracker based on EN 50530 P-U characteristics
- Additional losses detected with new test profiles

Performance of Floating PV Systems



Source: [1]

- Module temperatures about 5°C to 10°C lower than on rooftops [1], [2]
- Standard rating with *PR*:
PR 10-15% larger than typical *PR* (75 – 80%) of rooftop PV in Singapore [1], [2]

Additional benefits for on-shore FPV from the Singapore Tengeh Reservoir

- Reducing water evaporation
- Decreased algal growth

→ KPIs for double use benefits have to be developed; Verification and further R&D necessary

Performance Indices of Foldable PV Generators



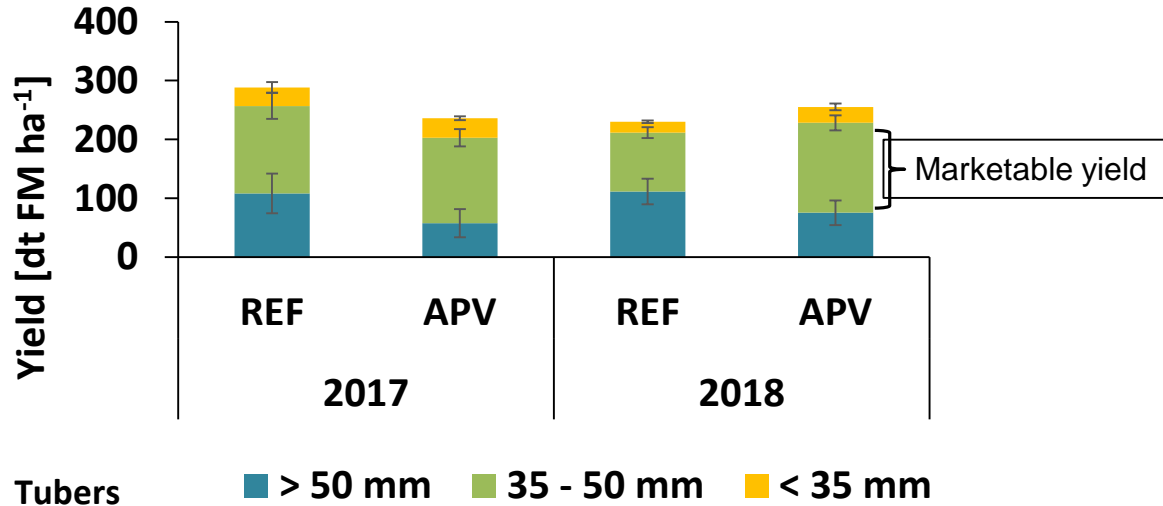
F. Baumgartner *et al.*, "'Urban Plant' Light-Weight Solar System for Parking and other Urban Double Use Applications," in 28th European Photovoltaic Solar Energy Conference and Exhibition, 2013, pp. 2897–2901.

- No standards for performance evaluation
- Avoiding bad weather conditions
 - fraction of mechanical load
 - light weight structural design. 130kg steel for each kWp
 - 1.5 % PV losses due to heavy wind, 2.3% gain winter (snow)
- Shading basins by PV modules reduces annual cleaning costs (reduced algal growth). Financial benefit ~ 0.02 € / kWh PV electricity.
- 95% of PV electricity used on site ⁵

Performance Indices for Agriculture and PV Usage



Agriculture: Example Yield Potatoes



Source: Universität Hohenheim

- 2017: Yield under agrivoltaic reduced by 18 %
- 2018: Yield under agrivoltaic increased by 11 %
- Higher share of tubers with diameter 35 - 50 mm under agrivoltaic in both harvests

