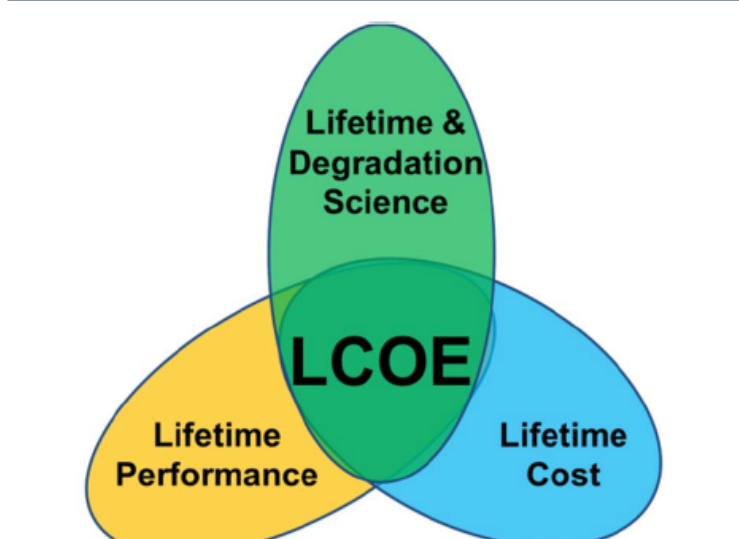


Introduction to the SunFarm Outdoor Test Facilities at the Solar Durability and Lifetime Extension Center in Case Western Reserve University

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Introduction to the SDLE SunFarm



SunFarm outdoor test facility

- Highly instrumented
- Not commonly seen in academic research
- 14 dual axis trackers
- 60 meters adjustable tilt fixed rack

Ability of SunFarm

- 148 full size PV modules
- With/ without mirror augmentation
- 10,000 samples
- 2X 3X 4X 5X accelerated exposure
- Metrology platforms for logging
- Environmental conditions
- System performance

PV lifetime and degradation science

- Determine degradation rates & lifetimes
- In outdoor and indoor exposures
- Using a stress-response framework
- Determine degradation mechanisms & rates
- For efficacy and lifetime prediction

We establish SDLE SunFarm

- For outdoor testing of long lived
- Materials, components and systems

PV modules

- 148 PV modules from 24 manufacturers all over the world
- Monocrystalline Silicon Modules
- Polycrystalline Silicon Modules



Manufacturer	Module	Description	total number
CSI	C56P	220 watt	6
Hyundai	HIS-M230MG	230 watt	6
Perlight	PLM-250M-60 Mono	240 watt	6
AUO	240-P Silver Frame	240 watt	6
REC	REC230PEBLK	230 watt	6
MX Solar	MX60 230	230 watt	6
Sanyo	HIT-N220A01	220 watt	6
Schott	POLY230	230 watt	6
Schuco	MPE240-P5-09	240 watt	6
Sharp	ND-U235Q1	235 watt	6
Solar World	SW230Poly 2.0 Frame	230 watt	6
ET Solar	ET-P660235BZ Zero Rack BLK	235 watt	6
Bosch	c-si M60-225-16	225 watt	6
Trina	TSM-230-PA05	230 watt	6
Conergy	PowerPlus 220W	220 watt	8
Siliken	SLK60PGL SLV/WHIT 220W	220 watt	8
LG	LG220M1C	220 watt	6
Astronergy	CHSM 6610P 235 watt	235 watt	6
Yingli	YL230P-295	230 watt	6
Magie	PowerPlus 230/PH	230 watt	6
Kycera	KD240CX-LPB	240 watt	6
Helios	67240	240 watt	6
UpSolar	UP-M240P	240 watt	6
EcoSolarly	EC 0230S156P-60	230 watt	6

Data logging

Network

- SunFarm office connected to CWRU fiber-optic network
- 24 port switch connects each tracker by Ethernet

Daystar Multi-tracer load unit

Module power monitoring

- Solecra inverters connected by Ethernet
- Enphase uses data-over-power with network-connected Envoy
- e-QED uses data-over-power also



Environmental metrology

- Campbell CR1000 data logger
- 16 analog channels
- 8 digital I/O
- Communicate by Ethernet
- Weather sensors, irradiance sensors, thermocouples



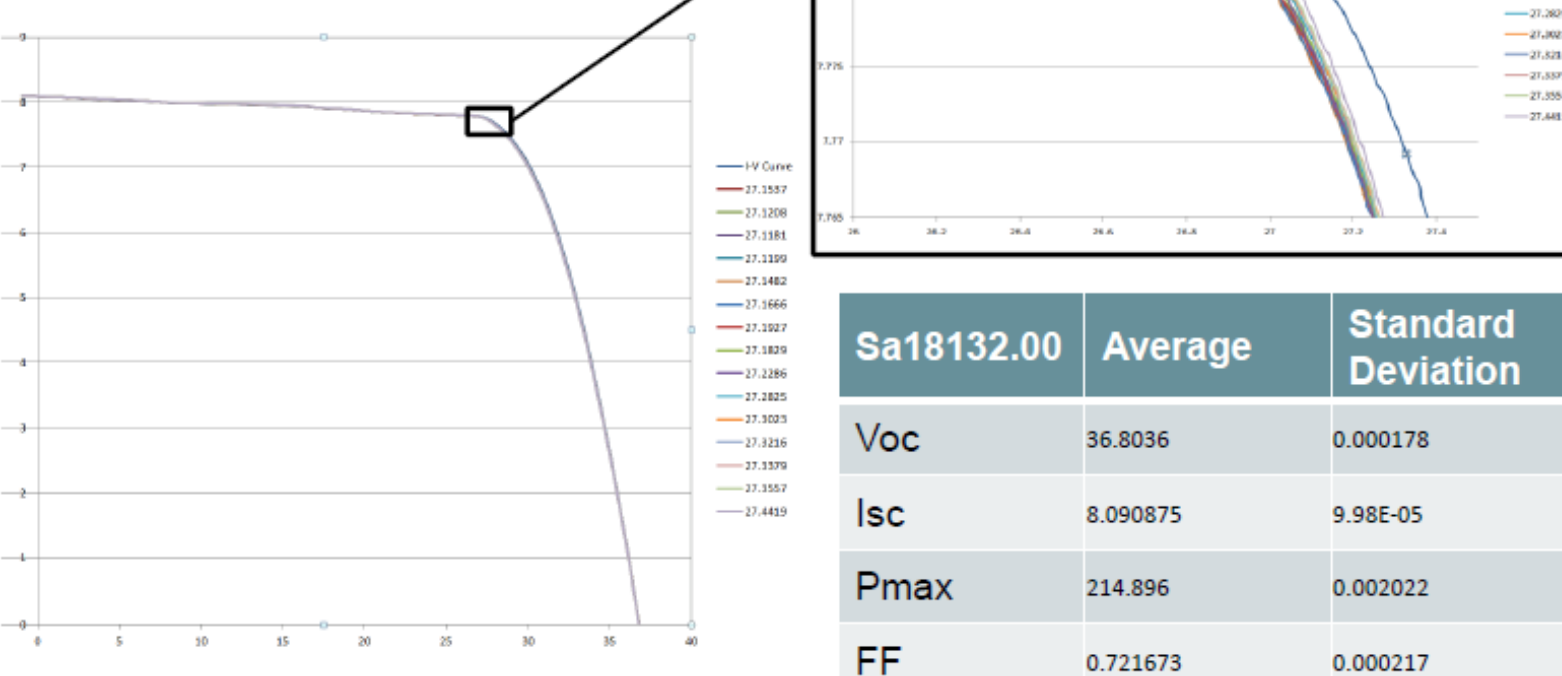
SunFarm on CWRU Campus: Part of SDLE Center



Modules Baseline

SPiRE solar simulator

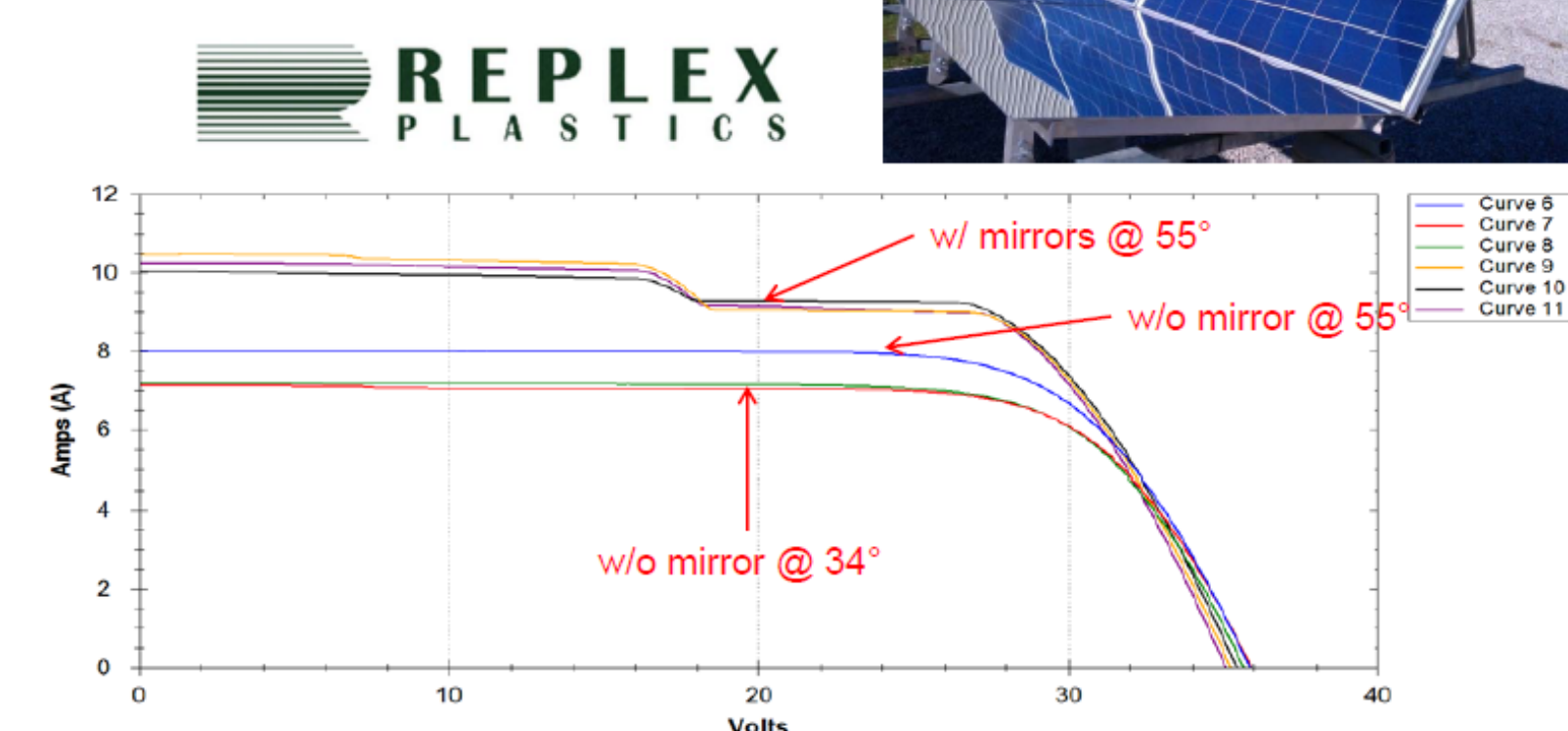
- 16 repeat tests on each module
- Measuring the Light Induced Degradation (LID) rate.
- Evaluating the stability of modules initial output power.



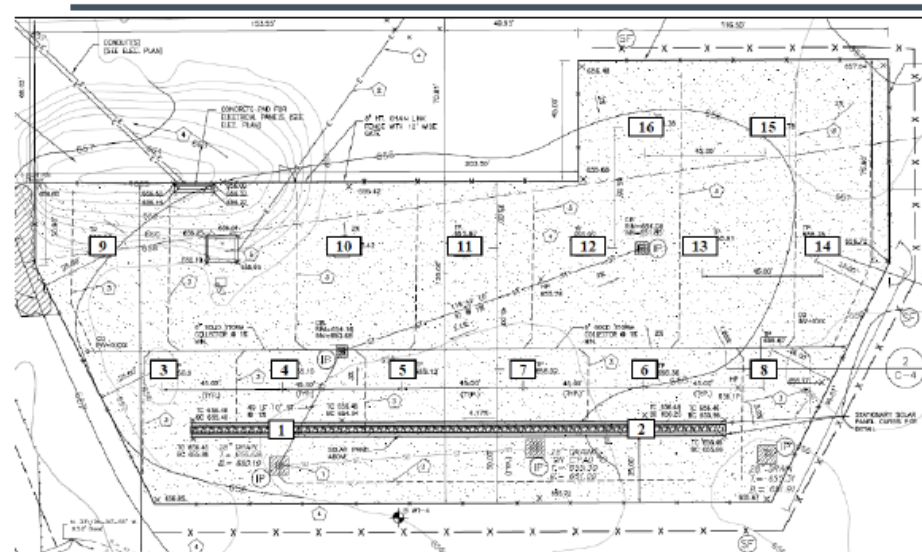
Mirror Augmented PV: Replex, Mount Vernon OH

I-V curve tracing by Daystar Multi-Tracer

- 3 mirror augmented 55° tile modules
- 1 without mirror 55° tile modules
- 2 without mirror 34° tile modules

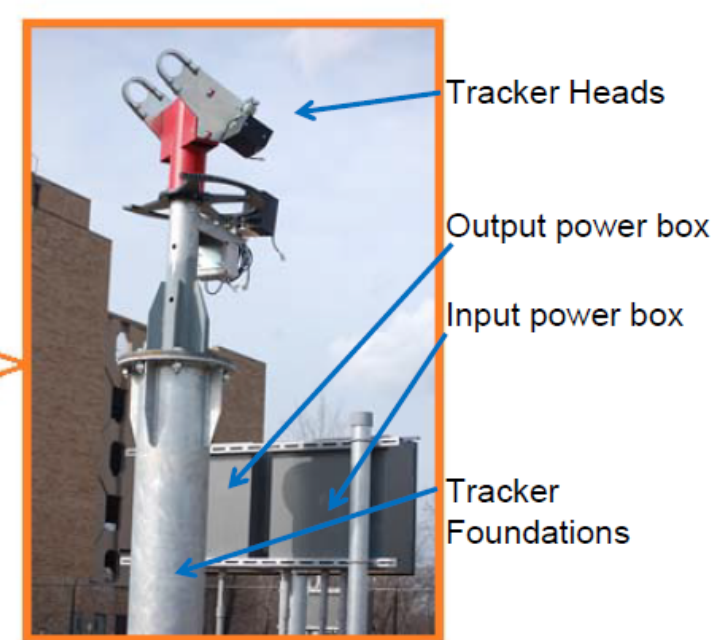


Layout of the S-DLE SunFarm Outdoor Test Facility



16 electrical sites including

- About 1 acre in size
- Fixed and 2-axis tracked sites
- 2 Sites adjustable tile racking
- 14 high precision dual axis trackers
- Opel Solar SF-20 trackers
- Manufactured by Feina (Spain)



Inverters

Microinverter reliability testing platform

- 120 microinverters from two manufacturers
- Evaluate microinverter life time & durability

Microinverters

- For each solar module
- Converts DC power to grid-compliant AC power
- Use power line communications



Evaluate power degradation rate

- Power output
- I-V curves
- Environmental conditions

Also 2 String Inverters

- Solecra PVI 18000



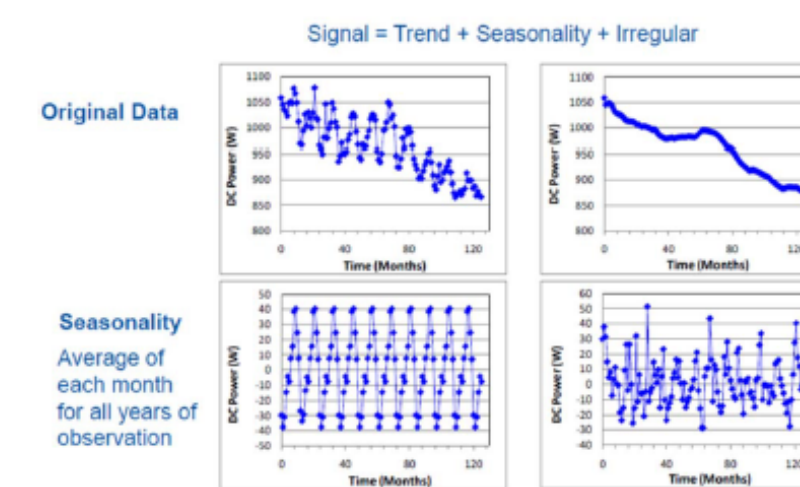
Mirror Augmented PV: CWRU SDLE SunFarm

Mirror Augmented PV (MAPV)

- 1.0X 1.5X 2.0X Suns low concentrated mirror

Daystar multi-tracer

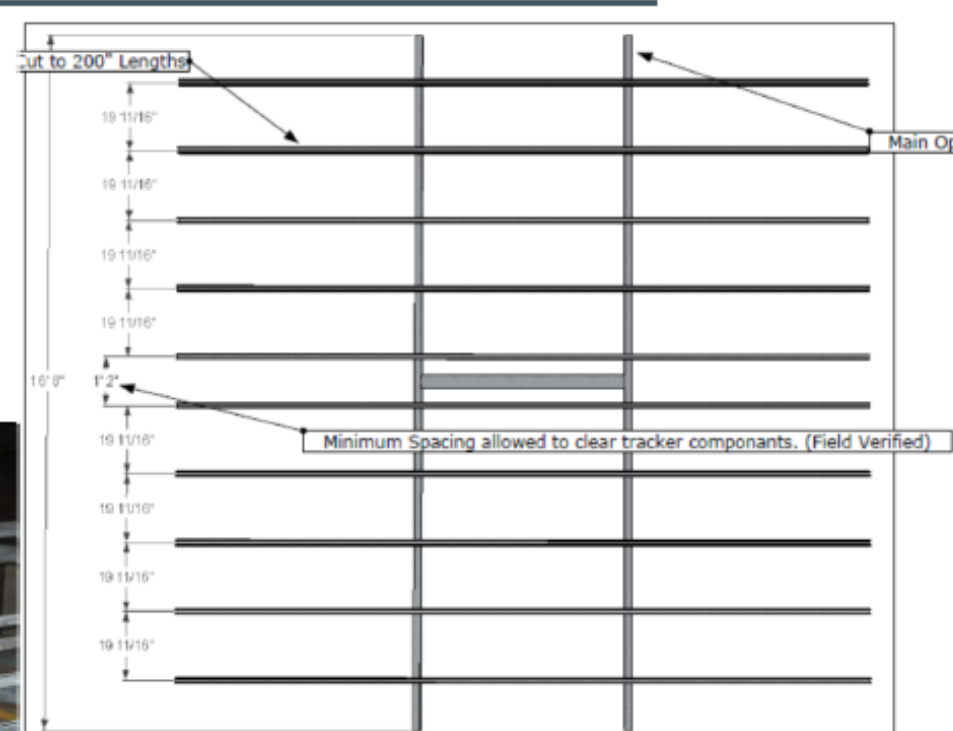
- Acquire power, IV, environmental conditions
- Correct for daily and seasonal variations
- Determine Rd parameters
- Map to Module performance at STC
- Utilizing Time Series Analysis determine the degradation rate of PV modules



Modular Mounting for Modules on the SF-20 Trackers

Tracker panels:

- 5m width x 4m length
- Up to 12 PV modules in landscape mode
- Capability of testing various
- Modules, components and materials
- Flexible Unistrut racking
- To fasten modules and sample trays



Electrical design

Grid-tied through reversing relay

Input power to trackers

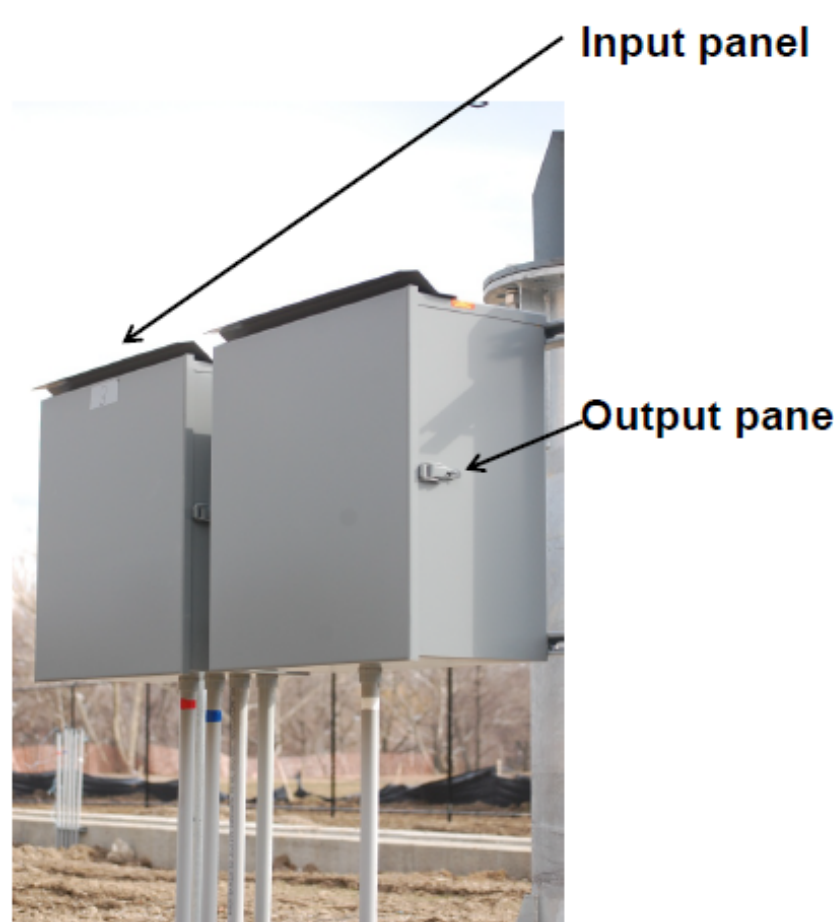
- 120V to power tracker motors, data loggers, etc.

Output power

- Inverters output 240V split-phase
- Enphase inverters get dedicated power panel with line filter
- e-QED and Solecra inverters on remaining two panels

Panels at sites

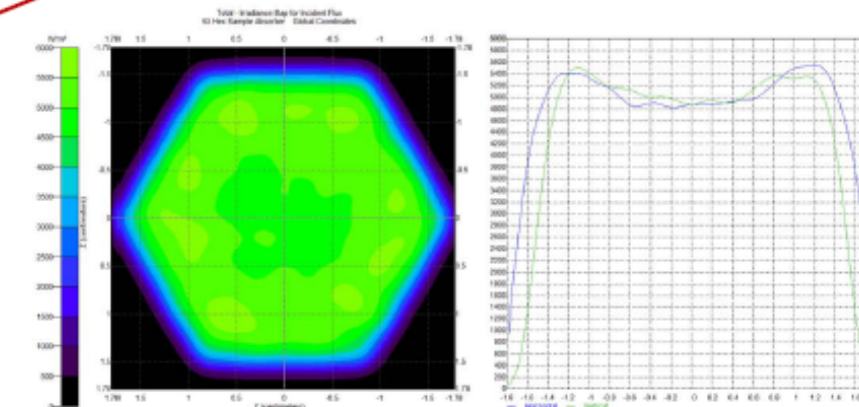
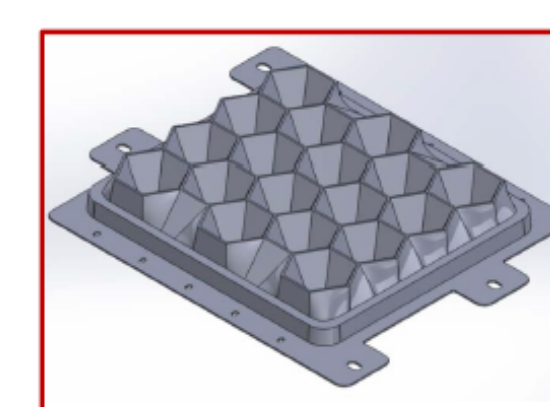
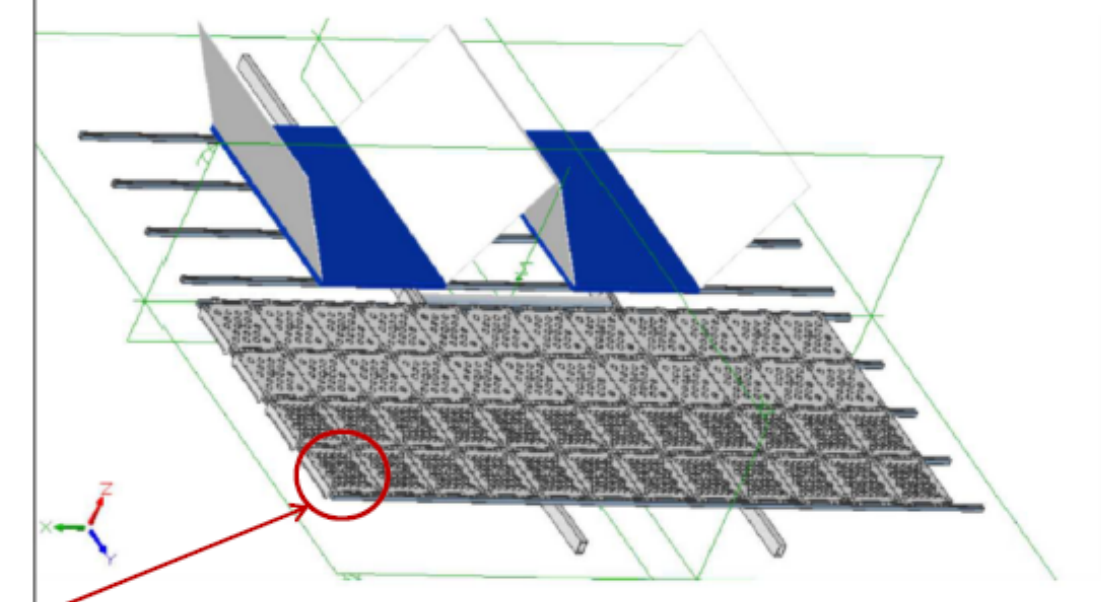
- Input panel contains data logger, Ethernet, and 120V outlet
- Output panel contains 240V connection with external disconnect and lockout-tagout



Outdoor Exposures At Multiple Irradiances: 1X, 2X, 4X, 5X

Samples and components

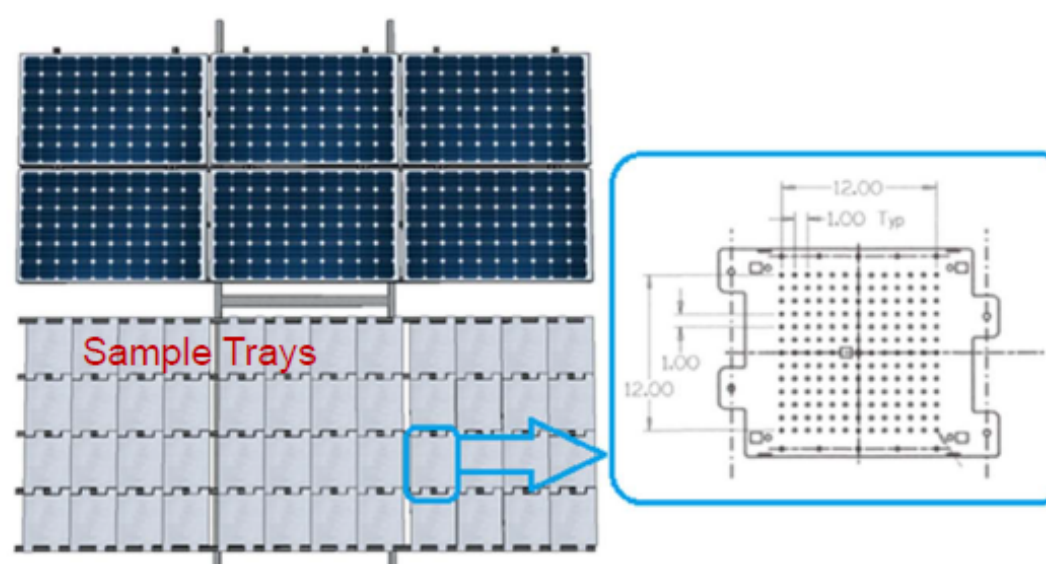
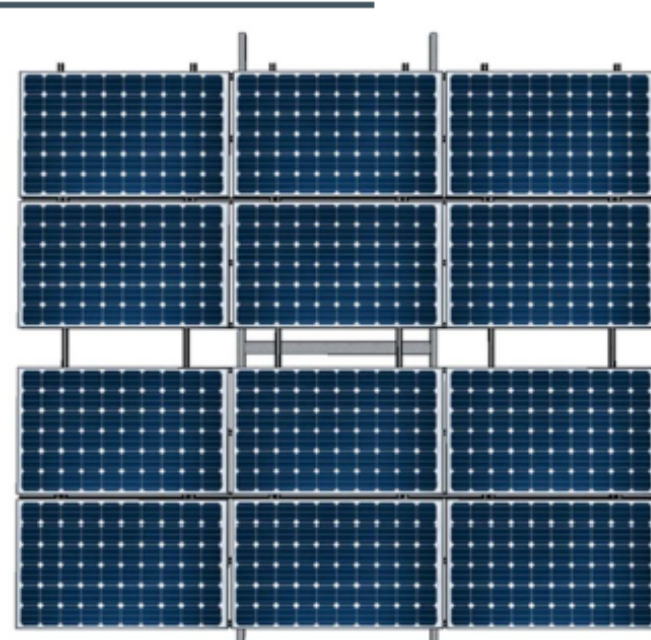
- Cut into 1.96cm*1.48cm
- Concentrated solar irradiance
- Illuminated in the center
- Illumination is uniform
- Concentration alternated with the shape



Trackers Layout

On 14 dual-axis trackers

- 112 PV modules from 18 manufacturers
- 336 sample trays total on the trackers
- With different shape of concentrators samples and components will be exposed to 1X, 2X, 4X, 5X, Suns irradiance as while as the real-world humanity and temperature.

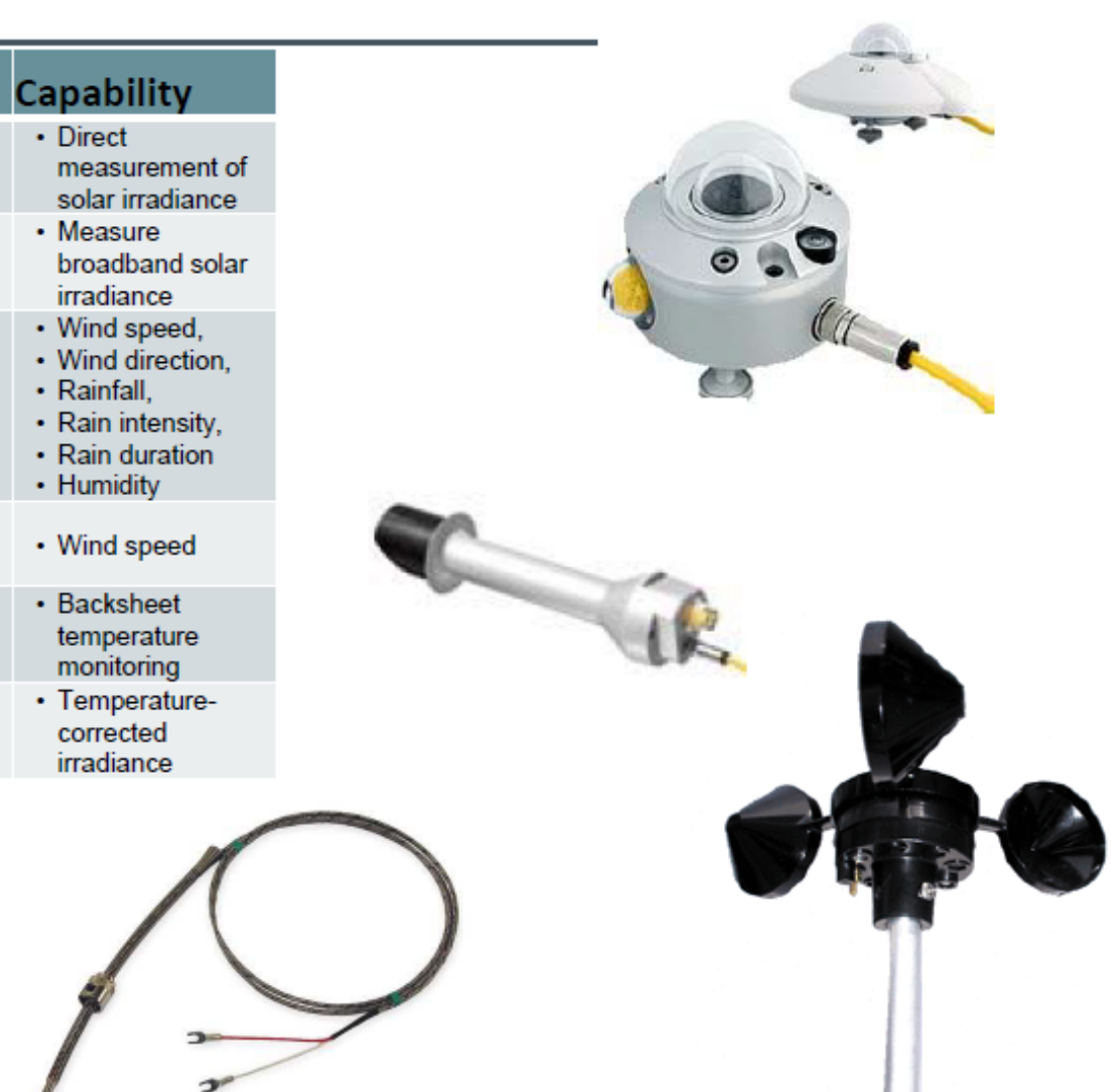


Additionally on fixed racking

- 36 PV modules
- from 6 manufacturers

Metrology

Facilities	Quantity	Capability
Pyrheliometer	1	Direct measurement of solar irradiance
Pyranometer	2	Measure broadband solar irradiance
Weather Transmitter	2	Wind speed, Wind direction, Rainfall, Rain intensity, Rain duration, Humidity
Anemometer	1	Wind speed
Thermocouples	148	Backsheet temperature monitoring
Split-Cell Reference	16	Temperature-corrected irradiance



Acknowledgements

Conclusion:

- Outdoor test facilities for power degradation rate of component, modules, PV systems
- For outdoor exposure of materials under real-world environment

SDLE Collaborating Partners

- UL, DuPont, eQED, Q-Lab, Xunlight26

SDLE Partners

- Replex, Evonik, Greenfield Solar, Xunlight, Energizer, Borrego Solar

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