SERIS
Solar Energy Research Institute of Singapore

PV Module Quality & Reliability at SERIS

Mauro PRAVETTONI, PhD
Head of PV Module Characterization
Solar Energy Research Institute of Singapore (SERIS)

Workshop, Santiago, Chile
4 April 2019

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).

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1. 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)

SERIS' Vision & Mission

SERIS
Solar Energy Research Institute of Singapore

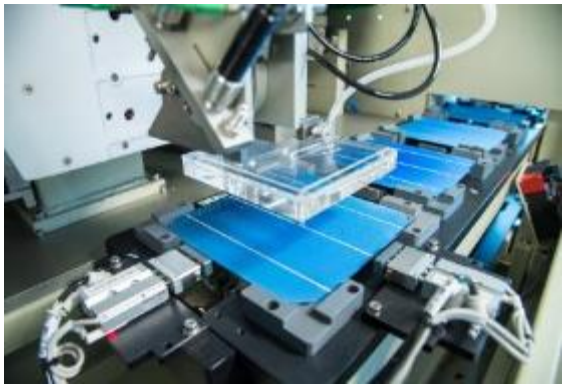
Vision

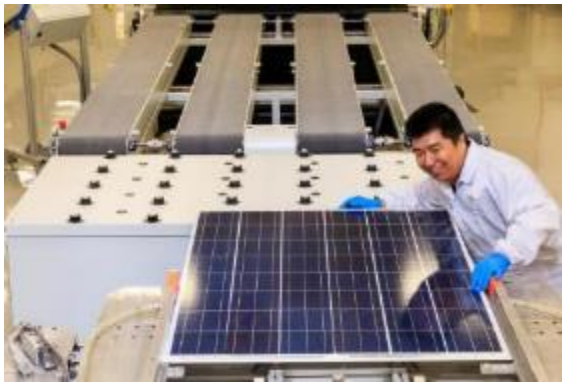
A leading solar energy research institute in the world, contributing to global sustainable development

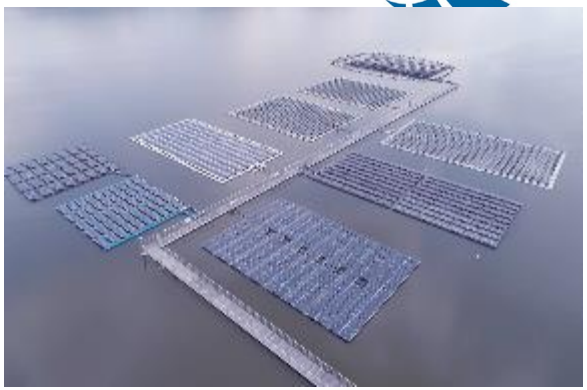
Mission

To develop and commercialise solar technologies suited for urban and tropical applications, and support industry development and the energy transformation towards higher solar adoption.

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
- Characterisation & simulation
- Module testing (indoor & outdoor)
- Module certification
- Module reliability study and failure root cause analysis
- PV Module recycling

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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PVM Cluster

Research areas focused reducing Levelized Cost of Electricity

- Decreasing cell-to-module losses
- New module designs and fabrication processes for **cost** reduction
- Develop **baseline** fabrication process for advanced solar cells
- PV **products** for urban applications
- Outdoor **performance** simulation
- **Pre-normative** testing
- **ISO 17025 accredited** laboratory
- Degradation study to improve module **reliability** and durability

PVM Cluster: the structure

Research areas focused reducing Levelized Cost of Electricity

Module technology team:

JP

- ❑ Decreasing cell-to-module losses
- ❑ New module designs and fabrication processes for **cost** reduction
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Module technology team: JP

Module fabrication Pilot line: CYT/CJ

PVM Cluster: the structure

Research areas focused reducing Levelized Cost of Electricity

- Module technology team: JP
- Module characterization & yield simulation team: MP
- Module fabrication Pilot line: CYT/CJ

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PVM Cluster: the structure

Research areas focused reducing Levelized Cost of Electricity

- Engineer: HL/SL/DP
- Technician: Jamil/Abdul/Chuah
- Admin staff: Zuraidah/Loh
- Module technology team: JP
- Module characterization & yield simulation team: MP
- Module fabrication Pilot line: CYT/CJ

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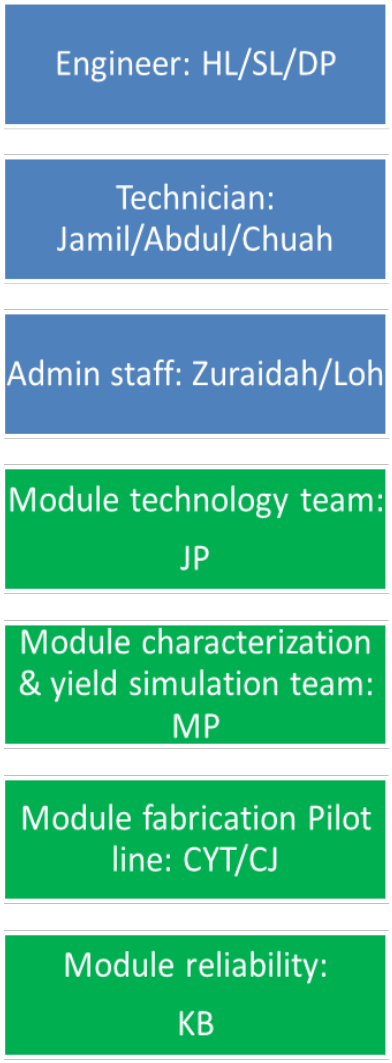

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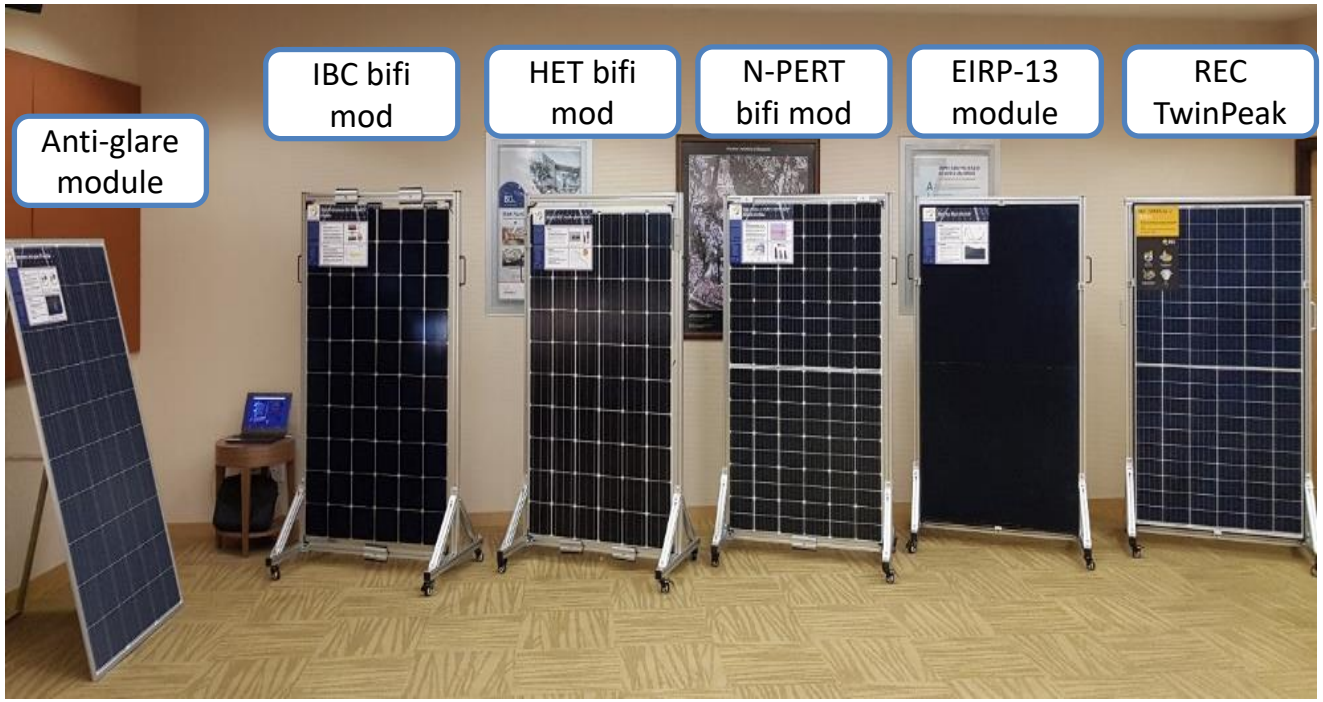
PVM Cluster: the structure

Research areas focused reducing Levelized Cost of Electricity

- Cluster director: WANG Yan
  - Cluster secretary & project planner: Mabel Leow
  - PVMT: Kenneth Goh
    - Engineer: HL/SL/DP
    - Technician: Jamil/Abdul/Chuah
    - Admin staff: Zuraidah/Loh
  - PVMD: KHOO Yong Sheng
    - Module technology team: JP
    - Module characterization & yield simulation team: MP
    - Module fabrication Pilot line: CYT/CJ
    - Module reliability: KB

PV Module development

Modules showcase during SERIS' 10th year anniversary



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R&D highlights: PV Module Testing

Transfer IEC standards to National standards

- IEC 63092-1&2: **new standards for BIPV**
  - Weight
  - Glare
  - Aesthetic
  - Ease of system integration
  - Building comfort, etc.

- IEC "informal" group for **VIPV:**
  - **Modelling & design (2D vs 3D)**
  - **Power rating:** STC to be defined
  - **Qualification:** car-oriented tests
  - **Energy rating**

PVM Testing Laboratory

ISO 17025 accredited: for the industry in the Tropics

Certification	• Latest IEC 61215, 61730 & UL1703 standards
Fault Analysis	• Detect and localize module defects
Golden Modules	• Precision measurements with Uncertainty reporting
Test-bedding	• Components and accessories e.g. smart Junction boxes, etc
Pre-normative Testing	• Industry relevant research for the Tropics • Extended stress tests
SQC batch test	• Quality checking batch to batch for system installation

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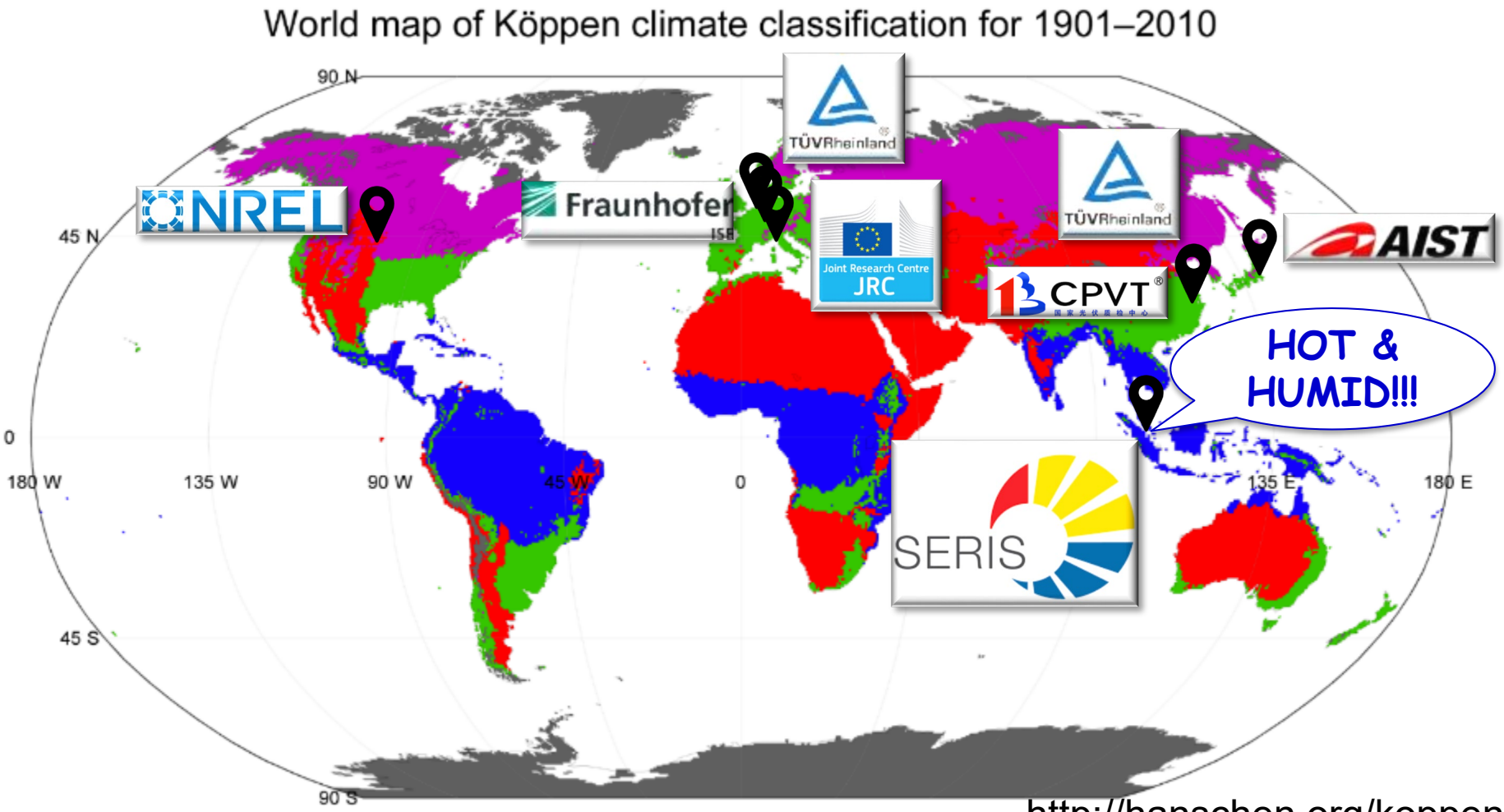
PV testing for the Tropics

A target leadership area for SERIS



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IEC TC 82 experts in SERIS

Dr Thomas REINDL
SERIS Deputy CEO
SES Cluster Director
Member of WG 3 (“Systems”)

Dr WANG Yan
PVM Cluster Director
Member of WG 2 (“Modules”), WG 6 (“BoS”) and WG 8 (“Cells”)

Dr Mauro PRAVETTONI
PVM Cluster, Senior Research Fellow
Member of WG 2 (“Modules”)
Member of WG 7 (“CPV”),
IEC/ISO 17025 TA for NATA

2019 TC82 Meeting

Busan, 15-19 October 2018

SERIS current activities in WG2

- IEC 61853-2 (concerns on “NMOT”):

Amendment in preparation (PL: Lee, CFV)

- IEC 60904-8 (“Spectral Responsivity”): Amendment to be launched

Proposed to include instructions for bifacial modules: SERIS to participate (PL: Winter, PTB)

- IEC 60904-9 (“Solar Simulator Classification”) Ed.3: CD commented

CDV presented in Busan. SERIS was part of the PT.

(PL: Hermann, TÜV-Rheinland)

- IEC 60891 (“T and G coefficients”) Ed.2: CD in preparation

SERIS part of the PT. (PL: Monokroussos, TÜV-Rheinland)

SERIS activities within WG2

- IEC TS 60904-1-2 (“Bifacial PV modules”) Ed.1

Published in 2019 (PL: Vakfouri, ex-Pasan).

Bifacial Round-Robin started in June (SERIS coordinates).

Possible future NP?

- Energy-rating for bifacial
- Floating PV
- PV-on-cars
- …

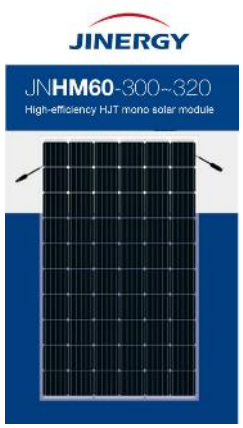
SERIS & IEC/TC82

New or revised standards relevant for

Topic	Relevant IEC standard	From -> To	Impact from/to SG
PID (reliability)	IEC TS 62804	<-> IEC	• SERIS gave feedback to PT • **PID in salt mist chamber** (maritime environment) • **PID test for SolarNova**
Bifacial	IEC TS 60904-1-2	-> IEC	1st International RR coordinated by SERIS
LeTID (reliability)	IEC 61215	IEC ->	Give SERIS' feedback
Energy rating	IEC 61853	IEC <->	• Criticalities of NMOT • Hot&humid climate
EL	IEC TS 60904-13	IEC <->	1st International RR coordinated by SERIS

Bifacial modules: pre-normative

The 1st International Proficiency Testing on bifacial modules



monofacial (REFERENCE)		bifacial					
P-type PERC	poly-Si	P-type PERC	HJT	N-type PERT	P-type PERC	N-type PERT	poly-Si
2 samples	2 samples	2 samples	2 samples	2 samples	2 samples	2 samples	2 samples
60 cells	60 cells	60 cells	60 cells	60 cells	72 cells	120 cells HC	144 cells HC
Frame	Frame	Frame	No frame	Frame	Frame	No frame	No frame

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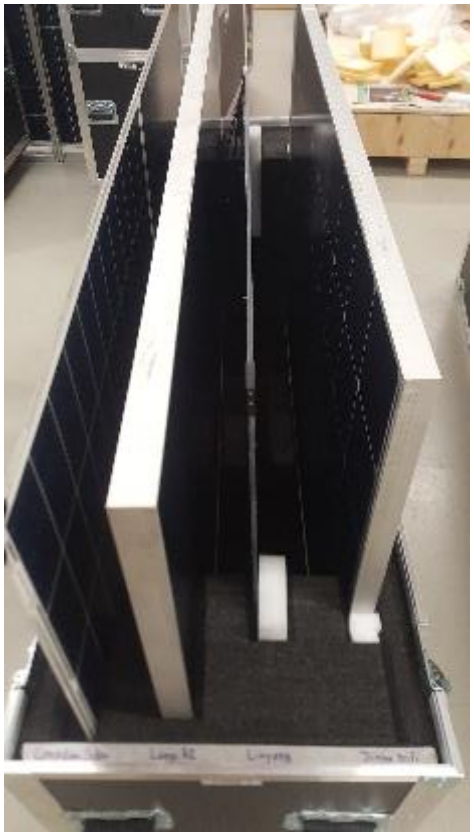
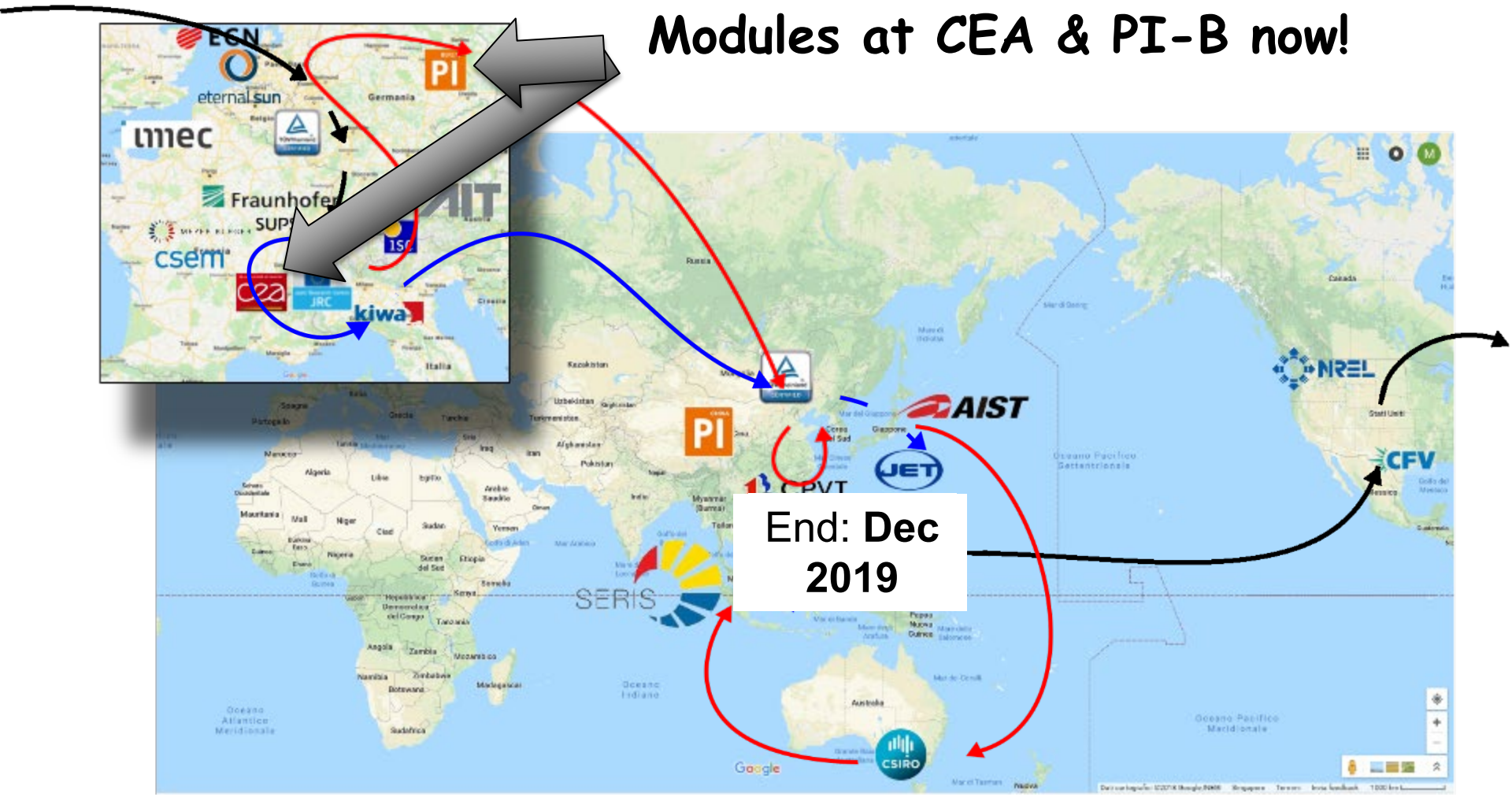
Shipment: SERIS provides…



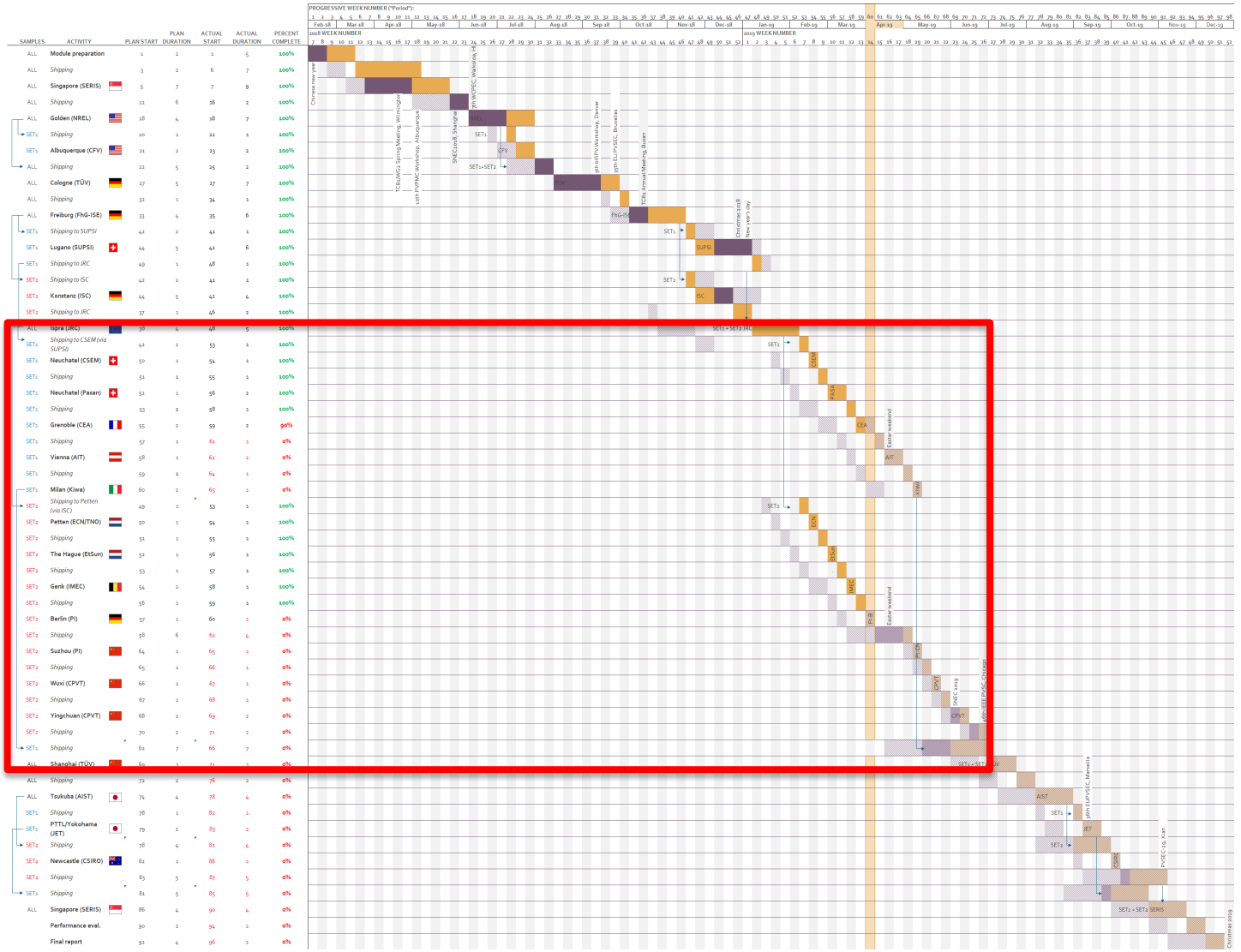
4 ATA Cases
4 module/case
~100 kg/case

New Standard for Bifacial PV Modules

SERIS to coordinate the 1st International Round Robin

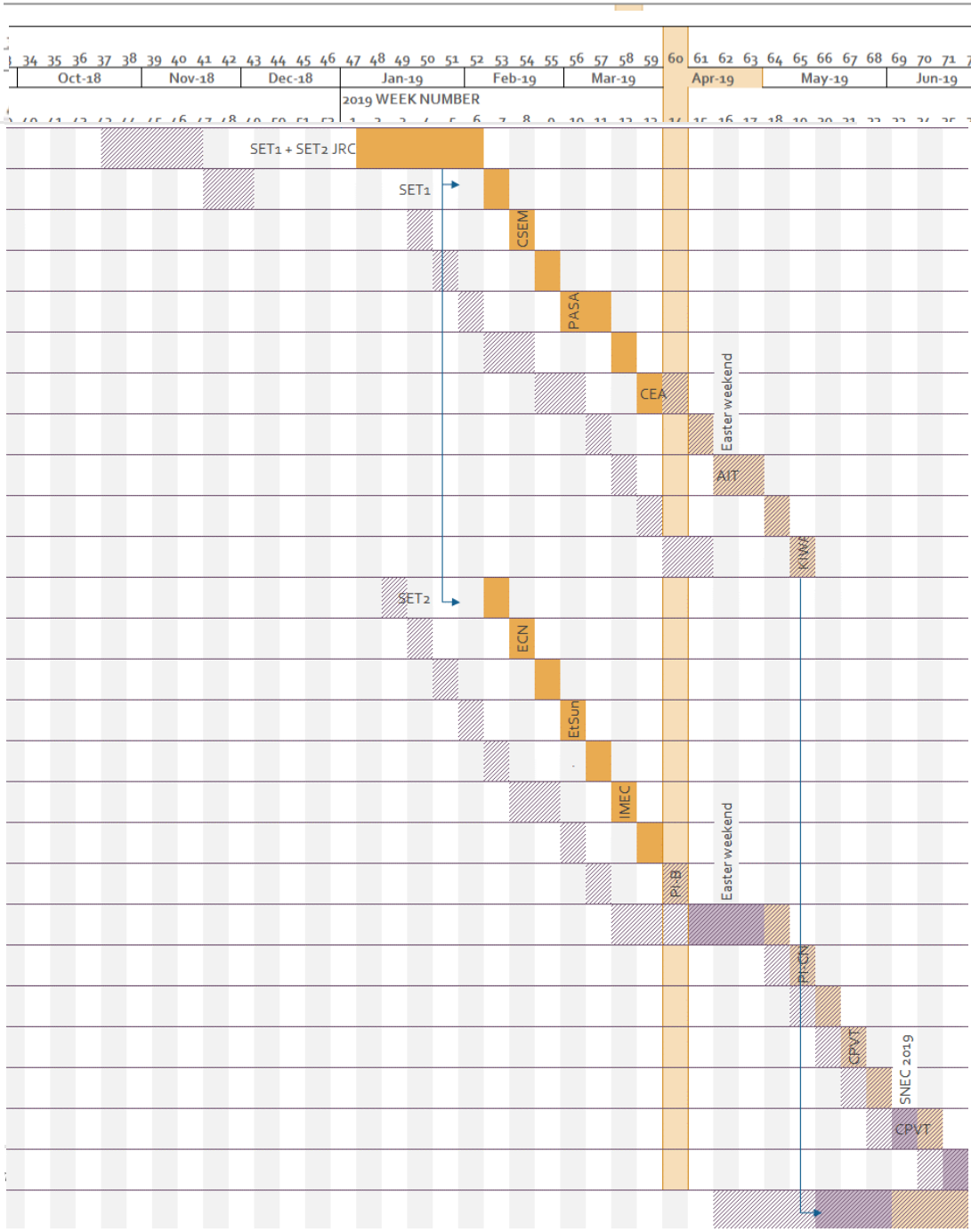


Gantt chart


SAMPLES
ACTIVITY
PLAN START
PLAN DURATION
ACTUAL START
ACTUAL DURATION
PERCENT COMPLETE
PROGRESSIVE WEEK NUMBER ("Period"):
2018 WEEK NUMBER
2019 WEEK NUMBER
Module preparation
Shipping
Singapore (SERIS)
Golden (NREL)
Albuquerque (CFV)
Cologne (TÜV)
Freiburg (FhG-ISE)
Lugano (SUPSI)
Konstanz (ISC)
Iapra (JRC)
Neuchatel (CSEM)
Neuchatel (Pasan)
Grenoble (CEA)
Vienna (AIT)
Milan (Kiwa)
Petten (ECN/TNO)
The Hague (EtSun)
Genk (IMEC)
Berlin (PI)
Suzhou (PI)
Wuxi (CPVT)
Yingchuan (CPVT)
Shanghai (TÜV)
Tsukuba (AIST)
PTTL/Yokohama (JET)
Newcastle (CSIRO)
Singapore (SERIS)
Performance eval.
Final report
Christmas 2018
New year's day
Easter weekend
Christmas 2019

Gantt chart

ALL	**Ispra (JRC)**		38	4	48	5	100%
SET1	*Shipping to CSEM (via SUPSI)*		42	2	53	1	100%
SET1	**Neuchatel (CSEM)**		50	1	54	1	100%
SET1	*Shipping*		51	1	55	1	100%
SET1	**Neuchatel (Pasan)**		52	1	56	2	100%
SET1	*Shipping*		53	2	58	1	100%
SET1	**Grenoble (CEA)**		55	2	59	2	90%
SET1	*Shipping*		57	1	61	1	0%
SET1	**Vienna (AIT)**		58	1	62	2	0%
SET1	*Shipping*		59	1	64	1	0%
SET1	**Milan (Kiwa)**		60	2	65	1	0%
SET2	*Shipping to Petten (via ISC)*		49	1	53	1	100%
SET2	**Petten (ECN/TNO)**		50	1	54	1	100%
SET2	*Shipping*		51	1	55	1	100%
SET2	**The Hague (EtSun)**		52	1	56	1	100%
SET2	*Shipping*		53	1	57	1	100%
SET2	**Genk (IMEC)**		54	2	58	1	100%
SET2	*Shipping*		56	1	59	1	100%
SET2	**Berlin (PI)**		57	1	60	1	0%
SET2	*Shipping*		58	6	61	4	0%
SET2	**Suzhou (PI)**		64	1	65	1	0%
SET2	*Shipping*		65	1	66	1	0%
SET2	**Wuxi (CPVT)**		66	1	67	1	0%
SET2	*Shipping*		67	1	68	1	0%
SET2	**Yingchuan (CPVT)**		68	2	69	2	0%
SET2	*Shipping*		70	2	71	2	0%
SET1	*Shipping*		62	7	66	7	0%



Statistical design (1)

Participants are divided in:

ISO 17025 accredited laboratories		Non-accredited laboratories
NREL JRC Fraunhofer-ISE TUV-Rheinland AIST	SERIS Kiwa SUPSI CEA-INES PI-Berlin PI-China CPVT JET AIT	Pasan CSEM-EPFL CSIRO ISC ECN/TNO Eternal-Sun IMEC
Group 1	Group 2	Group 3

Statistical design (2)

For the **bifacial** modules, to calculate:

- $z'_i = \frac{x_i - x_{PT}}{\sigma_{PT}(x)} \sqrt{\frac{n}{n+1}}$ the **"z-score"** (all laboratories)
- $E_{n,i} = \frac{x_i - x_{PT}}{\sqrt{U^2(x_i) + U^2(x_{PT})}}$ the **"E_n-score"** (only Group 1 & 2)

	$E_n \leq 1.0$ (satisfactory)	$E_n > 1.0$ (unsatisfactory)
$z \leq 2.0$ (satisfactory)	**The PT is satisfactory** Action: none	**The claimed uncertainty is too low, but the result fills the requirements of the PT** Action: check uncertainty
$z > 2.0$ (unsatisfactory)	**The result is within the claimed uncertainty, but not within the limits of the PT** Action: check procedure	**The result is too much biased and the reason should be clarified** Action: check uncertainty & procedure

Conclusions

SERIS testing reference for Singapore & the Tropics

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Thank you for your attention!

More information at www.seris.sg

We are also on:

SERIS
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Annual Report
2018

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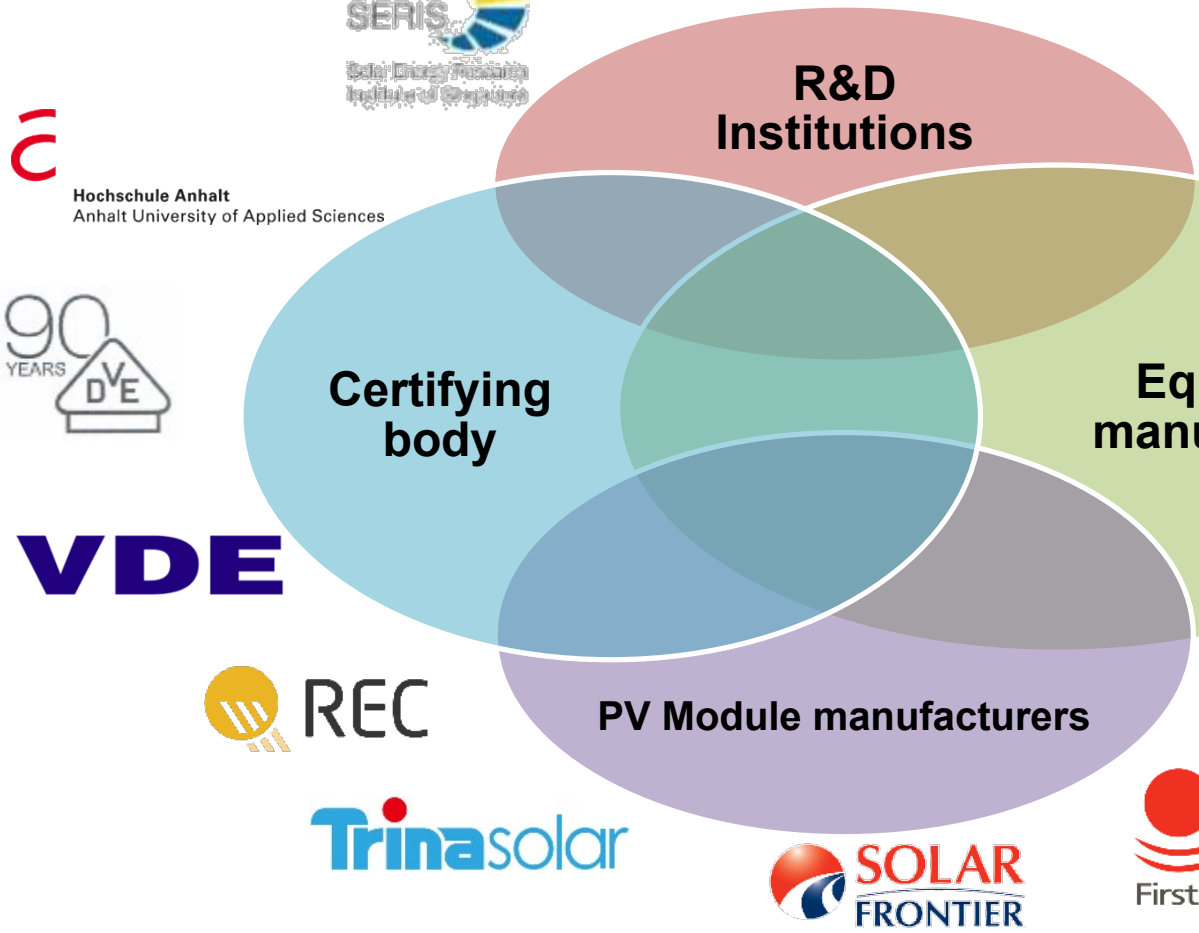
Solar Energy System (SES) Cluster



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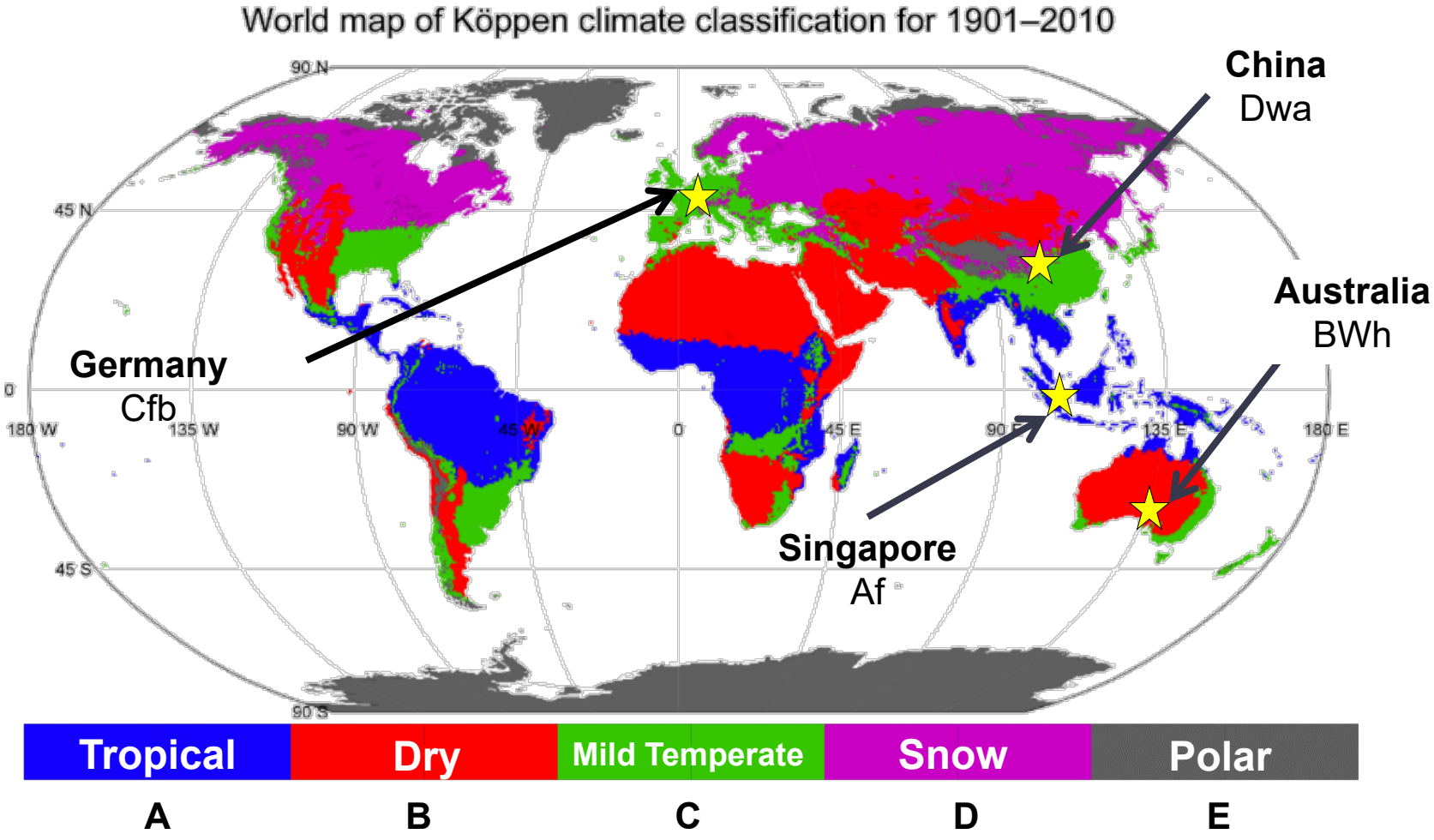

Project sites are located in 4 major climate zones

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Solar Energy System (SES) Cluster

Multi-Si 1

Multi-Si 2

CIS

CdTe