SERIS-ANU solar energy collaborations and Solarisation of Singapore

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1. SERIS
SERIS
Solar Energy Research Institute of Singapore

- National Lab founded at NUS in 2008; supported by NRF & EDB
- Focuses on applied solar energy research (solar cells, PV modules, PV systems)
- 160 researchers, state-of-the-art labs, ISO certified (9001, 17025)
- Close collaborations with industry & government agencies
- Strategic priorities: Develop & 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 architectures)
- Tandem solar cells on silicon (e.g. GaAs, perovskites)
- Characterisation & simulation

**PV modules:**
- Module development
- Module testing (indoor & outdoor)
- Module certification
- Characterisation & simulation
- 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
Silicon Materials and Cells Cluster

Silicon solar cell lab

- 1,400 m² lab
- Versatile R&D pilot lines for silicon wafer solar cells
- Full-size wafers, high throughput (~500 wafers/hr)
- Mono & multi-Si wafers
- Homojunction & heterojunction solar cells
2. SERIS-ANU solar energy collaborations
Example 1: Membership on Advisory Boards

Prof Andrew Blakers, ANU
Member/Chairman of SERIS’ International Advisory Panel
(since 2010)
Example 1: Membership on Advisory Boards

Prof Armin Aberle, SERIS Member of ECI’s Advisory Board (since 2013)
Example 2: Screen-printed IBC silicon solar cells
SERIS, ANU, Trina Solar

- 3-year R&D project (2010 to 2013) between SERIS, ANU and PV manufacturer Trina Solar.

- Joint development of a high-efficiency screen-printed IBC solar cell, suitable for low-cost high-volume production.

- IBC cells developed on SERIS’ R&D pilot line, followed by technology transfer to State Key Laboratory of PV Science and Technology at Trina Solar.

- By 2012, SPARC cells reached efficiencies of above 20% on large-area n-type substrates (6" wafers). Following the technology transfer by SERIS, Trina Solar continuously improved the efficiency of screen-printed IBC cells.
Example 2: Screen-printed IBC silicon solar cells
SERIS, ANU, Trina Solar

- In 2014, **ANU and Trina Solar** jointly announced an efficiency of 24.4% for a lab-scale 4.0 cm² IBC solar cell (FZ silicon, photolithographic patterning).

- Later in 2014, Trina Solar announced 22.9% efficiency for an industrial large-area (6" substrate) IBC solar cell.

- In 2018 Trina Solar reported a **new record efficiency of 25.0% for a large-area (243 cm²) n-type silicon IBC solar cell**. This is the first silicon cell made in China to attain an efficiency of 25% on large area.
Example 3: TruePower™ Alliance

SERIS, ANU, REC, Trina Solar and others

The overall goal of this project is to determine the optimum technology option for maximized long-term performance of PV systems, eventually leading to the lowest possible cost of PV electricity at any of the three major climate zones, through:

- **An advanced, flexible indoor test facility:**
  - Flexible, long light pulse (more than 100 ms)
  - Various spectra, diffuse/direct, broad range of module temperatures

- **Nominally identical, high-precision outdoor testing on module- and system-level in the three most relevant climate zones:**
  - "temperate" (4 distinct seasons)
  - "tropical" (constant hot and humid, intermittent)
  - "desert/arid" (high light intensity, dry)

- **Scientific interpretation and mathematical modelling:**
  - Prediction of the real-world performance of various PV module types in the three climate zones based on advanced indoor measurements
  - Standard set of indoor measurements replicating outdoor performance
TruePower™ project sites

World map of Köppen climate classification for 1901–2010

Project sites are located in 4 major climate zones
TruePower™ Alliance partners

- R&D institutions
- Equipment manufacturers
- PV module manufacturers
- Certifying body

Hochschule Anhalt
Anhalt University of Applied Sciences

Solar Energy Research
Institute of Singapore

Australian National University

Ekistics

SMA

ABB

Papendorf Software Engineering

Enliteltech

H.a.l.m.

Solarzentrum Stuttgart

REC

TrinaSolar

Solar Frontier

First Solar

GCL

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).
The “TruePower™ project”
High-precision real-world outdoor testing on module and system level

In collaboration with leading PV manufacturers:

- REC Solar (c-Si)
- Trina Solar (c-Si)
- GCL Poly (c-Si, bifacial)
- First Solar (CdTe)
- Solar Frontier (CIGS)

Alice Springs, Australia (desert)
Friedenshall, Germany (temperate)
Example 4: Option for SG to import solar energy from AUS

Andrew Blakers*, Joachim Luther and Anna Nadolny

Asia Pacific Super Grid – Solar electricity generation, storage and distribution

Abstract: This paper explores the large scale transmission of solar electricity to Southeast Asia from Australia. Despite the expense and losses incurred in long distance transmission of Australian solar electricity, it appears to be competitive with locally produced solar electricity because of high insolation levels in Australia. Supplementation of locally produced electricity (both from renewable and conventional sources) with power from Australia, together with substantial integrated energy storage, would allow a high solar electricity fraction to be achieved in Southeast Asia.

Keywords: solar energy, HVDC, photovoltaics, energy storage, renewable energy

tries have rapidly growing economies leading to rapidly growing energy demand (2). The continent of Australia has a population of 23 million people and an average population density of 3 people per square kilometer. Australia is well endowed with indigenous energy resources. In particular, Australia has immense solar energy resources in the centre and northwest (3).

A glance at the South East Asian page of a world atlas shows a long and narrow chain of islands between Australia and the Malay Peninsula. Major desert regions exist to the north (central China) and south (central and north west Australia). This dipole suggests the possibility of transporting large quantities of solar electricity to South East Asia via high voltage cables from large solar farms located in Australia, and solar and wind farms in China.
Example 4: Option for SG to import solar energy from AUS

Fig. 1: Planned route for HVDC backbone.
Example 4: Option for SG to import solar energy from AUS

- **Singapore’s electricity landscape (2018):**
  - Peak demand ~7.5 GWp
  - Annual electricity consumption:
    ~50 TWh (~97% from gas-fired power plants, ~0.4% from solar PV)
  - Goal: > 1 GWp of solar by 2030

- According to the **Solar PV Roadmap for Singapore (2013)**, only ~20% of SG’s annual electricity consumption can be provided by solar PV due to space constraints (~30% when adding off-shore floating PV)

- Larger share from renewables only possible in Singapore through:
  - Power cable connections to other countries
  - Solar fuel imports

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ARENA is allocating $20 million to accelerate the development of a potential renewable energy export supply chain, centred around hydrogen and related carrier materials.
3. Solarisation of Singapore
Urbanisation

![Urbanisation Map](image)

Los Angeles 12.3 million
London 10.1 million
New York 18.6 million

Cairo 18.4 million
Karachi 16.1 million
Mumbai (Bombay) 14.7 million

Kolkata (Calcutta) 16.9 million
Bangkok 8.3 million
Dhaka 15.1 million

Rio de Janeiro 12.8 million
São Paulo 20.8 million
Buenos Aires 15 million

Moscow 12 million
Delhi 24.9 million
Hong Kong 7.3 million
Beijing 19.6 million
Shanghai 22.9 million
Tokyo 37.8 million
Osaka 20.1 million
Seoul 25.6 million
Manila 12.7 million
Jakarta 5.5 million
Singapore 5.5 million
View on Marina Bay Sands: 2004 vs. 2016
Goal in SG: To be a global leader in “Urban Solar”

Holistic approach at SERIS:

- Turning challenges into opportunities
- Develop technical solutions and test-bed them in Singapore
- Market them to other megacities across the world
- Keep flexibility for location-specific needs (e.g. tropical climate conditions in the case of Singapore)
National Solarisation Centre (NSC)

- NSC was established on 1 Dec 2013 at SERIS, NUS
- It aims to support large-scale deployment of PV systems in S’pore
- NSC also addresses market and technological barriers to the adoption of solar energy in Singapore

The centre coordinates the following activities:

National Solar Repository
Floating PV Test-bedding
Solar Potential Analysis
PV Grid Integration Study
Centre of Excellence for Building Integrated Photovoltaics (BIPV)

The Centre for Building Integrated Photovoltaics (BIPV) was established at SERIS, NUS in 2017.

SERIS has broad expertise in the areas of building integrated photovoltaic (BIPV) system design and evaluation, yield projections, technical verification, project risk assessment, real-time analytical monitoring of PV/BIPV installations, project management, owner’s engineer and quality assurance.

BIPV façades testing of performance and thermal properties at the School of Design and Environment at the NUS Campus.
3D Modelling of Urban Areas - Results

- Marina Bay Sands (modern city, complex geometry)
PV deployment in SG by user type

~150 MW<sub>p</sub> installed by Dec 2017, target for 2020 is 350 MW<sub>p</sub>

Data source: EMA
Evaluation of Singapore’s water bodies
With a potential of several hundreds of MWp of Floating PV

⇒ SERIS is/was involved in Floating PV feasibility studies across Asia: Thailand, Indonesia, Cambodia, Laos and Myanmar

Source (map): WEnergy Global
**Floating PV**

- Floating PV is suitable for countries such as Singapore with limited land area but high density of water bodies
- Cooling effect on PV modules increases energy generation
- Reduction in water evaporation losses from the reservoirs

- 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

Floating PV testbed in Tengeh reservoir, S’pore
Summary / Conclusions

- Strong collaborations in solar energy between ANU and SERIS since 2010

- Singapore:
  - Focus in energy R&D is on Urban Solar;
  - Solarisation of Singapore is underway.
  - The goal is 1 GWp of installed solar PV before 2030.
  - Floating PV has large potential in SG (inland & off-shore).

- Australia:
  - Blessed with renewable energy resources (solar, wind)
  - Export of clean power, and/or solar fuels, to Southeast Asia could become a big business
Thank you for your attention!

More information at www.seris.sg

We are also on:

[Social media icons: Facebook, LinkedIn, YouTube]