UNSW SYDNEY

SPREE Seminar

Solar PV Power Plants

From The Eyes of End-User

First Session

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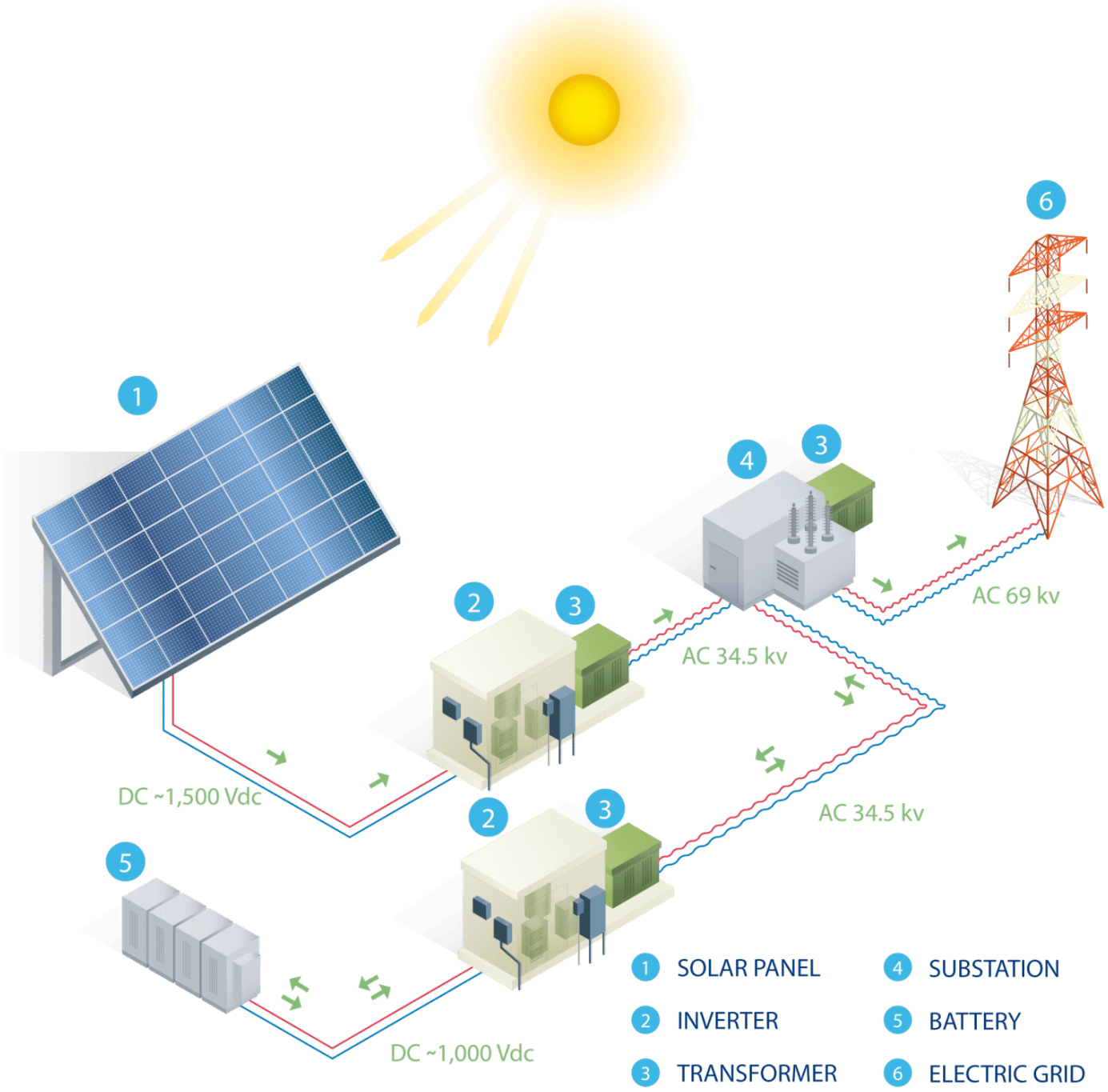
Abbreviations & Definitions - Refresher

- FC: Financial Close
- COD: Commercial Operation Date
- PPA: Power Purchase Agreement
- LCOE: Levelized Cost of Electricity / Energy
- GCR: Ground Coverage Ratio
- EPC: Engineering, Procurement & Construction
- DLP: Defect Liability Period
- O&M: Operation & Maintenance
- CAPEx: Capital Expenditure
- OPEx: Operational Expenditure
- DevEx: Project Development Expenditure

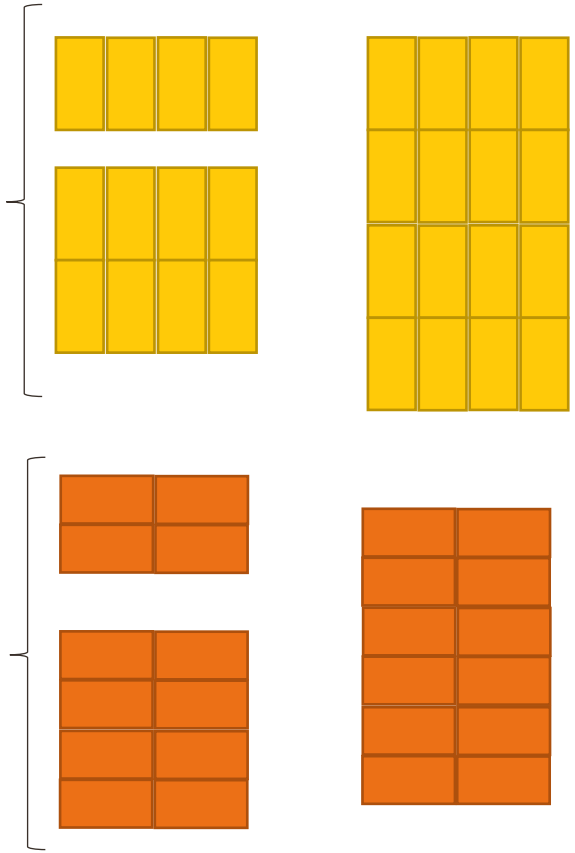
Utility Scale PV Power Plant



Equipment Installed - Module

PV Modules Arrangement

- On Ground
  - 1P / 2P / 3P / 4P / 5P ..
  - 2H / 3H / 4H / 5H / 6H … 8H ..
- On Rooftops
  - Different combinations



Directionally speaking, vertical orientation costs relatively lesser than horizontal one in the bigger picture of a project

Equipment Installed - Module

PV Modules Types

- Mono-facial

Poly-Si

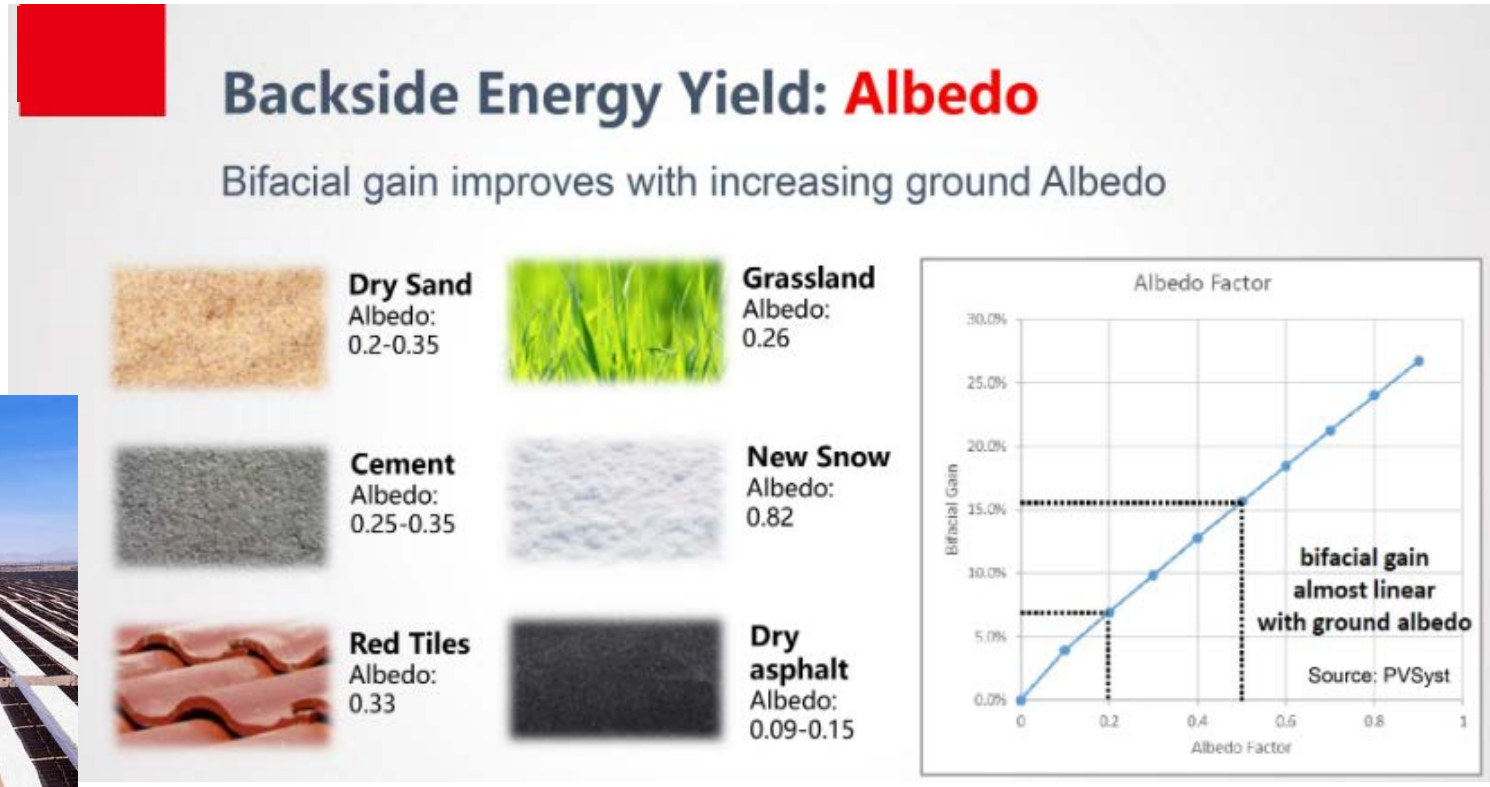
Mono-Si

Thin Film - CdTe

Equipment Installed - Module

PV Modules Types

- Bi-facial
  - Ground albedo
  - Bifacial gain



Equipment Installed - Module

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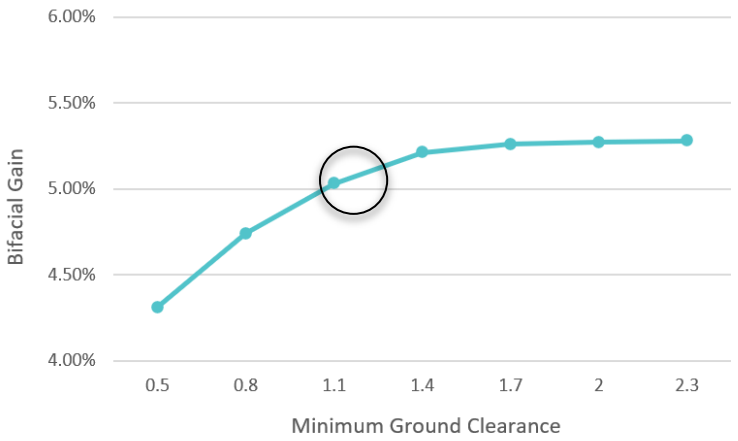
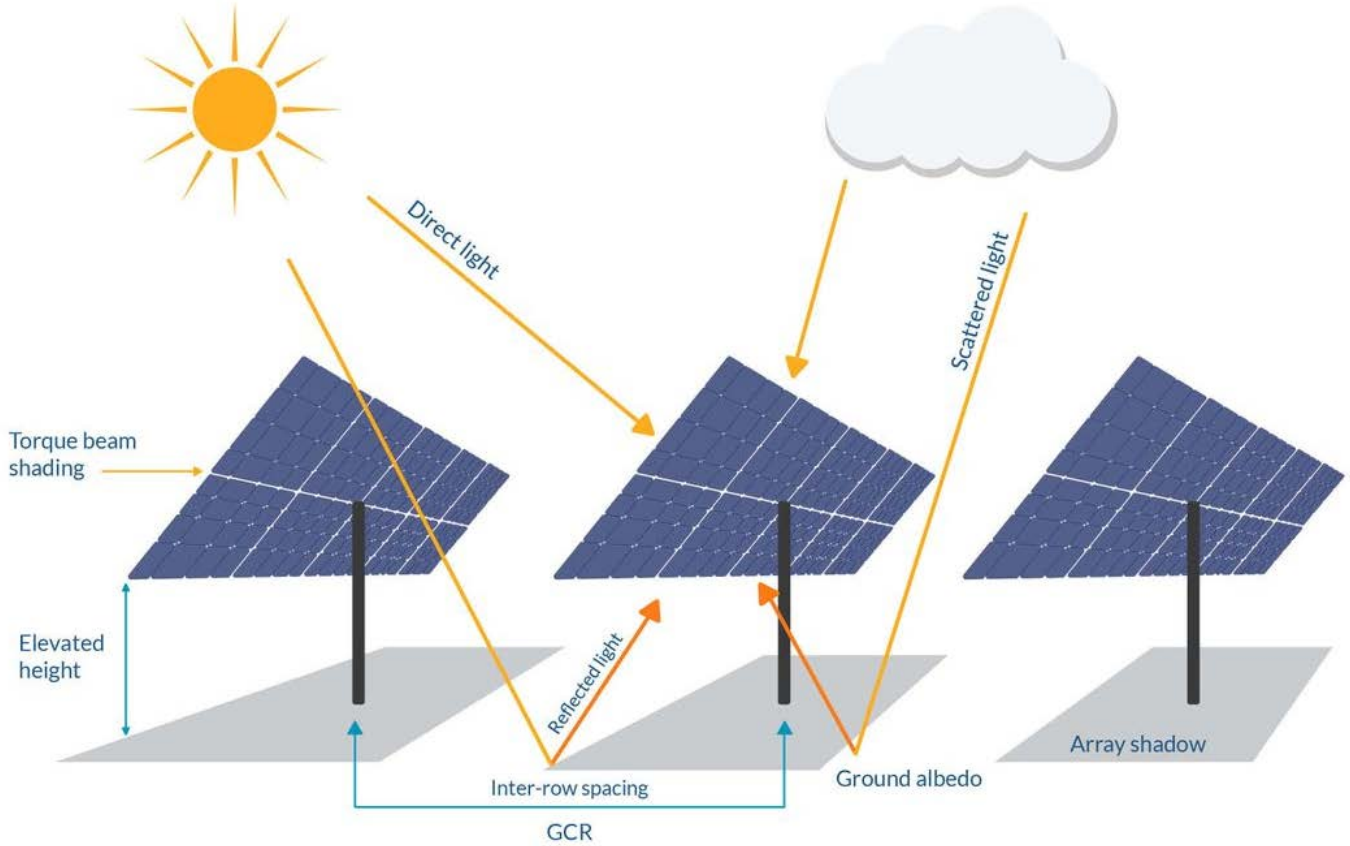
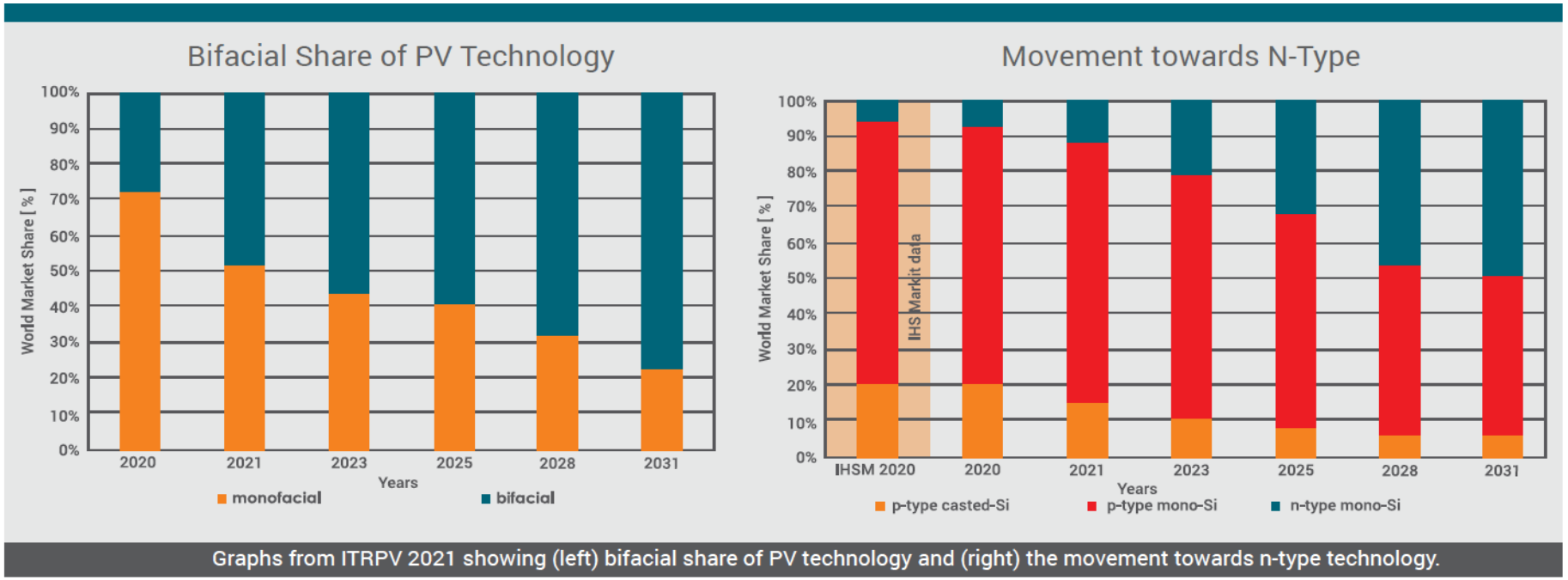




Equipment Installed - Module

- PV Modules Industry of the future will be mostly based on bifacial modules as they have helped in producing record low LCOEs till 2021.
- As summarized by International Technology Roadmap for Photovoltaics (ITRPV) in 2021, bifacials have already penetrated half of the PV market, from 2028 on reaching a market share of 70%.
- IRTPV is proposing a fast grow of n-type technologies in the future with a market share of 50% from 2031 onwards - all products then naturally being bifacial.



Graphs from ITRPV 2021 showing (left) bifacial share of PV technology and (right) the movement towards n-type technology.

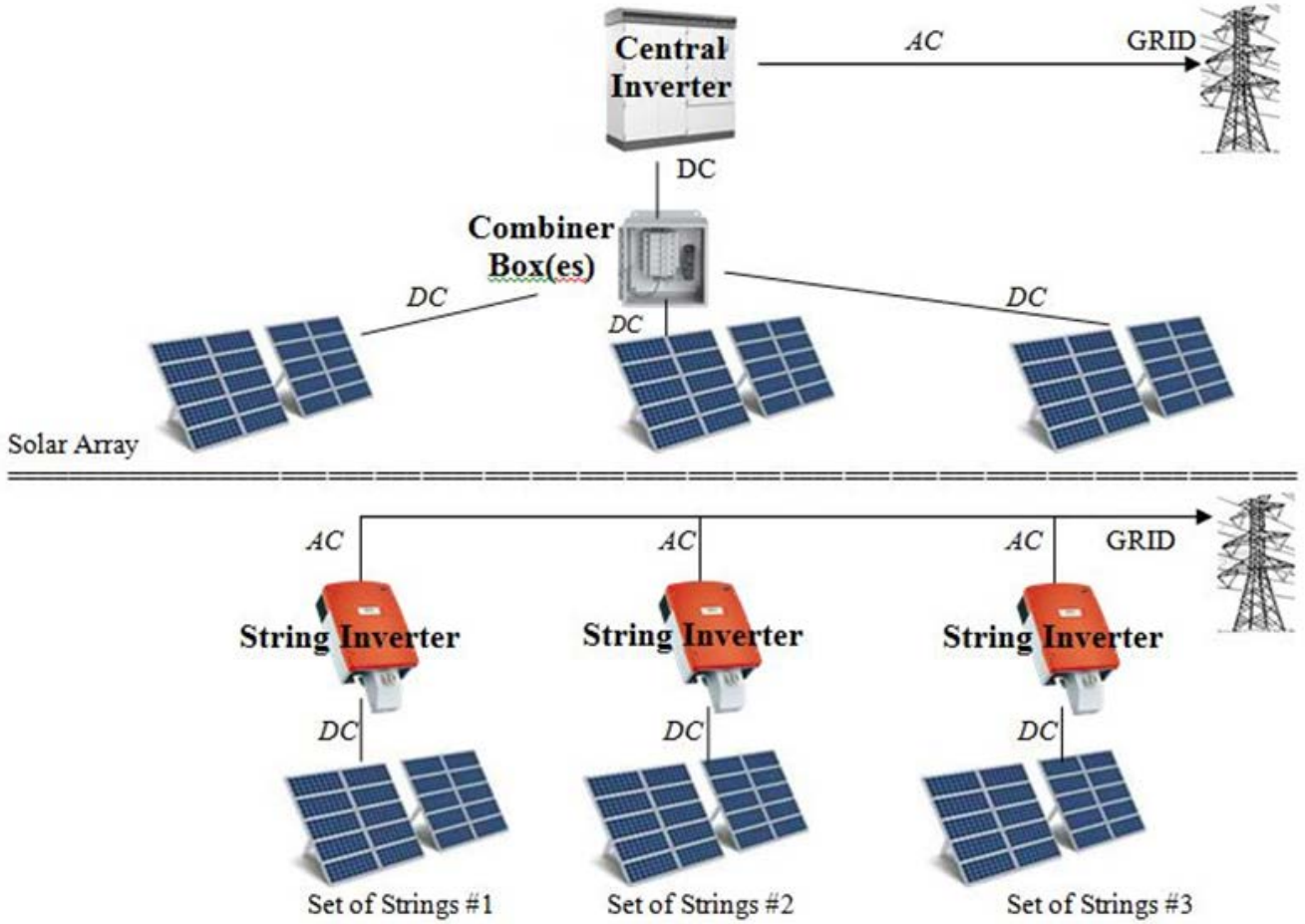
Equipment Installed - Inverter

Central Inverters

- Power range 1MW to 4MW
- Typical Efficiency: 98.5%
- Top suppliers: Sungrow, SMA, Ingeteam, ABB, GE, Schneider Electric etc.

String Inverters

- Power Range 20 kW to 30 kW
- Typical Efficiency: 98.5%
- Top suppliers: Huawei, Sungrow, ABB etc.



Equipment Installed - Inverter

Inverter	Pros	Cons
Central type	• Fewer component connections and number of inverters required in plant • Proven field reliability • Lower $/W price	• Failure of single inverter results mostly in loss of complete power block • Higher maintenance cost as more components (cooling system, filters) • Maintenance may take longer time • Higher installation cost and requires more area
String type	• Lower day-to-day maintenance (no fans, filter) • Relatively higher plant availability as fewer arrays are impacted with one inverter failure • Plug and play design - quick to replace • Lesser foot-print	• More inverter connections • No. of inverters are quite large for same sized plant as compared to central type • Relatively newer - less field-tested product

Equipment Installed

Mounting System Arrangement

Equipment Installed

Mounting System Arrangement

- Fixed Tilt
  - One side (N-S)
  - Dome shaped (E-W)
- Single Axis Tracker (N-S)
- Double Axis Tracker (N-S)

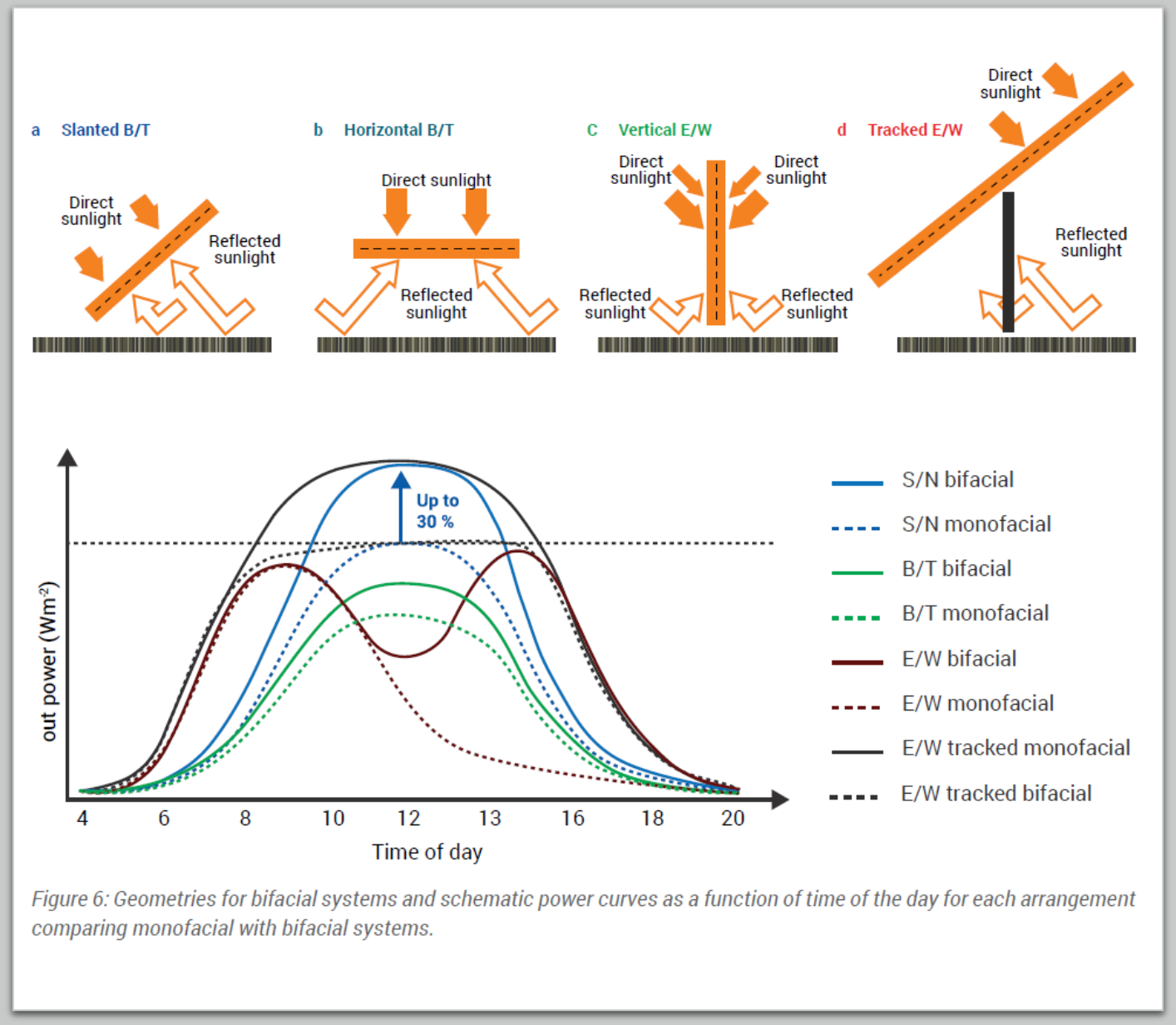
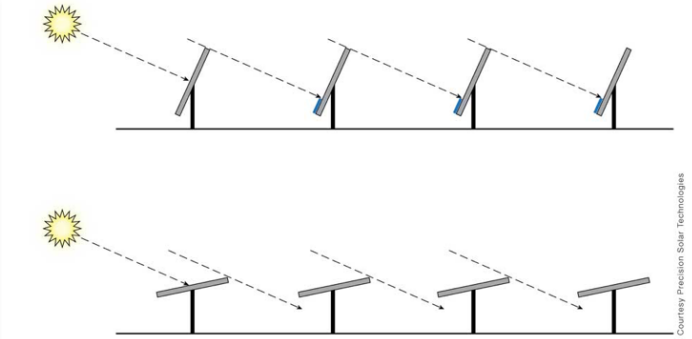


Figure 6: Geometries for bifacial systems and schematic power curves as a function of time of the day for each arrangement comparing monofacial with bifacial systems.

Equipment Installed

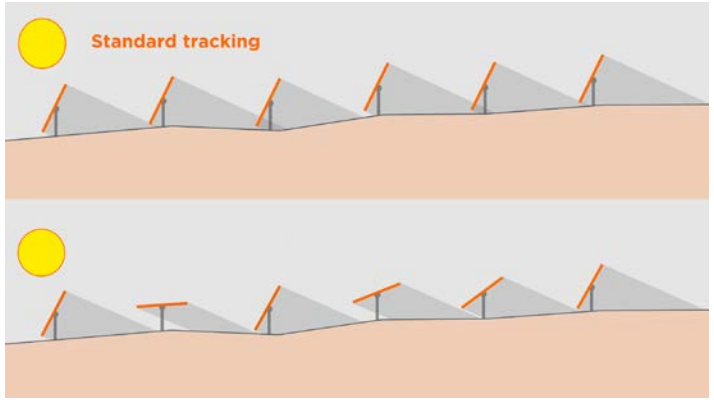
Single-Axis Trackers

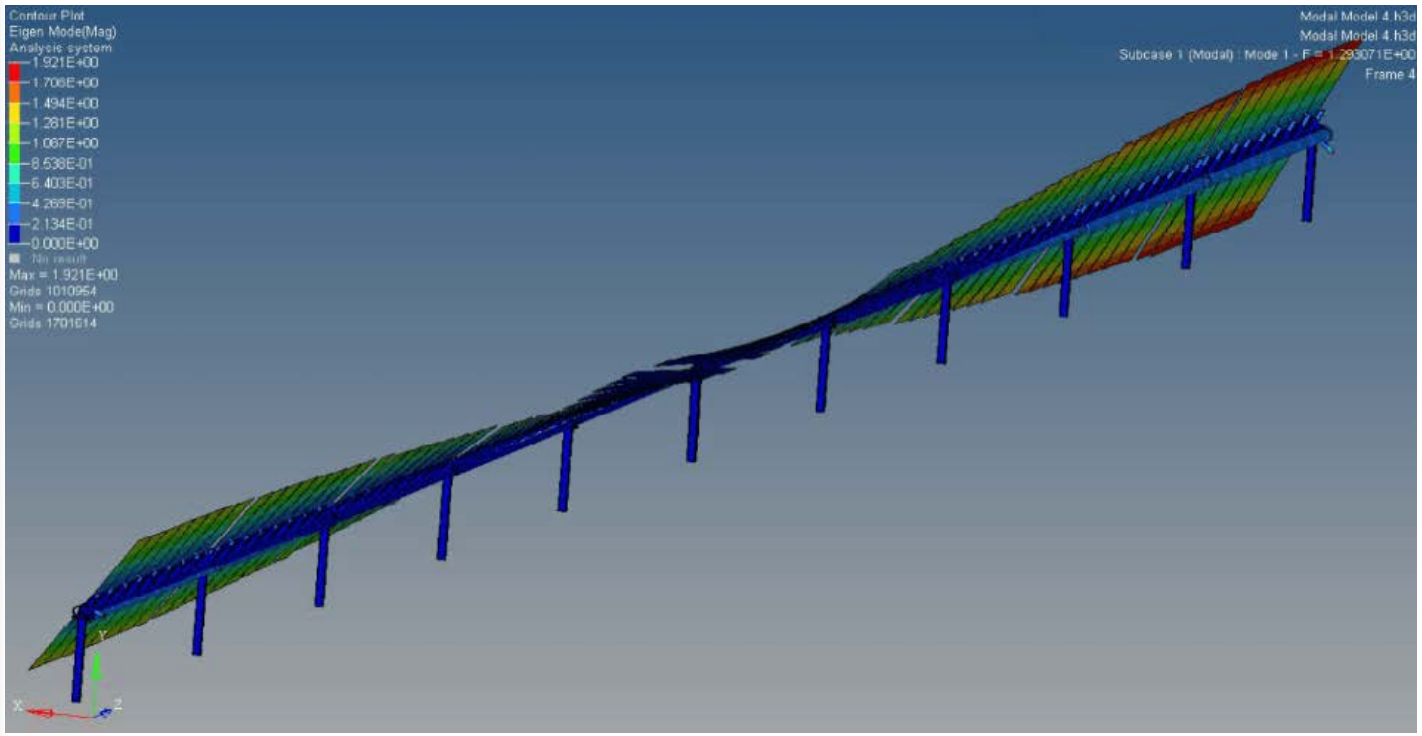
- Power drive mechanism
  - Single / dual / multiple
- Backtracking
- Wind stow position of trackers
- Tracking algorithms & angular accuracy
- Mismatches during installation of trackers between the trackers in X/Y/Z/angular planes to be controlled



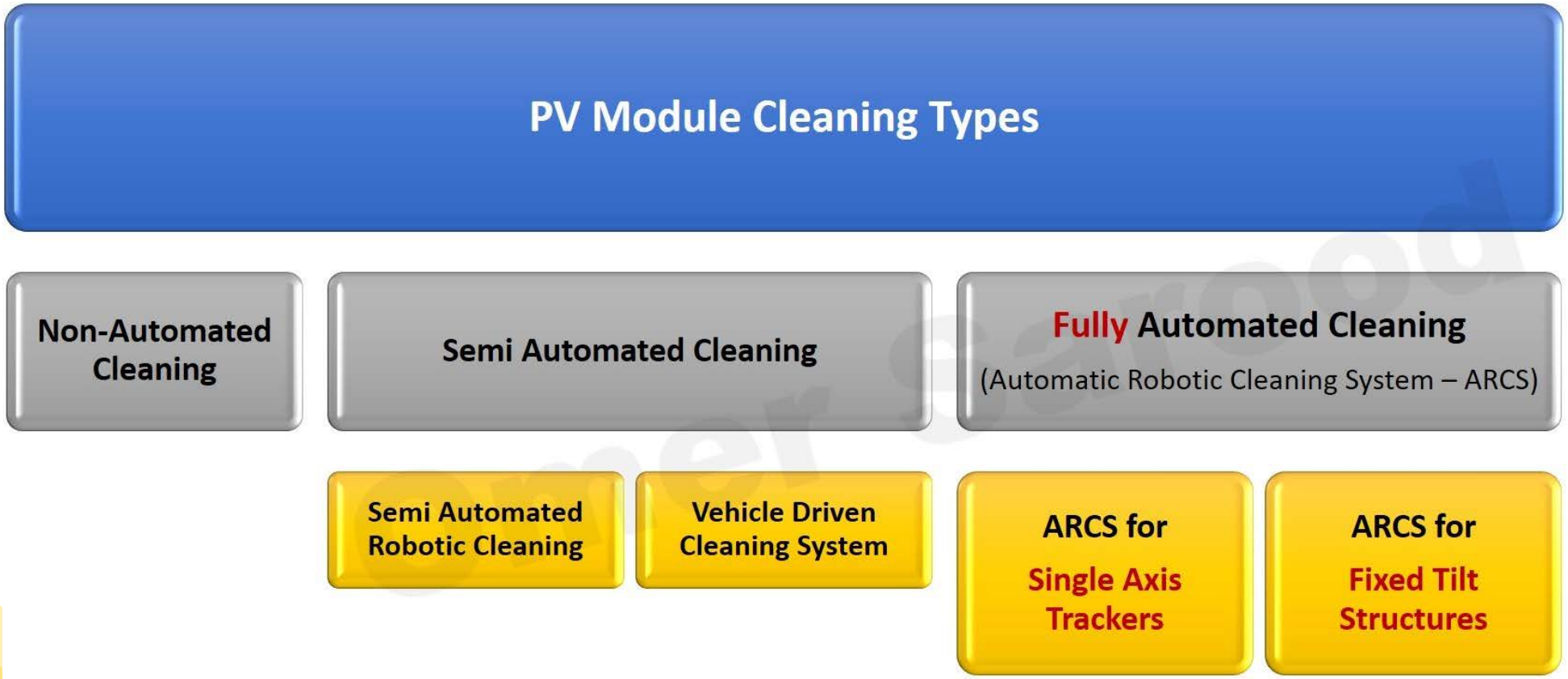
Courtesy Precision Solar Technologies

Backtracking When the sun's elevation angle is low in the sky, early or late in the day, self-shading between tracker rows has the potential to dramatically reduce system output. Backtracking rotates the array aperture away from the sun, eliminating deleterious effects of self-shading and maximizing ground cover ratio.





Equipment Installed – Cleaning Equipment



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Equipment Installed – Cleaning Equipment

- Semi-Automated Cleaning *(few examples)*

hyCleaner

Sunbrush

BP Metalmeccanica

Gekko

Miraikikai

Solarcleano F1

Equipment Installed – Cleaning Equipment

- Fully-Automated Cleaning *(few examples)*

Ecoppia

Solar LIT

SCM

NOMADD

PVH

Sol-Bright

Tetra

Sunpure

Equipment Installed – Cleaning Equipment

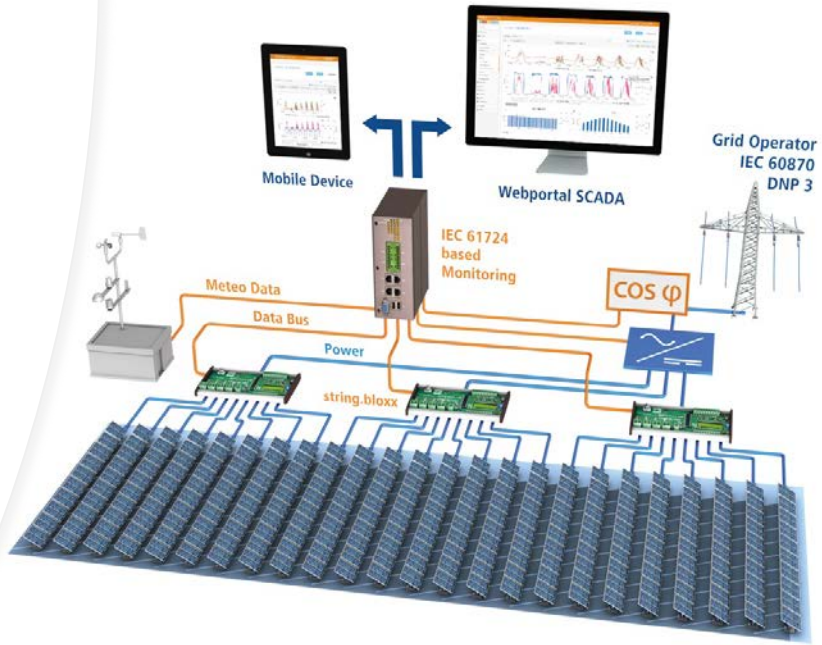
ARCS – Automatic Robotic Cleaning System

- This system comprises of the following engineered components, each required to be compatible with others:
  - **Robots**
  - **Communication System / SCADA**
  - **Structures**
    - Stations
      - Docking/Parking Station
      - Return Station
    - Bridges
      - Dynamic/Flexible Bridges (required only in case of Trackers)
      - Static/Fixed Bridges
    - Module Binders (to minimize deflection of modules)

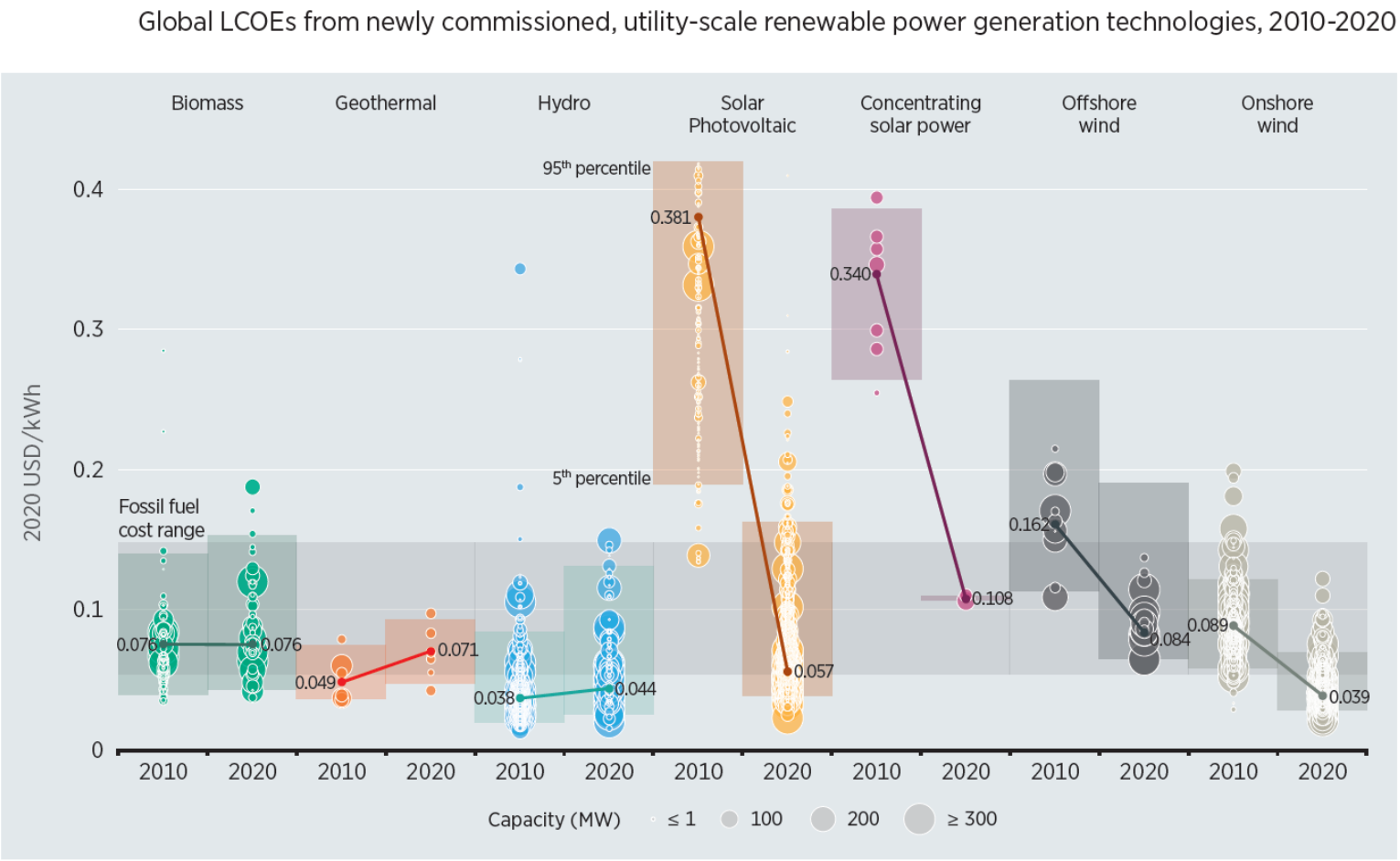
Equipment Installed - BoP

Typically, other important equipment installed at a Utility Scale Solar PV Power Plant is as follows:

- Transformers / Sub Station
- Weather Station
- PV Plant SCADA (Control System)
- HMIs
- Cables (DC & AC)
- Combiner boxes
- Others…



Project Development Perspective - LCOE



Source: IRENA Renewable Cost Database

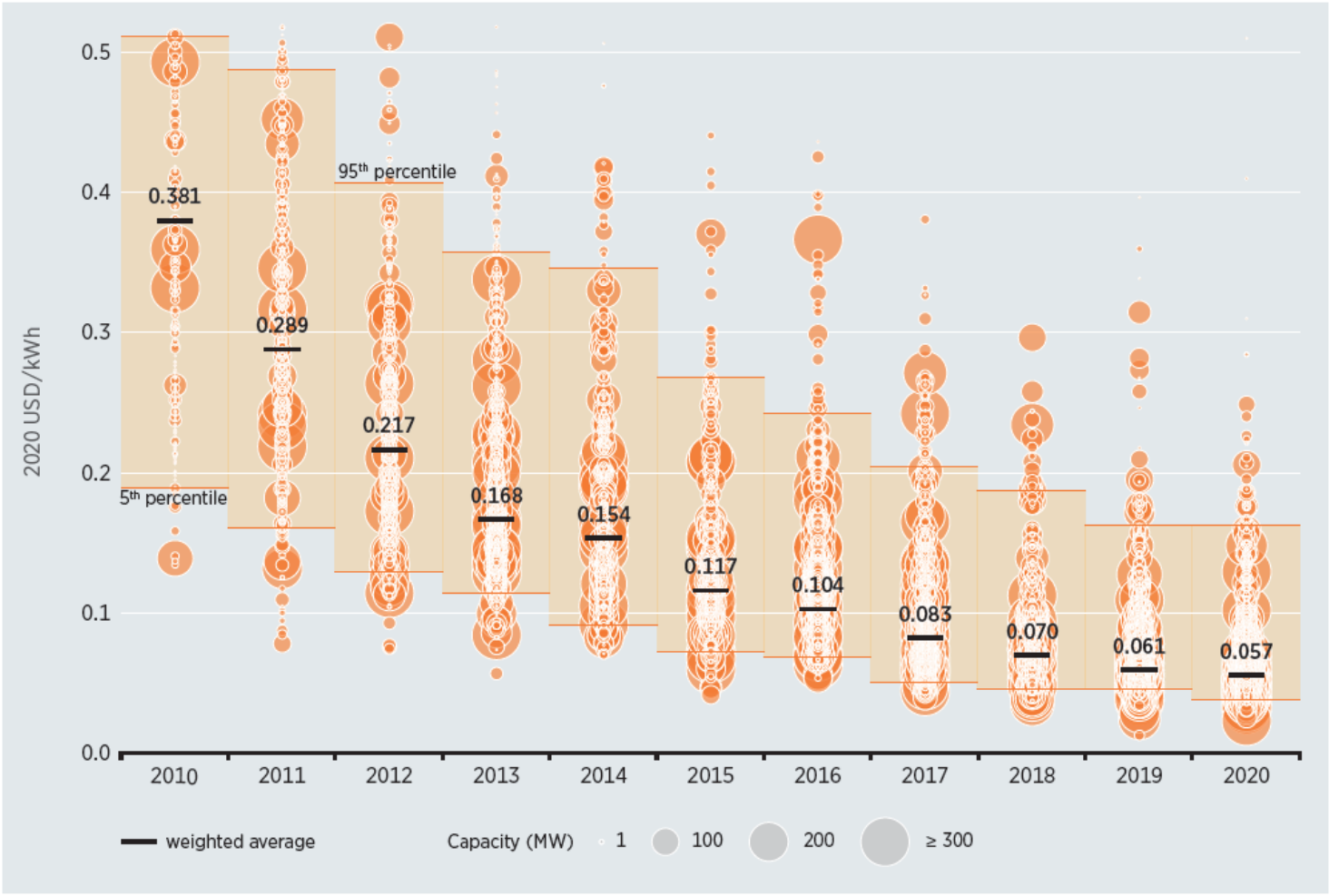
LCOE : Levelized Cost of Electricity /Energy

- measure of av. Net present cost of electricity generation for a power plant during its life
- Ratio of present value of total cost over the life and present value of all electricity generated over the life of the project
- Good tool used by Developers to have both fixed costs & variable costs of project into a single measurement

Project Development Perspective - LCOE

- The global weighted-average LCOE of utility-scale PV plants declined by **85%** between 2010 and 2020, from **USD 0.381/kWh to USD 0.057/kWh**.
- This 2020 estimate also represents a 7% year-on-year decline from 2019.
- The 5th and 95th percentile of projects in 2020 ranged from USD 0.039/kWh to USD 0.163/kWh, which is a 79% and 68% decline in the 5th and 95th percentile values, respectively, compared with 2010.
- Top 10 Lowest globally (Mid 2021):
  - **1.04¢/kWh** – Saudi Arabia, 600 MW, announced April 2021
  - 1.239¢/kWh – Saudi Arabia, 1.5 GW, announced April 2021
  - 1.316¢/kWh – Portugal, % of 10 MW, announced August 2020
  - 1.35¢/kWh – Abu Dhabi, 1.5 GW, announced April 2020
  - 1.50¢/kWh – New Mexico, USA, 100 MW, announced May 2020
  - 1.57¢/kWh – Qatar, 800 MW, announced January 2020
  - 1.61¢/kWh – Saudi Arabia, 300 MW, announced April 2020
  - 1.65¢/kWh – Portugal, 150 MW, announced July 2019
  - 1.69¢/kWh – Dubai, 900 MW, announced December 2019
  - 1.75¢/kWh – Brazil, 211 MW, announced July 2019

Global utility-scale solar PV project levelised cost of electricity and range, 2010-2020



Source: IRENA Renewable Cost Database

Project Development Perspective - LCOE

Solar PV module costs have declined so rapidly that new solar PV markets keep emerging around the globe

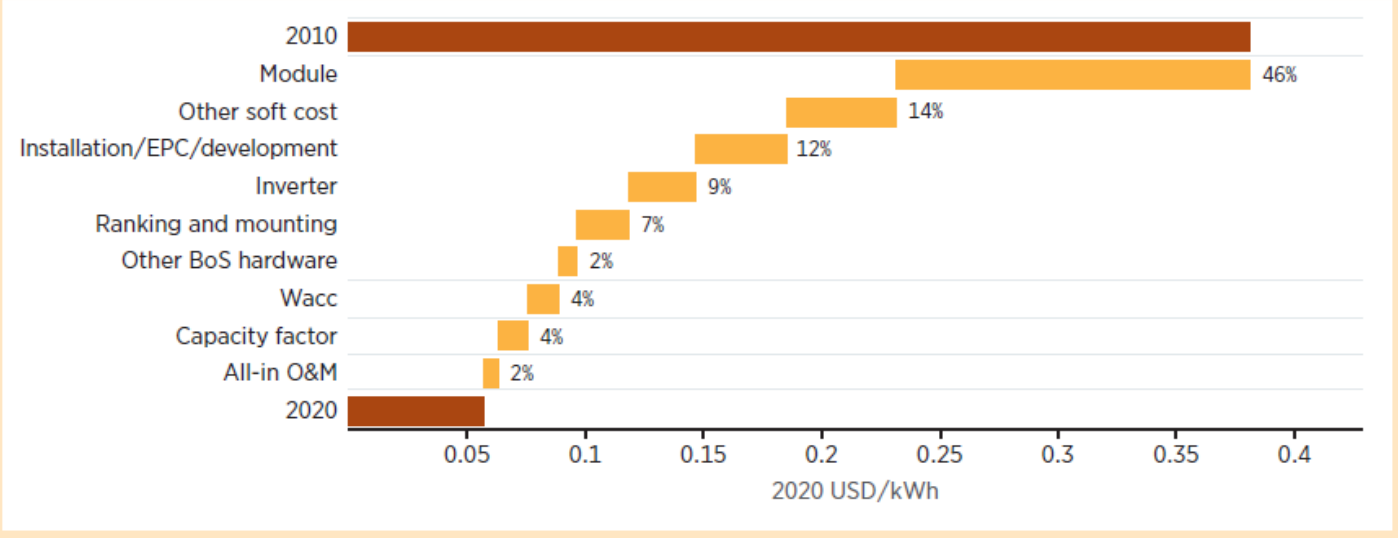
The PV industry is constantly seeing innovations:

- Increased adoption of larger polysilicon factories and improved ingot growth methods,
- to the increased ascendancy of diamond wafering methods
- the emergence and dominance of newer cell architectures etc.

Between 2010 & 2020:

- The decline in solar module cost contributed 46% to the LCOE reduction
- Cost reduction in inverters, racking and mountain and other BoS hardware, contributed another 18% to the LCOE reduction
- Installation, engineering, procurement and construction (EPC) and development costs with other soft costs were responsible for about a quarter of the LCOE decline

Between December 2009 and December 2020, crystalline silicon module prices declined between 89% and 95%



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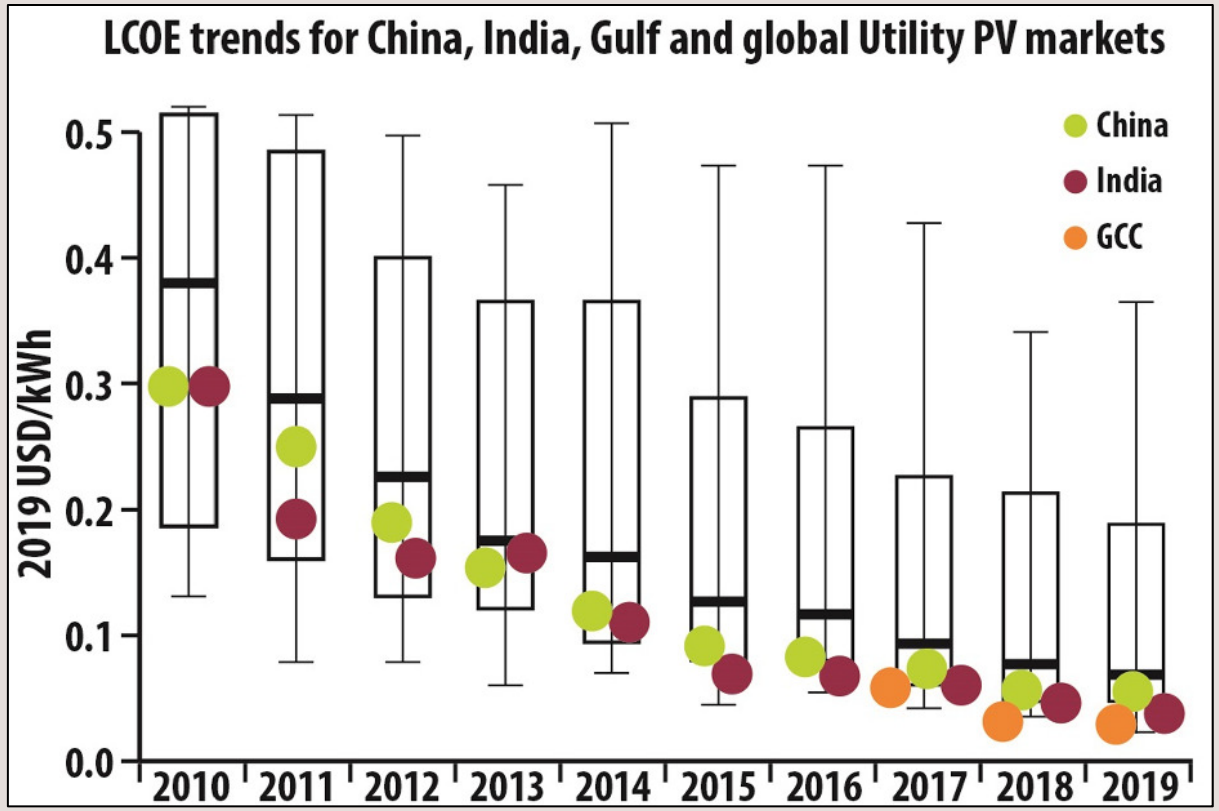
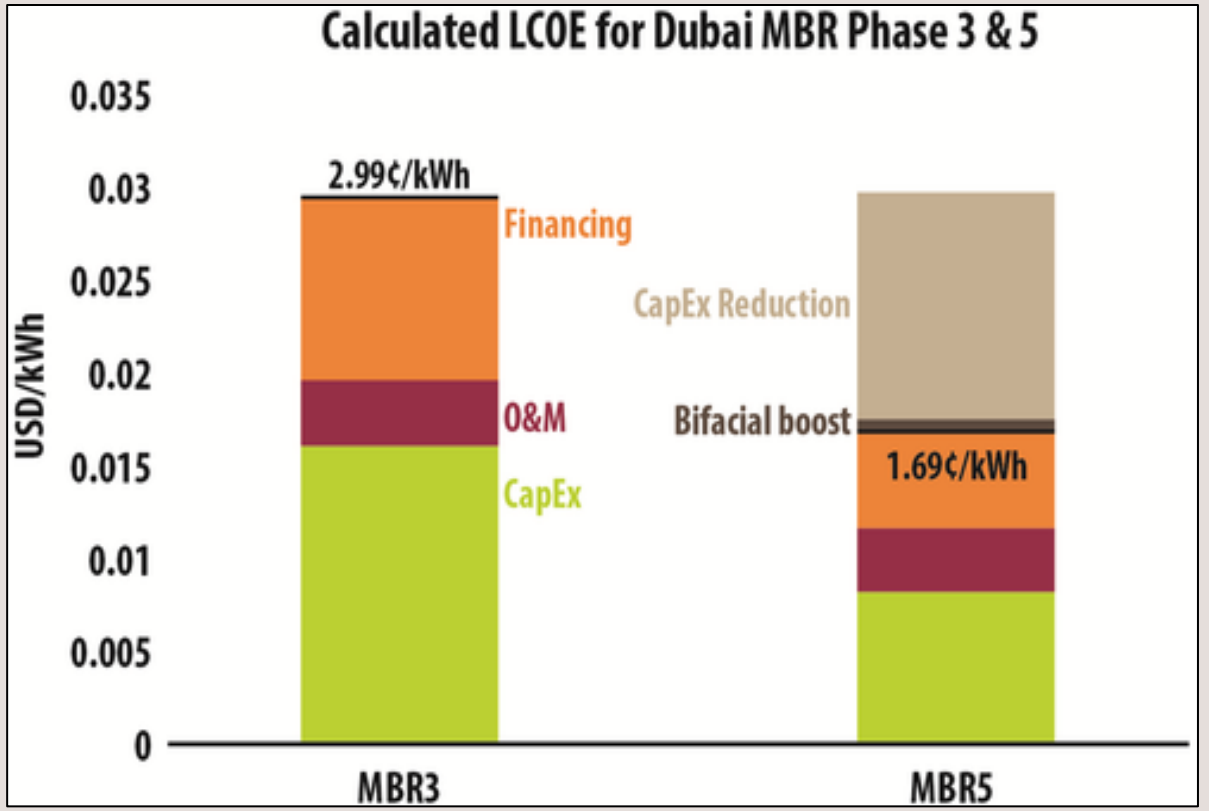
Project Development Perspective - LCOE

As per public domain information..





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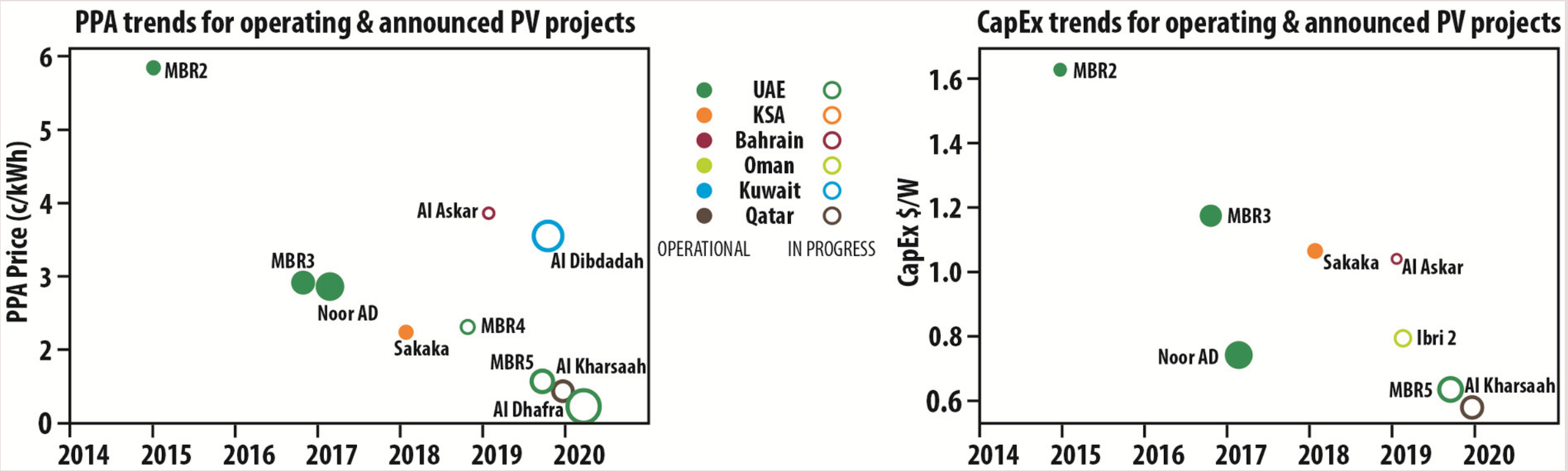

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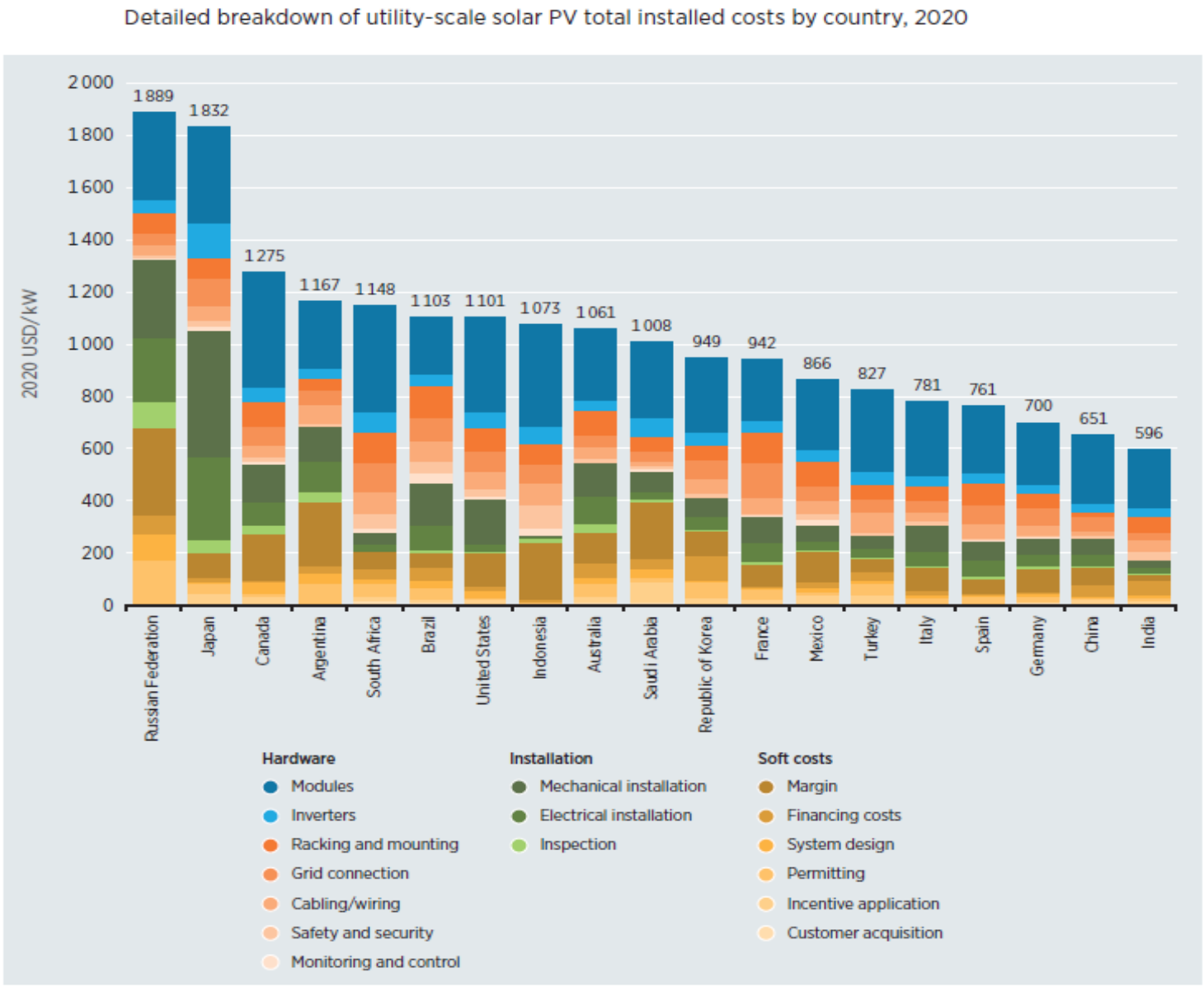

Source: IRENA Renewable Cost Database

Thanks!

Any questions?