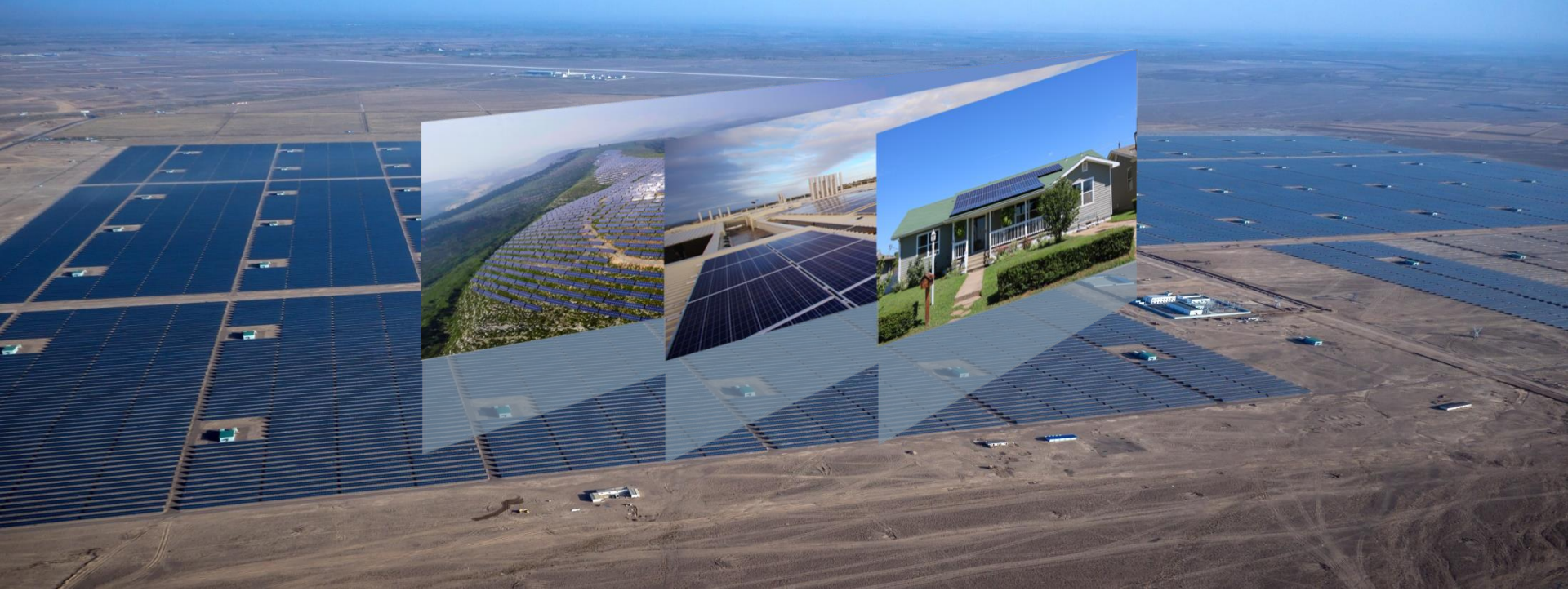

Progress and outlook at an industrial level R&D for Photovoltaic products

Xinyu Zhang
Solar Cell R&D Department Director, Jinko Solar

Solar
JinKO
Building Your Trust in Solar

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2 Representative work updates 2017

3 What do industrial level R&D team do: projects and interests

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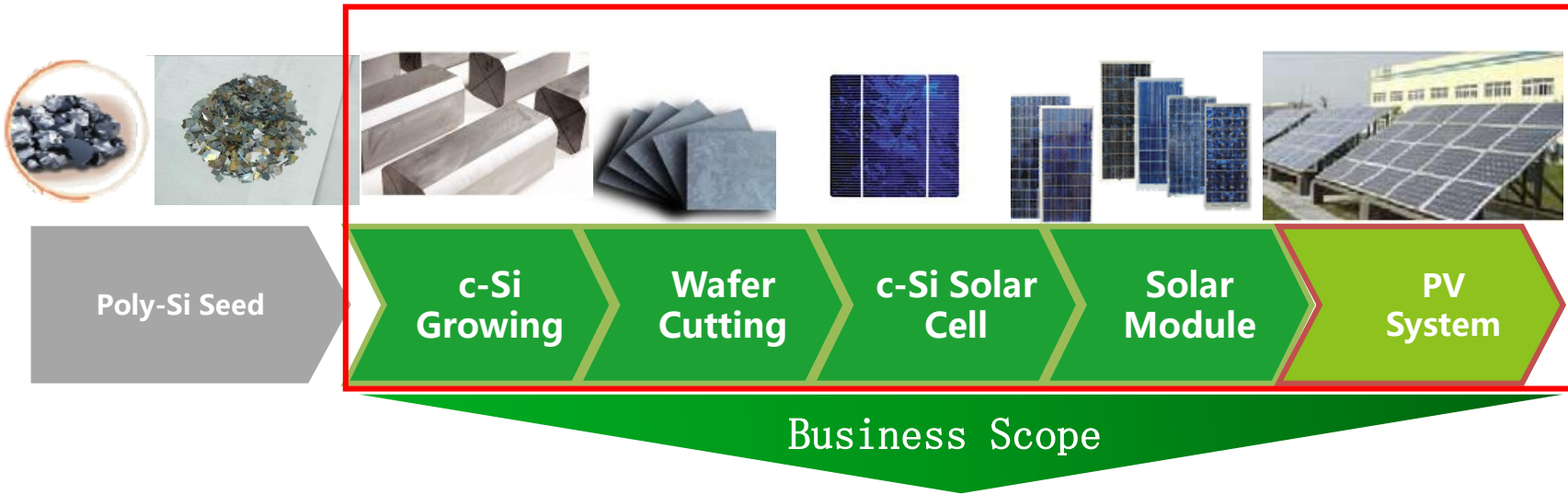
JINKO SOLAR: PV manufacturing company

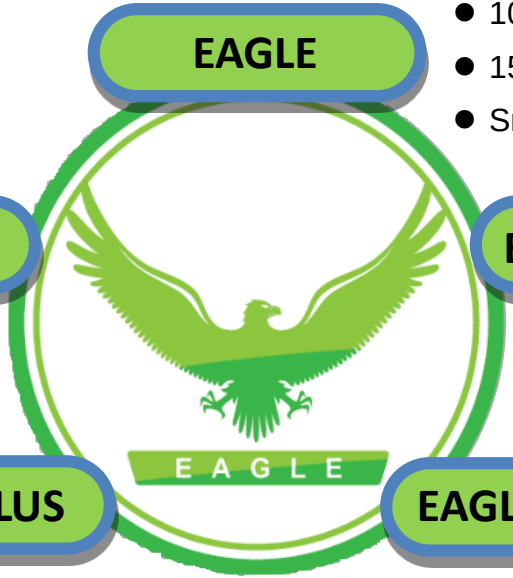


- Multi-business PV manufacturer: wafer → cell → module → system
- Share code (New York): JKS
- **9.7 GW shipment, No.1 in 2017**
- 7 manufacturing factories globally, 23 branches world-wide, 3 R&D departments
- Top 100 World Energy Company, Top 500 Chinese Company

The Jinko Map

Transition from a “company with global business” to a “globalised company”.

Main Product Family



- 1000V module
- 1500V module
- Smart module

- Conventional PERC module
- All-black PERC module

- MCT black-silicon Module
- All-black module

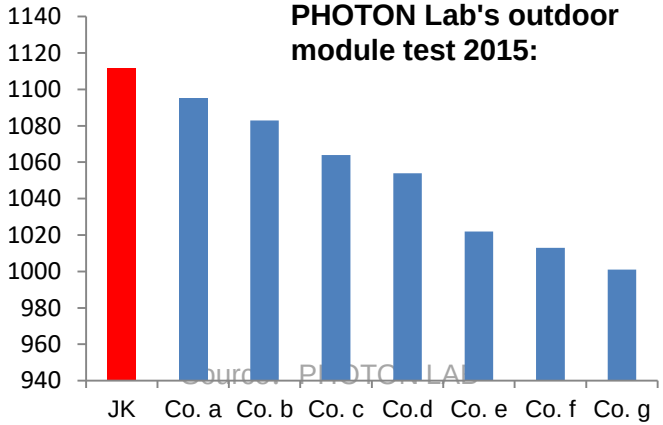
- Eagle P Plus
- Eagle Q Plus
- Eagle I Plus

- Conventional dual-glass module
- Edging sealed dual-glass module

Product performance

Photon
Ranked one of the Best Performers in 2012

Highest efficiency and performance P type module



PHOTON Lab's outdoor module test 2014:

Manufacturer	Model	Performance ratio (%) 2014	Yield (KWh/KW) 2014	Cell type
Jinko Solar	JKM275P-60	92.9	1154.1	Multi
Jinko Solar	JKM190M-72	92.2	1145.1	Mono
Company A	***	91.9	141.6	Multi
Company B	***	91.6	1138.0	Multi
Company C	***	91.3	1133.5	Mono
Company D	***	90.1	1118.9	Multi
Company E	***	89.8	1115.6	Mono
Company F	***	89.3	1109.8	Multi
Company G	***	88.0	1093.5	Multi
Company H	***	83.4	1036.0	Multi

Data from PHOTON LAB: Jinko product leads in power generation in 2014 and 2015 among the P type silicon modules, demonstrating the highest quality and reliability standards for industry.

High Quality Assurance（Jinko product to be “top runner”）

1. **The first company authorized with the 1st class efficiency certification for poly module by CQC**

2. **CQC TOP RUNNER**
   The first company authorized with the 1st class efficiency certifications in poly and mono product at the same time

3. **CGC TOP RUNNER**
   1500V/PERC/RIE/Dual glass technologies are certified by CGC advanced technology top runner

4. **ALL QUALITY MATTERS**
   Won the reward of “highest efficiency competition PV module” by TÜV Rheinland

5. **INDUSTRIAL LEADING PRODUCT**
   Jinko’s production poly modules offer main power rating (265-280W), 1-2 level higher than industrial main stream.

State key lab (3 locations)

(State accredited enterprise technical center)

– Solar Cell department

City of Haining, Zhejiang Province, China

Total area 15400m^2
SCD: >7000m^2

70+ researchers
(PhD. 10; Master 55)

>210 research equipment

Jinko technology to lead the industry

- ***High efficiency***
- ***High power generation***
- ***High reliability***

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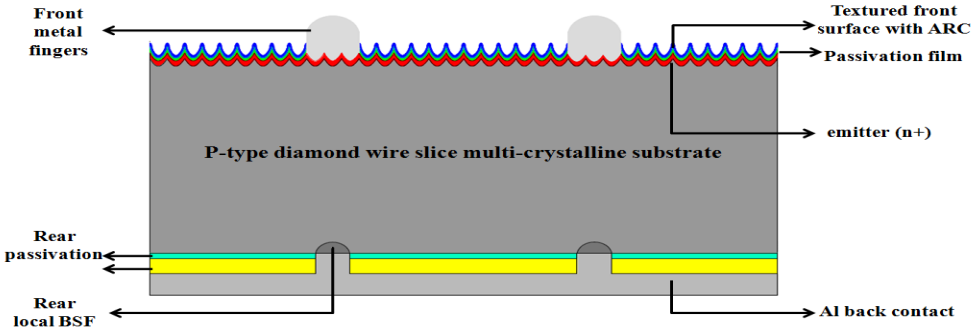
P-type multi-Si solar cell: 22.04% (Fraunhofer ISE)

2.1 High efficiency multi-Si PERC



- Control parameters are measured during the cell fabrication process.
- Front and rear J0 are measured on control wafers.
- Contact resistivity for the front and rear are measured by TLM.
- Bulk lifetime of the wafers are measured after high temperature proces
- Control parameter used for simulation purpose

Parameters	Values
Front J0	30fA/cm2
Rear J0	15fA/cm2
Bulk lifetime τ	500μs
Front contact J0	1500fA/cm2
Rear contact J0	600fA/cm2
Front contact resistivity	5mΩ.cm2
Rear contact resistivity	20mΩ.cm2

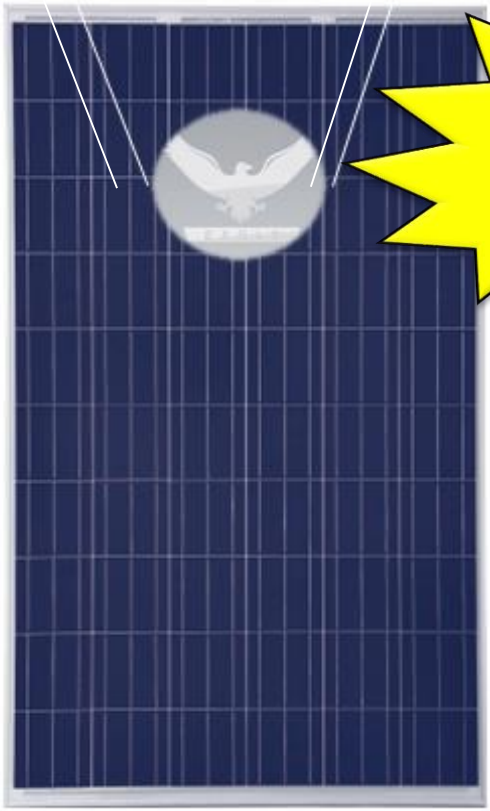
2.1 High Efficiency Solar Cell/Module Techniques

- Best cell: 23.45%
- Advanced structure average: >23%
- Mass production average: >21.7%

- Best cell: 22.5%
- Mass production average: >21.9%

- Best cell: 24%

2.1 High Efficiency Solar Cell/Module Techniques



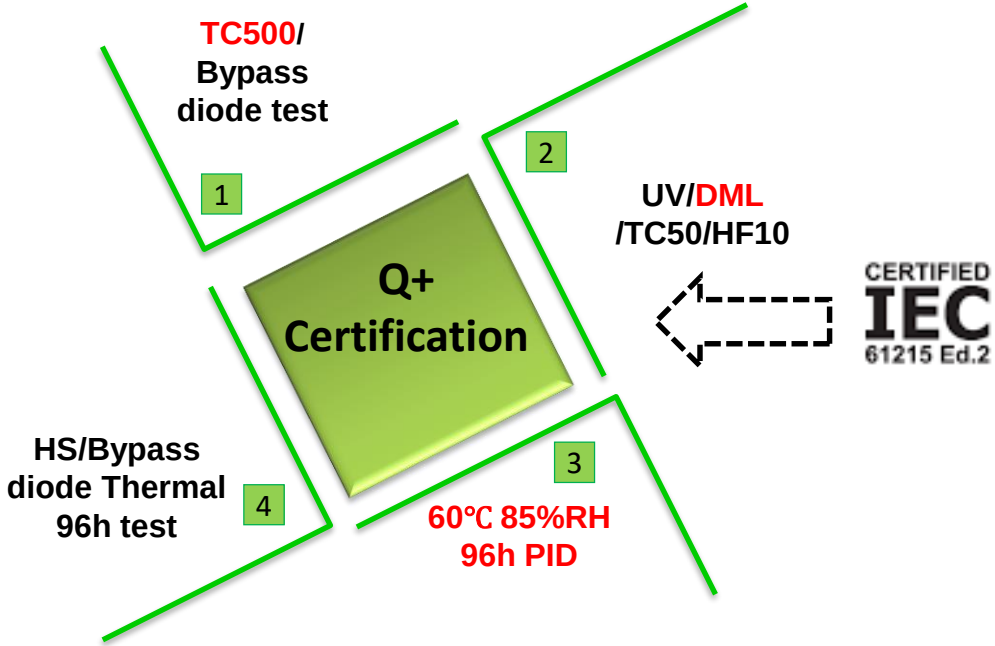
60P:
347.6W

Tested by TÜV Rheinland

60P:
356.7W

2.2 Quality and Reliability Control

Jinko solar was the first Chinese manufacturer achieve 3*IEC certification, first Chinese company to achieve Q+ certification, with the optimized by cell design, module material, fine processing control, and etc.

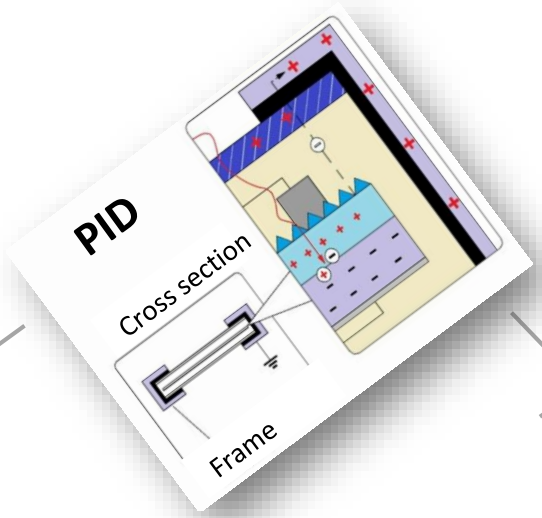


- Q+ certification is based on IEC 61215, but much tougher than it.
- All the items in red are beyond IEC 61215, demonstrating better performance of PV modules.

2.2 Quality and Reliability Control

Jinko is the first company to:

Pass the low temperature (-40 ℃) dynamic mechanical load test



Pass the 1000h, 85 ℃, RH85%, PID test

Pass the transportation and shipping of PV module stacks

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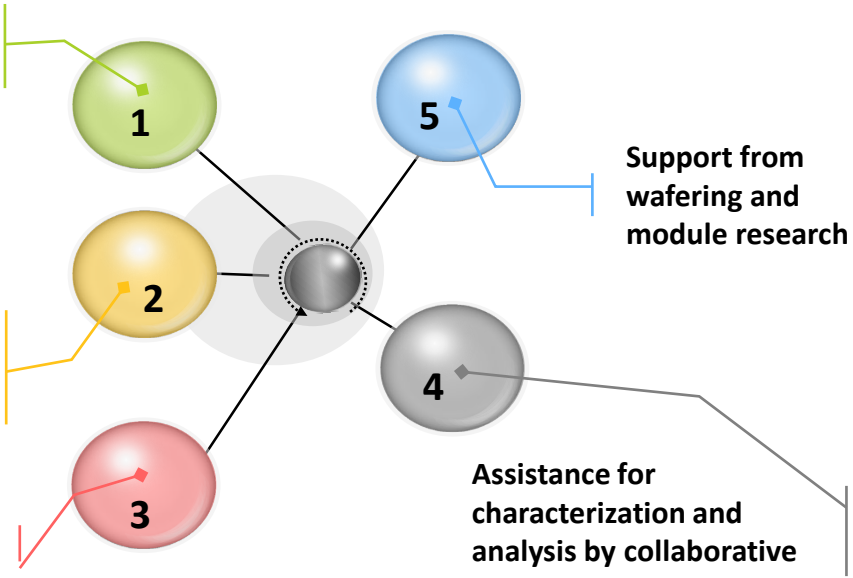
3.1 Advantages of Research at an industrial level

High throughput guaranties rich experimental data

Baseline results from production line enables reliable comparisons

Accessible to latest technologies and equipment



Support from wafering and module research

Assistance for characterization and analysis by collaborative partners

These significantly benefits industry players to speed up their technical development

Many good results achieved by Jinko, Longi, Trina, LG…

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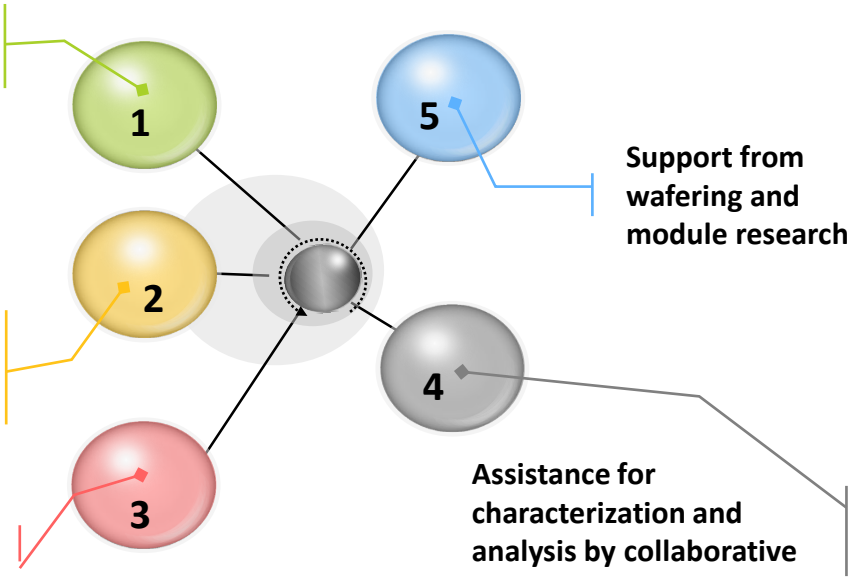

Support from wafering and module research

Assistance for characterization and analysis by collaborative partners

These significantly benefits industry players to speed up their technical development

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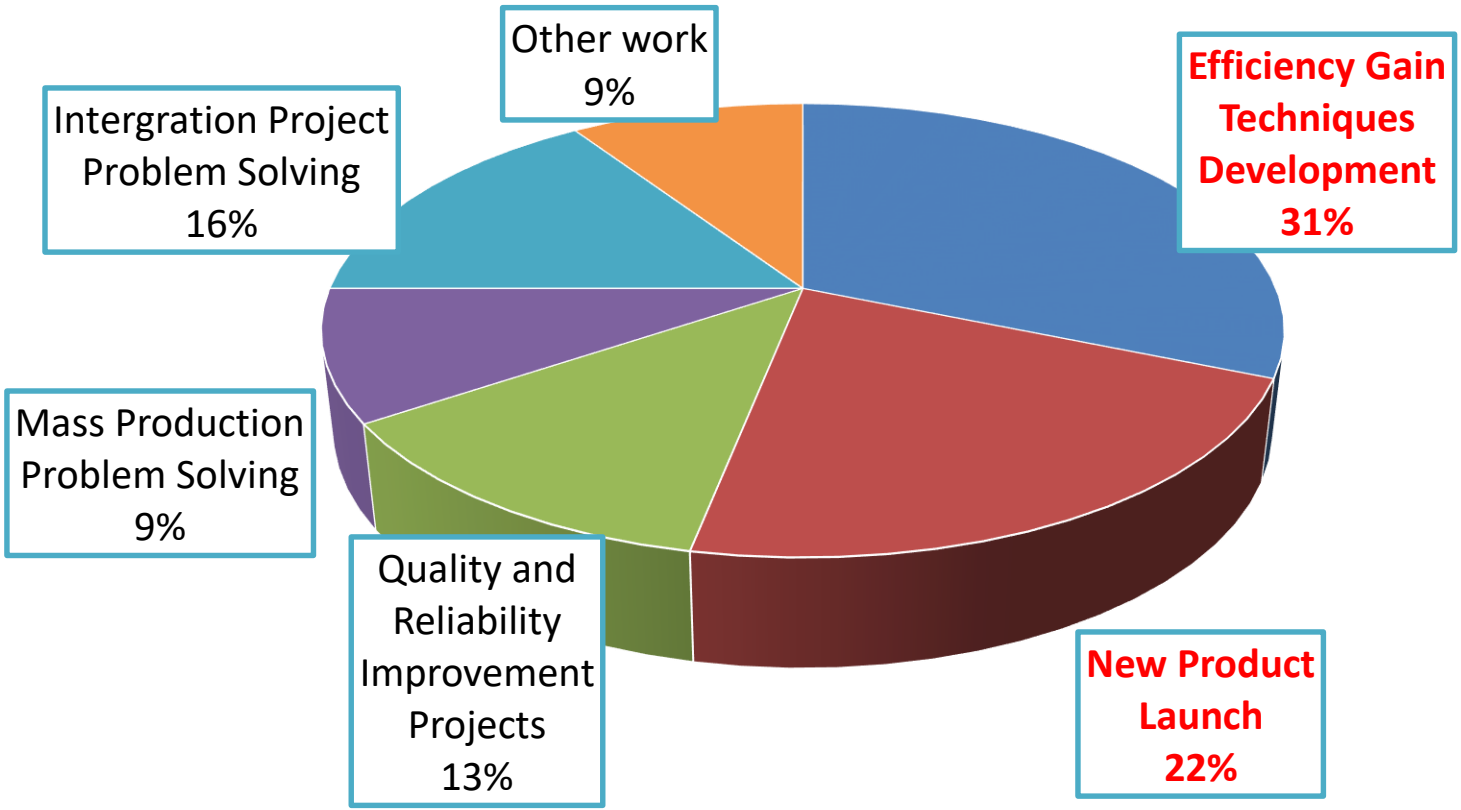
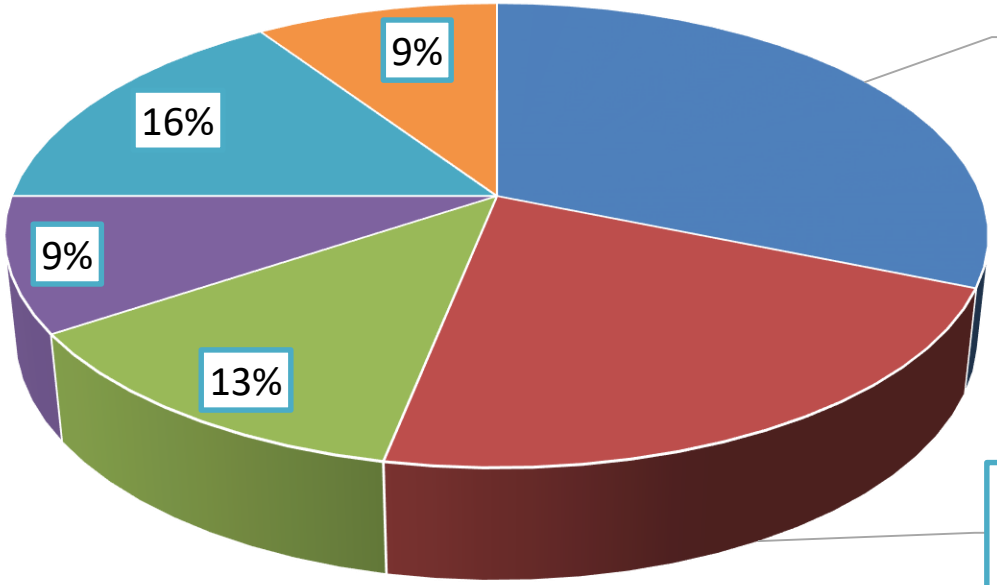
3.2 This is the real world

Distribution of R&D focus based on the number of projects



3.2 What people “think” R&D should do

Distribution of R&D focus based on the number of projects



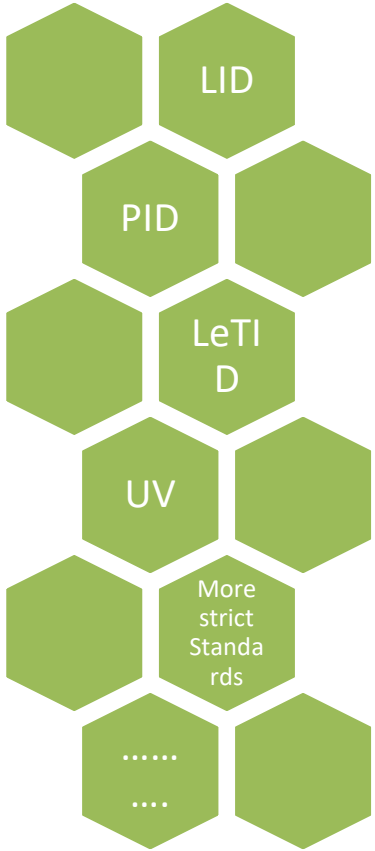
- Efficiency Gain Technique Development
- New Product Launch
- Quality and Reliability Improvement Projects
- Mass Production Problem Solving
- Intergration Project Problem Solving
- Other work

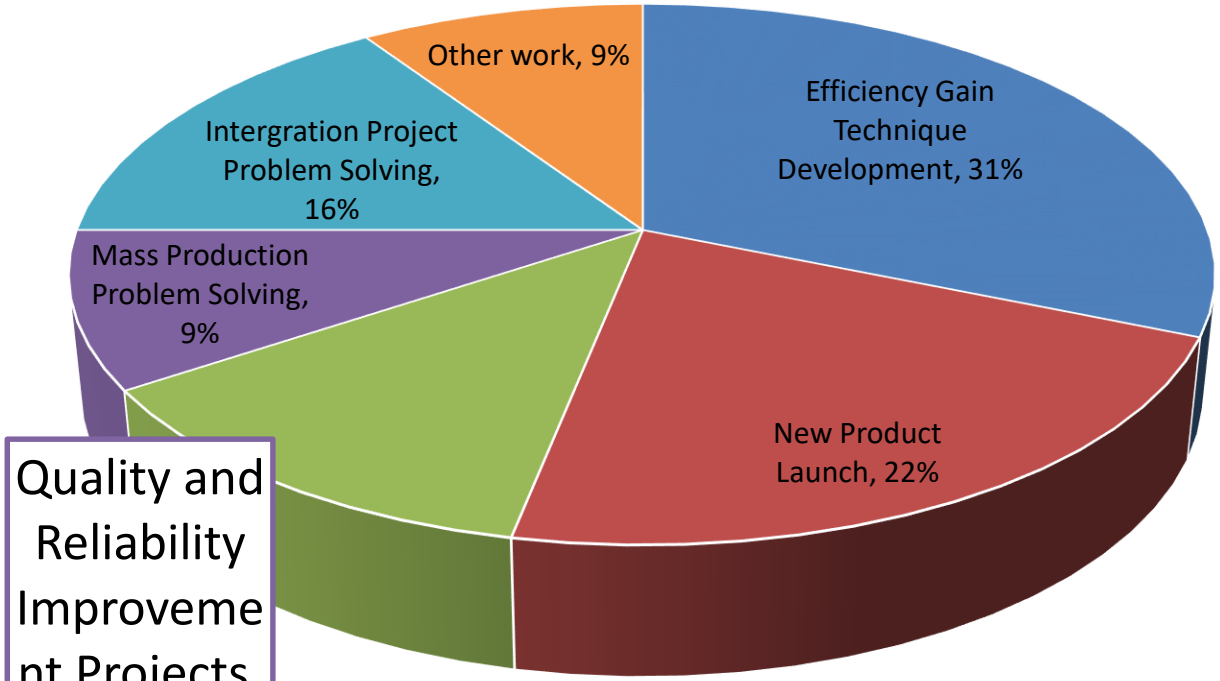
Efficiency Gain Techniques Development 31% → Early stage R&D work

New Product Launch 22% → Scale-up R&D work

3.3 Product Quality Topics Are Crucial

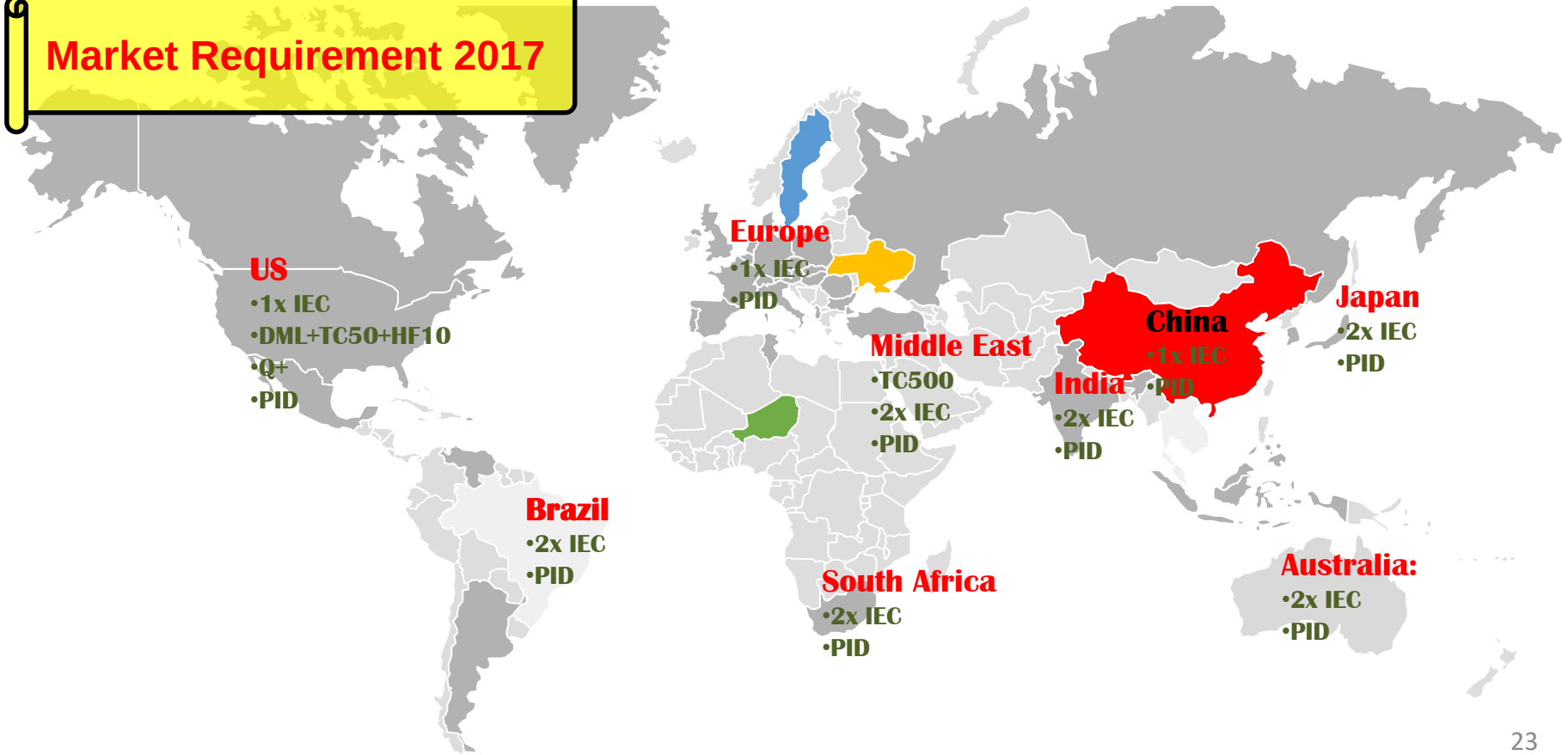
The PV market is and will be “quality” driven





3.3 Market requirements lead R&D directions

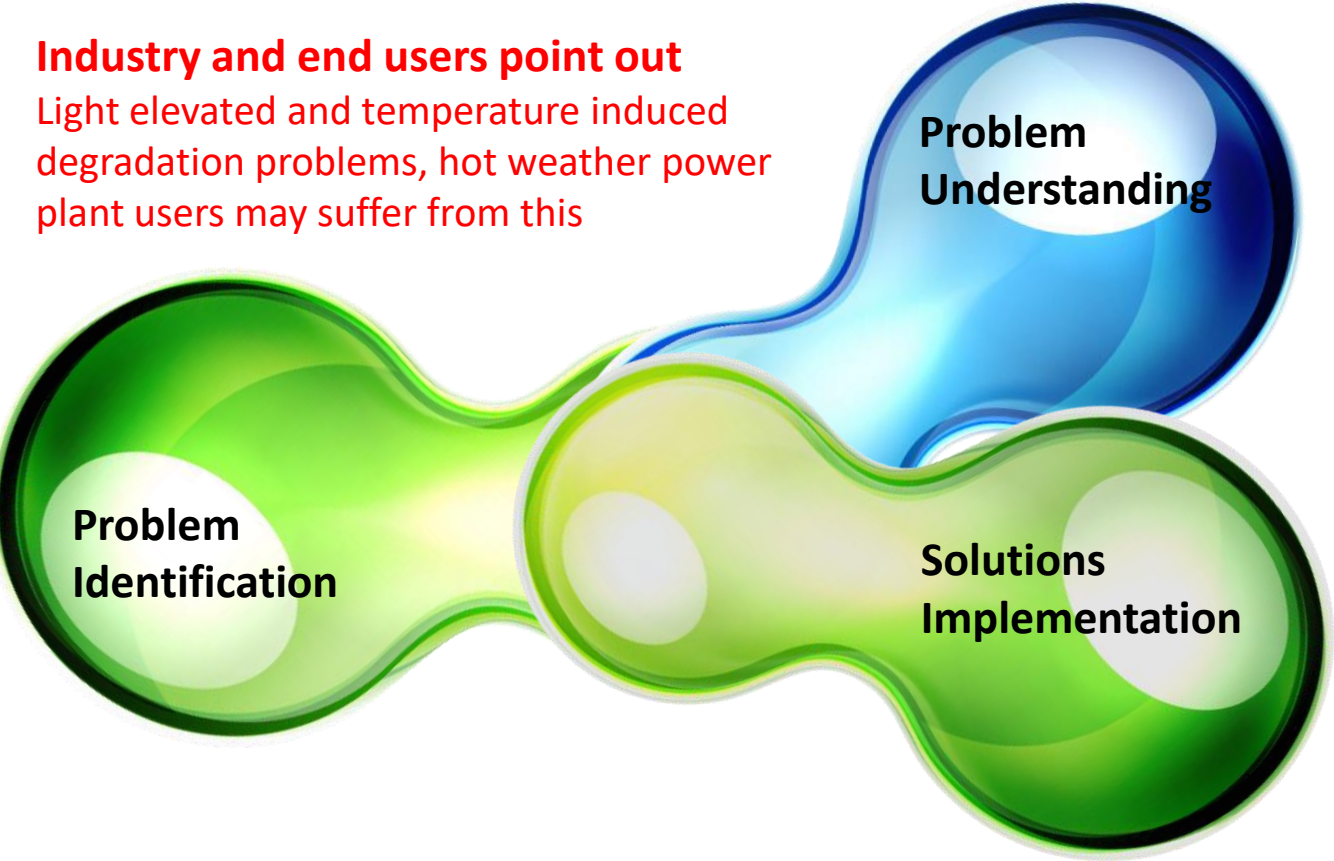
Market Requirement 2017



3.3 Giving LeTID as an example

Industry and end users point out

Light elevated and temperature induced degradation problems, hot weather power plant users may suffer from this



UNSW:

- Mechanism, possibilities, comparisons …
- Solutions, reliabilities…

JINKO R&D:

- Scale-up tests;
- Stability monitoring;
- Product updates

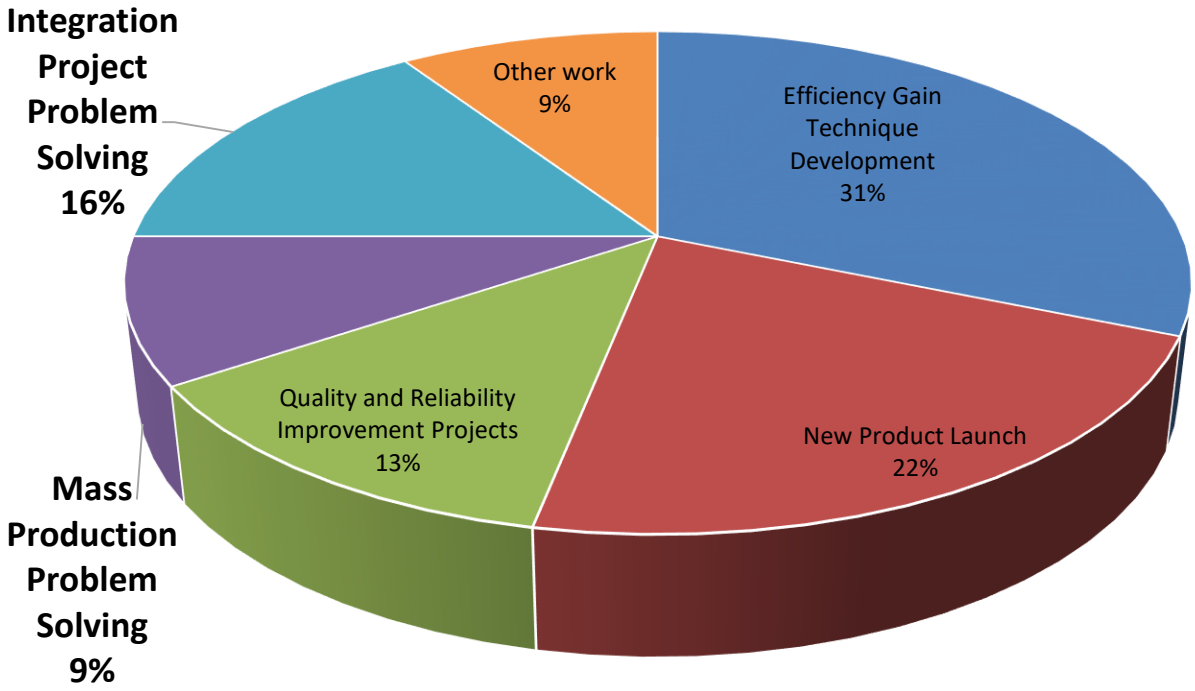
3.3 All sorts of problem solving …. and problem solving … and …

Integration problems:

- Wafer resistivity shift
- Wafer thinning
- Module EL failure issues
- Packaging problems…

Mass production problems:

- Efficiency variation
- A product rate
- Appearance issues
- BOM changes…



- ✓ A R&D engineer needs to be cautious, humble, and comprehensive-thinking.
- ✓ Cutting-edge explorations are exciting but risky, that's why we need partners!

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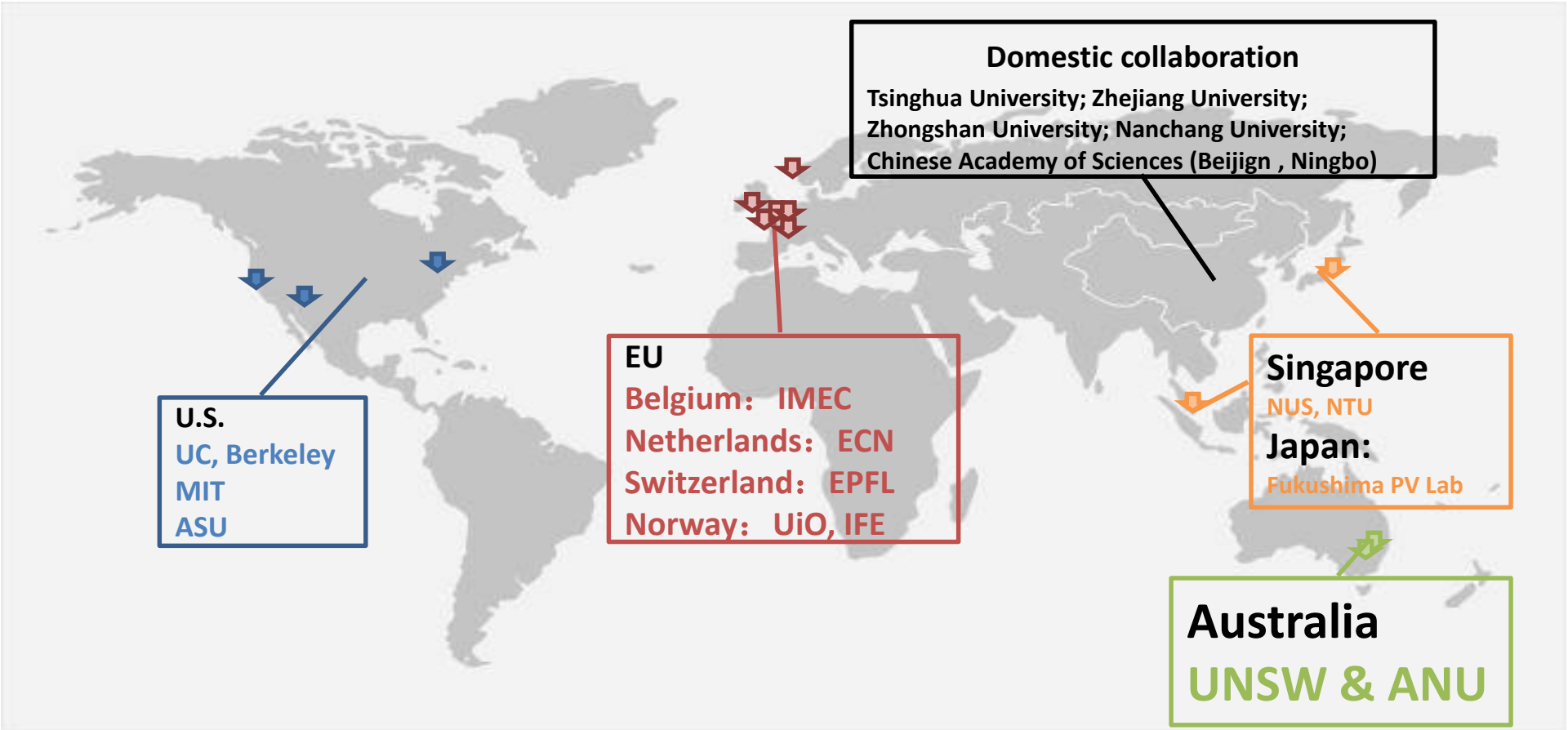
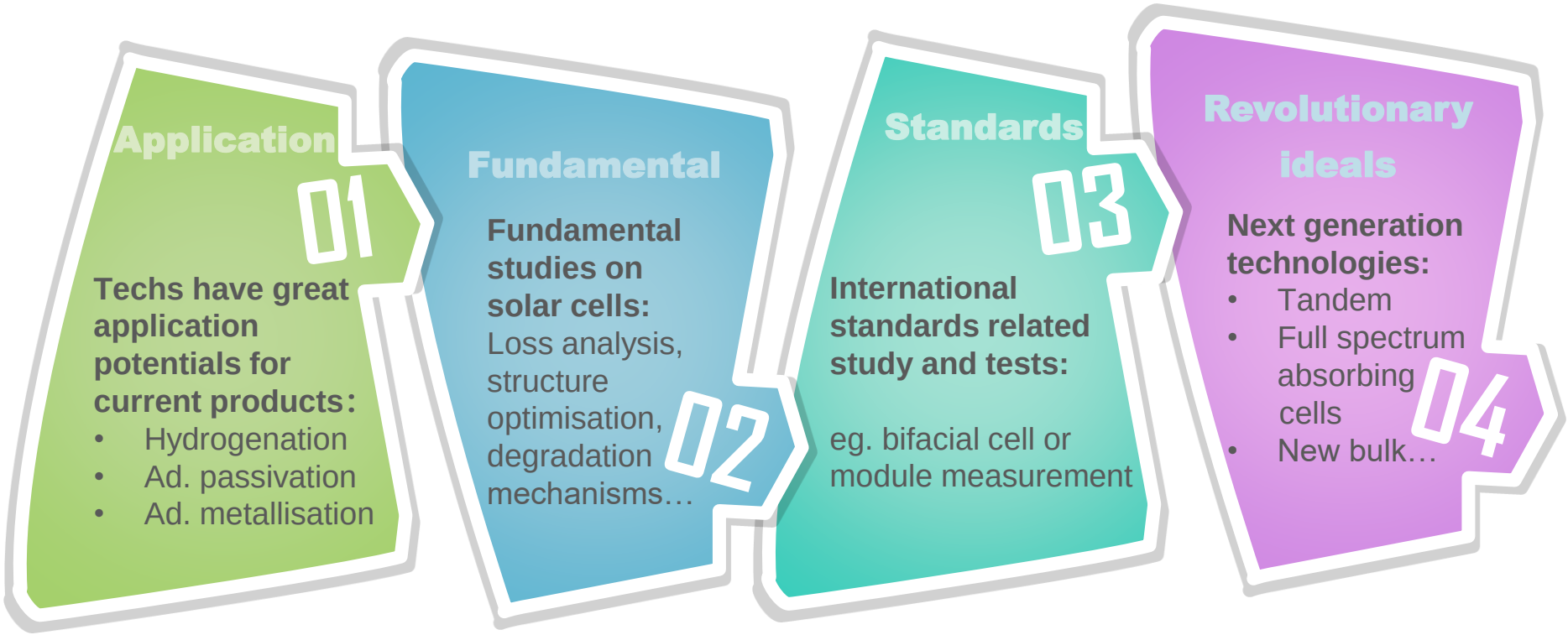
4. Global research collaboration network



4. Looking for research collaborations in various areas




Thank you for your time!
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