# BIFACIAL SYSTEMS OVERVIEW

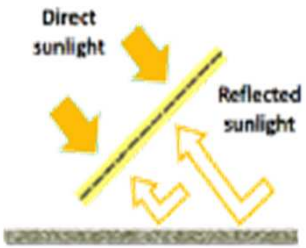
BifiPV workshop, Konstanz, 25/10/2017

*M. Joanny, J. Libal, R. Kopecek, Y. Veschetti, H. Colin*

# INTRODUCTION

- **The bifacial gain is the metric that determines** - together with the total cost of the installed bifacial PV system - **the LCOE (€/kWh) and the bancability of bifacial PV**

$$g_{bifacial}[\%] = \left( \frac{(e_{bifacial} - e_{monofacial})}{e_{monofacial}} \right) \times 100$$




*$e_{bifacial}$ = specific energy yield (kWh/kWp) of the PV system with bifacial modules*

*$e_{monofacial}$ = specific energy yield (kWh/kWp) of the PV system with monofacial modules on the same site, with the same configuration and during the same time period*

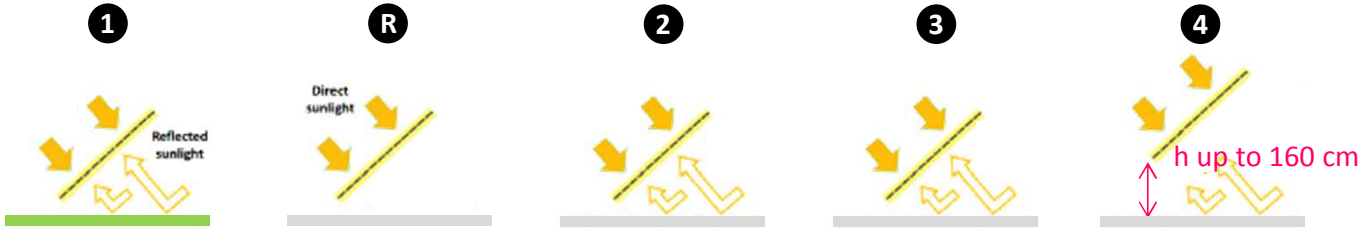
- This talk will give an overview on bifacial systems:
  - ✓ Summary of small scale bifacial systems (< 10 KWp) reported in Bifacial Book – chapter 5
  - ✓ Overview of large scale bifacial systems

# EXEMPLE OF SMALL SCALE BIFACIAL SYSTEM (< 10 KWP)

- **Location:**
  Chambéry, France
- **System:**
  5 x 3 kWp
  30° South
  Elevation min: 0,6m
- **Module:**
  CEA INES PERT
  BR 90%
- **Test duration:**
  12 months
  09/2016 – 09/2017

$G_{bifi}$ = 10 to 19%

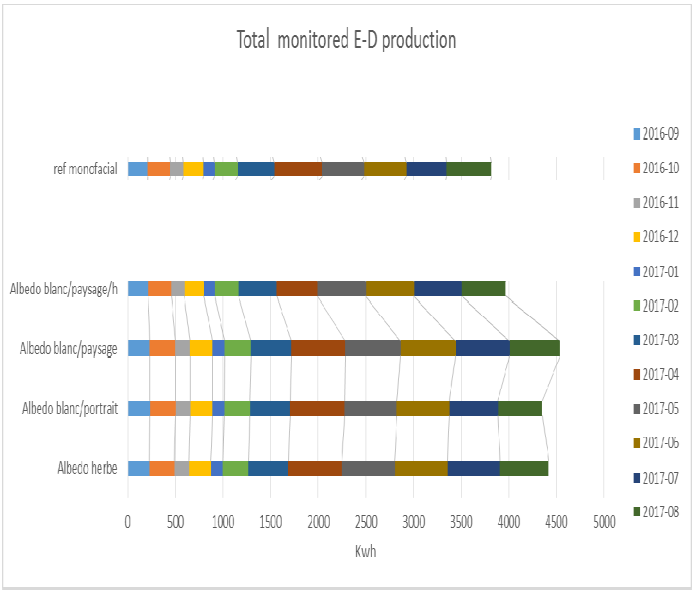
eric.pilat@cea.fr




| 1 | R | 2 | 3 | 4 |
|---|---|---|---|---|
| Grass<br>Portrait orientat° | /<br>Portrait orientat° | White gravel<br>Portrait orientation | White gravel<br>Landscape orientat° | White gravel<br>Landscape orientat° |
| $G_{bifi}$ = 10% | | $G_{bifi}$ = 12% | $G_{bifi}$ = 13% | $G_{bifi}$ = 19% |







# EXEMPLE OF SMALL SCALE BIFACIAL SYSTEM WITH TRACKING (< 10 KWP)

- **Location:**
  Hokkaido, Japan
- **System:**
  4,6 kWp
  33°S fixed vs tracked
  Elevation min: n.a.
- **Module:**
  PVGS EarthOn
- **Test duration:**
  5 months
  11/2015 – 03/2016

↗ ratio up to 168%

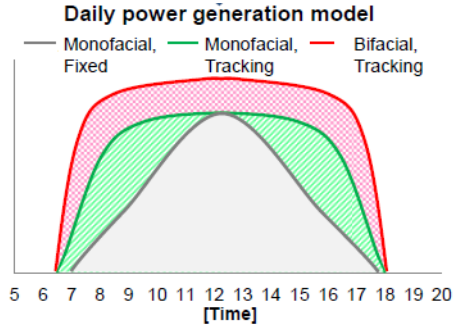
www.pvgs.jp

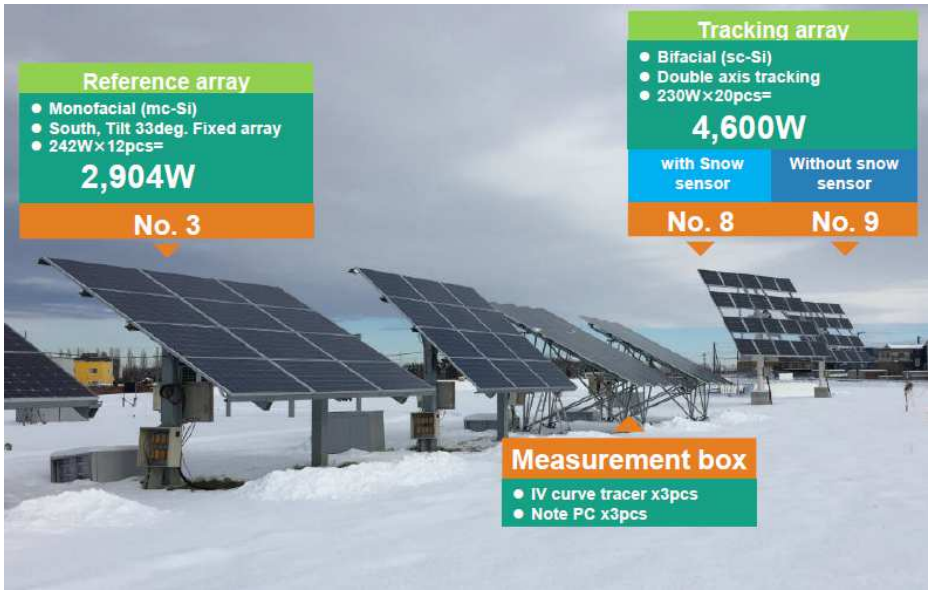
## Study of bifacial tracking system in snowy region

Bifacial and tracking enable to:

✓ suppress the snow efficiently

✓ generate higher daily production




| Month | Bifacial, tracking (with snow sensor) [kWh/kW] | mc-Si, fixed [kWh/kW] | Increase ratio of power |
|---|---|---|---|
| Nov, 2015 | 103.2 | 73.9 | 140% |
| Dec, 2015 | 98.4 | 54.2 | 181% |
| Jan, 2016 | 120.7 | 55.1 | 219% |
| Feb, 2016 | 144.1 | 78.9 | 183% |
| Mar, 2016 | 199.0 | 133.8 | 149% |
| Total of 5 months | 665.4 | 395.8 | 168% |
| Total of a year (Target) | 1,875.3 | 1,116.3 | 168% |

*[1] Naoki Ishikawa, 3rd BifiPV Workshop, Miyazaki, Japan, 2016*

# SUMMARY OF SMALL SCALE BIFACIAL SYSTEMS (< 10 KWP) REPORTED IN BIFACIAL BOOK

- **Albedo:**
  - ✓ most ground surface show **albedo ≥ 20 %**
  - ✓ enhancing ground reflectivity is possible (covering the ground with white sand, scallops shells or reflective painting or sheets) → **40% to 90% ground albedo can be achieved**

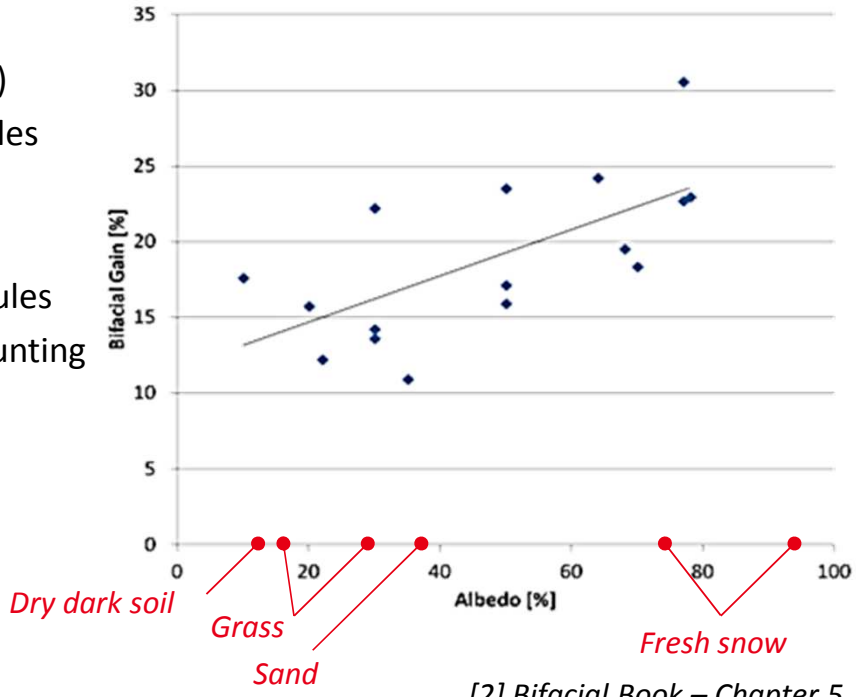
- **Systems for $G_{bifi}$ studies must be composed of:**
  - ✓ **several module rows** with several modules/row
  - ✓ a subsystem with **monofacial** modules as **reference** for determination of bifacial gain
  - ✓ **meteo data** (at least irradiance and module temperature) monitoring

- **Test duration:**
  - ✓ ideally **12 consecutive months** to cover all seasons (varying diffuse light fraction)

## MANY small scale bifacial systems worldwide

## BIFACIAL GAIN plotted vs albedo show significant fluctuation range due to:

- climate (diffuse light, snow)
- installation height of modules
- distance between modules
- module inclination
- rear side efficiency of modules
- design of modules and mounting racks (rear side shading)




*[2] Bifacial Book – Chapter 5*

$G_{bifi}$ = 10 to 20% and ≥ 30% if special measures are taken (artificially increase albedo) ; even more for tracking system

## KURANUMA pilot power plant

PVGS in collaboration with Nishiyama Sakata Denki Co were the first actors to build a large scale bifacial plant

- **Location:**
  Asahikawa, Japan
- **System:**
  250 kWp
  **1 064 modules**
  40° South, fixed tilt
  Elevation: 1,5 m min
  Albedo ≈ 20% bare soil
  to 90% fresh snow
- **Module:**
  PVGS EarthON 60
  254 Wp STC
- **Operation:**
  Oct. 2013

**250 kWp**

www.pvgs.jp

- Frames justified by cost issues and mechanical strength towards environmental impact (wind, snow …)
- PVGS with University of Miyazaki* showed that the impact of a metal plate (width = 75mm) located on the rear side of the module induces a power loss rate between 0.6% and 4.8% depending on its distance from the module.

**S. Goda, nPV Workshop, Netherlands, 2014*

*[3] Naoki Ishikawa, Satoshi Nishiyama, 3rd BifiPV Workshop, Japan, 2016*

# OVERVIEW OF LARGE SCALE BIFACIAL SYSTEMS

## Europe's largest bifacial solar PV plant in the Netherlands

[See W.Vermeulen today talk]

- **Location:**
  Vaassen, Netherlands
- **System:**
  400 kWp
  **1 428 modules**
  Fixed tilt
  Elevation: n.a.
  Albedo = white gravel
- **Module:**
  Yingli n-type PANDA
  280 Wp STC
- **Operation:**
  June 2017

**400 kWp**

*www.tempress.nl*

## HOKUTO Solar power plant

- **Location:**
  Asahikawa, Japan
- **System:**
  1,25 MWp
  **5 320 modules**
  40° South, fixed tilt
  Elevation: 1,5 m min
  Albedo ≈ 20% bare soil
  to 90% snow
- **Module:**
  PVGS EarthON 60
  254 Wp STC
- **Operation:**
  December 2013

**1,25 MWp**

www.pvgs.jp

Over a period of 32 months, an energy yield over 1,200 kWh/kW per year is obtained
The bifacial gain is considered to be over 20%

*[3] Naoki Ishikawa, Satoshi Nishiyama, 3rd BifiPV Workshop, Japan, 2016*

The rear side produces more energy due to higher albedo and accelerates the snow melting on the front side due to rear irradiance (thermalization effect).

## La SILLA power plant

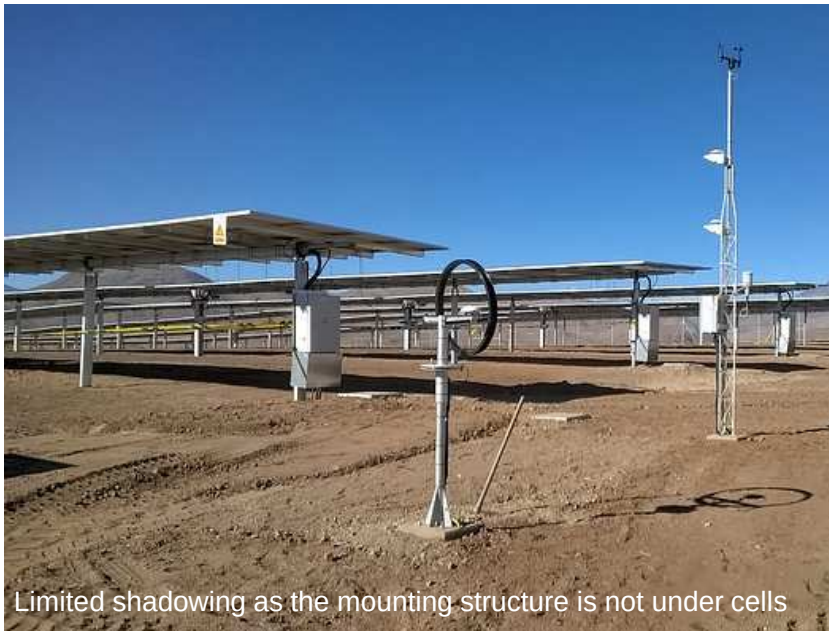
- **Location:**
  Chile
- **System:**
  1,7 MWp
  **6 070 modules**
  North, **single axis track**
  Elevation: n.a.
  Albedo = sand
- **Module:**
  BiSoN
  280 Wp STC
- **Operation:**
  Since 2016

**1,7 MWp**

www.enelgreenpower.com

A bifacial gain of 40% is expected

[See F.Bizzarri today talk]



Limited shadowing as the mounting structure is not under cells

*[5] M. Catena et al., EUPVSEC, Amsterdam, 2017*

and Imelsa

## La HORMIGA power plant

- **Location:**
  Chile
- **System:**
  2,5 MWp
  **9 090 modules**
  North, fixed tilt
  Elevation: n.a.
  Albedo = sand
- **Module:**
  BiSoN
  275 Wp STC
- **Operation:**
  Since 2016

**2,5 MWp**

A bifacial gain of 30% is expected


*[4] Radovan Kopecek et al., Photovoltaic Technical Conference, Marseille, 2016.*

radovan.kopecek@isc-konstanz.de

## SUNPREME Barton power plant, in Vermont (tough weather conditions)

- **Location:**
  Vermont, USA
- **System:**
  2,6 MWp
  ≈ **7 400 modules**

  Elevation: n.a.
  Albedo = grass
- **Module:**
  Sunpreme
  350 Wp STC
- **Operation:**
  Since beginning 2015

**2,6 MWp**

*www.sunpreme.com*

One of the largest commercial PV installation in Vermont with a target to generate over 3,2 GWh, which is enough to serve over 1 500 homes

[See A. Sinha today talk]

## Large bifacial SUNPREME power plant

- **Location:**
  New Jersey, USA
- **System:**
  12,8 MWp
  ≈ **41 300 modules**
  South, **single axis tilt**
  Elevation: n.a.
  Albedo ≈ 40% sand
- **Module:**
  Sunpreme MAXIMA
  310 Wp STC
- **Operation:**
  Since February 2016

**12,8 MWp**

www.sunpreme.com

Initial energy production numbers are showing the results expected with an 8-10% additional energy harvest
Different albedos will be evaluated to further maximize the energy harvest of the system

*[6] Ashok Sinha, 3rd BifiPV Workshop, Miyazaki, Japan, 2016*

## Xintai 40 MWp power plant with Jolywood bifacial panels

- **Location:**
  Xintai City, China
- **System:**
  40 MWp
  ≈ **129 000 modules**
  **Single axis tracker**
  Elevation: n.a.
  Albedo ≈ 25% (grass)
- **Module:**
  Jolywood double glass
  310 Wp STC

**40 MWp**

China leader project in Xintai city, Shangdong province, use 40 MW Jolywood n type mono double glass bifacial panels of 310 Wp combine with Actech single axis tracker

**YINGLI connects 50 MW PV project in Shanxi Province, as part of TOP RUNNER programme launched by China's National Energy Administration (NEA)**

The project is estimated to produce more than 80 GWh of electricity per year, enough to power about 37,000 homes

[See J.Ni today talk]

- **Location:**
  Datong City, China
- **System:**
  50 MWp
  **186 120 modules**

  Elevation: n.a.
  Albedo = grass
- **Module:**
  Yingli TwinMAX 60
  285 Wp STC
- **Operation:**
  Since June 2017

**50 MWp**

*www.yinglisolar.com*

# BIFACIAL VERTICALLY MOUNTED SYSTEMS

PPAM SOLKRAFT

Customer Energy Production Data

Byggvesta
7 pcs 300/270 Wp.
Test location from April 2016.
Shows yields clearly without seld-shading effect.

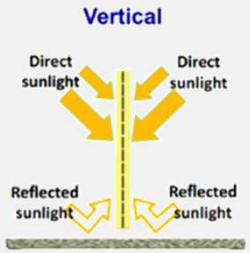
*[7] Ashok Sinha*
*3rd BifiPV Workshop, Miyazaki, Japan, 2016*

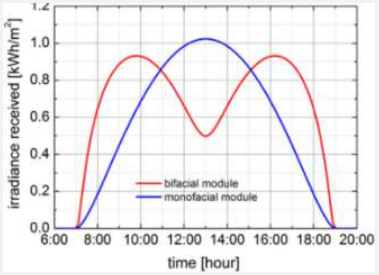
[See H.Hildebrand today talk]

*[8] Yannick Veschetti*
*3rd BifiPV Workshop, Miyazaki, Japan, 2016*

[See A.Dreisiebener today talk]

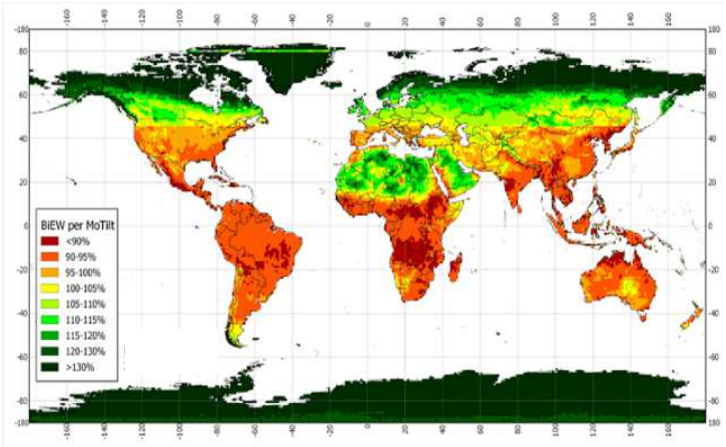
## GEOGRAPHICAL MAPPING OF THE PERFORMANCE OF VERTICALLY INSTALLED BIFACIAL MODULES




- 15% to 20% gain of vertical EW bifacial over tilted monofacial in high albedo sunbelt, this adds up to an expected gain (>10-20%) through reduced soiling and resulting cleaning costs
- Northern regions can obtain performance gain and avoid snow coverage

Vertical bifacial E/W versus monofacial N/S tilted (tilt=latitude angle)
(annual kWh performance simulation based on world irradiation and albedo map)



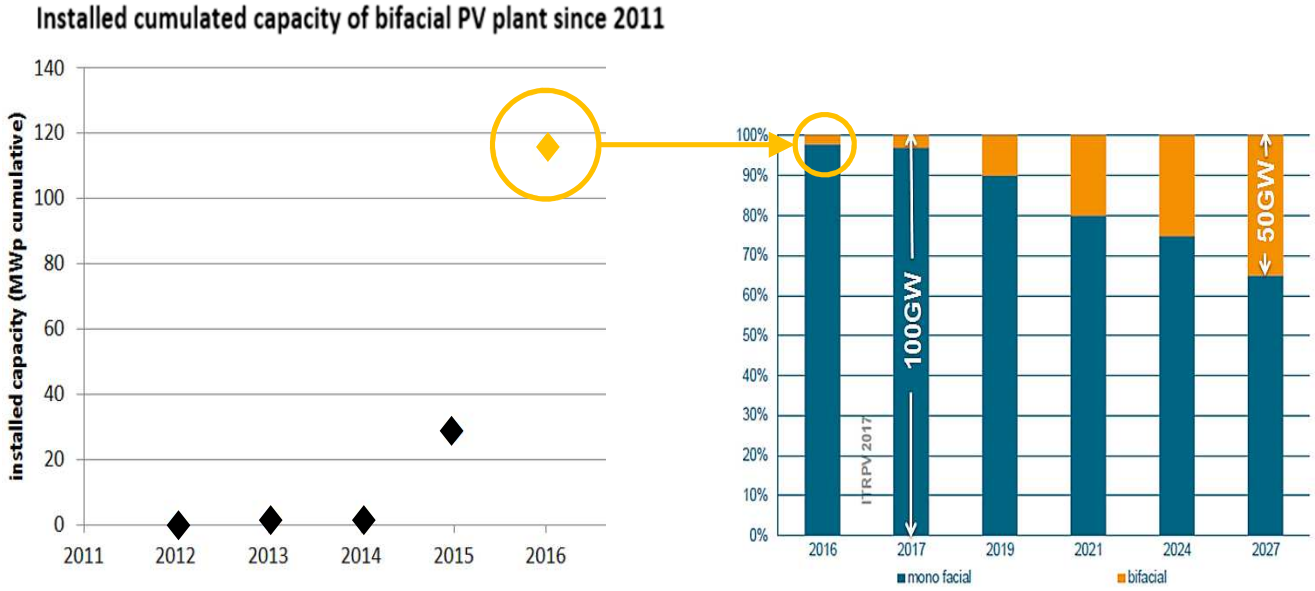

*[9] Eric Gerritsen, Masakazu Ito, EUPVSEC, Munchen, Germany, 2016*

eric.gerritsen@cea.fr

# CONCLUSION

- Even under not ideal conditions: $G_{bifi} \geq 10\%$
- If measures are taken to ↗ albedo ≥ 60%: $G_{bifi}$ of 20% - 30% are possible
- ↗ of module height is a key parameter influencing $G_{bifi}$
- Using single axis tracking can enhance $G_{bifi}$ up to 25% more

- High increase of MWp installed since 2015, and even higher are expected within the next years:



# CONCLUSION

- Even under not ideal conditions: $G_{bifi} \geq 10\%$
- If measures are taken to ↗ albedo ≥ 60%: $G_{bifi}$ of 20% - 30% are possible
- ↗ of module height is a key parameter influencing $G_{bifi}$
- Using single axis tracking can enhance $G_{bifi}$ up to 25% more

- High increase of MWp installed since 2015, and even higher are expected within the next years

- So far the 50 MWp plant in China remains the largest bifacial PV plant

1.25MW in Japan (PVGS EarthON modules)

1.7MW in Chile (MC BiSoN modules)

2.5MW in Chile (MegaCell BiSoN modules)

12.8MW in US (Sunpreme modules)

50 MW in China (Yingli modules)


# THANK YOU FOR YOUR ATTENTION



ines
INSTITUT NATIONAL
DE L'ENERGIE SOLAIRE