WEBINAR

Understanding bifacial's true potential: technology innovation and technical bankability of bifacial PV projects

MONDAY, 7TH OCTOBER 2019

PVTECH.ORG

JinkoSolar
Building Your Trust in Solar

PI Photovoltaik Institut Berlin

DNV·GL

Bifacial PV Technology: Ready for Mass Deployment

PV Magazine Webinar on Bifacial PV

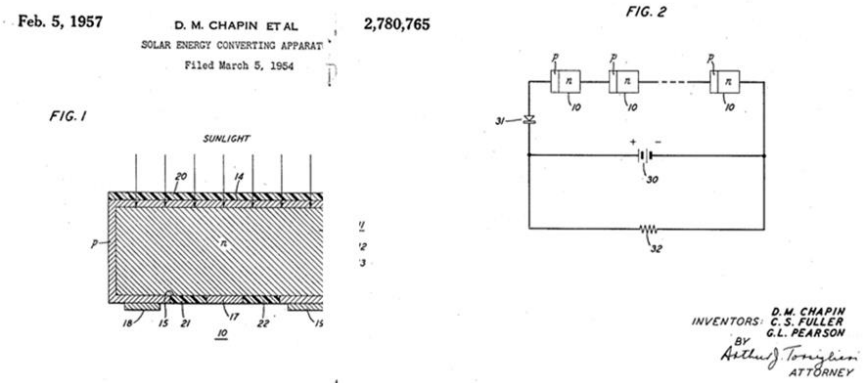
Dr. Lars Podlowski
VP Global Technical Services
PI Photovoltaik-Institut Berlin AG

Overview

- History of Bifacial PV
- Bifacial PV Technologies
  - Solar Cells
  - Solar Modules
- Impact of the System Design to the Achievable Energy Gain
- Yield Prediction Softwares
- Examples of Real Installations

History of Bifacial PV

- 1954: the world´s first solar cell design was bifacial



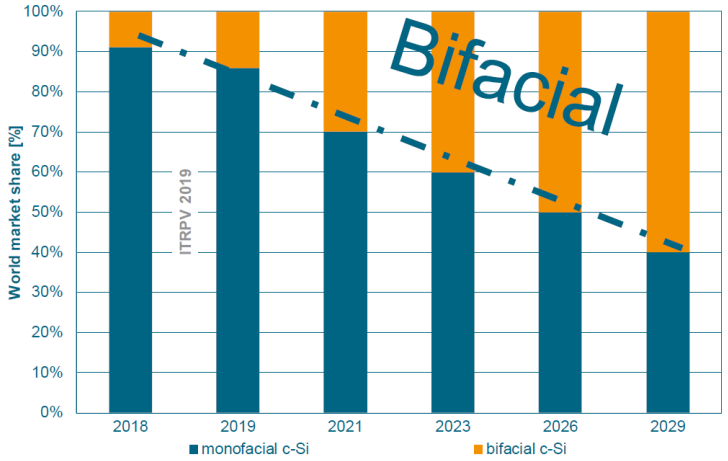
- late 1990ties: the world´s No.1 solar cell was a bifacial cell (Siemens PowerMax)

front side

rear side

History of Bifacial PV

- 2003 – 2010: 1st phase of commercialization with some early commercial products (Sanyo HIT; SolarWind) and a R&D programs of serious players (Hitachi; Sunpower)
- 2011 – 2016: 2nd phase of commerzialization with some early bifacial power plants (PVG; Sunpreme) and first companies building specific bifacial technology platforms and production lines (MegaCell; CIE; Linyang; ..)
- Since 2017: 3rd phase of commercialization; started with some large fields in correlation with Chinese „FrontRunner“ program. Now bifacial PV is one of the most attractive options for reducing LCOE
- Outlook: ITRPV says the majority of solar modules will be bifacial in 10 years



Bifacial PV Technologies

Table 2.1 Bifacial solar cells and their main parameters

	Cell concept	Bifaciality factor (on cell level)	Si base material	Junction and BSF doping method	Contacts	(Front) Efficiency potential
2.5.1	Heterojunction	>92%	n mono	a-Si:H p- and n-type doped	TCO/Ag printed TCO/Cu plated	22%–25%
2.5.2	n-PERT	>90%	n mono	Boron and Phosphorous diffusion	Ag and Ag/Al printed	21%–22%
2.5.3	p-PERT	>90%	p mono	Phosphorous and Boron diffusion	Ag and Ag/Al printed	21%–22%
2.5.4	PERC+	>80%	p-mono	Phosphorous diffusion and local Al BSF	Ag and Al printed	21%–22%
2.5.5	IBC	>70%	n-mono	Boron and Phosphorous diffusion	Ag and Ag/Al printed	22%–23%

3

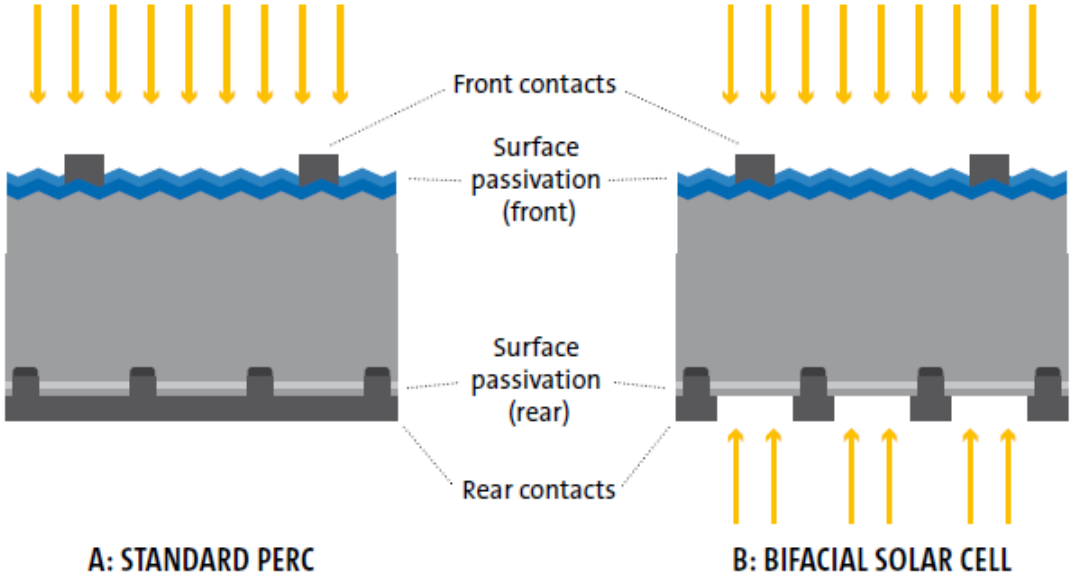
2

1

Bifacial book 2018

Bifacial PV Technologies

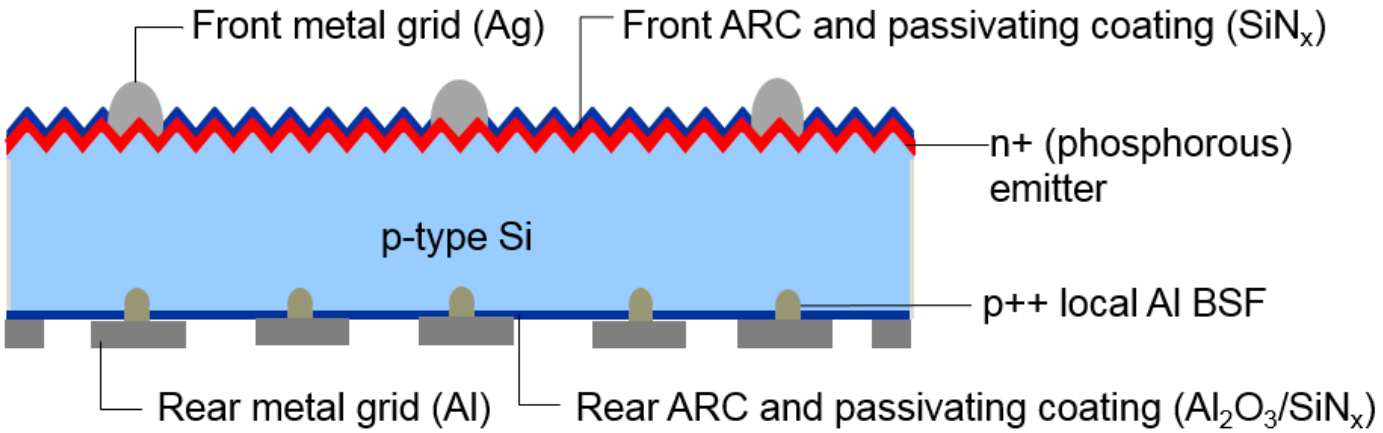
1 p-PERC



Source: SOLARWORLD White Paper:
"Calculating the Additional Energy Yield of Bifacial Modules"

Bifacial PV Technologies

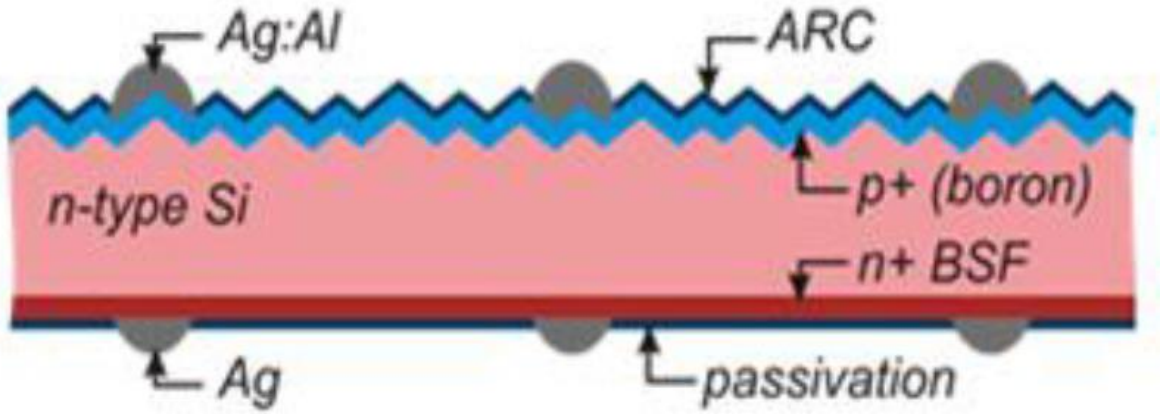
1 p-PERC



- p-PERC manufacturing process can easily be modified for a bifacial solar cell version

Bifacial PV Technologies

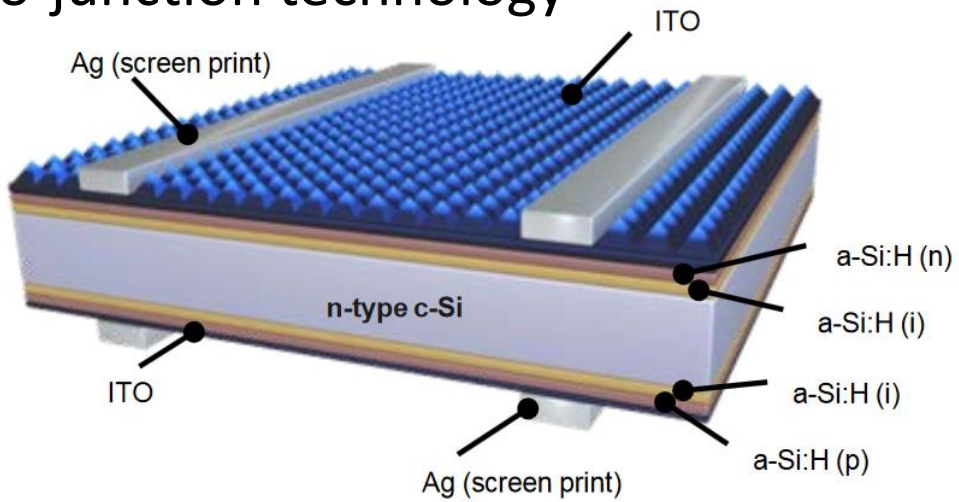
2 n-PERT



- n-PERT is the technology-of-choice for many bifacial solar cells because of better bifaciality

Bifacial PV Technologies

3 Hetero-junction technology



- HJT has the highest efficiency and best bifacial coefficient
- Very different manufacturing process requires higher investment in equipment

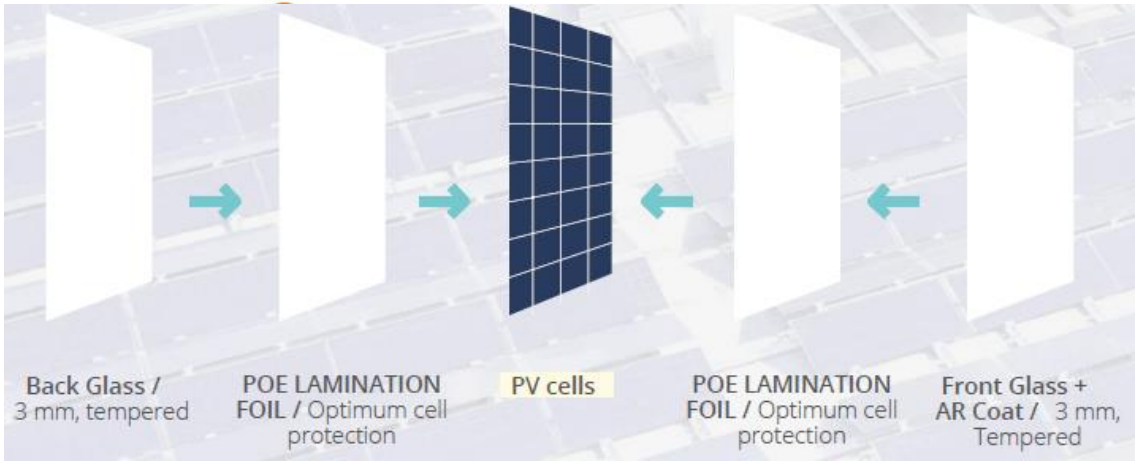
Source for graphics: MeyerBurger

Bifacial PV Modules

Standard module technology is double glass (p-PERC based)

PERC双面双玻60片组件(M2+)

PERC bifacial double-glass 60-cell module(M2+)



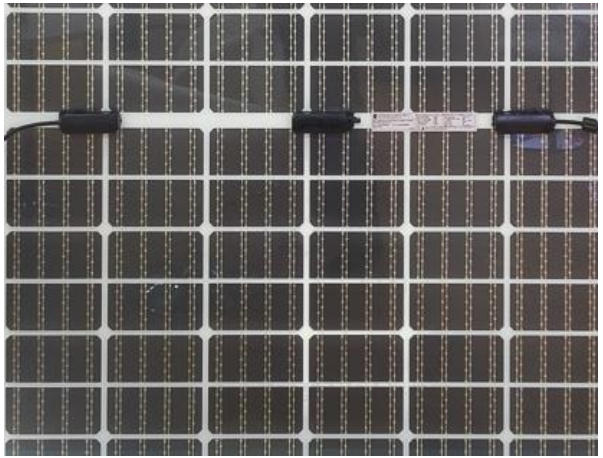
Source: www.solitek.eu

Bifacial PV Modules

Advanced module technology designs

White patterned glass improves front side STC power

Half-cut bifacial back-contact solar cells

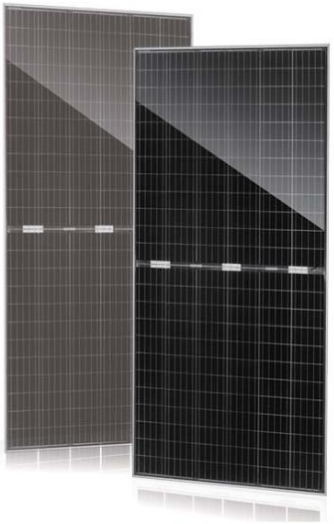


Bifacial shingled solar cells

Bifacial PV Modules

Substitution of rear glass by a clear backsheet

JinkoSolar Swan Bifacial Module

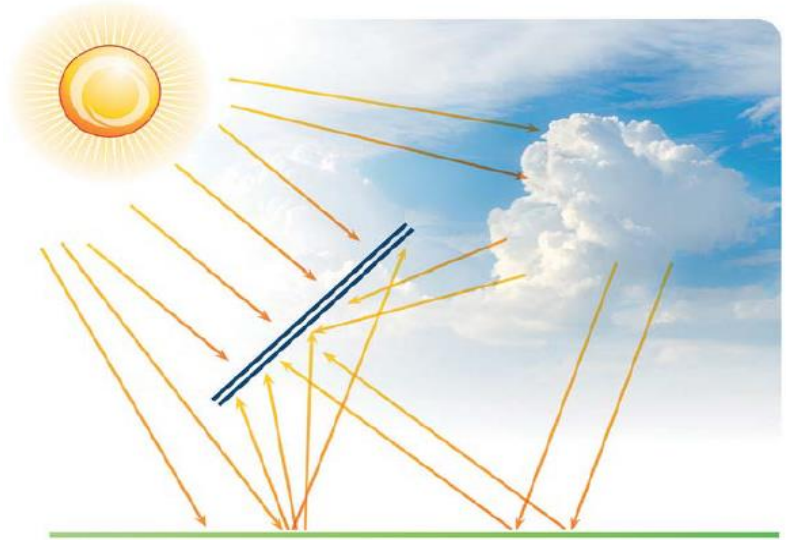


Bifacial PV Modules

- Today glass-glass is still the predominant technology for bifacial PV modules
- Glass-backsheet is becoming more relevant because it has the advantage of lower weight plus some former disadvantages got resolved
- Our position: there is not a clear better or worse module concept

Impact of the System Design to the Achievable Energy Gain

Bifacial PV: simple concept but many additional factors for energy gain

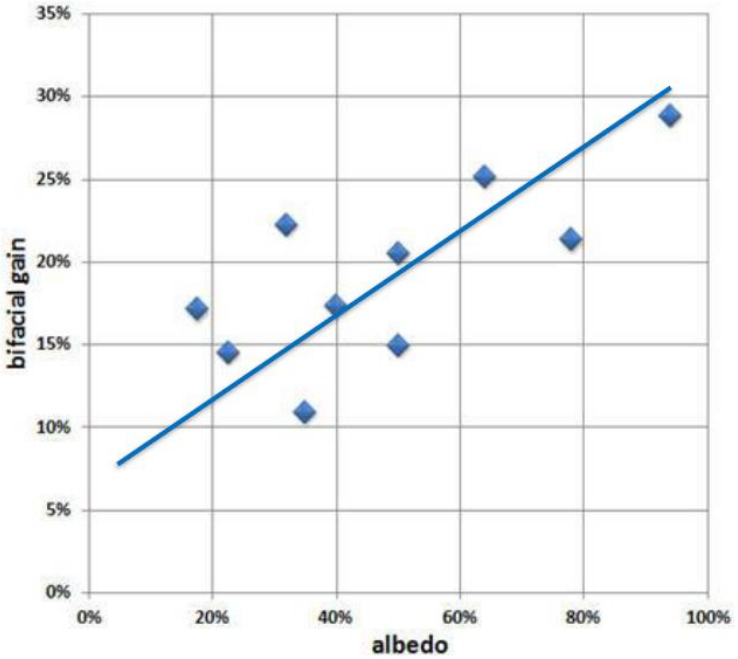


Source: SOLARWORLD White Paper:
"Calculating the Additional Energy Yield of Bifacial Modules"

- Albedo (which is not constant over the day and also seasonally)
- Level above ground
- Row spacing
- Uniformity of backside irradiance
- Tilt angle
- Light spectrum onto rear side
- Backside IAM
- Obstructions from racking structure
- Modules portrait or landscape
- Tracking algorithm

Impact of the System Design to the Achievable Energy Gain

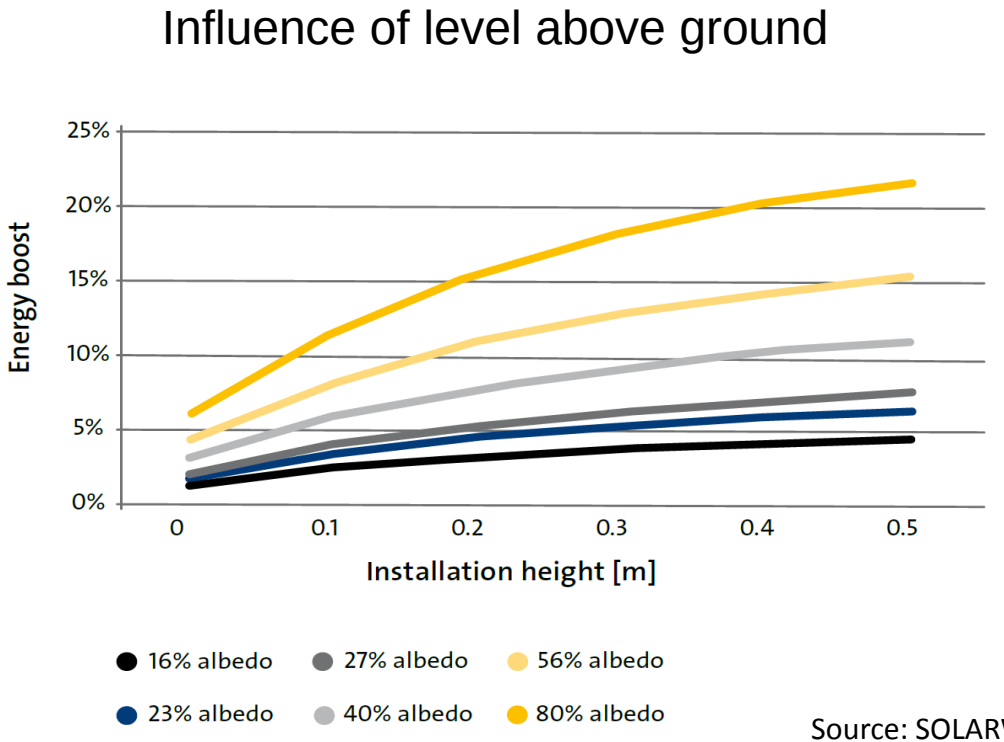
Influence of ground albedo



surface	albedo [%]
water	8
dry dark soil	13
grass	17-28
dry sand	35
dune sand	37
old snow	40-70
reflective roof coatings	80-90
fresh snow	75-95

Source: R. Kopeczek (ISC Konstanz):
Presentation at the “HERCULES” workshop 2018

Impact of the System Design to the Achievable Energy Gain



Source: SOLARWORLD White Paper:
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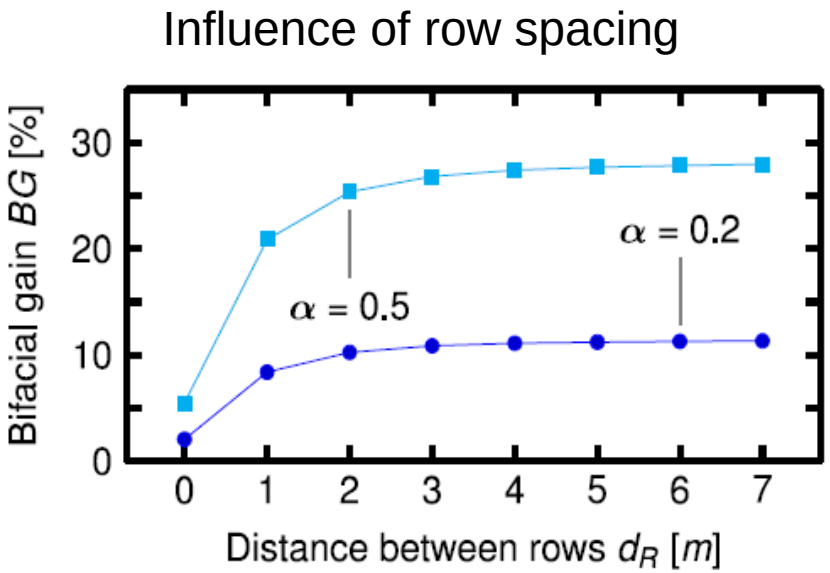
Impact of the System Design to the Achievable Energy Gain



- Larger row spacing is beneficial for bifacial gain
- Important factor for overall project optimization (technical and financial aspect)

Source: I. Shoukry et al.: 6th International Conference on Silicon Photovoltaics, SiliconPV 2016

Yield Prediction Softwares

„Well accepted methodology for energy modeling is the biggest hurdle with bifacial systems.“

Jenya Meydbray, Cypress Creek Renewables
(now with PVEL)

Source: presentation on the workshop on bifacial PV 2018

Yield prediction softwares

1. PVSYST

- has a bifacial option since 2017

2. SAM

- Free software developed by NREL

3. MOBIDIG

- Special software for bifacial PV from ISC Konstanz; user version under development

4. BIGEYE

- Software from ECN TCO

5. SolarFarmer

- By DNV

6. Name =?

- Software by IMEC and EnergyVille (Belgium)

7. PlantPredict

- Software tool from First Solar

… plus several others

Yield prediction softwares

A lot of activities to verify accuracy of software tools

1

PVEL, supported by DoE grant

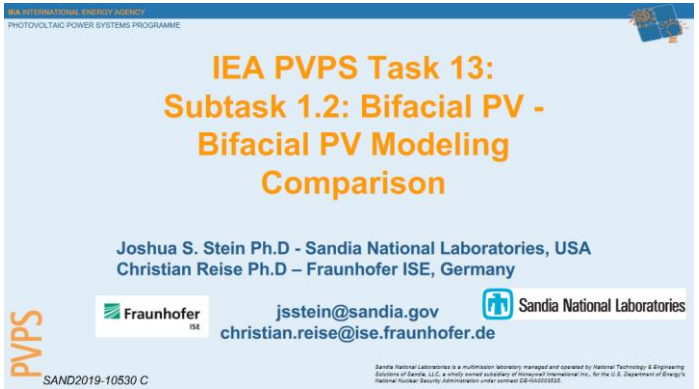
Deploy bifacial systems with monofacial reference in the field to validate energy modeling practices

- Bifacial Test Stations: single module IV curves, 2-portrait single axis trackers
- 4 manufacturers side by side with 1500V Strings on 2 albedos
- Impact of spectral albedo and temporal change in albedo

Partner with Energy Modeling community for field validation on reduced order models

- PVSyst, TNO, SAM, Solar Farmer, Plant Predict

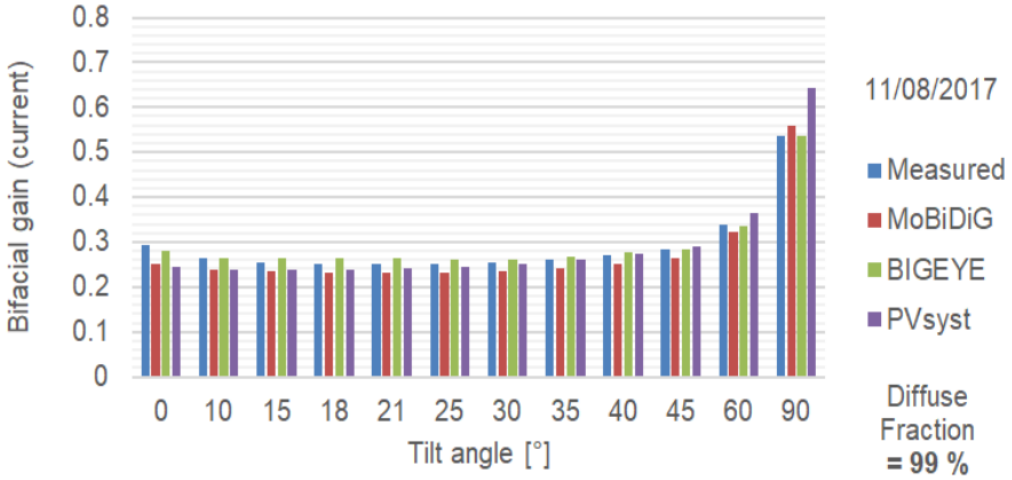
2



Source: workshop on bifacial PV 2019

Yield prediction softwares

First publications about comparison of test sites with simulation tools



Conclusions from the comparison [1]

- The three simulation tools
  - give similar results
  - are in agreement with the experiment
- bifacial yield modeling is reaching a stage of maturity.

Source: A. Burgers (workshop on bifacial PV 2019)

Examples of Real Installations

System data:

Capacity: 38 MWp DC

Installation: HSAT

Location: Arizona

Source: www.soltec.com

Examples of Real Installations

System data:

Capacity: 15 MWp DC

Installation: fixt-tilt

Location: New Jersey

Source: www.sunpreme.com

Examples of Real Installations

<u>System data:</u>

Capacity: 6 MWp DC

Installation: fixt-tilt agro-PV

Location: Jiangsu (China)

Source: own photo

Examples of Real Installations

System data:

Capacity: 1 MWp DC

Installation: vertical east-west agro-PV

Location: Germany

Source: www.next2sun.de

Examples of Real Installations

System data:

Capacity: 3 MWp DC

Installation: carport

Location: Qidong (China)

Source: own photo

Examples of Real Installations

System data:

Capacity: 30 MWp DC

Installation: rooftop

Location: China

Source: LINYANG company brochure

Examples of Real Installations

	Mono-facial	Bifacial
Fixed-tilt (rooftop)	100% (ref.)	105 – 115%
Fixed-tilt (ground)	100% (ref.)	107 – 130%
HSAT	110 – 122%	117 – 145%

- With no system design changes you can simply achieve 5-7% more energy.
- More than 10% energy is achievable for almost every system but it requires design modifications (ground albedo; row spacing; higher inclination; …)

Summary

1. Bifacial PV is not a new thing – it is just new to many people in the PV industry

2. There are two drivers of bifacial PV becoming mainstream

- p-PERC solar cells can easily be made bifacial
- Cost reduction of n-type wafers

3. Bifacial PV system design has to consider many more parameters and variables than conventional systems

- Can be combined with HSAT

4. Yield prediction software tools for bifacial systems have significantly improved

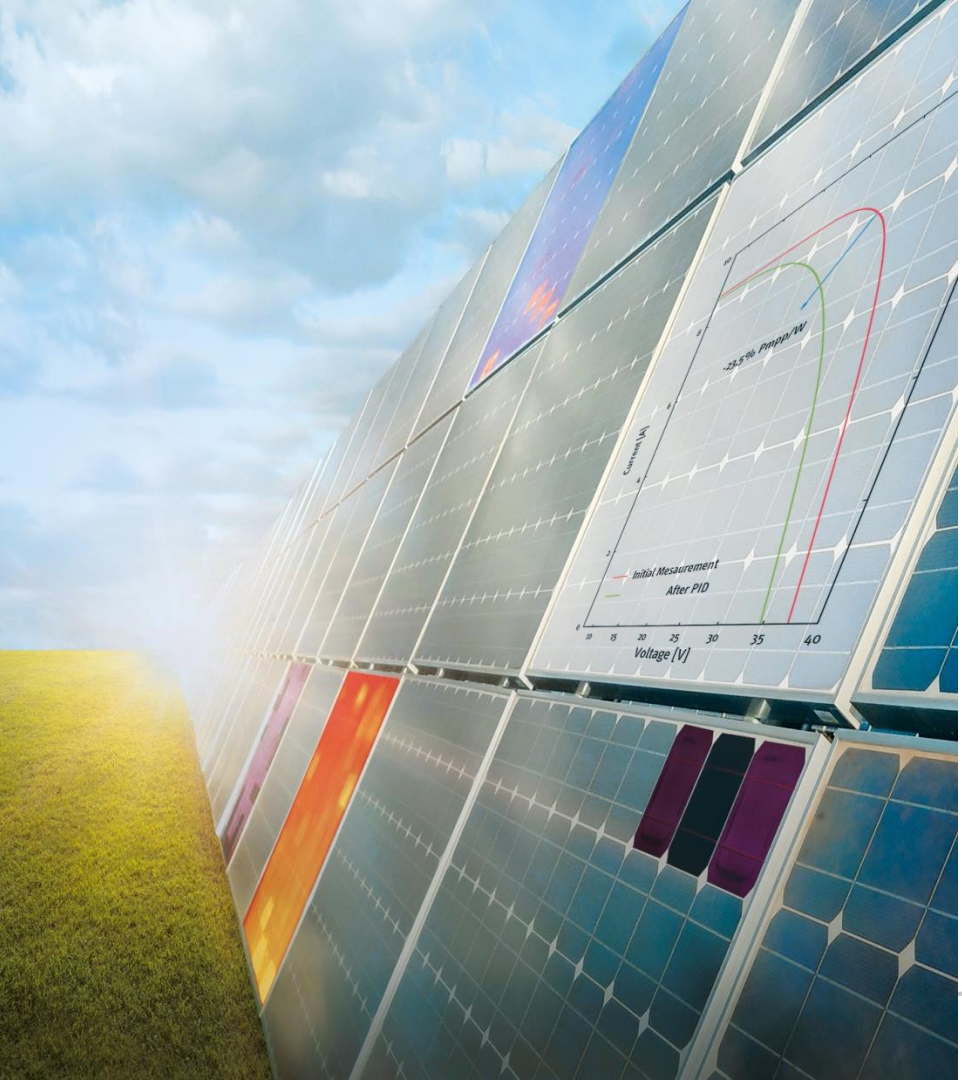
- PVSYST is known to finance partners
- Results can be verified with several other tools from institutes (SAM; MOBIDIG; …)

5. Bifacial PV offers a large potential for lower LCOE with very limited risk

- Requires thoughtful system design

Recommendations:

- Free download of white paper on bifacial PV at www.pi-berlin.com
- All publications from every „*Workshop on Bifacial PV*“ are available for free download at www.bifipv-workshop.com



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Your independent solar advisors!

Contact us:

PI Berlin
Dr. Lars Podlowski
podlowski@pi-berlin.com
www.pi-berlin.com

AMSTERDAM WORKSHOP

Bankability improvement for bifacial technology

The other side of the coin

7 Oct 2019

BIFACIAL TECHNOLOGY

1. Introduction
2. Design variables
3. Testing and certification
4. Bankability and modeling
5. Main mitigations
6. Bifacial main challenges
7. Conclusions / Questions

BIFACIAL TECHNOLOGY

Introduction

- **For Lenders, bifacial technology** is considered as **a "new technology"**

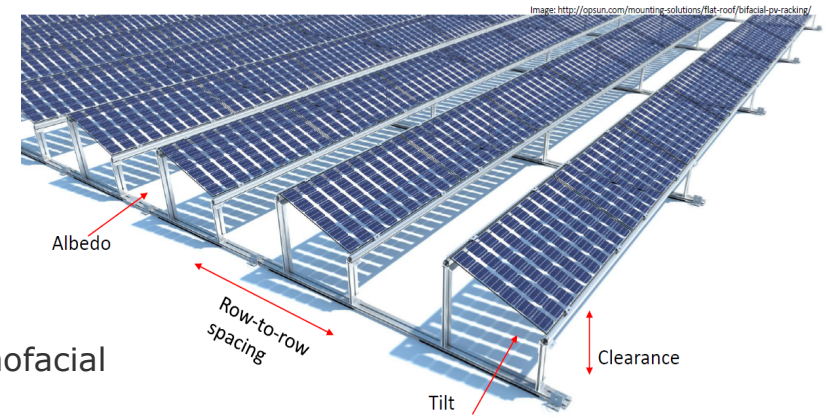
- **Lender's points of attention** regarding bankability study to grant the "non recourse loans" are:
  - The resource
  - The specific technological risks
  - The supplier's track record
  - Specific O&M risks
  - Additional risks

BIFACIAL TECHNOLOGY

Design variables

Front- and rear-side performance to be optimized to maximize bifacial gain without an offsetting reduction in front-side performance

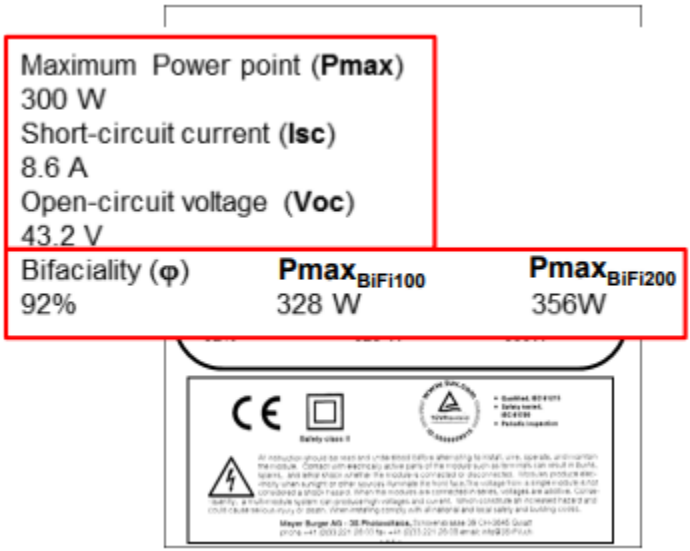
- **Albedo:** bright is better (but rare)
- **Ground clearance:** 0.5 m (NREL recommendation
- **Structure:**
  - **Height:** higher is better (but expensive)
  - **Spacing:** wider is better (but unpopular)
  - **Tilt angle:** Higher than what might be optimal for monofacial
- **DC/AC ratio:**
  - Less than 1.15 may be optimal depending on the site and design
  - Clipping



BIFACIAL TECHNOLOGY

Testing & Certification

- **Specific adaptation of existing standards needed** : higher currents
  - because of the power contribution from the rear side requires
- **Standard for bifaciality factor:** IEC TS 60904-1-2.
  - Important also for labelling. To be issued by the beginning of 2019
- **Re-testing guidelines** for differences in BOM for bifacial modules
  - not available yet for bifacial modules
- **Quality and reliability testing**



PV MODULE TECHNOLOGY BANKABILITY

Bankability and modeling

- The **bankability** of a project **depends on the confidence** of the energy output predictions which are generally modeled
- **Validation of bifacial energy modeling** has not been generally accepted in the industry yet
- IE community is actively **seeking sufficient field validation data** to support bankable energy forecasts

PV MODULE TECHNOLOGY BANKABILITY

Main Mitigation Measures / Initiatives

- Mixing technologies Mono/bi
- Reducing leverage of debt
- Increased warranty levels
- Manufacturer Bankability reports
- Collaboration with manufacturers
- The importance of BOM
- Maintenance Reserve Account
- Presentations to Banks

U.S. Department of Energy awards study of bifacial PV technology, which could prove a 10% increase in energy output

Research study by DNV GL will be the most comprehensive energy yield analysis for bifacial PV modules to date

PV MODULE TECHNOLOGY BANKABILITY

Main Challenges / Risks – PERC / Bifacial

Manufacturing

- Additional steps
- New Materials
- Quality Assurance System

Technical

- New product reliability and durability
- LID / LeTID
- Long term degradation
- Weight
- Mismatching

Design

- Site Selection
- Measurements
- Supporting Structure
- Lower GCR
- Backside shading
- Overtightening bolts. Frameless

Testing

- Not fully developed
- IEC 60904-1-2
- Warranties

Modelling

- Lack of validation
- Stability and actual value of Bifaciality factor
- Albedos Variability
- Tracking System

O&M

- Limited field experience
- Higher OPEX
- Clipping, actual vs predicted

PV MODULE TECHNOLOGY BANKABILITY

Conclusions

- Bifacial Technology is **a really promising technology**
- DNV GL notes that gains of **even 5% may require significant attention** to design and siting detail
- However, **standards and technology are subject to future improvements** for a better bankability

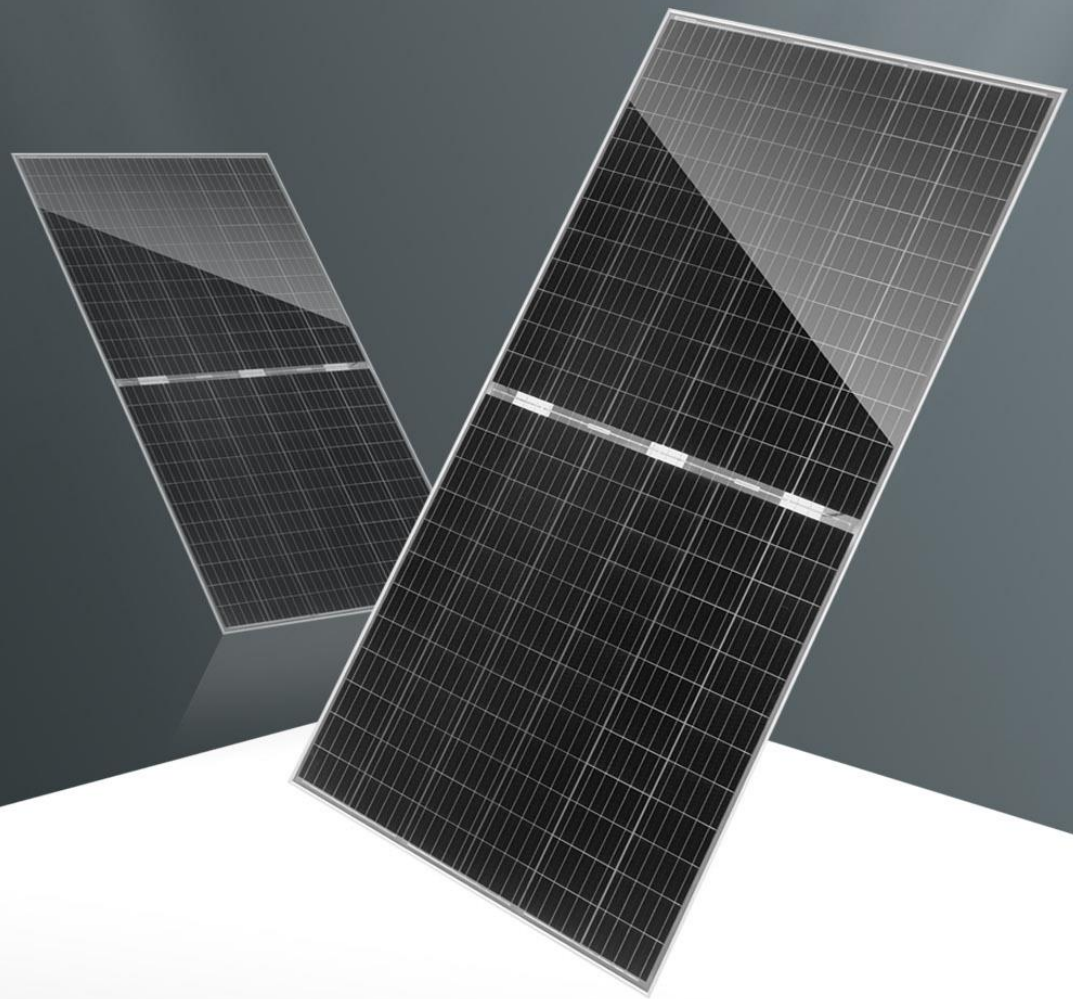
Thank you.

DNV GL Solar
stephane.lebeau@dnvgl.com
+33 609 161 821

www.dnvgl.com

SAFER, SMARTER, GREENER

Swan Bifacial Module



JinkoSolar Co., Ltd.

Solar
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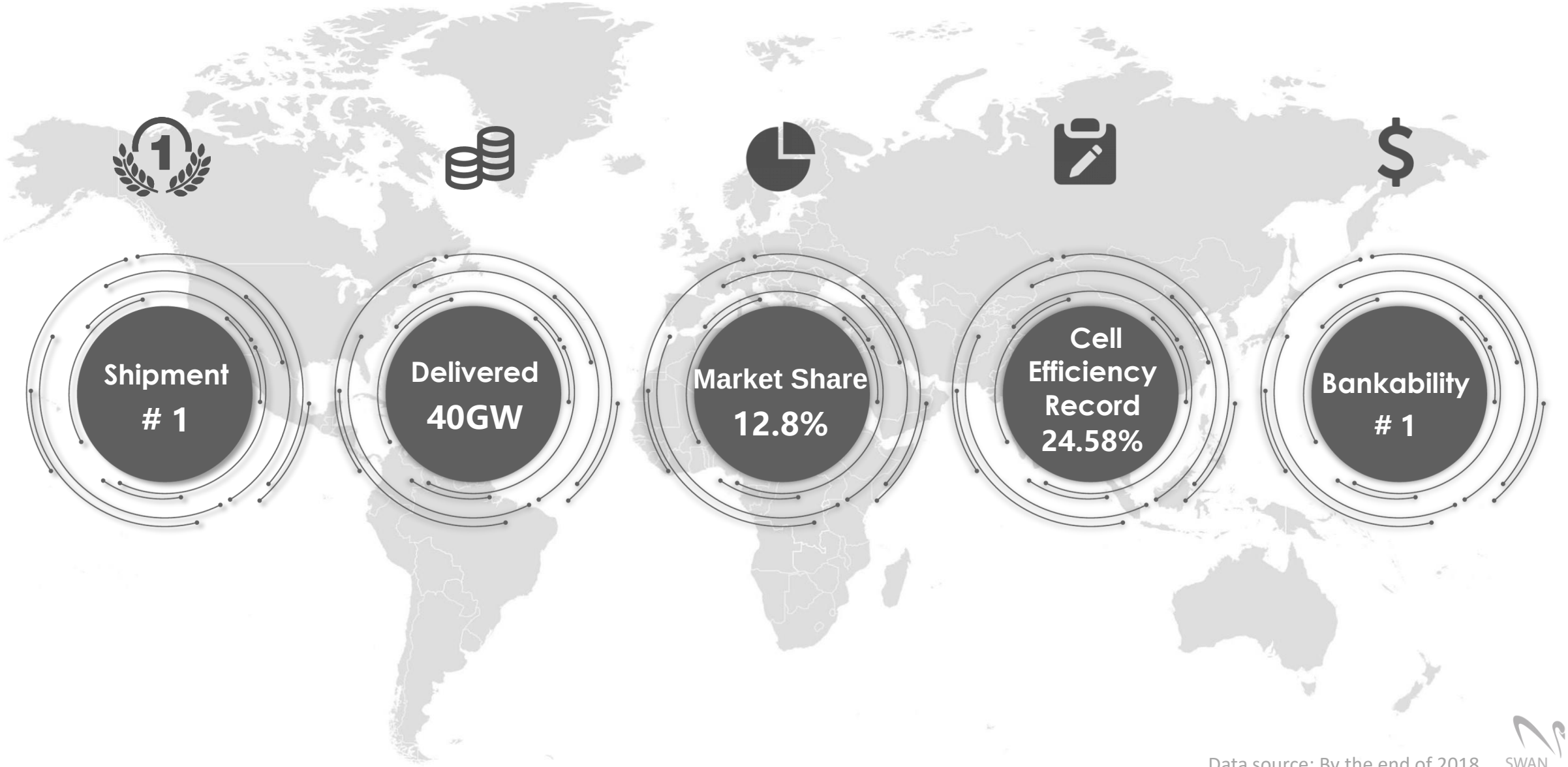
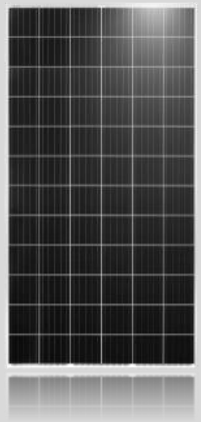
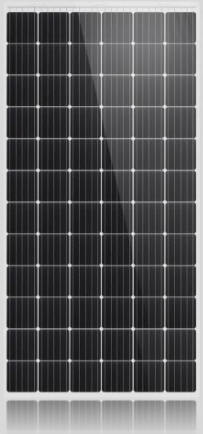
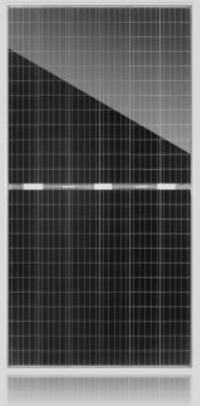
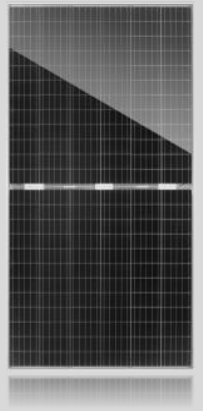
Short Introduction of JKS



Data source: By the end of 2018

JKS Product Portfolio 2019

Jinko Solar
Building Your Trust in Solar

Cheetah FC	Cheetah HC	Cheetah Dual	Swan Bifacial DG	Swan Bifacial TB
• 400Wp • Efficiency 20.17% • 25 Year Linear Power Warranty	• 410Wp • Efficiency 20.38% • 25 Year Linear Power Warranty	• 395Wp • Efficiency 19.69% • 30 Year Linear Power Warranty	• 400Wp(front only) • Efficiency 19.54% • 30 Year Linear Power Warranty	• 400Wp(front only) • Efficiency 19.54% • 30 Year Linear Power Warranty • Lower weight
				

SWAN

JKS Swan Bifacial Features

158.75mm
cell dimension

Bifacial Energy Yield
Up to 500+ Watt in Total

Front side max
power 415 Wp

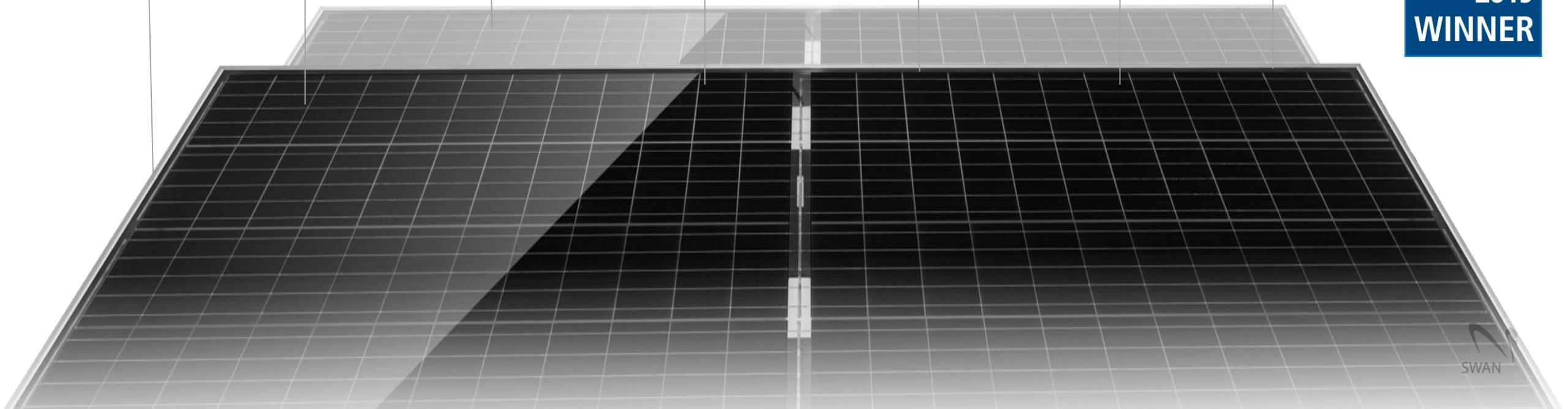
Rear side: plus 5-25%
additional power

Cheetah Cell efficiency
up to 22.3%

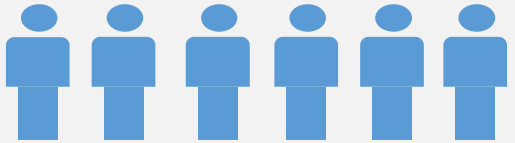
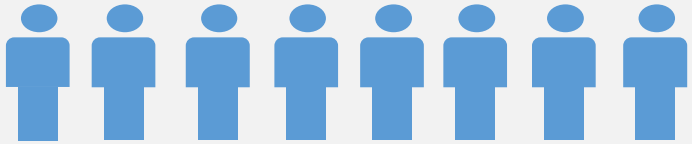
30 Years Linear
Power Warranty

Reduces BOS Cost by 3%
Reduces O&M Cost by 5%

inter solar award 2019 WINNER



Over 25% less Module Weight

weight ↓ 25%	labor cost ↓ 20%
Swan Bifacial TB module: **22~23kg**	
Framed Bifacial module: **31~32kg**	

- JKS Swan bifacial with transparent backsheet reduces the module weight over 25% compared to bifacial dual glass
- Effectively reducing the transportation and installation costs
- Saving labor cost related to module installation by over 20% using bifacial modules with transparent backsheet

Installation System Design

Bifacial with transparent backsheet

✓**Fewer** supporting structures

✓Compatible with the system of monofacial modules

↓ **15%** mounting construction cost

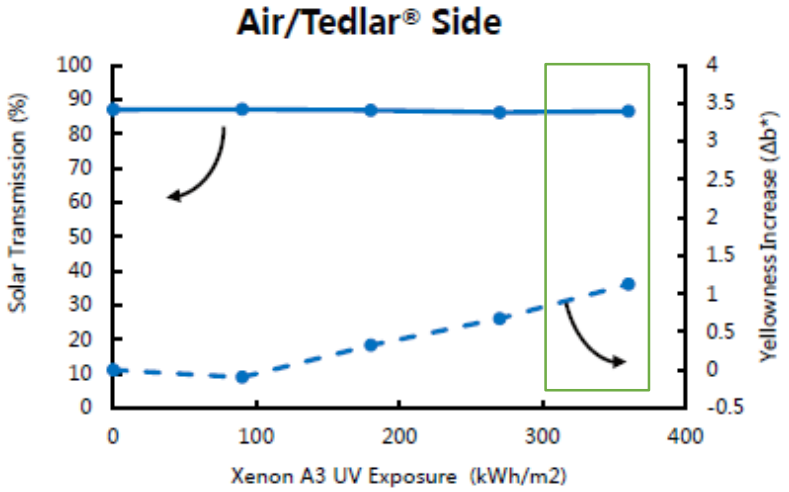
Bifacial with dual glass

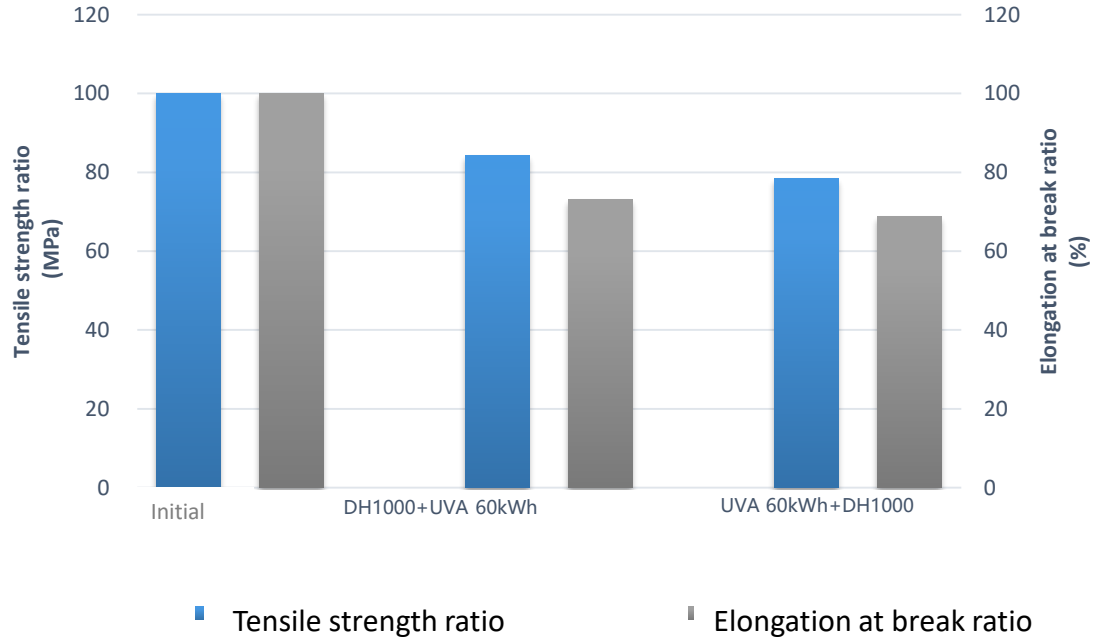
✓**More** supporting structures

✓Incompatible with the system of monofacial

Modules Stronger load-bearing structure is requested

Reliability of Backsheet





PVF film in transparent backsheet shows excellent transmission and mechanical property after 360 kWh/m² UV exposure, which equals a **more than 30-year** usage in desert area climate.

Case Studies – Reliability of Backsheet

Amsterdam BAPV Project

Location
Amsterdam, Netherlands

Completion Time
2000 – (18 years Service Life)

System information
Size: 6.228 kWp 51 full size panels

Module type
Bifacial with transparent backsheet

Inspection result in 2018
✓ **No signs of degradation of Tedlar in the front or back**
✓ **No yellowing**

California Rooftop Project

Location
Presidio National Park, Building 1016, San Francisco, CA

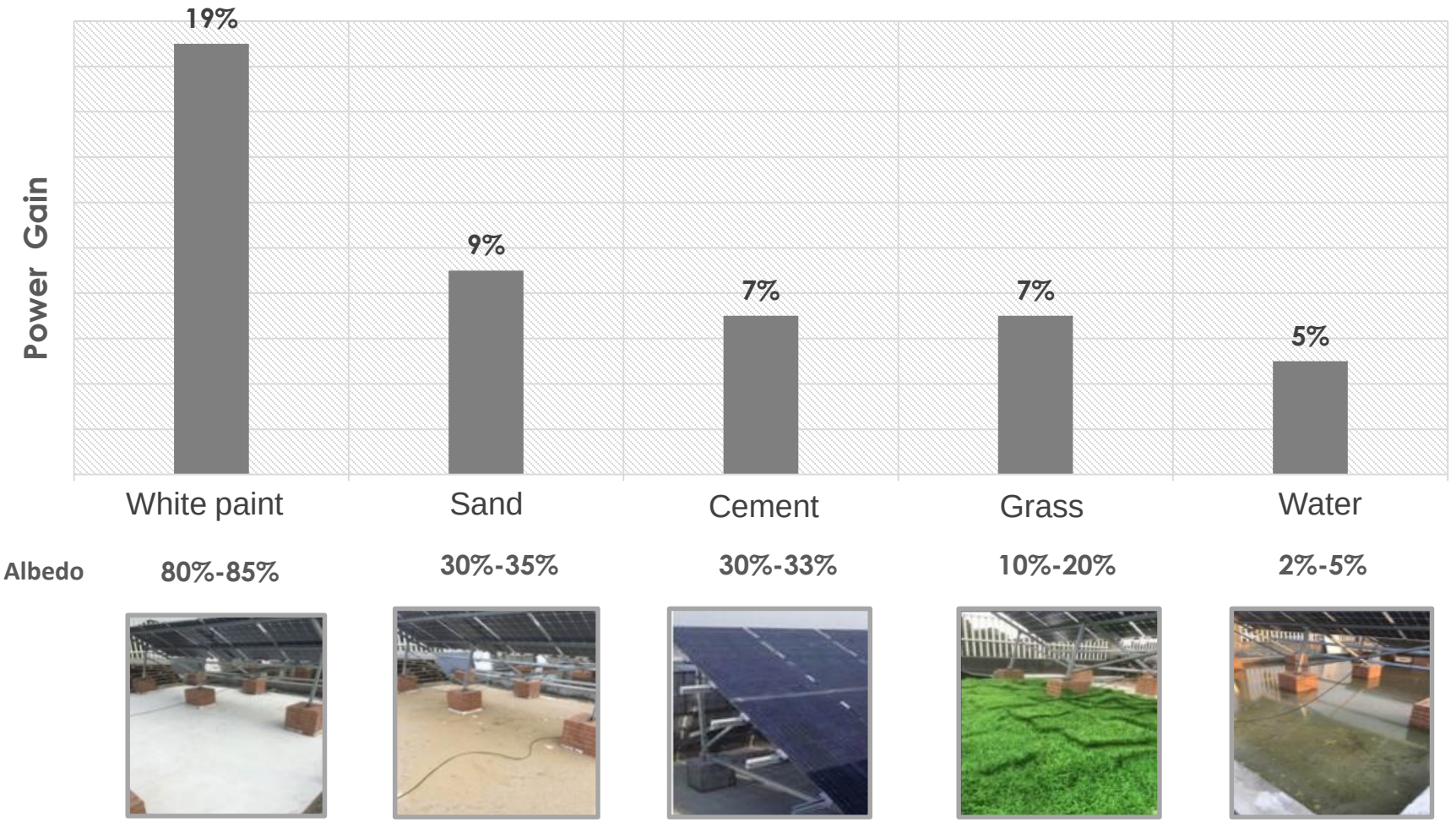
Completion Time
May 1996 – (23 years Service Life)

System information
Size: 1.25 kWp Projected System Output: 716,4 kWh/yr

Module type
Bifacial with transparent backsheet

Source: DuPont.

Real Energy Generation Gain



Location:
Jinko factory, Haining，30.3° N/ 120.4° E

Fixed Tilt angle:
30 °, close to the latitude

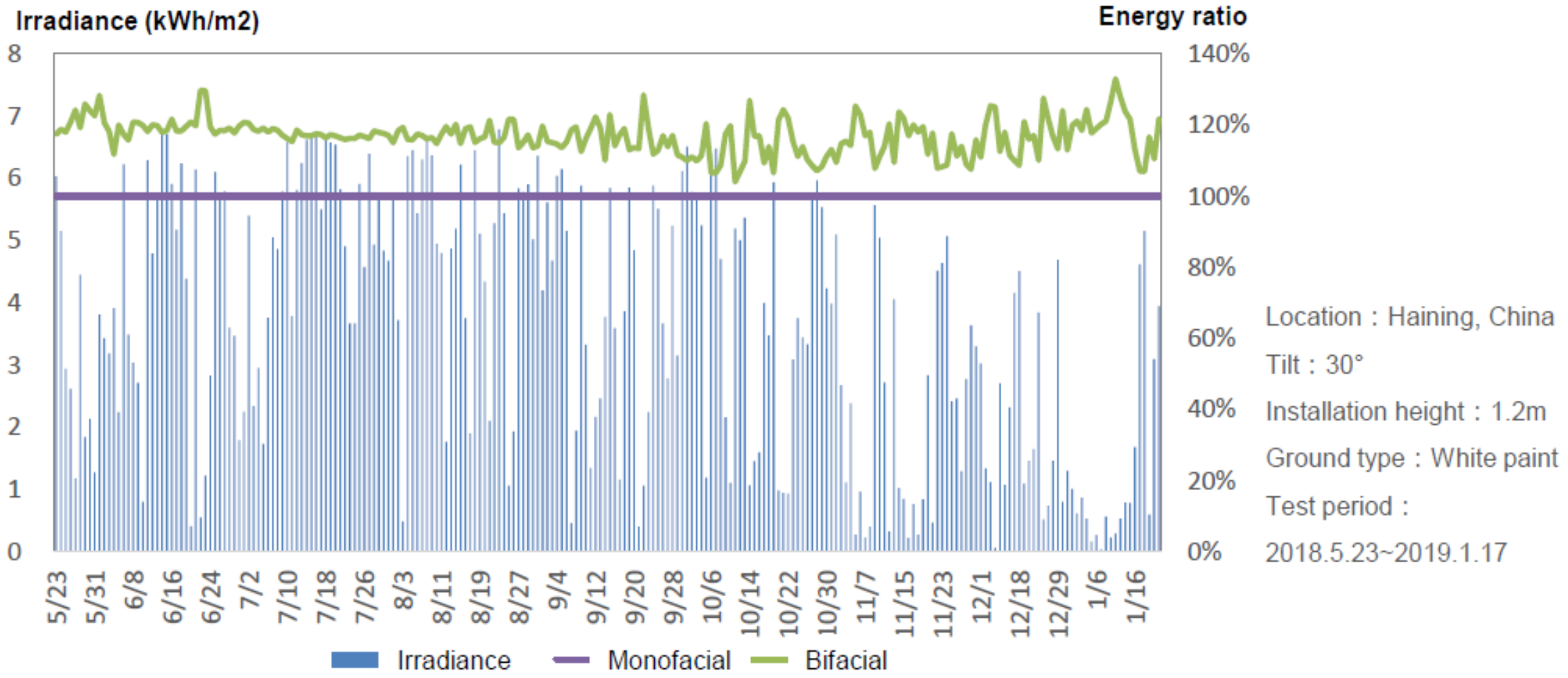
Mounting height:
distance from lower edge to ground is 1.2m

Capacity： 1.5kW/array

Energy gain：
Compared with mono-facial module in same condition

*Note: The PR of sand is higher than cement, because the yellow light reflected by sand is better for the energy gain.
Bifacial modules with transparent backsheet have almost the same bifacial factor as bifacial with dual glass.

Case Study 1： White paint Fixed installation



Location：Haining, China

Tilt：30°

Installation height：1.2m

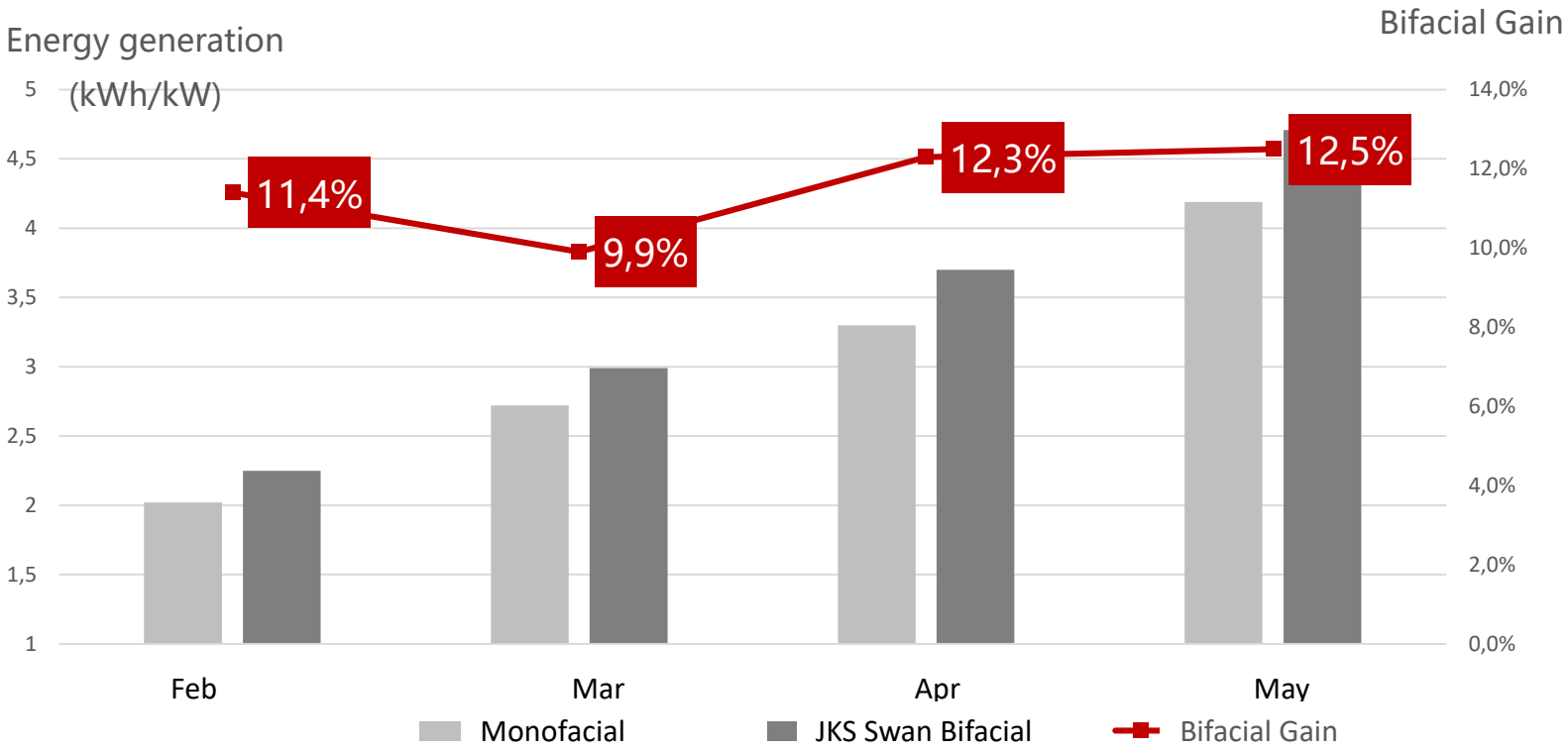
Ground type：White paint

Test period：

2018.5.23~2019.1.17

Swan bifacial reached average **16%** bifacial gain compared with monofacial modules, and in summer energy gain was up to **20%**.

Case Study 2: Sand Fixed Mounting System



Location: Haining, Zhejiang Province

Tilt Angle:30°

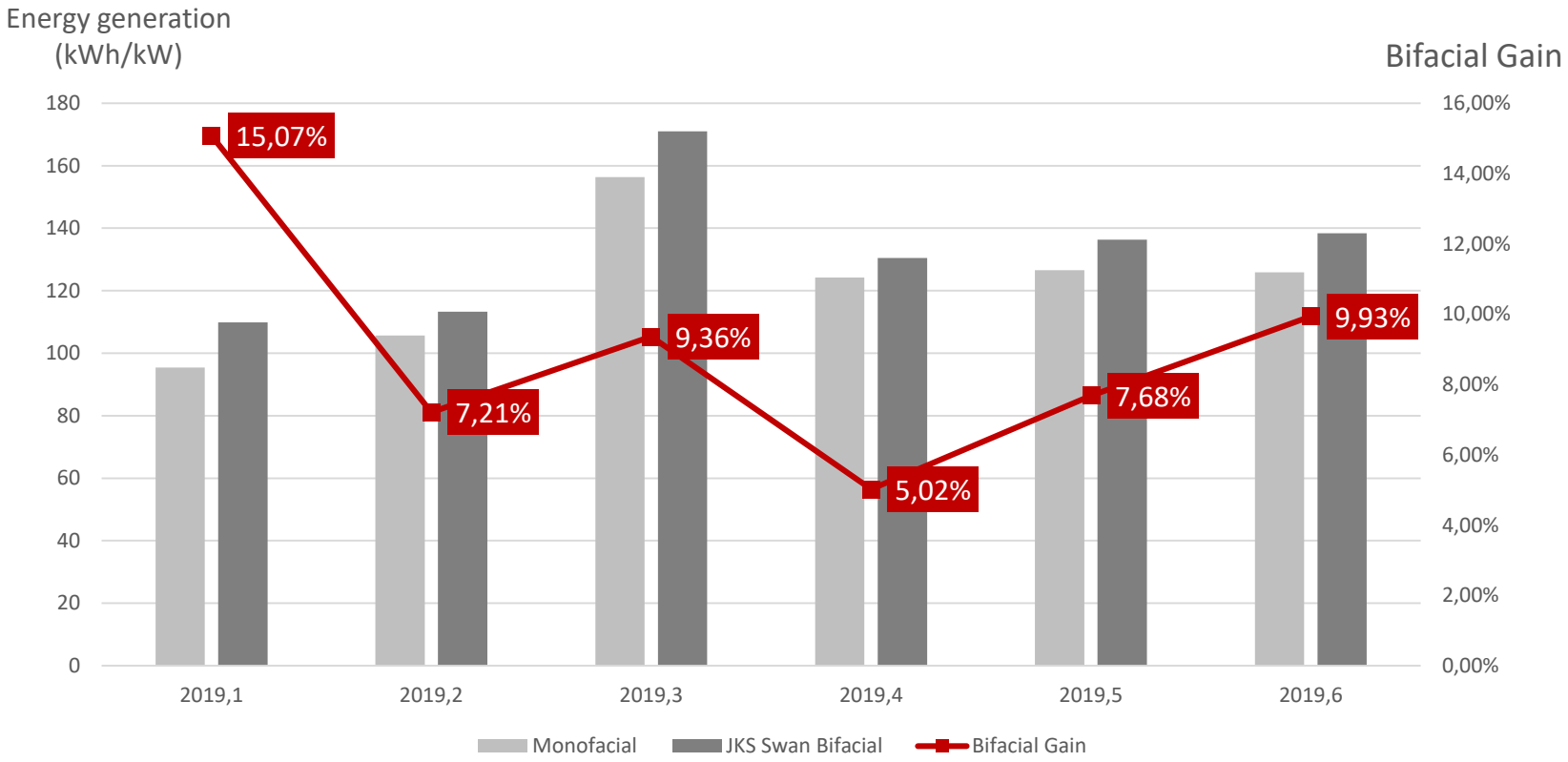
Installation Height: 1.2m above from the ground

Ground Type: Sand

Testing Date:2019.2.17~2019.5.27

- Swan bifacial with transparent backsheet
- Energy gain for bifacial modules between **10%-12.5%** compared with monofacial modules

Case Study 3: Grass Fixed Mounting System



Location: Lv Liang, ShanXi Province

Tilt Angle:30°

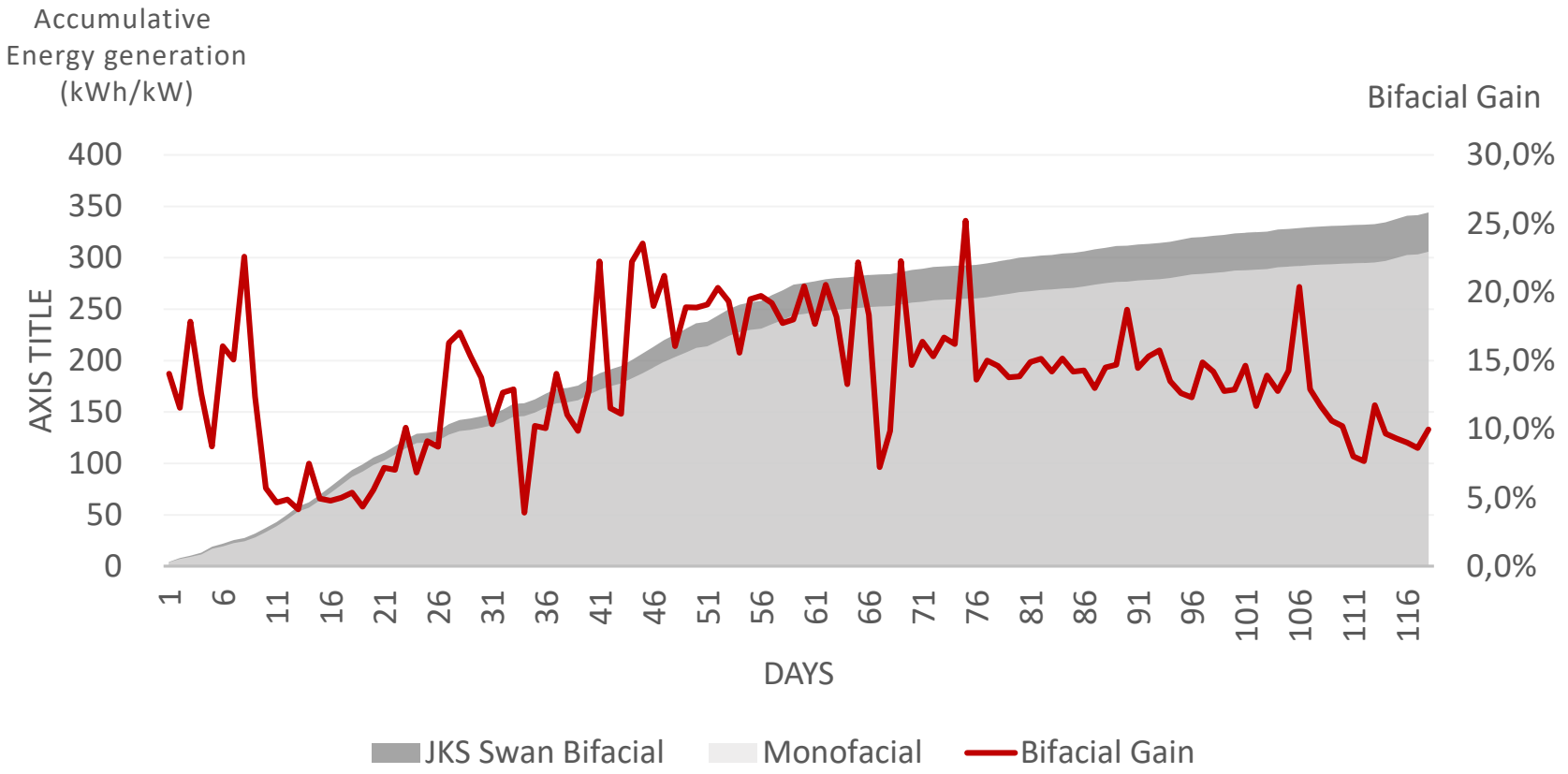
Installation Height: 0.3m-1.2m above from the ground

Ground Type: Grass/Soil

Testing Date:2019.1~2019.6

- Gain of bifacial modules is **9.05%** compared with monofacial modules
- Bifacial modules gain is proportionally higher in low-irradiance environments
- Energy gain reached **15.07%** in January with many overcast days

Case Study 4: Grass Tracker Mounting System



Location: Haining, Zhejiang Province

Tilt Angle:+/-60°

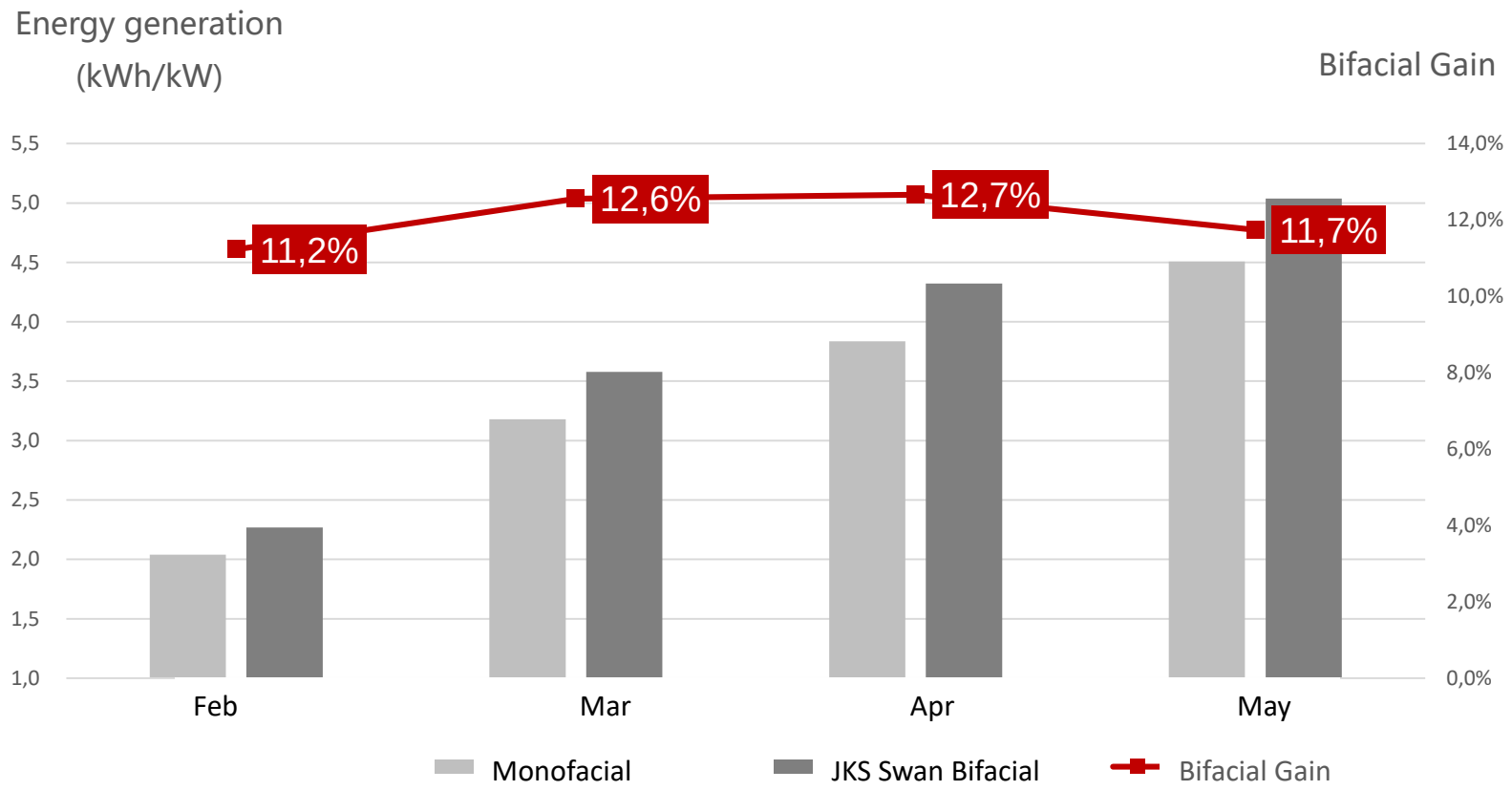
Installation Height: 1.2m above from the ground

Ground Type: Grass

Testing Date: 2019.2.17~2019.5.27

- Energy gain from Swan bifacial modules is **12.6%** compared with monofacial modules
- Grass turns yellow in autumn, leading to increasing energy gain

Case Study 5: Sand Tracker Mounting System



Location: Haining, Zhejiang Province

Tilt Angle:+/-60°

Installation Height: 1.2m above from the ground

Ground Type: Sand

Testing Date: 2019.2.17~2019.5.27

- Total energy generation monitoring from February to May
- Energy gain from bifacial modules is **11%-12.7%** compared with monofacial modules

Business case study

100MW

Project Size

72,000,000 $

TOTEX

CAPEX
70,000,000$

OPEX
2,000,000$
during 25 years

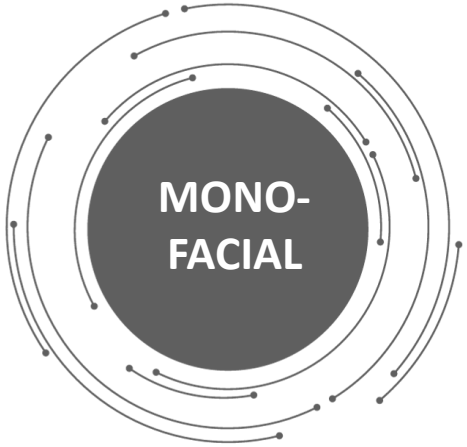
2,850,000 MWh

Energy yield
during 25 years

1,500 kWh/m2
Annual Irradiance

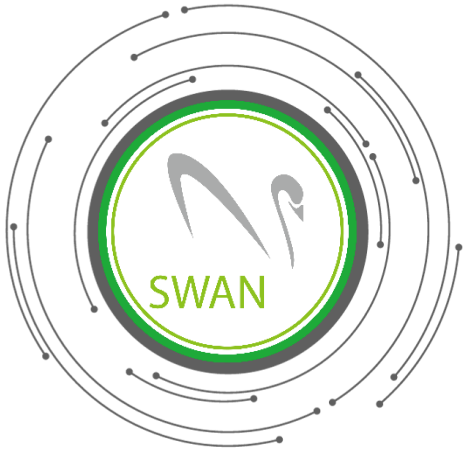
PR 85%

Business case study



Option 1: Monofacial 400Wp modules

- **TOTEX** 72m$
- **LCOE** 72m$/2,850,000MWh = **25.3$/MWh**



Option 2: Swan 400Wp modules

- **+10% energy yield**
- **Lower annual degradation**

- **TOTEX** 75m$
- **LCOE** 75m$/3,157,000MWh = **23.8$/MWh**
- **1.5$/MWh lower or 6% reduction of the LCOE** by using the SWAN modules (compared with Cheetah modules)
- Additional benefit: with Swan modules **the lifetime of the PV park increases to 30 years**

Assumption: Rest of the costs (loan interest, development costs, installation costs, etc.) remains the same in two different options.

Bifacial gain

Lighter

Module Installation Labor Cost

LCOE reduction
*(based on case study presented)

SWAN

Thanks