WEBINAR

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PVTECH TECHTalk

Jinko Solar

*Building **Your Trust** in Solar*

TÜV NORD

Assessing the benefits of TOPCon PV modules for utility-scale solar LCOE

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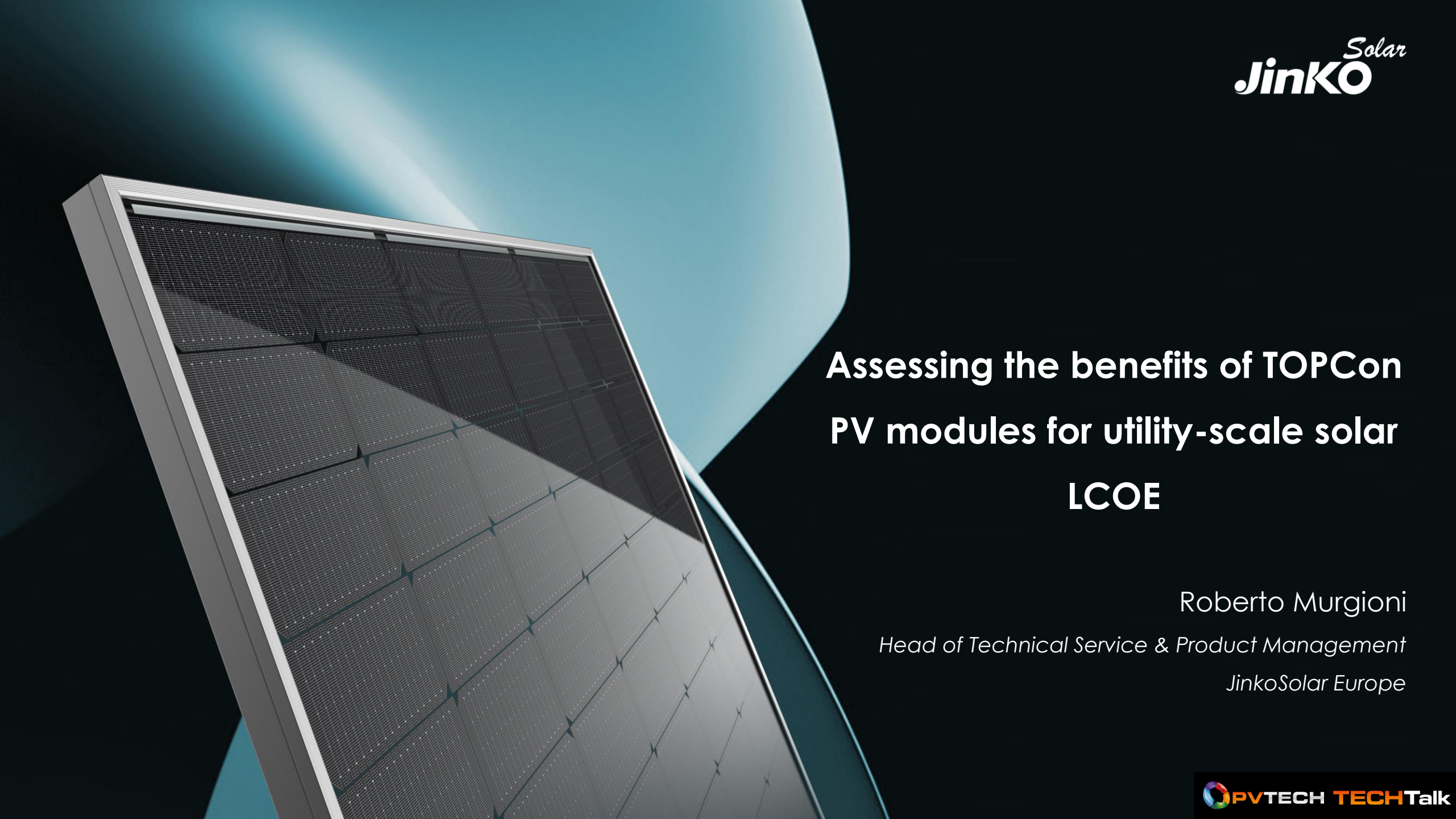

Assessing the benefits of TOPCon PV modules for utility-scale solar LCOE

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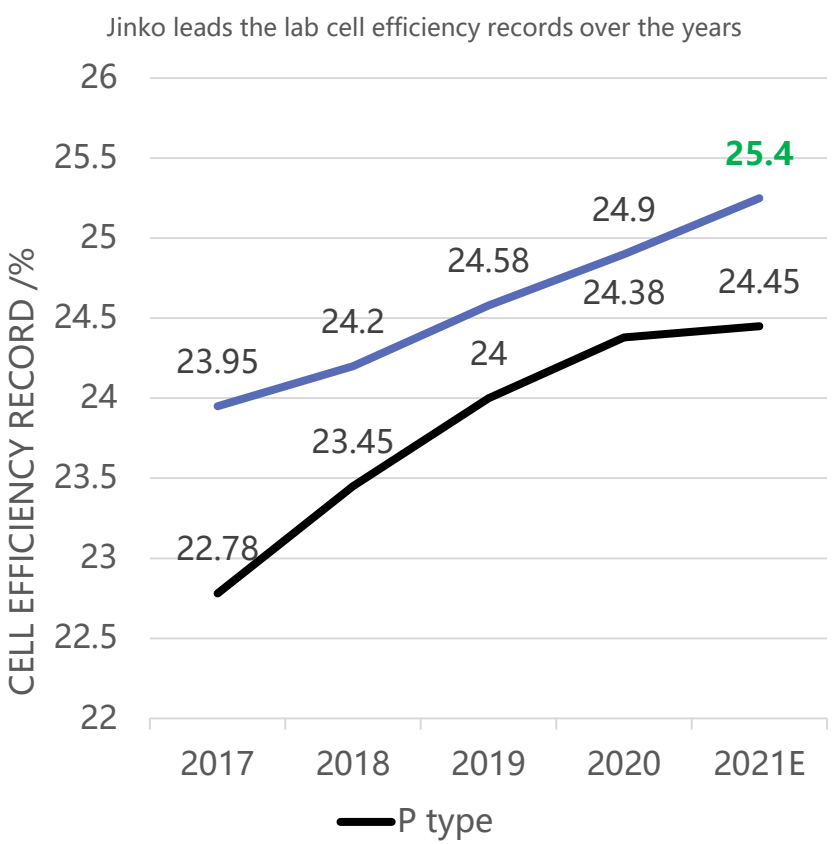
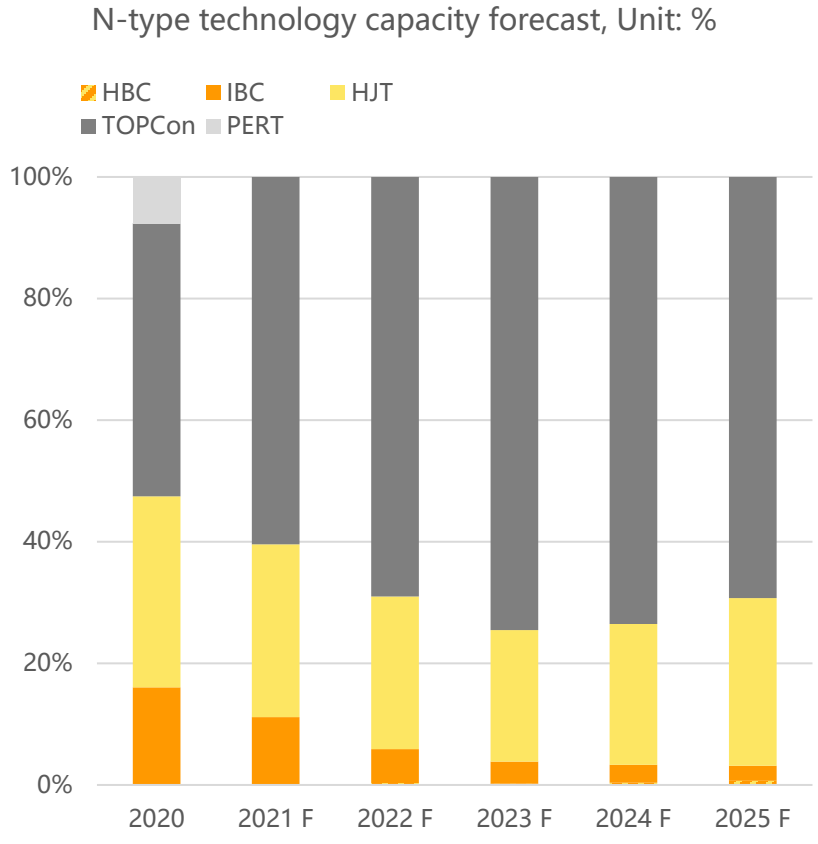
The Breakthrough of Cell Efficiency



Data source：Jinko R&D



Data source：PVinfo

24. 5%

Mass Production Efficiency

The application of HOT 2.0 technology has contributed to a new breakthrough in N-type cells, and the efficiency of mass-produced cells can reach 24.50%.

28.70%

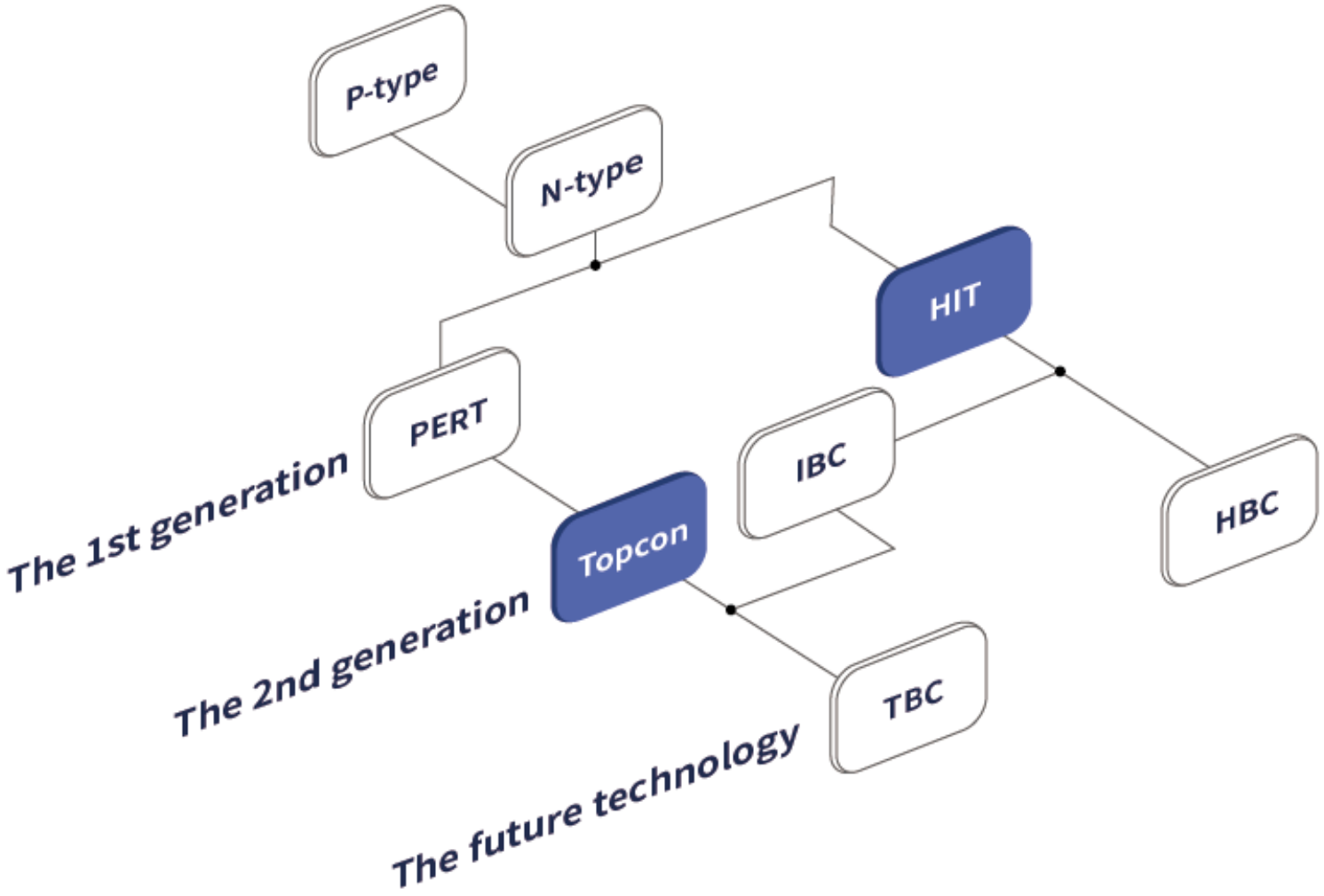
Higher Efficiency Limits

TOPCon cells have higher efficiency limit (28.2%~28.7%), much better than PERC cells .

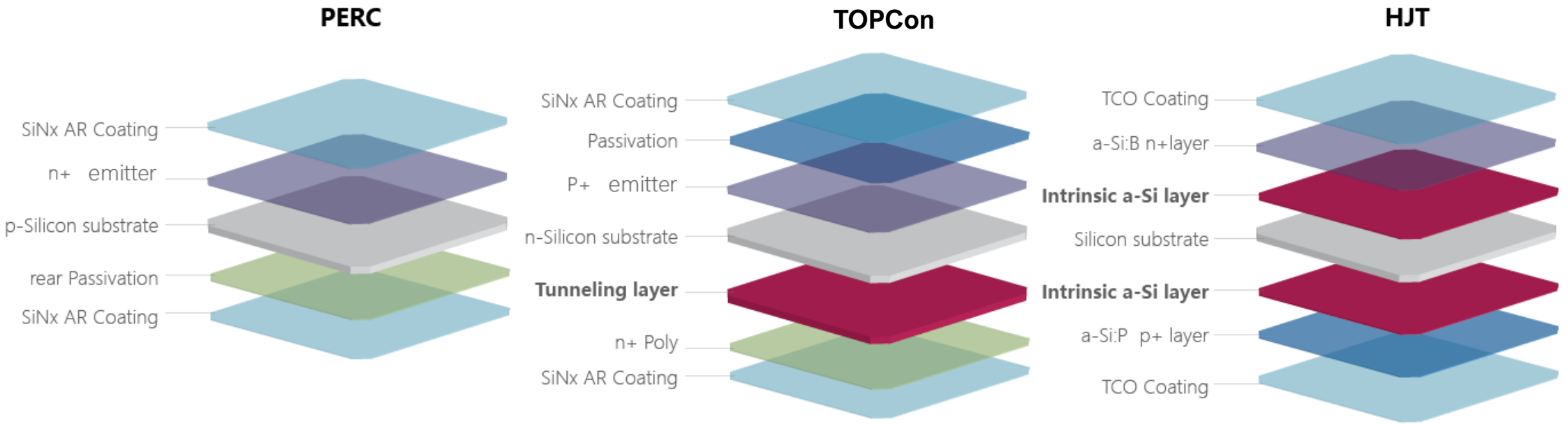
N-type Cell - The Technical Classification

Nowadays, the N-type cells studied are mainly divided into: PERT, TOPCon, HJT and IBC.

Of these, TOPCon and HJT are the focus of attention of the current N-type technology.



N-type Cell - TOPCon & HJT



Both TOPCon and HJT achieve power improvement through **passivation**. The former one uses tunneling oxide layer while HJT uses **intrinsic amorphous silicon film**. The differences in the methods lead to the differences in their respective processes, resulting in the difference in the commercial cost between the two (about **0.3￥/W**).

Technology Innovation - Selective Passivation Contact

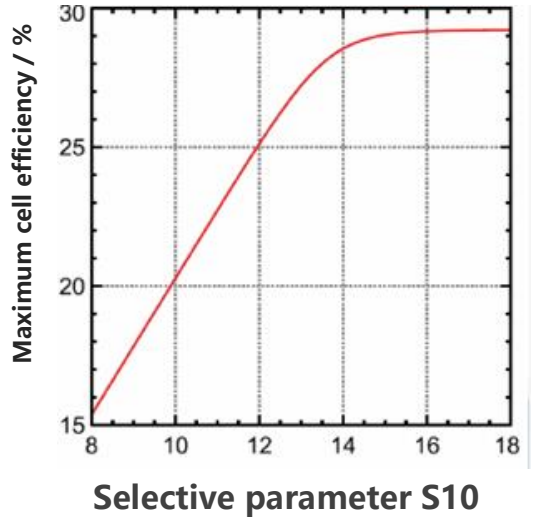
Passivation - The key technology determines the maximum efficiency

Passivation

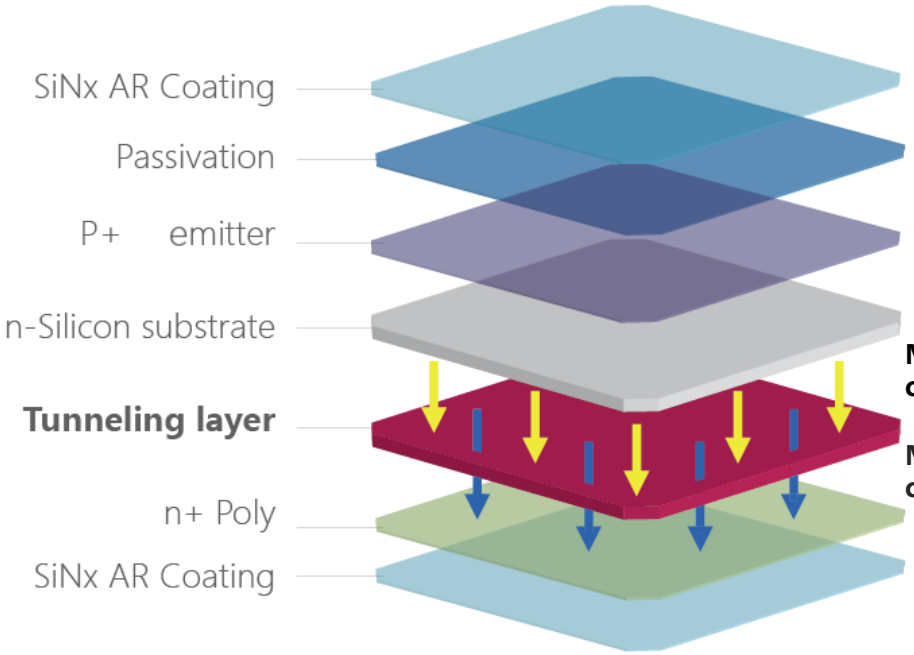
- Majority carrier pass → Resistance loss
- Minority carrier restrain → Carrier recombination

$$S_{10}=log_{10}{}^{*}\frac{V_{th}/J_0}{\rho_c}$$

Maximum cell efficiency increased



TOPCon



Low resistance loss & high Voc

Suitable for Multiple Applications

Utility

Tiger Neo 78P
- Maximum power 610W
- Lowest LCOE in certain scenario

Tiger Neo 60P/54P
- Maximum power 475W/425W
- Compatible with residential roofing and C&I
- High eff. module for DG market

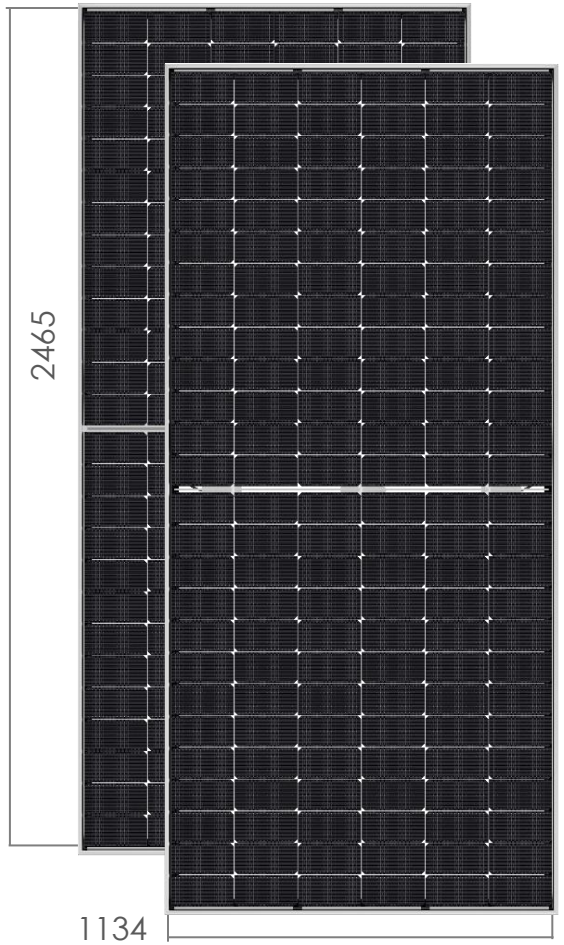
DG

C&I

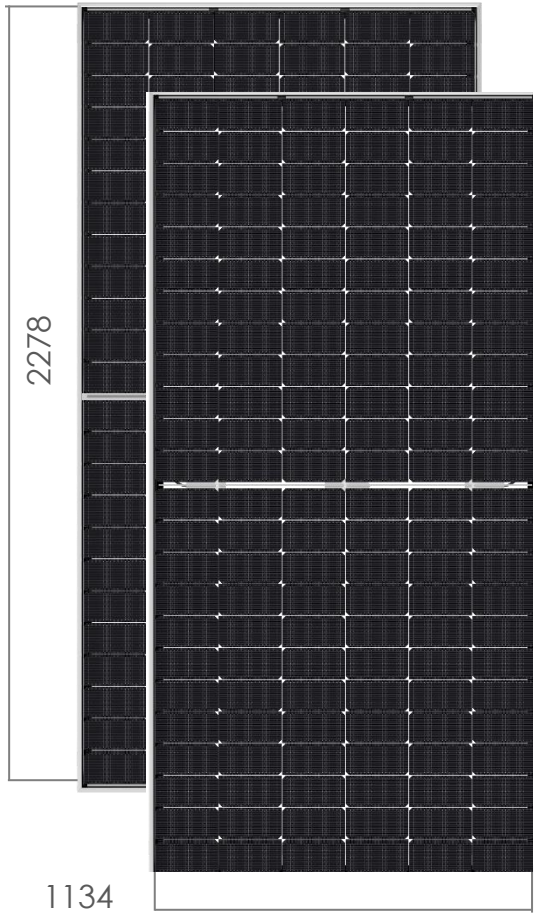
Tiger Neo 72P
- Maximum power 565W
- Low voltage， flexible string setting
- Moderate size, Suitable for MW – GW utility applications

Tiger-Neo Module Series

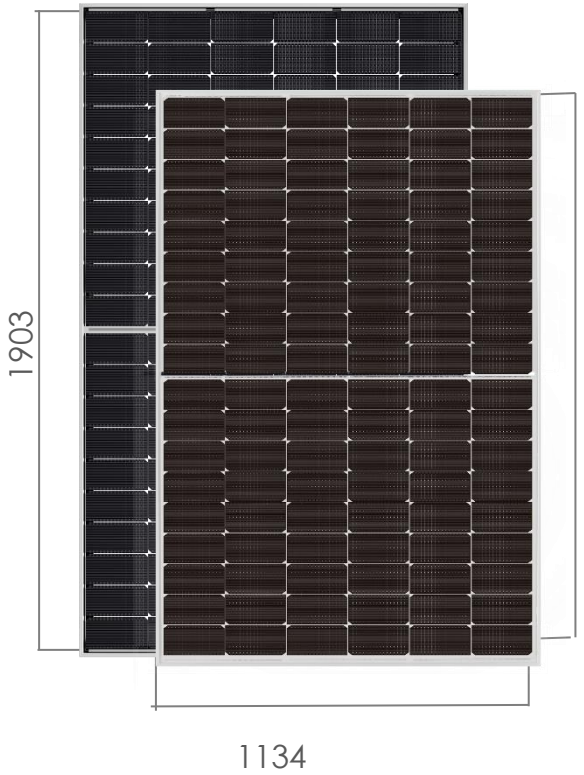
Tiger-Neo 78P
Max 615/610W
mono/bifacial module



Tiger-Neo 72P
Max 575/570W
mono/bifacial module



Tiger-Neo 60P/54P
Max 480/430W
mono module



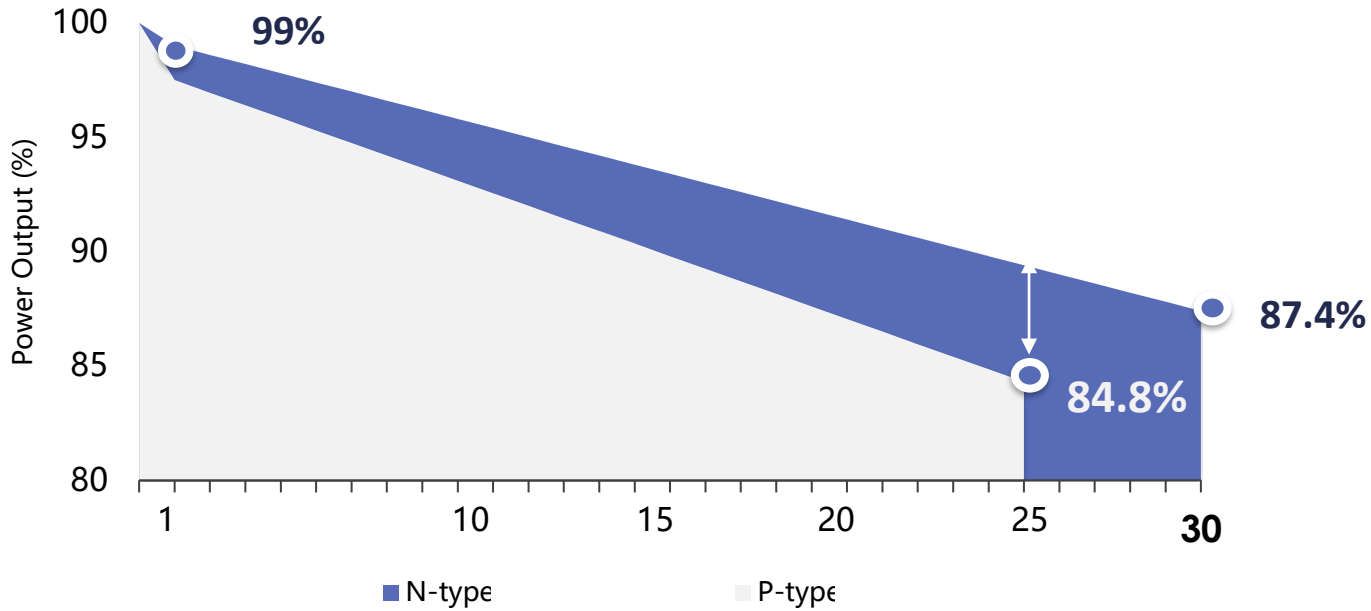
Product Advantage I Optimized Degradation Advanced Warranty

The power warranty could be as long as 30 years – significantly longer than traditional P-type modules. Year 1 degradation is lower than 1% which means the power output could remain over 87.4% compared to the 1st year

30 years Power Warranty

≤ 1%
First year degradation

-0.4%
Linear degradation



Product Advantage II

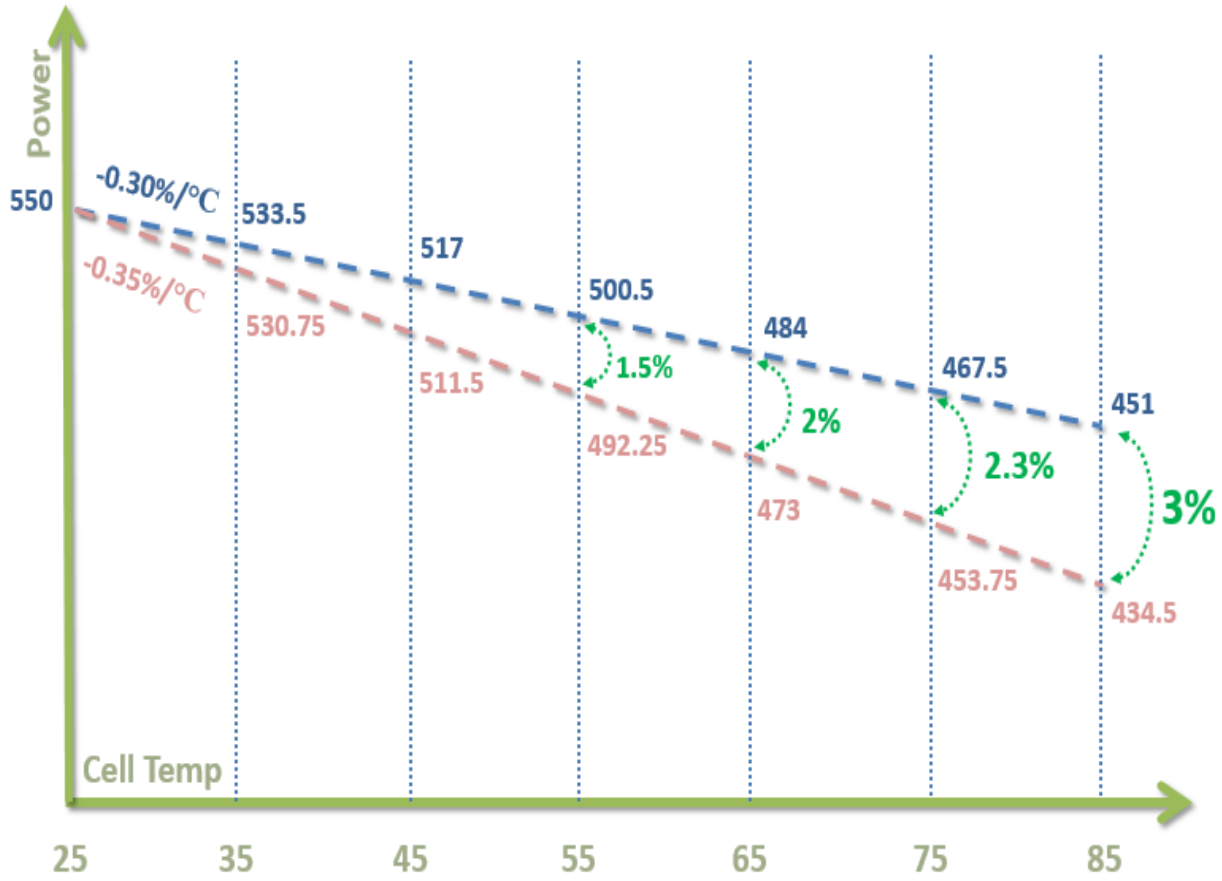
Optimized Temperature Coefficients

-0.30%/ ℃

P-type -0.35%

N-type -0.30%

- Under the same external environment, Tiger Neo's **operating temperature** is lower (**>1 %** compared with the same specification P type)
- Under high temperature conditions, this advantage is further extended (**~2%** higher)



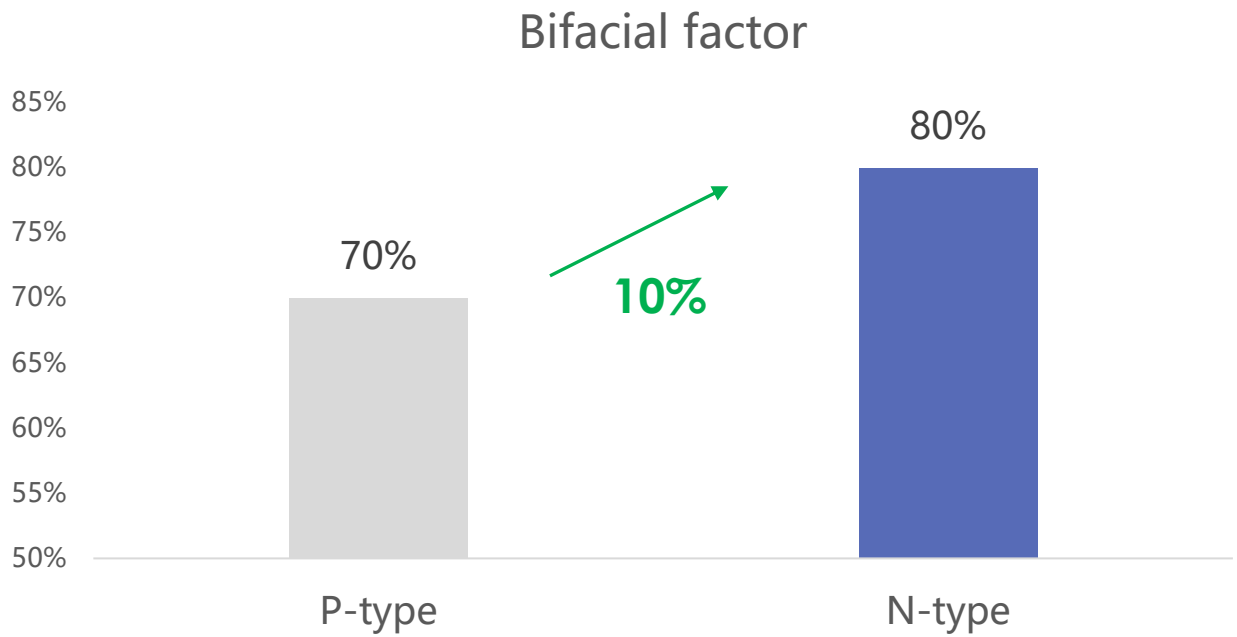
Product Advantage III

Bifacial Factor

80%

N-type's higher bifacial factor will deliver significant power gain of around

2.03%

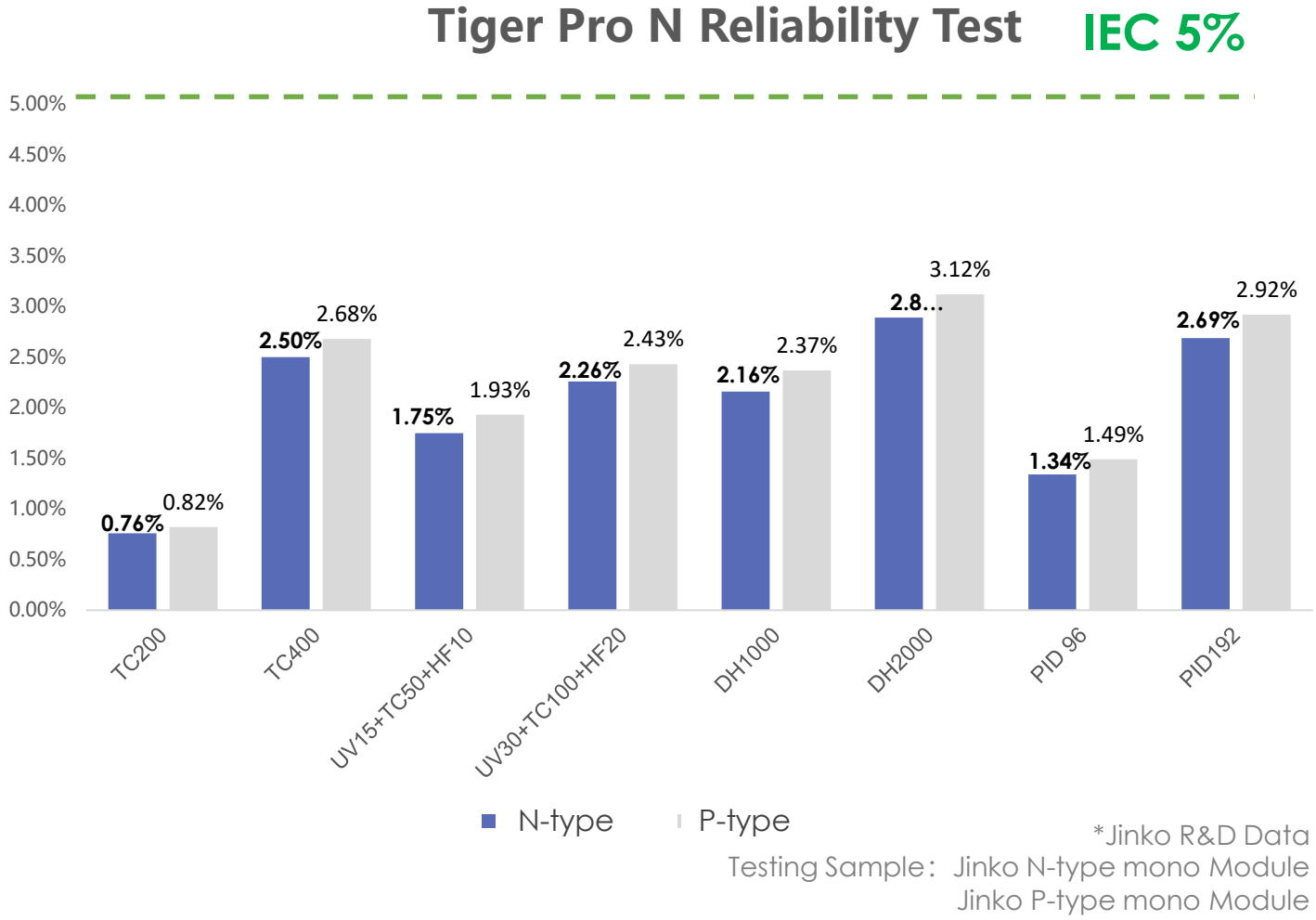


$$P_{\text{Integrated power}} = P_{\text{front}} * (1 + BSI * Bifi)$$

*Bifi: Module bifacial factor
*BSI: Bifacial stress irradiance coefficient
(depends on real irradiance & ground reflectivity)

Product Advantage IV
Enhanced Reliability

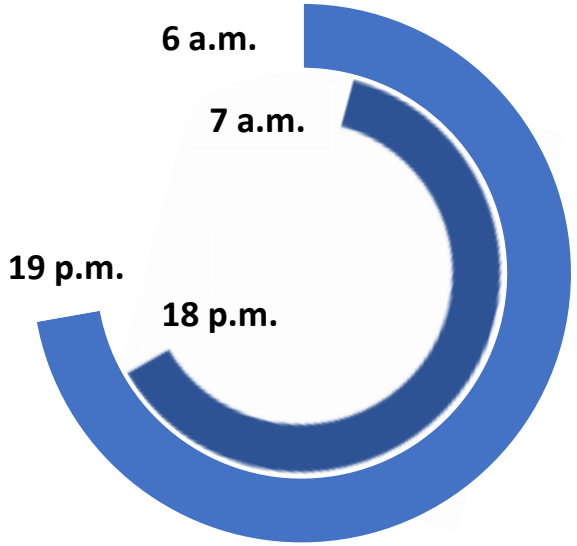
The N-type modules have better indicators than normal IEC standards and delivers excellent performance under test conditions.



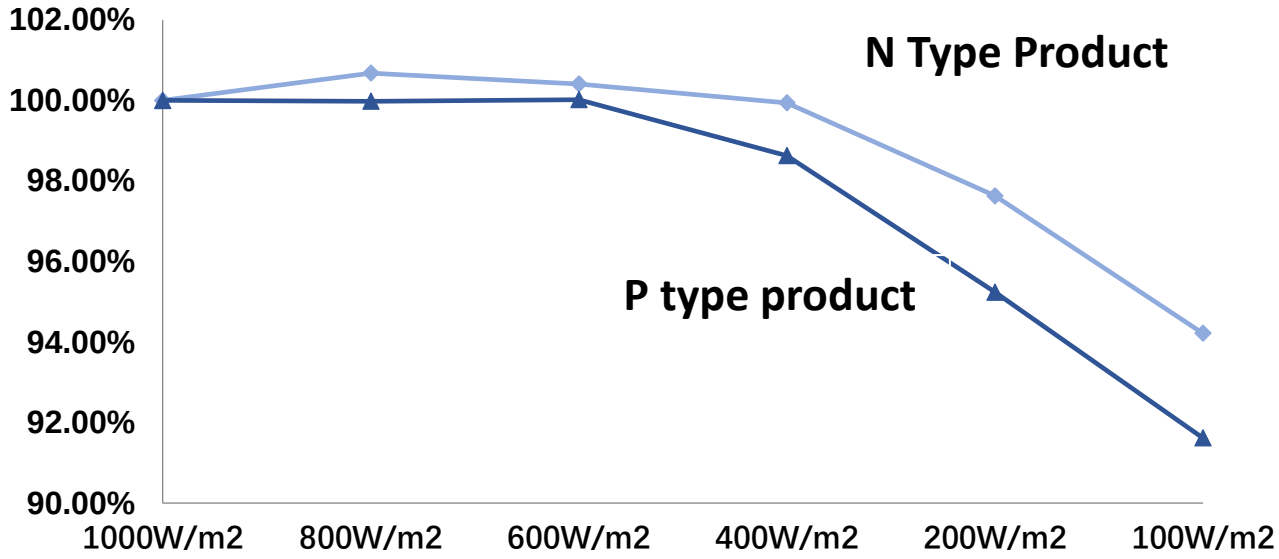
*Jinko R&D Data
Testing Sample: Jinko N-type mono Module
Jinko P-type mono Module

Product Advantage V Better Low Light Performance

N-type cell, higher internal resistance, longer minority carrier life, naturally better low light response

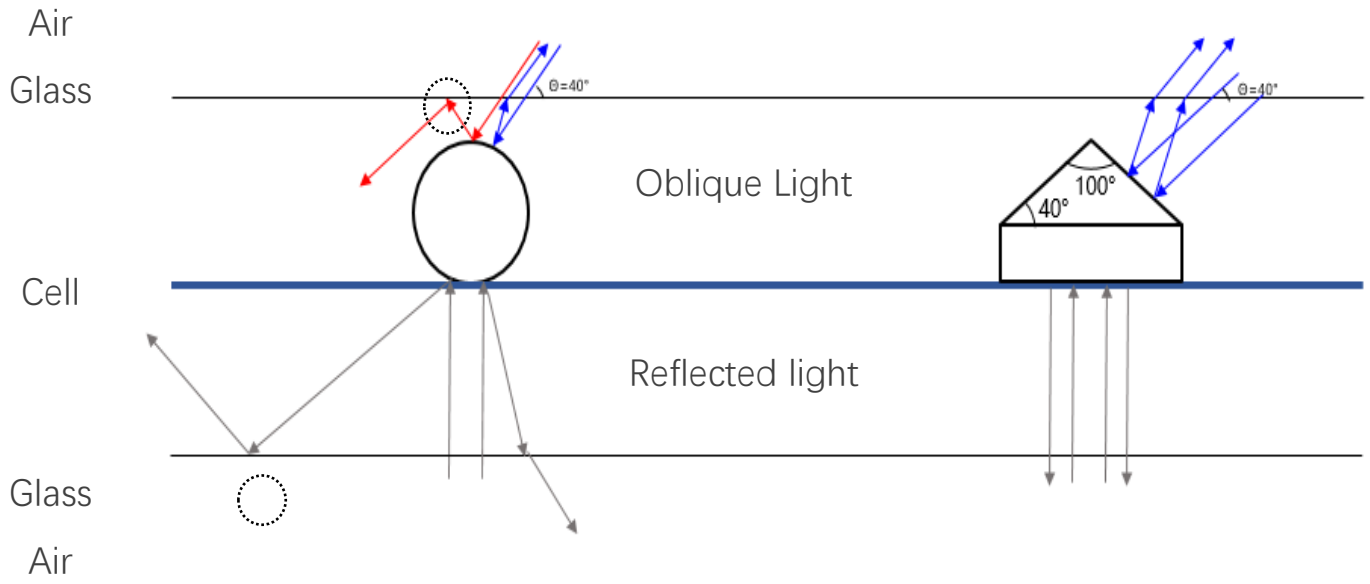


- Compared with traditional PERC modules, N-type TOPCon modules have a better response to low light, extending the power generation period by about 1H in the morning and evening.
- Low light coefficient, especially the performance below 600W/m2, N-type products outperform P-type products



Product Advantage VI Enhanced retention and capture of light – more electrons

The use of circular ribbon effectively increases the total reflection of oblique light with the absorption of rear reflected light further improving the bifacial factor



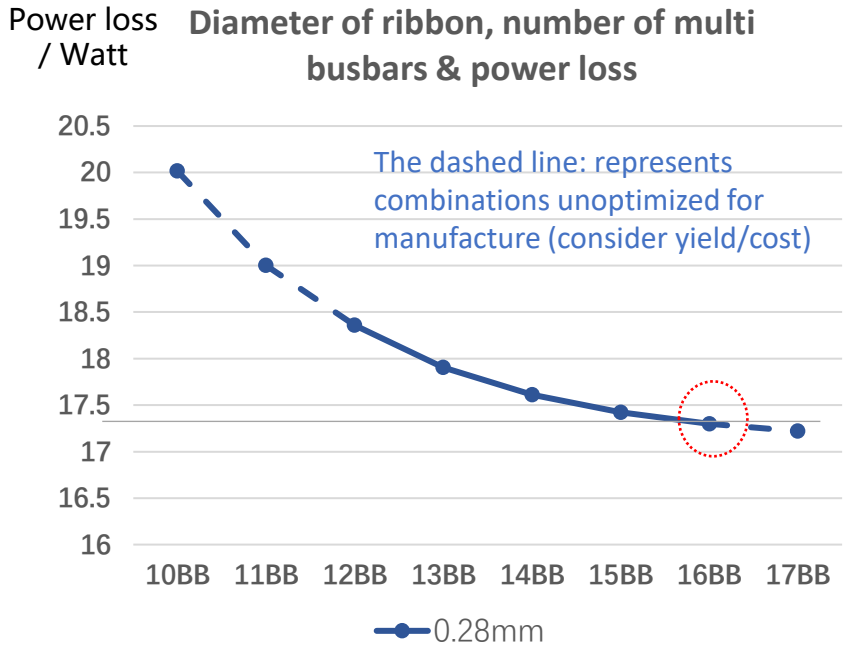
Tilt irradiation	Triangular ribbon	Circular ribbon
Integrated light utilization	**43.33%**	**54.44%**

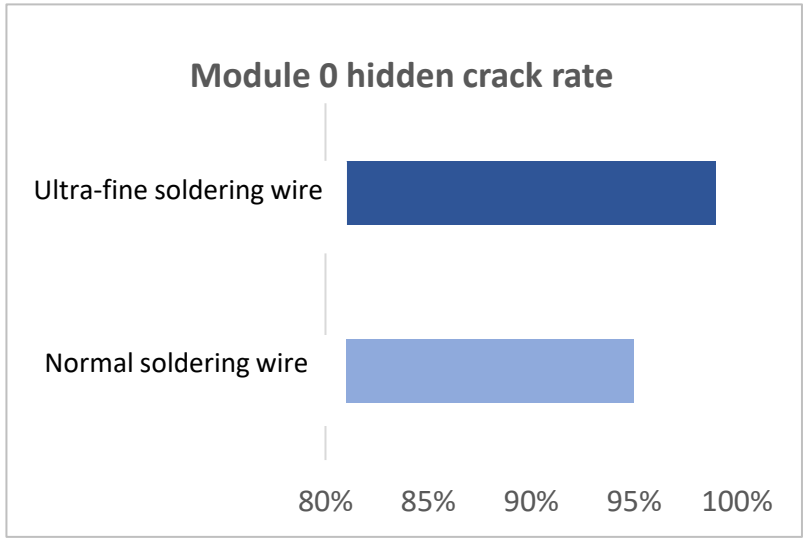
Rear Reflected light	Triangular ribbon	Circular ribbon P-type	Circular ribbon N-type
Bifacial factor	**67.8%**	**70%**	**85%**

Product Advantage VII

Better Busbar Matching

Jinko SMBB technology effectively improves current collection capability, reduces the risk of hidden cell cracks and improves power performance





Electrical Analysis： Busbar increases by 1, internal resistance decreases by ~ 4%, corresponding power increases by 0.18%.

Improved Energy Generation

over 3%

1 Optimized Temperature Coefficients

The advanced N-type HOT2.0 technology brings better temperature coefficients from -0.35% (P-type) to -0.30% (N-type)

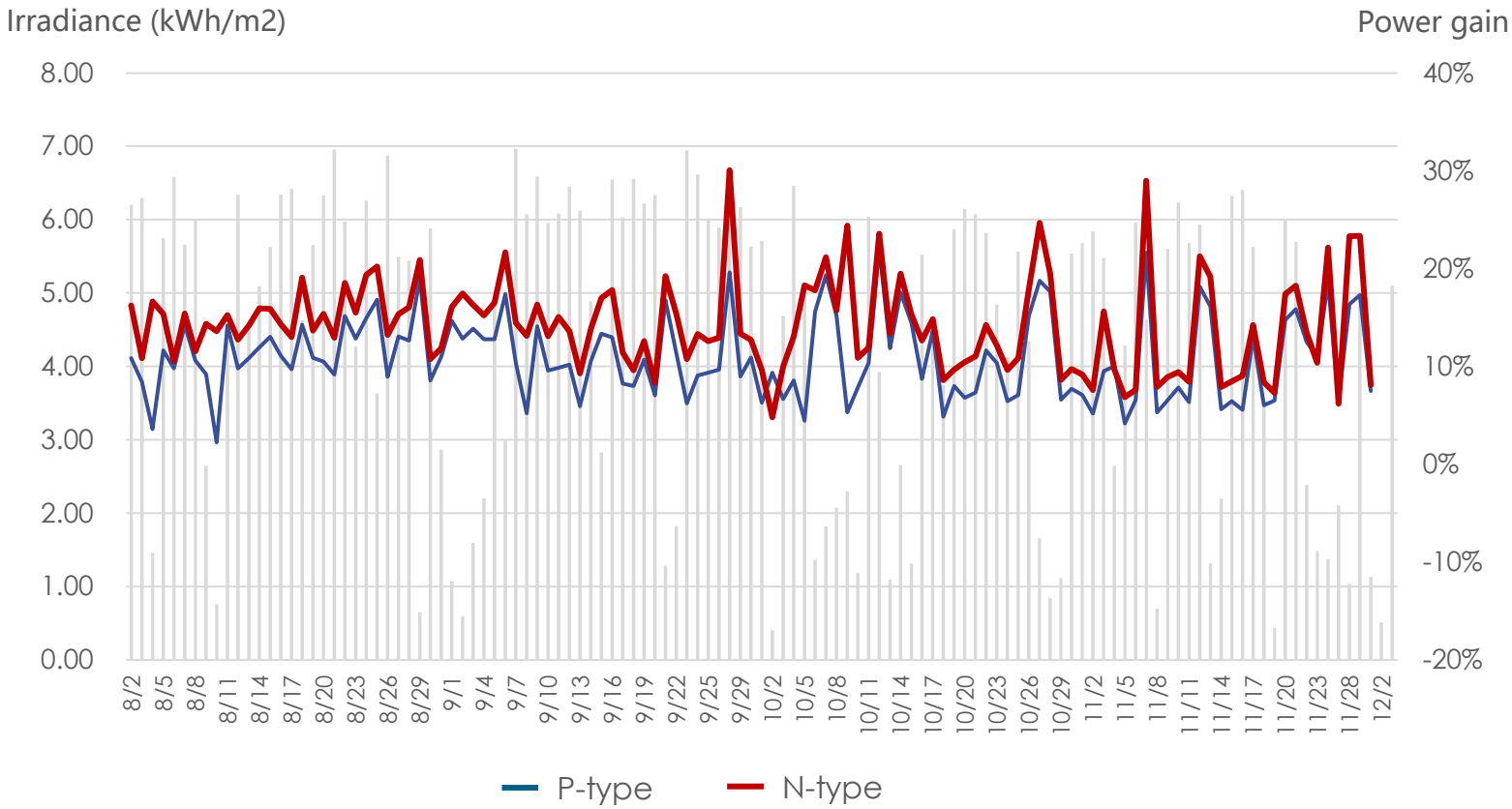
2 Higher Bifacial Gain

N-type modules have higher bifacial factor : 70% (P-type) up to 85% (N-type), significantly optimizing power generation capacity.

3 Lower LID / LETID

Low B content in N-type c-Si doped with P (significantly lower LETID from 0.9~1.2% (P-type) to 0.4% (N-type) and improved LID < 0.5%)

Outdoor Project Data Support-TOPCon vs. PERC



* Location: Haining Height: 0.7m Capacity: P-TV 6.93kWp
Angle: 30° Ground : cement N-TV 7.2kWp

P-type bifacial module

Power gain

9.7%

N-type bifacial module

Power gain

12.7%

The power generation difference reaches 3%

LCOE Analysis for Utility - Jinko N 605W vs. XXP 660W

* 200MW AC power station in Inner Mongolia N: 39.74°, E: 99.21°

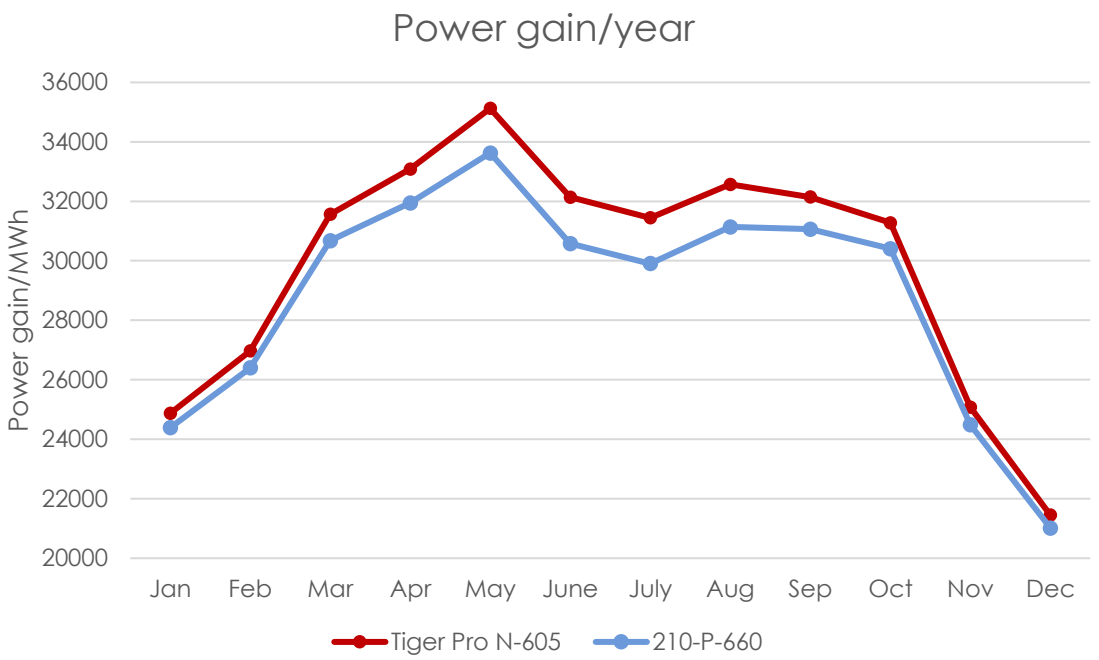
1. Initial- 1.18% lower than P-type

The table below shows the design of the project (tracker)

Cell	Jinko-N-605W	210-P-660W
Power	605W	660W
Efficiency	21.64%	21.25%
Length (mm)	2465	2384
Width (mm)	1134	1303
Voc (V)	54.76	45.90
1500V single series/pcs	25	30
Tracker installation fee	76.21%	80.19%
String/ tracker	4	3
No. of tracker	Base	101.9%
Power/ tracker (W)	**60500**	**59400**
Tracker length (m)	Base	Base+4m
No. of columns	Base	Base+1
Percentage (All column)	74%	80%

Tracker-theory (/W)	Base	104.2%
BOS cost	Base	**101.18%**

2. Power Gain-Around 12096 MWh/Y over P-type



BOS ↓ **1.18%**

IRR ↑ **5.31%**

LCOE ↓ **6%**

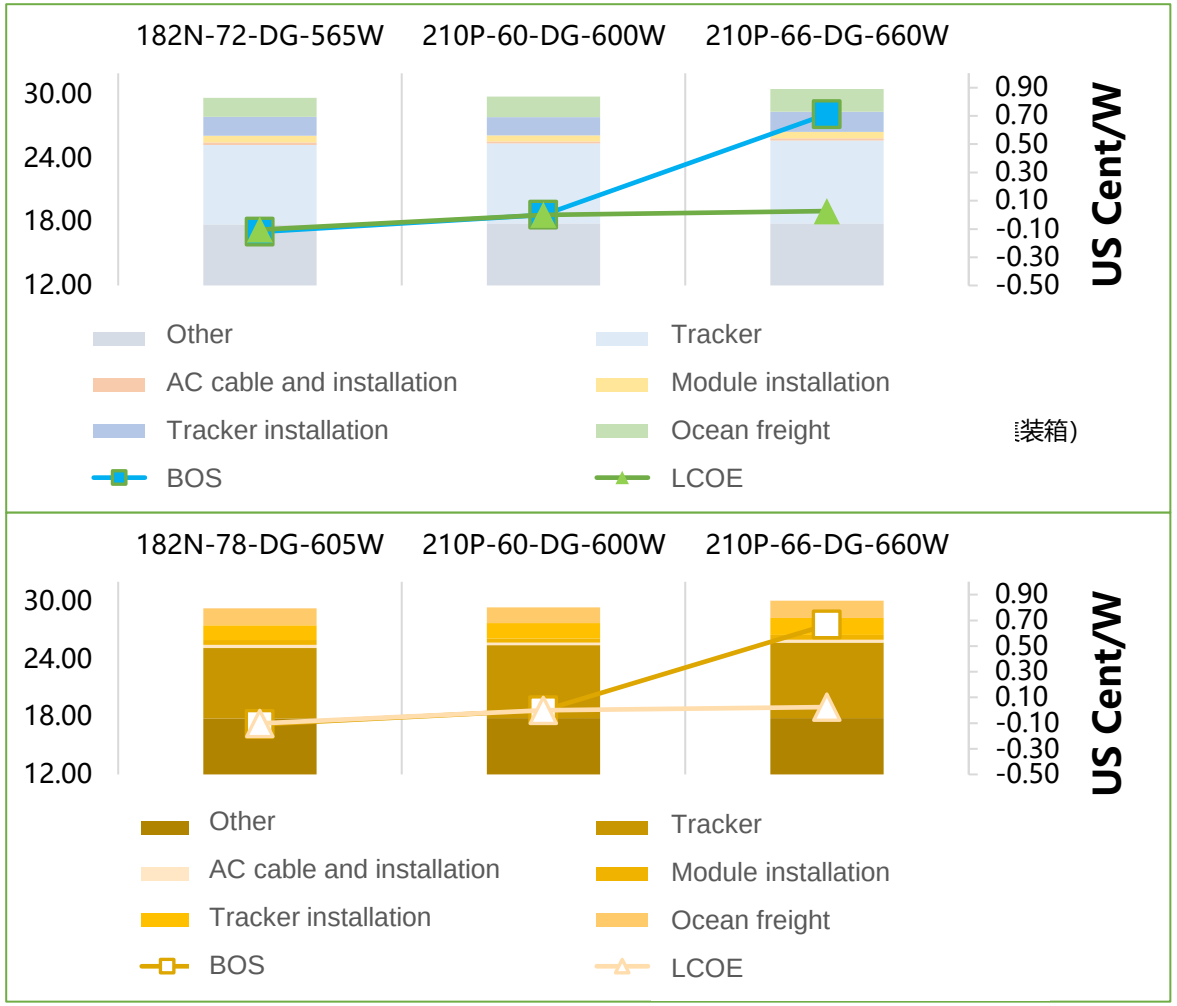
Utility LCOE Analysis - Jinko N 605W vs. XXP 660W

Saudi Arabia 2P tracker

	182N-72	210P-60	210P-66
Power (W)	565	600	660
ΔBOS (US Cent/W)	-	▲2.80%	▲0.40%
ΔLCOE (US Cent/W)	-	▲6.20%	▲4.94%

Spain 2P tracker

	182N-78	210P-60	210P-66
Power (W)	605	600	660
ΔBOS (US Cent/W)	-	▲2.65%	▲0.37%
ΔLCOE (US Cent/W)	-	▲4.78%	▲3.84%



System Design - the Combination of Inverters

String inverter

Isc 14.18A

Voc 55.40V

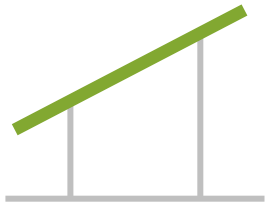
- Inverter upgrades for high-current modules continue, and as of Q2 2022, the vast majority of inverters are compatible with existing Tiger Neo high-current modules

Central inverter

GROWATT 古瑞瓦特 SMA HUAWEI SUNGROW 固德威 GOODWE 锦浪科技 GINLONG

System Design - the Combination of Mounting System

Fixed mounting system

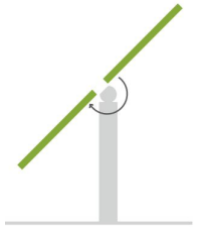


1P Tracker

NEXTracker A Flex Company

ARRAY TECHNOLOGIES

2P Tracker



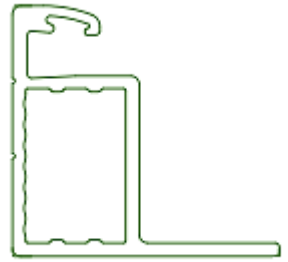
Arctech Solar

Soltec

High mechanical strength design

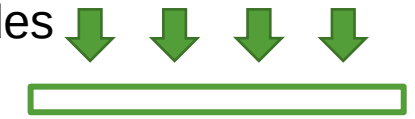
Enhanced frame design

- Thicker material
- Thicker cavity



Multiple installation modes

- Bolts installation
- Clamp installation



2400Pa

5400Pa

Tiger Neo Global Capacity

Tiger Neo will be ready for mass production in 2022 and capacity will reach approx. 42GW

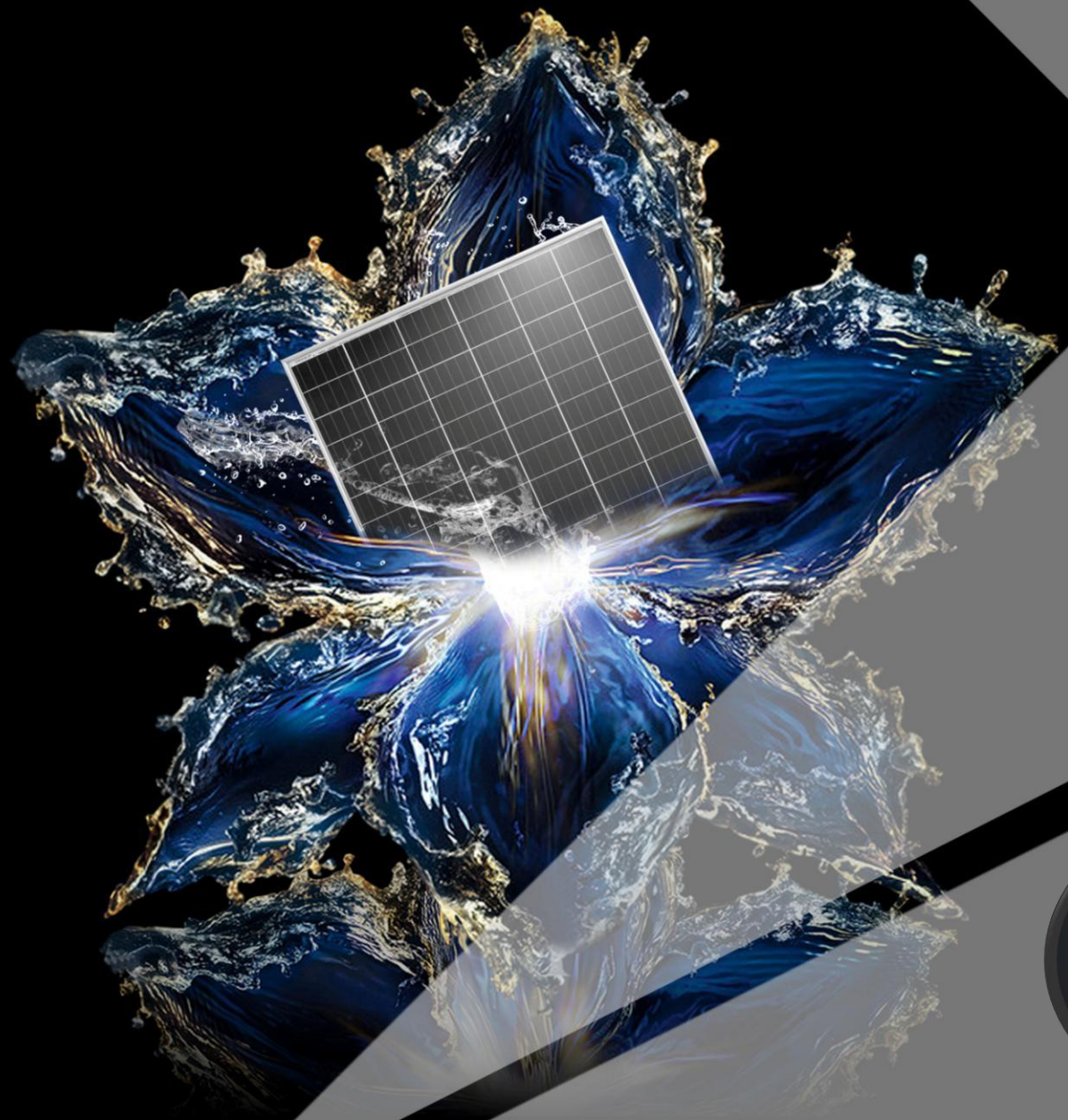
Q1

2022 Q1 mass-production

Approx. 42 GW

2022 capacity plan (whole year)

Thanks !



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Analysis of influences on LCOE by PV modules with different technologies

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02 LCOE Evaluation for Spain

03 LCOE Evaluation for China

04 Conclusions

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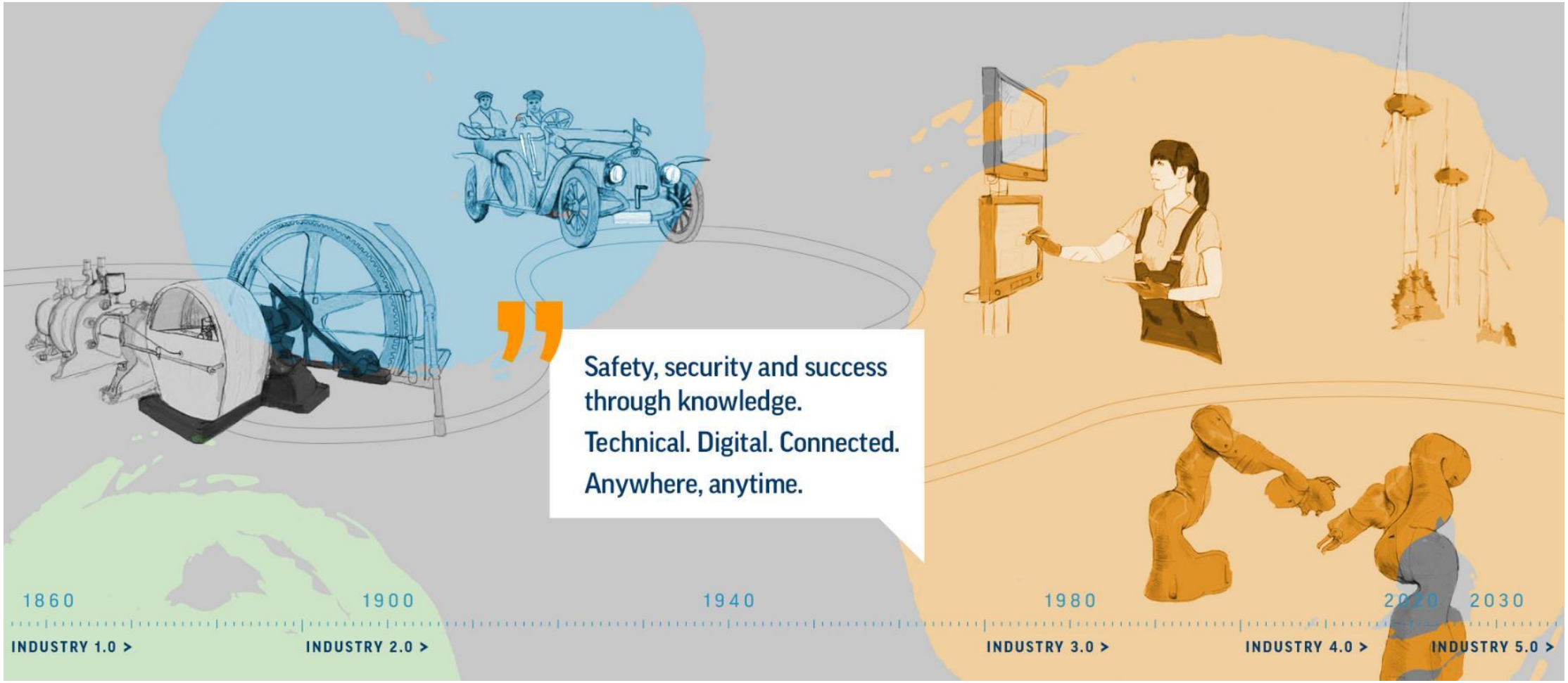
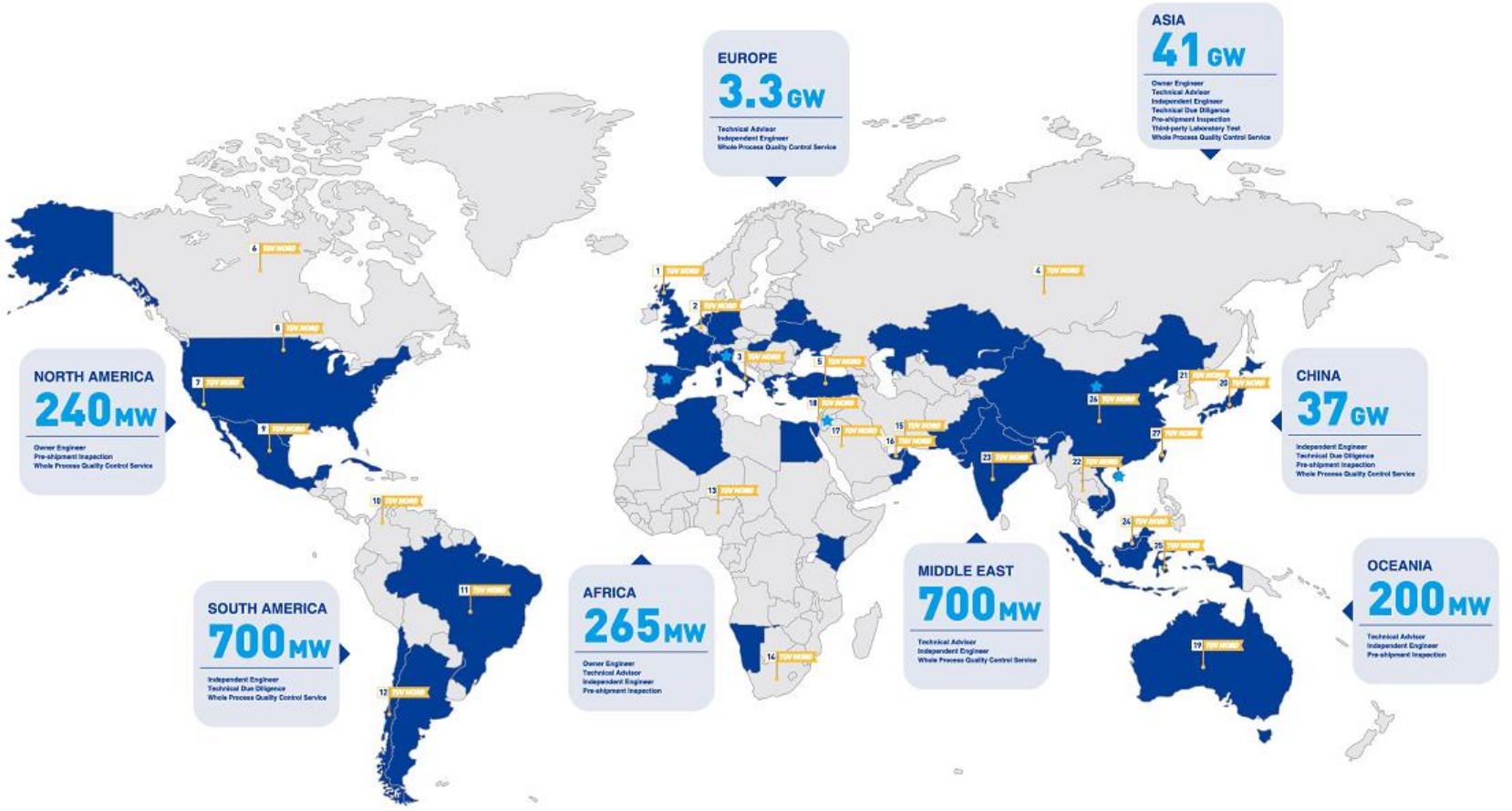


Global PV projects overview



150+

Global
Branches

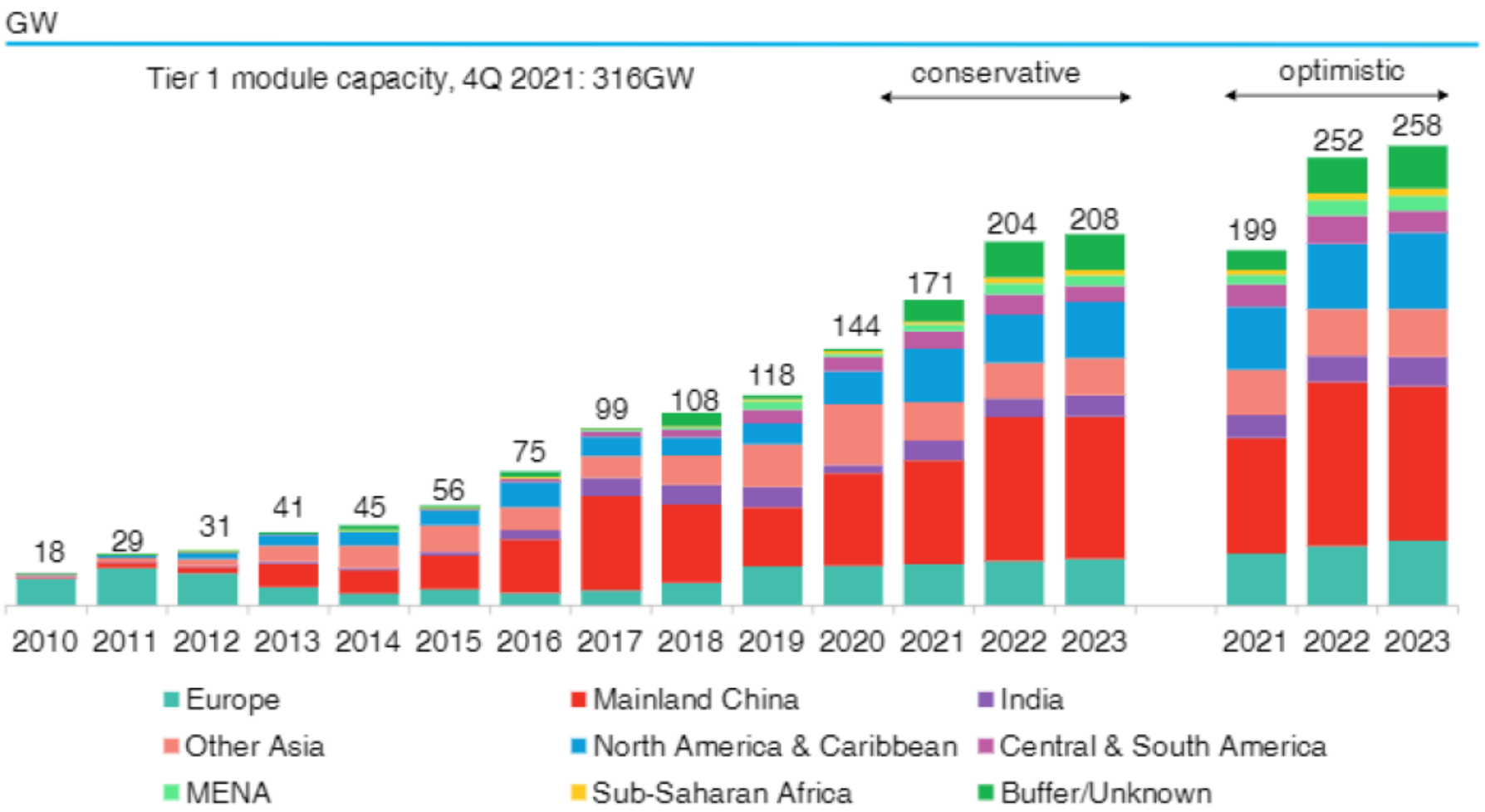
3000+

Certificates

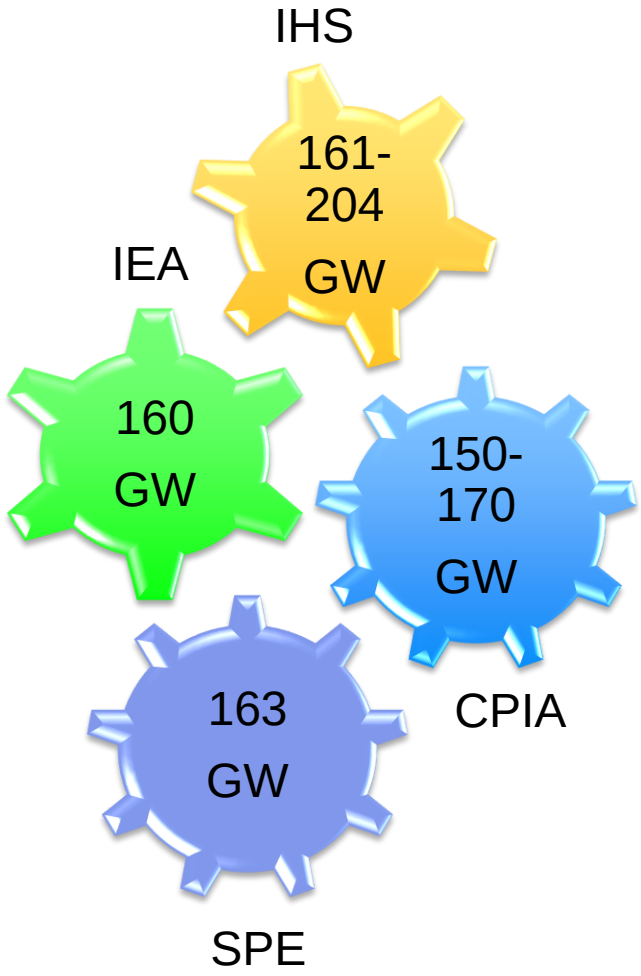
55GW+

Worldwide PV System
Performance Evaluation

PV new build, historical and forecast



Source: BloombergNEF



Source: CPIA

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Evaluation of LCOE - Levelized Cost Of Energy

Lifecycle cost

Costs during system operation

$$\mathrm{LCOE} = \frac{C + \sum_{t=1}^{n} \frac{(L_t + M_t + T_t)}{(1+r)^t} - \frac{R}{(1+r)^n} + \sum_{t=1}^{n} I_t}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Lifetime energy production

Energy yield during system operating time

Variables

Similar parameters

C: Total investment capital

n: Life-cycle (years)

L_t: t year's land fee

M_t: t year's OM fee

T_t: t year's tax

r： Discount rate

R: PV plant's residual value

I_t： No.t year's loan interest

E_t： t year's generated energy

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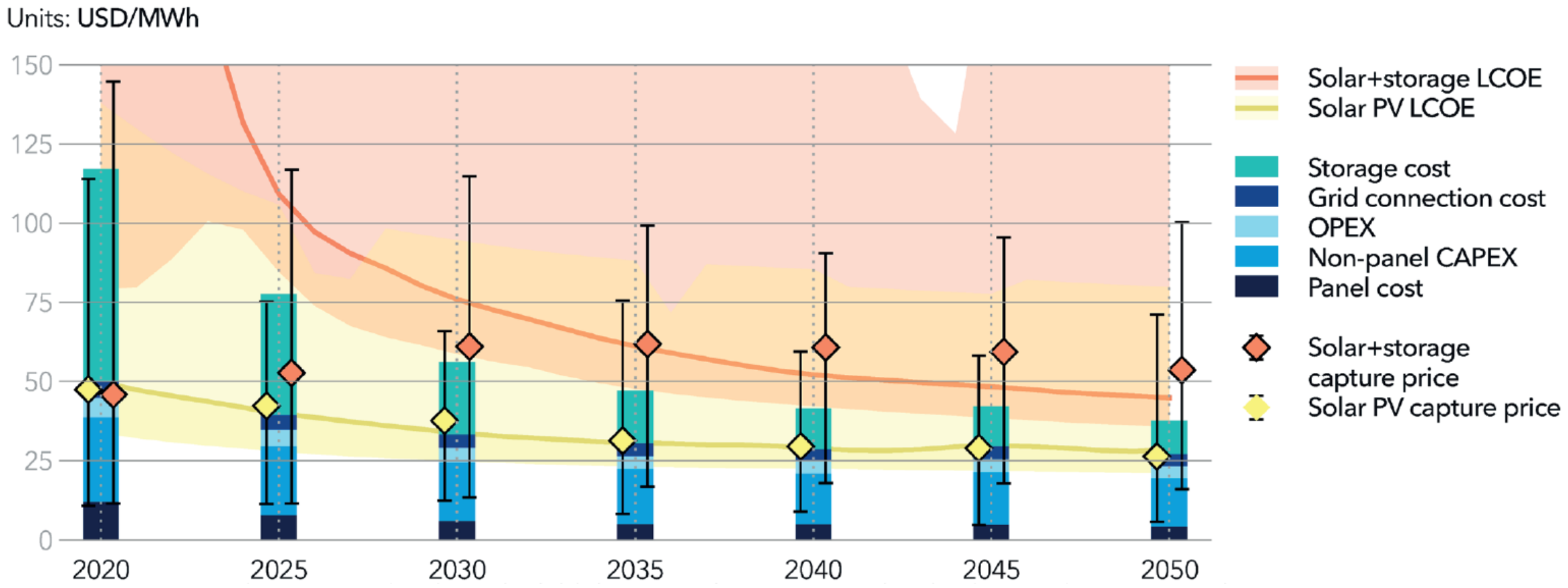
Global solar LCOE and capital expenditure



Source: DNV

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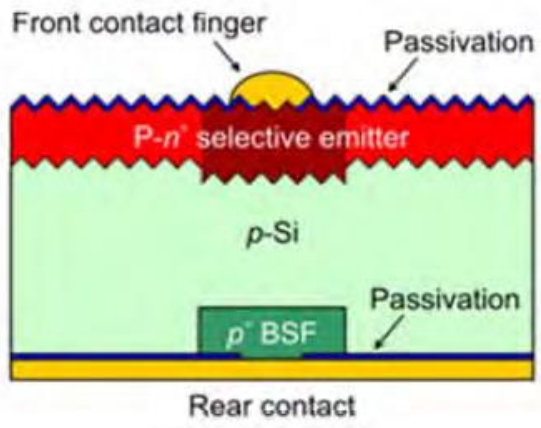
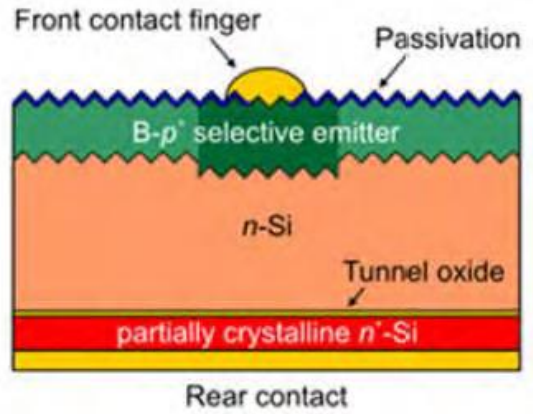
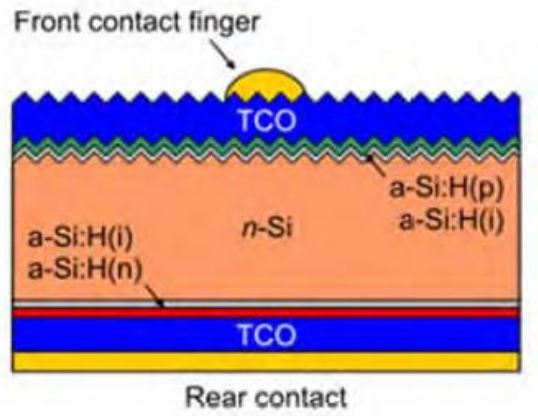
Emerging technologies for PV



PERC
Production efficiency
22.5%-23.1%
Theoretical efficiency
~24.5%



TOPCon
Production efficiency
23.5%-24.5%
Theoretical efficiency
28.2%-28.7%



HJT
Production efficiency
23.5%-24.5%
Theoretical efficiency
~27.5%

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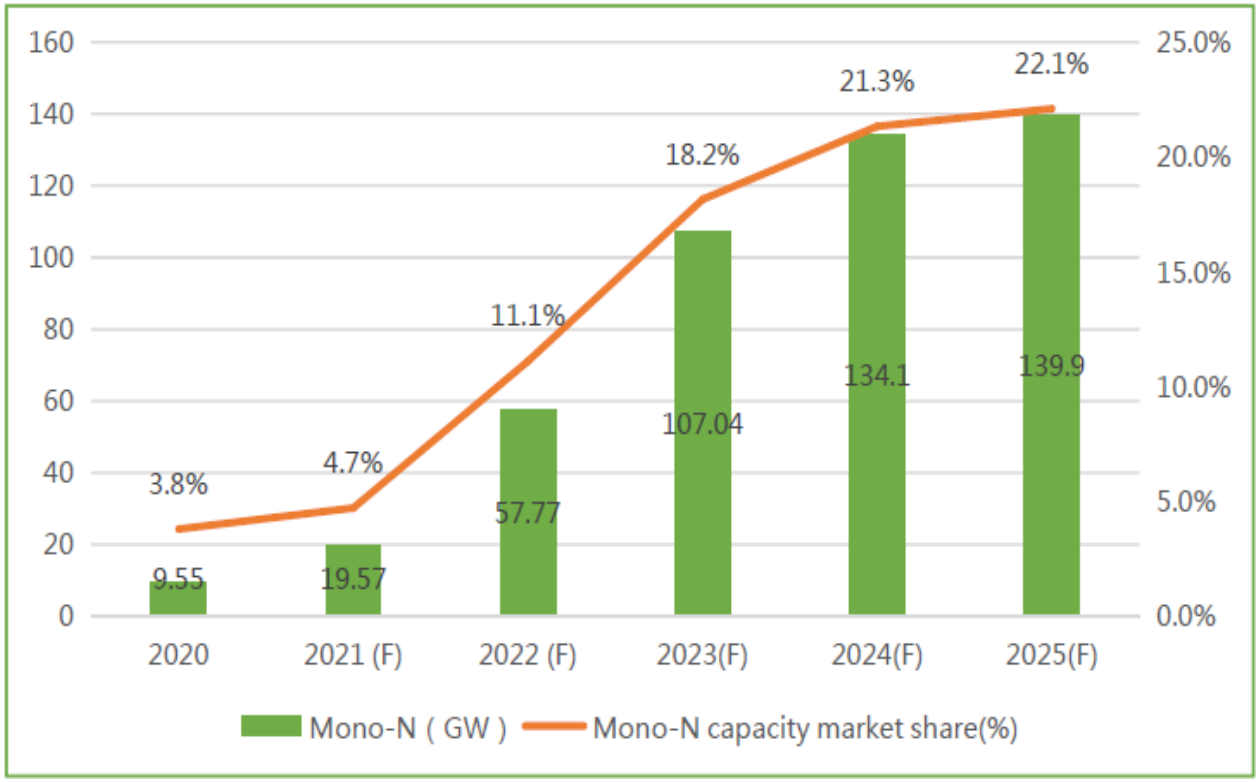
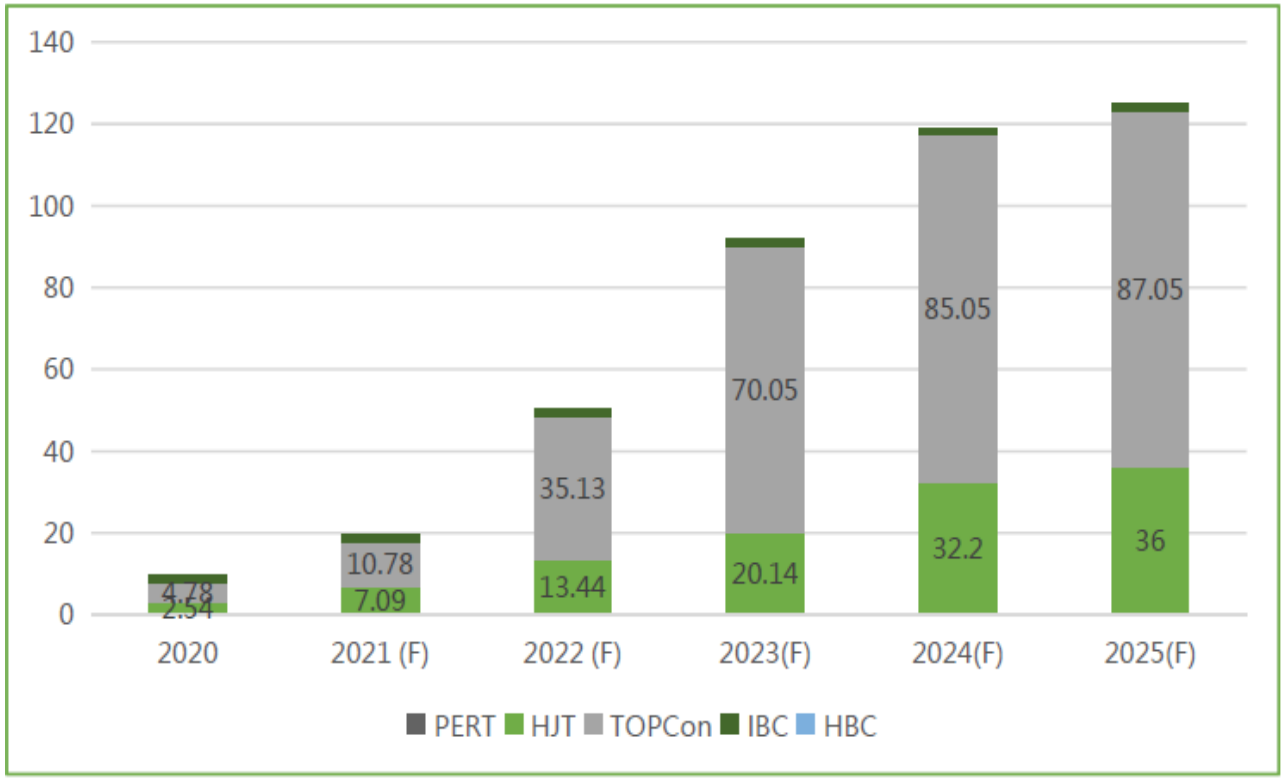
Emerging technologies for PV

- **N-type cell production trend**



- **TOPCon cell production trend**



Source: TRENDFORCE

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PV system locations & solar resources

Site Location	Lorca, Murcia, Spain	Gonghe, Qinghai, China
DC capacity (MW)	120MW	120MW
Mounting system	2P-tracker	1P-tracker
GPS	-1°53'25"W; 37°43'44“N	100°37'59"E; 36°5'48"N
Global horizontal irradiance	1788.8 kWh/m^2	1647.6 kWh/m^2
Altitude	509 m	2870 m
Mean ambient temperature	19.5° C	3.8° C

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System Design of Lorca Project

No. Module type	Case 1 JKM610N-78HL4-BDV		Case 2 Type A-665W
Dimension (mm)	2465×1134×35		2384×1303×35
Temperature coefficient of Pmax	-0.30%/°C		-0.34%/°C
Pmax at STC	610Wp		665Wp
Voc at STC	50.04V		46.10V
Isc at STC	14.11A		18.50A
Module efficiency	21.8%		21.4%
Bifaciality coefficient	80%		70%
Warranty (years)	30		25
Degradation in 1st year	1%		2%
Degradation from 2nd year	0.40%		0.45%
Modules in series per string	26		30
Total number of modules	196725		180450
Total number of strings	7567		6015
Strings per tracker	6		4
Total number of tracker	1262		1504
Pitch (m)	16.22		15.68
Ground coverage rate (GCR)		30.4%	
String Inverter		320kW	
No. of Inverter		312	

Power generation estimation of Lorca Project

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray GWh	E_Grid GWh	PR ratio
January	75.4	29.22	10.95	112.3	105.7	11.69	11.55	0.858
February	92.8	38.25	12.16	129.2	123.5	14.27	14.11	0.910
March	140.8	55.77	15.35	195.8	187.0	21.28	21.05	0.896
April	172.4	70.79	17.83	234.6	225.8	25.36	25.09	0.891
May	210.1	81.56	21.89	282.1	272.7	30.24	29.92	0.884
June	226.6	78.45	26.07	309.2	298.8	32.32	31.98	0.862
July	241.9	64.05	29.09	335.4	325.2	34.35	33.99	0.844
August	209.6	68.88	28.97	289.5	280.2	30.05	29.73	0.856
September	155.4	58.67	24.89	217.2	207.2	22.83	22.59	0.867
October	117.9	49.28	21.05	164.1	156.9	17.60	17.41	0.884
November	78.9	35.21	14.77	112.8	106.3	11.98	11.84	0.875
December	67.0	27.21	11.54	95.9	92.0	10.14	10.02	0.871
Year	1788.8	657.34	19.59	2478.0	2381.3	262.10	259.30	0.872

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

JKM610N-78HL4-BDV	
Year	Generation
1	by PV Syst
2	-0.40% of year 1
3	-0.80% of year 1
4	-1.20% of year 1
5	-1.60% of year 1
……	……
30	-11.60% of year 1

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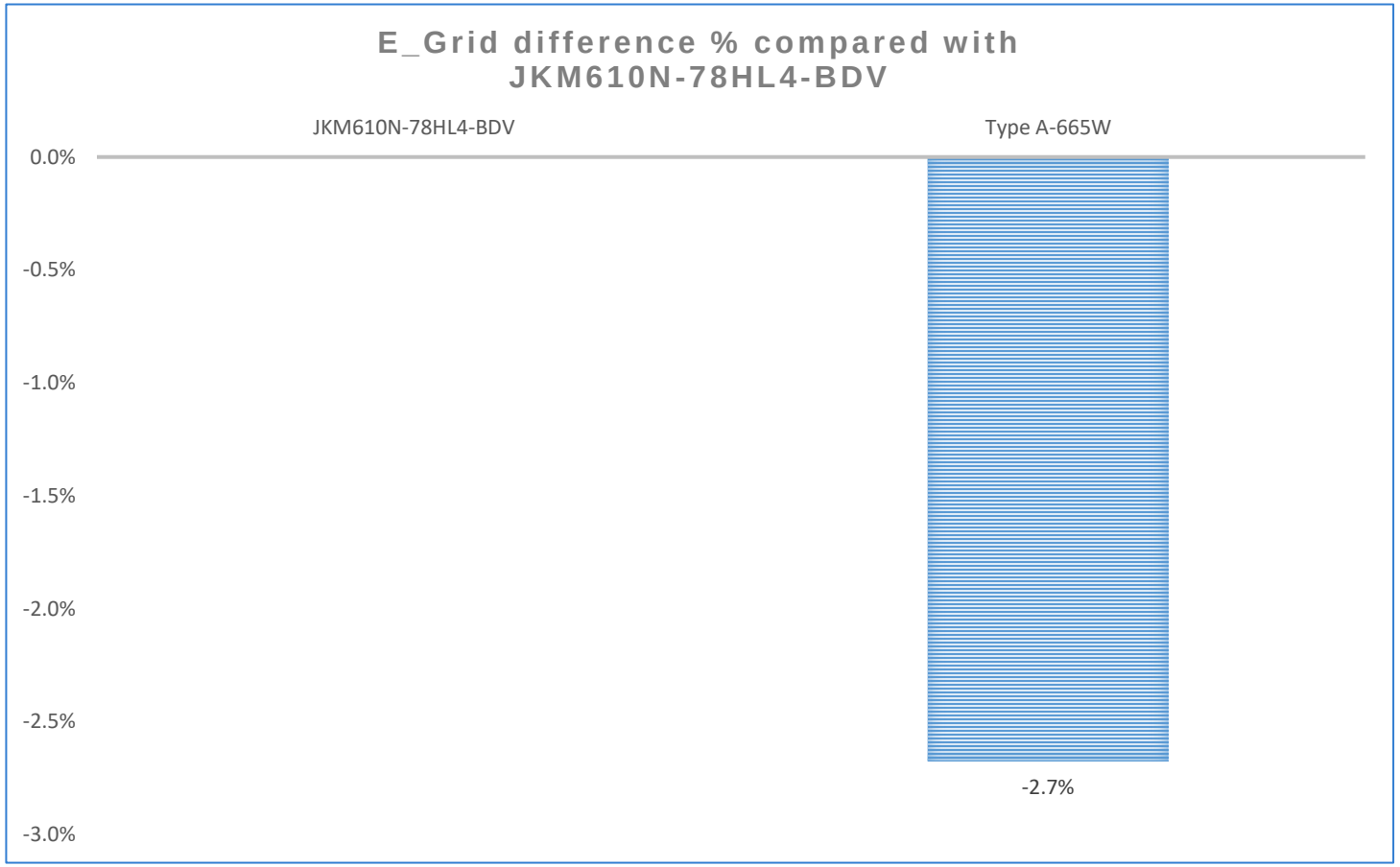
Power generation estimation of Lorca Project

- Higher module efficiency
- Higher bifaciality coefficient
- Better temperature coefficient
- Lower power degradation per year

- Higher energy generation during life-cycle



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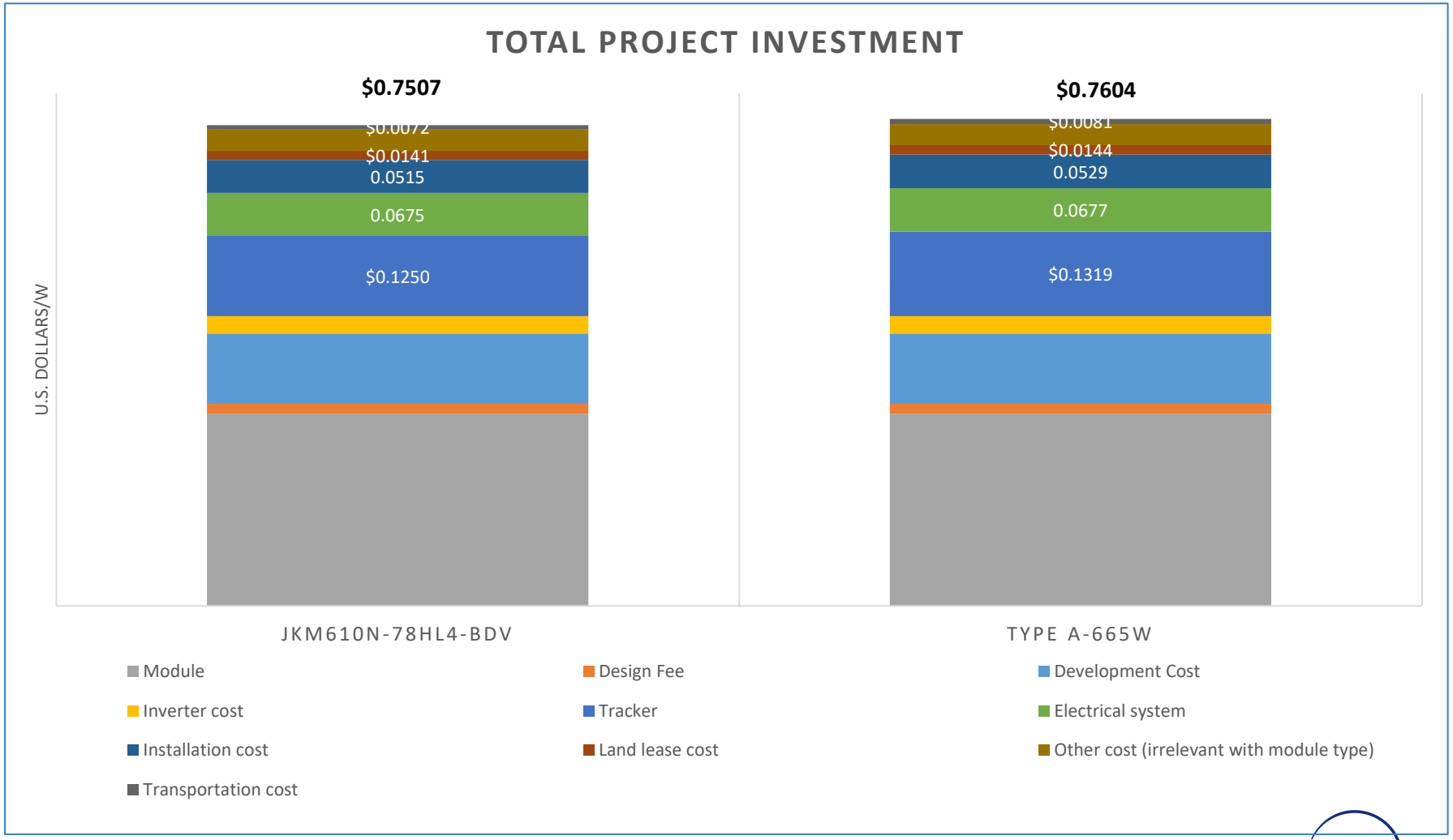
CAPEX of Lorca Project

Same / similar cost:

- Module & inverter
- Development & design
- Other cost (irrelevant with module type)

Major cost differences:

- Tracker
- Electrical system
- Installation cost
- Land lease cost

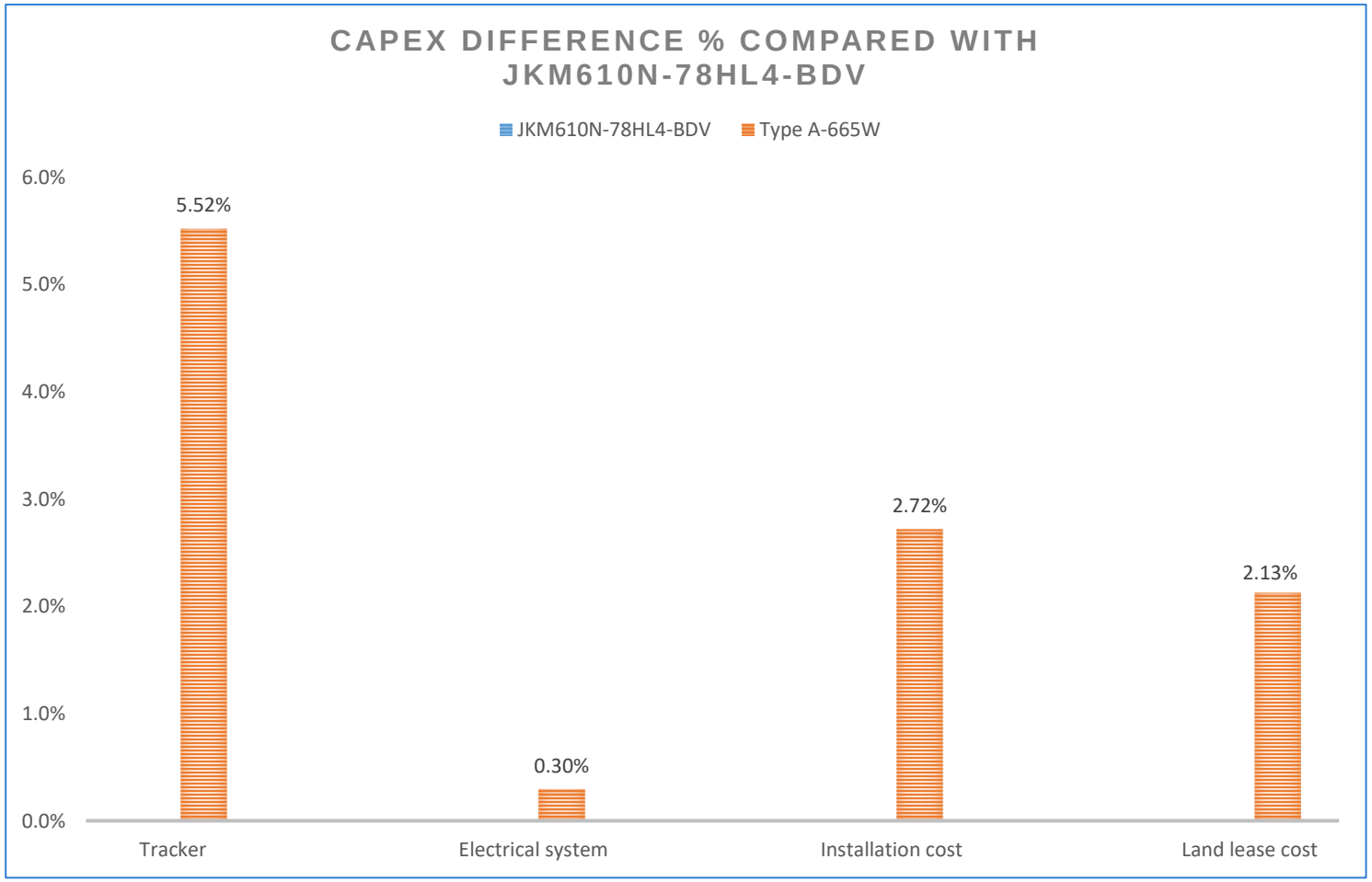


CAPEX of Lorca Project

- Higher power per tracker
- 4.0 mm^2 DC cable for smaller current

  6.0 mm^2 DC cable for higher current
- Larger modules are difficult to install
- With the same ground coverage rate,

  higher efficiency means less land



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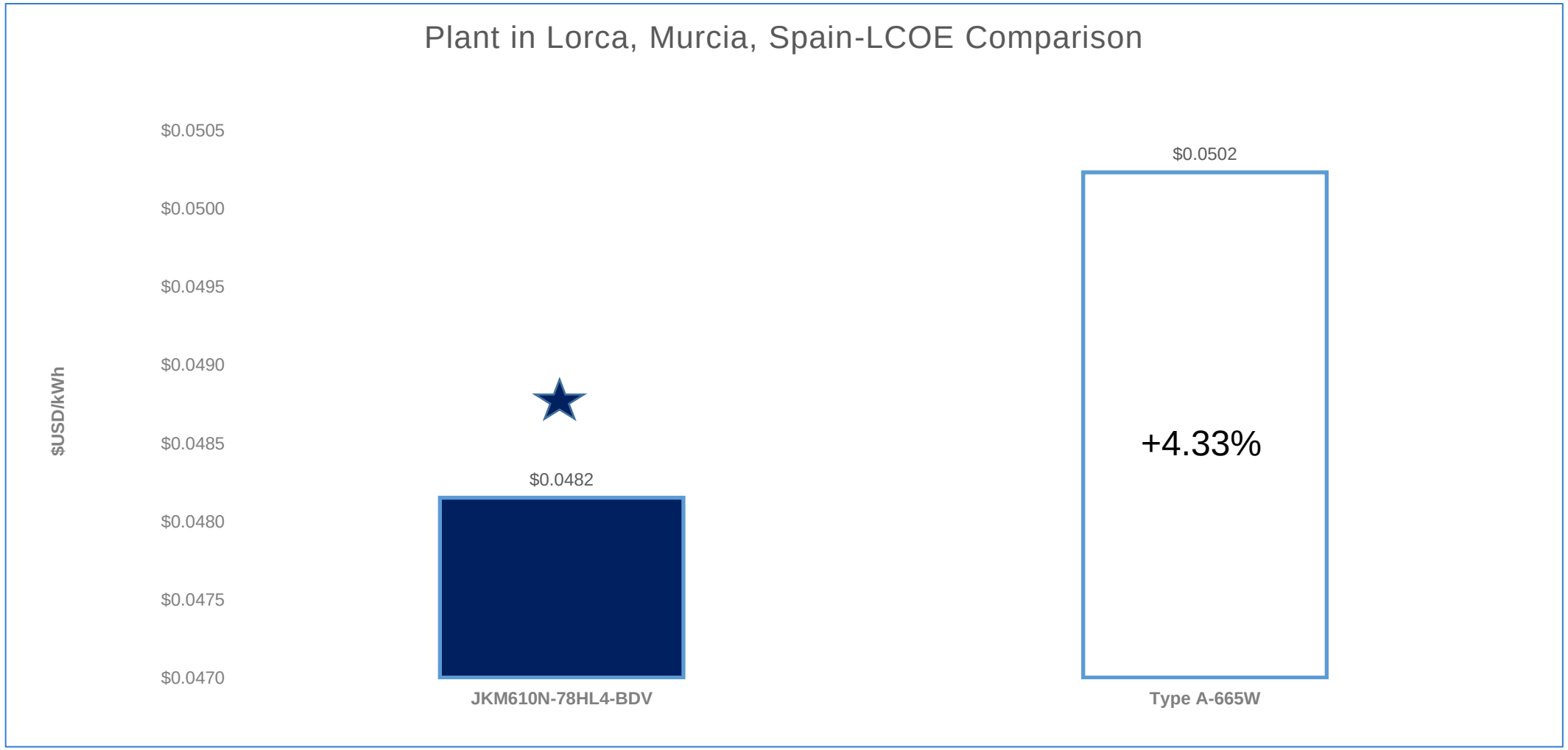
LCOE result of Lorca Project



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System Design of Gonghe Project

No. Module type	Case 3 JKM565N72HL4-BDV	Case 4 Type B-555W	Case 5 Type C-605W
Dimension (mm)	2278×1134×30	2384×1096×35	2172×1303×35
Temperature coefficient of Pmax	-0.30%/°C	-0.34%/°C	-0.34%/°C
Pmax at STC	565Wp	555Wp	605Wp
Voc at STC	50.83V	38.10V	41.70V
Isc at STC	14.19A	18.39A	18.42A
Module efficiency	21.9%	21.4%	21.4%
Bifaciality coefficient	80%	70%	70%
Warranty (years)		30	
Degradation in 1st year	1%	2%	2%
Degradation from 2nd year	0.40%	0.45%	0.45%
Modules in series per string	26	34	32
Total number of modules	212394	216240	198368
Total number of strings	8169	6360	6199
Strings per tracker	3	2	2
Total number of tracker	2723	3180	3100
Pitch (m)	7.50	7.85	7.14
Ground coverage rate (GCR)		30.4%	
String Inverter		320kW	
No. of Inverter		312	

Power generation estimation of Gonghe Project

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray GWh	E_Grid GWh	PR ratio
January	90.1	31.66	-9.29	137.9	128.4	15.15	14.99	0.906
February	106.6	35.24	-5.57	153.6	145.6	17.63	17.44	0.946
March	143.0	53.55	-0.37	203.2	191.2	22.82	22.58	0.926
April	168.1	70.32	5.29	230.6	219.9	25.50	25.23	0.912
May	185.0	79.12	9.37	250.8	239.3	27.50	27.20	0.904
June	174.8	86.94	12.73	226.5	217.5	25.52	25.24	0.929
July	182.2	84.95	15.44	236.8	227.0	25.59	25.32	0.891
August	168.0	66.76	14.73	230.1	218.1	24.75	24.48	0.886
September	133.9	61.53	10.10	184.3	173.7	20.35	20.13	0.910
October	118.2	48.70	4.13	165.4	156.0	18.52	18.32	0.923
November	95.7	29.65	-2.59	150.7	137.6	16.11	15.94	0.882
December	82.0	26.78	-7.91	124.2	115.5	13.50	13.35	0.895
Year	1647.7	675.21	3.89	2294.0	2169.7	252.94	250.21	0.909

Legends

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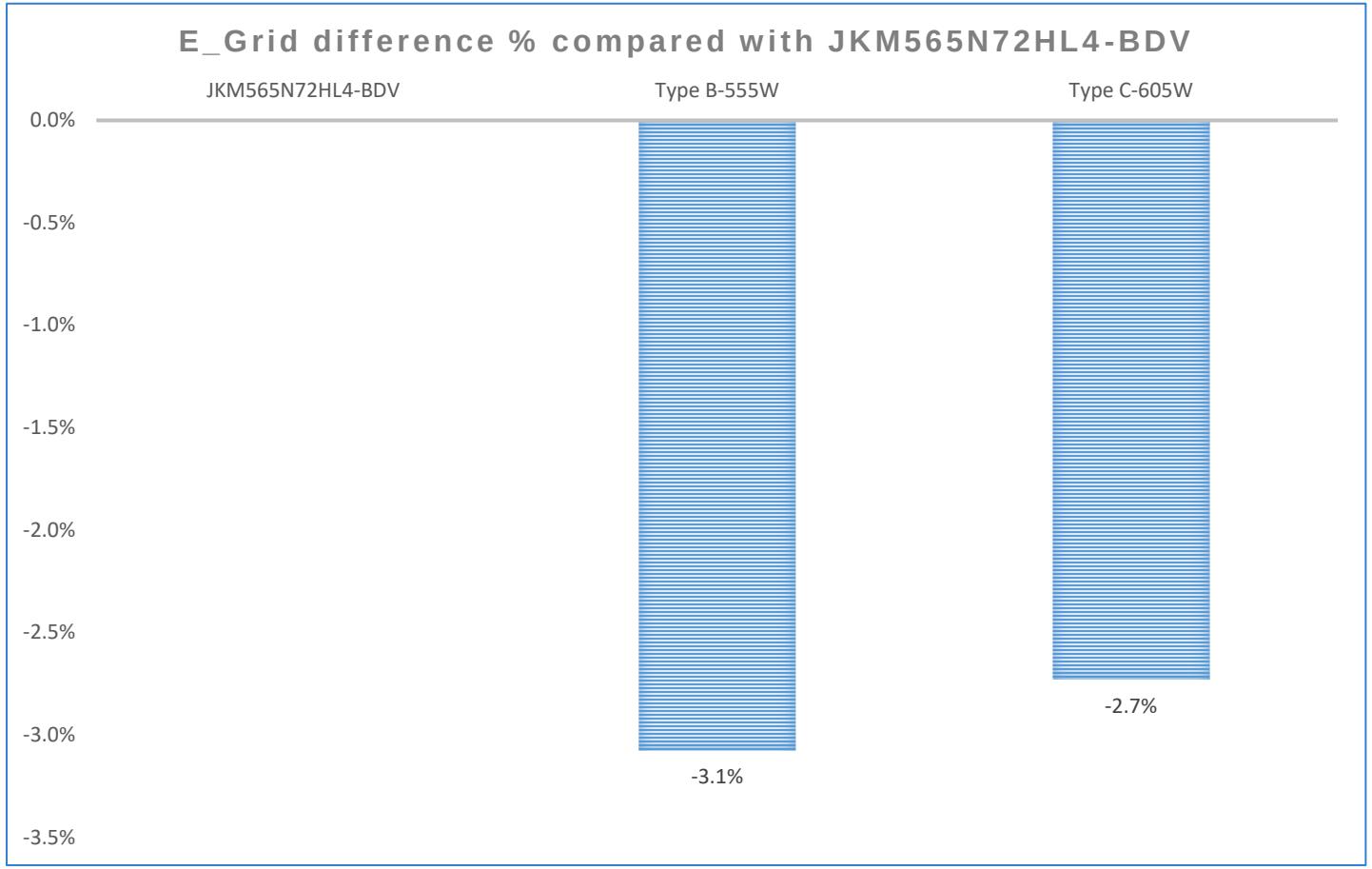
Power generation estimation of Gonghe Project

Similar to results in LORCA

- Higher module efficiency
- Higher bifaciality coefficient
- Better temperature coefficient
- Lower power degradation per year

- Higher energy generation during life-cycle



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CAPEX of Gonghe Project

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Major cost differences:

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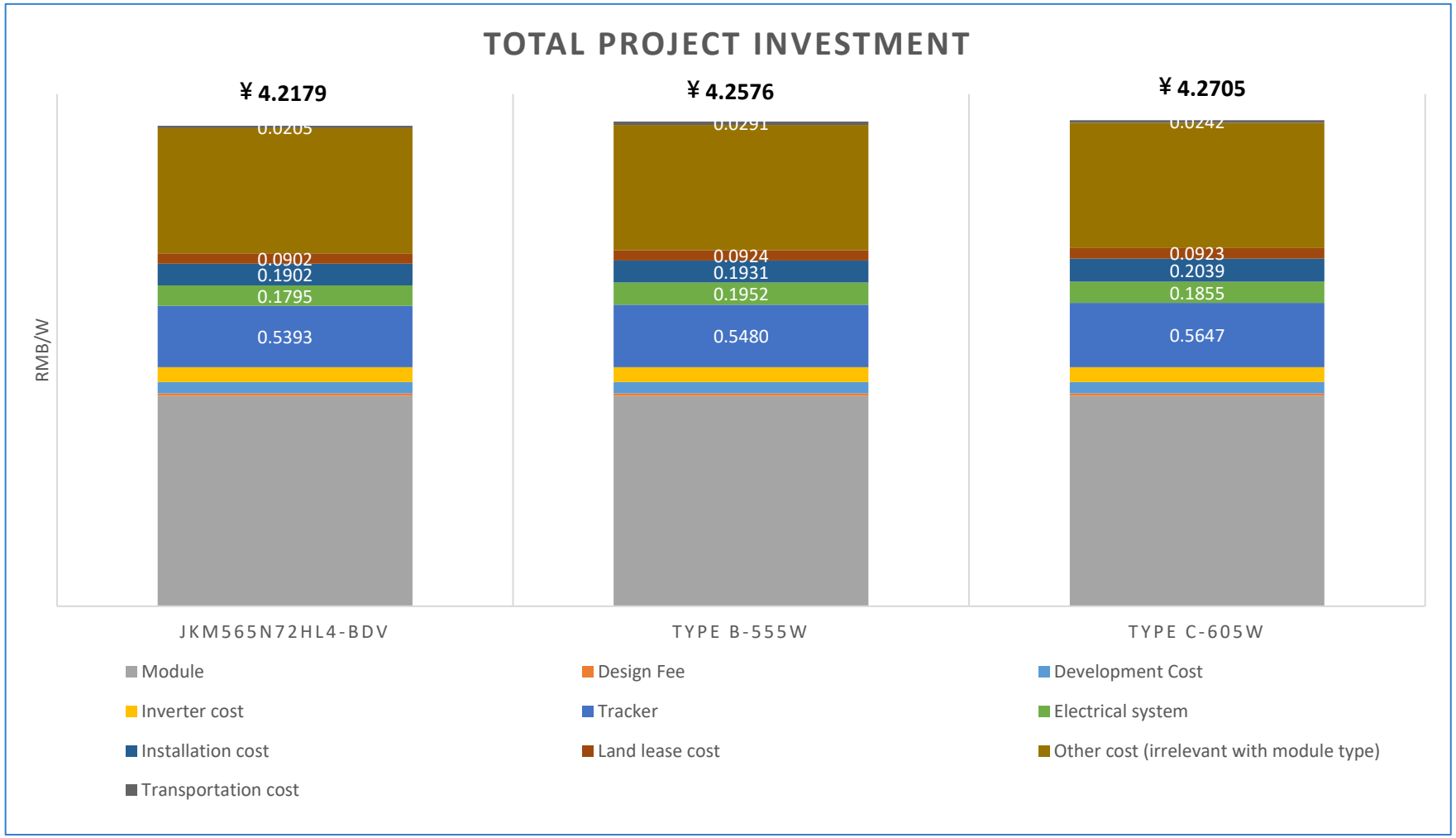

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CAPEX of Gonghe Project

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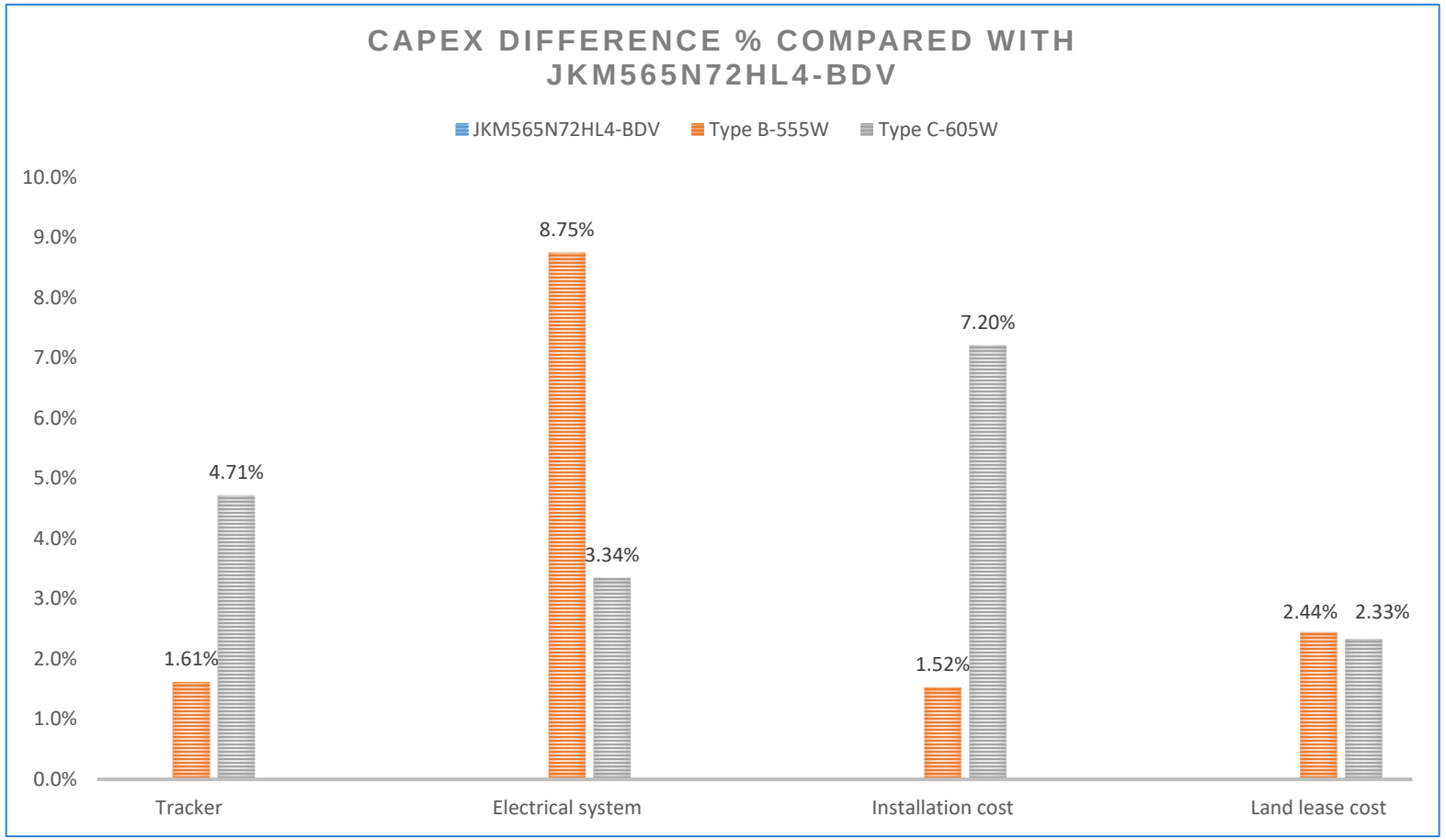

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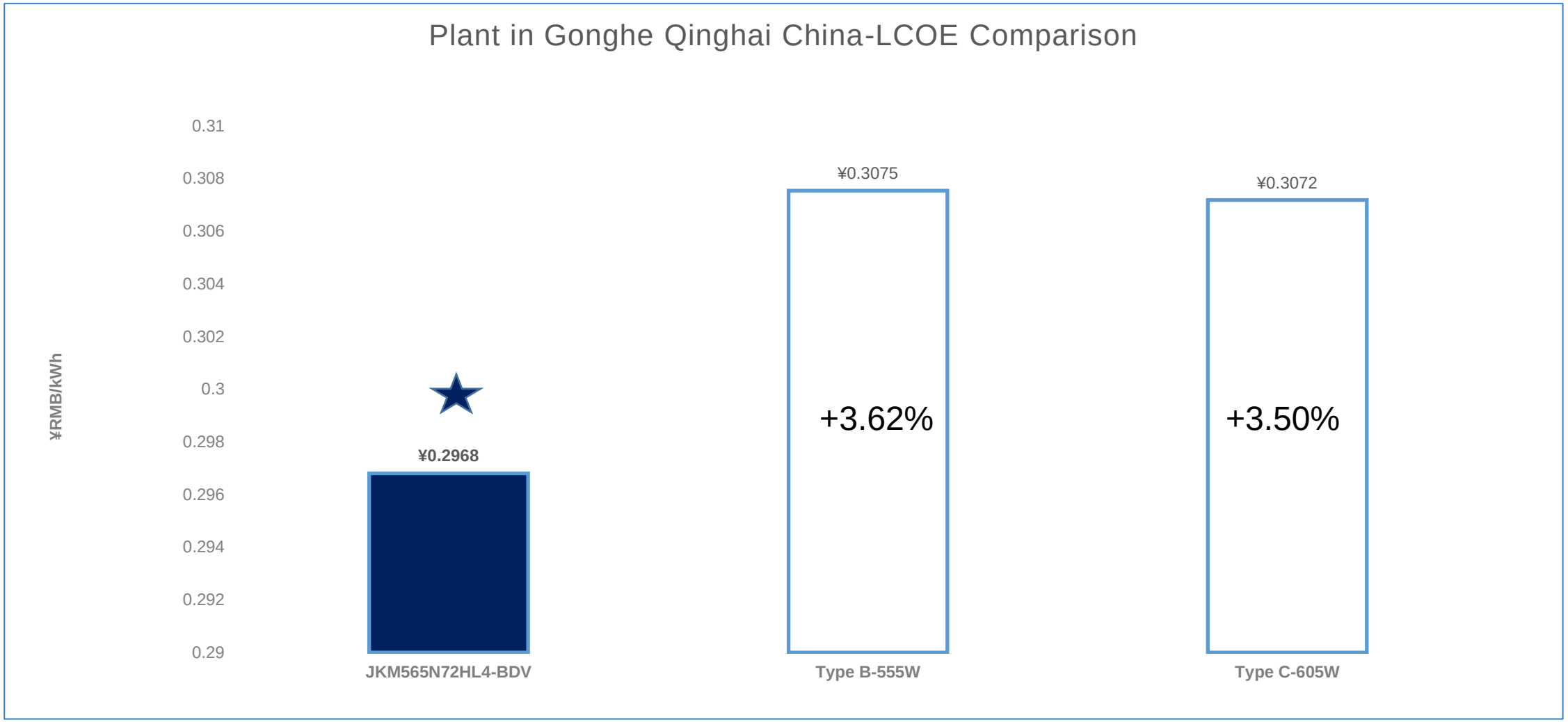
LCOE result of Gonghe Project



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Conclusions

- From the results of this analysis, when the unified DC side capacity, land availability, system design principles and module prices are determined, Jinko's N-type products have great advantages in terms of the cost per kilowatt-hour and profitability investment in large-scale ground power station projects in Spain and China. The advantages of Jinko's N-type modules are mainly reflected in:
  - High-efficiency modules can greatly reduce the initial investment cost of the project (modules, BOS equipment procurement costs, EPC construction costs, etc.);
  - It can reduce the land area required by the plant, thereby reducing the annual land lease cost;
  - Jinko's N-type modules have lower power degradation (1% in the 1st year, 0.4%/yr from the 2nd year) and higher bifaciality coefficient (80%).
- Therefore, the electricity generated during the whole life cycle of a project using N-type modules is increased, which significantly reduces the LCOE.

Thank you! Please contact us for more information.

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