

**TÜV Rheinland (Shanghai) Co., Ltd.**  
**Solar & Commercial Products**

## **Test Report**

Module Test and Levelized Cost of Electricity Assessment  
according to Client's Requirements

**TÜV Report No. CN256QMK 004**

**Shanghai, May 2026**

**Test report No.: CN256QMK 004**

Prüfbericht - Nr.:

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**Client****(Customer No. + address): LONGi Green Energy Technology Co., Ltd.**

Auftraggeber

(Kunden-Nr. + Adresse):

No. 388, Middle Hangtian Road, Chang'an District, Xi'an, Shaanxi, P.R. China

**Test Item:**

Photovoltaic (PV) Module(s)

**Date of receipt:**

13/09/2025

Gegenstand der Prüfung:

Eingangsdatum:

**Identification:**

Refer to section 3

Bezeichnung:

**Order No.:**

326136097

**Quotation No.:**

245885877

Auftragsnummer:

Angebotsnummer:

**Testing location:****TÜV Rheinland (Suzhou) Co., Ltd.**

Prüfart:

Building 14, Plainvim (Taicang) Modern Industrial Park, No. 525 South Lingang Road, Shaxi Town, Taicang, Suzhou, Jiangsu

**Test specification:**

IEC61853-1: edition 1.0 (2011) &amp; IEC61853-2: 2016 edition 1.0

Prüfgrundlage:


IEC61215-2:2021 MQT01, MQT02, MQT04, MQT06.1, MQT19


**Test Result:**

-

Prüfergebnis:

**tested by / geprüft:****reviewed by / kontrolliert:**

15/05/2026 Project Engineer/ Marc Yuan 

15/05/2026 Reviewer/ Chasel Xie 

Date	Title/Name	Signature	Date	Title/Name	Signature
Datum	Titel/Name	Unterschrift	Datum	Titel/Name	Unterschrift

**Other Aspects / Sonstiges:** N/A

**Abkürzungen:** P(ass) = entspricht Prüfgrundlage  
 F(ail) = entspricht nicht Prüfgrundlage  
 N/A = nicht anwendbar  
 N/T = nicht getestet

**Abbreviations:** P(ass) = passed  
 F(ail) = failed  
 N/A = not applicable  
 N/T = not tested

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## 1 Introduction

### 1.1 Background

LONGi Green Energy Technology Co., Ltd. (hereinafter referred to as LONGi or the Client) commissioned TÜV Rheinland to perform a comparative LCOE analysis between BC module LR8-66HYD-655M and a reference TOPcon module Reference Model.

The objective of this collaboration is to quantify the true economic and performance value of emerging cell technologies beyond nameplate power ratings basing on the two solar technologies. The project location is in Tipolo, Philippines, where local irradiance, temperature, and climatic variations play critical roles in module performance differentiation. This report builds on TÜV Rheinland's combined laboratory and field validation expertise to deliver a data-driven comparison under standardized, reproducible conditions.

### 1.2 Purpose and Scope

The purpose of this assessment is to provide an independent, technology-neutral evaluation of the relative energy yield and Levelized Cost of Electricity (LCOE) performance between the modules LR8-66HYD-655M and Reference Model under identical system configurations.

The report includes:

- Laboratory verification of key physical and electrical parameters according to international standards (IEC 60891, IEC 61853-1/2, and 2PfG 2926/05.25), including temperature coefficients, low-light response, incidence angle modifier (IAM), nominal operating temperature (NMOT), and reverse current coefficient (Arev).
- Field validation and integration of measured parameters into PVsyst simulations for the defined project site (Tipolo, Philippines).
- Economic modeling, incorporating consistent CAPEX, OPEX, and discount rate assumptions, to determine the lifetime LCOE and the corresponding Internal Rate of Return (IRR) for each module configuration.

All simulations were conducted under identical design conditions, differing only in module technology, to ensure direct comparability of the resulting energy yield and financial outcomes.

### 1.3 Remarks

This report was prepared by TÜV Rheinland as an independent technical advisor, based on data obtained through internal laboratory measurements, standardized testing, and client-provided module specifications.

The results presented herein reflect TÜV Rheinland's best professional judgment using the available data and industry-accepted methodologies. No warranties, expressed or implied, are made regarding the completeness of the information supplied by the Client within following statements:

- The test verdicts presented in this report relate only to the test specimen.
- This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
- Any question in regard to this report, please contact TÜV Rheinland (Shanghai) Co., Ltd. within one week after report issued.

## 2 Project description

### 2.1 Location

The LCOE comparison report has been undertaken for a location in Tipolo, Philippines. The figure below includes the geographical location of the Project's area.



Figure 2.1. Project's location (source: Google Earth)

The location details are shown in the table below:

Project	Latitude	Longitude	Altitude
Tipolo	10.01°	124.50°	35m

### 2.2 System Layout

Project	REFERENCE MODEL	BC1 (same DC)	BC2 (same Area)
Manufacture	-	LONGi	LONGi
Module Type	REFERENCE MODEL	LR8-66HYD-655M	LR8-66HYD-655M
Plant Peak Power [MWp]	135.8	135.8	141.1
No. of Modules	215310	207240	215310
DC/AC Ratio	1.20	1.20	1.25
Pitch [m]	5.31	5.30	5.31
No. of Inverter	376		
Inverter model	SG350-HX		
Module dimensions	2382x1134x30mm		
Installation Configuration	Fixed Tilt Angle: 5° / Orientation:0°S		
String Configuration	30 mod/string		

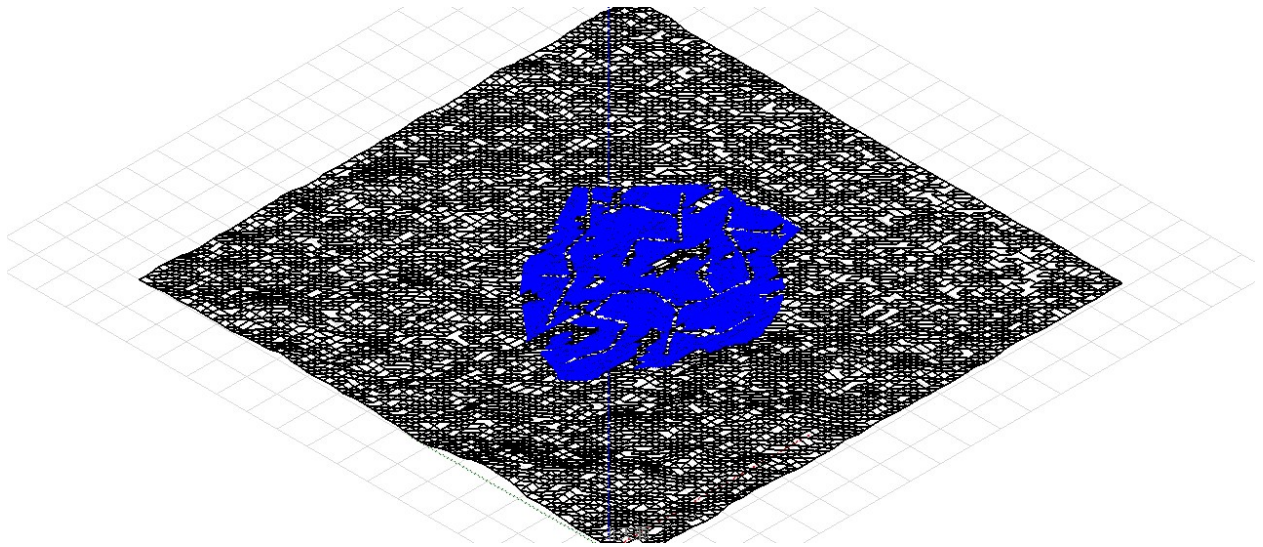


Figure 2.2. Project's layout in PVsyst

### 2.3 Solar resource assessment

TÜV Rheinland has conducted the solar resource assessment using the Meteonorm v8.1 database. For this Project, TÜV Rheinland extracted monthly and annual global horizontal irradiation (GHI) and plane-of-array (POA) data from Meteonorm v8.1. Meteonorm 8.1 is a meteorological database relying on 5 geostationary satellites and 8,325 worldwide ground-based measurements stations. Using an interpolation scheme the incoming radiation on every point on earth can be estimated. For the determination of the meteorological data by Meteonorm the standard meteorological new main period for temperature, dew point temperature, wind, precipitation and days with precipitation from 2016 to 2021.

Location	GHI (kWh/m <sup>2</sup> /yr)	DHI (kWh/m <sup>2</sup> /yr)
Tipolo	2094.2	840.4

Period	GHI Data for the Site [kWh/m <sup>2</sup> ]
January	150.3
February	153.8
March	196.3
April	197.4
May	187.5
June	178.6
July	181.5
August	185.3

September	178.5
October	189.7
November	153.3
December	142.1
Full Year	2094.2

**Data source: Meteonorm 8.1 (2016-2021)**

### 3 Module Panfile test result

#### 3.1 Testing Overview

##### General information:

P <sub>max</sub>	– Maximum power	V <sub>mpp</sub>	– Maximum power voltage
I <sub>mp</sub>	– Maximum power current	V <sub>oc</sub>	– Open circuit voltage
I <sub>sc</sub>	– Short circuit current	FF	– Fill factor
STC	– Standard Test Conditions	EL	– Electroluminescence imaging
IV	– Current-voltage characteristics	LI	– Low irradiance
TC	– Temperature coefficient	SR	– Spectral response
AOI	– Angular of Incidence		

##### Sampling procedure

<input type="checkbox"/>	Random sampling from production (e.g. during factory audit (FA) or inline inspection)
<input type="checkbox"/>	Random sampling from the warehouse, container or transportation boxes
<input checked="" type="checkbox"/>	Modules have been submitted by the manufacturer/ client without random sampling by TÜV Rheinland

##### Module Group Assignment

Sample No.	Serial No.	Module type	Remarks / constructional characteristics	Type of extra connectors used*	Test item
1	LRR011139250605200011	LR8-66HYD-655M	Mono half-cut cell c-Si module, 132 pcs	B	STC, IV, TC
2	LRR011139250605200012				STC, IV
3	LRR011139250605200074				AOI
4	A-001	REFERENCE MODEL	Mono half-cut cell c-Si module, 132 pcs	B	STC, IV, TC
5	A-002				STC, IV
6	A-003				AOI

Supplementary information: (\*) A: Client provided; B: TÜV Rheinland provided.

### 3.2 Visual inspection (accord. to IEC61215-2:2021, MQT 01)

Test Date [DD-MM-YYYY] .....		15-09-2025	—
Module type	Sample No.	Nature and position of initial findings	Verdict
LR8-66HYD-655M	1	No visual defect	P
	2	No visual defect	P
REFERENCE MODEL	4	No visual defect	P
	5	No visual defect	P
Supplementary information: Refer to Appendix 5: Photos of the modules.			

### 3.3 Performance at STC (accord. to IEC61215-2:2021, MQT 06.1)

Test Date [DD-MM-YYYY] .....		16-09-2025					—
Test method.....		<input checked="" type="checkbox"/> indoor	<input type="checkbox"/> outdoor			—	
Illuminated direction		<input checked="" type="checkbox"/> front side	<input type="checkbox"/> rear side			—	
Irradiance [W/m <sup>2</sup> ] .....		1000					—
Module temperature [°C] .....		25					—
Module type	Sample No.	Pmax [W]	Vmpp [V]	Impp [A]	Voc [V]	Isc [A]	FF [%]
LR8-66HYD-655M	1	655.1	42.51	15.410	49.26	16.275	81.7
	2	654.9	42.55	15.389	49.38	16.230	81.7
REFERENCE MODEL	4	630.8	41.74	15.112	48.86	15.757	81.9
	5	630.8	41.83	15.079	48.84	15.737	82.1
Supplementary information: Refer to Appendix 2: Statement of the estimated uncertainty of the test verdicts.							

### 3.4 Light induced degradation

Test Date [DD-MM-YYYY] .....		16-09-2025		—
Module type	Sample No.	Irradiance dose [kWh/m <sup>2</sup> ]		—
LR8-66HYD-655M	1	5		—
	2	5		—
REFERENCE MODEL	4	5		—
	5	5		—
Supplementary information: Refer to Appendix 5: Photos of the modules.				

### 3.5 Performance at STC after light soaking (accord. to IEC61215-2:2021, MQT 06.1)

Test Date [DD-MM-YYYY] .....		16-09-2025					—
Test method.....		<input checked="" type="checkbox"/> indoor	<input type="checkbox"/> outdoor			—	
Illuminated direction		<input checked="" type="checkbox"/> front side	<input type="checkbox"/> rear side			—	
Irradiance [W/m <sup>2</sup> ] .....		1000					—
Module temperature [°C] .....		25					—
Module type	Sample No.	P <sub>max</sub> [W]	V <sub>mpp</sub> [V]	I <sub>mpp</sub> [A]	V <sub>oc</sub> [V]	I <sub>sc</sub> [A]	FF [%]
LR8-66HYD-655M	1	655.1	42.50	15.416	49.25	16.254	81.8
	2	655.1	42.47	15.424	49.25	16.267	81.8
REFERENCE MODEL	4	630.8	41.79	15.095	48.87	15.763	81.9
	5	630.8	41.79	15.095	48.85	15.756	82.0
Supplementary information: Refer to Appendix 2: Statement of the estimated uncertainty of the test verdicts.							

### 3.6 Bifaciality Coefficients (accord. to IEC TS 60904-1-2:2019)

Module type	Sample No.	$\Phi_{P_{max}}$	$\Phi_{V_{oc}}$	$\Phi_{I_{sc}}$	—
LR8-66HYD-655M	1	0.7877	0.9937	0.7864	—
	2	0.7888	0.9941	0.7860	—
Average		0.7883	0.9939	0.7862	—
REFERENCE MODEL	4	0.8088	0.9940	0.8280	—
	5	0.8078	0.9942	0.8291	—
Average		0.8083	0.9941	0.8286	—
Supplementary information: The bifaciality coefficient employed is the minimum value of the I <sub>sc</sub> and P <sub>max</sub> bifaciality coefficients.					

### 3.7 Measurement for temperature coefficients (accord. to IEC61215-2:2021, MQT 04)

Test Date [DD-MM-YYYY].....:		20-09-2025	—
Irradiance [W/m <sup>2</sup> ] high / low.....:		1000 ± 50	—
Module temperature [°C] high / low.....:		75 / 15	—
Module type	Sample No.	Coefficient	Calculated Value
LR8-66HYD-655M	1	$\alpha$ [% / K].....:	0.030
		$\beta$ [% / K].....:	-0.23
		$\gamma$ [% / K].....:	-0.27
REFERENC E MODEL	4	$\alpha$ [% / K].....:	0.032
		$\beta$ [% / K].....:	-0.24
		$\gamma$ [% / K].....:	-0.29
Supplementary information: Temperature coefficients are measured with a pulsed solar simulator			

### 3.8 Incident angle measurement - IAM (refer to IEC 61853-2:2016, Clause 7)

Test Date [DD-MM-YYYY].....:		17-09-2025		—					
Test method.....:		<input checked="" type="checkbox"/> indoor	<input type="checkbox"/> outdoor	—					
Irradiance [W/m <sup>2</sup> ].....:		1000		—					
Module temperature [°C].....:		25		—					
Sample No.	Relative Transmission [%]								
	<b>Module type: LR8-66HYD-655M</b>								
3	0° AOI	10° AOI	20° AOI	30° AOI	40° AOI	50° AOI	60° AOI	65° AOI	70° AOI
	100.00%	100.00%	99.99%	99.95%	99.86%	99.58%	98.54%	97.18%	94.42%
	75° AOI	80° AOI	85° AOI	90° AOI	-				
	88.73%	76.88%	52.05%	0.00%	-				
Sample No.	Relative Transmission [%]								
	<b>Module type: REFERENCE MODEL</b>								
6	0° AOI	10° AOI	20° AOI	30° AOI	40° AOI	50° AOI	60° AOI	65° AOI	70° AOI
	100.00%	99.99%	99.95%	99.85%	99.61%	98.96%	97.02%	94.83%	90.86%
	75° AOI	80° AOI	85° AOI	90° AOI	-				
	83.61%	70.25%	45.56%	0.00%	-				
Supplementary information: N/A									

### 3.9 Reverse current coefficients (Arev) test

Module Type	LR8-66HYD-655M	REFERENCE MODEL
Sample No.	3	6
Start / end date (dd/mm/yyyy)	17-09-2025	
Arev (mA/V <sup>2</sup> )	1134.0	37.8
Supplementary information: See Annex 5 for details.		

### 3.10 Performance at various irradiance (refer to IEC 61853-1:2011, Clause 8)

Test Date [DD-MM-YYYY] .....		16-09-2025						—
Test method.....		<input checked="" type="checkbox"/> indoor			<input type="checkbox"/> outdoor			—
Sample No.....		2						—
Module type.....		LR8-66HYD-655M						—
Module temperature [°C]	Irradiance [w/m <sup>2</sup> ]	Pmax [W]	Vmpp [V]	Impp [A]	Voc [V]	Isc [A]	FF [%]	
25	1100	718.2	42.25	16.999	49.24	17.998	81.1	
	1000	653.4	42.37	15.423	49.17	16.355	81.3	
	800	523.2	42.34	12.358	48.88	13.095	81.8	
	600	390.7	42.37	9.221	48.47	9.820	82.1	
	400	258.2	42.00	6.149	47.93	6.549	82.3	
	200	125.5	40.79	3.078	46.83	3.289	81.5	
	100	60.3	39.66	1.520	45.69	1.645	80.2	
Sample No.....		5						—
Module type.....		REFERENCE MODEL						—
Module temperature [°C]	Irradiance [w/m <sup>2</sup> ]	Pmax [W]	Vmpp [V]	Impp [A]	Voc [V]	Isc [A]	FF [%]	
25	1100	692.1	41.80	16.557	48.88	17.382	81.5	
	1000	631.0	41.52	15.198	48.76	15.820	81.8	
	800	506.2	41.75	12.126	48.47	12.656	82.5	
	600	379.1	41.65	9.101	48.04	9.496	83.1	
	400	251.2	41.30	6.083	47.47	6.327	83.7	
	200	123.2	40.54	3.038	46.40	3.179	83.5	
	100	59.9	39.60	1.513	45.35	1.591	83.1	
Supplementary information: The non-illuminated side was covered with non-reflective background and aperture.								

### 3.11 NMOT

The results are based on test reports: CN25YPDE 001 and CN24LY9Q 001

Module Type	LR8-66HYD-660M*	LR7-72HGD-610M*
Start / end date (dd/mm/yyyy)	09/11/2025 - 30/12/2025	09/10/2024 - 20/11/2024
Valid days (at least 10)	Valid data for 10 days	
Irradiance [W/m <sup>2</sup> ] range	400 - 1011	400 - 1107
Ambient temperature [°C] range	12.3 – 28.1	21.5 - 36.7
Module temperature [°C] range	22.3 - 55.2	29.2 - 64.5
Wind velocity [m/s] range	0.25 – 5.92	0.25 - 7.74
Wind velocity difference [m/s] (at least 4 m/s)	**	**
Linear regression coefficient $u_0$ [W/(m <sup>2</sup> °C)]	35.79	30.13
Linear regression coefficient $u_1$ [Ws/(m <sup>3</sup> °C)]	2.32	6.89
Calculated NMOT [°C]	41.0	41.6
Supplementary information: Requirements are defined by IEC 61215-2:2016 and IEC 61853-2:2016. *LR8-66HYD-660M represents the NMOT for LR8-66HYD-655M & LR7-72HGD-610M represents NMOT for REFERENCE MODEL. **Within the available testing period the required wind speed difference of 4 m/s could not be reached. The method for NMOT determination is currently under discussion within the IEC standardization committee in order to adjust the procedure to obtain reliable results.		

## 4 LCOE (Levelized Cost of Electricity) assessment

### 4.1 Energy yield assessment

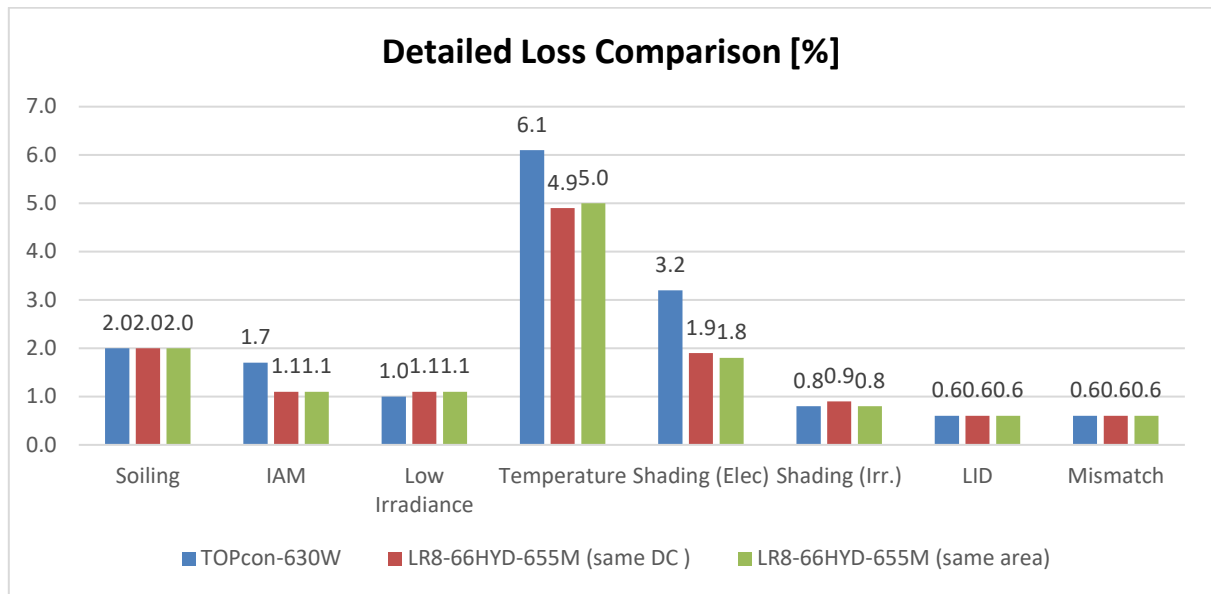
The energy yield assessment was performed based on long-term meteorological data from Meteonorm v8.1, combined with PAN file data presented in section 3. The simulation covered both REFERENCE MODEL and LR8-66HYD-655M, under two comparison baselines: same DC capacity and same installation area.

Annual and lifetime simulations were conducted using standard PV performance modeling principles, including soiling, incidence angle modifier (IAM), low-irradiance behavior, temperature coefficients, electrical shading, irradiance shading, LID, and mismatch losses, as illustrated in the detailed loss comparison below:

Detailed Loss(%)	Soiling	IAM	Low Irradiance	Temperature*	Shading* (Elec)	Shading (Irr.)	LID	Mismatch
REFERENCE MODEL	2.0	1.7	1.0	6.1	3.2	0.8	0.6	0.6
LR8-66HYD-655M (same DC)	2.0	1.1	1.1	4.9	1.9	0.9	0.6	0.6
LR8-66HYD-655M (same area)	2.0	1.1	1.1	5.0	1.8	0.8	0.6	0.6

\*Supplementary information: Since the measured  $A_{rev}$  parameter is only effective in PVsyst under the Module Layout / detailed electrical calculation mode for near-shading analysis, and this mode is limited to PV systems below 5 MW, the electrical shading effect was first simulated using a representative 2 MW field model. The 2 MW model was configured to represent the typical module layout, string arrangement, and near-shading conditions of the 135 MW project.

Based on the detailed electrical calculation with the measured  $A_{rev}$  values, the electrical shading loss factors were quantified. These derived loss ratios were then applied to the final 135 MW PVsyst model, which was simulated using the string-based partition approach by means of "according to module string" and modifying the "fraction for electrical effect" in the PVsyst near shading interface. In this way, the impact of the  $A_{rev}$  related electrical shading behavior was incorporated into the full-scale project simulation. Actual performance gains will depend on site-specific shading patterns and operational conditions.



A 20-year degradation model was applied to both technologies assuming identical site conditions. The first-year and lifetime energy yields are summarized below:

Project	REFERENCE MODEL	LR8-66HYD-655M (same DC capacity)	LR8-66HYD-655M (same installation area)
1 <sup>st</sup> -year Energy Output (MWh)	236568	244266	253111
Difference	BL	+3.25%	+6.99%
20-year Lifetime Yield (MWh)	4551568	4722883	4893901
Difference	BL	+3.76%	+7.52%

The simulations were carried out using the P50 statistical method, which represents the most probable energy yield estimate based on long-term variability and probabilistic uncertainty analysis. The detailed 20-year annual yield results are provided in Annex 3. The resulting net energy yield (P50) serves as the primary input for the subsequent Levelized Cost of Energy (LCOE) calculation.

## 4.2 LCOE Assessment

The Levelized Cost of Energy (LCOE) is calculated on a post-tax, real-term basis, representing the discounted average cost of generating one megawatt-hour (MWh) of electricity over the full project lifetime. The analysis assumes constant real prices and excludes the effect of inflation. All values are expressed in real EUR (2025 price level). LCOE Assessment is calculated by following equation:

$$LCOE_{real} = \frac{\sum_{t=0}^n \frac{CAPEX_t + OPEX_t - T_c \times Dep_t}{(1 + r_{real})^t}}{\sum_{t=0}^n \frac{E_t}{(1 + r_{real})^t}}$$

- $CAPEX_t$  : Capital expenditure in year t
- $OPEX_t$  : Operation and maintenance expenditure in year t
- $T_c$  : Corporate tax rate
- $Dep_t$  : Depreciation amount
- $r_{real}$  : Real discount rate
- $E_t$  : Power generation in year t
- n: Project life cycle

Where the following assumptions were made:

- Project lifetime (n): 20 years;
- Real discount rate ( $r_{real}$ ): 8.0%;
- Corporate tax rate ( $T_c$ ): 0%;
- Depreciation method: Full expensing — the total capital expenditure is deducted in year 0 for tax purposes;
- Decommissioning cost: 0% of CAPEX, accounted for in year 20;
- Annual energy degradation: 0.35% for LR8-66HYD-655M and 0.40% for REFERENCE MODEL according to the datasheet provided by the manufacture;
- Energy yield basis: P50 method, representing the most probable annual generation under long-term climate conditions;
- Financial scope: Project-level, post-tax assessment over a 20-year project lifetime, assuming 40% upfront equity and 60% debt financing. The debt is repaid over 12 years at an assumed 5.0% annual interest rate. Principal and interest payments are included in the financed LCOE calculation; inflation, refinancing, merchant revenues, and other non-contracted revenues are excluded.

#### 4.2.1 CAPEX costs

In the table below, the CAPEX costs of the Projects are summarised:

(Unit: USD/Wp)	REFERENCE MODEL	LR8-66HYD-655M (same DC capacity)	LR8-66HYD-655M (same installation area)
PV module	0.1200	0.1200	0.1200
PV area-electrical	0.1305	0.1275	0.1255
Power plant work	0.1580	0.1531	0.1520
Substation Project	0.0331	0.0331	0.0318
Civil and Road	0.0142	0.0142	0.0136
Other	0.0631	0.0628	0.0607
Basic reserves(2%)	0.0107	0.0105	0.0103
Total	0.5296	0.5212	0.5140
Difference	BL	-1.59%	-2.95%

Where the following assumptions were made:

- Project type: Utility-scale, ground-mounted PV project in the Philippines. The assessment compares the reference model with LR8-66HYD-655M under two design cases: same DC capacity and same installation area.
- Cost basis: Project-level CAPEX, expressed in USD/Wp DC. Costs are shown as all-in plant-side CAPEX items and normalized by DC capacity. The values reflect the assumed Philippine project conditions, including local construction, electrical works, substation scope, civil works, and project contingency.
- PV module: Module procurement cost. The same module unit cost of 0.1347 USD/Wp is applied across all cases to isolate the impact of design configuration and BOS-related cost differences.
- PV area-electrical: Electrical works within the PV field, including DC-side and AC-side electrical components, string/collection design, cabling, terminations, and related electrical installation within the PV array area.
- Power plant work: Main power plant construction and installation works, including field installation, mechanical/electrical integration, equipment installation, site execution, and EPC-related plant works not separately categorized under module, substation, or civil works.
- Substation project: Substation-related scope, including step-up equipment, MV/HV connection facilities, protection and control systems, and associated substation installation works. The cost may vary depending on the required project interconnection configuration.
- Civil and road: Site civil works, including internal roads, grading or earthworks allowance, drainage, foundations, fencing, and other access-related construction works.
- Other: Additional project costs not separately itemized above, including project management, engineering, permitting support, logistics, temporary facilities, and other indirect EPC or development-related costs.
- Basic reserves: A project contingency allowance set at 2% of the main CAPEX items to cover normal cost uncertainty and minor scope adjustments.

#### 4.2.2 O&M costs

In the table below, the O&M costs of the Projects are summarised:

<b>(Unit: USD/(Wp*yr))</b>	<b>REFERENCE MODEL</b>	<b>LR8-66HYD-655M (same DC capacity)</b>	<b>LR8-66HYD-655M (same installation area)</b>
Fixed O&M (labor, inspection, monitoring)	0.0090	0.0090	0.0087
Variable O&M (per kWh basis)	0.0015	0.0014	0.0014
Land lease / property fee	0.0035	0.0034	0.0034
Grid dispatch fee	0.0010	0.0010	0.0010
<b>Total</b>	<b>0.0150</b>	<b>0.0148</b>	<b>0.0144</b>
Difference	BL	-1.43%	-3.75%

Where the following assumptions were made:

- Project type: Utility-scale PV plant in Philippines; fixed-tilt system with string inverters.
- Cost basis: Real USD (2026); excludes VAT and financing-related costs; reflects the assumed long-term average O&M cost for utility-scale PV projects under Philippine market conditions.
- Fixed O&M: Includes preventive and corrective maintenance, inspection, cleaning, vegetation management, and SCADA monitoring labor.
- Variable O&M: Covers spare parts, inverter component replacement, and performance testing over project lifetime.
- Land lease / property fee: Annual lease payments or equivalent land access costs normalized over the lifetime.
- Grid dispatch fee: Includes GSP metering, DNO dispatch coordination, and grid balancing service fees.
- Scope exclusions: Insurance, merchant balancing charges, and extraordinary maintenance are excluded from the O&M normalization.

#### 4.2.3 LCOE calculation

In the table below, the LCOE results of the Projects are summarised:

Project	LCOE (USD/kWh)	Difference	Module Premium with same LCOE (USD/Wp)
REFERENCE MODEL	0.0380	BL	BL
LR8-66HYD-655M (same DC capacity)	0.0361	-5.1%	+0.0363
LR8-66HYD-655M (same installation Area)	0.0356	-6.3%	+0.0448

#### 4.2.4 Internal rate of return estimation

In addition to the LCOE calculation, the Internal Rate of Return (IRR) assessment was conducted to evaluate the project's financial performance under the same technical and economic framework. All parameters are expressed in real terms (2025 USD) to maintain consistency with the LCOE analysis.

In the table below, the Real IRR results of the Projects are summarised:

Project	Real IRR (%)
REFERENCE MODEL	13.1
LR8-66HYD-655M (same DC capacity)	14.9
LR8-66HYD-655M (same installation Area)	15.3

Where the following assumptions were made:

- Electricity sales price: Fixed at 0.0450 USD/kWh, representing a benchmark tariff or equivalent power purchase agreement (PPA) rate used for sensitivity analysis.
- Revenue basis: Annual revenues are calculated as  $R_t = E_t \times P_{elec}$ , where  $E_t$  follows the same P50 degradation-adjusted yield series used in the LCOE model.
- Cost inputs: CAPEX, OPEX, decommissioning, and taxation structure are identical to the LCOE framework.
- Depreciation method: Full expensing in year 0 (consistent with LCOE).
- Inflation and escalation: Not included; all values are in real terms.
- Output metric: The resulting IRR represents the real post-tax equity IRR at the project level, excluding financing effects or leverage assumptions.

## 5 Annex

### 5.1 Annex 1: Measuring equipment and used software

#### Measuring equipment

Device	Index no	Measured variable	Application
Primary calibrated reference solar cell	PV-012	Global irradiance coplanar with specimen	Pulsed solar simulator measurements
Thermopile detector	EQ-06012	Irradiance of monochromatic light	Spectral response measurement
Pulsed solar load	PV-446	Current, voltage, irradiance	Pulsed solar simulator measurements
IR-sensor	PV-201 PV-202 PV-204 PV-211	Specimen temperature	Pulsed solar simulator measurements
Goniometer	PV-376	Angle of rotation (effectively angle of incidence)	Aol pulsed solar simulator measurements

#### Measurement related software

Program name	Version no.	Date	Application
Pulsed Solar Simulator Software	HighLight-R2.4.5	02.06.2021	Operating software pulsed solar simulator
Spectral response measurement software	CEL-25ML Pro v1.0	24.11.2011	Operating software of the spectral response measurement system

## 5.2 Annex 2: Statement of the estimated uncertainty of the test verdicts

- The verdicts of performance rating are only related to the test samples that were subjected to the tests. They cannot be generalised to the modules from the series production.
- The STC measurement was performed with a pulsed solar simulator of Class AAA according to IEC60904-9:2020. The extended measurement uncertainty is:
  - Uncertainty in  $P_{mpp}$  within  $\pm 2.0 \%$ ,  $k=2$
  - Uncertainty in  $I_{sc}$  within  $\pm 1.8 \%$ ,  $k=2$
  - Uncertainty in  $V_{oc}$  within  $\pm 0.9 \%$ ,  $k=2$
  - SR samples are not available, so no MMF is applied in this project. This results in higher measurement uncertainty.
- The Aoi measurement was performed with a pulsed solar simulator of Class AAA according to IEC60904-9:2020. The non-uniformity of irradiance within the volume of rotation is within 2%. The extended measurement uncertainty is:

○ Aoi 0° $2\sigma I_{sc} \leq \pm 1.70\%$	○ Aoi 60° $2\sigma I_{sc} \leq \pm 2.57\%$
○ Aoi 10° $2\sigma I_{sc} \leq \pm 1.71\%$	○ Aoi 65° $2\sigma I_{sc} \leq \pm 2.93\%$
○ Aoi 20° $2\sigma I_{sc} \leq \pm 1.75\%$	○ Aoi 70° $2\sigma I_{sc} \leq \pm 3.49\%$
○ Aoi 30° $2\sigma I_{sc} \leq \pm 1.81\%$	○ Aoi 75° $2\sigma I_{sc} \leq \pm 4.49\%$
○ Aoi 40° $2\sigma I_{sc} \leq \pm 1.94\%$	○ Aoi 80° $2\sigma I_{sc} \leq \pm 6.53\%$

### 5.3 Annex 3: P50 Annual Energy production estimation

year	REFERENCE MODEL		LR8-66HYD-655M same DC		LR8-66HYD-655M same Area	
	Degradation coefficient	Annual Power Output (MWh)	Degradation coefficient	Annual Power Output (MWh)	Degradation coefficient	Annual Power Output (MWh)
1	100.00%	236568	100.00%	244266	100.00%	253111
2	99.60%	235622	99.65%	243411	99.65%	252225
3	99.20%	234675	99.30%	242556	99.30%	251339
4	98.80%	233729	98.95%	241701	98.95%	250453
5	98.40%	232783	98.60%	240846	98.60%	249567
6	98.00%	231837	98.25%	239991	98.25%	248682
7	97.60%	230890	97.90%	239136	97.90%	247796
8	97.20%	229944	97.55%	238281	97.55%	246910
9	96.80%	228998	97.20%	237427	97.20%	246024
10	96.40%	228052	96.85%	236572	96.85%	245138
11	96.00%	227105	96.50%	235717	96.50%	244252
12	95.60%	226159	96.15%	234862	96.15%	243366
13	95.20%	225213	95.80%	234007	95.80%	242480
14	94.80%	224266	95.45%	233152	95.45%	241594
15	94.40%	223320	95.10%	232297	95.10%	240709
16	94.00%	222374	94.75%	231442	94.75%	239823
17	93.60%	221428	94.40%	230587	94.40%	238937
18	93.20%	220481	94.05%	229732	94.05%	238051
19	92.80%	219535	93.70%	228877	93.70%	237165
20	92.40%	218589	93.35%	228022	93.35%	236279

Supplementary: 1<sup>st</sup> year degradation coefficient includes LID loss.

#### 5.4 Annex 4: Definitions of Losses

Shading: Losses due to orographic barriers, shading obstacles or self-shading by the rows of modules.

Incident Angle Modifier – IAM: Losses due to reflection at the surface of module.

Soiling: Losses due to soil, dust and other potential bodies on the surface of modules. If snow or heavy other heavy soiling: The soiling losses have been selected considering an O&M that includes adequate provisions for frequent cleaning of the modules and seasonal particularities as snow removal. Without such an O&M the soiling losses will be higher.

Temperature: Energy losses associated with the temperature behavior of the PV modules, considering the effects of module NMOT, ambient temperature, and module temperature coefficient.

Electrical loss according to strings of modules: The partial shading of a string of modules induces a loss of productivity of the rest of the string.

Light Induced Degradation (LID): Performance degradation that occurs for crystalline PV modules within the first few hours of sun exposure.

Mismatch: Losses due to differences in current of modules of the same string and differences in voltage of strings of a same MPP-tracking circuit, assuming sorting of modules before shipment from the factory.

## 5.5 Annex 5: Measurement and Calculation Method of $A_{rev}$

$A_{rev}$  is used to describe the reverse-bias behavior of PV modules under partial shading or current mismatch conditions. In this study, the  $A_{rev}$  value was derived from laboratory reverse I–V measurements.

First, the reference I–V curve of the module was measured under controlled irradiance and temperature conditions to determine the short-circuit current. Then, a defined partial-shading condition was applied to the selected cell or module area, and the corresponding reverse voltage and reverse current were recorded.

The  $A_{rev}$  value was calculated based on the quadratic reverse-current relationship used in PVsyst:

$$I_{rev} = I_{sc} + A_{rev} \cdot V_{rev}^2$$

Therefore:

$$A_{rev} = \frac{I_{rev} - I_{sc}}{V_{rev}^2}$$

When multiple measurement points are used,  $A_{rev}$  can be obtained by fitting against. The fitted coefficient is taken as the equivalent  $A_{rev}$  value for PVsyst simulation.

The derived  $A_{rev}$  is an equivalent parameter for evaluating the module's electrical behavior under partial shading and is used for comparative LCOE simulation rather than as a standalone module performance rating.

**5.6 Annex 6: Photos of the modules**



*Fig. 1: front view of LR8-66HYD-655M*



*Fig. 2: rear view of LR8-66HYD-655M*



*Fig. 3: label of LR8-66HYD-655M*



*Fig. 4: junction box of LR8-66HYD-655M*

**End of The Report**