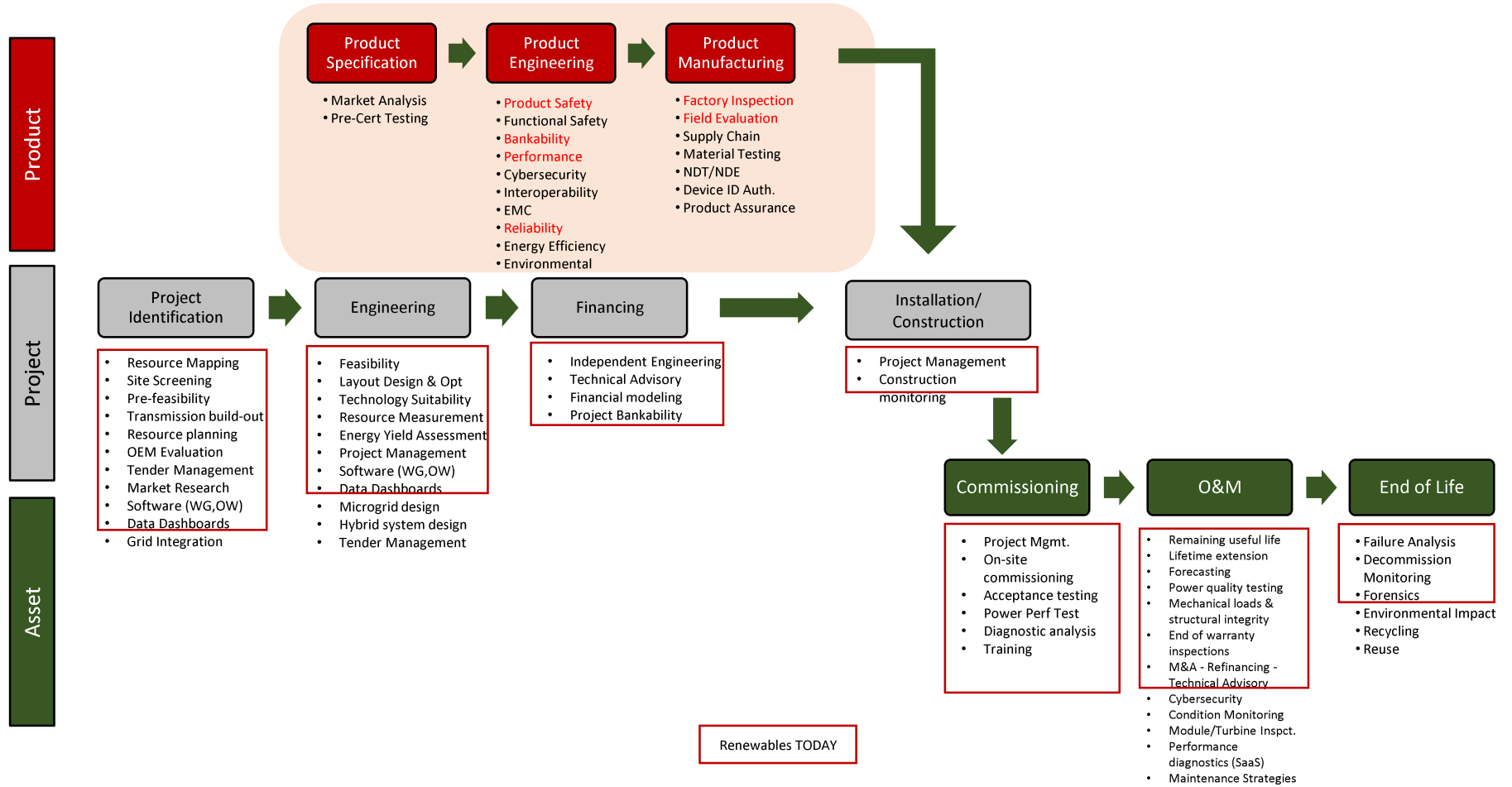


Solar PV Product Services Introduction



Renewables Value Chain



Solar Photovoltaic Products and Applications

Residential



Commercial & Industrial



Utility Scale



Floating PV



Carports & Charging Stations



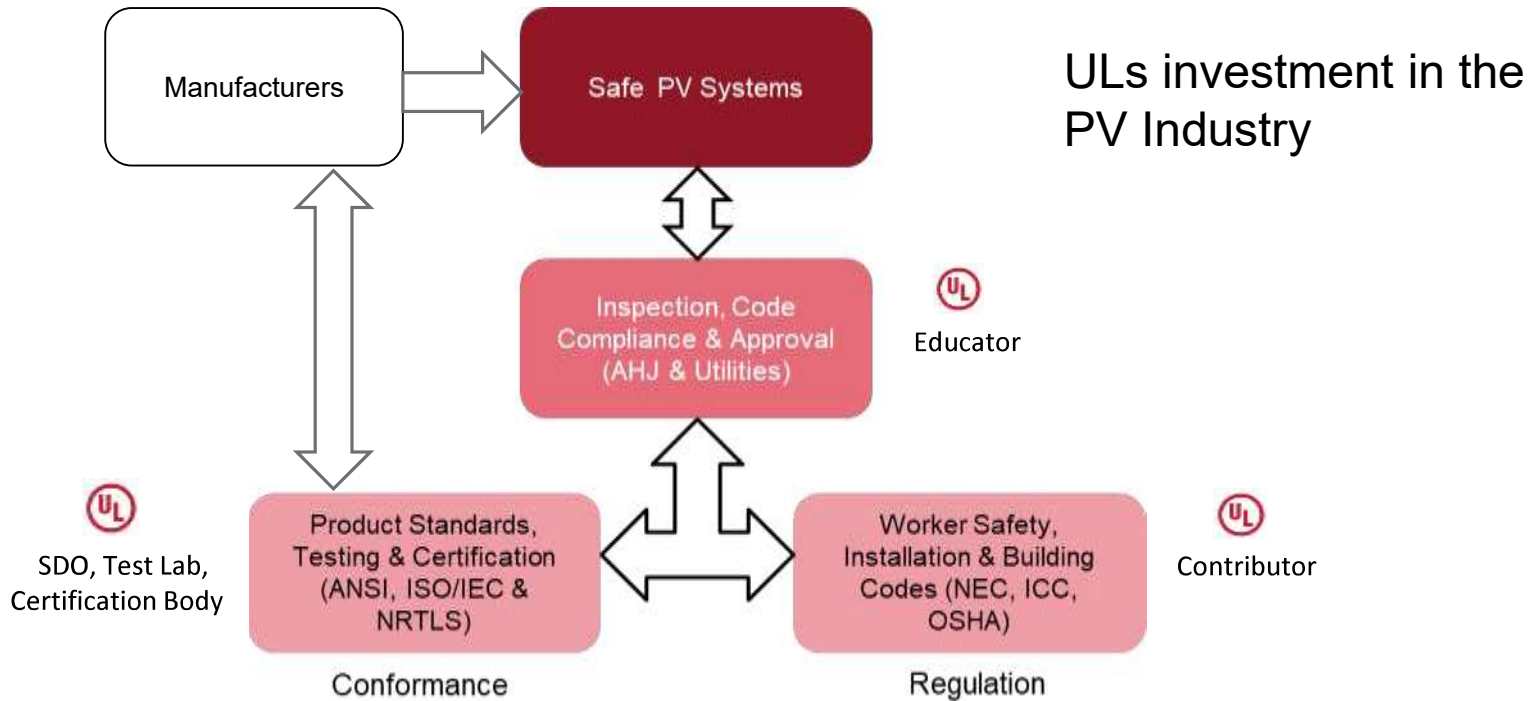
Building Integrated



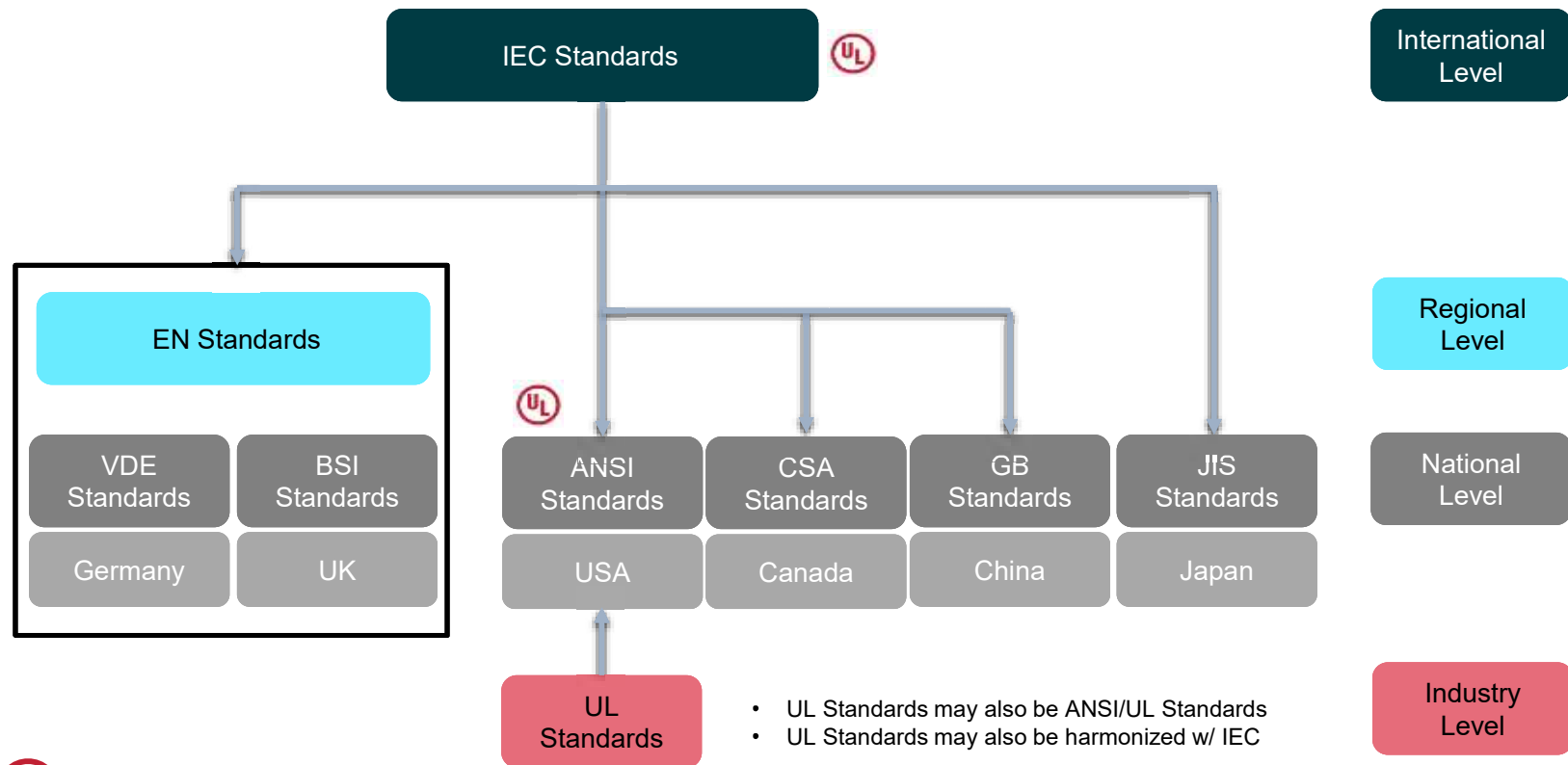
Solar Irrigation



UL Enables Adoption of Photovoltaic Technology



UL Collaborates in PV Standards Development



UL Standards Development Addressing PV Market Needs

North American Leader

1986 – UL1703 PV Modules and Panels
1999 – UL1741 Inverters and Converters
1999 – SU 1279 Solar Collectors

2005 – UL 4703 PV Wire
2007 – SU 2579 Low Voltage Fuse Holders
2007 – SU 5703 Max Operating Temp
2008 – SU 8703 Concentrator PV Modules
2010 – UL 2703 Mounting Systems
2010 – SU 4248-18 Fuse Holders
2010 – UL 489B Circuit Breakers
2010 – UL 6703/A Connectors
2010 – SU 98B Dead-Front Switches

2011 – SU 1699B Arc Fault Protection
2011 – UL 3703 Solar Trackers
2011 – UL 3730 Junction Boxes
2011 – SU 508i Disconnect Switches
2011 – SU 9703 Wiring Harnesses
2012 – UL 4730 Name Plate Rating
2014 – UL 62109-1 Power Converters
2016 – UL 61215 Terrestrial PV Modules – series
2016 – UL 1741SA Advanced Inverter Testing
2016 – UL 9540 Energy Storage Systems and Equipment
2017 – UL 61730 PV Module Safety (harmonized)
2018 – UL 9540a Thermal Runaway Fire in BESS
2018 – SU 3741 PV Hazard Control

2000 >

2010 >

2020

International Collaborator

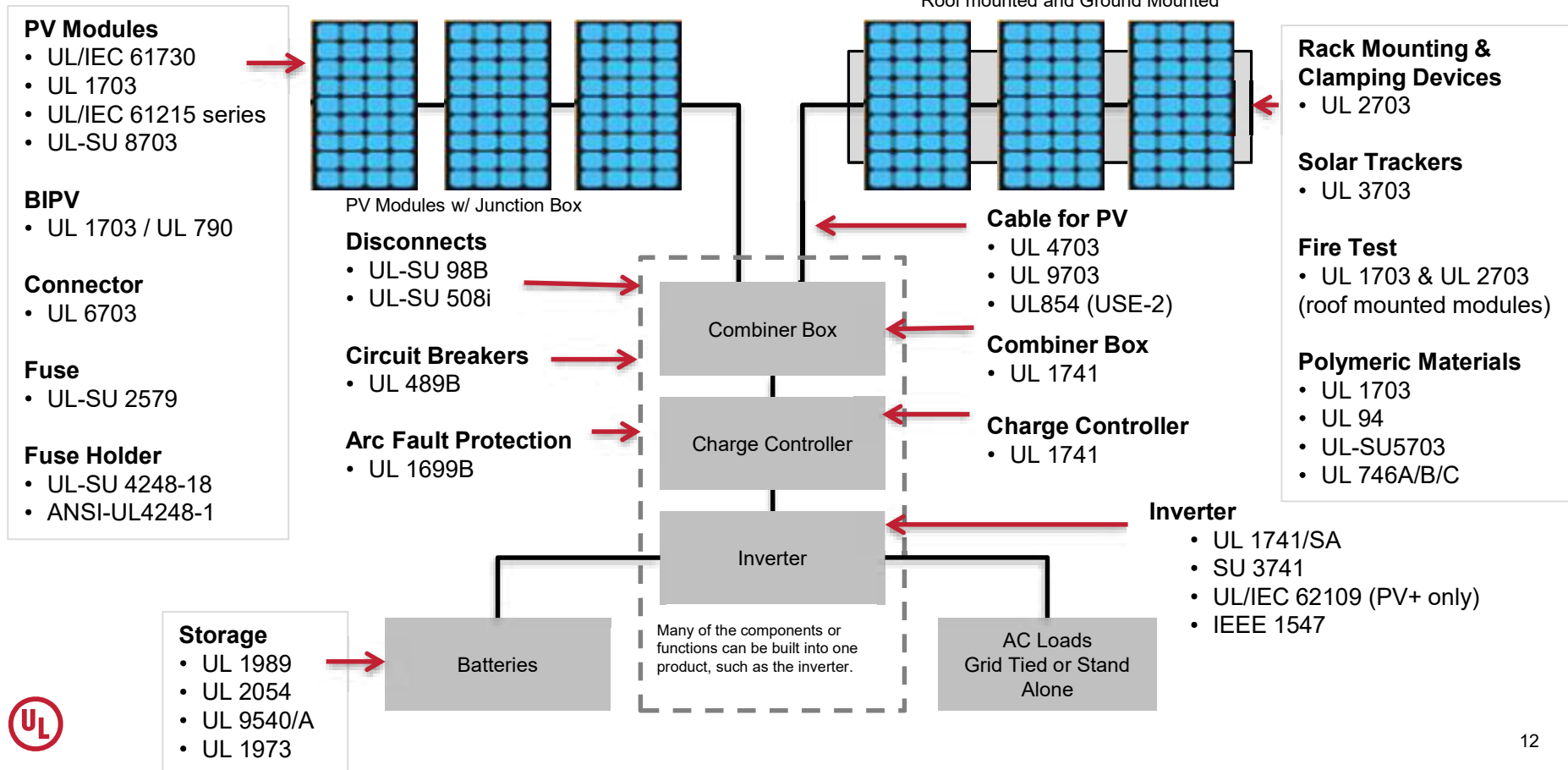
IEC 61215 Module Type Qualification - Series
IEC 61724 System performance monitoring
IEC 61730-1/2 Module safety
IEC 61853-1/2 Module performance
IEC 62093 BOS design Qualification
IEC 62109-1/2/3/4 Safety of Power Converters
IEC 62446 System commissioning and Inspection
IEC 62509 Battery charge controller performance
IEC 62548 PV array design requirements
IEC 62738 PV plant guidelines
IEC 62804 System voltage durability for modules
IEC 62938 Snow load testing
IEC 62947 Energy performance
IEC TS 60904-1-2 Measurement for Bifacial Modules



Solar PV Product Services Overview



Safety Certification of PV Products – Taxonomy of Standards



PV Module – Technologies

Mono-Crystalline

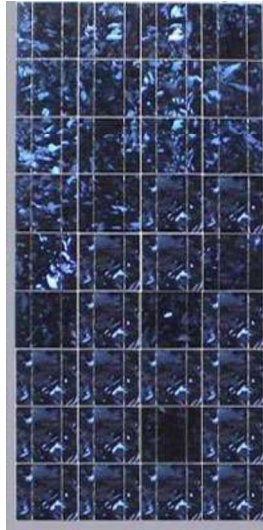
- Made from a single silicon crystal
- More expensive
- More efficient



18%-25% Efficiency

Poly-Crystalline

- Made from multiple silicon crystals
- Less expensive
- Less efficient



Thin Film

- Cadmium Telluride (CdTe)
- Amorphous Silicon (a-Si)
- Copper Indium Gallium Selenide (CIGS)
- Gallium Arsenide (GaAs)
- Least expensive and efficient

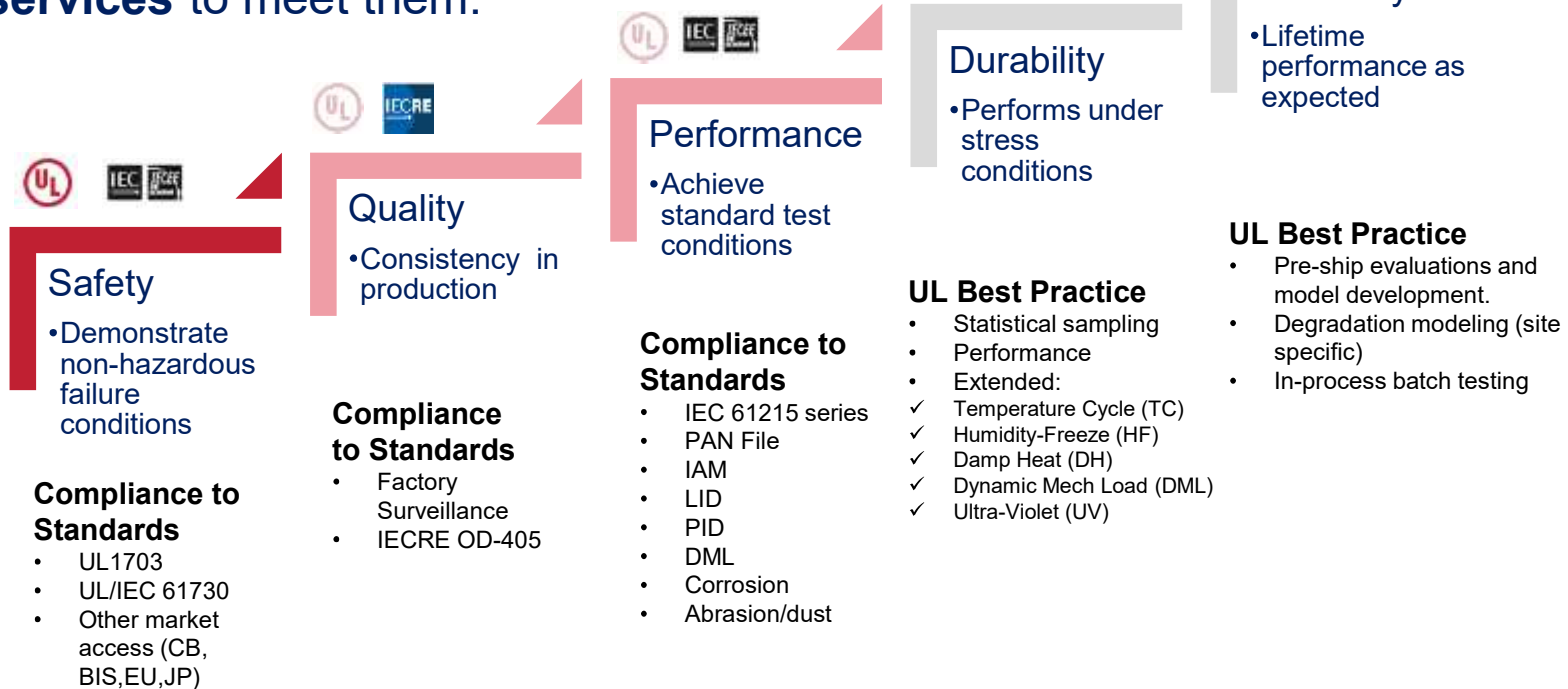


11%-19% Efficiency



PV Module Testing Services

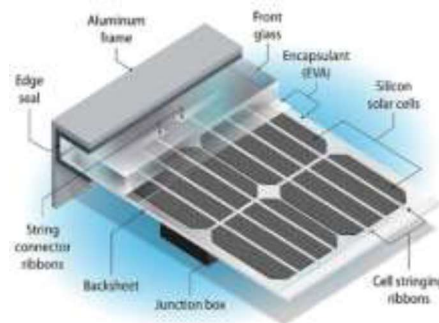
PV stakeholder testing **needs** and UL **services** to meet them.



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PV Module – Safety (US and Canada)

#	CCN	Description	Standard
51	QIGU	Certified for USA (< 600v)	ANSI/UL 1703 ANSI/UL 61730 (plus QIHO, QIHS,QIHZ)
45	QIGU7	Certified for Canada (< 600v)	ULC/ORD-C1703 CAN/CSA-C22.2 No. 61730 CAN/ULC-S107
73	QIIA	Certified for USA (> 600v)	ANSI/UL 1703 ANSI/UL 61730 (plus QIHO, QIHS,QIHZ)
62	QIIA7	Certified for Canada (>600v)	ULC/ORD-C1703 CAN/CSA-C22.2 No. 61730
3	QIIA2	Certified for USA (> 600v) component	ANSI/UL 1703 ANSI/UL 61730
3	QIIA8	Certified for Canada (> 600v) component	ULC/ORD-C1703 CAN/CSA-C22.2 No. 61730
1	QIGZ	Remanufactured for USA	ANSI/UL 1703
1	QIGZ7	Remanufactured for Canada	ULC/ORD-C1703 CAN/ULC-S107
6	QIHZ	“ALSO CERTIFIED TO “ (for International Markets)	IEC/EN 61730



Evaluation of PV Modules against harmful conditions or events that could result in a fire or shock hazard.



Safety Certification (module fails safe)

General:	Performance at STC, max power, insulation thickness, durability of markings, sharp edge test , bypass diode functionality
Electrical Shock:	Accessibility, cut susceptibility, continuity test, equipotential bonding, insulation test, wet leakage current, robustness of terminations
Mechanical Stress:	Module breakage, screw connections, load test, peel test, material creep, robustness of terminations
Environmental Stress:	Thermal cycling, humidity freeze, damp heat, cold conditioning, dry hot conditioning, UV exposure
Fire Hazard:	Temperature test, hot-spot endurance, fire resistance , ignitability, bypass diode, reverse current overload

PV Module – Safety (UL Fire Resistance)

PV Module “Type 1-15” Evaluation

Construction is categorized by 4 items:

- Superstrate material
- Encapsulant material
- Substrate material
- Frame type and geometry (if any)

Fire Performance is categorized by two items

- Spread of flame on the top surface of the module (UL 790), and
- Burning brand on the top surface of the module.



Spread of Flame



Burning Brand



Brands: A, B, C

Test	Fire Performance Characteristics		
Spread of Flame On Top Surface of Module or Panel (Section 31.1.2)	Flame Spread less than 6 ft. in 10 minutes	Flame spread less than 8 ft. in 10 minutes	Flame spread less than 13 ft. in 4 minutes
Burning Brand on Surface of Module or Panel (Section 31.1.3)	A Brand	B Brand	C Brand
One test is required for each of the above required tests.			



IMPORTANT: The PV module TYPE is used in conjunction with the UL 2703 racking system evaluation to establish a FIRE RATING

PV Module – Quality

UL Follow-up Service (FUS)



Verification of product construction:

- Electrical ratings
- Model differences
- Product labels suitable for use (permanence, adhesion)
- Substrate, encapsulant, adhesives, J-box gasket material
- Spacings from current carrying parts to the laminate edges
- Installation instructions (according to 22 item checklist)

Quarterly
Inspection

Must
Have
<<

Inspect the production test records to insure that:

- The proper number of samples are undergoing the required test,
- The required tests are being performed correctly,
- The proper information is being recorded and is up-to-date, and
- The instruments being used for the tests have been calibrated

Verify production line testing:

- Dielectric Voltage-Withstand Test (100%)
- Continuity of Grounding Verification (100%)
- Voltage, Current and Power Measurement Tests (100%)

Raise non-conformances when:

- Variations in construction are found,
- Method or frequency of test is not as described,
- Records maintained by the manufacturer are not as described,
- Manufacturer's inspection program is not being performed as described
- Unacceptable test results are witnessed by the UL representative

Non-compliant Action:

- Remove any UL markings, modify all products that do not comply or
HOLD SHIPMENT



The IECRE – Factory Audit Certificate



Annual
Review

- The three-part IECRE OD-405 series covers the requirements for quality system inspections of PV module factories.
- Published standard IEC TS 62942 defines the technical requirements (255 requirements aligned to PV manufacturers)
- UL is qualified Certification Body by the IECRE and authorized to perform the third party assessments, interpret results and issue certification

UL Factory Audit Report

The image shows a detailed UL Factory Audit Report form. It includes sections for Applicant Information (Name, Address, City, State, Zip, Country), Audit Scope (Type of Audit, Scope of Audit), and Assessment Summary (Findings, Non-Conformances, Corrective Action). The form is filled out with specific data for a PV module factory.

IECRE Certificate issued by UL

The image shows an IECRE Certificate issued by UL. It includes the Certificate No. (IECRE.PV.QC.18.0001-R0), the Quality Management Certificate (PV Module Factory), and the details of the factory (First Order, Inc., 2801 Cedar Park Boulevard, Fremont, CA 94539, USA). The certificate is valid until May 11, 2021.

PV Module – Performance (IEC Standards)

#	CCN	Description	Standard
1	QIHC	CLASSIFIED TO – ALSO CERTIFIED TO – Concentrator PV (CPV) Type Approval	IEC 62108 and/or CEI 82-25
3	QIHO	CLASSIFIED TO – ALSO CERTIFIED TO – Crystalline Silicon (cSi) Type Approval	IEC 61215 and/or EN 61215 and/or CSA 61215 and/or ANSI/UL 61215 1-1
2	QIHS	CLASSIFIED TO – ALSO CERTIFIED TO – Thin Film (TF) Type Approval	IEC 61646 and/or EN 61646 and/or CSA 61646 and/or ANSI/UL 61215 1-2/3/4

Performance Testing (module remains functional)

Diagnostic Measurement	Visual inspection, performance at STC , insulation test
Electrical Measurements	Measurement of temperature coefficients, NOCT, performance at low irradiance
Environmental Tests	Thermal cycling, humidity freeze, damp heat
Mechanical Tests	Robustness of termination, twist test, mechanical load, hail impact
Irradiation Tests:	Outdoor exposure, hot-spot endurance, UV exposure

Summary:

Ensures the modules operate above a minimum output power threshold after testing:

- The degradation of the maximum power output at standard test conditions (STC) does not exceed a maximum (i.e. 5%).
- Insulation tests pass, no sample has exhibited any open circuit or ground fault during the tests
- No major visible damage
- For thin-film, the measured output power after final light-soaking is not less than 90% of manufacturers minimum specification.
- Required for most national and international funding programs.



ALSO CERTIFIED TO –

PV Module – Performance (PAN File verification)

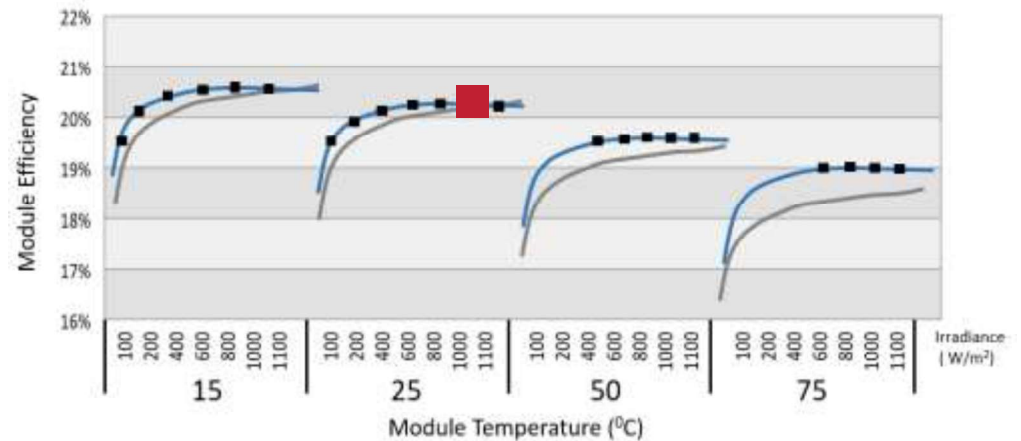
Standard: IEC 61853-1: Irradiance and temperature performance measurements and power rating

Reported values for each table entry include: I_{sc} , V_{oc} , P_{max}

Irradiance	Module Temperature			
	15 °C	25 °C	50 °C	75 °C
W/m ²				
1100	NA	STC		
1000				
800				
600				
400				NA
200			NA	NA
100			NA	NA

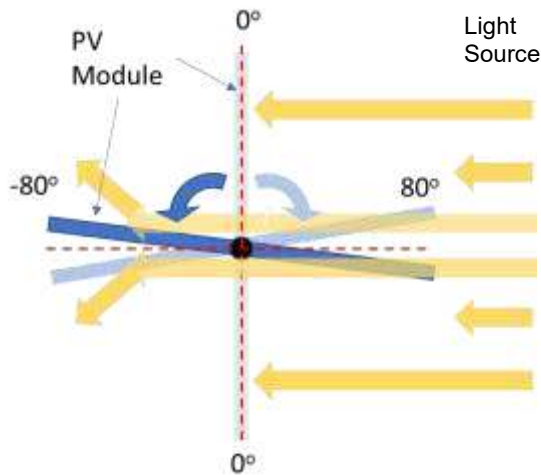


Pvsyst is a solar PV project simulation tool to provide estimation of production. PAN files are profiles of PV modules used in the simulation. For modules in a project, the default PAN file parameters may not be representative of the proposed modules actual performance. Or, default values may be a “golden” module.



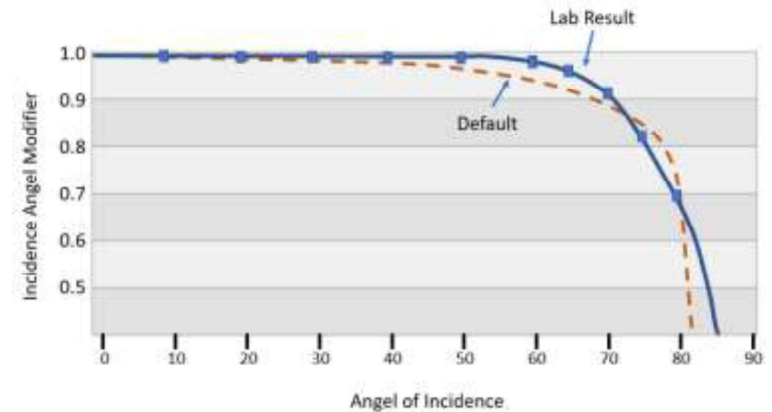
PV Module – Performance (Incidence Angle Modifier)

IEC 61853-2: Spectral responsivity, **incidence angle**, and module operating temperature measurements



Angle of Incidence	Relative Response
-80	0.70
-75	0.85
-70	0.9
-65	0.92
-60	0.95
-50	0.97
-40	0.98
-30	0.99
-20	1
-10	1
0	1
10	1
20	1
30	0.99
40	0.98
50	0.97
60	0.95
65	0.92
70	0.9
75	0.85
80	0.70

The Incidence Angle Modifier (IAM) is a derate factor associated with PV modules ability to convert light entering the module at different angles relative to direct normal.



Not actual measured data

PV Module – Performance (Light Induced Degradation)

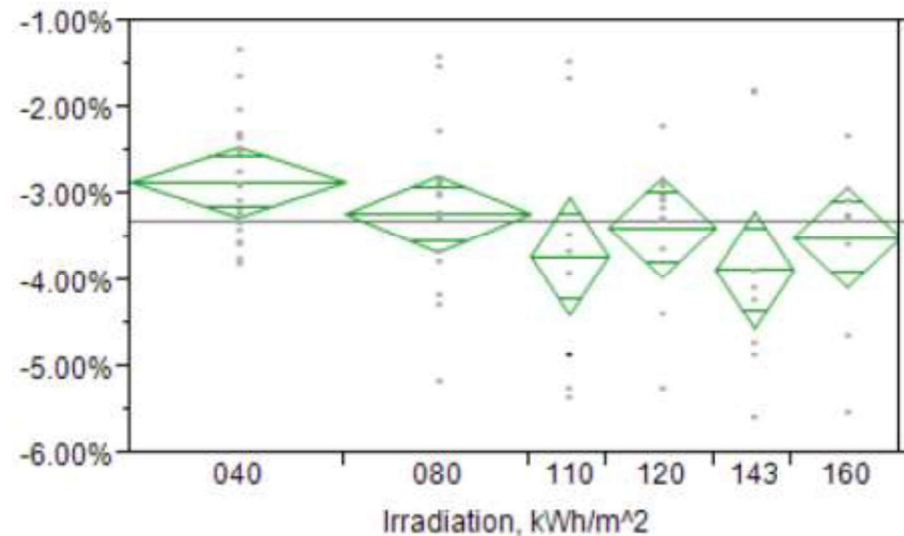
The Light Induced Degradation (LID) involves exposing PV modules to outdoor conditions and measuring the change of their performance over time. The objective of this test is to determine how the modules will perform at the beginning of their life cycle.

Standards:

- IEC 61215-1 (general)
- IEC 61215-1-1 (crystalline)
- IEC 61215-2 (procedure)

Test to stabilization:

- Pmax within 1% for three successive measurements using 25 kWh/m²



PV Module – Performance (Potential Induced Degradation)

What is PID?

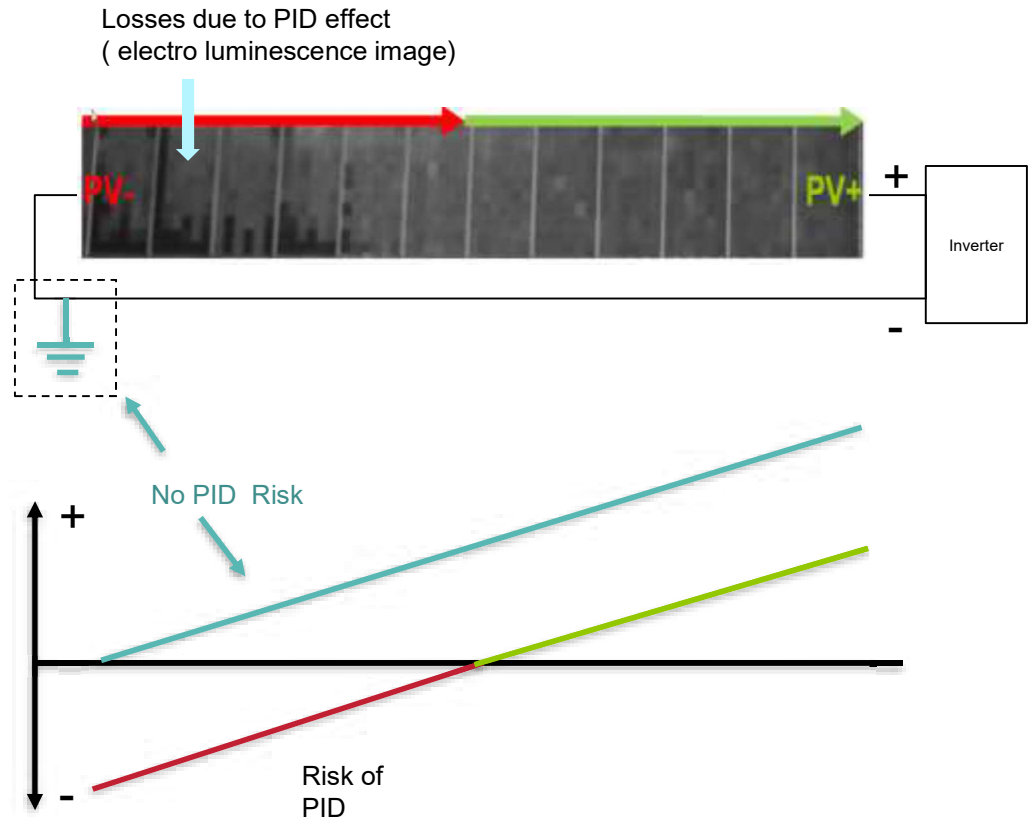
- The long term effect of exposure to high potentials in a photo-voltaic module string resulting in PV module output power loss.
- Typically occurs on large systems at the end of a ungrounded string as the voltage levels increase to the system level voltage (typically 1000v).
- High voltages initiate Na⁺ ion migration from the glass superstrate to the front of the cell resulting in shunting of the cell.

TS IEC 62804-1:2015 prescribes a very specific test procedure including:

- Module-rated system voltage and polarities
- Chamber air temperature 60°C ± 2°C
- Chamber relative humidity 85% ± 3%
- Test duration of 96 hours

The modules will be deemed to be PID-resistant if:

- Power loss is less than 5%
- There is no evidence of any major defect.



PV Module – Other Performance Tests

Description	Standard	Test Elements	Pass/Fail Criteria
Dynamic Mechanical Load	IEC TS 62782 Edition 1.0 2016-03	<ul style="list-style-type: none"> • Load of 1 000 Pa \pm 100 • 1000 cycles (3-7 /min) • Constant current applied 	<ul style="list-style-type: none"> • < 5% power loss • Insulation resistance • Wet leakage • EL and IR scan (informational)
Salt Mist	IEC 61701 Edition 2.0 2011-12	<ul style="list-style-type: none"> • Severity 5 • Duration 28 days • Constant current applied 	<ul style="list-style-type: none"> • < 5% power loss • Insulation resistance • Dielectric withstand • Ground continuity • Wet leakage
Ammonia Corrosion	IEC 62716 Edition 1.0 2013-06	<ul style="list-style-type: none"> • 20 cycles (480 h) • Material and facility per ISO 6988:1985 • Concentration per DIN 50018 	<ul style="list-style-type: none"> • < 5% power loss • Insulation resistance • Bypass diode check • Dielectric withstand • Ground continuity • Wet leakage



PV Module – Performance (Dust/Abrasion - Soiling)

Description	Standard	Test Elements	Pass/Fail Criteria
Dust and Abrasion	ASTM D968-17	Standard Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive	Informative Report
	IEC 60068-2-68 :1994	Environmental testing - Part 2: Tests - Test L: Dust and sand	Informative Report
	DIN EN 1096-2 :2012	Glass in building – Coated glass – Part 2: Requirements and test methods for class A, B and S coatings	Informative Report
	IEC 62788-7-3 under development	<ul style="list-style-type: none"> Measurement procedures for materials used in photovoltaic modules Part 7-3 Materials and coatings for photovoltaic modules or similar solar devices: Abrasion test methods for environment facing surfaces 	Not available



PV Safety – Racking, Trackers, AC Modules & BIPV

Product	Market	CCN	Standards	Comment
Racking Systems	US	QIMS	ANSI/UL 2703	End product
	US	QIMS2	ANSI/UL 2703	Component
	Canada	QIMS7	ULC/ORD-C1703, C22.2 No. 41	
	IEC			
Solar Trackers	US	QIKA	ANSI/UL 3703, UL 2703	Includes racking system
	US	QIKA2	ANSI/UL 3703	
	Canada		CSA 62817	
	IEC		IEC 62817, IEC TS 62727	
AC PV Modules	US	QHYZ	UL 1741, UL 1703, UL 61730	Includes microinverter
	Canada			
	IEC			
BIPV	US	QHZK	UL 1703, UL 790, UL 7103	New standard
	Canada	QHZK7	ORD-C1703, CAN/ULC-S107	
	IEC			EN 50583



PV Safety – Junction Box, Connectors, Wire

Product	Market	CCN	Standards	Comment
Junction Box	US	QIJB2	UL 3730	Typical J-box
	US	QIIO2	UL 1741, ANSI/UL 1703,	Smart J-box
	Canada			
	IEC		IEC 62790	
PV Connectors	US	QIJQ2	ANSI/UL 6703	Single-pole PV Connectors
	US	QIFA2	ANSI/UL 6703	Multi-pole PV connectors
	Canada	QIJQ7	CSA-C22.2 No. 182.5	Single-pole PV Connectors
	Canada	QIJQ8	CSA-C22.2 No. 182.5	Multi-pole PV connectors
	IEC		IEC 62852	
PV Wire	US	ZKLA	UL 4703	
	Canada			
	IEC		IEC 62930	Published 2017



PV Safety – Wiring Harness, Fuse Holders

Product	Market	CCN	Standards	Comment
PV Wiring Harness	US	QHVS	UL OOI 9703	
	Canada			
	IEC			
PV Fuse Holder	US	IZMR	UL 4248-19	
	Canada			
	IEC			

