

ENERGIZING LIFE TOGETHER



REC QUALITY: BEYOND EXPECTATIONS

Ensuring industry-leading standards
of solar panel quality



- **Introduction to REC**
 - A look at who we are and our facilities
- **Exceeding International Standards**
 - How REC's internal qualification process compares to international standards
- **Quality in Real World Applications**
 - See where REC's test sites are and real world performance results of REC modules
- **Built on Solid Ground**
 - How REC ensures Reliability and Durability through quality controls in manufacturing
- **Third Party Quality Confirmation**
 - A summary of recent Due Dilligence and Bankability audits of REC
- **Backing up our Quality**
 - Warranty and customer claims



Introduction



We know you rely on high performance solar panels for the whole of your system's lifetime.

We want you to trust our products and for you to be sure you are using the best solar panels available on the market.

We pride ourselves on the quality of our panels and that's why at REC, we strive to ensure our manufacturing process are of the highest standard possible.

The following slides show how REC goes beyond the recognized international standards to ensure our products can withstand extreme environments.

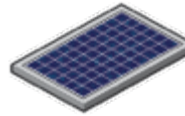


REC Group – A leading, global solar company



- Established in Norway 1996
- Vertically integrated with full ownership of all parts of the value chain:

Polysilicon → wafers → cells → modules → systems



- Strong cost position and balance sheet
- Present in all key markets and segments
- Revenues of more than 1,740 billion Euro in 2011
- Around 2,400 employees
- Headquarters Oslo, listed on the Oslo Stock Exchange (ticker: REC)

QUALITY

**VERTICALLY
INTEGRATED**

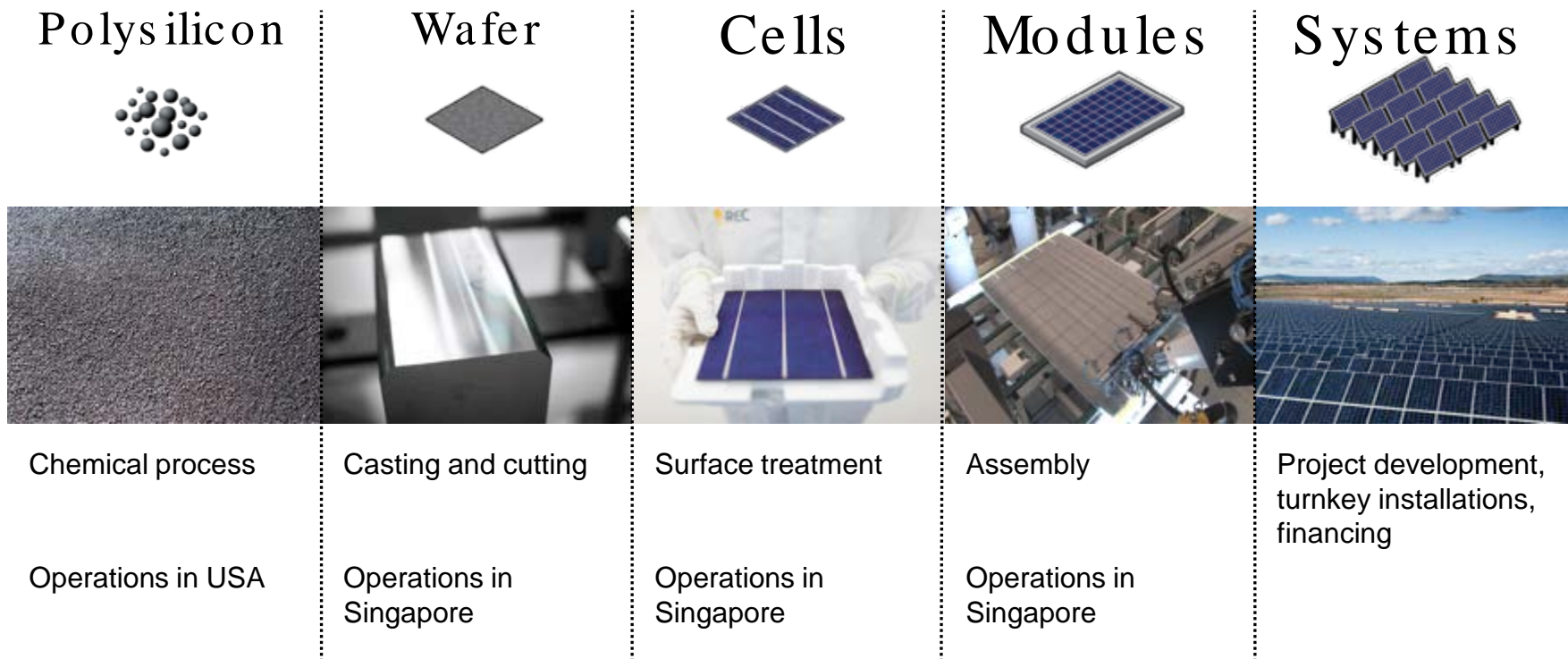
**EFFICIENT
TECHNOLOGY**

**FINANCIALLY
STRONG**

Vertically integrated manufacturing



REC is the world's most integrated solar company. The vertical integration of our organization from silicon, wafers, cells and modules, together with our project development experience, gives us the highest level of quality control throughout the complete manufacturing process.



REC's Integrated Manufacturing Facility in Singapore

REC Module Plant

- 4 Module lines
- 8 Operators/line

REC Cell Plant

- mc-Si cell type
- 8 cell lines
- 8 operators/line

REC Wafer Plant

- Wafer size: 156mm x 156mm
- Wafer type: p-type multicrystalline
- 2 wafer factories

Production Capacity
Modules: 820 MW

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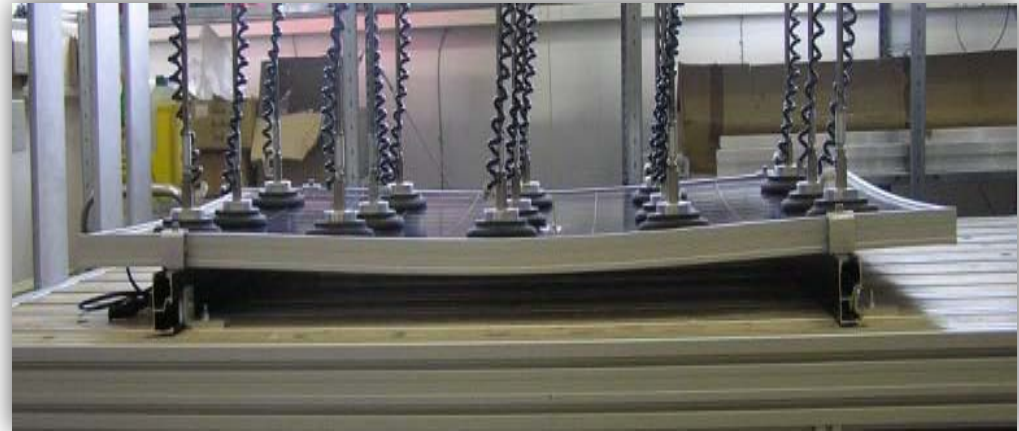
EXCEEDING
INTERNATIONAL
STANDARDS



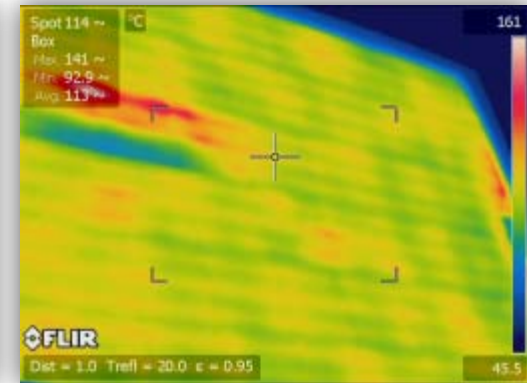
Product Qualification and Testing

Certification is good, but it is not a guarantee of quality.

- REC considers **IEC** and **UL** compliance as a minimum requirement.
- Strict test criteria beyond these standards must be passed before REC releases products to market.
- In designing and developing new products, REC works not only to meet international standards, but surpass them.
- Rigorous product quality testing is carried out in the following general categories:
 - Safety
 - Equipment calibration
 - Electrical performance
 - Mechanical performance
 - Product aesthetics



PE-series loaded at ultimate design load 5400 Pa with excess capacity



Visual inspection is via a combination of man and machine

International standards

IEC 61215, IEC 61730 & UL 1703

Hot spots	By-pass diodes	Fire safety	Leakage current	Reverse current overload	Salt spray
Thermal cycles	Damp heat	Humidity freeze	Mechanical load	UV test	Hail impact

International standards are developed to:

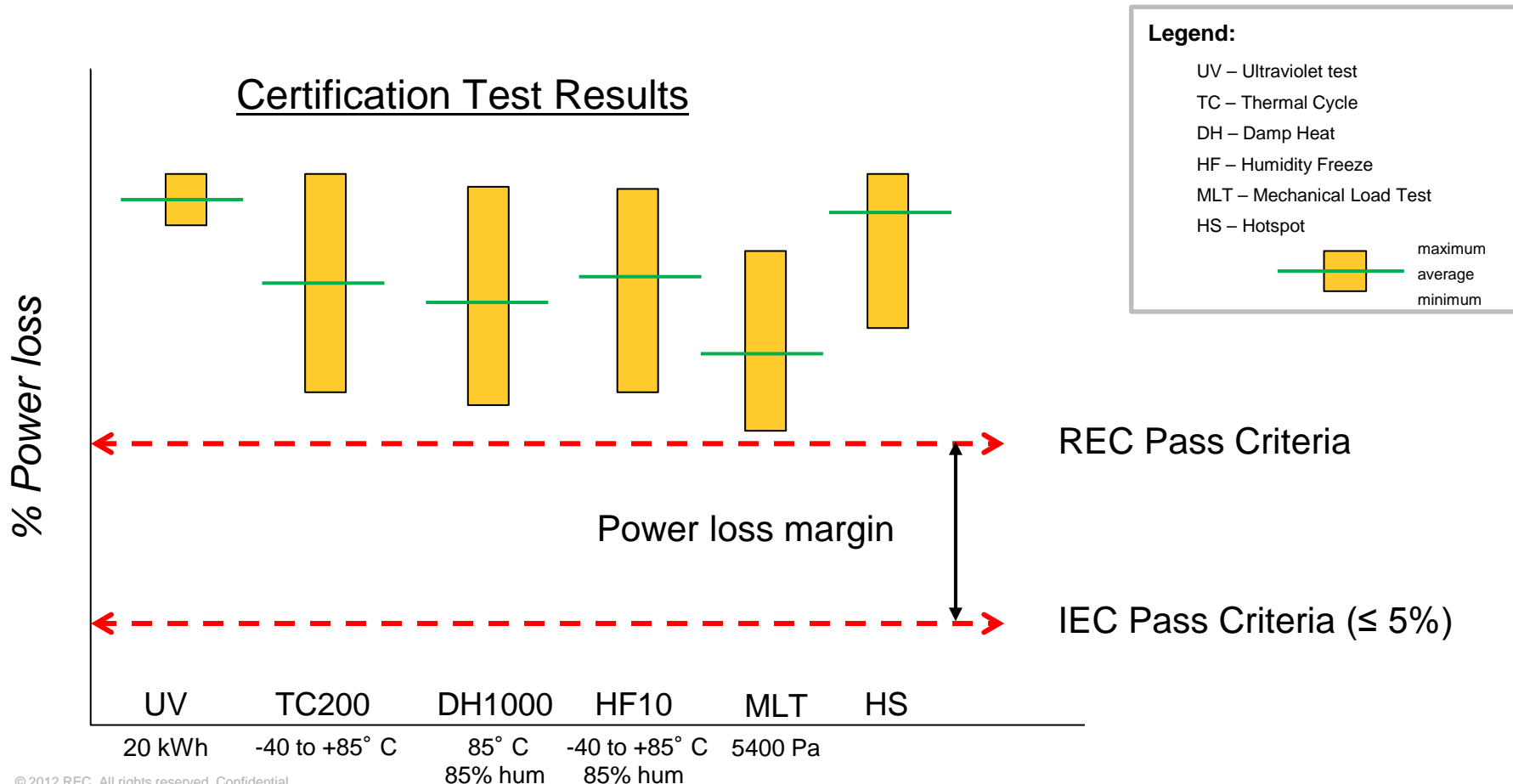
- ➔ Identify any design, material and process flaws
- ➔ Assess hazards caused by mechanical and environmental stresses.



Certification results above industry standards



The performance of REC panels during certification is far higher than the IEC certification threshold. As REC has strict internal qualification test requirements, passing the certification test is straightforward.



Pushing the standards



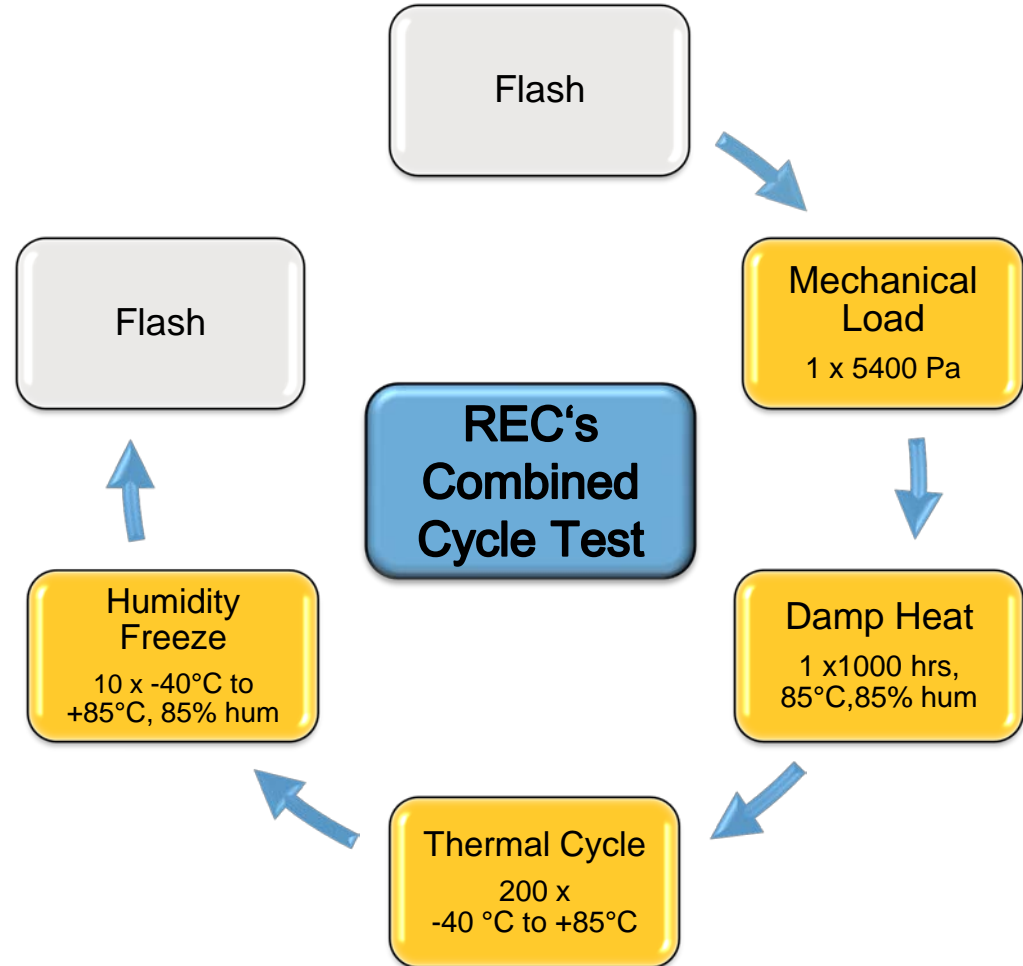
REC is not satisfied with simply passing the standards, so has created its own stringent internal testing procedure. The table below shows how REC's stringent internal qualification protocol compares to international standards:

Test	IEC 61215 & IEC 61730	UL 1703	REC
Mechanical load	5400 Pa	5400 Pa (Rated to 3600 Pa)	Test to failure Modules are tested in excess of 10,000 Pa
Thermal cycling	200 cycles	200 cycles	400 cycles
Damp heat	1000 hours	n/a	2000 hours
Humidity freeze	10 cycles	10 cycles	20 cycles to 40 cycles (dependent on component change)
Reverse current overload	135 % of series fuse rating current	135 % of series fuse rating current	135 % of series fuse rating current
UV	20 kWh pre-conditioning	NA	30 kWh pre-conditioning Component level testing of UV for reliability
Combined cycle	n/a	n/a	2 cycles

What is REC's Combined Cycle Test?

On top of standard accelerated tests, REC's internal quality protocol requires panels to pass a 'Combined Cycle Test' at IEC criteria to further ensure product reliability.

- REC panels are subjected to a series of multiple cycle accelerated tests.
- Even with this, our panels still perform far in excess of expectations.

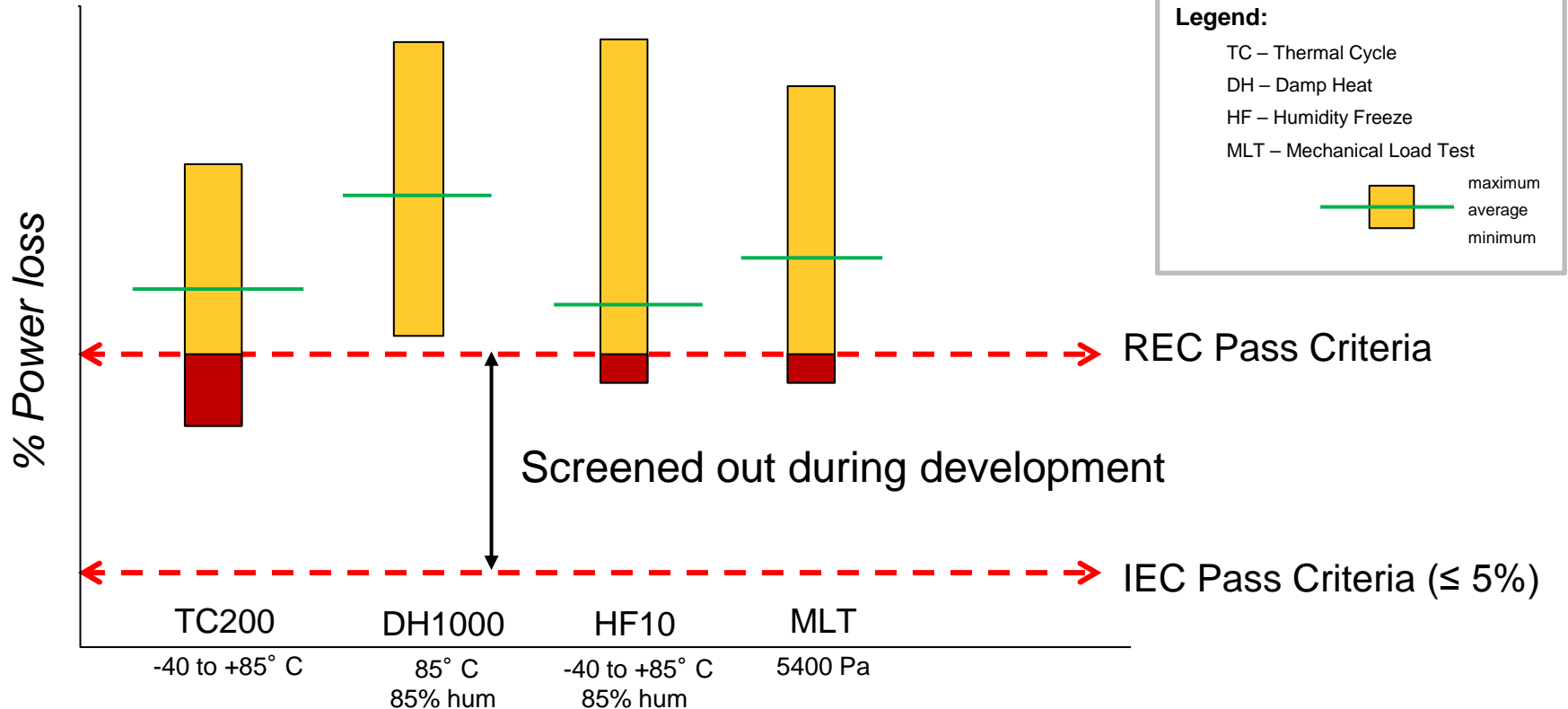


Internal qualification results above IEC standards



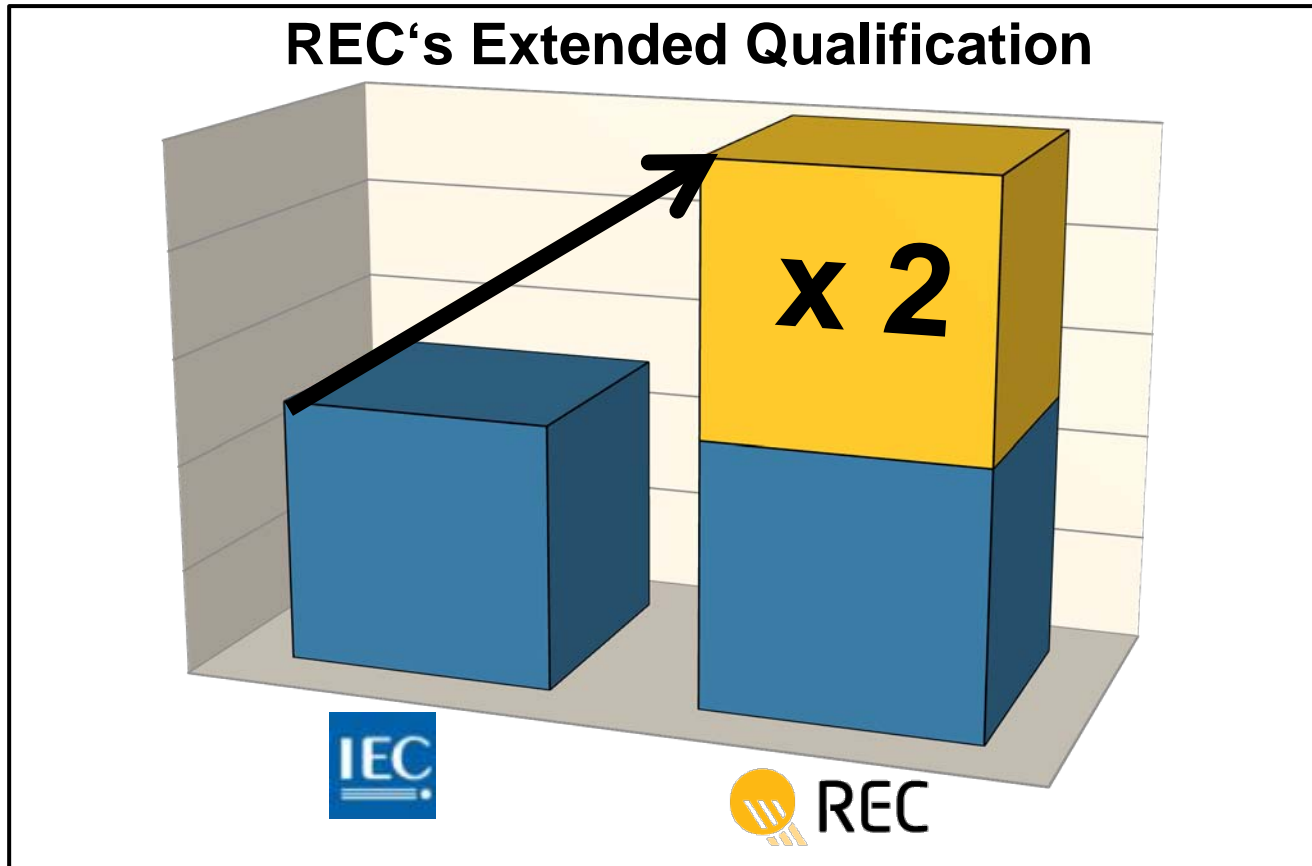
In line with REC's philosophy of the best quality design and performance, every design change or investigation undergoes an internal qualification process to identify characteristics that do not perform to expectations. This process has more stringent pass criteria than industry standards to ensure a reliable product.

REC Internal Qualification Test Results



REC goes further - Extended Qualification

Major design changes also undergo an Extended Qualification process, where panels are tested to twice the normal industry standards. This extreme testing ensures panels can perform in the most severe environments, ensuring reliability.

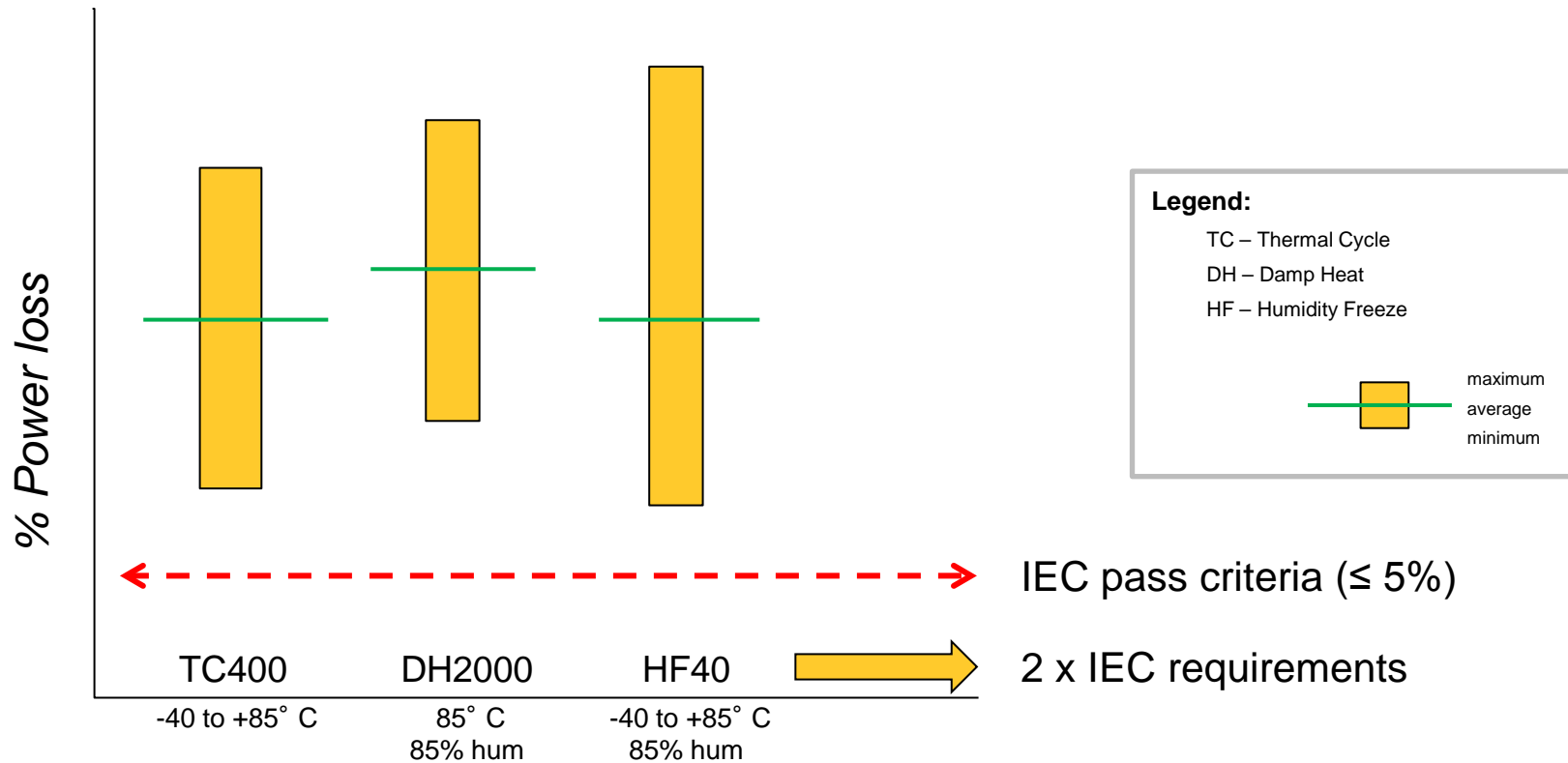


Extended qualification results double IEC Standards



Even at double the IEC test conditions, REC solar panels perform within the industry standard pass criteria.

REC Extended Qualification Test Results



How does REC carry out its qualification?



REC has its own laboratory equipped with state of the art equipment to test panels and new technologies. The qualification regime is implemented whenever a production or design change is proposed on the wafer, cell or module process to ensure it can withstand the world's most unforgiving environmental conditions.

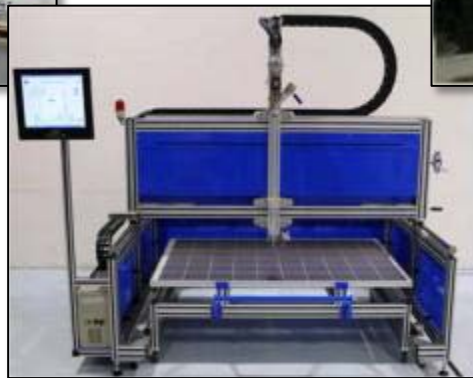
REC test laboratory facilities



Climate chambers



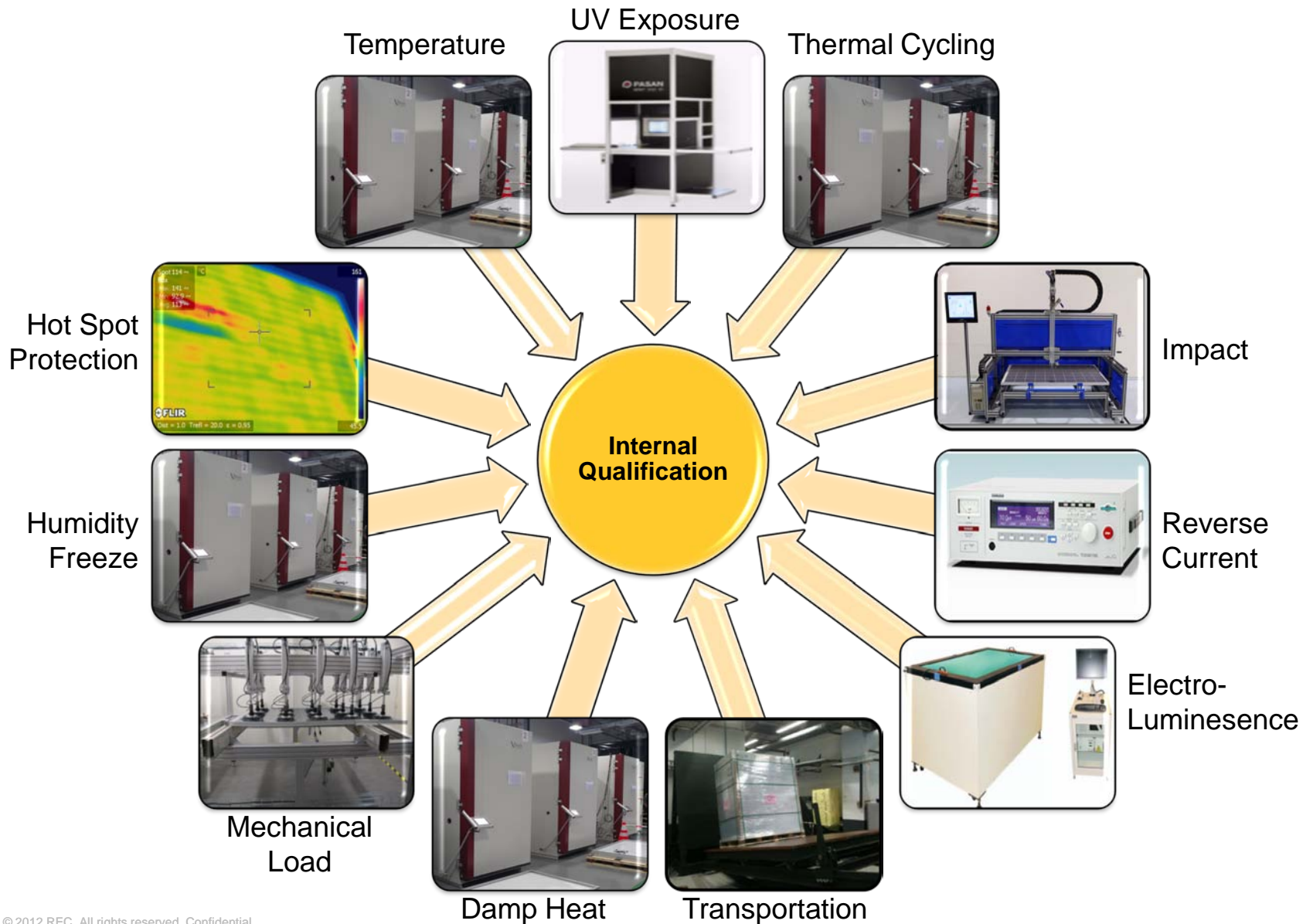
Tilt tables







Hail impact test






Mechanical Load Tester



Other signs of quality

Further certifications		
IEC 61701	Salt Mist Corrosion	
IEC 62716	Ammonia Resistance	
MCS	UK	
JET Factory Inspection	Japan	

Further listings		
CEC	California	
FSCE	Florida	
CSTB	France	

Environmental and Quality Standards



- REC Wafer (Singapore)
 - ISO 9001
 - ISO 14001
 - OHSAS 18001
- REC Cells Pte Ltd (Singapore)
 - ISO 9001
 - ISO 14001
 - OHSAS 18001
- REC Modules Pte Ltd (Singapore)
 - ISO 9001
 - ISO 14001
 - OHSAS 18001
 - UL Factory inspection (Quarterly)
 - TUV Factory inspection (Yearly)
 - JET Factory Inspection (Yearly)
 - MCS Factory inspection (Yearly)
- Third party audit reports
 - Mott MacDonald
 - Black and Veatch



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QUALITY IN REAL WORLD APPLICATIONS

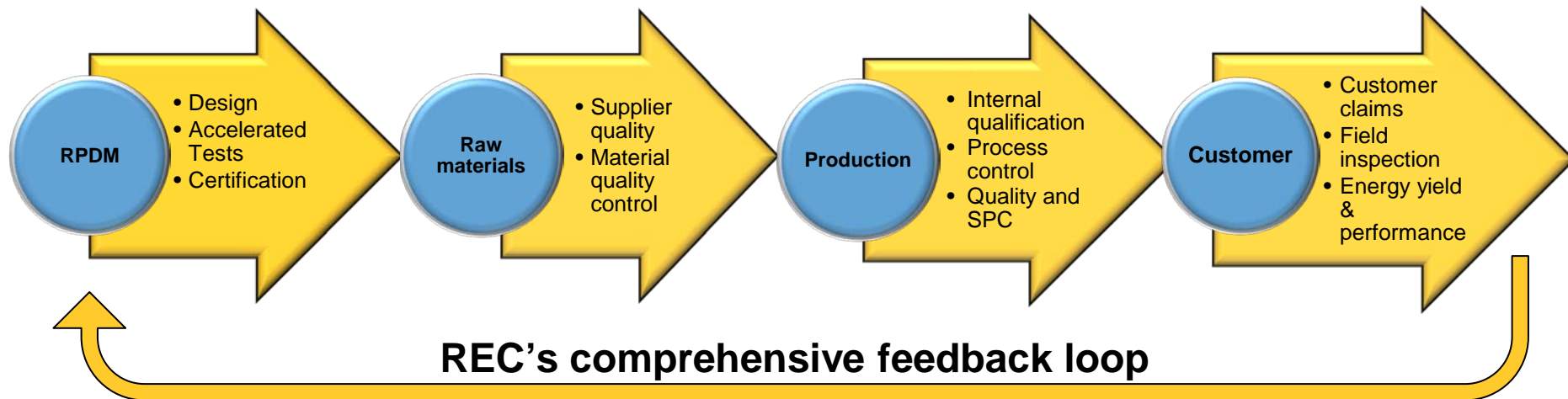


Ensuring quality in the field

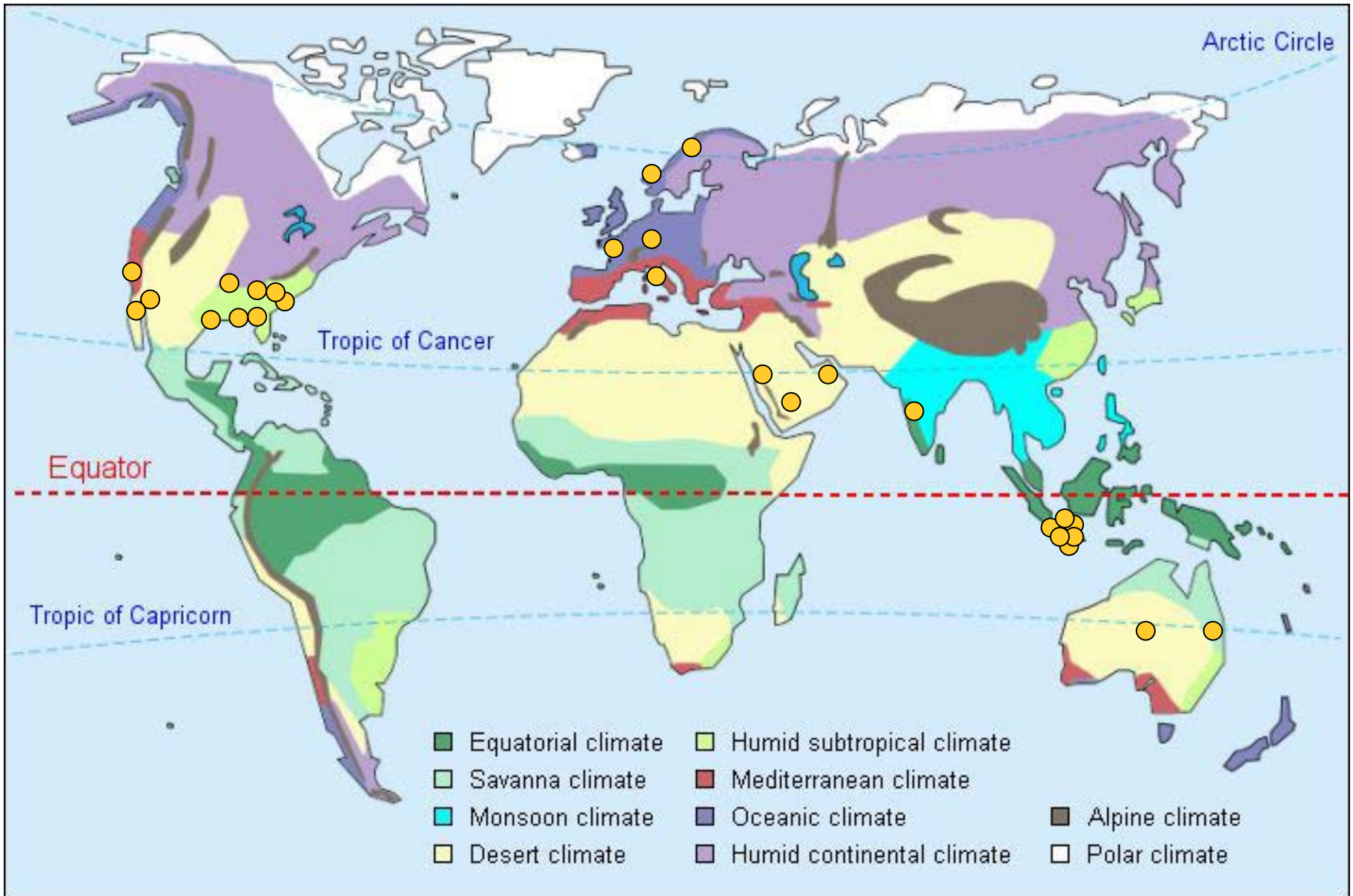
REC has developed a field inspection method and tracks systems across the world in different locations to ensure data collection on module performance and ensure understanding of actual module performance in different environmental conditions and climate exposures.

This enables a better technological understanding of our products:

- Validate known degradation mechanism and models and feeds back information into the design and development process
- Helps identify potential new phenomenon to develop mitigations.

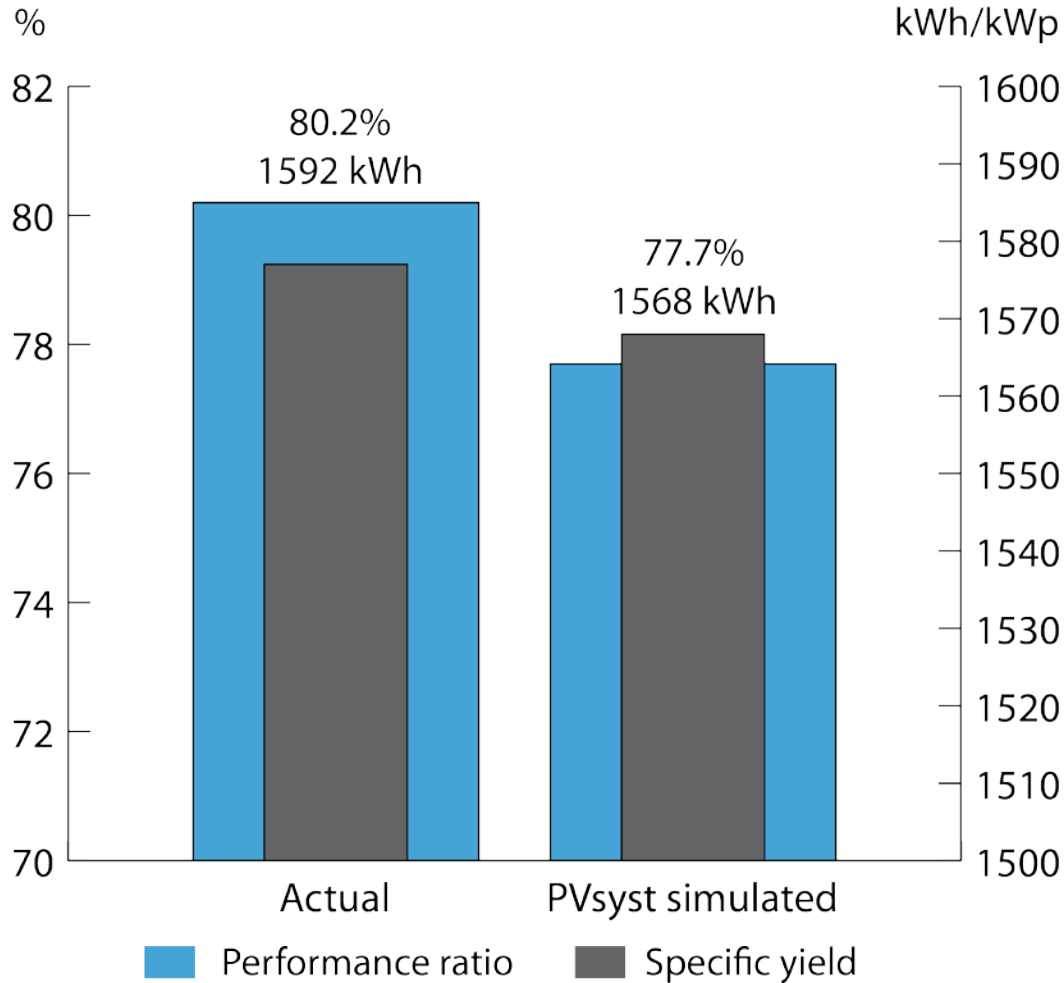


REC's test systems

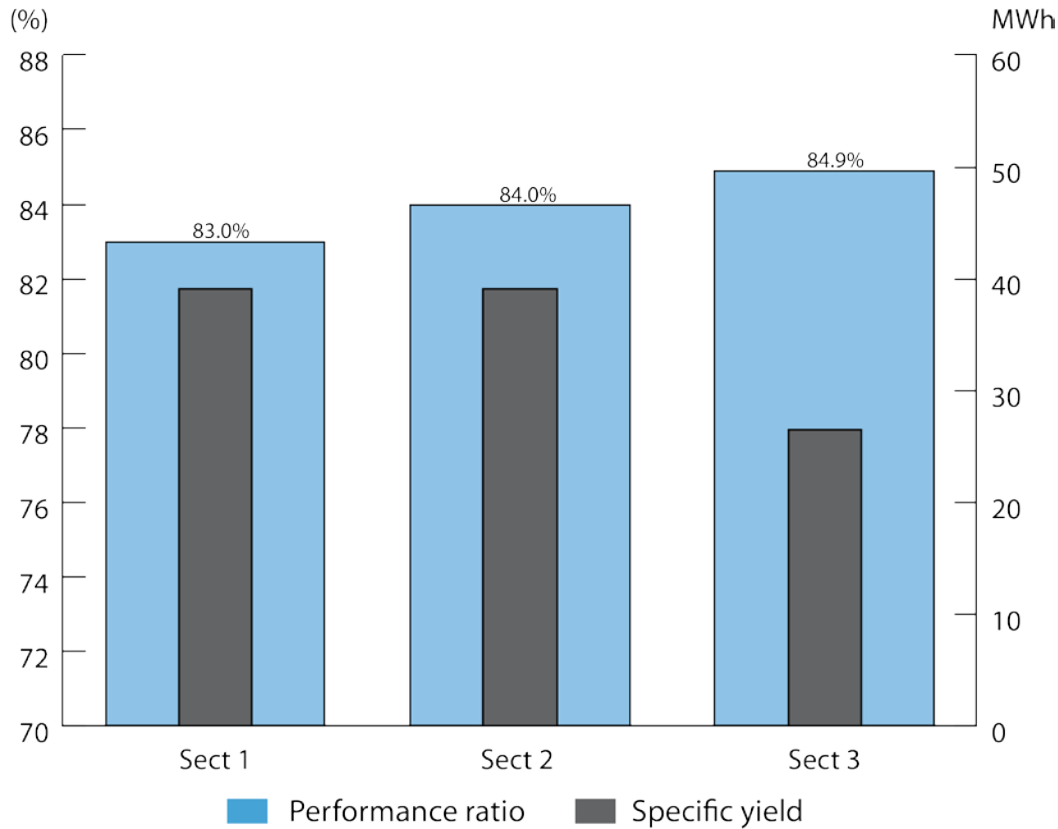


Proven performance in India

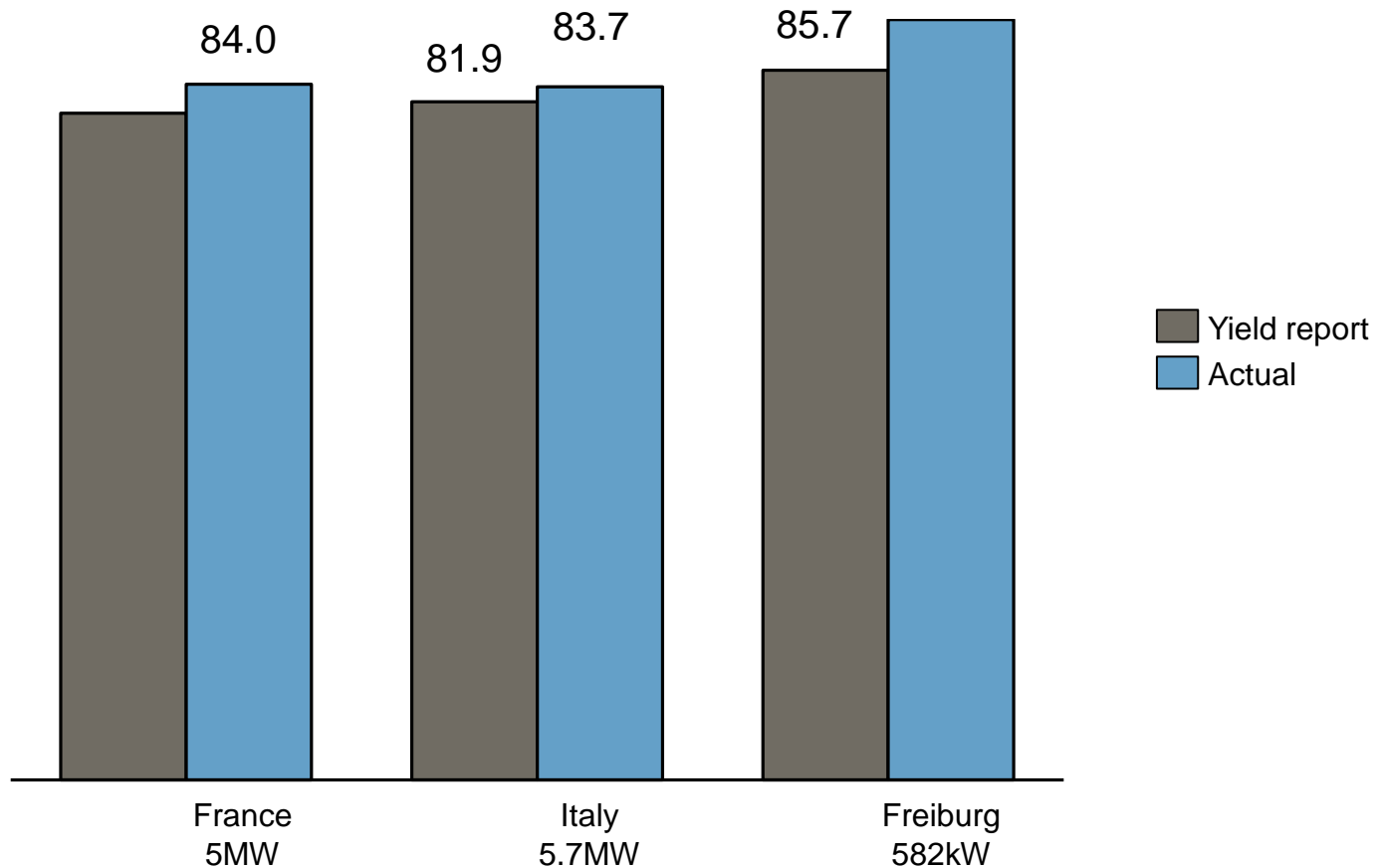
Pandit Deendayal Petroleum University in Gujarat, India (2.5% above expectations)



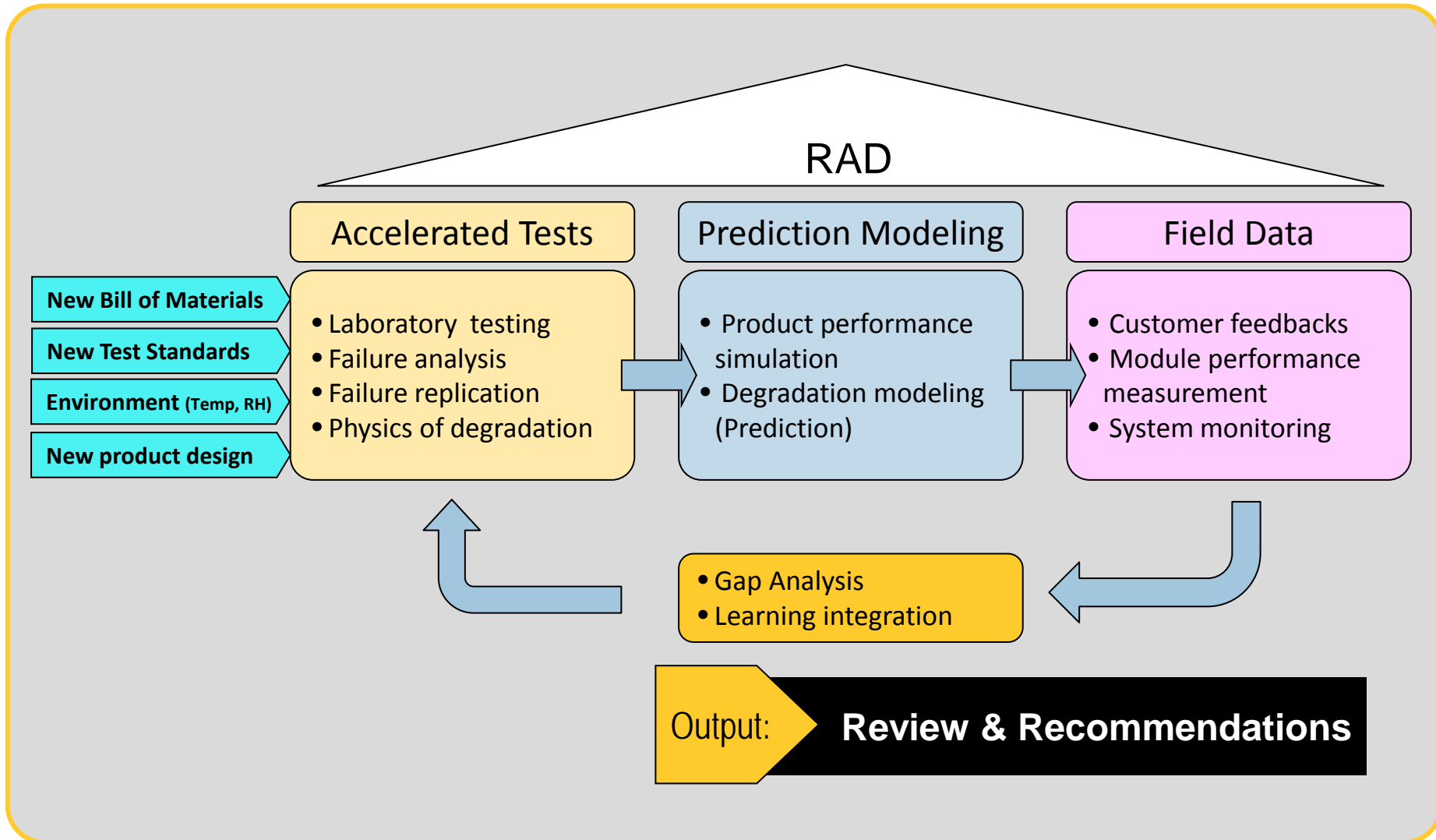
100kW REC Factory Rooftop, Tuas, Singapore



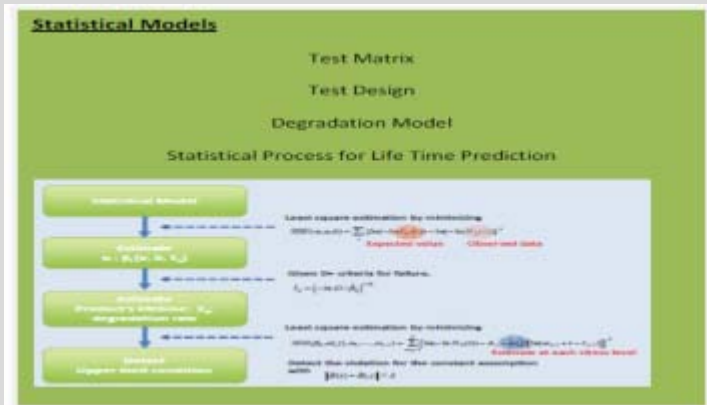
REC Systems' Performance Ratio* Examples (%)



* The performance ratio (PR) describes the relationship between the actual and theoretical energy outputs of the PV plant. The low conversion losses of REC panels (glass reflection, temperature losses, transformer losses ...) are leading to a high PR.



Statistical models show failure rates based on customer feedback and monitoring data to predict future claim levels.

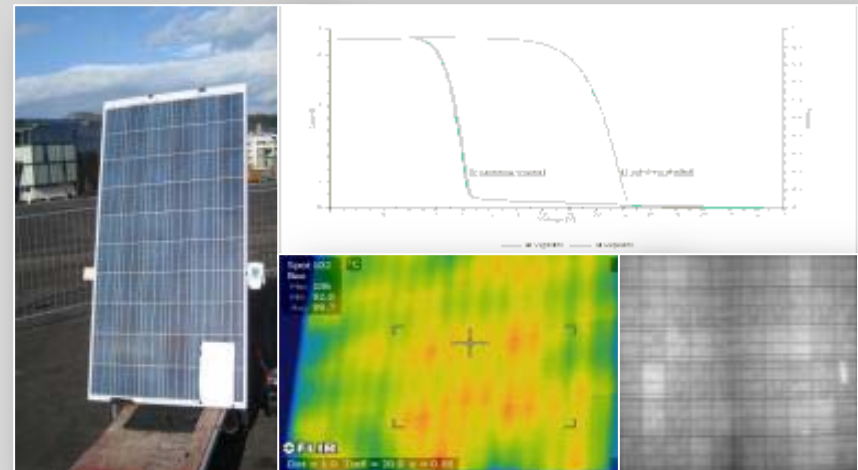
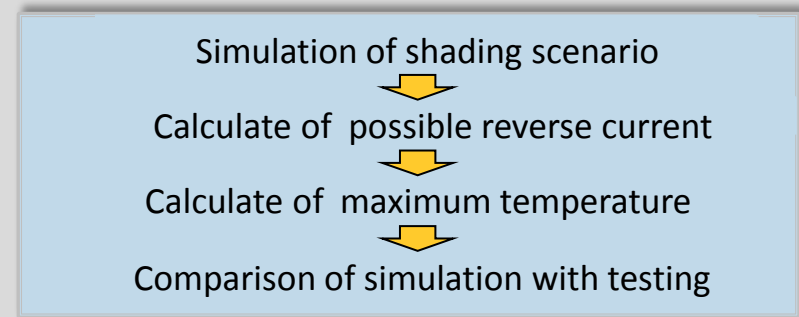


System modeling



- Used to predict system performance
- Compared with monitoring data results in an analysis of possible degradation causes

A physical model based on a technical understanding of the failure mechanism is used to predict effects on panels.



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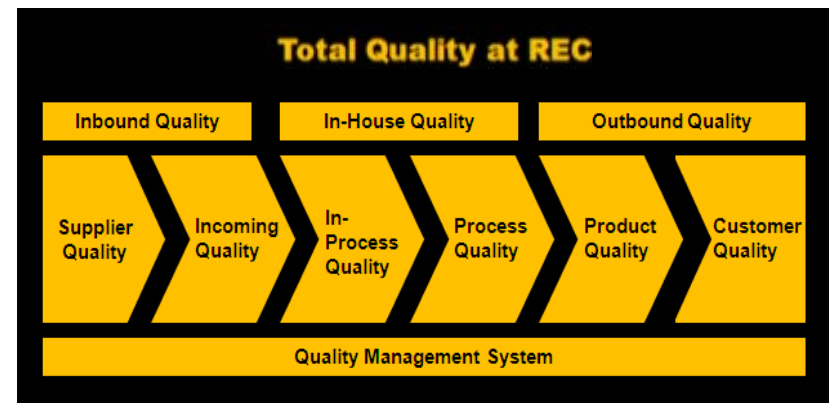
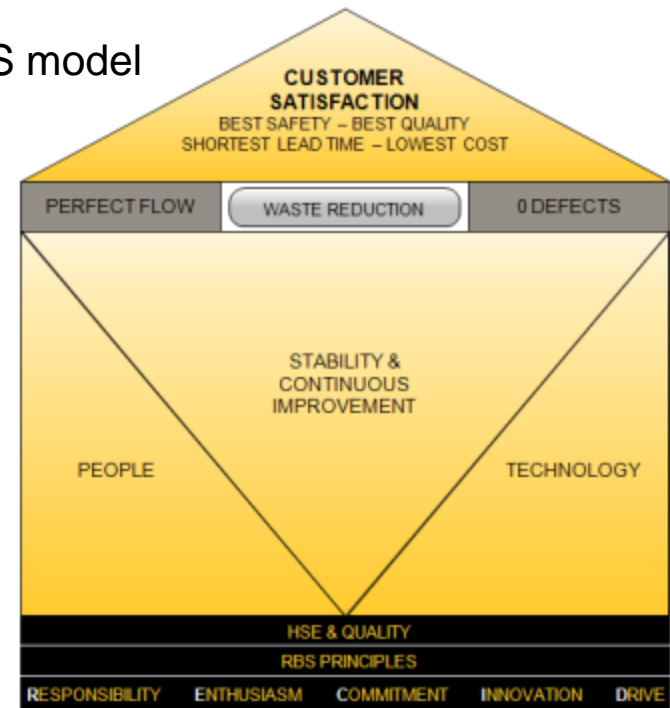
**BUILT
ON SOLID
GROUND**



Foundations for quality

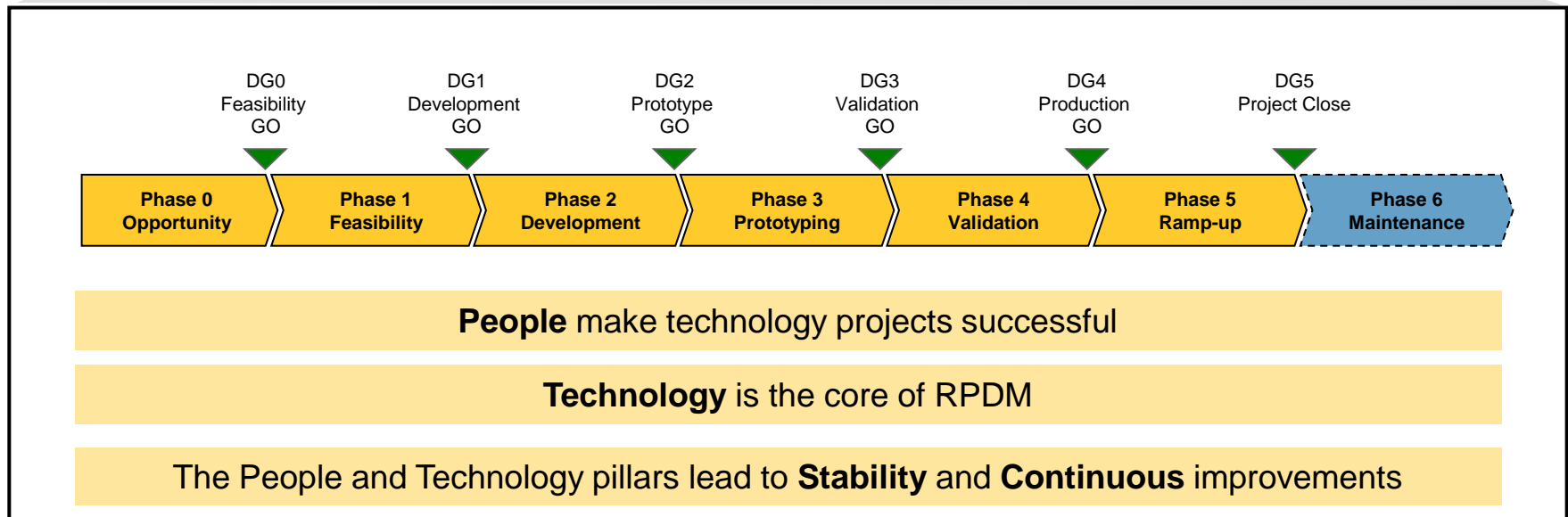
- REC panels are designed to:
 - Meet the highest quality standards
 - Provide stable power output over the product's lifetime
- Our solar panels offer a 25 year performance warranty – they need to be robust and durable.
- There is a wide variance in the methods of panel production among competitors and therefore varying degrees of product quality.
- The REC Business System (RBS)
 - Governs how we run our business
 - Implements systems to achieve our targets
 - Ensures the highest quality inputs make the highest quality products.

RBS model

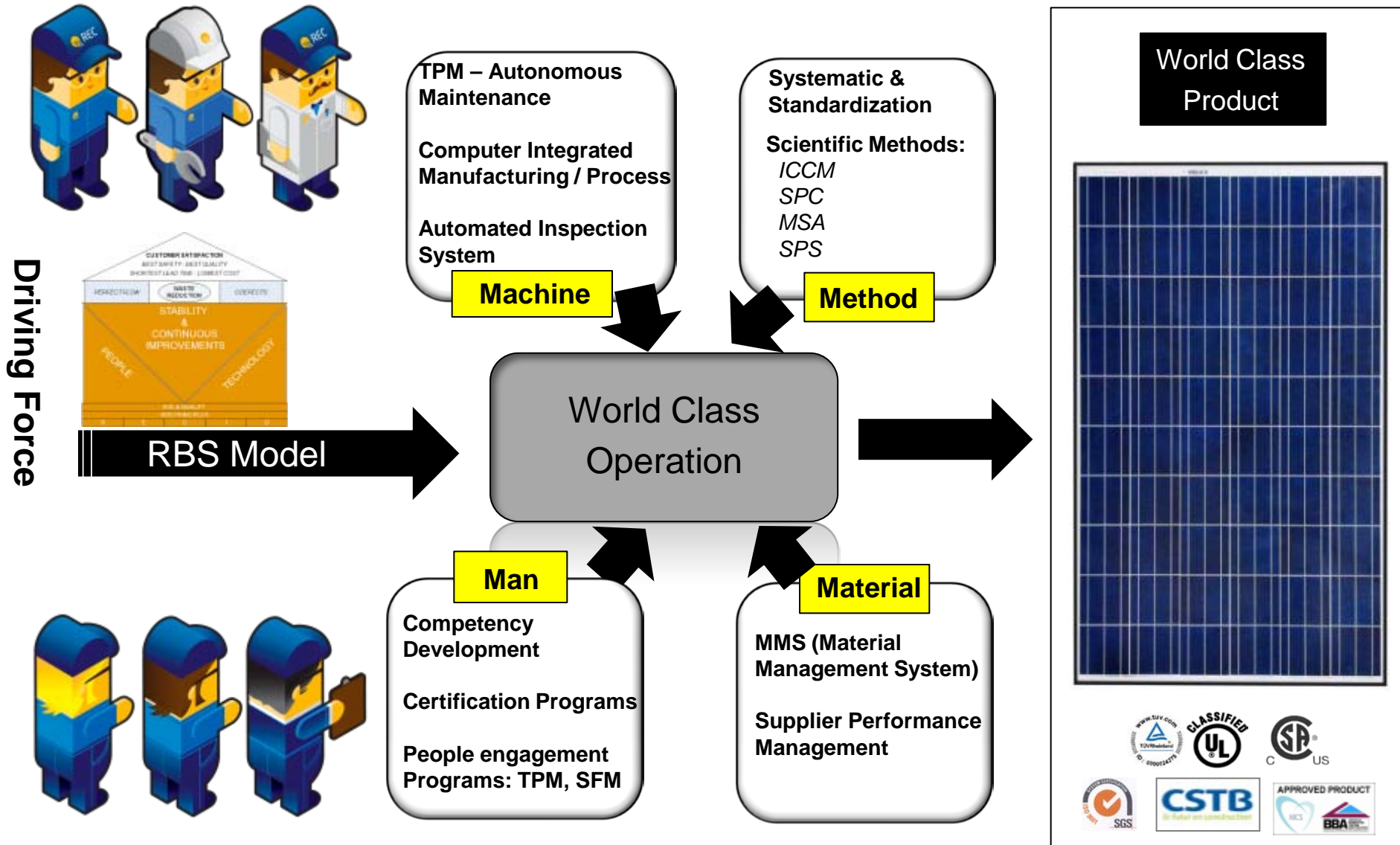


- RBS is the Standard Operating System for improving and sustaining safety, quality and productivity at REC.
- Our quality assurance system and technology development processes are critical elements of RBS.
- The RPDM decision process ensures all products are **tested** and **validated** prior to acceptance and that ongoing checks are implemented to **maintain** quality.

RPDM Decision gate architecture

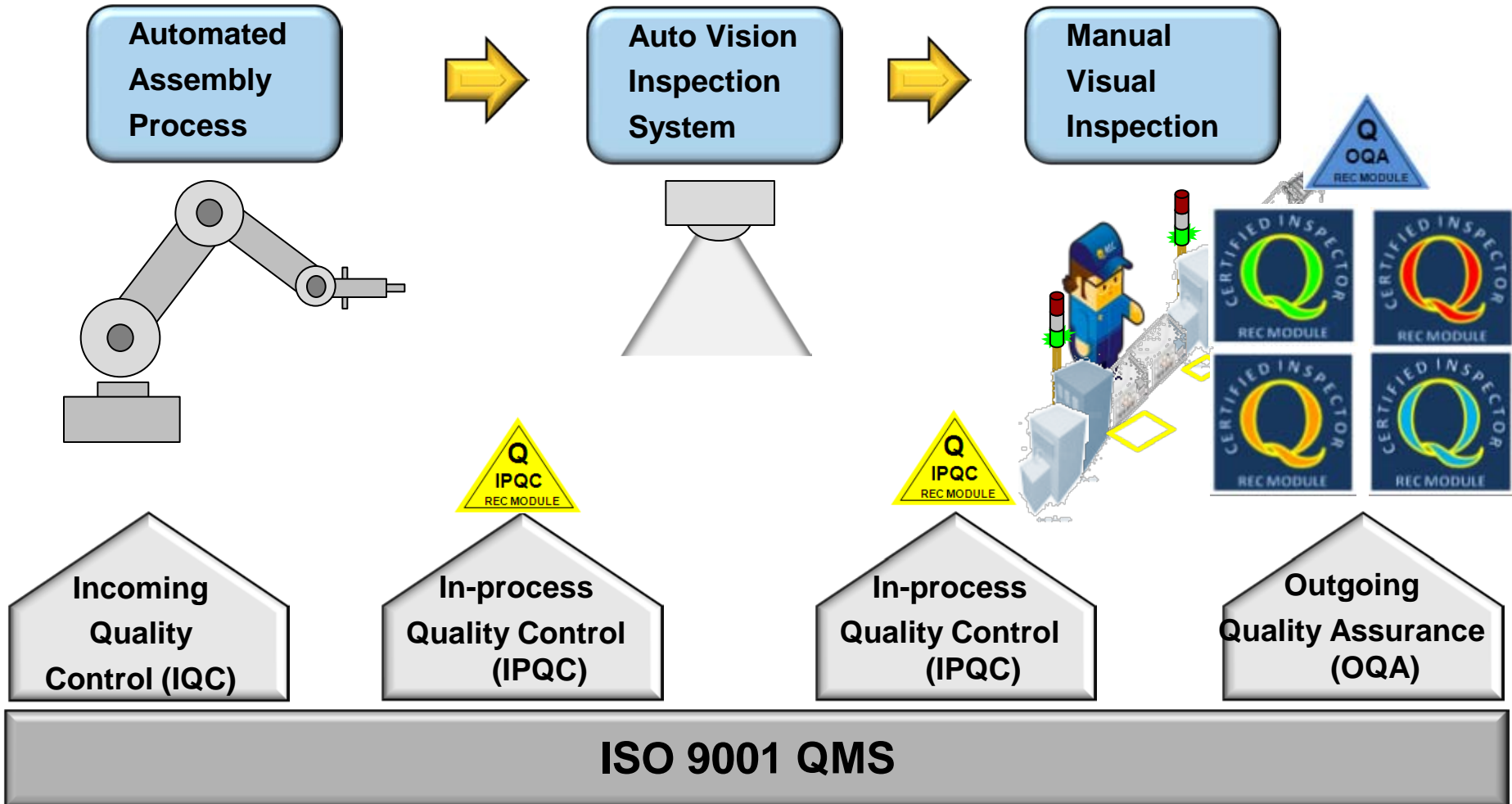


RBS controls quality through all key inputs



A highly automated manufacturing process

REC has the highest level of automated manufacturing in the industry, meaning our manufacturing has increased repeatability and reliability.



Wafer



Infra-red cameras

Inclusions and cracks

Sawmark detection system

Sawmarks can lead to weaker wafers or cause shunts

Camera systems

Chips & edge defects may lead to breakages in cell or module lines

Cell



Camera systems

Inspect geometry, wafer breakages, cell print defects

Colour camera system

Thickness of anti-reflection layer

I-V forward and reverse sweep test

Conducted on all cells

Infra-red thermal imager

Inspects all cells for hot-spots in reverse bias

Panel



Camera systems

At cell, string, matrix and laminate levels

Cell

Inspect all cells for cracks & chipped edges

String

Inspect all strings for cracks, chipped edges, spacing & ribbon misalignment

Matrix

Inspect all matrices for cracks, chipped edges, spacing, contamination, misalignment & polarity

Laminate

Cracks, chips, spacing, misalignment, contamination, label, backsheet damage, lamination issues, cell print defects.

Dark IV

Checks for shunt resistance and string polarity

Flash test

IV curve, max power and resistance testing

Hi-pot testing

Electrical insulation and ground continuity testing for each terminal

Visual inspection x 4

Cracked cells, chips, misalignment, contamination, labels, backsheet damage, lamination issues, cell print defects.

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THIRD PARTY QUALITY CONFIRMATION



Third party bankability audits

Third party findings confirm superior REC quality. Engineering companies have carried out performance and bankability studies on REC's integrated manufacturing plant in Singapore:

→ Black & Veatch (BV)



- US engineering, consulting & construction company
- Performed technical report on REC Peak Energy modules
 - Included review of manufacturing process in Singapore.
- Assess factors that would affect modules' longevity in the field and REC's ability to deliver on this.
 - Panel design,
 - Material quality,
 - Field performance,
 - Environmental tests
 - Manufacturing and quality control process
 - Comparisons with other similar modules available on the market.
- Carried out by a team of solar professionals with experience in panel manufacturing, power plant performance and supporting engineers.

→ Mott MacDonald (MM)



- UK engineering consultancy firm
- Carried out a technical review of the production of REC Peak Energy Series panels
 - Bankability
 - Risk assessment for developers and investors
- Reviewed and compared with other manufacturers
 - Panel specification
 - Warranties
 - Certifications
 - Track records
 - Cell and module manufacturing process
 - Quality plan
 - Procurement
 - Maintenance and logistics

Black & Veatch conclusions



“BV finds the design for the Modules to be similar or superior to the designs of other crystalline silicon PV modules.”

“The materials and components come from suppliers with long track records.”

“The module assembly facility is highly automated and the capital equipment appears to be state of the art.”

“BV believes that the cell placement and busbar soldering operations are superior to widely accepted industry practices.”

“REC performs 100% inline cell IR imaging and dark IV testing which are not widespread in the industry.”

“BV believes that the supplier selection and monitoring process is consistent with, or superior to, accepted industry practices.”

“BV notes that such warranty terms are more favorable than those offered by other module manufacturers.”

“Representatives of the quality assurance organization were present throughout the manufacturing line.”

“BV considers this quarantine practice to be among the best in the industry.”

“BV believes that such an automated inspection on 100 percent of the cells is an industry best practice.”

“The quality assurance facilities are well-organized and well-managed.”



Mott MacDonald conclusions



“MM has formed a very positive opinion of the facility due to the clean, organised and well-managed cell and module production lines.”

“The rate of automation of REC facilities provides important benefits and advantages against less automated factories.”

“[MM] considers that the REC modules are designed in accordance with the industry best-practice and thus that the technical characteristics of the REC modules are in line with similar higher class poly-crystalline modules manufactured by top-tier PV manufacturers.”

“The module mismatch loss is very small.”

“MM is satisfied with the high level of automation in the cell production line and with the extensive number of quality checks and testing procedures in place.”

“Suppliers have been benchmarked and classified.”

“MM considers that the annual PR values exhibited by the REC systems are highly satisfactory.”

“Once the wafers enter the cell-manufacturing line, they go through a 100% automated process with no manual labour involved.”

“The quality of the checks implemented in the cell manufacturing line give comfort that reliable cells are produced by REC.”

“REC’s internal quality requirements provide extra comfort on the long term behaviour of REC PV modules.”

“A good level of quality management processes.”

“This overall approach indicates that the company’s attention to detail will assist in maintaining a quality product.”



Summary of report findings*



Black & Veatch	Mott MacDonald
Specific items of mention (e.g. Best Practice/Industry Leading)	Specific items of mention (e.g. Best Practice/Industry Leading)
<ul style="list-style-type: none"> → Use of copper ribbon → Use of discrete solder points in cell stringing → Use of soldered contacts in junction box → Supplier selection and monitoring → EVA and backsheet preparation → EVA and backsheet trimming → Automated optical cell inspection on 100% of cells → Junction box potting → Frame joined using corner key → Electrical Safety Test of each module → Quality Assurance Organization → Document control system → Product serialization → Panel design → Automated Soldering machines → Inline cell testing → Module testing & quarantine practice → IP67 rated junction box → Warranty conditions → Number of quality checkpoints in production → Tabbing and stringing machines → Cell placement and bus bar soldering 	<ul style="list-style-type: none"> → Panel design → Internal quality testing → REC Warranty → Quality tests performed → REC internal laboratory facilities → Supplier controls → Maintenance activities → REC production facility quality → REC panel PR values → Automated production lines → Occurrence of micro-cracks → Positive power tolerance of 0/+5W → Low mismatch rate → Quality management processes → Number of quality checks and testing procedures in cell production is extensive → Dark IV curve measurements performed pre-laminate → Cleanliness, organization and management of production lines → Planned areas of study and research → Attention to detail

*The final reports are available from REC and subject to a NDA.

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BACKING UP
OUR
QUALITY

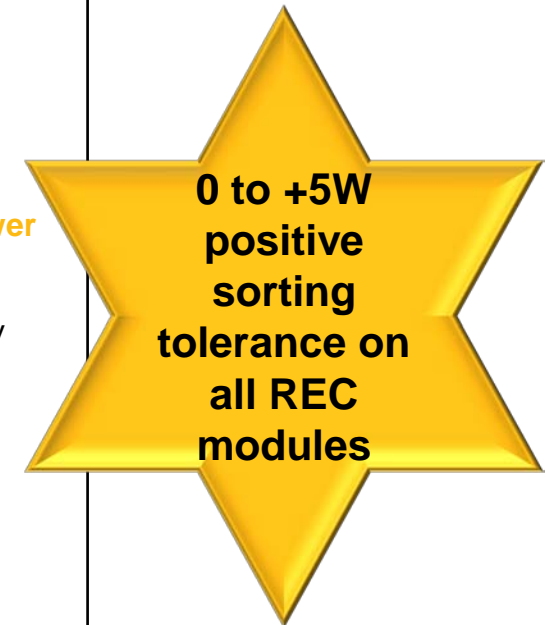
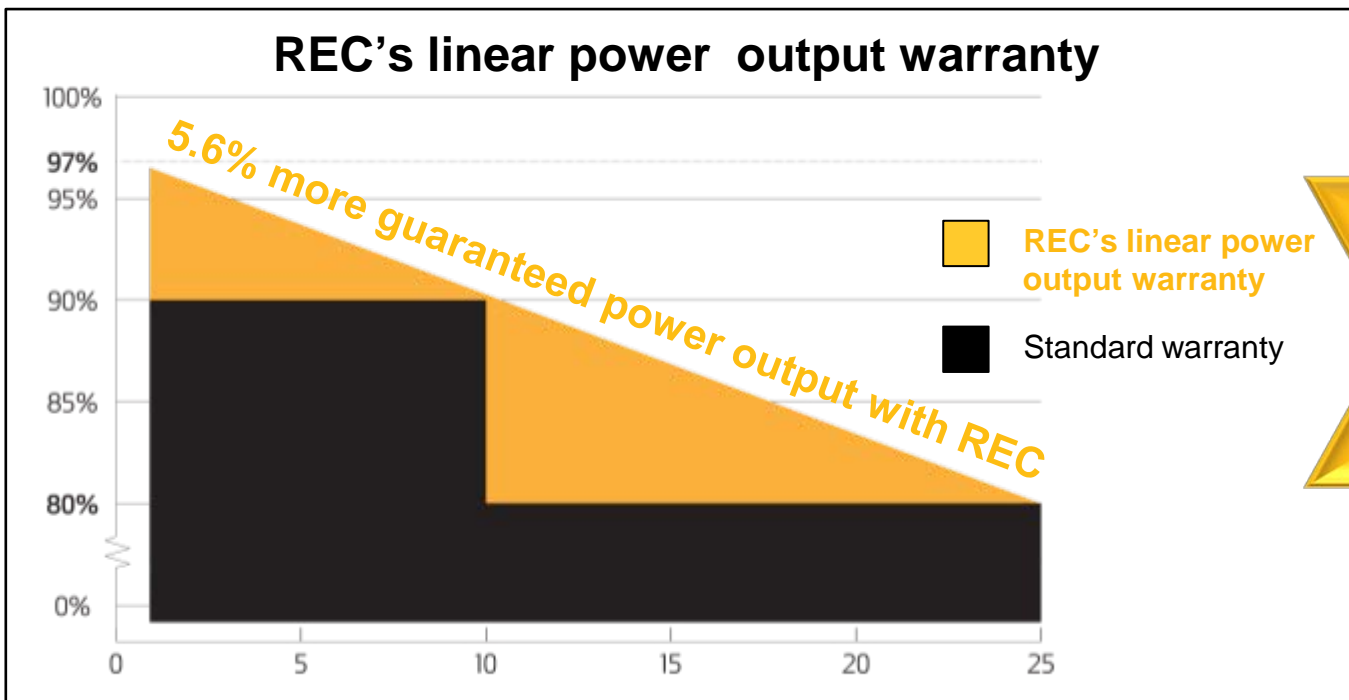


The REC warranty



REC's comprehensive product testing protocol enables us to offer an industry-leading warranty. This is our trust in the quality we produce.

A 10-year product warranty covers defects in materials and workmanship.



A 25-year Power Output Warranty covers the module's performance .

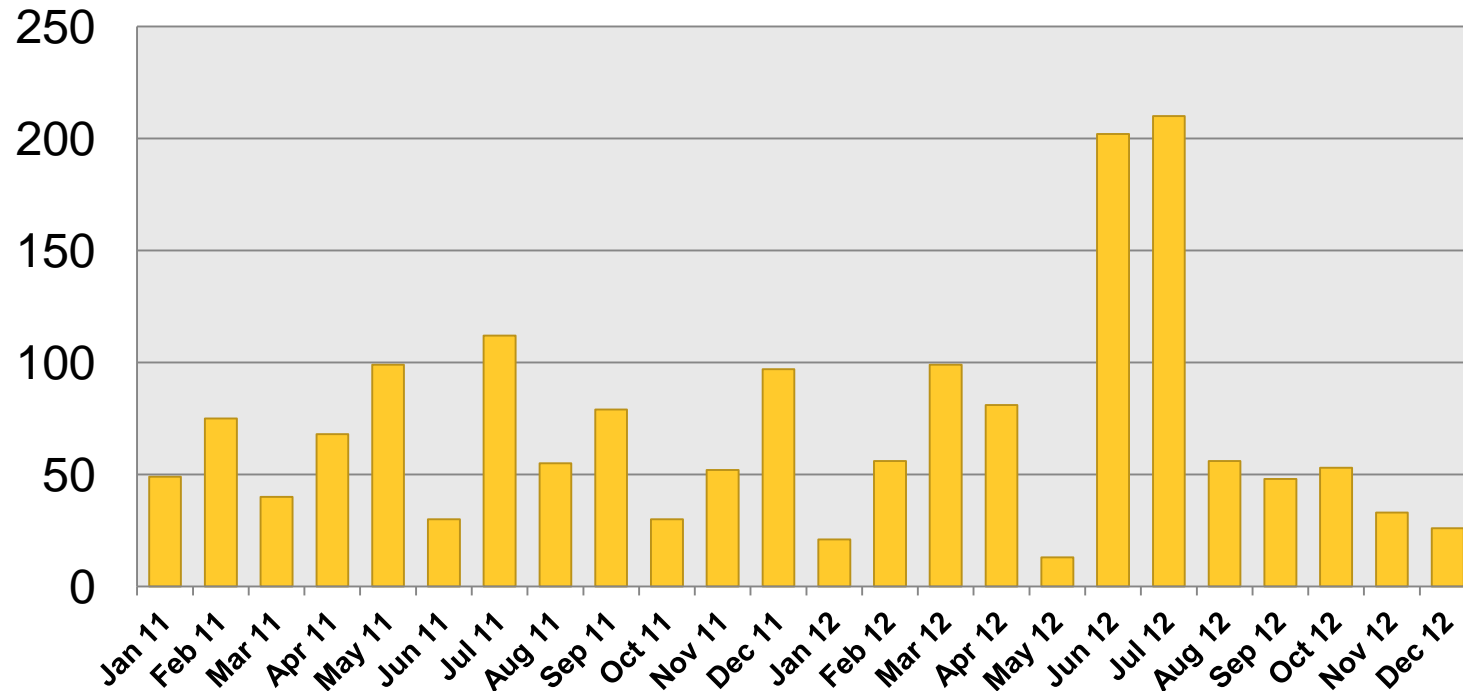
- Starting from 97% of nameplate power
- Maximum degradation of 0.7% per year

REC's low customer claims level is evidence of quality



- Reduced panel power or plant downtime will adversely affect the performance of a PV plant.
- Faults can occur at different times for many different reasons.
- One bad panel can affect the performance of an entire string of sub-array.

REC Warranty Claims (ppm)



REC takes warranty claims seriously



REC panels have a very low claims rate (ppm).

- Power Output claims are **extremely rare**
 - backed up by feedback from customers on the higher than expected yields of REC panels.
- REC averages less than 100 claims per million modules – a world class figure.
- REC targets a resolution of all customer claims within 14 days.
- REC claims are dealt with by a dedicated team of people across the globe.
- The highly automated manufacturing process gives product reliability and manufacturing repeatability.



- Quality throughout is the highest priority at REC.
- Quality is built into our business practice and culture.
- Our products are tested under significantly more demanding conditions than what is required by international standards.
- The highly automated manufacturing process gives reliability and repeatability.
- Our reputation for quality is supported by our field performance, low claims rate and third party audits.



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