Quality Controlled PV - ensuring superior & consistent performance & reliability with continuous third party oversight

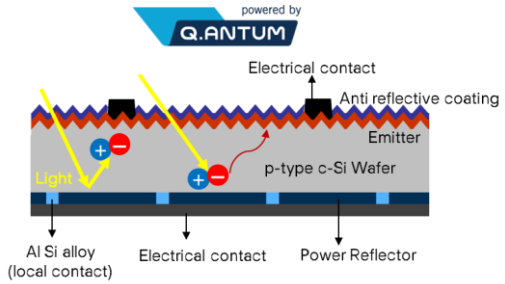
Max B. Koentopp, Global R&D, Germany

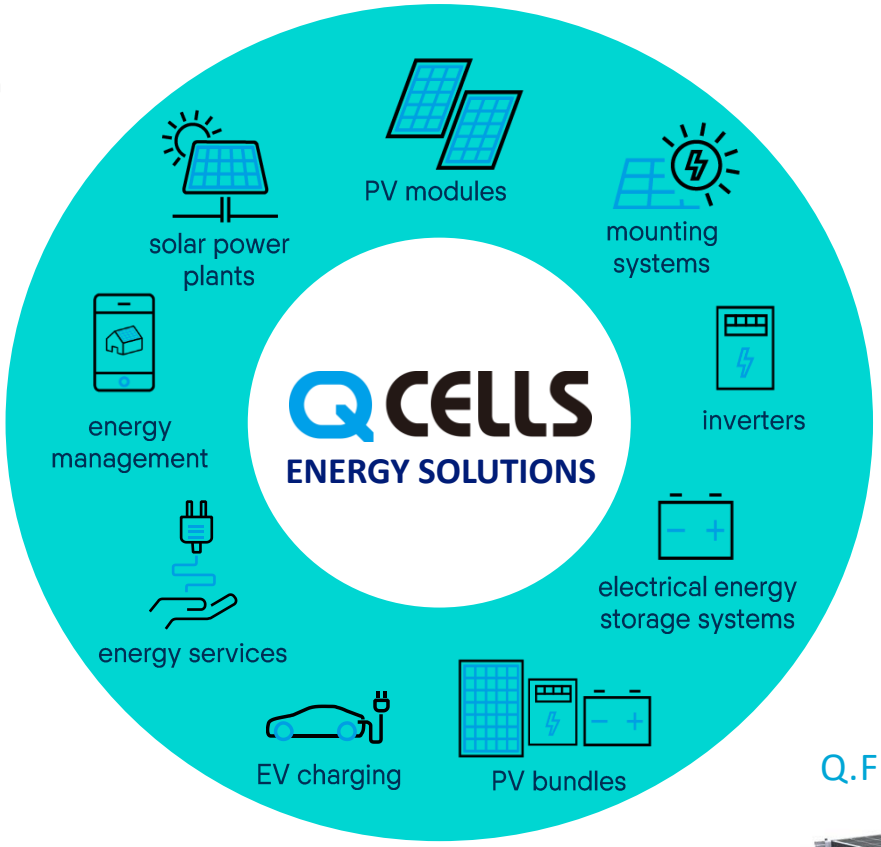
Outline

Introduction	Who we are Q CELLS US manufacturing Global R&D in Germany
Quality Controlled PV (QCPV) Program with TÜV Rheinland	Ensuring consistency & reliability on a global scale Part I : Product Qualification Part II : Continuous Testing Part III: Material Monitoring
Long term verification	Degradation rates from our test field installations
The new Q.TRON Modules	Superior performance & reliability based on Q.UANTUM NEO technology

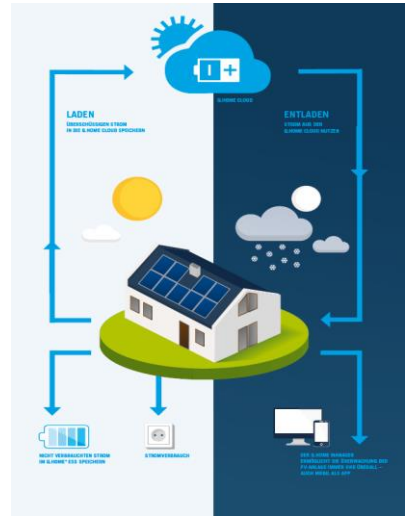
Q CELLS Energy Solutions

Q CELLS
Yield Security

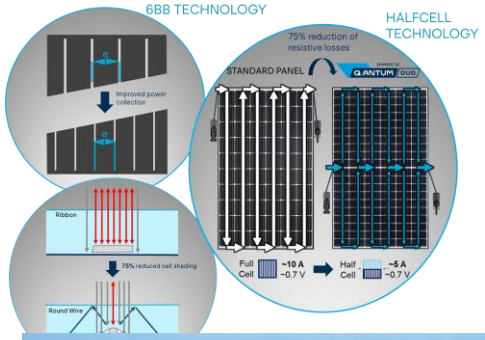




Q.HOME CLOUD



Q.HOME+ ESS HYB-G2/G3



Q.FLAT

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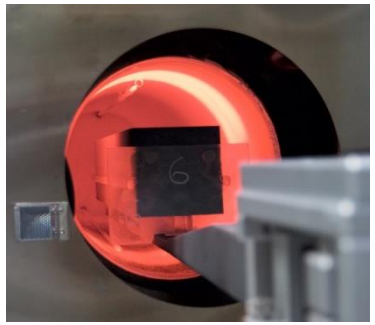
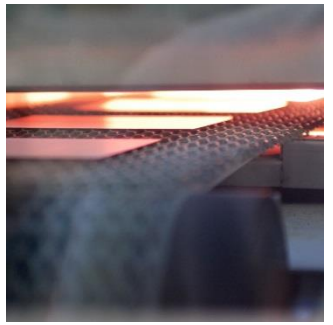
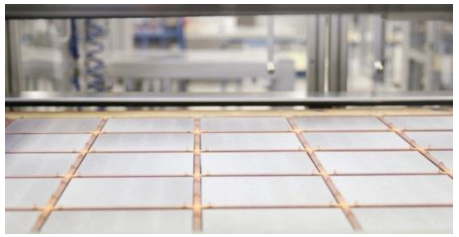
Q CELLS US Plant - Dalton, GA

- opened in 2019
- 1.7GW annual module production capacity
- 1.4GW extension currently under construction
- ramp-up of new capcity in first half of 2023

Global R&D in Germany







R&D Center
– Advanced Solar PV Research –

Development of next generation solar cell & module technologies & manufacturing processes

About 200 people in R&D

Pilot Line
– For cell and modules –

Rapid transfer to production

Mass Production
– Superior Support–

Global support

Ensuring Reliability on a Global Scale

Unique Challenge: Industry specific long warranty periods of 25+years

- Test protocols that allow qualification times of a few months while guaranteeing a service life of 25 years needed

Extended stress test protocol IEC TS 63209 & third party verification programs such as PVEL PQP used widely

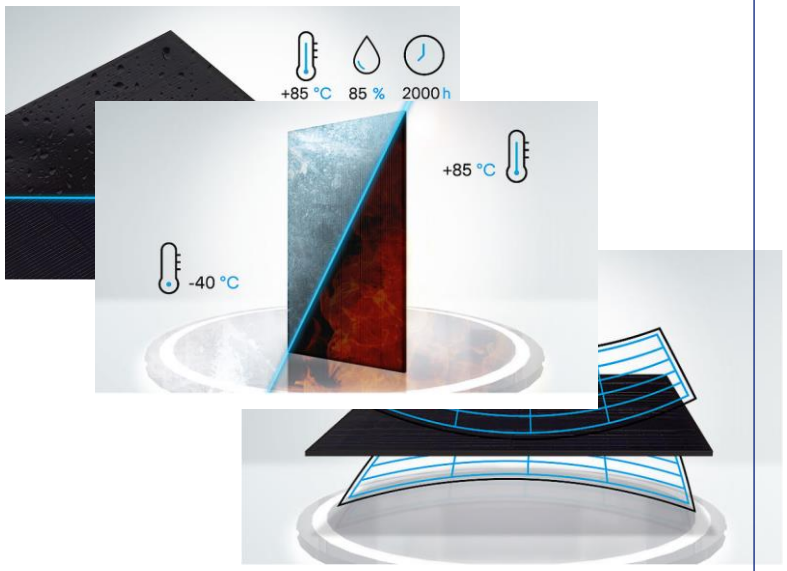
- Reduce customer specific testing requests, sampling audits, witnessing, special requirements
- How can **effort and lead time** be reduced further and third-party oversight already built in from the start?
- **Qcells developed Quality controlled PV program together with TÜV Rheinland, introduced 2021.**

Quality Controlled PV Program (QCPV)

Quality Controlled PV
TÜVRheinland CERTIFIED
www.tuv.com ID 1111232615

Part 1: Initial qualification

- Test thoroughly
- Over 40 individual, realistic and harsh tests
- Based on IEC TS 63209 extended stress testing
- Include tests for recent failure modes

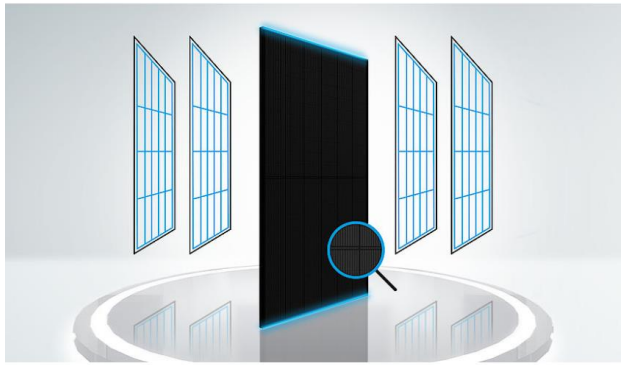


Long term durability of product verified

Modules will meet warranty promises

Part 2: Monitoring of production

- Test continuously
- Random sampling of production to guarantee consistent product quality and durability
- Sampling supervised by independent TÜV Rheinland experts
- TÜV Rheinland witnessing of reliability tests in Germany, Korea, Malaysia and China.



High quality of production verified

All supplied modules have same high quality

Part 3: Monitoring of material & supplier

- Ensure and continuously monitor incoming material quality in mass production
- Specialized tests to immediately detect variations in component & material quality
- Check of supplier via audits and change control

High quality of used material verified

No unexpected issues in the field

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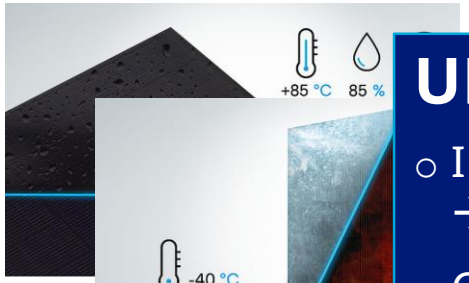

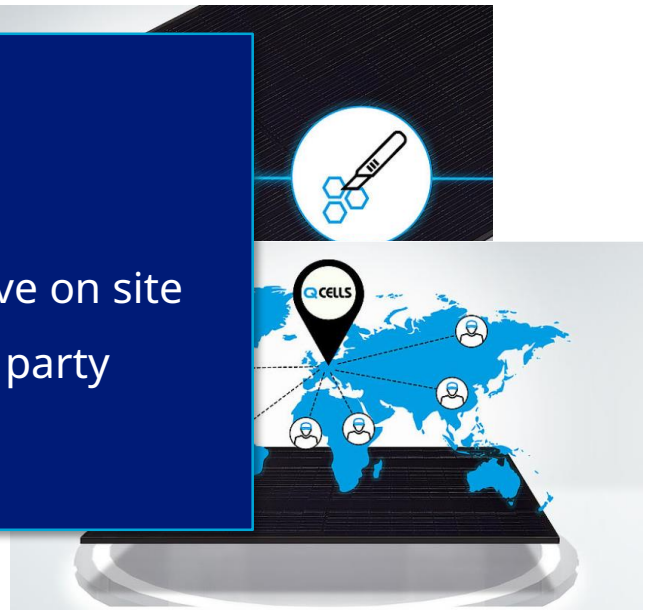

UNIQUE IN THE PV INDUSTRY:

- IEC 63209 extended qualification already included for all products
  → no need for third party sampling
- Comprehensive third-party oversight via TÜV Rheinland representative on site
- Continuous monthly monitoring of mass production w/ random third party sampling
- Continuous monitoring of material & supplier

Long term durability of product verified

Modules will meet warranty promises

High quality of production verified

All supplied modules have same high quality

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No unexpected issues in the field

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Where We Test: Our Module Test Centers

Germany - one of the largest module test labs in the world

- 30+ climate chambers
- 4 light soaking chamber, 4 UV-systems
- 4 mechanical load testers
- 3 flasher systems (bifacial, incl. EL, dry, wet isolation, high potential)
- many proprietary test setups for known failure modes
- annual throughput > 4000 modules

Additional large module test centers

- Korea
- Malaysia
- China

- aligned procedures defined by Global R&D in Germany
- regular audits and trainings by German R&D
- throughput of many thousand modules per year
- TÜV Rheinland employees permanently present at each lab. Testing performed under their supervision
- accredited test results and certificates

Part I: Initial Qualification

Extended initial certification (based on IEC TS 63209)

IEC 61730/61215 only covers early failures

IEC TS 63209 extends this for select failure modes→ best practice

- 600 cycles Temperature Cycle (TC) test (3xIEC)
- 2000 h Damp Heat (DH) (2xIEC)
- backsheet UV sequence (aligned with IEC TS 63209 in new edition)
- static+ dynamic load test followed by TC + HF
- PID
- LETID

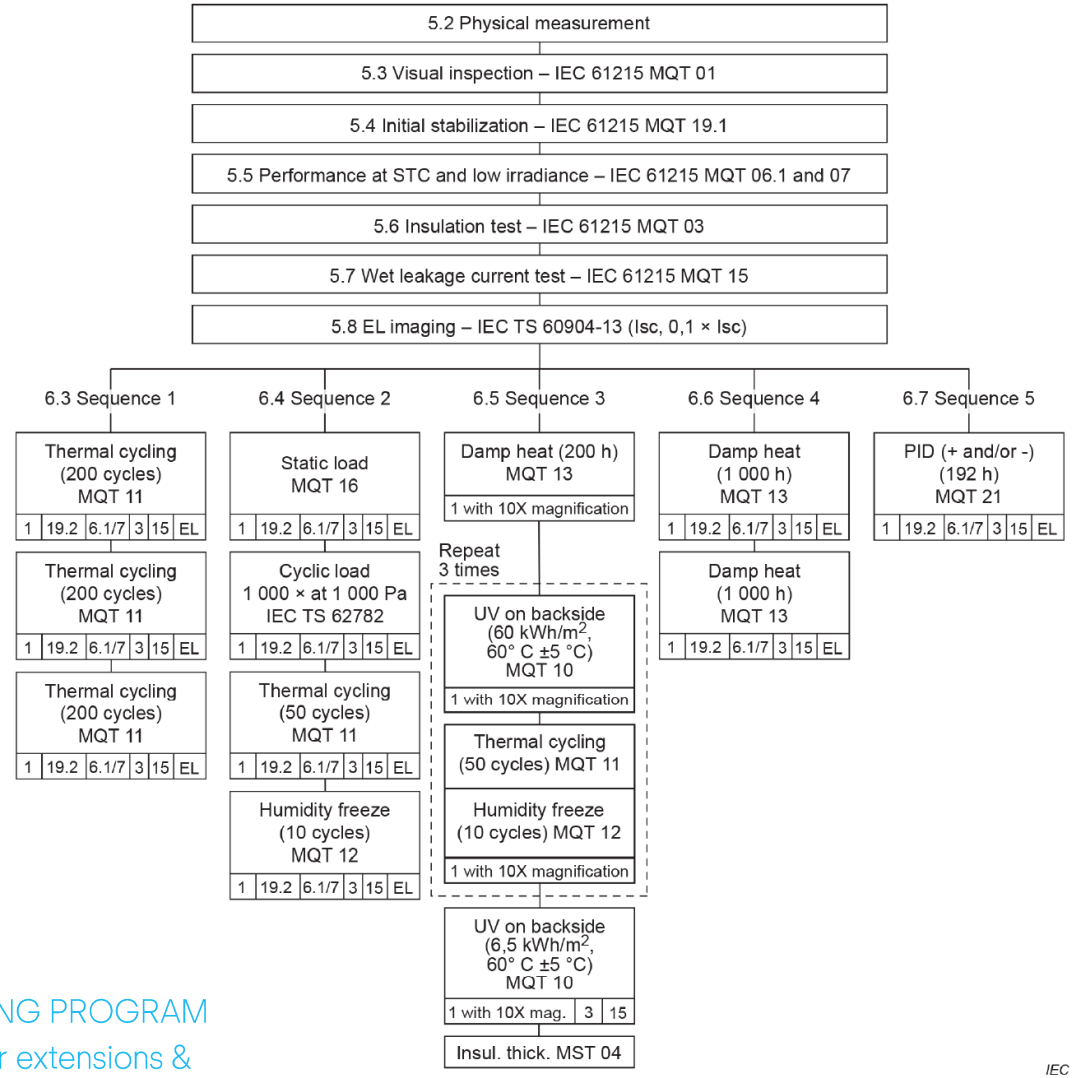
TÜVRheinland® CERTIFIED
Quality Controlled PV
www.tuv.com
ID 1111232615

2nd edition of QCPV aligned with coming edition of IEC61215/61730
→ will be rolled out together

Add realistic tests for known failure modes

- extended polymer materials qualification (e.g. UV & humidity)
- many other proprietary tests

IEC TS 63209-1:2021 © IEC 2021



LEARNING PROGRAM
Regular extensions & updates
Based on industry requirements & observations

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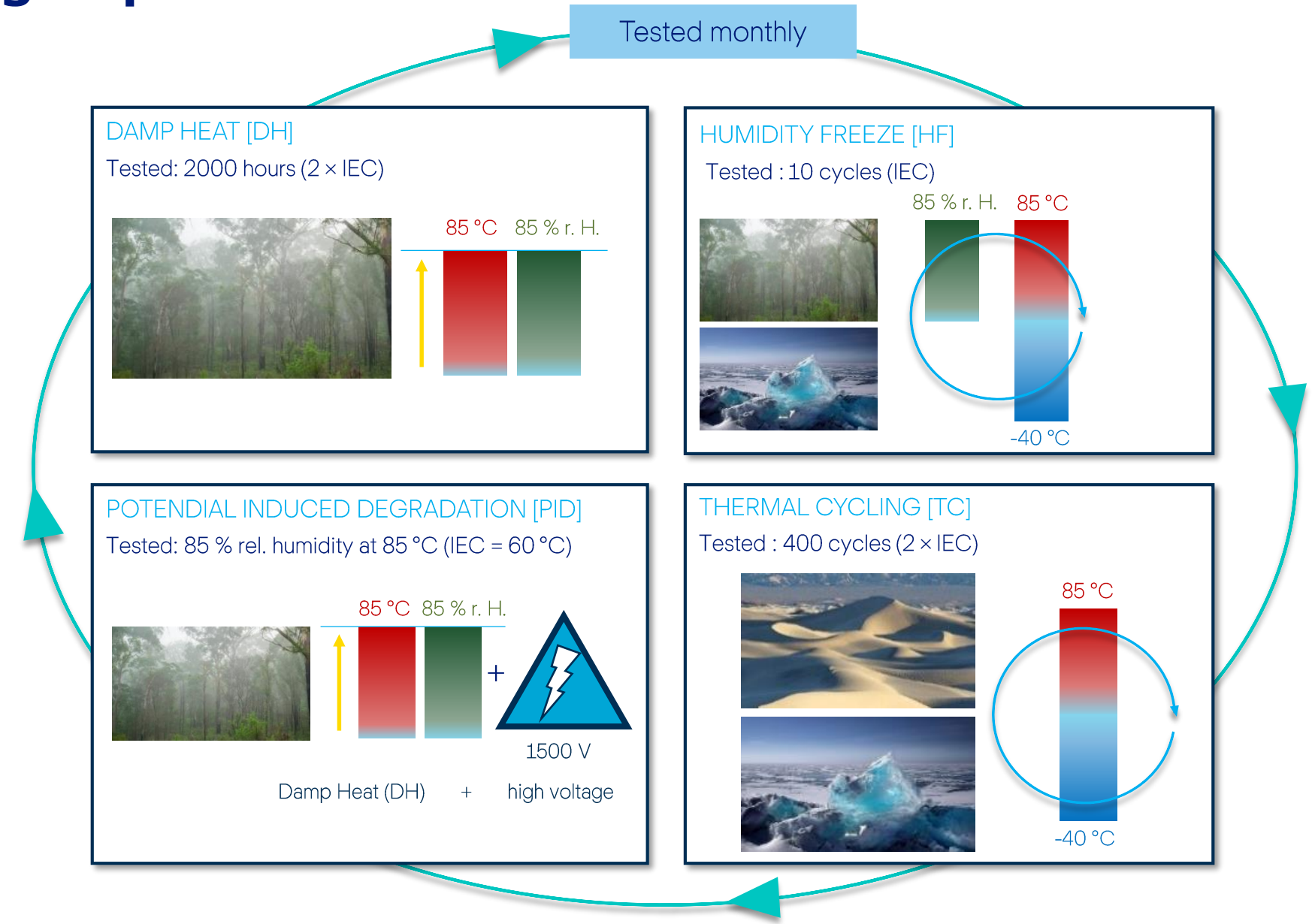
Part II: monitoring of production

- rolled out with G9 in 2020
- Monthly random sampling & durability testing
- regular testing of full IEC TS 63209 sequence including random sampling
- third party witnessing
  → built in third-party durability verification program as an alternative to programs such as PQP
- removes need for individual customer testing programs
  →saves lead time, cost & effort for projects



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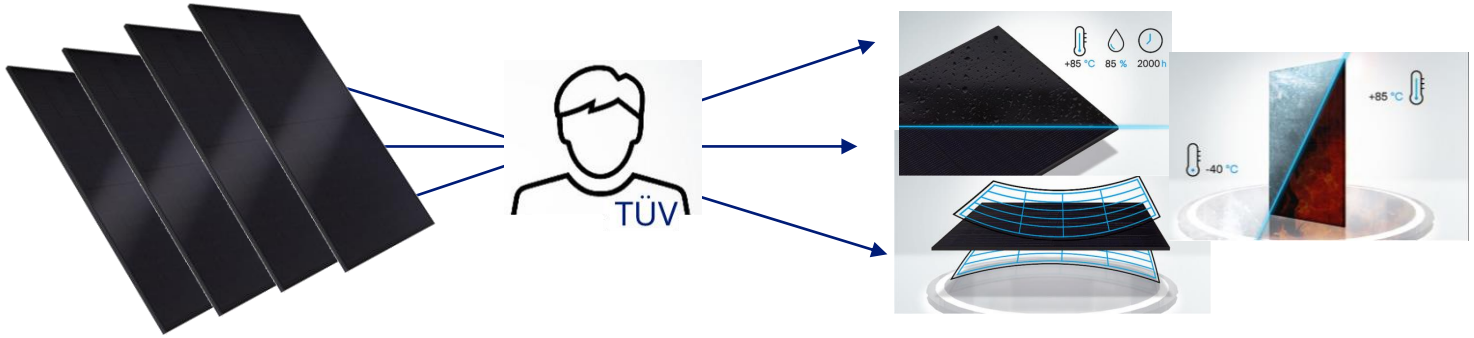
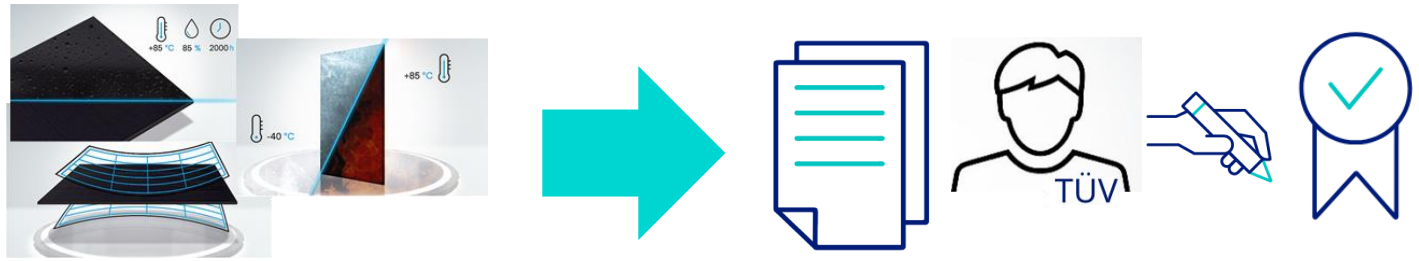
Part II: monitoring of production

1. Random sampling at every production site by TÜV Rheinland (RH) representative.

2. TÜV RH representative randomly assigns each module to one of the monitoring test sequences

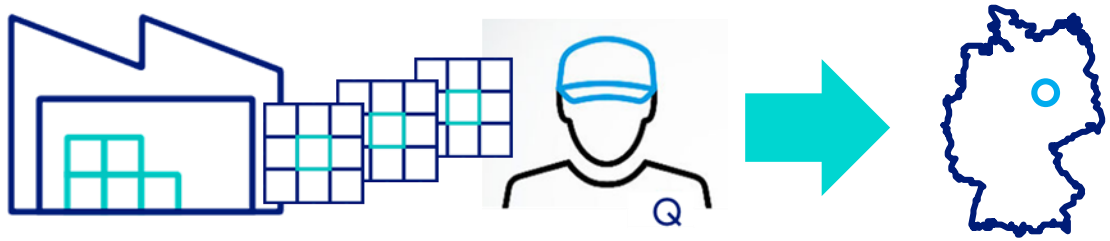


3. Tests are done under supervision by TÜV, a standardized test report is created and TÜV RH checks and confirms the report

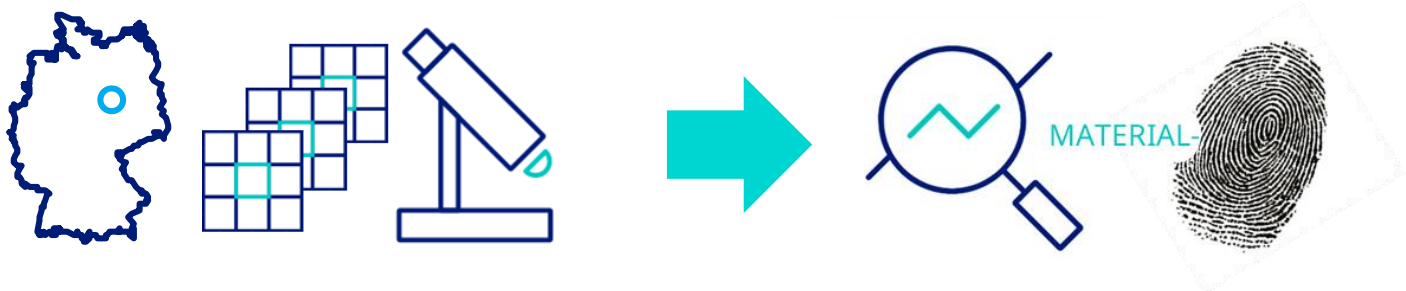


Part III: Monitoring of Materials

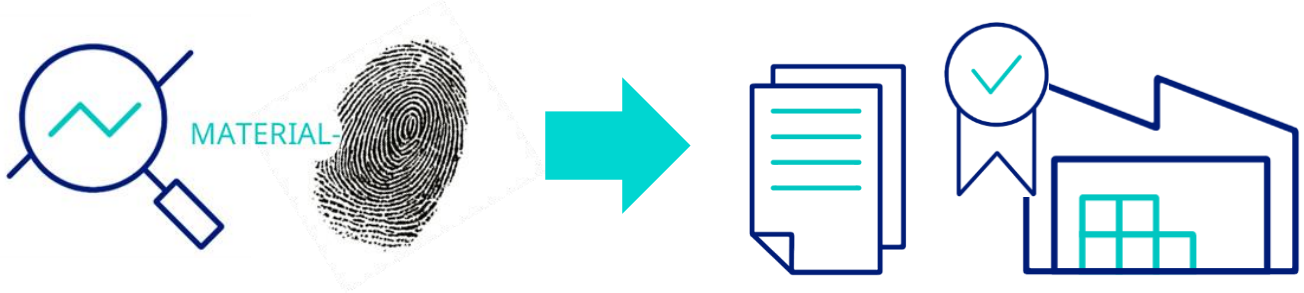
1. Monthly samples from current production lot sent to Germany for analysis & testing



2. Advanced chemical analytics & characterization methods for fingerprint determination



3. Results are verified against specification, uploaded in material fingerprint database & shared with production sites



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Part III: Monitoring of Materials & Supplier

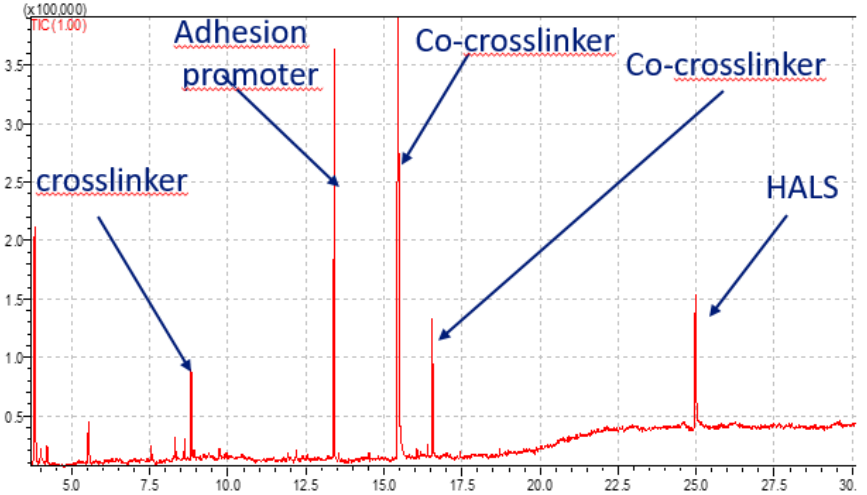
- Determination of material fingerprint
- Use of sophisticated test methods
- Ensures same material quality and characteristics by
  - continuous monitoring of material characteristics
  - **detection of issues** invisible in climate chamber testing

- Strict supplier & material specifications
- Comprehensive supplier audit program based on
  - risk classification of materials
  - previous experience with suppliers
  - special focus on core materials

Examples for fingerprint monitoring:

EVA:

- GCMS, DSC – verify composition & additives



Backsheet:

- GCMS, DSC – verify composition & additives
- Tensile test – verify mechanical properties

Paste:

- Chemical analysis – verify composition & properties

Backsheet Tensile Test

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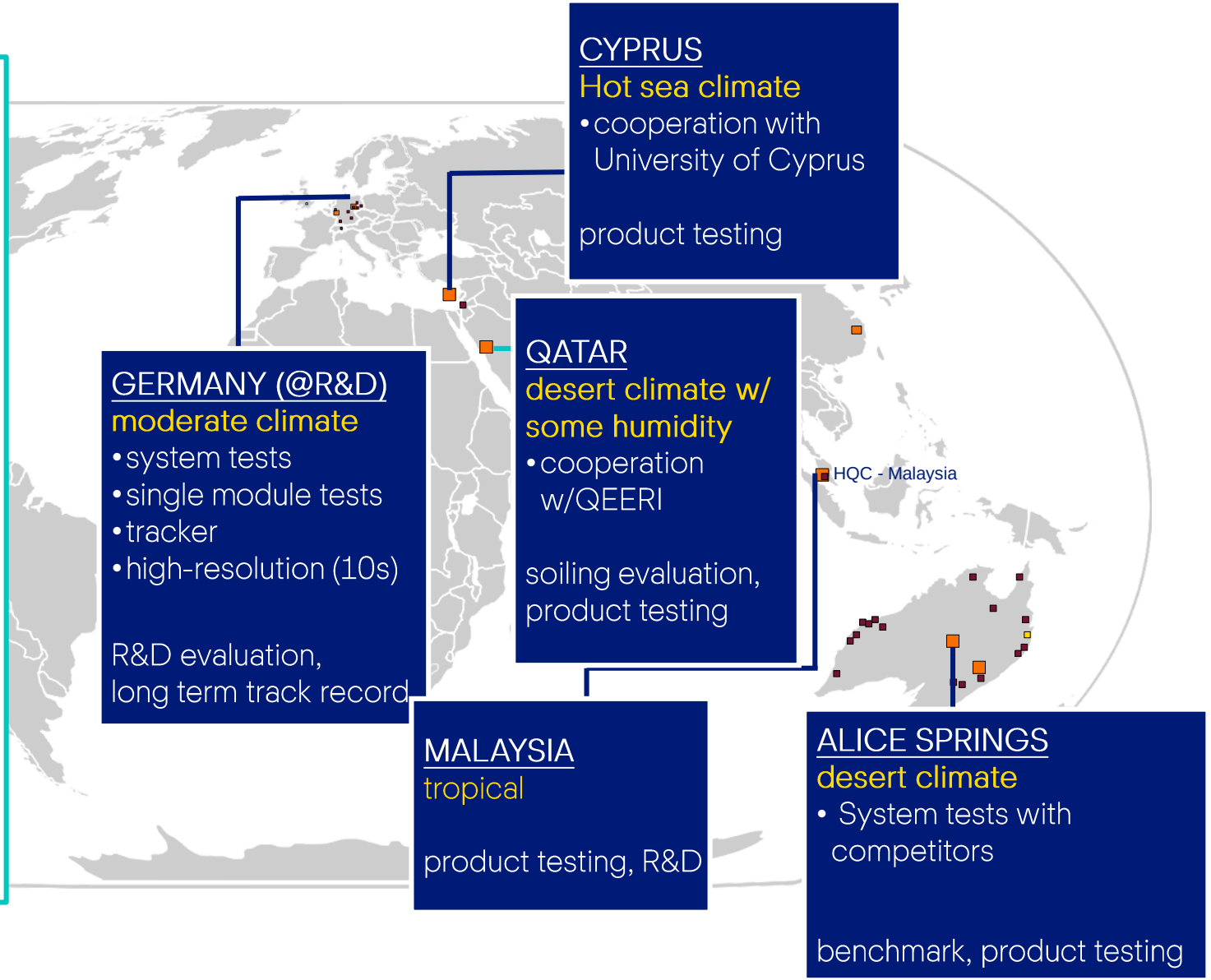
Long Term Verification: Global Test Sites

Target

- ✓ Reliability data in different climate zones
- ✓ Verification of modelled energy yield with real outdoor results
- ✓ Degradation rates
- ✓ Evaluation of new technologies

Properties & Design

- ➢ Precision metrology, calibrated regularly
- ➢ Data every 10 sec
- ➢ Optimal orientation and inclination
- ➢ Comparable set up (inverter / system components/ monitoring)



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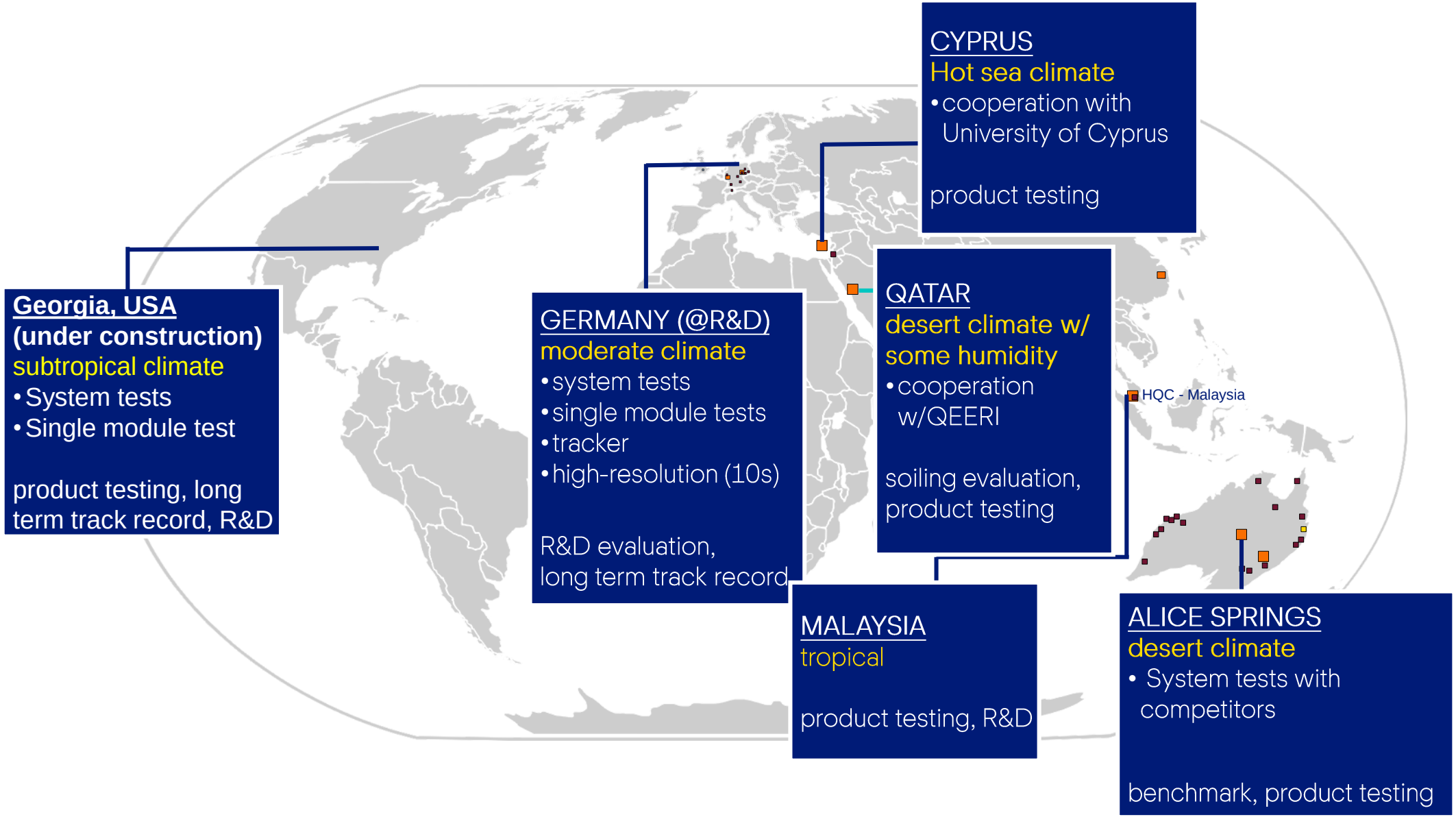
Long Term Verification: Global Test Sites



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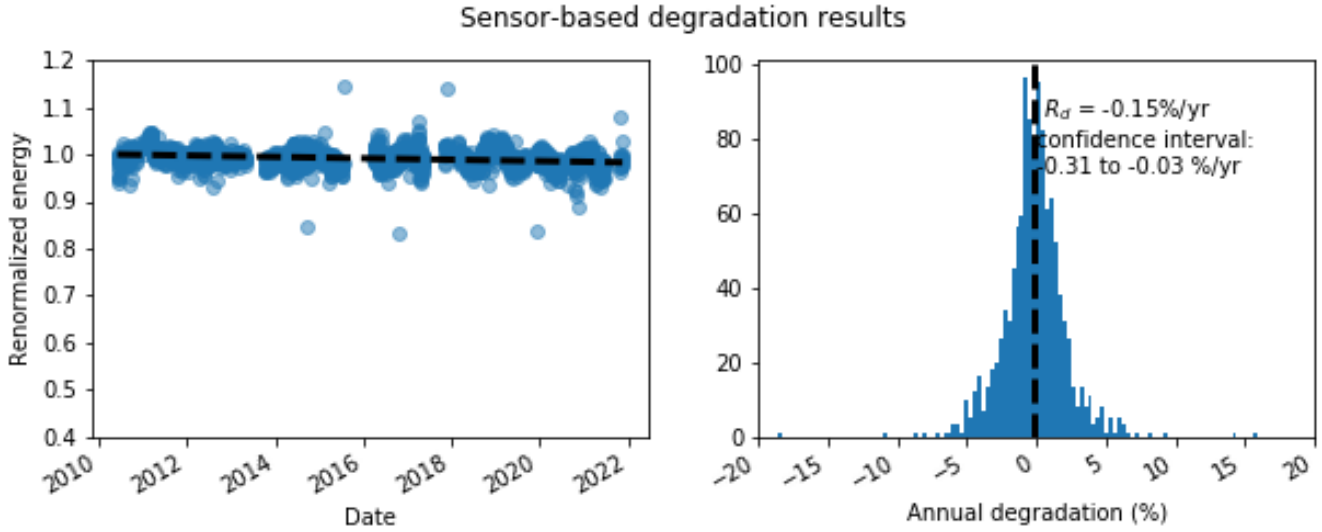
Long Term verification: Degradation rates

- Monitoring of all relevant product generations for 25 years
- RdTools used for degradation rate determination

- **oldest system from 2010** **-0.15% / a**
  12 multicrystalline modules

Location:
Bitterfeld, Germany



https://github.com/NREL/rdtools

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Long Term verification: Degradation rates

- Monitoring of all relevant product generations for 25 years
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- oldest system from 2010 -0.15% / a
  12 multicrystalline modules

- **oldest Q.ANTUM system from 2013 -0.40% /a**
  10 early Q.ANTUM modules

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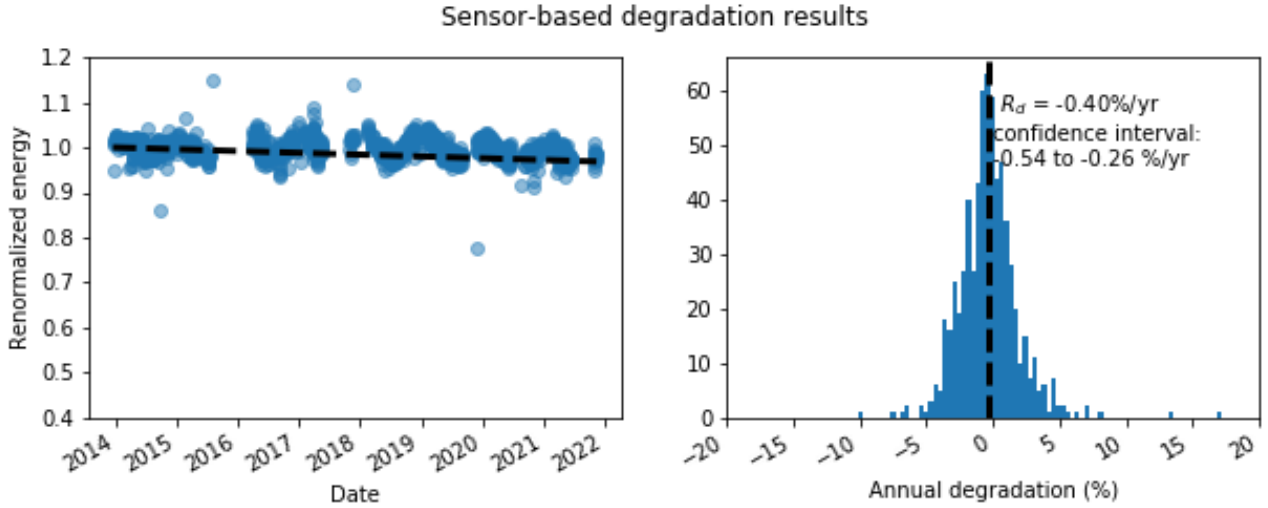
Bitterfeld, Germany



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Long Term verification: Degradation rates

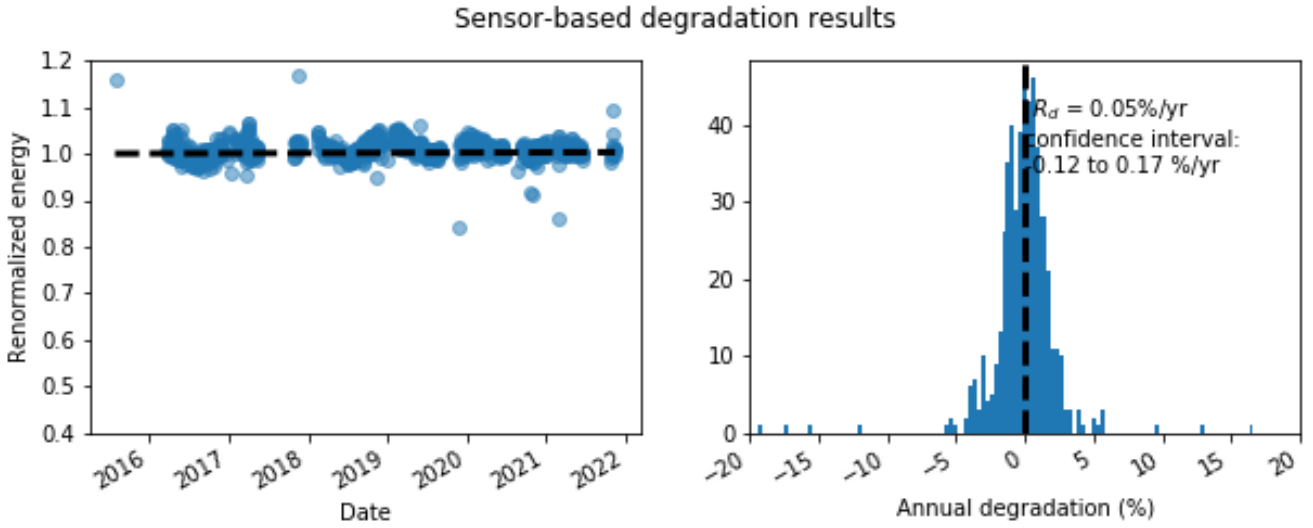
- Monitoring of all relevant product generations for 25 years
- RdTools used for degradation rate determination

- oldest system from 2010 -0.15% / a
  12 multicrystalline modules

- oldest Q.ANTUM system from 2013 -0.40% /a
  10 early Q.ANTUM modules

- **Q.UANTUM system from 2015 -0.05% / a**
  10 Q.PEAK Q.ANTUM modules

Location:
Bitterfeld, Germany



Very stable performance observed with degradation rate well within warranty

https://github.com/NREL/rdtools

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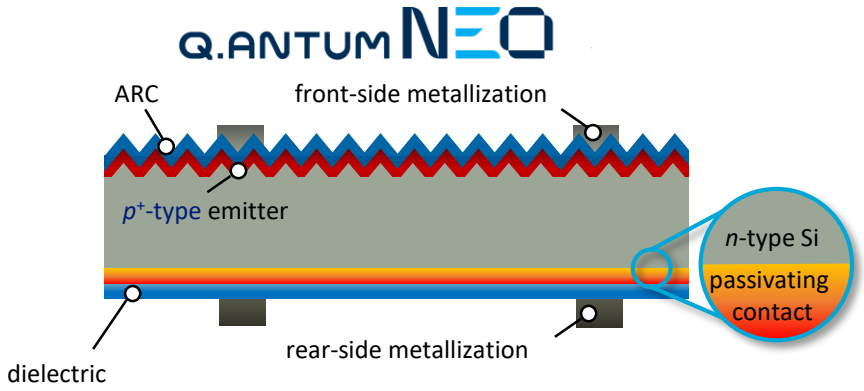
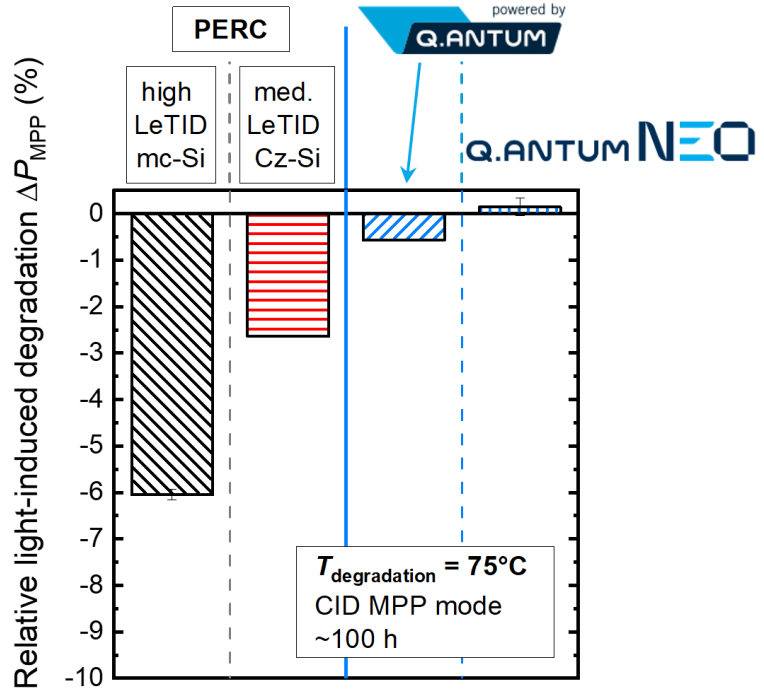
Outlook: Qcells Q.UANTUM NEO Technology

→ **incorporating passivating contact technology**



- **Passivating rear-side contact**
- ***n*-type Cz silicon substrate**
- Lean & cost-effective process
  (HE, ARC module optimized, screen print, …)
- comaptibile w/ standard Q.antum module technology
- **Efficiency headroom > 25%**



- Effective suppression of degradation effects:
  no PID, LID, LETID

- Low temperature coefficient
  a_{PMPP}**= -0.30%/K** due to high Voc

→ **Several percent higher specific energy yield (location dependent)**

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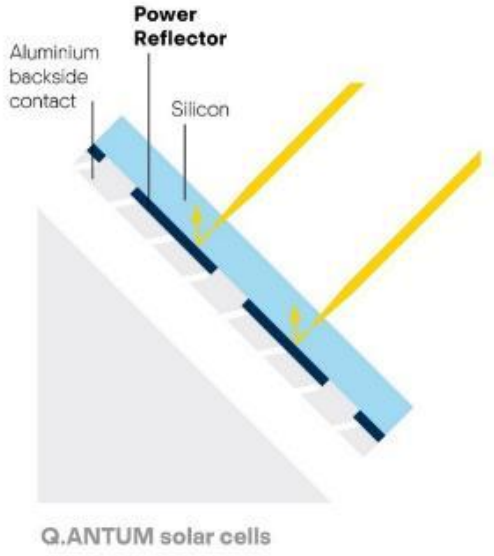
Qcells Module Technology -- The Q.TRON Module

SOLAR CELLS
powered by Q.ANTUM

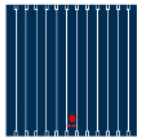
- Commercialized **9+ years** ago
- Billions of Q.ANTUM cells
- **More than 23 GW** of Q.ANTUM solar modules



MODULE TECHNOLOGY
powered by Q.ANTUM DUO

- **More than 10 GW** of Q.ANTUM DUO modules produced
- Intersolar PV Award 2018
- PVEL Top Performer 2019-2022

Multi Busbars

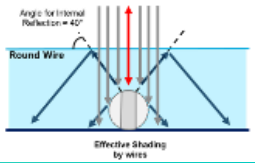


Reduced electrical losses due to shorter distances 6/12 BB technology → +1.0-2.0% Power

Half-cells

+3.0% Power

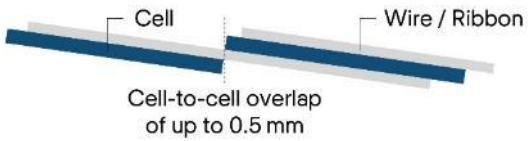
Round wires



+2.5% Power

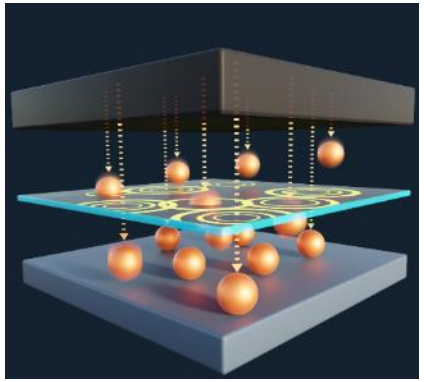
ZERO-GAP TECHNOLOGY
powered by Q.ANTUM DUO Z

- Optimum use of space
- Continuity of Q.ANTUM DUO Technology
- Compatible with proven production methods for highest performance, quality & reliability



Q.TRON
Q.ANTUM NEO

- Larger wafer (166mm)
- NEO Power Transmitter on cell level for highly reduced electrical loss on backside and leading cell & module efficiencies



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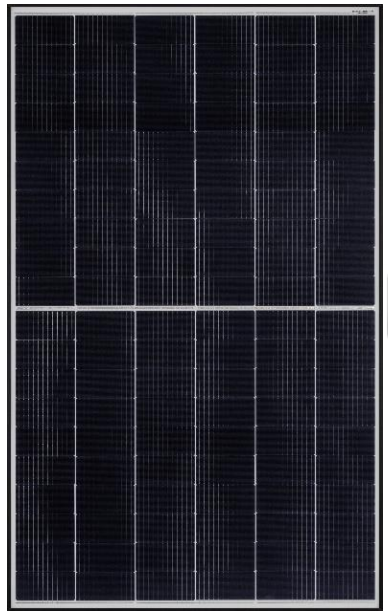
Q.TRON Modules

Q.ANTUM NEO



25 YR Warranty
Product & Performance

Q CELLS
Advanced
Yield Security

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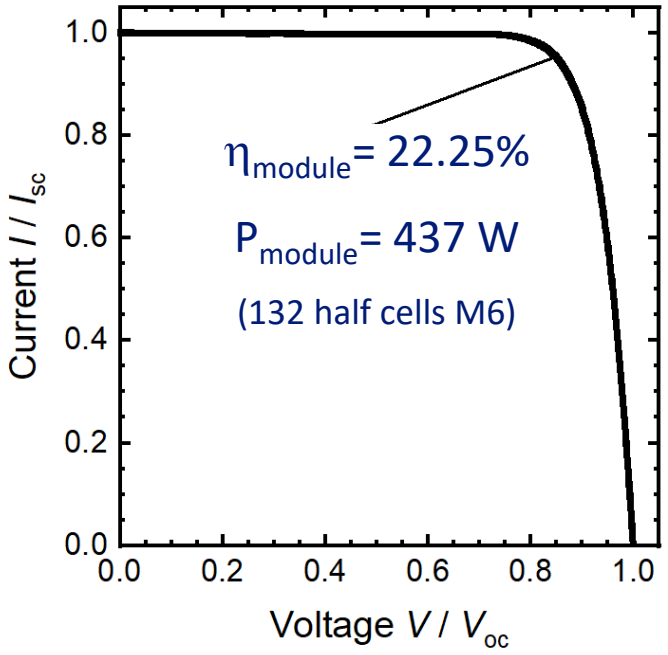
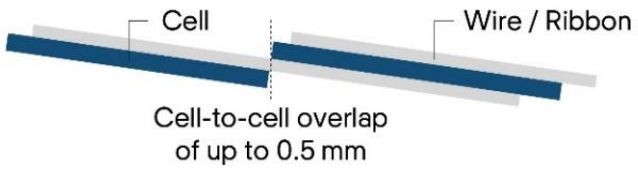


22.25% full-area module efficiency (437 W)
(full module size, 132 HC M6 layout)

CTM ~ 100%
w/ state-of-the art interconnection
(half-cells, multi-wire, zero-gap)

ZERO-GAP TECHNOLOGY



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Q.TRON – SOLAR MODULE PORTFOLIO

White

120 Cells

Q.TRON-G1+

400 Wp / 22.3 %

Black

120 Cells, All-Black

Q.TRON BLK-G1+

395 Wp / 22.0%

Q.TRON
with Q.ANTUM NEO

Higher performance in field conditions

+

Guaranteed: at least 90.58 % of the initial power after 25 years

+

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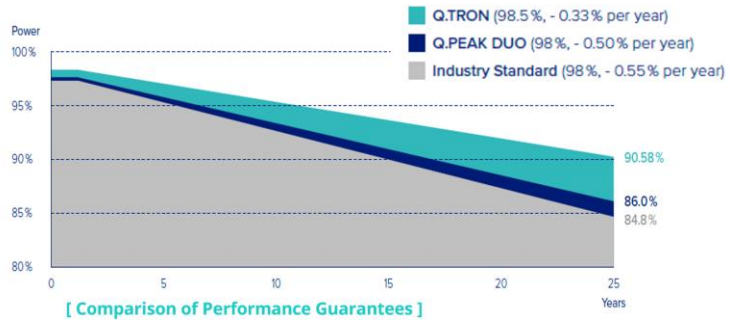
qcells Advanced Yield Security

25 YEARS Warranty Product & Performance



[Comparison of Performance Guarantees]

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Conclusion

Quality Controlled PV (QCPV)

- most extensive and stringent testing scheme available to date
- constant third party oversight and presence of TÜV Rheinland engineers at all test labs
- independent and random onsite testing of running mass production
- regular material fingerprint analysis and monitoring
  examples established: EVA, backsheets, metal pastes
- dynamically updated based on industry requirements
- Qcells is the first mover in the Quality Controlled PV program
- program has been running since G9; update will align it with IEC TS 63209 and upcoming editions of IEC 61215/61730

Qcells monitors performance of its products in test fields around the globe

- more than 10 years of field data show stable performance of Q CELLS products with degradation rates well within warranty

Q.TRON Module Introduction

- Q.ANTUM NEO cells boost module power to 400Wp & module efficiency to 22.3%
- Improved warranty and reliability
- Extension of Qcells Dalton, GA production site by 1.4GW

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Qcells
Advanced Yield Security

25 YEARS
Warranty
Product & Performance

qcells

We are hiring!

https://qcells.com/us/footer/careers-at-q-cells

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