cspservices
concentrating solar power services

Turning Free Sunlight into Bankable Power

Quality Assurance for CSP Plants

Dr. Klaus Pottler

CSP Services GmbH

Heliostat Consortium Resource, Training, and Education (RTE)

Zoom Seminar – 21 October 2026 - Host: Brooke Stanislawski

CSP Services

Who are we?

- Private company, found in 2007 as DLR-Spin-off
- Offices in Cologne, Germany and in Almería, Spain
- Workforce about twenty scientists and engineers
- Extensive experience regarding QA for CSP plant construction
- Recognized company for prototype tests and solar field quality assurance

Highlights

- Contribution to >90% of all installed CSP fields (outside China)
- Several hundred successful projects with more than 200 clients
- QDec: reference system for curved mirrors QC (>95% of global production)
- QFoto: used in trough assembly QC (>2.800 MW_{el} of steel structures)

Awards

- DLR Innovation Award: 2009
- CSPPLAZA Technology Innovation-Award: 2019
- SolarPACES Technology Innovation Awards: 2009, 2014, 2018, 2021, 2026















CSP Services

CSP Services turns scientific expertise into practical solutions:

Helping CSP projects improve performance, reduce technical risks, and operate more efficiently











CONTENTS

Part 1: Considerations about Bankability

Part 2: Experience from Historic CSP Plants: Building Trust or Caution?

Part 3: Improving Plant Quality through Standardization and Guidelines

Part 4: Ensuring Long-Term Investor and Lender Confidence through Rigorous Quality Control

PART 1

Considerations about Bankability

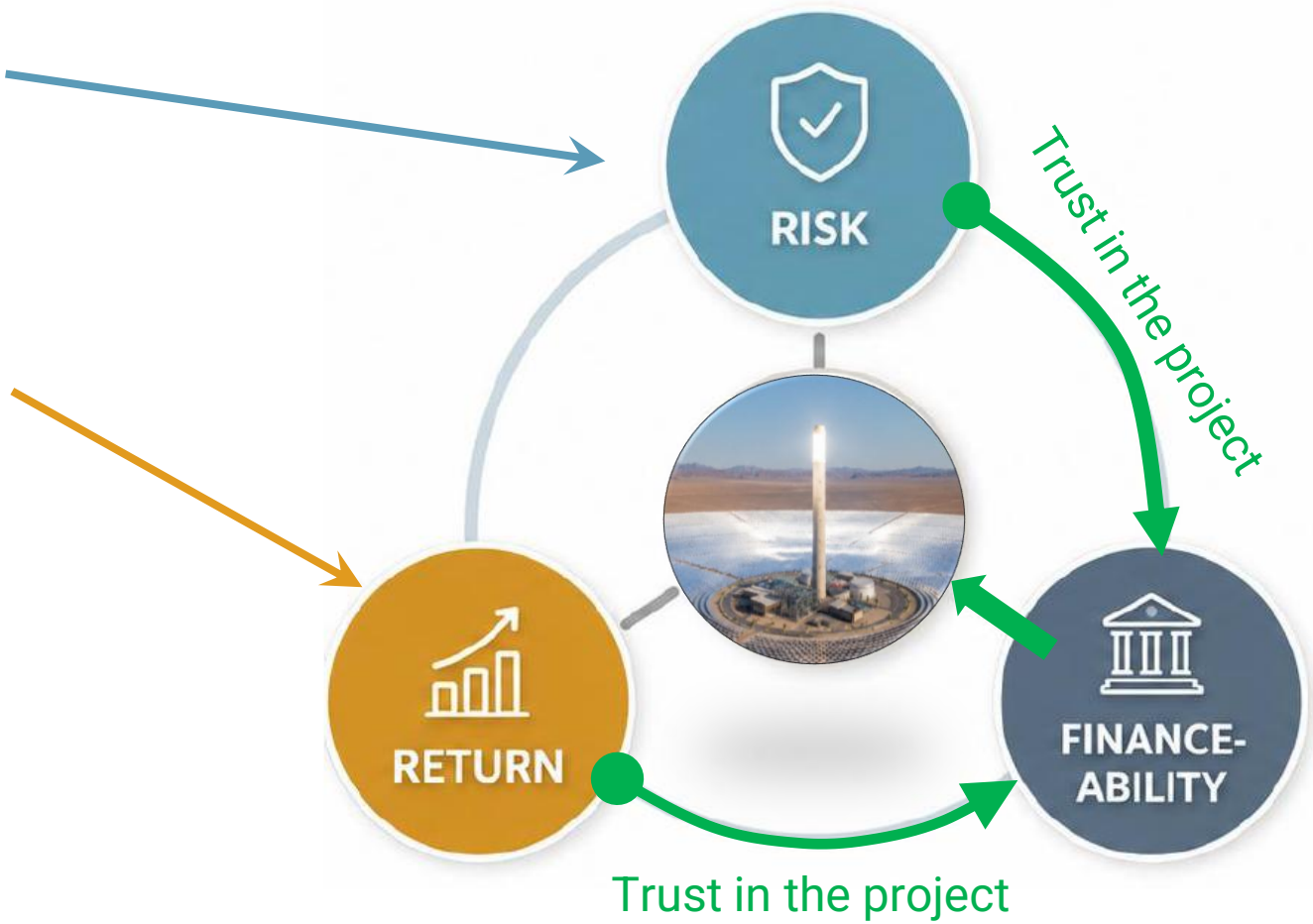
When is a project considered "bankable"?

Key questions from the **Lender:**

- Can the project reliably repay the loan, even if something goes wrong?
- **Will I get my money back?**

Key questions from the **Investor:**

- Will the project perform well enough to generate a good return on investment?
- **Will my investment make enough money?**



Original graph from: "Risk, Bankability & Mitigation in Renewable Energy Projects", Webinar QPQ International, 12 May 2026

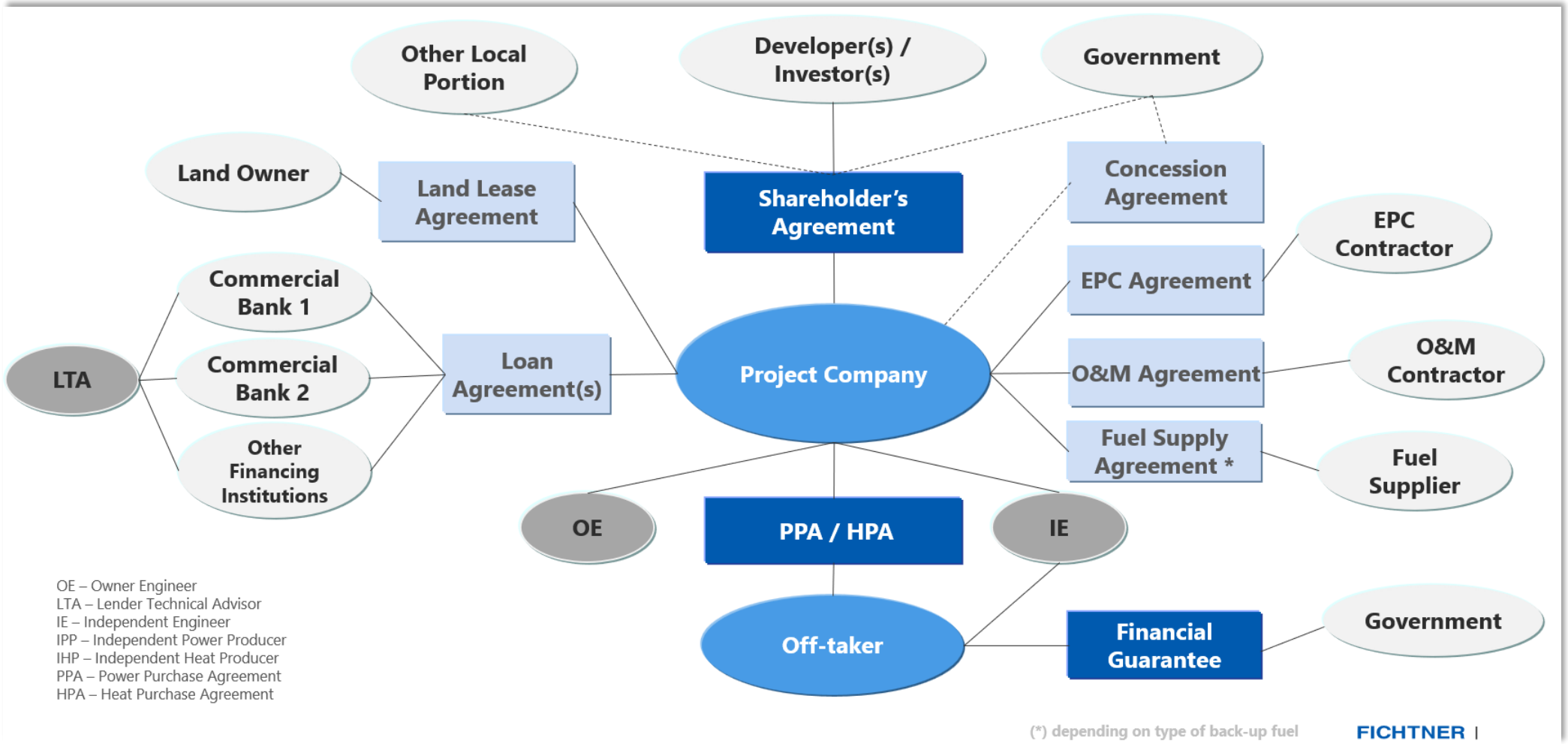
Maintaining trust with investors and lenders – or losing it?

Performance issues

Startup delays due to unexpected construction flaws	First-years underperformance due to unknown root causes	Long-term underperformance due to irreparable design or construction faults



From feasibility to operation: Stakeholder complexity



Excerpt from the presentation "From Feasibility to Operation: Making Solar Thermal Projects Bankable", SolarPACES 2026, Courtesy of Johannes Kretschmann, Fichtner GmbH & Co. KG

PART 2

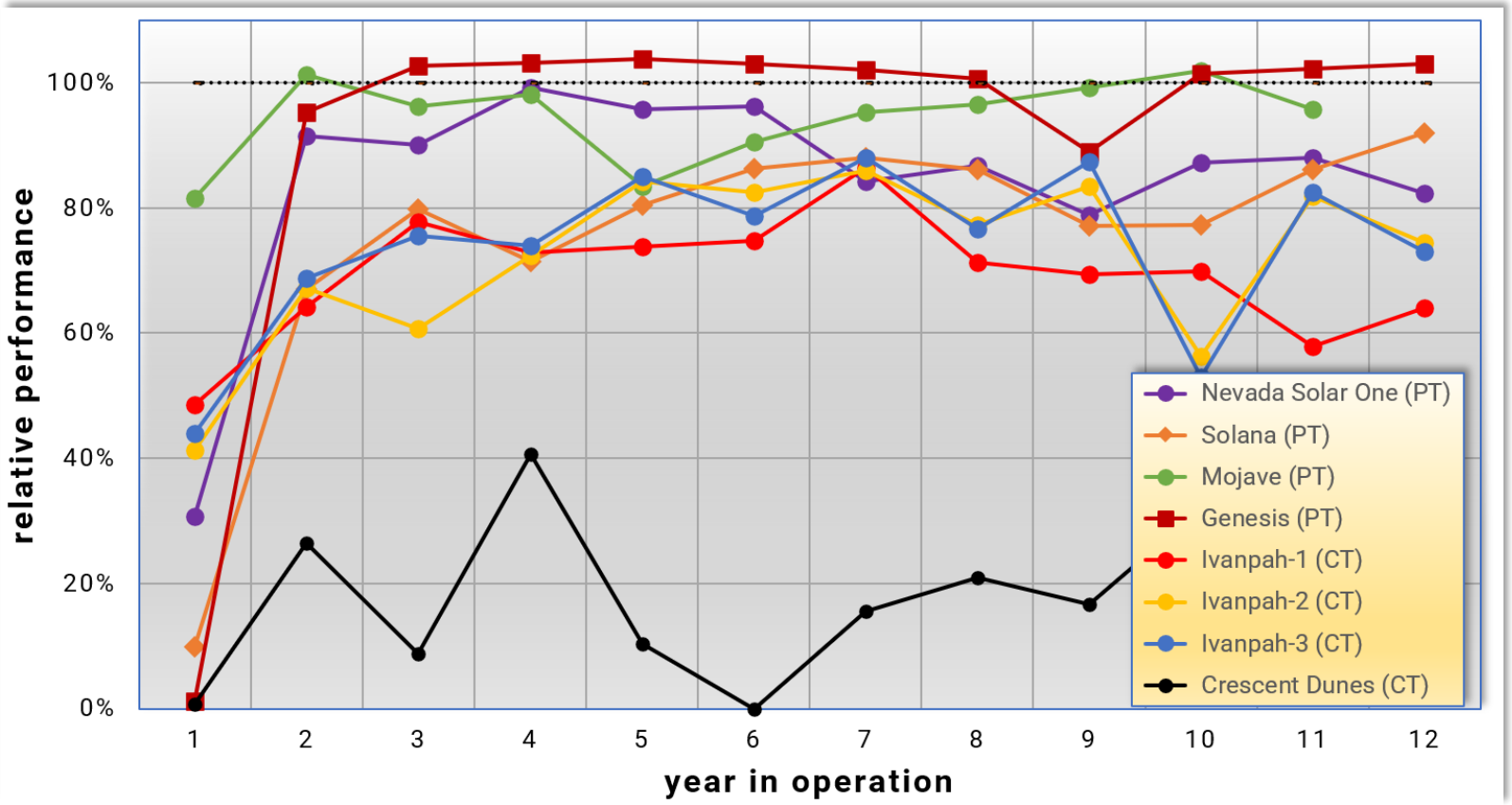
Experience from Historic CSP plants: Building Trust or Caution?

Historical performance of CSP plants in the USA

Historic performance data of second-generation US-plants show:

Source: https://www.eia.gov/electricity/data/eia923

- Startup needs time
- Only some plants perform close to design (especially “Genesis”)
- Many CSP plants fall short of their published design performance
  (Note: Published “100%” design values may not reflect the final as-built configuration due to changes during project development and construction)
- One plant never operated reliably (“Crescent Dunes”)



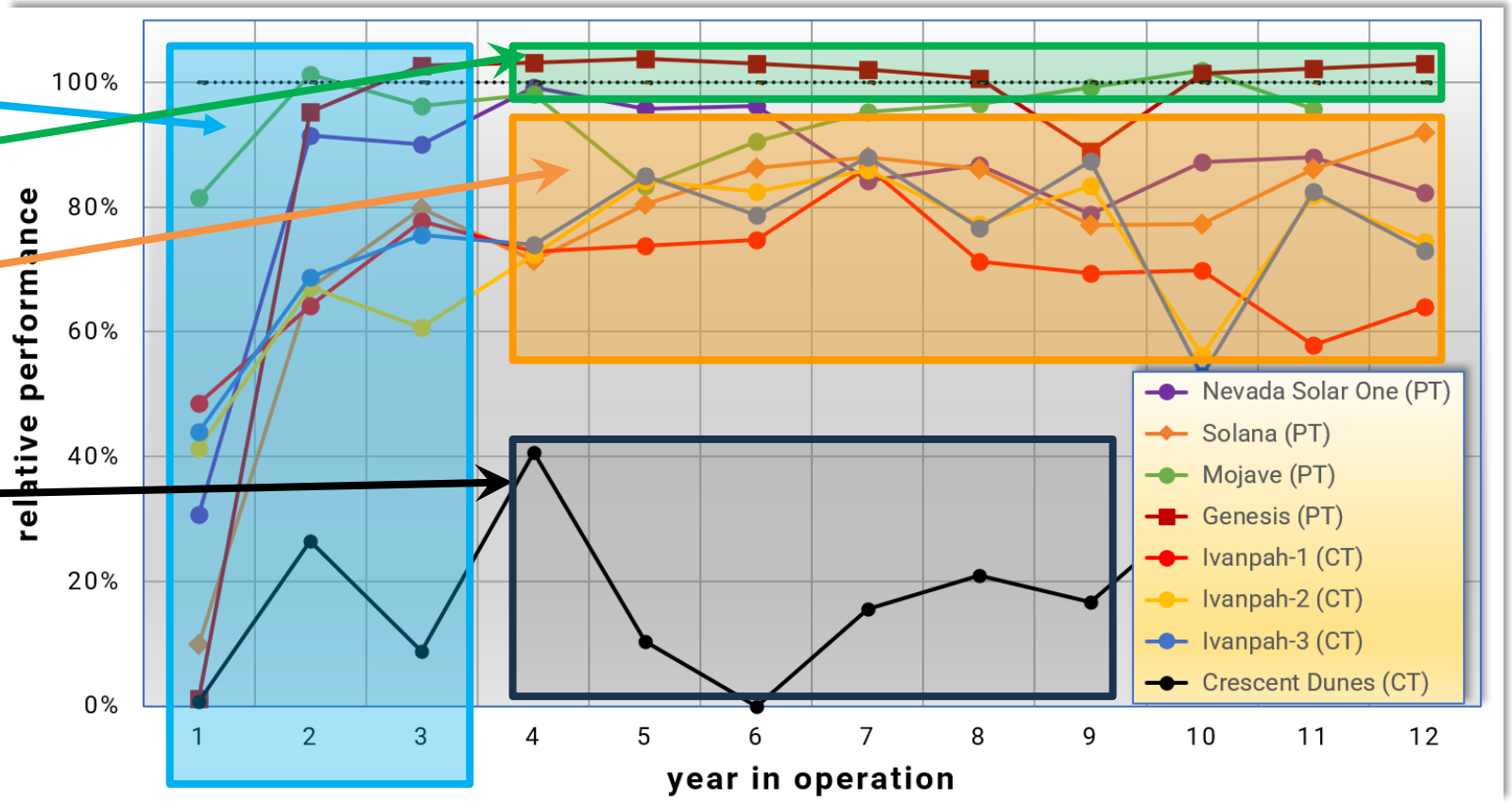
Published plant electricity output versus projected output of plants in the USA

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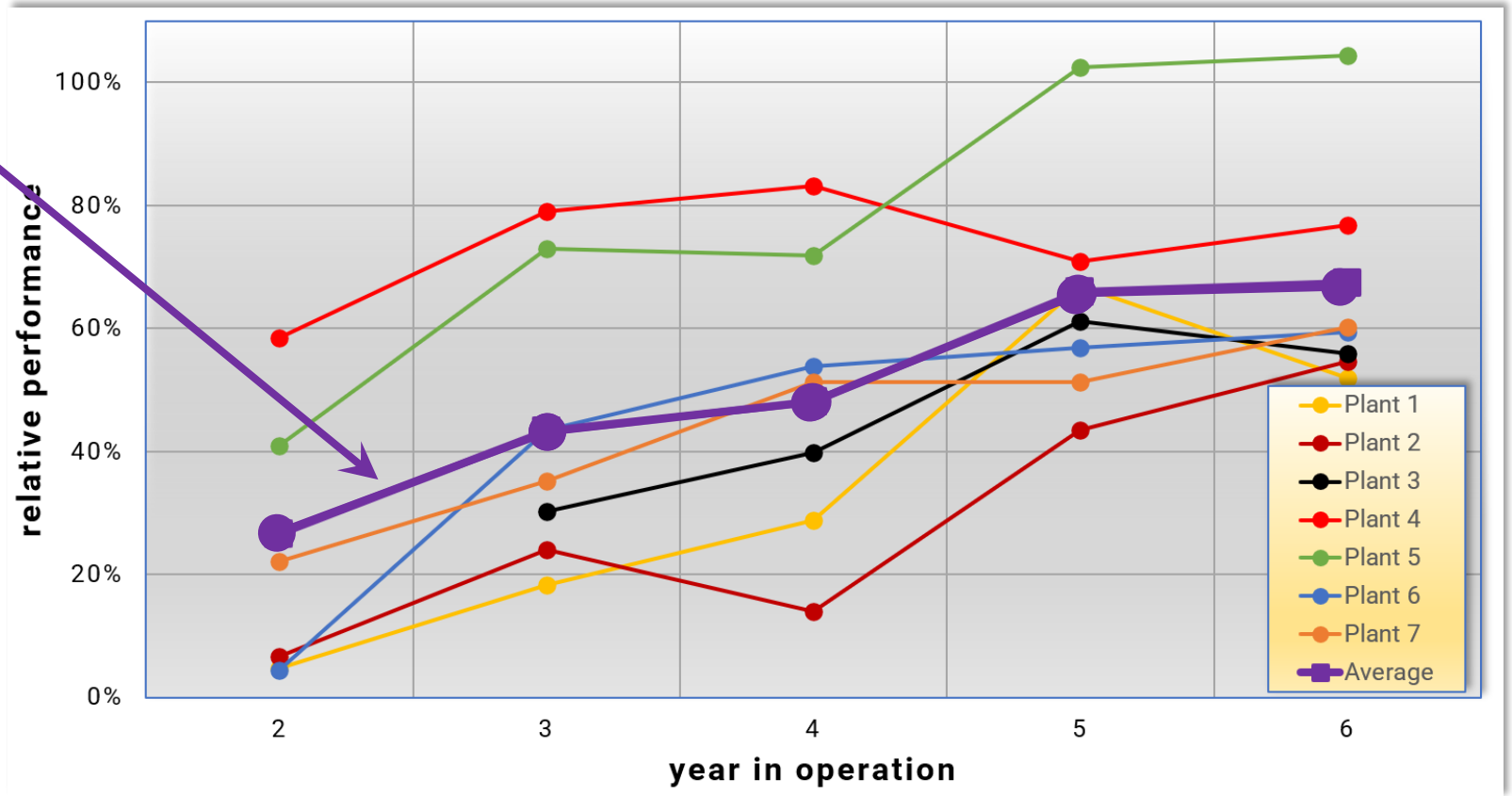
Published plant electricity output versus projected output of plants in the USA

Historical performance of CSP plants in China

Sources: China Solar Thermal Power Industry Blue Book 2025, pp. 22–29
China Solar Thermal Power Industry Blue Book 2022 (English Edition), p. 36
China Solar Thermal Power Industry Blue Book 2021 (English Edition), p. 11

Operation after commissioning: Years 2 to 6 (China)

- Bold purple curve shows average over seven plants
- Mean energy production gap due to various issues such as:
  - Reasonable deviations from original design
  - Solar resource variability
  - Solar field, control, storage, power block, grid, etc.



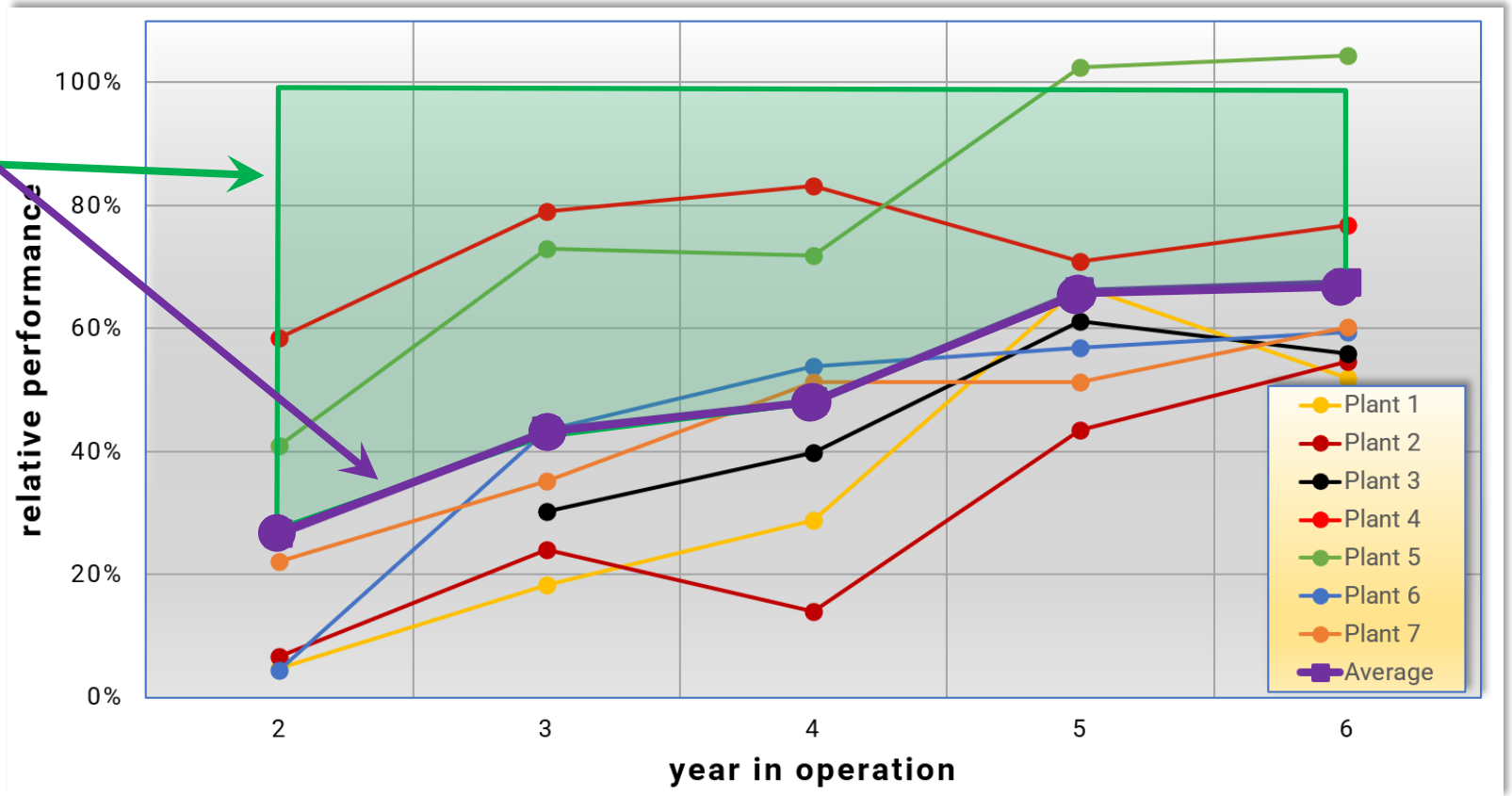
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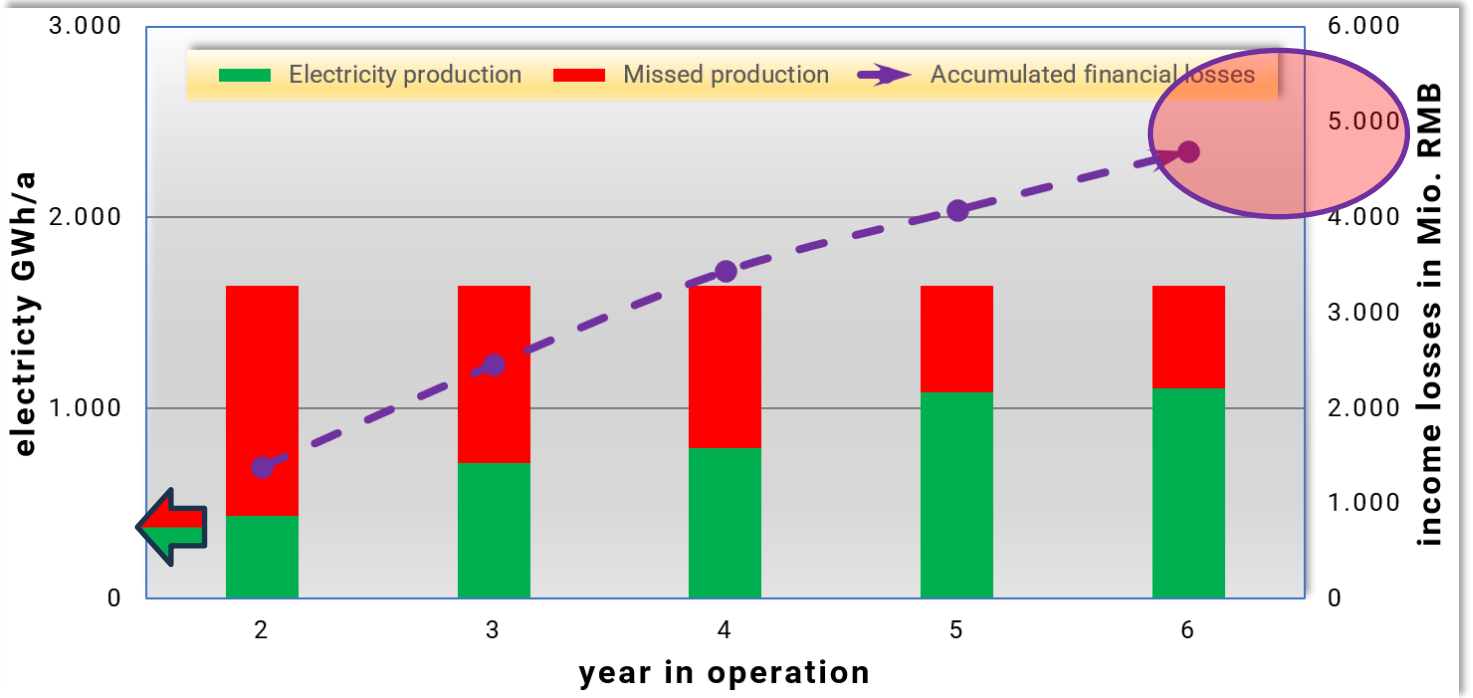


Published plant electricity output versus projected output of plants in China

Financial impact of delayed startup for CSP plants in China

Possible impact of delayed plant startup to full power

- Additional costs for analysis, repairs, and legal tasks
- Decreased profit or financial losses for EPCs, investors and lenders
- Emotional strain for everyone involved
- **Reduced willingness to start and finance new projects?**



Financial impact of slow startup based on real performance data (feed-in tariff: 1.15 RMB/kWh ≈ 0.17 USD/kWh)

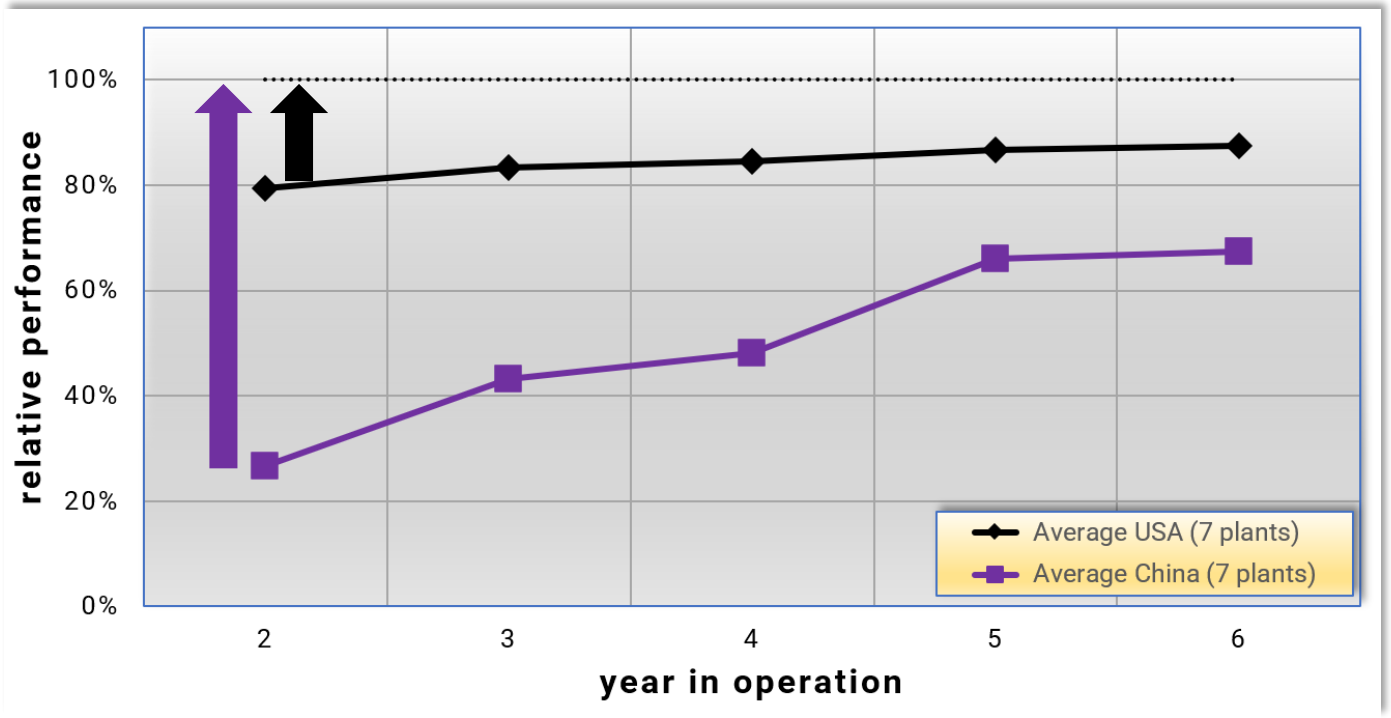
Info: 1'000 Mio. RMB ≈ 150 Mio. USD (Oct. 2026)

Performance of plants - USA vs. China: Years 2-6

Results of comparison (average over 7 power plants, without Crescent Dunes)

- It must be verified that the projected yearly power output values are still valid (due to design changes, etc.)
- If they are valid:
  - In the first 6 operation years, neither American nor Chinese plants reach their projected power output
  - Chinese plants have a high potential to perform better

Bankability ?



Comparison of electricity output of American and Chinese plants versus projected output

PART 3

Improving Plant Quality through Standardization and Guidelines

Standardization is essential for CSP Projects

Enabling framework

- Core framework for solar thermal: ISO/TC 180, CEN/TC 312 & high-temperature CST/CSP technologies: IEC/TC 117
- National and complementary frameworks, SolarPACES guidelines, National standards and industry expert groups, ...

Standardization transforms technical performance expectations into measurable, verifiable, and contractually enforceable requirements.

Standardization provides the foundation for effective quality assurance.

Standards for CSP Projects – why do they help?

Common technical definitions reduce uncertainty, improve quality, and strengthen project bankability

1. Clear Contracting & Performance Guarantees

- Harmonized definitions of efficiency, energy yield, durability, lifetime, and reliability
- Measurable guarantees, verification procedures, and acceptance criteria in EPC contracts

2. Improved Bankability & Reduced Project Risk

- Transparent, independently verifiable performance expectations
- Reduced technical uncertainty and improved allocation of project risks
- Greater confidence for investors, lenders, owners, and EPC contractors

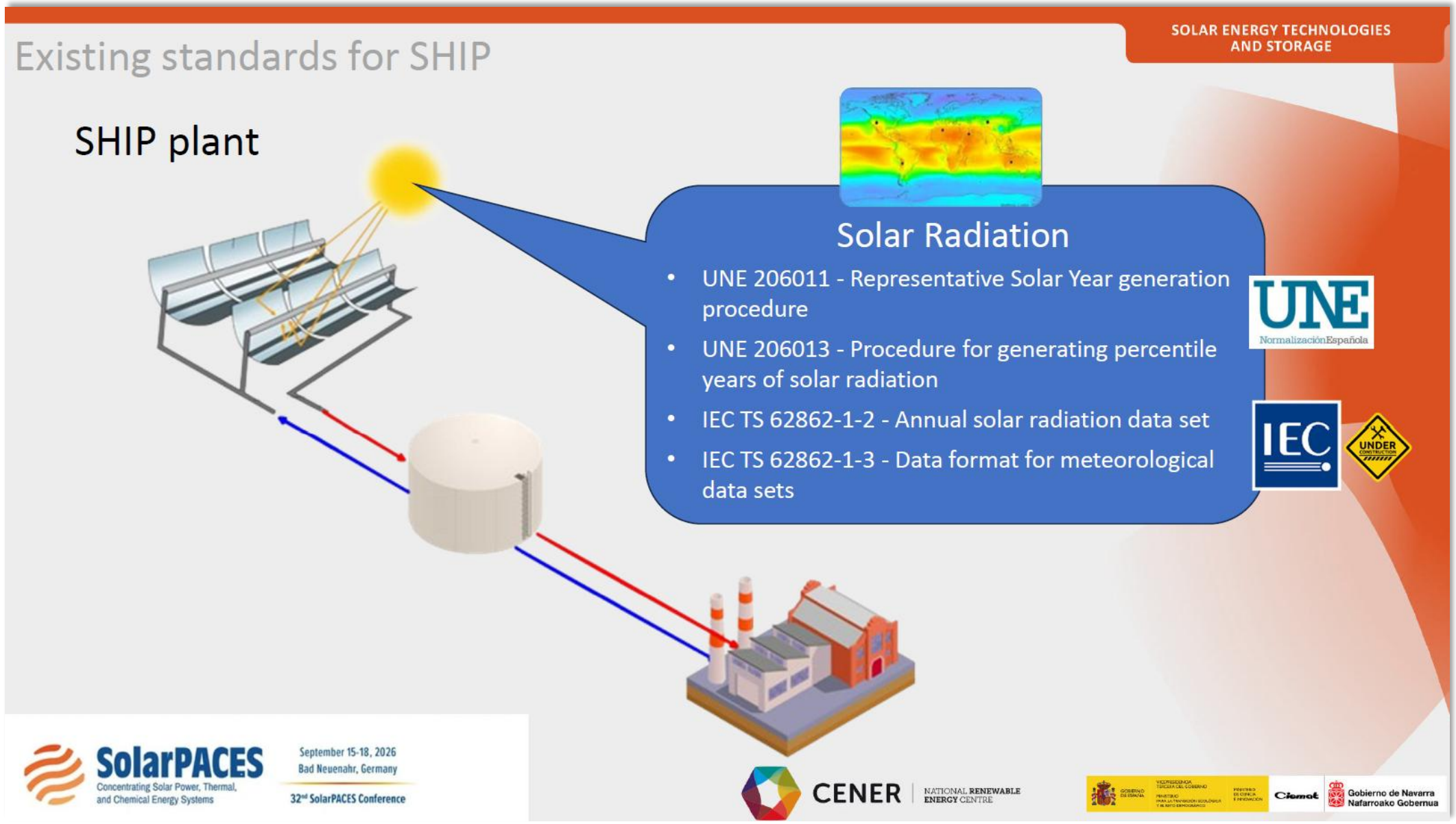
3. Higher Quality & Reliability

- Standardized specifications, testing, inspection, and QA/QC procedures
- Comparable performance and consistent quality requirements
- Basis for certification, long-term reliability, and market acceptance

4. Lower Costs & Improved Competitiveness

- Reduced engineering effort, contractual ambiguity, and technical disputes, less rework and fewer failures during construction
- Economies of scale through repeatable solutions and competitive procurement

Standardization examples



Slide reproduced from the meeting of the SolarPACES "Standardization" Working Group, 14 September 2026.

Courtesy of
Fabienne Sallaberry
CENER Solar Testing Laboratory

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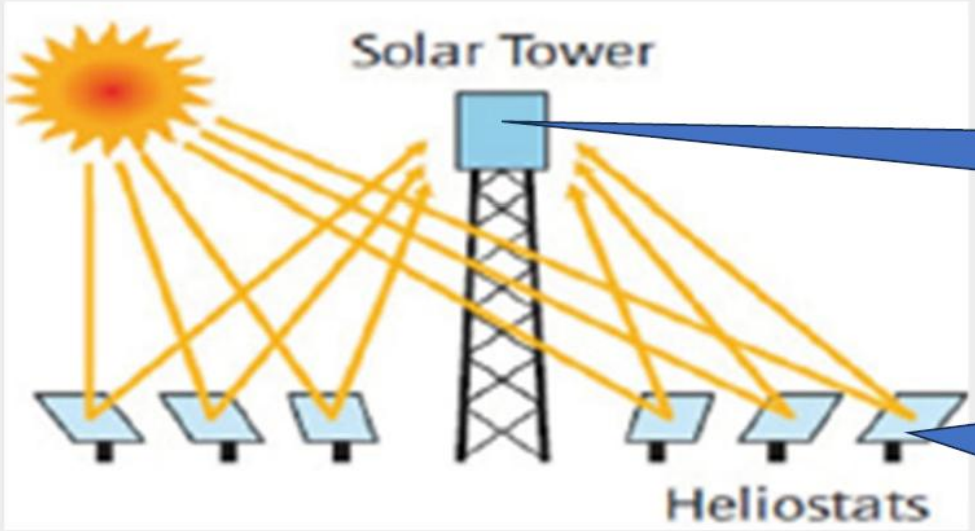
Standardization examples

SOLAR ENERGY TECHNOLOGIES AND STORAGE

Existing standards for SHIP

SHIP plant

Central tower



Design

- **IEC 62862-4-1** - General requirements for the **design of solar power tower plants**

Receiver

- **IEC TS 62862-4-4 -** Technical specifications for **receiver coatings** of solar power tower plants

UNDER CONSTRUCTION

Heliostat

- **IEC 62862-4-2 - Heliostat field control** system of solar tower plants
- **IEC 62862-4-3 -** Technical requirements and **design qualification** of heliostats for solar power tower plants

NEW

UNDER CONSTRUCTION

SolarPACES
Concentrating Solar Power, Thermal, and Chemical Energy Systems
September 15-18, 2026
Bad Neuenahr, Germany
32nd SolarPACES Conference

CENER | NATIONAL RENEWABLE ENERGY CENTRE

Ciemat

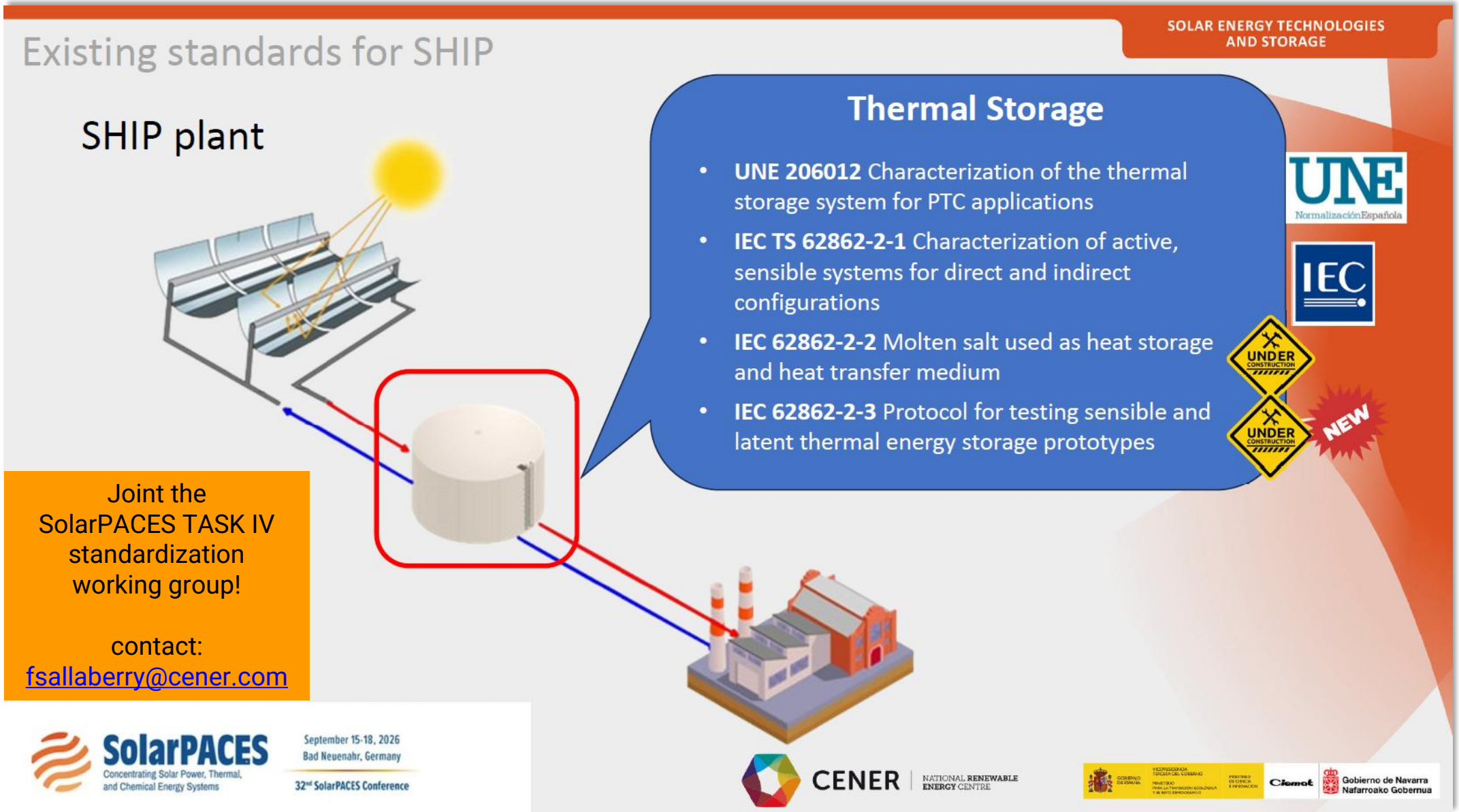
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Standardization examples



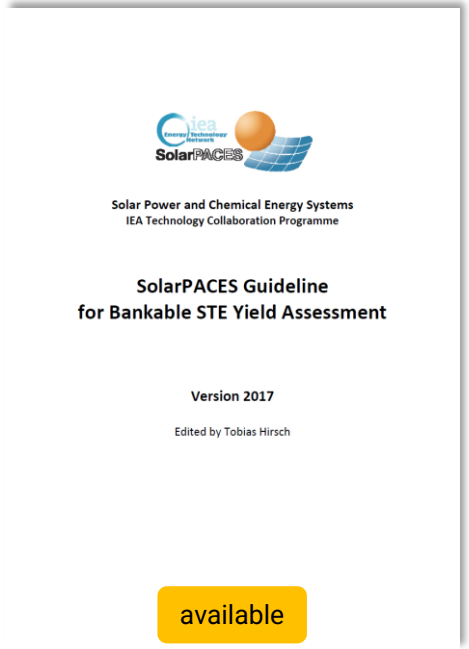
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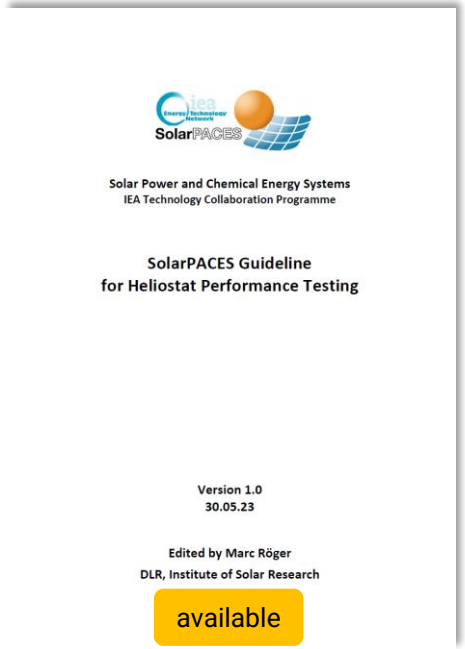
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SolarPACES Guidelines

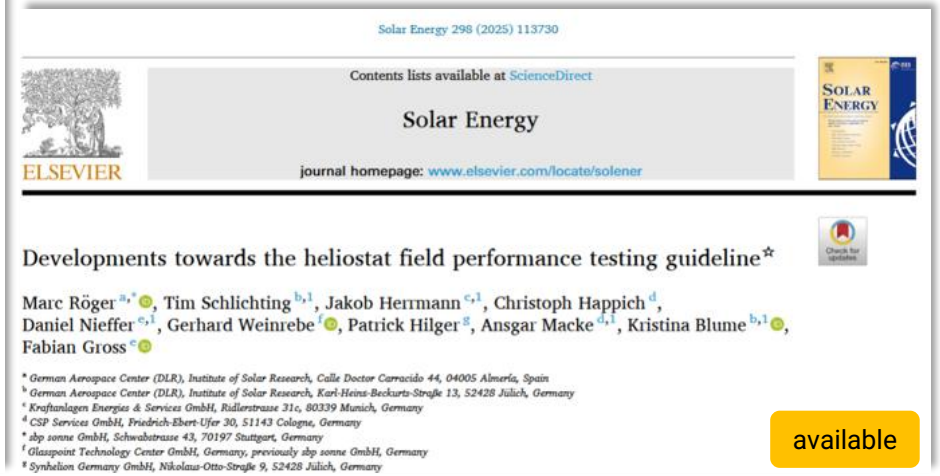
- Guideline for Bankable STE Yield Assessment
  Version 2017, 9 January 2017, 172 pages: https://www.solarpaces.org/wp-content/uploads/SolarPACES_Guideline_for_Bankable_STE_Yield_Assessment_-_Version_2017.pdf
- Guideline for Heliostat Performance Testing
  Version 1.0, 30 May 2023, 47 pages (to be included in IEC-TC-117-62862-4-3): https://doi.org/10.5281/zenodo.15365474
- Guideline for Heliostat Field Acceptance
  - Guideline itself not yet publicly available: Version 0.9, 5 October 2023, 89 pages
  - Röger, et. al., Developments towards the heliostat field performance testing guideline, Solar Energy, Vol 298, 113730, 2025: https://doi.org/10.1016/j.solener.2025.113730



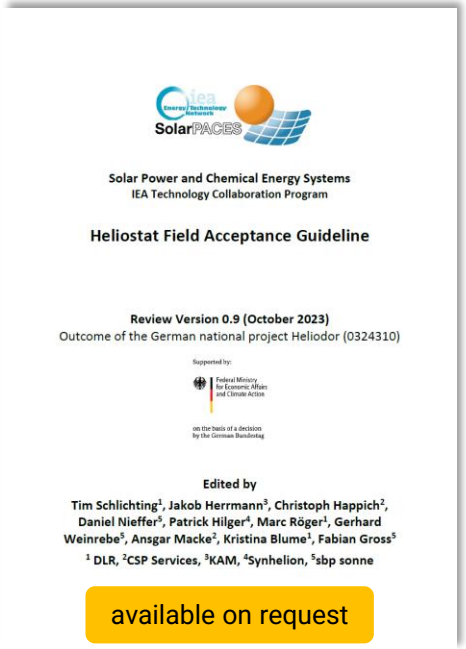
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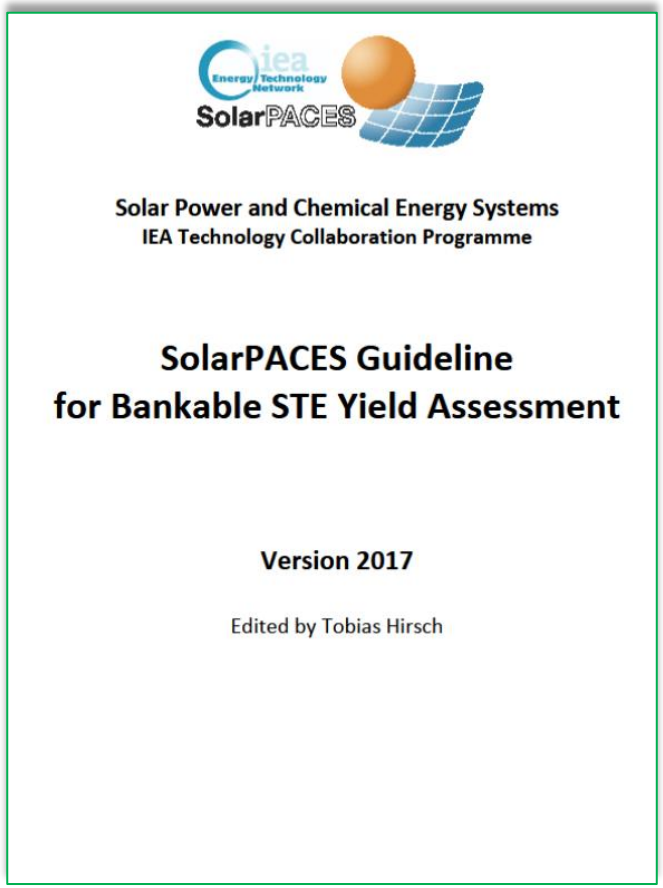
available



available on request

SolarPACES Guideline for Bankable STE Yield Assessment

- Publicly available: Version 2017, 9 January 2017, 172 pages
  https://www.solarpaces.org/wp-content/uploads/SolarPACES_Guideline_for_Bankable_STE_Yield_Assessment_-_Version_2017.pdf



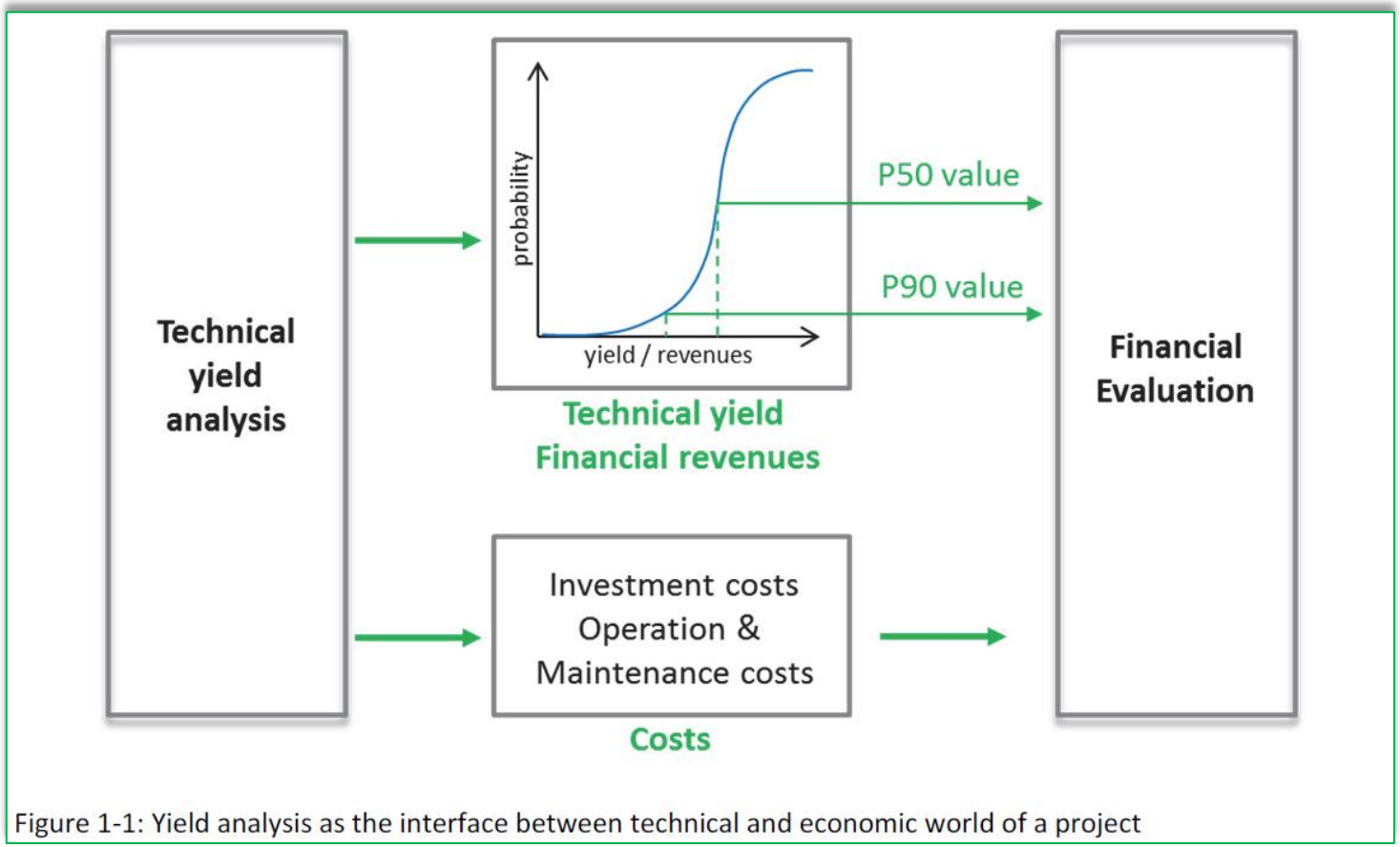
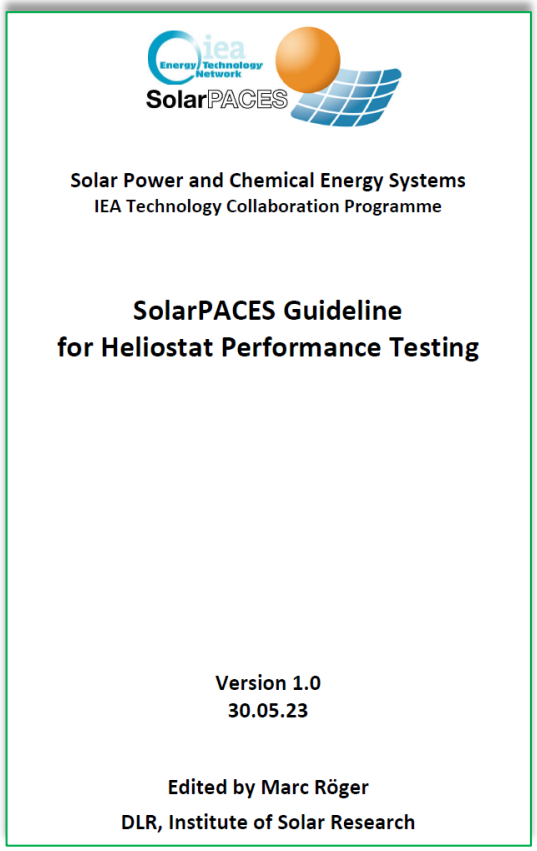
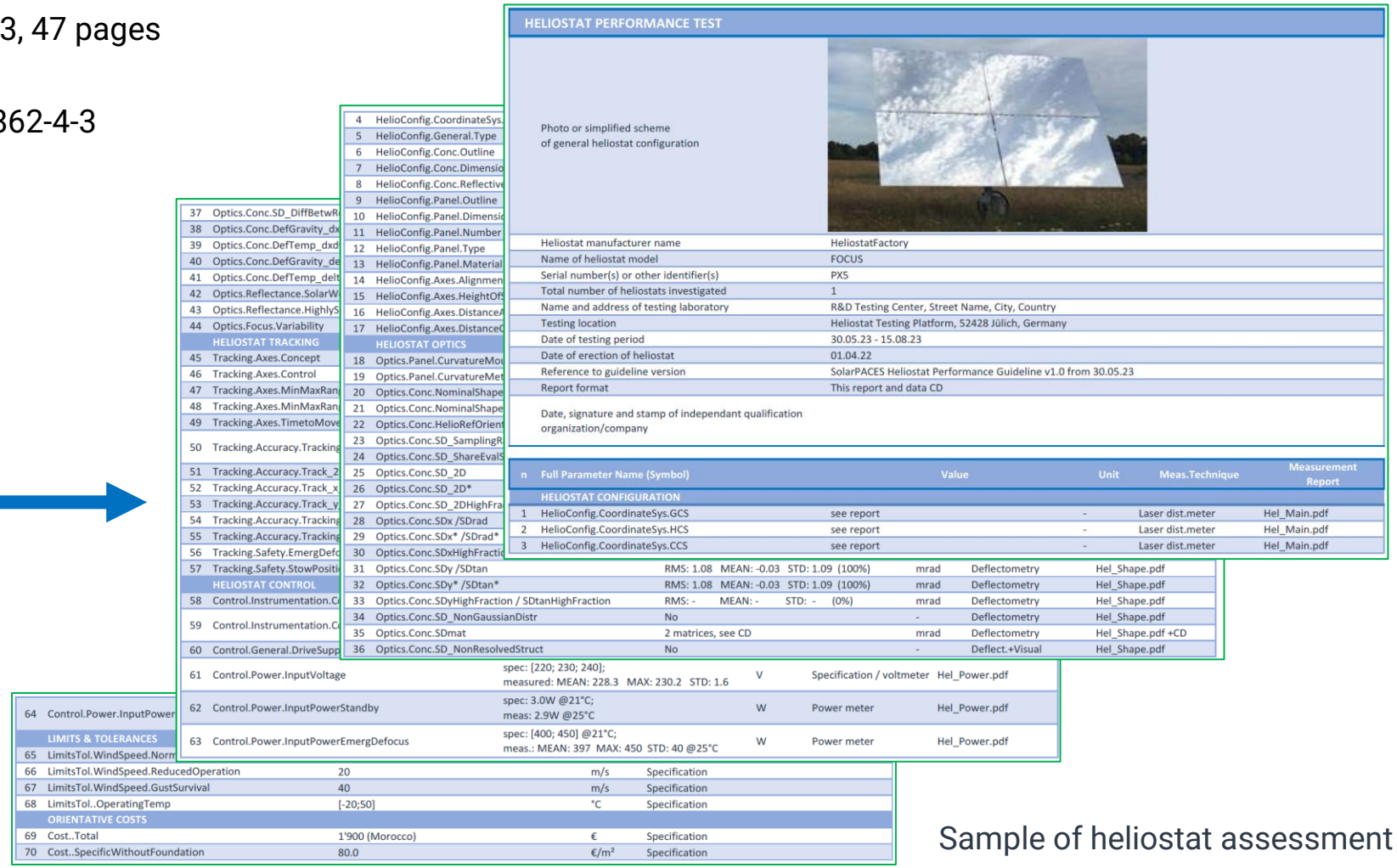


Figure 1-1: Yield analysis as the interface between technical and economic world of a project

SolarPACES Guideline for Heliostat Performance Testing

- Publicly available: Version 1.0, 30 May 2023, 47 pages
  https://doi.org/10.5281/zenodo.15365474
- To be included in Standard IEC-TC-117-62862-4-3



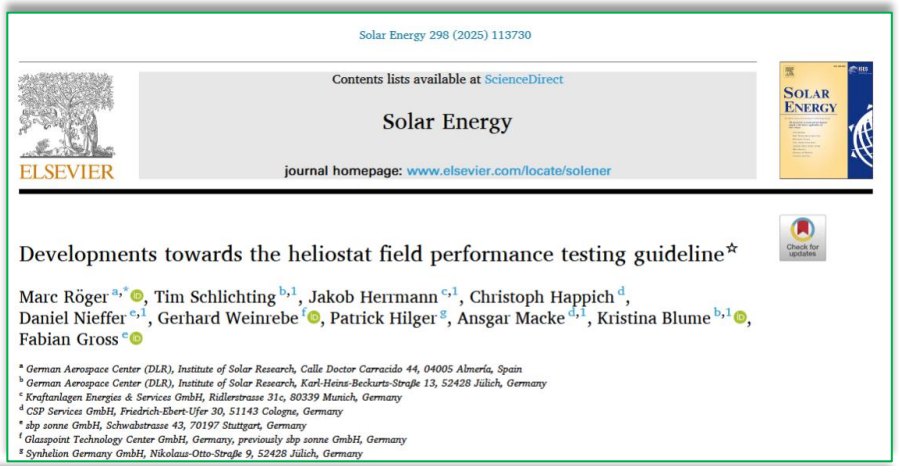


Sample of heliostat assessment

SolarPACES Guideline for Heliostat Field Acceptance

- Publicly available, open access:
  https://doi.org/10.1016/j.solener.2025.113730

- Actual Guideline still in review: Version 0.9, 5 October 2023, 89 pages



Solar Energy 298 (2025) 113730

Contents lists available at ScienceDirect

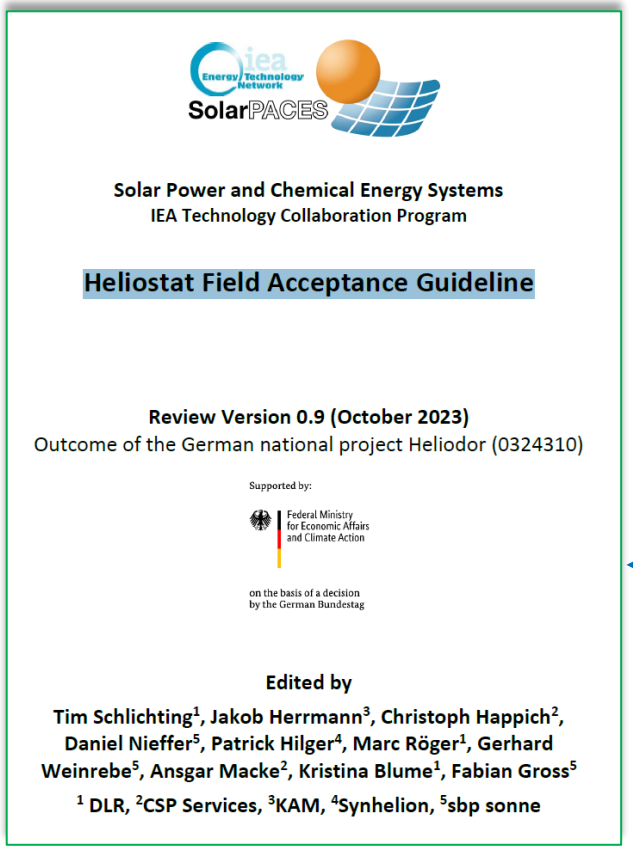
Solar Energy

journal homepage: www.elsevier.com/locate/solener

Developments towards the heliostat field performance testing guideline☆

Marc Röger [a,*], Tim Schlichting [b,1], Jakob Herrmann [c,1], Christoph Happich [d], Daniel Nieffer [e,1], Gerhard Weinrebe [f], Patrick Hilger [g], Ansgar Macke [d,1], Kristina Blume [b,1], Fabian Gross [e]

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[b] German Aerospace Center (DLR), Institute of Solar Research, Karl-Heins-Beckurts-Straße 13, 52428 Jülich, Germany
[c] Kraftanlagen Energies & Services GmbH, Ridlerstrasse 31c, 80339 Munich, Germany
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[e] sbp sonne GmbH, Schwabstrasse 43, 70197 Stuttgart, Germany
[f] Glasspoint Technology Center GmbH, Germany, previously sbp sonne GmbH, Germany
[g] Synhelion Germany GmbH, Nikolaus-Otto-Straße 9, 52428 Jülich, Germany



Solar Power and Chemical Energy Systems
IEA Technology Collaboration Program

Heliostat Field Acceptance Guideline

Review Version 0.9 (October 2023)
Outcome of the German national project Heliodor (0324310)

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Edited by
Tim Schlichting[1], Jakob Herrmann[3], Christoph Happich[2], Daniel Nieffer[5], Patrick Hilger[4], Marc Röger[1], Gerhard Weinrebe[5], Ansgar Macke[2], Kristina Blume[1], Fabian Gross[5]
[1] DLR, [2]CSP Services, [3]KAM, [4]Synhelion, [5]sbp sonne

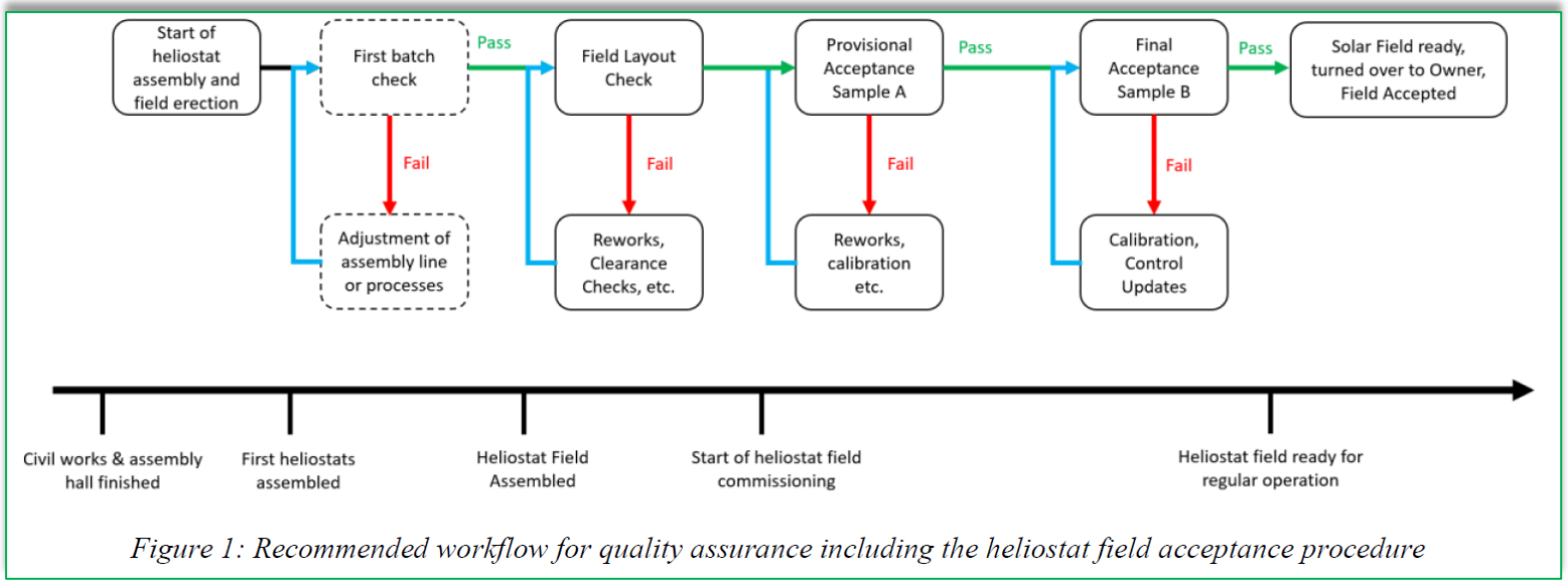


Figure 1: Recommended workflow for quality assurance including the heliostat field acceptance procedure

Standardization is essential for CSP Projects

Enabling framework

- Core framework for solar thermal: ISO/TC 180, CEN/TC 312 & high-temperature CST/CSP technologies: IEC/TC 117
- National and complementary frameworks, SolarPACES guidelines, National standards and industry expert groups, ...

Standardization transforms technical performance expectations into measurable, verifiable, and contractually enforceable requirements.

Standardization provides the foundation for effective quality assurance.

However: Standards alone do not ensure quality!

Their implementation and verification through rigorous quality control are essential.

PART 4

Ensuring Long-Term Investor and Lender Confidence through Rigorous Quality Control

Risk reduction to enhance plant performance

Project Development & Design	Procurement & Construction
Solar resource (ground & satellite data): **-> Correctly assessed (P50/P90)?**	Key components (mirrors, receivers, pipes, valves): -> **Does supplier selection include a quality assessment?** **> Is delivered component quality regularly verified?**
Core plant technology (CT, PT): **-> Well adapted to site?** **-> Overall design review done?**	Subsystem quality (concentrators, piping, storage tanks): **-> Are assembled subsystems quality checked?**
Solar field technology (parabolic troughs, heliostats): ➔ **Has (new) technology been qualified by a third party?**	Overall system quality (solar field, storage, power block): **-> Are systems pretested with best available tools?**

Risk reduction in different phases of solar field development

Project develop-ment
Know your solar resources
Solar resource assessment

Plant design
Use suitable technology
Expert review
Prototype test

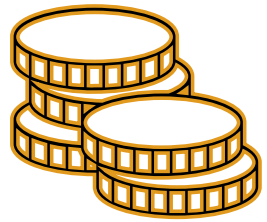
Procure-ment
Buy high-quality components
Mirror quality assessment

Assembly
Safeguard assembly line
Steel structure geometry check

Solar field erection
Optimize concentrator alignment
Alignment check after installation

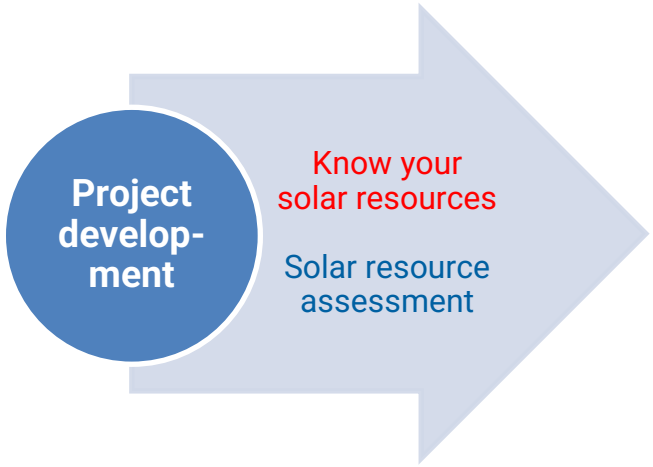
Commis-sioning
Improve heliostat tracking
Heliostat field calibration

Operation
Keep efficiency
Regular tracking and receiver health check



Regular drone-based optical checks enable quick hot commissioning and accelerated plant startup -> “Hybrid commissioning”

Solar resource assessment -> CSPS-AWS Tier 1 & Tier 2



Solar resource assessment -> CSPS-AWS Tier 1 & Tier 2

Automatic solar ground measurements

- Custom made Tier1 or Tier2 stations
- Albedo, soiling and sunshape measurement
- Installation on site and regular cleaning
- One year measurement campaigns
- Ground data reduces bias of satellite data
- Improved long-term datasets
- Lower yield uncertainty
- Support for long-term risk assessment
- Enhanced bankability (P50 & P90)

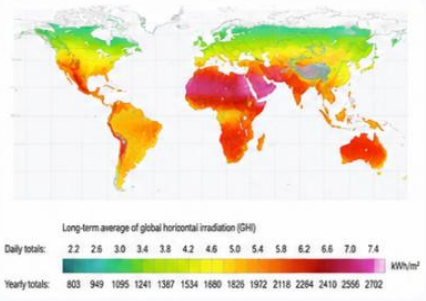


1 Ground measurement (quality controlled data)



- Detailed description of a specific spot
- Low uncertainty
- Short time range (~1 year)

2 Satellite-based solar model data



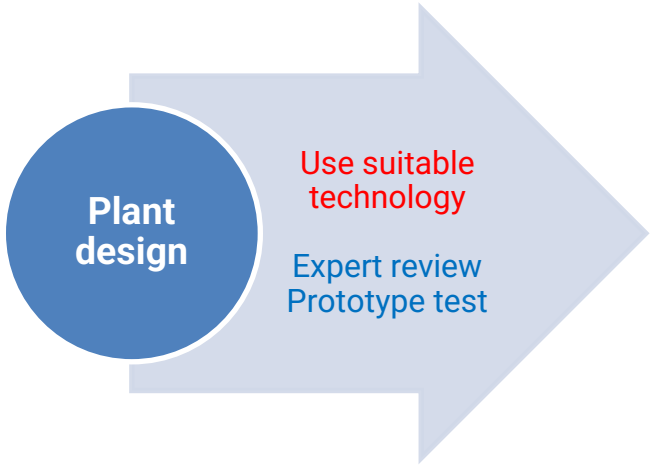
- Description of a larger area
- Higher uncertainty
- Long time range (~ decades)

3 Site Adaptation



- Detailed description of project site area
- Bias removal
- Improved values of frequency distribution
- Reduced uncertainty
- Long-time range with improved data quality (~decades)

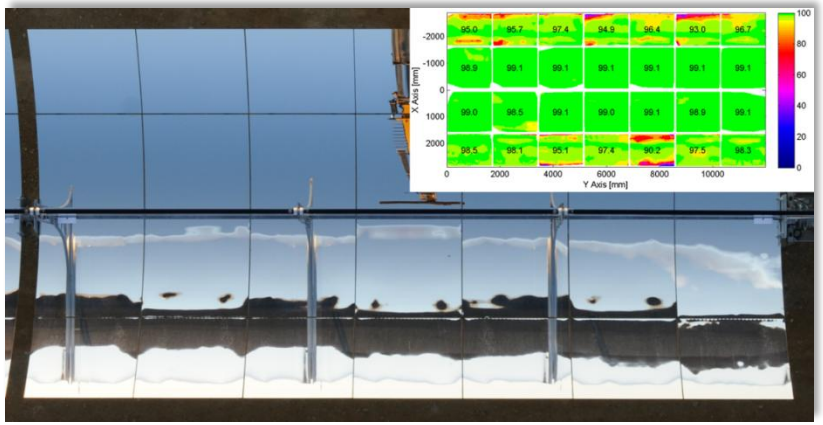
Plant design -> Expert review & prototype test



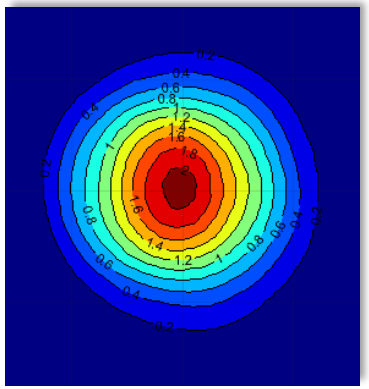
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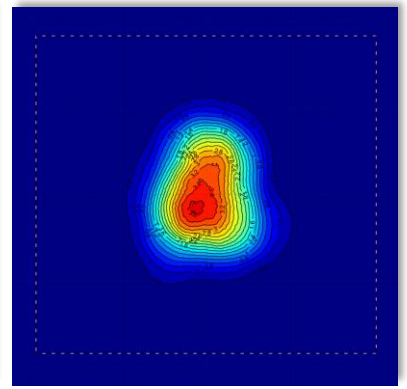
Expert Services

- Technology design review
- Concentrator prototype assessment
- Test loop testing and qualification
- Specific key component testing



Concentrator shape measurement

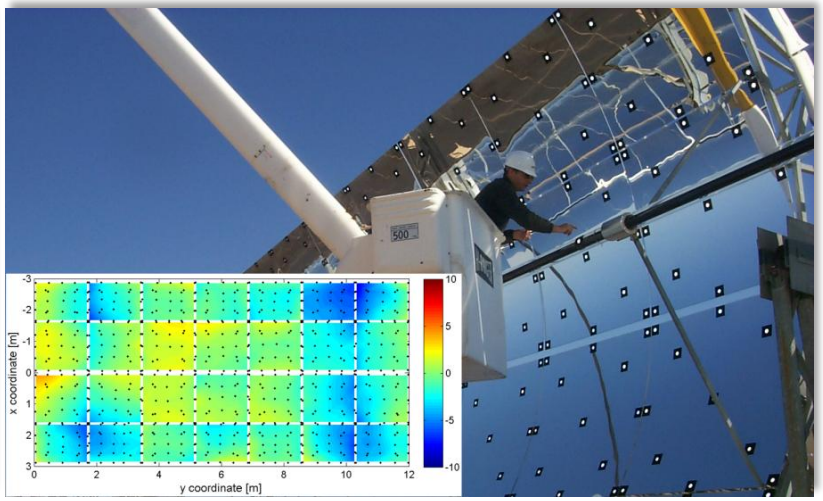




Heliostat beam quality



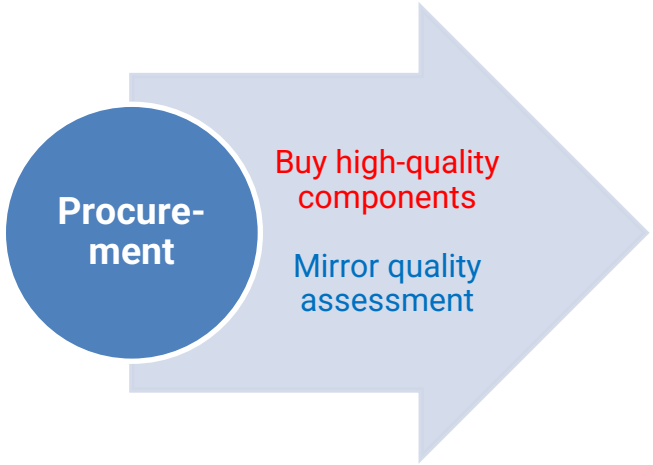
Intercept check





3D Photogrammetry measurement – shape / deformation

Mirror quality assessment -> QDec Deflectometry



Mirror quality assessment -> QDec Deflectometry

Measurement system for concentrator shape

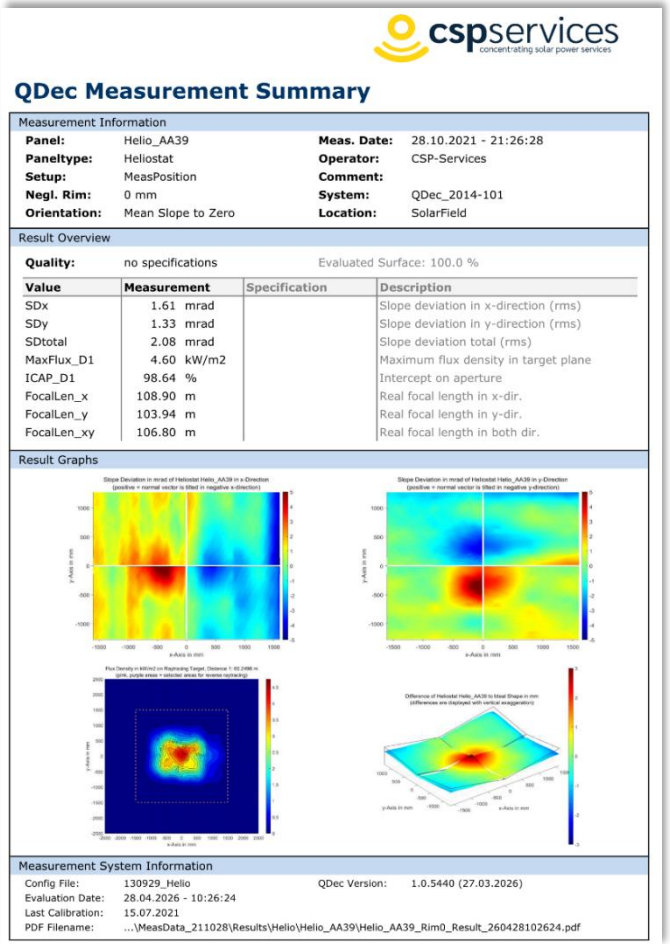
- Automatic production quality check of reflector panels
- From single mirrors up to complete concentrators
- Fast and robust non-contact measurement
- Outstanding measurement accuracy in high resolution
- Simple operation and maintenance
- Recognized standard in CSP industry



Assessment of mirrors in mass production



Check of heliostat concentrators on site



cspservices
concentrating solar power services

QDec Measurement Summary

Measurement Information

Panel:	Helio_AA39	Meas. Date:	28.10.2021 - 21:26:28
Paneltype:	Heliostat	Operator:	CSP-Services
Setup:	MeasPosition	Comment:	
Negl. Rim:	0 mm	System:	QDec_2014-101
Orientation:	Mean Slope to Zero	Location:	SolarField

Result Overview

Quality: no specifications Evaluated Surface: 100.0 %

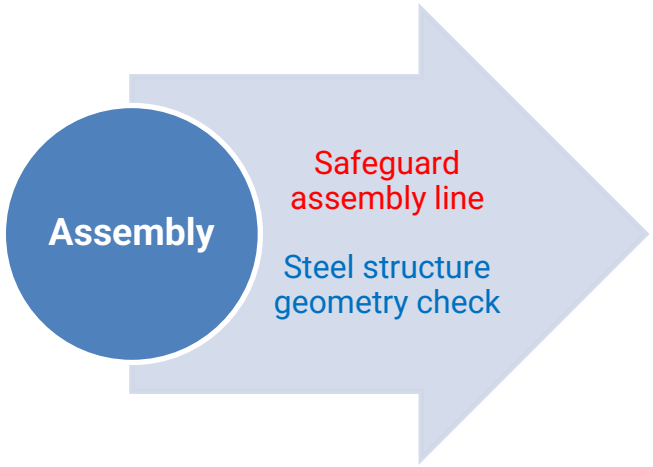
Value	Measurement	Specification	Description
SDx	1.61 mrad		Slope deviation in x-direction (rms)
SDy	1.33 mrad		Slope deviation in y-direction (rms)
SDtotal	2.08 mrad		Slope deviation total (rms)
MaxFlux_D1	4.60 kW/m2		Maximum flux density in target plane
ICAP_D1	98.64 %		Intercept on aperture
FocalLen_x	108.90 m		Real focal length in x-dir.
FocalLen_y	103.94 m		Real focal length in y-dir.
FocalLen_xy	106.80 m		Real focal length in both dir.

Result Graphs

Measurement System Information

Config File:	130929_Helio	QDec Version:	1.0.5440 (27.03.2026)
Evaluation Date:	28.04.2026 - 10:26:24		
Last Calibration:	15.07.2021		
PDF Filename:	...\MeasData_211028\Results\Helio\Helio_AA39\Helio_AA39_Rim0_Result_260428102624.pdf		

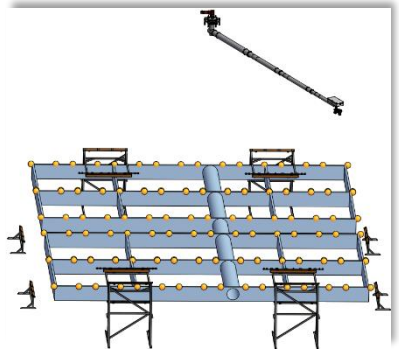
Steel structure geometry check -> QFoto Photogrammetry

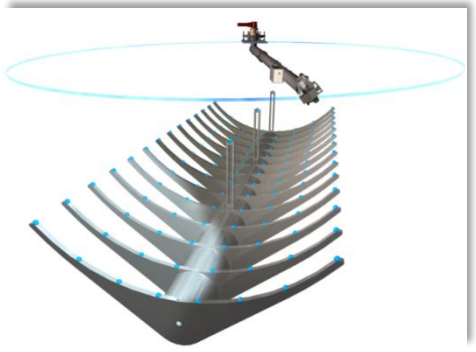


Steel structure geometry check -> QFoto Photogrammetry

Check of concentrator structures

- Semi-automatic production quality check for steel structures
- From small to very large structures
- Self-calibrating and robust non-contact measurement
- High measurement accuracy
- Adapted to severe temperatures and to dusty regions
- Simple operation and maintenance

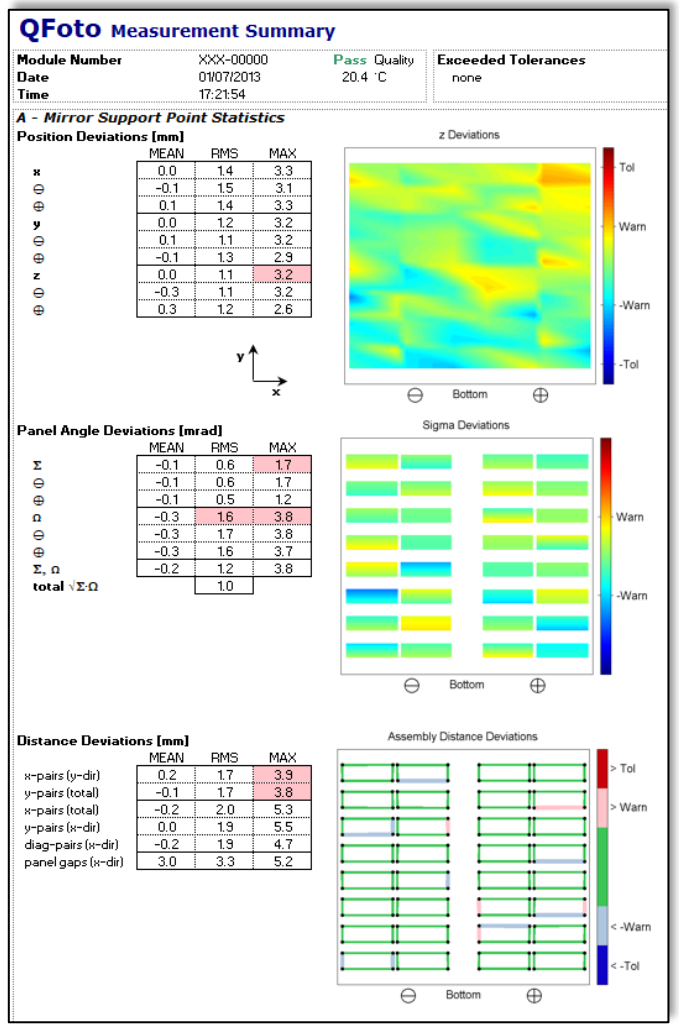




For heliostats and parabolic trough structures



QC of trough steel structure in assembly line



QFoto Measurement Summary

Module Number	XXX-00000	Pass Quality	Exceeded Tolerances
Date	01/07/2013	20.4 °C	none
Time	17:21:54		

A - Mirror Support Point Statistics

Position Deviations [mm]

	MEAN	RMS	MAX
x	0.0	1.4	3.3
⊖	-0.1	1.5	3.1
⊕	0.1	1.4	3.3
y	0.0	1.2	3.2
⊖	0.1	1.1	3.2
⊕	-0.1	1.3	2.9
z	0.0	1.1	3.2
⊖	-0.3	1.1	3.2
⊕	0.3	1.2	2.6

z Deviations: Tol, Warn, -Warn, -Tol; Bottom

Panel Angle Deviations [mrad]

	MEAN	RMS	MAX
Σ	-0.1	0.6	1.7
⊖	-0.1	0.6	1.7
⊕	-0.1	0.5	1.2
Ω	-0.3	1.6	3.8
⊖	-0.3	1.7	3.8
⊕	-0.3	1.6	3.7
Σ, Ω	-0.2	1.2	3.8
total √Σ·Ω		1.0	

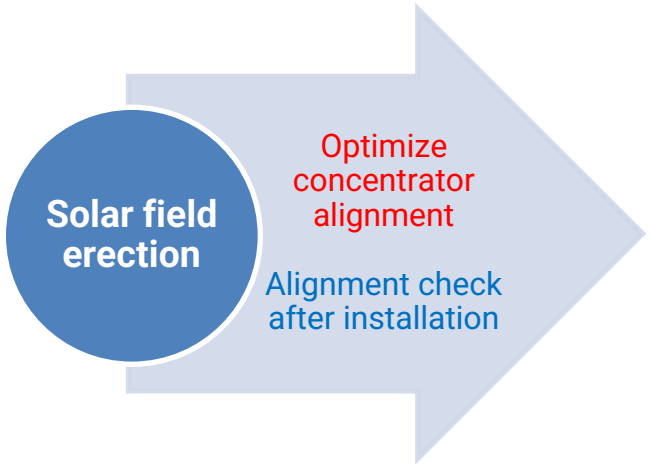
Sigma Deviations: Warn, -Warn; Bottom

Distance Deviations [mm]

	MEAN	RMS	MAX
x-pairs (y-dir)	0.2	1.7	3.9
y-pairs (total)	-0.1	1.7	3.8
x-pairs (total)	-0.2	2.0	5.3
y-pairs (x-dir)	0.0	1.9	5.5
diag-pairs (x-dir)	-0.2	1.9	4.7
panel gaps (x-dir)	3.0	3.3	5.2

Assembly Distance Deviations: > Tol, > Warn, < -Warn, < -Tol; Bottom

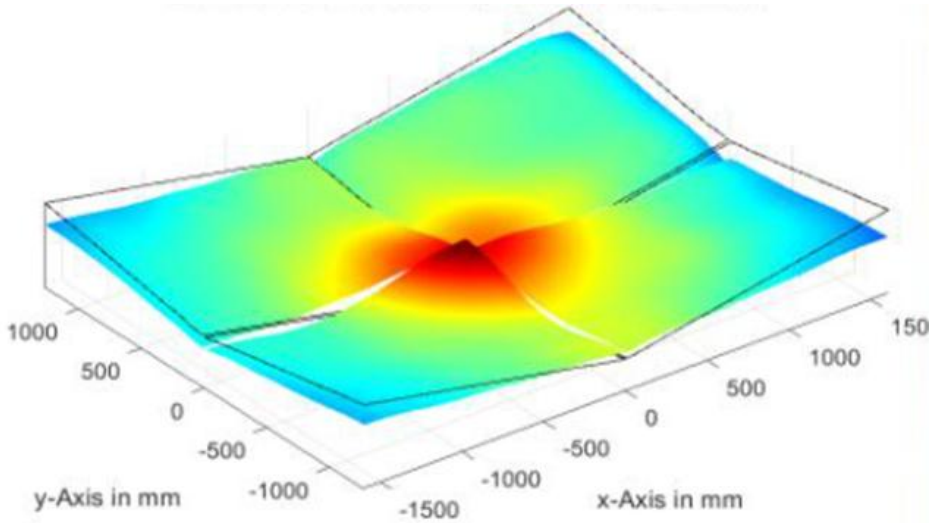
Alignment check after installation -> QDec-H Deflectometry

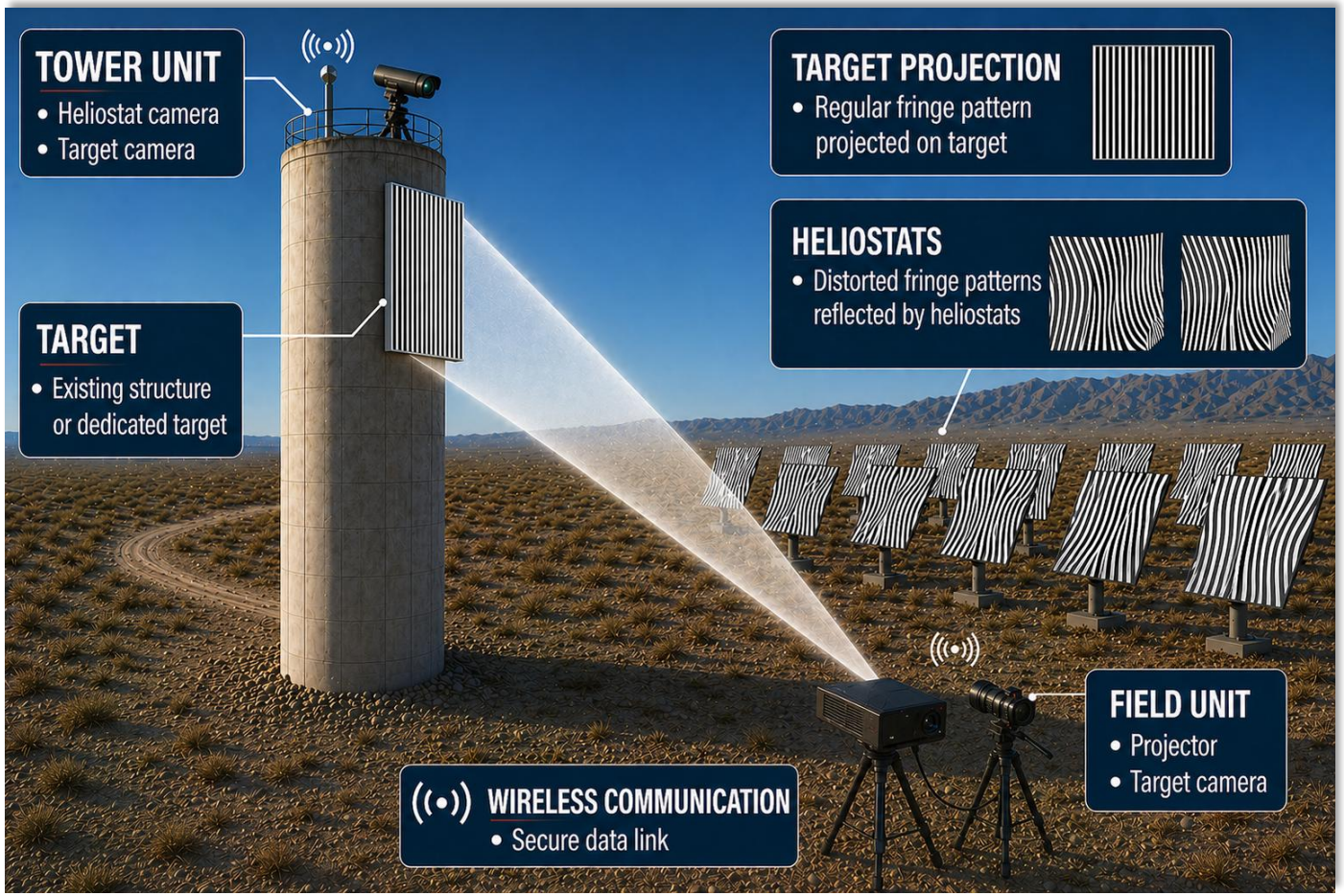


Alignment check after installation -> QDec-H Deflectometry

Test of Heliostat Field Geometry

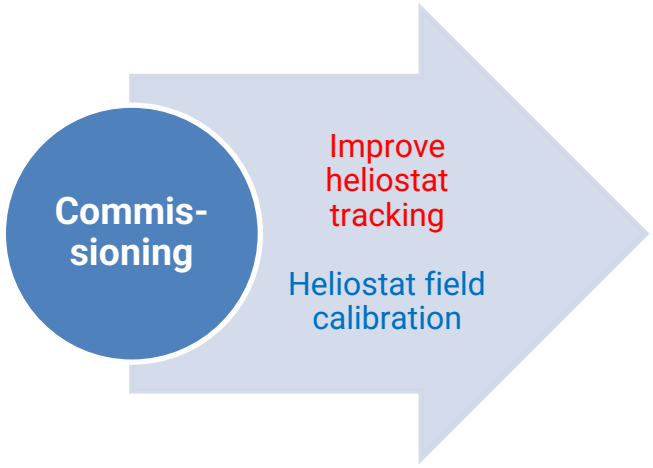
- Heliostat assembly and installation verification
- Heliostat field acceptance testing
- Solar field optimization
- Damage and root cause investigation
- Digital twin validation and model calibration





QDec-H: Shape check of (all) installed heliostats on-site at the power plant. Modifications to the heliostats are not required

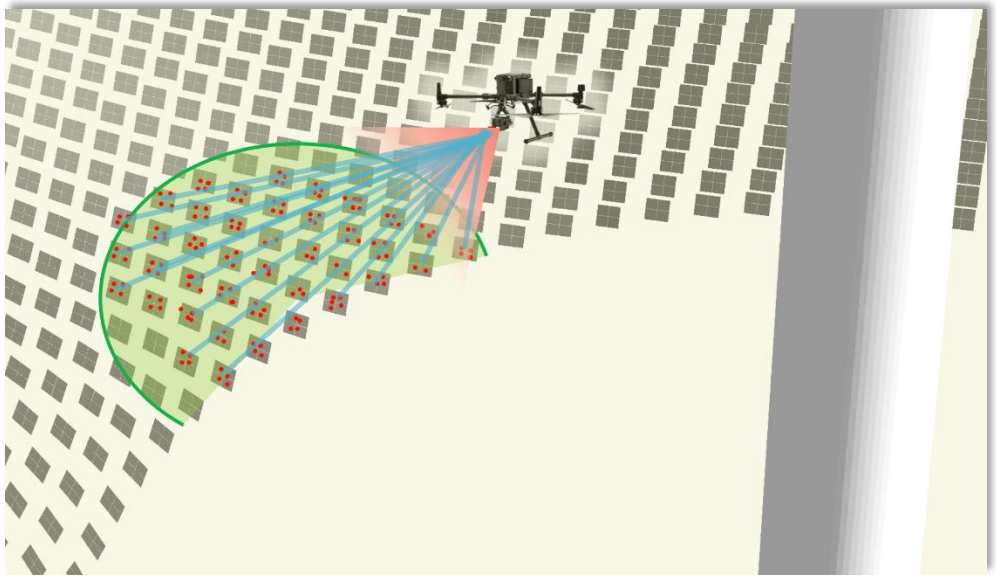
Heliostat field calibration -> HelioPoint



Heliostat field calibration -> HelioPoint

Heliostat Field Calibration

- Quick full-field or partial-field calibration
- Parallel calibration of large groups of heliostats
- Independent from tower infrastructure and sun conditions
- Recurring calibration in O&M programs
- Calibration after incidents (e.g. storms)

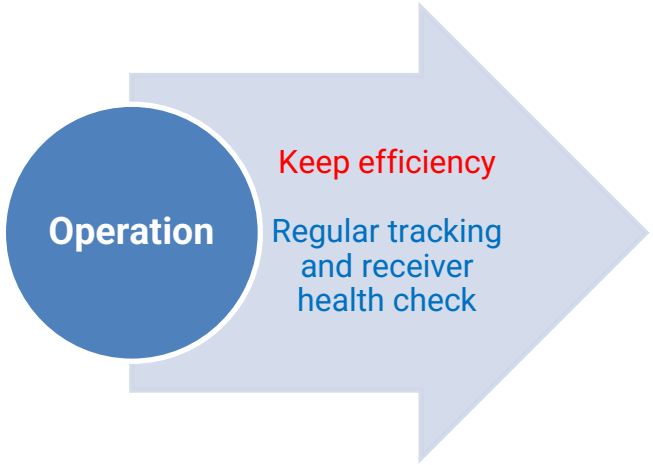


Data acquisition for a group of heliostats



Drone equipped with flashlight

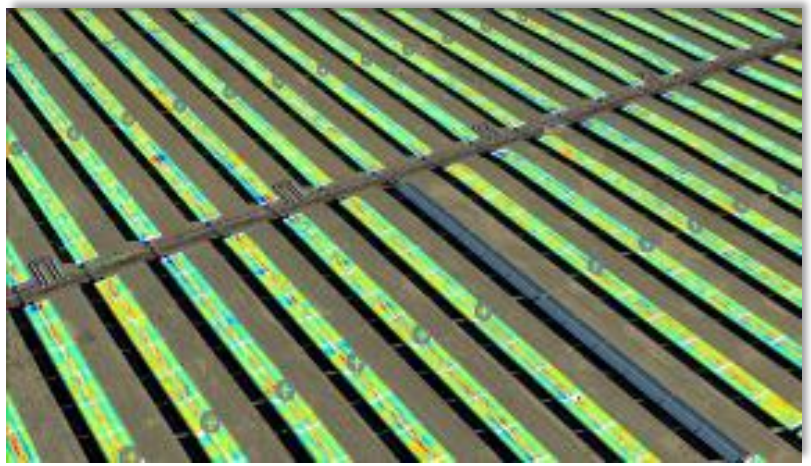
Regular tracking and receiver health check -> QScan Drone



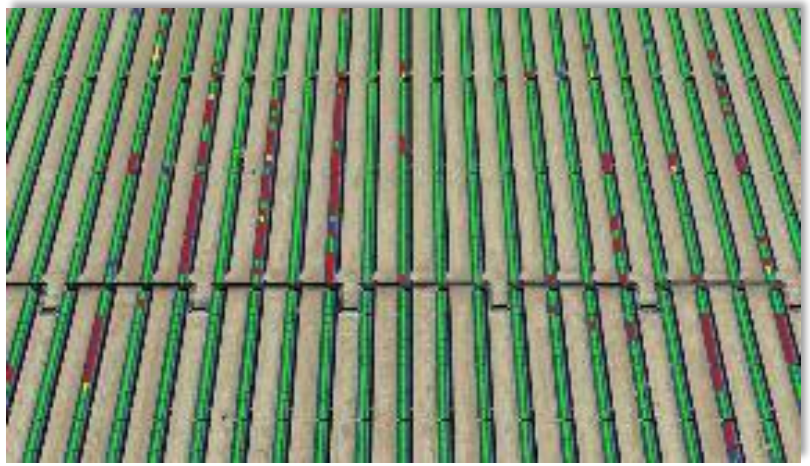
Regular tracking and receiver health check -> QScan Drone

Drone flights in operational plant

- Performance optimization of solar fields in operation
- Tracking optimization
- Receiver health test
- Root cause analysis in case of malfunctions

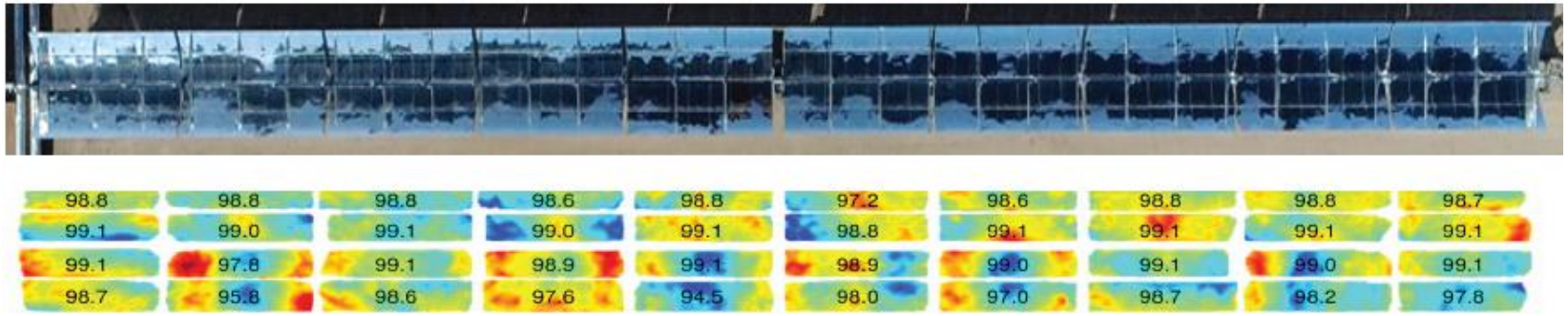


Geometry assessment



Receiver health check





High-resolution shape deviation map and estimated local intercept factor

Selected services for a plant's lifecycle

Prototyping

- Prototype review and geometry tests: **Expert Review, QScan-Shape, Photogrammetry**
- Laboratory tests (mirrors, receivers): **DLR-Quarz**

Construction

- Mirror shape quality control system (automatic): **QDec**
- Steel structure quality control system (semi-automatic): **QFoto**
- Solar field quality control service (semi-automatic): **QScan-Shape**

Commissioning

- Parabolic trough solar field check: **QScan-Shape**
- Heliostat solar field check: **QDec-H**

Operation

- Parabolic trough solar field check **QScan-Shape, QScan-Thermal**
- Heliostat solar field check **HelioPoint**
- Laboratory tests (HTF, molten salt) **DLR-Quarz**

CSP Services Website
www.cspservices.de

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Quality assurance is an investment, not a cost !

It mitigates risks, protects cash flows, and prevents costly delays and performance shortfalls.