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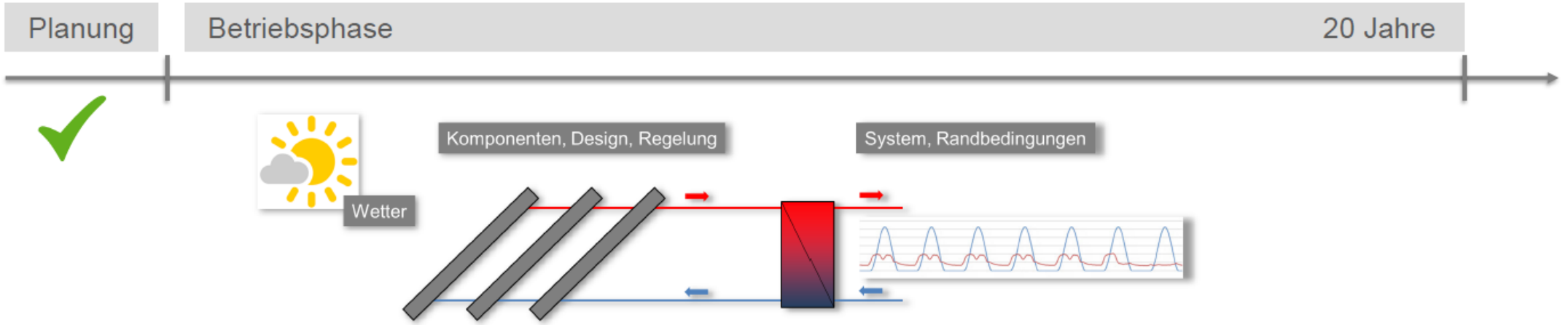
SolarEngineering GUGGENBERGER

SunPeek

Neue digitale Tools zur optimalen Betriebsführung von solarthermischen Großanlagen

Fernwärmetage 2024, Linz

Herausforderungen Monitoring Solarthermie



Herausforderungen

1) CAPEX: Solare Großanlagen haben **hohe Anfangsinvestition**.
2) OPEX: Betreiber muss über Laufzeit von 20-30 Jahren **langfristig hohen Solarertrag sicherstellen**.
3) Bewertung der Anlagenperformance selbst für Expert*innen anspruchsvoll.
4) Es gibt am Markt **keine Standard-Software** für detailliertes **Performance-Monitoring**.

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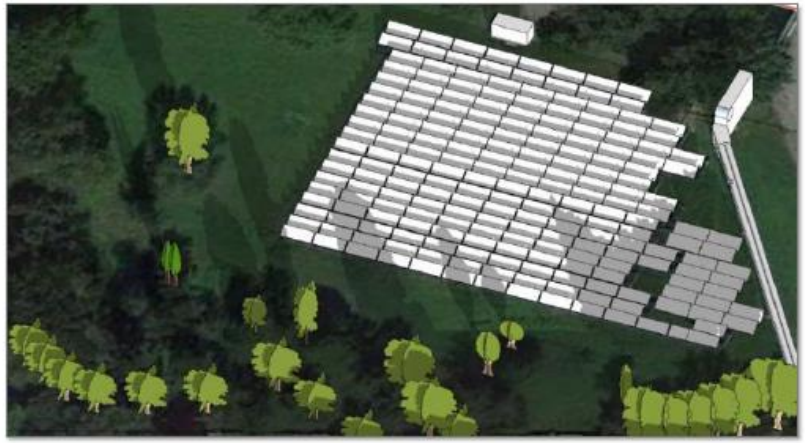
Einflussfaktoren Solarertrag / Performance



- **Kollektoren**
  - Wirkungsgradkennline, Trägheit
  - Verschmutzung, Zustand Wärmedämmung
- **Anlagendesign / Anlagenzustand**
  - Reihenabstände, Aufständerungswinkel, Hydraulik
  - Eigenverschattung, Fremdverschattung
- **Betriebs- und Regelungsstrategien**
  - Volumenströme, Temperaturen
- **Sekundärseite, externe Einflüsse**
  - Abnahmeleistung, Rücklauftemperaturen, …
  - Wetter (Einstrahlung, Außentemperaturen, …)
- **Messung**
  - Repräsentativität Strahlungsmessung
  - Repräsentativität Windmessung
  - Messunsicherheit
  - Datenqualität, fehlende Messdaten

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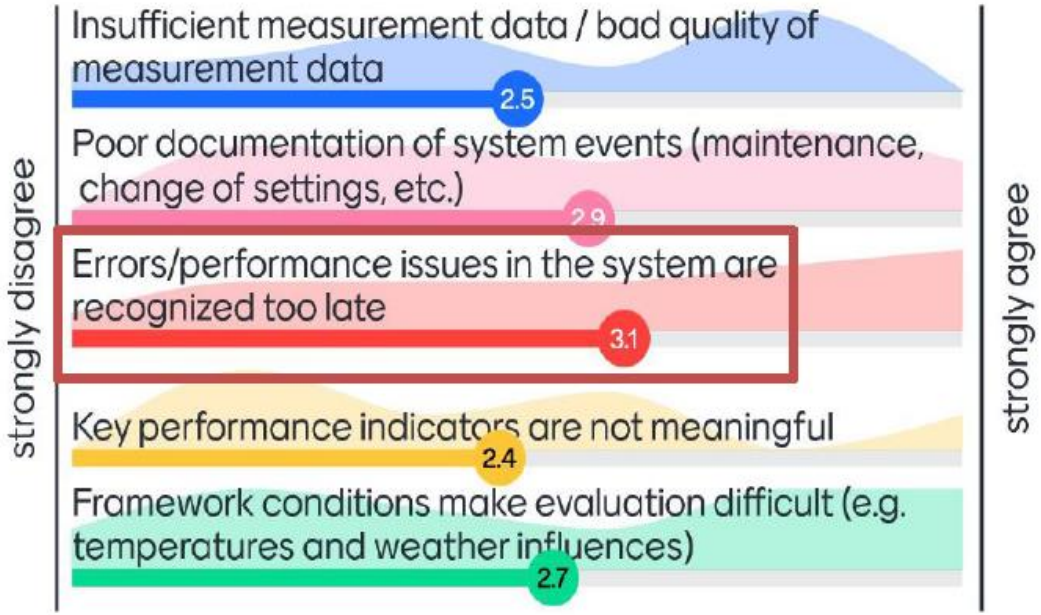
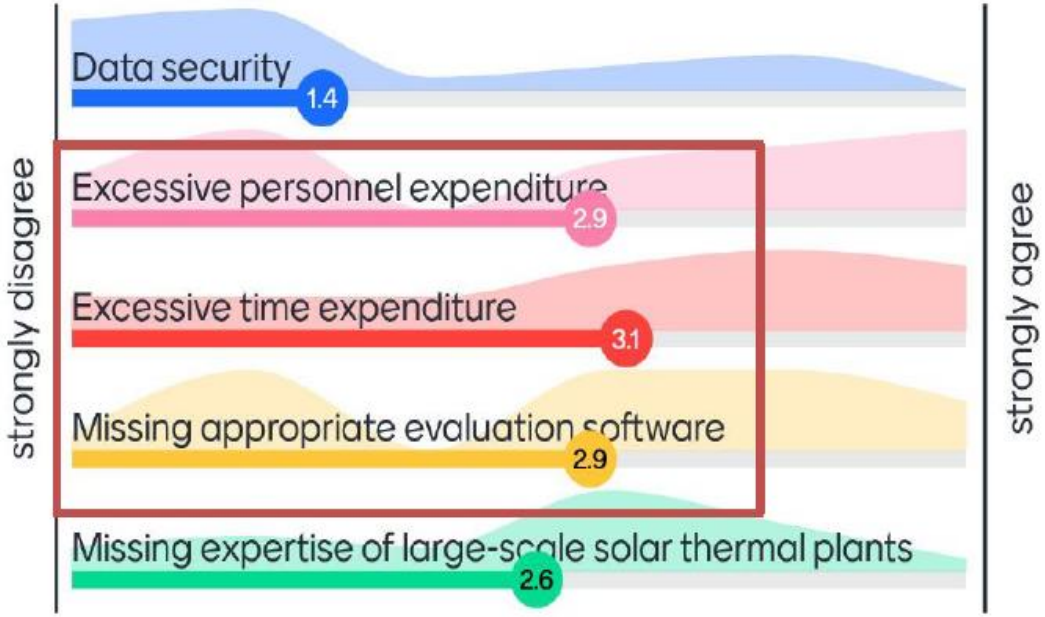
Stakeholder Befragung

Herausforderungen Monitoring

2 Challenges: What are the biggest challenges in monitoring at the moment? (Part 1)



2 Challenges: What are the biggest challenges in monitoring at the moment? (Part 2)



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ISO 24194:2022

Solar energy — Collector fields — Check of performance

(ISO 24194:2022)

Sonnenenergie — Kollektorfelder — Überprüfung der Leistungsfähigkeit (ISO 24194:2022)

Energie solaire — Champs de capteurs — Vérification de la performance (ISO 24194:2022)

- Defines **2 methods** on paper:
  - ✓ Thermal Power Check
  - ✓ Daily Yield Check
- Applicable **Collector types**:
  - ✓ glazed flat plate collectors
  - ✓ evacuated tube collectors
  - ✓ tracking, concentrating collectors

Life cycle

Now

Published
ISO 24194:2022
Stage: **60.60**

Corrigenda / Amendments

Under development
ISO 24194:2022/Amd 1

General information

Status : Published
Publication date : 2022-05
Stage : International Standard published [60.60]

Edition : 1
Number of pages : 30

Technical Committee : ISO/TC 180/SC 4
ICS : 27.160

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Usages & Applications
of ISO 24149 Thermal Power Check

- **Answer** the fuzzy question
  - „How well is a solar thermal plant working?“
  - *Quantitative answer:* Percentage “ratio measured vs. estimated output”
- Standardized performance, **eliminates influence factors**
  - Location, weather, collectors used, field design, operating temperatures, control strategy etc.
  - Performance becomes *comparable* among plants.

- Usage1: **Guarantee Procedure** (plant commissioning etc.)
  - Guarantee question: "Does the plant meet the guaranteed performance?“

- Usage 2: **Performance Monitoring** (operating phase)
  - Ongoing performance evaluation → Detect performance degradation / plant problems

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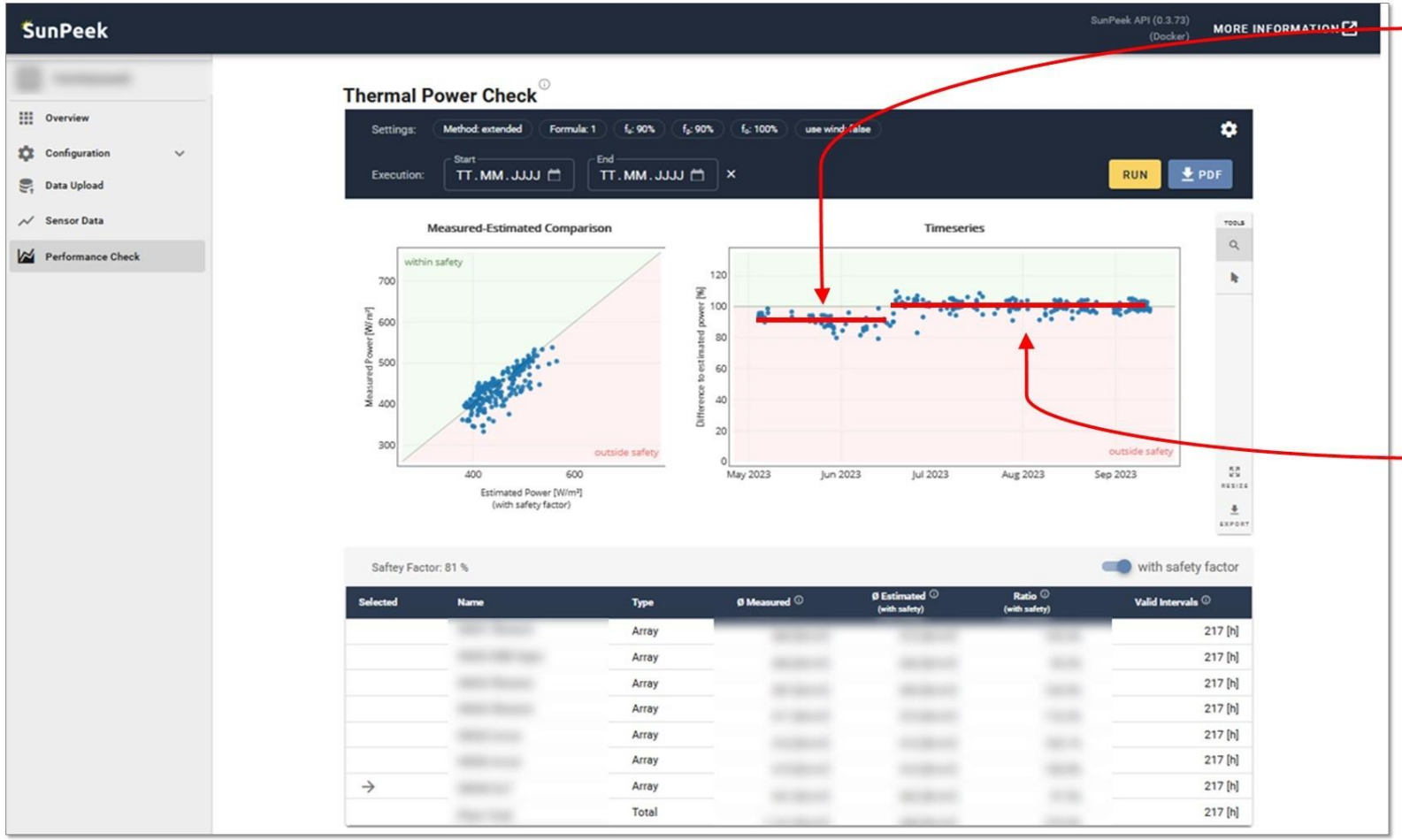
ISO 24194 Thermal Power Check: Example

Before / After Cleaning Collectors



Before cleaning

After cleaning

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Calculation Estimated Power: 3 Models

ISO 24194 Thermal Power Check

Formula (1): Non-concentrating collectors

$$\dot{Q}_{\text{estimate}} = A_{\text{GF}} \cdot \left[\eta_{0,\text{hem}} K_{\text{hem}}(\theta_{\text{L}}, \theta_{\text{T}}) G_{\text{hem}} - a_{1,\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}}) - T_{\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}})^2 - a_5(\mathrm{d}\vartheta_{\text{m}}/\mathrm{d}t) \right] \cdot f_{\text{safe}}$$

Formula (2): Non- or low-concentrating collectors

$$\dot{Q}_{\text{estimate}} = A_{\text{GF}} \cdot \left[\eta_{0,\text{b}} K_{\text{b}}(\theta_{\text{L}}, \theta_{\text{T}}) G_{\text{b}} + \eta_{0,\text{b}} K_{\text{d}} G_{\text{d}} - a_{1,\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}}) - T_{\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}})^2 - a_5(\mathrm{d}\vartheta_{\text{m}}/\mathrm{d}t) \right] \cdot f_{\text{safe}}$$

Formula (3): Concentrating collectors with high concentration

$$\dot{Q}_{\text{estimate}} = A_{\text{GF}} \cdot \left[\eta_{0,\text{b}} K_{\text{b}}(\theta_{\text{L}}, \theta_{\text{T}}) G_{\text{b}} - a_{1,\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}}) - a_5(\mathrm{d}\vartheta_{\text{m}}/\mathrm{d}t) - a_8(\vartheta_{\text{m}} - \vartheta_{\text{a}})^4 \right] \cdot f_{\text{safe}}$$

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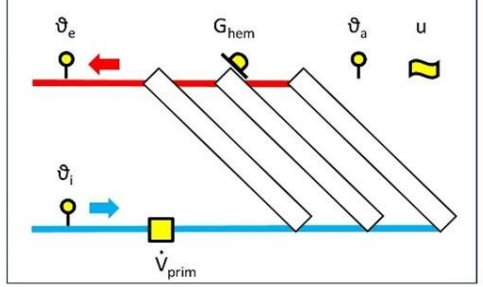
Measurement Data, Data Selection Criteria

ISO 24194 Thermal Power Check

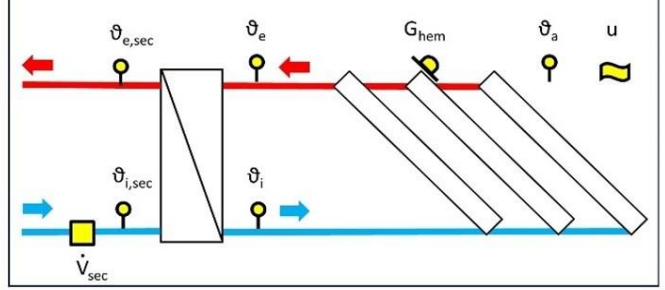
Measurement on **primary** side

[DIR-CF.1] System without heat exchanger - single subfield



Measurement on **secondary** side

[HEX-CF.1] System with heat exchanger - single subfield



+ Global Solar Radiation
+ (optional) global or direct / diffuse
+ Wind velocity

Operation condition	Limits			Comments
	Formula (1)	Formula (2)	Formula (3)	
Shadows	No shadows			See 5.5
Change in collector mean temperature	≤5 K			To avoid big change in collector temperature during one hour
Ambient temperature	≥5 °C			To avoid snow, ice, condensation on solar radiation sensors
Wind velocity	≤10 m/s			To be measured so it is representative for the wind velocity 1 m to 3 m above highest point of collectors
G_{hem}	≥800 W/m²	-	-	
G_b	-	≥600 W/m²	≥600 W/m²	

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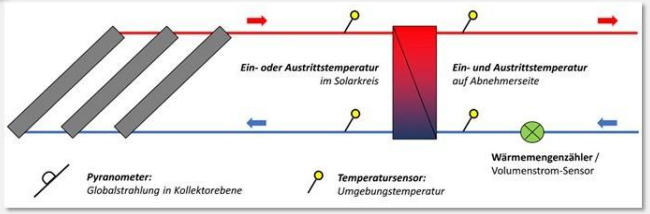
Calculation Estimated Power

ISO 24194 Thermal Power Check

1 Measurement Data



2 Data selection / filtering

Operation condition	Limits			Comments
	Formula (1)	Formula (2)	Formula (3)	
Shadows	No shadows			See 5.5
Change in collector mean temperature	≤5 K			To avoid big change in collector temperature during one hour
Ambient temperature	≥5 °C			To avoid snow, ice, condensation on solar radiation sensors
Wind velocity	≤10 m/s			To be measured so it is representative for the wind velocity 1 m to 3 m above highest point of collectors
G_{hem}	≥800 W/m²	-	-	
G_b	-	≥600 W/m²	≥600 W/m²	

3 Averaging

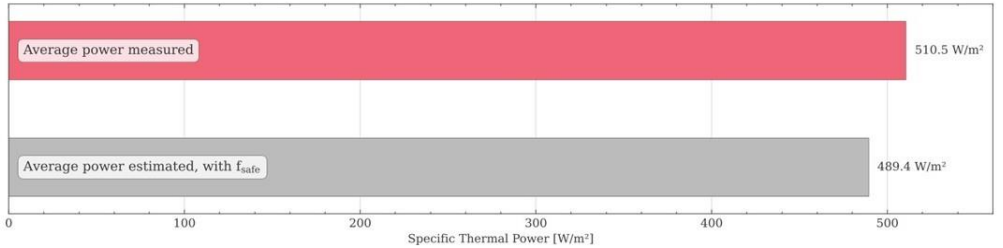
$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

4 Calculation of Estimated Power / 3 Models

$$\dot{Q}_{estimate} = A_{GF} \cdot \left[\eta_{0,hem} K_{hem}(\theta_L, \theta_T) G_{hem} - a_{1,\Delta Q}(\vartheta_m - \vartheta_a) - T_{\Delta Q}(\vartheta_m - \vartheta_a)^2 - a_5 (d\vartheta_m / dt) \right] \cdot f_{safe}$$

Thermal Power Check corrects performance for

- Operating temperatures
- Weather (Solar radiation, ambient temp., wind)
- Components (Collectors, heat transfer fluids)



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„Safety Factor“

Treatment of Uncertainties in ISO 24194 Thermal Power Check

$$\dot{Q}_{\text{estimate}} = A_{\text{GF}} \cdot \left[\eta_{0,\text{hem}} K_{\text{hem}}(\theta_{\text{L}}, \theta_{\text{T}}) G_{\text{hem}} - a_{1,\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}}) - T_{\Delta Q}(\vartheta_{\text{m}} - \vartheta_{\text{a}})^2 - a_5 (\mathrm{d}\vartheta_{\text{m}} / \mathrm{d}t) \right] \cdot f_{\text{safe}}$$

f_{safe} Combined safety factor:

$$f_{\text{safe}} = f_{\text{P}} \cdot f_{U} \cdot f_{\text{O}}$$

f_{P}: Safety factor considering heat losses from pipes etc. in the collector loop. To be estimated based on an evaluation of the pipe losses (e.g. by Formula (23))

f_{U}: Safety factor considering measurement uncertainty. To be estimated - with the requirements given in 7.2, a factor of 0,95 (level I) and 0,9 (level II and III) can be used – or detailed documentation for the uncertainty calculation is required according to ISO/IEC Guide 98-3.

f_{O}: Safety factor for other uncertainties e.g. related to non-ideal conditions such as:

— non-ideal flow distribution. To be estimated - should be close to one.

— unforeseen heat losses. To be estimated - should be close to one.

SunPeek Software

SunPeek

Public Demo Server:
https://demo.sunpeek.org/

- **Open-source, web-based software**
  - Uses OSI-approved licenses. Allows commercial use!
  - Allows integration with own tools.
- Intended as **reference implementation** of ISO 24194
  - Transparent & easy access to ISO methods.
  - Simplifies operation of solar thermal plants.
- Development hub / platform, parallel to ISO standard development
  - Extension of methods, technologies and software features.
  - Community building in research & industry. Inputs to ISO 24194.
- Project governance is defined, **contributors are welcome**!
  - First development within a network of academic and industry experts.
  - AEE INTEC, SOLID, GASOKOL, Schneid.
- SunPeek **implements & extends** ISO 24194
  - Automate ISO methods, web API, pdf reports. Extend ISO where necessary.

Current SunPeek Steering Committee members

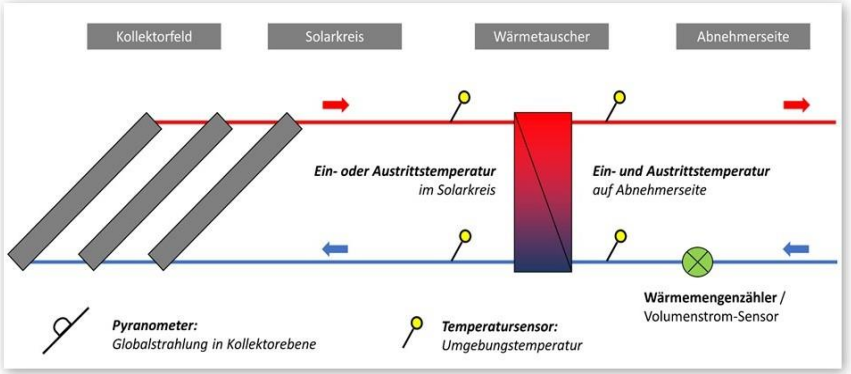




SunPeek Extensions & Adaptations

to ISO 24194:2022 Thermal Power Check

https://demo.sunpeek.org/



1) **More than 1 collector field / array**
   - ✓ Data treatment & estimated power per array
2) **Mixed collectors**
   - ✓ E.g. single & double glazed, flat-plate & concentrating
   - ✓ Differences in collector data sheets (SST/QDT, IAM,…)
3) **Non-standardized measurements**
   - ✓ Virtual sensors, Fluids Database
4) **Nasty data**
   - ✓ Auto-treat data formats, valid data, time zones, …
5) **Extended filtering → more data**
   - ✓ Extend TPC with more information in partial load

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SunPeek pdf Report

of ISO 24194 Thermal Power Check

https://demo.sunpeek.org/

Thermal Power Check according to ISO 24194

Plant name	FHW Arcon South _Test_
Plant owner	SOLID
Included arrays	Arcon South
Measuring period	2017-05-01 00:00 (UTC+1) to 2017-05-31 23:59 (UTC+1)
Date	2023-09-20
Algorithm details	Formula: 1. Wind: Used. Mode: extended.
Check done by	SunPeek version dev 46ec0b6 on branch 560-create-pdf-reports-for-static-documentation

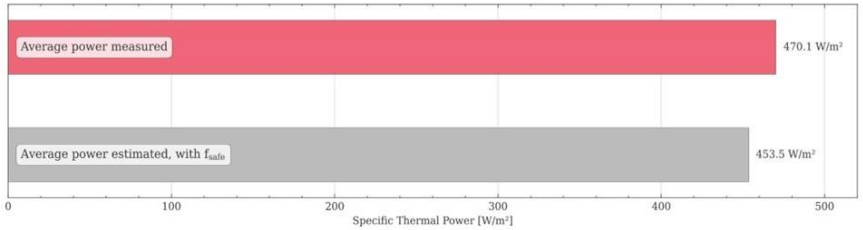
This report is based on ISO 24194:2022(E) "Solar energy — Collector fields — Check of performance".
Report generated with SunPeek: https://docs.sunpeek.org

SunPeek

Thermal Power Check ISO 24194

Thermal Power Check fulfilled:

This takes a combined safety factor $f_{safe} = 0.9$ into account.
The minimum number of intervals (20, defined in ISO 24194:2022(E)) has been reached:
n=75 intervals found, each 1 hour long.



Notes

Plant name: "FHW Arcon South _Test_".
Included arrays: "Arcon South".
Data from 2017-05-01 00:00 (UTC+1) to 2017-05-31 23:59 (UTC+1).

Thermal Power Check according to ISO 24194:2022(E).
Algorithm details: Formula: 1. Wind: Used. Mode: extended.

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SunPeek Software & Licenses

https://demo.sunpeek.org/

web UI
Graphical user interface.
Interactive use in browser.

web API
Restful API. Automate
with other software tools.

Python package
Algorithm development.
Integrate with other projects.

Docker
Standardized distribution
and installation.

- ✓ SunPeek is **free** to use, modify and distribute, including **commercial** use.
- ✓ Open-source ensures **transparency** in guarantee procedures.
- ✓ SunPeek uses **OSI-approved licenses.**
- ✓ **Open data is optional**. No need to share measurement data!

SunPeek Web-UI
BSD-3 Clause
- „Permissive“, virtually no restrictions
- Used in similar open-source projects (e.g. pvlib).
- Simplifies integration with own software.

SunPeek Backend
LGPL (GNU General Public License)
- „Weakly Protective“
- Must release changes under same license.
- Ensures consistent implementation of ISO 24194.

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“Task 68 Guide” to ISO 24194 Thermal Power Check

Cooperation from „IEA SHC Task 68“ Efficient Solar District Heating Systems

- Application of ISO 24194 underpins the need for clarification, background information and some practical amendments / tweaks.
- Software implementation SunPeek, for automated and transparent ISO 24194 Thermal Power Check.
- Main target groups: plant operators, plant designers, collector manufacturers, researchers.

Inputs from industry & research welcome!

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SunPeek

Further Information

https://demo.sunpeek.org/

- ✓ Simple system configuration, ~10 minutes
- ✓ Interactive & automated analysis, pdf report
- ✓ Supports Windows / Mac / Linux
- ✓ Beta Release Planned, June 2024

SunPeek

✓	**Hub**	https://sunpeek.org/
✓	**Public Demo**	https://demo.sunpeek.org/
✓	**Software Repository**	https://gitlab.com/sunpeek/
✓	**Support**	support@sunpeek.org
✓	**Open Dataset**	https://doi.org/10.5281/zenodo.7741083
✓	**Data-in-Brief Article**	https://doi.org/10.1016/j.dib.2023.109224
✓	**Zenodo Community**	https://zenodo.org/communities/sunpeek
✓	**JOSS Article**	in preparation
✓	**Visit us**	ISEC Graz, Bad Staffelstein, EuroSun Cyprus