



**AEE INTEC**

**SOLID**  
solar energy systems

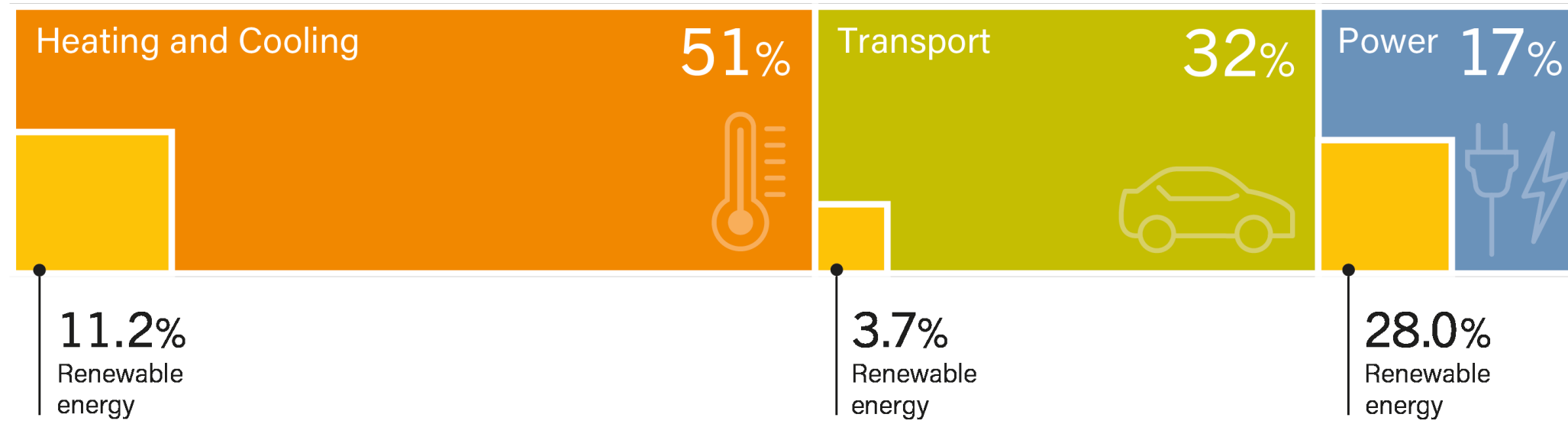
# **SunPeek** & ISO 24194

Open-Source Software  
for Large Solar Thermal Plants:  
Monitoring and Guarantees

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Marnoch Hamilton-Jones, Maria Moser, Peter Zauner

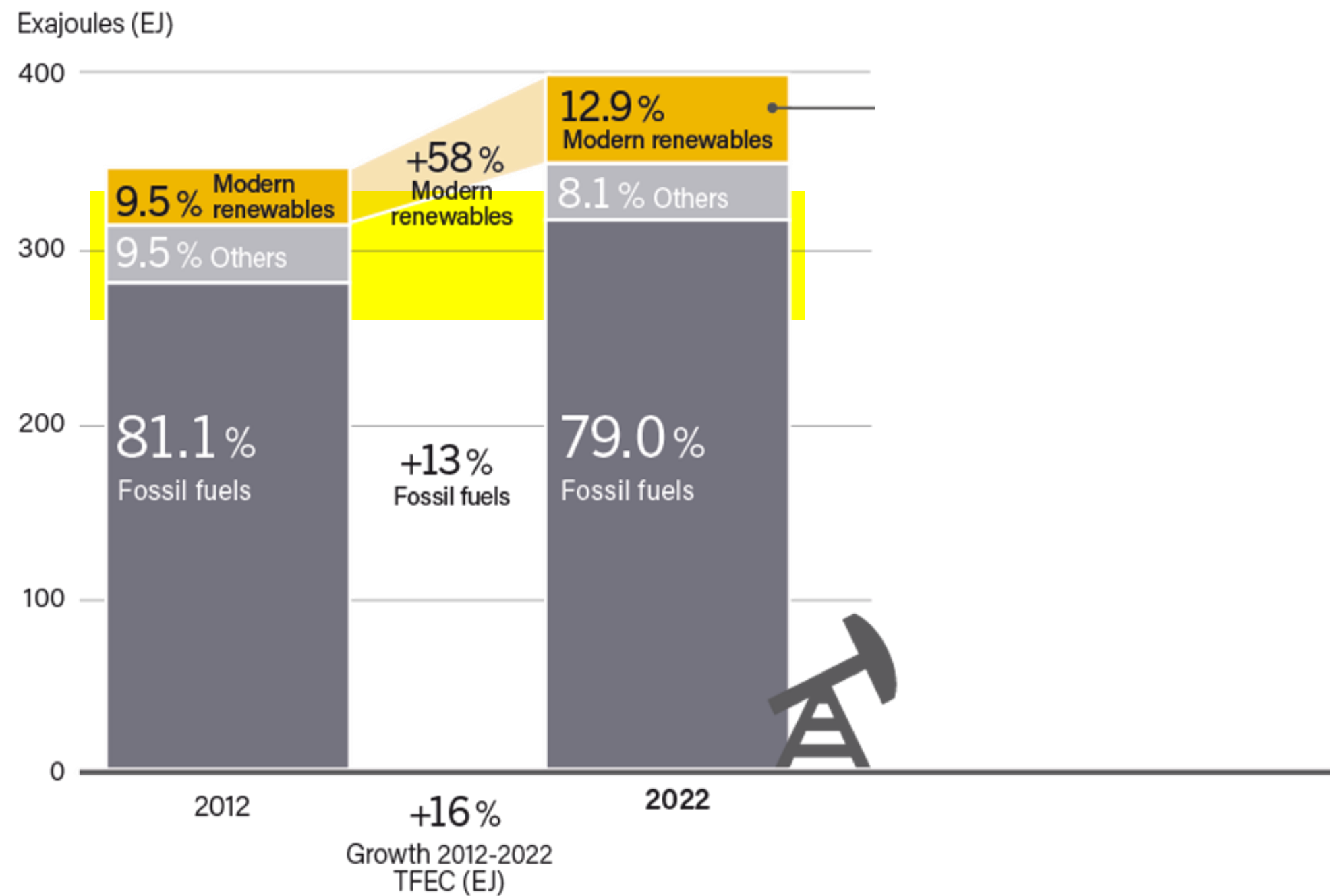
# Motivation



11.2% Renewable energy

3.7% Renewable energy

28.0% Renewable energy



Indicators	Recent years	2030 <sup>1)</sup>	2050 <sup>1)</sup>	Progress (off / on track)
<b>ELECTRIFICATION WITH RENEWABLES</b>				
Share of renewables in electricity generation	28% <sup>2)</sup>	68%	91%	
Renewable power capacity additions	295 GW/yr <sup>3)</sup>	975 GW/yr <sup>4)</sup>	1 066 GW/yr	
Annual solar PV additions	191 GW/yr <sup>5)</sup>	551 GW/yr	615 GW/yr	
Annual wind energy additions	75 GW/yr <sup>6)</sup>	329 GW/yr	335 GW/yr	
Investment needs for RE generation	486 USD billion/yr <sup>7)</sup>	1 300 USD billion/yr	1 380 USD billion/yr	
Investment needs for power grids and flexibility	274 USD billion/yr <sup>8)</sup>	605 USD billion/yr	800 USD billion/yr	
<b>DIRECT RENEWABLES IN END-USES AND DISTRICT HEAT</b>				
Share of renewables in final energy consumption	17% <sup>9)</sup>	35%	82%	
Solar thermal collector area	585 million m <sup>2</sup> /yr <sup>10)</sup>	1 552 million m <sup>2</sup> /yr	3 882 million m <sup>2</sup> /yr	
Modern use of bioenergy (direct use)	21 EJ <sup>11)</sup>	46 EJ	53 EJ	
Geothermal consumption (direct use)	0.9 EJ <sup>12)</sup>	1.4 EJ	2.2 EJ	
Renewables based district heat generation	0.9 EJ <sup>13)</sup>	4.3 EJ	13 EJ	
Investment needs for renewables end uses and district heat	13 USD billion/yr <sup>14)</sup>	290 USD billion/yr <sup>15)</sup>	210 USD billion/yr	

Source: IRENA World Energy Transitions Outlook 2022

# How to Decarbonize?

Friesach,  
Source: Solar Engineering Guggenberger



Fernheizwerk Graz (FHW)  
Source: Picfly.at Thomas Eberhard



Höglätten Hämösand  
Source: Absolicon



St. Ruprecht an der Raab,  
Source: Gasokol GmbH



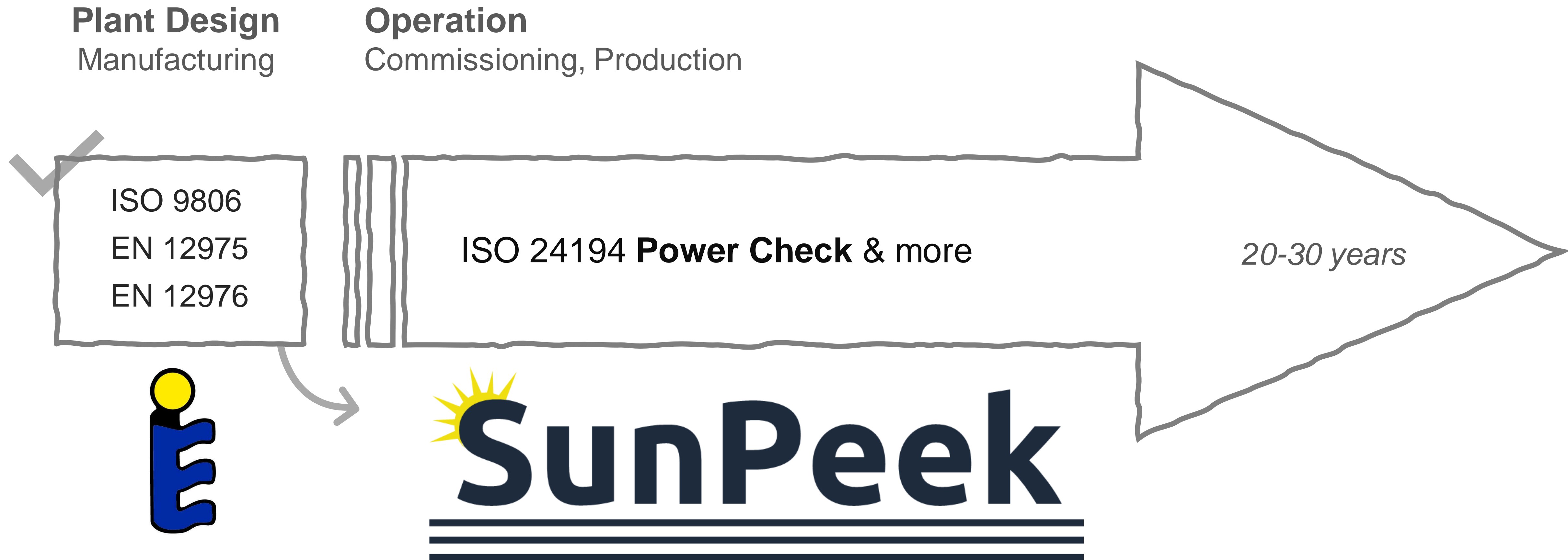
Fernwärme Ettenheim  
Source: Peter Blaser



Stadtwärme Greifswald  
Source: Ritter XL Solar



# Challenges Monitoring Solar thermal plants



# ISO 24194:2022 “Check of Performance”

- New ISO standard for assessing performance of solar thermal collector fields / plants.
  - ✓ **In-situ**, for plants in operation!
  - ✓ Refers to ISO 9806 (single collector lab tests)
  - ✓ Refers to ISO 9060 (instruments for solar radiation)
  - ✓ Refers to ISO 9488 (solar vocabulary)
  
- Defines **2 methods** on paper:
  - ✓ *Power Check*
  - ✓ Daily Yield Check
  
- Applicable **Collector types**:
  - ✓ Glazed flat plate collectors
  - ✓ Evacuated tube collectors
  - ✓ Tracking, concentrating collectors

## 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)

### Life cycle

Now

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

### Corrigenda / Amendments

↳ Under development  
**ISO 24194:2022/Amd 1**

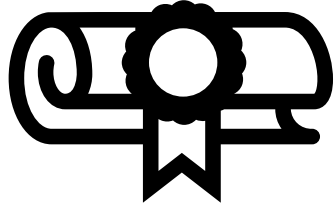

### General information

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

Edition : 1  
Number of pages : 30

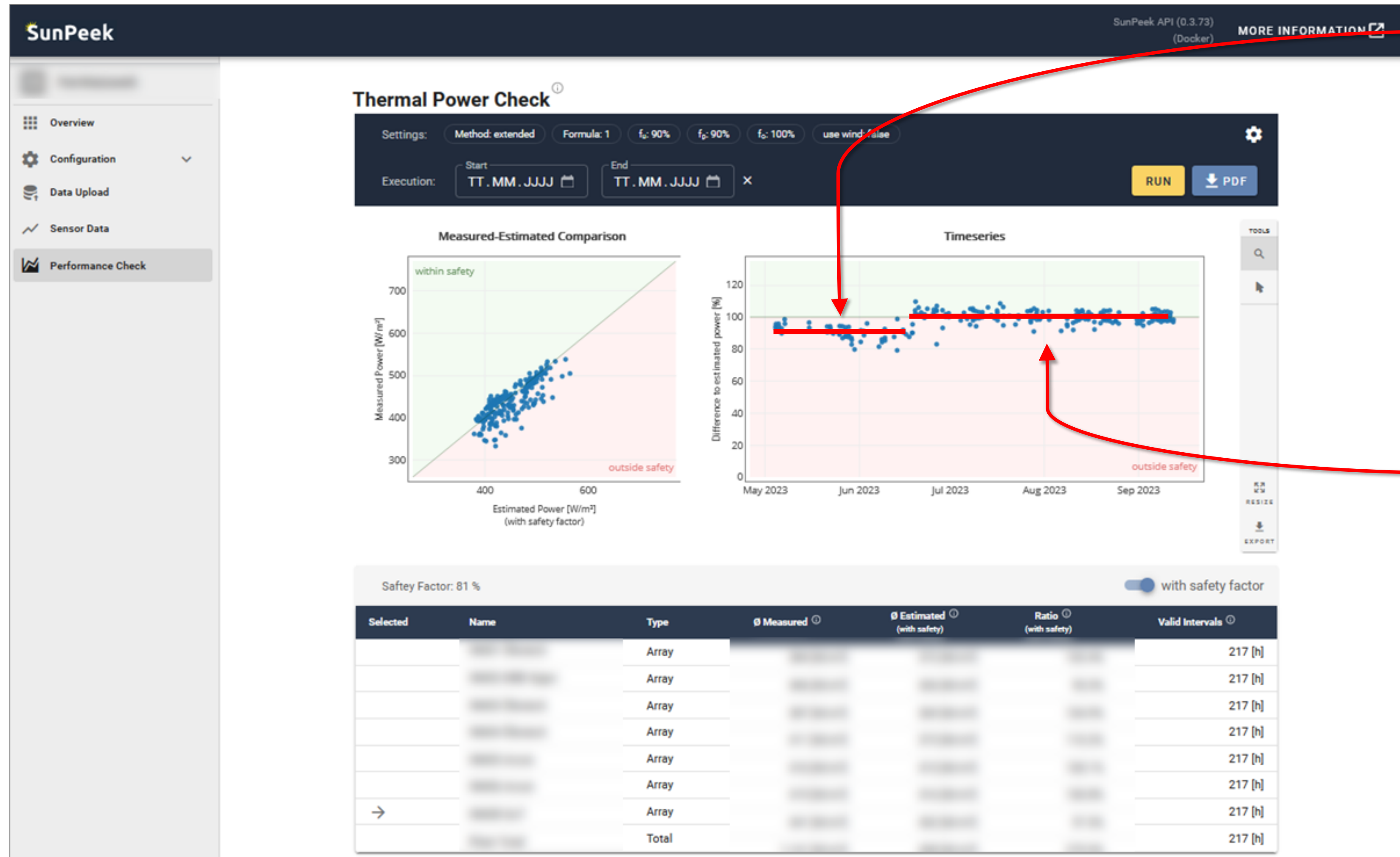
Technical Committee : **ISO/TC 180/SC 4**  
ICS : **27.160**

# Usage & Application of SunPeek & ISO 24194 Power Check

- **Answers** the fuzzy question:
  - „How well is a solar thermal plant working?“ → „How well should it work?“
- **Standardized performance. Corrects for main influence factors.**
  - *Factors out:* Weather, temperatures, collectors used, location, field design etc.
  - *Quantitative:* Percentage “ratio measured vs. estimated output”
  - *Comparable:* Performance becomes *comparable* among plants & over time.
-  **Usage1: Guarantee Procedure** (plant commissioning etc.)
  - Question: "Does the plant meet some guaranteed performance?"
-  **Usage 2: Performance Monitoring** (operating phase, ongoing)
  - Question: How to Detect performance degradation / plant problems+ Act predictively

# SunPeek Example 1: Ongoing Monitoring

## Before / After Cleaning Collectors



Before cleaning



After cleaning



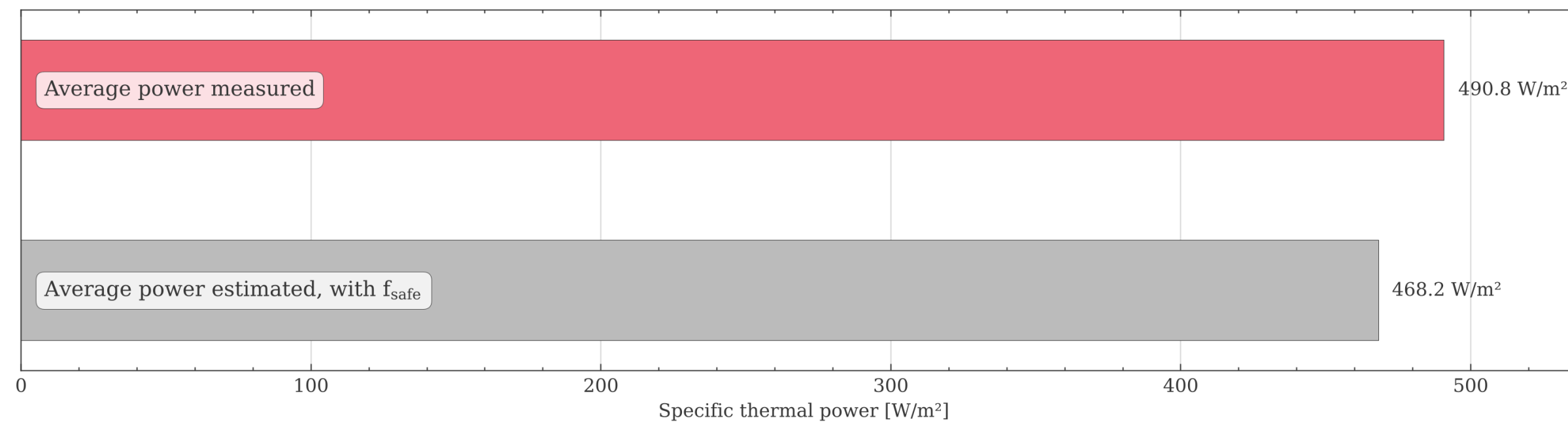
# SunPeek Example 2: Power Guarantees

## Measured vs. Estimated Power

### Power Check according to ISO 24194:2022

**Power Check fulfilled:**

Ratio measured / estimated power = 104.8%  
 This takes a combined safety factor  $f_{safe} = 0.9$  into account.  
 The minimum number of intervals (20, defined in ISO 24194:2022) has been reached: n=64 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).

Power Check according to ISO 24194:2022  
 Algorithm details: Formula: 2. Wind: Used. Averaging mode: Extended.

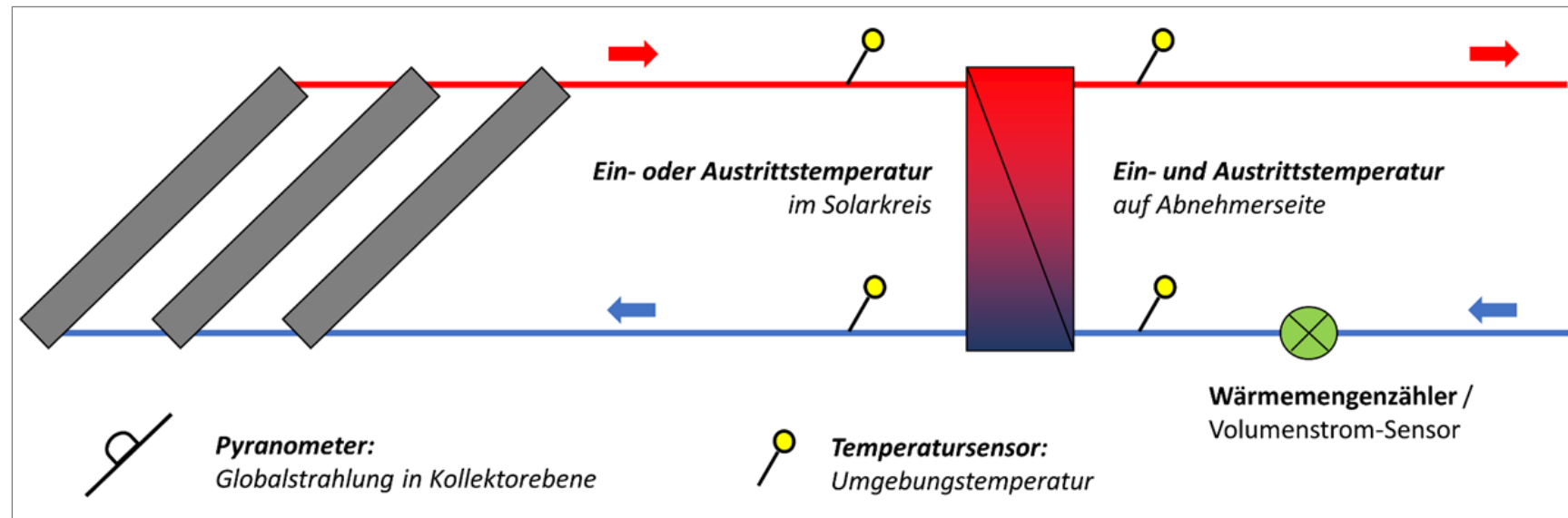




# How to Calculate the Estimated Power

## ISO 24194 Power Check

### 1 Different 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/m <sup>2</sup>	-	-	
$G_b$	-	≥600 W/m <sup>2</sup>	≥600 W/m <sup>2</sup>	

### 3 1-Hour Averages

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

### 4 3 Formulae: Non-concentrating, low-, high-concentrating collectors

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

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

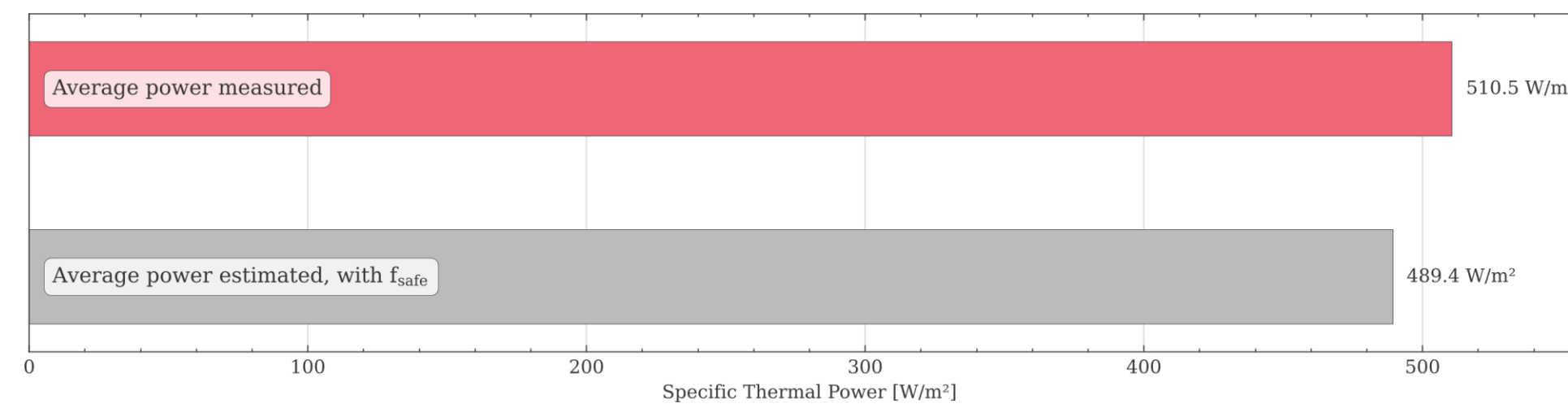
$$\dot{Q}_{estimate} = A_{GF} \cdot \left[ \eta_{0,b} K_b (\theta_L, \theta_T) G_b - a_{1,\Delta Q} (\vartheta_m - \vartheta_a) - a_5 (d\vartheta_m / dt) - a_8 (\vartheta_m - \vartheta_a)^4 \right] \cdot f_{safe}$$

### 5 "Safety Factor"

$f_{safe}$  Combined safety factor

$$f_{safe} = f_P \cdot f_U \cdot f_0$$

### 6 Target – Actual Comparison

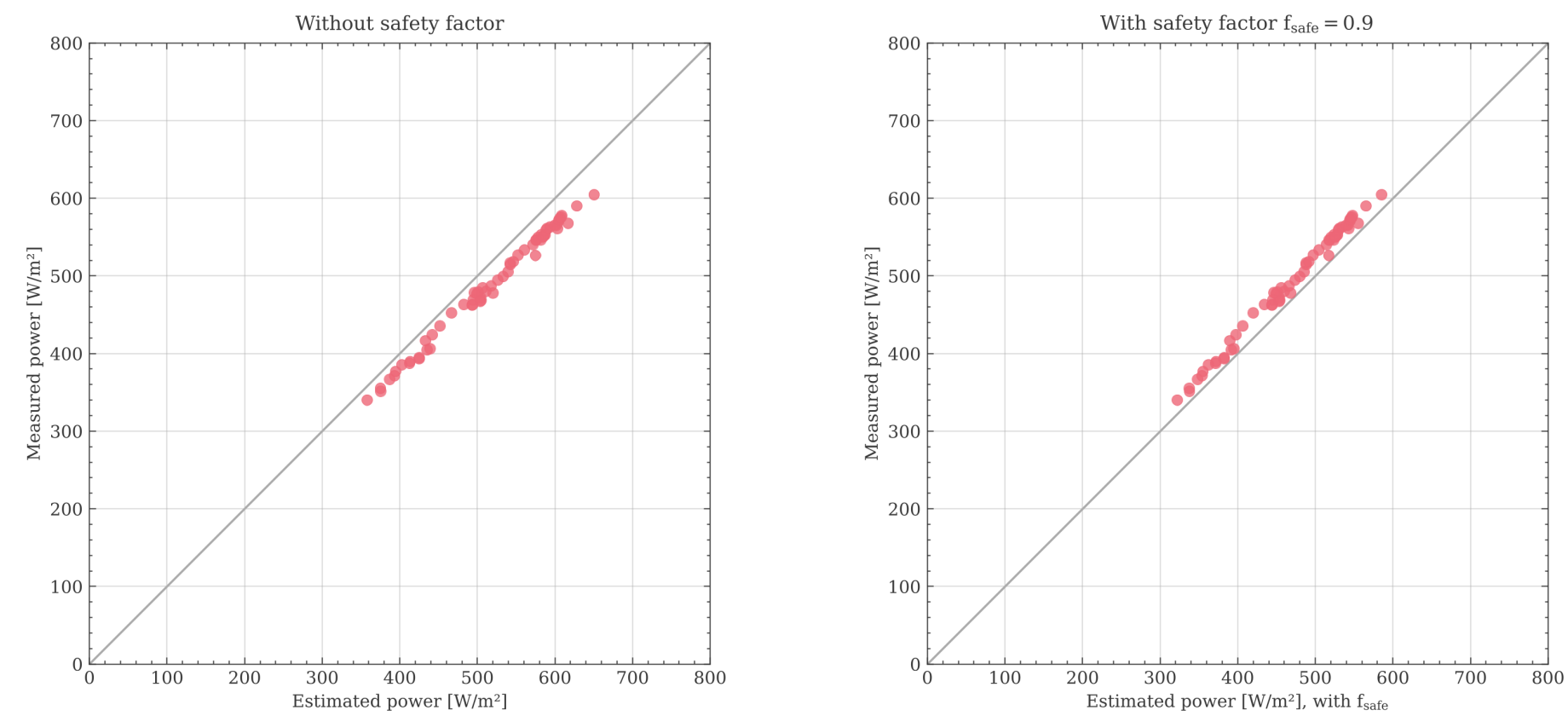


# SunPeek pdf Report of ISO 24194 Power Check

## Power Check according to ISO 24194:2022

### Thermal Power Output: Measured vs. Estimated

Plant: FHW Arcon South \_Test\_  
Included arrays: Arcon South



#### Notes

Each dot in the plots is the average thermal power output of a 1 hour interval.  
The left plot is based on estimated and measured data without safety factor. The right plot takes the combined safety factor  $f_{safe} = 0.9$  into account.  
Algorithm details: Formula: 2. Wind: Used. Averaging mode: Extended.



<https://docs.sunpeek.org>  
Generated with SunPeek version dev a933a3d on branch 625-power-check-pdf-report-fix-line-too-long.

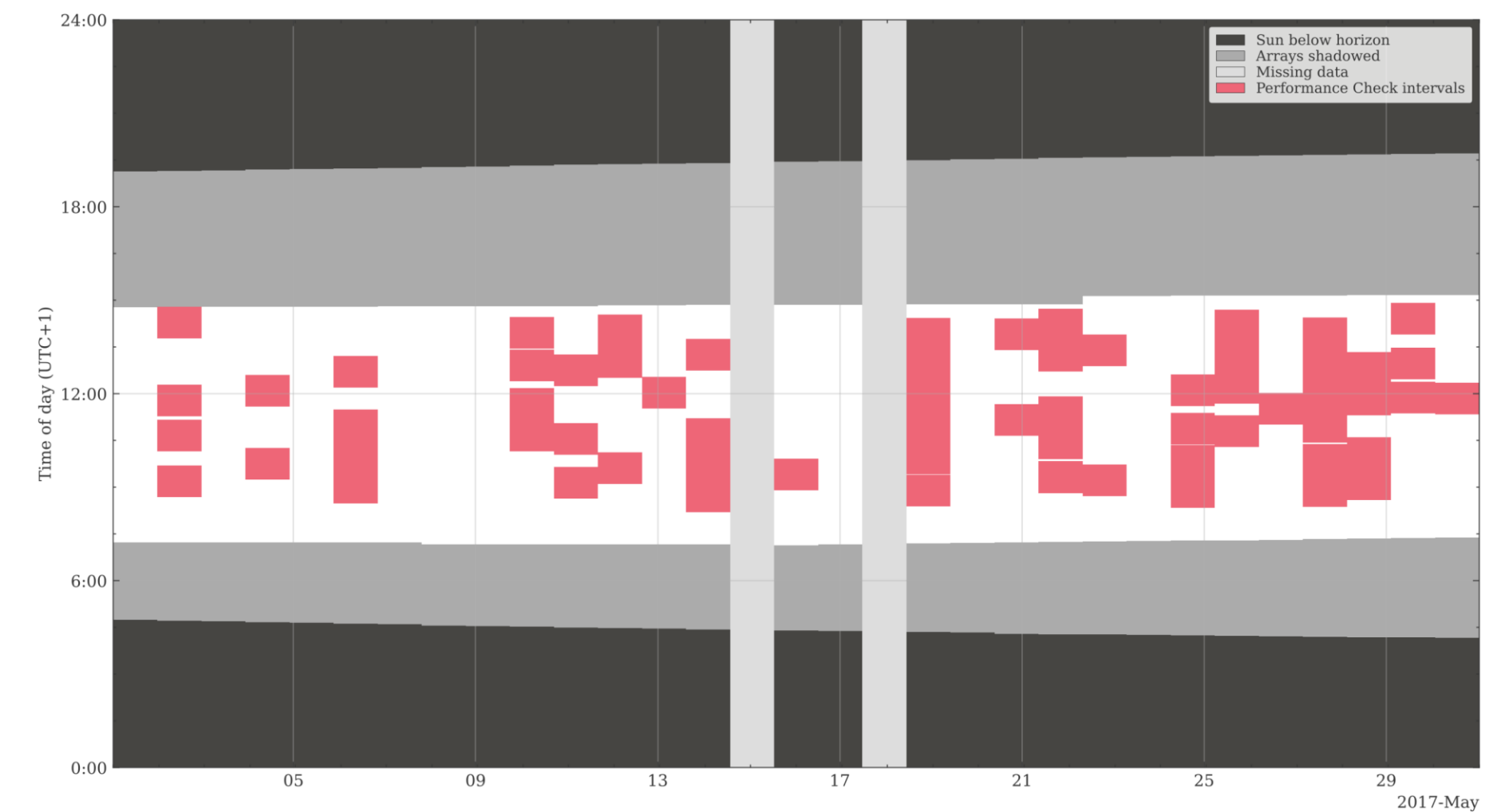
## Power Check according to ISO 24194:2022

**Power Check fulfilled:**

Ratio measured / estimated power = 104.8%  
This takes a combined safety factor  $f_{safe} = 0.9$  into account.  
The minimum number of intervals (20, defined in ISO 24194:2022) has been reached: n=64 intervals found, each 1 hour long.

### Intervals used for Power Check

n=64 intervals, each 1 hour long. Total interval duration: 64 hours 0 minutes.  
Algorithm details: Formula: 2. Wind: Used. Averaging mode: Extended.



<https://docs.sunpeek.org>  
Generated with SunPeek version dev a933a3d on branch 625-power-check-pdf-report-fix-line-too-long.



# SunPeek GUI, Graphical User Interface

<https://demo.sunpeek.org>



The screenshot displays the SunPeek GUI interface, which is a web-based dashboard for solar plant monitoring. The interface is organized into several panels and sections:

- Navigation Menu:** Located on the left, it includes options for Overview, Configuration, Plant, Arrays, Sensor Mapping, Sensors, Data Upload, Sensor Data, and Performance Check.
- Select Collector Dialog:** A modal window showing a list of collectors with columns for ID and Collector Name. The list includes various models like Arcon 3510, powerSol 55, Greenonetec 3803, and others.
- Performance Check Panel:** This panel shows the results of a thermal power check. It includes settings for Method (ISO), Formula (AUTO (2)), and various safety factors (f<sub>g</sub>: 90%, 100%, 100%). The measurement period is set from 04/30/2017 to 06/01/2017. The results are visualized in two charts: a Measured-Estimated Comparison scatter plot and a Timeseries line chart. Both charts indicate that the power is 'within safety'.
- Summary Table:** A table at the bottom right provides a summary of the performance check results, including the safety factor (90%), measured and estimated power, and the ratio of measured to estimated power.

Selected	Name	Type	Gross Area	Ø Measured (with safety)	Ø Estimated (with safety)	Ratio (with safety)	Valid Intervals
	Arcon South	Array	515.66 [m <sup>2</sup> ]	512 [W/m <sup>2</sup> ]	488 [W/m <sup>2</sup> ]	104.9%	47 [h]
→	Plant Total	Total	515.66 [m <sup>2</sup> ]	512 [W/m <sup>2</sup> ]	488 [W/m <sup>2</sup> ]	104.9%	47 [h]

# SunPeek: Practical Extensions of ISO 24194:2022 Power Check

## 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

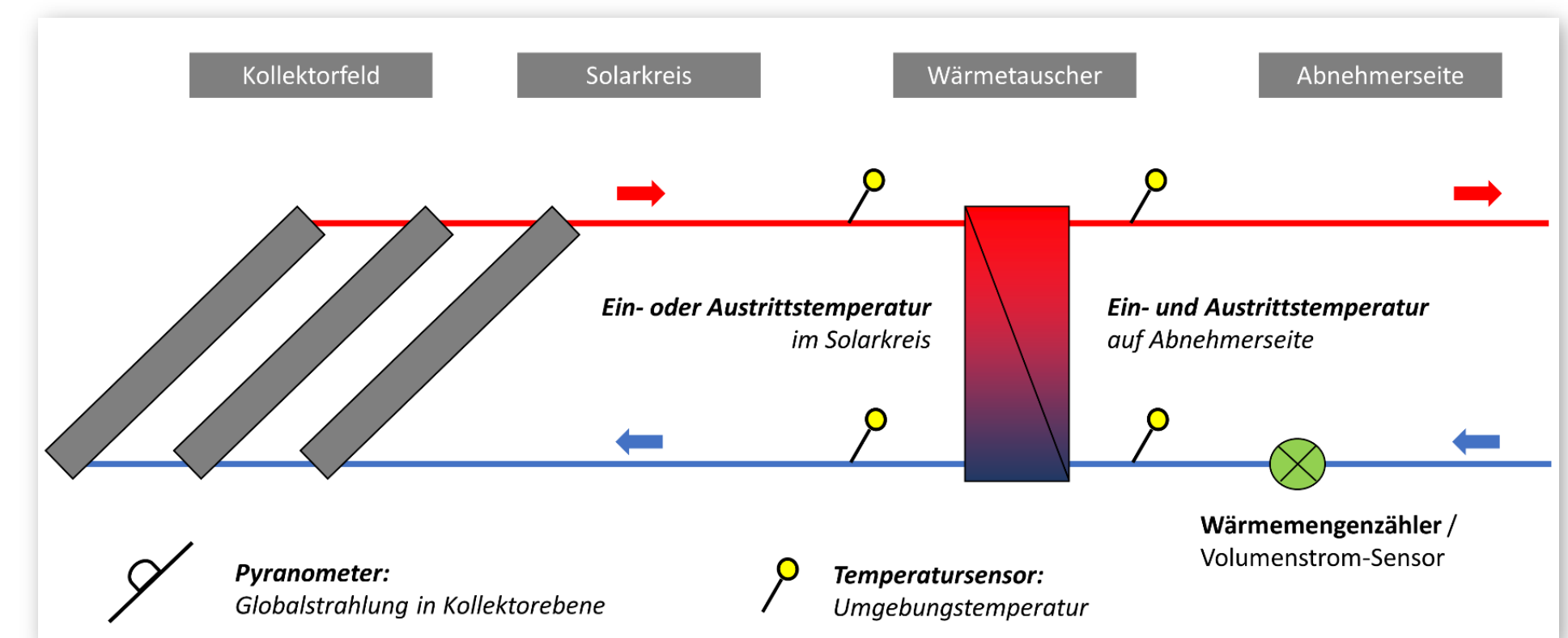
- ✓ E.g. Heat transfer fluid properties, database

## 4) Nasty data

- ✓ Auto-treat data formats, valid data, time zones, ...

## 5) Extended filtering method

- ✓ More modern data analysis
- ✓ Faster results, more partial loads



# SunPeek: Platform

## Open-source, web-based software

- *Designed as Reference Implementation of ISO 24194, and more.*
- **Objective:** Simplify operation of solar thermal plants → **Reduce LCOH**
- **Features:** Transparency, Automation, High quality implementation

## Platform / Development Hub

- *Governed by community / Research, Industry, Associations.*
- **Objective:** Discuss & **Extend** methods & implementations where necessary.
- **Objective:** Efficient development, exchange with **TC 180 / ISO 24194**

## Contributors are Welcome.

- *First developed by AEE INTEC, SOLID, GASOKOL, Schneid.*
- **Objective: Participation**
- **How?** Project Governance Basics (“How to be SunPeek?”) are defined.

The SunPeek logo features the word "SunPeek" in a bold, dark blue, sans-serif font. The letter "S" is stylized with a yellow sunburst effect at its base. To the right of the text are two vertical black lines of varying thickness.

# SunPeek: Software & Licenses

<https://demo.sunpeek.org/>



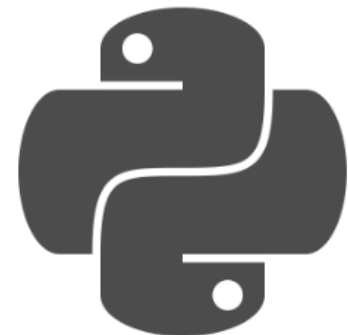
## web UI

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.

## BSD-3 Clause

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



## Summary

- ✓ SunPeek is **free** to use, also **commercially**, free to modify and distribute.
- ✓ **Open Data is optional**. No need to share measurement data!

## Backend: LGPL (GNU General Public License)

- „Weakly Protective“
- Must release changes under same license.
- Ensures *consistent implementation* of ISO 24194.



# SunPeek: Planned Features

## 1) Link to Solar Keymark Database

- Predefined Collectors

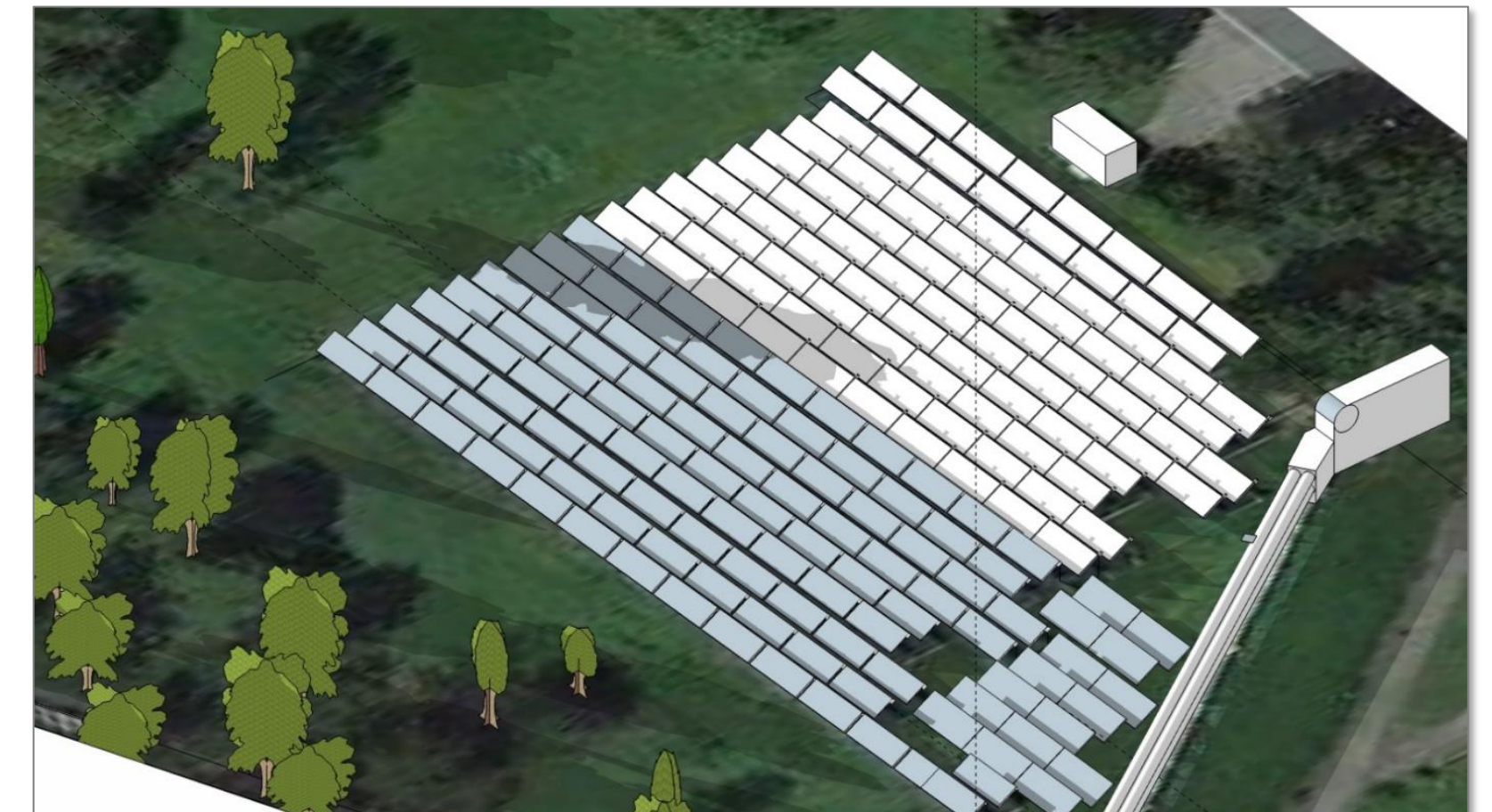
## 2) More Automation

## 3) Radiation modelling

- Correction of diffuse radiation masking for fair assessment
- Multiple collector arrays with different orientation
- Tracking collectors
- ✓ Internal Shading (done)

## Feedback to ISO

- Inputs to ISO 24194 via TC 180 / SC4





# Who is SunPeek?

## Steering Committee Maintainers



## Initiators



## Funding



## Community, Users & Enablers





# “Task 68 Guide” t to ISO 24194 Power Check

Guide to  
ISO 24194:2022  
Power Check

*Draft Version* 1.1

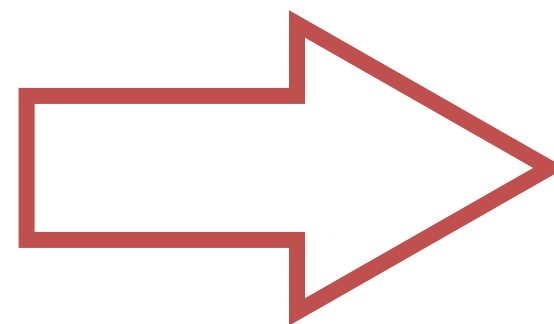
*Date* 2024-03-23



**SHC**

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

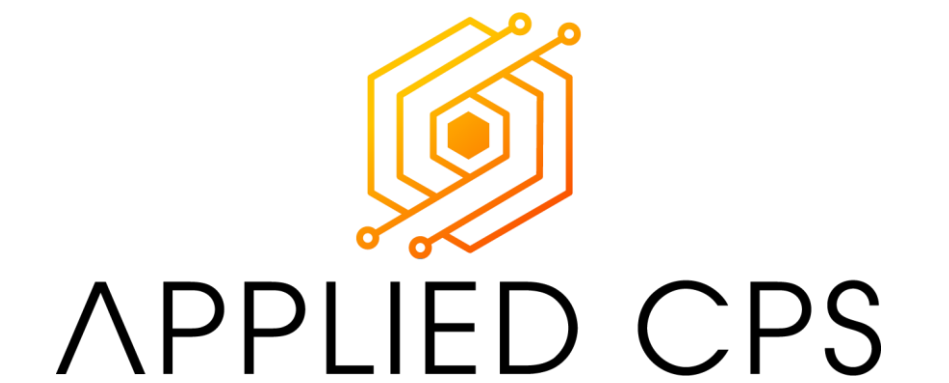
- **Task 68 Deliverable**
- **Practical application** of ISO 24194 underpins need for clarification, background information and some practical amendments / tweaks.
- **SunPeek software:** ISO 24194 Reference implementation. Automated & transparent Power Check.
- **Target groups:** Plant operators, Plant designers, Collector manufacturers, Researchers.



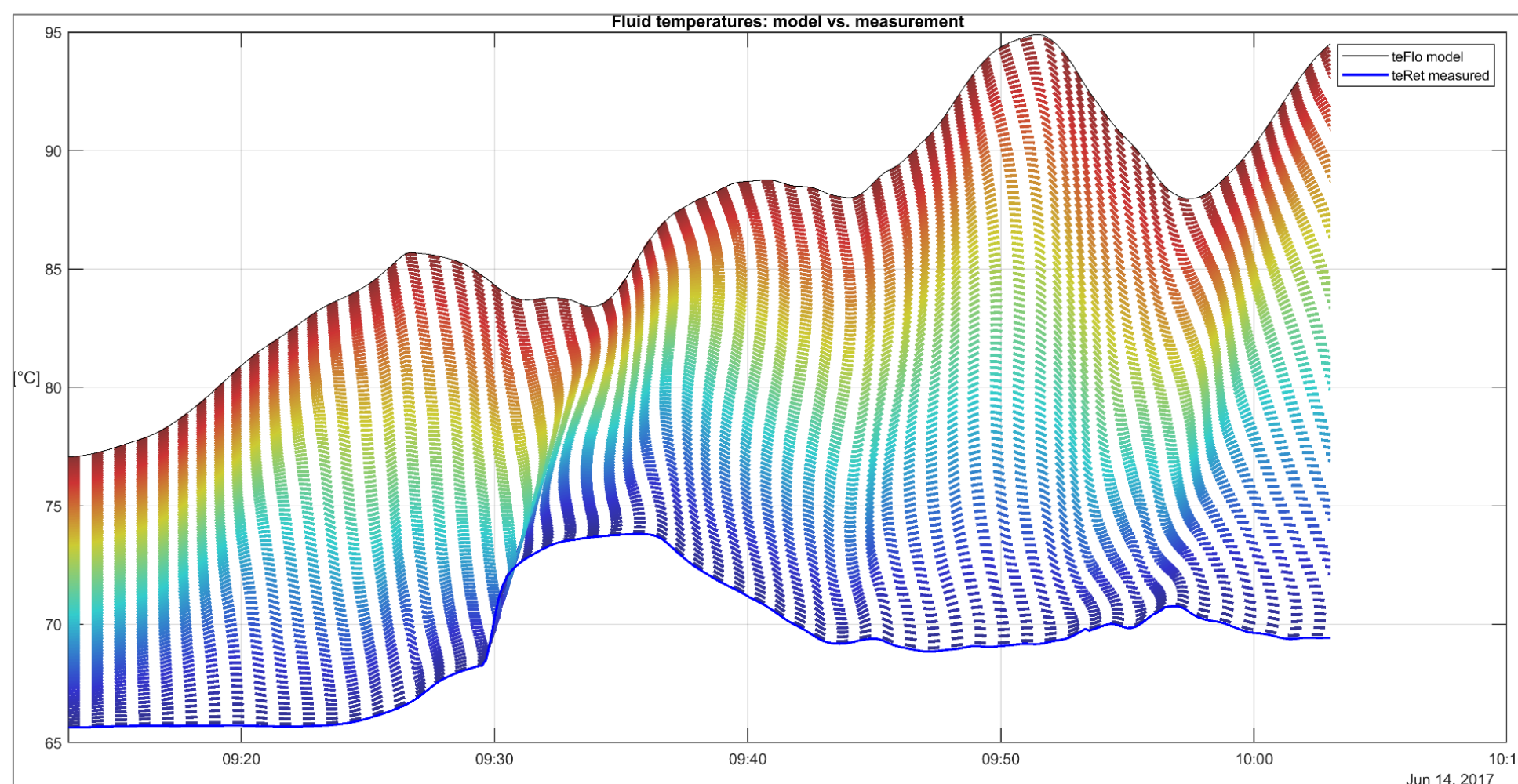
Inputs from industry & research welcome!  
**Contact us if interested!**



Open-Source Software for  
Optimized Operation  
of Large Solar Thermal Plants.



Open-Source Scientific  
Development Platform





# SunPeek Information

<https://www.sunpeek.org>



- ✓ Support [support@sunpeek.org](mailto:support@sunpeek.org)
- ✓ Software Repository <https://gitlab.com/sunpeek/>
- ✓ Public Demo <https://demo.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>

**Open-Source Software for Optimized Operation of Large Solar Thermal Plants**

## SunPeek

**About SunPeek**

SunPeek is an open-source tool for **performance monitoring** and **guarantee procedures** of large-scale solar thermal plants. SunPeek introduces the **first open-source implementation** of the Power Check method and is intended as the reference software tool for ISO 24194:2022 ("Collector fields - Check of Performance").

SunPeek has been successfully deployed to several large-scale solar plants. Included with SunPeek is a pre-configured demo plant, featuring one year of open measurement data from the "Fernheizwerk" plant in Graz, Austria. Featuring simple software licenses, SunPeek is available for free for **scientific and commercial use**. Our vision is to advance the state-of-the-art of quality assurance in large solar thermal plants and evolve SunPeek towards an **industry-standard solution** in plant monitoring.

Explore the public SunPeek demo, visit <https://demo.sunpeek.org>

**Screenshots**

Plant configuration

ISO 24194 PDF Report



**AEE INTEC**

**IDEA TO ACTION**

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