AEE INTEC

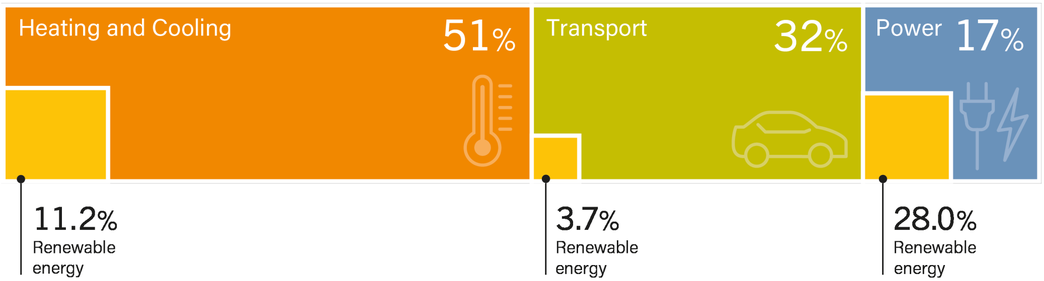
SOLID solar energy systems

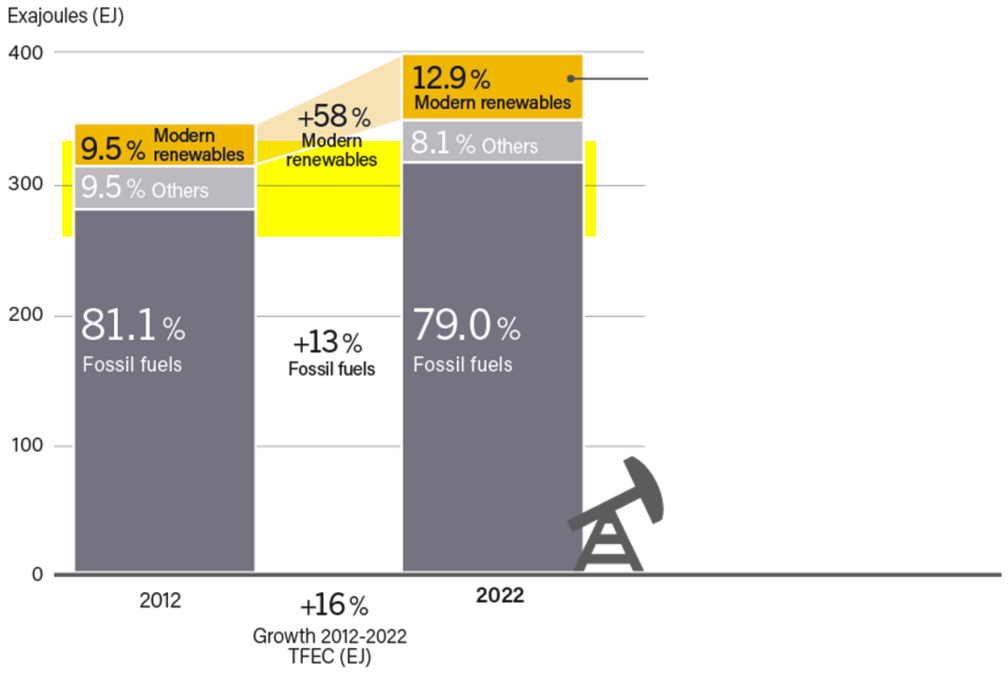
# SunPeek & ISO 24194

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

Philip Ohnewein, Daniel Tschopp, Lukas Feierl,
Marnoch Hamilton-Jones, Maria Moser, Peter Zauner

# Motivation




| Indicators | Recent years | 2030 [1] | 2050 [1] | Progress (off / on track) |
|---|---|---|---|---|
| **RENEWABLES** | | | | |
| **ELECTRIFICATION WITH RENEWABLES** | | | | |
| Share of renewables in electricity generation | 28 % [2] | 68 % | 91 % | |
| Renewable power capacity additions [3] | 295 GW/yr [4] | 975 GW/yr | 1 066 GW/yr | |
| Annual solar PV additions [3] | 191 GW/yr [5] | 551 GW/yr | 615 GW/yr | |
| Annual wind energy additions [3] | 75 GW/yr [6] | 329 GW/yr | 335 GW/yr | |
| Investment needs for RE generation | 486 USD billion/yr [7] | 1 300 USD billion/yr | 1 380 USD billion/yr | |
| Investment needs for power grids and flexibility | 274 USD billion/yr [8] | 605 USD billion/yr | 800 USD billion/yr | |
| **DIRECT RENEWABLES IN END-USES AND DISTRICT HEAT** | | | | |
| Share of renewables in final energy consumption | 17 % [9] | 35 % | 82 % | |
| Solar thermal collector area | 585 million m²/yr [10] | 1 552 million m²/yr | 3 882 million m²/yr | |
| Modern use of bioenergy (direct use) | 21 EJ [11] | 46 EJ | 53 EJ | |
| Geothermal consumption (direct use) | 0.9 EJ [12] | 1.4 EJ | 2.2 EJ | |
| Renewables based district heat generation | 0.9 EJ [13] | 4.3 EJ | 13 EJ | |
| Investment needs for renewables end uses and district heat [14] | 13 USD billion/yr [15] | 290 USD billion/yr | 210 USD billion/yr | |

Source: **IRENA** World Energy Transitions Outlook 2022

Source: REN21 Renewables 2023 GSR

Source: REN21 Renewables 2024 GSR

# How to Decarbonize?

Friesach,
Source: Solar Engineering Guggenberger

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

Högslätten Härnösand
Source: Absolicon

St. Ruprecht an der Raab,
Source: Gasokol GmbH

Fernwärme Ettenheim
Source: Peter Blaser

Stadtwerke Greifswald
Source: Ritter XL Solar

# Challenges Monitoring Solar thermal plants

**Plant Design**
Manufacturing

**Operation**
Commissioning, Production

ISO 9806
EN 12975
EN 12976

ISO 24194 **Power Check** & more

*20-30 years*

SunPeek

# 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]

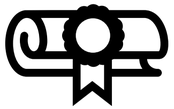
**Edition** : 1
**Number of pages** : 30

**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.

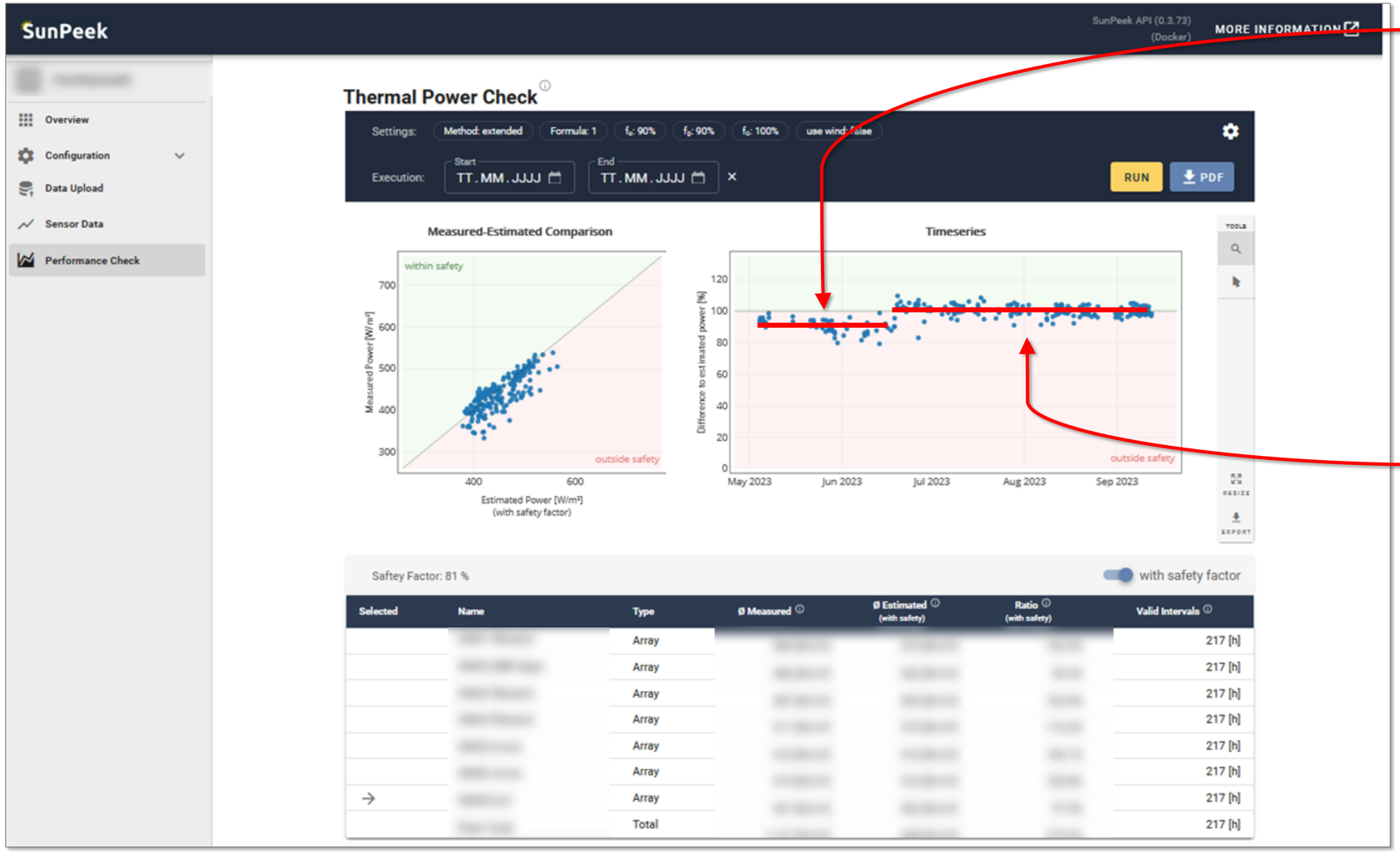


- Usage1: **Guarantee Procedure** (plant commissioning etc.)
  - Question: "Does the plant meet some guaranteed performance?“

- 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

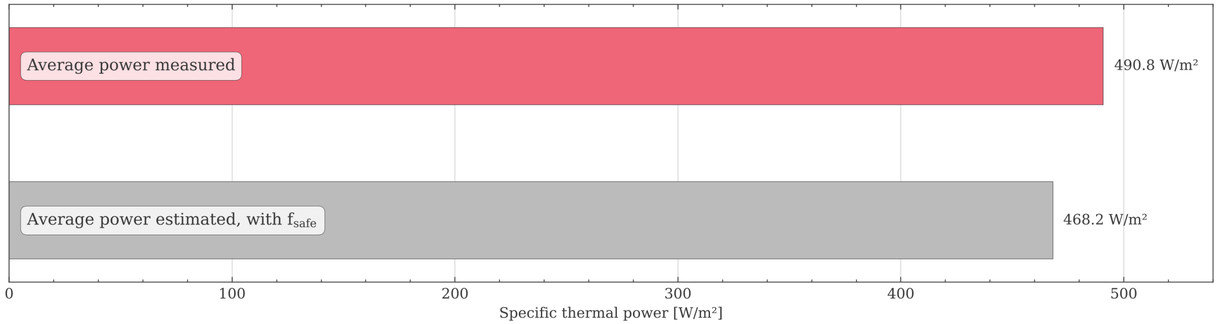
# SunPeek Example 2: Power Guarantees

## 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**

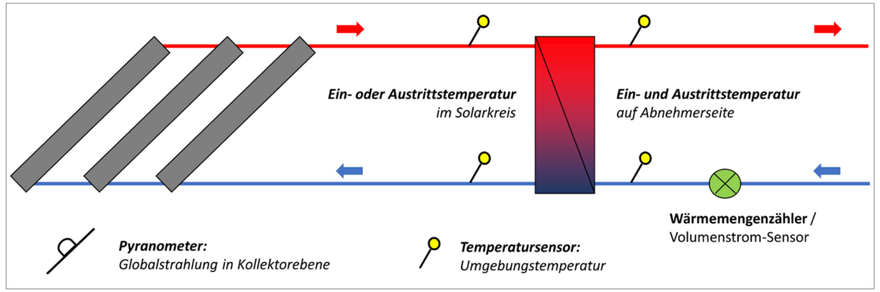
Plant name: "FHW Arcon South _Test_".
Included arrays: "Arcon South".
Data from 2017-05-01 00:00 (UTC+1) to 2017-05-31 23:59 (UTC+1).

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/m² | - | - | |
| $G_b$ | - | ≥600 W/m² | ≥600 W/m² | |

### 3 1-Hour Averages

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

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

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

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

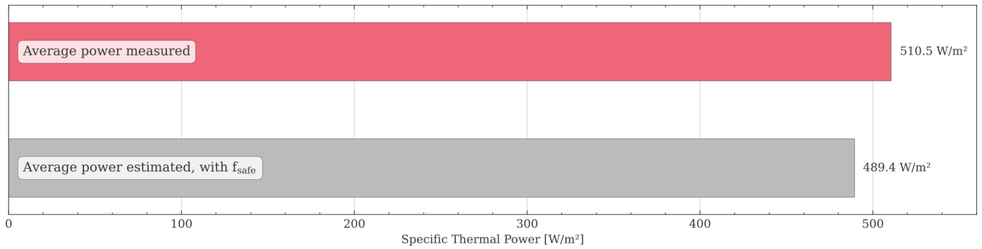
$$\dot{Q}_{estimate} = A_{GF} \cdot \left[ \eta_{0,b} K_b(\theta_L, \theta_T) G_b - a_{1,\Delta Q}(\vartheta_m - \vartheta_a) - a_5 (d\vartheta_m / dt) - a_8 (\vartheta_m - \vartheta_a)^4 \right] \cdot f_{safe}$$

### 5 "Safety Factor"

$f_{safe}$ Combined safety factor

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

### 6 Target – Actual Comparison



# SunPeek pdf Report

## of ISO 24194 Power Check

### Power Check according to ISO 24194:2022

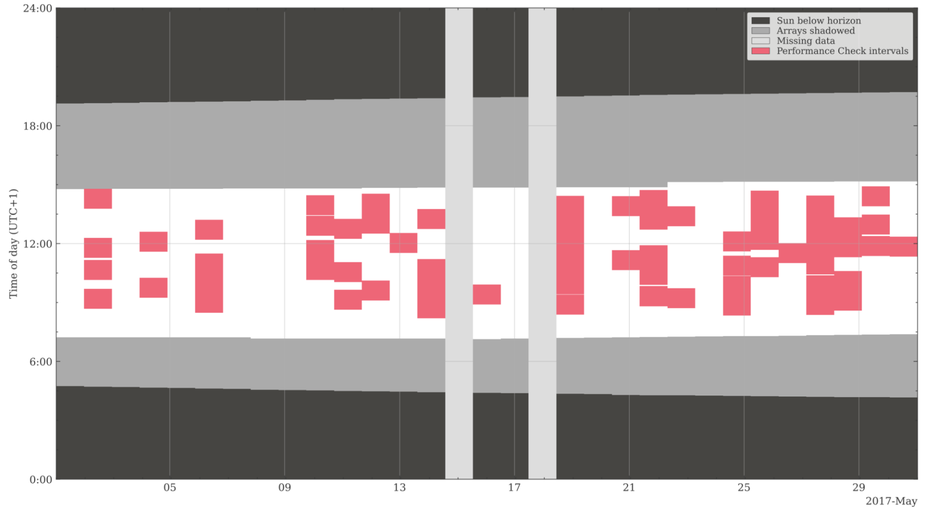
**Power Check fulfilled:**

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.

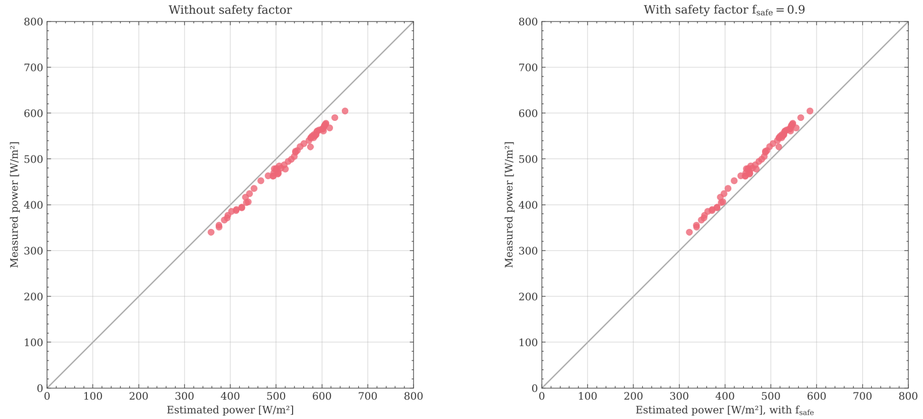





### Power Check according to ISO 24194:2022

### Thermal Power Output: Measured vs. Estimated

Plant FHW Arcon South _Test_
Included arrays Arcon South

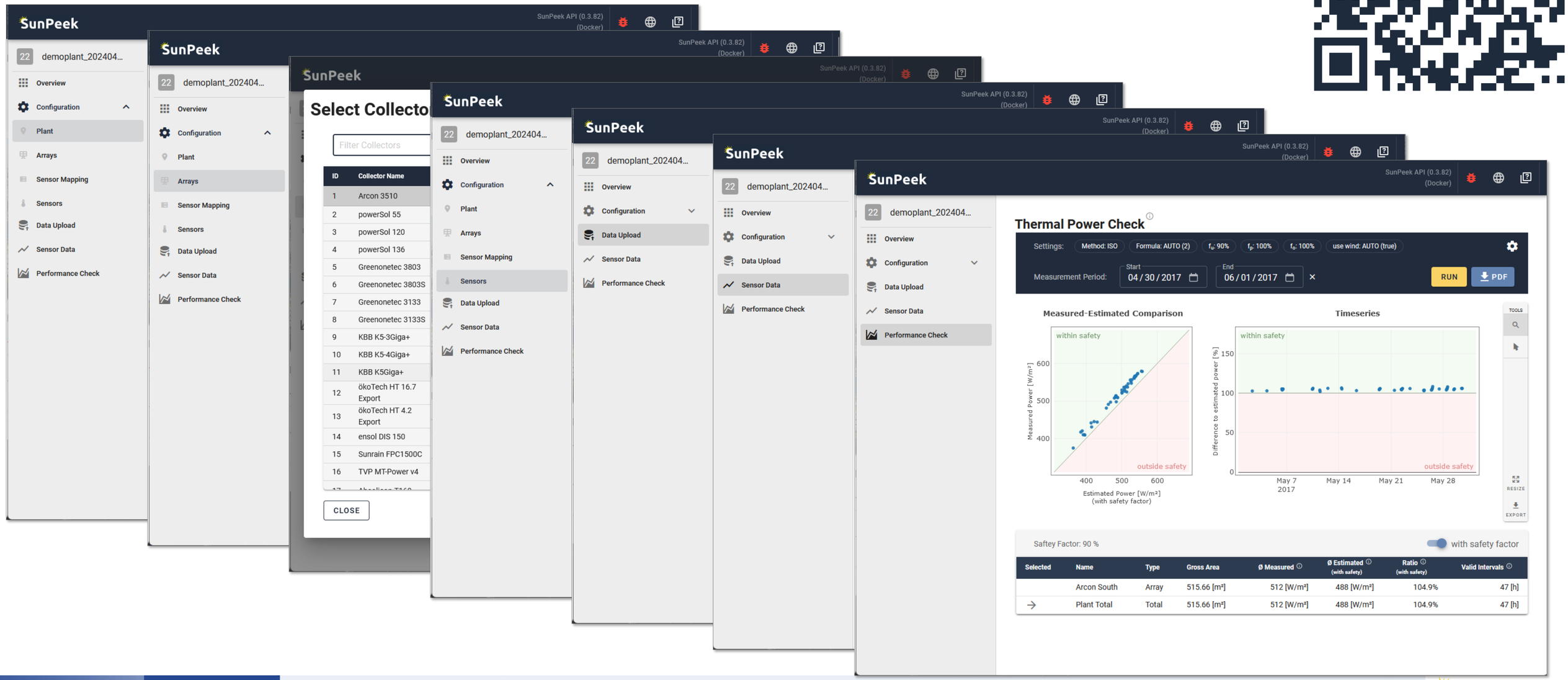



**Notes**

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.

# SunPeek GUI, Graphical User Interface

https://demo.sunpeek.org



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

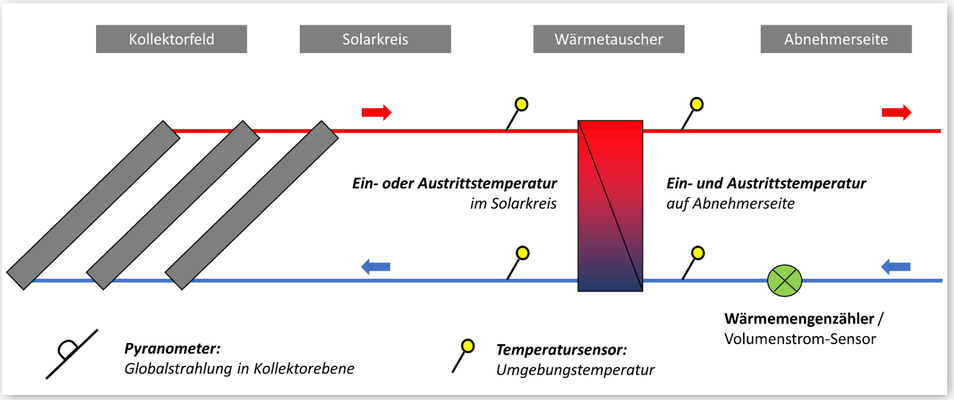
### 1) More than 1 collector field / array
- ✓ Data treatment & estimated power per array

### 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.

# 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?

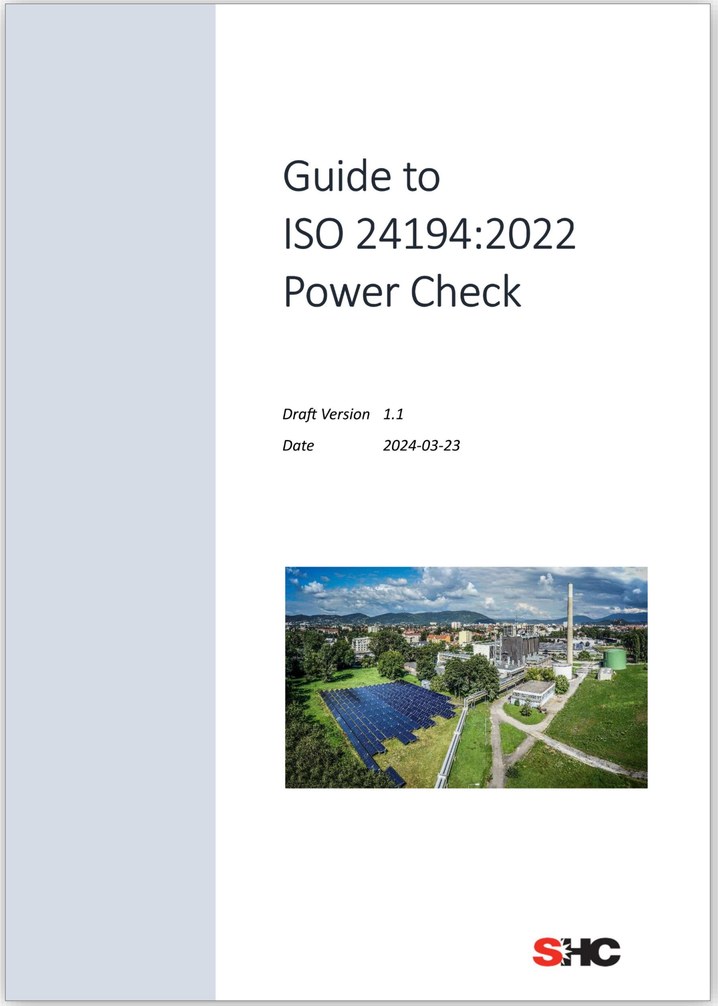
## Steering Committee Maintainers

## Initiators

## Funding

## Community, Users & Enablers

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




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

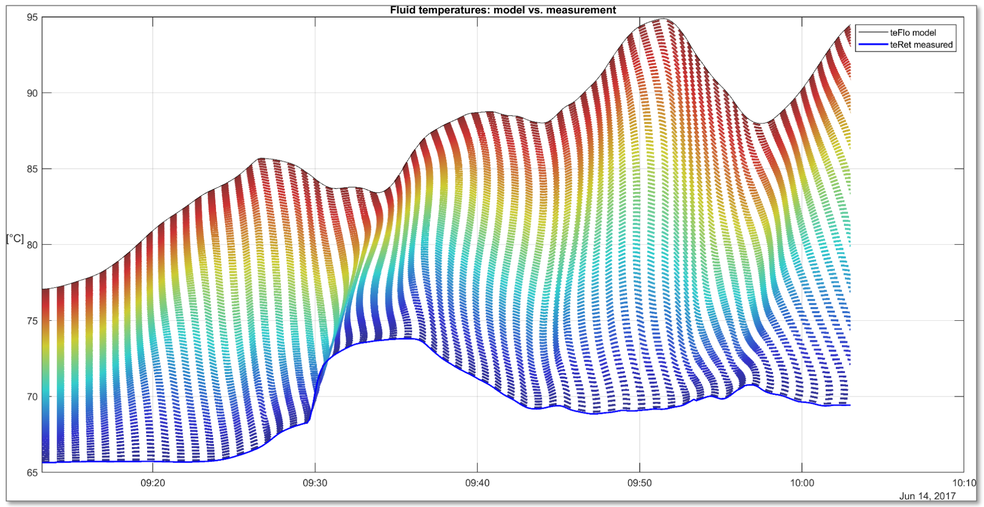
- **Task 68 Deliverable**
- **Practical application** of ISO 24194 underpins need for clarification, background information and some practical amendments / tweaks.
- **SunPeek software:** ISO 24194 Reference implementation. Automated & transparent Power Check.
- **Target groups:** Plant operators, Plant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

Inputs from industry & research welcome!

**Contact us if interested!**

AEE INTEC

SunPeek




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

APPLIED CPS

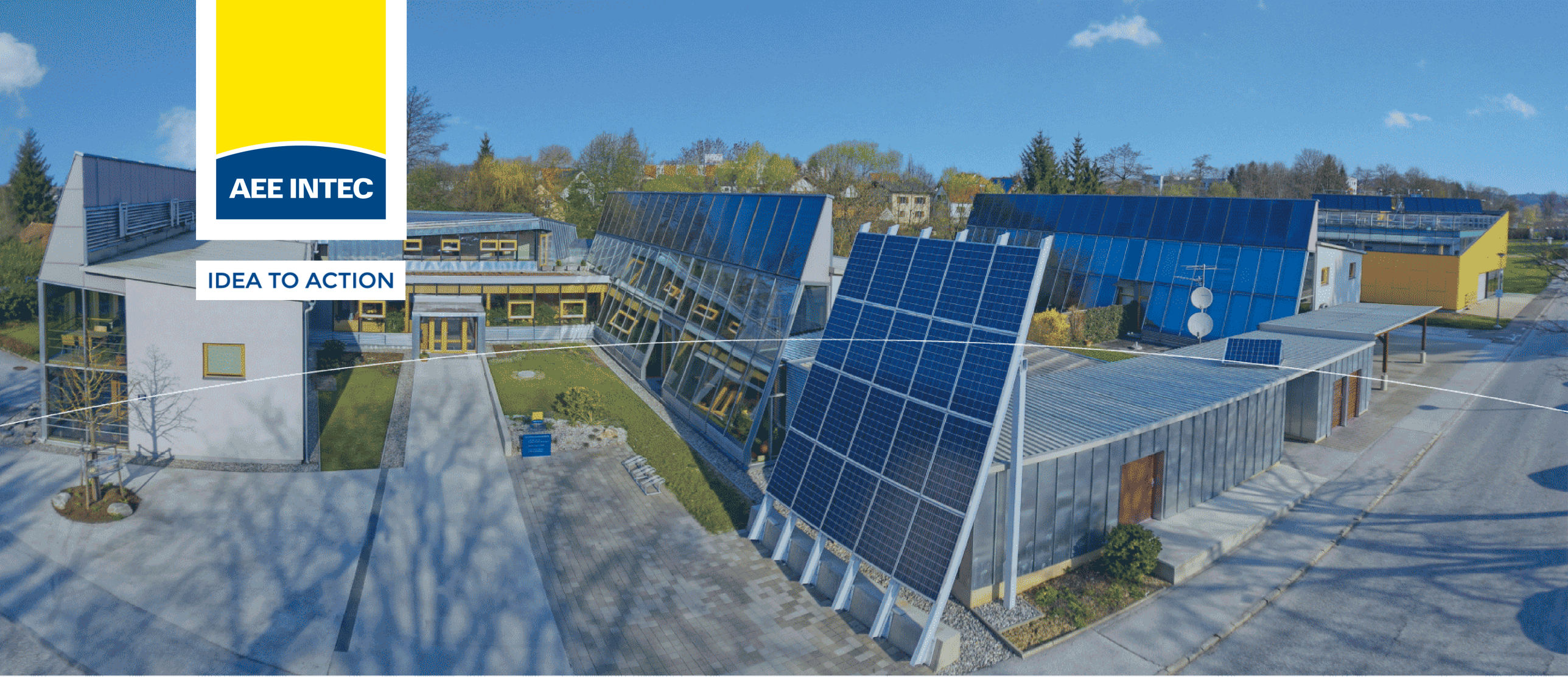
## Open-Source Scientific Development Platform

# SunPeek Information

https://www.sunpeek.org

| | | |
|---|---|---|
| ✓ | **Support** | 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 |




AEE – Institut für Nachhaltige Technologien (AEE INTEC)
8200 Gleisdorf, Feldgasse 19, Österreich

Website: www.aee-intec.at
Linkedin: linkedin.com/company/aee-intec/mycompany/

**Daniel Tschopp**
d.tschopp@aee.at
+43 (0)3112 5886

**Philip Ohnewein**
p.ohnewein@aee.at
+43 660 4741783

https://www.sunpeek.org
sunpeek@sunpeek.org