AEE INTEC

SOLID
solar energy systems

GASOKOL
Solar. Seit 1981.

SCHNEID

Fraunhofer
ISE

LESAT

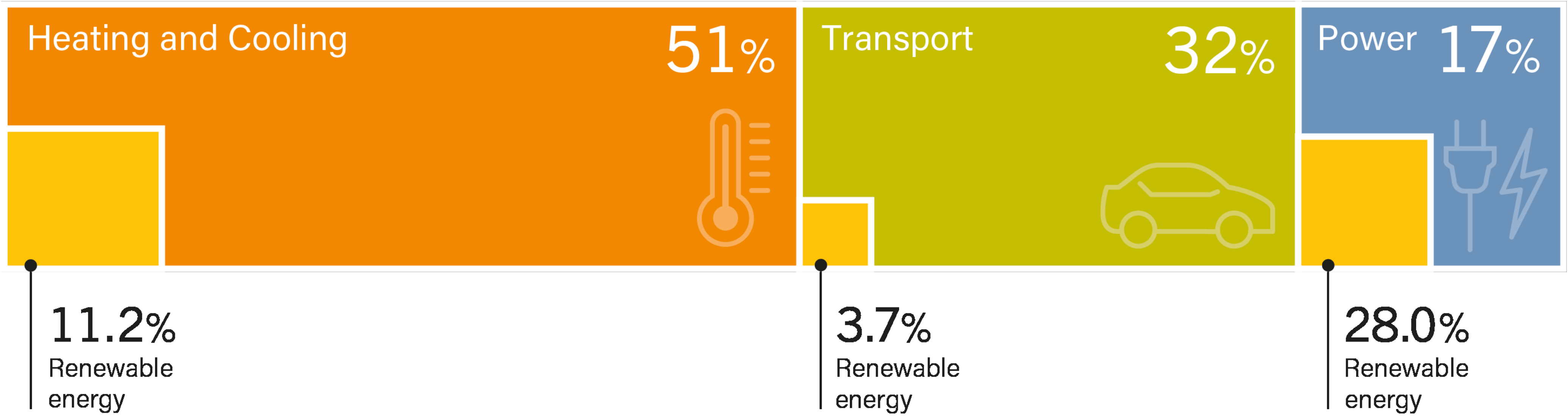
ISFH

SunPeek

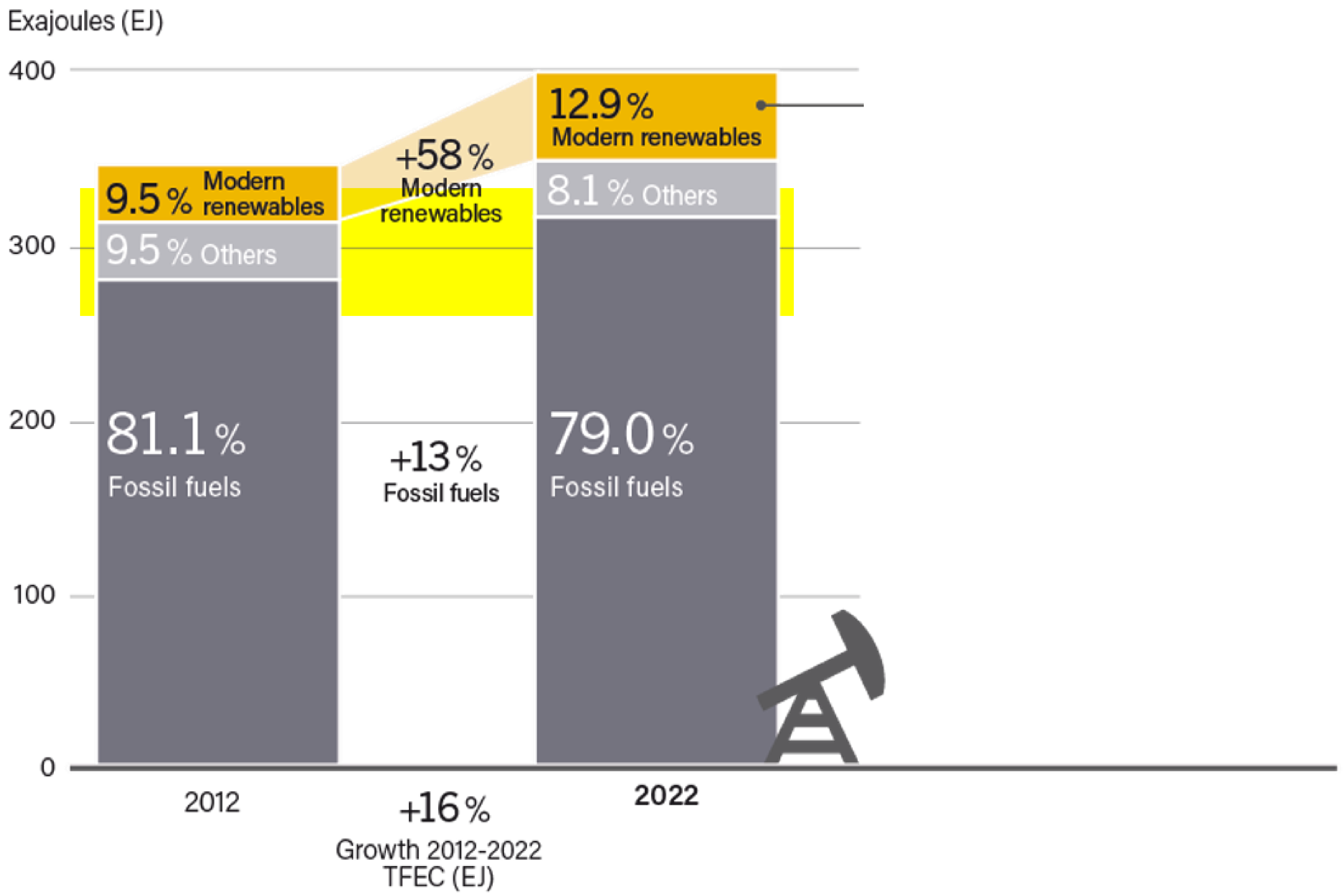
Open-Source-Software für Performancebewertung und Monitoring solarthermischer Anlagen nach ISO 24194

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

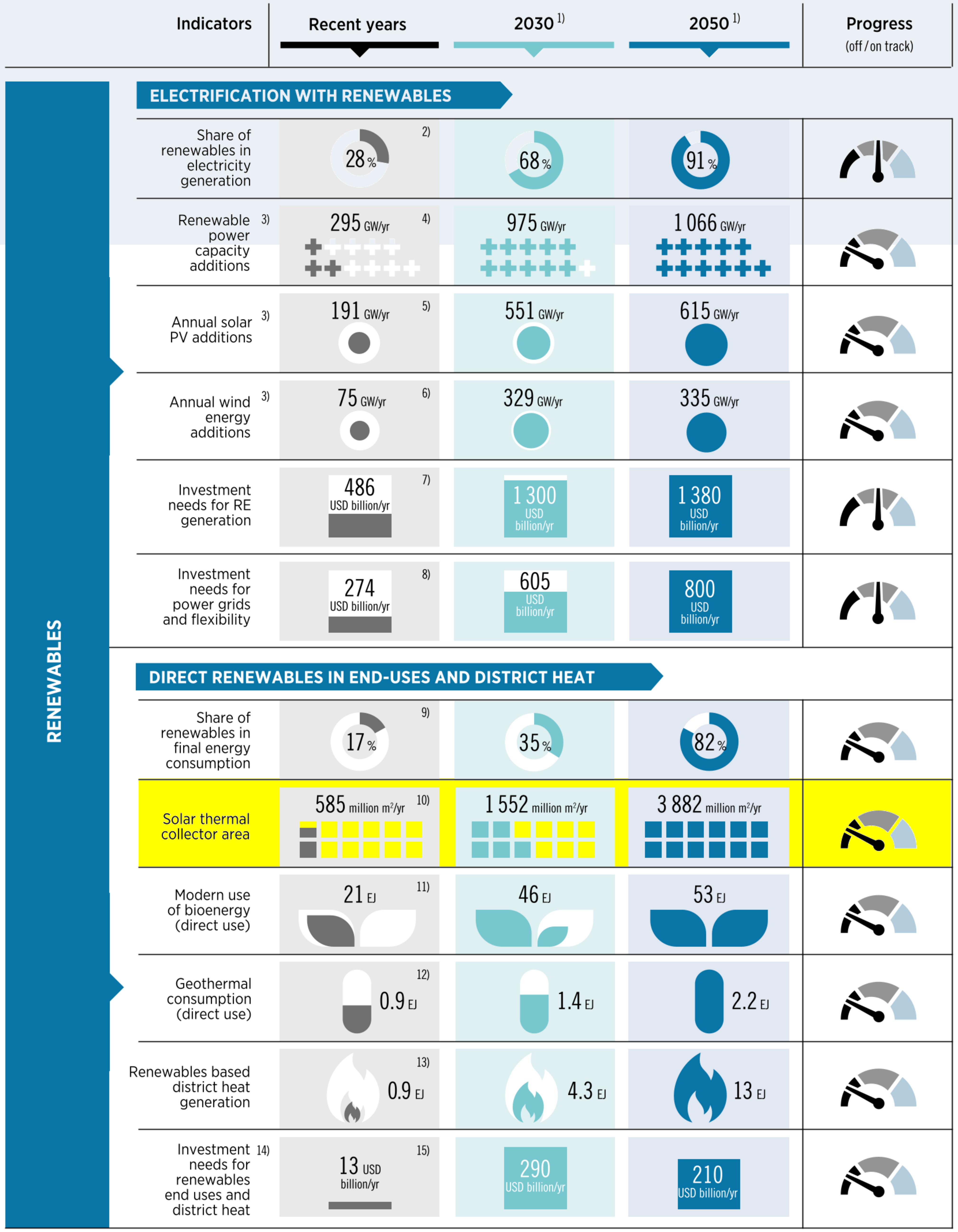
Motivation



Source: REN21 Renewables 2023 GSR



Source: REN21 Renewables 2024 GSR



RENEWABLES

Indicators	Recent years	2030 1)	2050 1)	Progress (off / on track)
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 m^2/yr 10)	1 552 million m^2/yr	3 882 million m^2/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

Dekarbonisieren – aber wie?

Friesach,
Source: Solar Engineering Guggenberger

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

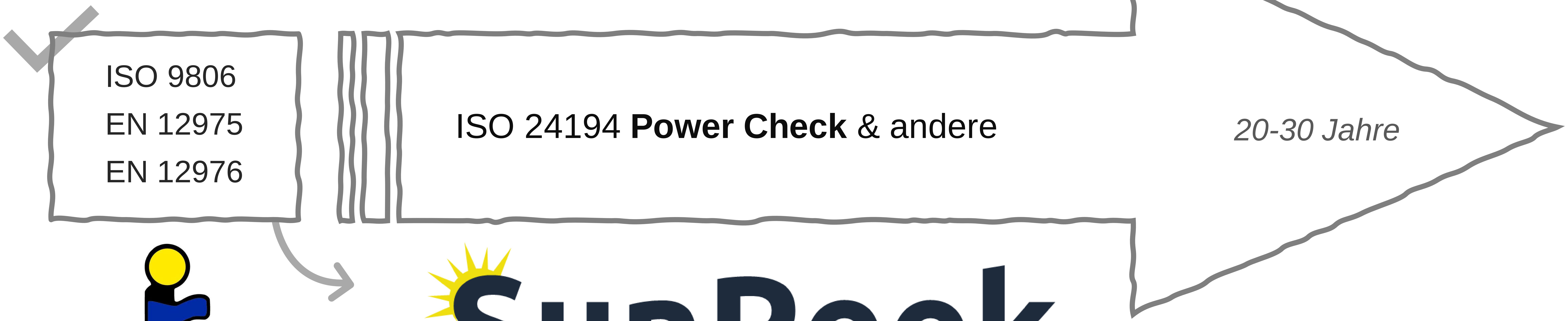
Höglätten Härnösand
Source: Absolicon

St. Ruprecht an der Raab,
Source: Gasokol GmbH

Fernwärme Ettenheim
Source: Peter Blaser

Stadtwerke Greifswald
Source: Ritter XL Solar

Herausforderung Monitoring



Anlagendesign
Produktion

Anlagenbetrieb
Inbetriebnahme,
Wärmebereitstellung

ISO 9806
EN 12975
EN 12976

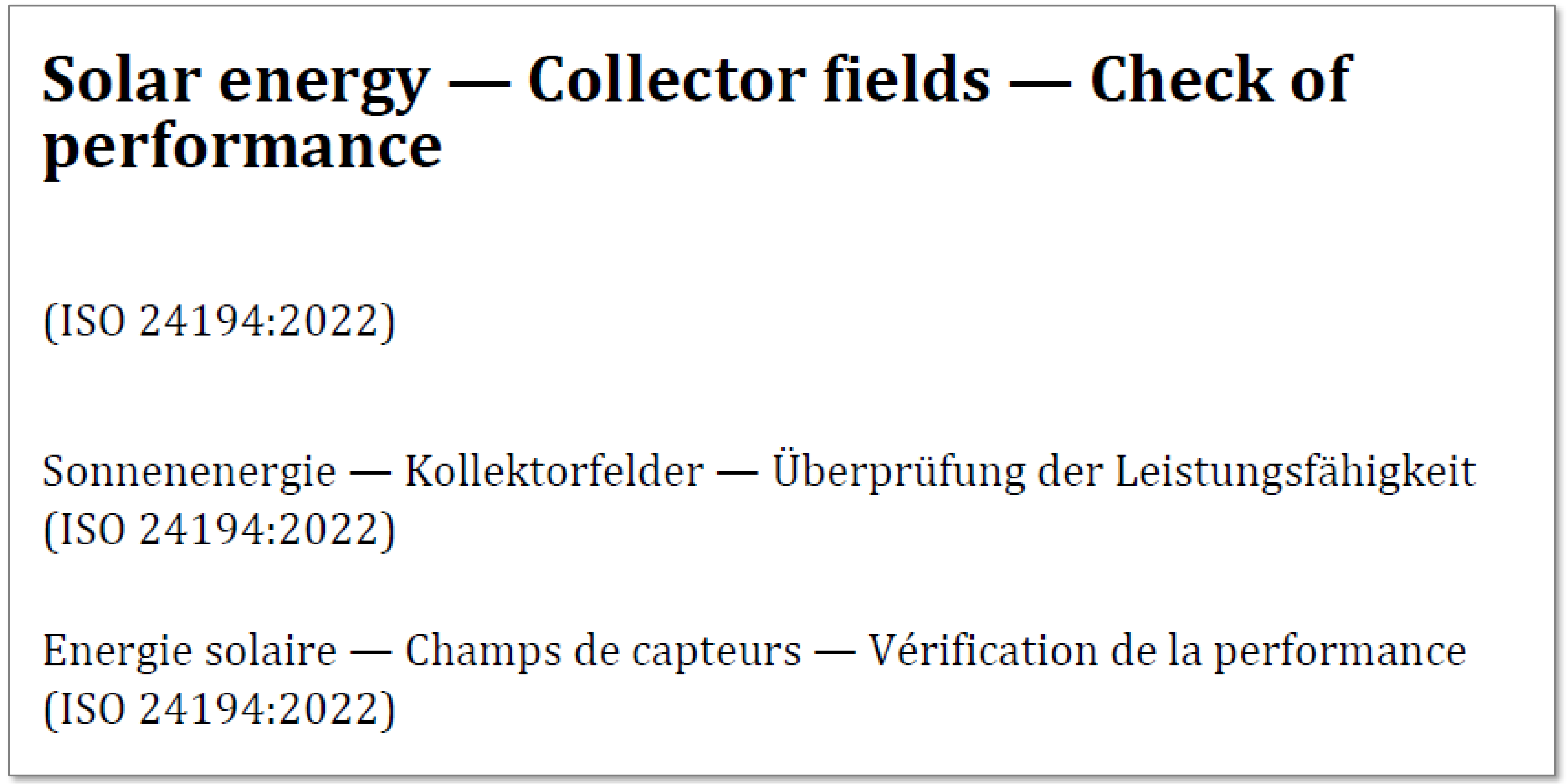
ISO 24194 **Power Check** & andere

20-30 Jahre

ISO 24194:2022 “Check of Performance”

- Neue ISO-Norm für die Performance-Bewertung von solarthermischen Kollektorfeldern und Anlagen.
    - ✓ **In-situ**, für Anlagen in Betrieb!
    - ✓ Basierend auf ISO 9806 (Einzelkollektortest)
    - ✓ Basierend auf ISO 9060 (Solarstrahlungsmessgeräte)
    - ✓ Basierend auf ISO 9488 (Sonnenenergie - Vokabular)

- **2 Methoden** definiert:
    - ✓ *Power Check*
    - ✓ Daily Yield Check
- Anwendbar auf verschiedene **Kollektortypen**:
    - ✓ Verglaste Flachkollektoren
    - ✓ Vakuumröhrenkollektoren
    - ✓ Nachgeführte, konzentriende Kollektoren

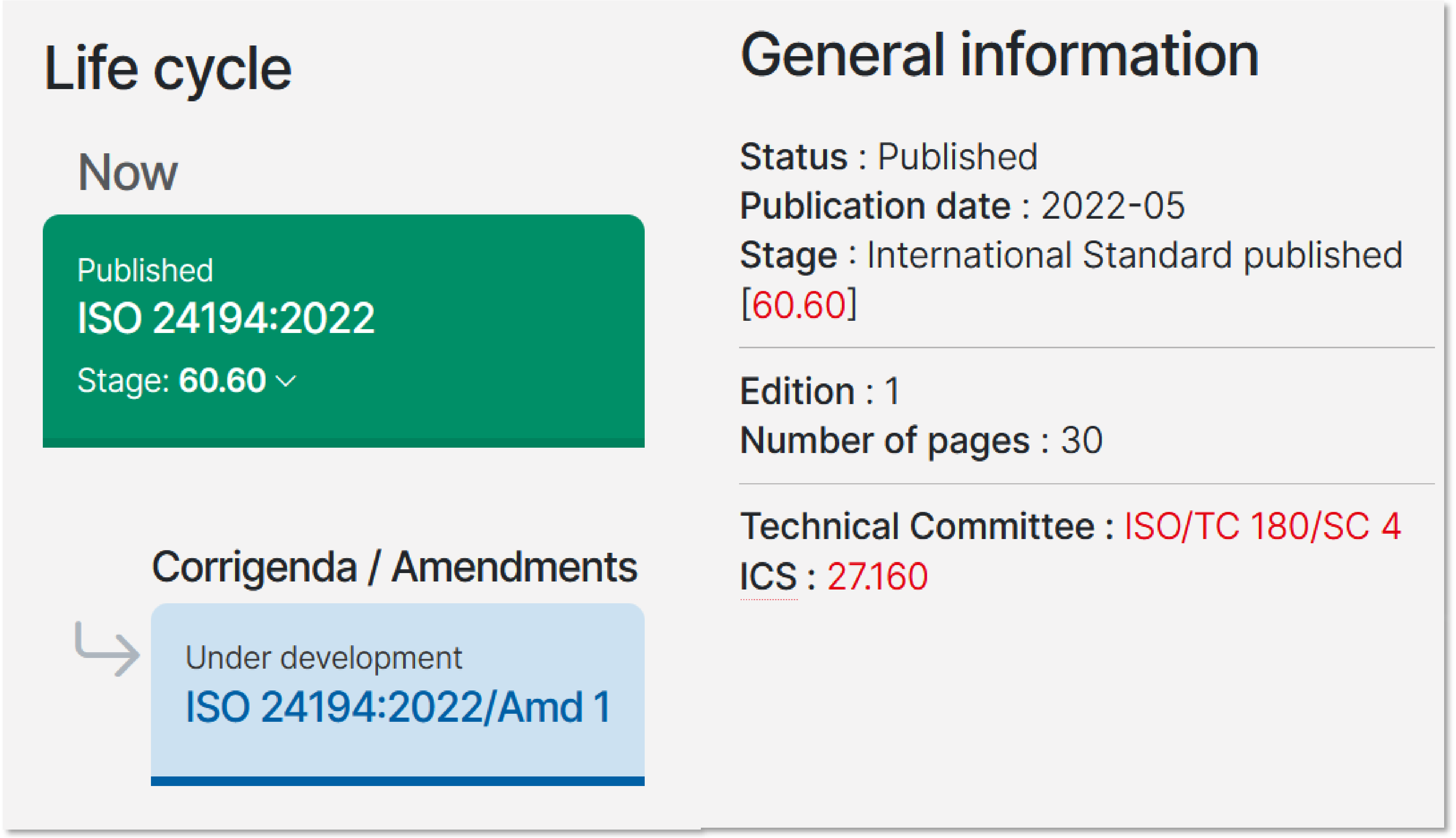


Solar energy — Collector fields — Check of performance

(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

Anwendung

von SunPeek & ISO 24194 Power Check

- **Antwort** auf die nebulose Frage :
  - „Wie gut funktioniert die Anlage?“ → „Wie gut sollte sie funktionieren?“
- Standardisierter Output
  - *Korrigiert:* Wetter, Temperaturen, verwendeter Kollektortyp, Standort, Felddesign, etc.
  - *Quantitativ:* Prozentangabe “Messung vs. geschätzter Output”
  - *Vergleichbar:* Performance wird *vergleichbar* zwischen Anlagen & über die Zeit.

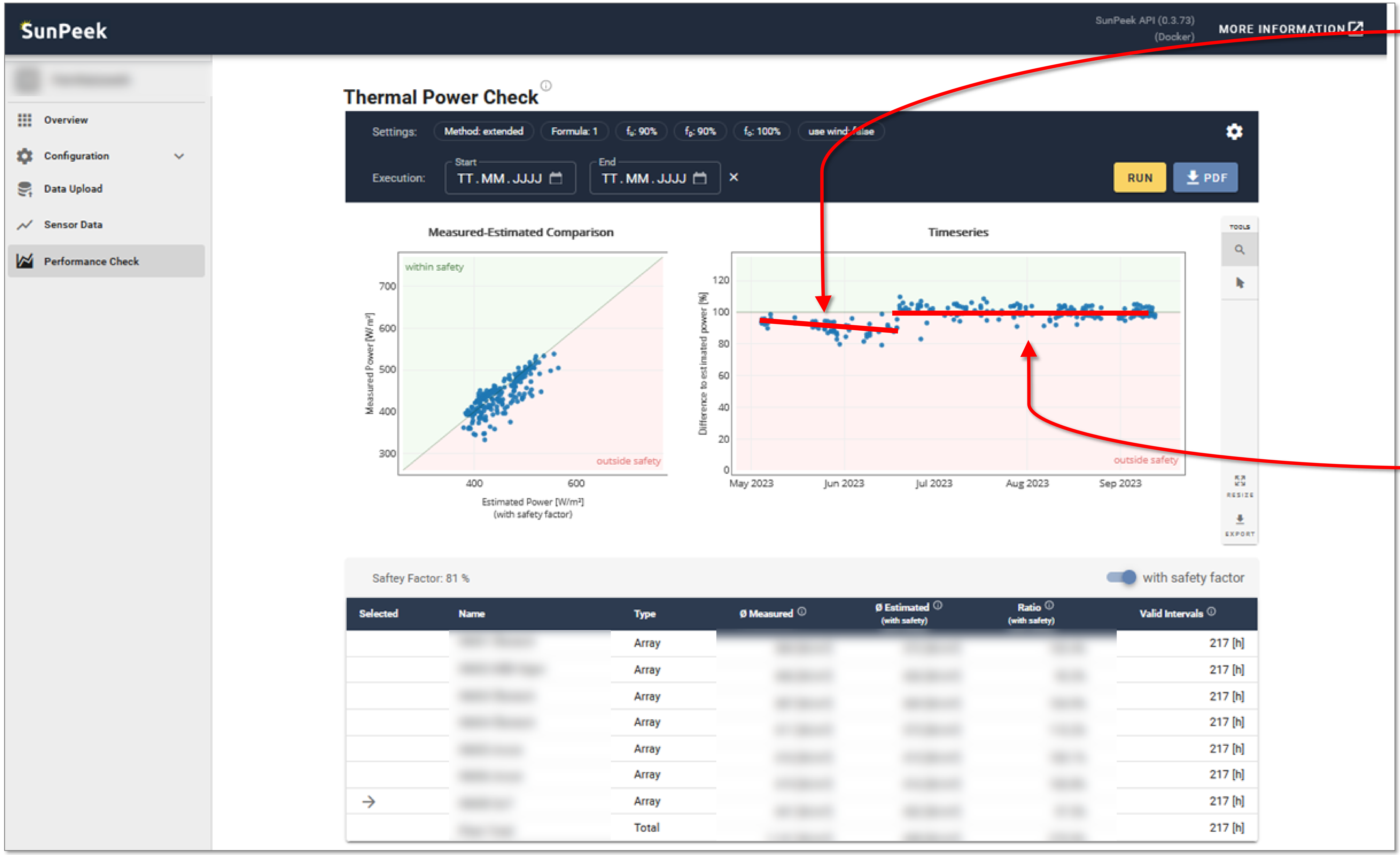
- Anwendung 1: **Garantie-Verfahren** (Inbetriebnahme etc.)
  - Frage: “Erfüllt die Anlage die garantierte Performance?“

- Anwendung 2: **Performance Monitoring** (Betriebsphase, laufend)
  - Frage: Erkennen von Leistungsverschlechterung, Problemen -> vorausschauendes Handeln

SunPeek Beispiel 1: Laufendes Monitoring

Vor / Nach Kollektorreinigung

application by


SunPeek
SunPeek API (0.3.73) (Docker)
MORE INFORMATION
Overview
Configuration
Data Upload
Sensor Data
Performance Check
Measured-Estimated Comparison
within safety
outside safety
Measured Power [W/m²]
700
600
500
400
300
400
600
Estimated Power [W/m²] (with safety factor)
Timeseries
Difference to estimated power [%]
120
100
80
60
40
20
0
May 2023
Jun 2023
Jul 2023
Aug 2023
Sep 2023
TOOLS
RESIZE
EXPORT
RUN
PDF

Thermal Power Check

Settings: Method: extended | Formula: 1 | f: 90% | f: 90% | f: 100% | use wind: false

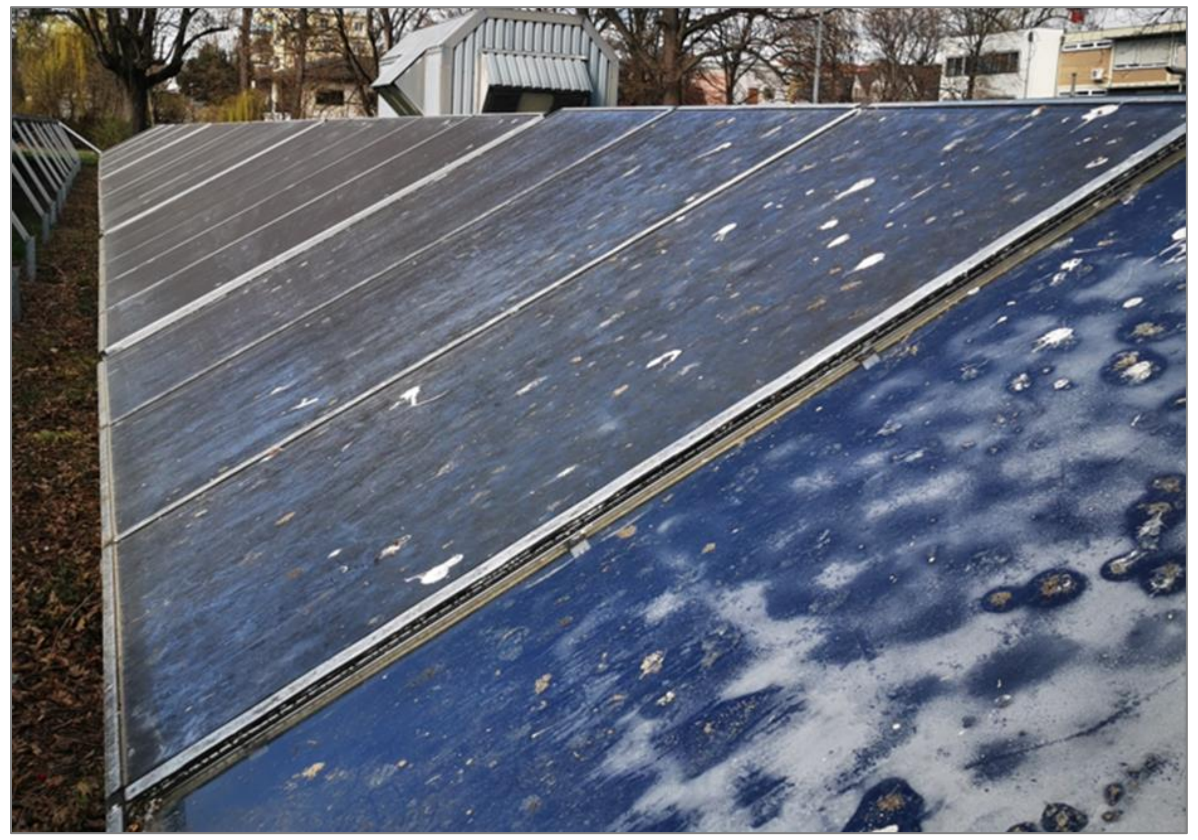
Execution: Start TT.MM.JJJJ | End TT.MM.JJJJ

Saftey Factor: 81 %

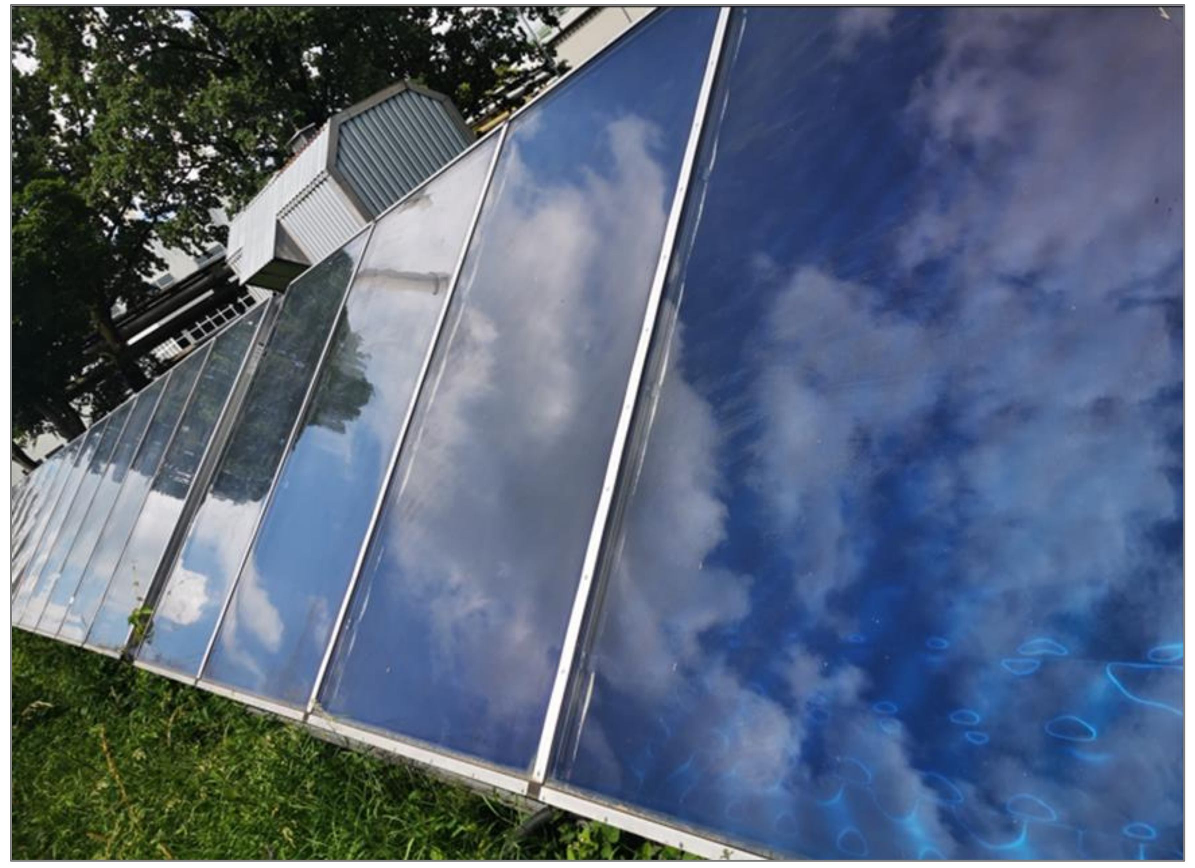
with safety factor

Selected	Name	Type	Ø Measured	Ø Estimated (with safety)	Ratio (with safety)	Valid Intervals
	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
→	[redacted]	Array	[redacted]	[redacted]	[redacted]	217 [h]
	[redacted]	Total	[redacted]	[redacted]	[redacted]	217 [h]

Vor Reinigung

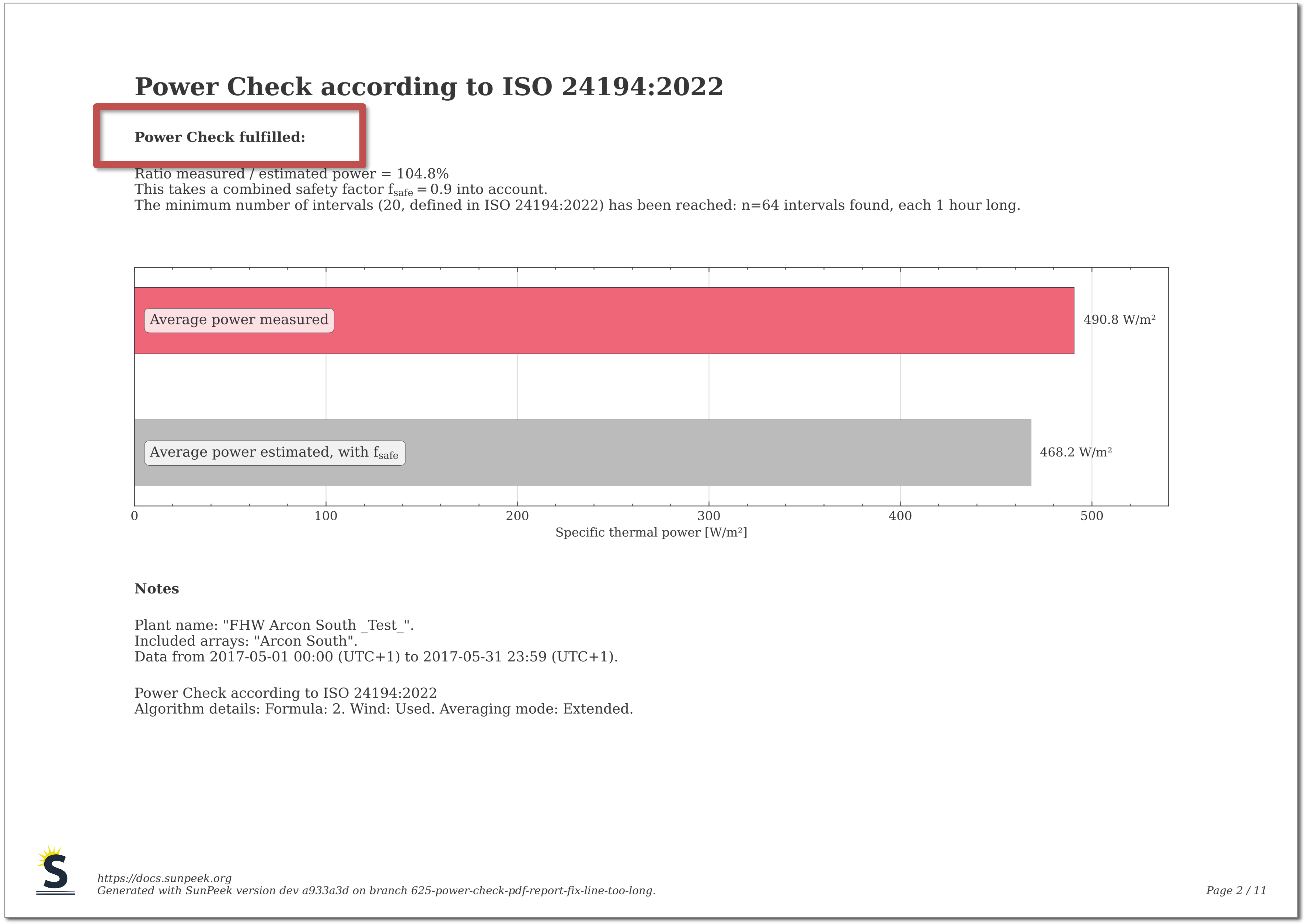


Nach Reinigung



SunPeek Beispiel 2: Leistungsgarantie

gemessene vs. geschätzte Leistung



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.

Average power measured
490.8 W/m²
Average power estimated, with f_{safe}
468.2 W/m²
0
100
200
300
400
500
Specific thermal power [W/m²]

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).

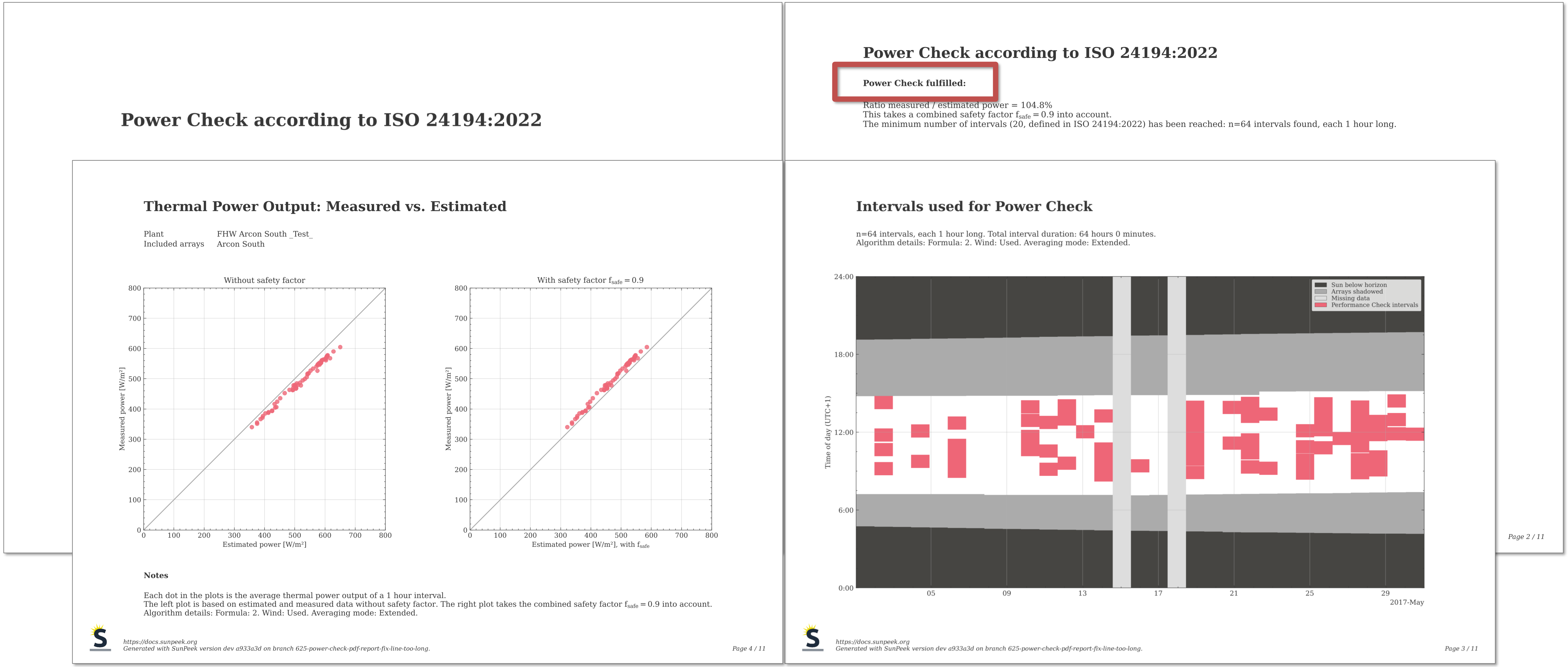
Power Check according to ISO 24194:2022
Algorithm details: Formula: 2. Wind: Used. Averaging mode: Extended.

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

Page 2 / 11

SunPeek pdf Report

vom ISO 24194 Power Check



Power Check according to ISO 24194:2022

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.

Page 2 / 11

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.

24:00
18:00
12:00
6:00
0:00
Time of day (UTC+1)
05
09
13
17
21
25
29
2017-May
Sun below horizon
Arrays shadowed
Missing data
Performance Check intervals

https://docs.sunpeek.org
Generated with SunPeek version dev a933a3d on branch 625-power-check-pdf-report-fix-line-too-long.
Page 3 / 11

Thermal Power Output: Measured vs. Estimated

Plant	FHW Arcon South _Test_
Included arrays	Arcon South

Without safety factor
With safety factor $f_{safe} = 0.9$
Measured power [W/m²]
Estimated power [W/m²]
Estimated power [W/m²], with f_{safe}
0
100
200
300
400
500
600
700
800

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.

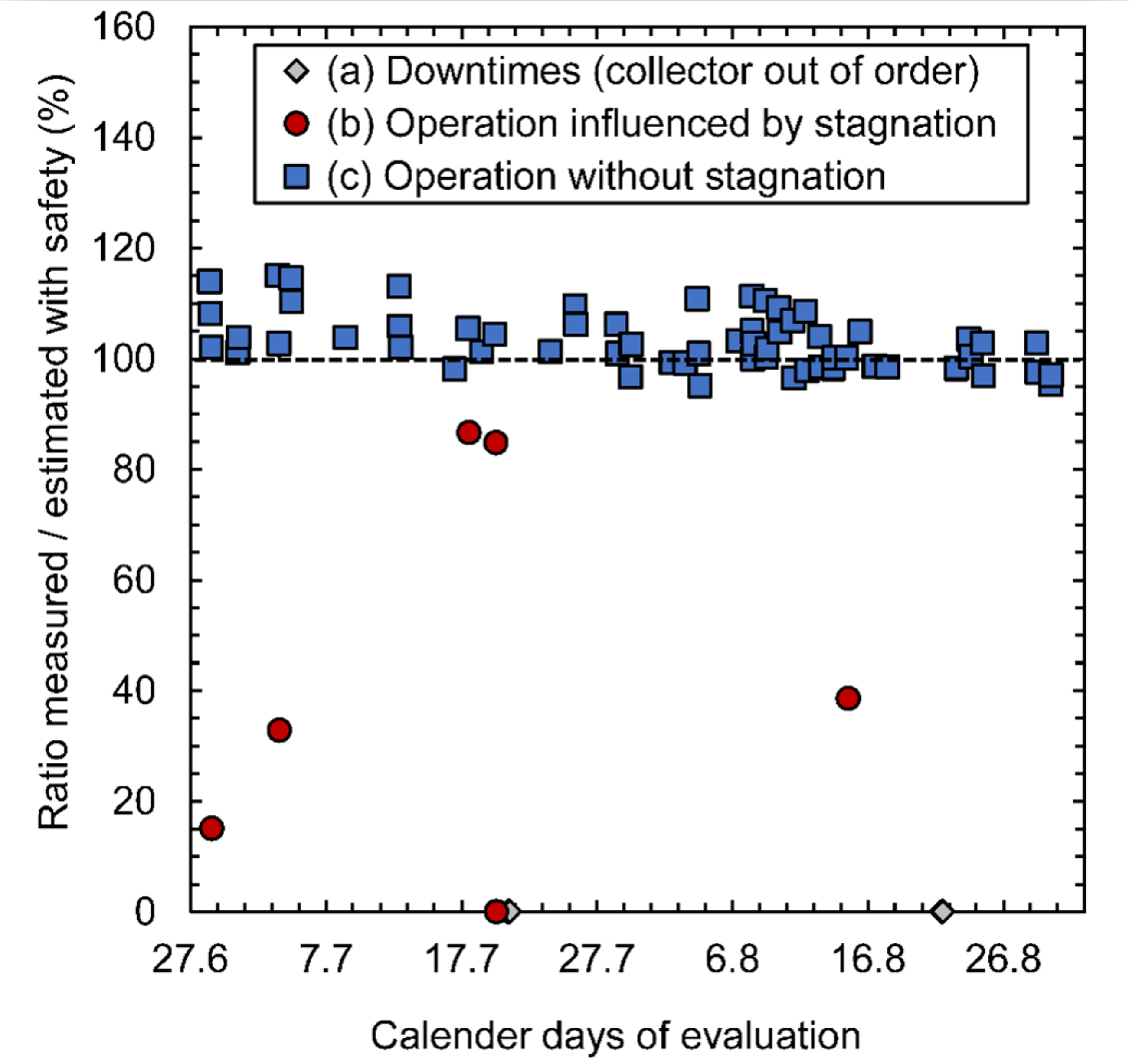
https://docs.sunpeek.org
Generated with SunPeek version dev a933a3d on branch 625-power-check-pdf-report-fix-line-too-long.
Page 4 / 11

SunPeek Beispiel 3: Laufendes Monitoring

Stagnation

application by

- SDH Anlage mit häufiger Stagnation (~40 Tage im Jahr 2022)
- ISO 24194 berücksichtigt Stagnation nicht → Verzerrung!



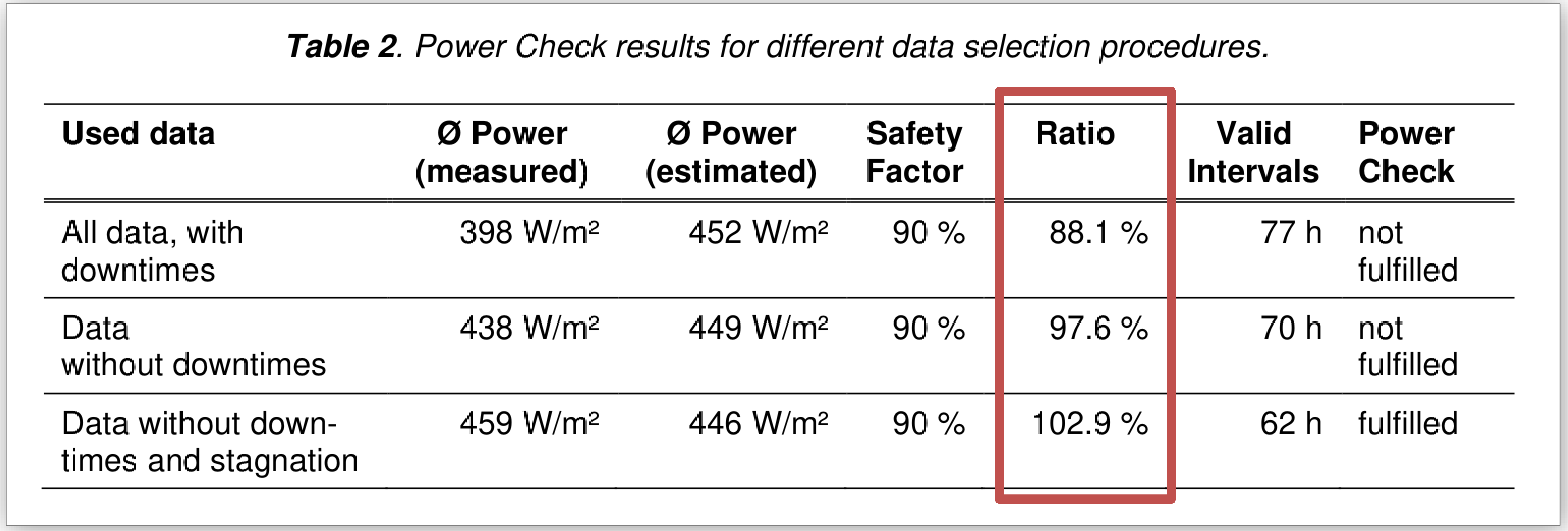


Table 2. *Power Check results for different data selection procedures.*

Used data	**Ø Power (measured)**	**Ø Power (estimated)**	**Safety Factor**	**Ratio**	**Valid Intervals**	**Power Check**
All data, with downtimes	398 W/m²	452 W/m²	90 %	88.1 %	77 h	not fulfilled
Data without downtimes	438 W/m²	449 W/m²	90 %	97.6 %	70 h	not fulfilled
Data without downtimes and stagnation	459 W/m²	446 W/m²	90 %	102.9 %	62 h	fulfilled

- SunPeek: Auswertung mit/ohne Stagnation derzeit in Umsetzung

SunPeek GUI, Graphical User Interface

https://demo.sunpeek.org

SunPeek
SunPeek API (0.3.82) (Docker)
22 demoplant_202404...
Overview
Configuration
Plant
Arrays
Sensor Mapping
Sensors
Data Upload
Sensor Data
Performance Check
Filter Collectors
CLOSE
TOOLS
RESIZE
EXPORT
Measured-Estimated Comparison
within safety
outside safety
Measured Power [W/m²]
Estimated Power [W/m²] (with safety factor)
400
500
600
Timeseries
Difference to estimated power [%]
0
50
100
150
May 7 2017
May 14
May 21
May 28

Select Collector

ID	Collector Name
1	Arcon 3510
2	powerSol 55
3	powerSol 120
4	powerSol 136
5	Greenonetec 3803
6	Greenonetec 3803S
7	Greenonetec 3133
8	Greenonetec 3133S
9	KBB K5-3Giga+
10	KBB K5-4Giga+
11	KBB K5Giga+
12	ökoTech HT 16.7 Export
13	ökoTech HT 4.2 Export
14	ensol DIS 150
15	Sunrain FPC1500C
16	TVP MT-Power v4

Thermal Power Check

Settings: Method: ISO | Formula: AUTO (2) | f_u: 90% | f_p: 100% | f_o: 100% | use wind: AUTO (true)

Measurement Period: Start 04 / 30 / 2017 End 06 / 01 / 2017

RUN PDF

Saftey Factor: 90 %

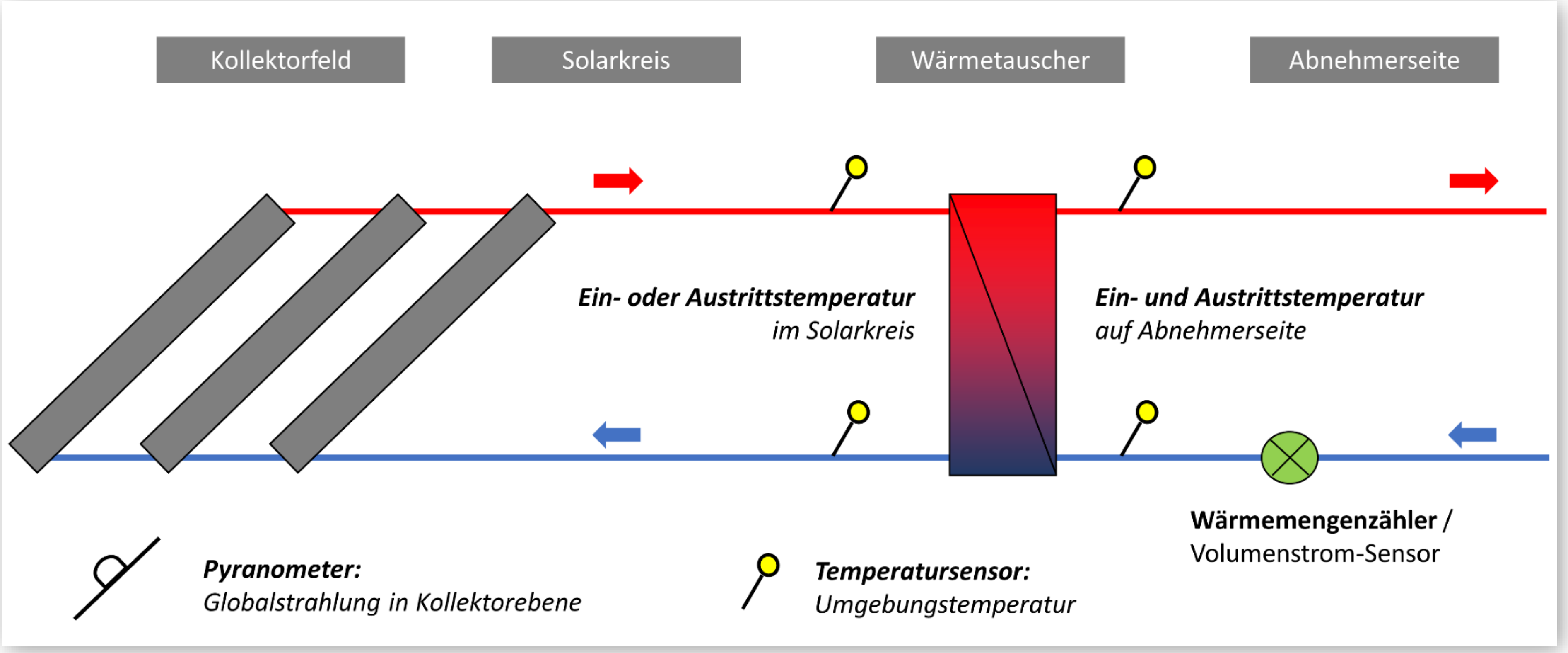
with safety factor

Selected	Name	Type	Gross Area	Ø Measured	Ø Estimated (with safety)	Ratio (with safety)	Valid Intervals
	Arcon South	Array	515.66 [m²]	512 [W/m²]	488 [W/m²]	104.9%	47 [h]
→	Plant Total	Total	515.66 [m²]	512 [W/m²]	488 [W/m²]	104.9%	47 [h]

SunPeek: praktische Erweiterungen

vom ISO 24194:2022 Power Check

1) **Mehr als ein Kollektorfeld**
   - ✓ Datenverarbeitung & geschätzte Leistung pro Feld
2) **Gemischte Kollektortypen**
   - ✓ z.B. einzel- & doppeltverglast, Flachkollektor & konzentrierende Kollektoren
   - ✓ Unterschiede in den Kollektor-Datenblättern (SST/QDT, IAM,…)
3) **Nicht standardisierte Messungen**
   - ✓ z.B. Eigenschaften von Wärmeträgerflüssigkeiten, Datenbank
4) **Schlechte Datenqualität**
   - ✓ Automatische Verarbeitung verschiedener Datenformate, gültige Daten, Zeitzonen, …
5) **Erweiterte Filtermethoden**
   - ✓ Modernere Datenanalyse
   - ✓ Schnellere Ergebnisse


Kollektorfeld
Solarkreis
Wärmetauscher
Abnehmerseite
Ein- oder Austrittstemperatur
im Solarkreis
Ein- und Austrittstemperatur
auf Abnehmerseite
Wärmemengenzähler /
Volumenstrom-Sensor
Pyranometer:
Globalstrahlung in Kollektorebene
Temperatursensor:
Umgebungstemperatur

SunPeek: Plattform

Open-source, web-basierende Software

- *Entwickelt als Referenz-Implementation von ISO 24194 Power Check, und anderen*
- **Ziel:** Vereinfachter Betrieb von Solaranlagen → **geringere LCOH**
- **Features:** Transparenz, Automatisierung, High quality Implementation

Plattform / Development Hub

- *Gelenkt von der Community / Forschung, Industrie, Verbänden.*
- **Ziel:** Diskussion & **Erweiterung** von Methoden & Implementierungen (falls notwendig)
- **Ziel:** Effiziente Entwicklung, Austausch mit **TC 180 / ISO 24194**

Mitarbeit sehr willkommen!

- *Erstentwicklung von AEE INTEC, SOLID, GASOKOL, Schneid.*
- **Ziel: Teilnahme**
- **Wie?** Grundlagen der Projektverwaltung vorhanden ("How to be SunPeek?")

SunPeek: Software & Lizenzen

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.

open source initiative Approved License®

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.

open source initiative Approved License®

SunPeek: Geplante Erweiterungen

1) Link zur Solar Keymark Database

- Vordefinierte Kollektoren

2) Mehr Automatisierung

3) Modellierung der Einstrahlung

- Korrektur für abgeblocke Diffusstrahlung durch vordere Kollektorreihe
- Mehrere Kollektorfelder mit unterschiedlicher Ausrichtung
- Nachgeführte Kollektoren
- ✓ Interne Verschattung (erledigt)

Feedback zur ISO

- Inputs zur ISO 24194 via TC 180 / SC4

The Solar Keymark
CEN Keymark Scheme

AEE INTEC

Wer ist SunPeek?

Initiators

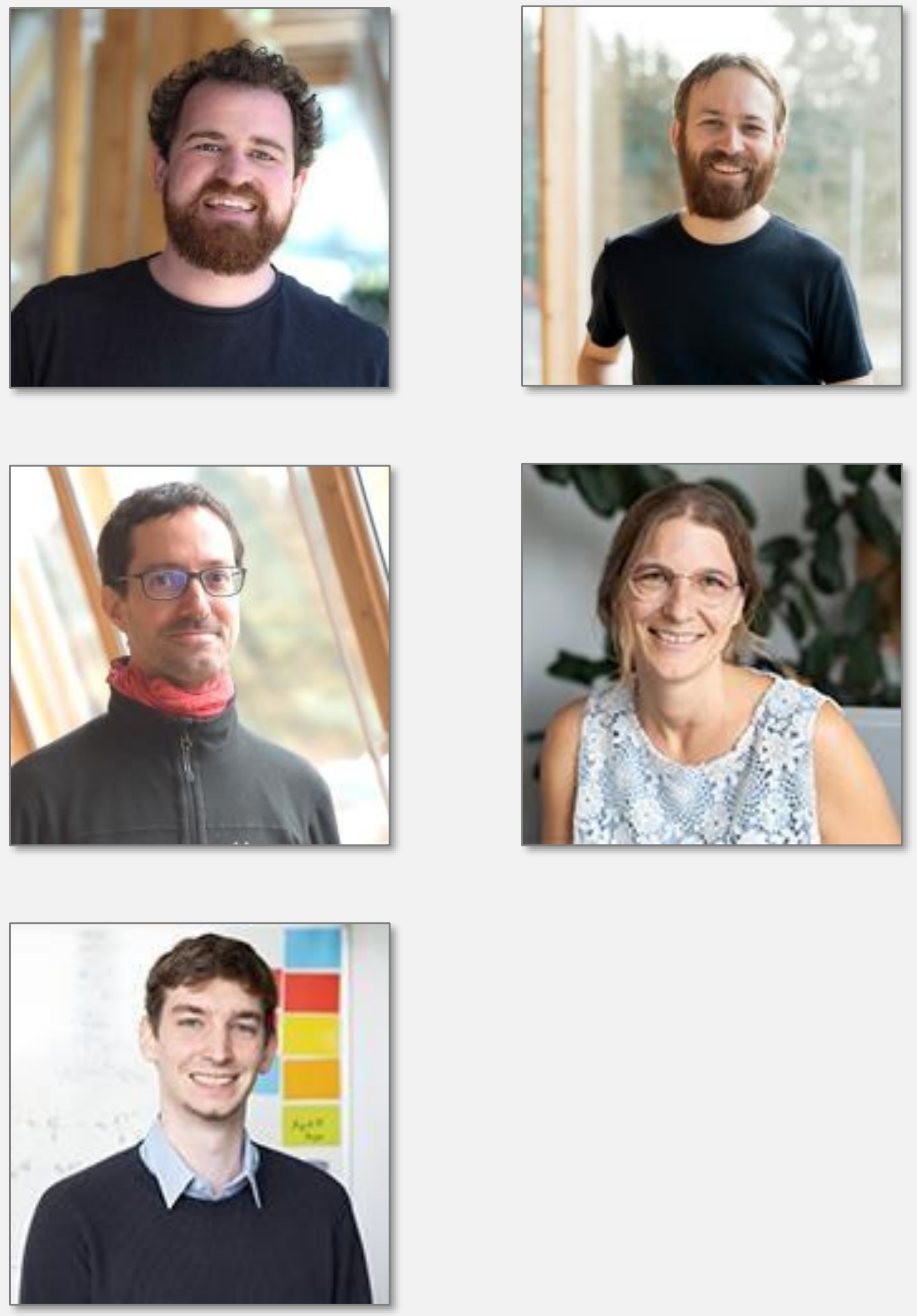
AEE INTEC

SOLID
solar energy systems

GASOKOL
Solar. Seit 1981.

SCHNEID

Steering Committee & Maintainers



Community, Users & Enablers

GitLab

NUMFOCUS
OPEN CODE = BETTER SCIENCE

SHC TASK 68

LESSAT

Fraunhofer
ISE

Technische Hochschule Ingolstadt

ISFH

DLR Deutsches Zentrum für Luft- und Raumfahrt

nahwärme St. Ruprecht

SolarEngineering
GUGGENBERGER

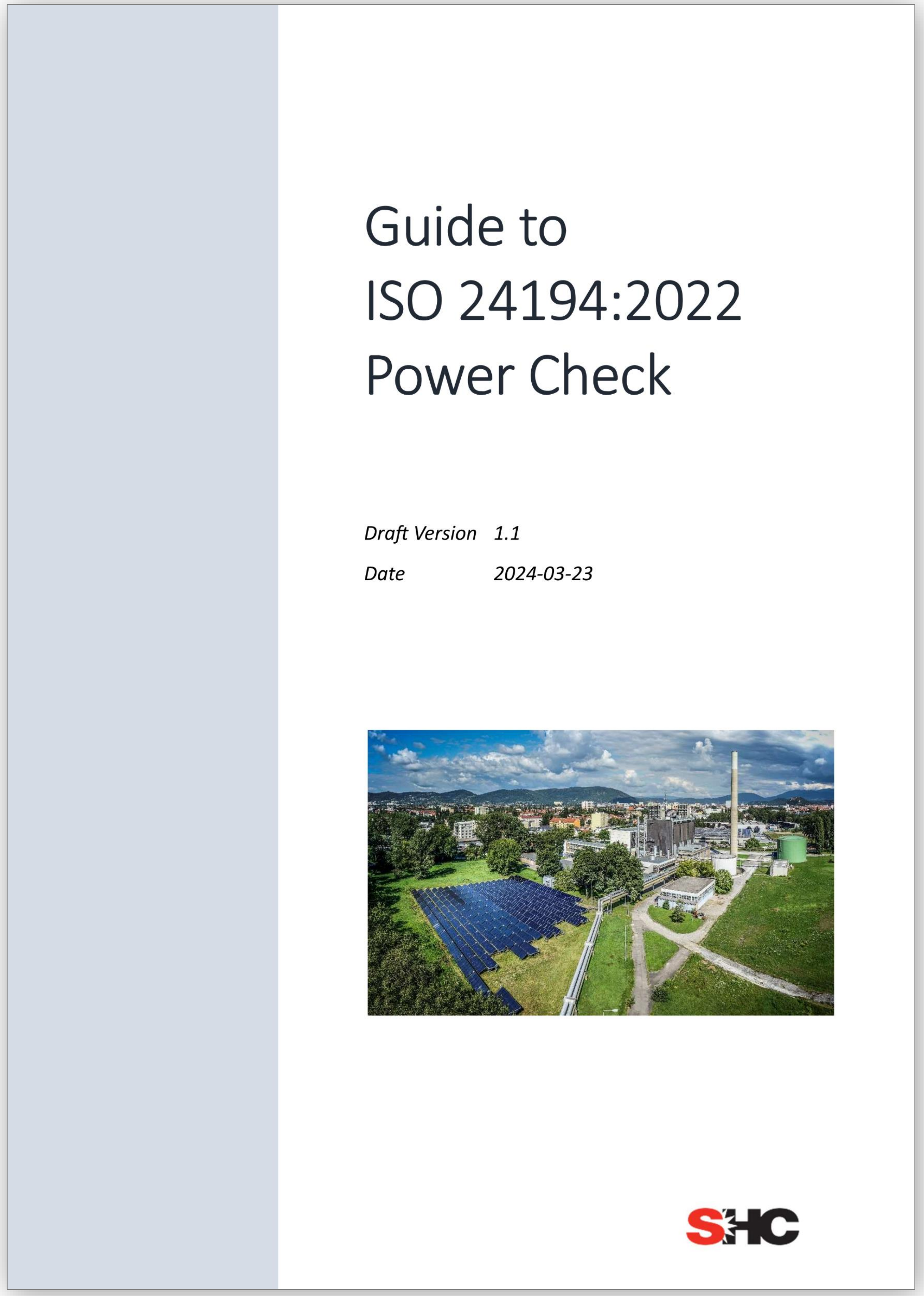
Funding

klima+ energie fonds

acr

Guide to ISO 24194:2022

Power Check



Guide to
ISO 24194:2022
Power Check

Draft Version *1.1*
Date *2024-03-23*

- Zusammengestellt von Expert:innen aus IEA SHC **Task 68** + weiteren Stakeholdern aus Industrie und Forschung
- **Task 68 Deliverable**
- **Anwendung von ISO 24194 in der Praxis**: Klarstellung, Hintergrundinformationen und praktische Änderungen / Optimierungen der Norm
- **SunPeek Software**: ISO 24194 Power Check Referenzimplementierung, automatisierte und transparente Leistungsprüfung
- **Zielgruppen**: Anlagenbetreiber:innen, Anlagenplaner:innen, Kollektorhersteller:innen, Forscher:innen
- **Geplantes Erscheinungsdatum**: Sommer 2024

- Bei Interesse für Updates / Mitarbeit bitte um **Kontaktaufnahme!**

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

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

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

IDEA TO ACTION

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