Monitoring und Garantieverfahren für Solare Großanlagen

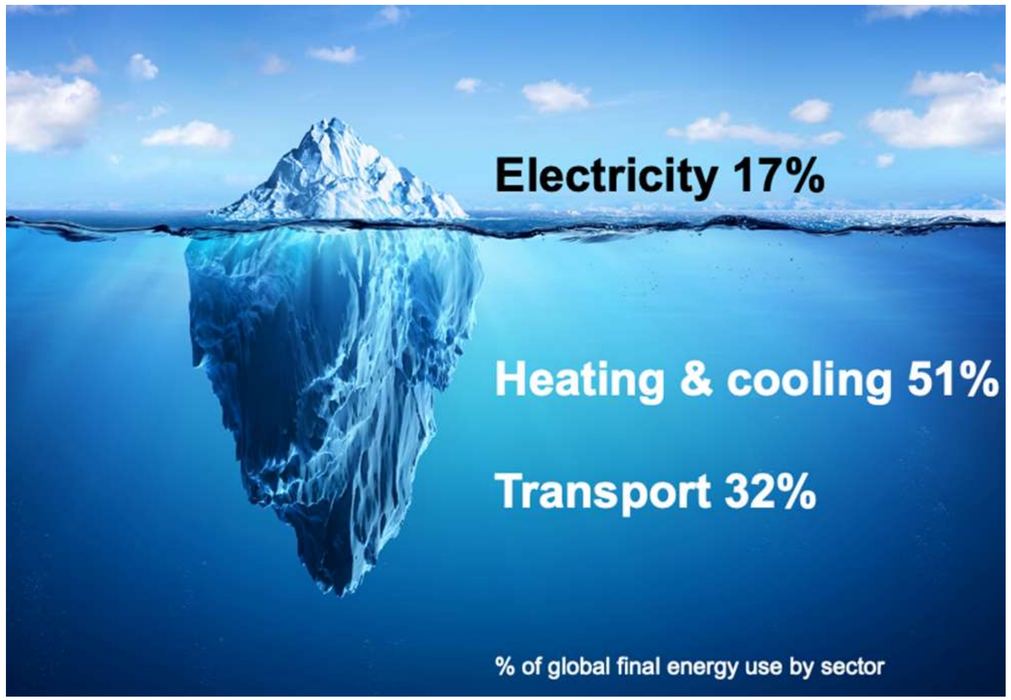
Neue digitale Methoden und aktuelle Entwicklungen

Philip Ohnewein

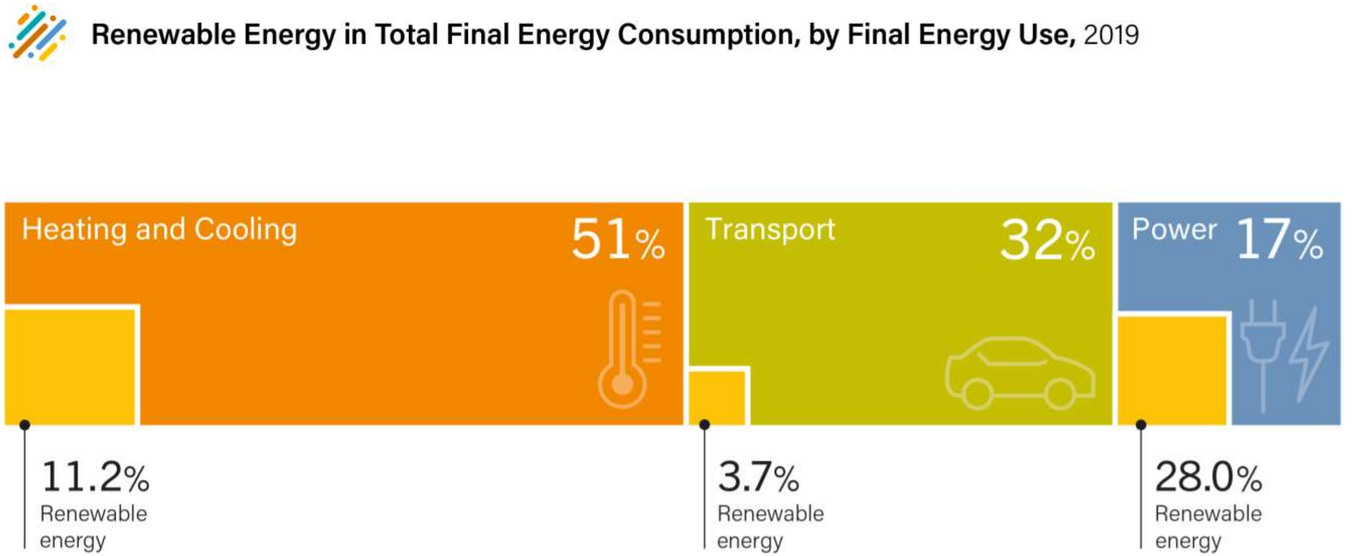
Agenda

1	*Kontext*	**Markt & Chancen**
2	*Monitoring*	**Status Quo & interaktiver Teil**
3	*HarvestIT*	**Garantieverfahren & Software**
4	*Ausblick*	**D-CAT**

Energie & Erneuerbare



Source: https://twitter.com/janrosenow



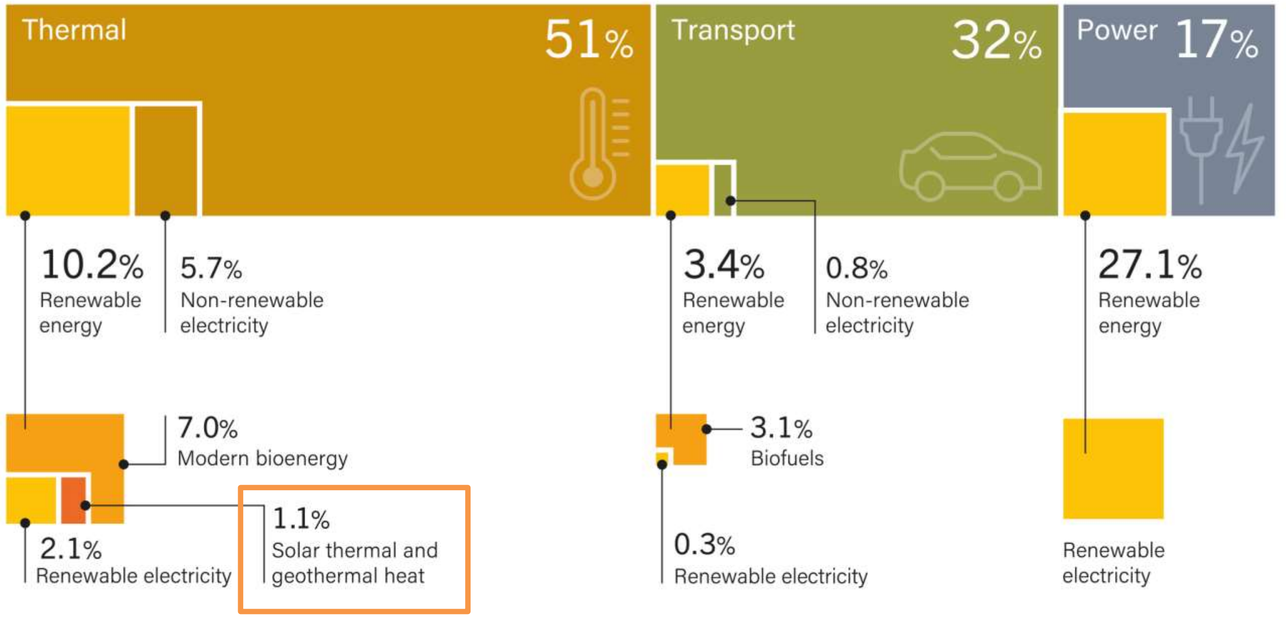
Note: Data should not be compared with previous years because of revisions due to improved or adjusted methodology.

Source: Based on IEA data.

Source: REN21 RENEWABLES 2022 GLOBAL STATUS REPORT

Energie & Erneuerbare

Renewable Energy in Total Final Energy Consumption
by Final Energy Use, 2018



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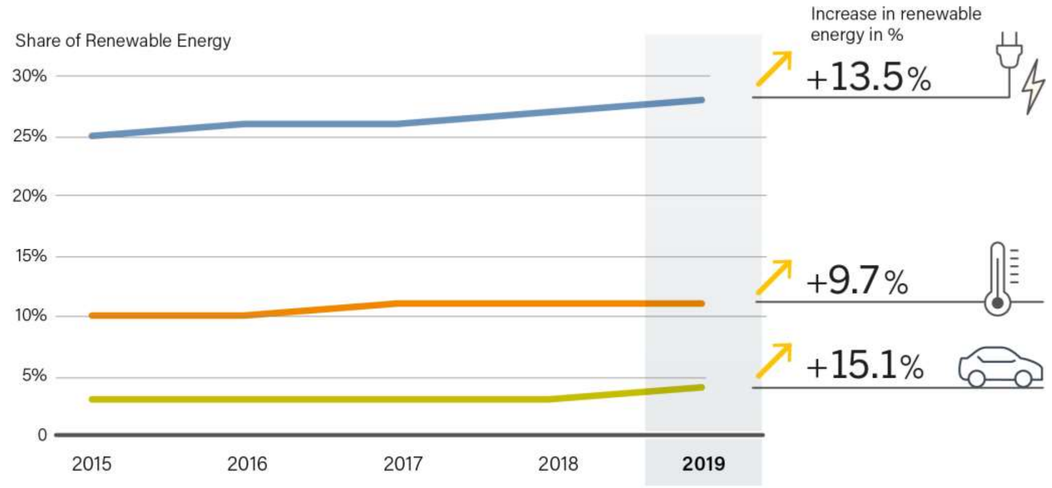
Source: Based on IEA data.

REN21 RENEWABLES 2021 GLOBAL STATUS REPORT

Energie & Erneuerbare



REN21 RENEWABLES 2022 GLOBAL STATUS REPORT

POLITISCHE RAHMEN-BEDINGUNGEN IN EUROPA

EU-Mitgliedsstaaten sollen den Anteil erneuerbarer **WÄRME** bis 2030 jedes Jahr um **1.3 %** erhöhen.

ERNEUERBARE WÄRMEQUELLEN

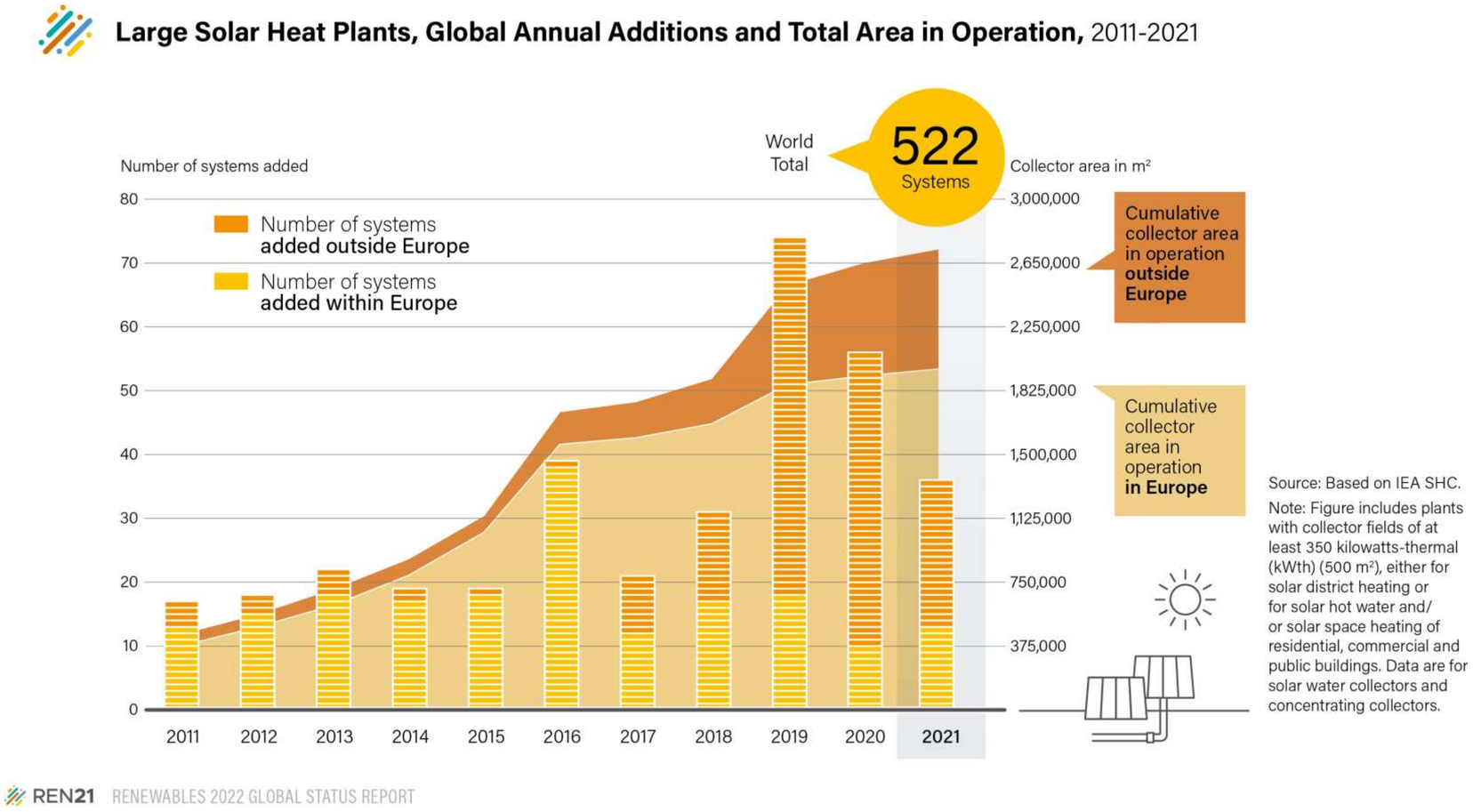
SOLARE FERNWÄRME HILFT, DIESES ZIEL ZU ERREICHEN.

2012 bis 2017:
0.6%
wurden pro Jahr erreicht.

2021 bis 2030:
1.3%
sollen pro Jahr erreicht werden.

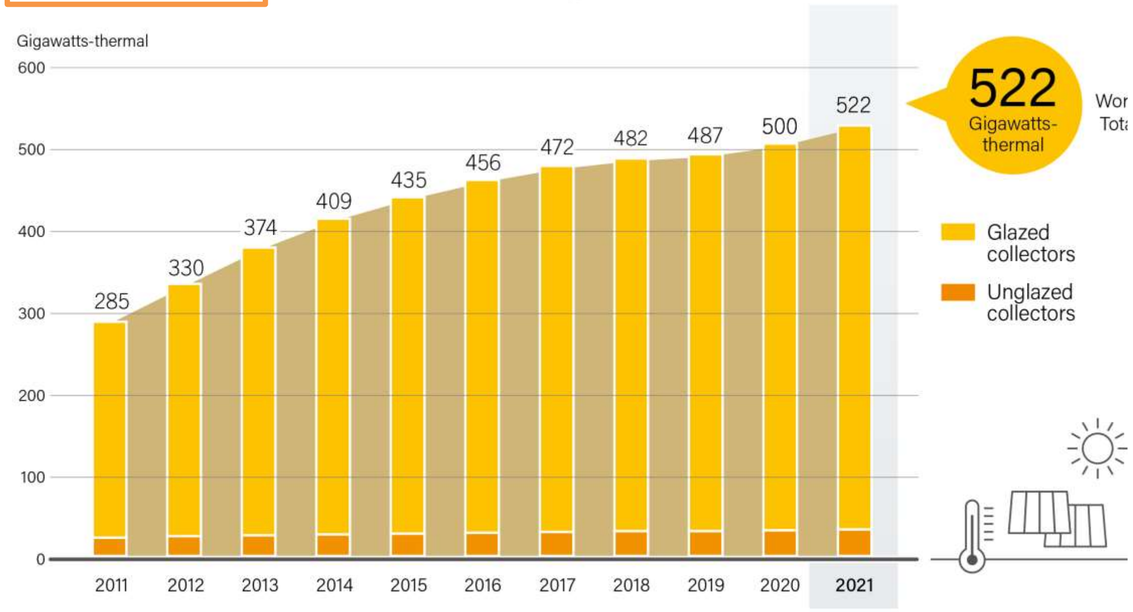
IEA SHC TASK 55

LST: Large Solar Thermal



ST & PV

Solar Water Heating Collectors Global Capacity, 2011-2021

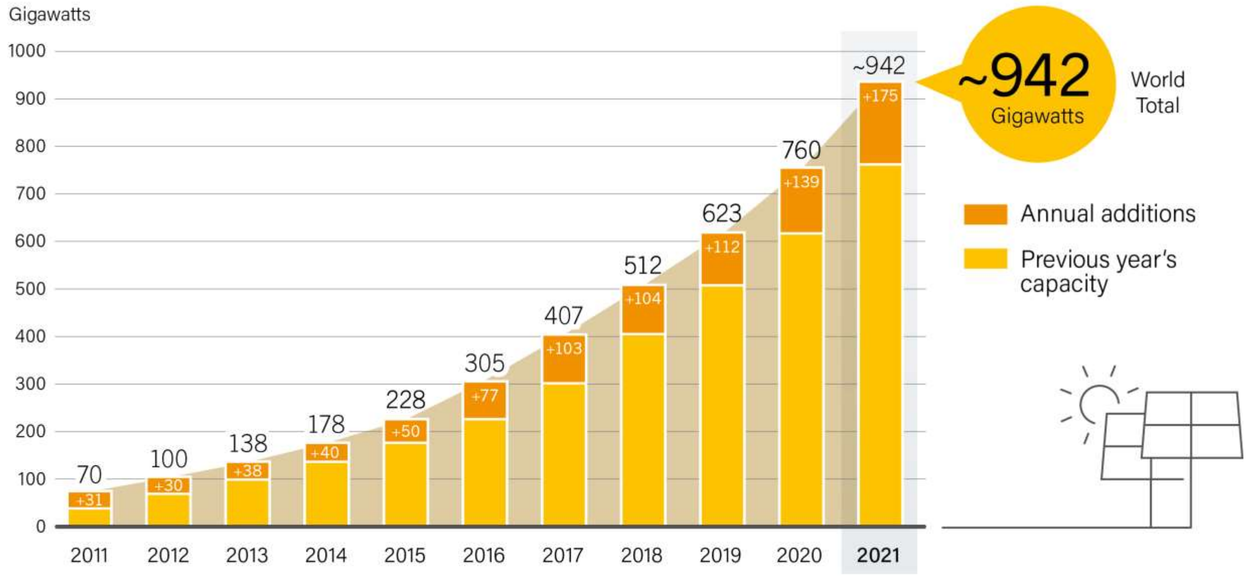


Source: Based on IEA SHC.

Note: Data are for glazed and unglazed solar water collectors and do not include concentrating, air or hybrid collectors.

REN21 RENEWABLES 2022 GLOBAL STATUS REPORT

Solar PV Global Capacity and Annual Additions, 2011-2021



Source: Based on IEA PVPS.

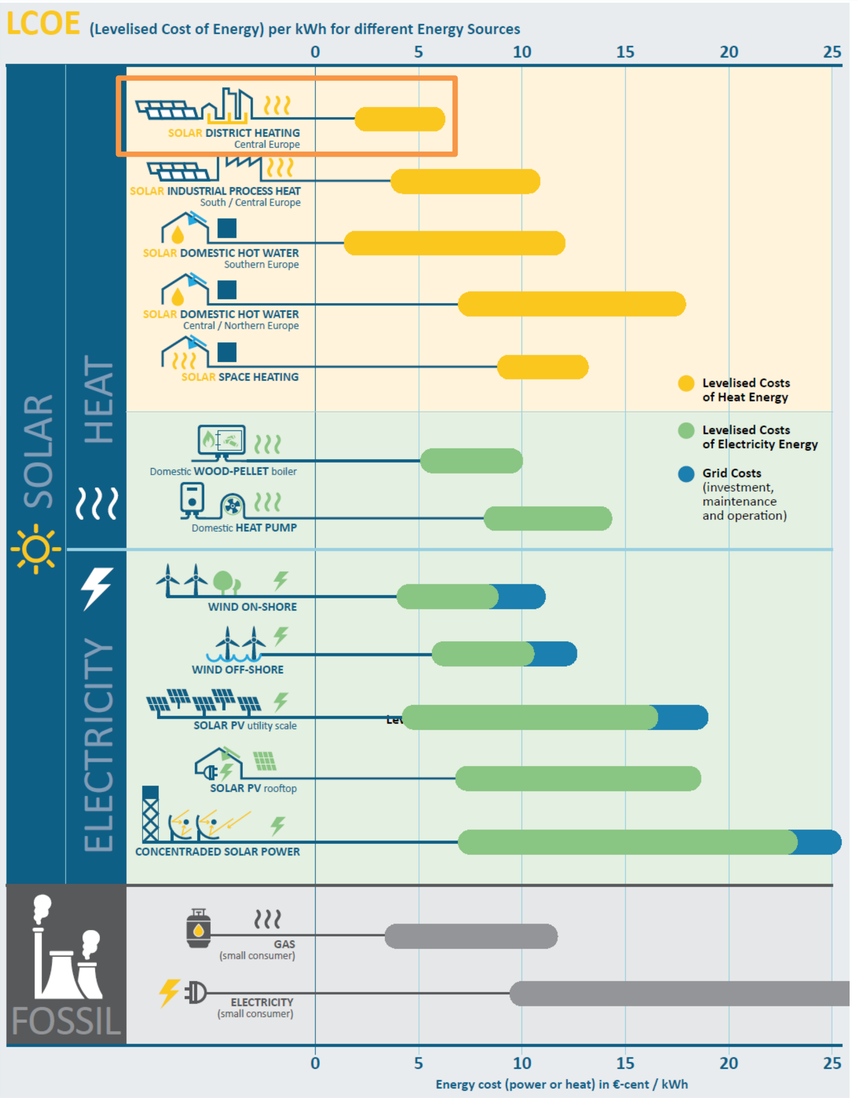
REN21 RENEWABLES 2022 GLOBAL STATUS REPORT

LST Dänemark

https://solvarmedata.dk

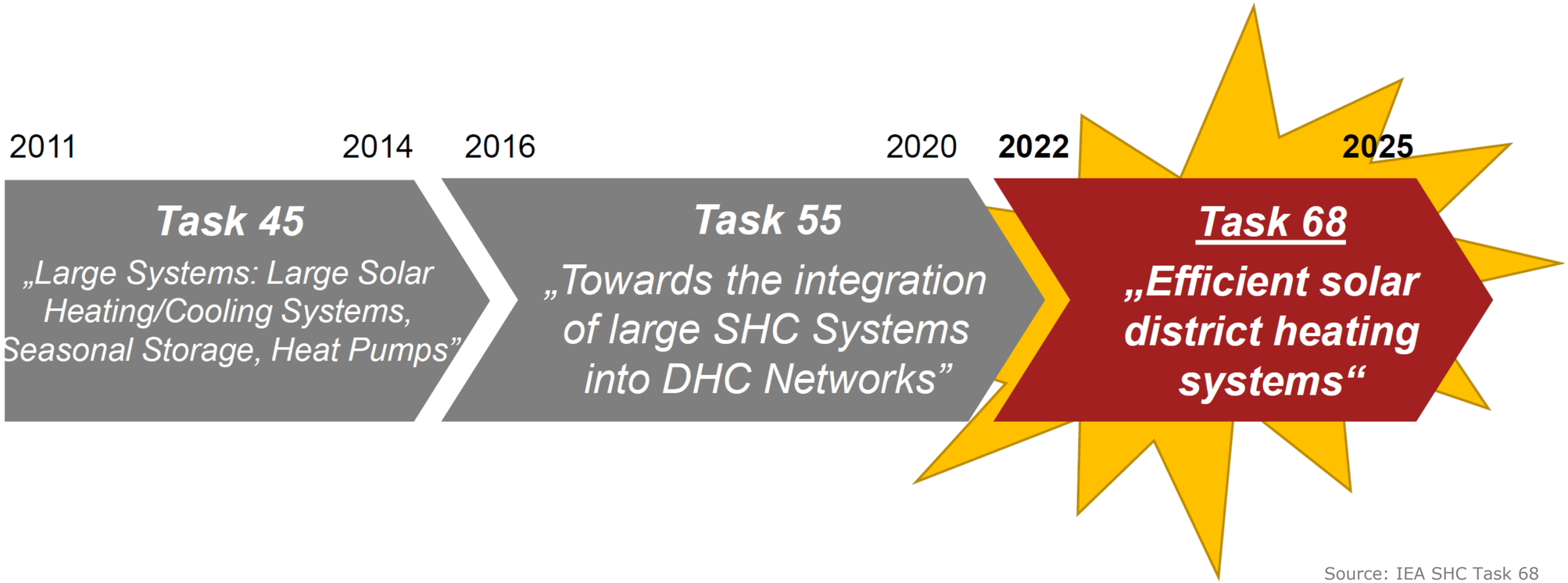
ESTIF: solariseheat.eu

Solar Heat Europe
ESTIF



IEA SHC Tasks

History of tasks in the context of solar district heating (SDH) systems



Source: IEA SHC Task 68

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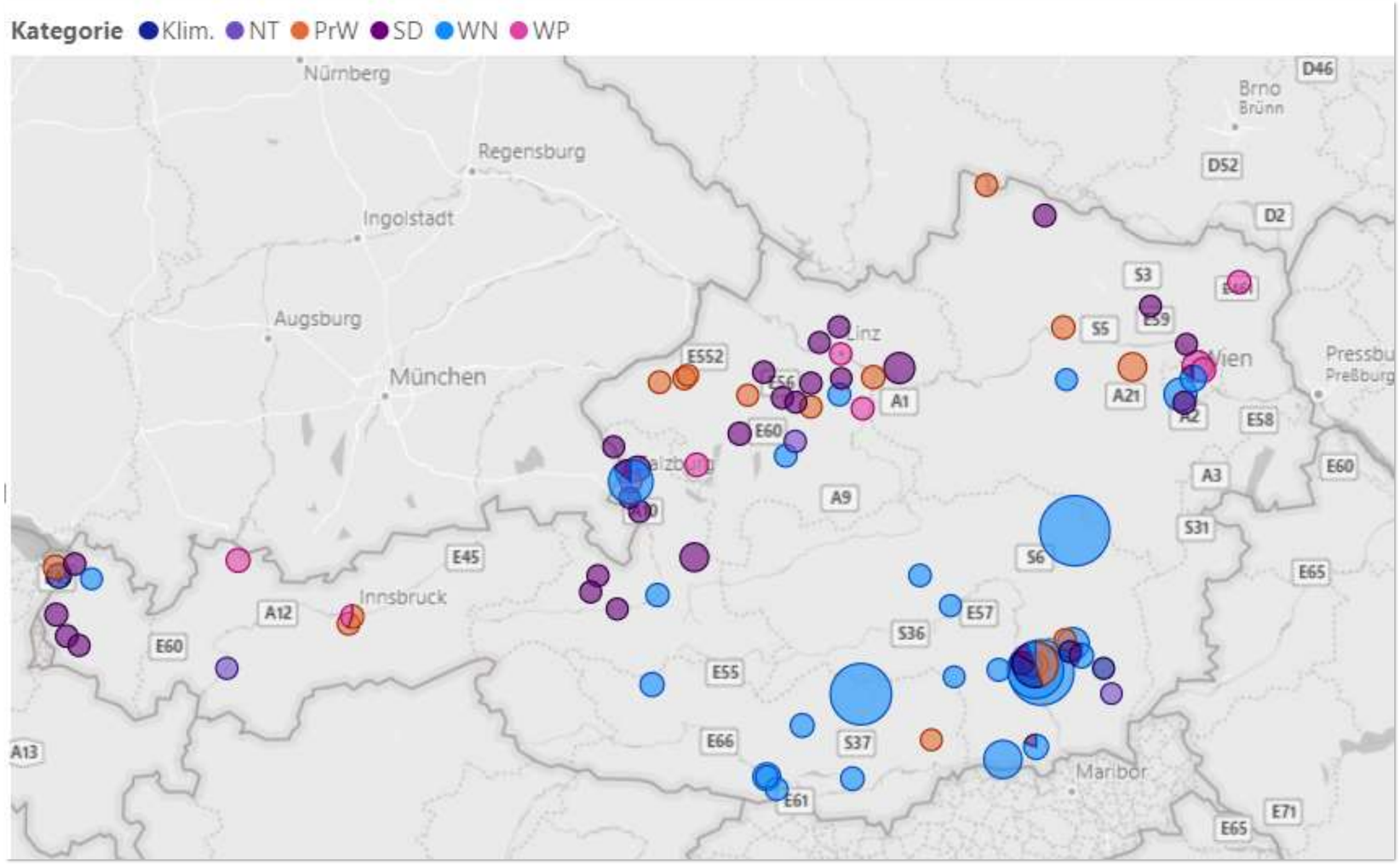
4	*Ausblick*	**D-CAT**

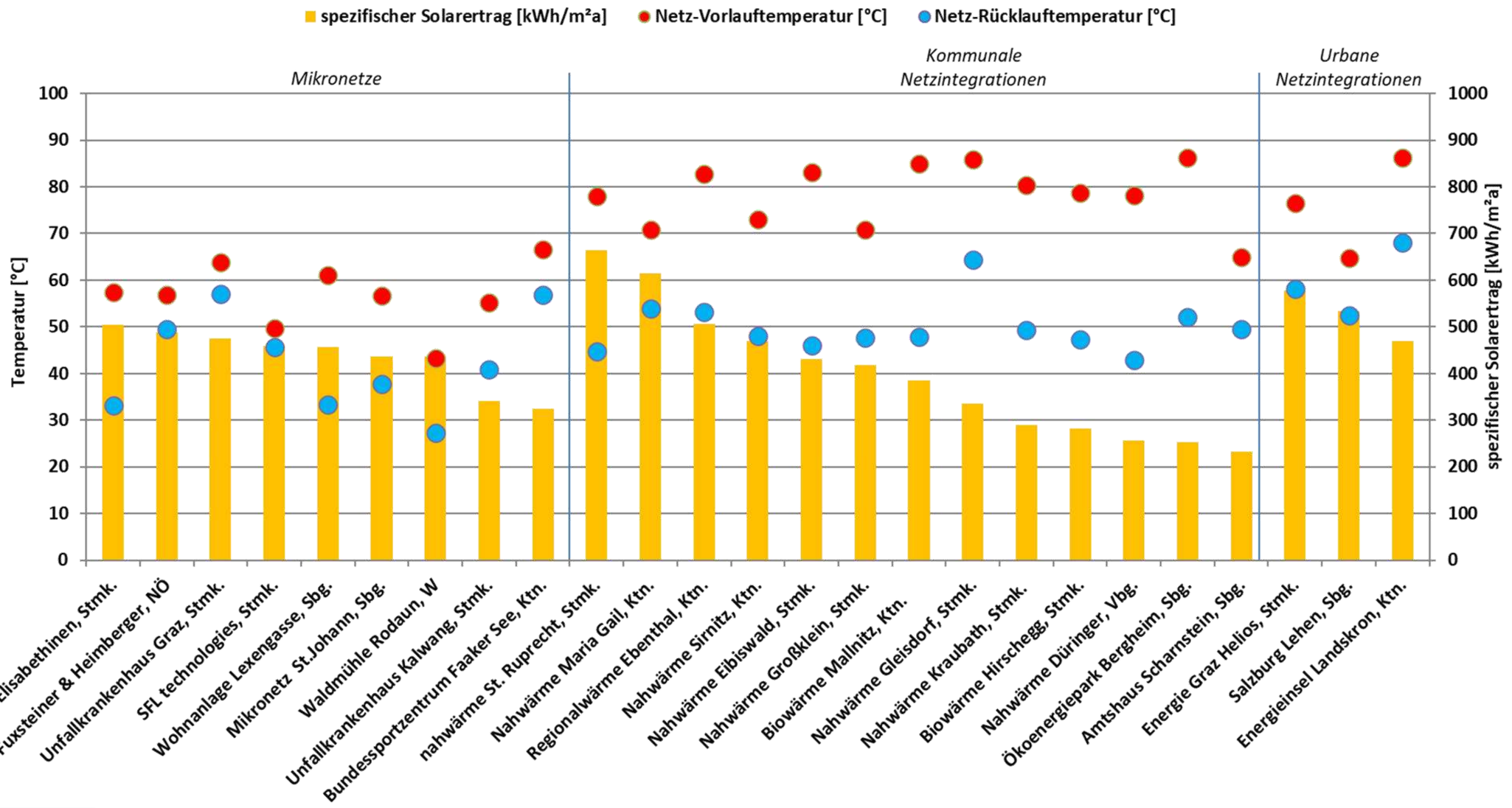
Begleitforschung 2010 – 2019

- Special funding program since 2010 for solar thermal plants > 100 m²
- Investment incentive of 40-50% of the eligible costs
- Accompanying research: Consulting, Monitoring, Knowledge Transfer



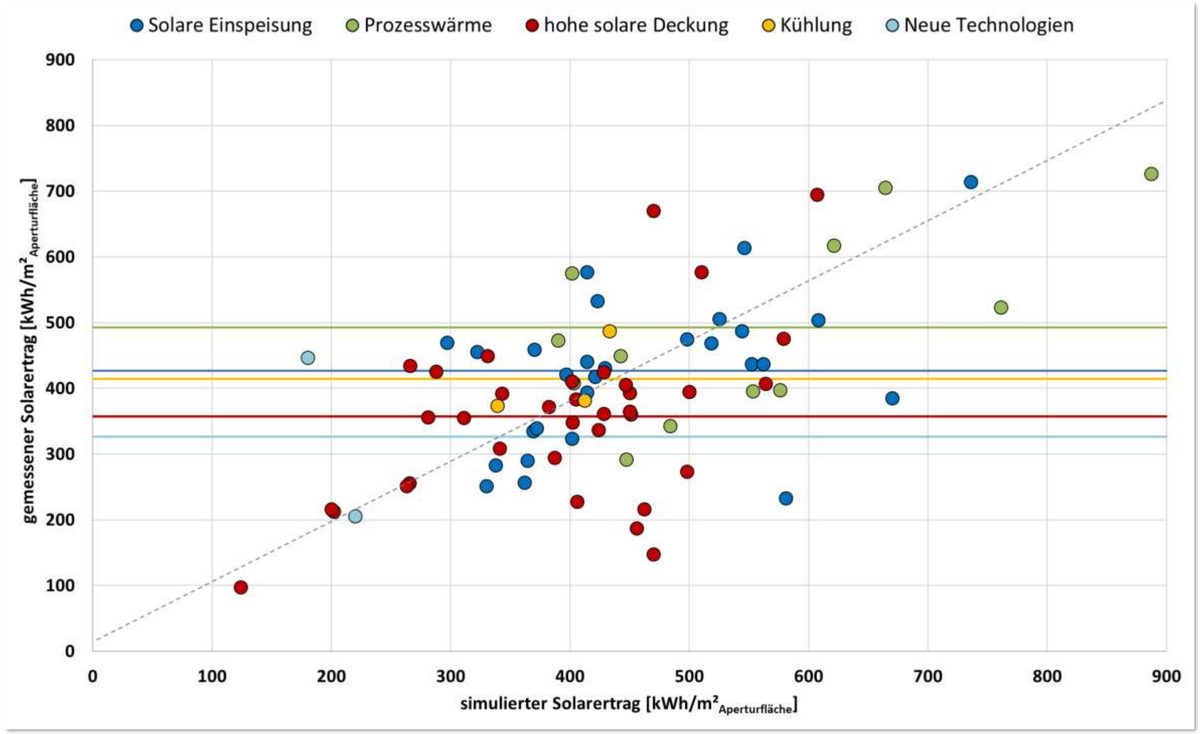
Bubble size == plant size [100 m² … 6.922 m²]

Solare Netzeinspeisung

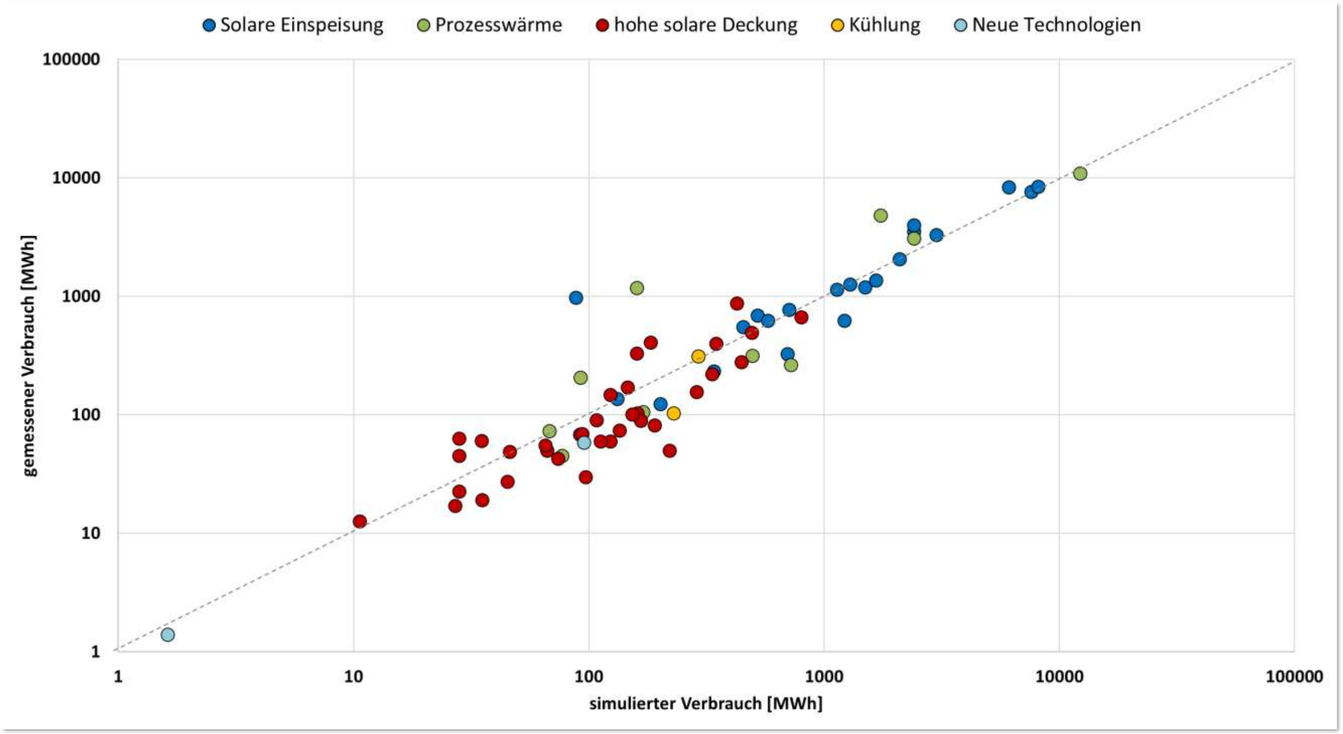


Planung vs. Messung

Abweichung Ertrag
Simulation vs. Messung



Abweichung Verbrauch
Simulation vs. Messung



Garantieverfahren

Motivation für praktische Anwendung

Umfeld

a) Es gibt am Markt **keine Standard-Software** für Solarthermie-Garantien.

b) Garantie & Performance-Bewertung ist **schwierig**, auch für Experten.

c) Big Data. Daten stehen zur Verfügung, nutzen wir sie.

Finanzierung

- CAPEX: Solare Großanlagen haben **hohe Investitionskosten.**
- OPEX: Betreiber muss **langfristig hohen Solarertrag** sicherstellen, damit sich die Investition rechnet.

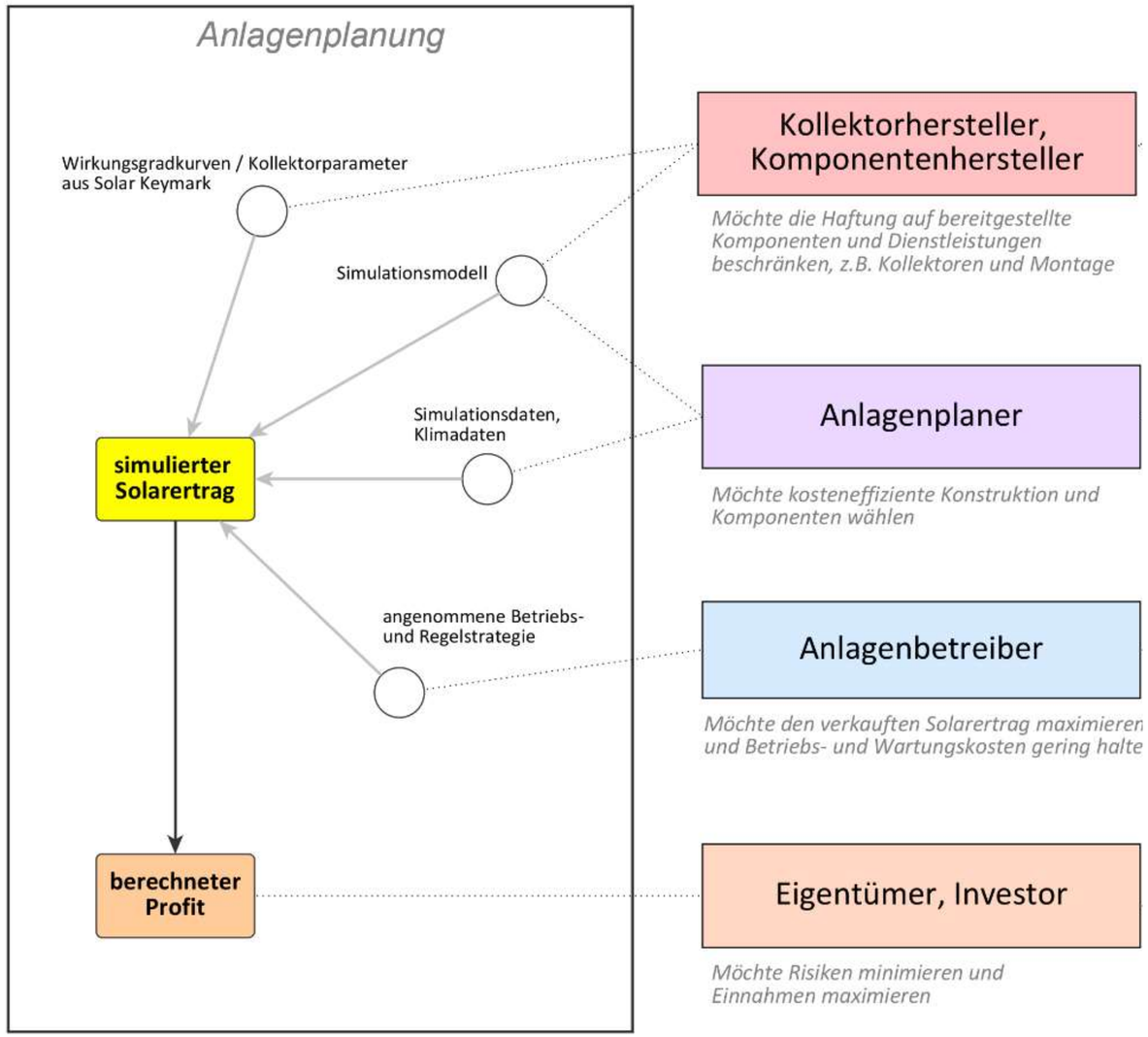
Garantieverfahren

Kernfragen & Ziele HarvestIT:

1) **Leistungs- und Ertragsgarantie** für Kollektorfelder
2) **Bewertung der Kollektorfeldperformance** unter Berücksichtigung des Anlagenbetriebs (Temperaturen, Verbrauch etc.)
3) **Anwendung für kommerzielle Anlagen im Betrieb**

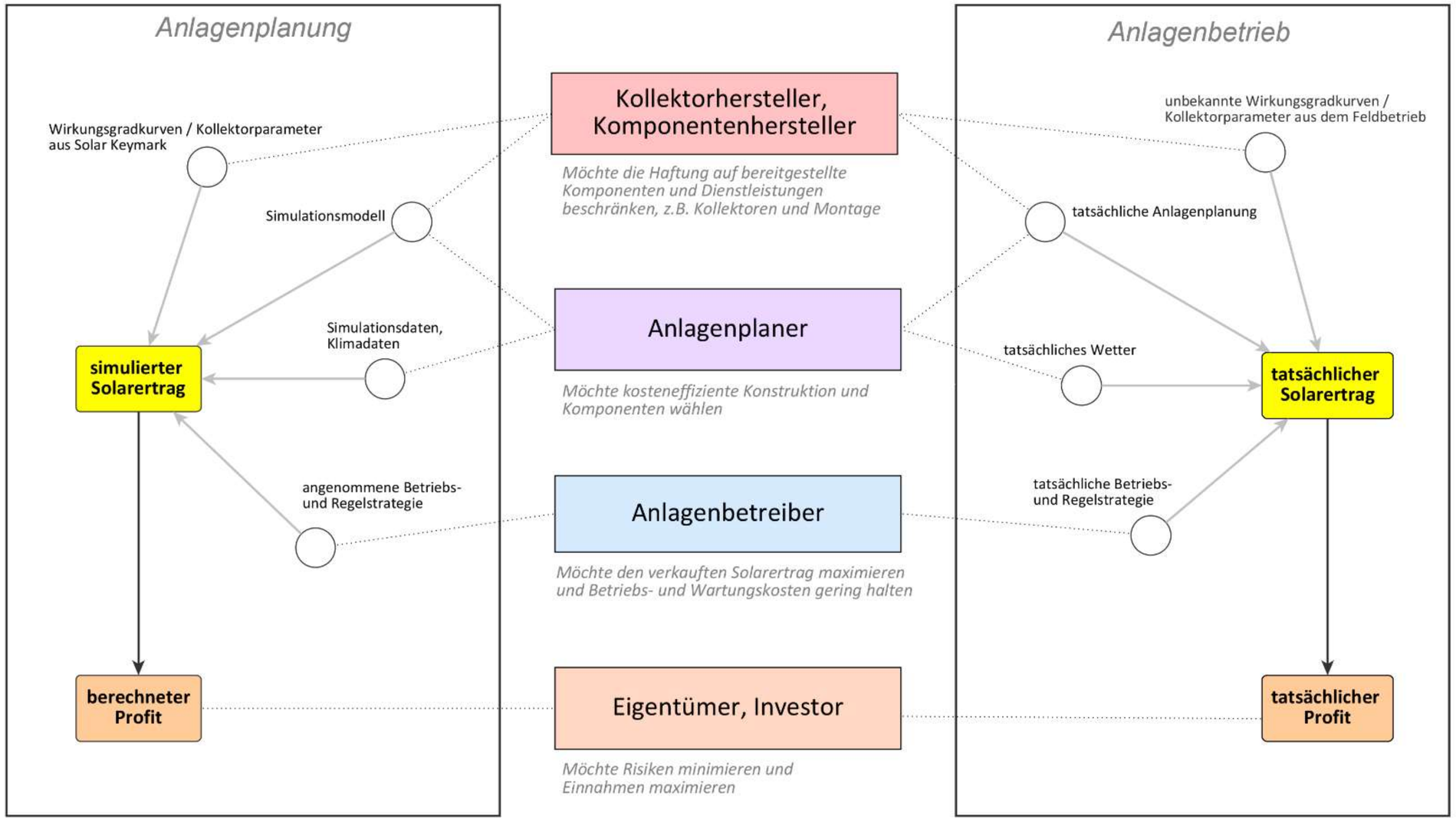
Garantieverfahren

Rollen & Verantwortung



Garantieverfahren

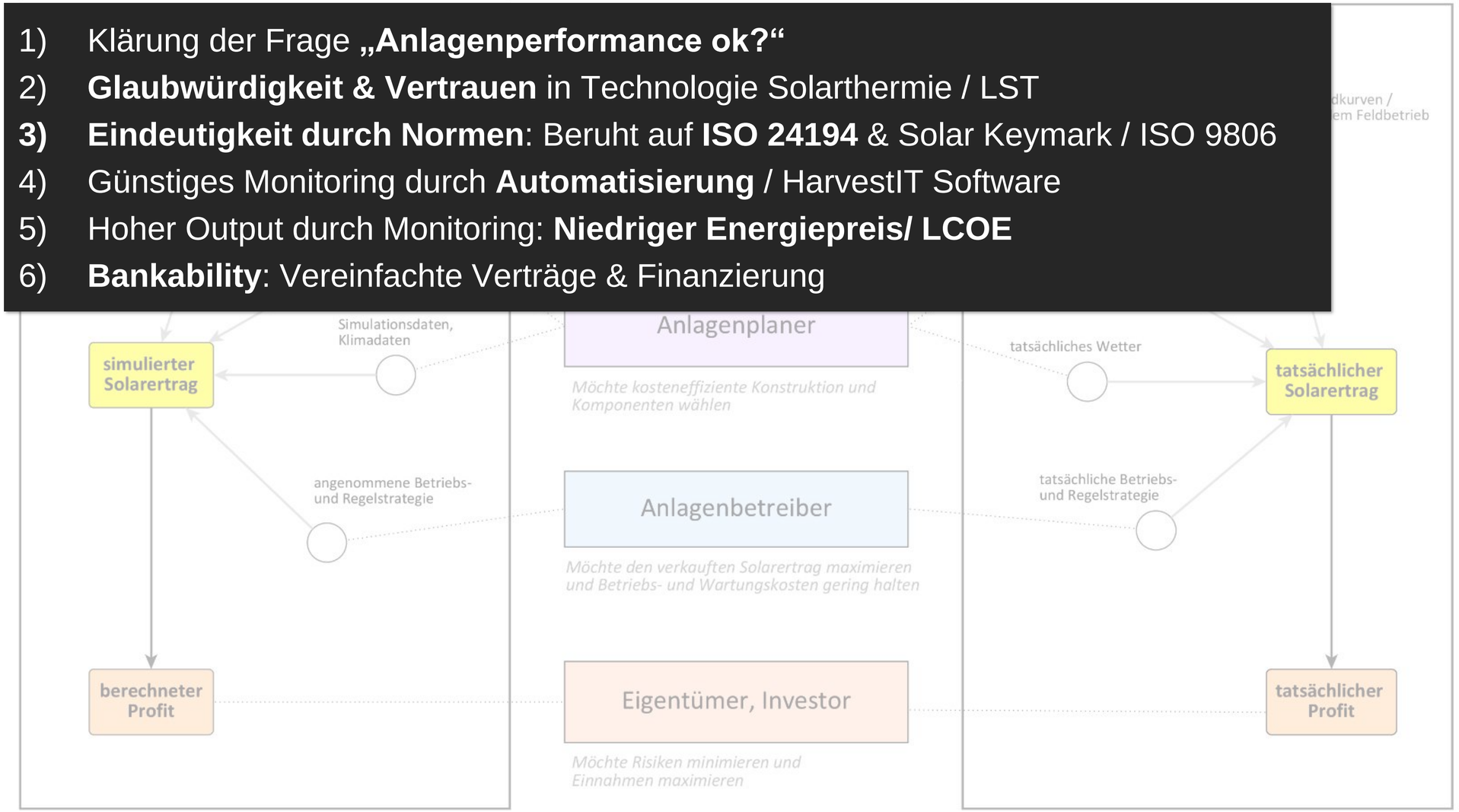
Rollen & Verantwortung



Garantieverfahren

Bedeutung

1) Klärung der Frage **„Anlagenperformance ok?“**
2) **Glaubwürdigkeit & Vertrauen** in Technologie Solarthermie / LST
3) **Eindeutigkeit durch Normen**: Beruht auf **ISO 24194** & Solar Keymark / ISO 9806
4) Günstiges Monitoring durch **Automatisierung** / HarvestIT Software
5) Hoher Output durch Monitoring: **Niedriger Energiepreis/ LCOE**
6) **Bankability**: Vereinfachte Verträge & Finanzierung



Projekt HarvestIT

Source: Picfly.at Thomas Eberhard

HarvestIT:

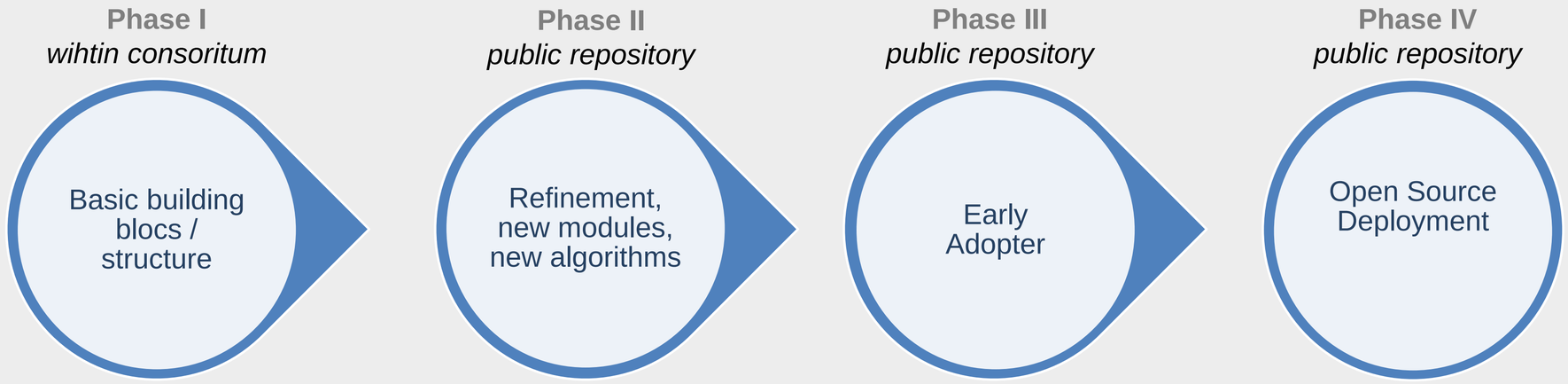
Advanced monitoring of large-scale solar thermal plants with open-source software

- FFG – FastTrackDigital 1st Call
- Project duration: 2021-11 to 2023-10

HarvestIT Software

Roadmap to Deployment

Tool development



HarvestIT: Bitte mitmachen

Questionnaire
Monitoring Tools

https://www.menti.com

code **2742 8296**

Development Phase II – IV
Early Adopter oder Developer
ab Ende 2022

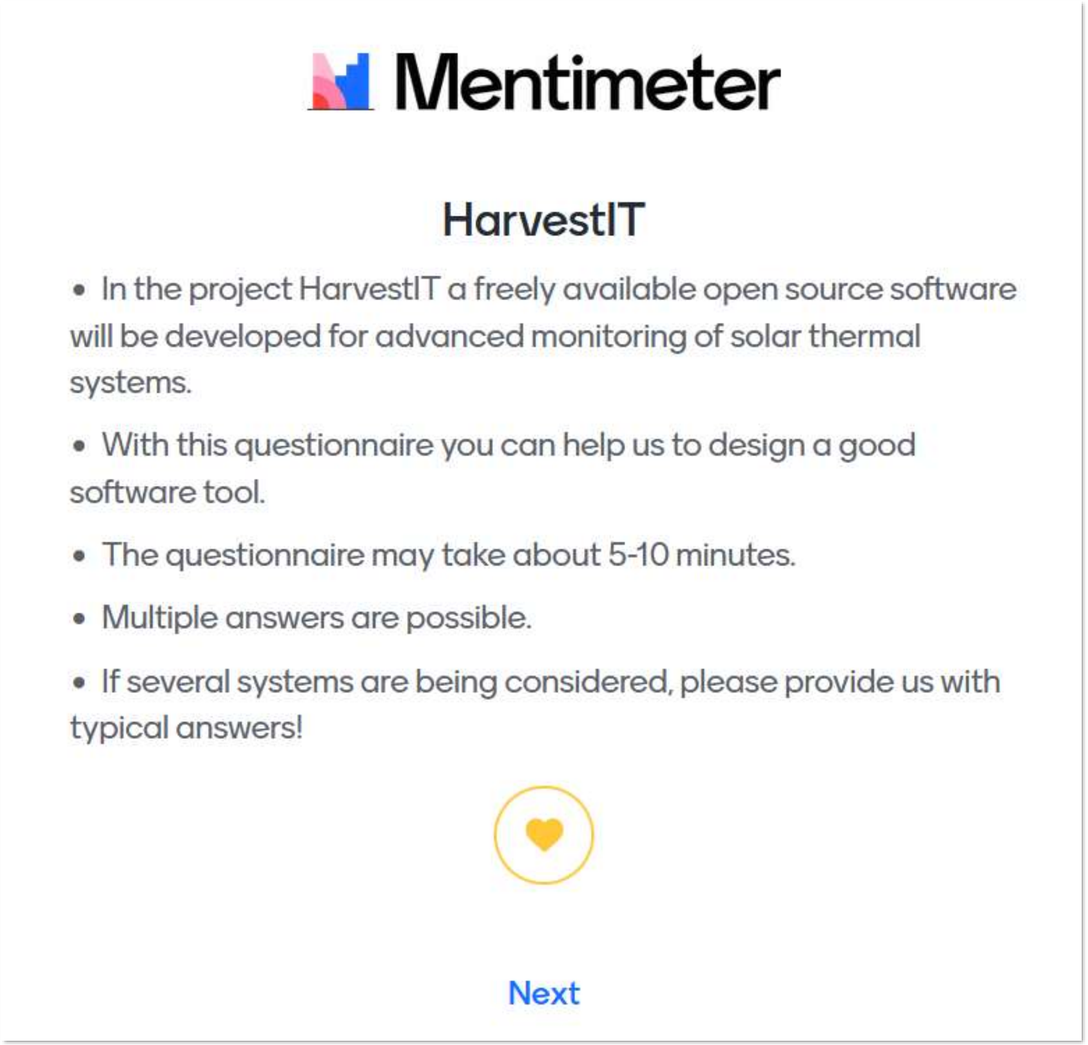
Write to d.tschopp@aee.at

HarvestIT Projekt Updates
Any feedback welcome!

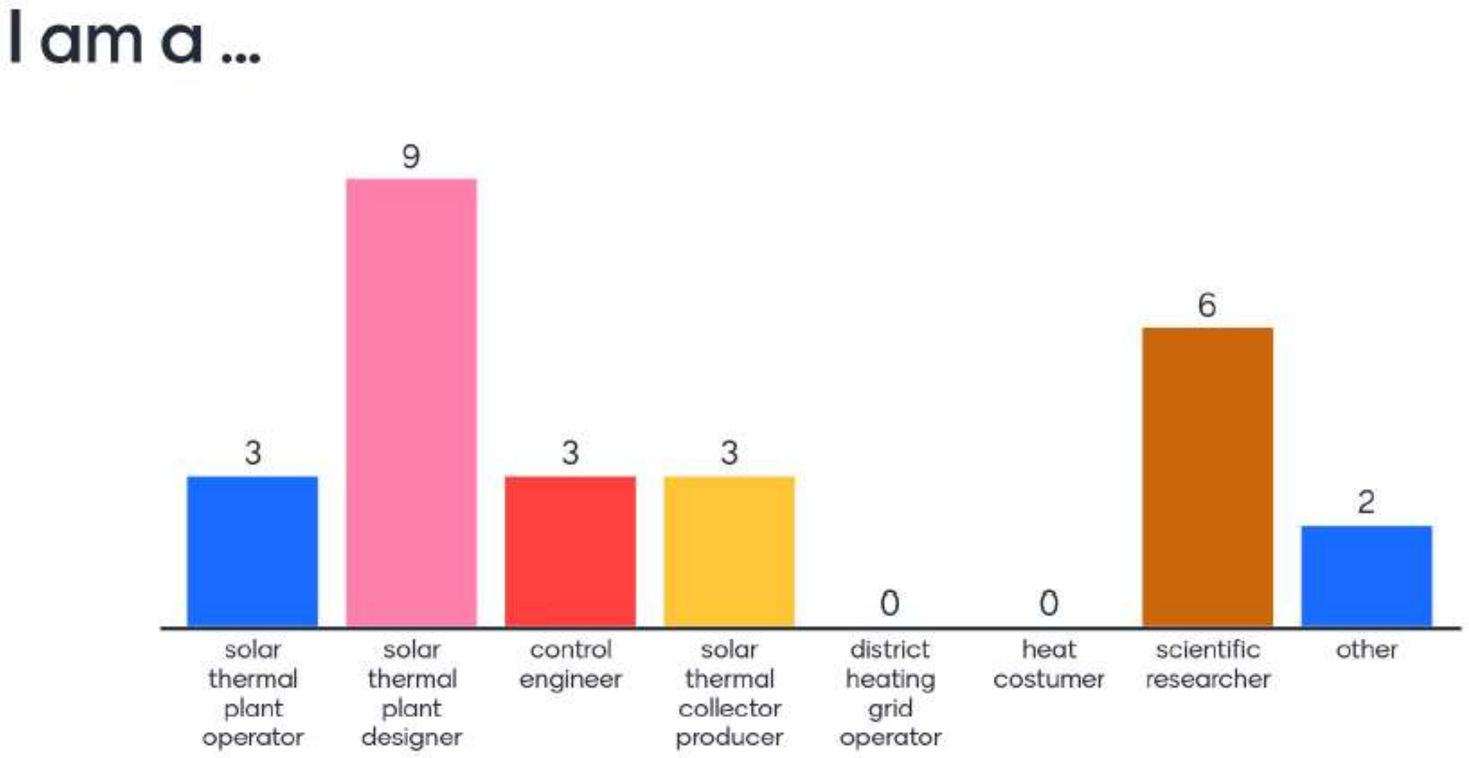
www.collector-array-test.org

Fragebogen Monitoring

26 Teilnehmer (19 davon Großteil der Fragen beantwortet)

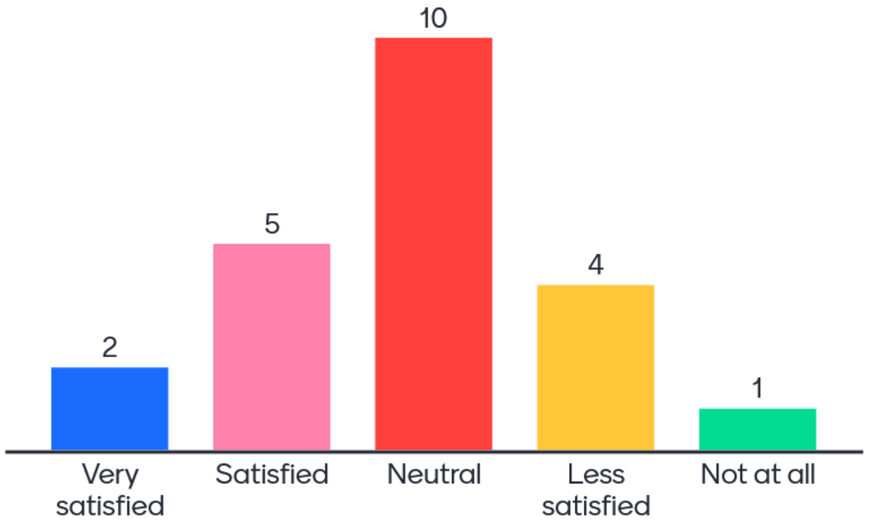


Fragebogen Teilnehmer



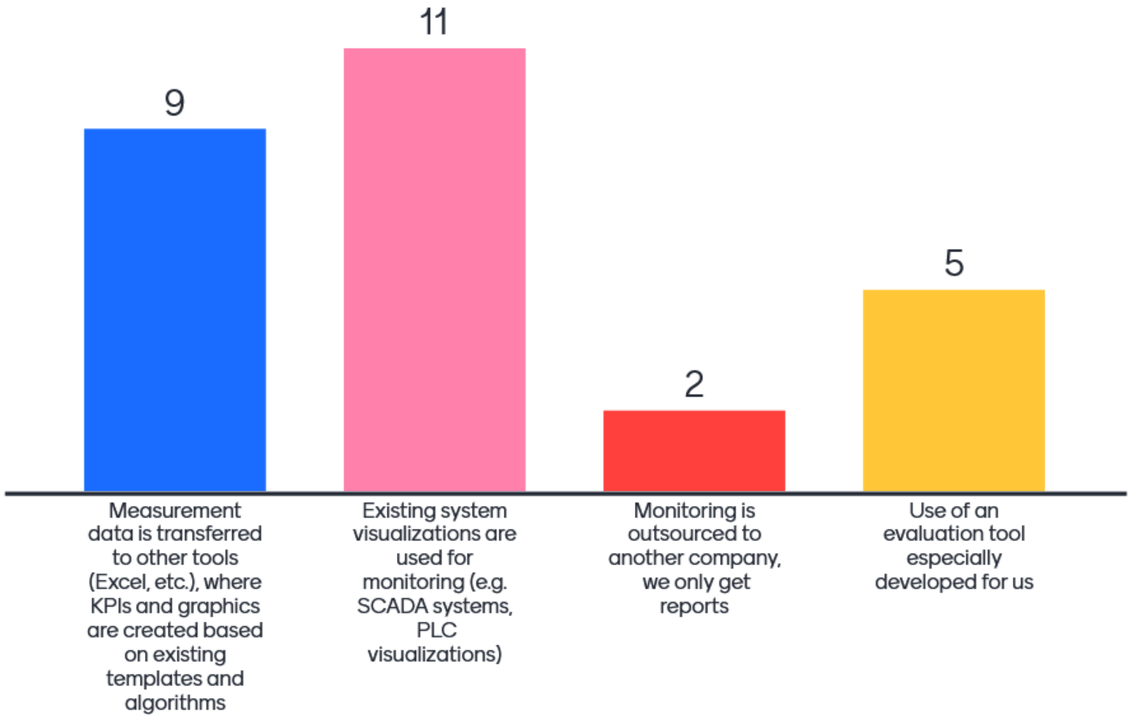
Zufriedenheit Monitoring

1 Satisfaction: How satisfied are you with the current monitoring procedures of the solar thermal plants you operate or deal with?

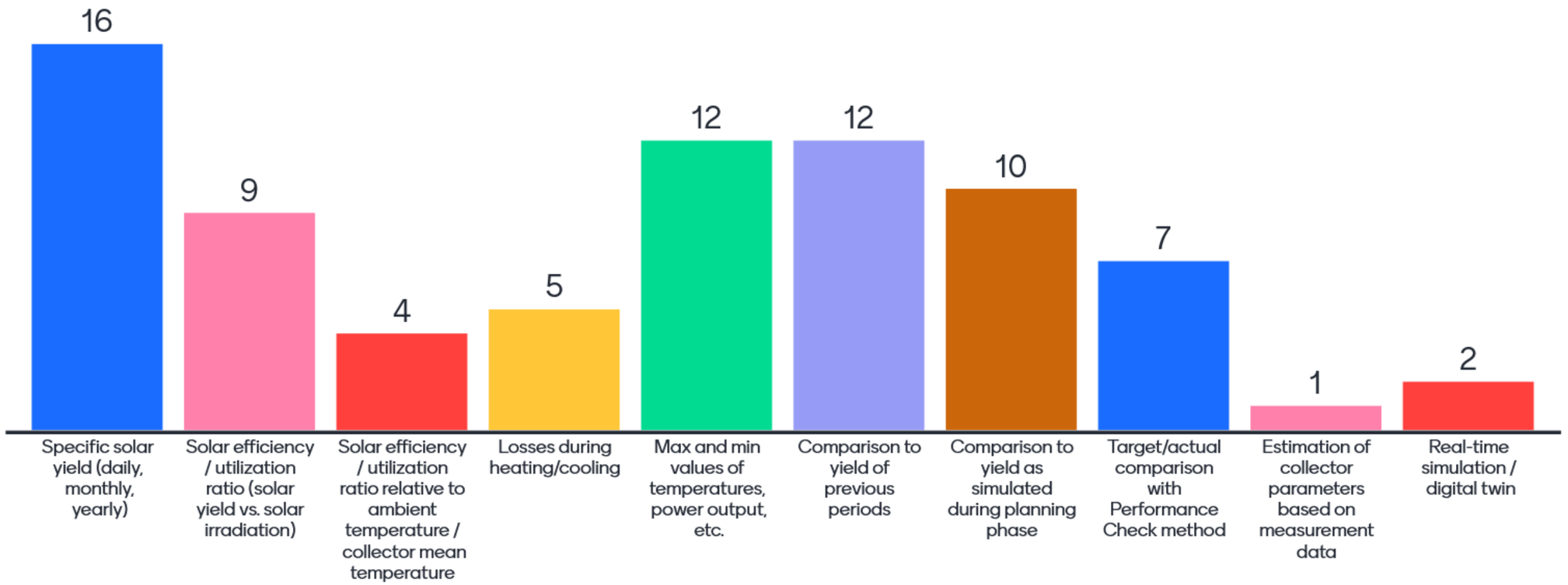


Monitoring aktuell

4 Tool: Which tools do you use to analyse the system?

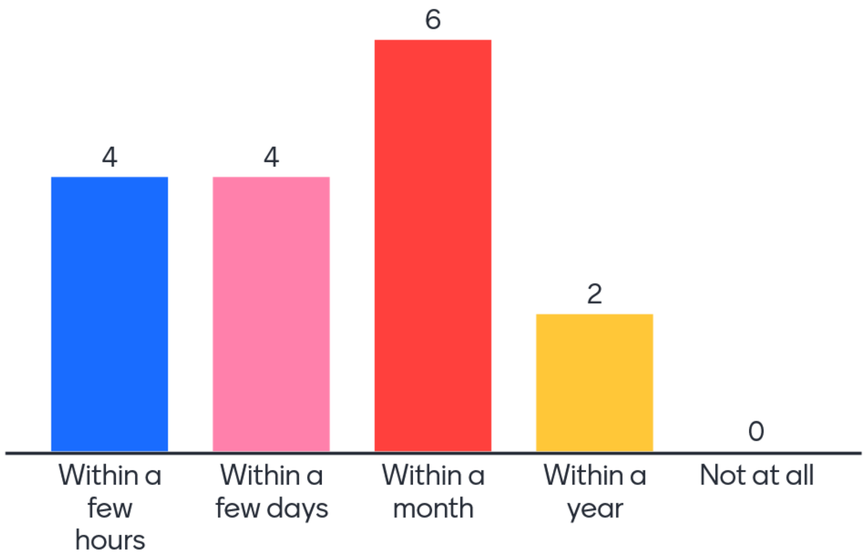


Performance indicators used

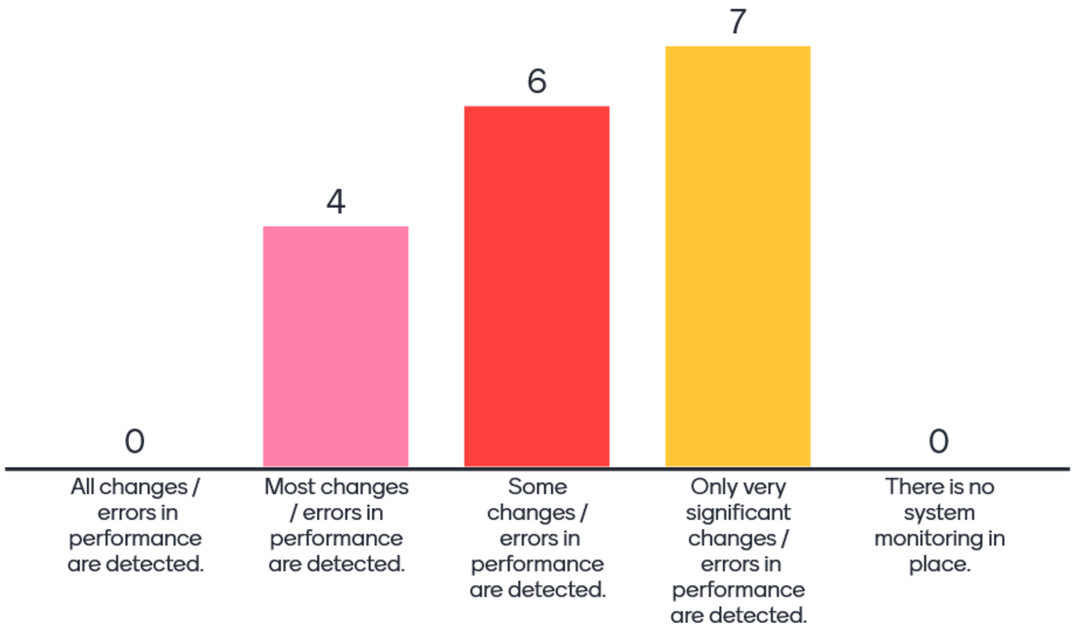


Monitoring aktuell

8 Detection time frame : How quickly are performance changes and errors detected?

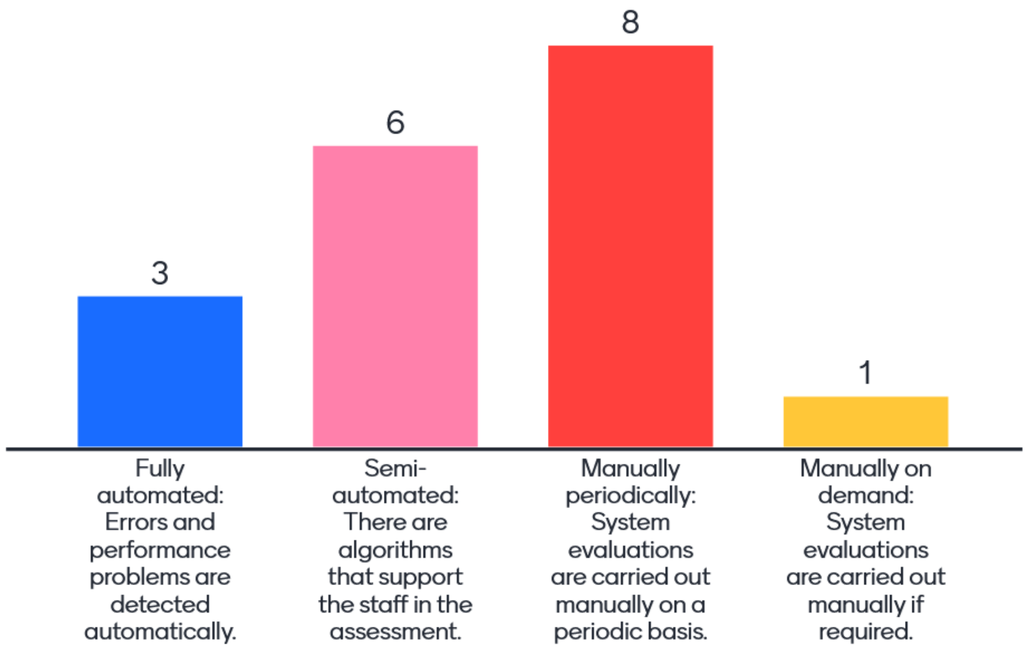


7 Plant performance: How well are performance changes and errors detected?



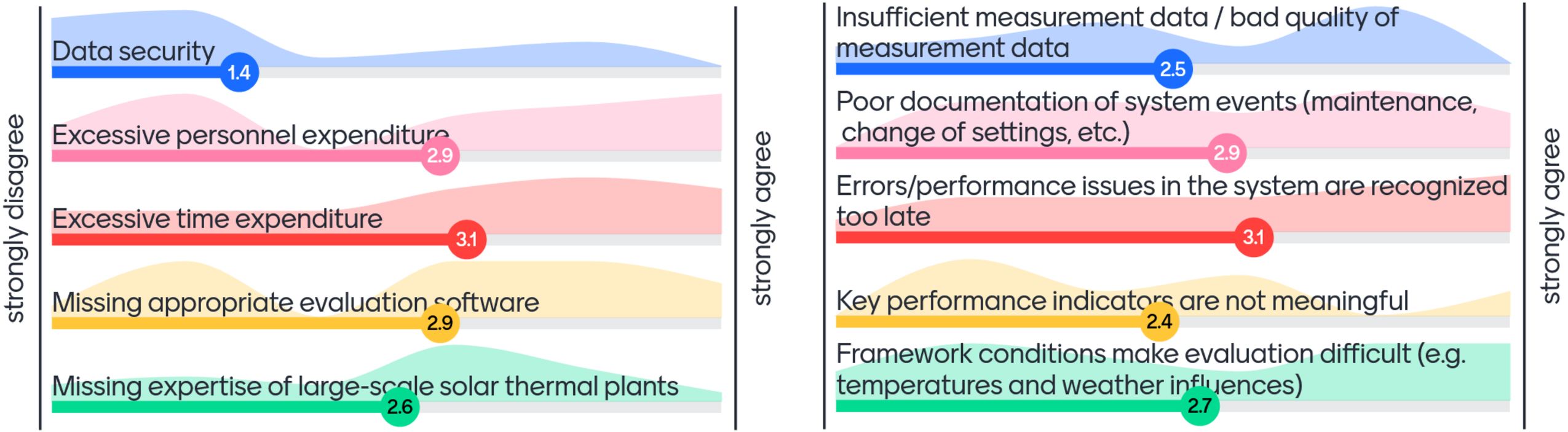
Monitoring aktuell

3 Process: How is the monitoring of the system achieved in your field of work?



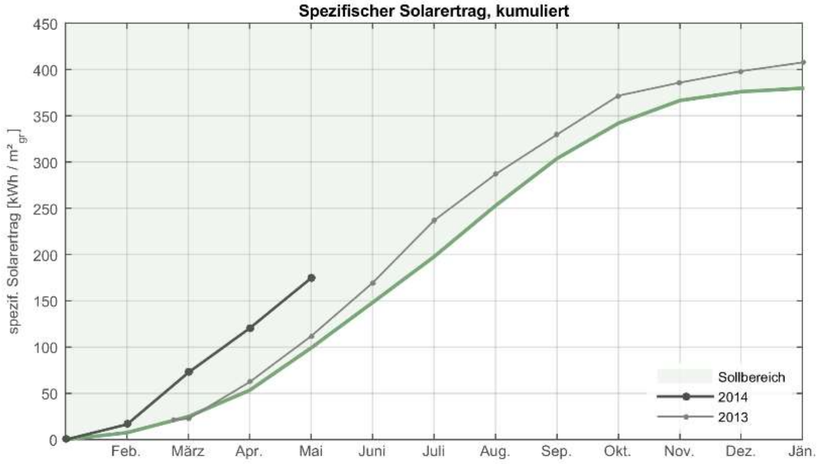
Challenges

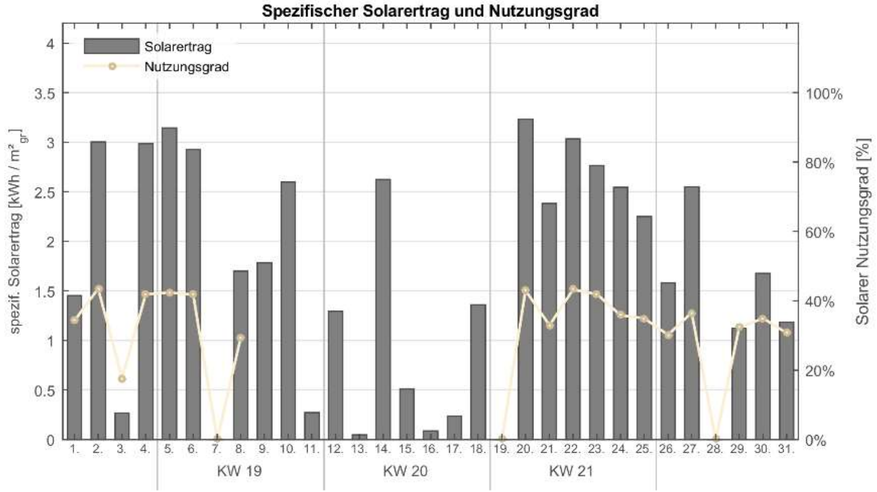
What are the biggest challenges?

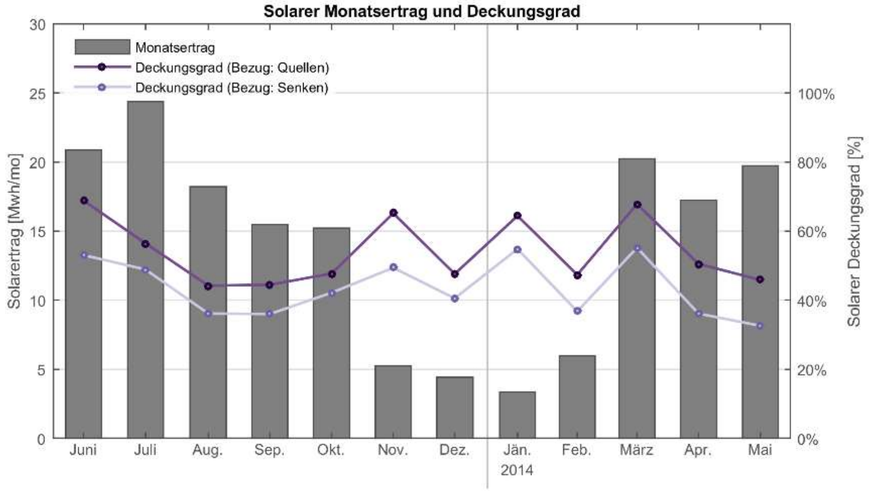


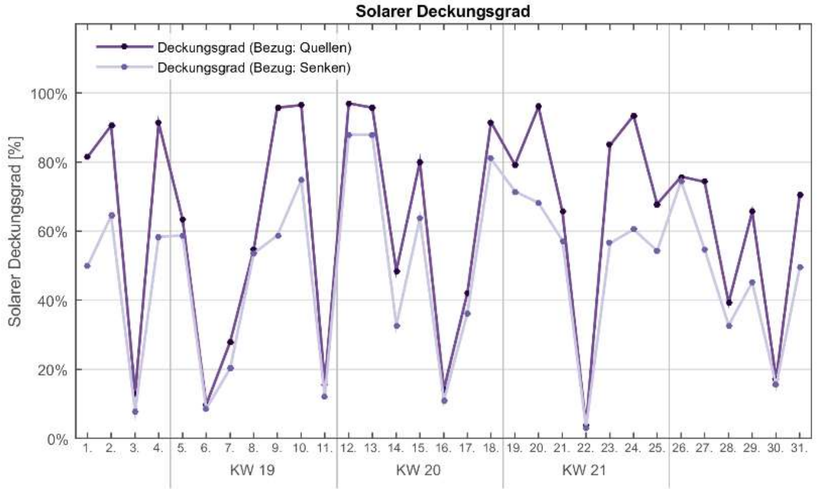
Typische Auswertungen

Kollektorfeld-Performance









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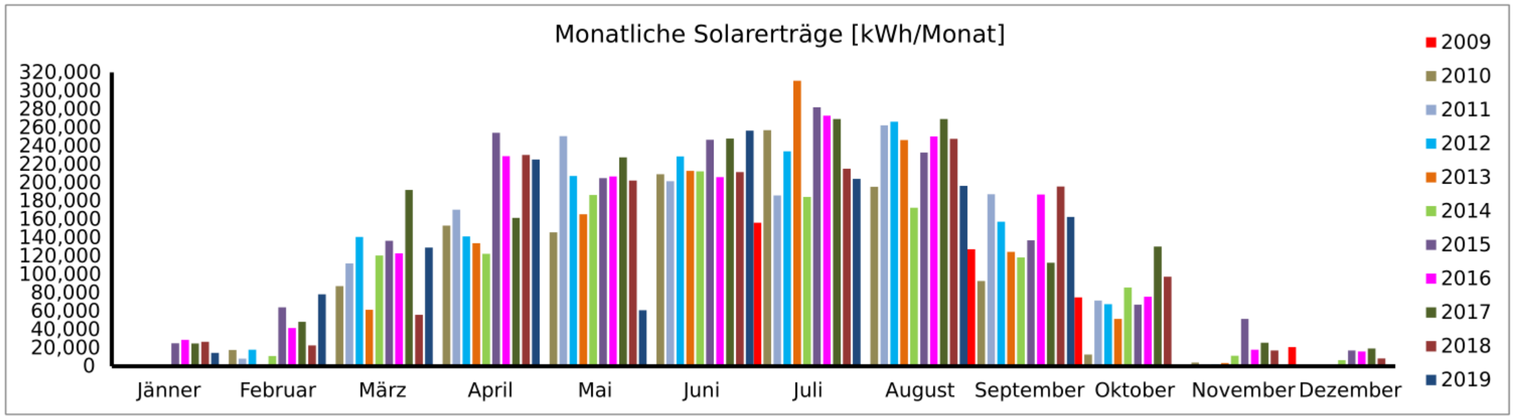

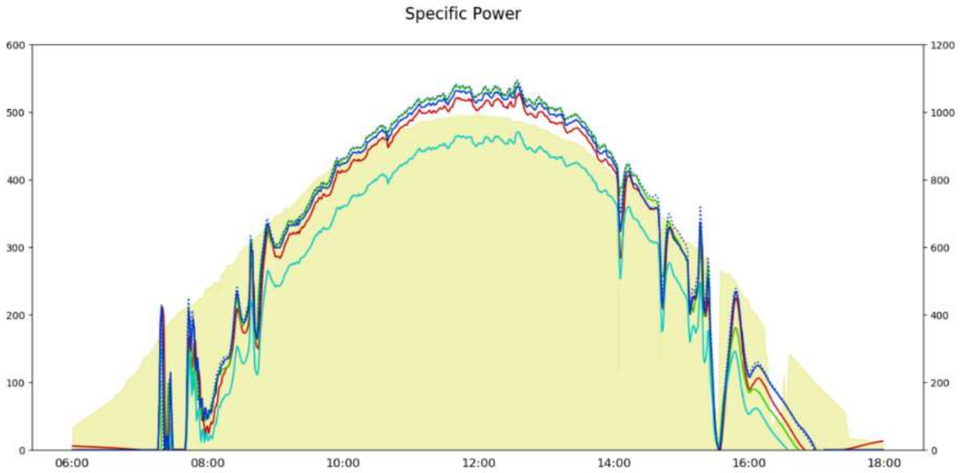

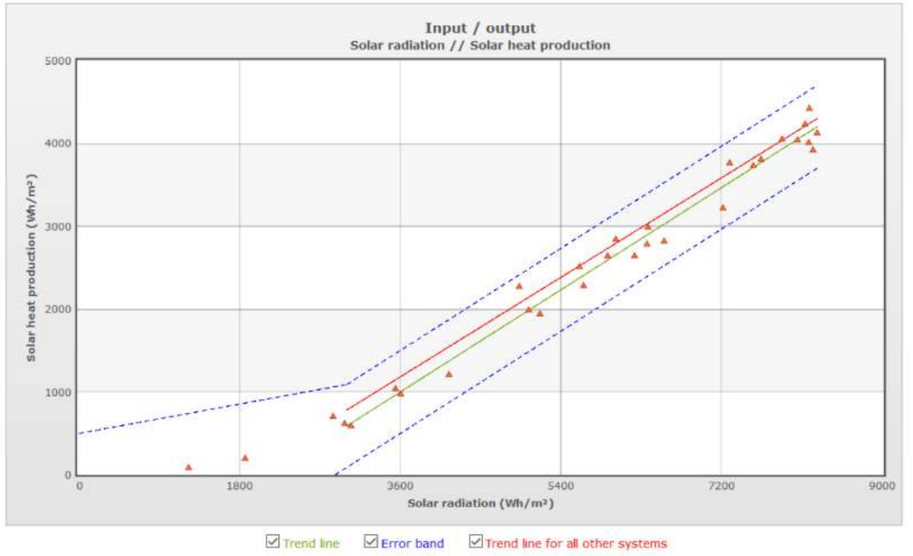

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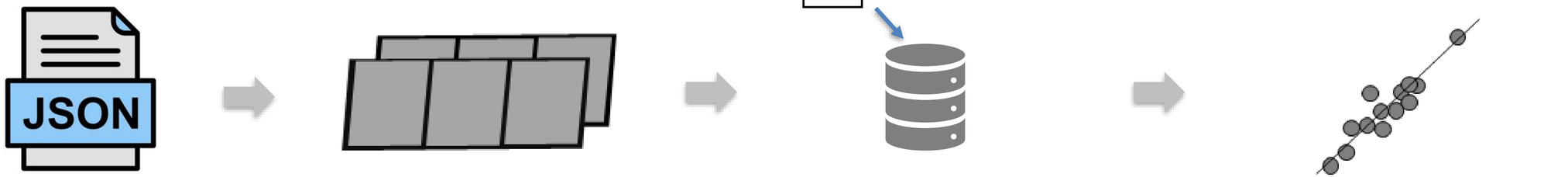
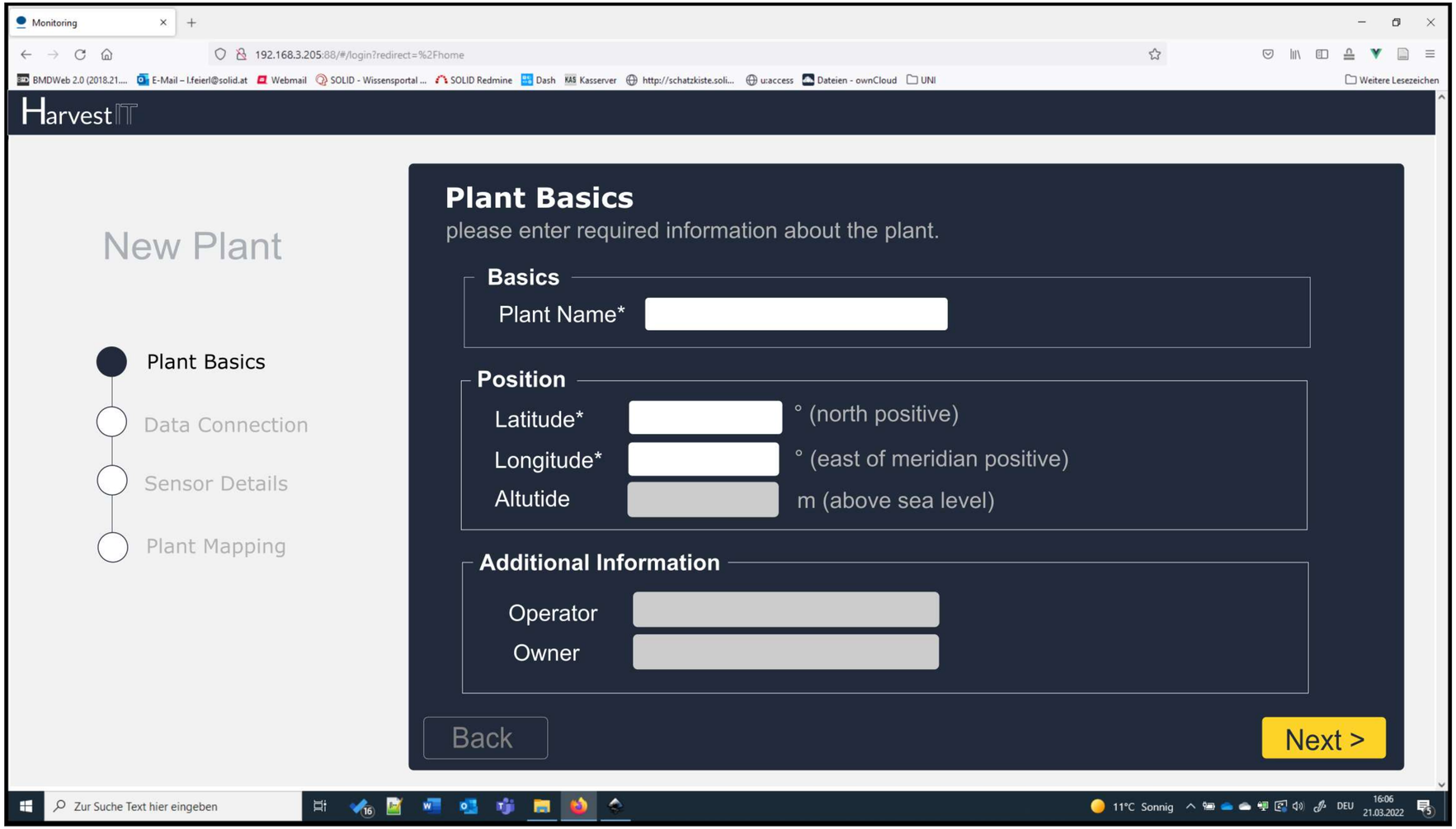
Performance Check Anwendung



Configuration HarvestIT Plant Daten Einbindung Performance Check

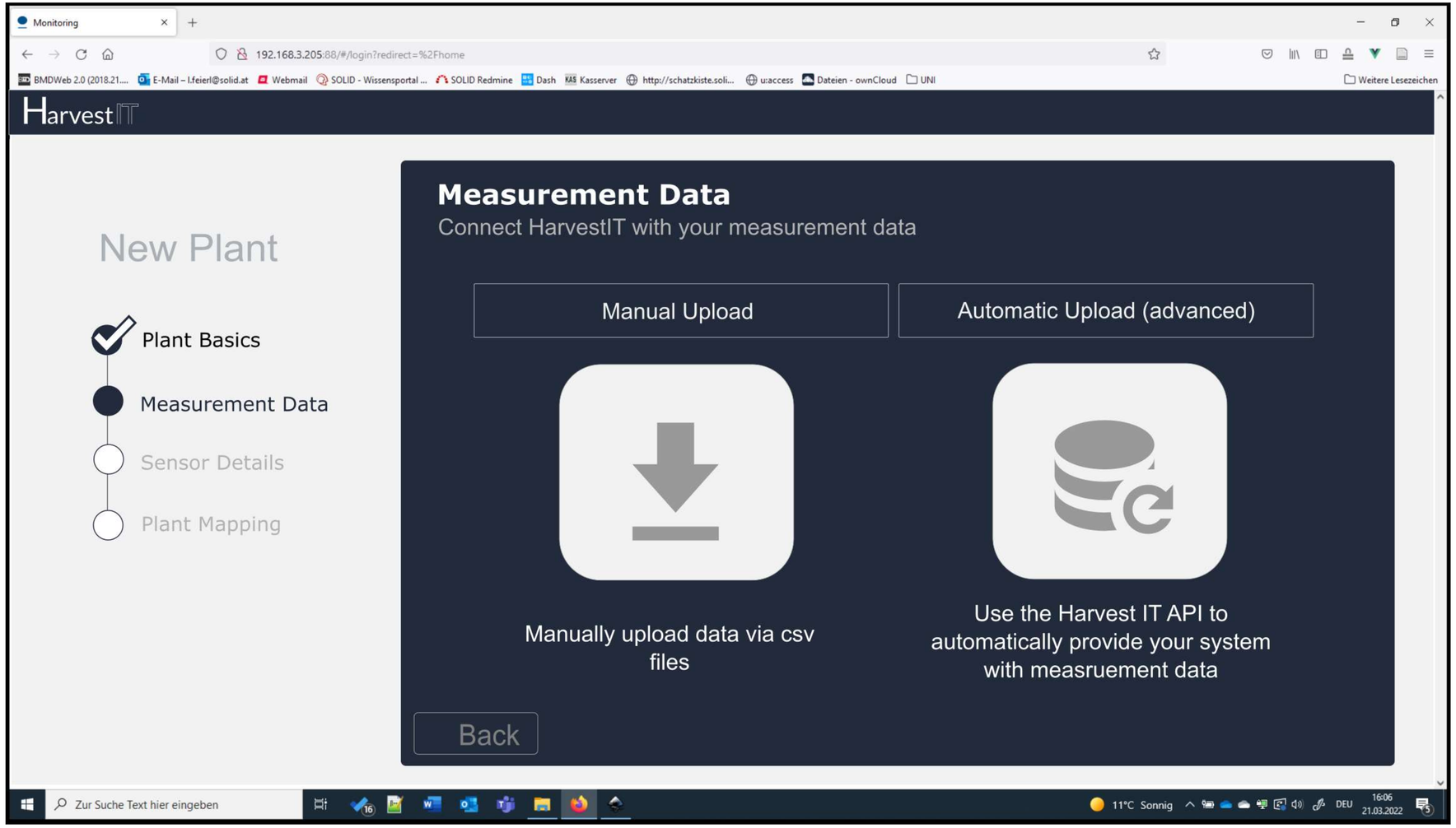
Web Front-End

Plant Basics



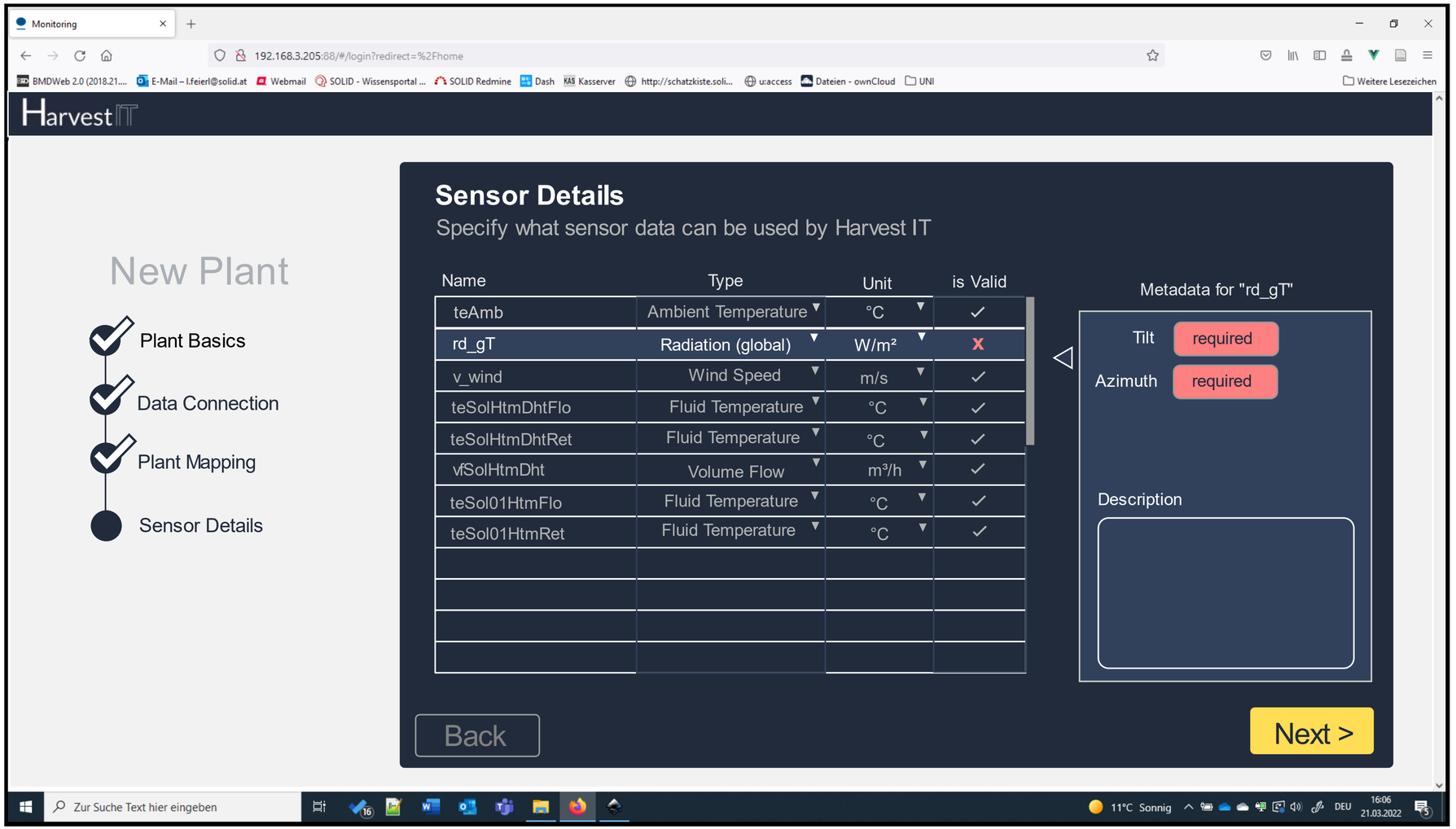
Web Front-End

Measurement Data



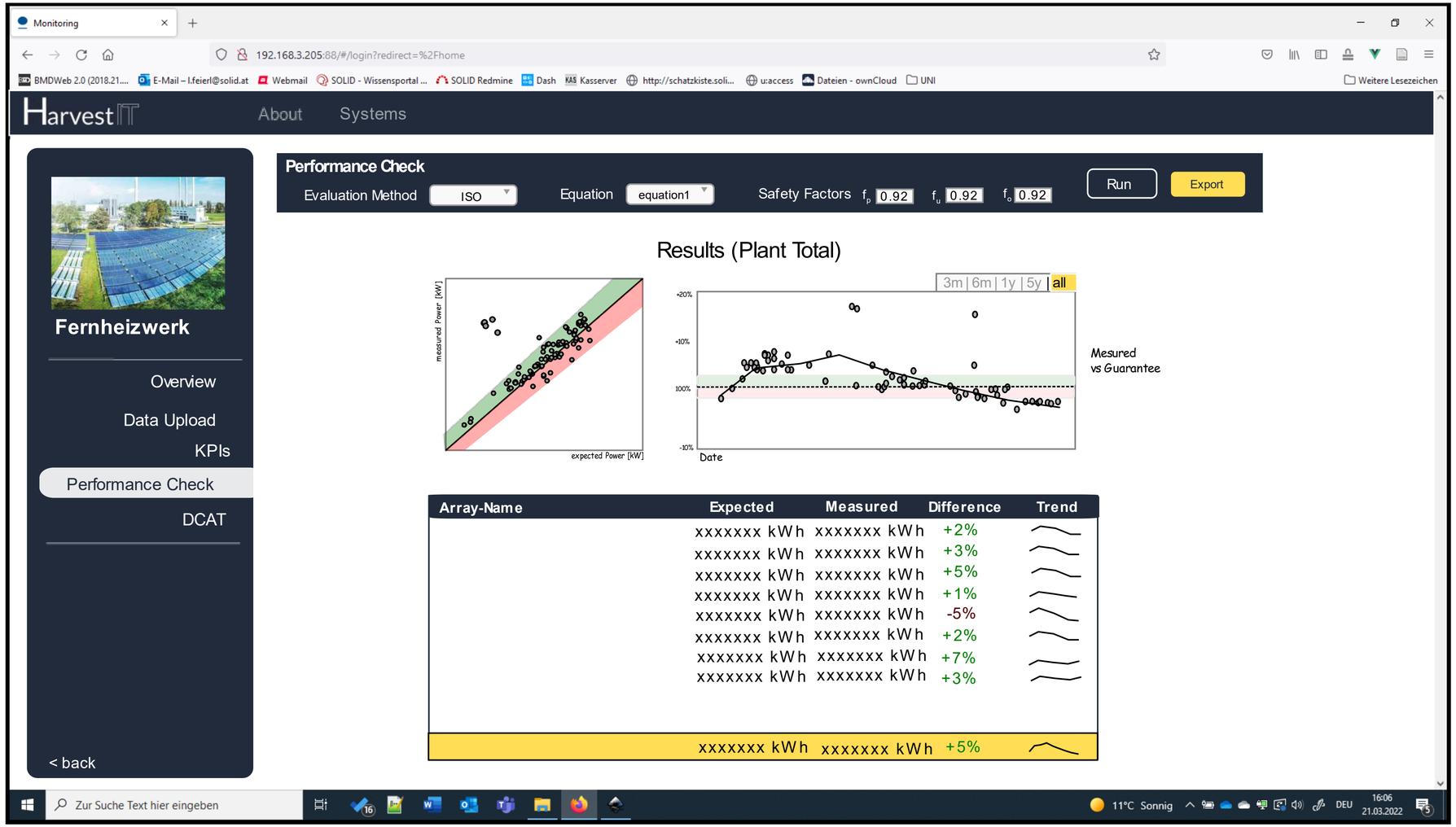
Web Front-End

Sensor Details



Web Front-End

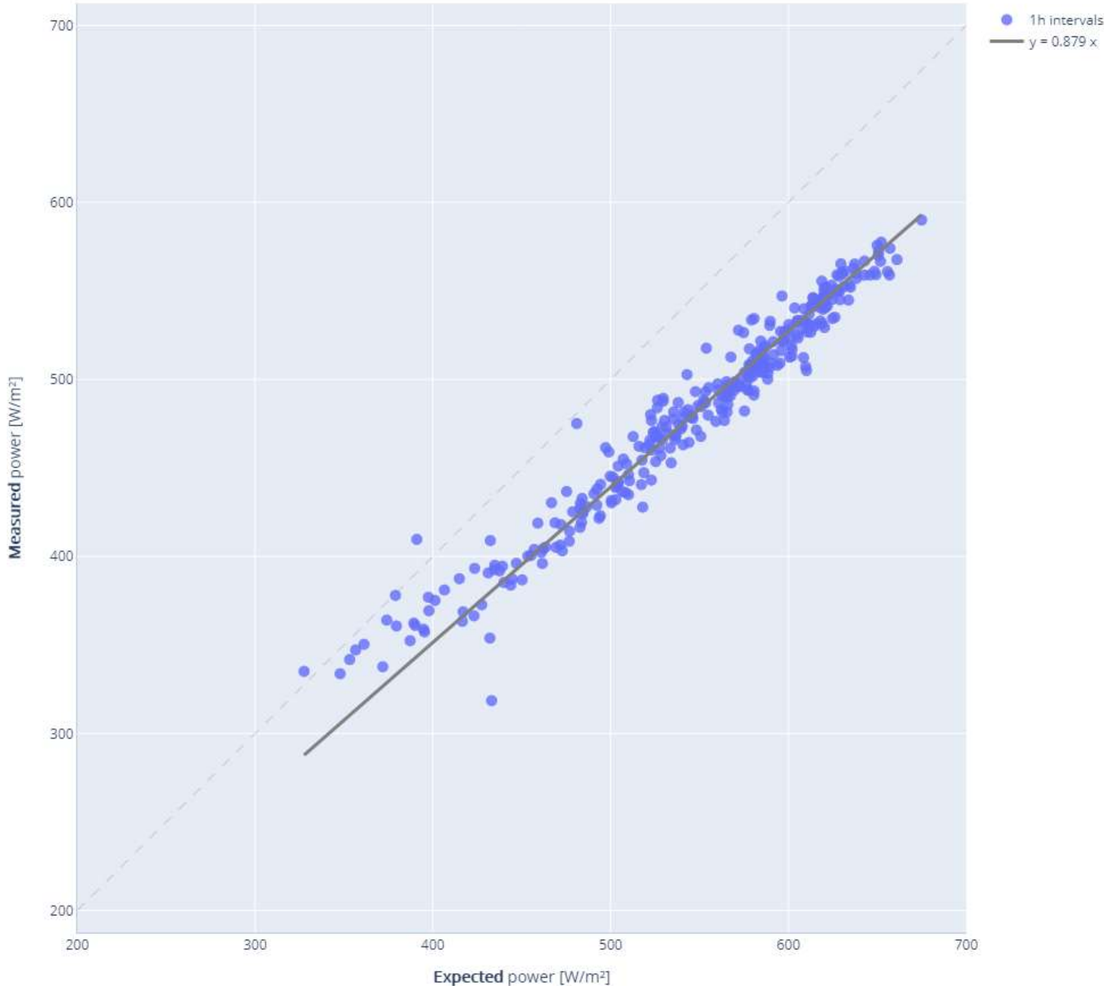
Results



Performance Check Methode

Grafischer Output, Beispiel

Performance Check (PC Method 'ISO DIS 24194', equation 2) for plant **collField_ArcS**,
data 2017-03-01 to 2017-10-31, n=328



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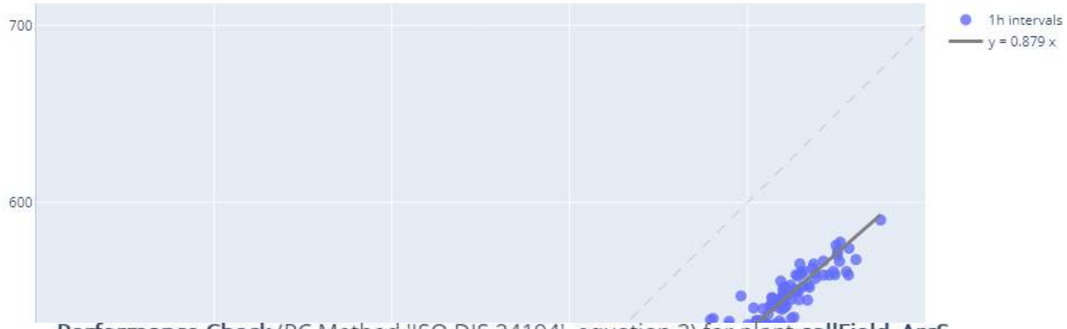

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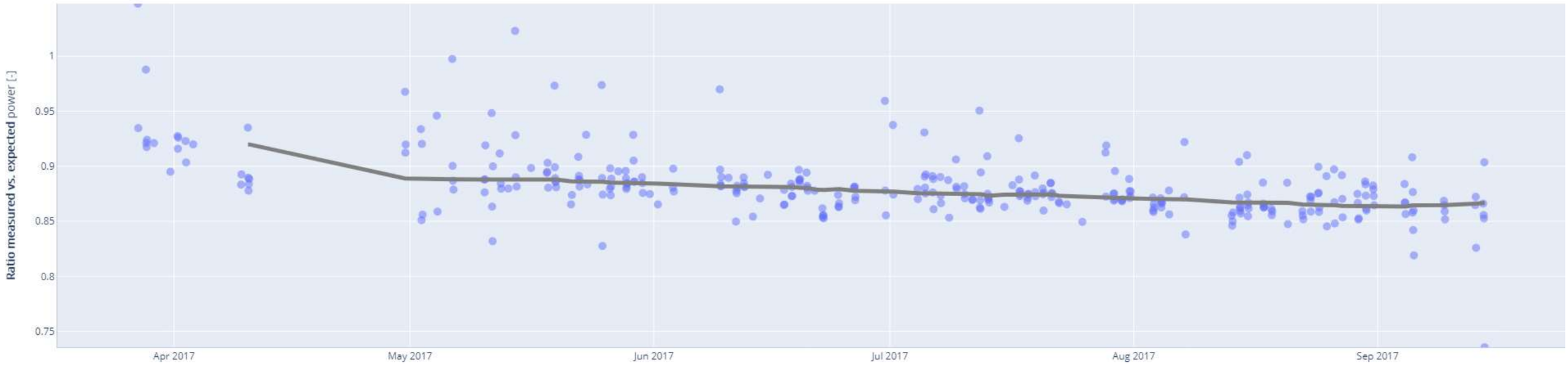

Open Source License

- All partners committed to releasing HarvestIT under an OSI approved license.
- Most likely the permissive **“3-Clause BSD”** → enables **commercial use.**
- **No need to share / upload data to the “cloud”.** Open Source <> Open Data.

Note: This license has also been called the "New BSD License" or "Modified BSD License". See also the 2-clause BSD License.

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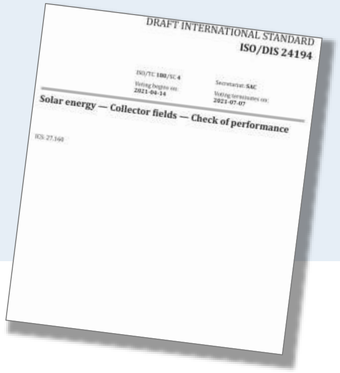
Performance Check Methode


DRAFT INTERNATIONAL STANDARD
ISO/DIS 24194
Solar energy — Collector fields — Check of performance

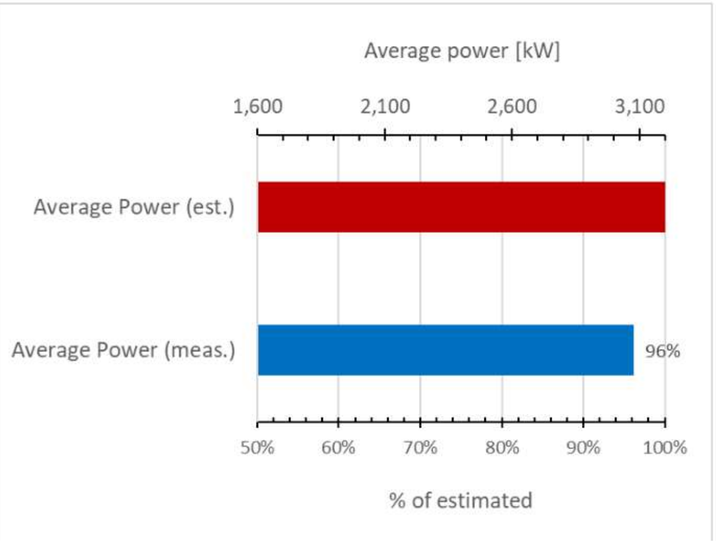
- Soll-Ist-Vergleich für stationäre Zustände
- Neue ISO Norm für Kollektorfelder:
  ISO/DIS 24194 Solar energy — Collector fields — Check of performance
- Aktueller Status: 60.60 = International Standard Published

DRAFT INTERNATIONAL STANDARD
ISO/DIS 24194

ISO/TC **180**/SC **4** | Secretariat: **SAC**

Voting begins on: **2021-04-14** | Voting terminates on: **2021-07-07**

Solar energy — Collector fields — Check of performance



Performance Check Methode

Stationäre Zustände

Stationäre Zustände

- nur in diesen Zuständen gilt die Gleichung
- 1h Mittelwerte der Messwerte als Input

Operation condition	Limits			Comments
	Eq.1	Eq.2	Eq.3	
Shadows	No shadows			See section 5.4
Incidence angle	≤ 30°	-		See section 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 - 3 m above highest point of collectors
G_{hem}	≥ 800 W/m²	-	-	
G_b		≥ 600 W/m²	≥ 600 W/m²	

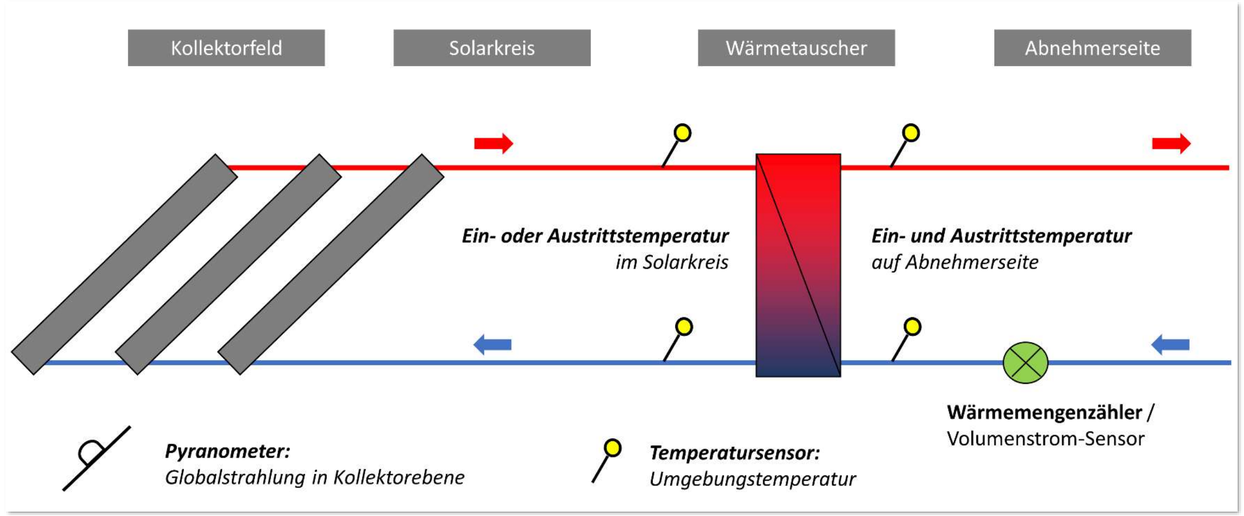
Table 1. Restrictions on operation conditions (power method). Measured and calculated power shall only be compared for data fulfilling restrictions above.

Quelle: ISO/DIS 24194:2021(E)

Performance Check Methode

ISO Norm 24194: **ein** Kollektorfeld, gleiche Kollektoren, gleiche Aufständerung

$$\dot{Q}_{est} = n_{col} \cdot A_{G,col} \cdot \left[\eta_{0,hem}\, G \; - a_1(\overline{T} - T_a) \; - a_2(\overline{T} - T_a)^2 \; - a_5 \frac{d\overline{T}}{dt} \right] \cdot f_{\text{safe}}$$



Anwendungsvoraussetzungen

1. Kollektorparameter
   - Solar Keymark / ISO 9806
2. Berechnung Soll-Leistung (Gl. 1)
3. Messung Leistung
   - G Gesamtstrahlung Kollektorebene
   - $\bar{T}$ Vor- und Rücklauftemperaturen
   - T_a Außentempertur

Performance Check Methode

Weiterentwicklung HarvestIT: **mehrere** Kollektorfelder

Anwendung auf mehrere Teilfelder

- unterschiedliche Kollektoren
- unterschiedliche Ausrichtung und Aufständerung
- in der Regel Strahlungsmessung nur für 1 Teilfeld

Anwendungsvoraussetzungen

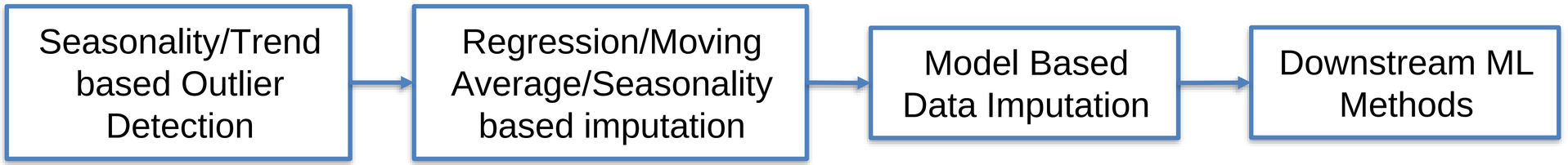
1. Kollektorparameter → pro Kollektortyp
2. Berechnung Soll-Leistung (Gl. 1)
   - G Gesamtstrahlung Kollektorebene
     → pro Teilfeld → Algorithmus für Strahlungsumrechnung
   - $\bar{T}$ Vor- und Rücklauftemperaturen → pro Teilfeld
   - T_a Außentemperatur → 1x pro Anlage
   - Wind → optional
3. Messung Leistung

   → gesamt pro Anlage (optional auch pro Teilfeld)

   → Stoffwerte (Datenblatt, CoolProp)

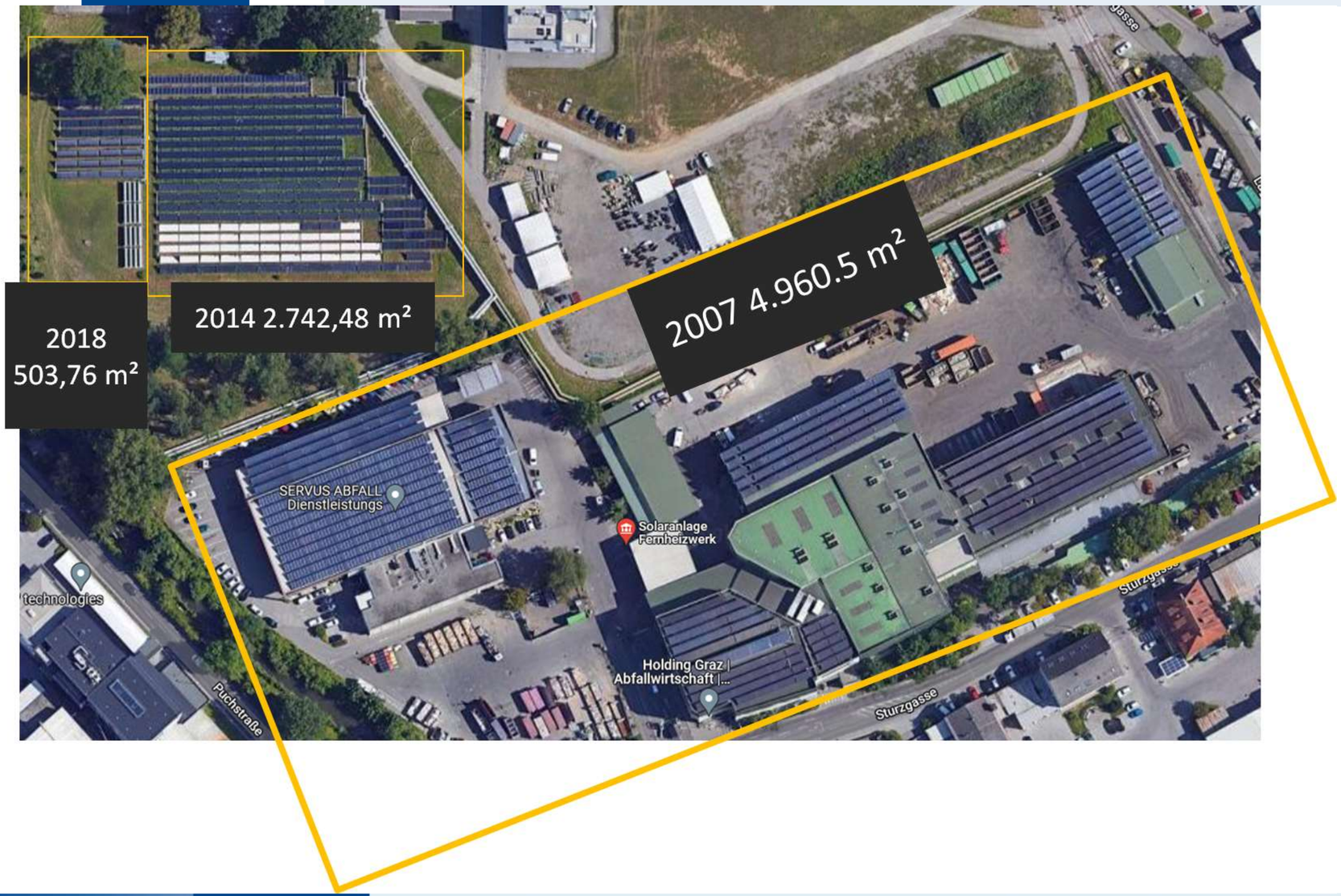
EnableDigitalDH

- Bad data is a major barrier to ML applications in energy sector.
- Statistical / ML based outlier detection and imputation pipeline
  - Based on seasonality, trend detection and imputation.
  - Not possible to fully automate, good results with some manual input.
- Further imputation of longer missing periods using physical component models.
  - Only works with specific types of missing data, hard to apply to arbitrary data.
- Sample implementation code to be released later in 2022.



HarvestIT Testanlagen

Fernheizwerk Graz



Bruttofläche: 8.206 m² / 5,7 MWp
Bauzeit 2007 - 2018

Solare Fernwärme
7 verschiedene Kollektorhersteller
Unterschiedliche Technologien.

HarvestIT Testanlagen

Nahwärme St. Ruprecht a.d. Raab

Bruttofläche: 1.590 m² / 1,1 MWp

117 Stk. Großflächenkollektoren á 13,6 m²
13 Reihen mit je 9 Kollektoren
Gesamtes Kollektorfeld: ca. 60m x 60m
Pufferspeicher: 100 m³

HarvestIT Testanlagen

AVL Graz

Bruttofläche: 3.463 m² / 2,4 MWp
Solarthermische Prozesswärme & Kälte

Spezif. Solarertrag: 358 kWh/m²
Absorptionskältemaschine: 650 kW
Speicher: 70 m³ (auch Lastmanagement)
CO_2 Einsparung: 320 Tonnen pro Jahr

HarvestIT Testanlagen

Desert Mountain High School

Bruttofläche: 4.935 m² / 3,5 MWp
Solare Kühlung

Spezif. Solarertrag: 757 kWh/m²
Ökotech und Arcon Sunmark Kollektoren
Kühlung JAZ: 0,57
Absorptionskältemaschine: 1.750 kW
Kühlturm: 4.250 kW
Speicher: 34,5 m³

HarvestIT Testanlagen

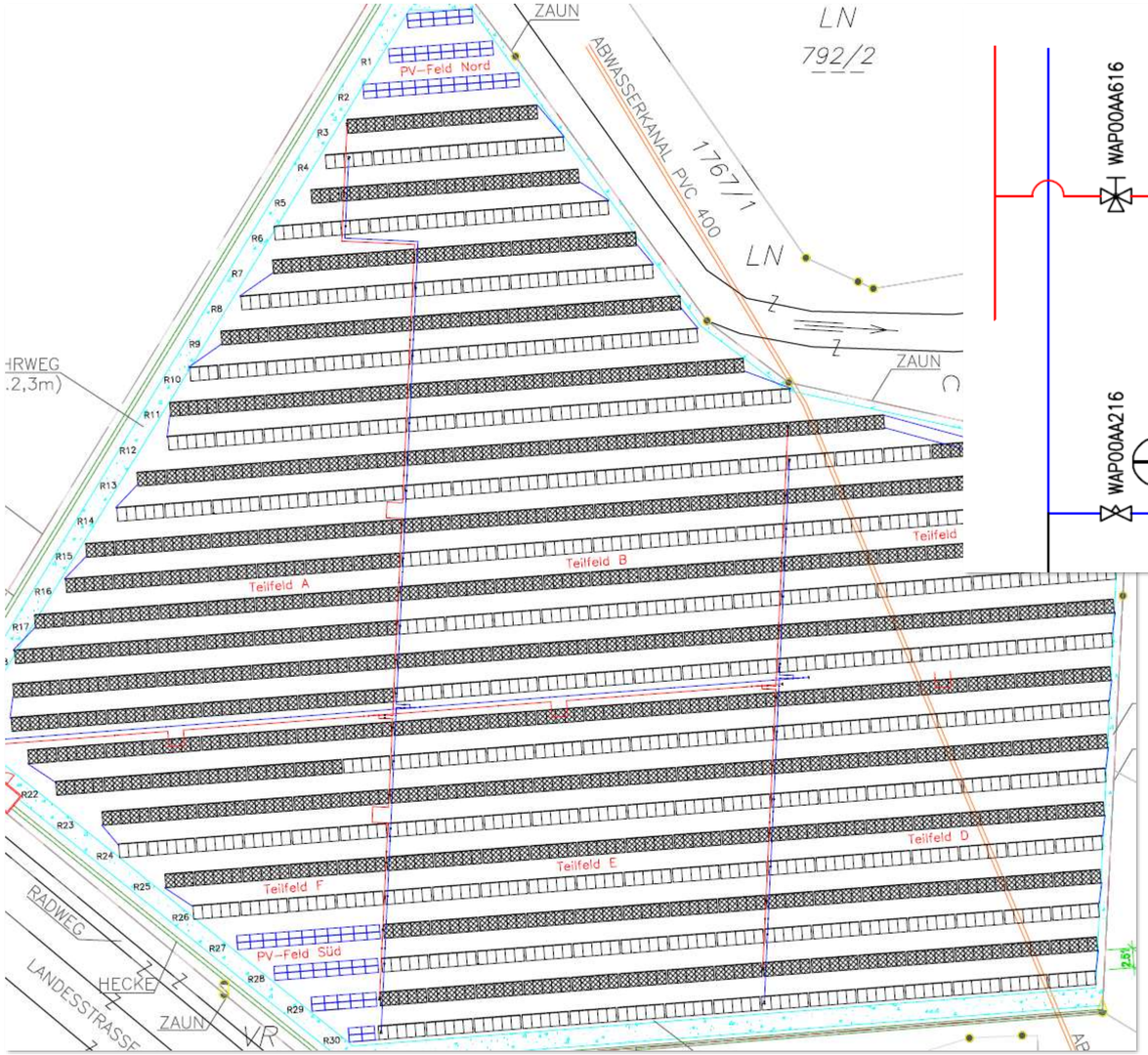
Nahwärme Friesach

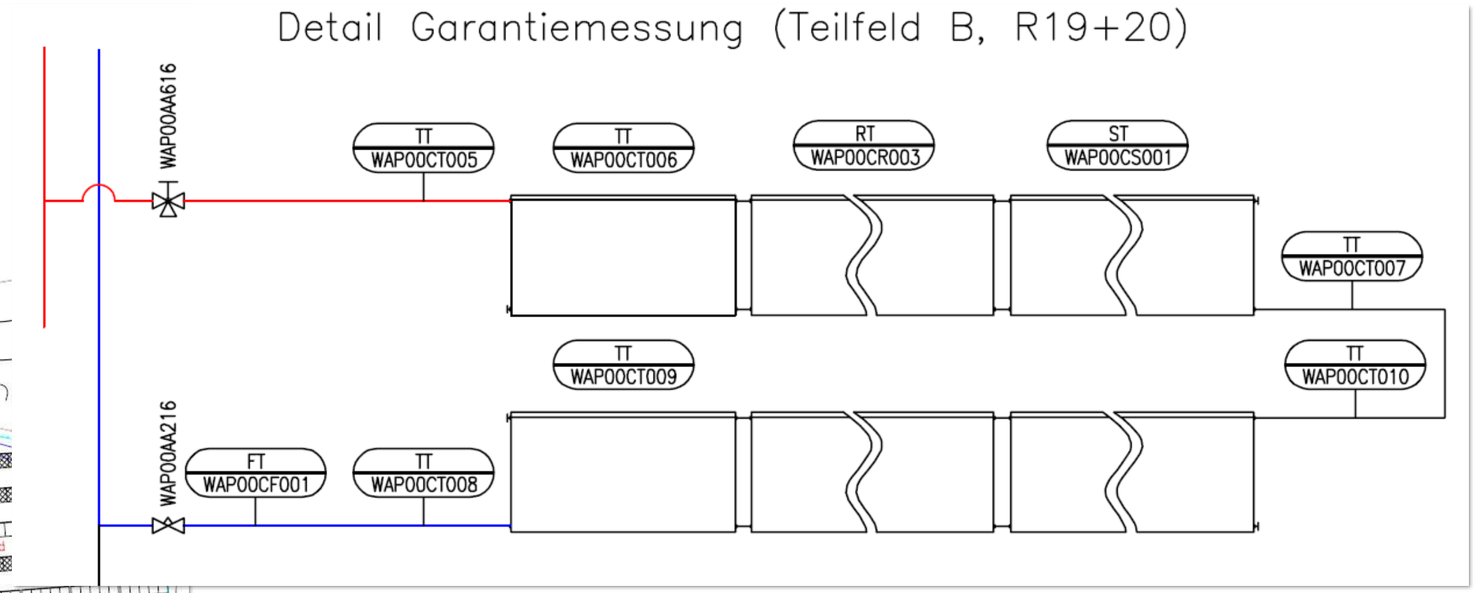
Bruttofläche: 5.750 m² / 4 MWp
Pufferspeicher: 1.000 m³

Inbetriebnahme: 2021, Betreiber: KPV
GreenOneTec Großflächenkollektoren
GK3133S / GK3133D

HarvestIT Testanlagen

Nahwärme Friesach





Agenda

1	*Kontext*	**Markt & Chancen**
2	*Monitoring*	**Status Quo & interaktiver Teil**
3	*HarvestIT*	**Garantieverfahren & Software**
4	*Ausblick*	**D-CAT**

D-CAT
Dynamic Collector Array Test

Einzelkollektoren

- **Normtest ISO 9806** / QDT / Solar Keymark Datenblatt
- Laborsetting

Kollektorfeld

Kollektoren	Kennlinie, Verschmutzung, Wärmedämmung
Anlage	Design, Hydraulik Abstände, Aufständerung, Verschattung
Betrieb	Betrieb, Regelstrategie, Volumenströme
Externe Einflüsse	Wetter; Abnahme Temperaturen, Volumenstrom
Messung	Wind- & Strahlung repräsentativ? Messunsicherheit?

Kein standardisiertes Testverfahren.

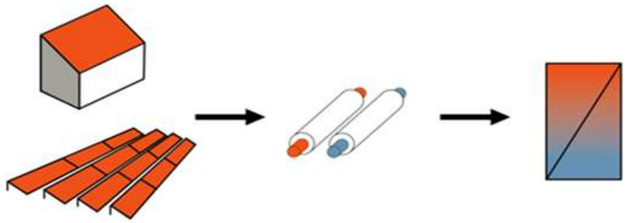
Anforderungen D-CAT:

1) In-situ = Kollektorfeld unter realen Betriebsbedingungen
2) Kein Eingriff in den laufenden Anlagenbetrieb!
3) Automatisierung: Betriebsdaten → Parameter ~Solar Keymark

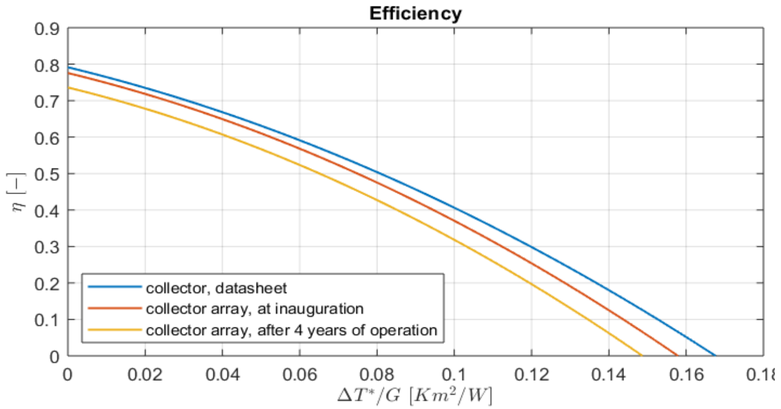
D-CAT

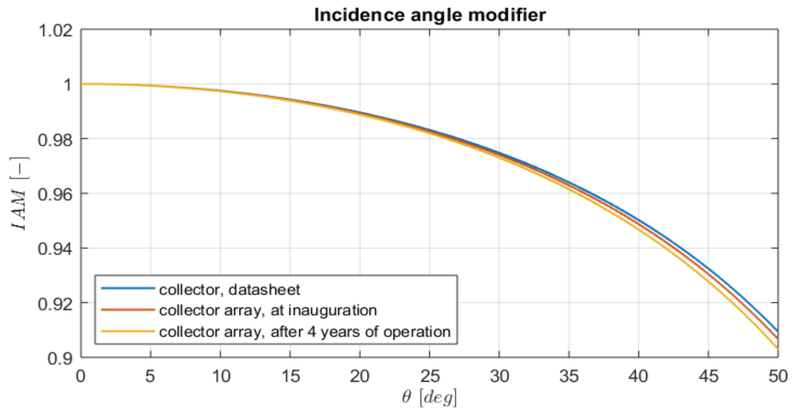
Vision beispielhafte Resultate

Performance parameters related to aperture area		η0	a1	a2						
Units		-	W/(m²K)	W/(m²K²)						
Test results - Flow rate and fluid see note 1		0.769	2.67	0.009						
Bi-directional incidence angle modifiers?	No	*Kϑ values are obligatory for 50°.*								
Incidence angle modifiers Kθ(θ)	Angle	10°	20°	30°	40°	50°	60°	70°	80°	90°
	Kθ(θ)	1.00	0.99	0.98	0.95	0.91	0.84	0.69	0.24	0.00
Incidence angle modifier not bi-directional - leave fields blank										



Yield datasheet	Yield in-situ
431 kWh/m²$_{Agr}$	417 kWh/m²$_{Agr}$ (-3.2%)





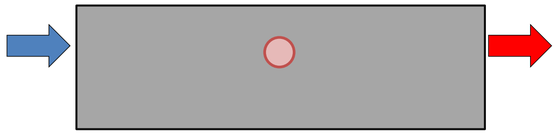
D-CAT

1) Bewertung **Energie-Ertrag**
2) Vorhersage Energiepreis / **LCOE**
3) Predictive / on-demand **Maintenance** z.B. Reinigung

Kollektorfeldmodelle

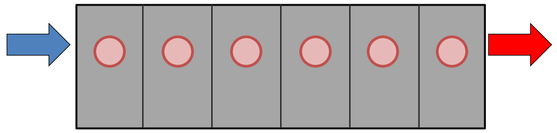
Erweiterungen für D-CAT

A) Single collector model
ISO 9806 (QDT)



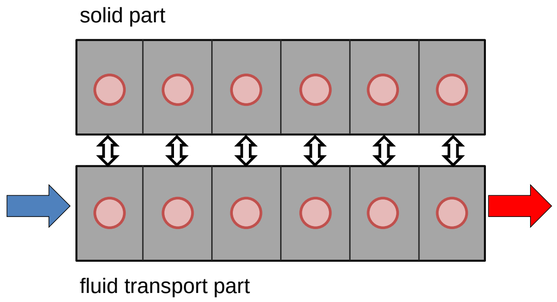
only **1** temperature $T_{m:}$ $T_m = (T_{in} + T_{out}) / 2$
- Assumes 0 travel time, instantaneous power

B) MeQuSo 1N model



N temperatures, 1 for each compartment
- Takes travel time into account
- Simplest extension of classic QDT to collector arrays

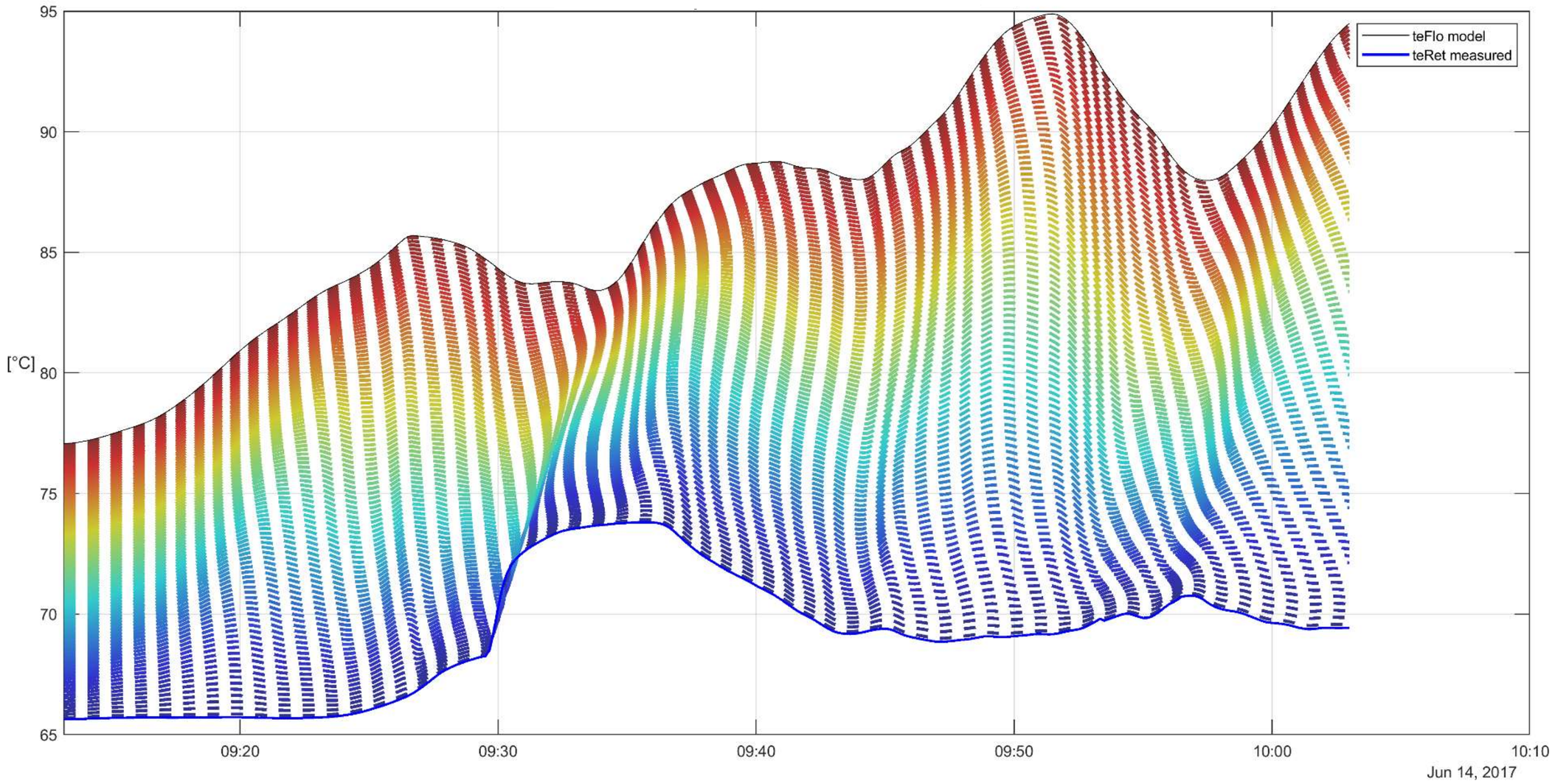
C) MeQuSo 2N model



2N temperatures
- 1 for each solid compartment (radiation, heat loss)
- 1 for each fluid compartment
- Realistic modeling of collector array temperatures

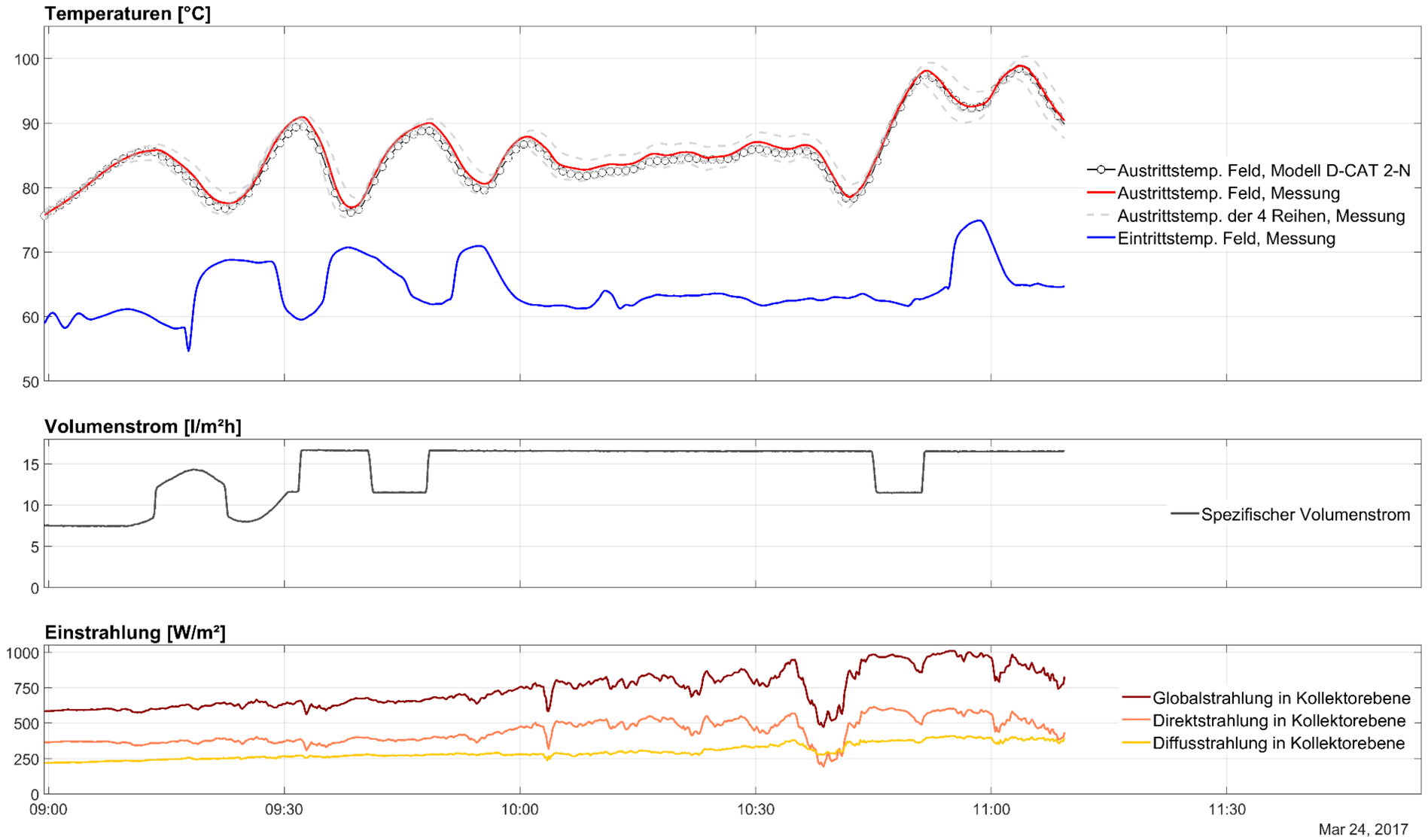
D-CAT Kollektortemperaturen

in Strömungsrichtung für mehrere Segmente



D-CAT

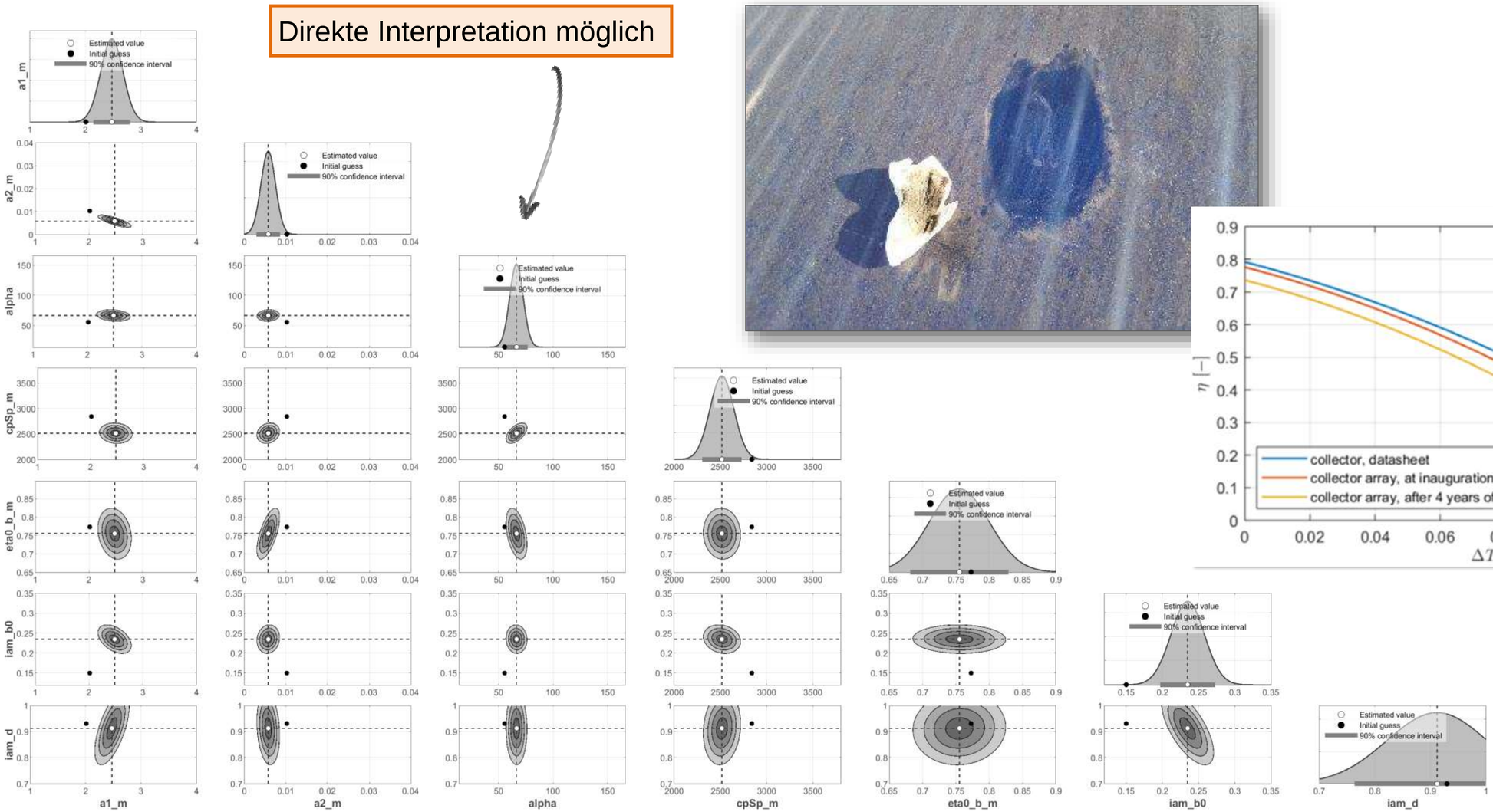
Vergleich mit Messdaten

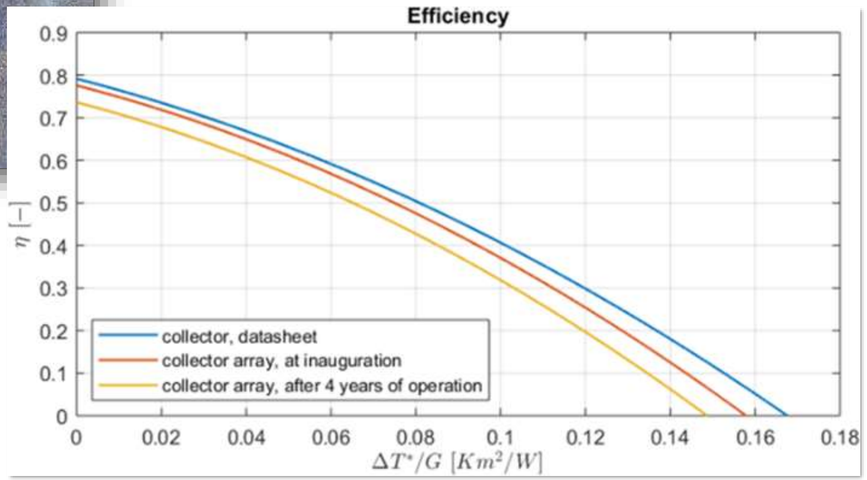


D-CAT

Parameter + Unsicherheiten

Direkte Interpretation möglich





D-CAT

Exemplarische Ergebnisse

Parameter	***Info***	*Solar Keymark*		*Umrechnung Modell 1-N → 2-N*	*Parameter*	***Ergebnis aus FHW-Daten***	
		Bezug: Apertur	*Umrechnung Bezug: Brutto*	*Rahmenbedingungen: bei dT=55 K, rdE=500 W*			
a1	Umrechnung Datenblatt	2.2261	2.0670	2.0120	a1	2.4768	
a2	Umrechnung Datenblatt	0.0097	0.0090	0.0102	a2	0.0058	
	Berechnung bei Rahmenbedingungen			2.573	a_eff	2.796	**+8.7%**
eta0	Umrechnung Datenblatt	0.8024	0.7450	0.7729	eta0	0.7550	**-2.3%**
iam_b0	ohne Umrechnung	0.1501		0.1501	iam_b0	0.2348	**30°: -1.3%** **45°: -3.7%** **60°: -10.0%**
iam_d	ohne Umrechnung	0.93		0.93	iam_d	0.9120	**-1.9%**
cp	Umrechnung Datenblatt & Schätzung	7876	7313	2838	cp_m	2516	
F‘	Schätzung	0.95		55.5	alpha	66.5	

Parameterumrechnung: Umrechnung der Parameter von Datenblatt / Solar Keymark 1-N → 2-N unter folgenden Rahmenbedingungen:

- Typical temperature difference absorber – ambient: dT = 55 K
- Effective radiation: rdE = 500 W/m²
- Volumenstrom = 16 lit/m²h

ACR Innovationspreis 2021

für D-CAT an SOLID + AEE INTEC

Related publications

IEA Fact Sheet	Tschopp, D. et al. (2021) Application of Performance Check (PC) Method to Large Collector Arrays. IEA SHC FACT SHEET 55 B-D1.1. IEA SHC.	Download
IEA Fact Sheet	Nielsen J. E., “Guarantee of annual output. IEA-SHC TECH SHEET 45.A.3.2”, 2014. Available online: http://task45.iea-shc.org/fact-sheets	Download
Project Final Report	Ohnewein, P. et al. (2020) Dynamic Collector Array Test (D-CAT). Final Report FFG Project 848766 - MeQuSo. Development of methods for quality assessment of large-scale solar thermal plants under real operating conditions. Gleisdorf: AEE INTEC.	Download
Journal paper	Tschopp, D. et al. (2022) ‘Measurement and modeling of diffuse irradiance masking on tilted planes for solar engineering applications’, Solar Energy, 231, pp. 365–378. http://doi.org/10.1016/j.solener.2021.10.083.	Download
Journal Review Paper	Tschopp, D. et al. (2020) ‘Large-scale solar thermal systems in leading countries: A review and comparative study of Denmark, China, Germany and Austria’, Applied Energy, 270, p. 114997. doi:doi.org/10.1016/j.apenergy.2020.1149970.	Download

Projekt HarvestIT

FFG Fast Track Digital, 1. Ausschreibung: Projekt 887648 „Advanced monitoring of large-scale solar thermal plants with open source software solution“.

Dieses Projekt wird aus Mitteln des Klima- und Energiefonds gefördert.

Der DIH Süd wird gefördert und unterstützt von FFG, Land Steiermark und Land Kärnten.

HarvestIT

https://www.collector-array-test.org

AEE INTEC

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