HarvestIT

Software für Performance-Nachweise für Solare Großanlagen

Philip Ohnewein & Projektteam

F&E 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.

2022

AEE - Institut für Nachhaltige Technologien wurde 1988 als außeruniversitäre Forschungs-einrichtung gegründet und ist heute eines der führenden Institute im Bereich erneuerbarer Energie und Ressourceneffizienz.

1988

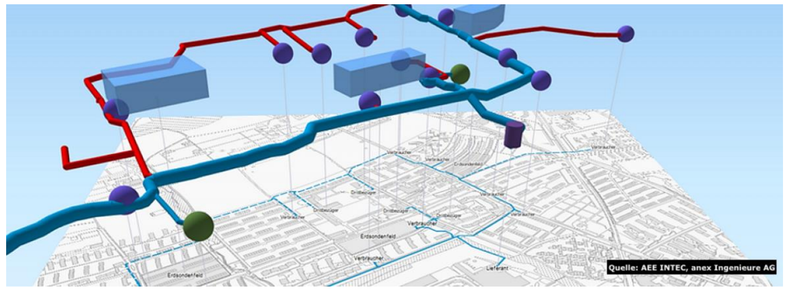
Solare Großanlagen bei AEE INTEC

Ausgewählte Aktivitäten

Forschungsnetzwerke, Publikationen
Solar Heat Worldwide
Markstatistik Österreich
Internationale Kooperationen

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

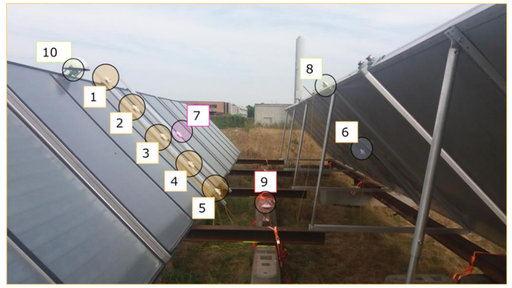
Systemintegration
Solarthermie in Wärmenetzen, Kombination mit Großwärmespeicher, Industrielle Anwendungen

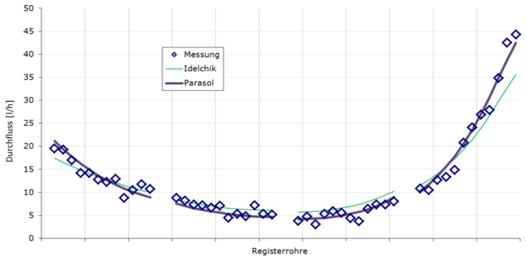


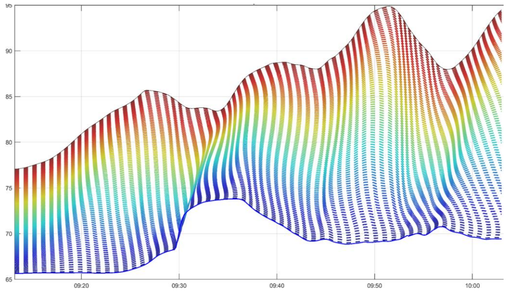
Wissenschaftliche Fragestellungen
Strahlungsmodellierung

Strömungs- und Temperaturverteilung

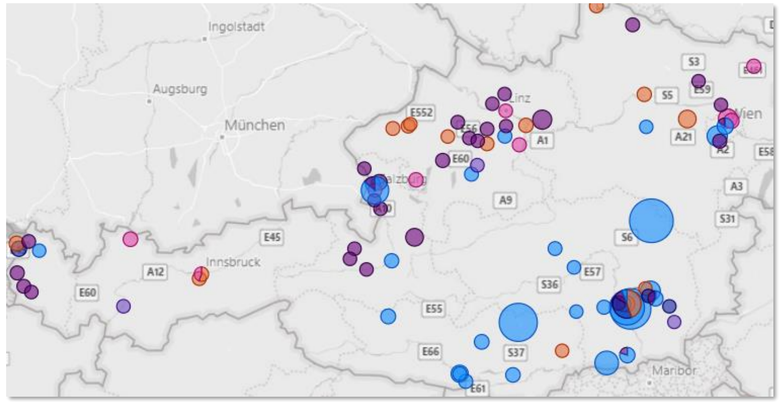
In-situ Testverfahren, Monitoring







Begleitforschung
zum KLIEN-Förderprogramm „Solare Großanlagen“

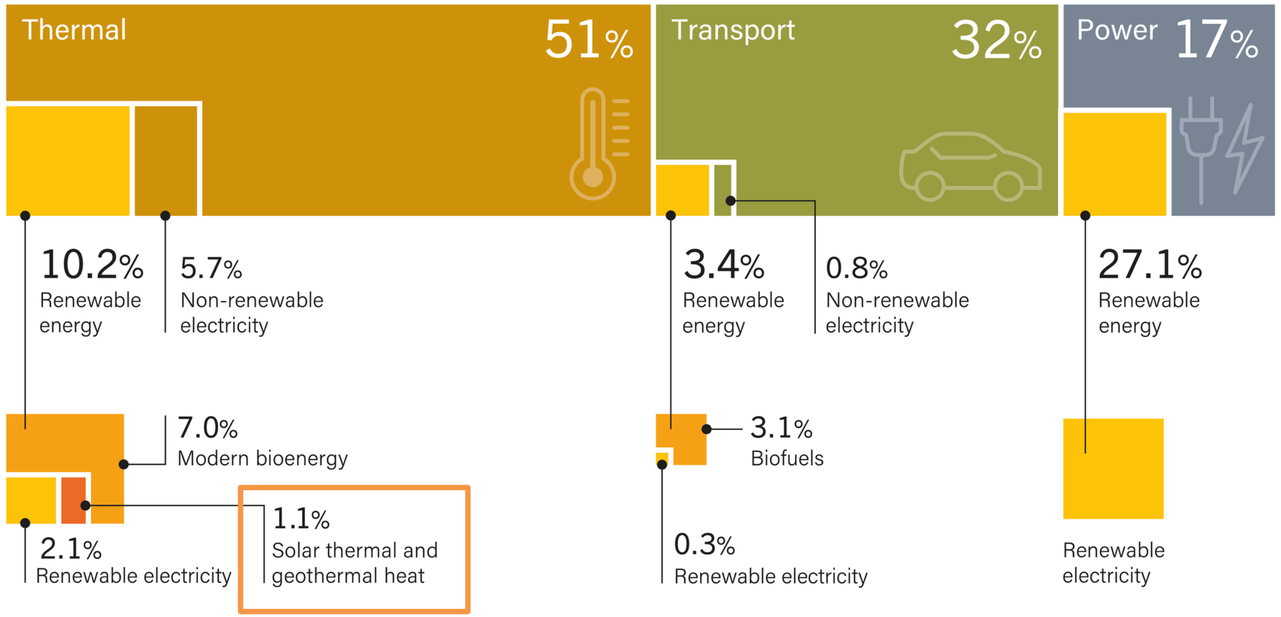


Agenda

1	*Kontext*	**Große Solarthermie: Markt & Chancen**
2	*Monitoring*	**Herausforderungen & Lösungen**
3	*HarvestIT*	**Software für Performance-Nachweise**
4	*Ausblick*	**D-CAT**
5	*We want you!*	**Einladung zur Zusammenarbeit**

Energie & Erneuerbare

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



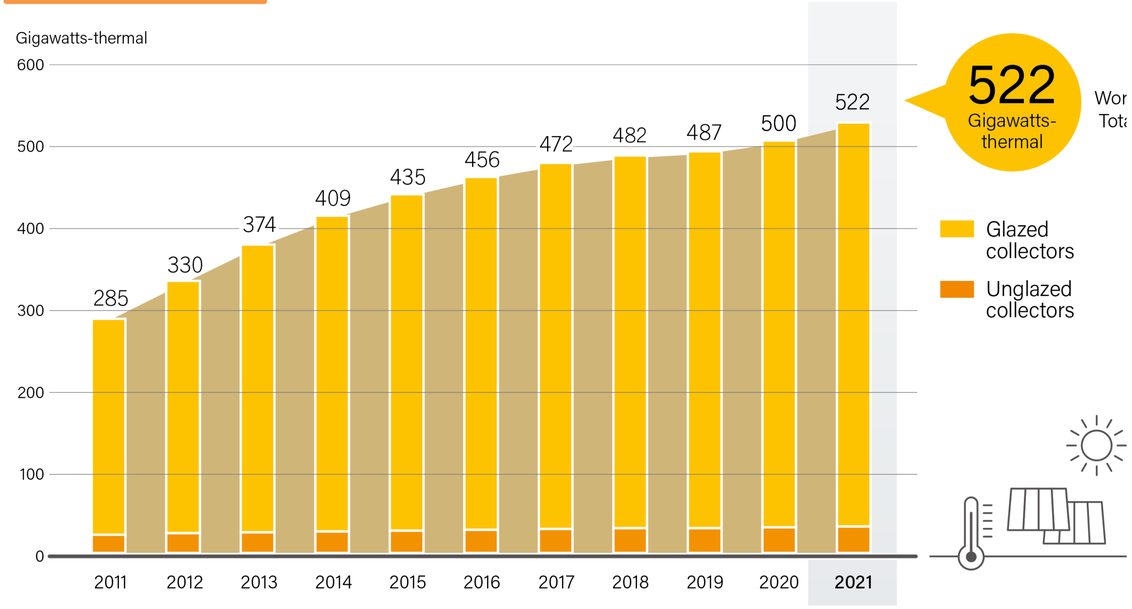
Note: Data should not be compared with previous years because of revisions due to improved or adjusted methodology.

Source: Based on IEA data.

REN21 RENEWABLES 2021 GLOBAL STATUS REPORT

Solarthermie & Photovoltaik

Solar Water Heating Collectors Global Capacity, 2011-2021

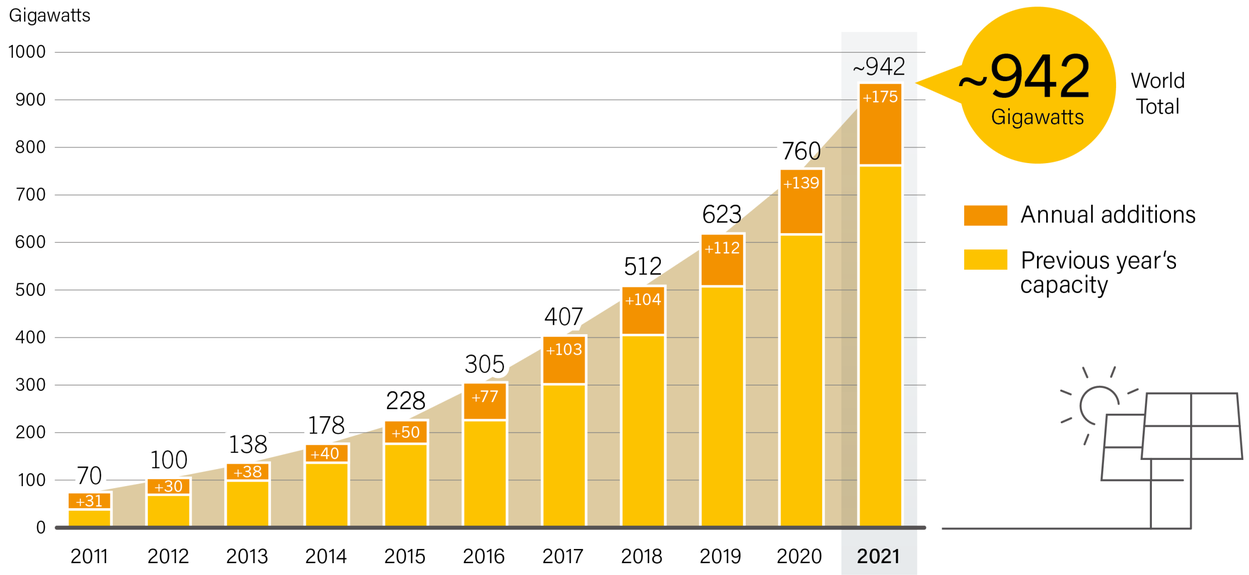


Source: Based on IEA SHC.

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

Solarthermie Markt

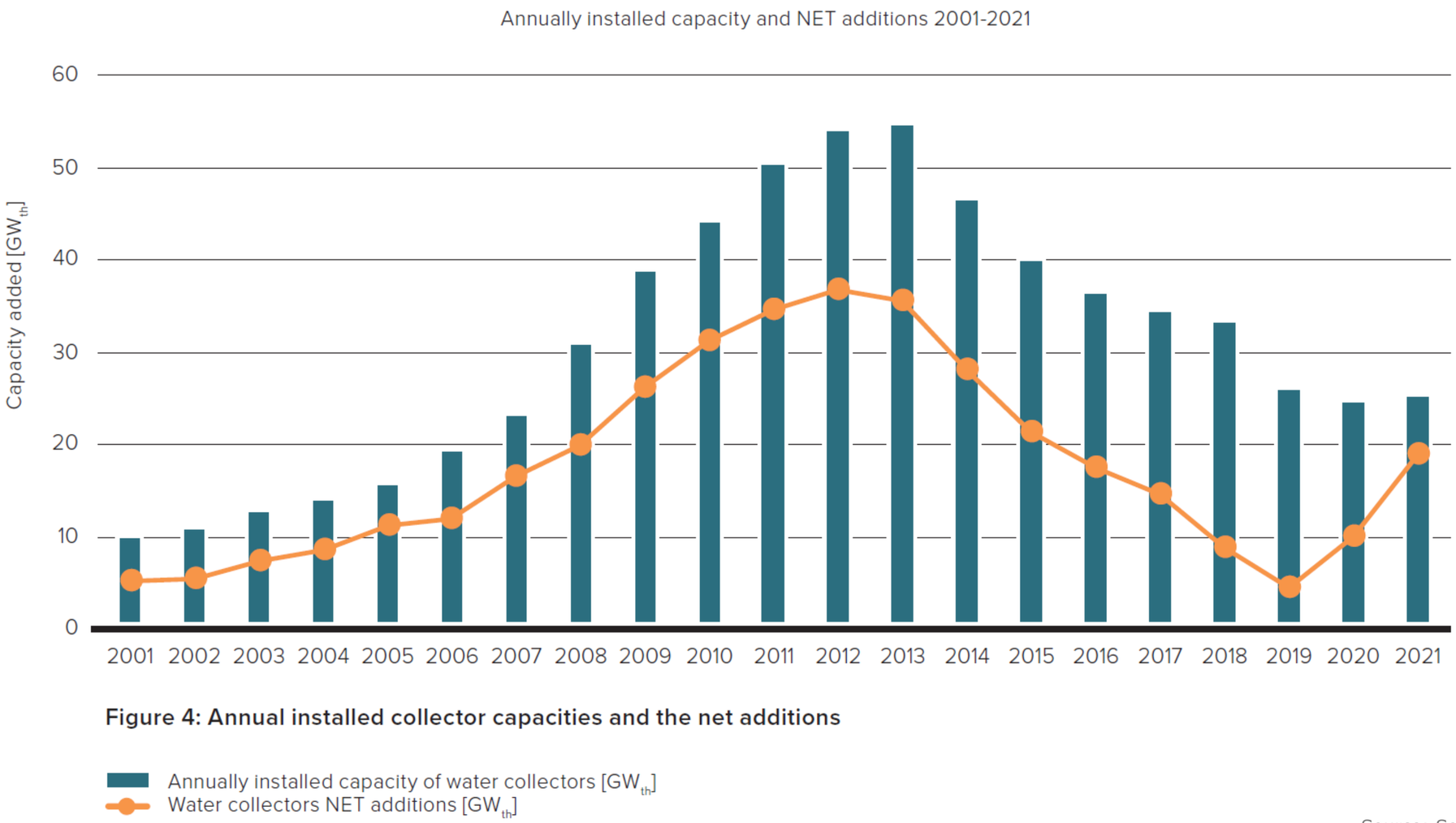


Figure 4: Annual installed collector capacities and the net additions

Source: Solar Heat Worldwide 2022

Solare Großanlagen

LST: Large Solar Thermal

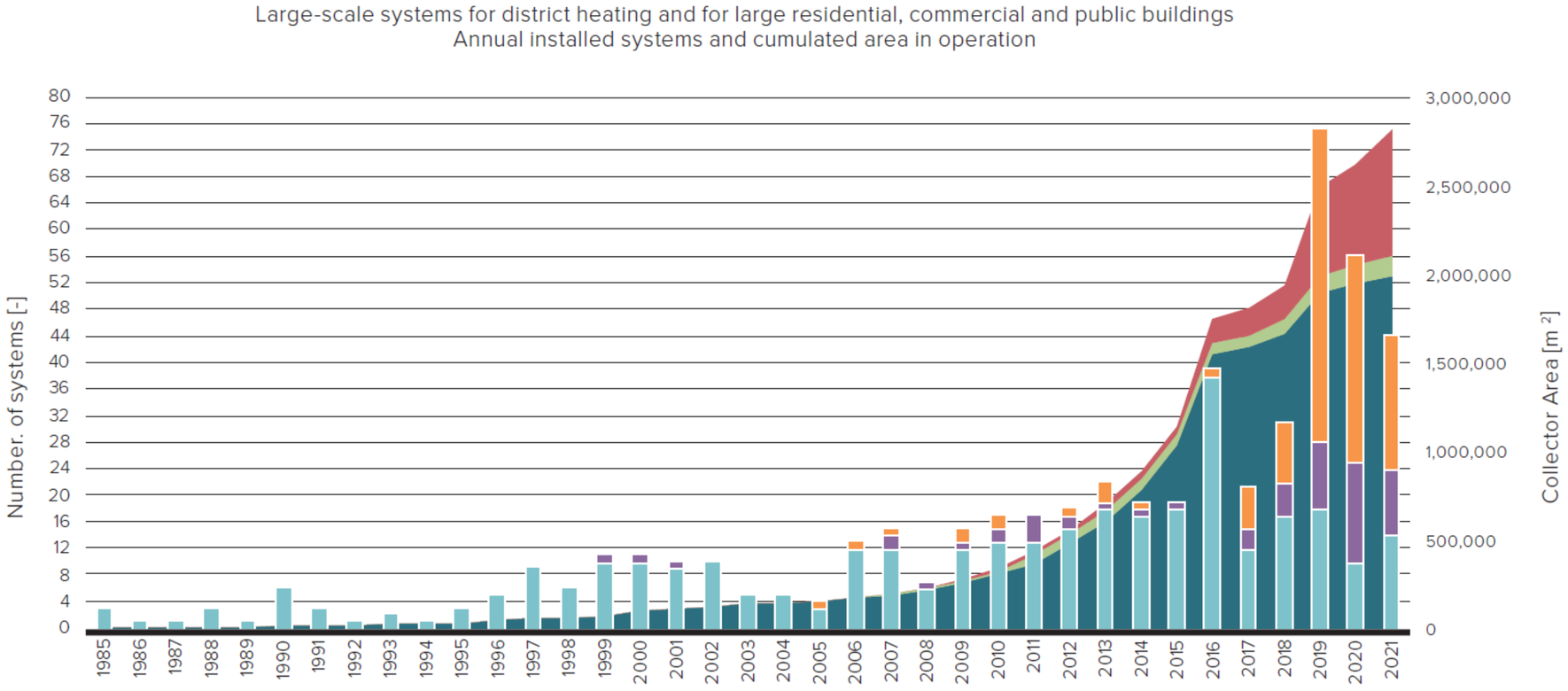


Figure 8: Large-scale systems for solar district heating and large residential, commercial and public buildings worldwide – annual achievements and cumulated area in operation in 2021

(Data sources: Daniel Trier - PlanEnergi, DK, Jan-Olof Dalenbäck - Chalmers University of Technology, SE, Sabine Putz - IEA SHC Task 55, AT, Bärbel Epp - solrico.com/, DE, AEE INTEC, AT, Janusz Starościk – SPIUG, PL, Zheng Ruicheng, China Academy of Building Research, CHN).

- Cumulated collector area in operation in Europe [m²]
- Cumulated collector area in operation in China [m²]
- Number of systems installed in "Other countries" [m²]
- Cumulated collector area in operation "Other countries" [m²]
- Number of systems installed in Europe [-]
- Number of systems installed in China [-]

Source: Solar Heat Worldwide 2022

Potenzial Solarthermie

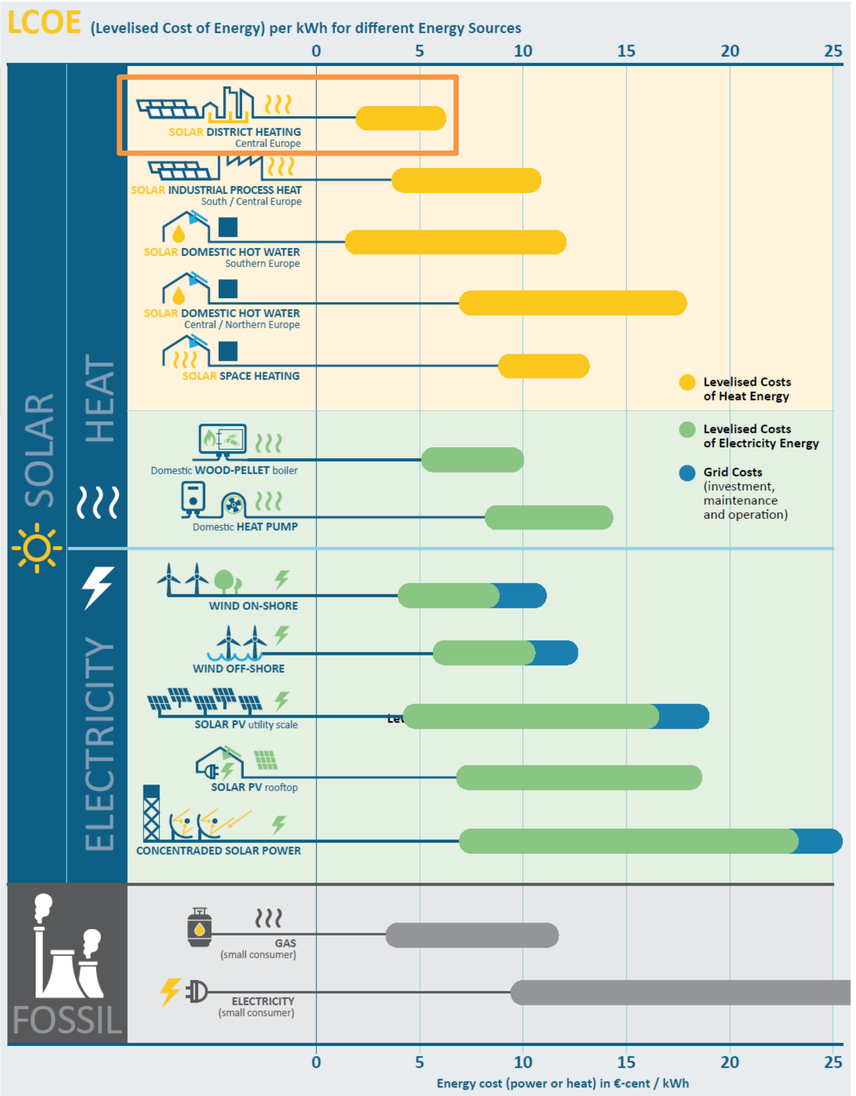
TABLE ES.1 A roadmap to 2050 – tracking progress of key energy system components to achieve the 1.5°C target

	Indicators	Recent years	2050 [22]	Off / On track
RENEWABLES	**ELECTRIFICATION WITH RENEWABLES**			
	Share of renewables in electricity generation	26 % [1]	90 %	
	Addition of renewable energy technologies	264 GW/yr [2]	836 GW/yr	
	Annual solar PV additions	126 GW/yr [3]	444 GW/yr	
	Annual wind energy additions	115 GW/yr [4]	248 GW/yr	
	Investment needs for RE generation	0.3 USD trillion/yr [5]	1 USD trillion/yr	
	DIRECT RENEWABLES IN END USES			
	Share of renewables in final energy consumption	16 % [6]	79 %	
	Solar thermal collector area	25 million m²/yr [7]	165 million m²/yr	
	Modern bioenergy consumption [23]	18 EJ [8]	58 EJ	
	Geothermal consumption	0.9 EJ [9]	4 EJ	
	District heat generation - buildings	0.4 EJ [10]	7.3 EJ	

Source: IRENA World Energy Transitions Outlook 2022

ESTIF
Solar Thermal Roadmap 2030

Solar Heat Europe
ESTIF



Source: ESTIF Solar Thermal Roadmap 2030, https://solariseheat.eu

Solare Großanlagen

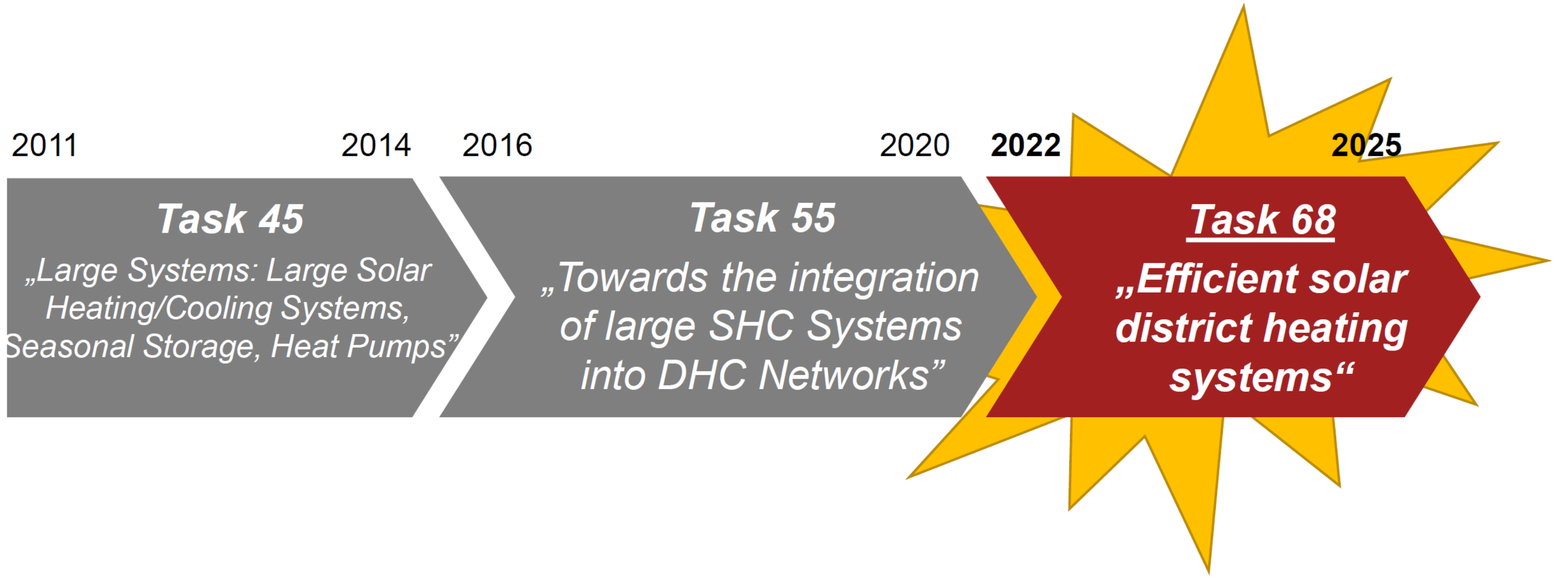
- Thermische Kraftwerke zur Bereitstellung von solarer Wärme.
- Anlagengröße >500 m^2 Kollektorfläche = 350 kW_{th}
- Wärmegestehungskosten ~30-60 €/MWh

Quelle: www.kuster.co.at

Quelle: www.solar-district-heating.eu

IEA SHC Tasks

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



Source: IEA SHC Task 68

F&E Projekt HarvestIT

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

- FFG – FastTrackDigital 1st Call
- Projektlaufzeit: 2021-11 bis 2023-10

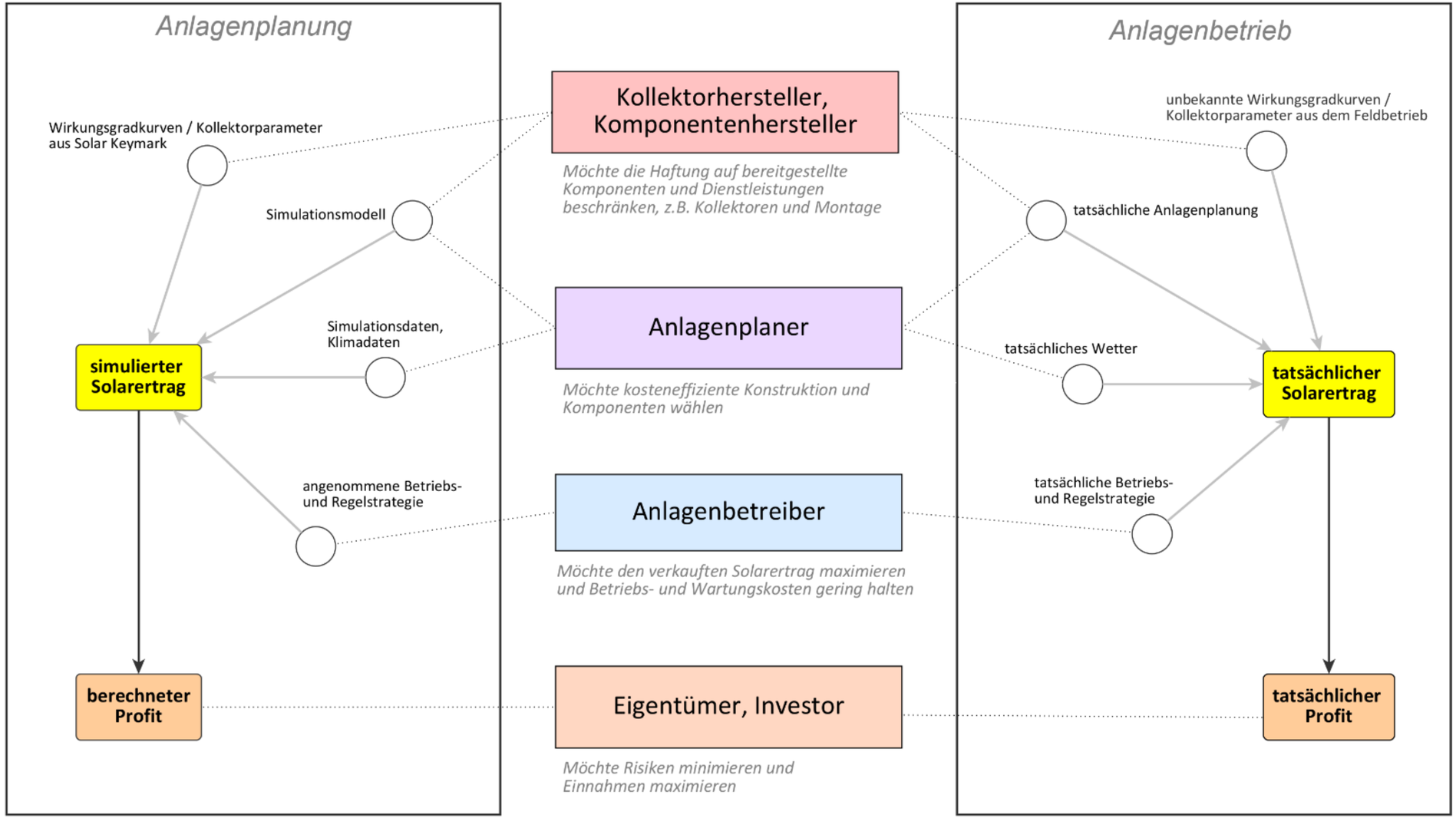
Source: Picfly.at Thomas Eberhard

Agenda

1	*Kontext*	**Große Solarthermie: Markt & Chancen**
2	*Monitoring*	**Herausforderungen & Lösungen**
3	*HarvestIT*	**Software für Performance-Nachweise**
4	*Ausblick*	**D-CAT**
5	*We want you!*	**Einladung zur Zusammenarbeit**

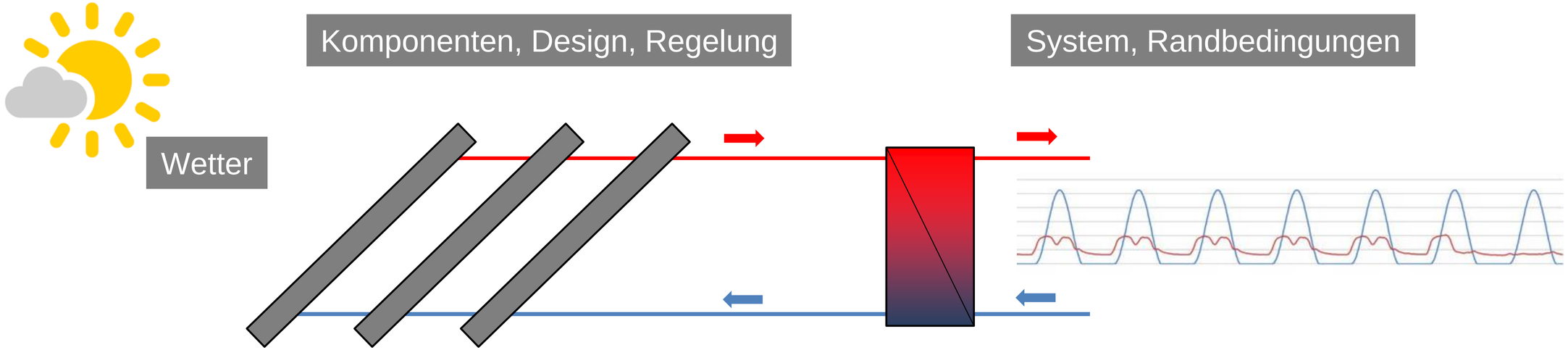
Stakeholder

Errichtung & Betrieb solare Großanlage



Herausforderung Monitoring für solare Großanlagen

1) CAPEX: Solare Großanlagen haben **hohe Anfangsinvestition.**
2) OPEX: Amortisation über Laufzeit 20-30 Jahre.
   Betreiber muss **langfristig hohen Solarertrag** sicherstellen.
3) Bewertung der Anlagenperformance selbst für Expert*innen sehr schwierig.
4) Es gibt am Markt **keine Standard-Software** für Solarthermie-Garantien.



Stakeholder Befragung

Mentimeter

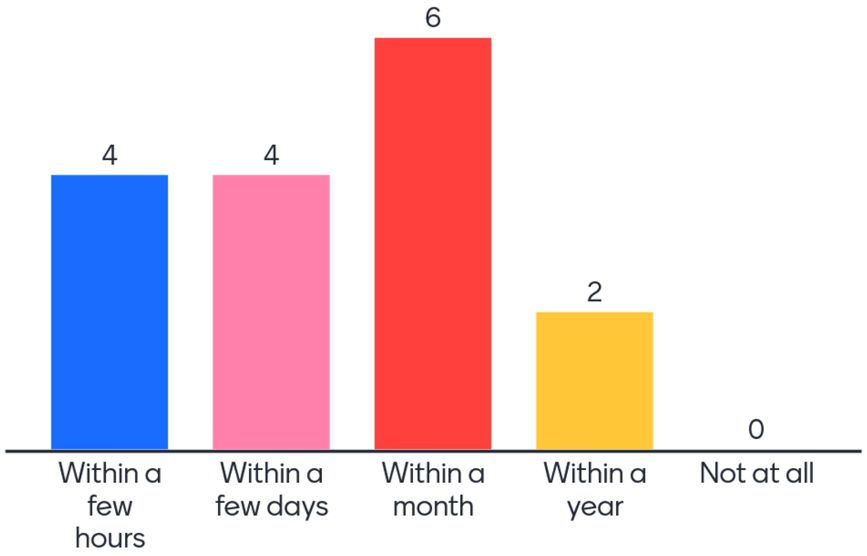
HarvestIT

- In the project HarvestIT a freely available open source software will be developed for advanced monitoring of solar thermal systems.
- With this questionnaire you can help us to design a good software tool.
- The questionnaire may take about 5-10 minutes.
- Multiple answers are possible.
- If several systems are being considered, please provide us with typical answers!

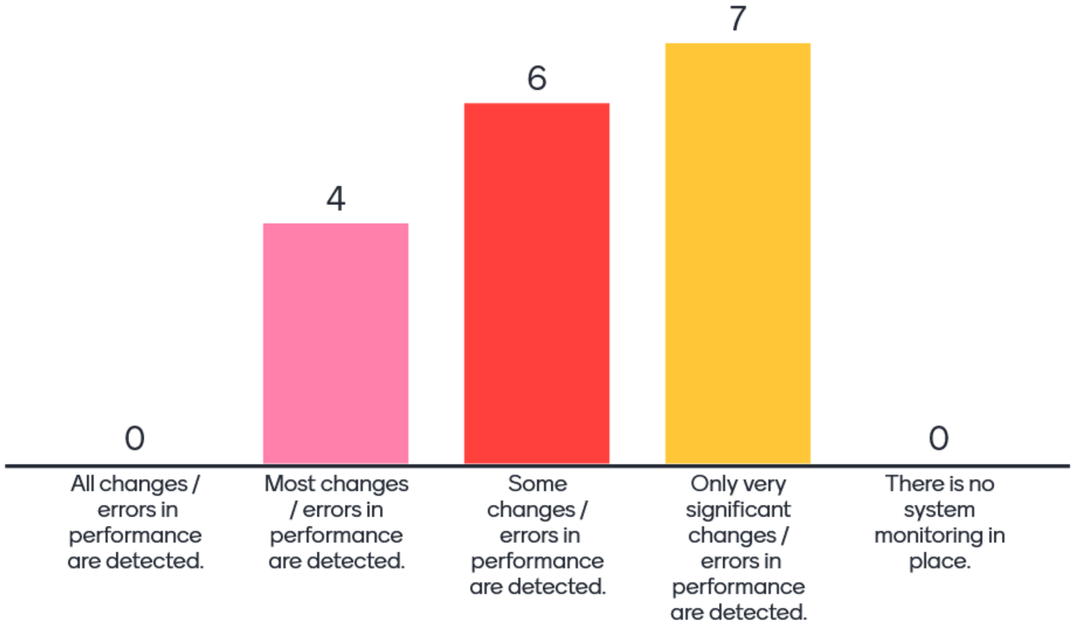
Next

Stakeholder Befragung

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

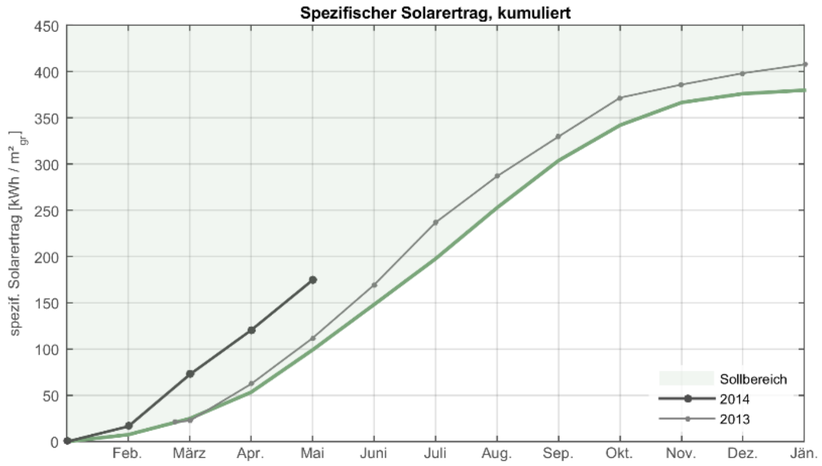


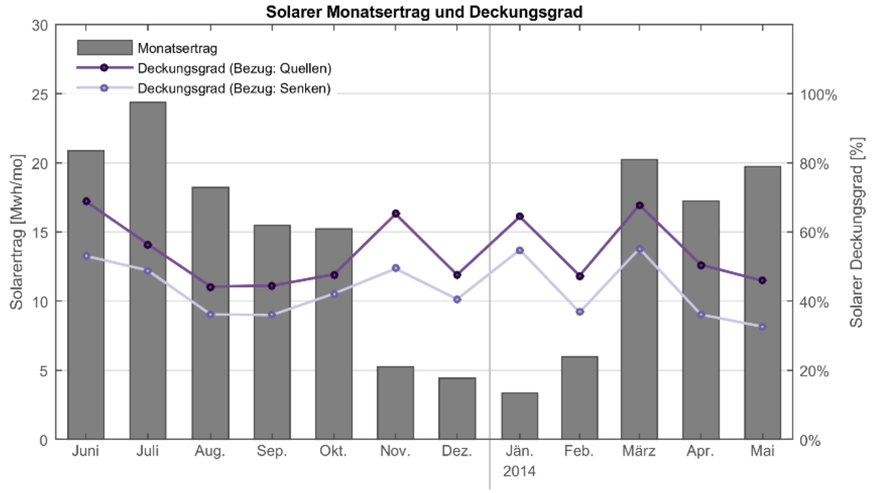
7 Plant performance: How well are performance changes and errors detected?

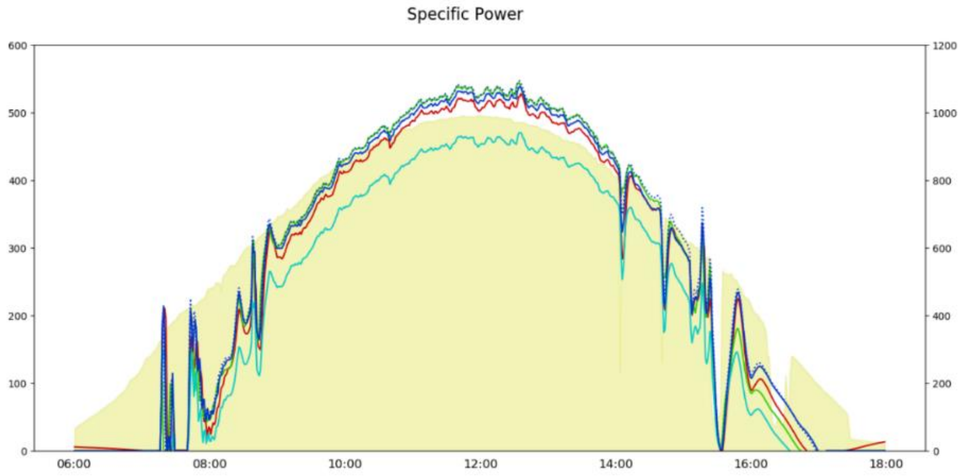


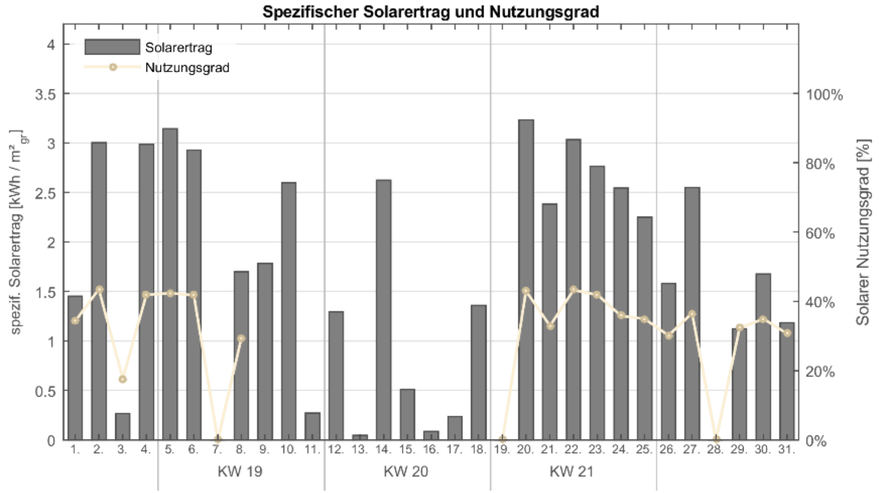
Typische Monitoring KPIs

Bewertung Performance große Solaranlagen



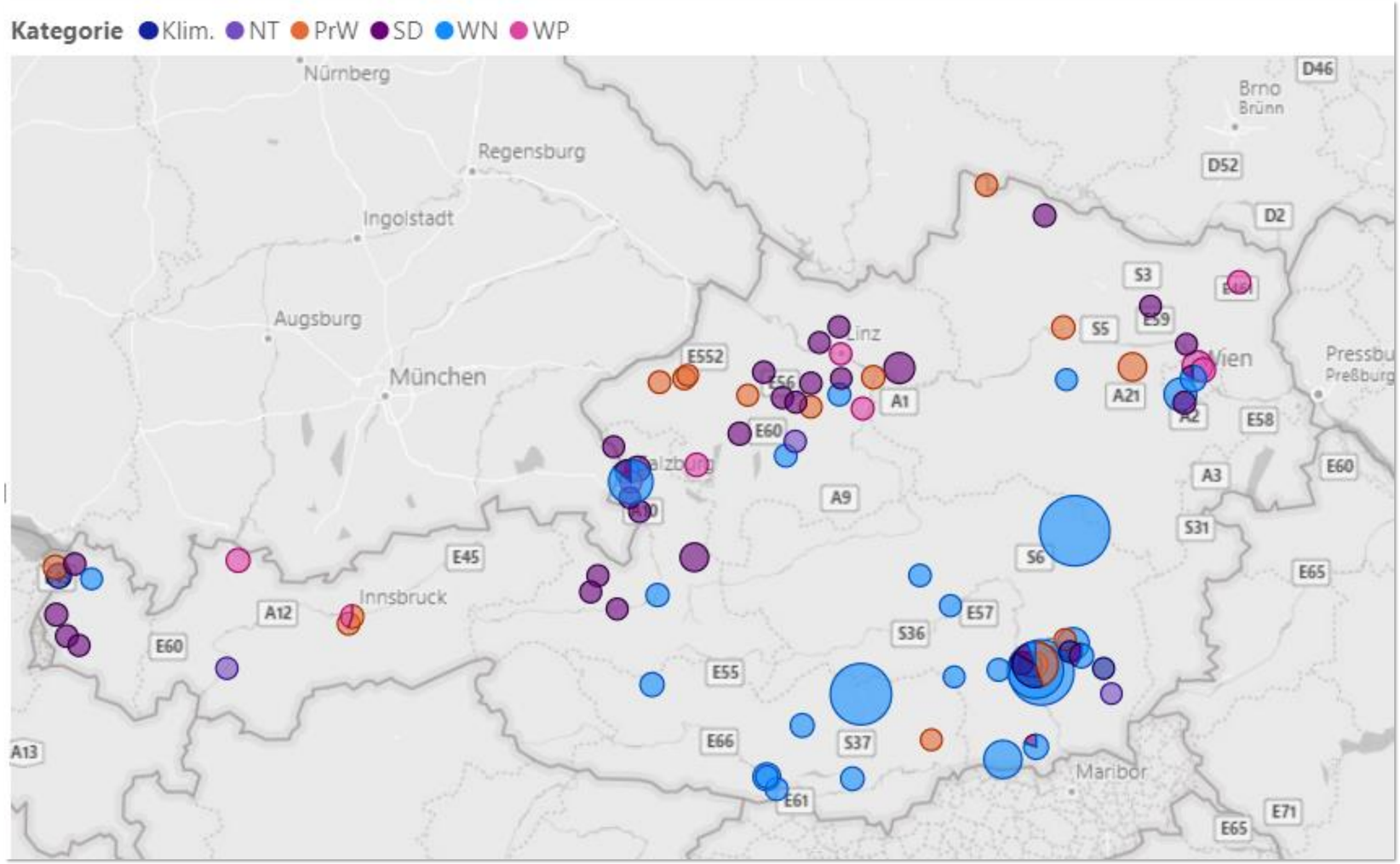






Begleitforschung Solare Großanlagen, 2010 – 2019

- Förderprogramm seit 2010 für große thermische Solaranlagen > 100 m² Kollektorfläche
- Investmentförderung von 40-50% der förderbaren Kosten
- Begleitforschung: Beratung, Monitoring, Know How Transfer

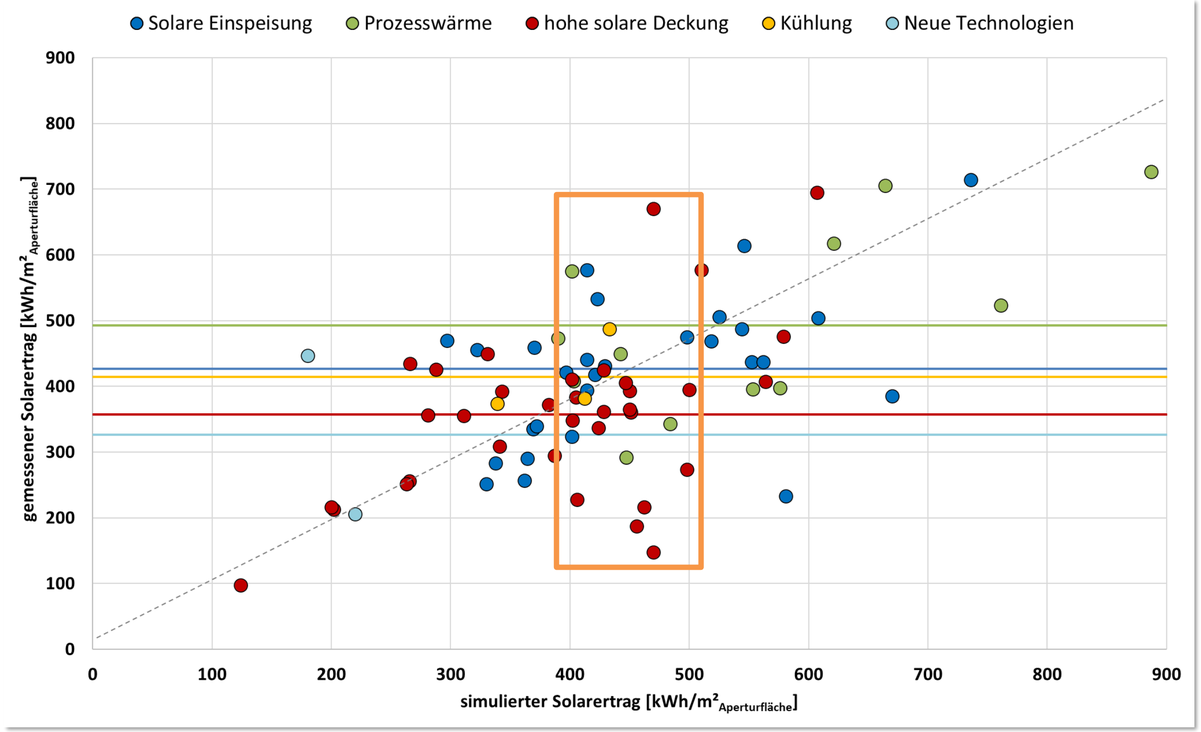


Durchmesser = Anlagengröße [100 m² … 6.922 m²]

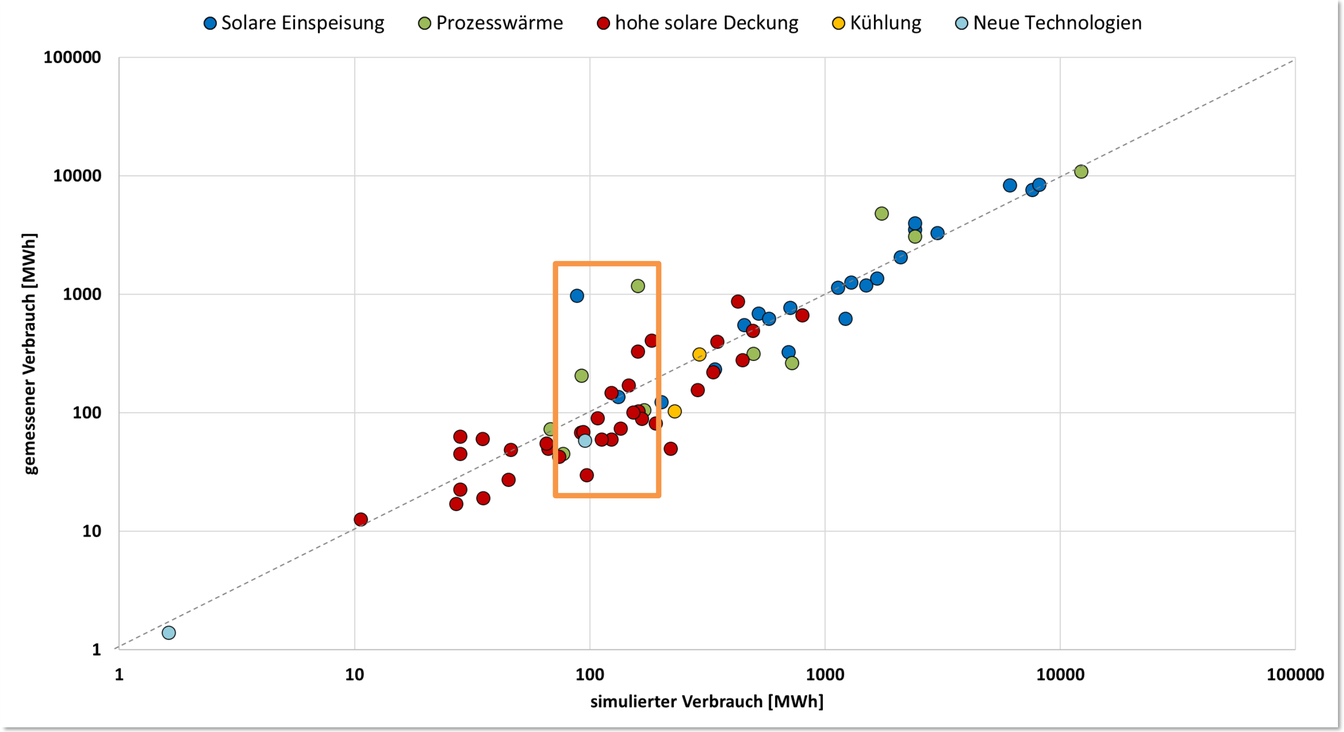
Begleitforschung Solare Großanlagen

Planung vs. Messung

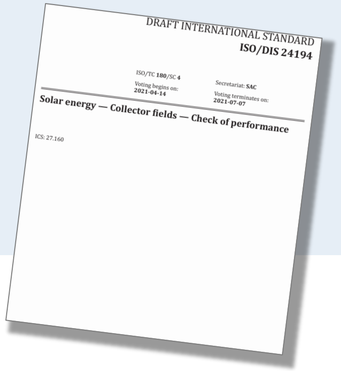
Abweichung **Ertrag**
Planung vs. Messung



Abweichung **Verbrauch**
Planung vs. Messung



Performance Check Methode


DRAFT INTERNATIONAL STANDARD
ISO/DIS 24194

ISO/TC 180/SC 4
Voting begins on: 2021-04-14
Secretariat: SAC
Voting terminates on: 2021-07-07

Solar energy — Collector fields — Check of performance

ICS: 27.160

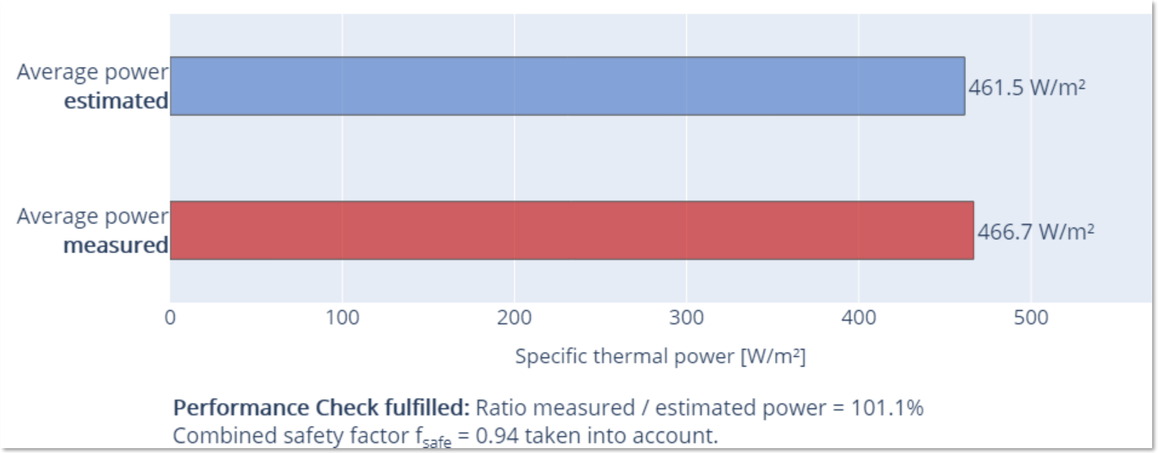
- ISO Norm für Kollektorfelder:
  ISO/DIS 24194 Solar energy — Collector fields — Check of performance
- Aktueller Status: 60.60, International Standard Published

DRAFT INTERNATIONAL STANDARD
ISO/DIS 24194

ISO/TC **180**/SC **4**
Voting begins on: **2021-04-14**

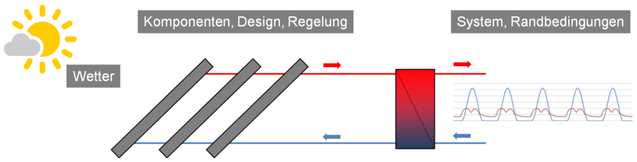
Secretariat: **SAC**
Voting terminates on: **2021-07-07**

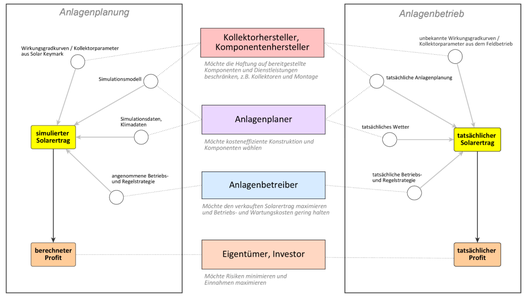
Solar energy — Collector fields — Check of performance

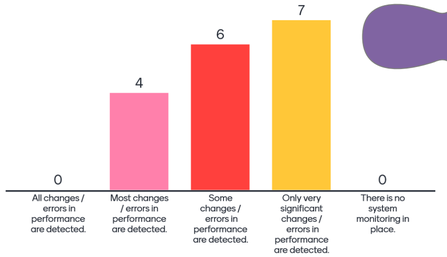


Notwendigkeit & Vision

Open Source Software für die Solare Großanlagen Branche







1) Einheitliche, transparente Klärung der Frage **„Anlagenperformance ok?“**
2) **Technische Grundlage**: Neue Norm **ISO 24194**, Solar Keymark Norm ISO 9806
3) **Anerkannt** durch alle Stakeholder. **Branchenlösung** für Monitoring / Garantie.
4) Günstiges Monitoring durch **Automatisierung** der Datenanalyse.
5) Dauerhaft hoher Output: **Niedriger Energiepreis / LCOE**
6) **Glaubwürdigkeit & Vertrauen** in Technologie solare Großanlagen.
7) **Bankability**: Vereinfachte Verträge & Finanzierung

Agenda

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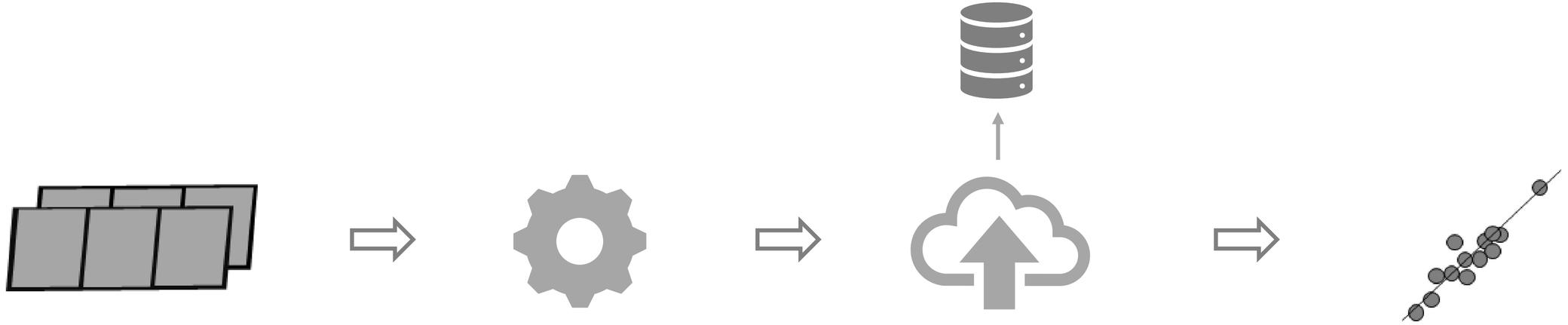
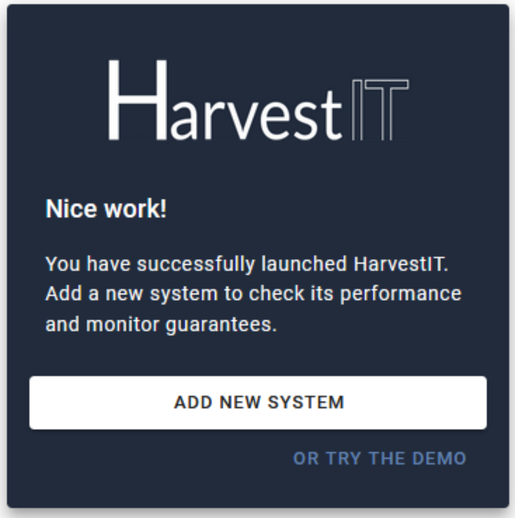
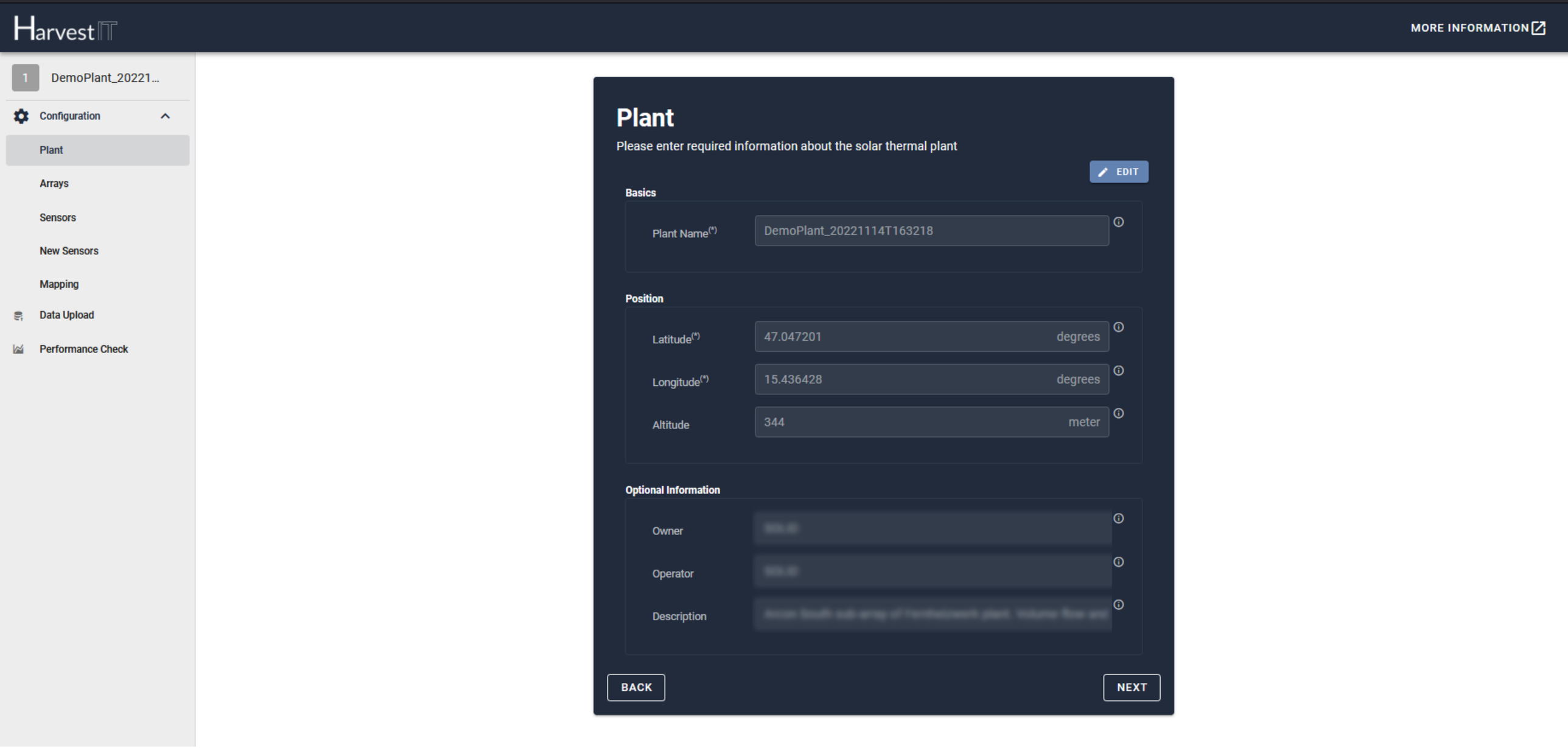
5	*We want you!*	**Einladung zur Zusammenarbeit**

HarvestIT Gesamtdurchlauf




HarvestIT
Nice work!
You have successfully launched HarvestIT. Add a new system to check its performance and monitor guarantees.
ADD NEW SYSTEM
OR TRY THE DEMO


HarvestIT
MORE INFORMATION
1
DemoPlant_20221...
Configuration
Plant
Arrays
Sensors
New Sensors
Mapping
Data Upload
Performance Check
Plant
Please enter required information about the solar thermal plant
EDIT
Basics
Plant Name(*)
DemoPlant_20221114T163218
Position
Latitude(*)
47.047201
degrees
Longitude(*)
15.436428
degrees
Altitude
344
meter
Optional Information
Owner
Operator
Description
BACK
NEXT

1 DemoPlant_20221...

Configuration

- Plant
- Arrays
- Sensors
- New Sensors
- Mapping

Data Upload

Performance Check

Collector Arrays

Configure which collector arrays are installed at the solar thermal plant

ADD ARRAY

Name	Collector Area	Tilt	Azimuth	Collector Type	
[illegible]	[illegible]	30°	180°	[illegible]	

BACK

NEXT

HarvestIT

MORE INFORMATION

1 DemoPlant_20221...

Configuration

- Plant
- Arrays
- Sensors
- New Sensors
- Mapping

Data Upload

Performance Check

Sensor Details

Configure the sensor details so HarvestIT can interpret the data.

Sensor	Sensor Type	Unit	Info	Status
is_shadowed	bool	dimensionless	-	✓
rd_bT	direct_radiation	watt / meter ** 2	EDIT	✓
rd_DNI	dni_radiation	watt / meter ** 2	-	✓
rd_dT	diffuse_radiation	watt / meter ** 2	EDIT	✓
rd_gT	global_radiation	watt / meter ** 2	EDIT	✓
rh_amb	float_0_1	dimensionless	-	✓
te_amb	ambient_temperature	kelvin	-	✓
te_dew_amb	missing	kelvin	-	✗
te_flo	fluid_temperature	kelvin	-	✓
te_ret	fluid_temperature	kelvin	-	✓
ve_wind	wind_speed	meter / second	-	✓
vf	volume_flow	meter ** 3 / second	EDIT	✓

BACK NEXT

New Plant

1. Add Plant
2. Add Arrays
3. Add Sensors
4. Map Sensors
5. Set Details
6. Add Data

Data Upload

Please use the input below to upload the measurement data again to make sure that the data is safed

Choose files or drag them here

[redacted].csv (25.3 MB)

BACK

NEXT

HarvestIT

MORE INFORMATION

1 DemoPlant_20221...

Configuration

Data Upload

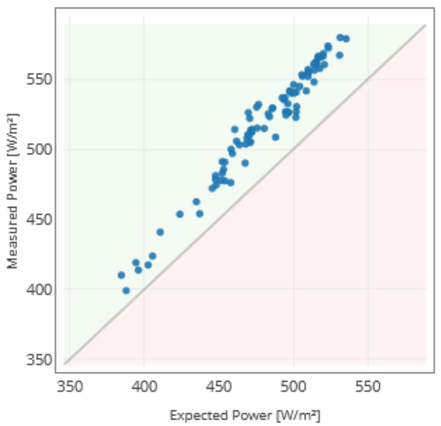
Performance Check

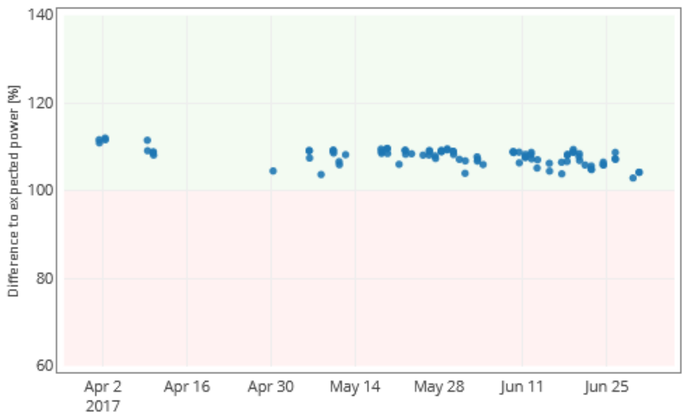
Performance Check

Method ISO | Equation 1 | Safety Factors: f_u 95 % | f_p 95 % | f_o 95 %

RUN DEMO

PC-Guarantee fulfilled (with 107.8 %)



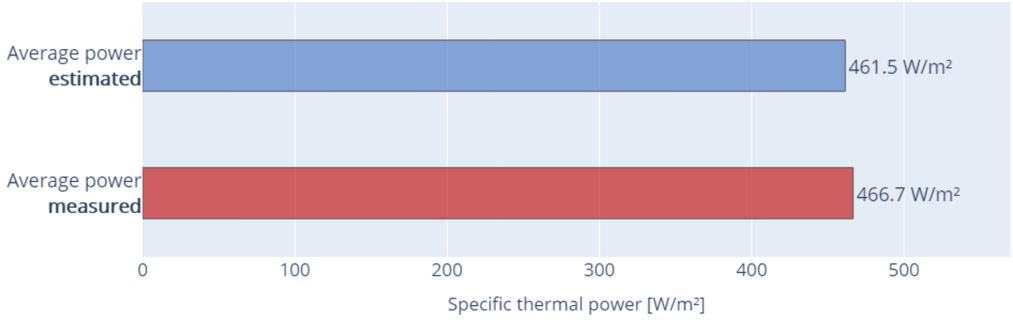


Array Name	Measured Power	Expected Power	Difference
Arcon South	No Data	43,683.7 [watt / meter ** 2]	No Data
Plant Total	**47,099.8 [watt / meter ** 2]**	**43,683.7 [watt / meter ** 2]**	**107.8 %**

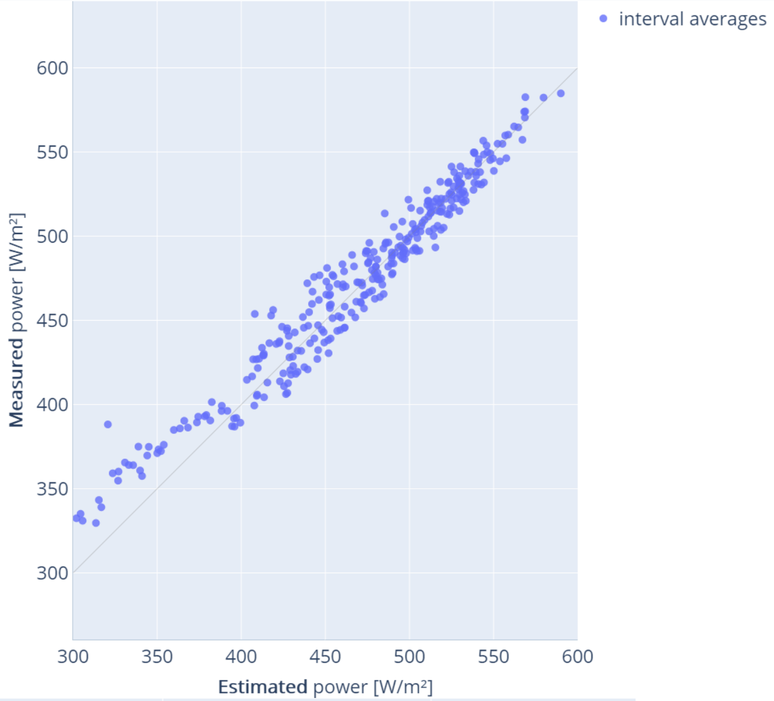
Performance Check Methode

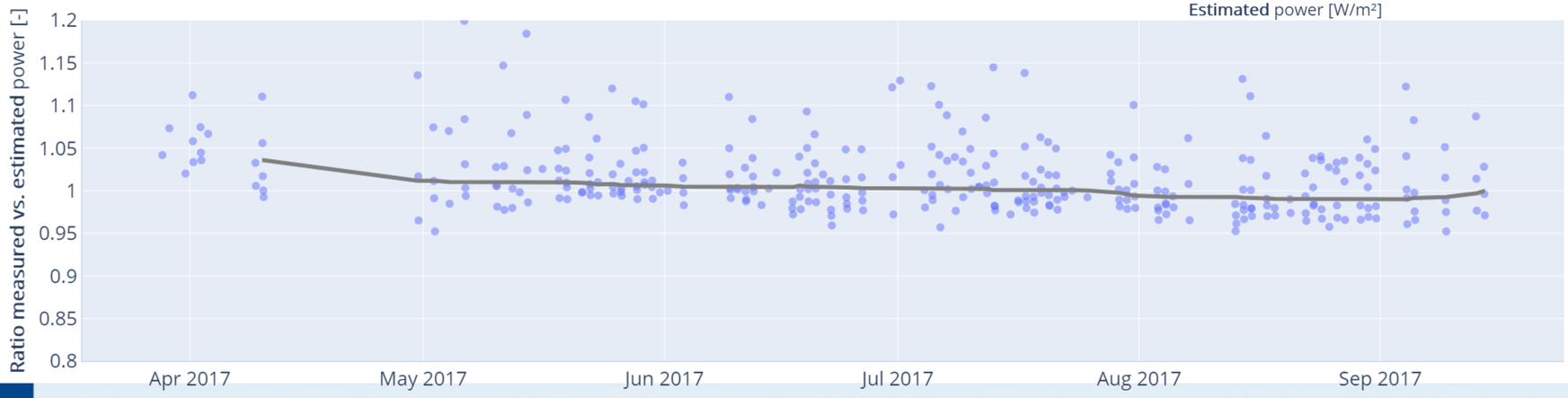
Grafischer Output

Check of Performance (PC Method 'ISO DIS 24194', improved, equation 2).
Data from 2017-02-28 23:00:00+00:00 to 2017-10-31 23:00:00+00:00.
n=331 intervals with duration 1:00:00.



Performance Check fulfilled: Ratio measured / estimated power = 101.1%
Combined safety factor f_{safe} = 0.94 taken into account.





HarvestIT

Ergebnisse, Nutzung

HarvestIT Outcomes

web UI
Grafische Oberfläche, Interaktive Nutzung

web API
Restful API. Integration in eigene Software Tools.

Python package
Nutzung mit anderen Projekten. Weiterentwicklung

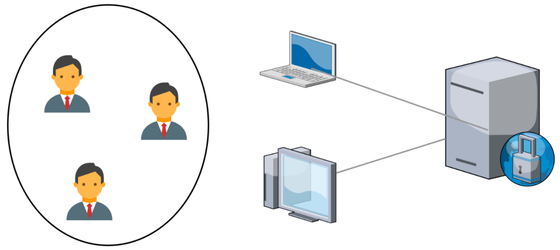
open source initiative
Approved License®

Kommerzielle Nutzung ausdrücklich erlaubt.

HarvestIT Usages

1 User
Lokale Nutzung

Betreiber / Firma
Gehostet im eigenen Firmennetzwerk



Öffentlichkeit
Förderstellen, Open Data

Forschung & Entwicklung
Forschungsinstitute, Industrie

HarvestIT Beispiel-Anlagen

Fernheizwerk Graz

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

Solare Fernwärme
7 verschiedene Kollektorhersteller
Unterschiedliche Technologien.

HarvestIT Beispiel-Anlagen

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 Beispiel-Anlagen

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 Beispiel-Anlagen

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 Beispiel-Anlagen

Nahwärme Friesach

Bruttofläche: 5.750 m² / 4 MWp
Pufferspeicher: 1.000 m³

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

Performance Check Methode

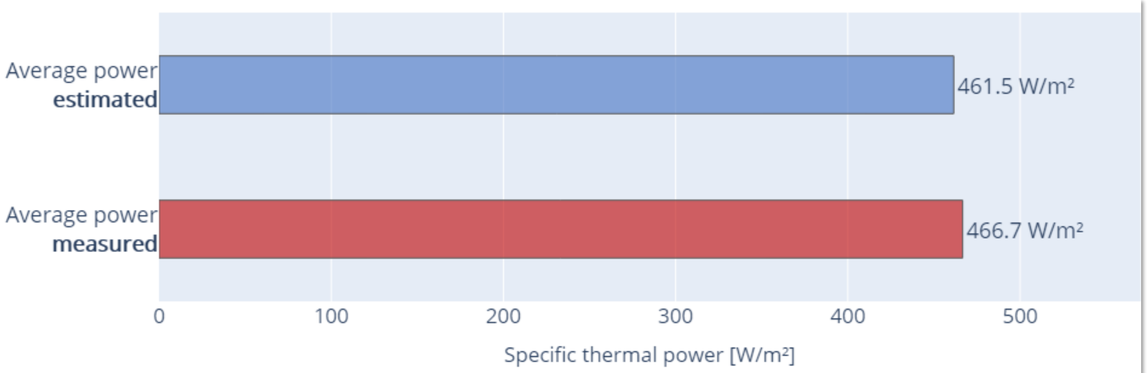
ISO Norm für Kollektorfelder:
ISO/DIS 24194 Solar energy — Collector fields — Check of performance

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



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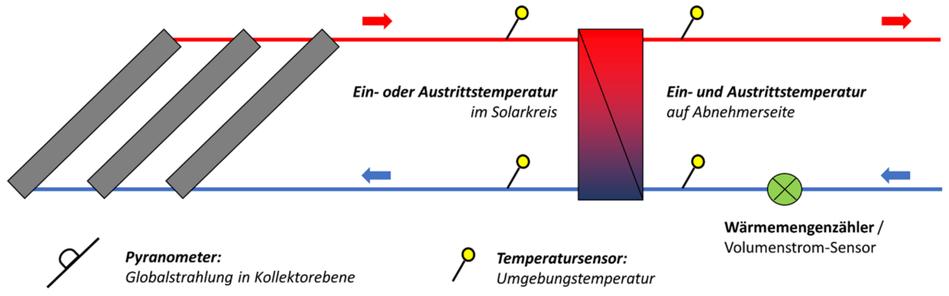
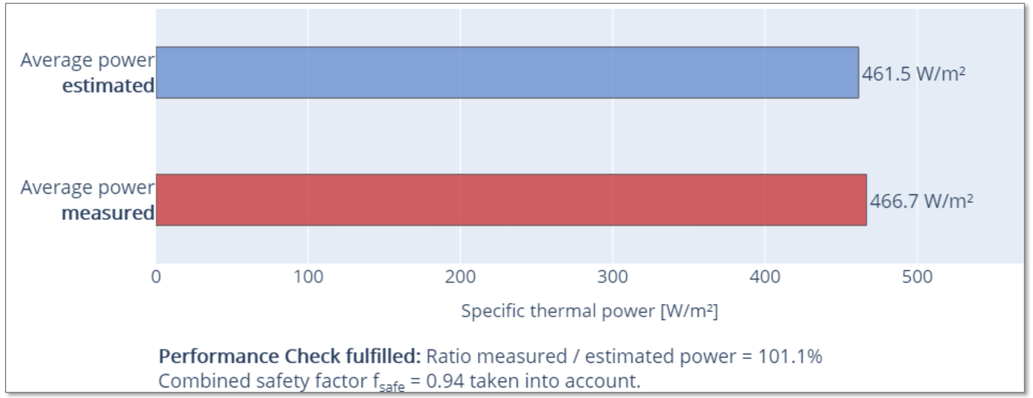
Performance Check Methode



Messung Betriebsdaten

Soll-Wert

Ist-Wert



Solar Keymark Datenblatt

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										

Datenanalyse

Data cleaning, Speicherung, Verschattung, virtuelle Sensoren etc.

ISO 24194 Modell

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

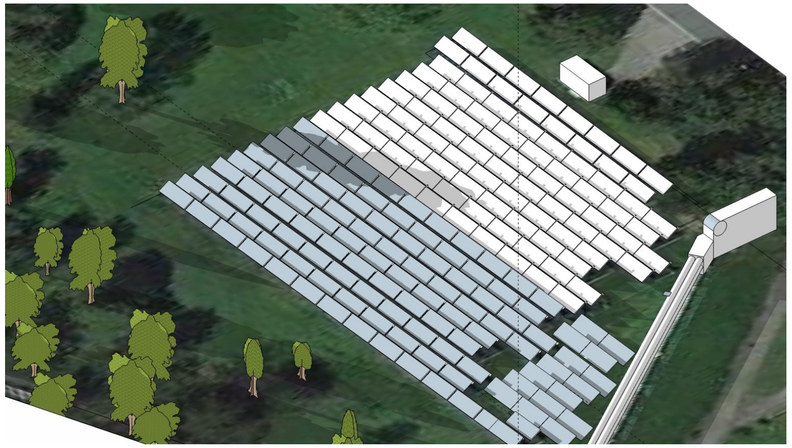
Erweiterung der ISO Norm Methode

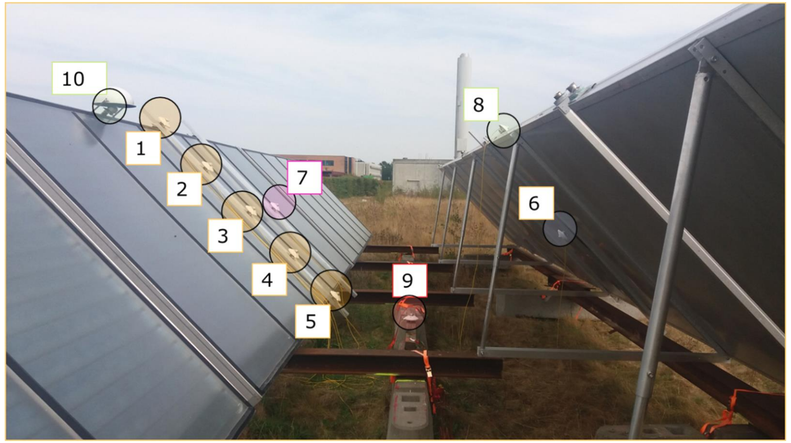
Verwendung für Anlagen in der Praxis

ISO 24194 / Papier-Norm
→ **Software** Implementierung
→ Transparenz, Nachvollziehbarkeit, Anwendbarkeit

HarvestIT: Erweiterung auf reale Anlagen

1) Mehrere Kollektorfelder, mehrere Kollektortypen.
2) Unterschiedliche Messausstattungen in realen Anlagen.
   Virtuelle Sensoren
3) **Strahlungsmodellierung**
   Unterschiedliche Ausrichtungen Kollektorfelder
   Interne Verschattung
   Korrekte Diffusstrahlung für faire Bewertung
4) Wärmeträger-Fluide, Stoffwerte
5) Vollautomatische Datenaufbereitung & Datenanalyse





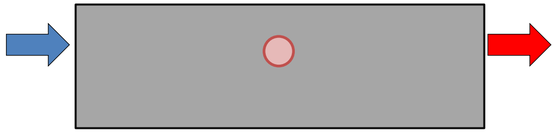
Agenda

1	*Kontext*	**Große Solarthermie: Markt & Chancen**
2	*Monitoring*	**Herausforderungen & Lösungen**
3	*HarvestIT*	**Software für Performance-Nachweise**
4	*Ausblick*	**D-CAT**
5	*We want you!*	**Einladung zur Zusammenarbeit**

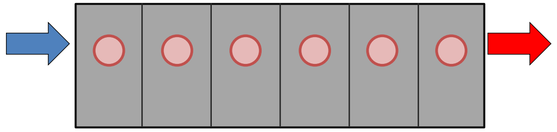
Kollektorfeldmodelle

Erweiterungen für D-CAT

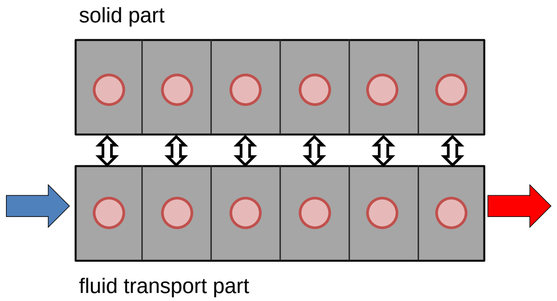
Single collector model
ISO 9806 (QDT)



MeQuSo 1N model



MeQuSo 2N model

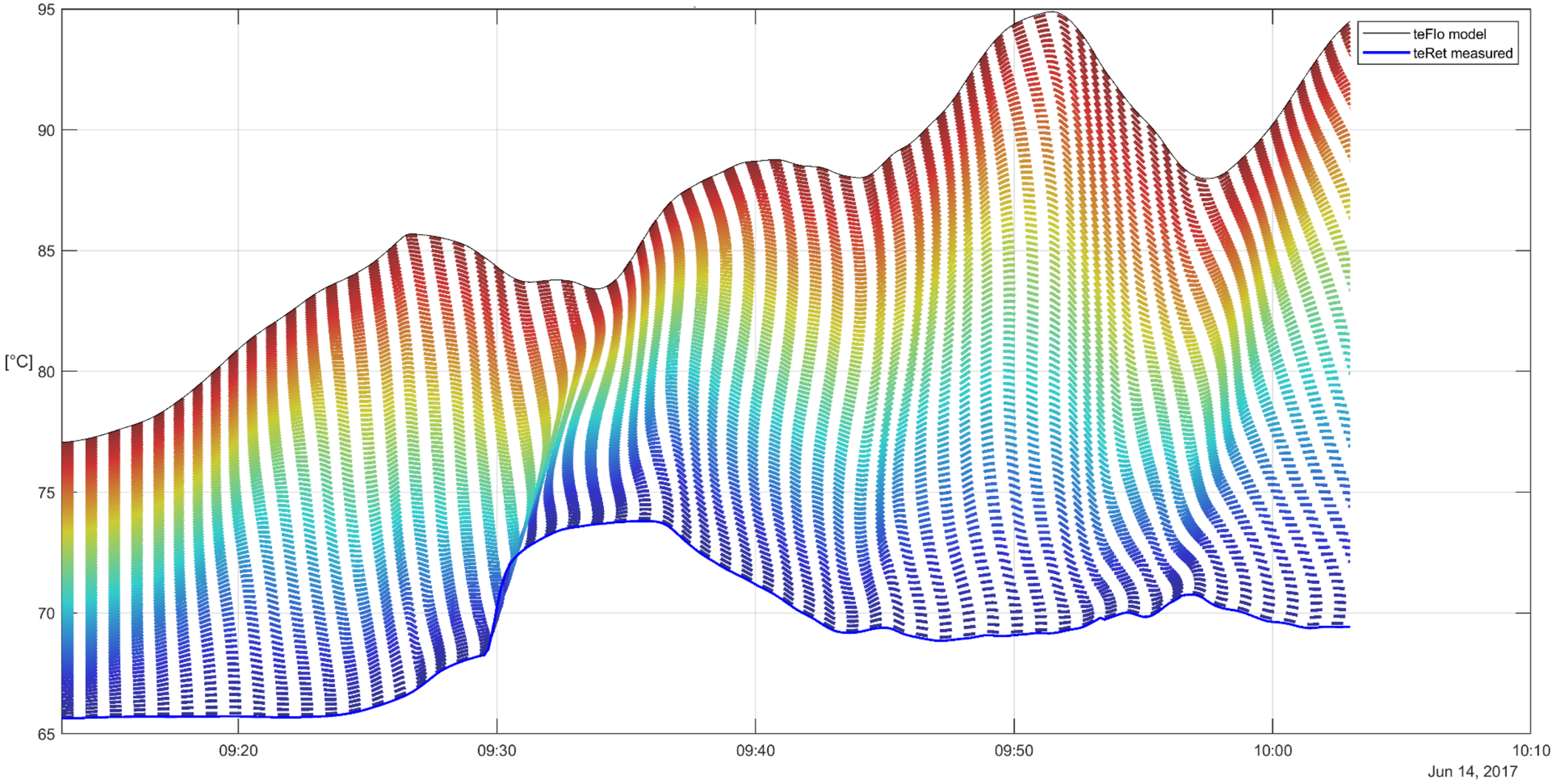


$$(mc)_f \frac{\partial T_f}{\partial t} = D\alpha(T_m - T_f) - \dot{C}_f \frac{\partial T_f}{\partial x}$$

$$(mc)_m \frac{\partial T_m}{\partial t} = (\tau\alpha)(K_b(\theta)G_b + K_d G_d) - a_1(T_m - T_a) - a_2(T_m - T_a)^2 - D\alpha(T_m - T_f)$$

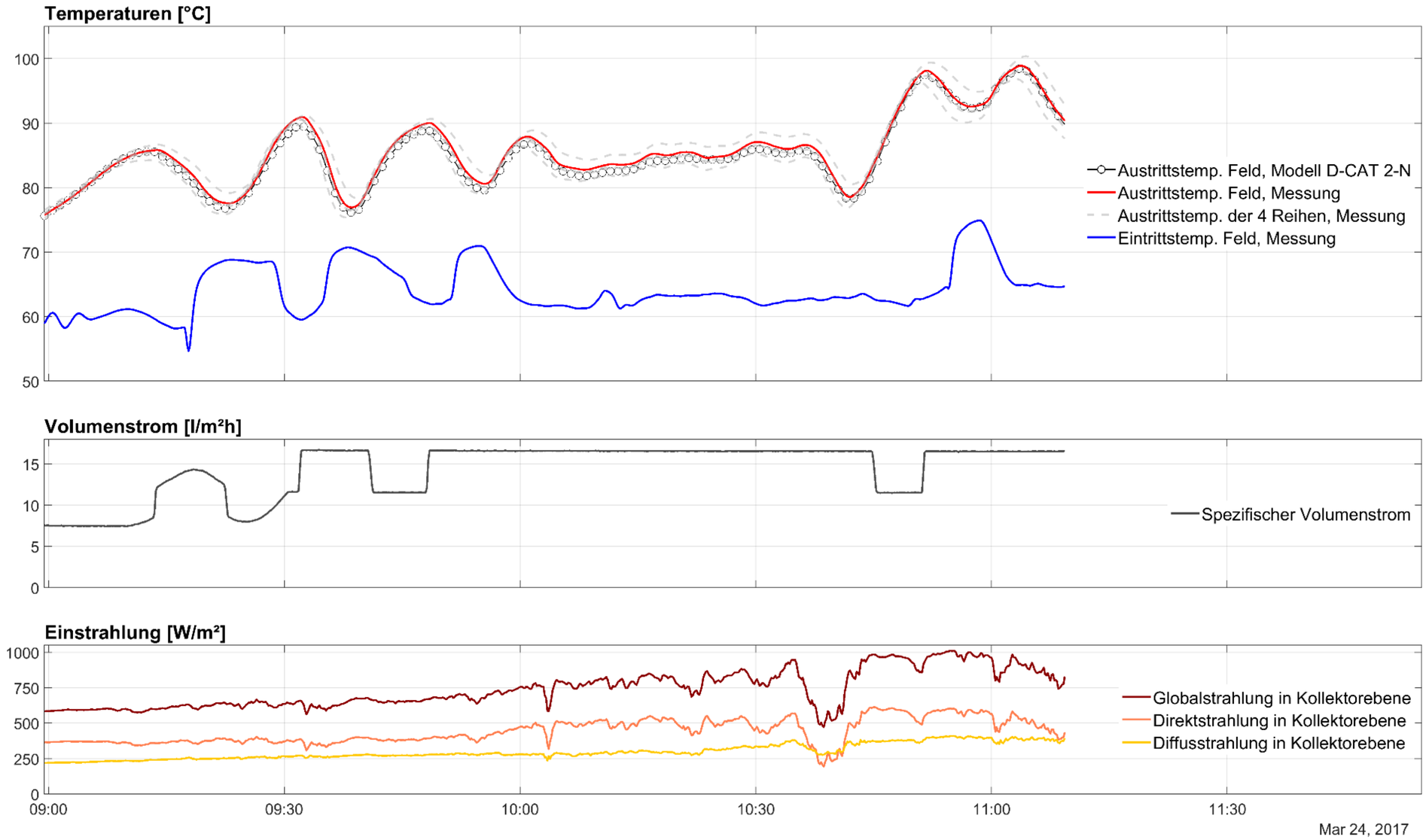
D-CAT Kollektortemperaturen

in Strömungsrichtung für mehrere Segmente



D-CAT

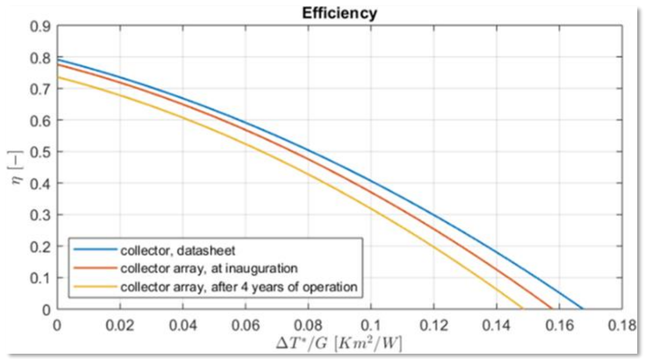
Vergleich mit Messdaten



D-CAT

Dynamic Collector Array Test

1) **Ertrag** kWh statt Leistung kW
   → Bewertung Energiepreis, LCOE
2) Verbessertes physikalisches **Modell**
   → Vorteil: Mehr und dynamischere Daten für Analyse
3) **Dynamischer in-situ Kollektorfeld-Test**
   → Erweiterung QDT aus ISO 9806 auf Kollektorfelder
   → Kein Eingriff in den laufenden Anlagenbetrieb!
   → Automatisierung: Betriebsdaten → Parameterschätzung
4) **Faire Bewertung**
   → Aussage zur Ursache von Mindererträgen
   → Saubere Trennung der Effekte in Betriebsdaten
   Kollektoren / Anlage vs. Wetter / Betrieb / etc.
5) **Predictive Maintenance** z.B. Planung Reinigung



ACR Innovationspreis 2021

für D-CAT an SOLID + AEE INTEC

Agenda

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3	*HarvestIT*	**Software für Performance-Nachweise**
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HarvestIT Software Roadmap

Software development roadmap

Phase I	Phase II	Phase III	Phase IV
wihtin consoritum	within consortium	public repository	public repository
Basic blocks, Structure	Refinement, Test plants	Early Adopters	Open Source Deployment
ongoing	winter 2022	~mid 2023	Oct. 2023

GitLab

Interesse? Möglichkeiten zur Mitarbeit:

- Auswertung eigener Anlagen
- Mitentwicklung möglich / Developer
- Entwicklungsprozess einsehen & mitgestalten

HarvestIT: Interesse?

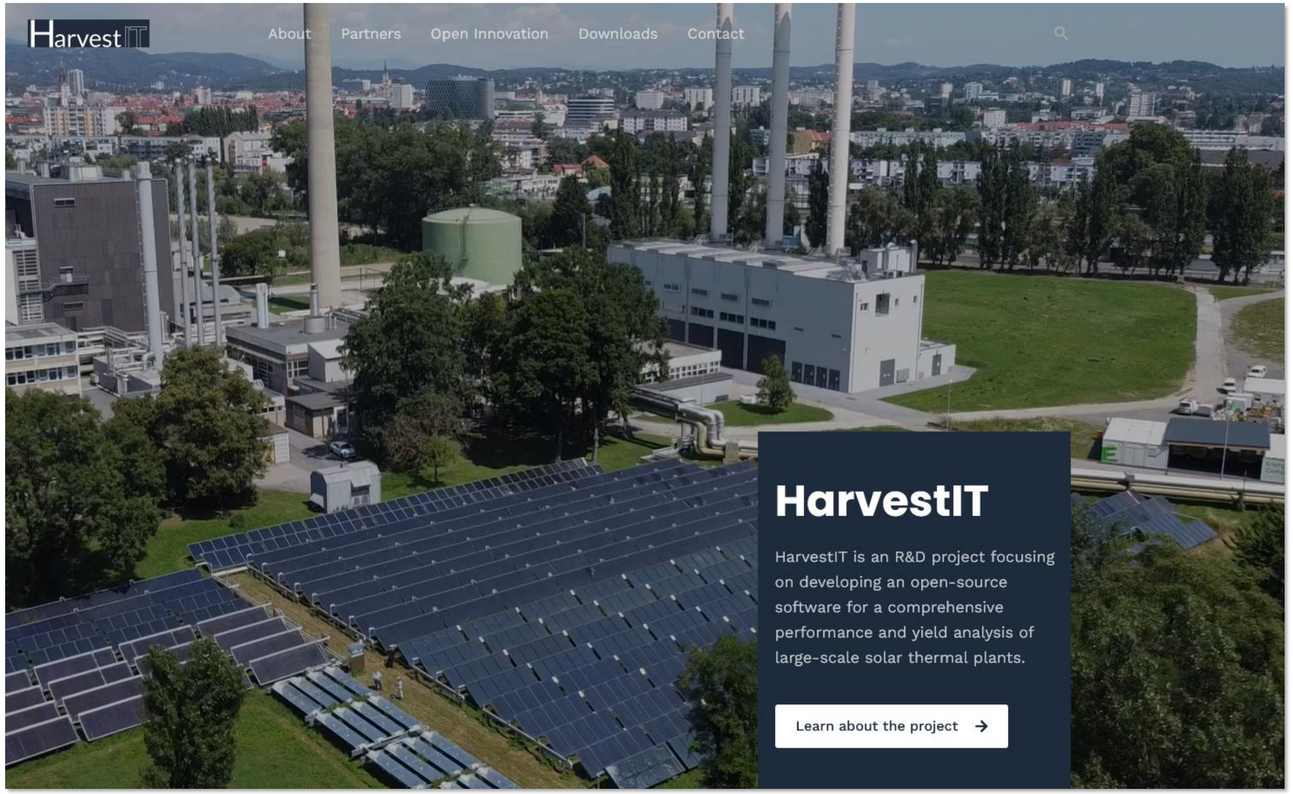
Bitte mitmachen!

Anwenden, Mitarbeiten
Early Adopter, Developer, Infos

HarvestIT Website

Kontakt: d.tschopp@aee.at

www.collector-array-test.org



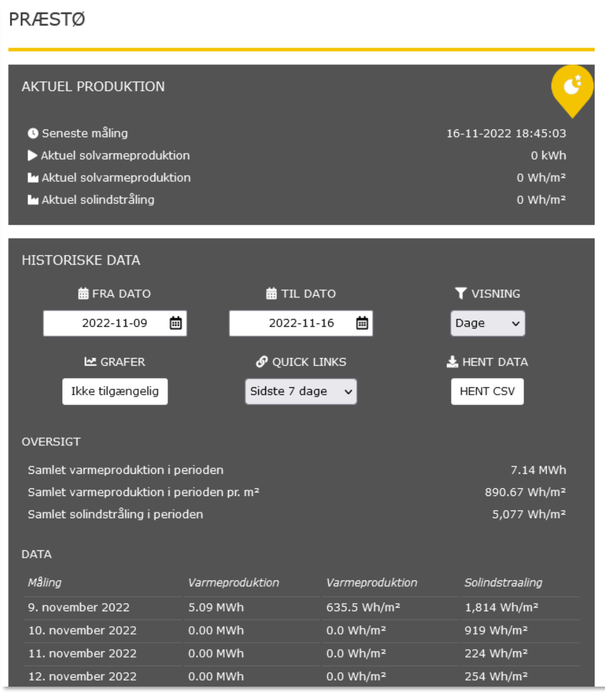
HarvestIT Vision & Perspektiven

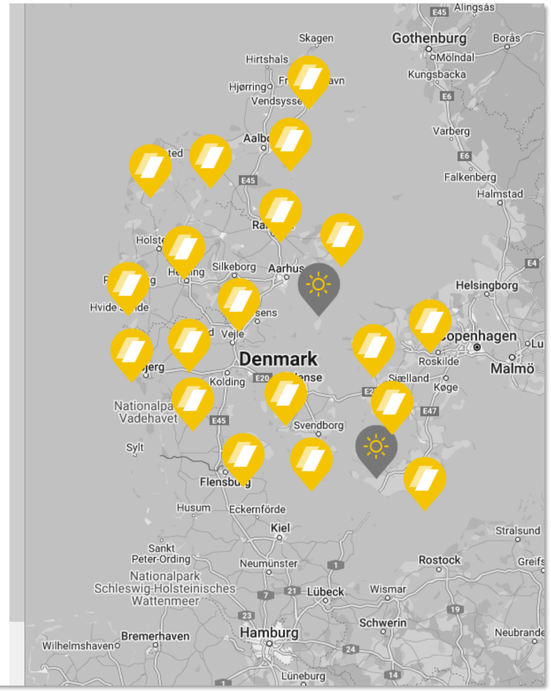
Branchentool für Solarthermie

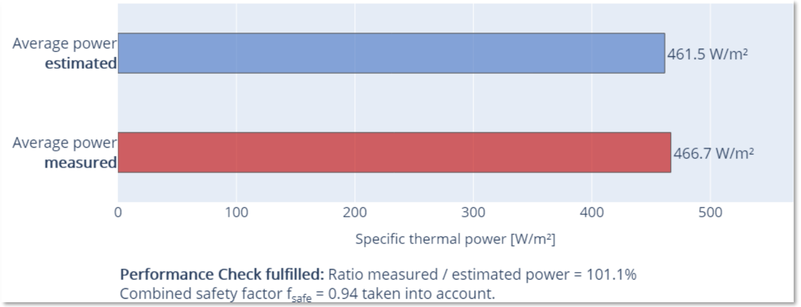
- Einheitliche, transparente Klärung der Frage **„Anlagenperformance ok?“** **Anerkannt** durch alle Stakeholder.
- **Technische Grundlage**: Neue Norm **ISO 24194**, Solar Keymark Norm ISO 9806
- Günstiges Monitoring durch **Automatisierung** der Datenanalyse.
- Dauerhaft hoher Output, **niedriger Energiepreis**
- **Glaubwürdigkeit & Vertrauen** in Technologie solare Großanlagen.

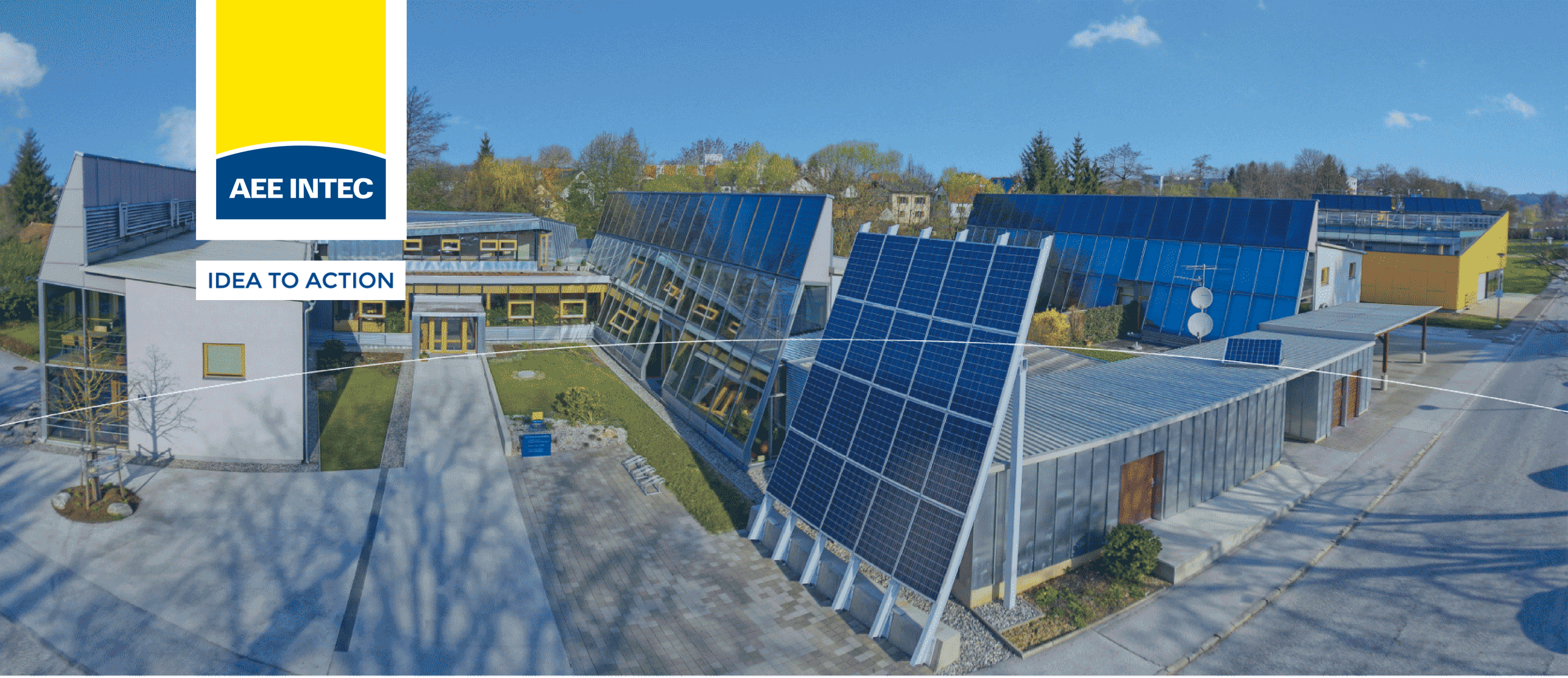
Mögliche Perspektiven & Entwicklungen

- Anlagenübersicht, Auswerteplattform
- Einheitliche Performance-Auswertungen
- Nutzen für alle Beteiligten herausarbeiten
- Open data → Task 68









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