WEBINAR

DIGITAL INNOVATION FOR SOLAR THERMAL SYSTEMS

23 June 2026

AGENDA

11.10 - 11.20	Interaction with the audience
11.20 - 11.40	The **SUN-DT** project by Marcelino Sánchez (CENER), Project Coordinator
11.40 - 11.50	The **DIGISOLAR** project by Xavier Albets (DCarbo), Project Coordinator
11.50 - 12.00	**SunPeek** by Marnoch Hamilton-Jones (AEE)
12.00 - 12.10	**Pytrnsys suite** by Damian Birchler (SPF)
12.10 - 12.25	Q&A
12.25 - 12.30	Closing

Moderators: Céline Suchet (EUREC) and Konstantinos Genikomsakis (ESTELA)

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SUN-DT

CSP 4.0: The Era of Intelligent Solar Energy

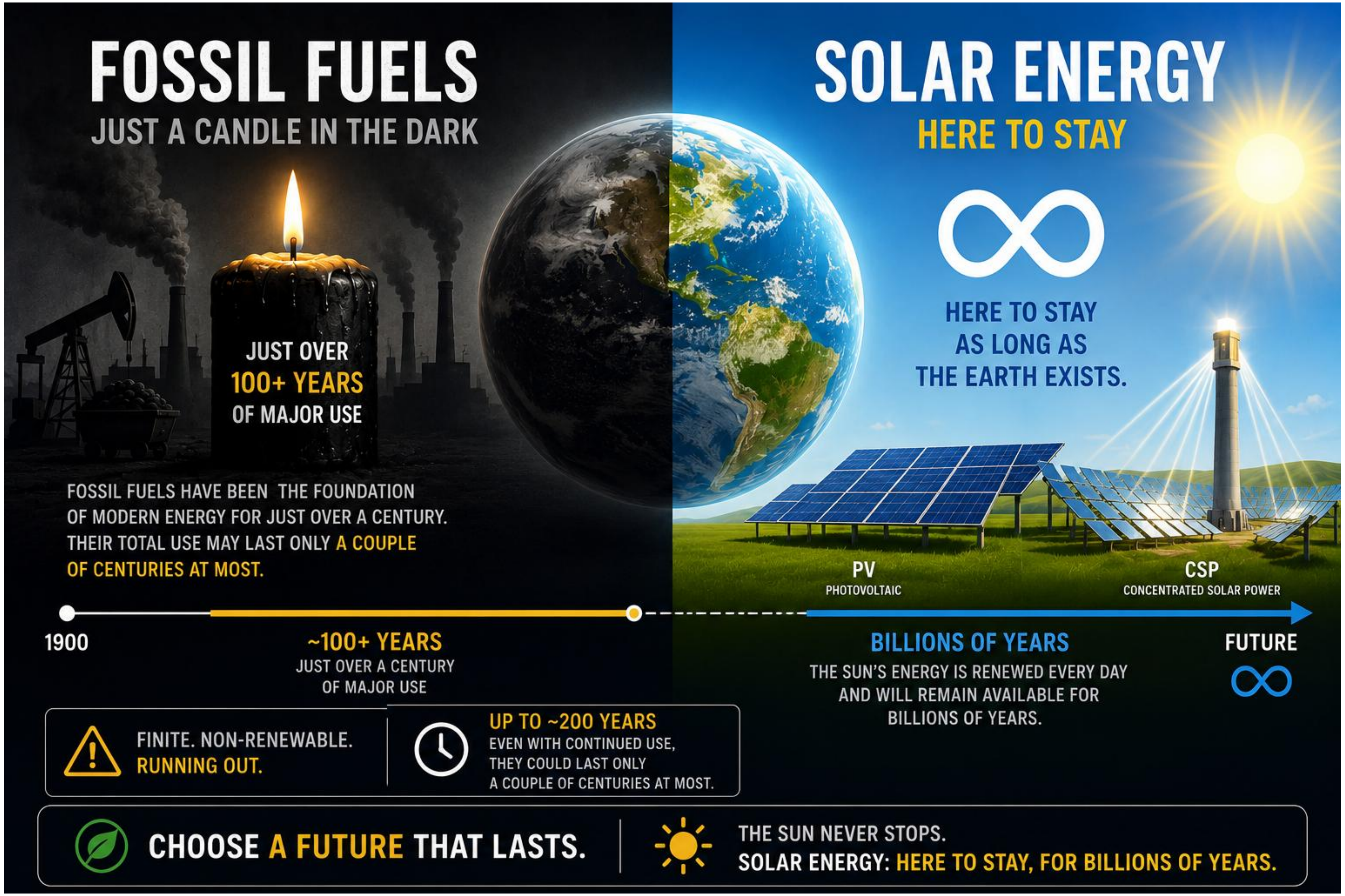
From Digitalization to Intelligent Energy Systems

Based on SUN-DT project experience

Webinar “Harnessing the Sun, Driven by Data: Digital Innovation for Solar Thermal Systems“

June 23, 2026

WHY INTELLIGENT SOLAR ENERGY MATTERS NOW



WHY INTELLIGENT SOLAR ENERGY MATTERS NOW

WHAT IS CSP?

<u>Concentrated Solar converts sunlight into high temperature heat</u>

- This heat can be converted into:
  - **Electricity**
  - Industrial **process heat**
  - **Green hydrogen** production
- **Dispatchable renewable energy with thermal storage**

CSP should play a key role in:

- Industrial decarbonization
- Energy transition
- Sustainable energy systems

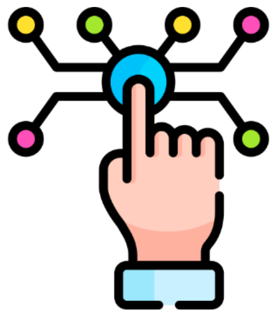
CSP TECHNOLOGIES

SOLAR TOWERS: THE MOST ADVANCED CSP TECHNOLOGY

- **Higher Performance**
  - Higher solar **concentration ratios**
  - Higher operating **temperatures** (>560°C)
  - Higher conversion **efficiency**
- **Better Energy Storage**
  - **More kWh stored** per unit volume
  - **Low-cost**, **massive** energy storage using **environmentally friendly** molten salts
  - **Dispatchable electricity** day and night
- **Strategic Value**
  - **Grid** flexibility and reliability (synchronous generation)
  - High-temperature **industrial heat**
  - Green **hydrogen** production
  - **Environmentally friendly storage** solution

Solar Tower CSP uniquely combines renewable generation and large-scale energy storage, making it a critical technology for a secure and carbon-neutral energy system.

WHY CSP IS A DIGITALIZATION TESTBED?



CSP TOWER PLANTS ARE:

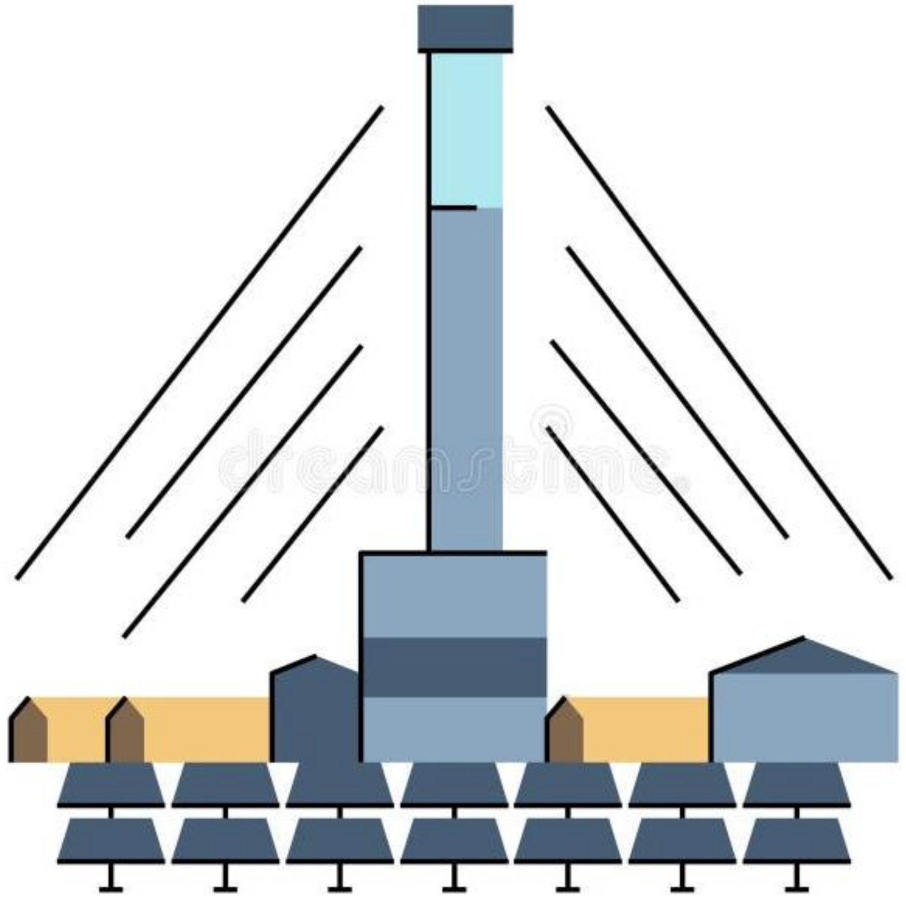
- Highly complex
    - Thousands of heliostats
    - Thermal and optical interactions
- Dynamic
- Data-intensive
- Multi-physics systems

REQUIRES:

- Advanced sensing
- AI-based prediction
- Digital Twins
- Real Time Analytics

If it works in CSP, it's highly valuable for any other energy systems

CSP + DIGITALIZATION



CSP + Digitalization enables:

- Smarter Operation
- Lower O&M costs
- Higher reliability
- Better grid integration
- Industrial Decarbonization
- Smart Energy transition

DIGITAL TOOLS: FROM DATA TO INTELLIGENCE

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Digitalization connects **3 layers**:

MEASUREMENT	MODELING	DECISION-MAKING
▪ Sensors (irradiance, temperature, electrical variables) ▪ Drones, cameras, remote sensing ▪ SCADA and high-frequency data	▪ Physical and performance models ▪ Digital twins ▪ Degradation models	▪ AI & machine learning ▪ Predictive O&M ▪ Dispatch & energy optimization

VALUE COMES FROM INTEGRATION OF ALL 3!!

THE SUN-DT PROJECT

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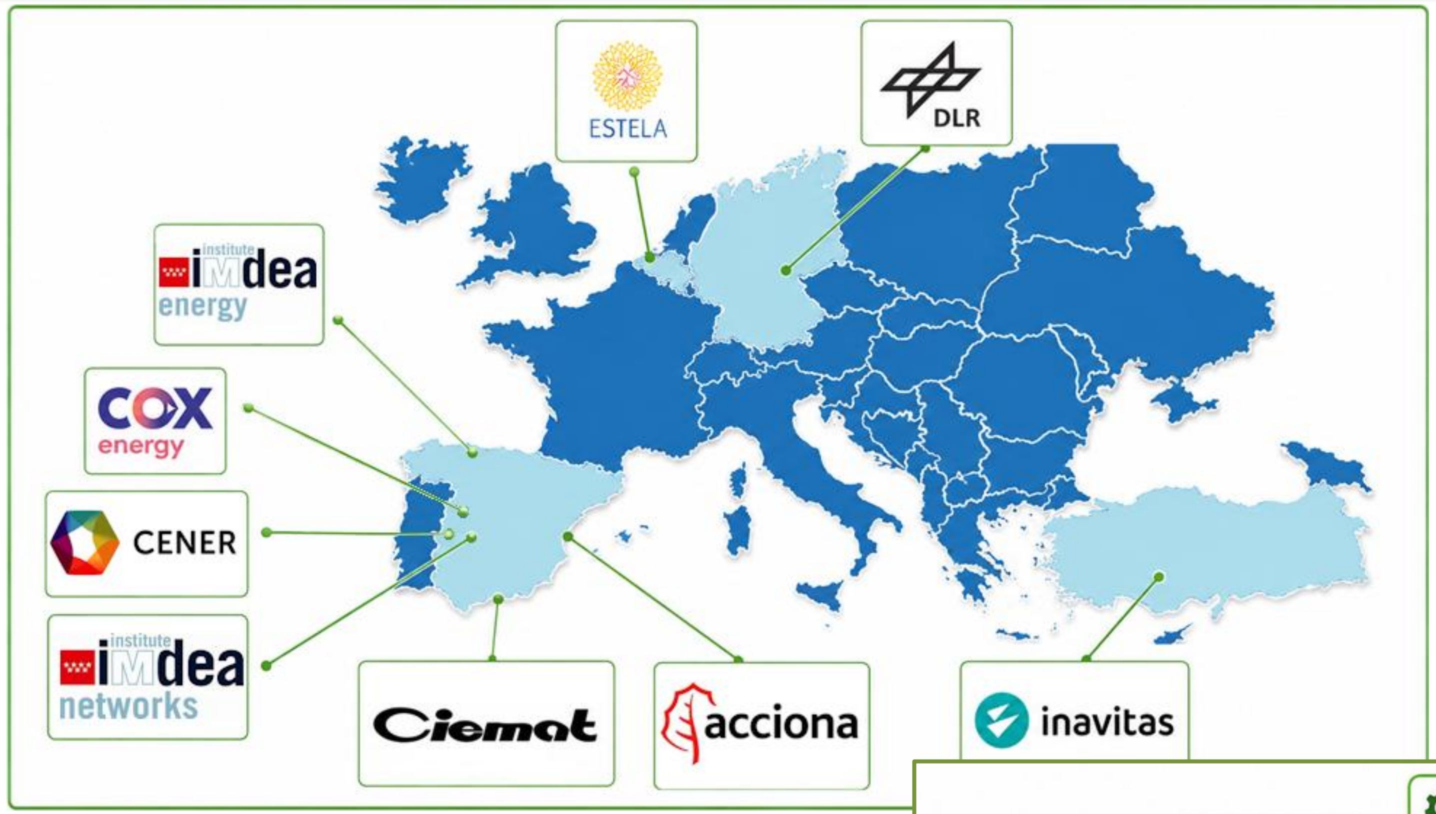
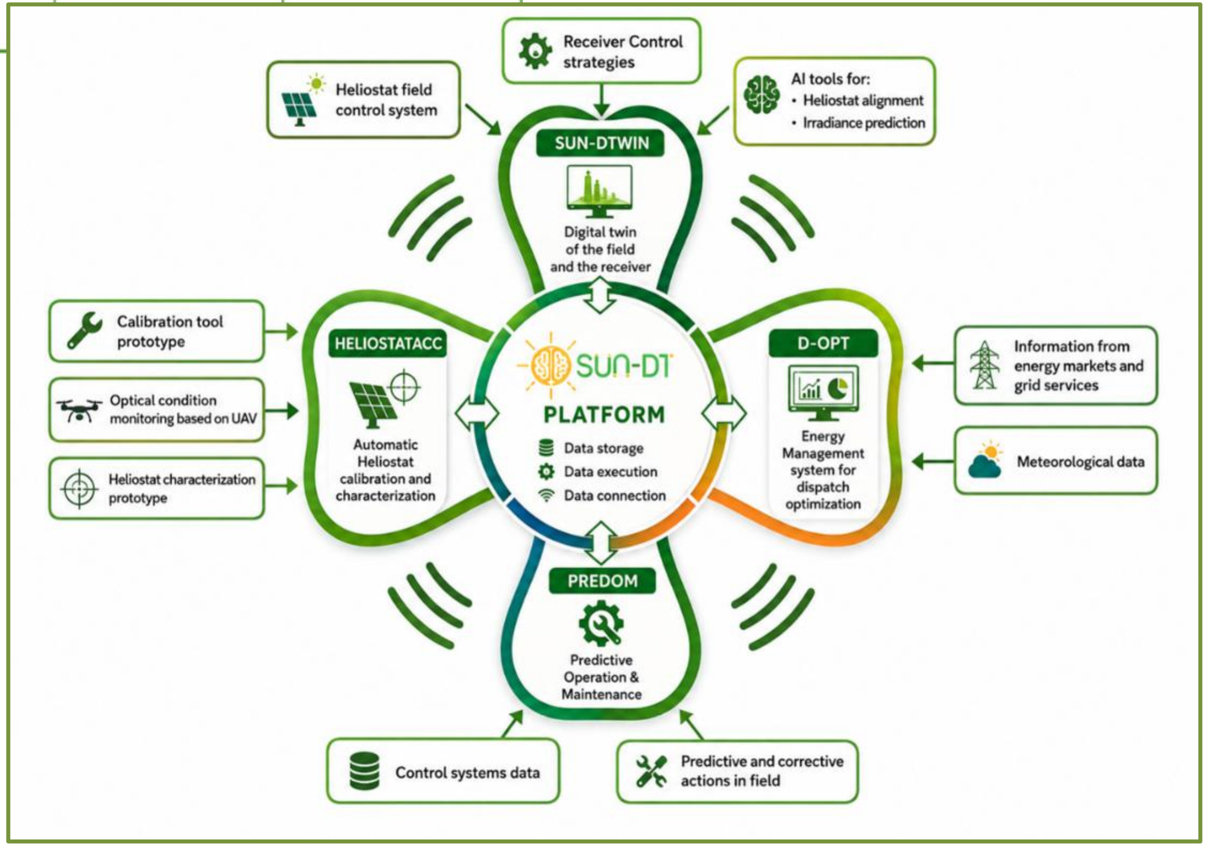


Smart Use of Novel Digital Tools for advanced performance and reduced costs in CSP tower plants



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THE SUN-DT PROJECT

Objective

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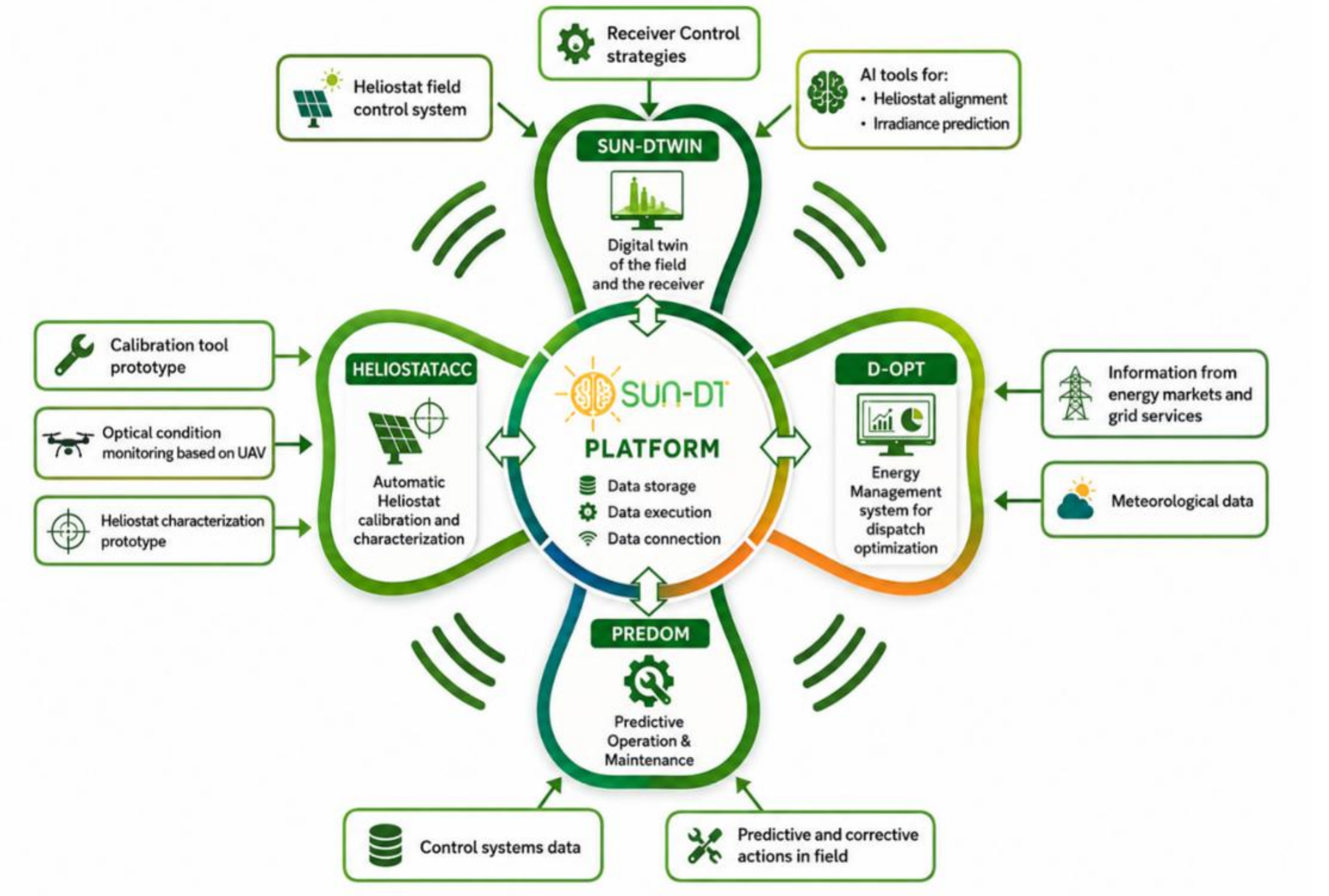
IMPROVE PERFORMANCE, REDUCE O&M COSTS, ENABLE SMARTER PLANT OPERATION

SUN-DT – Develops the Smart Use of Novel Digital Tools

- Advanced **measurement & calibration tools**
- **Digital-twin** of solar field and receiver
- **Energy Management System (EMS)**
- **Predictive O&M tools**

Integration into a **unified decision-support platform**



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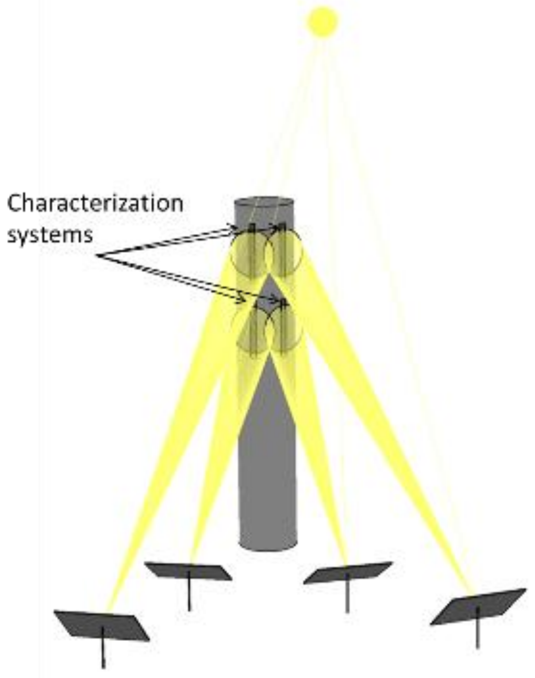
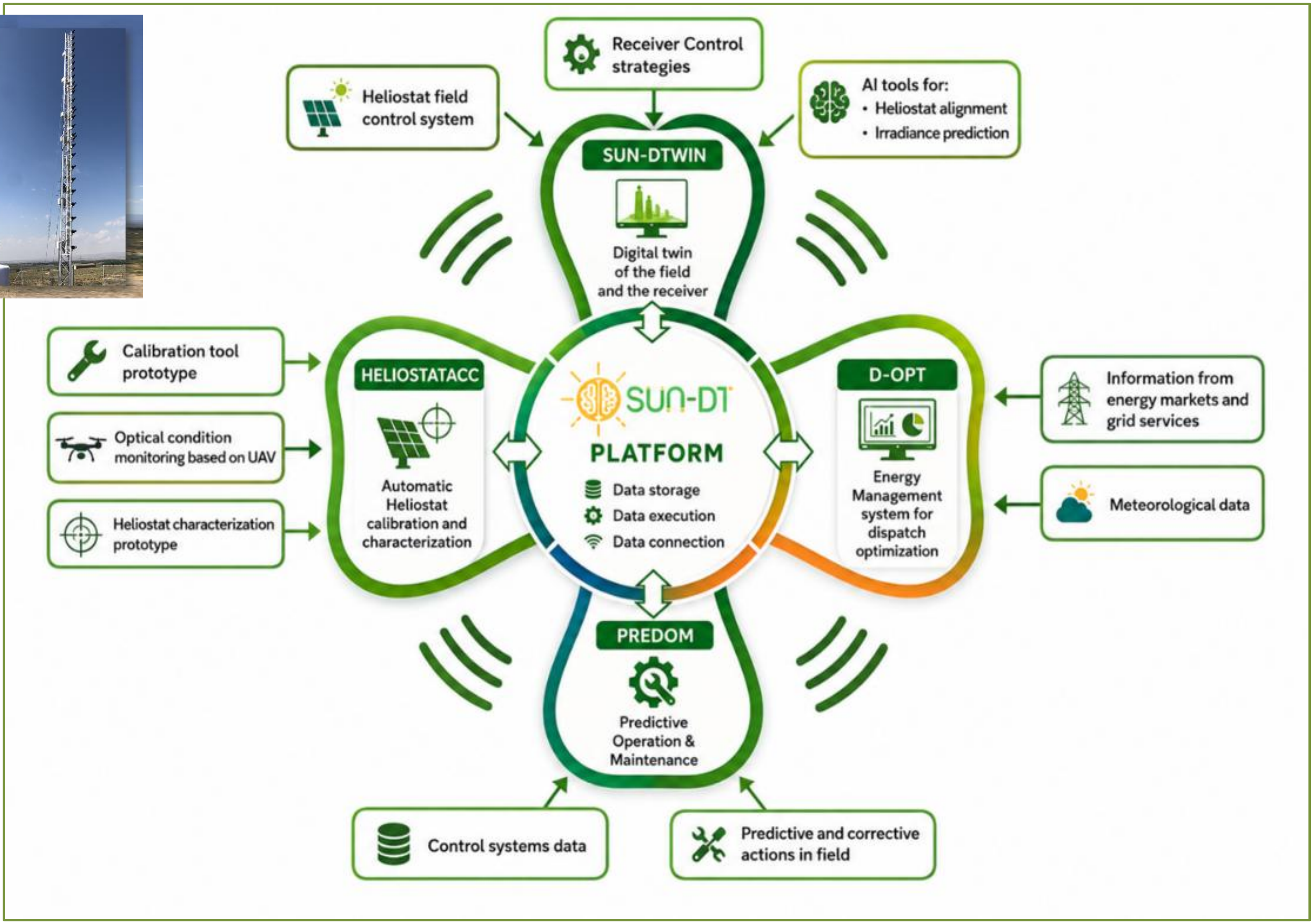
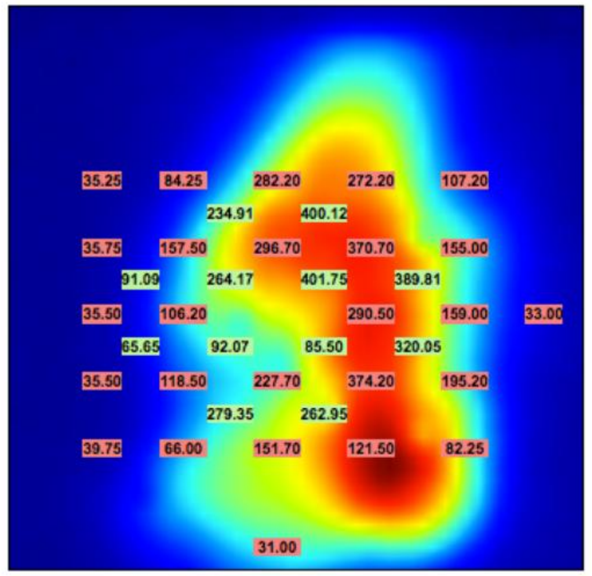
THE SUN-DT PROJECT







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Methodology

SUN-DT

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STAGE 0: SELECTION → STAGE 1: MATURING → STAGE 2: INTEGRATION → STAGE3: TESTING FOR VALIDATION

DIGITAL TOOLS

- Component control
- Performance measurement
- Self-diagnostic
- Ancillary services to power system
- Digital Twins
- Artificial Intelligence

OUR TOOLS

- HELIOSTATACC
- SUN-DTWIN
- D-OPT
- PREDOM

SUN-DT PLATFORM

INTEGRATED DATA. SMARTER DECISIONS

CSP EXPERIMENTAL TEST FACILITIES


IMDEA


JÜLICH

COMMERCIAL CSP PLANTS


CERRO DOMINADOR


KHI SOLAR ONE

OPTIMIZE
Smarter design and operation

INTEGRATE
Seamless tools and workflows

VALIDATE
Reliable testing in real conditions

DELIVER
From R&D to commercial plant

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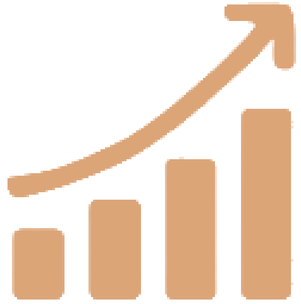
Expected results (I/II)

- **Increase in overall plant efficiency (4–10%):**

  – Improved efficiency of the heliostat field and receiver.
  – Fewer faults thanks to predictive maintenance.
  – Less unplanned downtime (higher availability).

- **Improvement in annual output (+5%):**
  – Up to 99% availability of the solar field → +2–3% in thermal output.



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Expected results (II/II)

- **Reduction in OPEX (~15%) through:**
  - Automation of tasks and reduction in human error.
  - Predictive control of operating modes.
  - Reduced need for corrective maintenance.

- **Reduction in CAPEX (~3%):**
  - Optimized design of the solar field without oversizing.

DIGITALIZATION IN SOLAR ENERGY AND THE ENERGY TRANSITION: CHALLENGES AND OPPORTUNITIES

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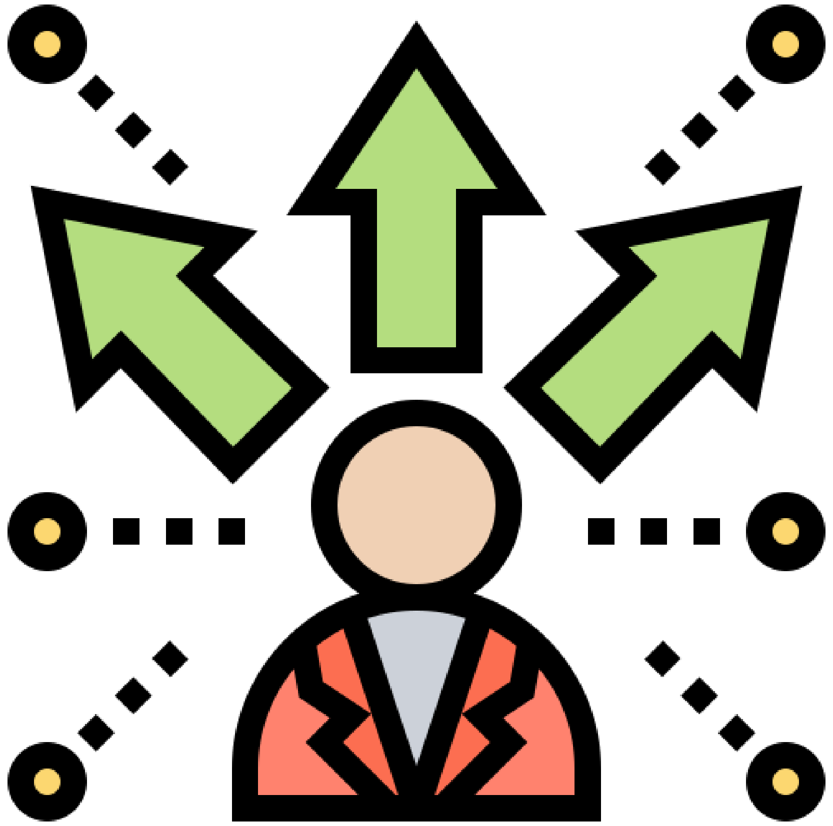
CHALLENGES:

- Data management, **cybersecurity,** and standardization
- Implementation and training **costs**
- Need for **regulation** and industry **collaboration**



OPPORTUNITIES:

- **New** data-driven **business** models
- **Digital twins** for design and optimization
- **Greater reliability** and transparency

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Digitalization for an Inclusive Energy Transition

- The model shifts from a single consumer to a system with **prosumers**
- **Real-time data availability** on energy generation, consumption, and storage
- Greater **transparency** on environmental footprint, costs, and energy origin
- More **informed energy decisions:** what to consume, when, and why
- **Grid management** becomes a **shared responsibility**

CONCLUSIONS

CSP + Digitalization = Intelligent Renewable Energy

✓ Digitalization is transforming renewable energy systems
✓ CSP is an ideal platform for AI, Digital Twins and advanced analytics
✓ Solar Tower CSP provides renewable electricity, large-scale storage, grid flexibility and industrial decarbonization
✓ SUN-DT demonstrates how intelligent tools can improve efficiency, reliability and competitiveness

The future **energy system needs** renewable assets that are **clean, dispatchable and intelligent.** Through AI, Digital Twins and advanced analytics, **SUN-DT is helping Solar Tower CSP evolve** towards that vision.

SUN-DT

Smart Use of Novel Digital Tools for advanced performance and reduced costs in CSP tower plants

Thank you for your attention!

Marcelino Sánchez

Email: msanchez@cener.com

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SUN-DT

Smart Use of Novel Digital Tools for advanced performance and reduced costs in CSP tower plants

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DIGISOLAR in a NUTSHELL

Dr. Daniel Carbonell
Dr. Xavier Albets-Chico
DCARBO ENERGY CONSULTING
DIGISOLAR Coordinator Team

Advanced digital tools for optimised planning, maintenance and operation of solar thermal hybrid systems

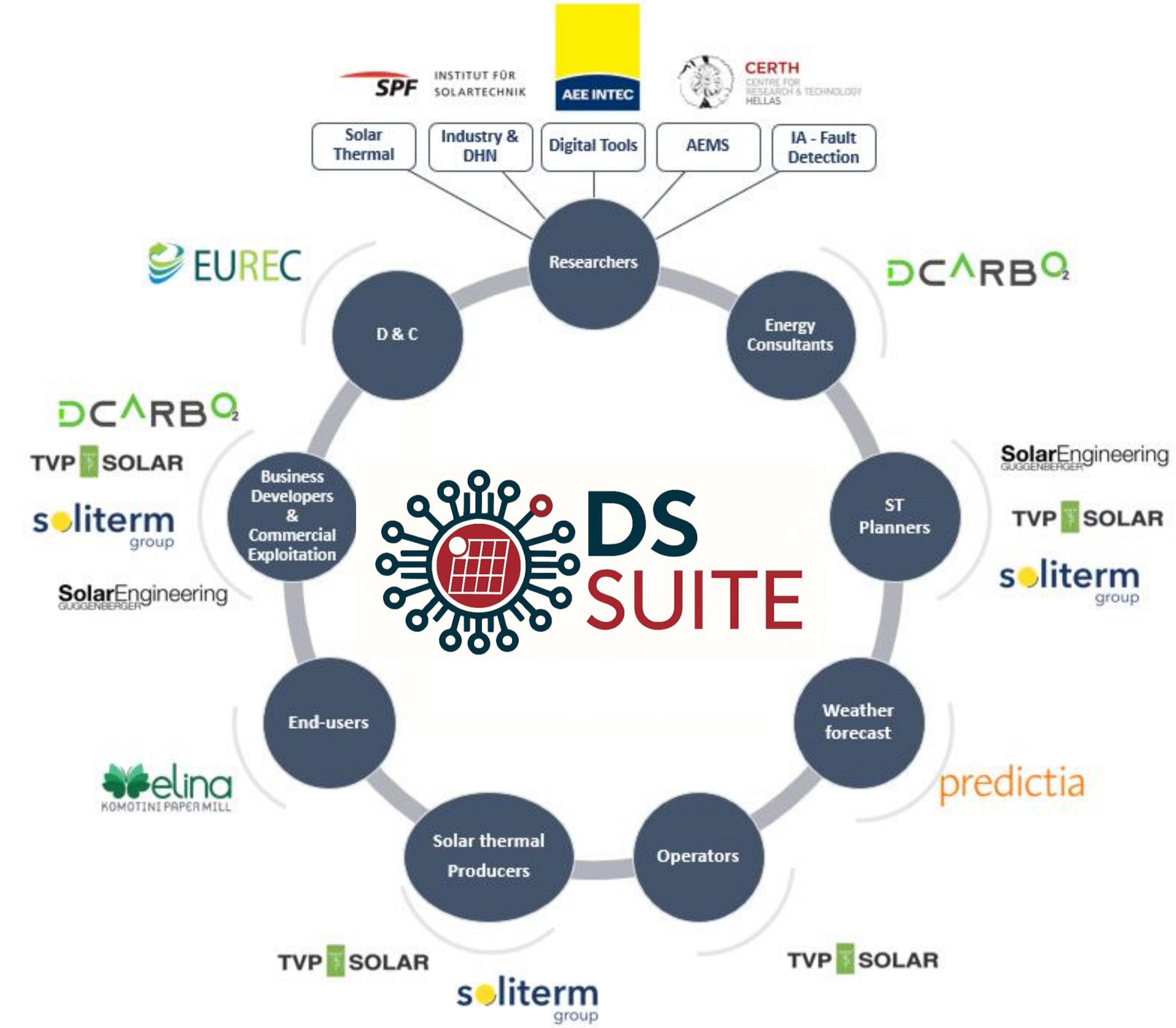
DIGISOLAR will reinforce Europe's leadership in renewables, driving a sustainable future.

DIGISOLAR

DCARBO2

General data, consortium and project budget

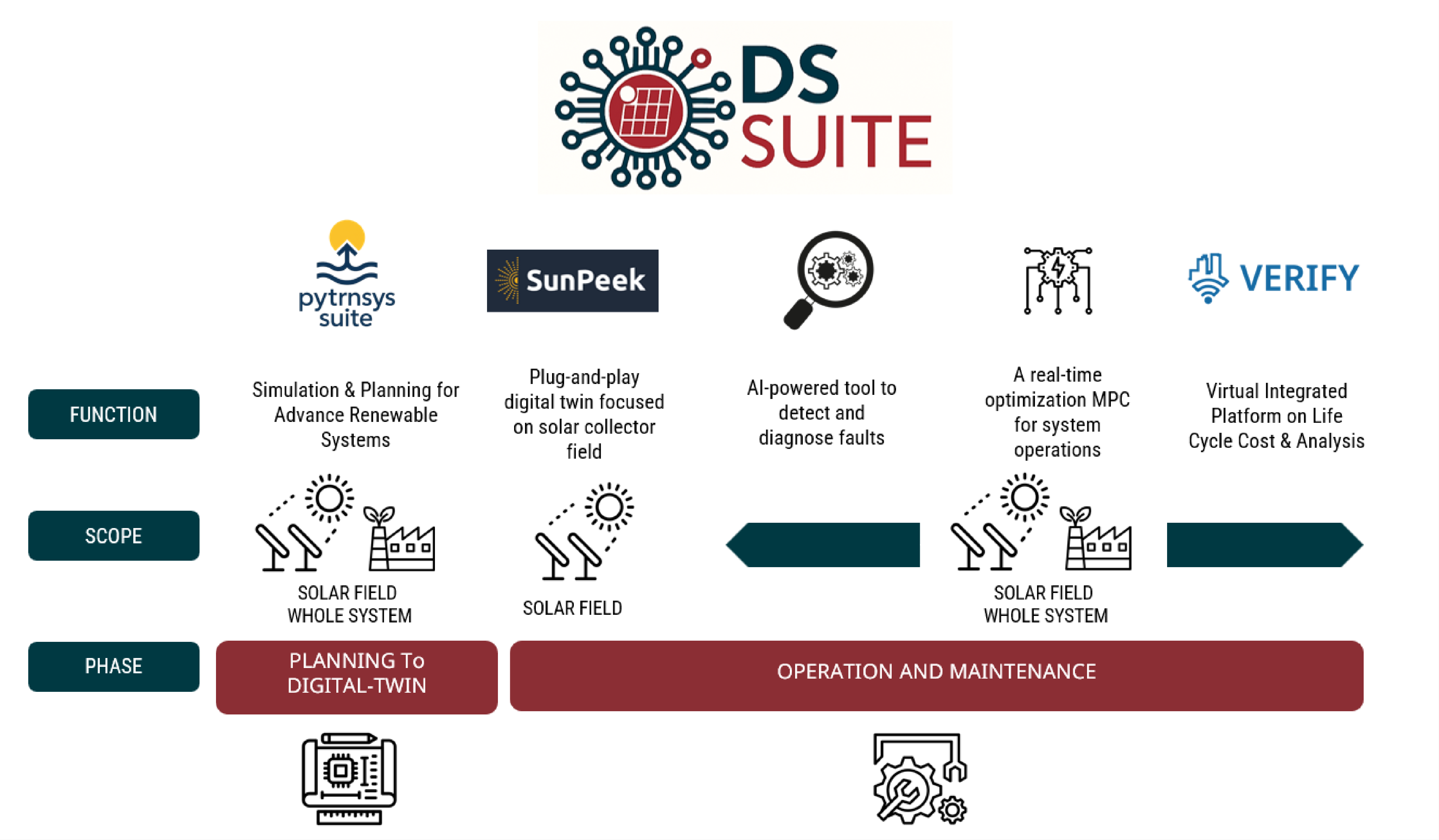
- **Budget**
  - Overall 5.7 M€
  - EU funded 2.9 M€
  - Swiss funded 2.0 M€
- **Start 01.09.2025; End: 31.08.2029**
- **11 partners, 7 countries**
- **End TRL 7**
- **Demonstration in 4 pilot plants**



Video available here

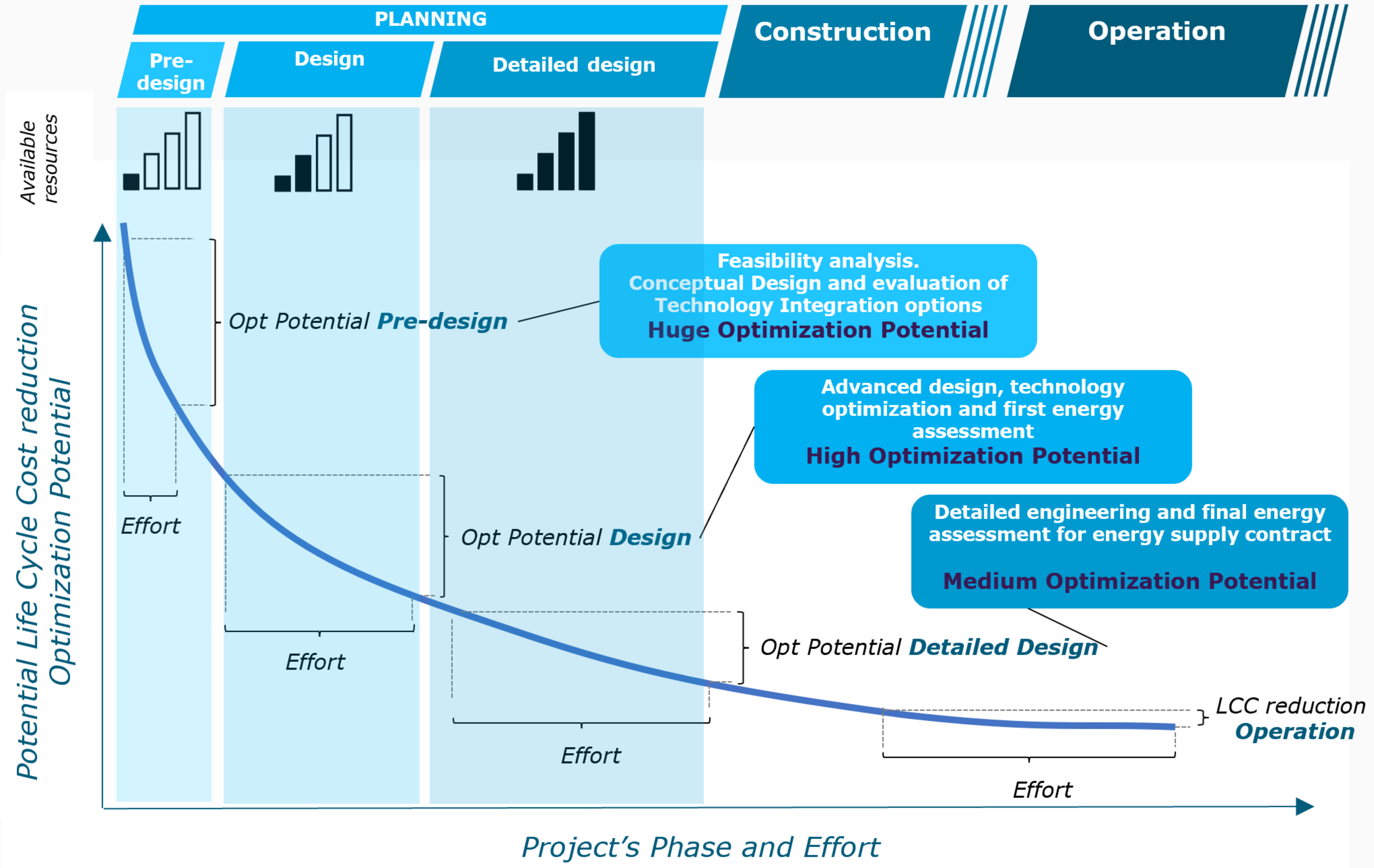
The DIGISOLAR software suite (DS Suite)

- Support planning, operation and optimisation of large-scale hybrid-ST systems
- Achieve high shares of renewables to accelerate the decarbonization for industrial process and DH



All-in-one harmonized Planning to digital-twin at system level

pytrnsys suite



DIGISOLAR

SPF INSTITUT FÜR SOLARTECHNIK

DCARBO2

SunPeek: Quality assurance tool for solar termal plants in operation

Friesach,
Source: Solar Engineering Guggenberger

Högslätten Härnösand
Source: Absolicon

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

SunPeek

Performance Verification

„Does the solar plant perform as expected?“

Performance Monitoring

„Does performance change over time?“

DIGISOLAR

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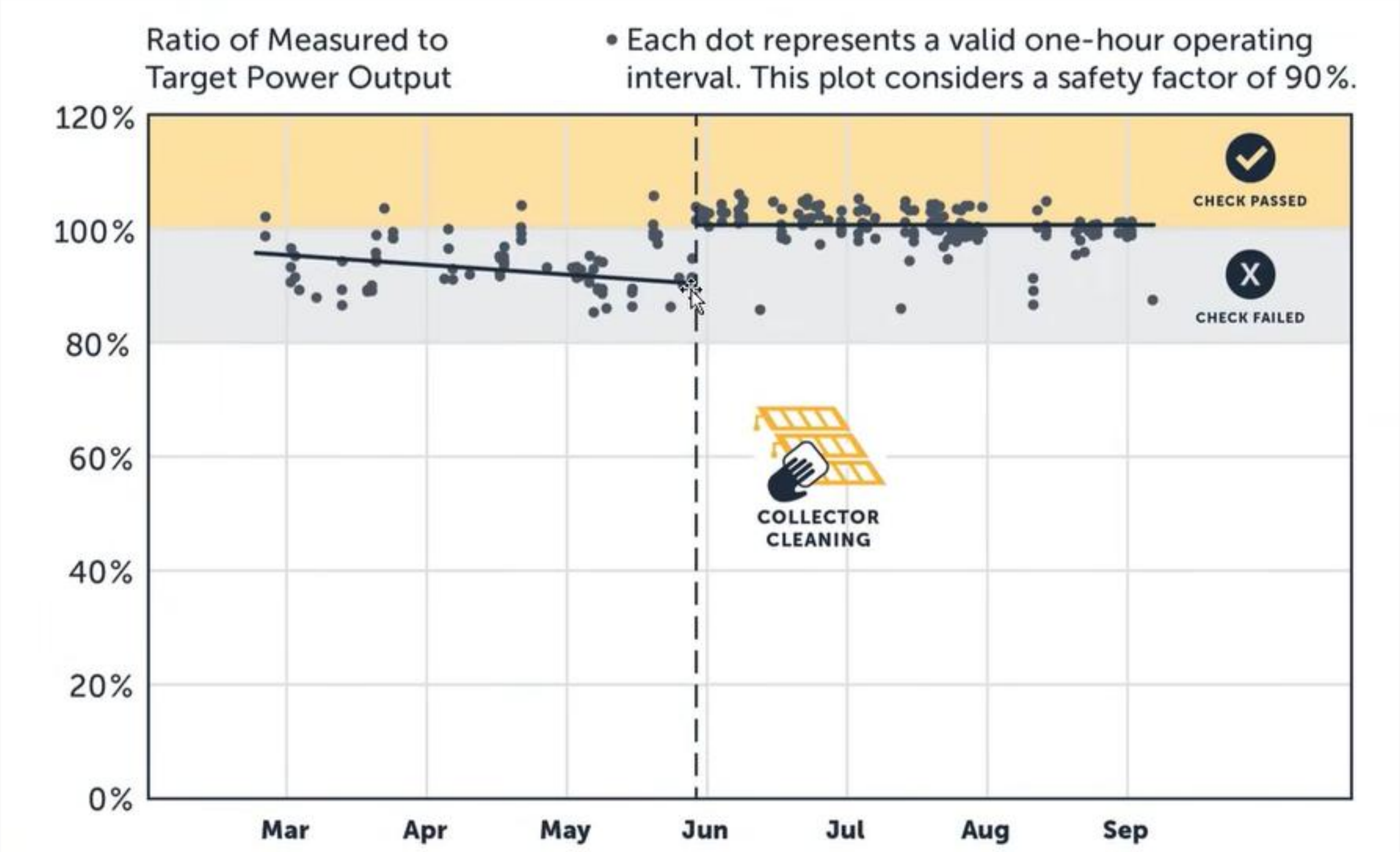
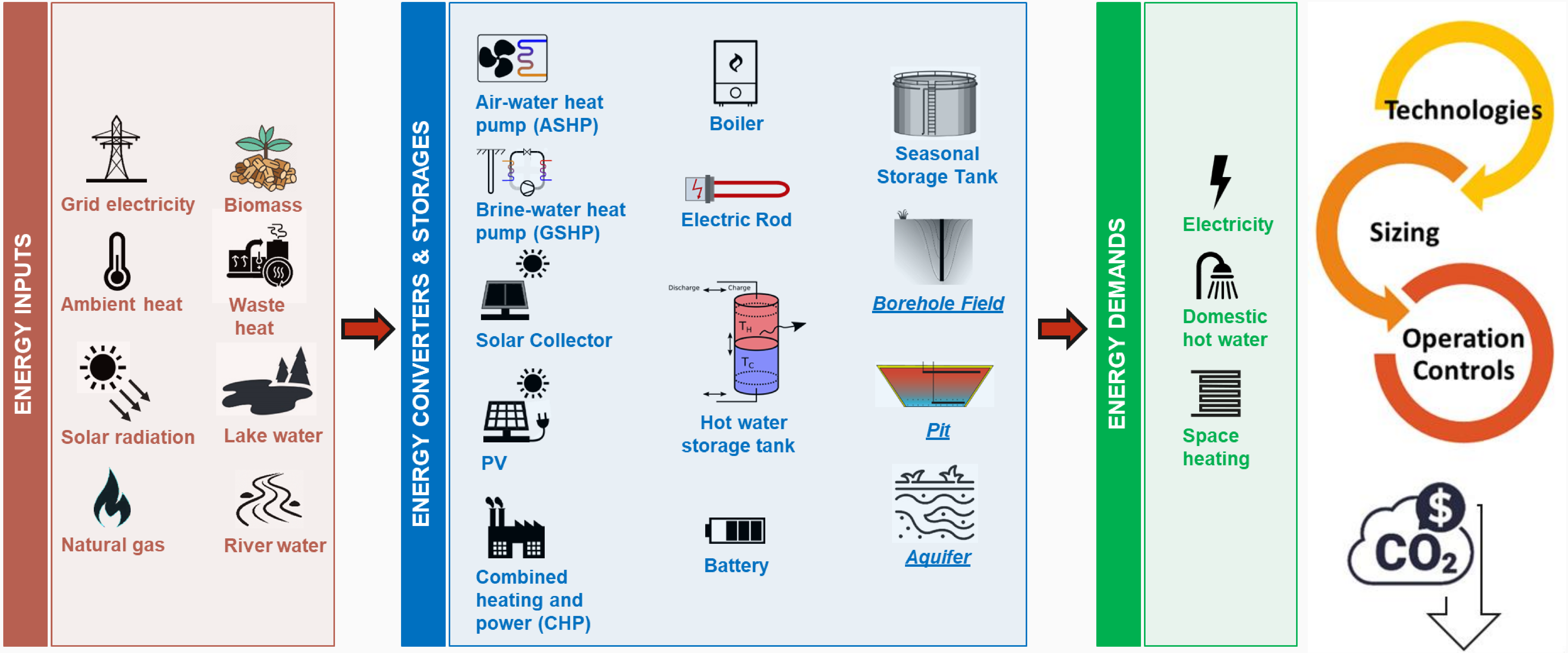


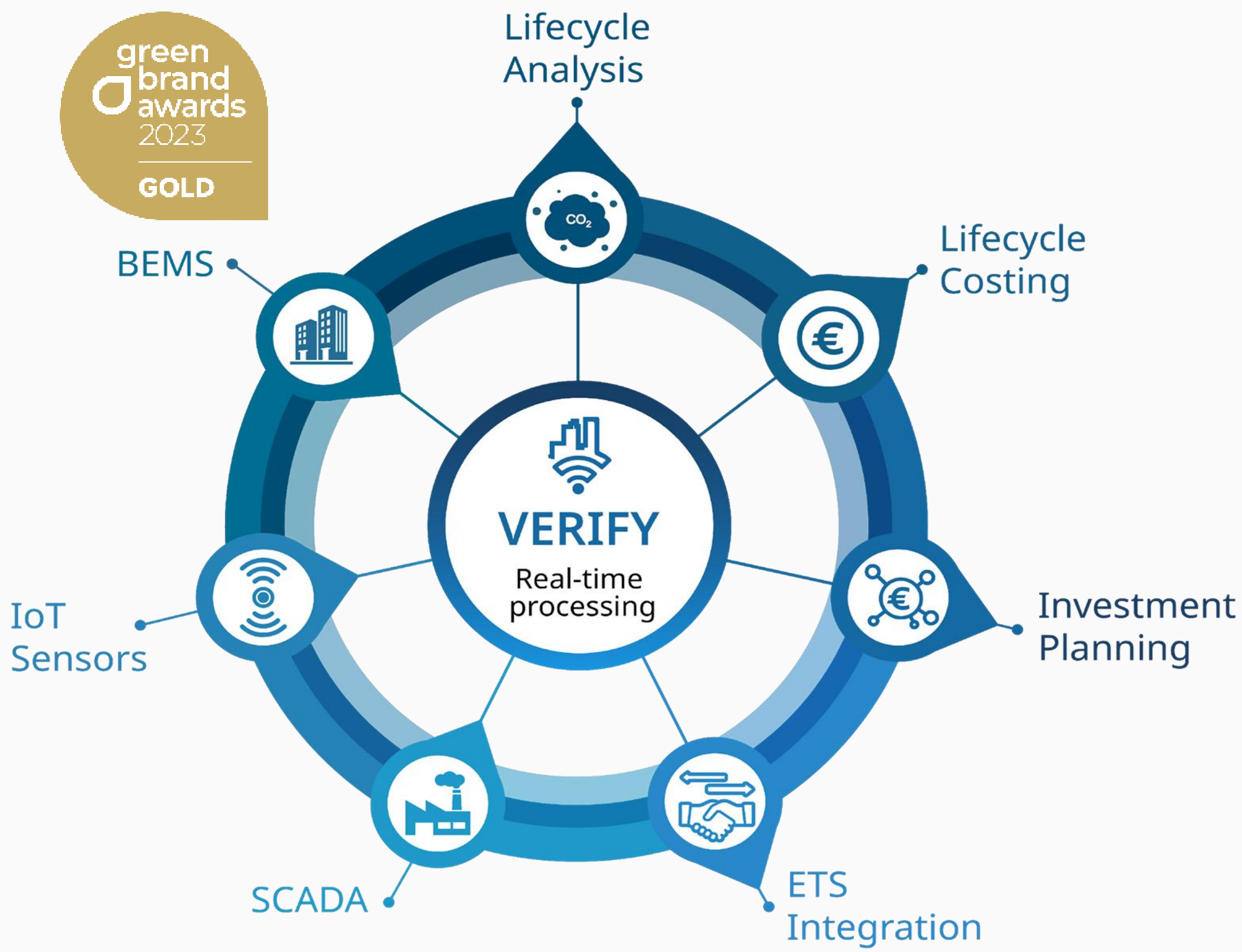
FDD: Fault detection and diagnosis

- Ratio of measured to target power output
- Each dot represents a valid one-hour operating interval.
- This plot considers a safety factor of 90%

AEMS: Advance Energy Management System for optimal dispatch



VERIFY: Life Cycle analysis (LCA) and Life Cycle Costs (LCC)



- Accounts for **real-time field production** and **consumption** data of energy components & **dynamic** changes in the energy, environmental and economic landscape
- Utilizes both **primary** (IoT) and **secondary** (APIs) data
- Designed for EU's **Emissions Trading System (ETS2.0)** - *operational by 2027-*
- Combines multiple **commercial** and **innovative** technologies for energy production, management and storage. **Parameters can be adapted:** per demo, per thermal comfort preferences, per billing systems, per energy infrastructure
- Follows international standards, such as **ISO 14040 / 14044**

District Heating (Italy)

- High Vacuum flat plate collector
- Collector area: 1’000 m2   - 707 kW peak power
- Thermal energy storage: 350 - m3
- Other technologies: CHP, heat pump (147 kW)

DIGISOLAR

engie TVP SOLAR DCARBO2

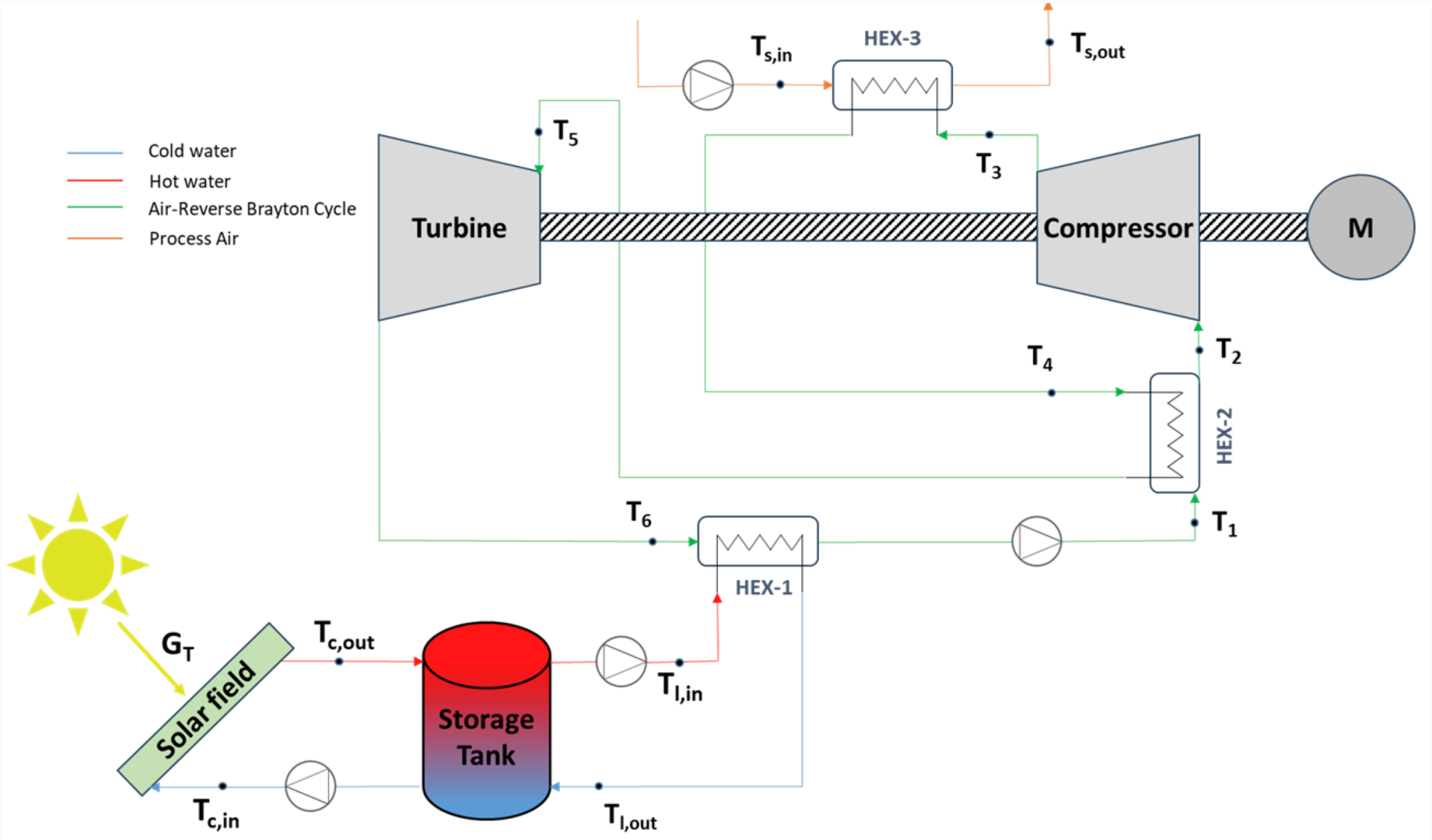
Pulp and Paper (Turkey)

- Parabolic through collectors (PTC)
- 10’000 m2 - 3.5 MW
- Thermal energy storage: 350 - m3
- Process cooling , air conditioning and hot water
- Absorption chiller 4.9 MW (cooling)

Food processing and district heating (Germany)

- Flat plate collector (Savosolar)
- 28’872 m2 - 20 MWth
- 12.8 GWh/year; 443 kWh/m2
- Hot water 75 ºC
- TES 8’000 m³
- Solar contribution 50 %
- 16 MWth biomass boiler
- 2 x 350 kWth biogas generation
- 1.1 MWe co-generation
- 2 MWp PV

Pulp and paper (Greece)



- Steam generation
- High Vacuum Flat plate collector
- 700 m2 HVFP with 400 kWth
- 100 kWp PV
- 15 m3 water TES at 130 ºC
- 9 MW Biomass steam boiler
- 378 kW high temperature heat pump
- Air Brayton cycle
- 195 ºC

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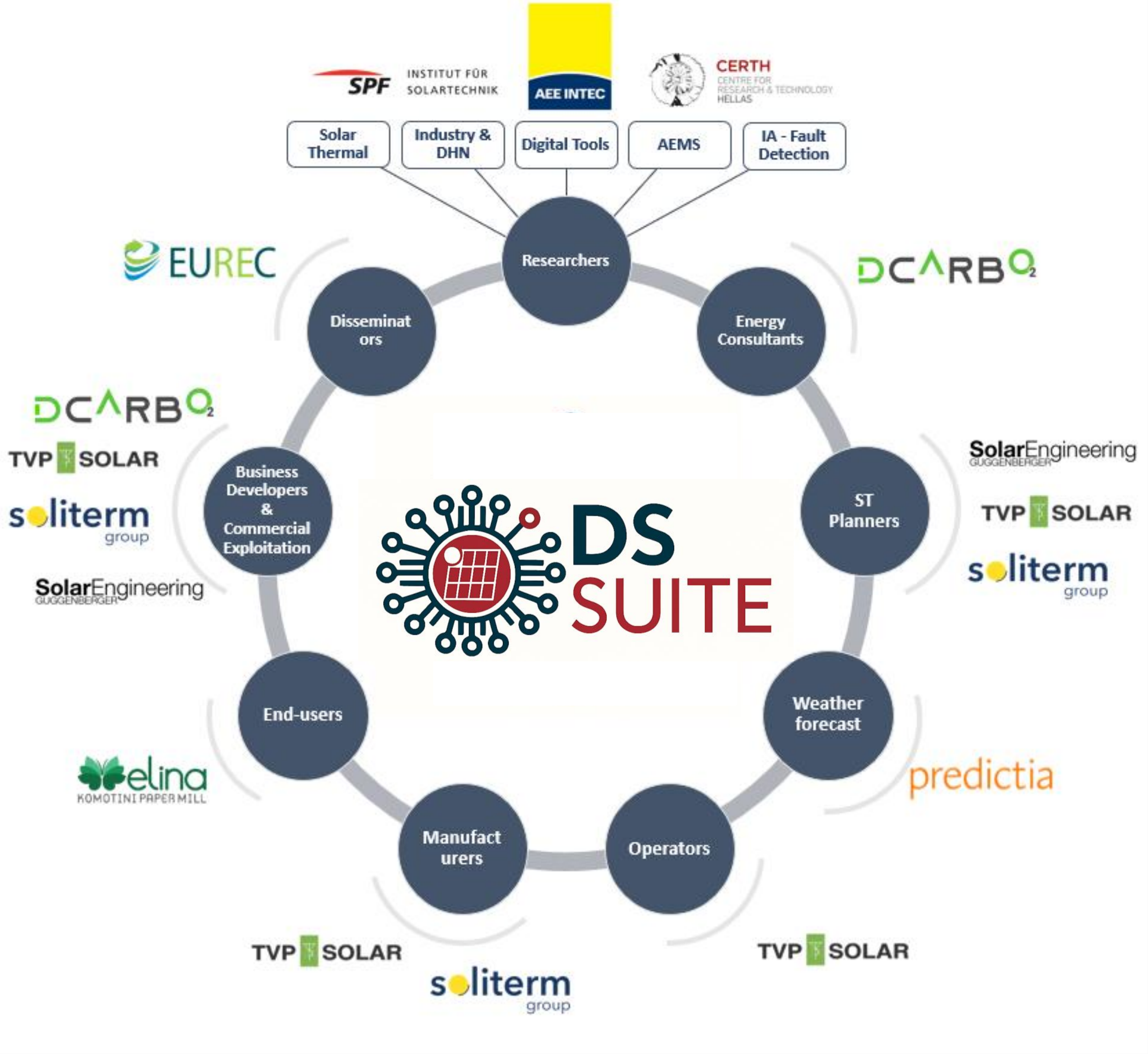

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DCARBO ENERGY CONSULTING S.L.

DIGISOLAR

SunPeek *Performance Monitoring for Solar Thermal*

Marnoch Hamilton-Jones
SunPeek Maintainer
AEE Institute for Sustainable Energies

AEE INTEC

Robust, standards backed performance verification and monitoring for operation solar thermal plants

SunPeek Philosophy

Design

Operation

ISO 9806

EN 12975

EN 12976

ISO 24194

"Solar energy — Collector fields — Check of performance"

SunPeek

Auswirkungen

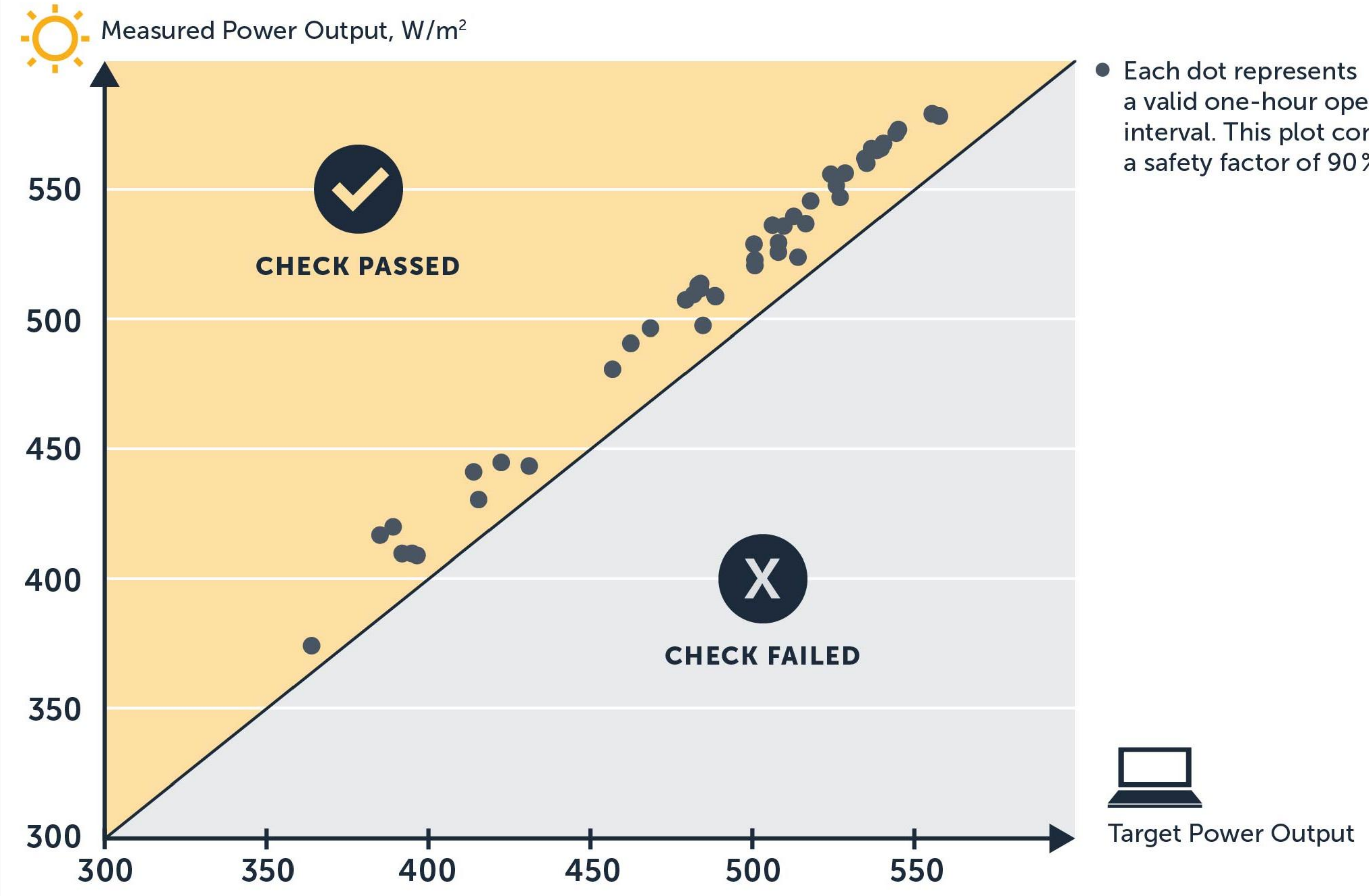
Performance Verification

„Does the solar plant perform as expected?"

Performance Monitoring

„Does performance change over time?"

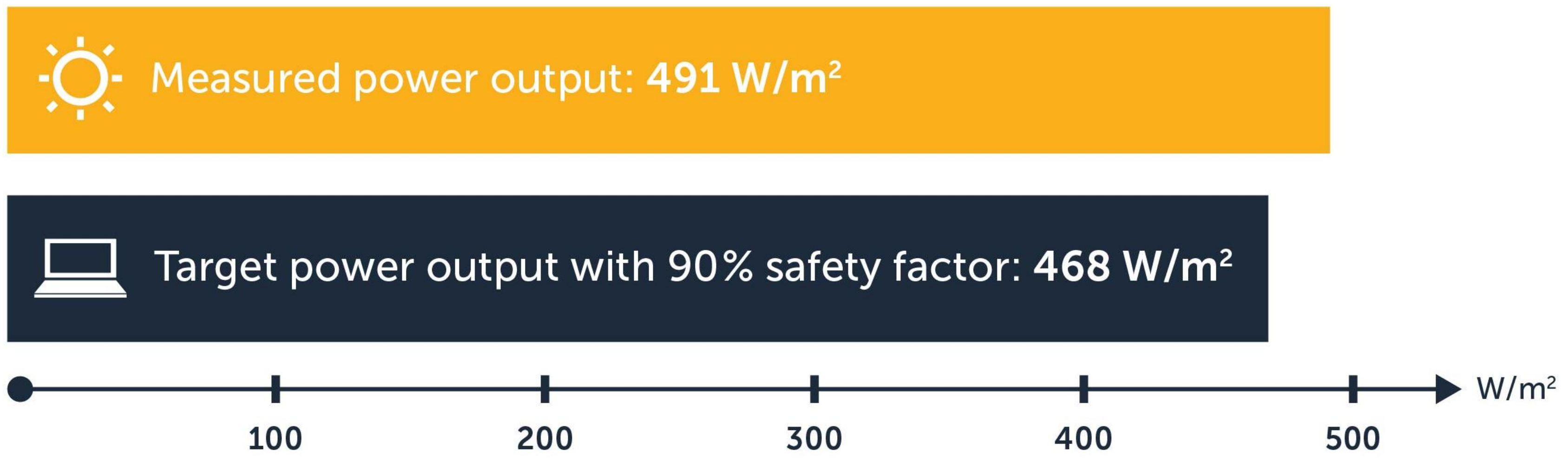
How does it work?



- Each dot represents a valid one-hour operating interval. This plot considers a safety factor of 90 %.

Power Check is fulfilled if measured power output during valid operating intervals is greater than target power output including safety margin.

A check requires at least 20 hours with stable plant operation.



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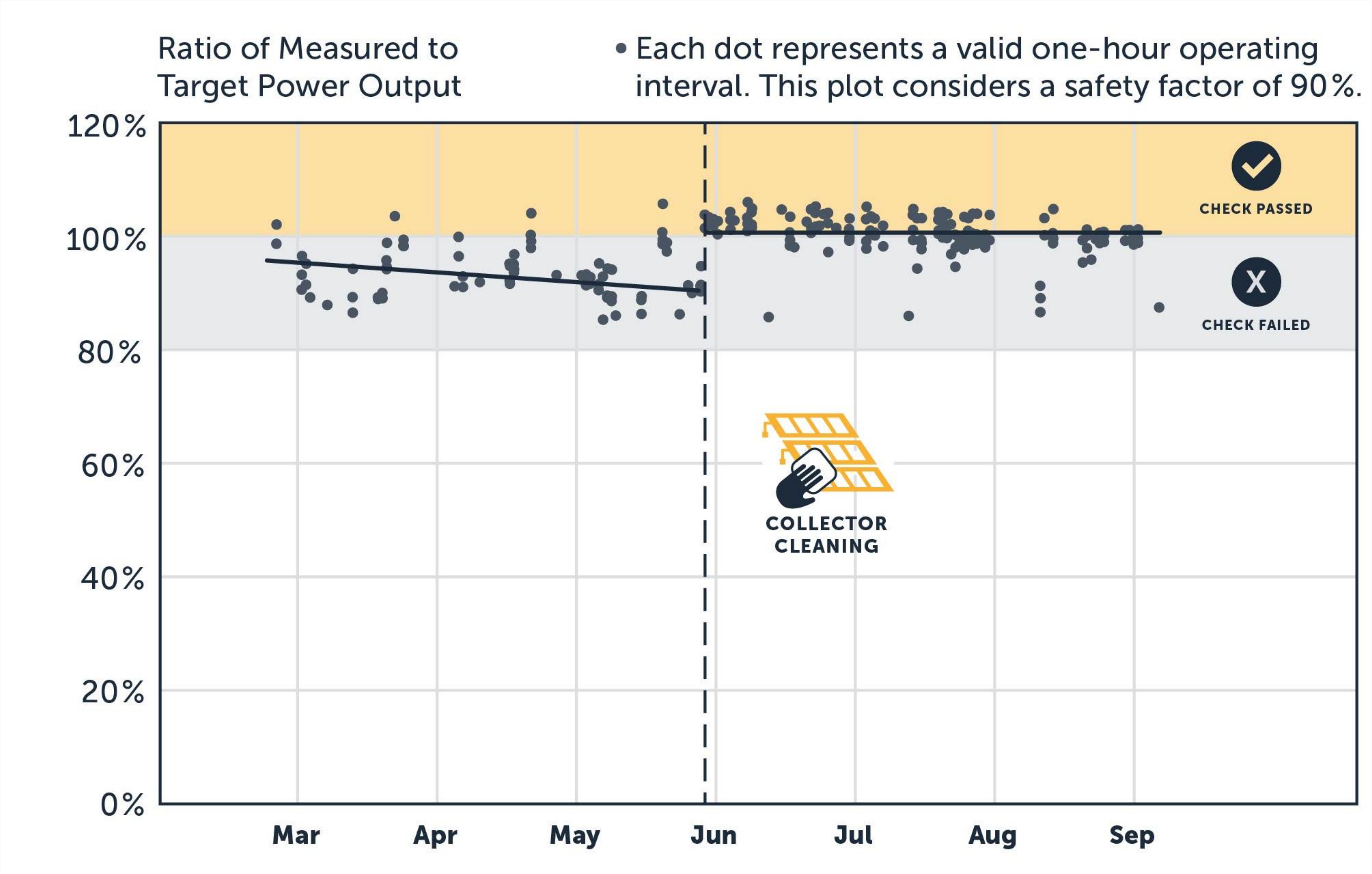
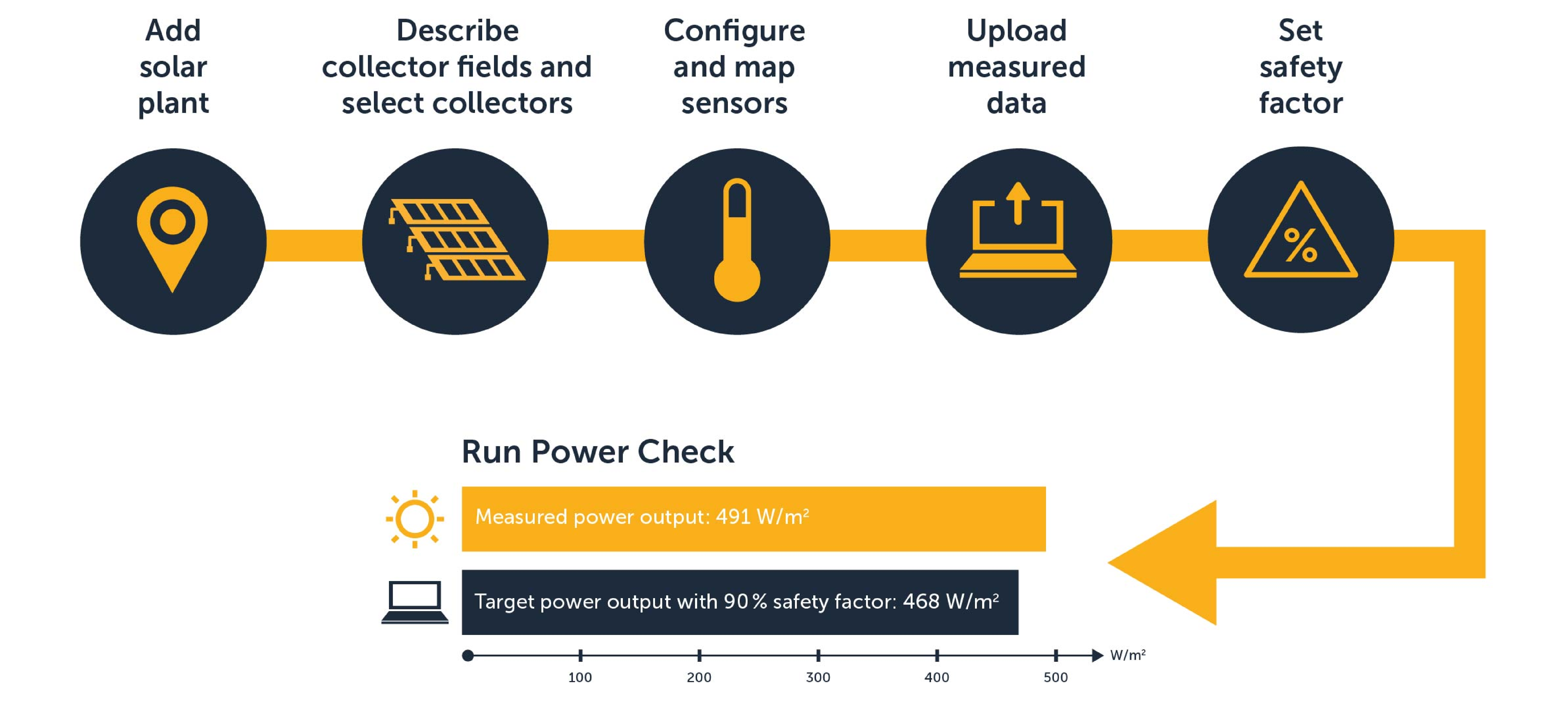
SunPeek for ongoing Monitoring



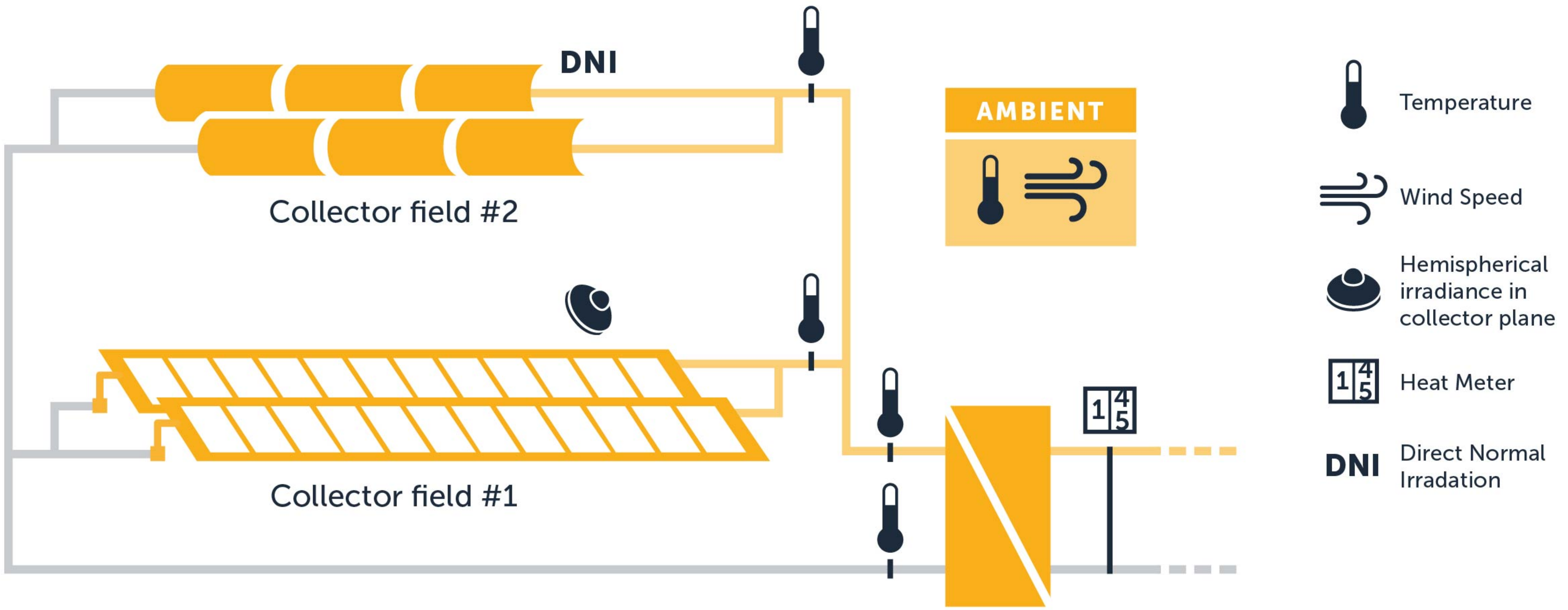
Steps to SunPeek Power Check



Power Check: Required Data - Case example

Which sensors do you need to run the Power Check?

The required sensors depend on the system hydraulics.
This is one possible measurement setup.



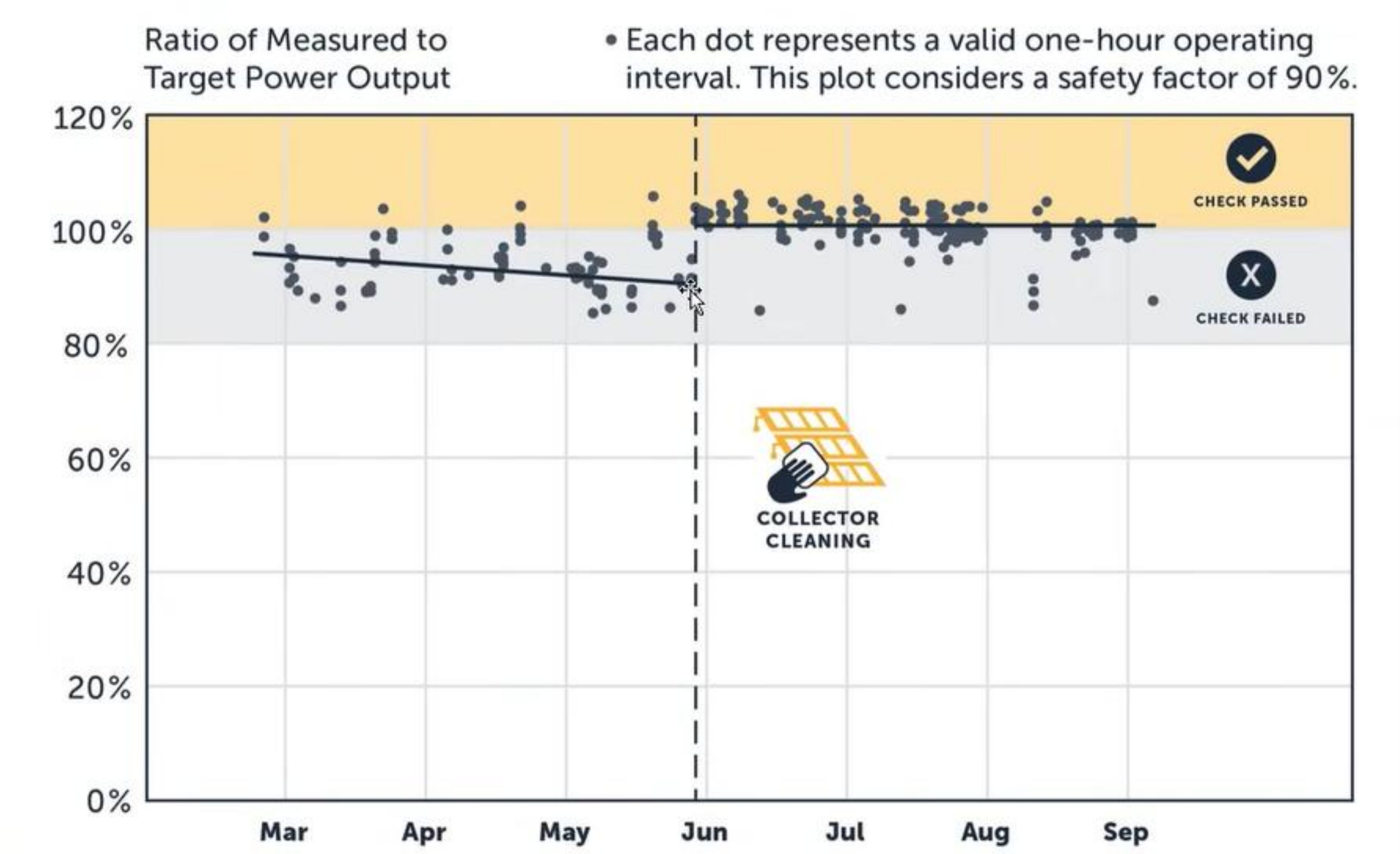
New Features

New functionality for the DigiSolar Suite, integrated via SunPeek

DIGISOLAR

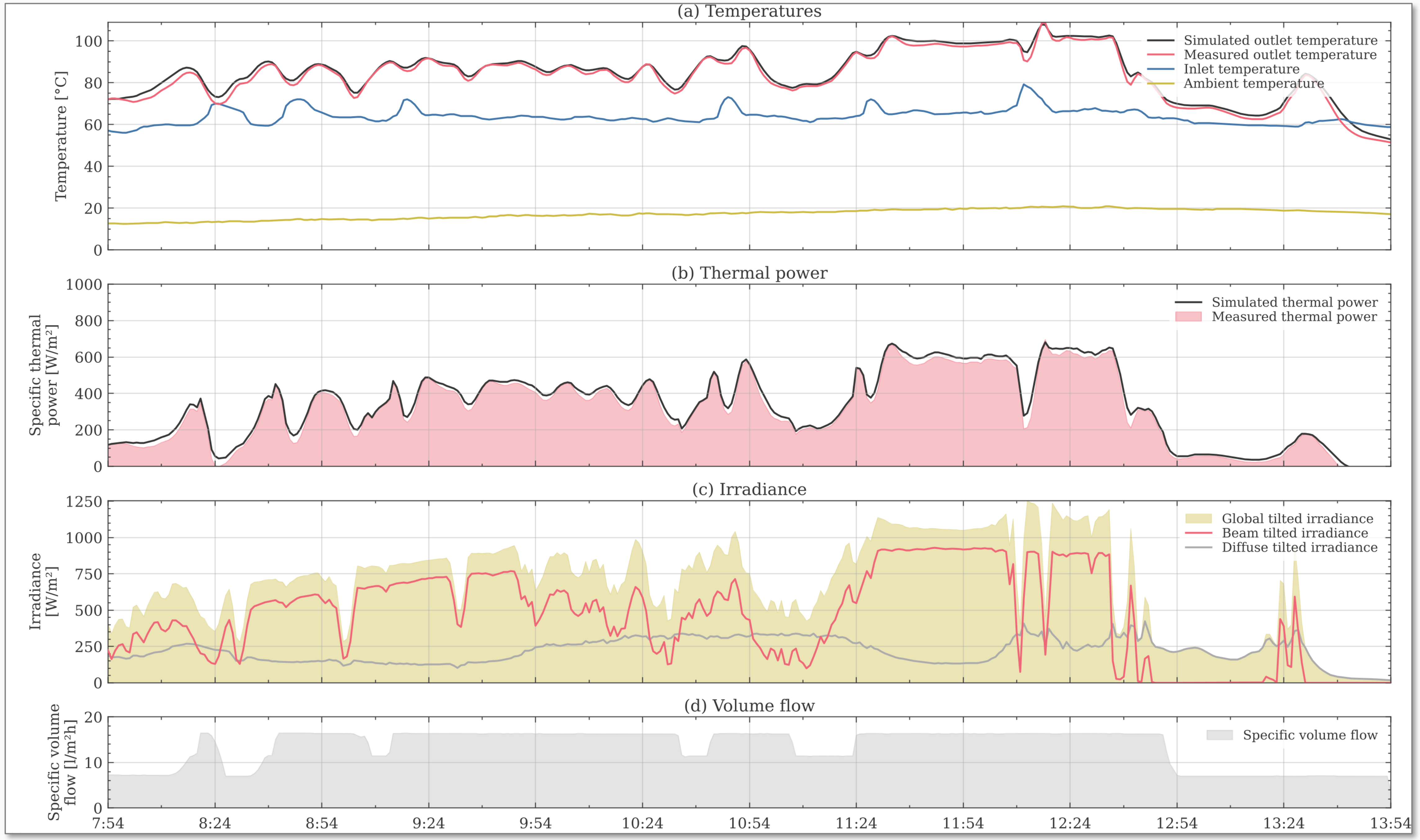
DCARBO2

Detection of Performance Anomalies



- Gradual degradation of performance can be hard to spot
- Can be cause by e.g. collector soiling, insulation degradation etc.
- Explicit detection methods will be added during DigiSolar
- Detection of certain short-term anomalies (e.g. tracking drift for tracked collectors) will also be added

SunPeek: D-CAT Method



- Integration into SunPeek in DigiSolar
- Dynamic model of the collector array
- Can be used in periods where ISO methods find few valid intervals due to stable operation filtering criteria
- Potential to spot performance issues sooner
- Future extension: yield forecasting based on actual condition of array.

Analysis Process

Triggering SunPeek Data Ingestion and Analysis

- **General User** → manual use → Javascript web app
- **Technical Expert** → automatic use → Python API
- **Monitoring System** → automatic use → http REST API

Plant Configuration *[manual, one-off]*

- **Component definition**: Define location and main components: collectors, collector fields, etc. Define settings like collector area, tilt and azimuth angles, row spacing.
- **Data channel mapping**: Map data channel names to components. Define sensor settings and physical units.
- **Configuration storage**: Plant configuration stored in SQL database.

Data Ingestion *[automatic]*

- **Data Parsing**: Parse raw input data to time series. Attach configuration info: Physical units, type of error checks
- **Virtual Sensors**: Calculated time series data. Allows introducing custom data models.
- **Sensor data storage**: Time series sensor data stored in Parquet storage. Includes both measured and virtual sensors.
- **Data Handling**: Run on-the-fly gross error checks on time series data. Provide quality-checked data as pandas Series.

Data Analysis *[automatic]*

ISO 24194 Power Check

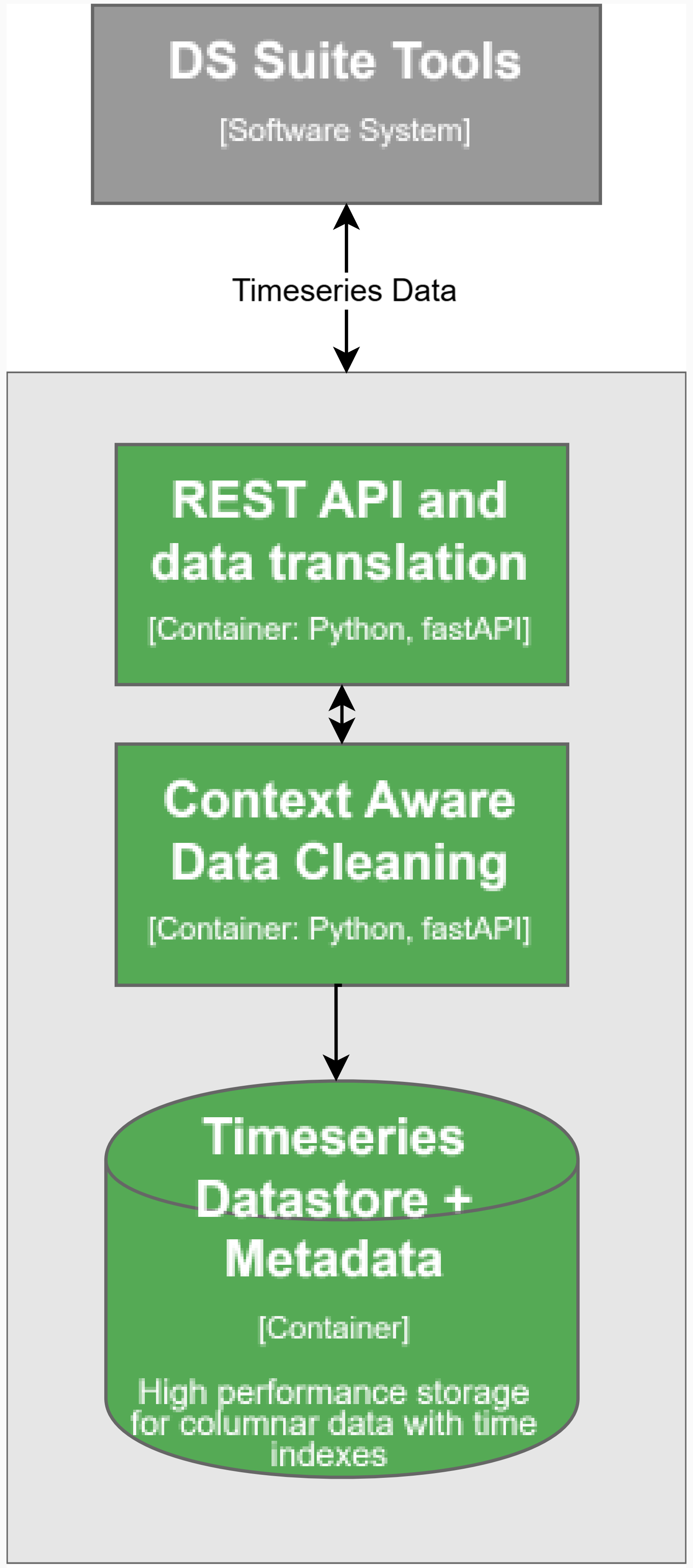
- Algorithm
- Reporting
- Result Export

Other analysis methods:
D-CAT, annual yield check, etc.

- Algorithm
- Reporting
- Result Export

Data Management

- Existing robust context aware data processing and error checking architecture will be moved to new component built in DigiSolar
- All tools in the suite will benefit from this this data handling through central data ingestion and storage component



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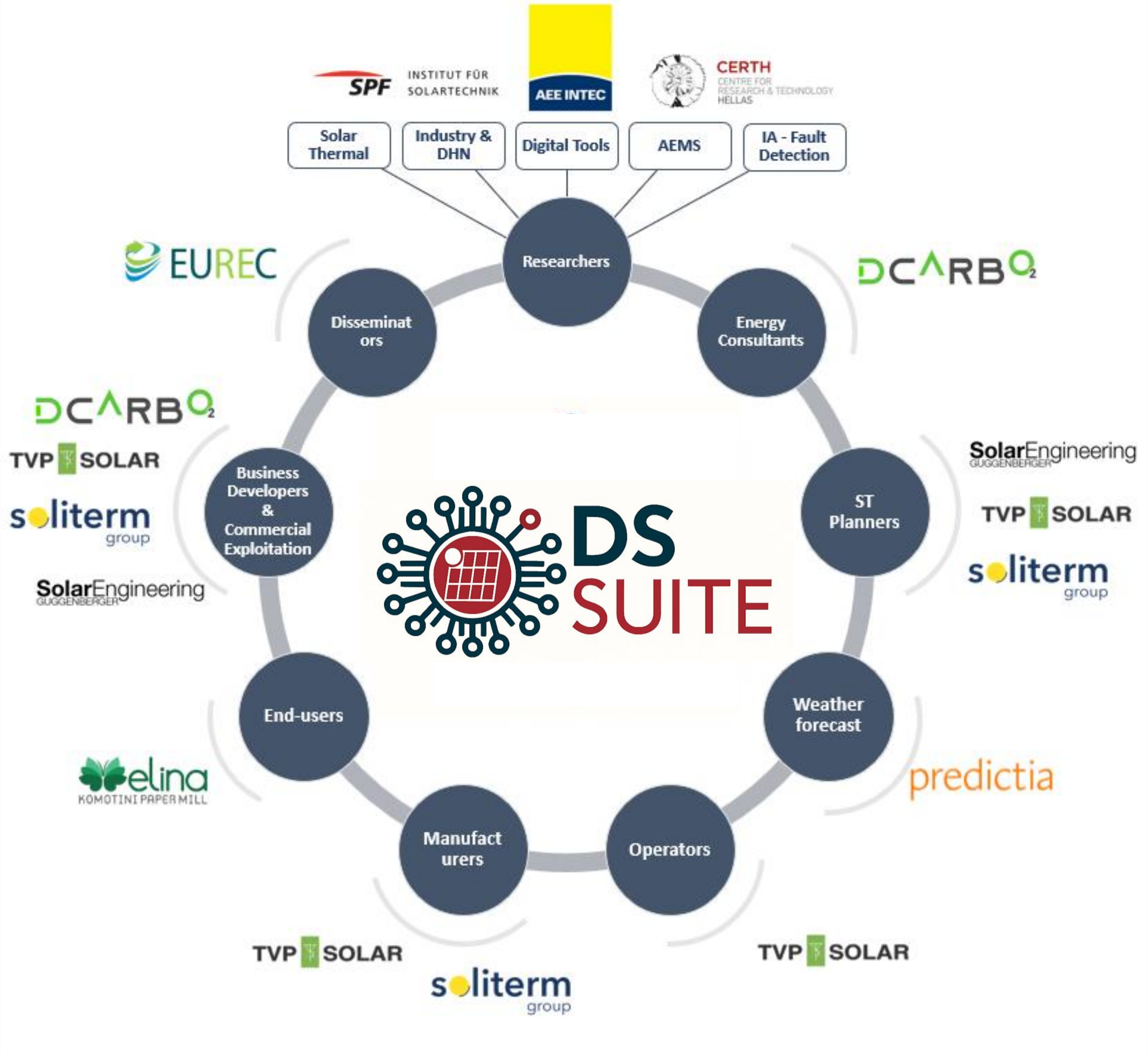

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Renewable Energies Group

DIGISOLAR

pytrnsys suite

Damian Birchler

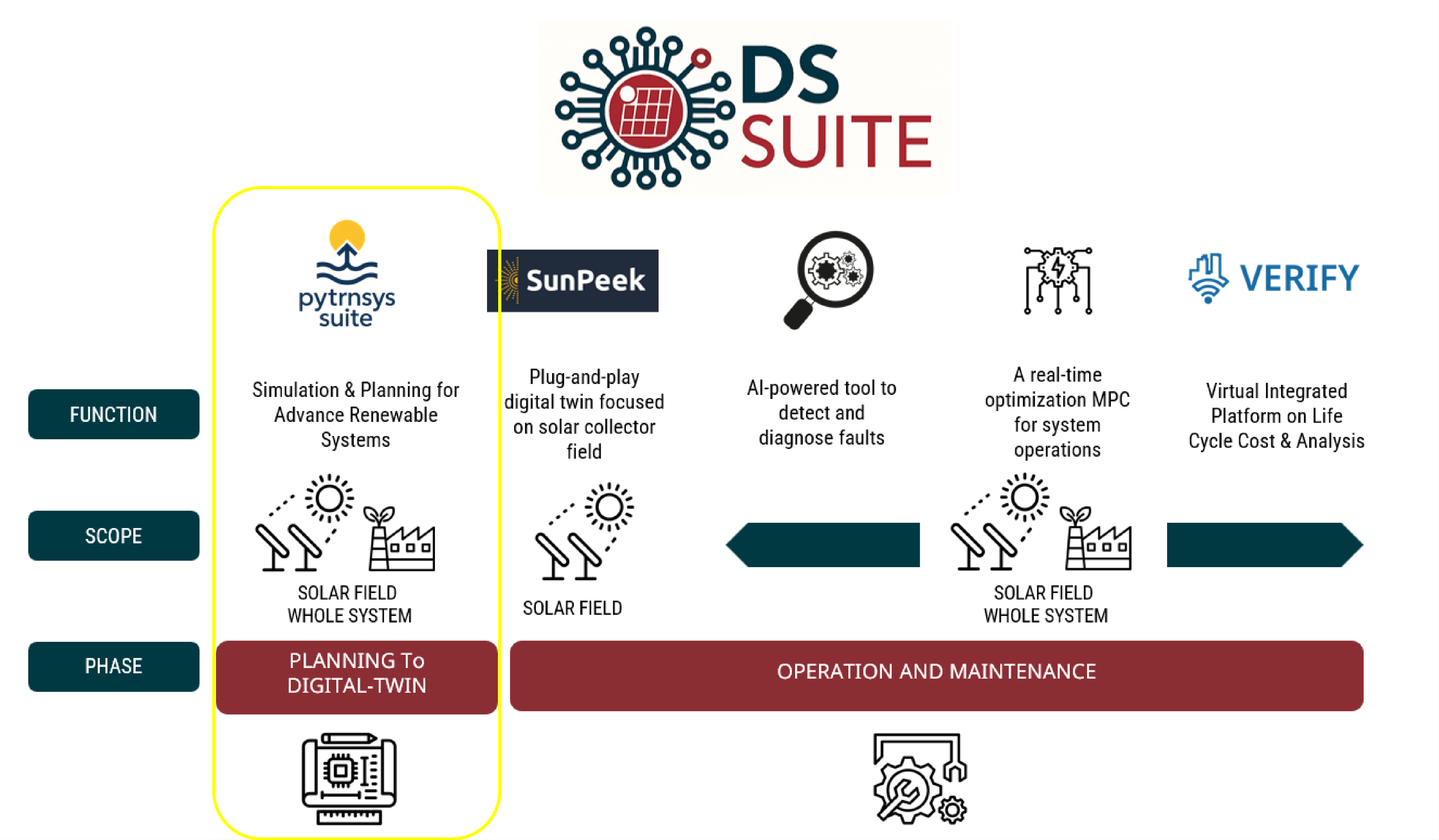
SPF Institute for Solar Technology

OST Eastern Switzerland University of Applied Sciences

SPF INSTITUT FÜR SOLARTECHNIK

The pytrnsys suite

- The all-in-one harmonized Planning-To-Digital-Twin framework
- It is
    - web-based
    - reliable, investor-trusted
    - applicable across all project phases
    - uses the same computational engine throughout (pyTRNSYS)



Under development

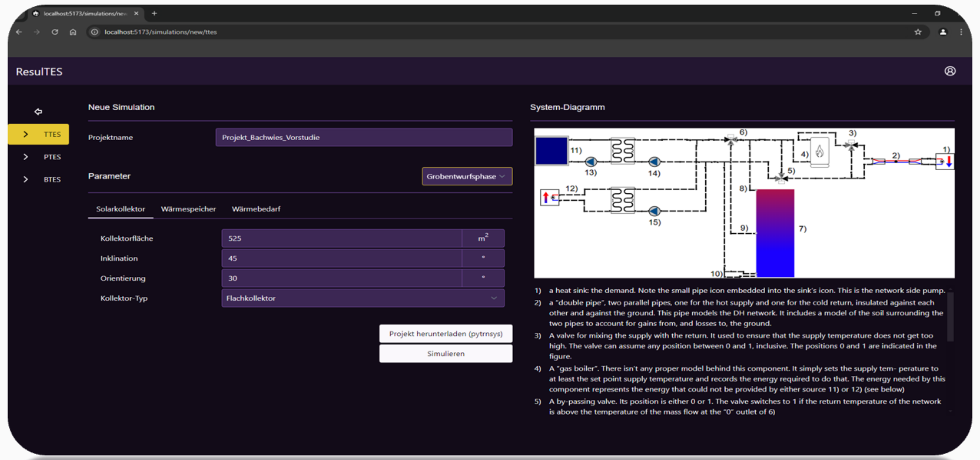
Future development

Feasibility

Design

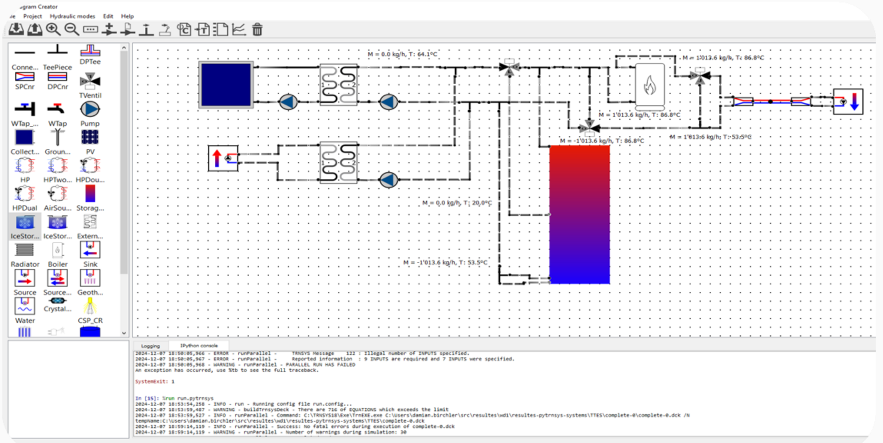
Operation

online frontend



- Runs in cloud
- Easy to use, online access tool
- Predef. configurations hybrid ST systems.
- User must only parametrize predefined configurations. No modelling needed.
- **Export to pytrnsys GUI**.

pytrnsys



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- Pytrnsys GUI for customisation.
- TRNSYS licence needed.
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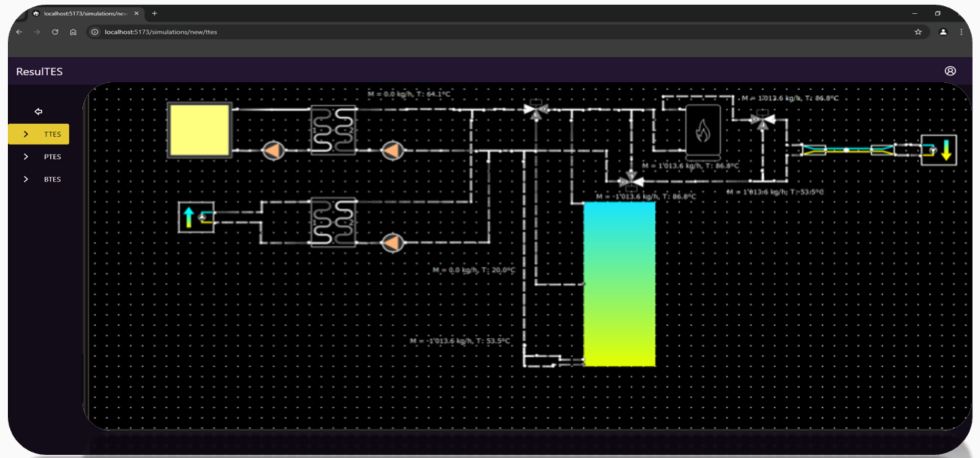
monitoring frontend



- Runs in cloud
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- Performance evaluation.

DIGISOLAR

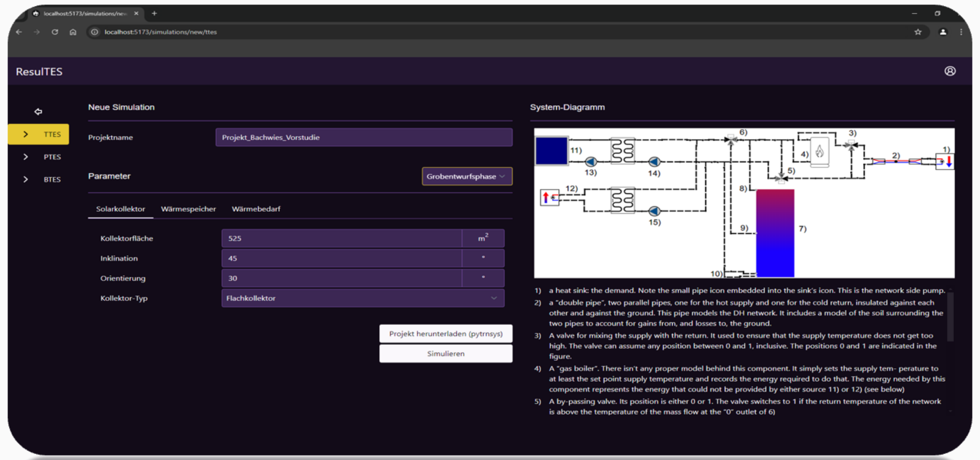
DCARBO2

Under development

Future development

Feasibility | Design | Operation

online frontend



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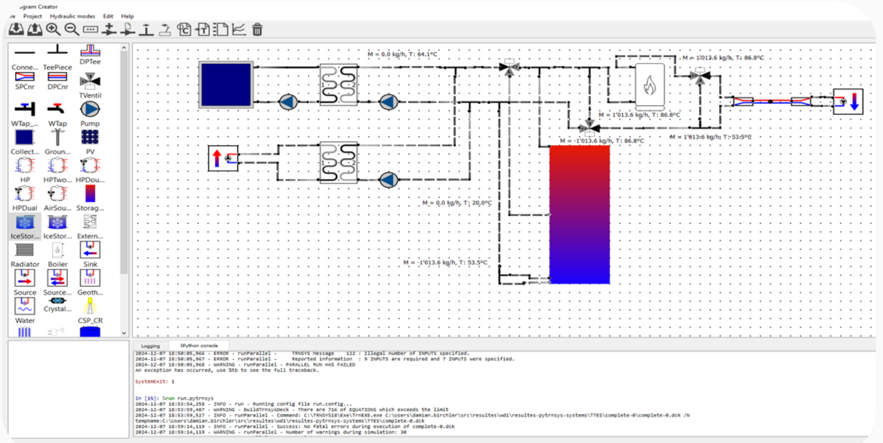

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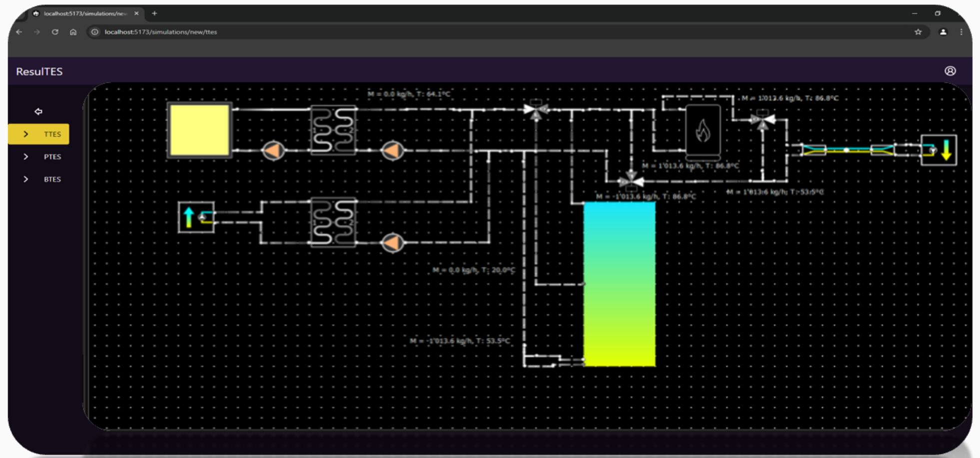

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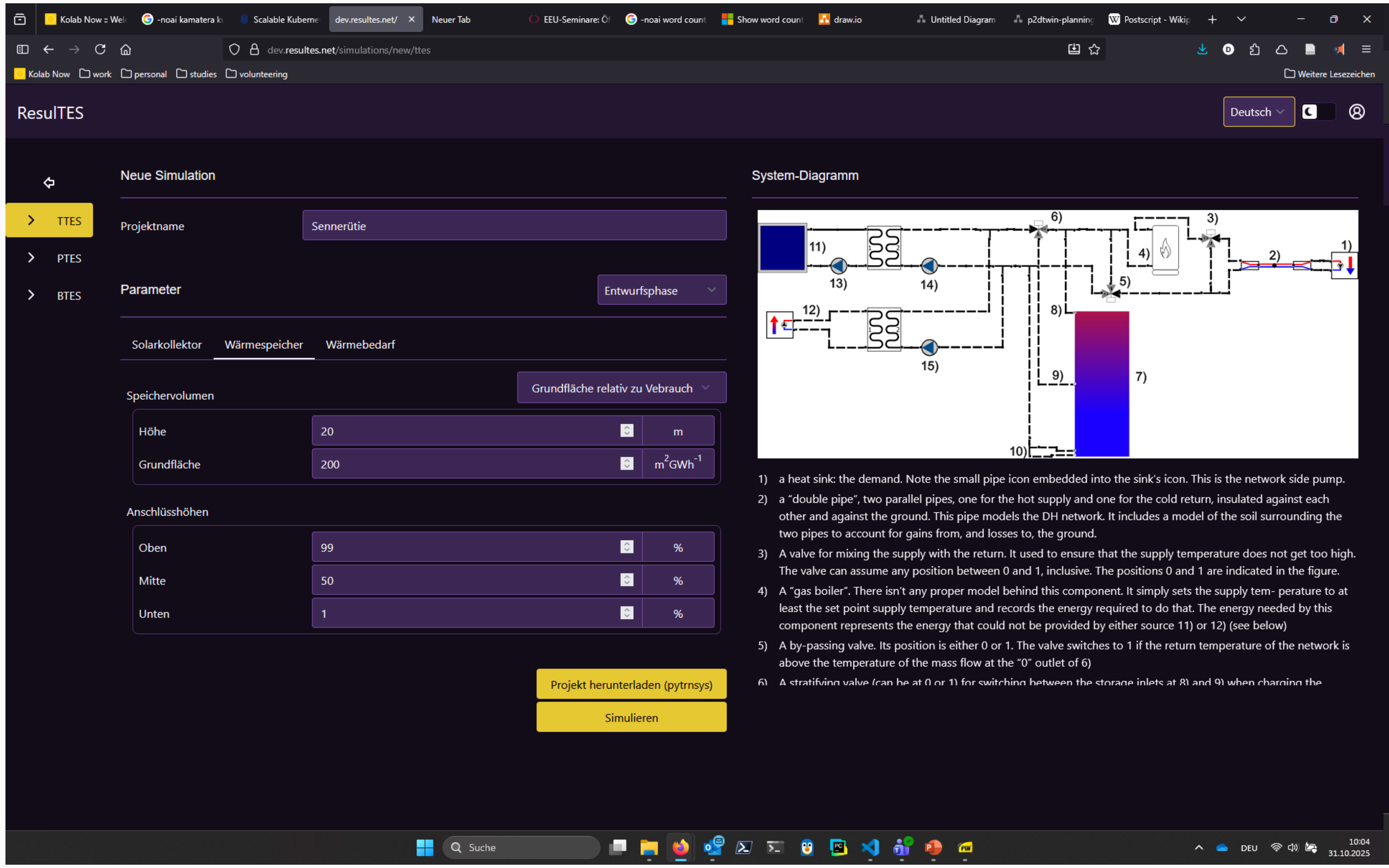
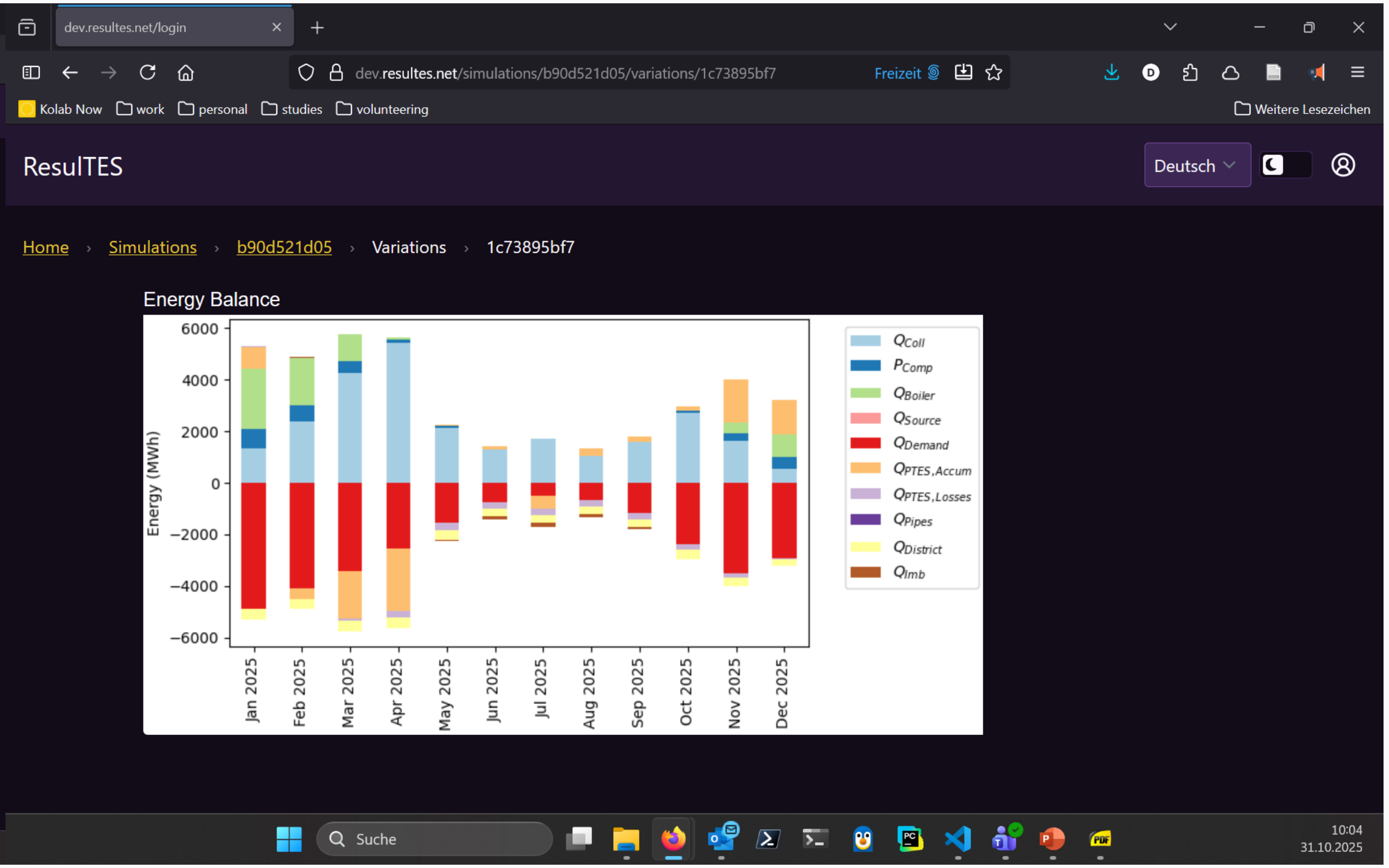
DIGISOLAR

DCARBO2

Feasability





DIGISOLAR

DCARBO2

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Feasibility | Design | Operation

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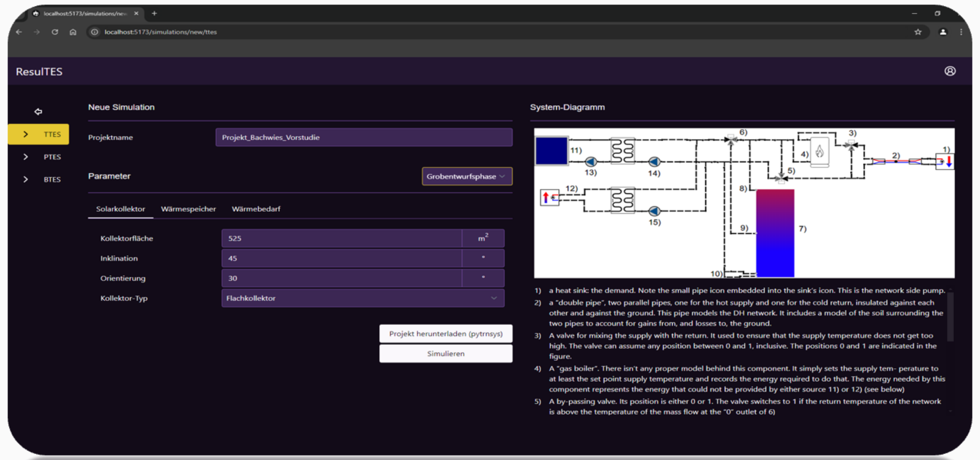

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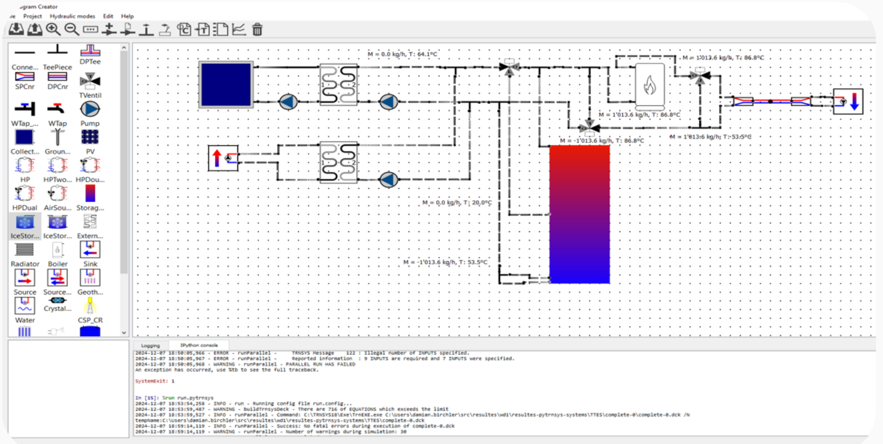

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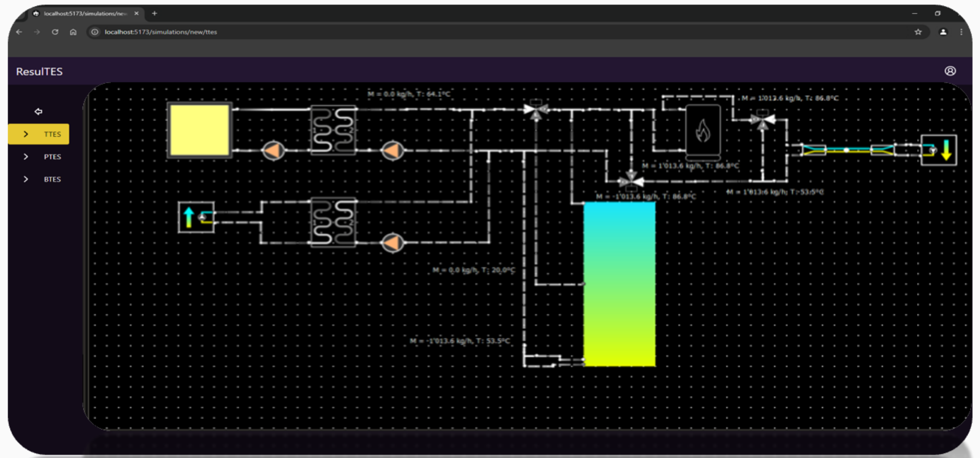

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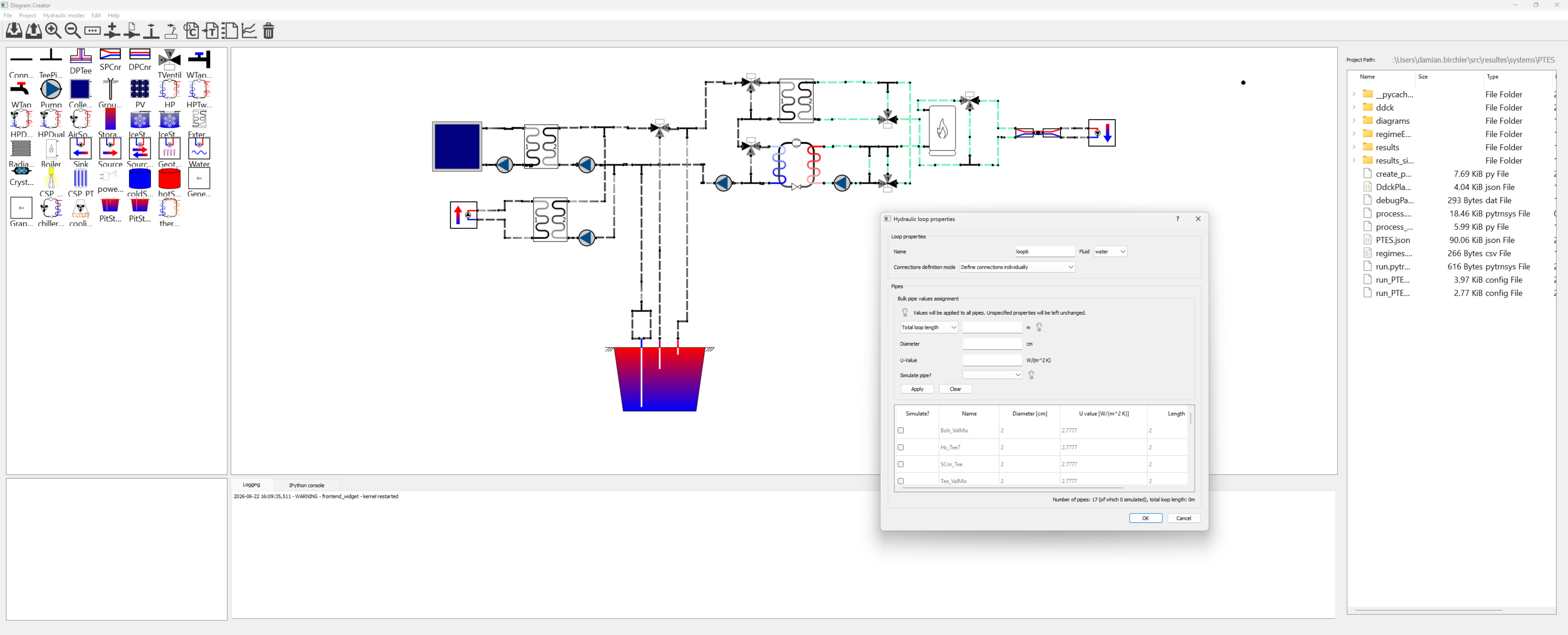
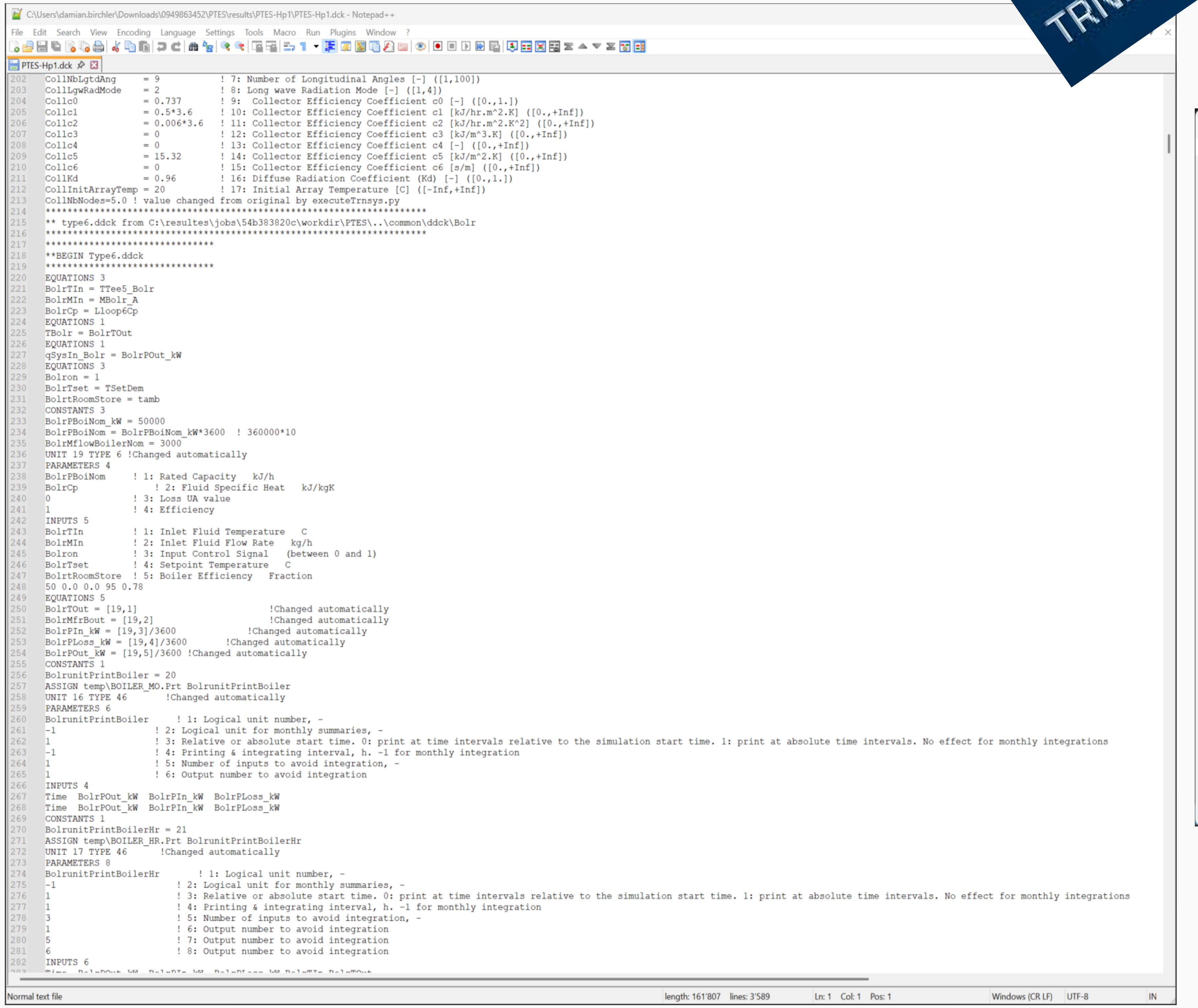
DIGISOLAR

DCARBO2

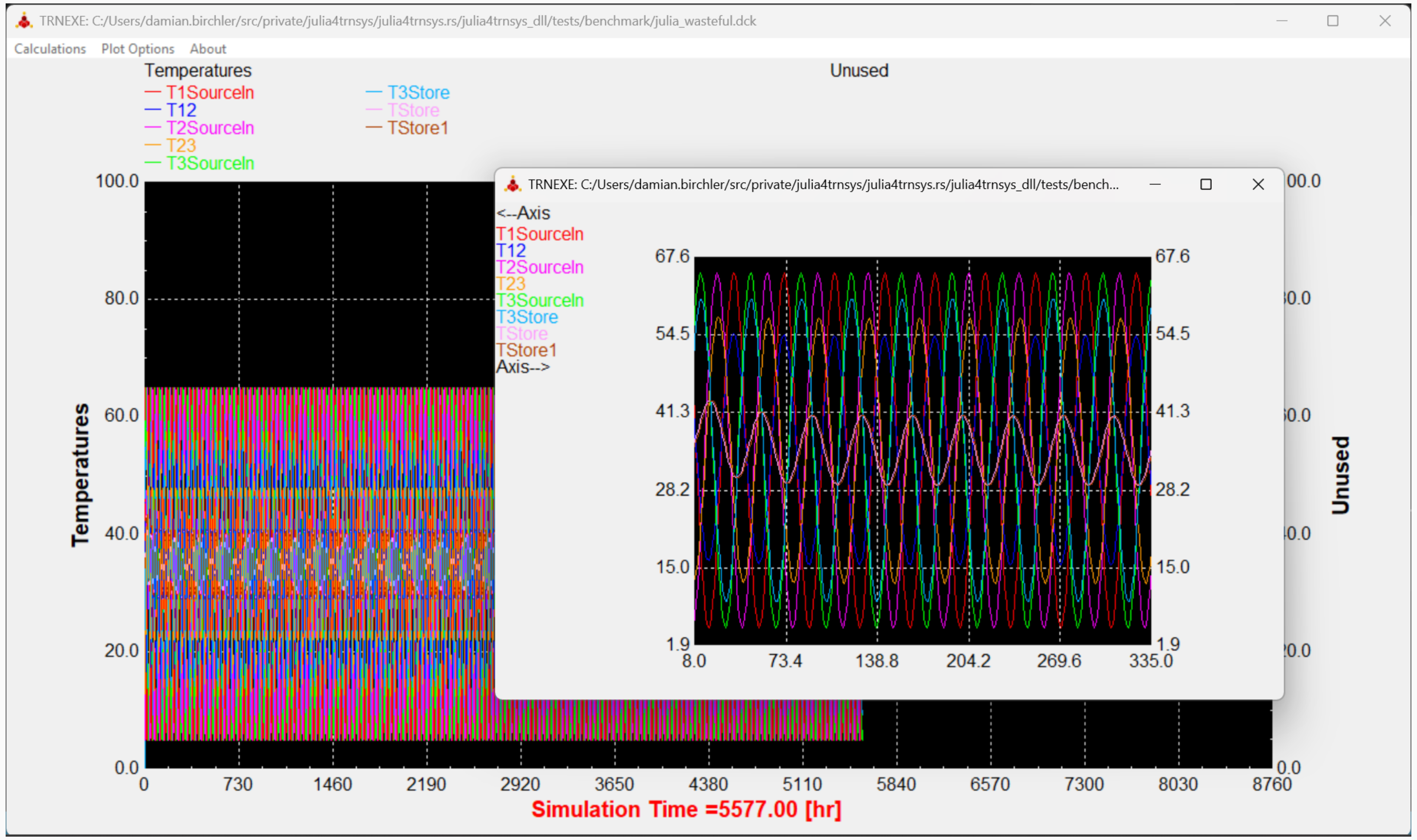
Design – pytrnsys GUI



Design - TRNSYS



```
CollNbLgtdAng     = 9            ! 7: Number of Longitudinal Angles [-] ([1,100])
CollLgwRadMode    = 2            ! 8: Long wave Radiation Mode [-] ([1,4])
Collc0            = 0.737        ! 9:  Collector Efficiency Coefficient c0 [-] ([0.,1.])
Collc1            = 0.5*3.6      ! 10: Collector Efficiency Coefficient c1 [kJ/hr.m^2.K] ([0.,+Inf])
Collc2            = 0.006*3.6    ! 11: Collector Efficiency Coefficient c2 [kJ/hr.m^2.K^2] ([0.,+Inf])
Collc3            = 0            ! 12: Collector Efficiency Coefficient c3 [kJ/m^3.K] ([0.,+Inf])
Collc4            = 0            ! 13: Collector Efficiency Coefficient c4 [-] ([0.,+Inf])
Collc5            = 15.32        ! 14: Collector Efficiency Coefficient c5 [kJ/m^2.K] ([0.,+Inf])
Collc6            = 0            ! 15: Collector Efficiency Coefficient c6 [s/m] ([0.,+Inf])
CollKd            = 0.96         ! 16: Diffuse Radiation Coefficient (Kd) [-] ([0.,1.])
CollInitArrayTemp = 20           ! 17: Initial Array Temperature [C] ([-Inf,+Inf])
CollNbNodes=5.0 ! value changed from original by executeTrnsys.py
**********************************************************************
** type6.ddck from C:\resultes\jobs\54b383820c\workdir\PTES\..\common\ddck\Bolr
**********************************************************************
*******************************
**BEGIN Type6.ddck
*******************************
EQUATIONS 3
BolrTIn = TTee5_Bolr
BolrMIn = MBolr_A
BolrCp = Lloop6Cp
EQUATIONS 1
TBolr = BolrTOut
EQUATIONS 1
qSysIn_Bolr = BolrPOut_kW
EQUATIONS 3
Bolron = 1
BolrTset = TSetDem
BolrtRoomStore = tamb
CONSTANTS 3
BolrPBoiNom_kW = 50000
BolrPBoiNom = BolrPBoiNom_kW*3600  ! 360000*10
BolrMflowBoilerNom = 3000
UNIT 19 TYPE 6 !Changed automatically
PARAMETERS 4
BolrPBoiNom     ! 1: Rated Capacity   kJ/h
BolrCp              ! 2: Fluid Specific Heat   kJ/kgK
0               ! 3: Loss UA value
1               ! 4: Efficiency
INPUTS 5
BolrTIn         ! 1: Inlet Fluid Temperature   C
BolrMIn         ! 2: Inlet Fluid Flow Rate   kg/h
Bolron          ! 3: Input Control Signal   (between 0 and 1)
BolrTset        ! 4: Setpoint Temperature   C
BolrtRoomStore  ! 5: Boiler Efficiency   Fraction
50 0.0 0.0 95 0.78
EQUATIONS 5
BolrTOut = [19,1]                          !Changed automatically
BolrMfrBout = [19,2]                       !Changed automatically
BolrPIn_kW = [19,3]/3600               !Changed automatically
BolrPLoss_kW = [19,4]/3600         !Changed automatically
BolrPOut_kW = [19,5]/3600 !Changed automatically
CONSTANTS 1
BolrunitPrintBoiler = 20
ASSIGN temp\BOILER_MO.Prt BolrunitPrintBoiler
UNIT 16 TYPE 46       !Changed automatically
PARAMETERS 6
BolrunitPrintBoiler     ! 1: Logical unit number, -
-1                  ! 2: Logical unit for monthly summaries, -
1                   ! 3: Relative or absolute start time. 0: print at time intervals relative to the simulation start time. 1: print at absolute time intervals. No effect for monthly integrations
-1                  ! 4: Printing & integrating interval, h. -1 for monthly integration
1                   ! 5: Number of inputs to avoid integration, -
1                   ! 6: Output number to avoid integration
INPUTS 4
Time  BolrPOut_kW  BolrPIn_kW  BolrPLoss_kW
Time  BolrPOut_kW  BolrPIn_kW  BolrPLoss_kW
CONSTANTS 1
BolrunitPrintBoilerHr = 21
ASSIGN temp\BOILER_HR.Prt BolrunitPrintBoilerHr
UNIT 17 TYPE 46      !Changed automatically
PARAMETERS 8
BolrunitPrintBoilerHr       ! 1: Logical unit number, -
-1                      ! 2: Logical unit for monthly summaries, -
1                       ! 3: Relative or absolute start time. 0: print at time intervals relative to the simulation start time. 1: print at absolute time intervals. No effect for monthly integrations
1                       ! 4: Printing & integrating interval, h. -1 for monthly integration
3                       ! 5: Number of inputs to avoid integration, -
1                       ! 6: Output number to avoid integration
5                       ! 7: Output number to avoid integration
6                       ! 8: Output number to avoid integration
INPUTS 6
```

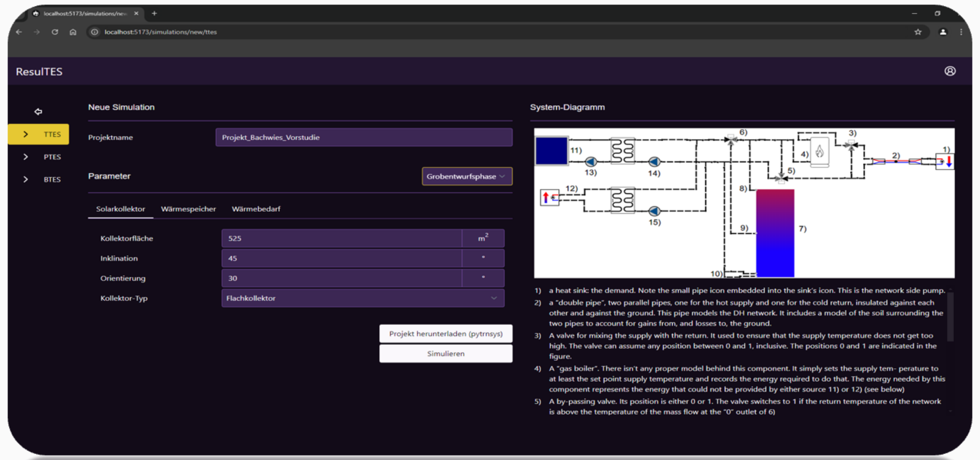


Under development

Future development

Pre-Design	Design	Operation

online frontend



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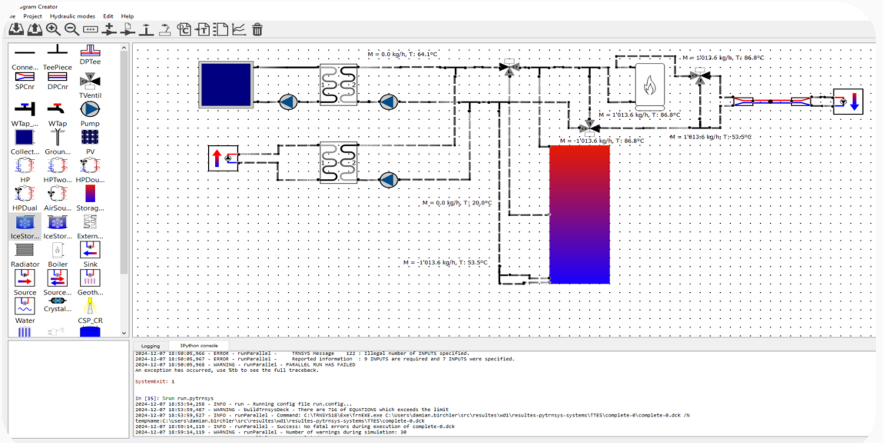

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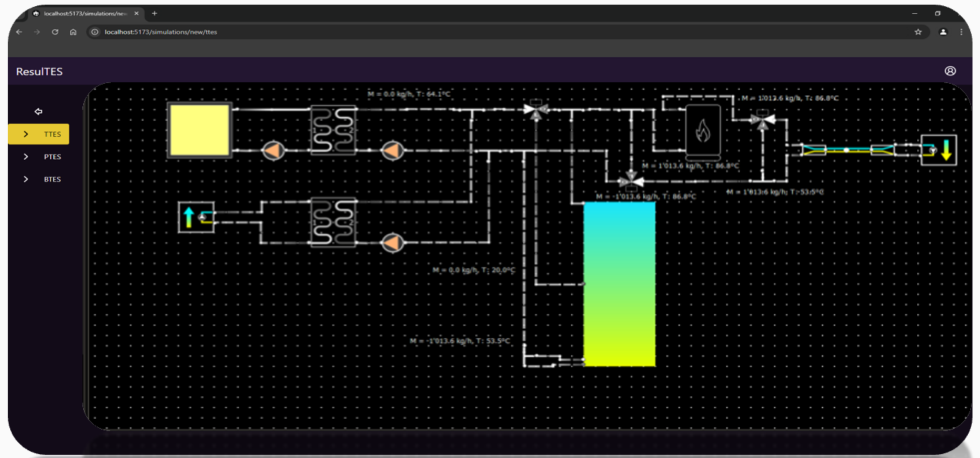

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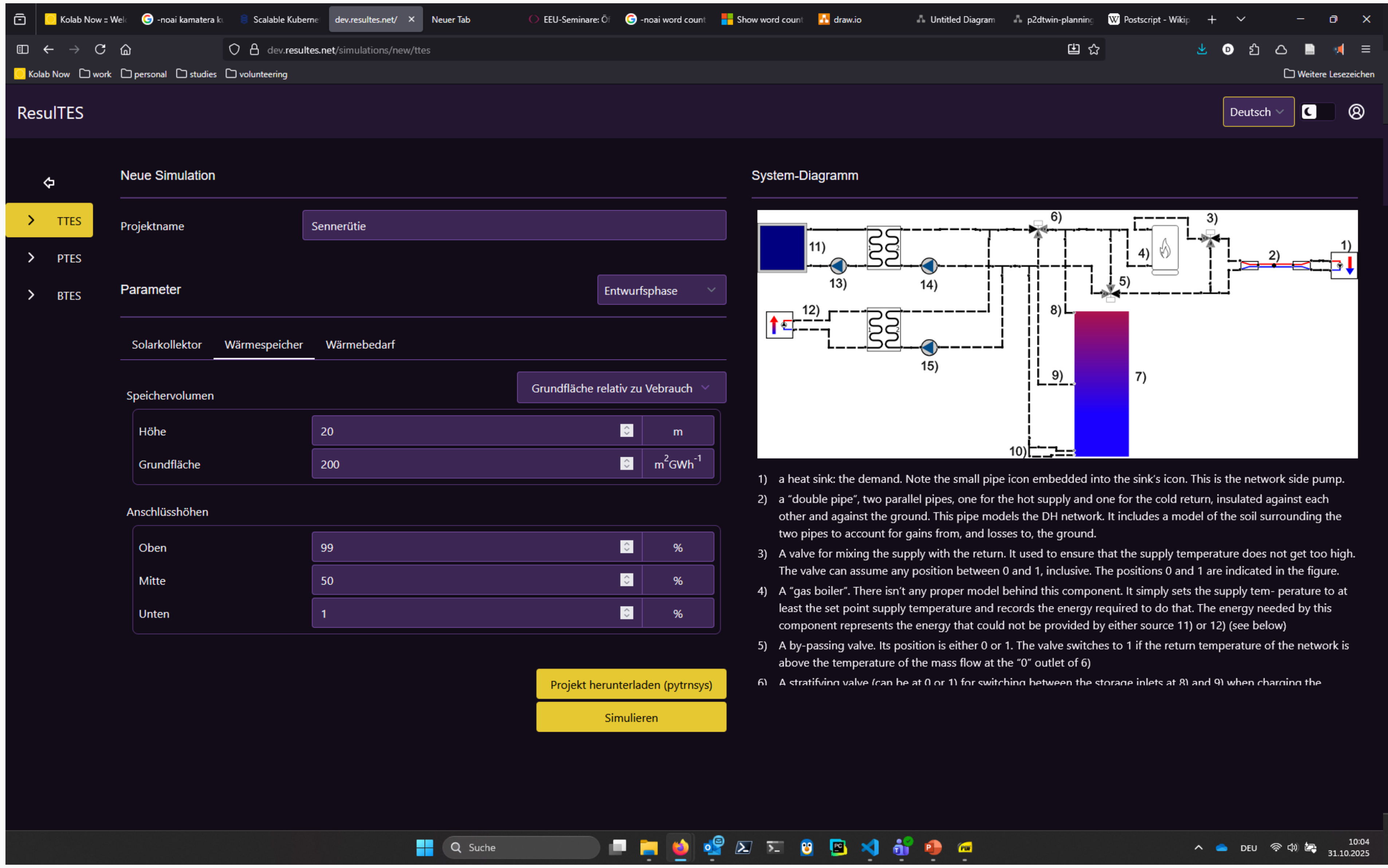
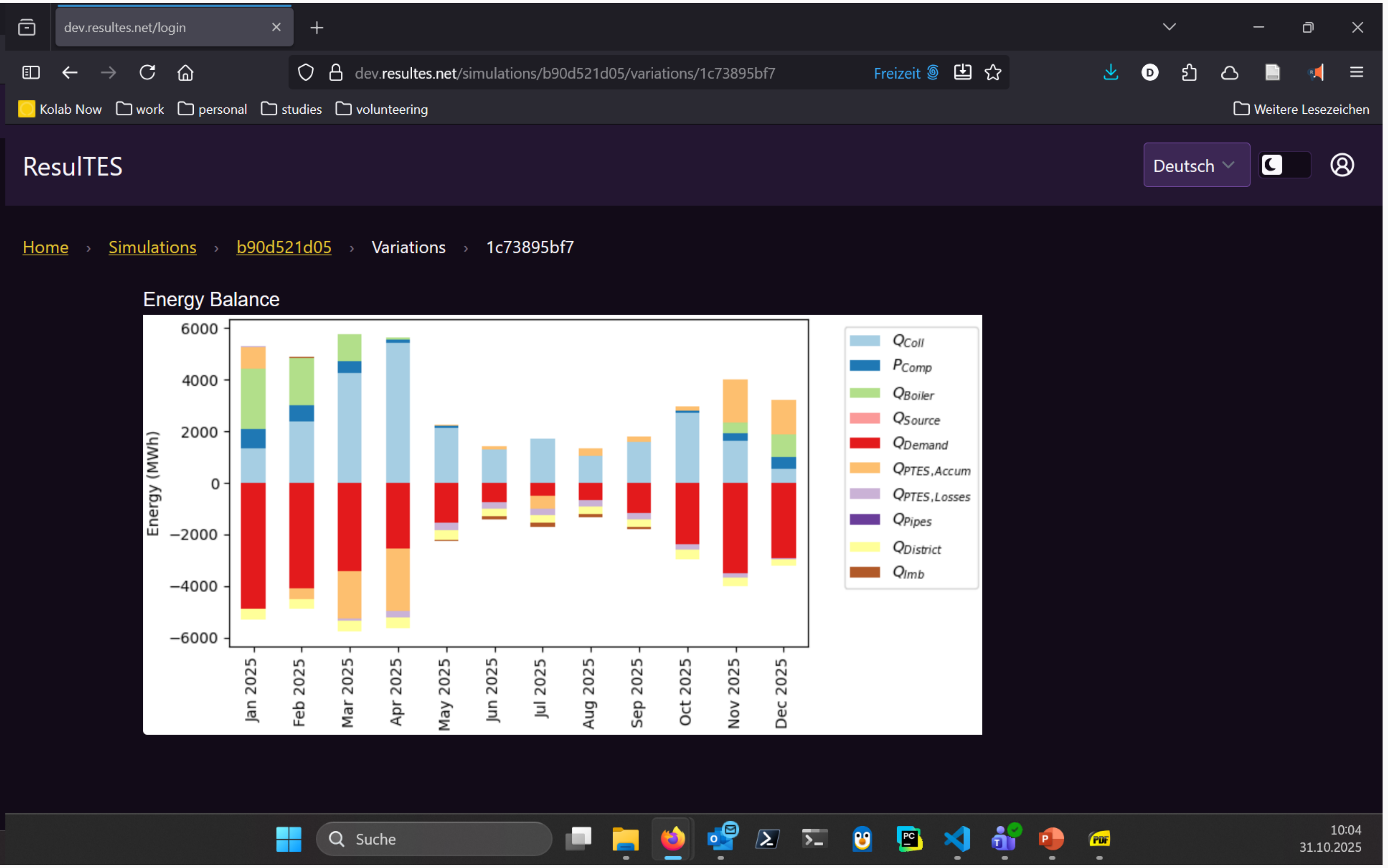
Demo of pre-design phase/web UI

Live at dev.resultes.net

Ask me for registration code if you're interested in trying it out.





Developments within DigiSolar

New systems

- Model three DigiSolar plants in pytrnsys suite (Izmir, Bad Rappenau, Komotini)
- Five representative, big commercial hybrid-ST system “archetypes”

New functionality

- Digital Twin
  - Connect to plant
  - Compare expected KPIs from simulation to actual KPIs from measurements continuously
  - Used to validate MPC/AEMS
  - Used by FDD

DIGISOLAR

Funded by

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the European Union

Funded by the European Union's Horizon Research and Innovation programme under Grant Agreement number: 101235027 – DIGISOLAR – HORIZON-CL5-2024-D3-02. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Schweizerische Eidgenossenschaft
Confédération suisse
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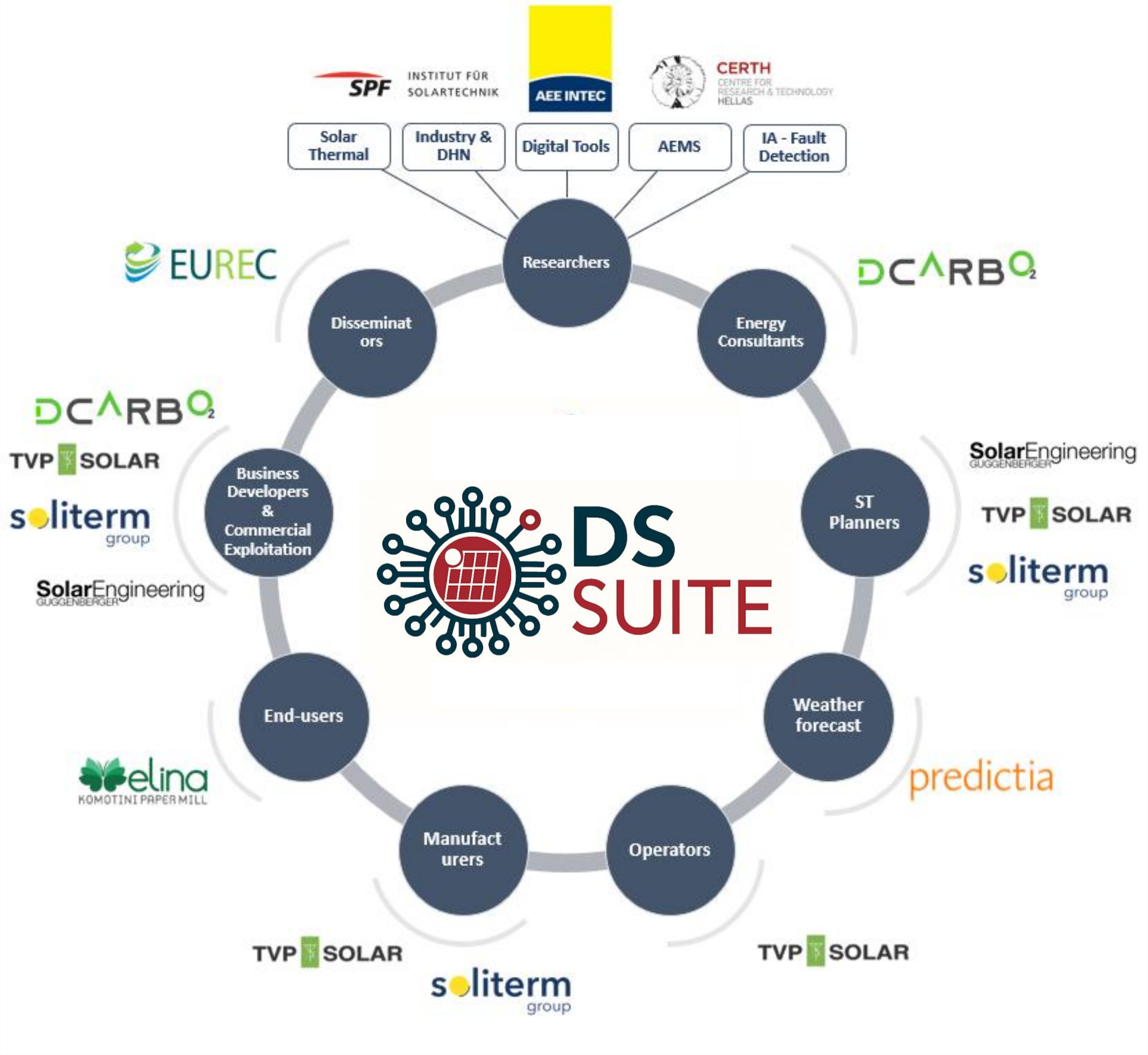
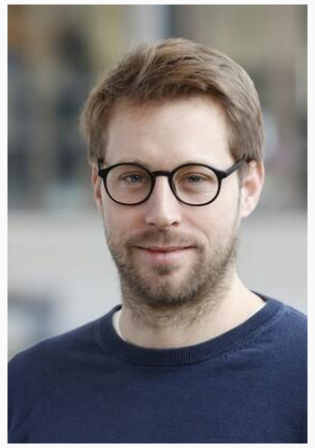
DIGISOLAR has received funding from the Swiss State Secretariat for Education, Research and Innovation SERI under the contract 25.00331.

Thank you





Damian Birchler
damian.birchler@ost.ch

THANK YOU

FOR YOUR ATTENTION

DIGISOLAR

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