SOLAR X

SolarX – Work Package I
Solar management & control strategies

25.09.2025 | Maitane Ferreres, Gregor Bern, Anna Dittmann, Wiebke Herzberg, Peter Schöttl, Sarah Riley, Anna Vaclavikova

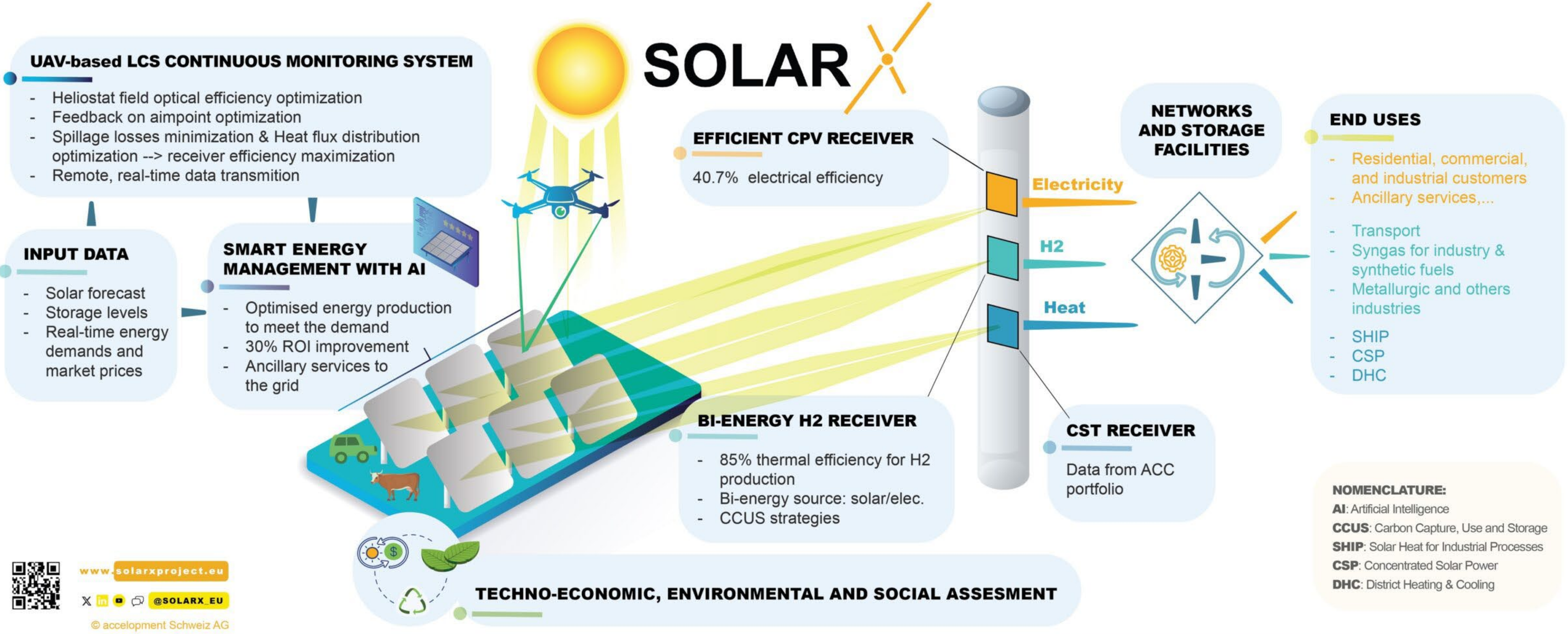
Lead: Fraunhofer ISE

Contributing: UDL, ACC, EMD, DTU, CNRS, CYI

Co-funded by the European Union

Funded by the European Union (grant no. 101084158) and supported by the Swiss State Secretariat for Education, Research and Innovation (SERI). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

WP1 Solar management & control strategies: Overview



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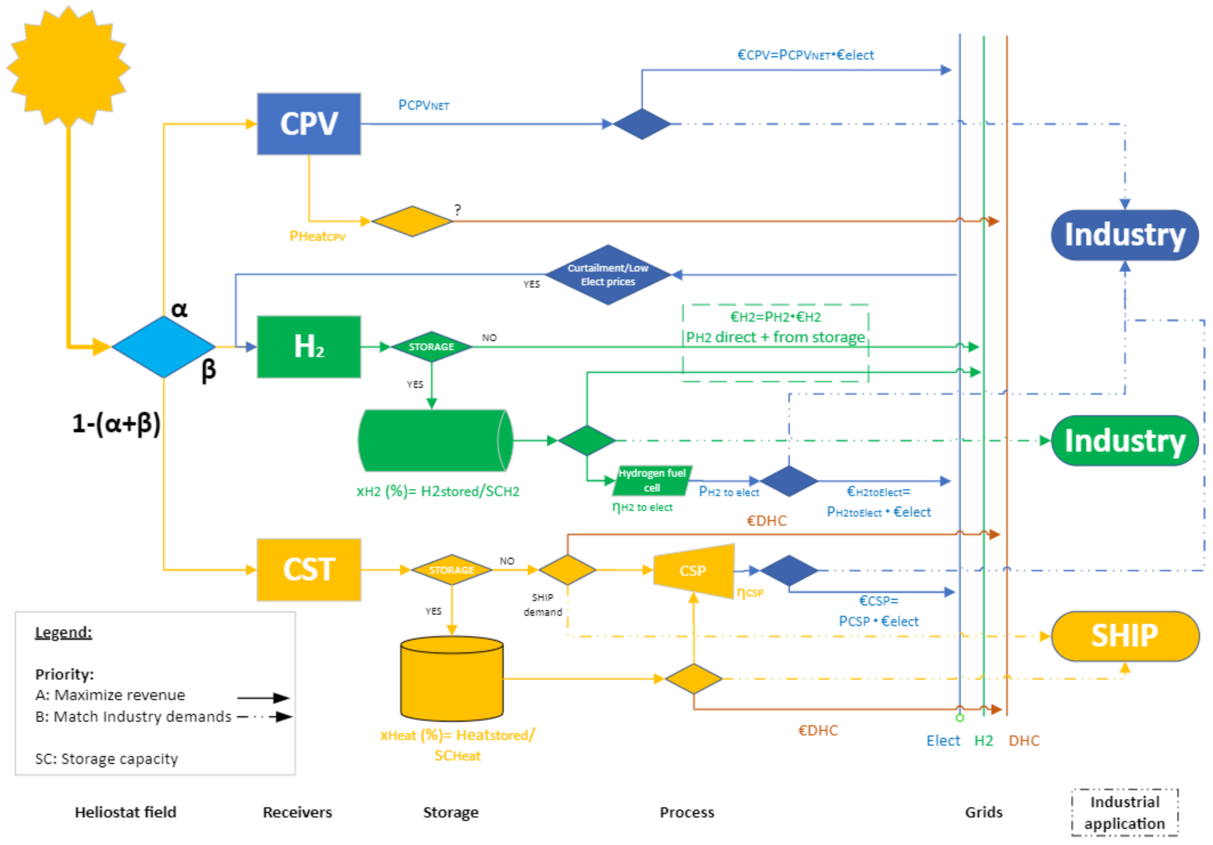
Funded by the European Union under the Horizon Europe Framework Programme (Project name: SOLARX; grant number: 101084158). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them. The project is also supported by the Swiss State Secretariat for Education, Research and Innovation (SERI).

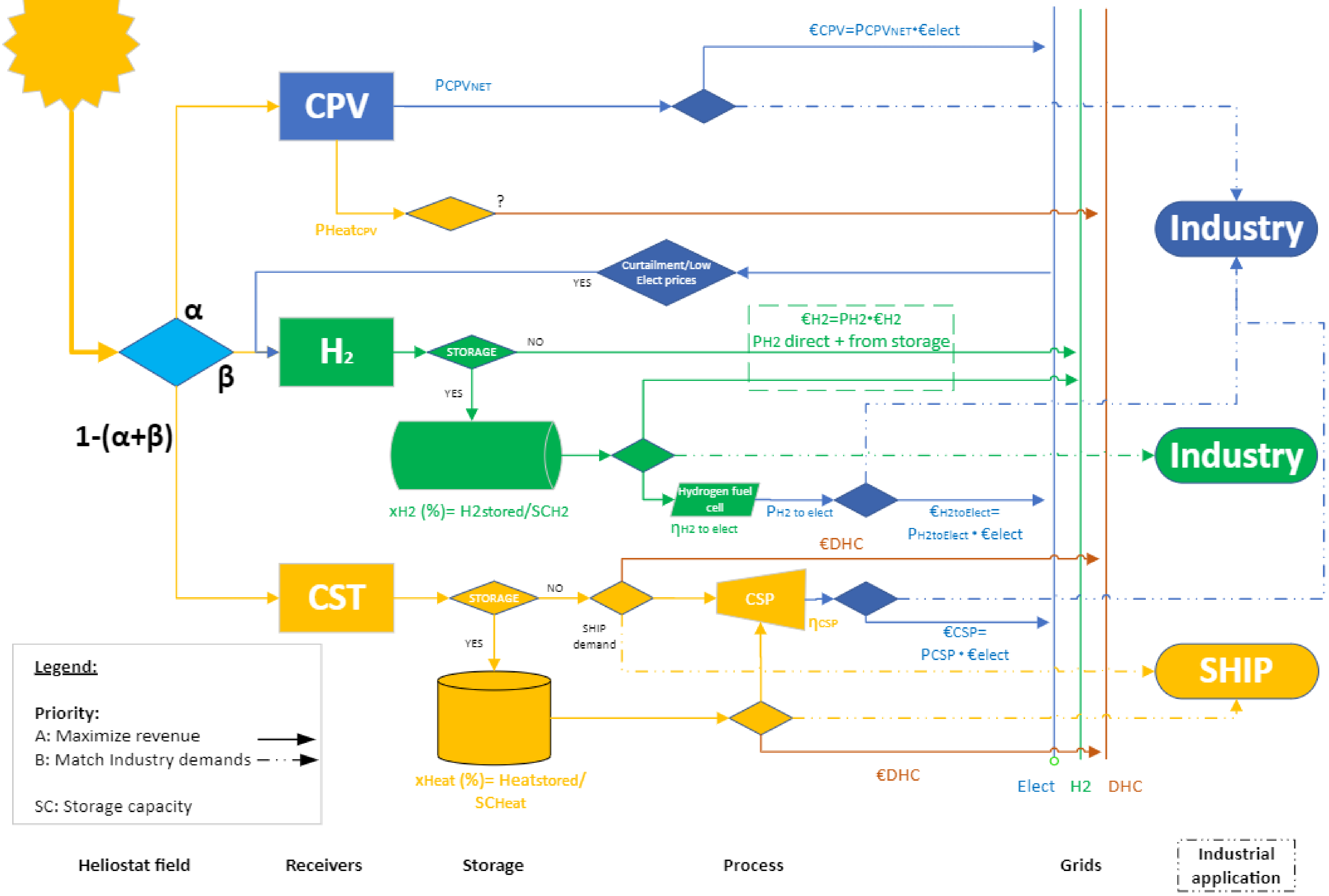
SolarX Solar Management
Agenda

- **SolarX System Model**
  - *System integration and energy flow model*
  - *Parameterization and flux management*
  - *Exemplarily Study Case*
- **SolarX System Monitoring**
  - *Solar Resource Assessment – DNI Nowcasting*
  - *Fast and Precise Heliostat Calibration*
  - *Lessons Learned*
- **Summary**

SolarX System Model

System integration and energy flow model

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Industry
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NO
YES
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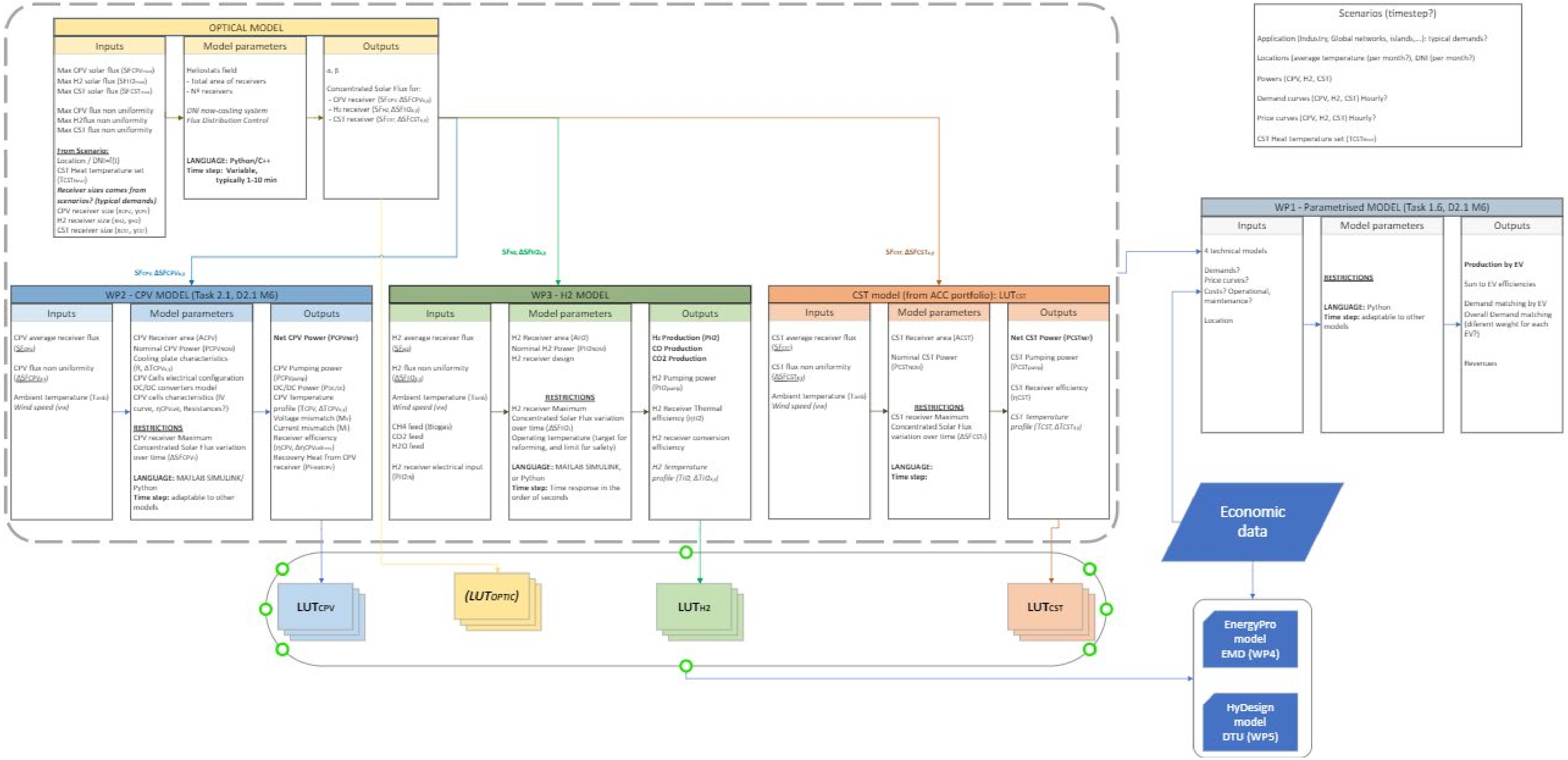
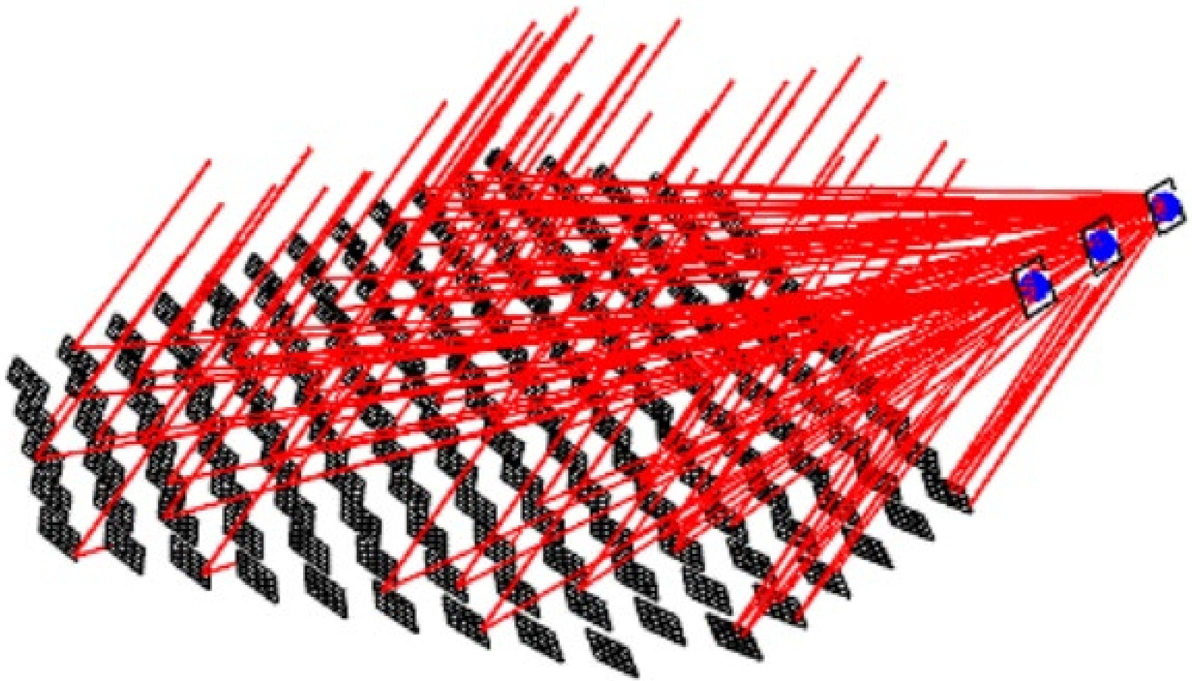
Industry
Hydrogen fuel cell
ηH2 to elect
PH2 to elect
€H2toElect=
PH2toElect • €elect
€DHC
CST
STORAGE
NO
YES
SHIP demand
CSP
ηCSP
€CSP=
PCSP • €elect
SHIP
xHeat (%)= Heatstored/ SCHeat
€DHC
Elect
H2
DHC
Legend:
Priority:
A: Maximize revenue
B: Match Industry demands
SC: Storage capacity
Heliostat field
Receivers
Storage
Process
Grids
Industrial application

SolarX System Model

System data interaction – heliostat field | receivers



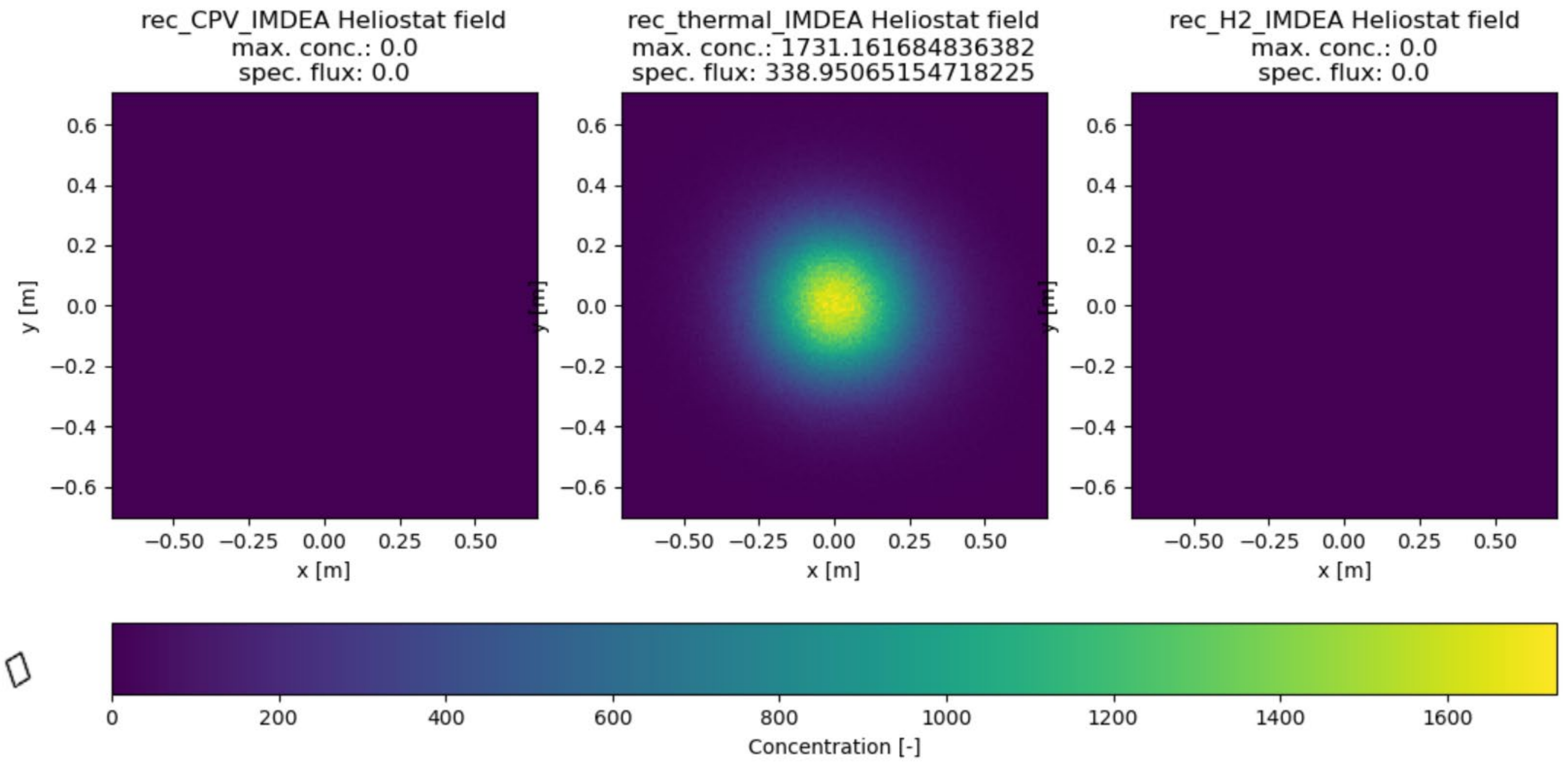
SolarX System Model
Parameterization and flux control

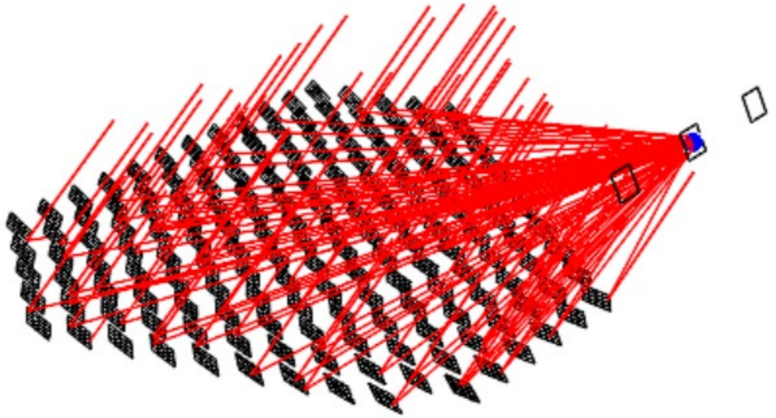


SolarX System Model
Parameterization and flux control

Methodology:

1. Ray tracing simultion per sun position for single receivers





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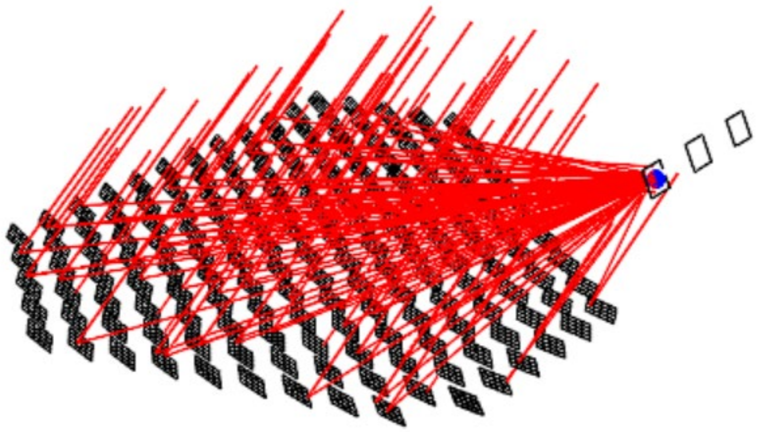

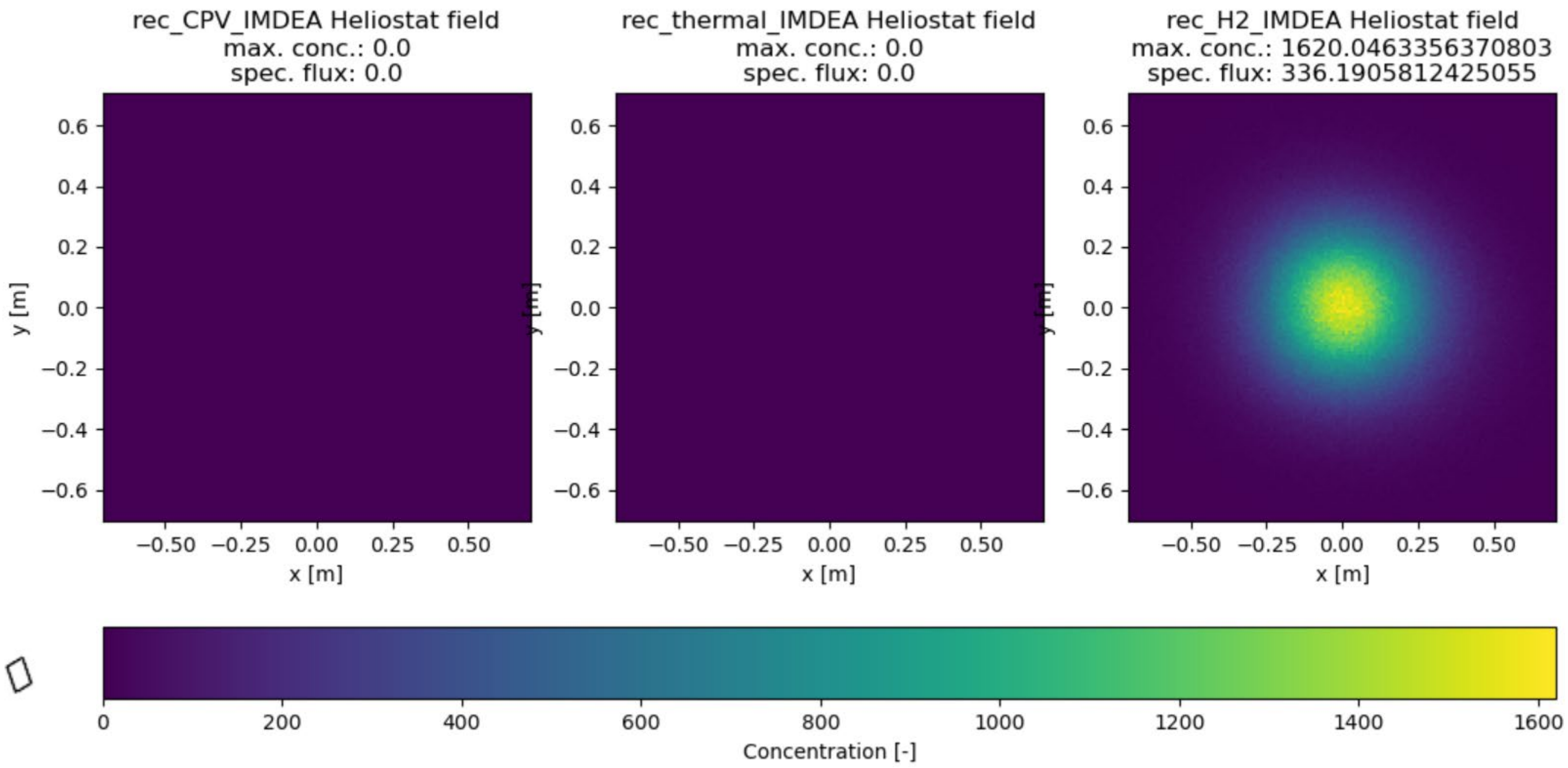

SolarX System Model

Parameterization and flux control

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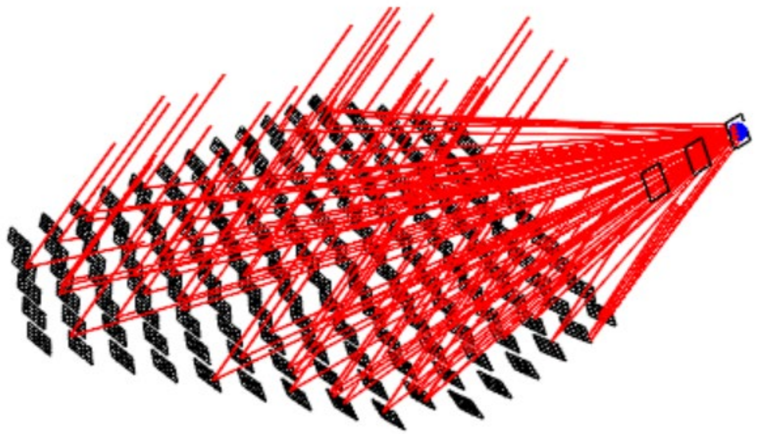
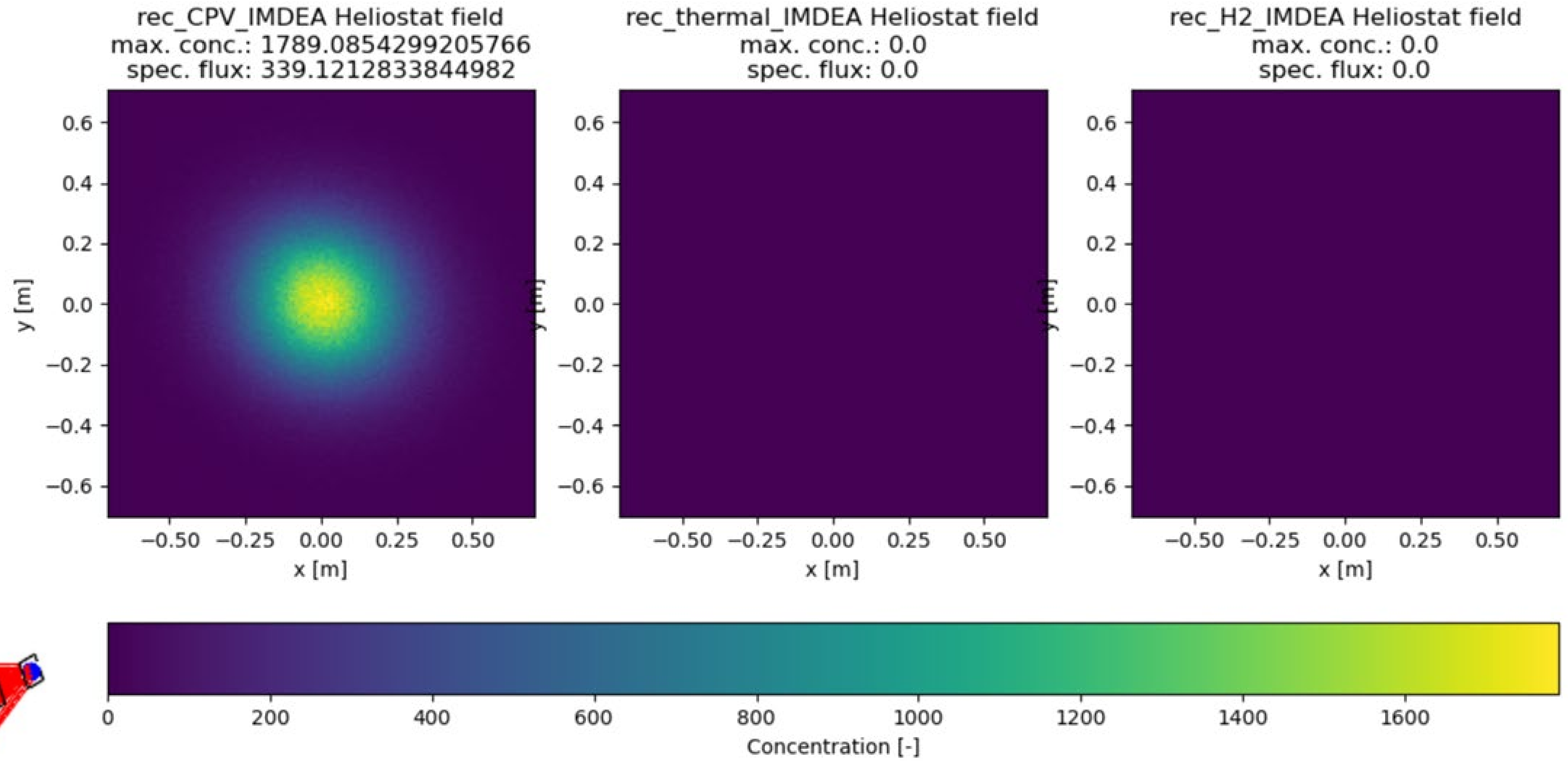
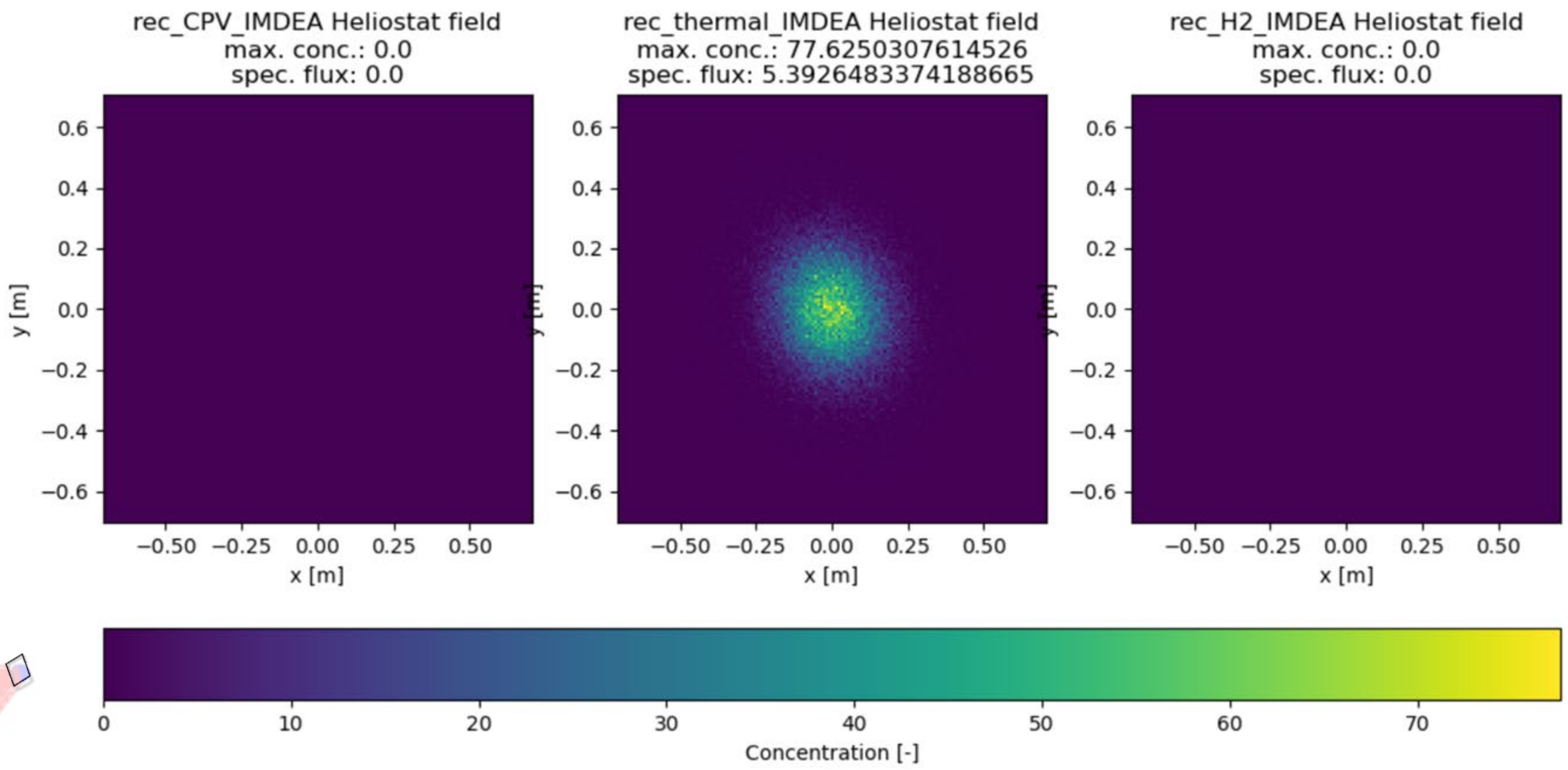


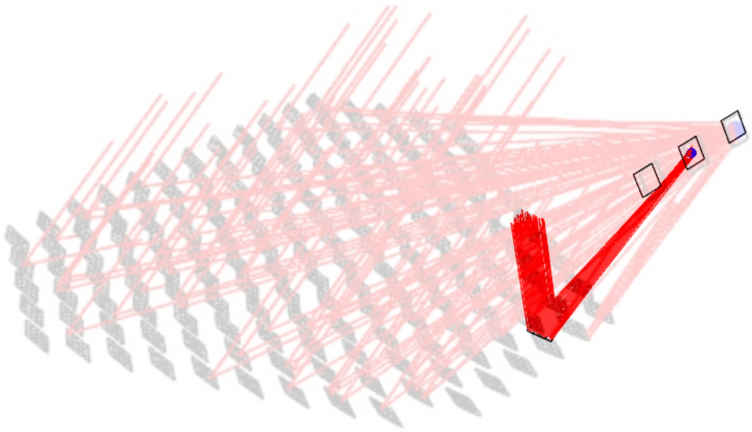


SolarX System Model
Parameterization and flux control

Methodology:

1. Rayy tracing simultion per sunposition for single receivers
2. From binray ray out files **select the impact of single heliostat** in the receivers





SolarX System Model
Parameterization and flux control

Methodology:

1. Ray tracing simultion per sunposition for single receivers
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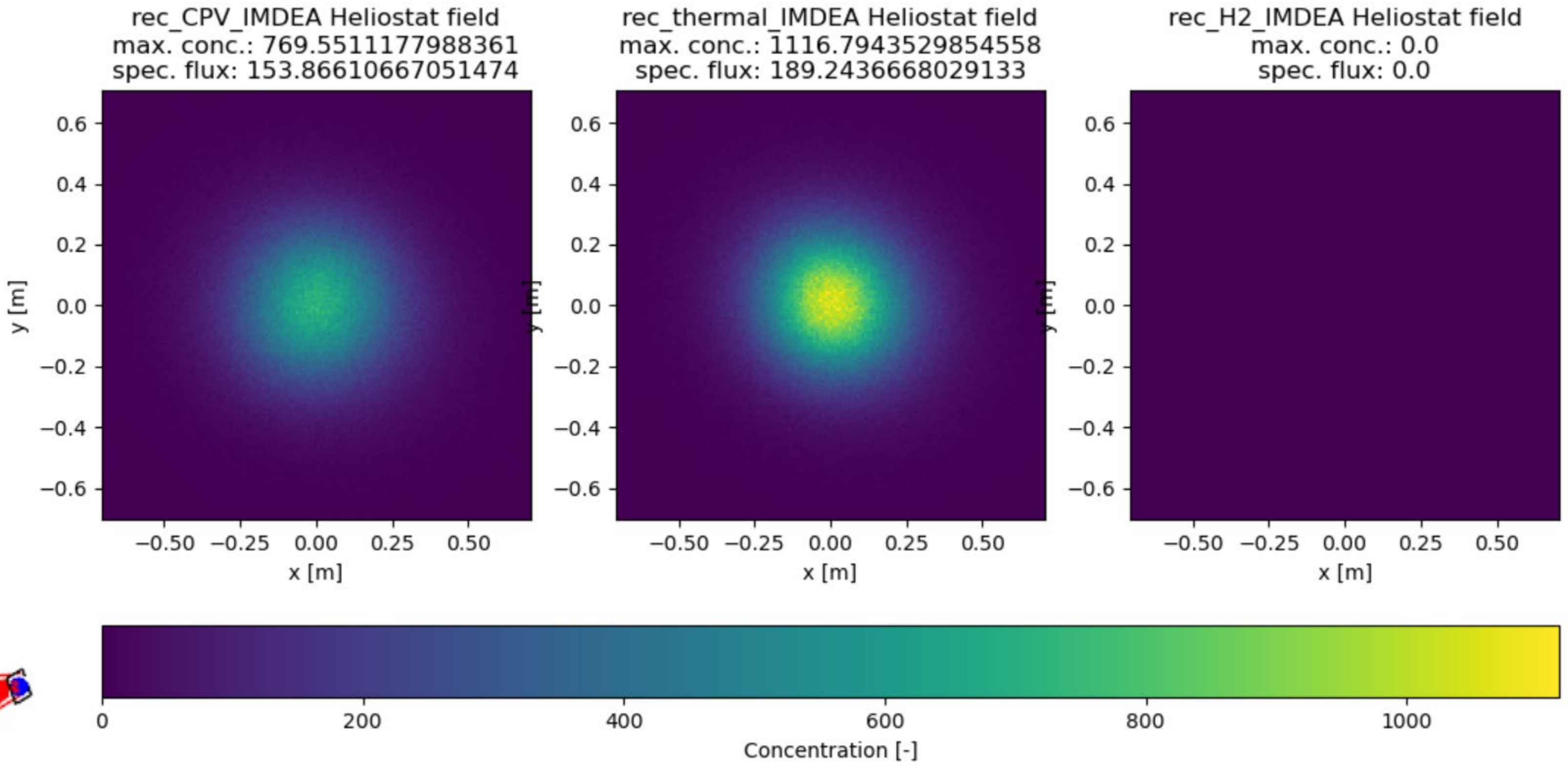
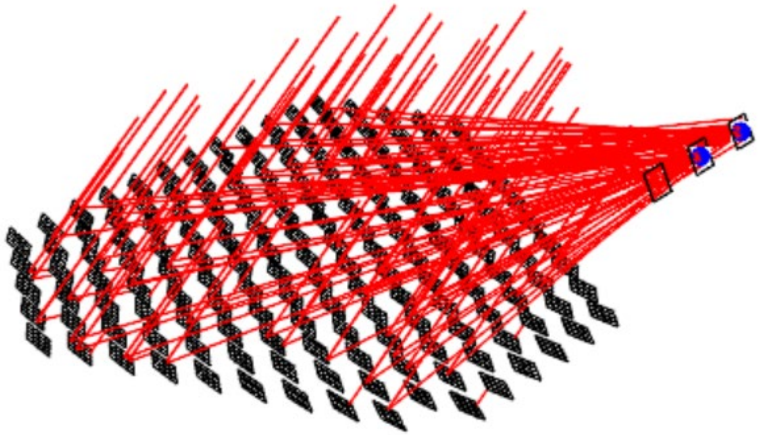
3. *From single heliostat* ***create the desired combination of ratios*** *in receivers*





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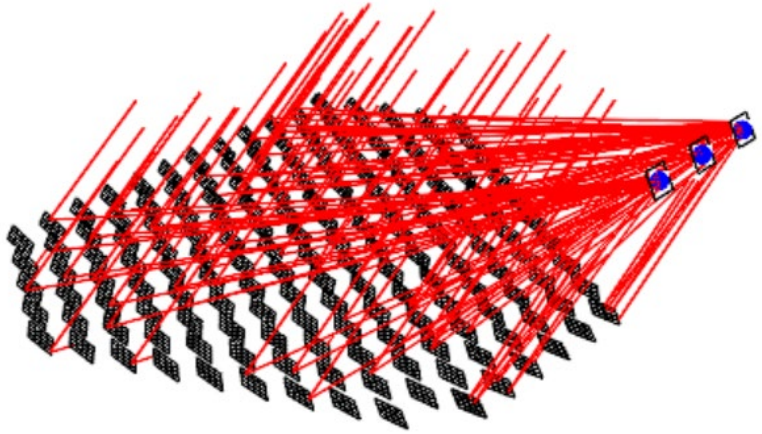

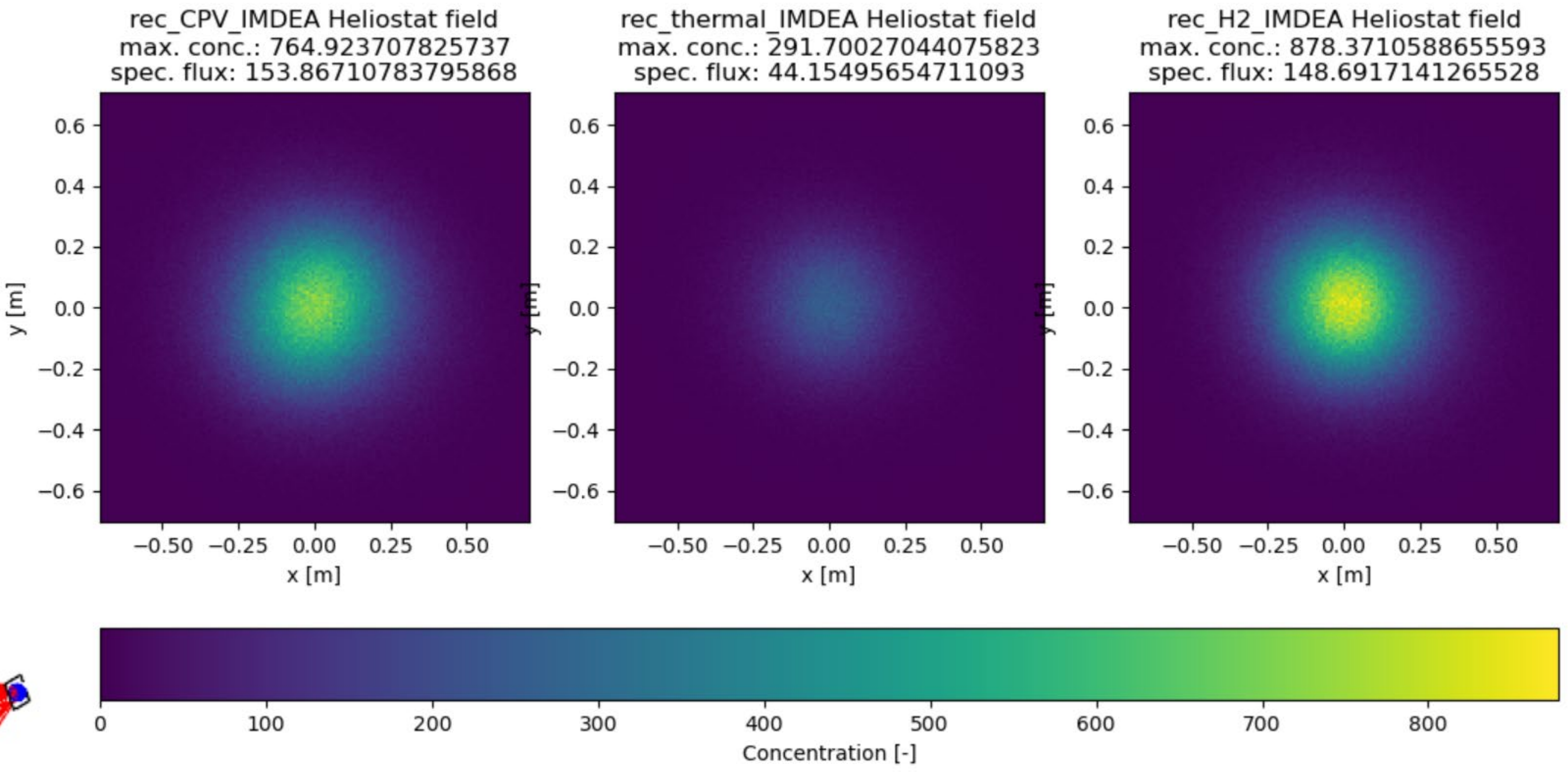

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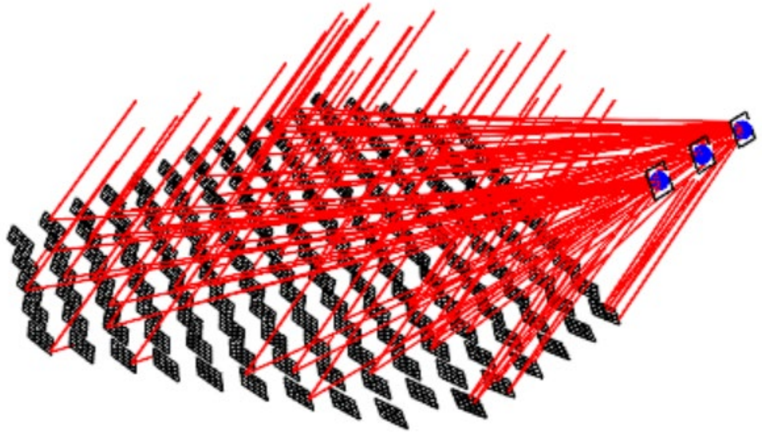
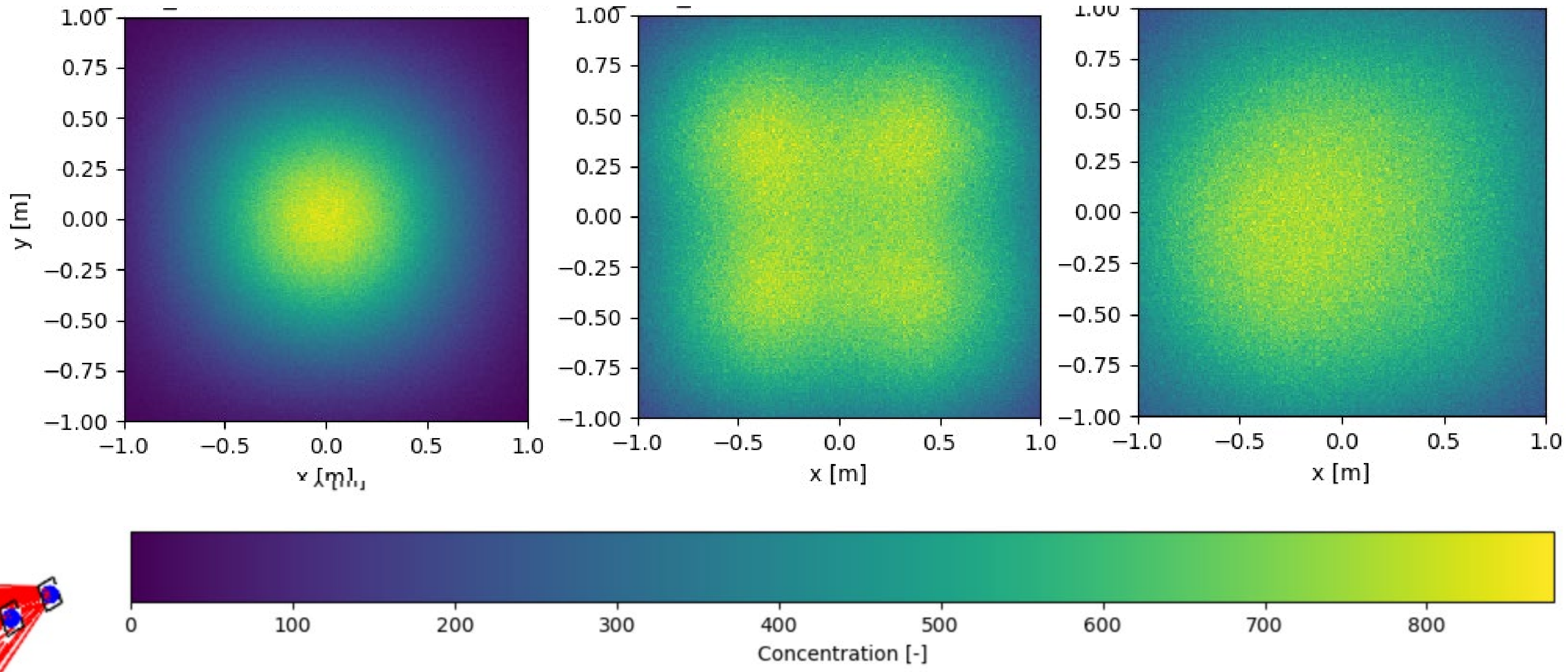
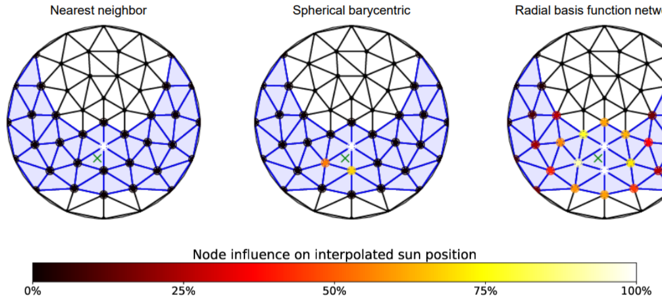


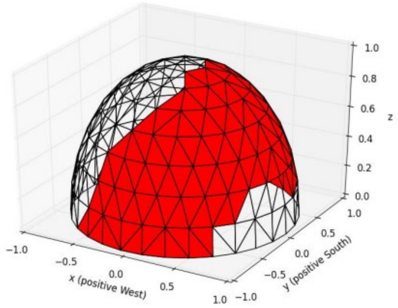


SolarX System Model
Parameterization and flux control

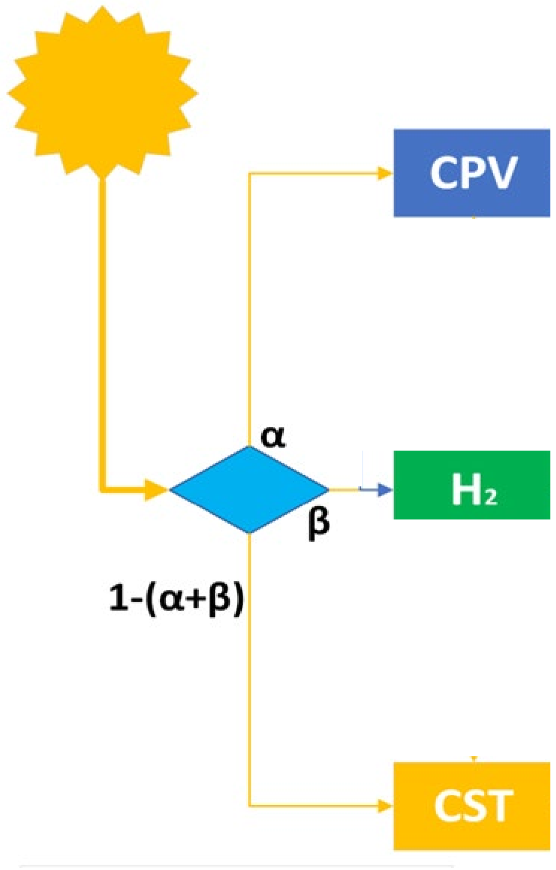
Approach:

- Ray tracing simulations for **12 sun positions**





- Ray tracing simulations for **12 sun positions**
- **66 combinations of shares in the receivers:**
  - *α: 0%, 10%, … 100%*
  - *β: 0%, 10%, … 100%*
  - *1-(α- β): 0%, 10%, … 100%*



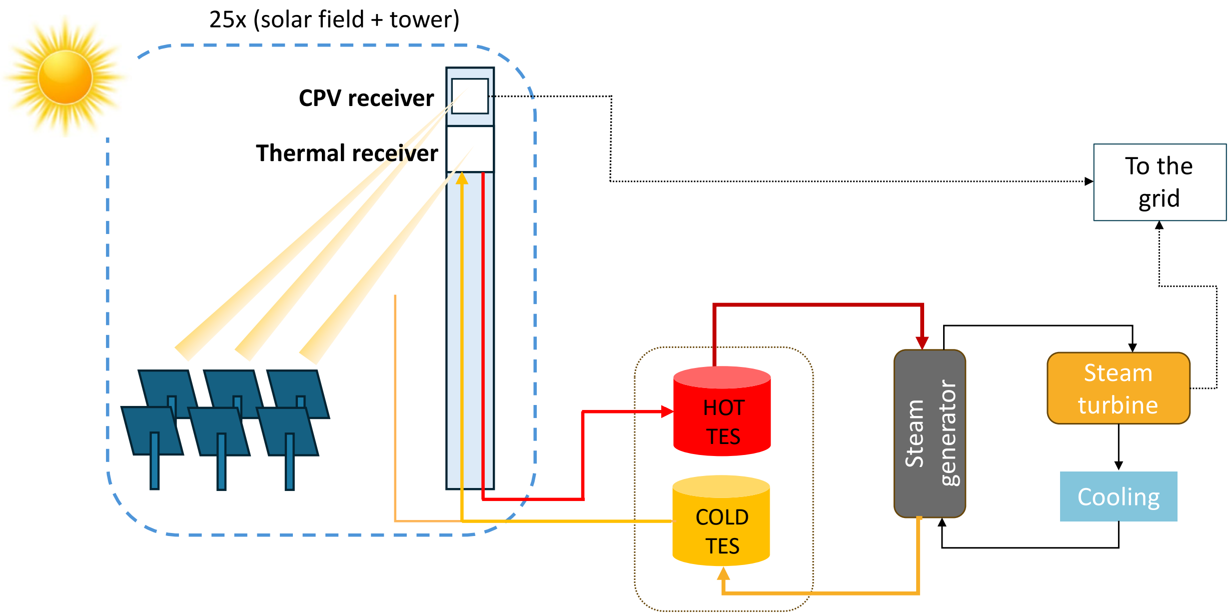
Result: *Database of **729 concentration maps***

SolarX System Model
Exemplarily Study Case

- Paper by **Alicia Crespo et al.** at SolarPACES Conference Proceedings 2024

- System design for SolarPACES
  - 2x2 m2 CPV receiver
  - 3x3 m2 thermal receiver
  - Four different heliostat fields designs: 4000 m2; 6000 m2; 8000 m2; 10000 m2

→ Specific flux per sun position and ratio as an input to **EnergyPRO**



SolarX System Model
Exemplarily Study Case

Scientific publication:

- Presented in SolarPACES, September 2025
- 24.09. Sala 6
- Publication following…

Two-Stage Aiming Strategy Optimization for Enhanced Thermal Safety and Optical Efficiency in External Receivers

Maitane Ferreres Eceiza[1], Sarah Riley[1], Peter Schöttl[1], Gregor Bern[1], and Werner Platzer[1]

[1] Fraunhofer Institute for Solar Energy Systems ISE. Heidenhofstr. 2, 79110 Freiburg, Germany

*Correspondence: Maitane Ferreres Eceiza, maitane.ferreres.eceiza@ise.fraunhofer.de.

1. Introduction

Optimizing the heliostat field aiming strategy is crucial to maximize solar radiation capture while preventing thermal stress and damage to the receiver. One of the primary challenges in Solar Tower Systems (STS) is managing the flux distribution on the receiver surface precisely and under transient conditions. Uneven flux can lead to hotspots, causing material degradation and reducing the receiver's lifespan. On the other hand, excessive spillage, where reflected sunlight misses the receiver, results in energy losses. Therefore, developing an aiming strategy that balances flux uniformity, on each panel of the receiver, and minimizes spillage is essential for enhancing plant performance and reliability. The approach presented in this work integrates solar field control with thermal receiver operation, providing the basis for advanced digital twin-based operation strategies.

2. Methodology

Two-stage optimization method was employed:

2.1 Stage 1 Optimization

The stage 1 optical optimization in this paper aims to achieving a uniform flux distribution on the receiver while minimizing spillage, by employing two clustering strategies: Distance-based clustering, which by grouping heliostats by their distance from the receiver accounts for the increase in spillage the farther a heliostat is placed from the receiver ("cone effect") [1], and cosine-loss-based clustering, which focuses on the efficiency of heliostats based on the angle of incident solar radiation [1]. A genetic algorithm (GA) [2] is used to minimize a weighted sum of these KPIs ("non-uniformity" and "spillage"), balancing the trade-off between uniform flux distribution and minimizing spillage. Ray tracing generates the heliostat concentration maps required for evaluating candidate solutions.

2.2 Stage 2 Optimization

The Stage 2 optimization ensures that the aiming strategy complies with the receiver's thermal and hydraulic constraints during operation. The allowable flux density (AFD) model is integrated into the simulation to define the maximum allowable flux based on the receiver's material properties and the heat transfer fluid (HTF) characteristics [3]. An ant colony optimization (ACO) [4] algorithm is employed to refine the aim points further, focusing on thermal safety, while minimizing spillage. The ACO algorithm simulates the foraging behavior of ants to explore the solution space efficiently, and iteratively refines the aim points, ensuring the flux distribution adheres to the AFD limits. The thermal performance is then assessed using ColSim, a dynamic system simulation tool, evaluating critical parameters such as film temperature, bulk fluid temperature, and surface temperature to ensure material integrity and optimal energy conversion efficiency.

3. Results

The GA optimization achieved a substantial reduction in the flux concentration uniformity towards the ideal uniform distribution (by up to 50%) compared to the baseline strategy during periods of high solar zenith angles. This more uniform flux distribution minimized thermal

gradients on the receiver surface, reducing the risk of associated material stress. The distance-based aiming strategy effectively managed the cone effect at higher zenith angles, resulting in lower spillage rates. The cosine-loss-based strategy also contributed to spillage reduction, especially during periods with significant cosine losses in the heliostat field.

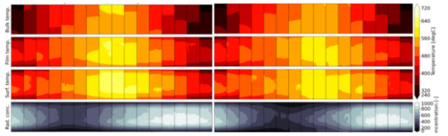


Fig. 1: *Comparison of concentration, receiver surface temperature, bulk fluid temperature, and film temperature at a specific timestep (March 27 at 08:10) for all panels of an external receiver before (left) and after (right) performing ACO optimization. This illustrates the effectiveness of stage 2 optimization in reducing the maximum film temperature from 616.0°C to 597.8°C while the bulk temperature is maintained above 565 °C.*

The stage 2 optimization ensured that the receiver's film temperature remained below the critical threshold of 600°C throughout various operating conditions. The ACO algorithm effectively adjusted aim points to prevent exceedance of the Allowable Flux Density (AFD) limits without any negative effect on the bulk temperature (see Figure 1).

On clear days the optically optimized distance-based strategy achieved solar gains approximately 1% higher than the baseline due to a reduction in overall spillage translating to significant energy output over time. The uniform flux distribution enhanced the efficiency of heat transfer within the receiver, contributing to improved thermal performance. The combined optimized strategies demonstrated stable performance across different sun positions and direct normal irradiance (DNI) conditions. The adaptive clustering and ACO aim point shifting allowed the system to respond effectively to environmental changes, reducing maximum film temperatures and avoiding thermal spikes even under transient conditions, thereby enhancing the receiver's operational safety and longevity.

Acknowledgements

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[1] A. Sánchez-González and D. Santana, "Solar flux distribution on central receivers: A projection method from analytic function," Renewable Energy, vol. 74, pp. 576–587, 2015, doi: 10.1016/j.renene.2014.08.016.

[2] D.E. Goldberg, J.H. Holland, "Genetic Algorithms and Machine Learning". Machine Learning 3, 95–99, 1988. https://doi.org/10.1023/A:1022602019183

[3] L. L. Vant-Hull, "The role of "allowable flux density" in the design and operation of molten salt solar central receivers" ASME. J. Sol. Energy Eng., vol. 124, no. 2, pp. 165–169, 2002.

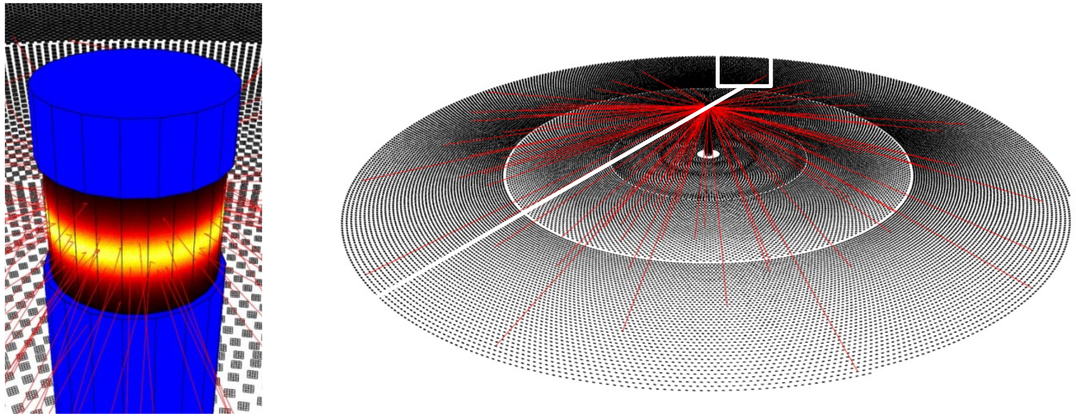
[4] M. Dorigo and T. Stützle, "Ant colony optimization," IEEE Computational Intelligence Magazine, vol. 1, no. 4, pp. 28–39, 2006.

Abstract handed in for SolarPACES conference

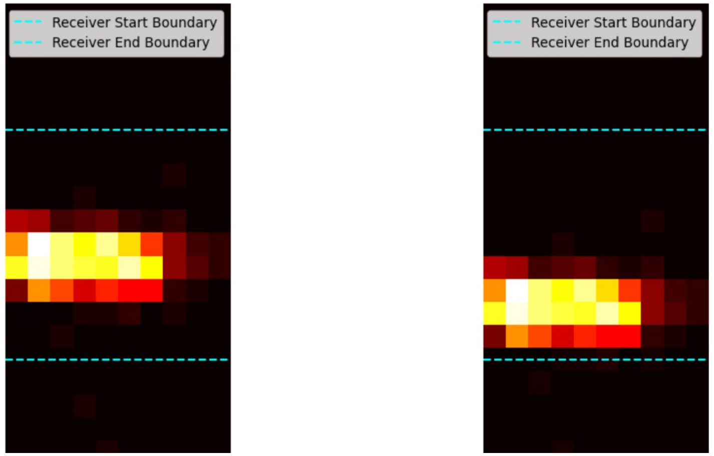
SolarX System Model
Exemplarily Study Case

Optimized heliostat aim strategies for the Cerro Dominador: **trade-off between maximizing efficiency and ensuring receiver integrity.**

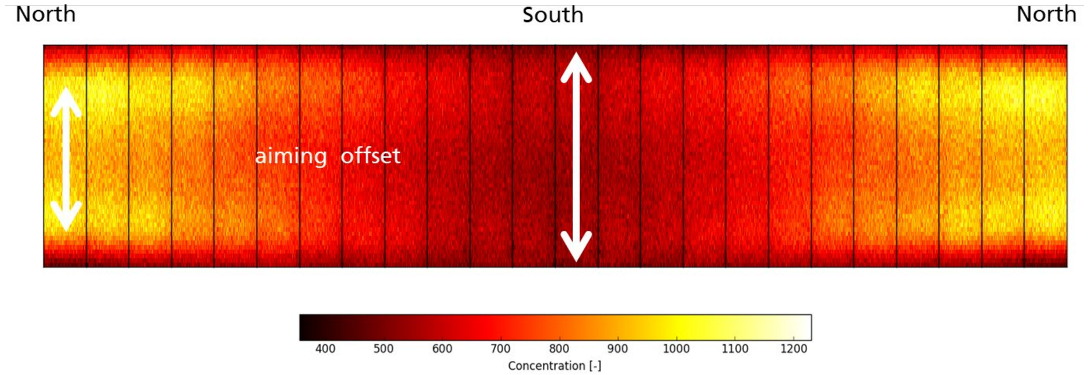
ARIA method to implement aim point optimizations
→ enable testing of different aiming strategies



Ray tracing model of 600 MW_{th} Solar Island (heliostat field/receiver)



2D concentration map of a heliostat on one panel



Vertical aiming strategy with circumferential profile

SolarX System Model
Exemplarily Study Case

- Publication of HelioSlider in Solar Energy (Heliostat Field Issue)

- Design heliostat field for new scenarios:
    - Location?
    - Receiver sizes?
    - Oversizing of the heliostat field?
    - Multi-tower?

→ **Definition of scenarios**

HelioSliders: Novel Heliostat Field Design Approach based on Collision Analysis of Shadow Projections

Peter Schöttl[a,*], Joseph Kehinde Ishola[a], Caroline Ganzer[b], Maitane Ferreres Eceiza[a], Gregor Bern[a]

[a] Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany
[b] Max Planck Institute for Dynamics of Complex Technical Systems, Sandtorstrasse 1, 39106 Magdeburg, Germany

Abstract

This paper presents HelioSliders, an innovative, pattern-free methodology for heliostat field design that is applicable to both single-focus and multi-focus Solar Tower systems. By projecting the heliostat mirror outlines onto a horizontal plane – using perspective projection from a designated aim point for blocking and parallel projection along the sun vector for shading – the algorithm generates two-dimensional blocking and shading contours. These representations are used in a 2D rigid-body simulation in which each heliostat is dynamically repositioned within defined inner and outer boundaries. The algorithm ensures that the overlapping of the blocking and shading contours of neighboring heliostats is minimal. An artificial gravitational force draws the heliostats toward the receiver, thereby minimizing spillage and atmospheric attenuation.

The HelioSliders method is demonstrated through optical benchmarks using ray tracing, where its performance is compared with three reference designs that cover both conventional single-focus Solar Tower systems and advanced multi-focus Beam-Down configurations. Compared to the reference designs, HelioSliders achieved a relative increase in annual optical efficiency of 1.4 %, 0.9 % and 0.8 % and a relative reduction in field area of 21.0 %, 13.2 % and 0.3 %, for the Gemasolar, PS10 and Bi-Focal Beam-Down scenarios, respectively. Sensitivity analyses show that optimizing parameters – HelioSliders algorithm-related, but also system-related, such as the heliostat aspect ratio – can further improve annual optical efficiency and reduce the field's physical footprint. The results highlight that HelioSliders offers a versatile, computationally efficient, and adaptable framework for designing highly efficient heliostat fields.

Keywords: central receiver solar tower systems, heliostat field design, shadow projection, 2D rigid-body simulation, ray tracing benchmark

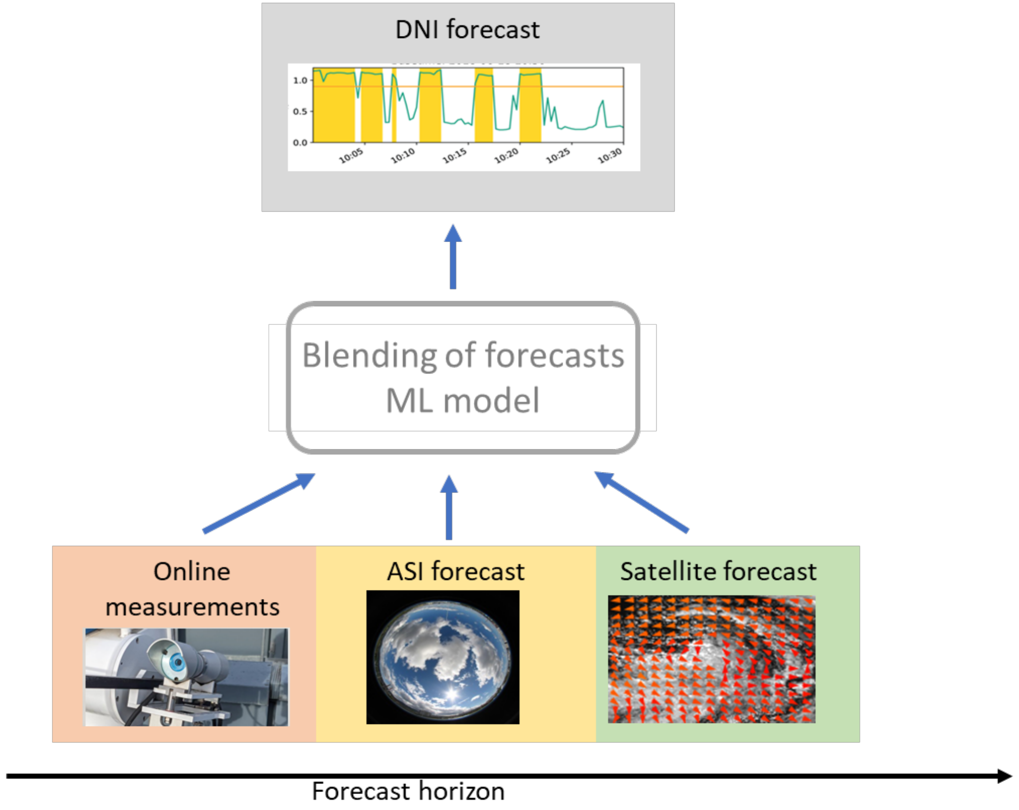
Contents

1. Introduction

SolarX System Monitoring
Solar Resource Assessment – DNI Nowcasting

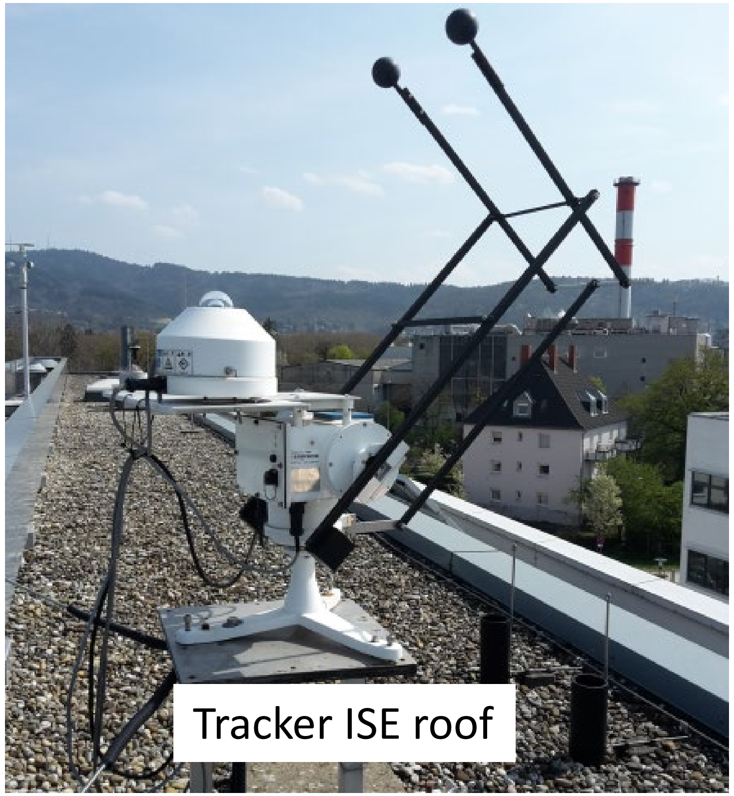
Forecasting model combining:
- Measurement based forecast
- All Sky Imager (ASI) based forecast
- Satellite based forecast

Forecast parameters:
- Maximal forecast horizon: 1 h
- Resolution: 1 min



SolarX System Monitoring
Solar Resource Assessment – DNI Nowcasting

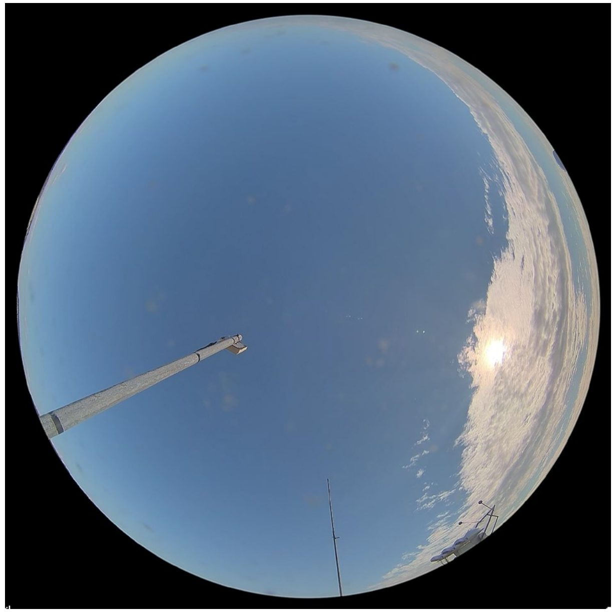

ASI ISE roof


Tracker ISE roof

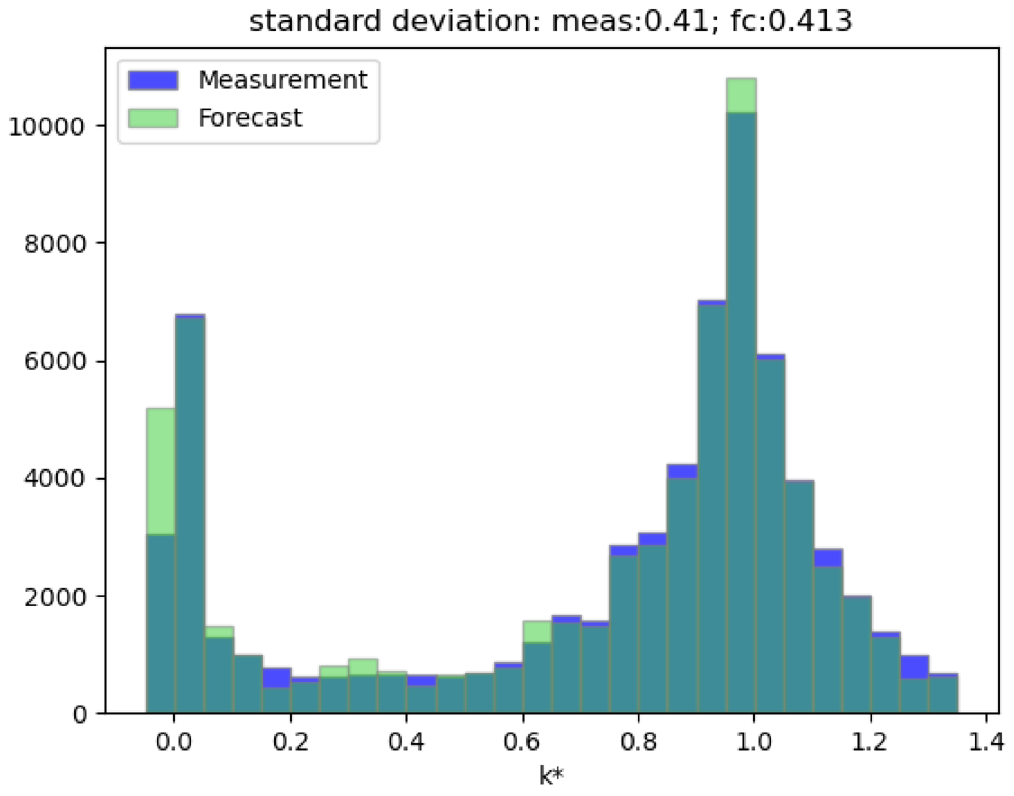

ASI IPM roof

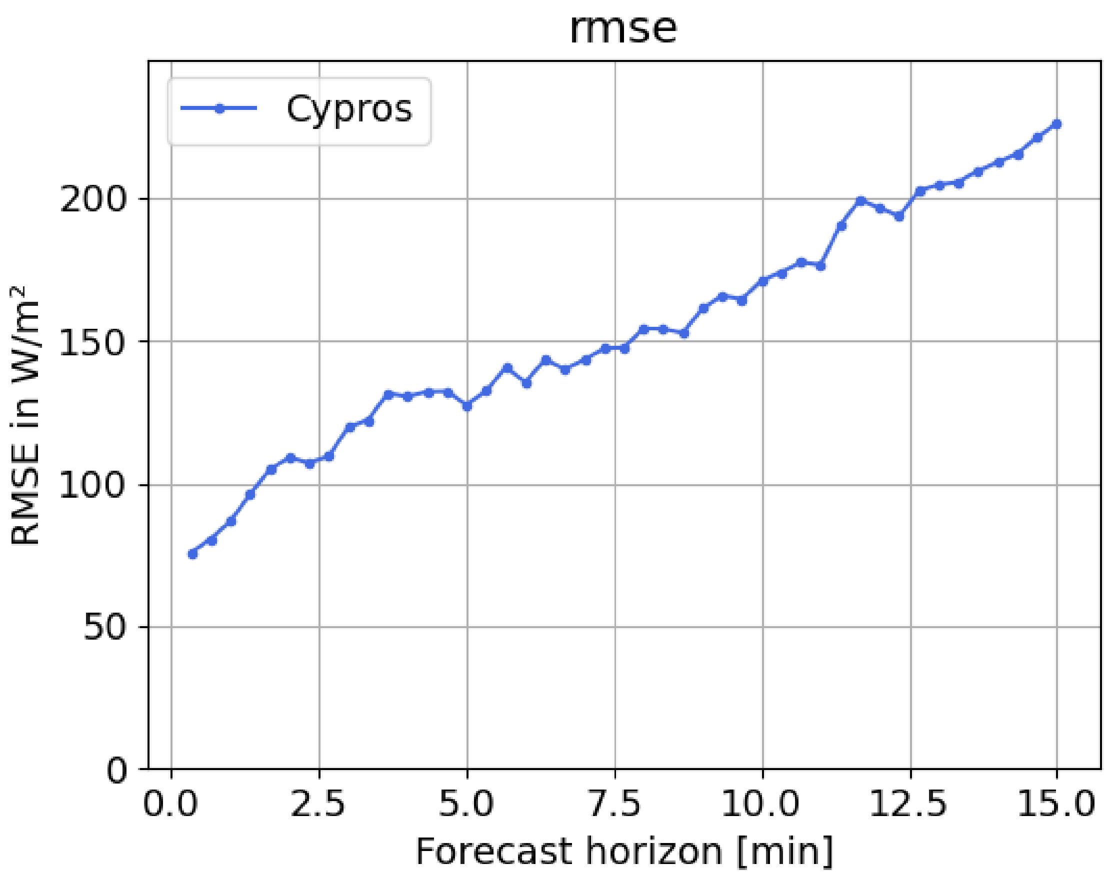
SolarX System Monitoring

Solar Resource Assessment – DNI Nowcasting



SolarX System Monitoring
Solar Resource Assessment – DNI Nowcasting





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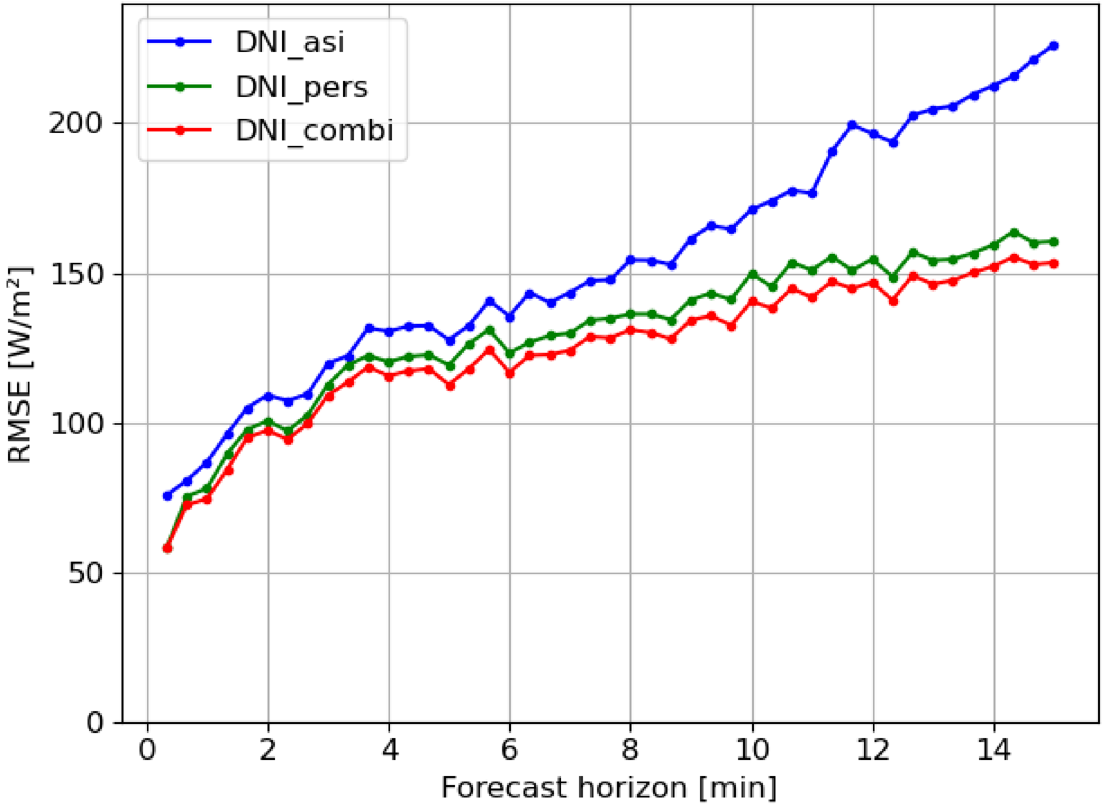

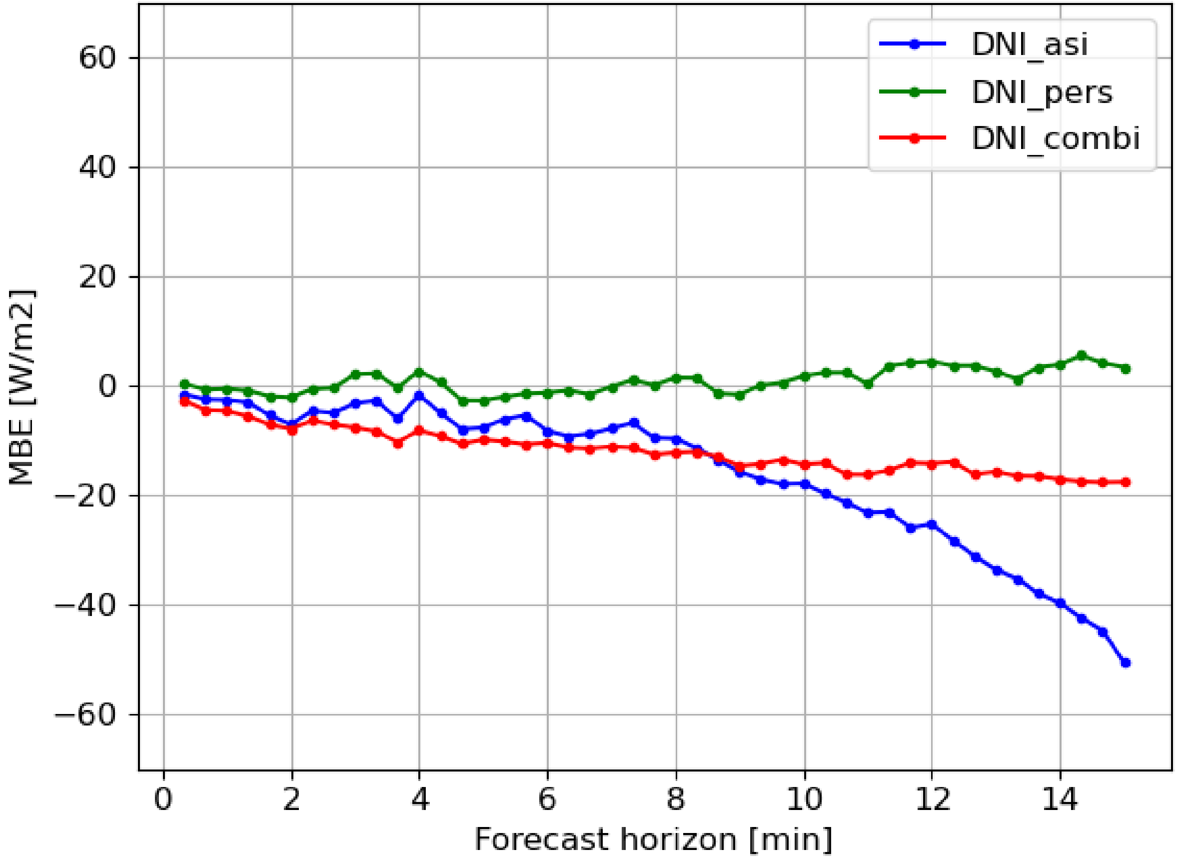

SolarX System Monitoring
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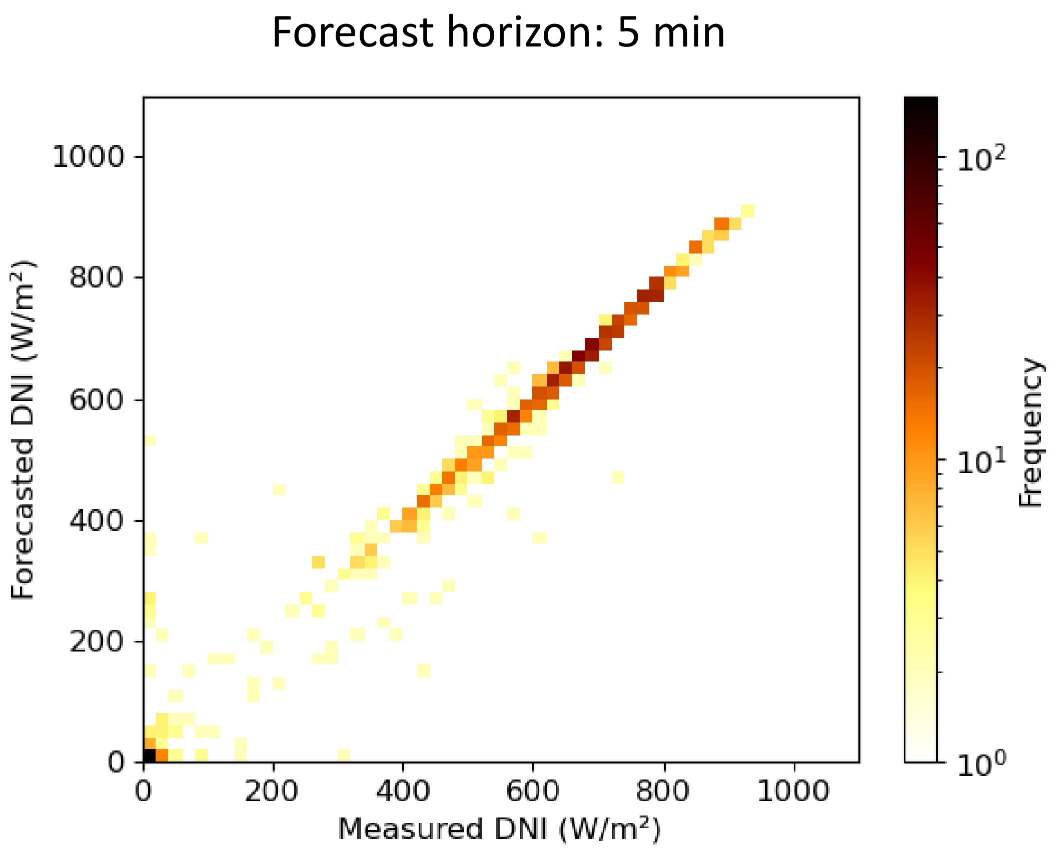
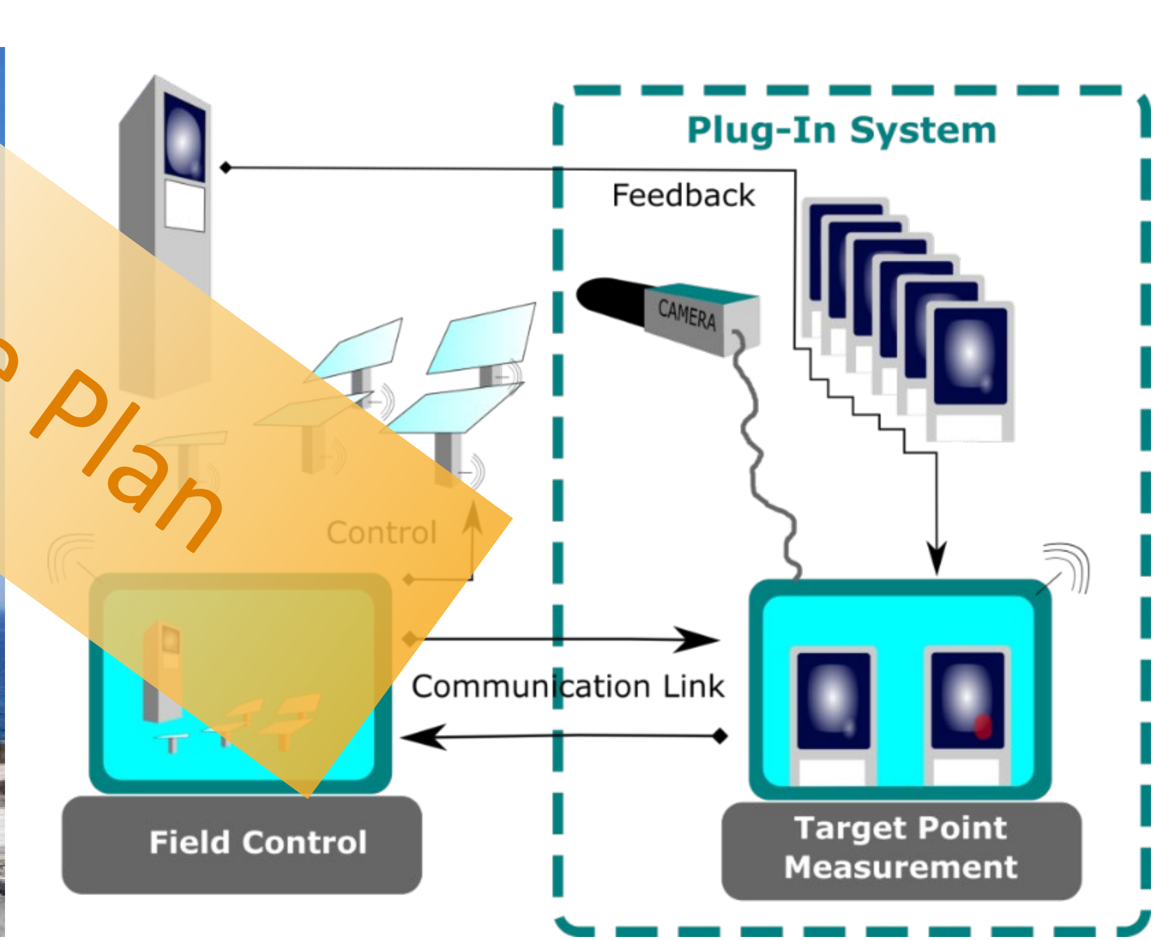


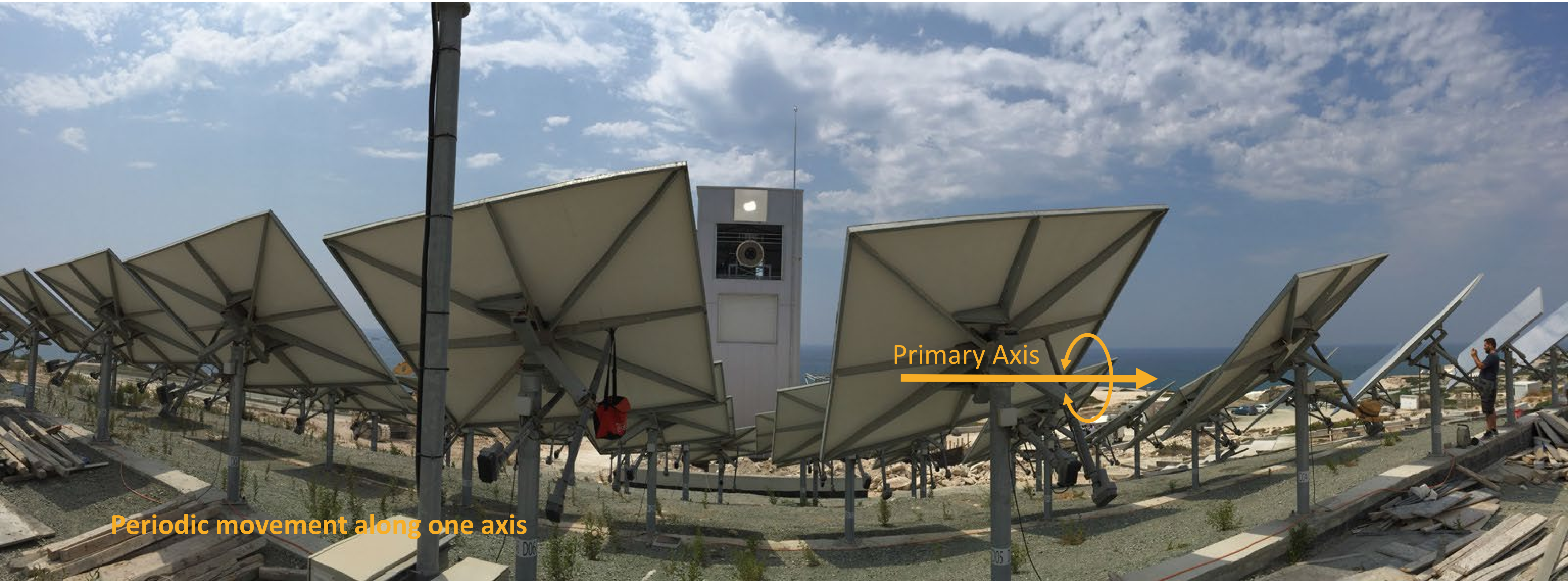
- A DNI forecast based on ASI data was implemented
- A DNI forecast based on satellite data wa implemented
- A combined forecast based on measurements, ASI and satellite data was calculated for the location Freiburg
- A combined forecast based on measuremetns and ASI data was calculated for the location Cyprus
- Results are very promising
- Data collection at Cyprus is ongoing.
- Next step – integration with optical model for yield forecast and control

SolarX System Monitoring
Fast and Precise Heliostat Calibration



SolarX System Monitoring
HelioControl Approach

Definition of requirements at PROTEAS



SolarX System Monitoring
HelioControl Approach

Definition of requirements at PROTEAS

SolarX System Monitoring
HelioControl Approach

Integration Concept

- Finalization of definitions with CYI and Heliostat Field Developer:
  - Implementation of geometric definitions of PROTEAS (F-ISE)
  - Heliostat control adaptation (HS-developer)
  - Full field availability (CYI)
  - Two aim point availability? (CYI)

- Eventually hardware integration / colocation
- Test and demonstration

The Plan

SolarX System Monitoring
HelioControl Approach

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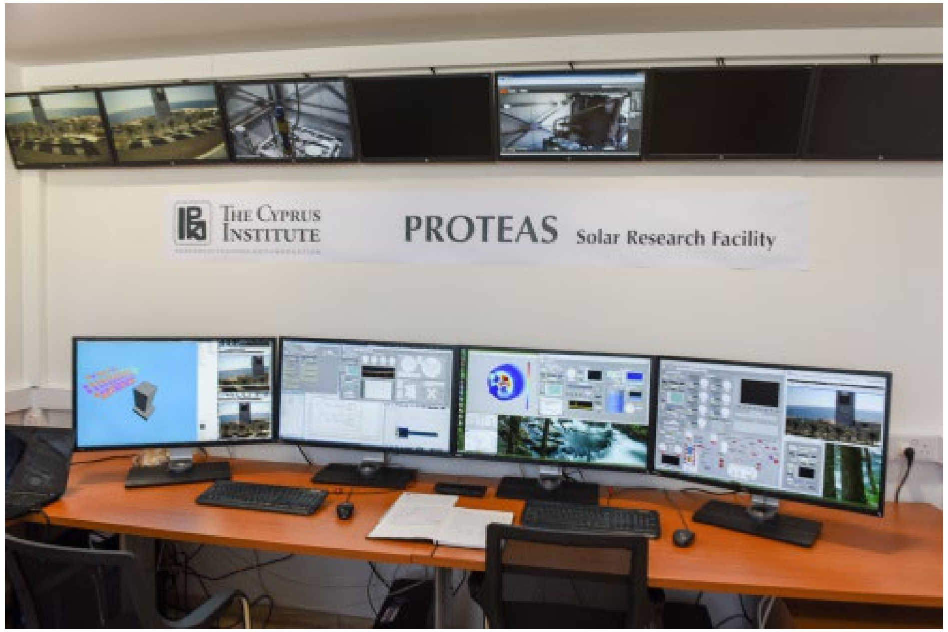


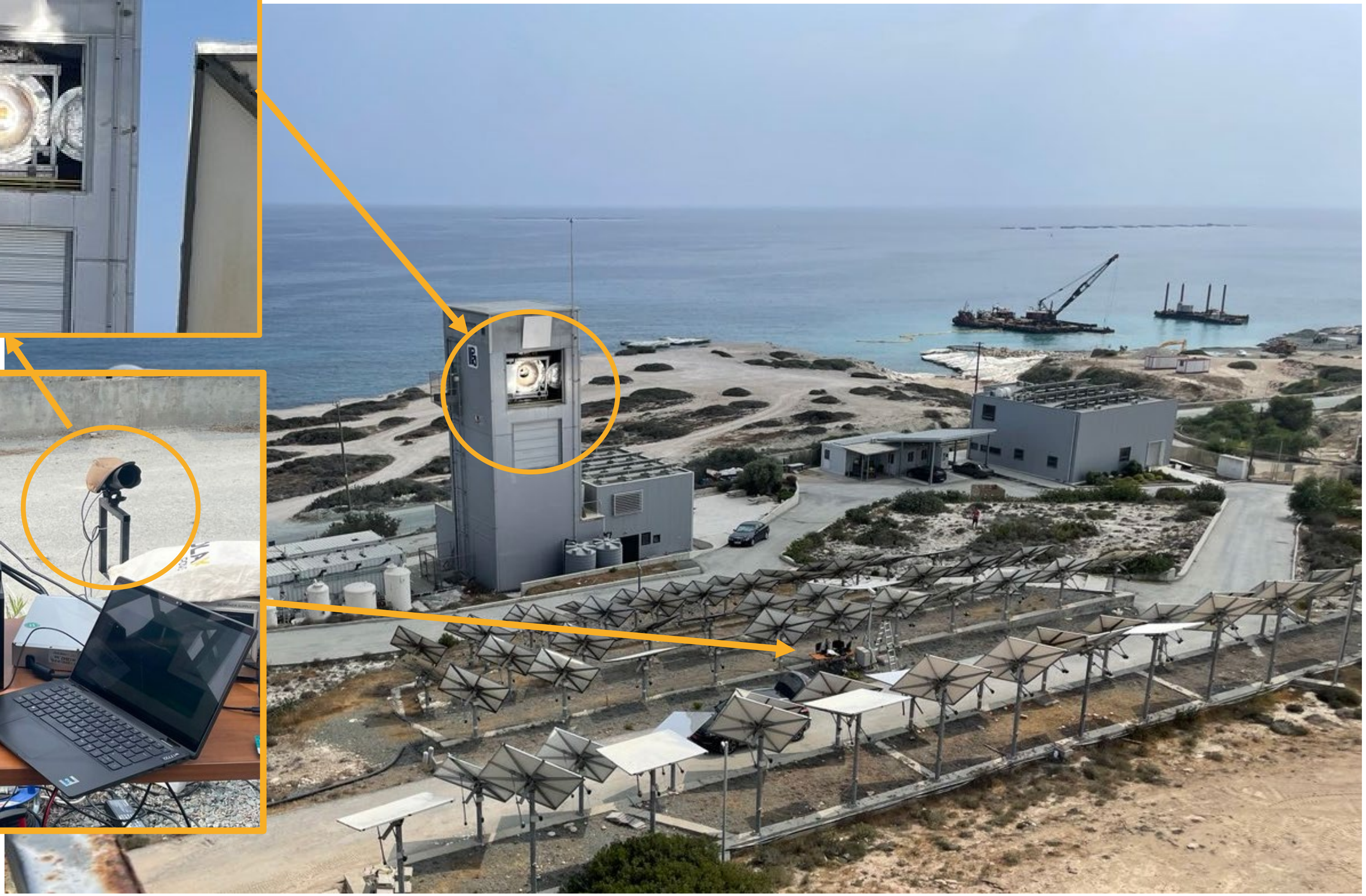
SolarX System Monitoring

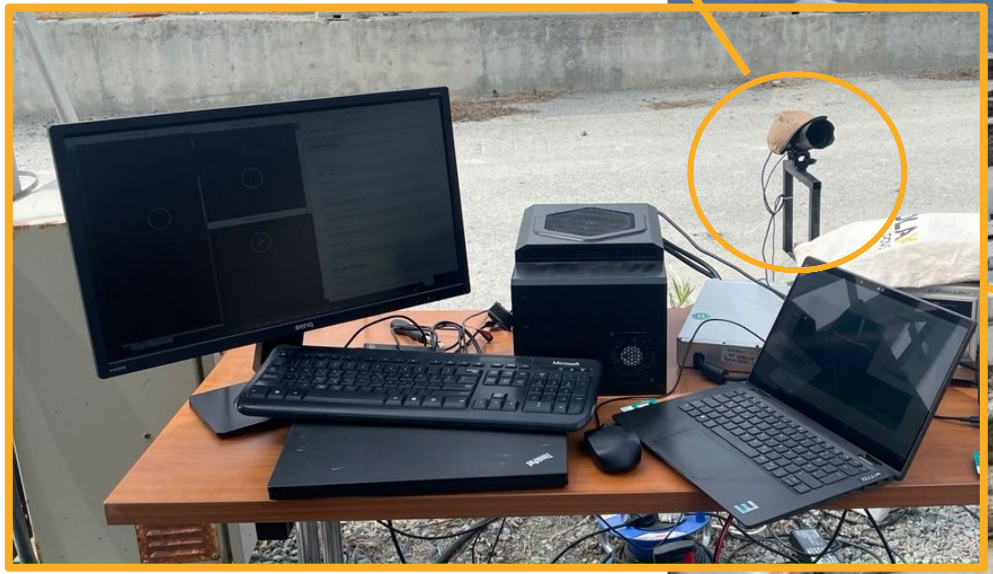
HelioControl Approach

SolarX System Monitoring
HelioControl Approach

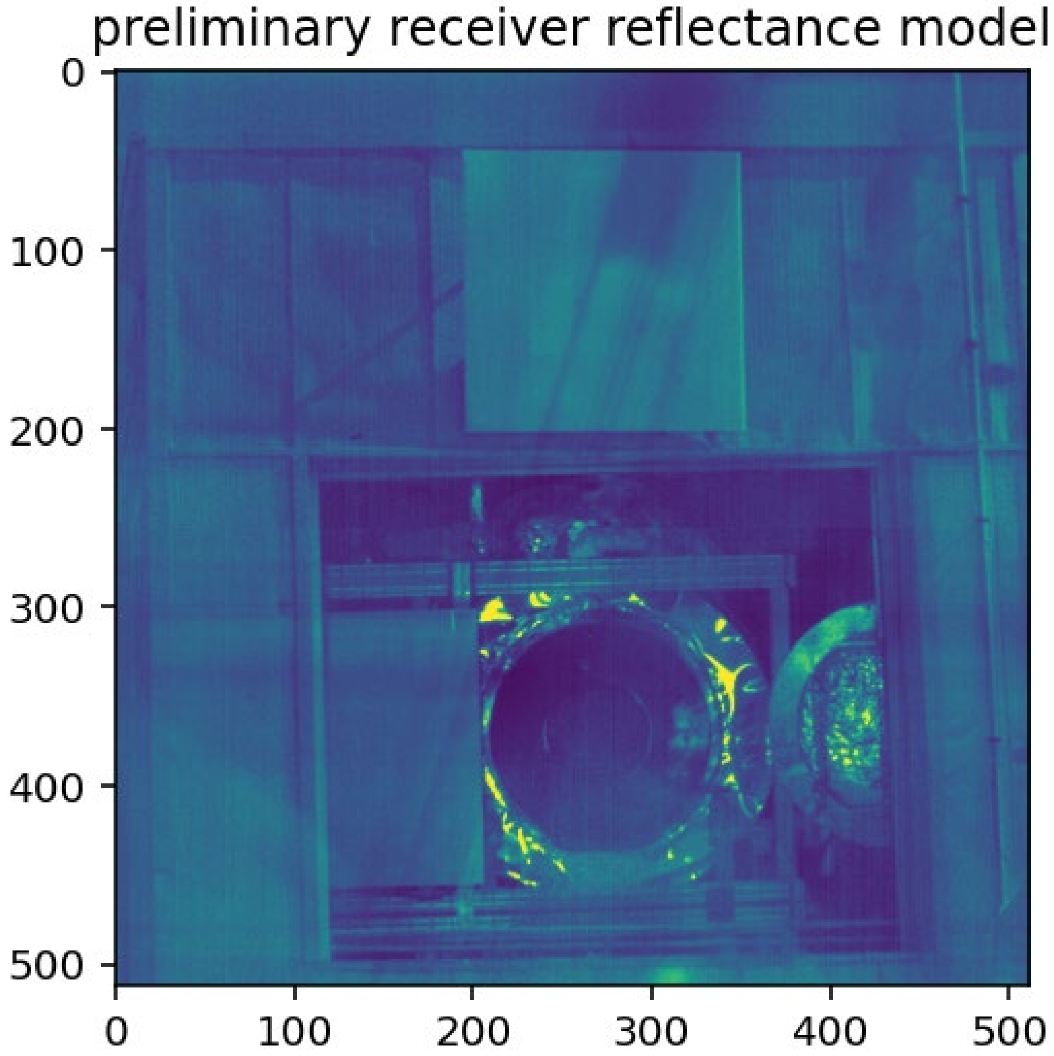
SolarX itoring

HelioCon

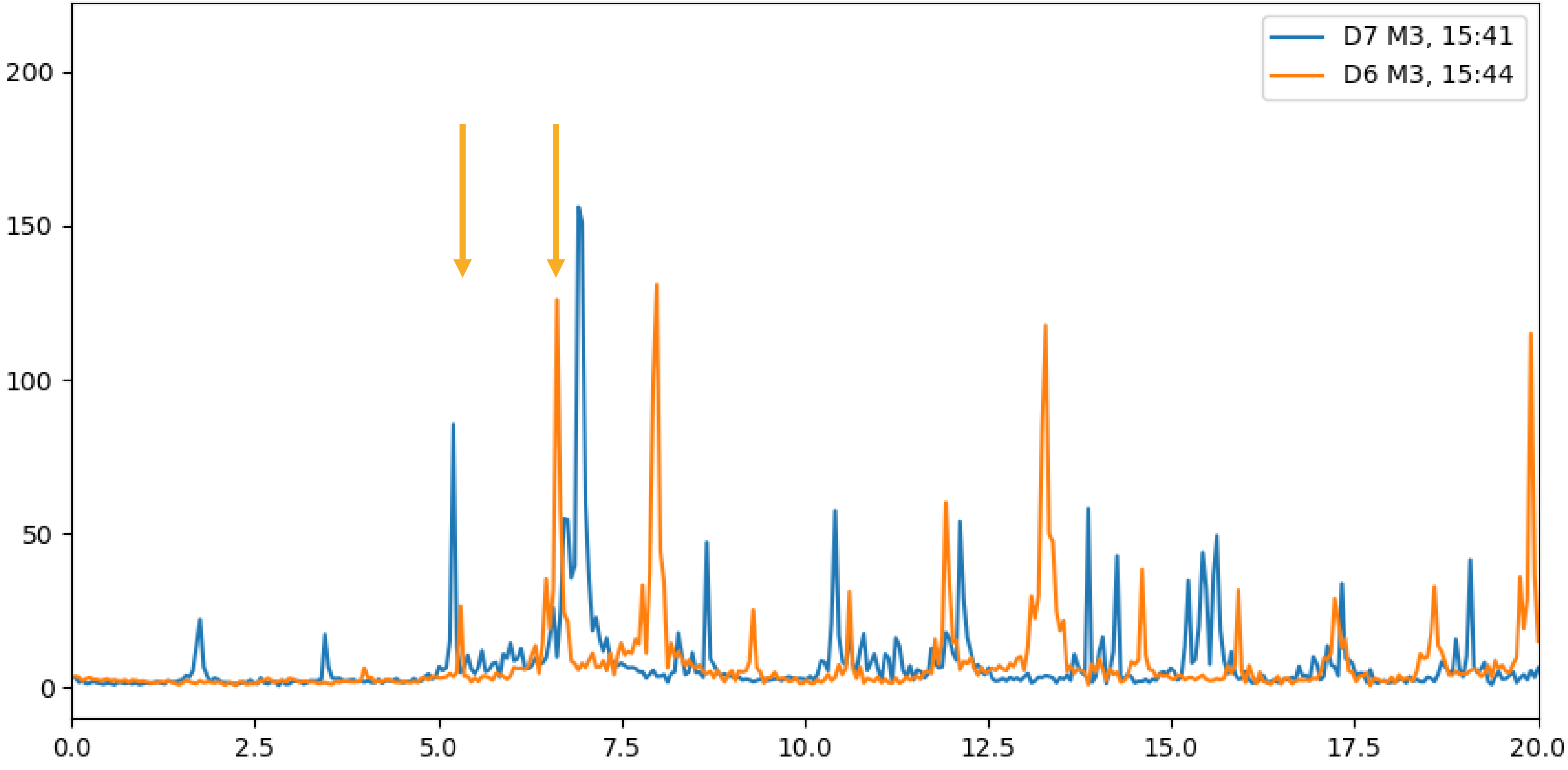




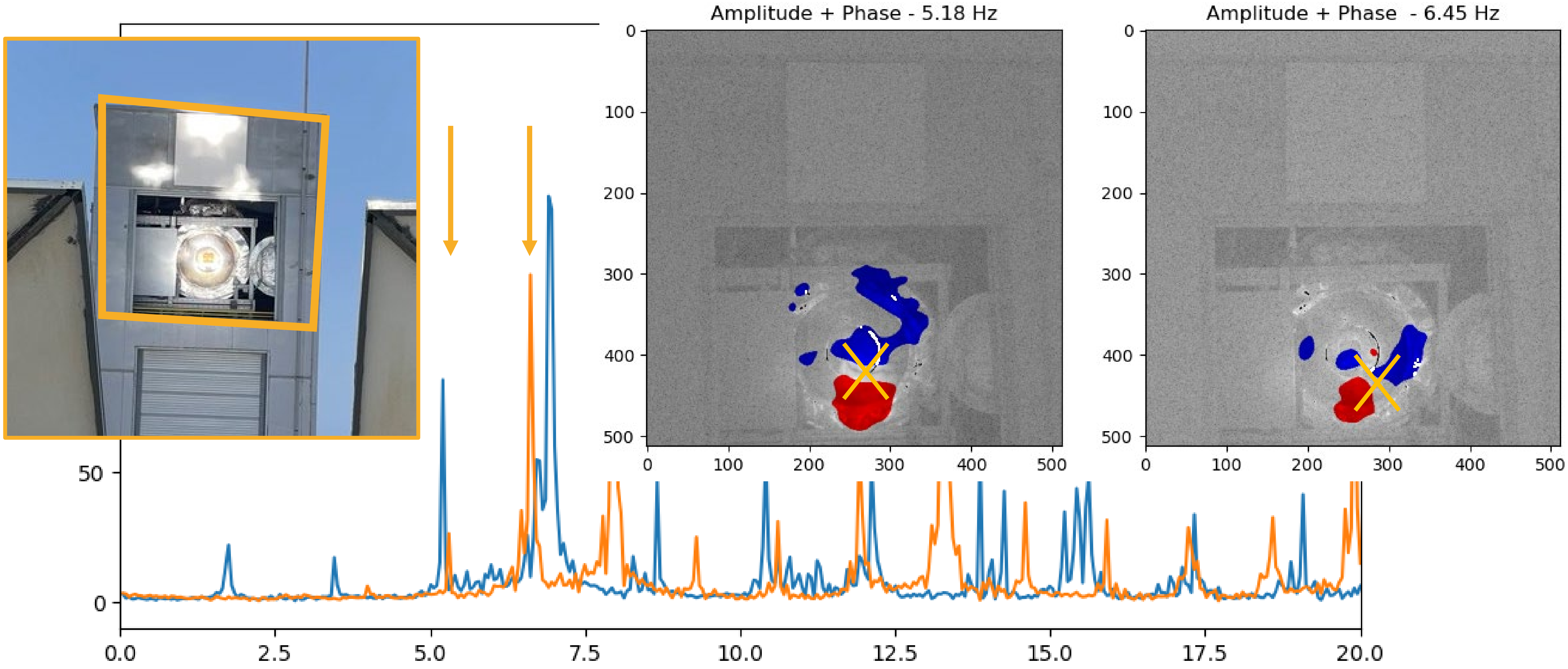
SolarX System Monitoring
HelioControl Approach



SolarX System Monitoring
HelioControl Approach



SolarX System Monitoring
HelioControl Approach (Amplitude + Phase)

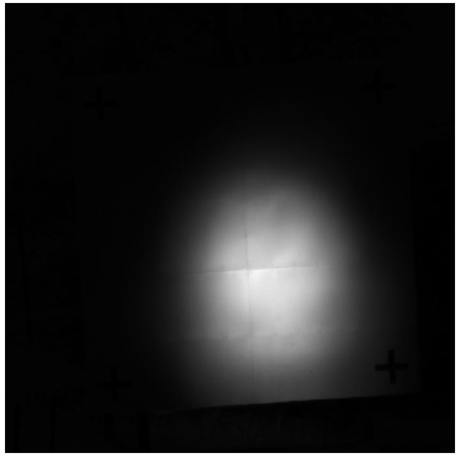


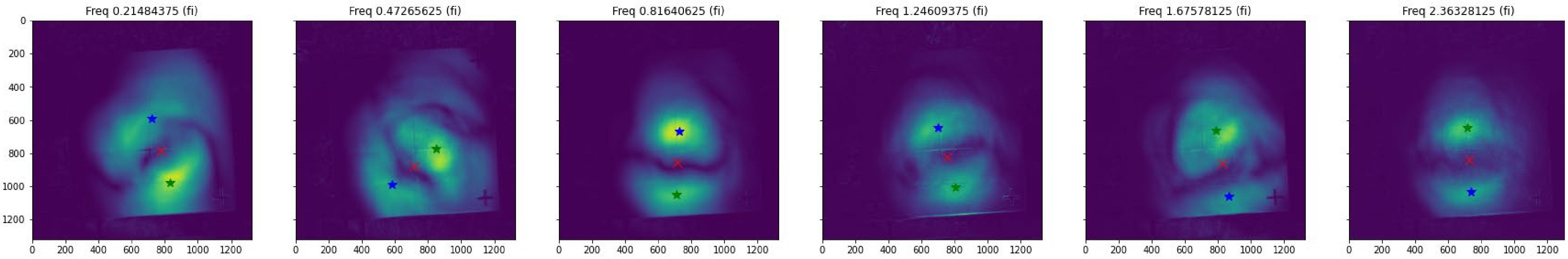
SolarX System Monitoring
HelioControl Approach

- ~70 measurement data sets acquired
- First promising results
- However:
  - Implementation with additional „vibrating drives“ not recommended
  - Natural frequencies of heliostats are too close
  - **Implementation with heliostat drives allows for frequency control**
  - **→ proven at small scale, to be demonstrated in commercial scale**

SolarX System Monitoring
HelioControl Approach – What it should look like

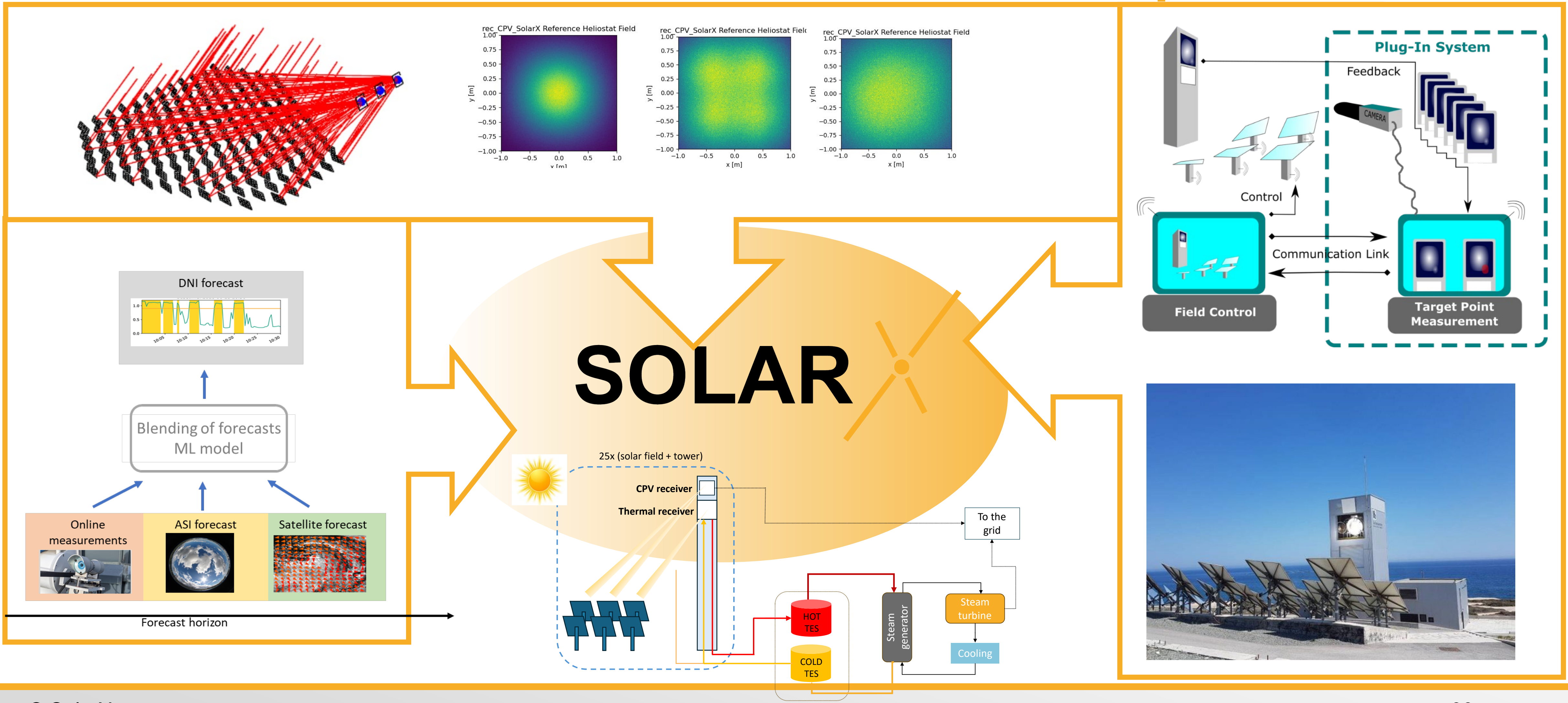
- Test of HelioControl Method with Vast Solar in Australia, Brisbane
- Fast Setup (Camera: 30 minutes)
- No optimization at all
- 6 aim points in 20 seconds (0.3/s)
- Theoretically 2.0/s is possible
- → Comparison with BCS





SolarX Solar Management

Towards Model Predictive - and Closed Loop Control



Contact

Maitane Ferreres Eceiza

maitane.ferreres.eceiza@ise.fraunhofer.de

Anna Dittmann

Anna.dittmann@ise.fraunhofer.de

Dr. Gregor Bern

gregor.bern@ise.fraunhofer.de

Fraunhofer Institute for Solar Energy Systems ISE

www.ise.fraunhofer.de

Dispatchable concentrated Solar-to-X energy solution for high penetration of renewable energy

www.solarx-project.eu

Co-funded by the European Union

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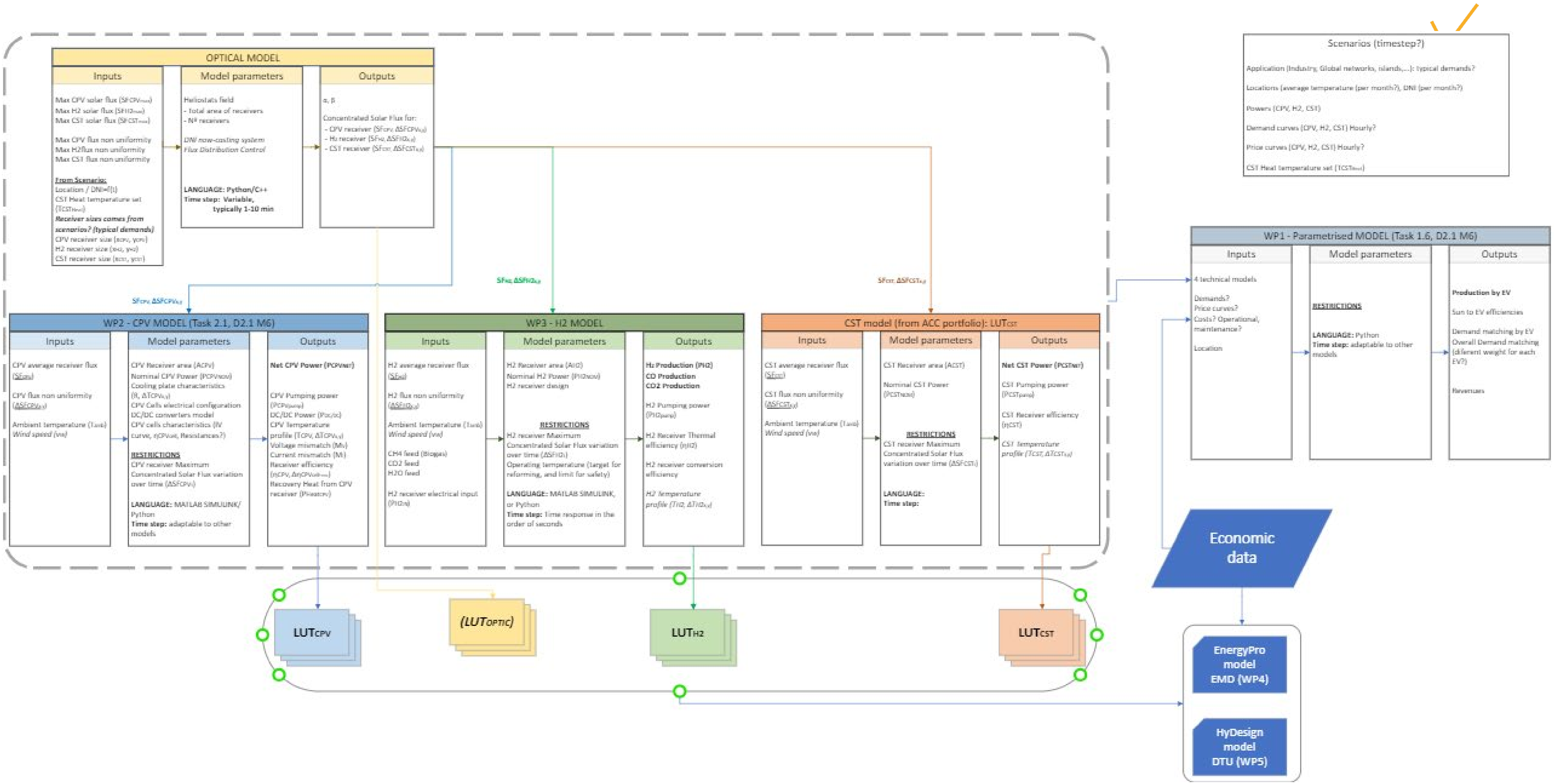
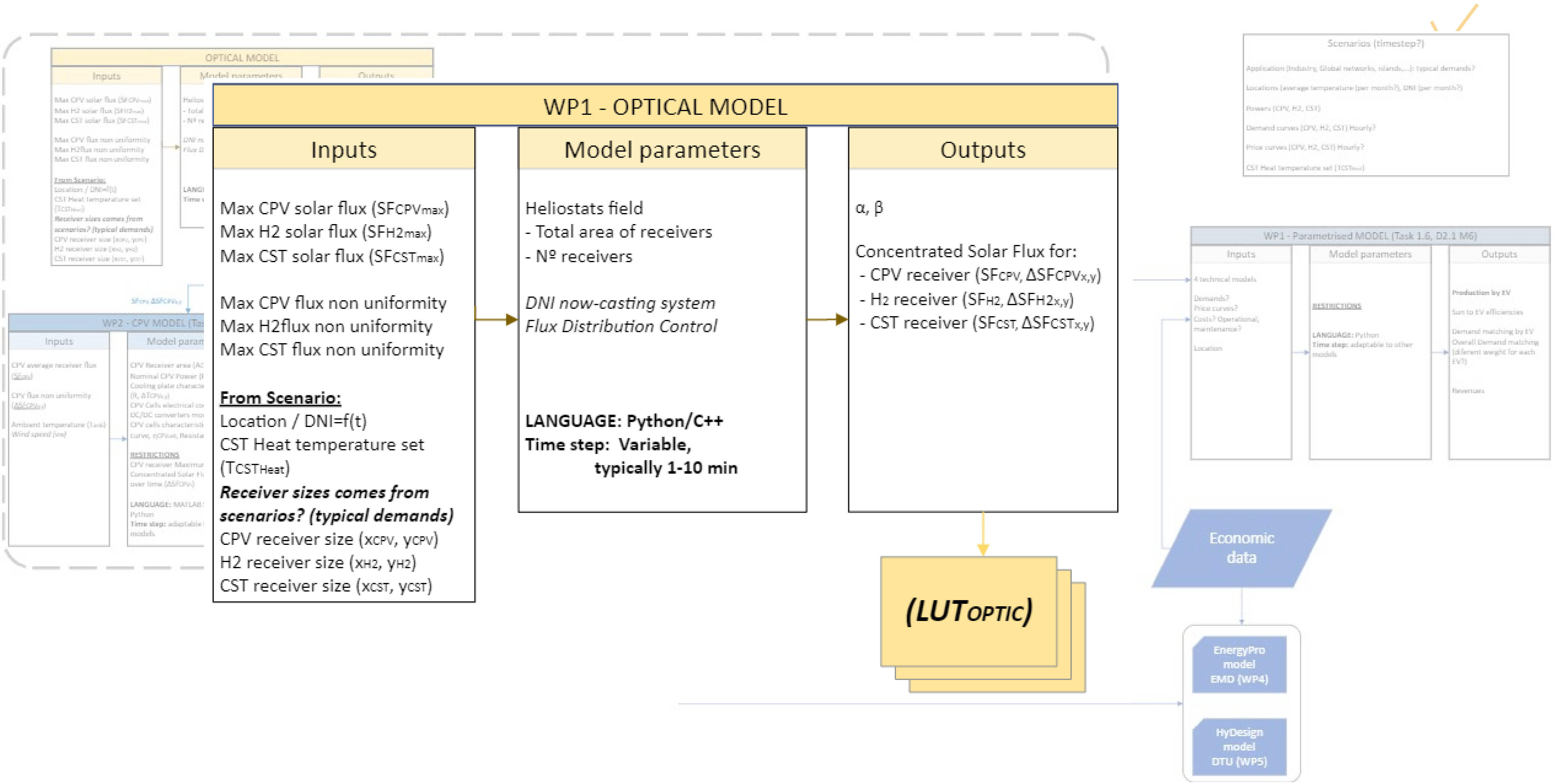
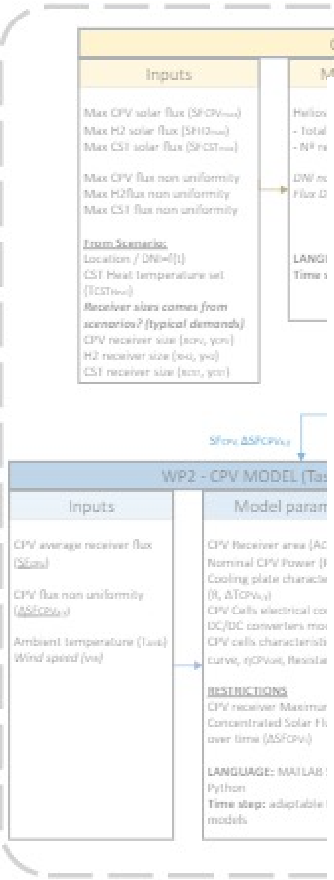


OPTICAL MODEL
Inputs
Max CPV solar flux
Max H2 solar flux
Max CST solar flux
Max CPV flux non uniformity
Max H2flux non uniformity
Max CST flux non uniformity
From Scenario:
Location / DNI=f(t)
CST Heat temperature set
Receiver sizes comes from scenarios? (typical demands)
CPV receiver size
H2 receiver size
CST receiver size
Model parameters
Heliostats field
- Total area of receivers
- Nº receivers
DNI now-casting system
Flux Distribution Control
LANGUAGE: Python/C++
Time step: Variable, typically 1-10 min
Outputs
α, β
Concentrated Solar Flux for:
- CPV receiver
- H₂ receiver
- CST receiver
WP2 - CPV MODEL (Task 2.1, D2.1 M6)
Inputs
CPV average receiver flux
CPV flux non uniformity
Ambient temperature
Wind speed
Model parameters
CPV Receiver area (ACPV)
Nominal CPV Power
Cooling plate characteristics
CPV Cells electrical configuration
DC/DC converters model
CPV cells characteristics (IV curve, Resistances?)
RESTRICTIONS
CPV receiver Maximum Concentrated Solar Flux variation over time
LANGUAGE: MATLAB SIMULINK/ Python
Time step: adaptable to other models
Outputs
Net CPV Power
CPV Pumping power
DC/DC Power
CPV Temperature profile
Voltage mismatch
Current mismatch
Receiver efficiency
Recovery Heat from CPV receiver
WP3 - H2 MODEL
Inputs
H2 average receiver flux
H2 flux non uniformity
Ambient temperature
Wind speed
CH4 feed (Biogas)
CO2 feed
H2O feed
H2 receiver electrical input
Model parameters
H2 Receiver area
Nominal H2 Power
H2 receiver design
RESTRICTIONS
H2 receiver Maximum Concentrated Solar Flux variation over time
Operating temperature (target for reforming, and limit for safety)
LANGUAGE: MATLAB SIMULINK, or Python
Time step: Time response in the order of seconds
Outputs
H₂ Production
CO Production
CO2 Production
H2 Pumping power
H2 Receiver Thermal efficiency
H2 receiver conversion efficiency
H2 Temperature profile
CST model (from ACC portfolio): LUTCST
Inputs
CST average receiver flux
CST flux non uniformity
Ambient temperature
Wind speed
Model parameters
CST Receiver area (ACST)
Nominal CST Power
RESTRICTIONS
CST receiver Maximum Concentrated Solar Flux variation over time
LANGUAGE:
Time step:
Outputs
Net CST Power
CST Pumping power
CST Receiver efficiency
CST Temperature profile
Scenarios (timestep?)
Application (Industry, Global networks, islands,...): typical demands?
Locations (average temperature (per month?), DNI (per month?)
Powers (CPV, H2, CST)
Demand curves (CPV, H2, CST) Hourly?
Price curves (CPV, H2, CST) Hourly?
CST Heat temperature set
WP1 - Parametrised MODEL (Task 1.6, D2.1 M6)
Inputs
4 technical models
Demands?
Price curves?
Costs? Operational, maintenance?
Location
Model parameters
RESTRICTIONS
LANGUAGE: Python
Time step: adaptable to other models
Outputs
Production by EV
Sun to EV efficiencies
Demand matching by EV
Overall Demand matching (diferent weight for each EV?)
Revenues
LUTCPV
(LUTOPTIC)
LUTH2
LUTCST
Economic data
EnergyPro model EMD (WP4)
HyDesign model DTU (WP5)


WP1 - OPTICAL MODEL
Inputs
Max CPV solar flux (SFCPVmax)
Max H2 solar flux (SFH2max)
Max CST solar flux (SFCSTmax)
Max CPV flux non uniformity
Max H2flux non uniformity
Max CST flux non uniformity
From Scenario:
Location / DNI=f(t)
CST Heat temperature set (TCSTHeat)
Receiver sizes comes from scenarios? (typical demands)
CPV receiver size (xCPV, yCPV)
H2 receiver size (xH2, yH2)
CST receiver size (xCST, yCST)
Model parameters
Heliostats field
- Total area of receivers
- Nº receivers
DNI now-casting system
Flux Distribution Control
LANGUAGE: Python/C++
Time step: Variable, typically 1-10 min
Outputs
α, β
Concentrated Solar Flux for:
- CPV receiver (SFCPV, ΔSFCPVx,y)
- H2 receiver (SFH2, ΔSFH2x,y)
- CST receiver (SFCST, ΔSFCSTx,y)
(LUTOPTIC)
Economic data
EnergyPro model EMD (WP4)
HyDesign model DTU (WP5)



WP2 - CPV MODEL (Task 2.1, D2.1 M6)

Inputs

CPV average receiver flux (SF_{CPV})
FLUX DISTRIBUTION
BETTER THAN :
CPV flux non uniformity ($\Delta SF_{CPVx,y}$)

Ambient temperature (T_{amb})
Wind speed (v_W)

Model parameters

CPV Receiver area (A_{CPV})
Nominal CPV Power (P_{CPVNOM})
Cooling plate characteristics (R, $\Delta T_{CPVx,y}$)
CPV Cells electrical configuration
DC/DC converters model
CPV cells characteristics (IV curve, ηCPV_{cell}, Resistances?)

RESTRICTIONS
CPV receiver Maximum Concentrated Solar Flux variation over time (ΔSF_{CPVt})

LANGUAGE: MATLAB SIMULINK/ Python
Time step: adaptable to other models

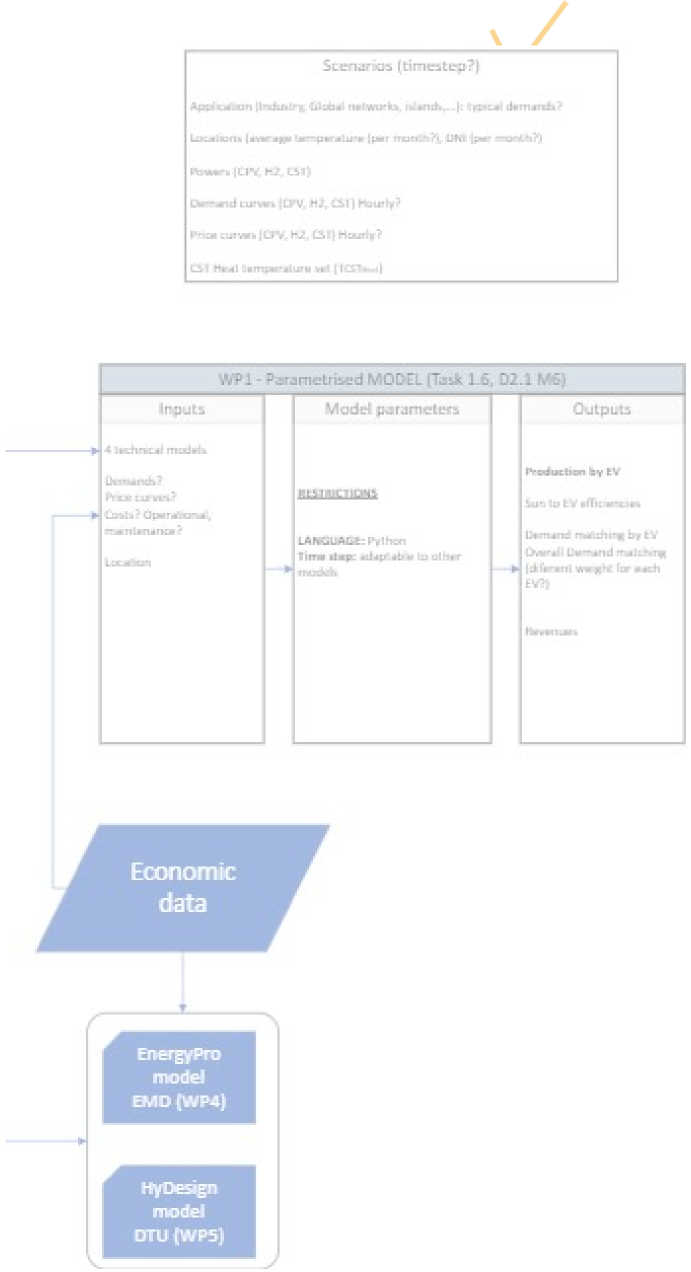
Outputs

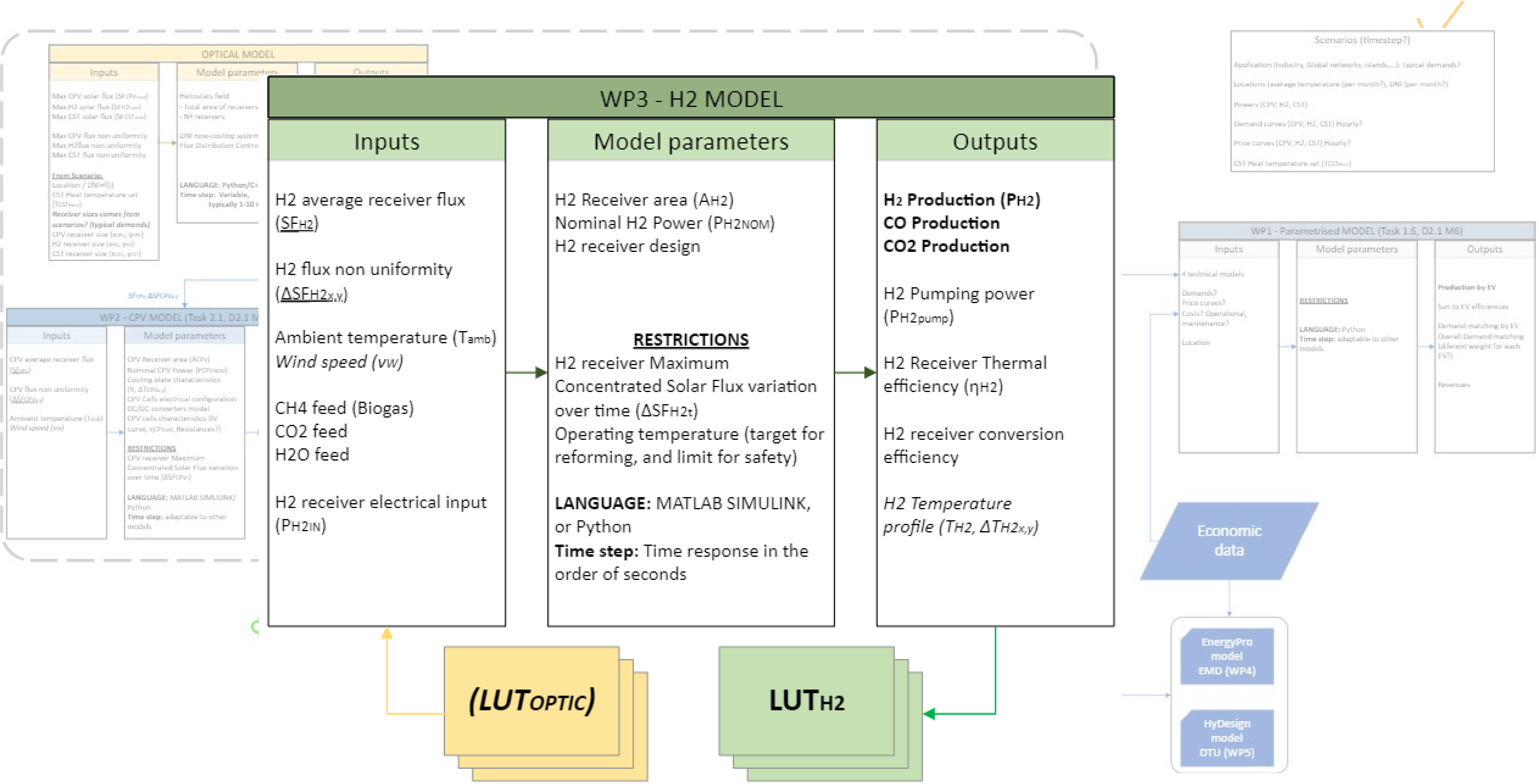
Net CPV Power (P_{CPVNET})

SECONDARY OUTPUTS:
CPV Pumping power ($P_{CPVpump}$)
DC/DC Power ($P_{DC/DC}$)
CPV Temperature profile (T_{CPV}, $\Delta T_{CPVx,y}$)
Voltage mismatch (M_V)
Current mismatch (M_I)
Receiver efficiency (ηCPV, $\Delta \eta CPV_{cell-rec}$)
Recovery Heat from CPV receiver ($P_{HeatCPV}$)

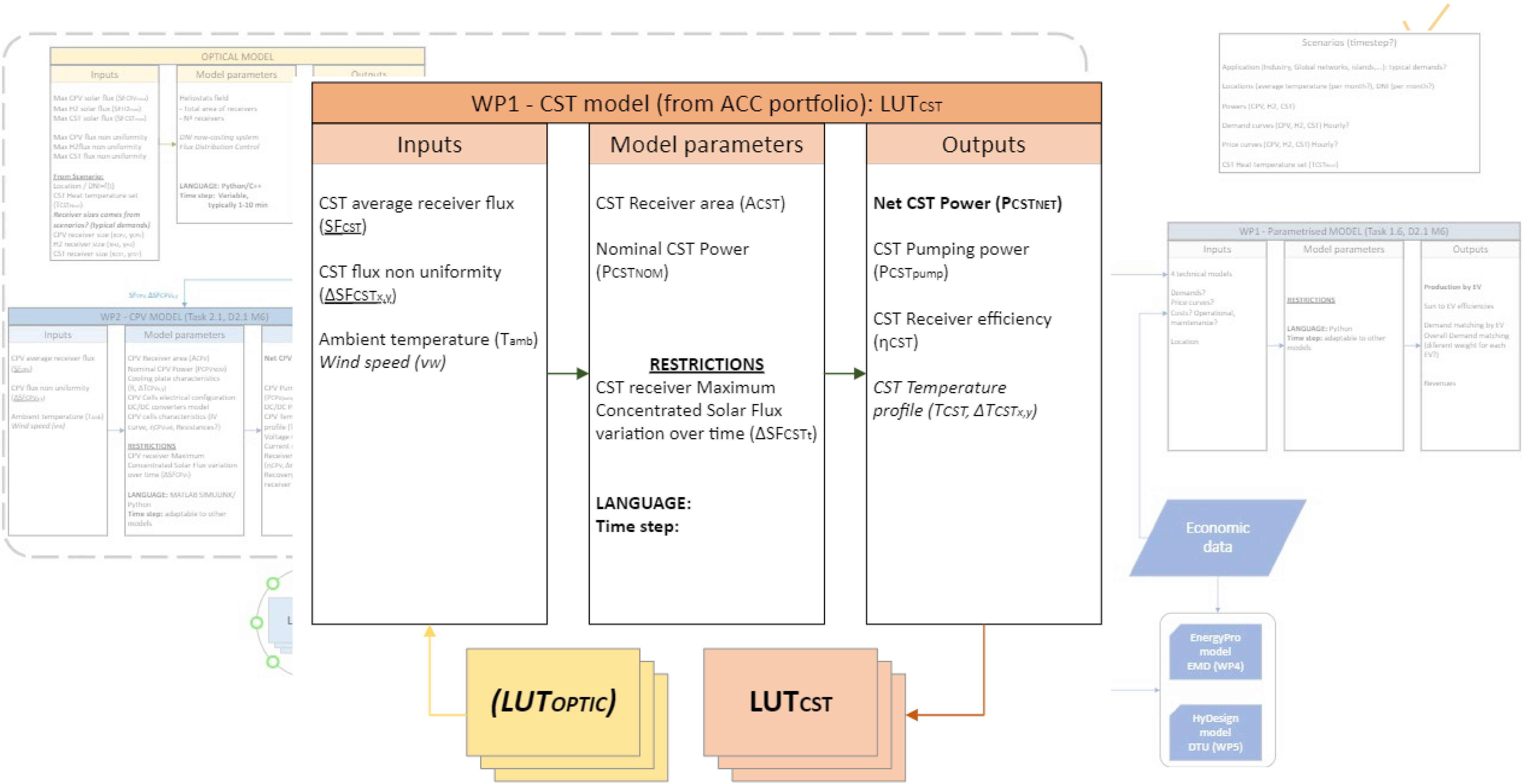
(LUT_{OPTIC})

LUT_{CPV}

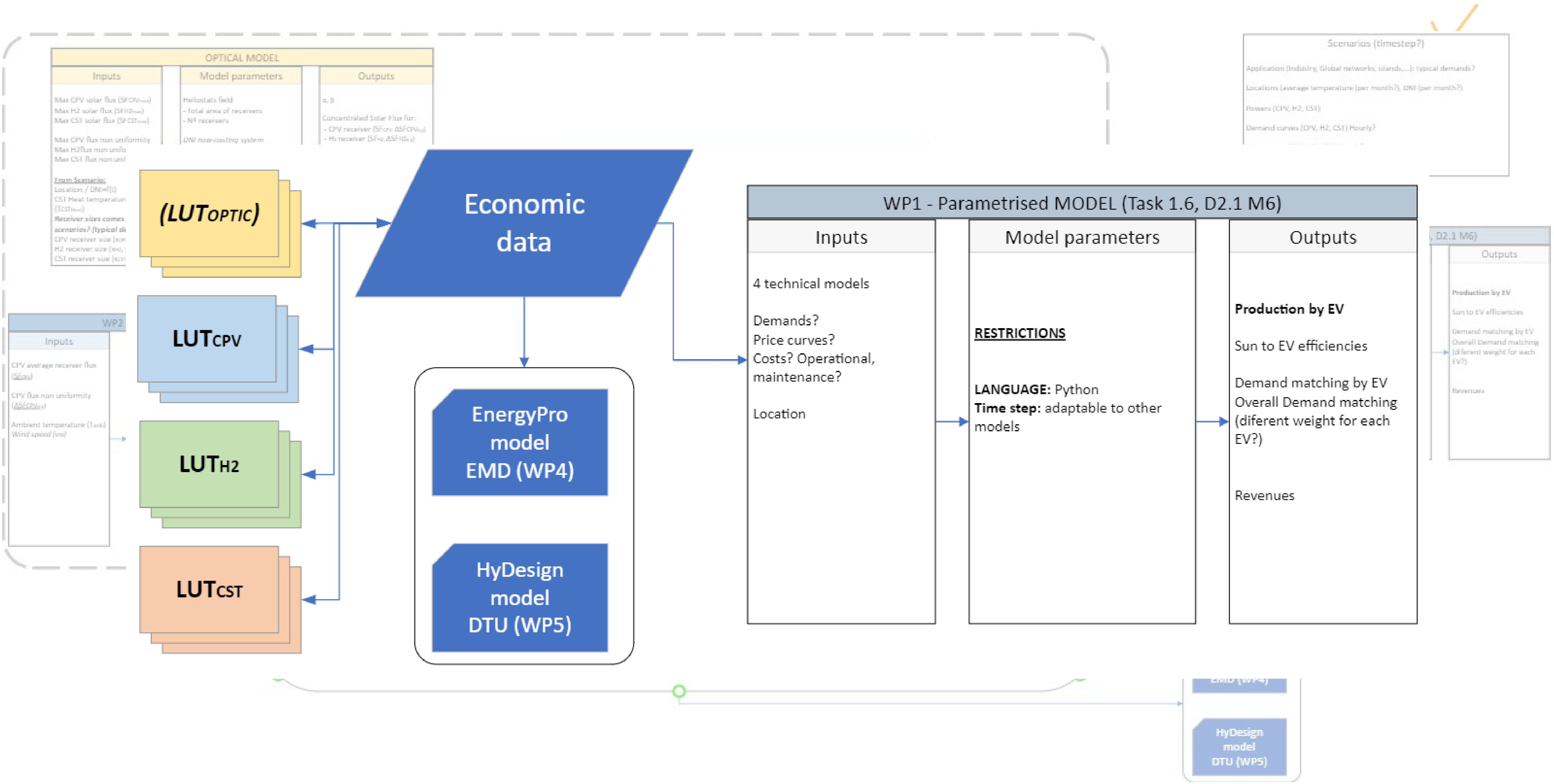




OPTICAL MODEL
Scenarios (timestep?)
WP2 - CPV MODEL (Task 2.1, D2.1 M
WP1 - Parametrised MODEL (Task 1.6, D2.1 M6)
WP3 - H2 MODEL
Inputs
H2 average receiver flux (SF_{H2})
H2 flux non uniformity ($\Delta SF_{H2x,y}$)
Ambient temperature (T_{amb})
Wind speed (vw)
CH4 feed (Biogas)
CO2 feed
H2O feed
H2 receiver electrical input (P_{H2IN})
Model parameters
H2 Receiver area (A_{H2})
Nominal H2 Power (P_{H2NOM})
H2 receiver design
RESTRICTIONS
H2 receiver Maximum Concentrated Solar Flux variation over time (ΔSF_{H2t})
Operating temperature (target for reforming, and limit for safety)
LANGUAGE: MATLAB SIMULINK, or Python
Time step: Time response in the order of seconds
Outputs
H_2 Production (P_{H2})
CO Production
CO2 Production
H2 Pumping power (P_{H2pump})
H2 Receiver Thermal efficiency (η_{H2})
H2 receiver conversion efficiency
H2 Temperature profile (T_{H2}, $\Delta T_{H2x,y}$)
(LUT_{OPTIC})
LUT_{H2}
Economic data
EnergyPro model EMD (WP4)
HyDesign model DTU (WP5)



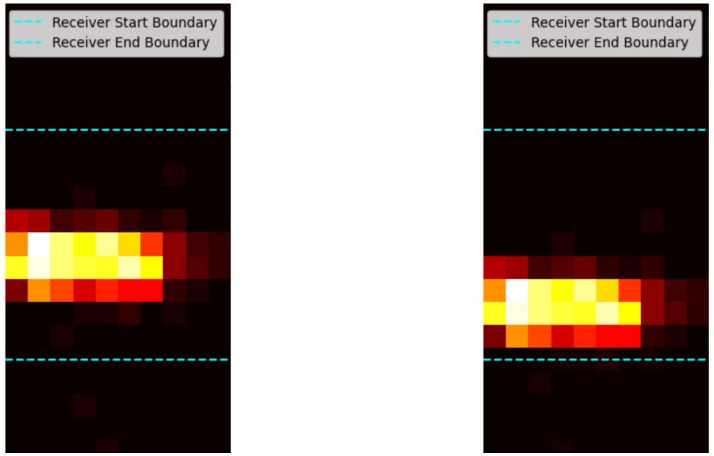
WP1 - CST model (from ACC portfolio): LUTCST
Inputs
CST average receiver flux (SFCST)
CST flux non uniformity (ΔSFCSTx,y)
Ambient temperature (Tamb)
Wind speed (vw)
Model parameters
CST Receiver area (ACST)
Nominal CST Power (PCSTNOM)
RESTRICTIONS
CST receiver Maximum Concentrated Solar Flux variation over time (ΔSFCSTt)
LANGUAGE:
Time step:
Outputs
Net CST Power (PCSTNET)
CST Pumping power (PCSTpump)
CST Receiver efficiency (ηCST)
CST Temperature profile (TCST, ΔTCSTx,y)
(LUTOPTIC)
LUTCST
OPTICAL MODEL
WP2 - CPV MODEL (Task 2.1, D2.1 M6)
Scenarios (timestep?)
WP1 - Parametrised MODEL (Task 1.6, D2.1 M6)
Economic data
EnergyPro model EMD (WP4)
HyDesign model DTU (WP5)


(LUTOPTIC)
LUTCPV
LUTH2
LUTCST
Economic data
EnergyPro model EMD (WP4)
HyDesign model DTU (WP5)
WP1 - Parametrised MODEL (Task 1.6, D2.1 M6)
Inputs
4 technical models
Demands?
Price curves?
Costs? Operational, maintenance?
Location
Model parameters
RESTRICTIONS
LANGUAGE: Python
Time step: adaptable to other models
Outputs
Production by EV
Sun to EV efficiencies
Demand matching by EV
Overall Demand matching (diferent weight for each EV?)
Revenues

T1.3 Adaptative aiming strategy
Objective

Provide **flexible aiming options** by creating optimized heliostat aim strategies for the Cerro Dominador: **trade-off between maximizing efficiency and ensuring receiver integrity.**

ARIA method to implement aim point optimizations → enable testing of different aiming strategies



2D concentration map of a heliostat on one panel

T1.3 Adaptative aiming strategy
External thermal receiver: Methodology

SOLAR X

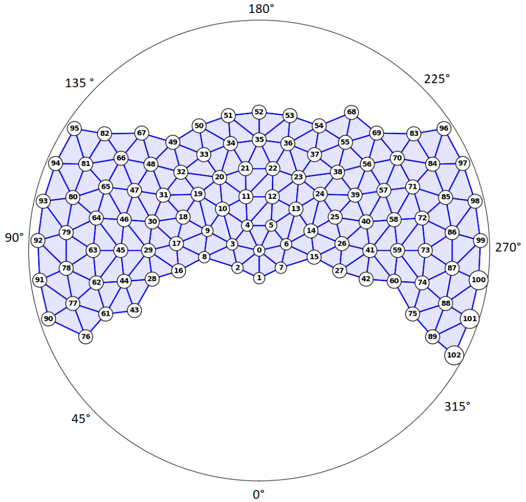
Optical optimization: Per sun node in sky discretization map

Raytracing simulation → Concentration maps per heliostat per panel → Genetic Algorithm for optimal optical aiming → Concentration maps

Thermal optimization: Per simulation step (every 10 minutes)

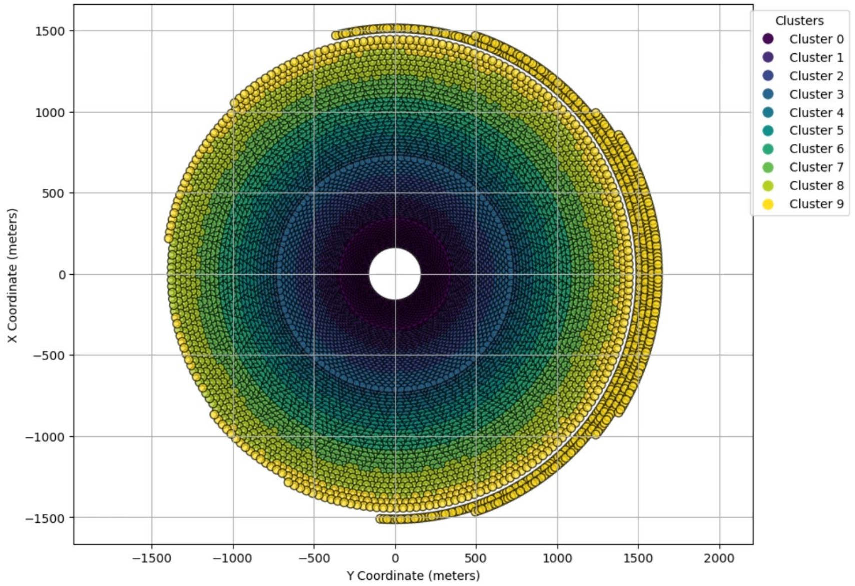
ColSim Simulation: Fluid Film Temperature Calculation → Allowable Flux Density Calculation → Ant Colony Optimization for heliostat shifting/defocusing

Optimal Aiming Strategy



Sky discretization map for the sun's movement throughout the year at Cerro Dominador

T1.3 Adaptative aiming strategy
Optical Optimization



Distance based clustering of the heliostat field

Two heliostat field clustering methods considered:

- Distance based: Clusters based on their relative distance to the receiver.
- Cosine loss based: Cluster based on the energy loss due to the angle between sun and heliostat (cosine effect).

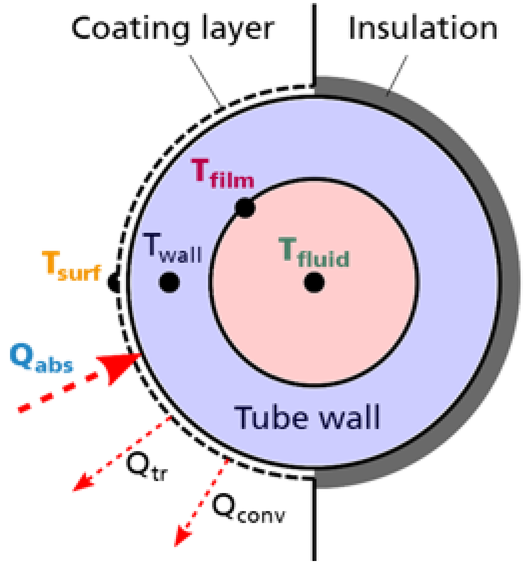
Genetic algorithm:

The GA to find the optimal **number of clusters** and **optimal aim points** on the receiver per sun position.

Weighted sum of (lower fitness value indicates a better solution):

- Total Spillage: The amount of flux that misses the receiver.
- Concentration standard deviation: Measures uniformity in concentration distribution.

T1.3 Adaptative aiming strategy
Thermal Optimization



Allowable flux density (AFD) modelling:

Determination of the **exceeding flux density** to maintain safe thermal levels for the molten salt from row-by-row:

- AFD<0: excess concentration → determines amounts of heliostat to be shifted
- AFD>0: flexibility to have additional concentration from negative regions

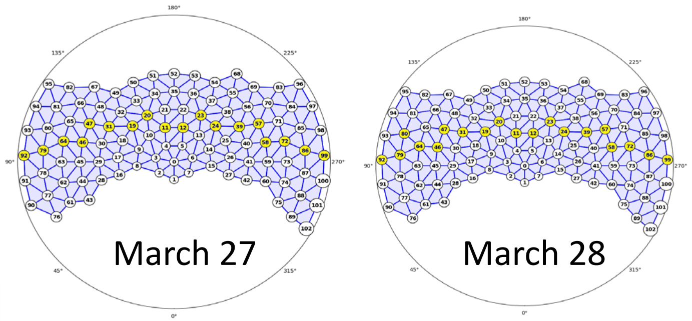
Ant Colony Optimization (ACO):

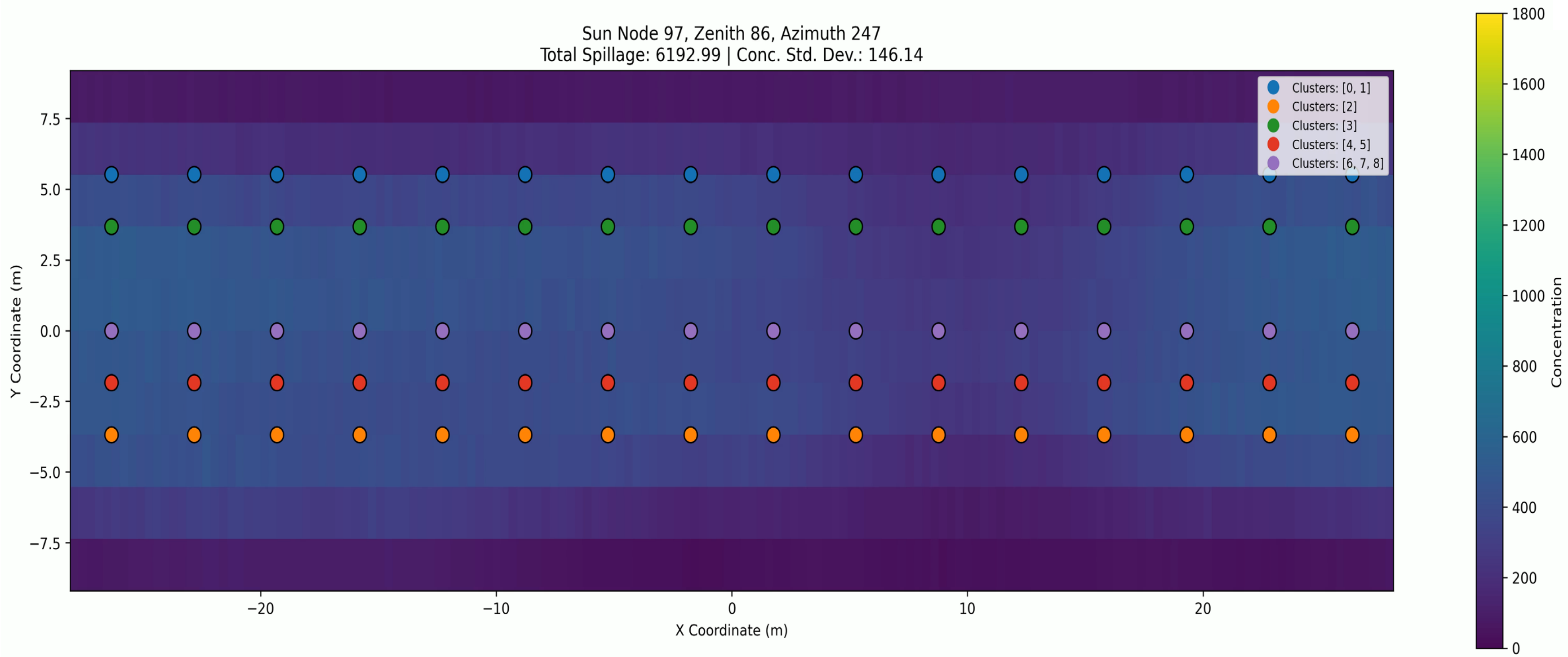
Nature-inspired algorithm simulating ant foraging behavior: Ants (candidate solutions) search for optimal heliostat-aim-point combinations based on the shift factor equation.

- Parameters: Shift factor per heliostat and cluster
- Termination Criteria: Flux density reaches AFD limit while minimizing spillage.

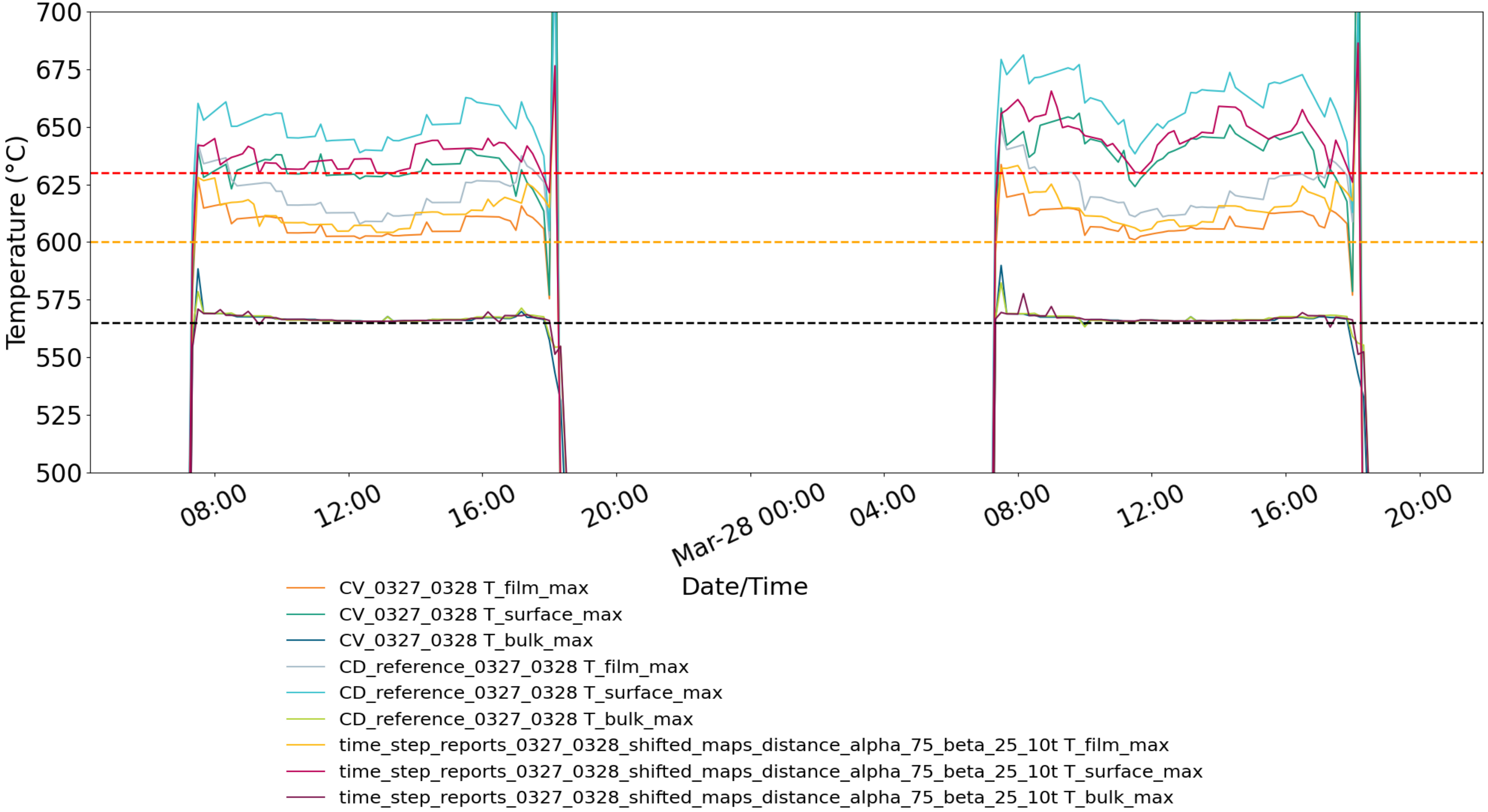
T1.3 Adaptative aiming strategy
Optical Optimization Results

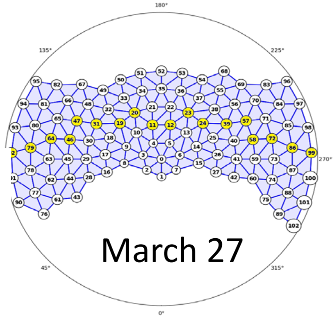
Geneticalgorithm aiming optimization resultsfor distancebasedculstering

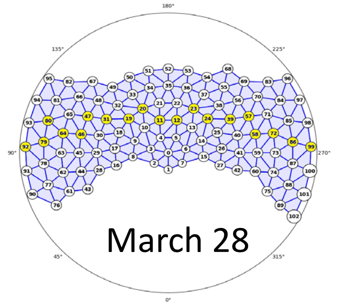




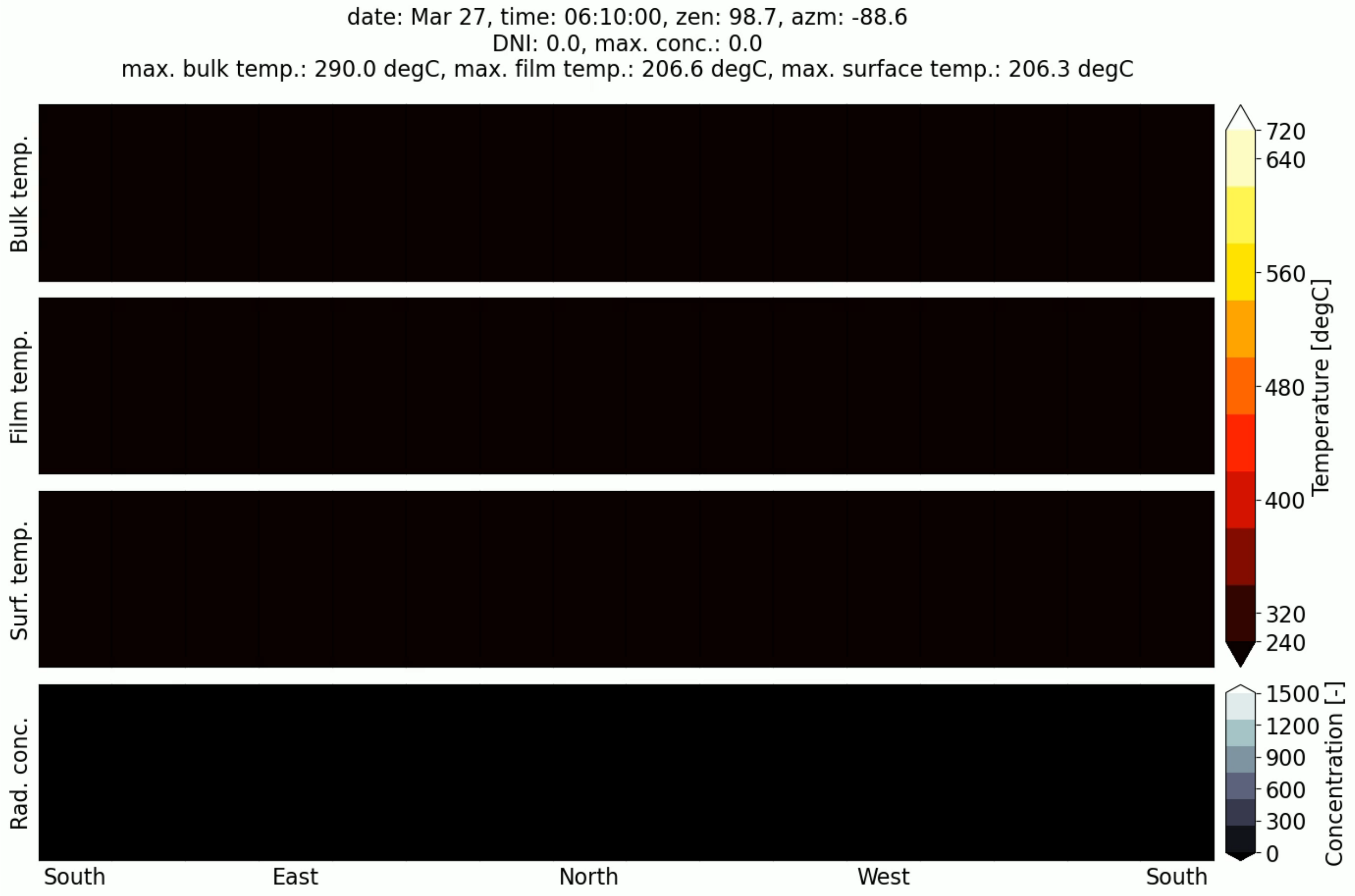
T1.3 Adaptative aiming strategy
Thermal Optimization Results
(no defocusing)

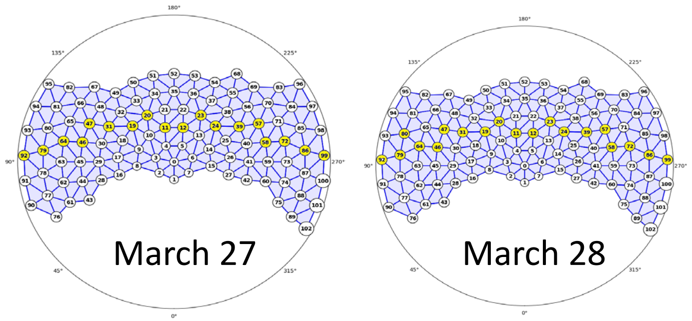






T1.3 Adaptative aiming strategy
Thermal Optimization Results
(no defocusing)





Solar Gain (MWh)			
Date	Equitorial Aiming	Circumferential Vertical	CD Reference Aiming
27.03.2005	5638,9	5694,4	5583,3
28.03.2005	7472,2	7527,8	7416,7
HTF Average Power (MW)			
	Equitorial Aiming	Circumferential Vertical	CD Reference Aiming
27.03.2005	221,1	223,4	219,9
28.03.2005	296,3	29,9	294,0

T1.3 Adaptative aiming strategy
Thermal Optimization Results
(with defocusing)