# Welcome!

## Webinar #7: MODELLING SOLAR THERMAL SYSTEMS
## 27 JULY 2017

**Agenda**:

* Introduction
* Solar Components in Thermoflex-PEACE
* Design Mode
* Off-design simulation: controls @ operating points
* Link to Excel, "dynamic" simulation and annual yield
* Hybrid plants and other examples
* Q & A Session

Presenter: IGNACIO MARTIN (SPAIN)
Support: Meritt Elmasri (U.S. HQ)

# Thermoflow Training and Support

- Standard Training
- On-site training course
- Advanced Workshop
- Webinars when new version is released
- Help, Tutorials, PPT, Videos
- Technical Support

→ **Feature Awareness Webinars**

# Feature Awareness Webinars

1- Assemblies in TFX

2- Scripts in Thermoflow programs, GTP-GTM-TFX

3- Multi Point Design in GTP-GTM

4- Reciprocating Engines in TFX

5- TIME in GTM

6- Matching ST Performance in STP

**7- Modeling Solar Systems in TFX**

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# Solar Thermal Development in TFX

Tflow18: Parabolic Trough + HT Fluid + Heat Exchangers

Tflow19: Linear Fresnel Collectors, DSG

Tflow20: SF with two-tank thermal storage

Tflow22: Solar Tower and Heliostats

Tflow26: Solar PV

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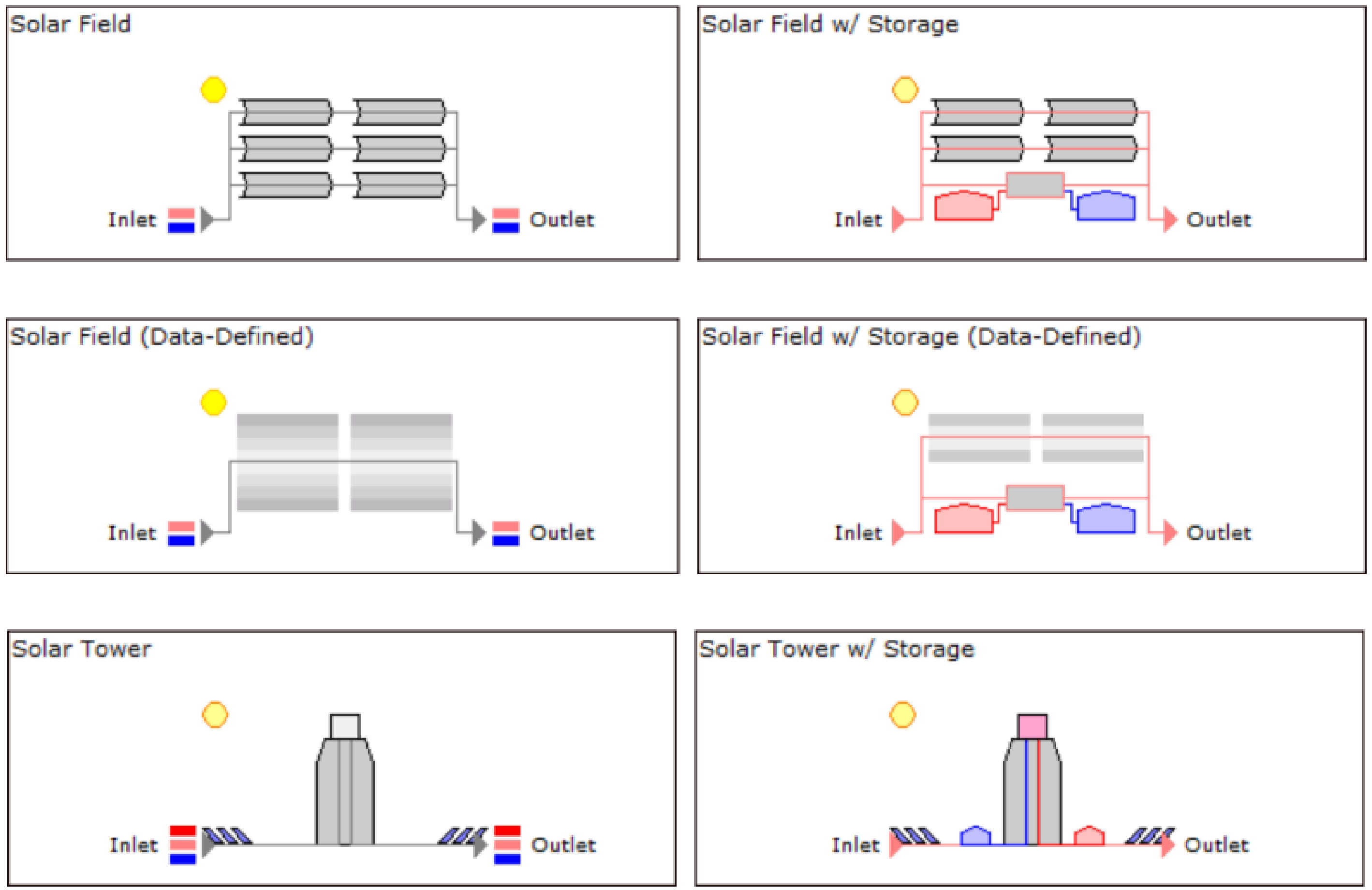
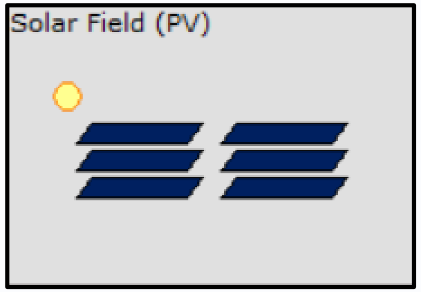
# Solar Components in TFX-PEACE

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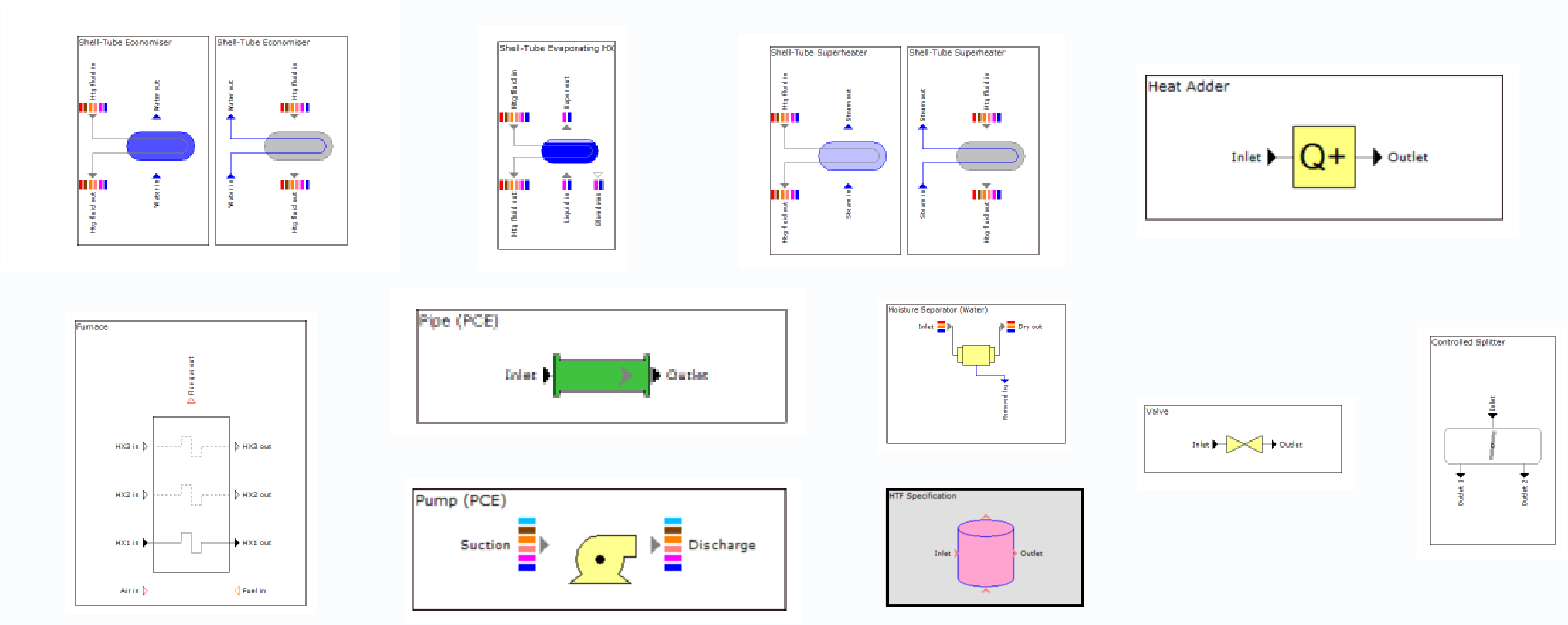
# Solar Components in TFX-PEACE - 2

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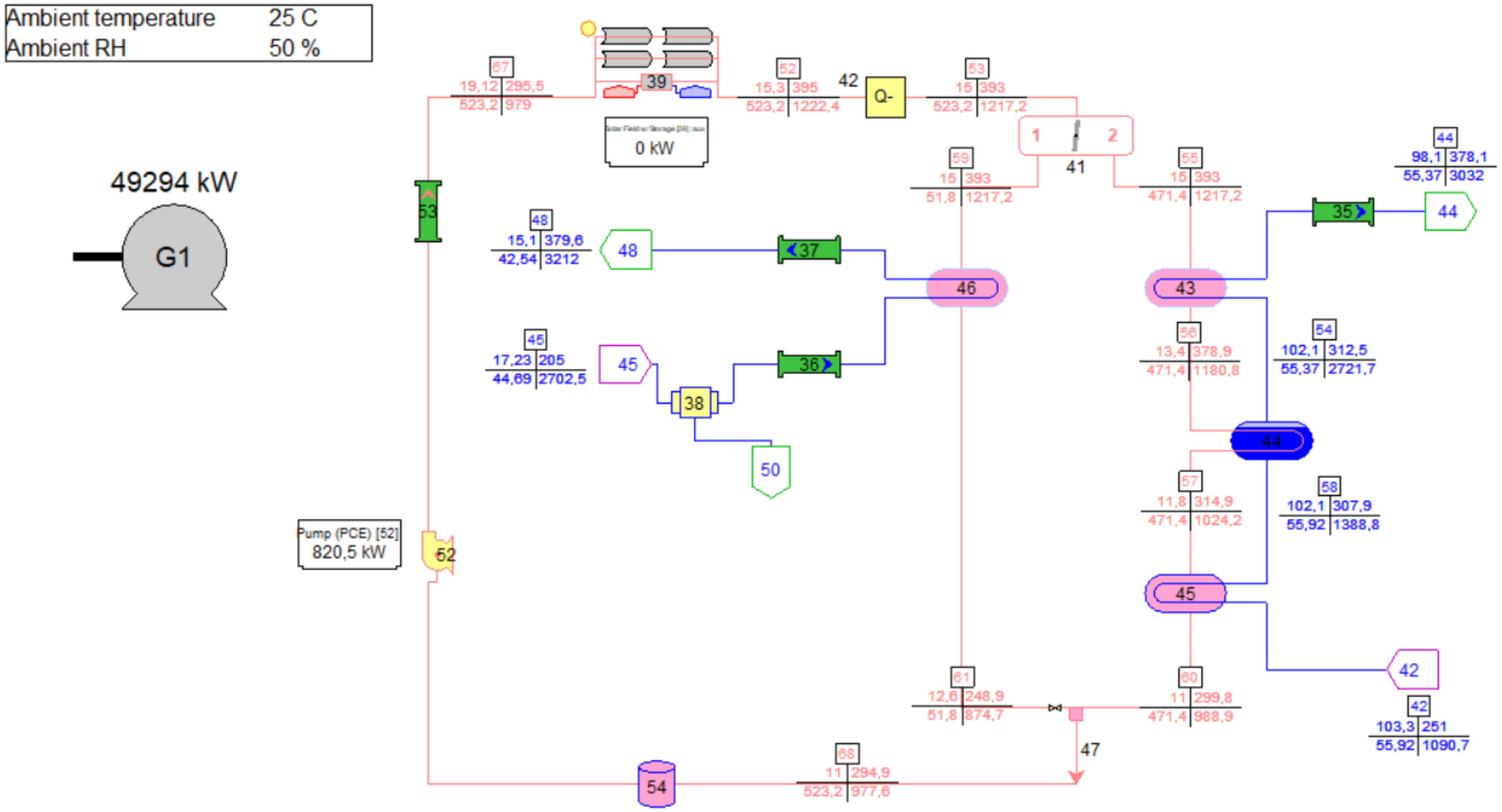
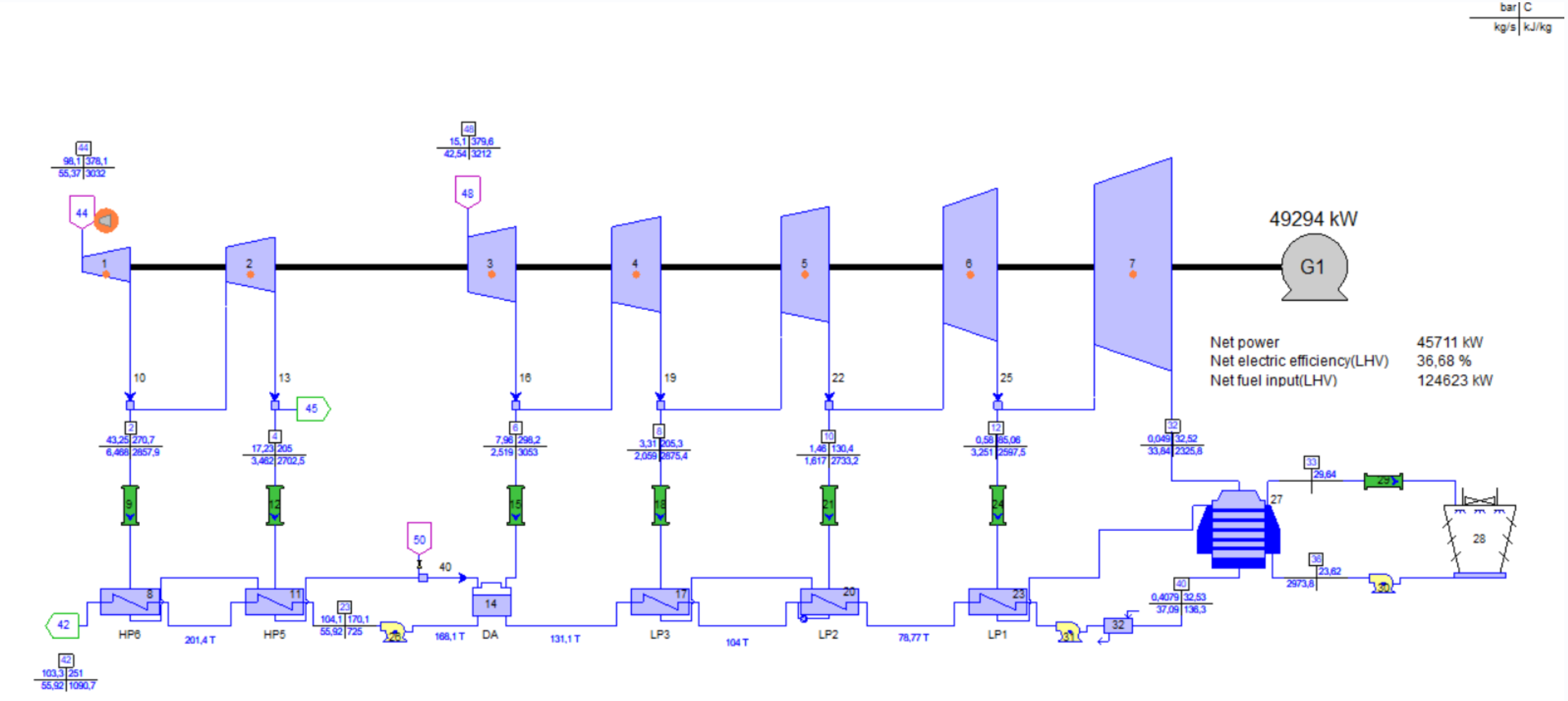
# Example:
# 50 MW Parabolic Trough
# w/ Molten Salts storage

# Solar part



Ambient temperature 25 C
Ambient RH 50 %
49294 kW
G1
0 kW
Pump (PCE) [52]
820,5 kW

# Water-Steam Cycle

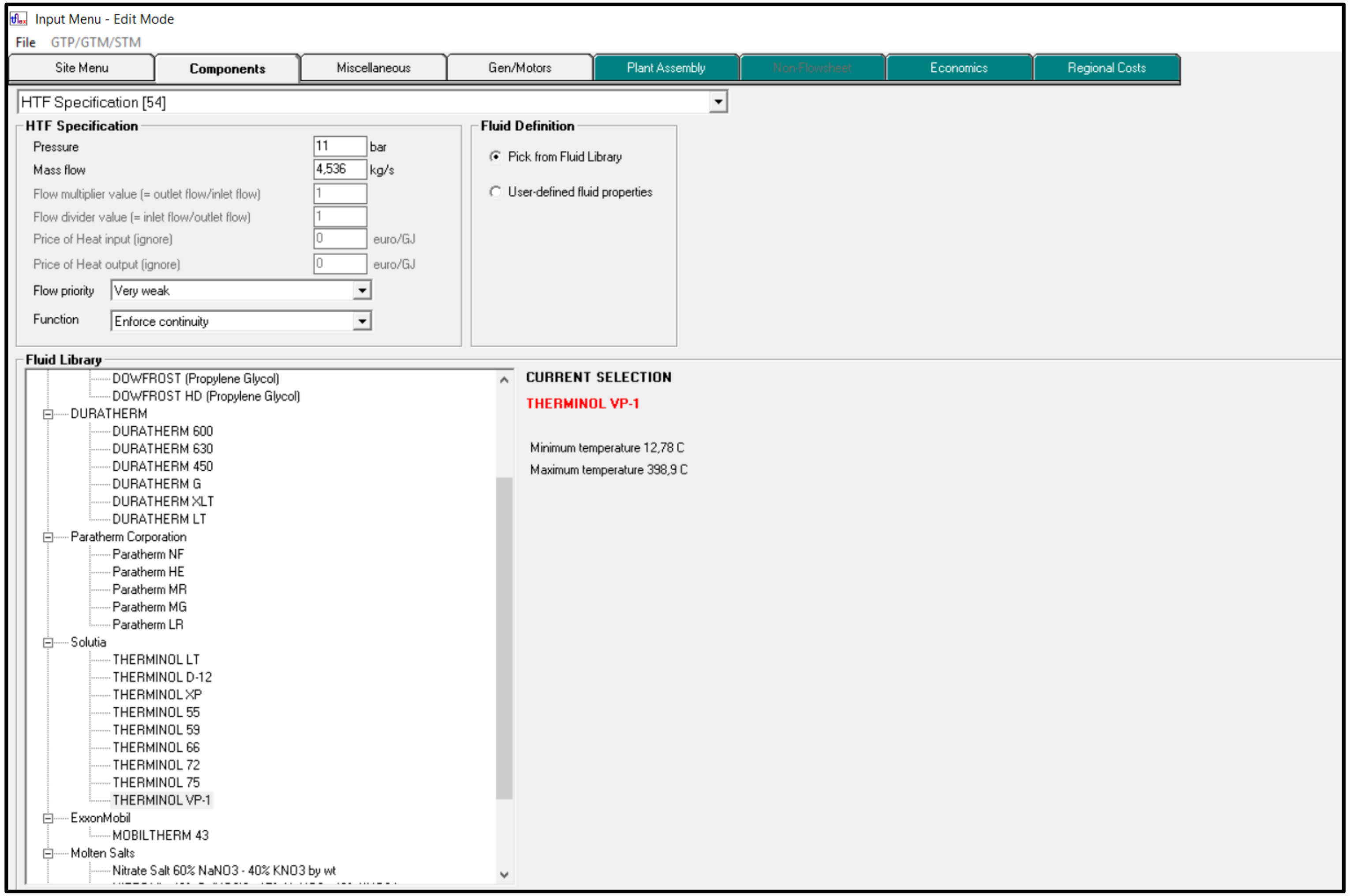


# Design, TD Mode

**Main Inputs**

- Ambient Conditions (affecting the cycle efficency and heat input)
- HTF Specification & minimum Pressure
- Solar Field type, HTF exit Temperature, (HTF mass Flow)
- Splitter: Fraction of HTF to Steam Generator – Reheater
- Superheater / Reheater: Exit Steam Temperature
- Evaporator: Pinch Point / (Steam mass Flow)
- Economizer: Water exit Temperature or Approach Subcooling
- Pressure Drops: user assumptions or defaults

# HTF Specification



# Flow Specification

HTF to Steam Generator

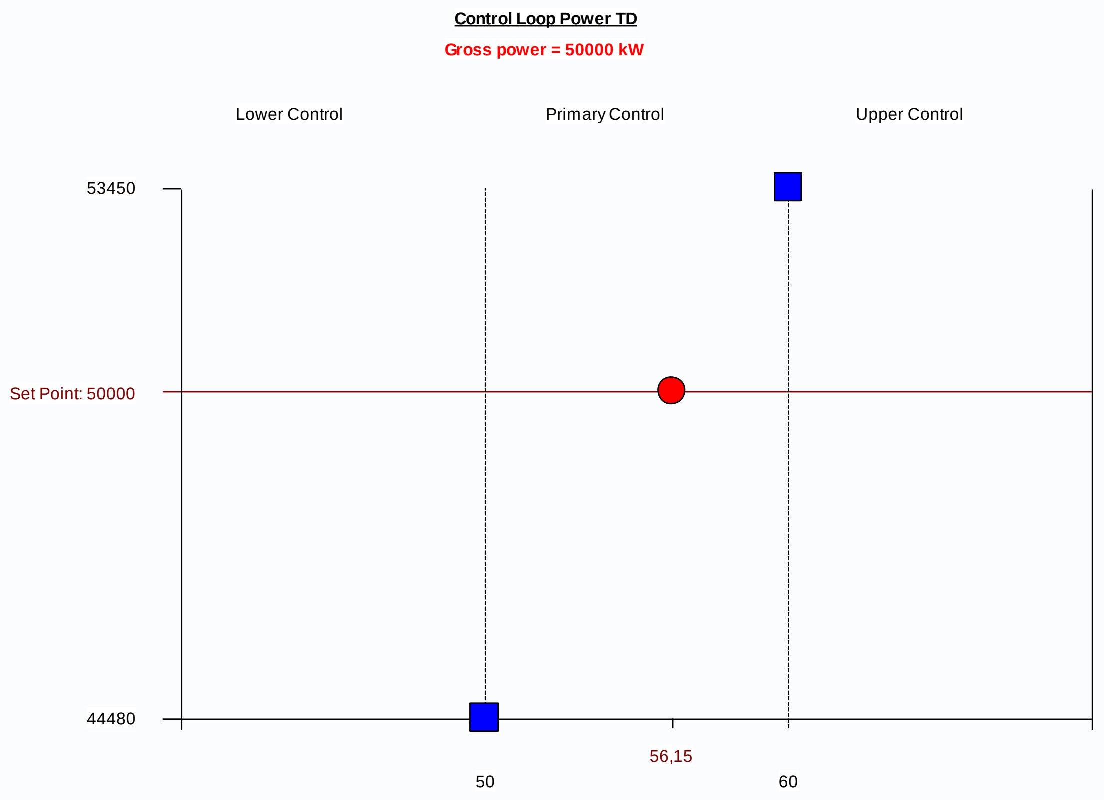
- HTF mf (strong) + Evaporator Pinch → Steam mf
- HTF mf (strong) + Steam mf → Evaporator Pinch (if > “mínimum pinch”)
- Evaporator Pinch + Steam Production → HTF mf

HTF to Reheater

- Fractions from Splitter (Strong)
- Component sets Shell Flow+ Cold End Approach Diference (*minimum Flow*)

Control Loop to determine HTF / Steam mf to achieve a Power Output

# Control Loop



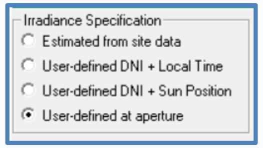

Primary Control: Shell-Tube Evaporating HX (PCE) [44] : Desired steam production = 56,15 kg/s

# Design, ED Mode

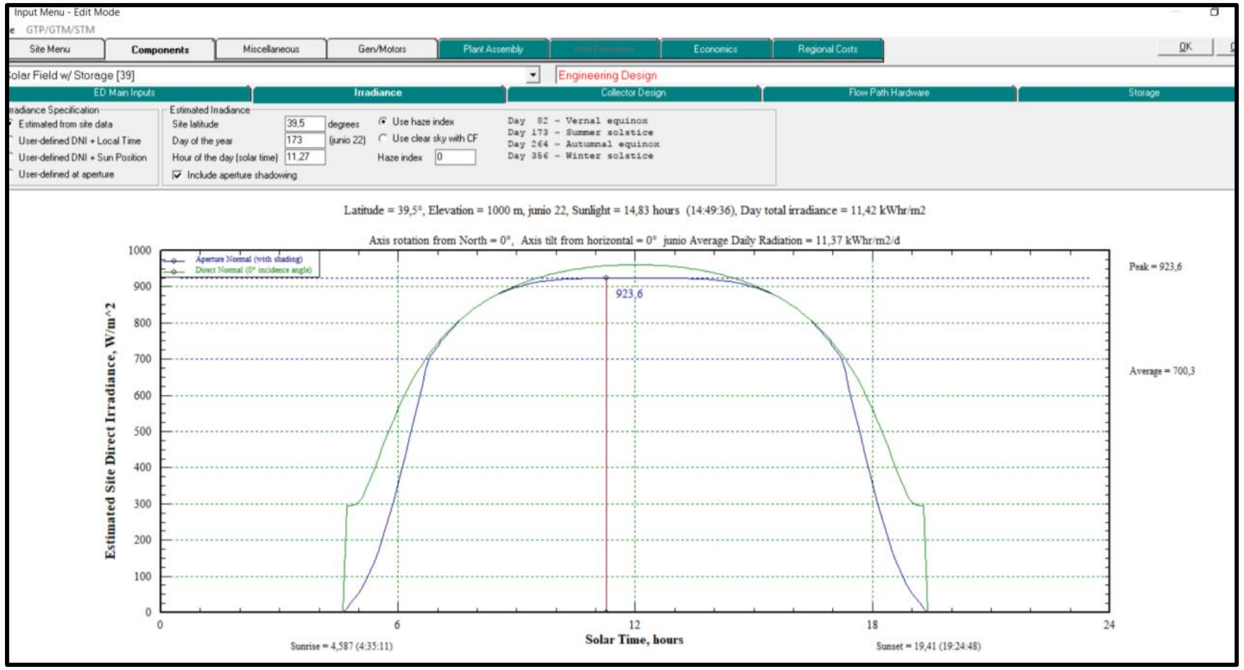
**Main Inputs**

- Solar Field
  - Irradiance
  - Collector Design
  - Flow Path
  - Storage
- Heat Exchangers: Hardware
- Pressure Drops: computed (check pipes DP)

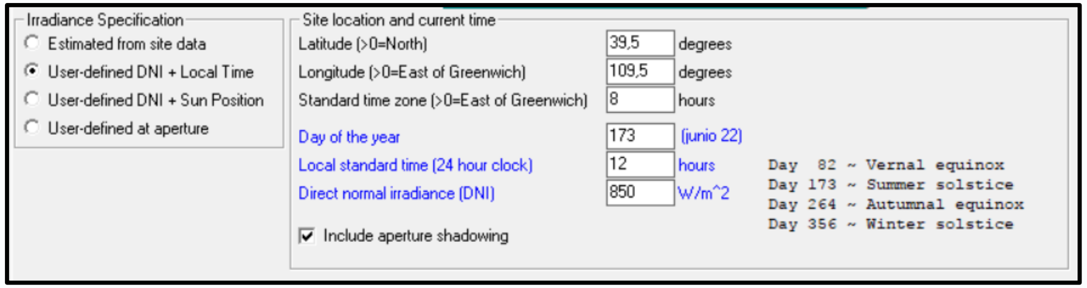
# Irradiance



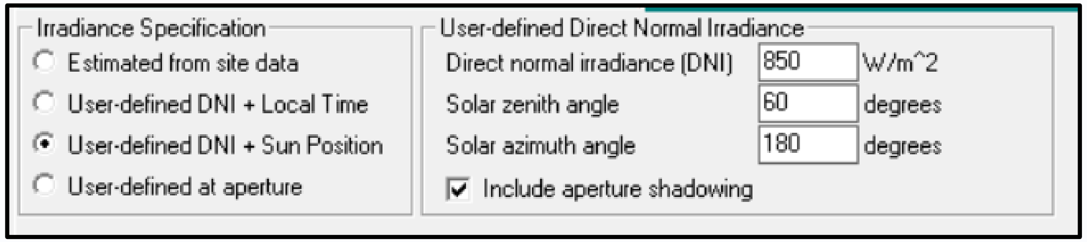
Irradiance Specification
Estimated from site data
User-defined DNI + Local Time
User-defined DNI + Sun Position
User-defined at aperture

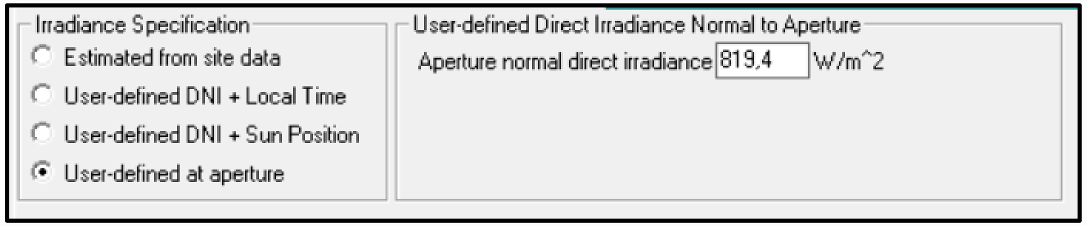
Input Menu - Edit Mode
GTP/GTM/STM
Site Menu
Components
Miscellaneous
Gen/Motors
Plant Assembly
Economics
Regional Costs
OK
Solar Field w/ Storage [39]
Engineering Design
ED Main Inputs
Irradiance
Collector Design
Flow Path Hardware
Storage
Irradiance Specification
Estimated from site data
User-defined DNI + Local Time
User-defined DNI + Sun Position
User-defined at aperture
Estimated Irradiance
Site latitude 39,5 degrees
Day of the year 173 (junio 22)
Hour of the day (solar time) 11,27
Include aperture shadowing
Use haze index
Use clear sky with CF
Haze index 0
Day 82 ~ Vernal equinox
Day 173 ~ Summer solstice
Day 264 ~ Autumnal equinox
Day 356 ~ Winter solstice
Latitude = 39,5°, Elevation = 1000 m, junio 22, Sunlight = 14,83 hours (14:49:36), Day total irradiance = 11,42 kWhr/m2
Axis rotation from North = 0°, Axis tilt from horizontal = 0° junio Average Daily Radiation = 11,37 kWhr/m2/d
Aperture Normal (with shading)
Direct Normal (0° incidence angle)
Estimated Site Direct Irradiance, W/m^2
923,6
Peak = 923,6
Average = 700,3
Solar Time, hours
Sunrise = 4,587 (4:35:11)
Sunset = 19,41 (19:24:48)

Irradiance Specification
Estimated from site data
User-defined DNI + Local Time
User-defined DNI + Sun Position
User-defined at aperture
Site location and current time
Latitude (>0=North) 39,5 degrees
Longitude (>0=East of Greenwich) 109,5 degrees
Standard time zone (>0=East of Greenwich) 8 hours
Day of the year 173 (junio 22)
Local standard time (24 hour clock) 12 hours
Direct normal irradiance (DNI) 850 W/m^2
Include aperture shadowing
Day 82 ~ Vernal equinox
Day 173 ~ Summer solstice
Day 264 ~ Autumnal equinox
Day 356 ~ Winter solstice

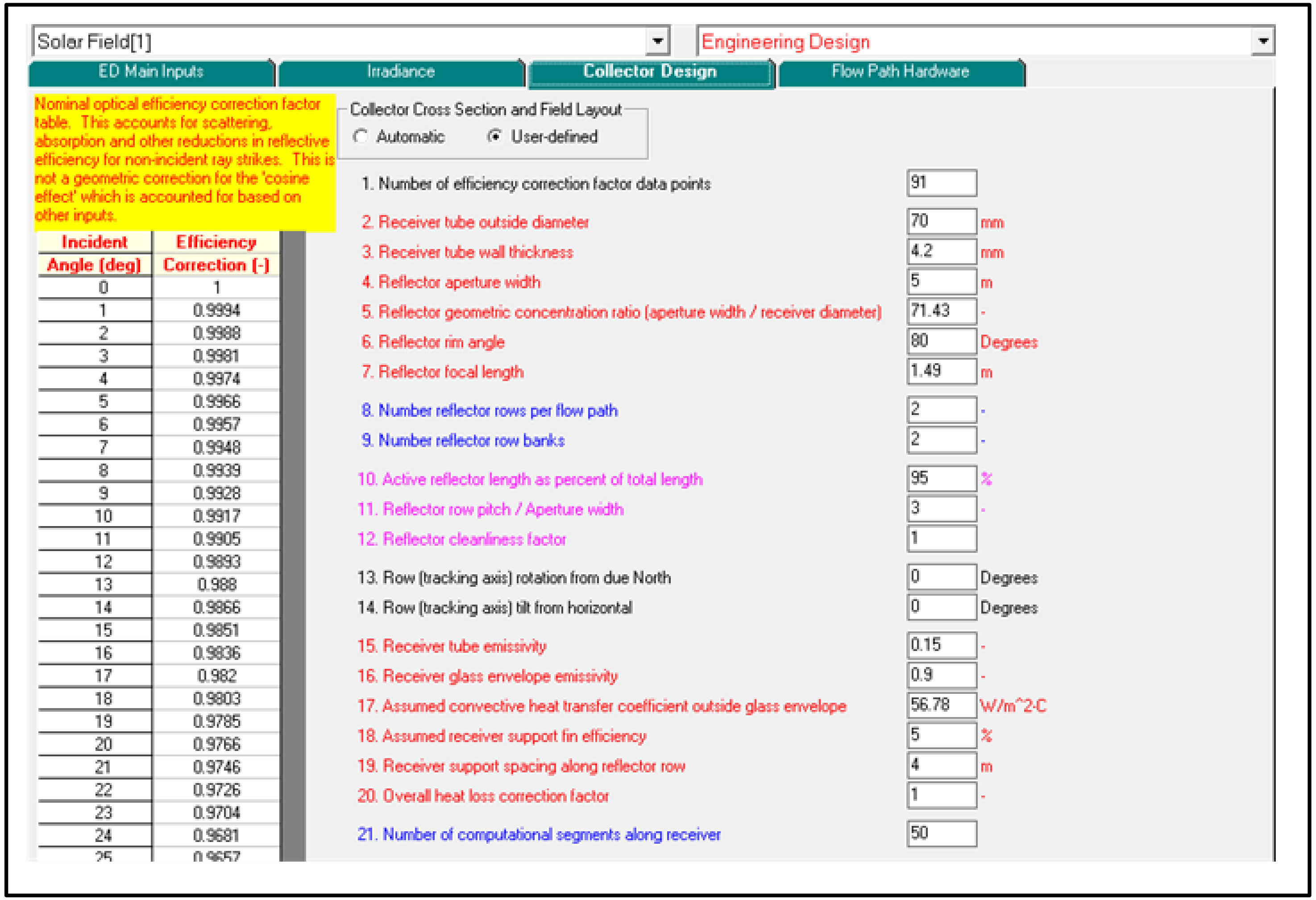



Irradiance Specification
Estimated from site data
User-defined DNI + Local Time
User-defined DNI + Sun Position
User-defined at aperture
User-defined Direct Normal Irradiance
Direct normal irradiance (DNI) 850 W/m^2
Solar zenith angle 60 degrees
Solar azimuth angle 180 degrees
Include aperture shadowing

Irradiance Specification
Estimated from site data
User-defined DNI + Local Time
User-defined DNI + Sun Position
User-defined at aperture
User-defined Direct Irradiance Normal to Aperture
Aperture normal direct irradiance 819,4 W/m^2

# Collector Design, Physical Model



Solar Field[1]

Engineering Design

ED Main Inputs | Irradiance | Collector Design | Flow Path Hardware

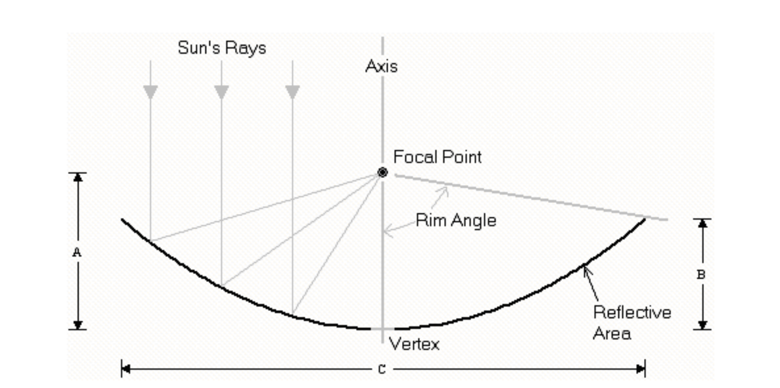
Nominal optical efficiency correction factor table. This accounts for scattering, absorption and other reductions in reflective efficiency for non-incident ray strikes. This is not a geometric correction for the 'cosine effect' which is accounted for based on other inputs.

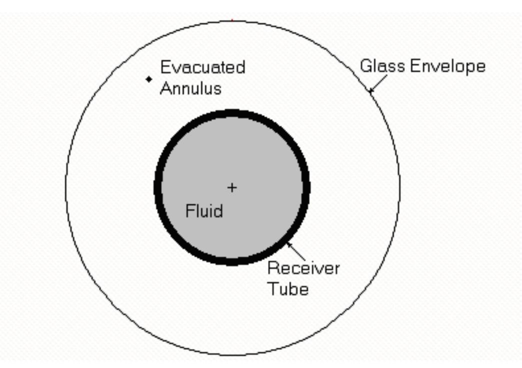
| Incident Angle (deg) | Efficiency Correction (-) |
|---|---|
| 0 | 1 |
| 1 | 0.9994 |
| 2 | 0.9988 |
| 3 | 0.9981 |
| 4 | 0.9974 |
| 5 | 0.9966 |
| 6 | 0.9957 |
| 7 | 0.9948 |
| 8 | 0.9939 |
| 9 | 0.9928 |
| 10 | 0.9917 |
| 11 | 0.9905 |
| 12 | 0.9893 |
| 13 | 0.988 |
| 14 | 0.9866 |
| 15 | 0.9851 |
| 16 | 0.9836 |
| 17 | 0.982 |
| 18 | 0.9803 |
| 19 | 0.9785 |
| 20 | 0.9766 |
| 21 | 0.9746 |
| 22 | 0.9726 |
| 23 | 0.9704 |
| 24 | 0.9681 |
| 25 | 0.9657 |

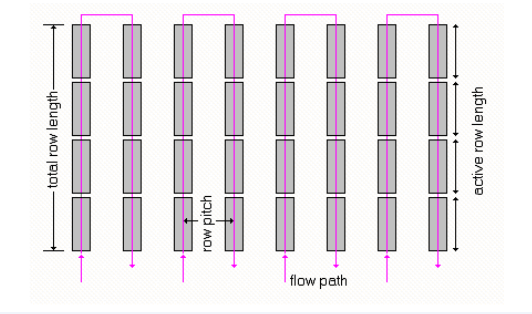
Collector Cross Section and Field Layout

Automatic | User-defined

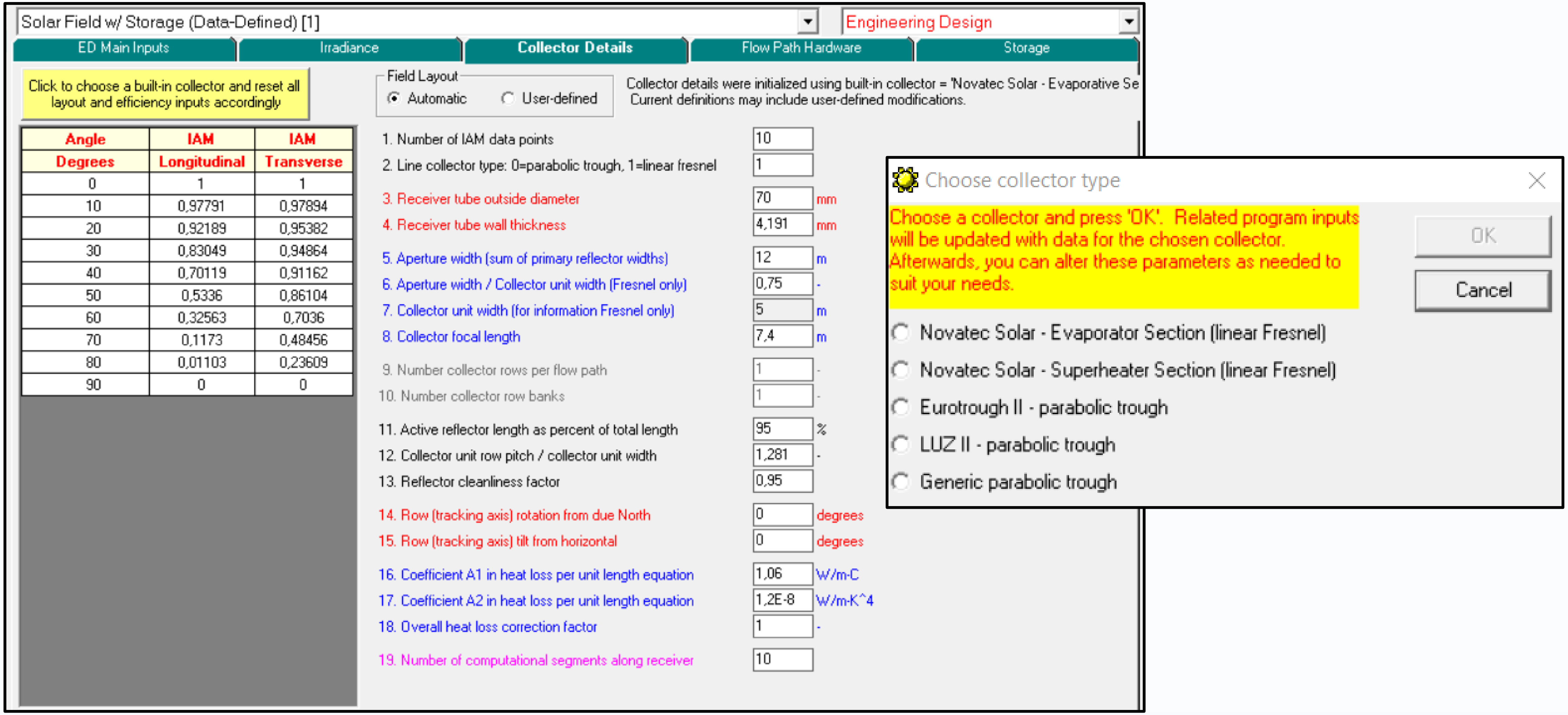
| | | |
|---|---|---|
| 1. Number of efficiency correction factor data points | 91 | |
| 2. Receiver tube outside diameter | 70 | mm |
| 3. Receiver tube wall thickness | 4.2 | mm |
| 4. Reflector aperture width | 5 | m |
| 5. Reflector geometric concentration ratio (aperture width / receiver diameter) | 71.43 | - |
| 6. Reflector rim angle | 80 | Degrees |
| 7. Reflector focal length | 1.49 | m |
| 8. Number reflector rows per flow path | 2 | - |
| 9. Number reflector row banks | 2 | - |
| 10. Active reflector length as percent of total length | 95 | % |
| 11. Reflector row pitch / Aperture width | 3 | - |
| 12. Reflector cleanliness factor | 1 | |
| 13. Row (tracking axis) rotation from due North | 0 | Degrees |
| 14. Row (tracking axis) tilt from horizontal | 0 | Degrees |
| 15. Receiver tube emissivity | 0.15 | - |
| 16. Receiver glass envelope emissivity | 0.9 | - |
| 17. Assumed convective heat transfer coefficient outside glass envelope | 56.78 | W/m^2-C |
| 18. Assumed receiver support fin efficiency | 5 | % |
| 19. Receiver support spacing along reflector row | 4 | m |
| 20. Overall heat loss correction factor | 1 | - |
| 21. Number of computational segments along receiver | 50 | |



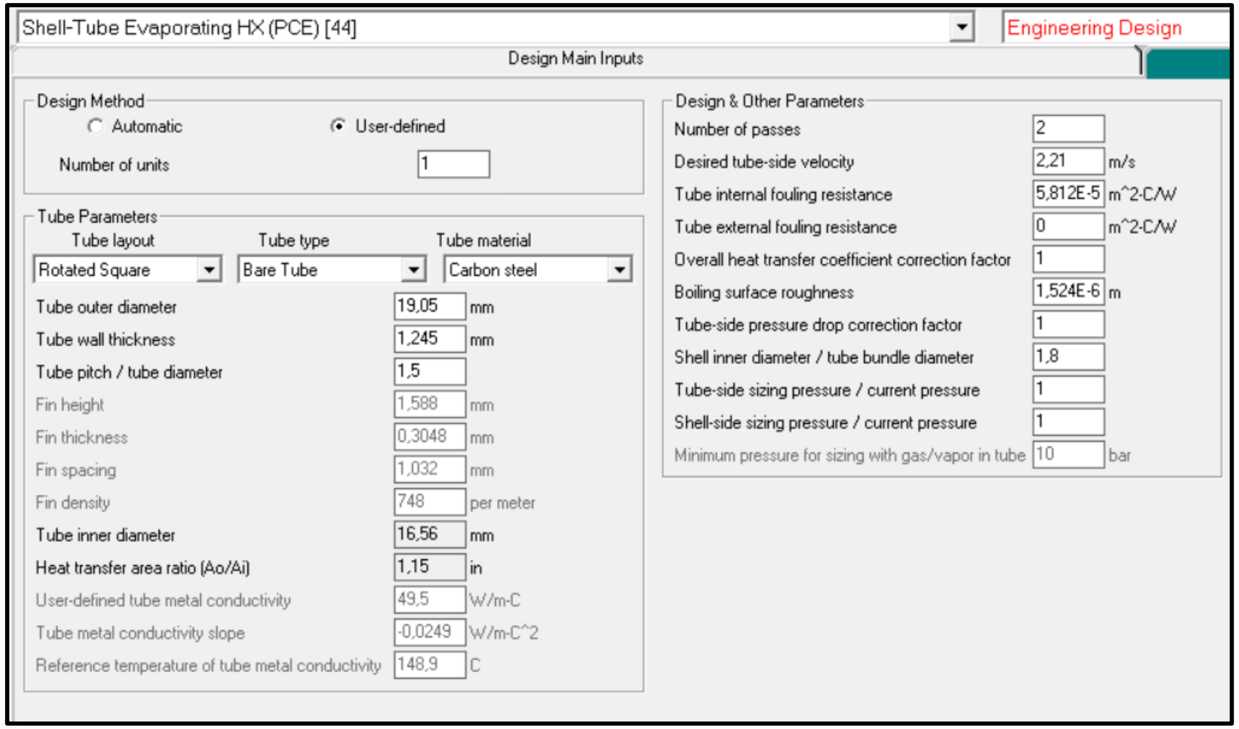



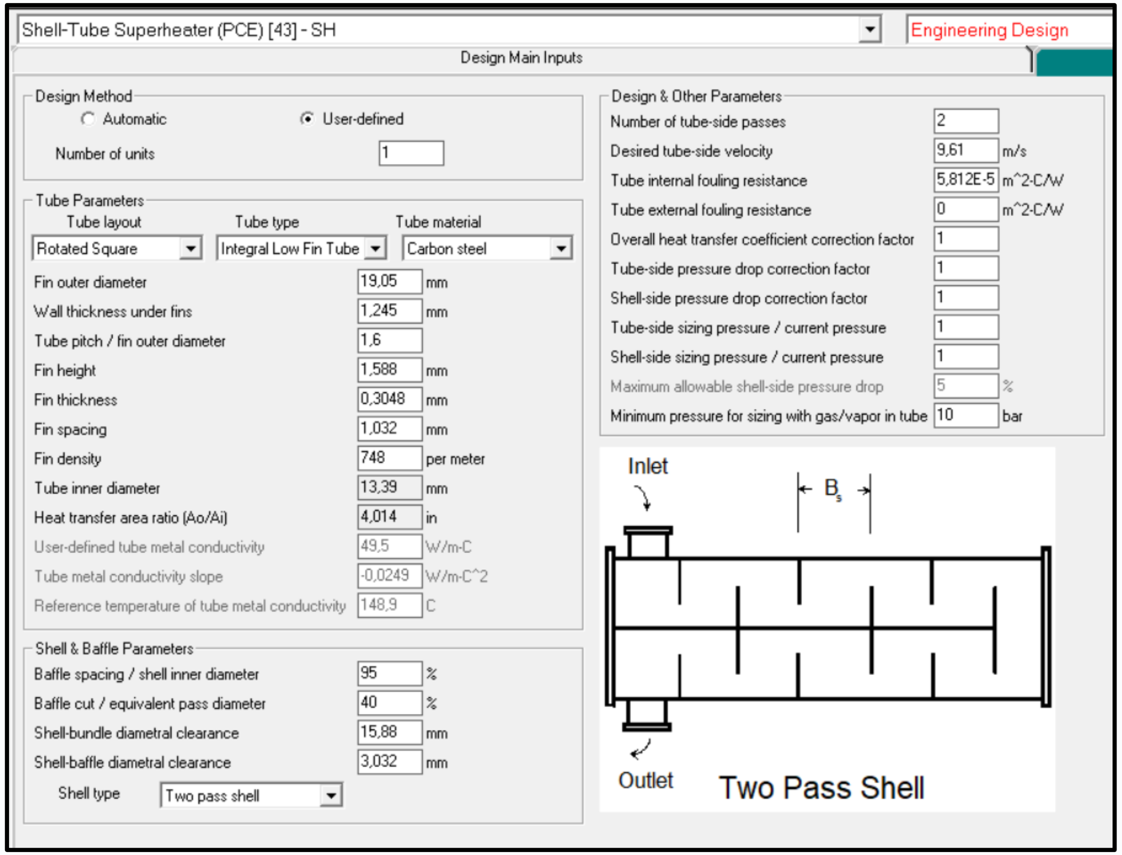



# Collector Design, Data-Defined



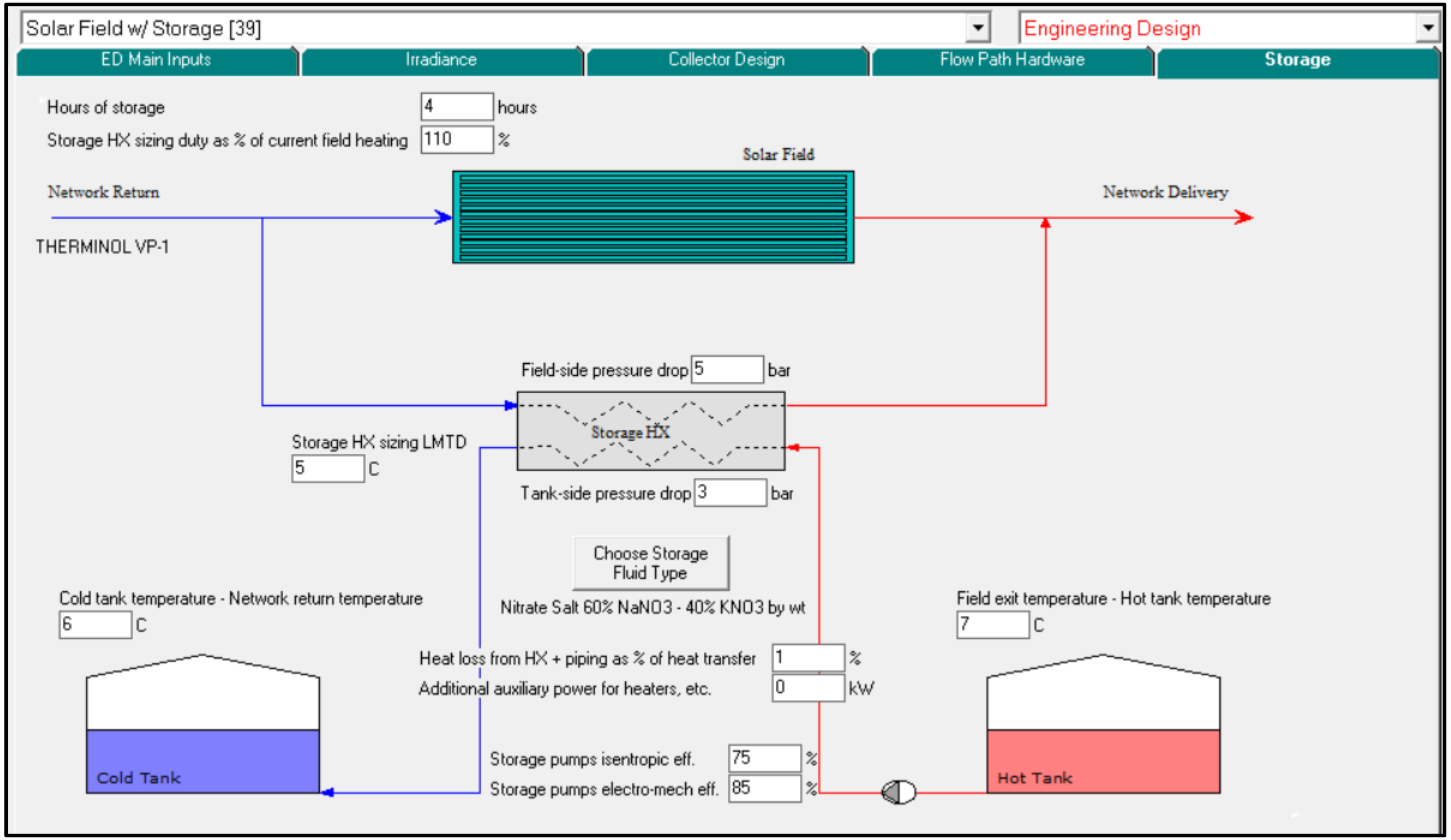
# Heat Exchangers Hardware



# Storage System

- Solar Multiplier
- Hours of Storage
- HX Size (%)
- Delta T cold / hot side
- Sizing LMTD
- Molten Salts specification
- Pressure Drops



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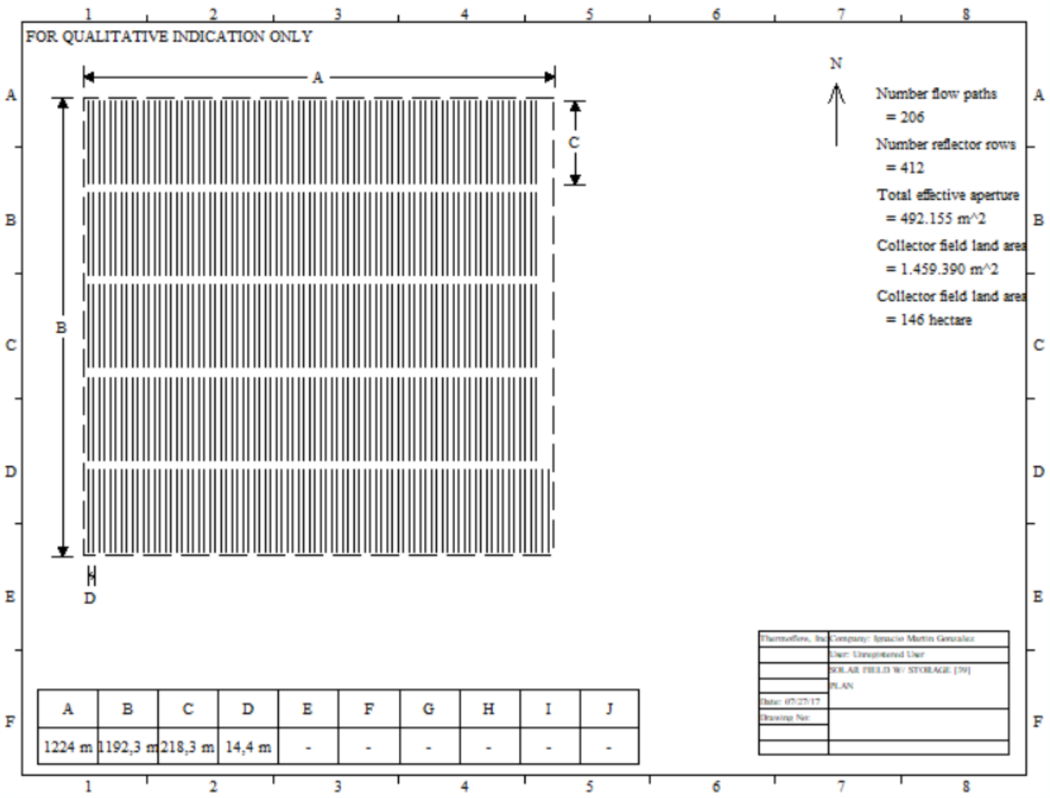
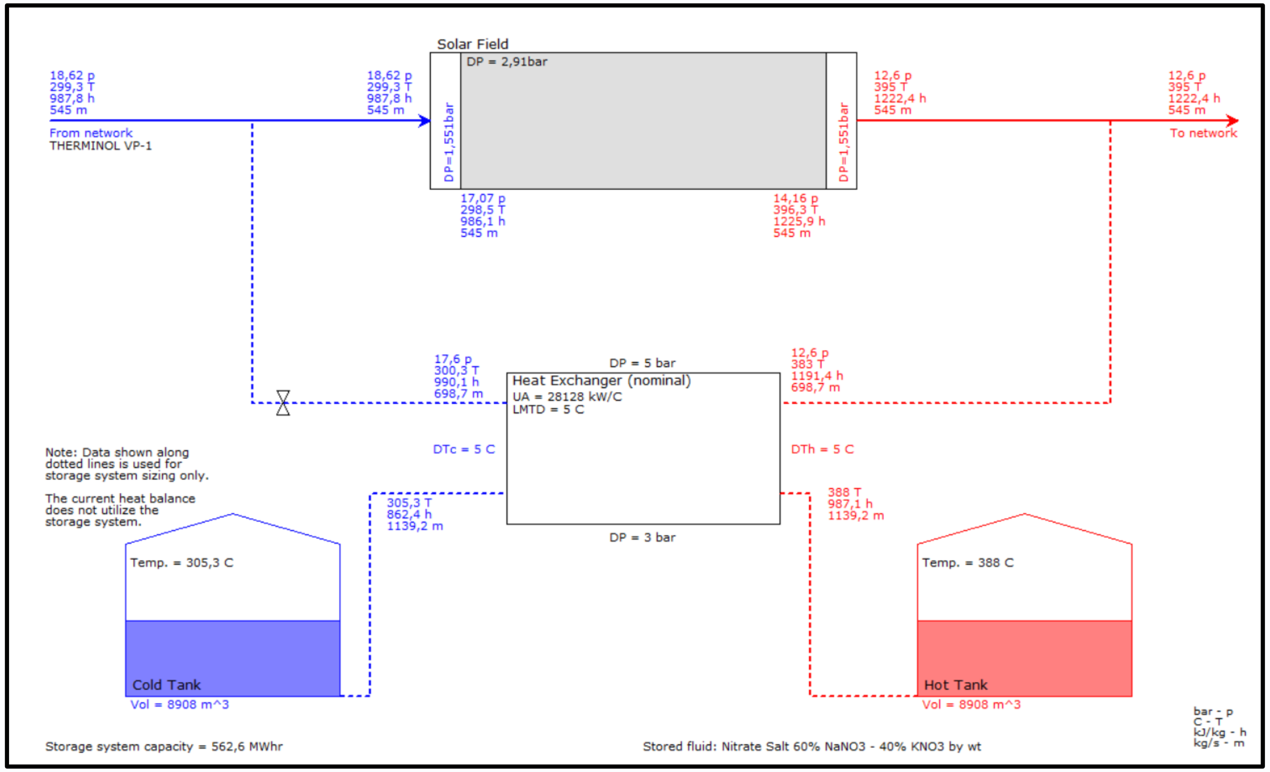
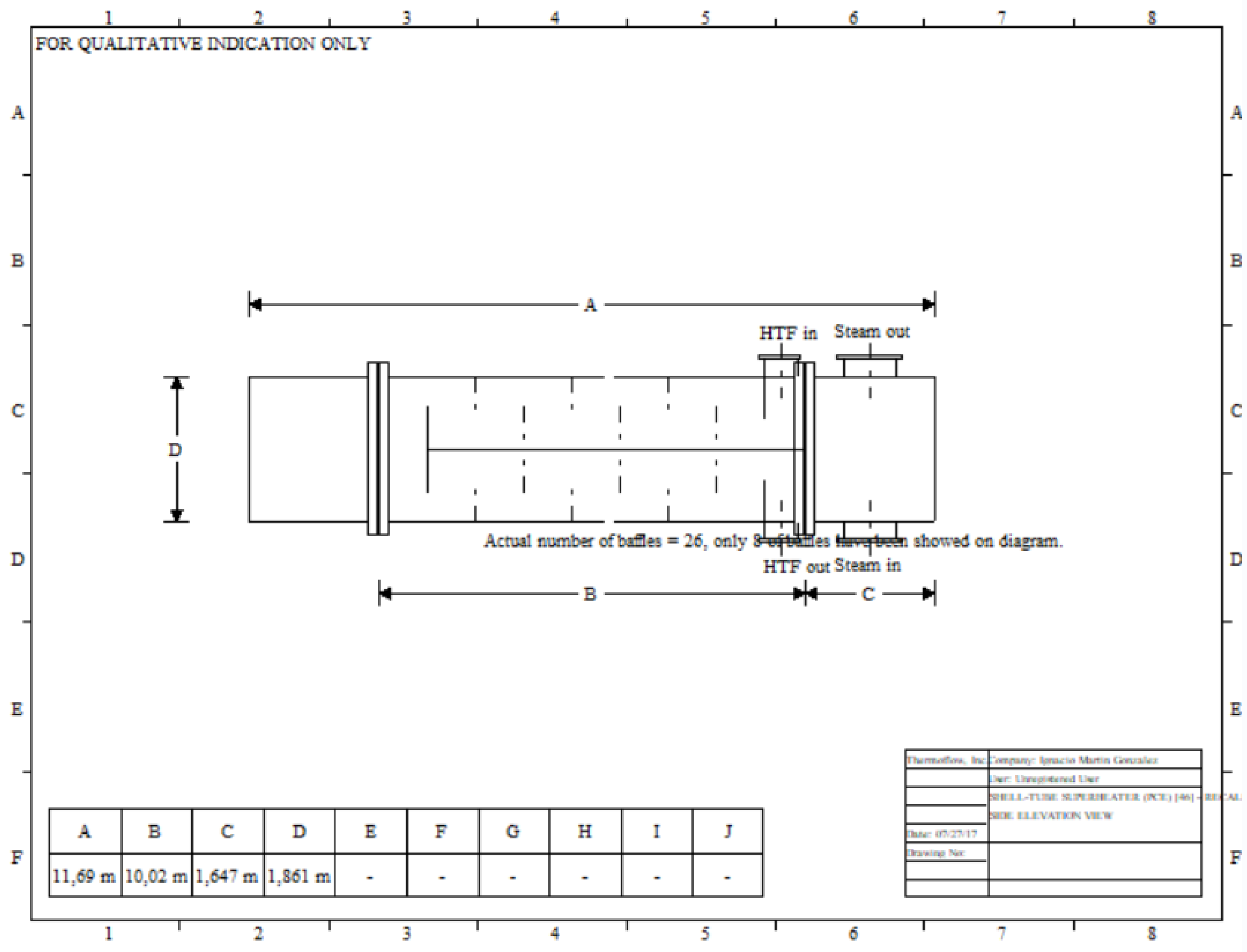
# ED Mode, Outputs



# ED Mode, Outputs




| Estimated Shell-Tube Heat Exchanger Data | | |
|---|---|---|
| Shell-Tube Superheater (PCE) [46] - Recalentador | | |
| Number of units | 1 | |
| | | |
| 1. Tube Description (per unit) | | |
| Tube type | Bare Tube | |
| Tube material | Carbon steel | |
| Total external heat transfer area | 1.760 | m^2 |
| Nameplate tube flow pressure | 16,08 | bar |
| Tube outer diameter | 19,05 | mm |
| Tube inner diameter | 16,56 | mm |
| Tube wall thickness | 1,245 | mm |
| Tube layout in crossflow | Rotated Square | |
| Number of tubes per pass | 1471 | |
| Number of passes | 2 | |
| Number of tubes in heater | 2942 | |
| Tube length per pass | 10,02 | m |
| Tube pitch | 29,53 | mm |
| Heat transfer area ratio (Ao/Ai) | 1,15 | |
| | | |
| 2. Shell Description (per unit) | | |
| Nameplate shell flow pressure | 12,36 | bar |
| Shell material | Carbon steel | |
| Shell length | 10,02 | m |
| Tube bundle diameter | 1.830 | mm |
| Shell inner diameter | 1.840 | mm |
| Shell wall thickness | 9,525 | mm |
| Tube sheet thickness | 11,11 | mm |
| Overall length | 11,7 | m |
| Shell type | Two pass shell | |
| Number of baffles | 26 | |
| Baffle spacing | 371 | mm |
| Baffle cut / equivalent pass diameter | 18 | % |
| Equivalent pass diameter | 1307,2 | mm |
| Shell outer diameter | 1861,2 | mm |
| | | |
| 3. Weight (per unit) | | |
| Tube dry weight | 16.123 | kg |

# ED Mode, Outputs

PEACE Output - Simplified

File Edit

Financial: Cost Report | Cash Flow

Cost Summary | Cost Breakdown

| Cost Summary | Estimated Cost | |
|---|---|---|
| 1. Sum of Costs for Equipment and PEACE Components | 214.692.700 | euro |
| | | |
| 2. Sum of User-defined Costs | 0 | euro |
| | | |
| 3. Sum of PEACE Components, Linked Files, and User-defined Costs (Contractor's Internal Cost) | 214.692.700 | euro |
| Contractor's Soft & Miscellaneous Costs | 10.890.050 | euro |
| | | |
| 4. Contractor's Price | 225.582.800 | euro |
| Owner's Soft & Miscellaneous Costs | 19.322.340 | euro |
| | | |
| 5. Total - Owner's Cost (0,75 euro per USD) - See Cautionary Note Below | 244.905.100 | euro |
| | | |
| 6. Plant Net Electric Output | 46,24 | MWe |
| | | |
| Cautionary Note: | | |
| In Simplified PEACE mode, THERMOFLEX does not provide complete plant cost estimates | | |
| as is done in the Comprehensive PEACE mode or in GT PRO and STEAM PRO. | | |
| In Simplified PEACE mode, THERMOFLEX only includes capital cost estimates for PEACE components and for linked GT PRO, GT MASTER, and | | |
| STEAM MASTER files. Complete plant cost estimates often contain features not included in the THERMOFLEX | | |
| model. It is the user's responsibility to carefully review the cost estimate and its scope to ensure suitability | | |
| to the project at hand. | | |
| | | |
| Costs for features not included in the model should be included via the user-defined cost inputs available from: | | |
| 'Edit Inputs' -> 'Economics & Regional Costs' menu -> 'User-Defined Costs' tab. | | |
| * Cost estimates as of August 2016. | | |

PEACE Output - Simplified

File Edit

Financial: Cost Report | Cash Flow

Cost Summary | Cost Breakdown

| Cost Breakdown | Unit Cost | Cost Adj. Factor | Ref. Cost | Est. Cost | |
|---|---|---|---|---|---|
| Wet Cooling Tower (PCE) | | | 1.357.428 | 1.472.806 | euro |
| Wet Cooling Tower (PCE) [28] | 1.357.428 | 1 | | | |
| | | | | | |
| Pipe (PCE) | | | 951.348 | 1.092.052 | euro |
| Pipe (PCE) [9] | 21.991 | 1 | | | |
| Pipe (PCE) [12] | 21.991 | 1 | | | |
| Pipe (PCE) [15] | 26.073 | 1 | | | |
| Pipe (PCE) [18] | 34.464 | 1 | | | |
| Pipe (PCE) [21] | 44.167 | 1 | | | |
| Pipe (PCE) [24] | 129.147 | 1 | | | |
| Pipe (PCE) [29] | 193.456 | 1 | | | |
| Pipe (PCE) [35] | 139.441 | 1 | | | |
| Pipe (PCE) [36] | 66.112 | 1 | | | |
| Pipe (PCE) [37] | 85.835 | 1 | | | |
| Pipe (PCE) [53] | 188.671 | 1 | | | |
| | | | | | |
| Shell-Tube Economiser (PCE) | | | 217.735 | 232.253 | euro |
| Shell-Tube Economiser (PCE) [45] | 217.735 | 1 | | | |
| | | | | | |
| Shell-Tube Evaporating HX (PCE) | | | 744.996 | 800.112 | euro |
| Shell-Tube Evaporating HX (PCE) [44] | 744.996 | 1 | | | |
| | | | | | |
| Shell-Tube Superheater (PCE) | | | 548.888 | 587.184 | euro |
| Shell-Tube Superheater (PCE) [43] - SH | 253.286 | 1 | | | |
| Shell-Tube Superheater (PCE) [46] - Reheater | 295.602 | 1 | | | |
| | | | | | |
| Solar Field w/ Storage | | | 173.219.300 | 192.588.500 | euro |
| Solar Field w/ Storage [39] | 173.219.300 | 1 | | | |

# Off Design

- Resizing
  - Resizing the Solar Field (Check Pipes, Pumps involved)
  - Storage System Tank Temperatures and capacity
  - Resizing the Heat Exchangers (number of tubes & length / Shell geometry)
- Inputs
- Controls
- Operating Modes
- Link to MS Excel for “dynamic” simulation

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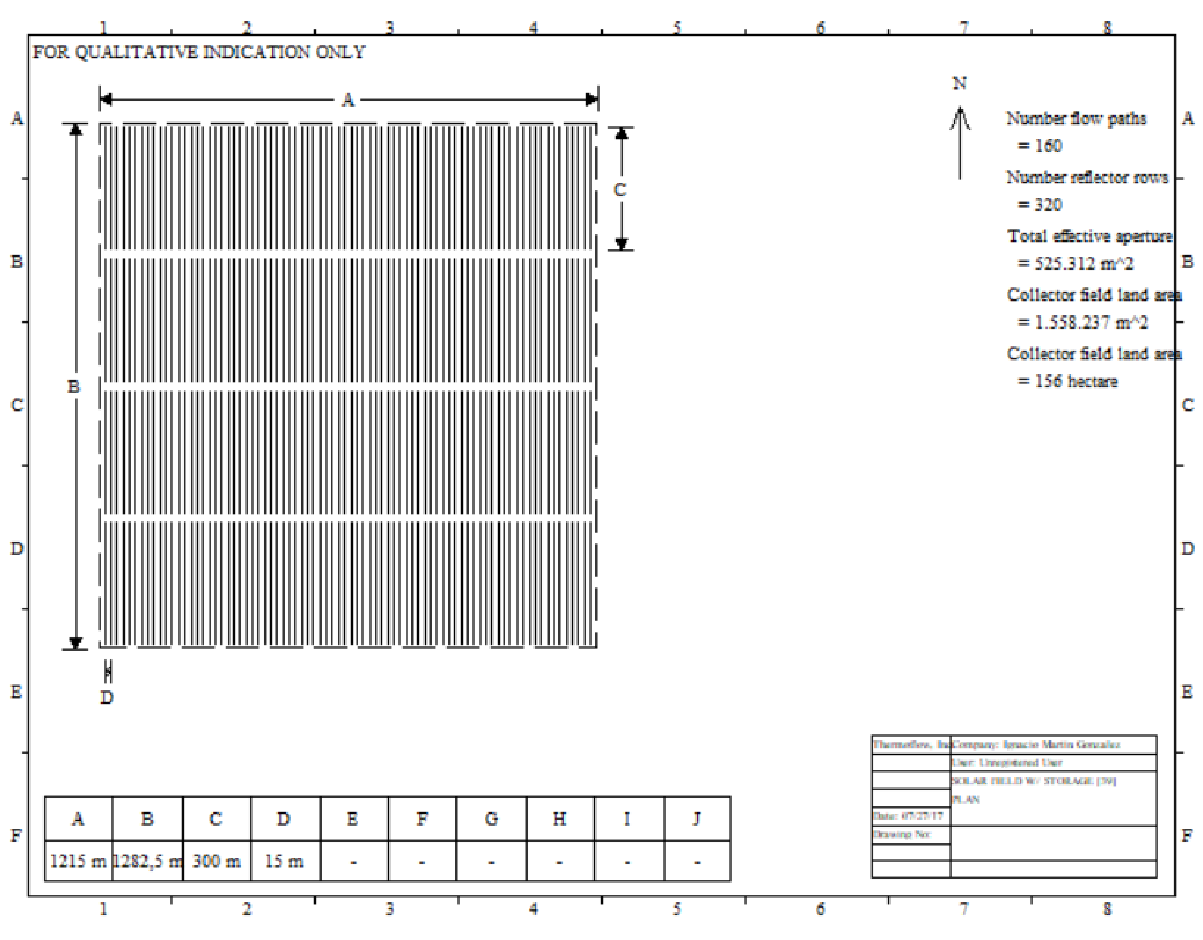
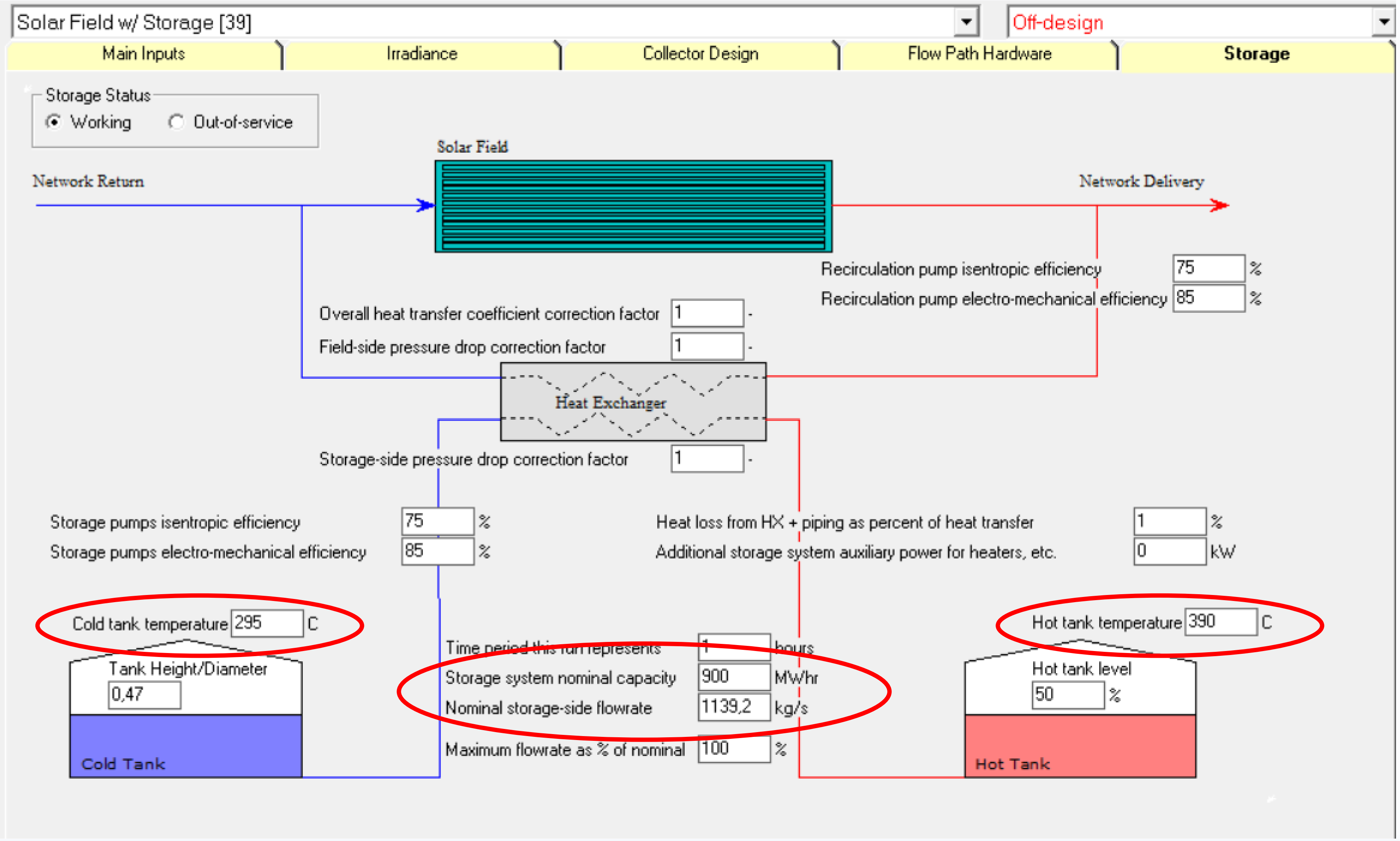
# Resizing the Solar Field

| | | |
|---|---|---|
| 1. Number of efficiency correction factor data points | 91 | |
| 2. Receiver tube outside diameter | 70 | mm |
| 3. Receiver tube wall thickness | 4 | mm |
| 4. Reflector aperture width | 5,76 | m |
| 5. Reflector geometric concentration ratio (aperture width / receiver diameter) | 82,28 | - |
| 6. Reflector rim angle | 80,2 | degrees |
| 7. Reflector focal length | 1,71 | m |
| 8. Total reflector row length | 300 | m |
| 9. Active reflector length as percent of total length | 95 | % |
| 10. Reflector row pitch | 15 | m |
| 11. Reflector cleanliness factor | 0,95 | |
| 12. Number flow paths | 160 | - |
| 13. Number reflector rows per flow path | 2 | - |
| 14. Number reflector row banks | 4 | - |
| 15. Row (tracking axis) rotation from due North | 0 | degrees |
| 16. Row (tracking axis) tilt from horizontal | 0 | degrees |
| 17. Receiver tube emissivity | 0,15 | - |
| 18. Receiver glass envelope emissivity | 0,9 | - |
| 19. Assumed convective heat transfer coefficient outside glass envelope | 56,78 | W/m^2-C |
| 20. Assumed receiver support fin efficiency | 5 | % |
| 21. Receiver support spacing along reflector row | 4 | m |
| 22. Overall heat loss correction factor | 1 | - |
| 23. Number of computational segments along receiver | 10 | |



# Resizing the Storage System



# Off-Design

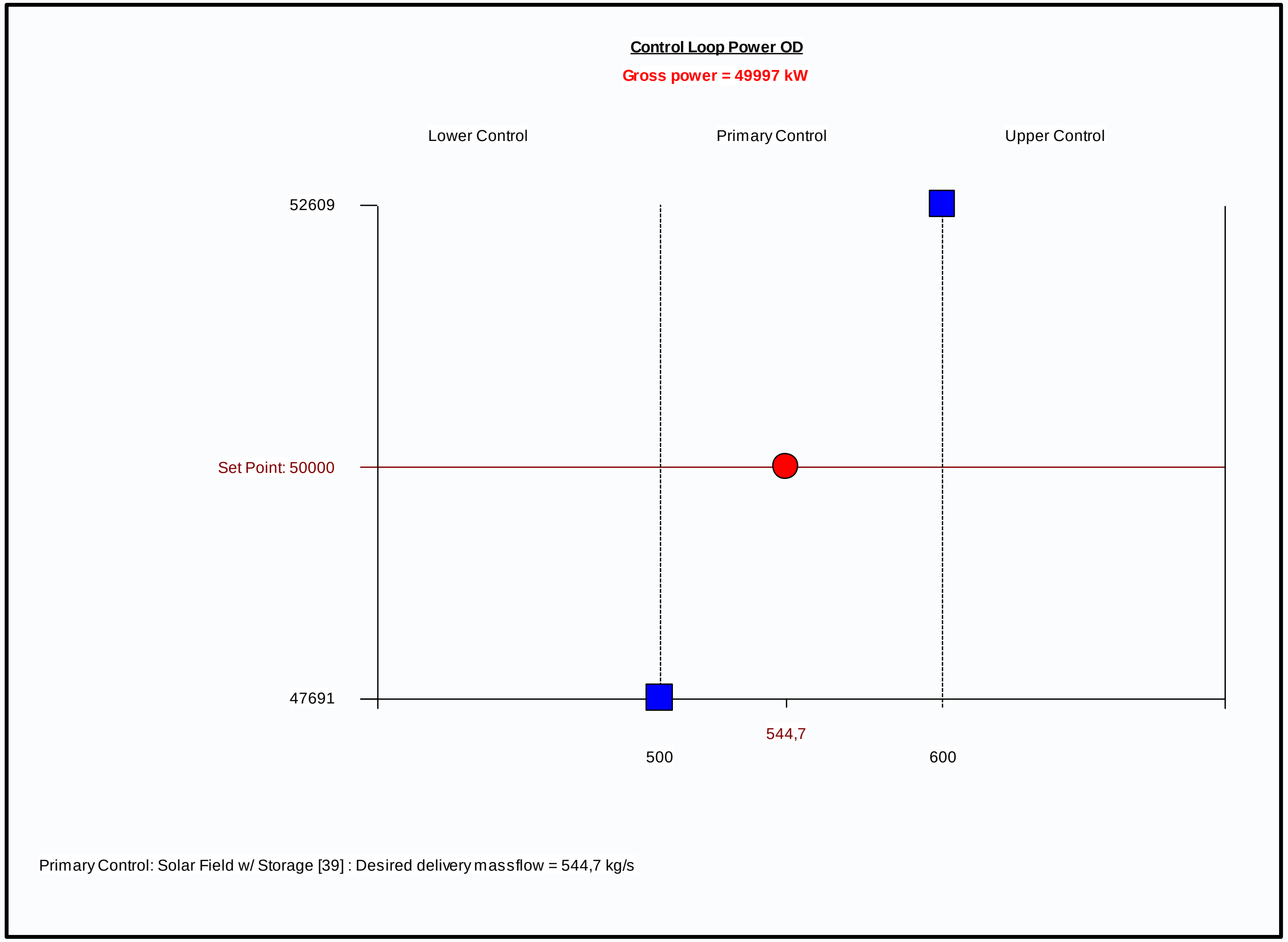
**Main Inputs**

- Power Output
- Ambient Conditions
- Irradiance
- Time period each run represents
- Hot Tank Level
- Solar Field / Storage System status

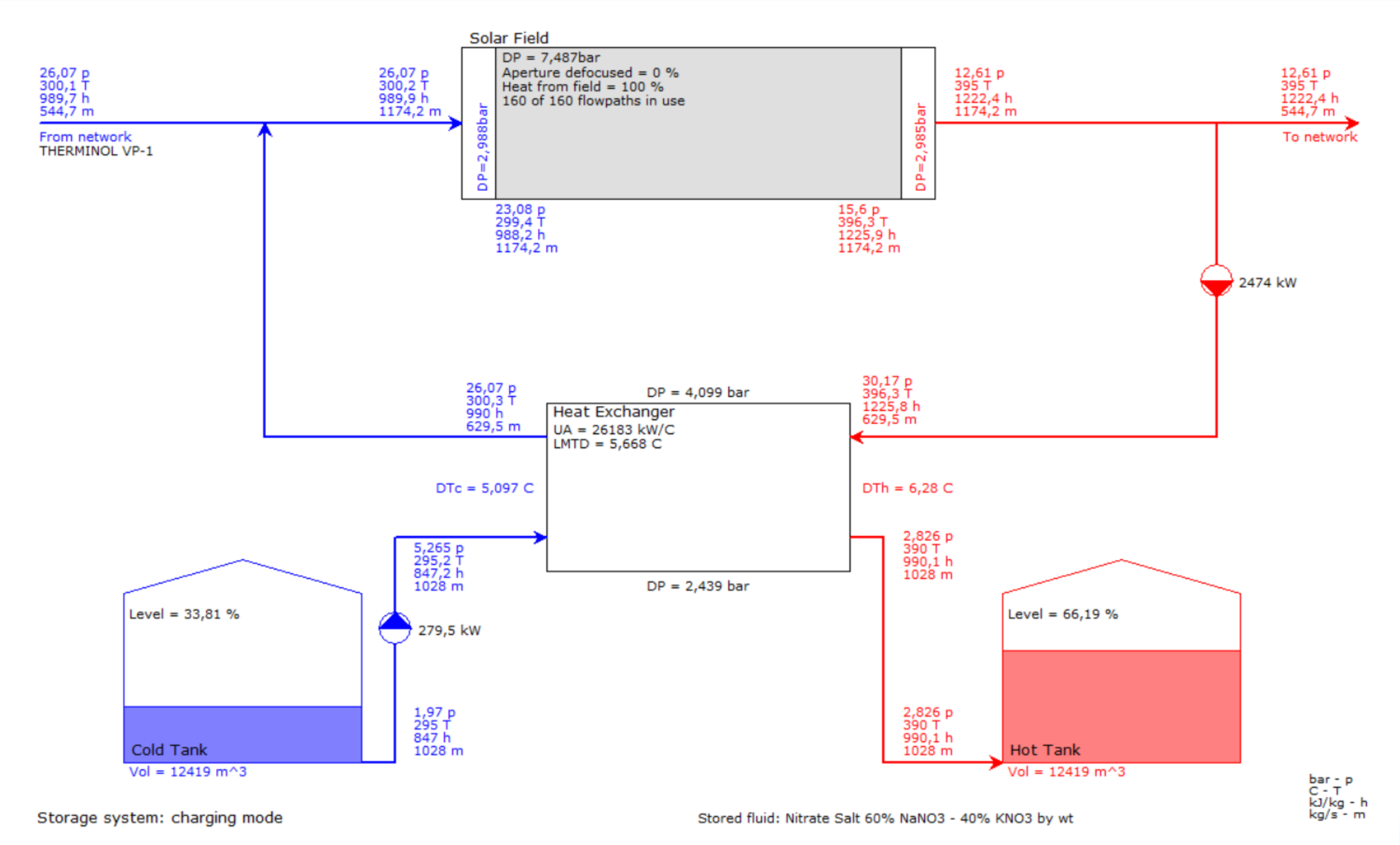
# Off Design Controls

- Solar Field
  - Desired Delivery mass Flow
  - Number of operating Flow paths
  - Low Heat Input Field shutdown (% of design)
  - High Heat Input field Flow limit (% of design)
- Storage System
  - Working / out of service
  - Hot Tank level
  - Maximum mf (% of design)
- Flow determination
  - Control Loop for Desired Delivery mf to satisfy Power Output demand
  - HX Flow specification (network / component)
  - Controlled Splitter: parameter matching (TSH = TRH)

# Off Design, Control Loop



# Off Design Flow Diagram



# Off Design simulation

1. Check Operating Modes in TFX, define the Control Loops for each case
2. ELINK, define variables, limits, logic functions to operate at each mode
3. Run a 24 hours case for Summer and Winter conditions
4. Calculate the Annual Yield

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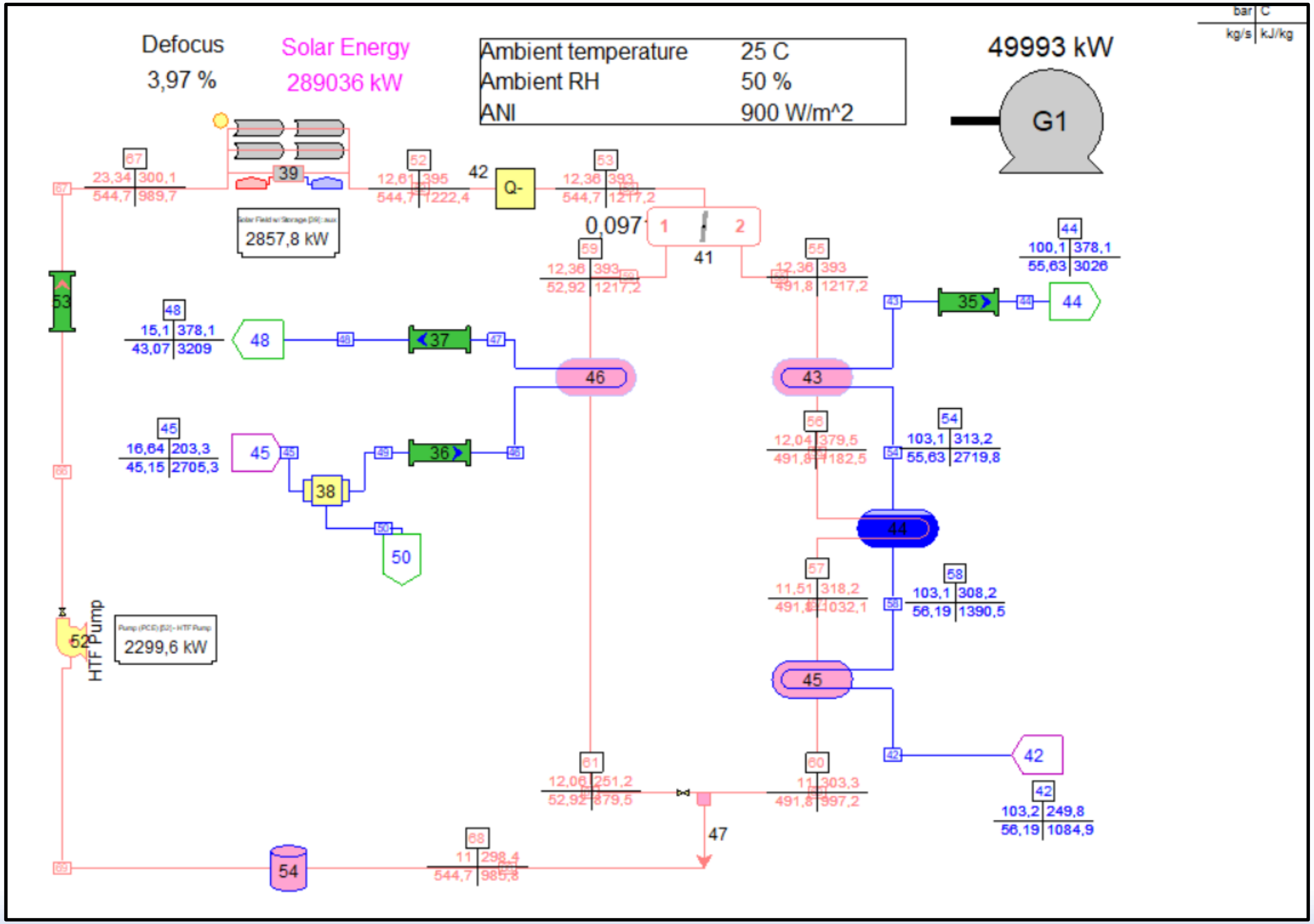
# Off-Design Operating Modes

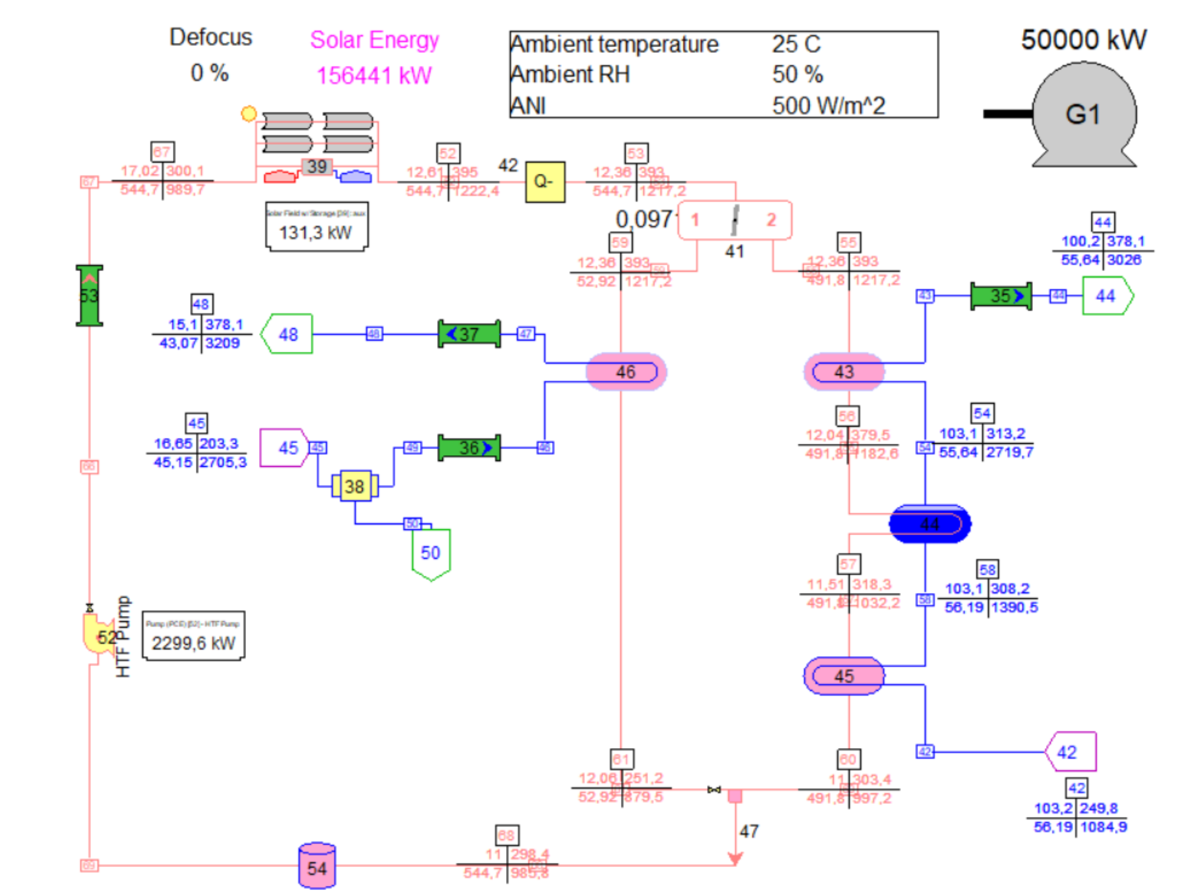
| | | 1 | 2 | 3 | 4 | 5 | 6 | … |
|---|---|---|---|---|---|---|---|---|
| **Inputs** | Irradiance | High | Very High | High | High | Low | No | |
| | Power demand | 100 | 100 | 100 | 100 | 100 | | |
| | Storage in service | 1 | 1 | 0 | 1 | 1 | 1 | |
| | Hot Tank level | <100 | <100 | | 100 | >min | >min | |
| **Outputs** | Power | 100 | 100 | 100 | 100 | 100 | X | |
| | Charging | 1 | 1 | | | | | |
| | Discharging | | | | | 1 | 1 | |
| | Defocus | | 1 | 1 | 1 | | | |

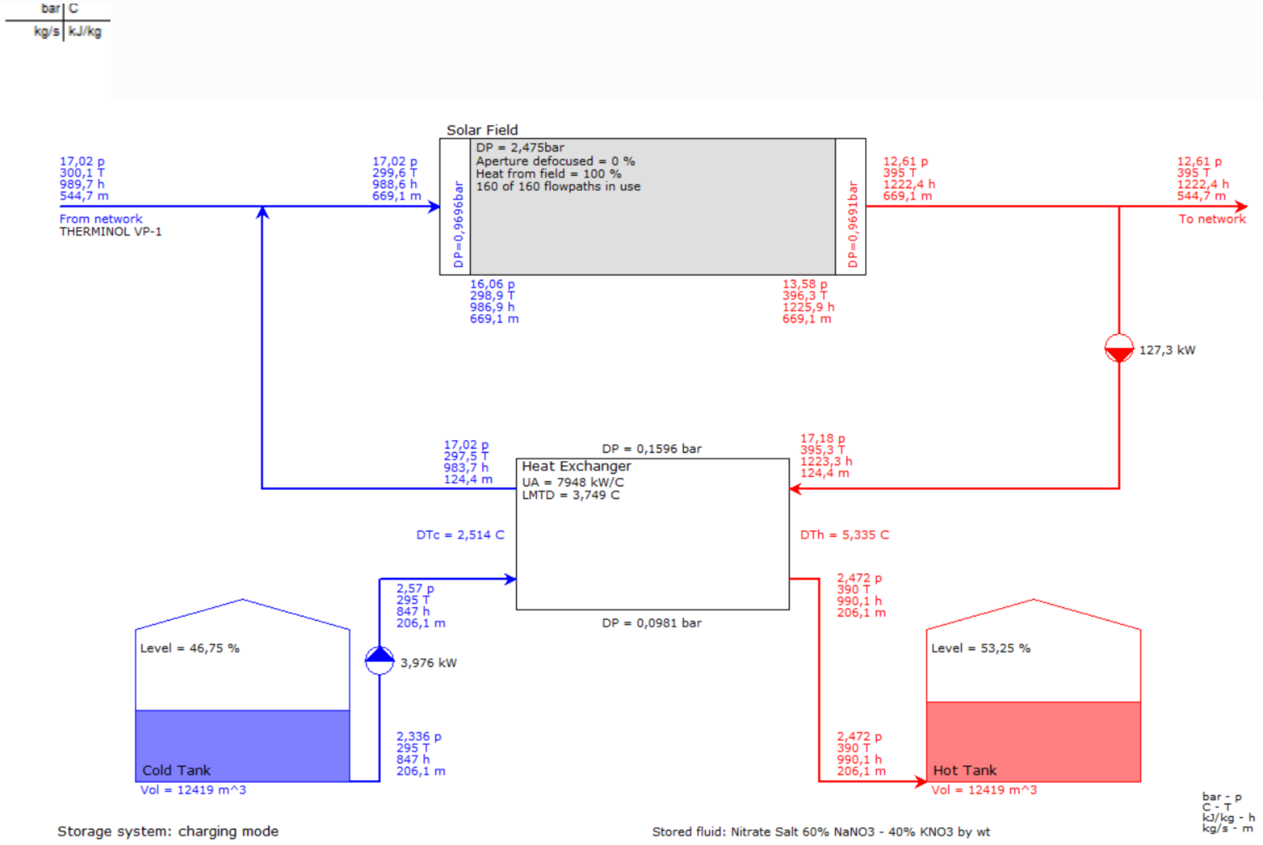
Thermoflow

# Off-Design simulation, mode 2

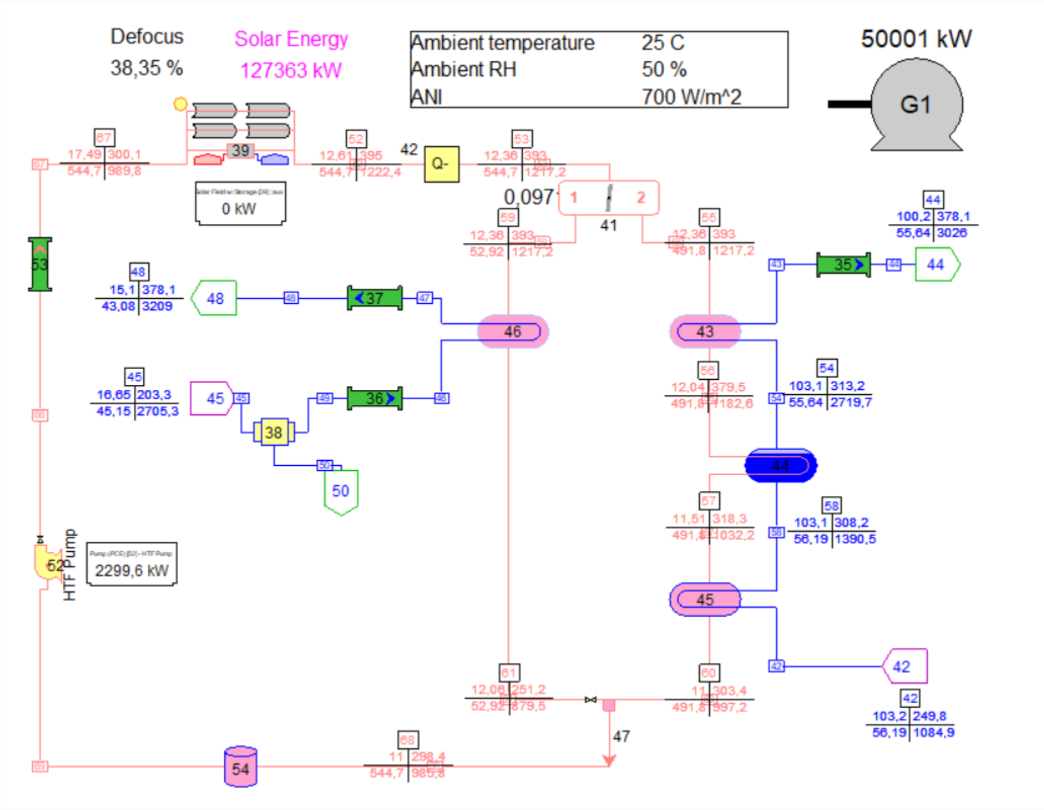


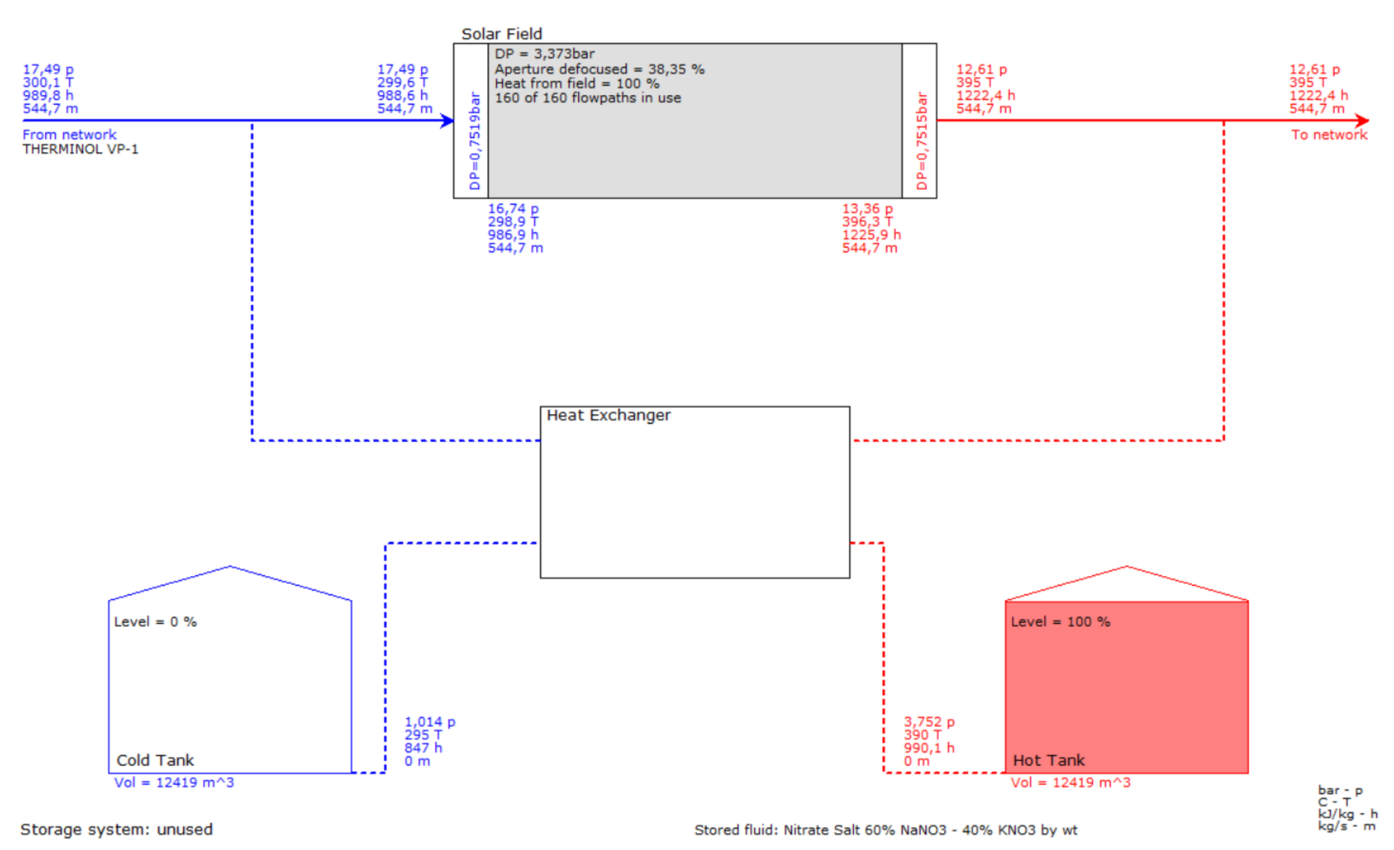
# Off-Design simulation, mode 1



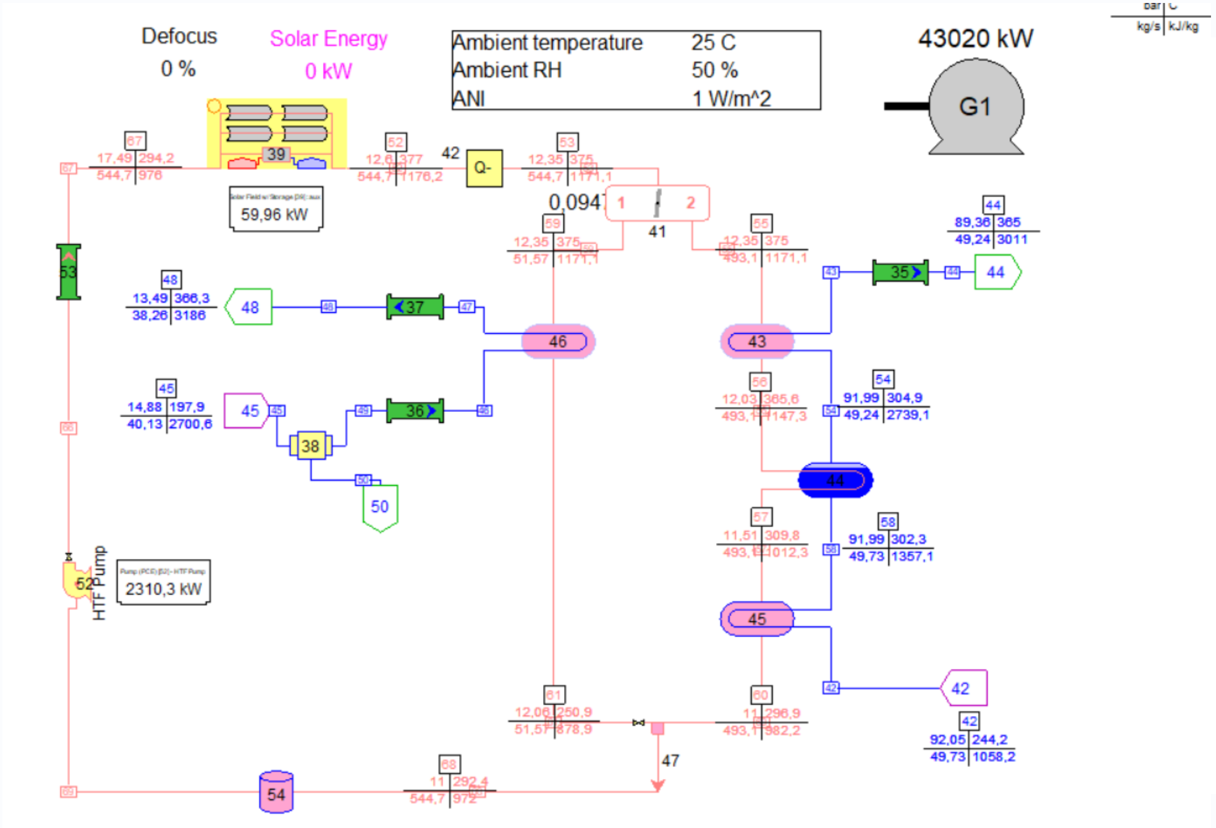



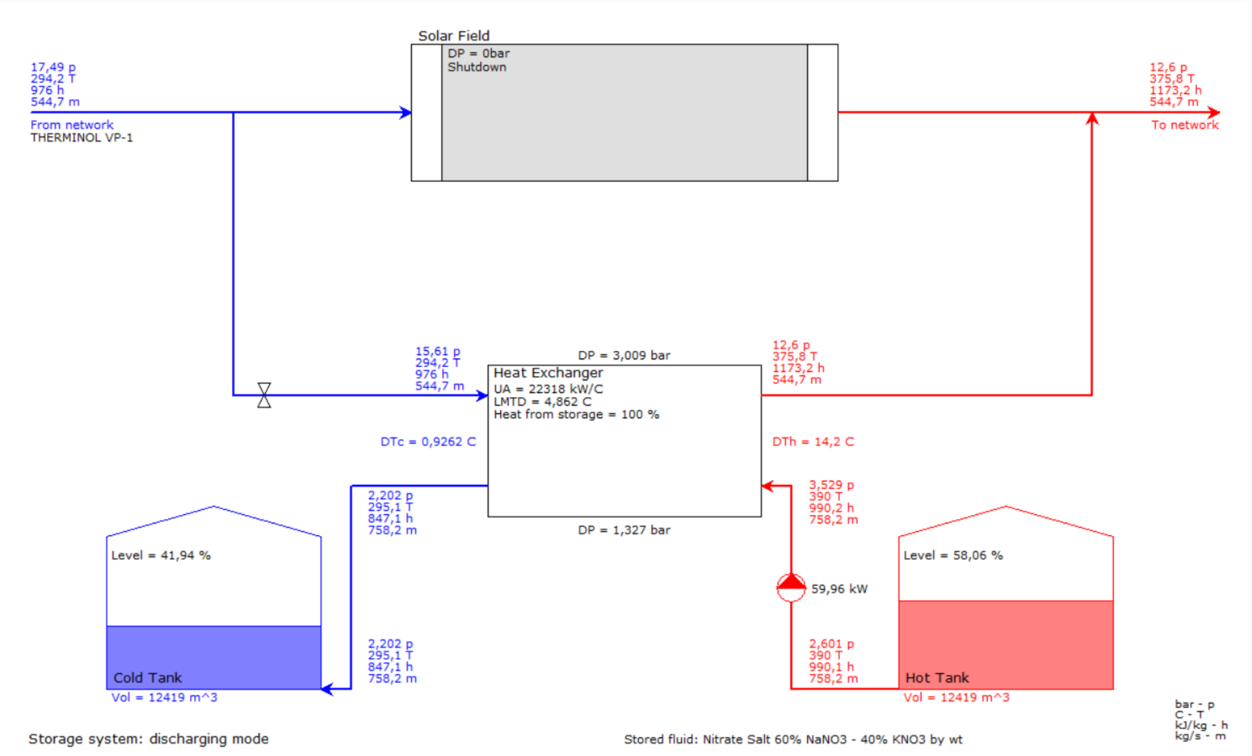
# Off-Design simulation, mode 4



# Off-Design simulation, mode 6



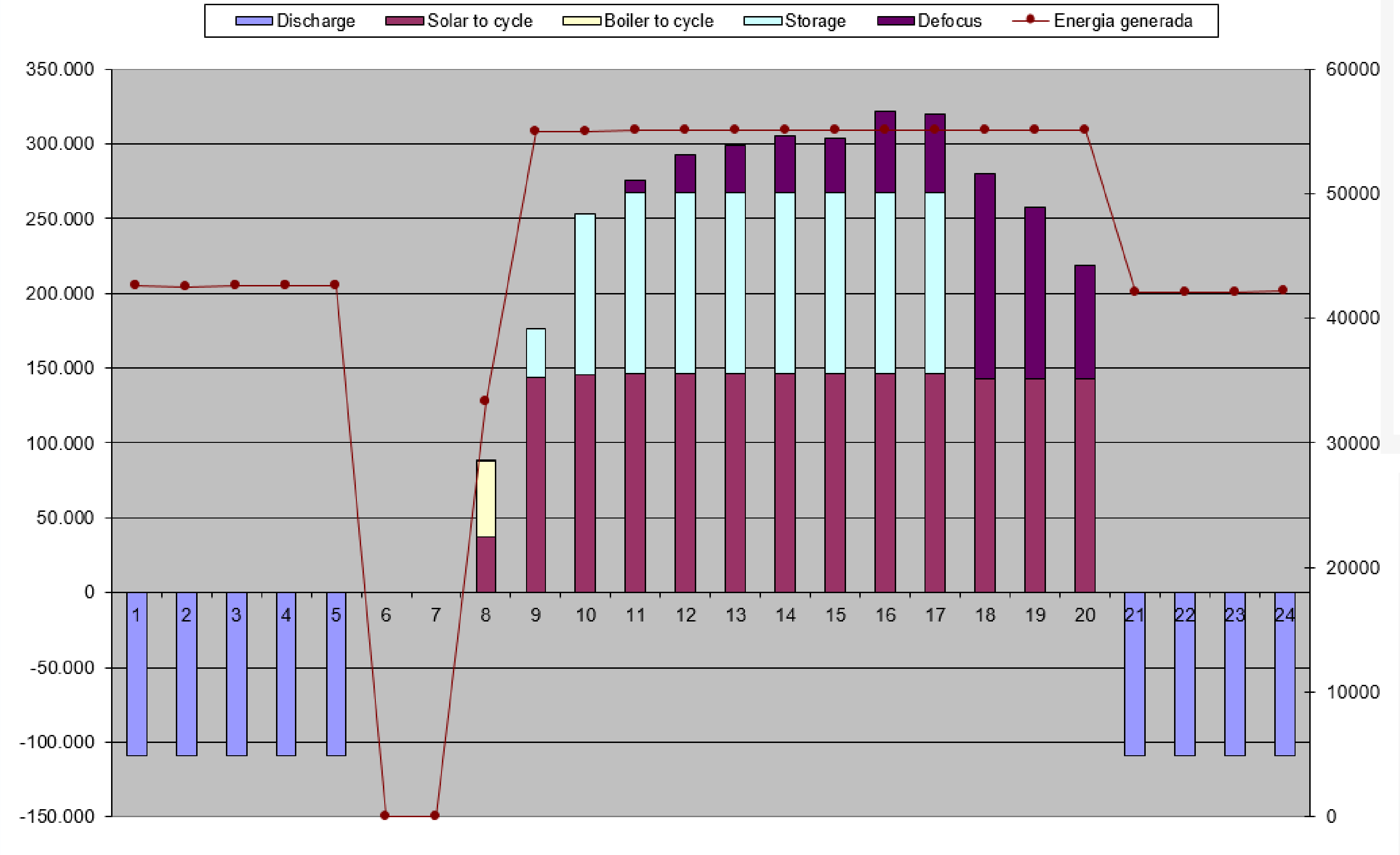
# ELINK: Operating Modes

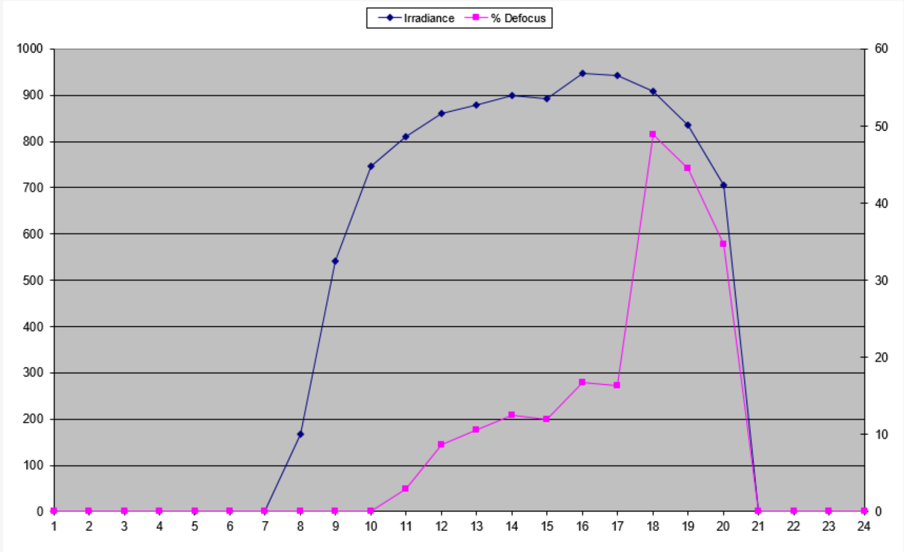
ELINK 25.0

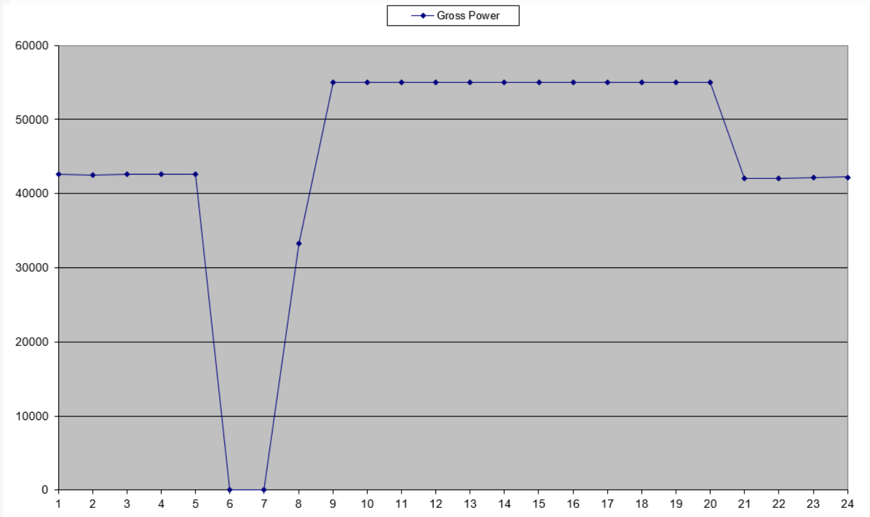
| | | Base Case | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 3b | 4 | 5 | 6 | |
| Computation Message -> | | Messages | Messages | Messages | Messages | OK | Messages | Messages | Messages |
| **INPUT VARIABLE DESCRIPTION** | **Units** | **Input** | Input | Input | Input | Input | Input | Input | Input |
| Solar Field w/ Storage[39] Storage system status: 0=working, 1=out-of-servi | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Control Loop [1] Enabled 0:No 1:Yes | | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| Set point of Control Loop [1] | kW | 50000 | 50000 | 50000 | 50000 | 50000 | 50000 | 50000 | 50000 |
| Primary control input lower bound for control loop [1] | kg/s | 500 | 500, | 500, | 500, | 500, | 500, | 500, | 500 |
| Primary control input upper bound for control loop [1] | kg/s | 700 | 700, | 700, | 700, | 700, | 700, | 700, | 700 |
| Solar Field w/ Storage[39] Desired delivery massflow | kg/s | 525, | 700, | 700, | 700, | 0, | 700, | 700, | 0, |
| Solar Field w/ Storage[39] Hot tank level at start of this period | % | 50 | 24 | 50 | 50 | 24 | 50 | 50 | 24 |
| Solar Field w/ Storage[39] Hot tank temperature | C | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| Solar Field w/ Storage[39] Cold tank temperature | C | 292 | 292 | 292 | 292 | 292 | 292 | 292 | 292 |
| Solar Field w/ Storage[39] Maximum tank-side flowrate as % of r | % | 100 | 100,0 | 100,0 | 100,0 | 84,6 | 84,6 | 84,6 | 84,6 |
| Solar Field w/ Storage[39] Time period this run represents | hours | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **OUTPUT VARIABLE DESCRIPTION** | **Units** | **Output** | Output | Output | Output | Output | Output | Output | Output |
| Gross power | kW | 49995 | 31342 | 49995 | 49992 | 0 | 50007 | 41745 | 49995 |
| Net power | kW | 43106 | 27140 | 44668 | 42979 | -6,761 | 44929 | 36895 | 43106 |
| Gross electric efficiency(LHV) | % | 38,88 | 37,86 | 38,88 | 38,88 | 0 | 38,78 | 38,37 | 38,88 |
| Net electric efficiency(LHV) | % | 33,52 | 32,79 | 34,74 | 33,43 | 0 | 34,84 | 33,92 | 33,52 |
| Gross heat rate(LHV) | kJ/kWh | 9259 | 9508 | 9259 | 9259 | 0 | 9284 | 9382 | 9259 |
| Net fuel input(LHV) | kW | 128580 | 82780 | 128580 | 128580 | ####### | 128962 | 108787 | 128580 |
| Solar Field w/ Storage[39] Delivery massflow | kg/s | 525, | 259,7 | 525, | 525, | 0 | 588,9 | 446,5 | 525, |
| Solar Field w/ Storage[39] Percentage of active aperture defocused to limit field heating | % | 0 | 0 | 0 | 9,819 | 0 | 0 | 0 | 0 |
| Solar Field w/ Storage[39] Storage operation flag: (0=off, 1=charging, -1=discharging) | | 1 | 0 | 1 | 1 | 1 | -1 | -1 | 1 |
| Solar Field w/ Storage[39] Field-side charging flow | kg/s | 524,7 | 0 | 232,1 | 537,9 | 110,3 | 0 | 0 | 524,7 |
| Solar Field w/ Storage[39] Field-side discharging flow | kg/s | 0 | 0 | 0 | 0 | 0 | 255,4 | 446,5 | 0 |
| Solar Field w/ Storage[39] Tank-side charging flow | kg/s | 911,9 | 0 | 404,5 | 935 | 192,2 | 0 | 0 | 911,9 |
| Solar Field w/ Storage[39] Tank-side discharging flow | kg/s | 0 | 0 | 0 | 0 | 0 | 374,6 | 791, | 0 |
| Solar Field w/ Storage[39] Ending hot tank level | % | 71,06 | 24 | 59,34 | 71,6 | 28,44 | 41,35 | 31,73 | 71,06 |

| | | |
|---|---|---|
| Low Irradiance limit | | 425 |
| Hot Tank minimum level | | 25 |
| Very Low irradiance limit | | 150 |
| Field Shut down limit | | 100 |

# ELINK: 24 hours “dynamic” simulation



Thermoflow

# ELINK: Annual Yield calculation

**Sample (Elink4) Hourly Simulation-Entire Year.xlsm**

| | |
|---|---|
| Start Case | 1 |
| End Case | 10 |
| Current Cas | 10 |

Compute Cases

Press to Cancel

| Case Number | Week of Year | Day of Year | Hour of Day | Daily Average Temperature | Hourly Average Temperature | Haze Factor |
|---|---|---|---|---|---|---|
| - | - | - | - | °C | °C | - |
| 10 | 1 | 1 | 10 | -1,9 | 2,5 | 0,14 |

<- This row of data comes from the Input Data Stack based on the 'Current Case'. Don't edit this by hand.

**INPUT DATA STACK** / **OUTPUT DATA TABLE**

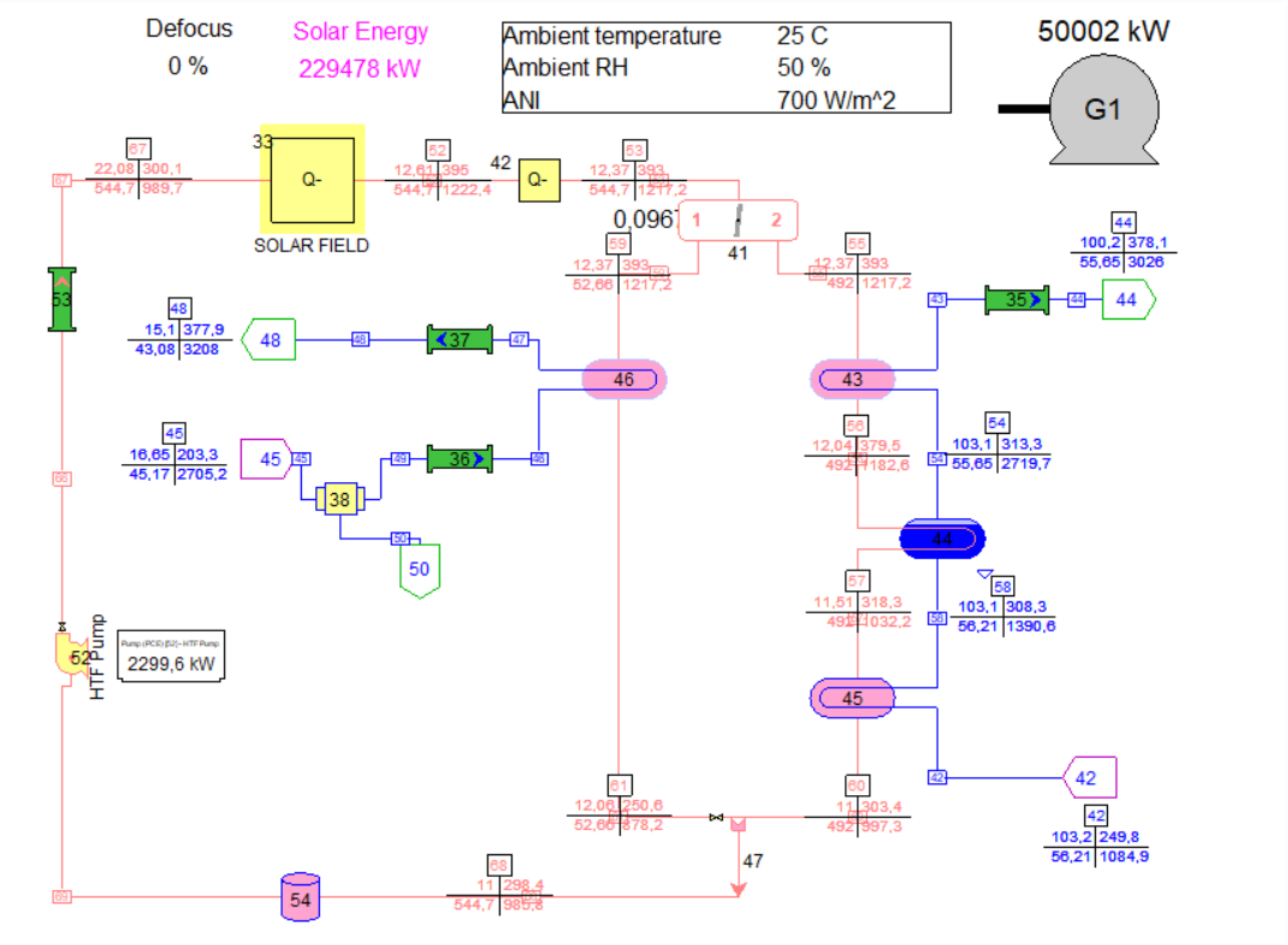
| Row | Case Number | Week of Year | Day of Year | Hour of Day | Daily Average Temperature | Hourly Average Temperature | Haze Factor | Aperture normal direct irradiance | Azimuth angle | Zenith angle | Altitude angle | Aperture tracking angle | Oil flow in field | Net heat absorbed by oil | Solar field efficiency | Steam Delivery Pressure | Steam Delivery Temperature | Steam Delivery Flow | Compute Date+Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | - | - | - | - | °C | °C | - | W/m^2 | Degrees | Degrees | Degrees | Degrees | kg/s | kW | % | bar | C | kg/s | |
| 24 | 1 | 1 | 1 | 1 | -1,9 | -6,7 | 0,14 | 316,611298 | 149,849396 | 66,360497 | 23,639502 | 48,9292679 | 112,622284 | 19983,2246 | 58,366562 | 121,96629 | 378,792755 | 11,76 | 8/19/16 17:48 |
| 25 | 2 | 1 | 1 | 2 | -1,9 | -6,2 | 0,14 | 0 | 70,0407639 | 150,69028 | -60,690269 | -27,819592 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 26 | 3 | 1 | 1 | 3 | -1,9 | -5,4 | 0,14 | 0 | 83,0701981 | 139,04192 | -49,041912 | -40,750237 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 27 | 4 | 1 | 1 | 4 | -1,9 | -4,4 | 0,14 | 0 | 92,5584106 | 127,08339 | -37,083385 | -52,889126 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 28 | 5 | 1 | 1 | 5 | -1,9 | -3,1 | 0,14 | 0 | 100,776154 | 115,19633 | -25,196327 | -64,40876 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 29 | 6 | 1 | 1 | 6 | -1,9 | -1,9 | 0,14 | 0 | 108,757729 | 103,62126 | -13,621261 | -75,645477 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 30 | 7 | 1 | 1 | 7 | -1,9 | -0,6 | 0,14 | 0 | 117,150589 | 92,59549 | -2,5954826 | -87,083626 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 31 | 8 | 1 | 1 | 8 | -1,9 | 0,6 | 0,14 | 68,5349731 | 126,486618 | 82,416489 | 7,5835128 | 80,5975723 | 0 | 0 | 0 | 122,00001 | 325,914734 | 0,00 | 8/19/16 17:48 |
| 32 | 9 | 1 | 1 | 9 | -1,9 | 1,7 | 0,14 | 281,897308 | 137,257782 | 73,489937 | 16,510071 | 66,4079666 | 96,1009674 | 17209,6523 | 56,348091 | 121,97488 | 379,754669 | 10,10 | 8/19/16 17:49 |
| 33 | 10 | 1 | 1 | 10 | -1,9 | 2,5 | 0,14 | 316,611298 | 149,849396 | 66,360497 | 23,639502 | 48,9292679 | 112,622284 | 19983,2246 | 58,366562 | 121,96629 | 378,792755 | 11,76 | 8/19/16 17:49 |
| 34 | 11 | 1 | 1 | 11 | -1,9 | 3,0 | 0,14 | 308 | 164,3 | 61,68 | 28,32 | 26,66 | 19252 | 57,91 | 122 | 379,1 | 11,32 | 108,30 | 4/30/14 17:19 |
| 35 | 12 | 1 | 1 | 12 | -1,9 | 3,1 | 0,14 | 299,1 | 180 | 60,04 | 29,96 | -8,689E-06 | 18521 | 57,42 | 122 | 379,3 | 10,88 | 103,90 | 4/30/14 17:19 |
| 36 | 13 | 1 | 1 | 13 | -1,9 | 3,0 | 0,14 | 308 | 195,7 | 61,68 | 28,32 | -26,66 | 19252 | 57,91 | 122 | 379,1 | 11,32 | 108,30 | 4/30/14 17:19 |
| 37 | 14 | 1 | 1 | 14 | -1,9 | 2,5 | 0,14 | 316,6 | 210,2 | 66,36 | 23,64 | -48,93 | 19983 | 58,36 | 122 | 378,8 | 11,76 | 112,70 | 4/30/14 17:19 |
| 38 | 15 | 1 | 1 | 15 | -1,9 | 1,7 | 0,14 | 281,9 | 222,7 | 73,49 | 16,51 | -66,41 | 17209 | 56,35 | 122 | 379,8 | 10,1 | 96,15 | 4/30/14 17:19 |
| 39 | 16 | 1 | 1 | 16 | -1,9 | 0,6 | 0,14 | 68,53 | 233,5 | 82,42 | 7,584 | -80,6 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:19 |
| 40 | 17 | 1 | 1 | 17 | -1,9 | -0,6 | 0,14 | 0 | 242,8 | 92,6 | -2,595 | 87,08 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:19 |
| 41 | 18 | 1 | 1 | 18 | -1,9 | -1,9 | 0,14 | 0 | 251,2 | 103,6 | -13,62 | 75,65 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 42 | 19 | 1 | 1 | 19 | -1,9 | -3,1 | 0,14 | 0 | 259,2 | 115,2 | -25,2 | 64,41 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 43 | 20 | 1 | 1 | 20 | -1,9 | -4,4 | 0,14 | 0 | 267,4 | 127,1 | -37,08 | 52,89 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 44 | 21 | 1 | 1 | 21 | -1,9 | -5,4 | 0,14 | 0 | 276,9 | 139 | -49,04 | 40,75 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 45 | 22 | 1 | 1 | 22 | -1,9 | -6,2 | 0,14 | 0 | 290 | 150,7 | -60,69 | 27,82 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 46 | 23 | 1 | 1 | 23 | -1,9 | -6,7 | 0,14 | 0 | 313 | 161 | -70,98 | 14,14 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 47 | 24 | 1 | 1 | 24 | -1,9 | -6,9 | 0,14 | 0 | 2,732E-05 | 166 | -76,04 | -6,793E-06 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 48 | 25 | 1 | 2 | 1 | -1,9 | -6,7 | 0,14 | 0 | 46,8 | 160,9 | -70,92 | -14,15 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 49 | 26 | 1 | 2 | 2 | -1,9 | -6,2 | 0,14 | 0 | 69,91 | 150,6 | -60,64 | -27,84 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 50 | 27 | 1 | 2 | 3 | -1,9 | -5,4 | 0,14 | 0 | 82,96 | 139 | -49 | -40,78 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 51 | 28 | 1 | 2 | 4 | -1,9 | -4,4 | 0,14 | 0 | 92,47 | 127 | -37,04 | -52,93 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 52 | 29 | 1 | 2 | 5 | -1,9 | -3,2 | 0,14 | 0 | 100,7 | 115,2 | -25,15 | -64,46 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 53 | 30 | 1 | 2 | 6 | -1,9 | -1,9 | 0,14 | 0 | 108,7 | 103,6 | -13,58 | -75,7 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |
| 54 | 31 | 1 | 2 | 7 | -1,9 | -0,6 | 0,14 | 0 | 117,1 | 92,54 | -2,544 | -87,14 | 0 | 0 | 122 | 325,9 | 8,172E-08 | 0,00 | 4/30/14 17:20 |

ELINK Main | Help+Information | Input+Output Data

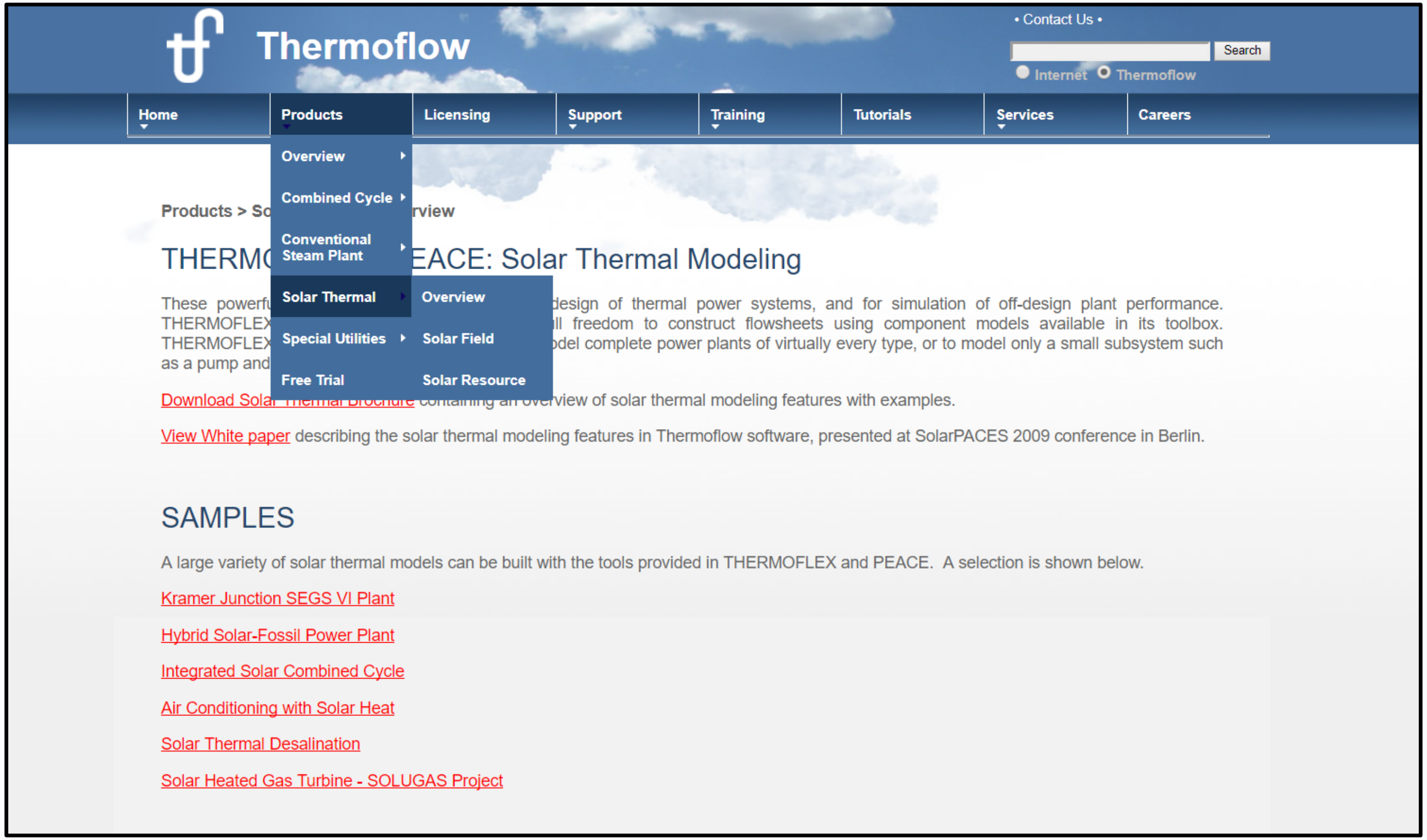
# Running your own software for detailed Solar Field calculations?

→Replace the SF with a Heat Adder

→ELINK: enter the Heat Transfer, oulet state
& Pessure Drop to the Heat Adder
Add the associated Auxiliary Power



# Solar Thermal info and examples



# Solar Thermal Samples

**THERMOFLEX**
(S5-07)SolarThermal_ParabolicTrough:
(S5-07a)SolarThermal_Tower:
(S5-08)Integrated Solar Combined Cycle:
(S5-09)SolarThermalStorage_RankineCycle_OD:
(S5-09B) MoltenSaltThermalStorage_RankineCycle_OD:
(S5-10) SolarThermal_Fresnel_DirectSteamGeneration:
(S5-10a) SolarThermal_Fresnel_DSG_FossilBackup:
(S5-22)SolarPV with Gas Turbine Backup using Scripting:

**EXCEL**
(S5-09)SolarThermalStorage_AnnualOperation
(S5-08) Integrated Solar Combined Cycle
(S5-09b)MoltenSaltThermalStorage_RankineCycle_OD
(S5-10) SolarThermal_Fresnel_DirectSteamGeneration
(S5-10a) SolarThermal_Fresnel_DSG_FossilBackup
(ELINK4)Hourly Simulation - Entire Year

# Q & A Session

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