SAM Webinars 2017: Overview of New Industrial Process Heat and CSP Capabilities in SAM 2017.1.17

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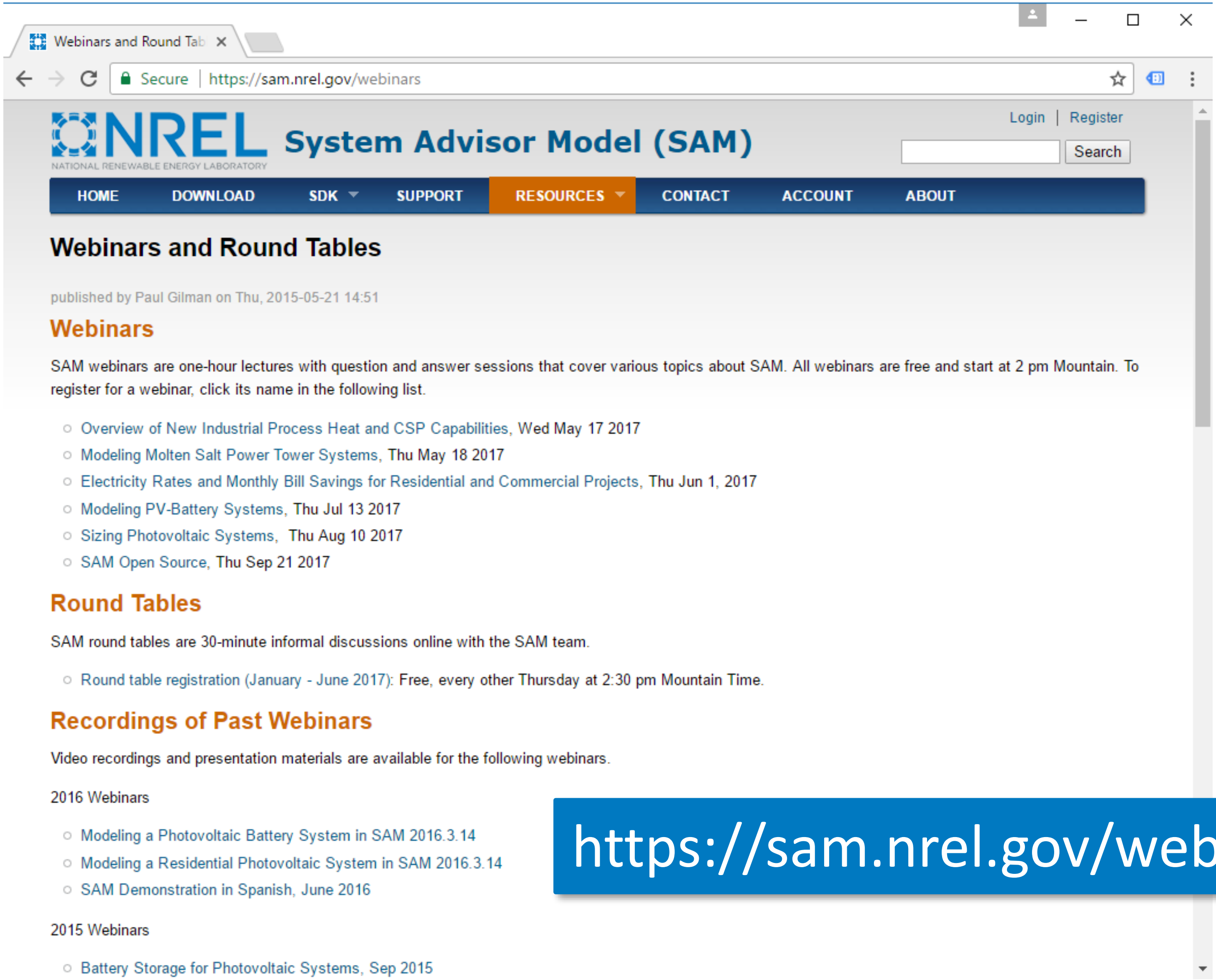
May 17, 2017

SAM Webinars 2017

- **Overview of New Industrial Process Heat and CSP Capabilities, May 17**
- Modeling Molten Salt Power Tower Systems, May 18
- Electricity Rates and Monthly Bill Savings for Residential and Commercial Projects, June 1
- Modeling PV-Battery Systems, July 13
- Sizing Photovoltaic Systems, August 10
- SAM Open Source, September 21

Registration Links and Webinar Recordings



https://sam.nrel.gov/webinars

Outline

- What’s new for CSP in SAM 2017.1.17
- Industrial process heat (IPH) applications
- Levelized cost of heat
- Parabolic trough IPH model
- Linear direct steam IPH model
- Q&A

New in CSP for SAM 2017.1.17

- CSP Generic model uses a different set of regression equations for thermal losses, power cycle conversion efficiency, and parasitic consumption
  - You will need to calculate different coefficients than for the CSP Generic model in older versions of SAM
- Power Tower model improvements to dispatch and solar field optimization algorithms
  - Tomorrow's webinar will discuss in detail
- New solar industrial process heat models

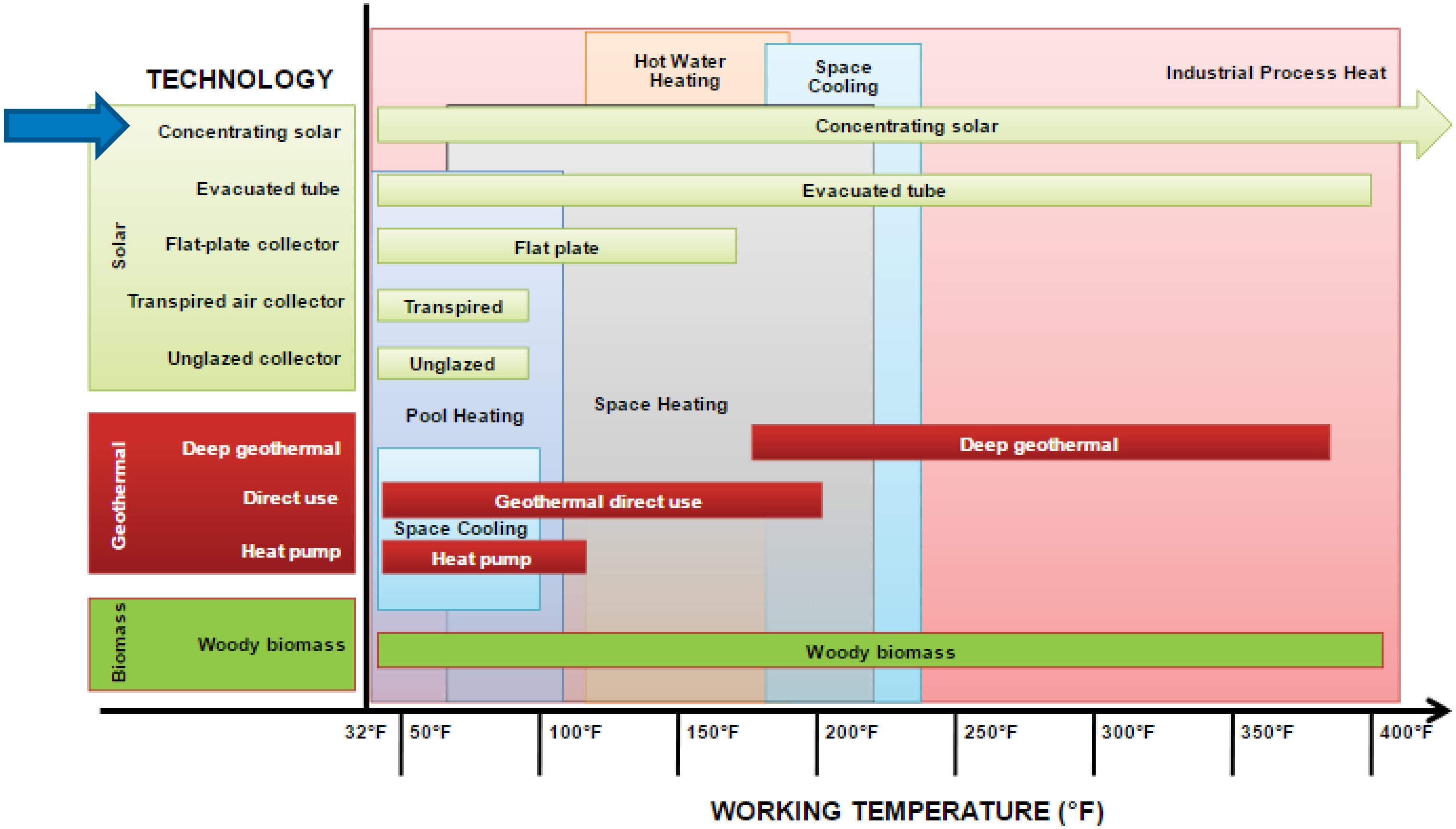
A note on terminology

- Concentrating solar power (CSP)
  - A field of concentrating solar collectors coupled to a power cycle for electricity generation. Typically high-temperature, large-scale systems.
- Solar industrial process heat (SIPH, or IPH for short)
  - Concentrating solar collectors used to provide direct team or heat for a thermal process.
  - Typically replaces or supplements a fossil-fired boiler

CSP = Electricity Generation

IPH = Process Heat

IPH applications for trough and linear Fresnel collectors



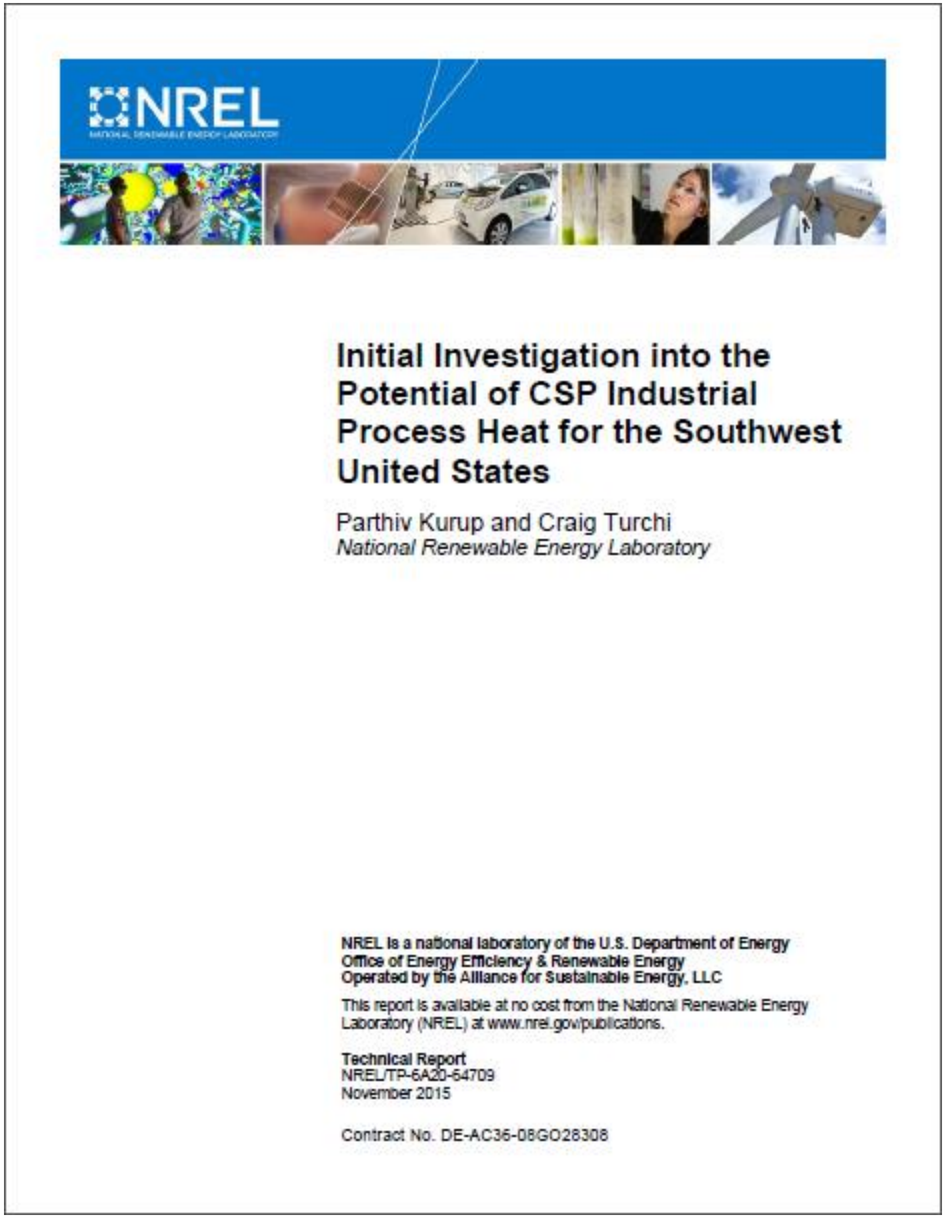
HTF of choice: Direct Steam | Mineral Oil | Synthetic Oil

Source: EPA Renewable Heating and Cooling website, Kurup (2015) paper on IPH for Southwest U.S.

Overview of market status for IPH prepared by NREL for DOE

- Applications
- Collector costs
- Examples of systems
- References to other sources of information

www.nrel.gov/docs/fy16osti/64709.pdf


NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States

Parthiv Kurup and Craig Turchi
National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-6A20-64709
November 2015

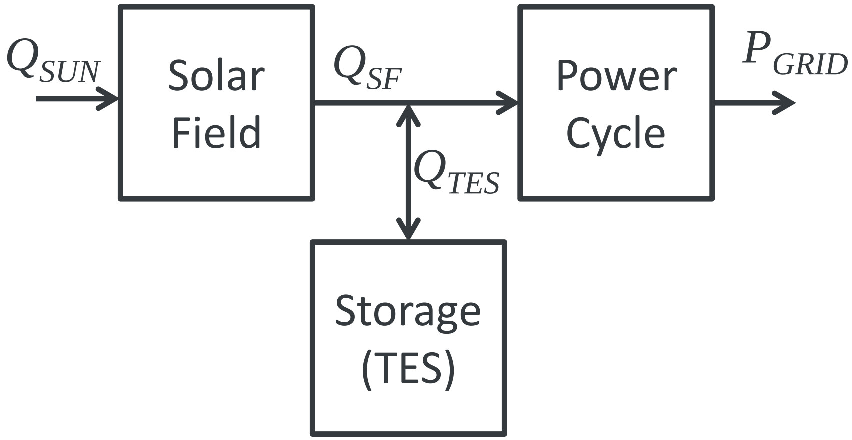
Contract No. DE-AC36-08GO28308

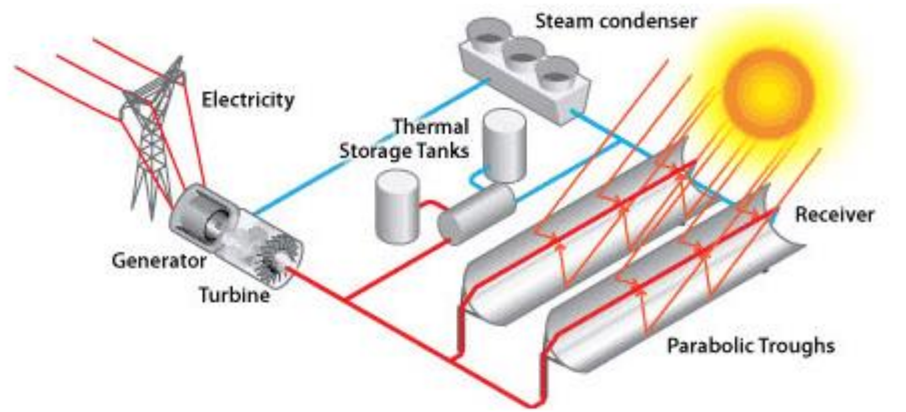
Levelized cost of heat (LCOH)

$$LCOH = \frac{(Total\ installed\ project\ cost) * (FCR) + (Annual\ O\&M)}{Annual\ thermal\ generation}$$

- Accounts for installation and operating costs, project financial requirements, and thermal output of collectors
- Compare cost per kWh of solar-thermal energy to cost per MMBtu of natural gas
- Not a cash-flow method
- Requires calculating the fixed charge rate, which is the revenue per amount of investment required to cover the investment cost
    - Described in SAM’s “LCOE Calculator” Help topic

IPH models in SAM were adapted from CSP models





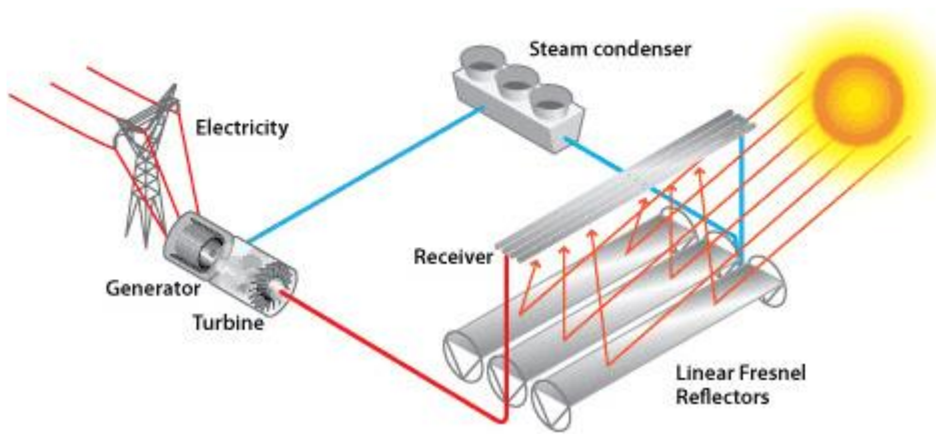
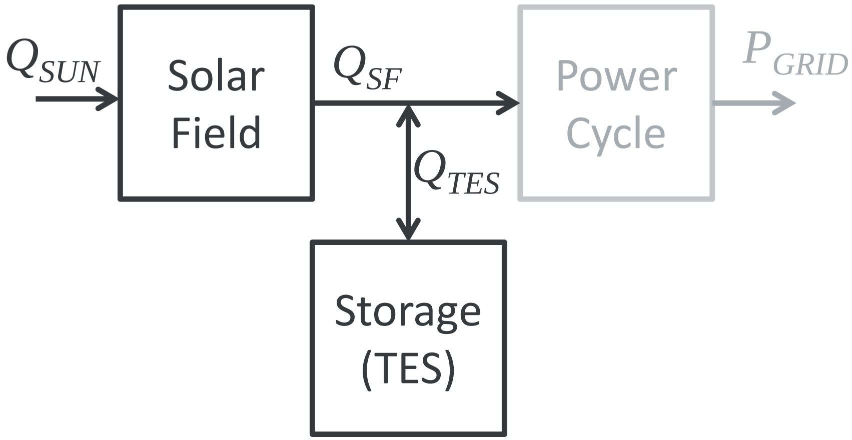


Image source DOE EERE

Before SAM 2017.1.17, model IPH by ignoring power cycle



Power cycle capacity equal to solar field capacity

Boiler operating pressure to saturated steam pressure at solar field outlet temperature

Auxiliary heater outlet temperature to solar field outlet temperature

Power cycle startup time and power to zero, startup temperature to field inlet temperature

Max overdesign operation to 2 times design, and minimum operation to 0.02

Cost and financial models not designed for thermal application

Technique described in 2015 milestone report to DOE, available on SAM website:
“Geothermal Risk Reduction via Geothermal/Solar Hybrid Power Plants”

Two solar industrial process heat models in SAM 2017.1.17

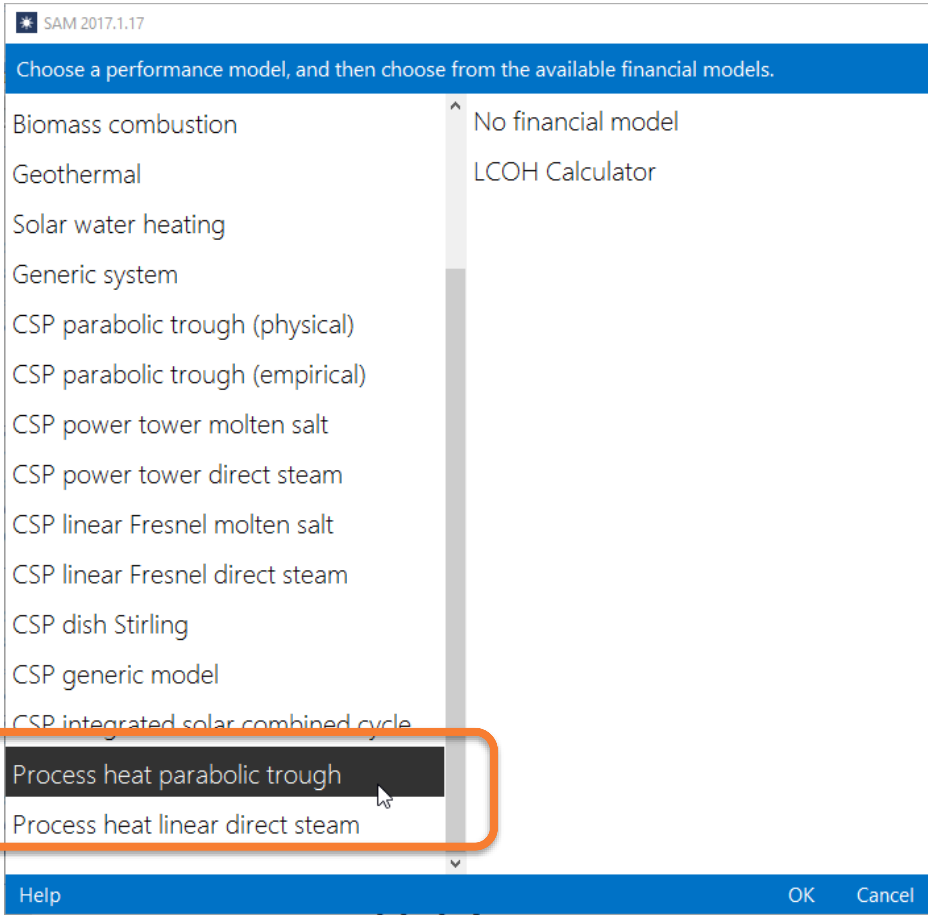
- IPH parabolic trough
    - Physical model of trough collectors and receivers
    - Pressurized water, oil, or salt HTF
- IPH linear direct steam
    - General optical model of field
    - Most of receiver at a single temperature
    - Saturated steam with user-specified steam quality
    - Two-phase steam at field outlet, completely condensed at inlet

If you are learning about concentrating solar for IPH…

- The IPH trough model may be a better starting point because it characterizes the system performance more completely
  - Physical models of collector and receiver
  - Calculate pressure drops
  - Flow rate limitations
- IPH direct steam model requires more data as input
  - Optical efficiency tables or IAM coefficients
  - Pressure drops

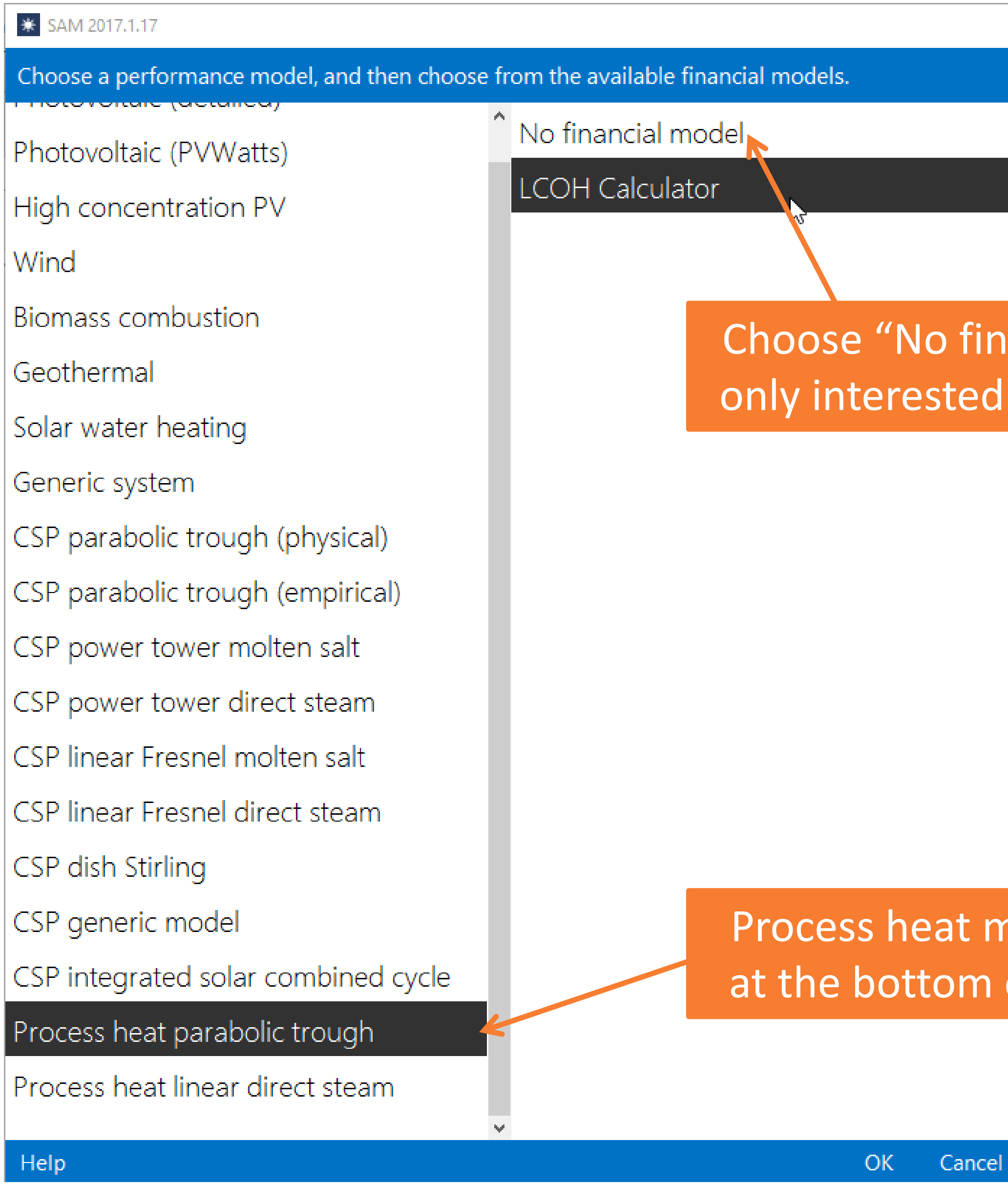
IPH models in SAM 2017.1.17

- Physical trough and linear direct steam models with power cycle removed
- Basic financial model uses fixed-charge-rate method to calculate "levelized cost of heat"
- Thermal storage not yet implemented, coming soon! (for IPH trough with oil or salt HTF only)



IPH Parabolic Trough

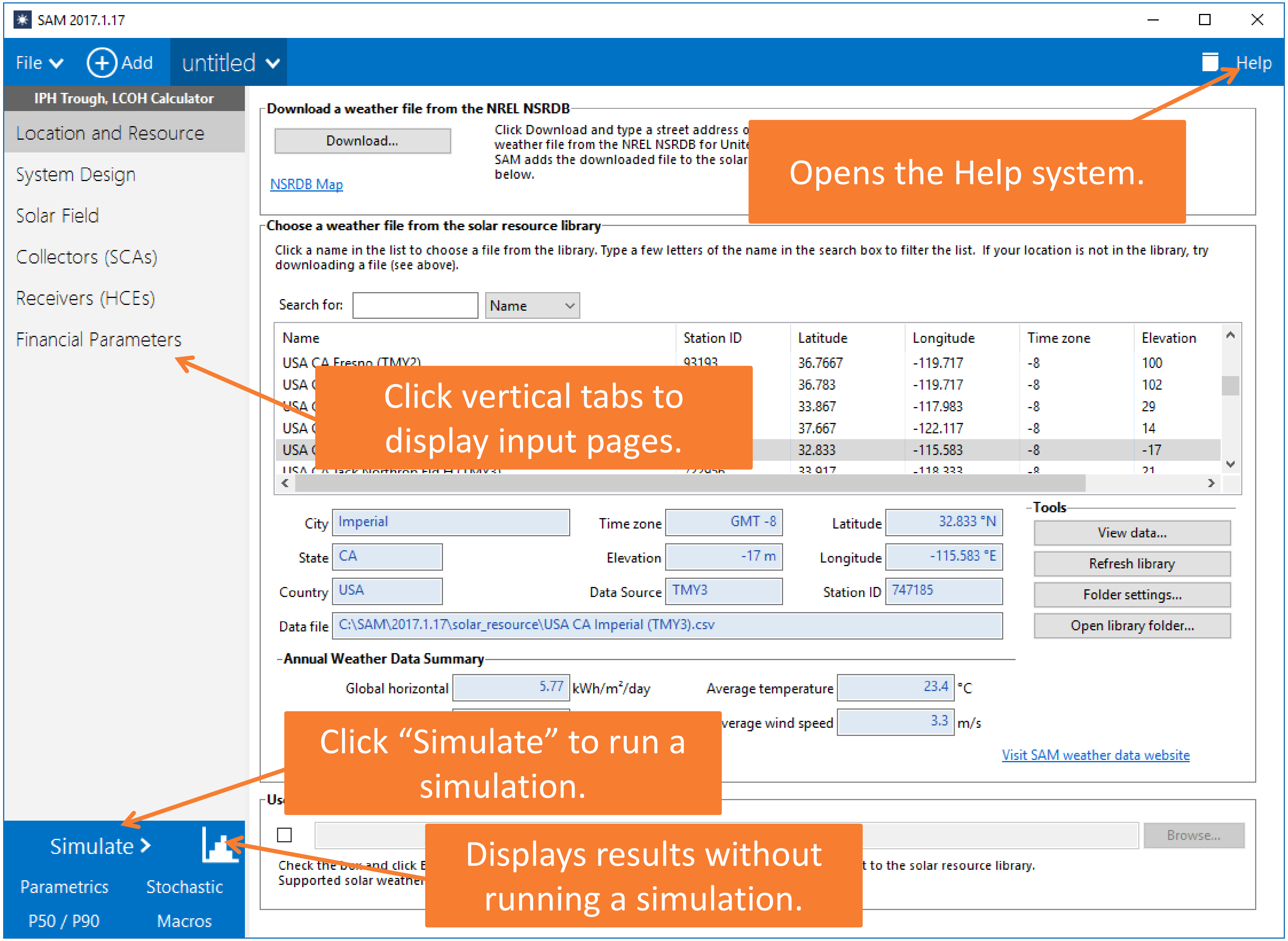
Choose performance model and financial model



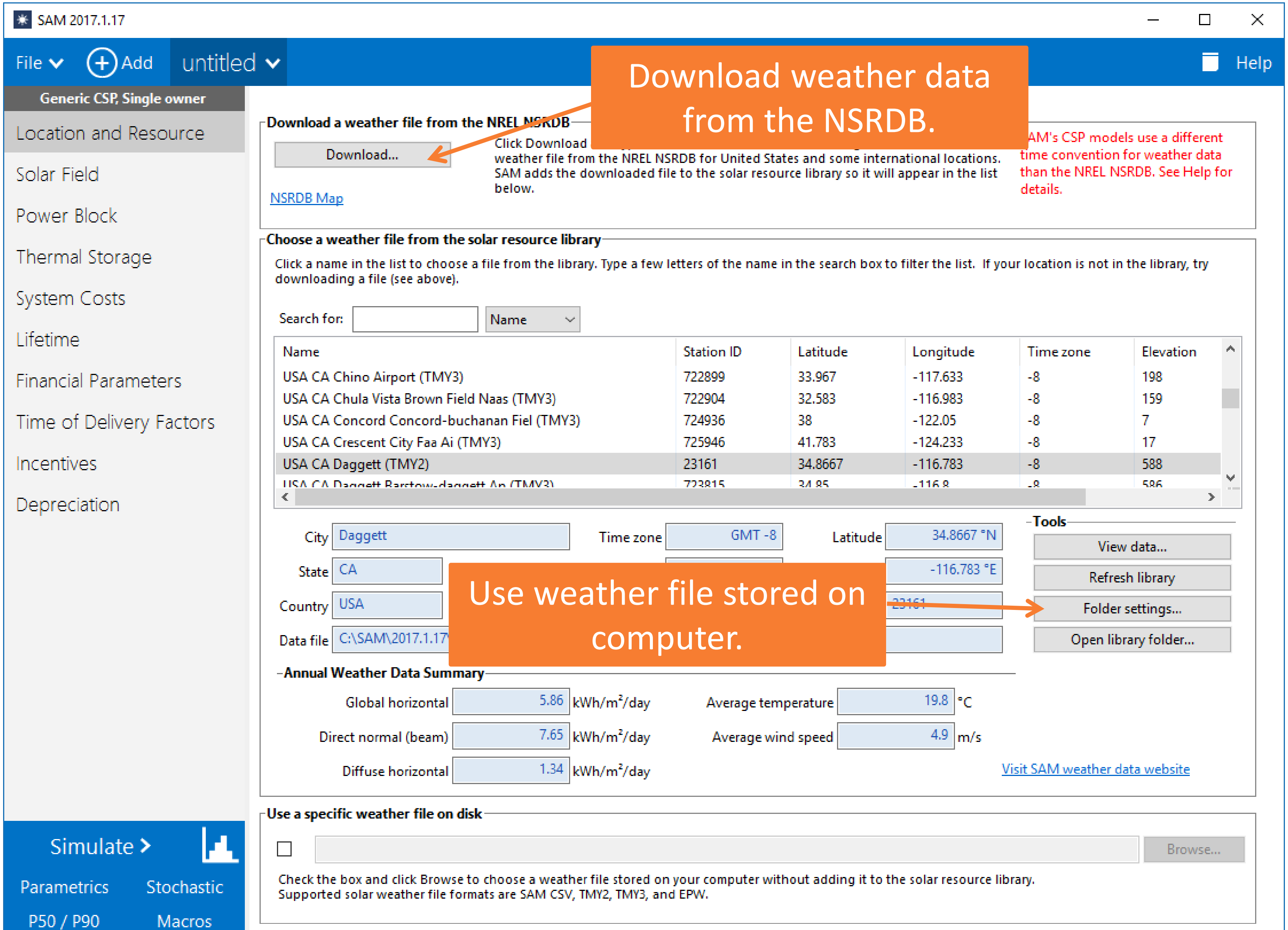
Choose “No financial model” if you are only interested in system performance.

Process heat models are at the bottom of the list.

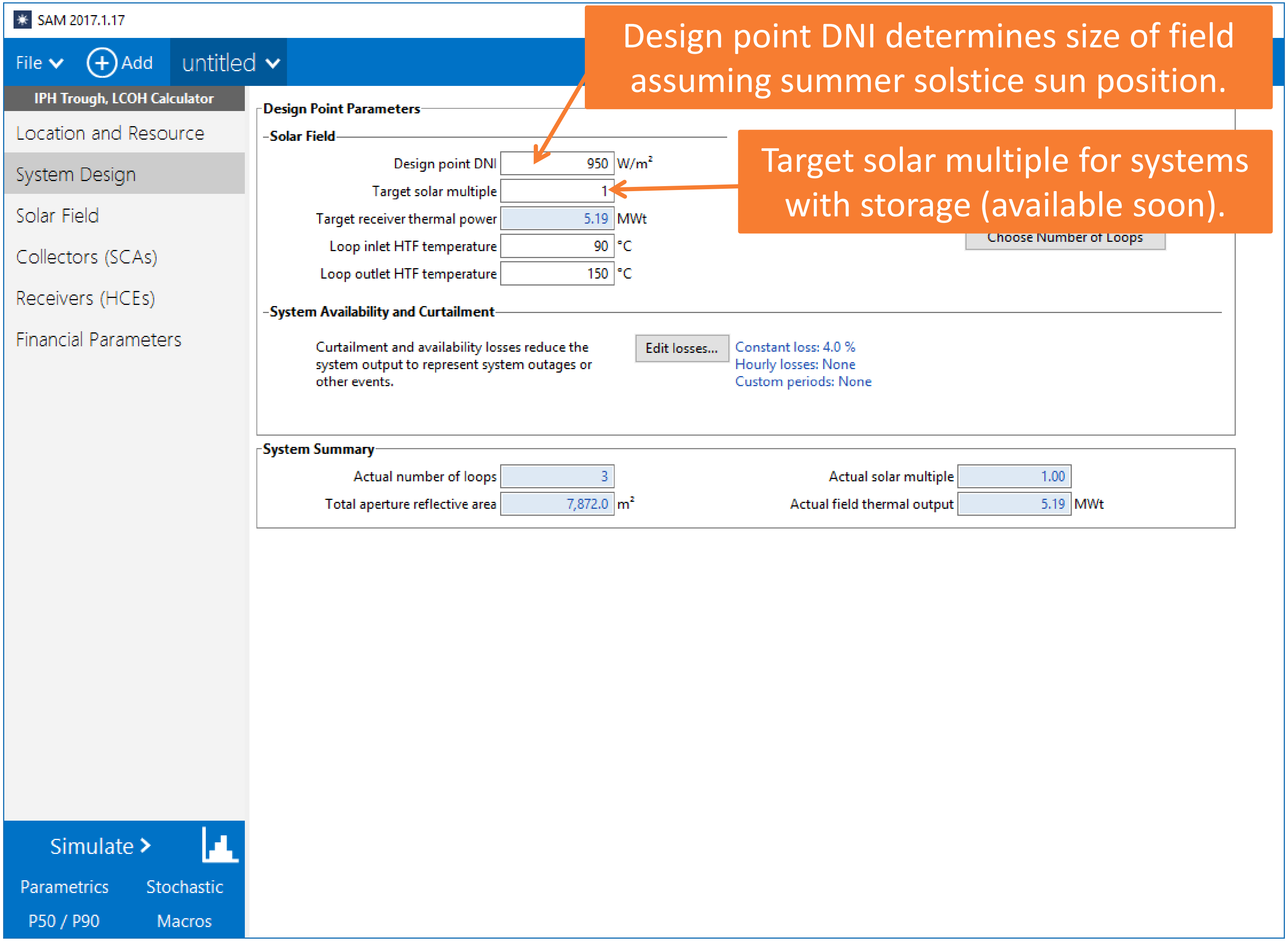
Input pages provide access to input parameters



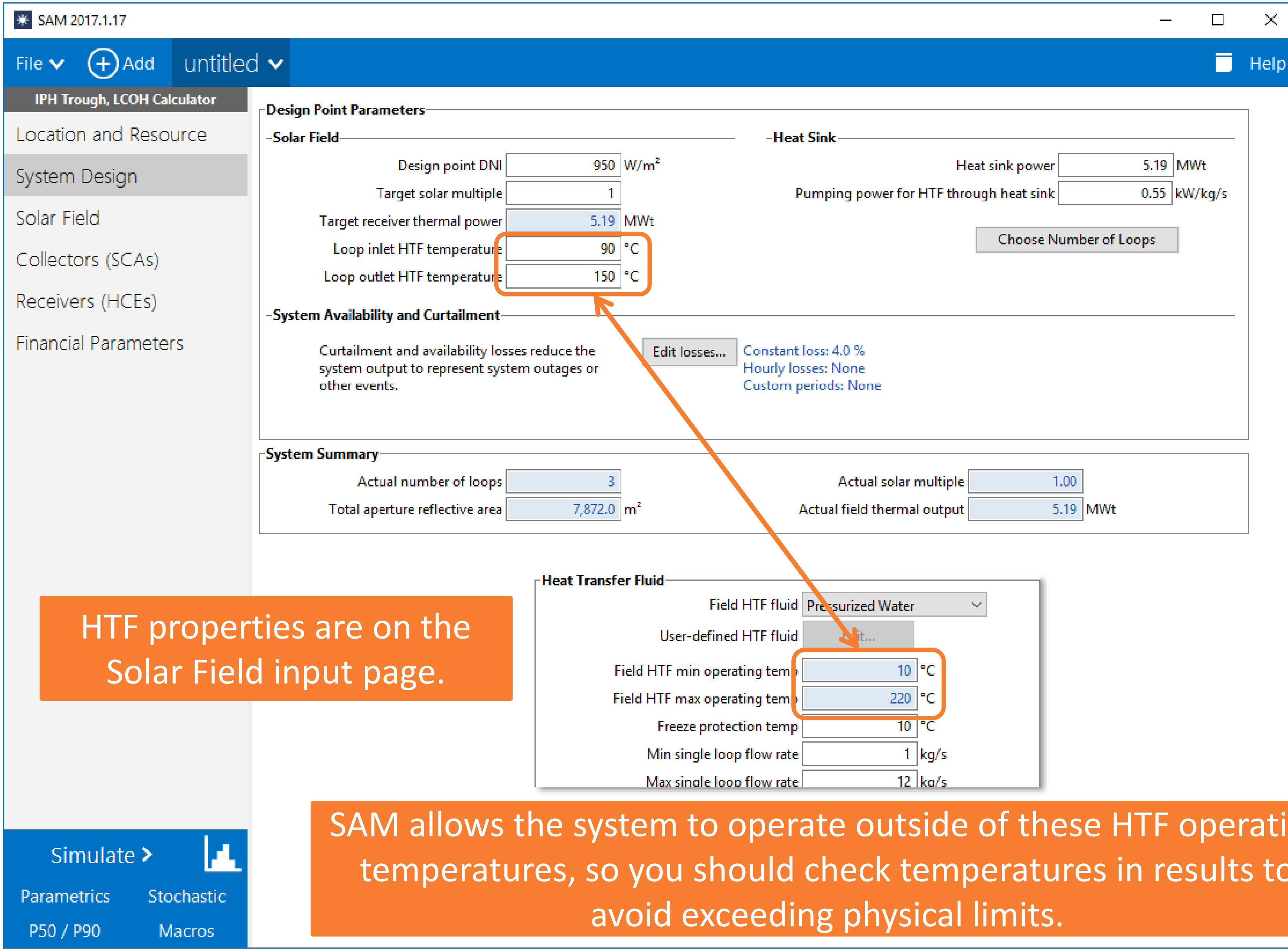
Weather file provides information about solar resource and ambient conditions



System Design page provides access to main design parameters



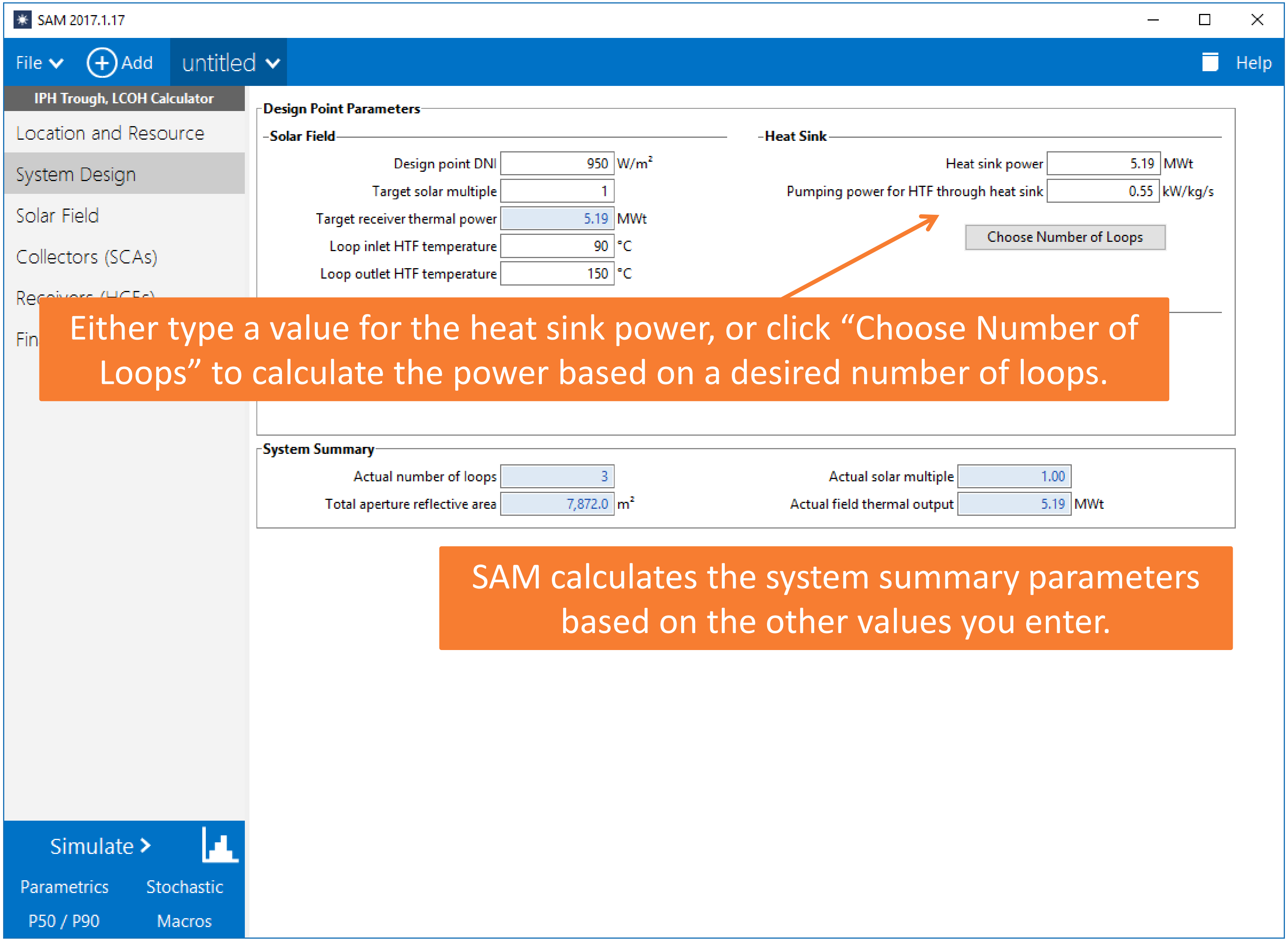
Loop inlet and outlet temperatures should be within HTF operating ranges



HTF properties are on the Solar Field input page.

SAM allows the system to operate outside of these HTF operating temperatures, so you should check temperatures in results to avoid exceeding physical limits.

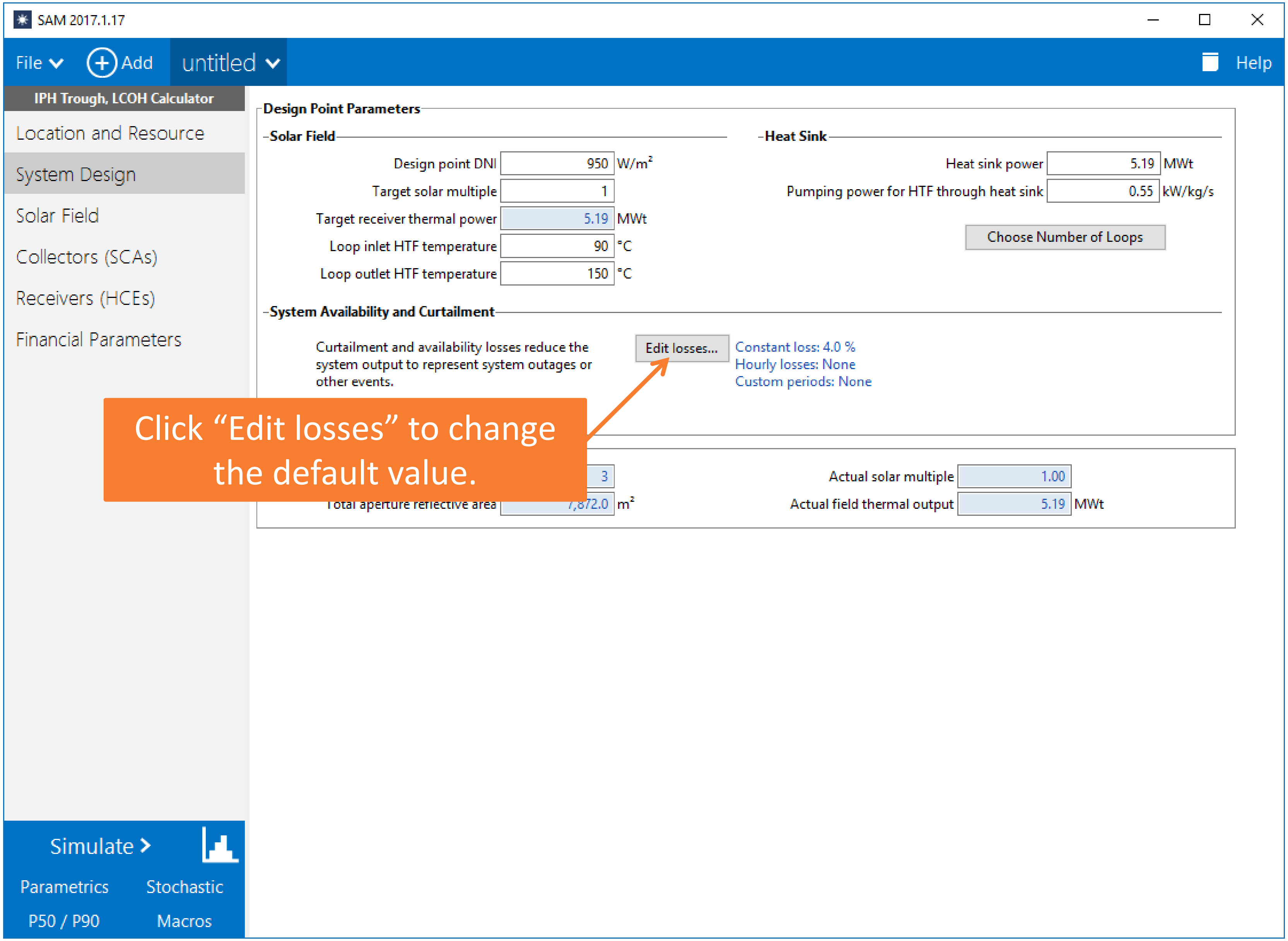
Heat sink power is the capacity or thermal load of the system in thermal megawatts



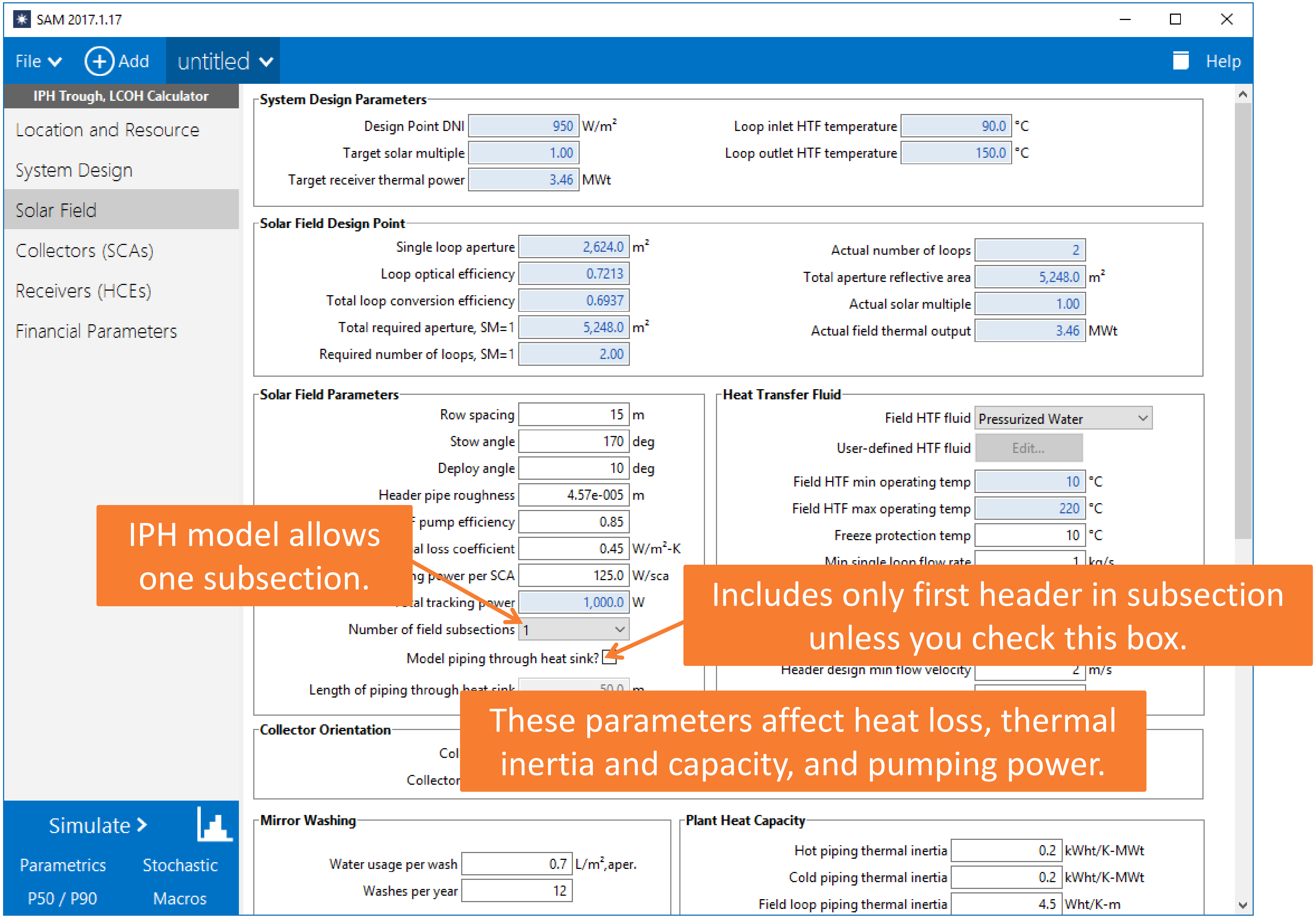
Either type a value for the heat sink power, or click "Choose Number of Loops" to calculate the power based on a desired number of loops.

SAM calculates the system summary parameters based on the other values you enter.

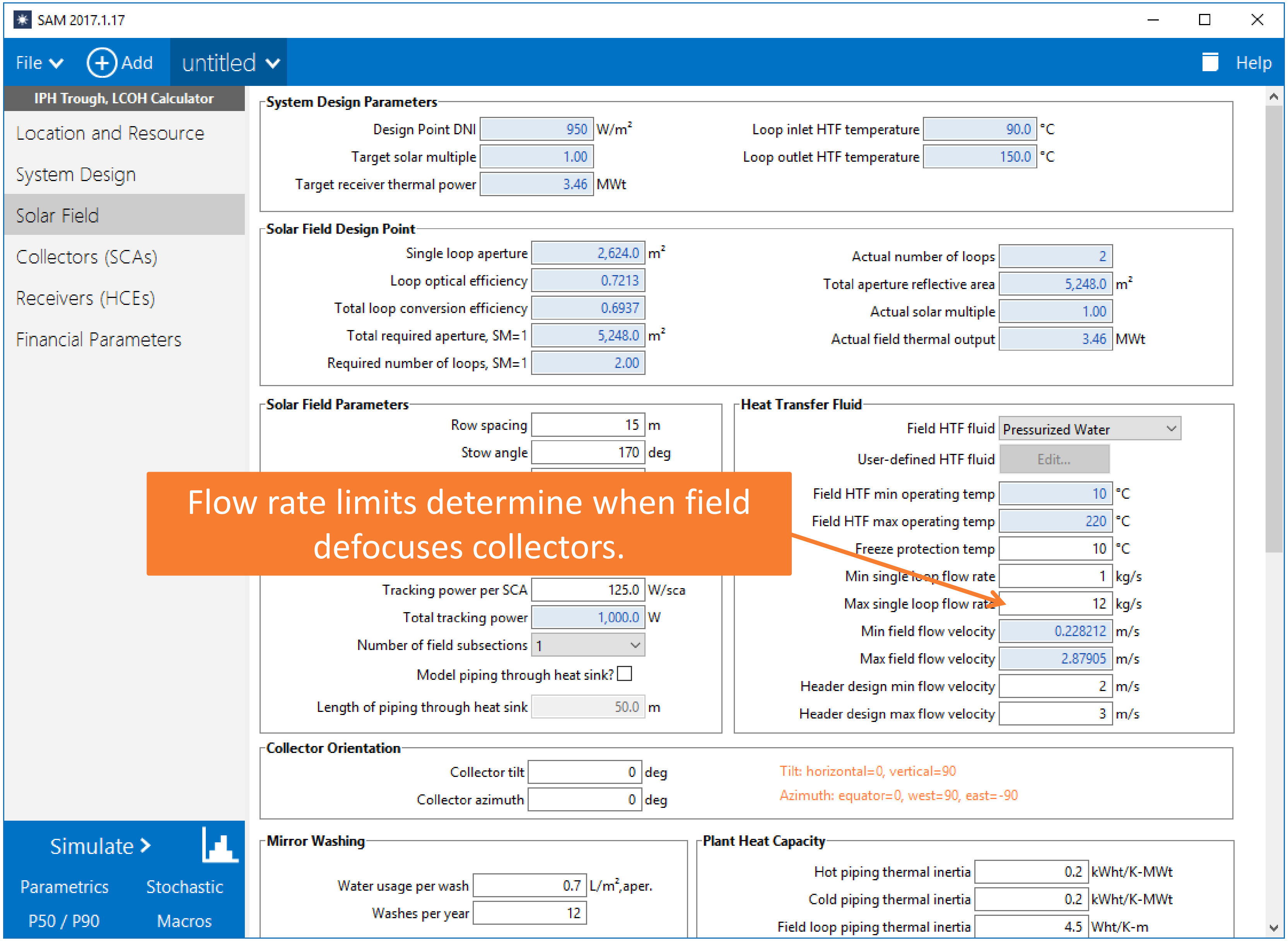
The "constant loss" of 4% is equivalent to a 96% annual availability factor and may not be appropriate for IPH



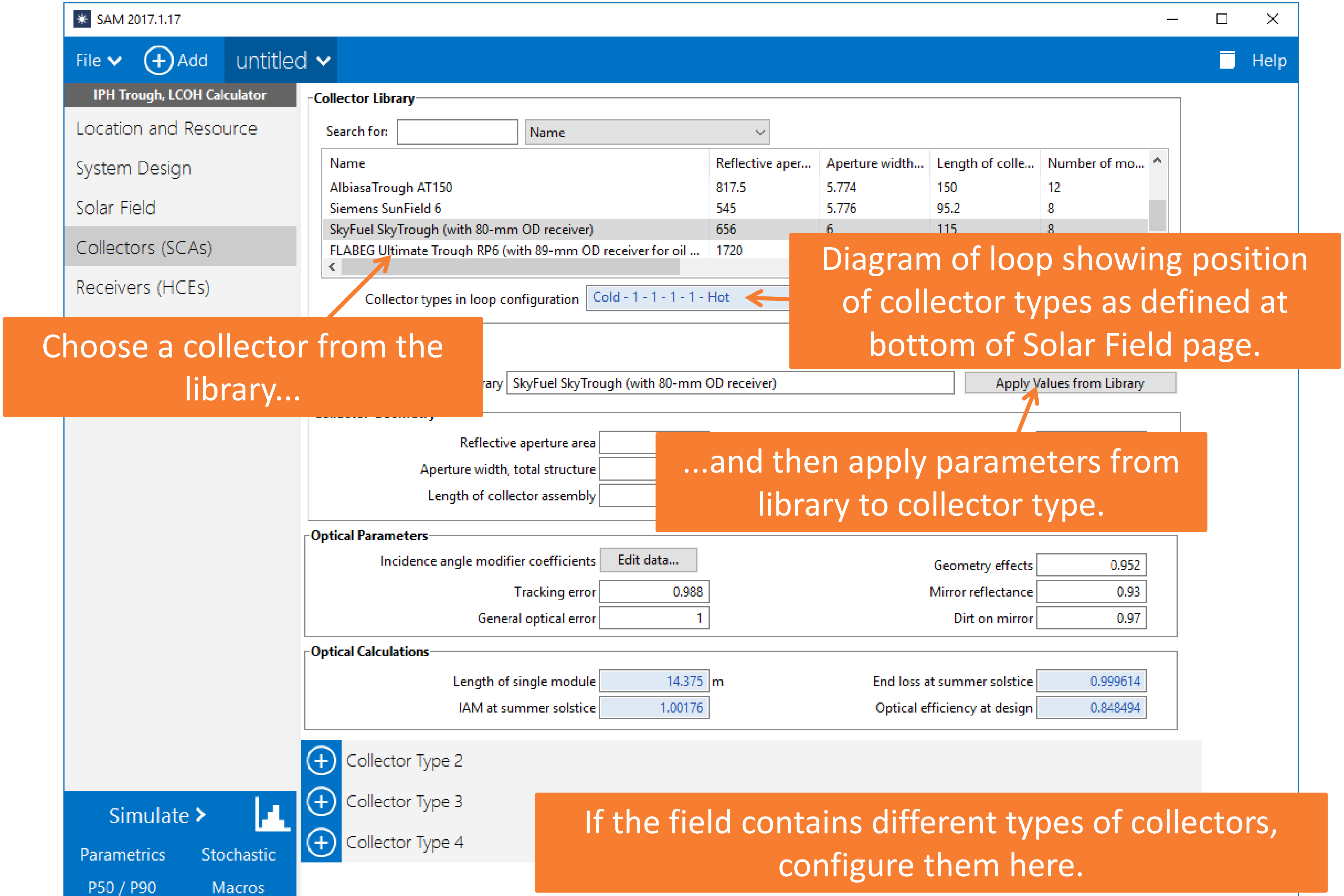
Solar Field inputs are the same as physical trough model, except for piping between solar field and heat sink



Unlike CSP model, IPH model only defocuses field when HTF flow rate exceeds maximum flow limit



Collectors are the same as the CSP physical trough model

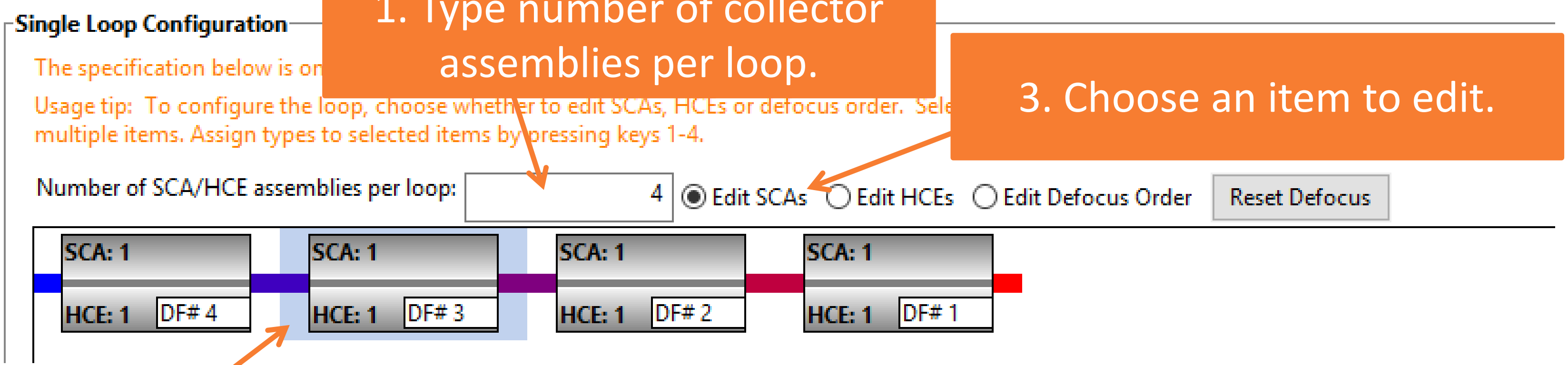


Use the loop configuration to set number of collectors per loop, assign collector and receiver types, and defocus order

Loop configuration is at bottom of Solar Field page. You may need to scroll down the window to see it.

1. Type number of collector assemblies per loop.

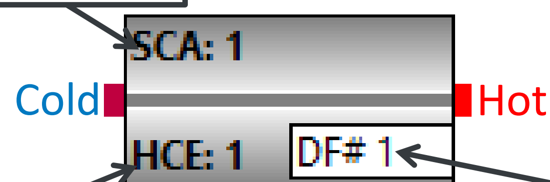
3. Choose an item to edit.



2. Click a collector to select it.

4. Type a number on your keyboard to change a number.

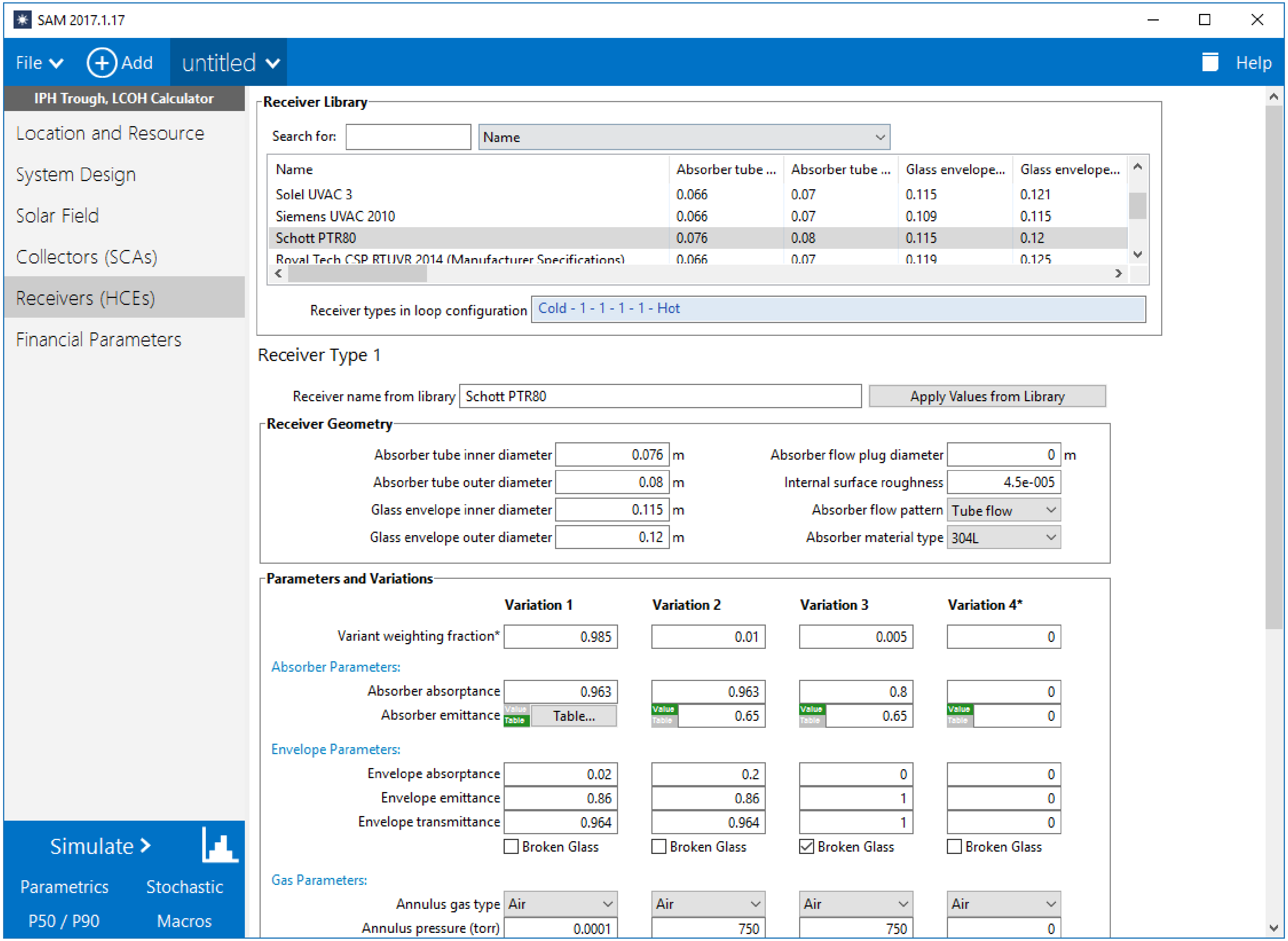
Collector type number



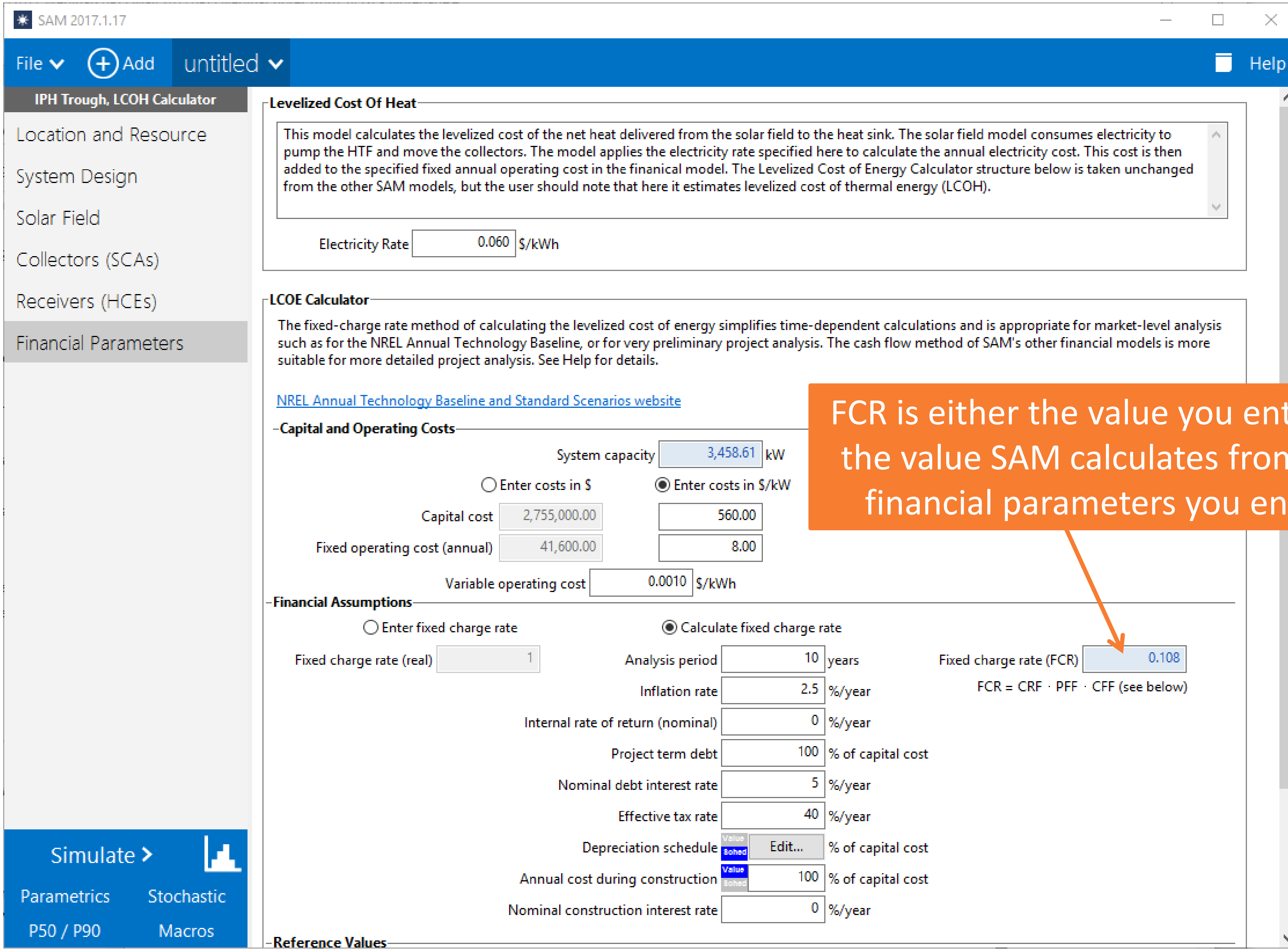
Receiver type number

Defocus order is not applicable for IPH model.

Receivers are the same as the CSP physical trough model



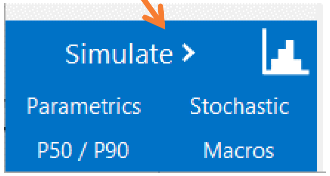
Either provide a fixed charge rate (FCR), or use the calculator and provide financial parameters



FCR is either the value you enter, or the value SAM calculates from the financial parameters you enter.

Run a simulation to generate results

Click Simulate



When you run a simulation, SAM performs a set of calculations for each hour of the year to calculate the thermal energy produced by the solar field.

If you included the LCOH calculator when you created the case, it also calculates the LCOH using the sum of the hourly energy values to represent the total annual thermal energy produced by the field.

The Metrics table displays a summary of results

- Annual energy and annual field energy are the same when freeze protection energy is zero
- Electricity load is for pumping and tracking power

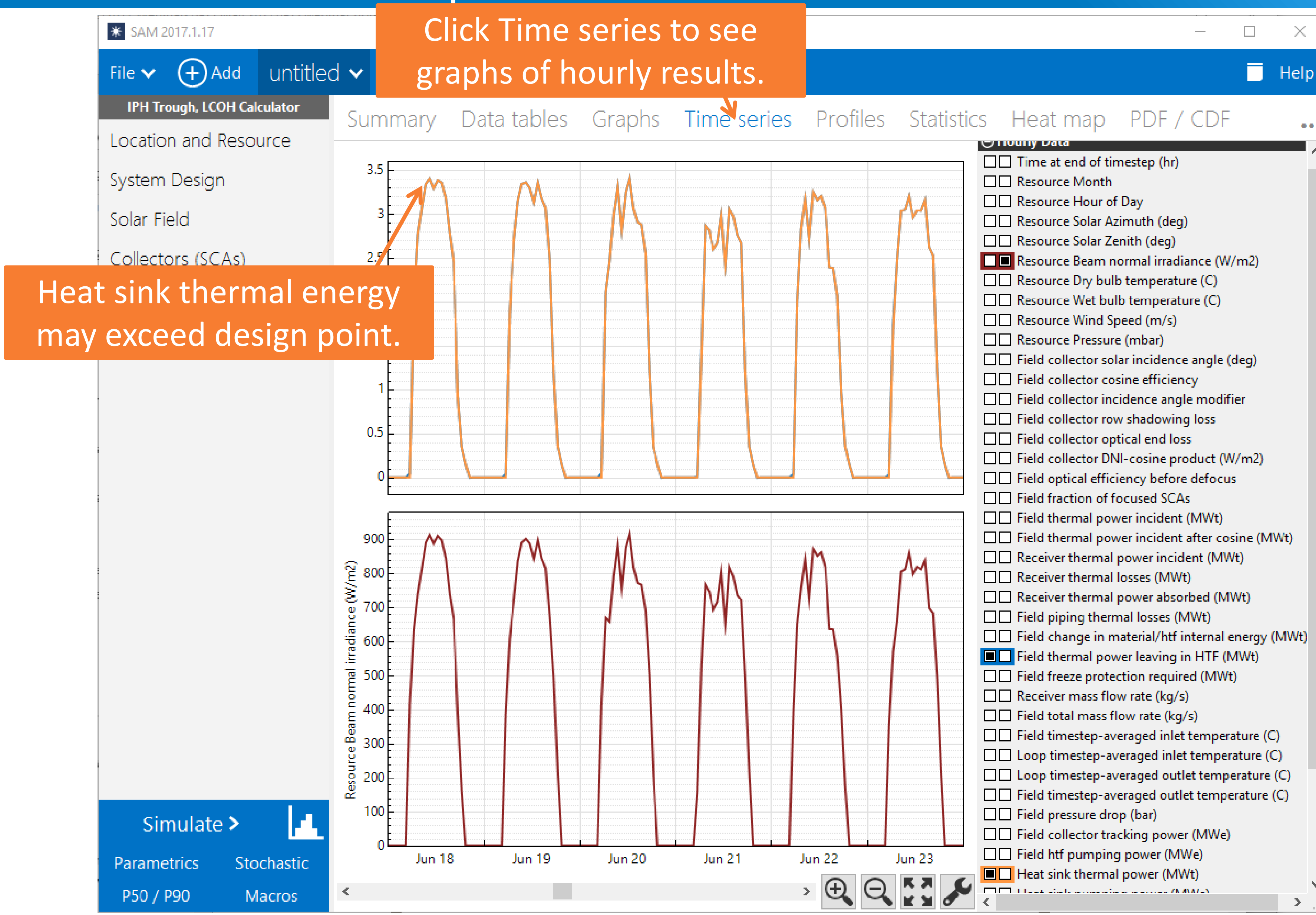
Metric	Value
Annual energy (year 1)	7,389,923 kWh-t
Annual field energy (year 1)	7,389,923 kWh-t
Annual thermal freeze protection (year 1)	0 kWh-t
Annual electricity load (year 1)	25,762 kWh-e
Levelized cost of heat	3.33 ¢/kWh-t

Increase freeze protection temperature on Solar Field page to add freeze protection energy.

Heat Transfer Fluid

Field HTF fluid	Pressurized Water
User-defined HTF fluid	Edit...
Field HTF min operating temp	10 °C
Field HTF max operating temp	220 °C
Freeze protection temp	10 °C
Min single loop flow rate	1 kg/s
Max single loop flow rate	12 kg/s
Min field flow velocity	0.228212 m/s
Max field flow velocity	2.87905 m/s
Header design min flow velocity	2 m/s
Header design max flow velocity	3 m/s

With no freeze protection, field thermal power is the same as heat sink thermal power

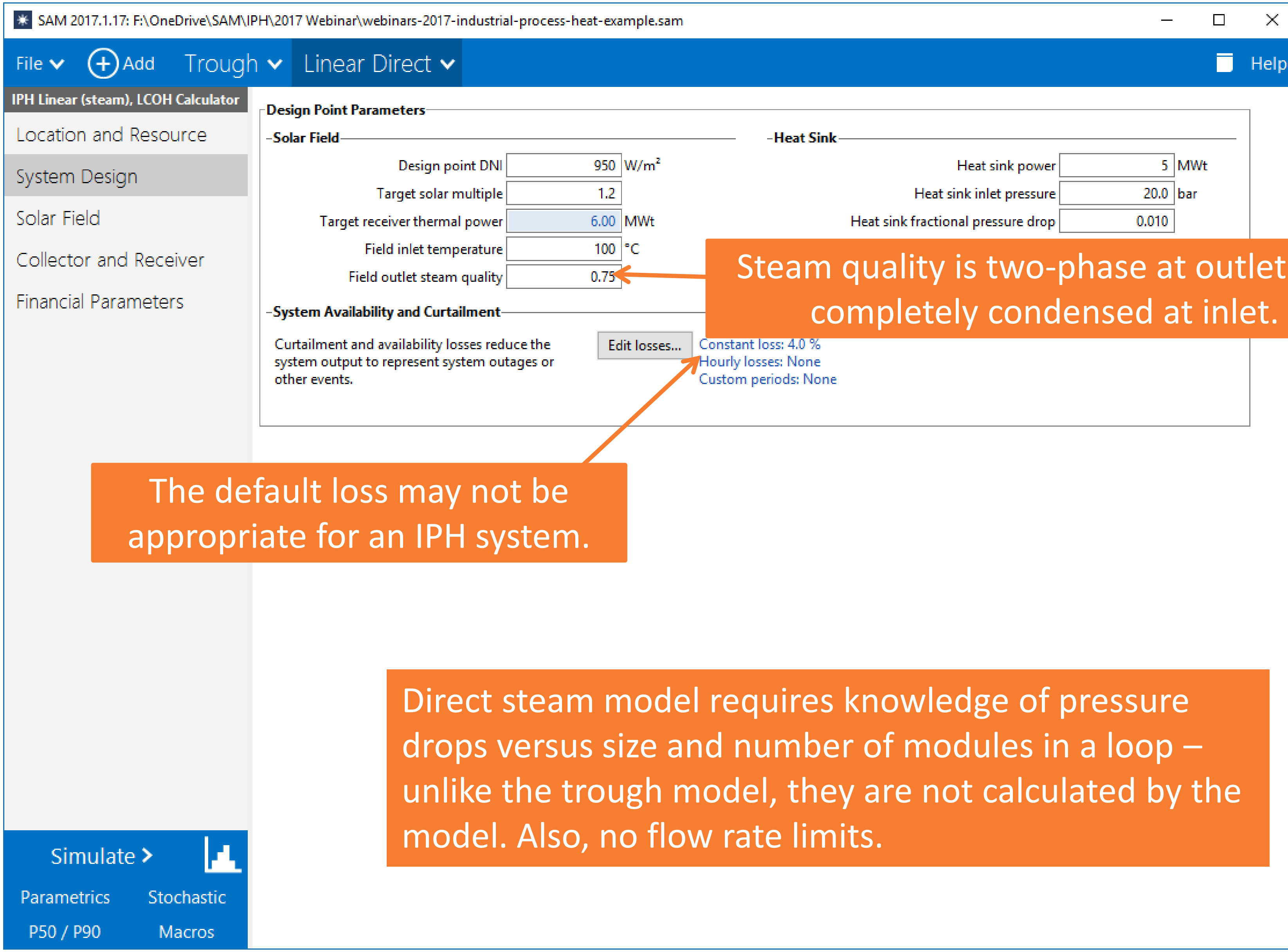


IPH Trough Example: Freeze protection energy with VP-1 oil as HTF instead of pressurized water

1. Change HTF on Solar Field page
   - HTF operating temperatures change with the HTF
   - For a real analysis, you would need to change the costs to account for the different HTF
2. On the System Design page, change design loop inlet and outlet temperature to be consistent with oil HTF
3. On the Solar Field page, change the freeze protection temperature to 220 °C
4. Run a simulation, and note the differences in results
   - Field and heat sink energy are different
   - Heat loss and pumping power changes with HTF

IPH Linear Direct Steam

For IPH direct steam, you do not configure the loop

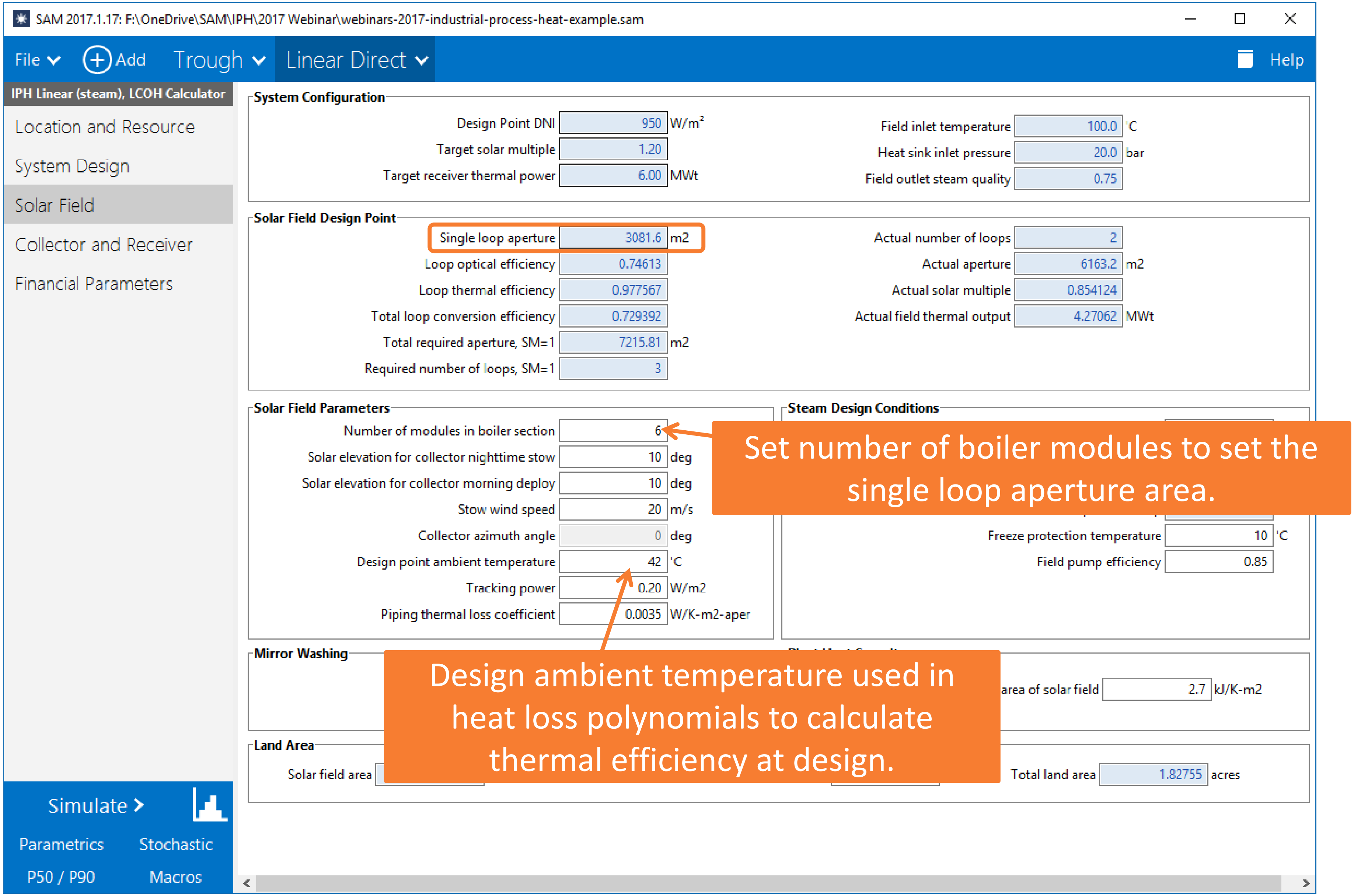


Steam quality is two-phase at outlet and completely condensed at inlet.

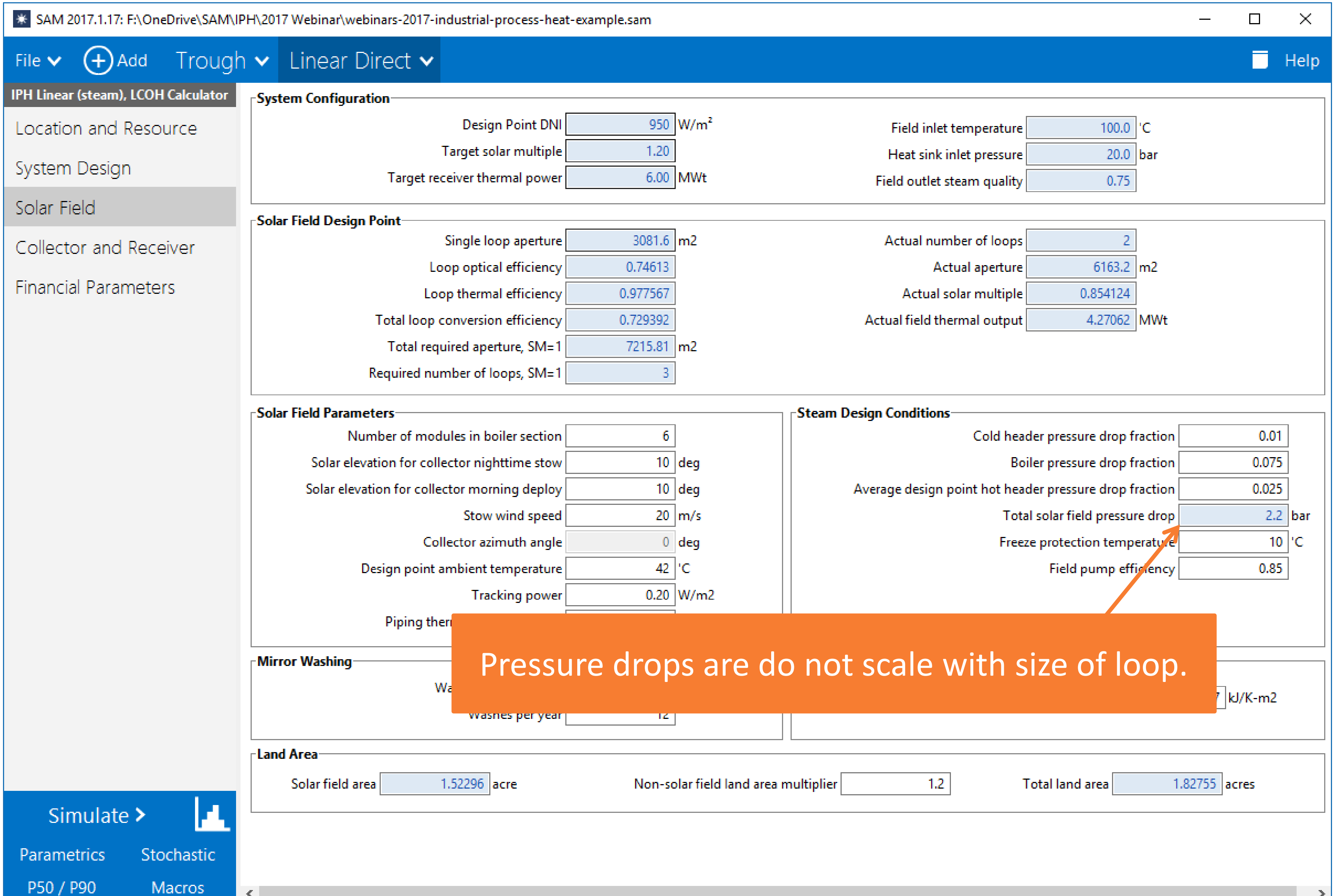
The default loss may not be appropriate for an IPH system.

Direct steam model requires knowledge of pressure drops versus size and number of modules in a loop – unlike the trough model, they are not calculated by the model. Also, no flow rate limits.

Solar field consists of a single boiler section with no superheater

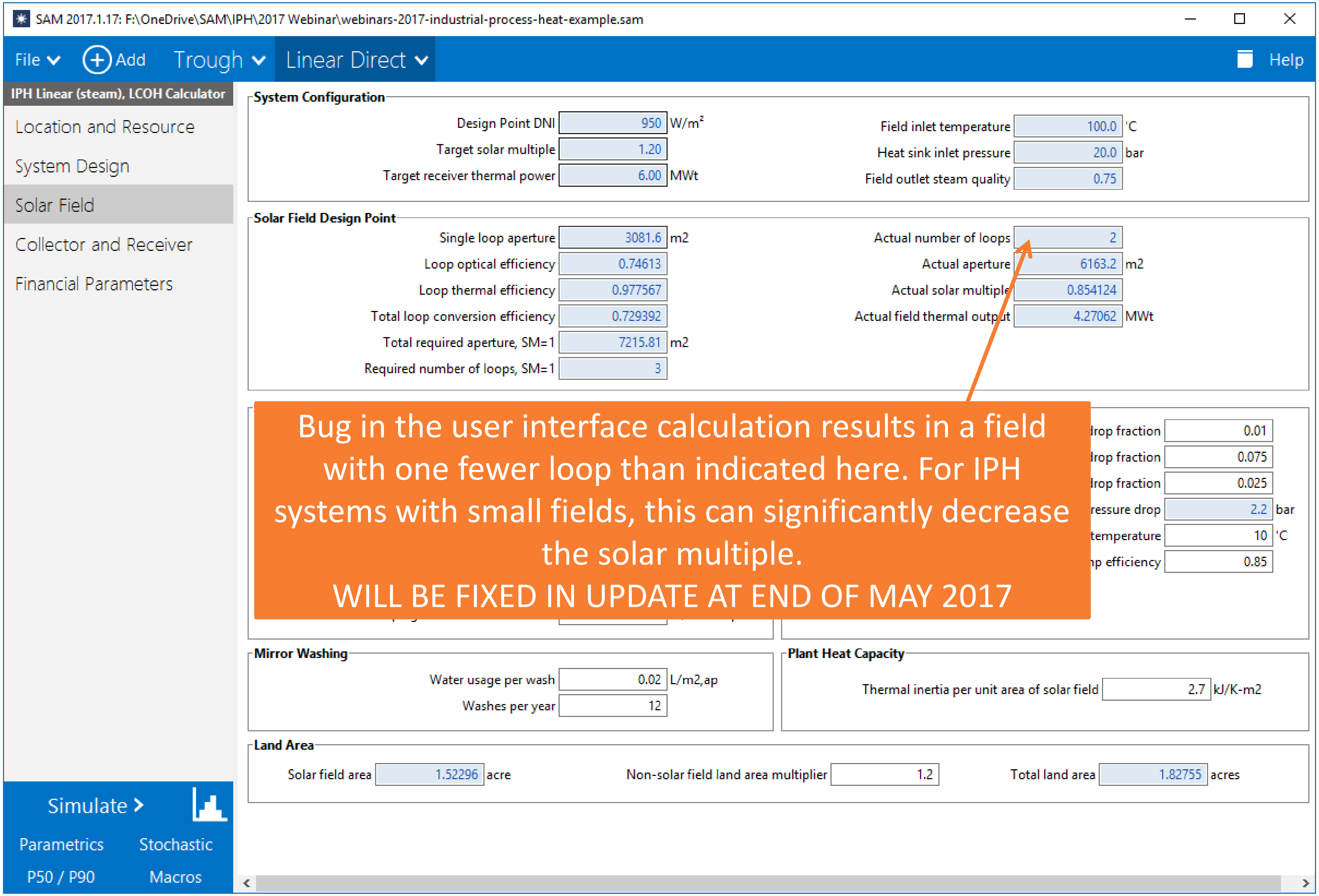


Pressure drops not modeled physically



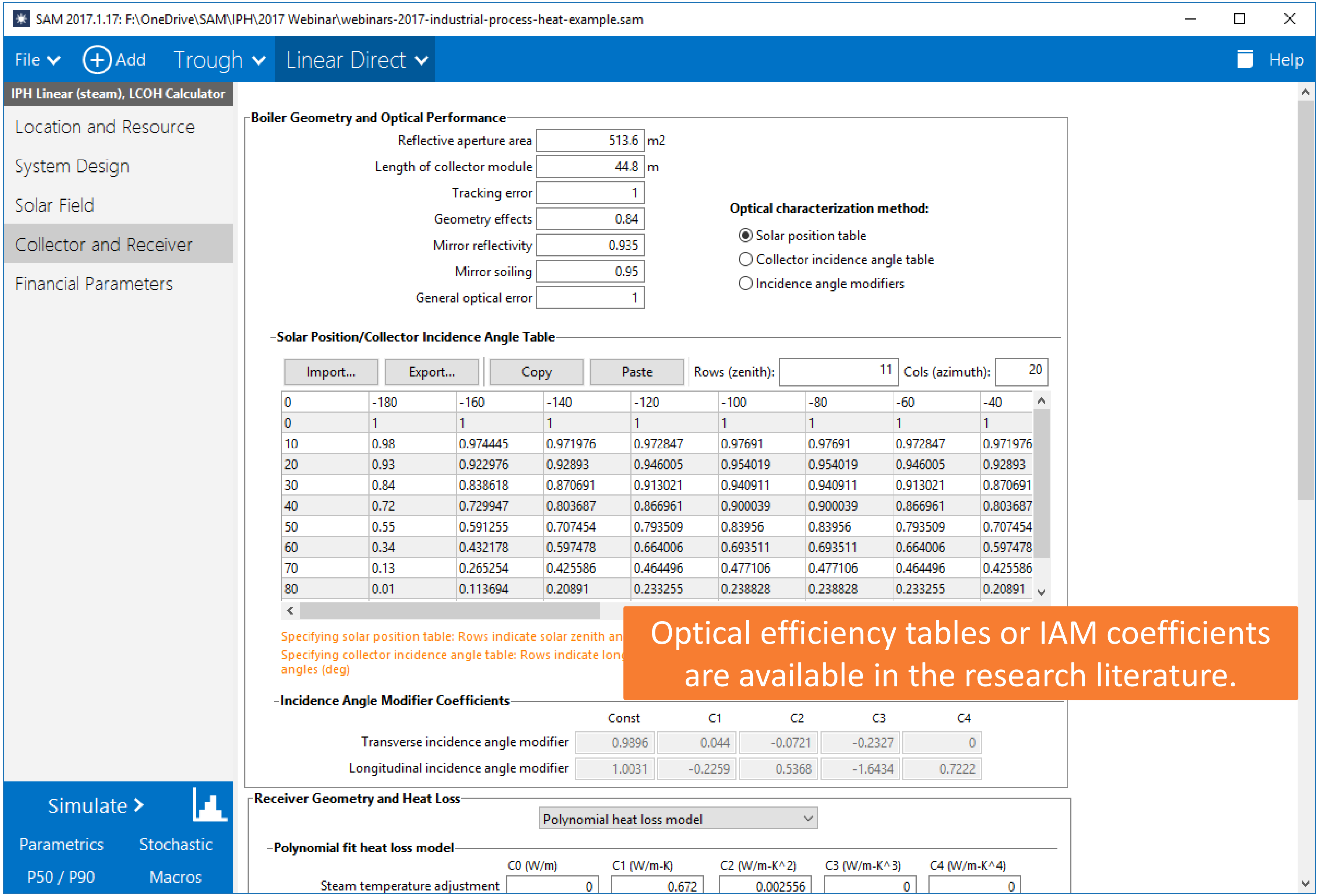
Pressure drops are do not scale with size of loop.

BUG: Actual number of loops is not calculated correctly



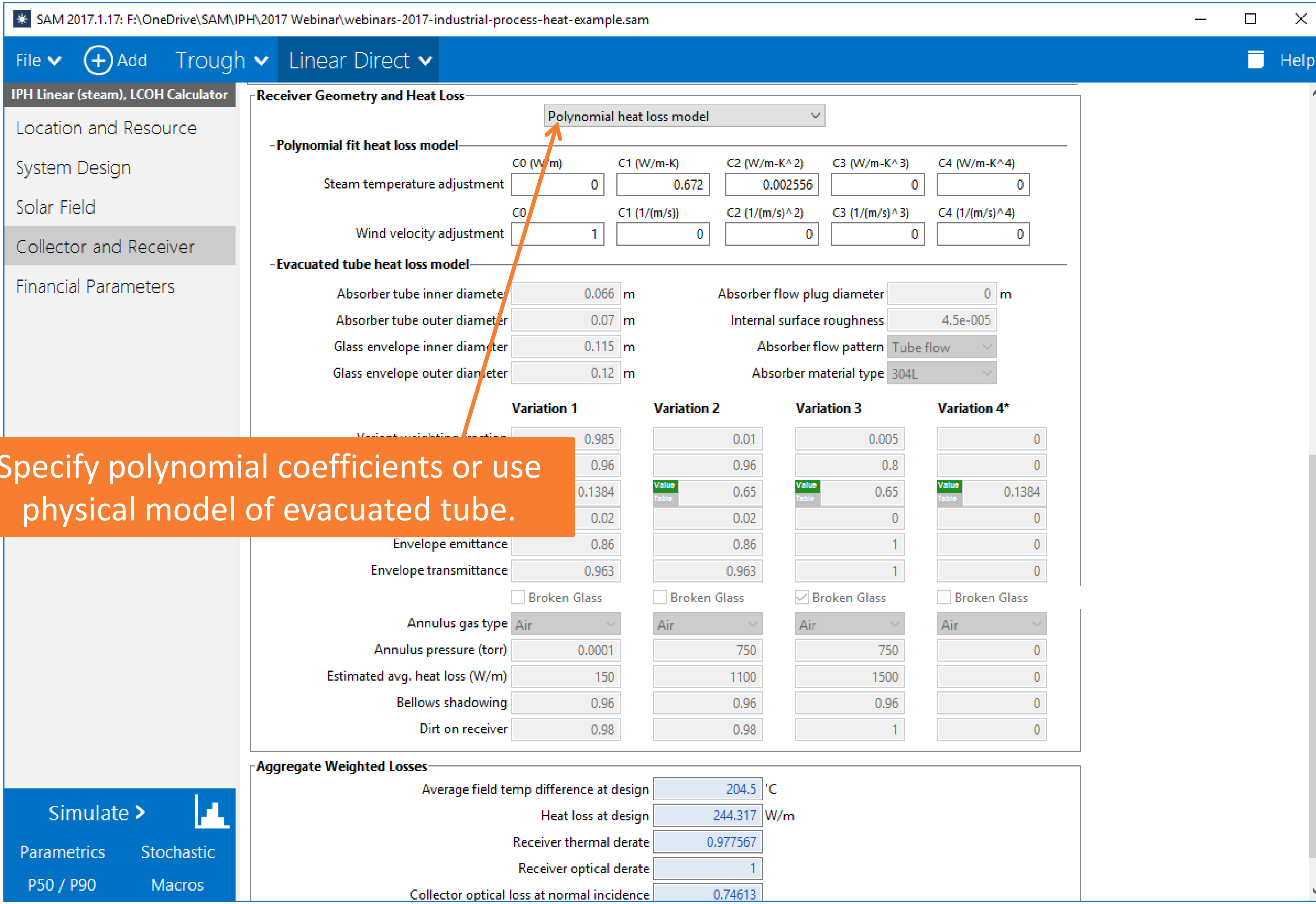
Bug in the user interface calculation results in a field with one fewer loop than indicated here. For IPH systems with small fields, this can significantly decrease the solar multiple.
WILL BE FIXED IN UPDATE AT END OF MAY 2017

Boiler section is a generic optical model, and requires that you characterize the field optical efficiency outside of SAM



Optical efficiency tables or IAM coefficients are available in the research literature.

Receiver parameters



Specify polynomial coefficients or use physical model of evacuated tube.

Q&A Session

- If you have questions after the webinar or are watching a video recording, please contact us with questions:
  - https://sam.nrel.gov/support
  - sam.support@nrel.gov

Thank you!

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