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greenius User Day

30. September 2015

Simulation of a parabolic trough plant power with molten salt as HTF

DLR

Overview

- In the framework of another project a comparison of annual performance calculations with greenius and Ebsilon®Professional was done
- This comparison was made because of difficulties to include thermal inertia of the solar field in the EBSILON®Professional model
- In order to investigate the impact of thermal inertia on annual yield of a parabolic trough plant a model of the plant was set up in both tools, the results without thermal inertia where compared and then the impact of thermal inertia was calculated with greenius
- greenius does already consider thermal inertia of the solar field and from previous studies it is known that neglecting this effect may lead to an overestimation of annual electricity output in the range of 7-12% (for a typical 50 MWe trough plant using thermal oil as HTF and with 7 h thermal storage)

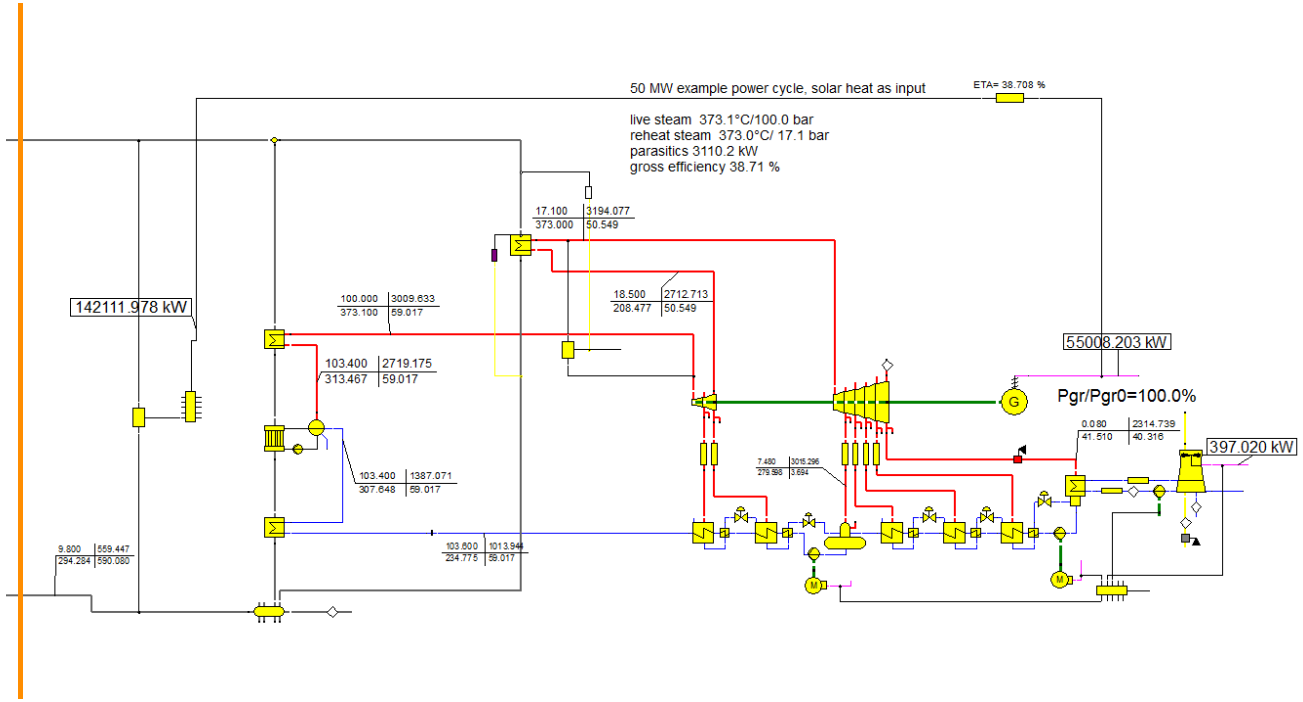
EBSILON®Professional (1)

- EBSILON®Professional[1)] is a commercial software for steady state thermodynamic cycle calculations of power plants developed and offered by STEAG Energy Services GmbH
- DLR's Institute of Solar Research was involved in the development of the EbsSolar library, a library with unit models for CSP components
- With this library EBSILON®Professional allows to simulate also time series (e.g. for annual performance calculations of CSP plants with hourly time steps)
- EBSILON®Professional offers also a scripting language which may be used to implement an operating strategy for the CSP plant under consideration

1) More information: http://www.steag-systemtechnologies.com/ebsilon_professional+M52087573ab0.html

EBSILON®Professional (2)

- We are using this software to generate lookup tables for power block performance which can be used in greenius
- For this purpose we cut off the solar field and just use the power block and the solar steam generator (HTF heat exchangers)

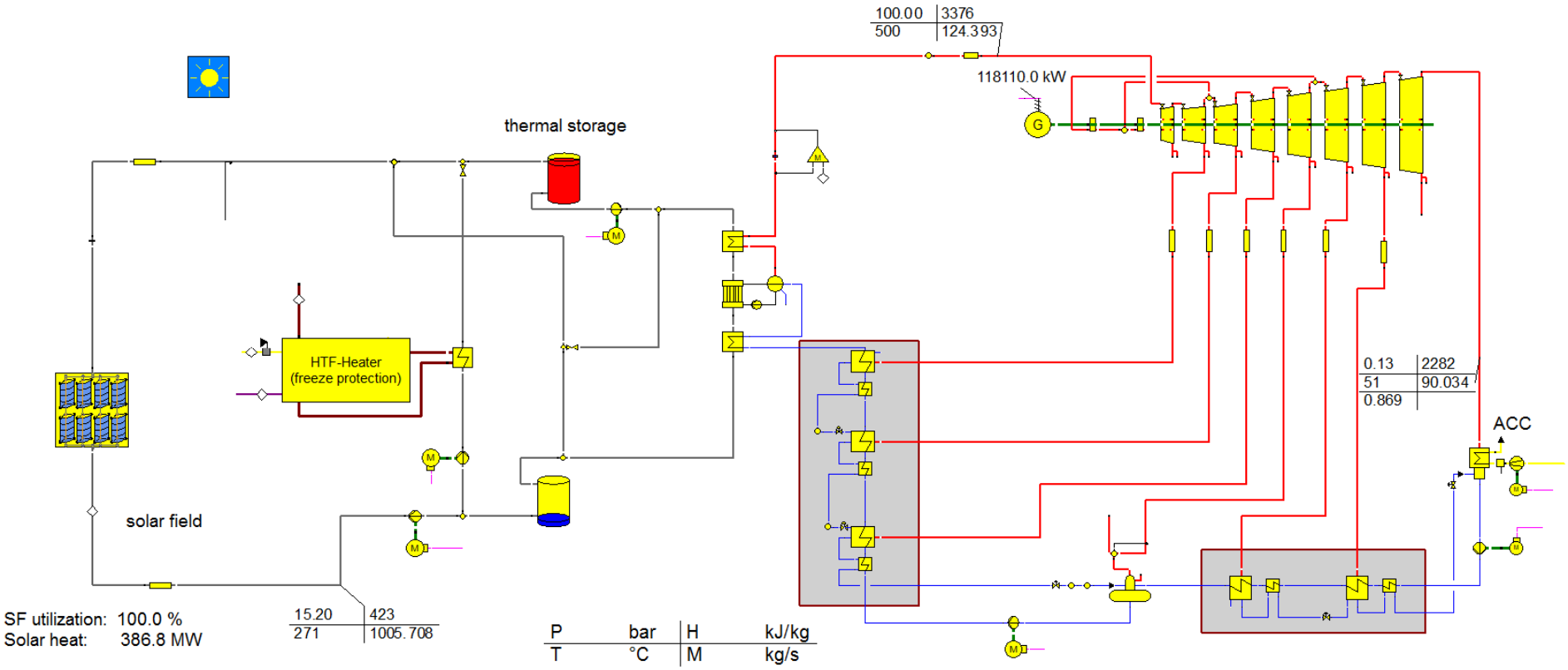


Comparison of greenius and EBSILON®Professional

	greenius	EBSILON®Professional
Model approach	Simplified	Full thermodynamics
Power block model	Lookup table, considering load, HTF inlet temperature, ambient temperature	Detailed with steam extractions, turbine stages, condenser
Interface variables between solar field and power block	Heat flow, HTF temperatures	Mass flow, enthalpy and pressure of HTF
Time for the simulation of 1 year (60 min timesteps)	4 seconds	1 hour

Are the results obtained with both tools comparable?

CSP plant used for comparison

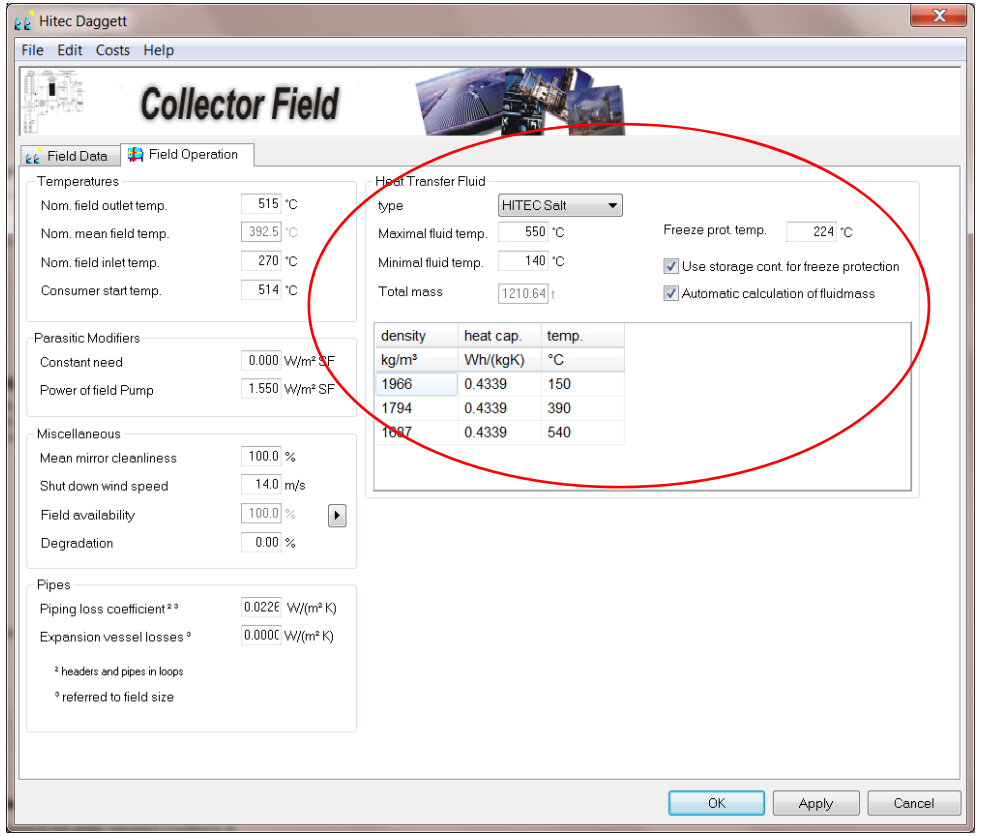


Details of the CSP plant used for comparison

Parameter	Value	Unit
Solar field size	608040	m^2
Trough type	ULTIMATE TROUGH®	
Receiver type	Schott PTR®70	
Heat transfer and storage fluid	HITEC® heat transfer salt	
Nominal solar field outlet temperature	515	°C
Nominal storage capacity	849	MWh
Minimal storage content	210	MWh
Nominal power block output (gross)	118.1	MW
Cooling type	Air cooled condenser	
Freeze protection	From thermal storage backed up with gas	

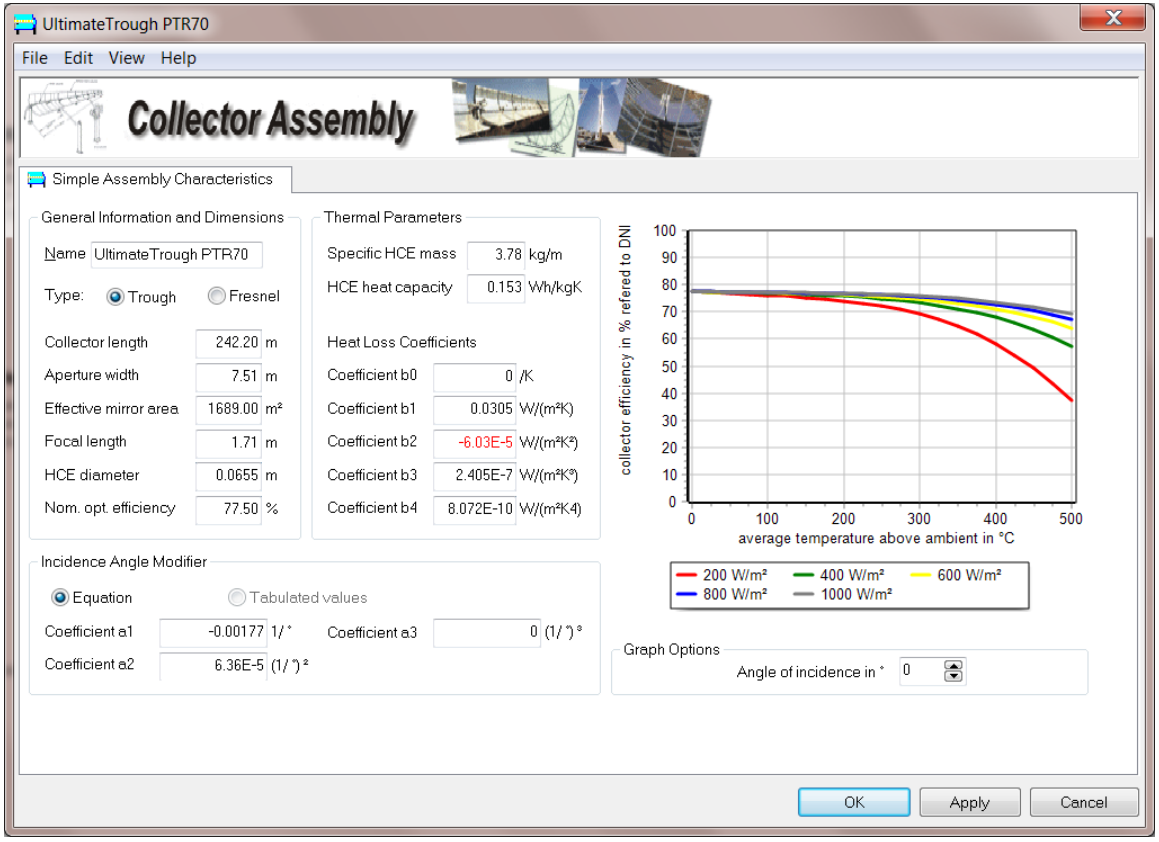
Steps to simulate the molten salt CSP plant in greenius

- HITEC heat transfer salt added to the possible heat transfer fluids
- HITEC Heat transfer salt is offered by Coastal Chemical Co., L.L.C., Houston, TX
- It is a mixture of $NaNO_3$–KNO_3–$NaNO_2$ in the proportions 7–53–40 wt.%
- Max. operating temperature range: 142°C – 538°C (with nitrogen blanketing)



Steps to simulate the molten salt CSP plant in greenius

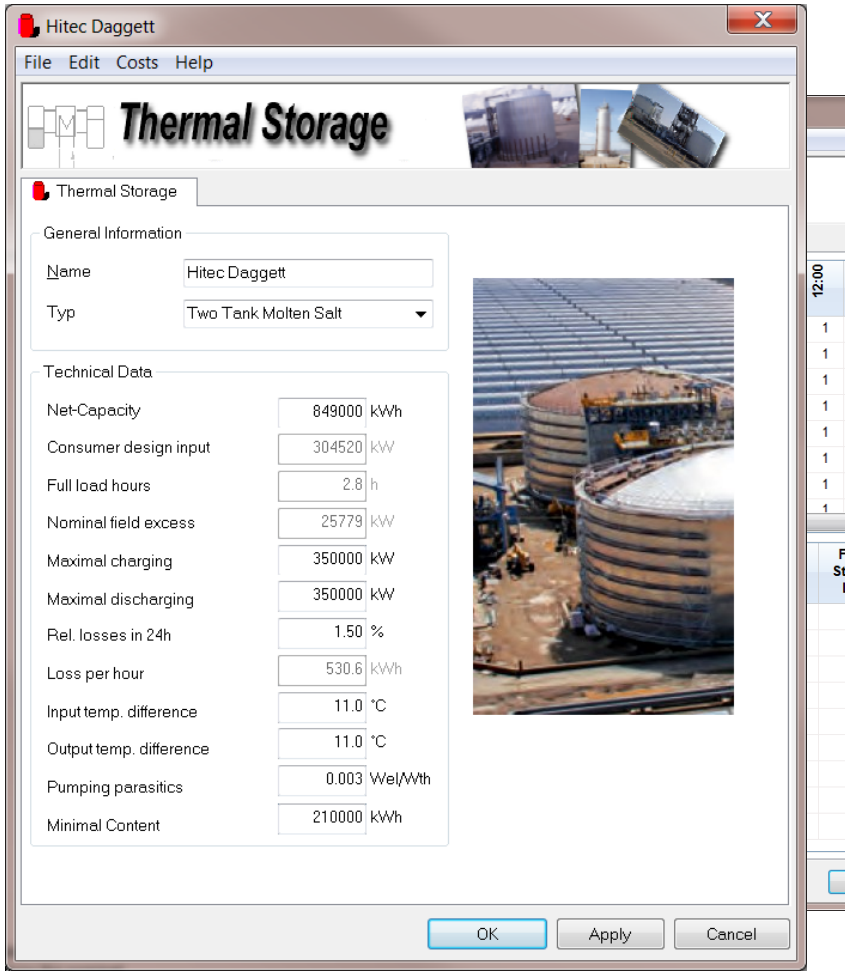
- Add the relevant collector dataset (ULTIMATE TROUGH® with Schott PTR®70)



Steps to simulate the molten salt CSP plant in greenius

Define and include the relevant operating strategy:

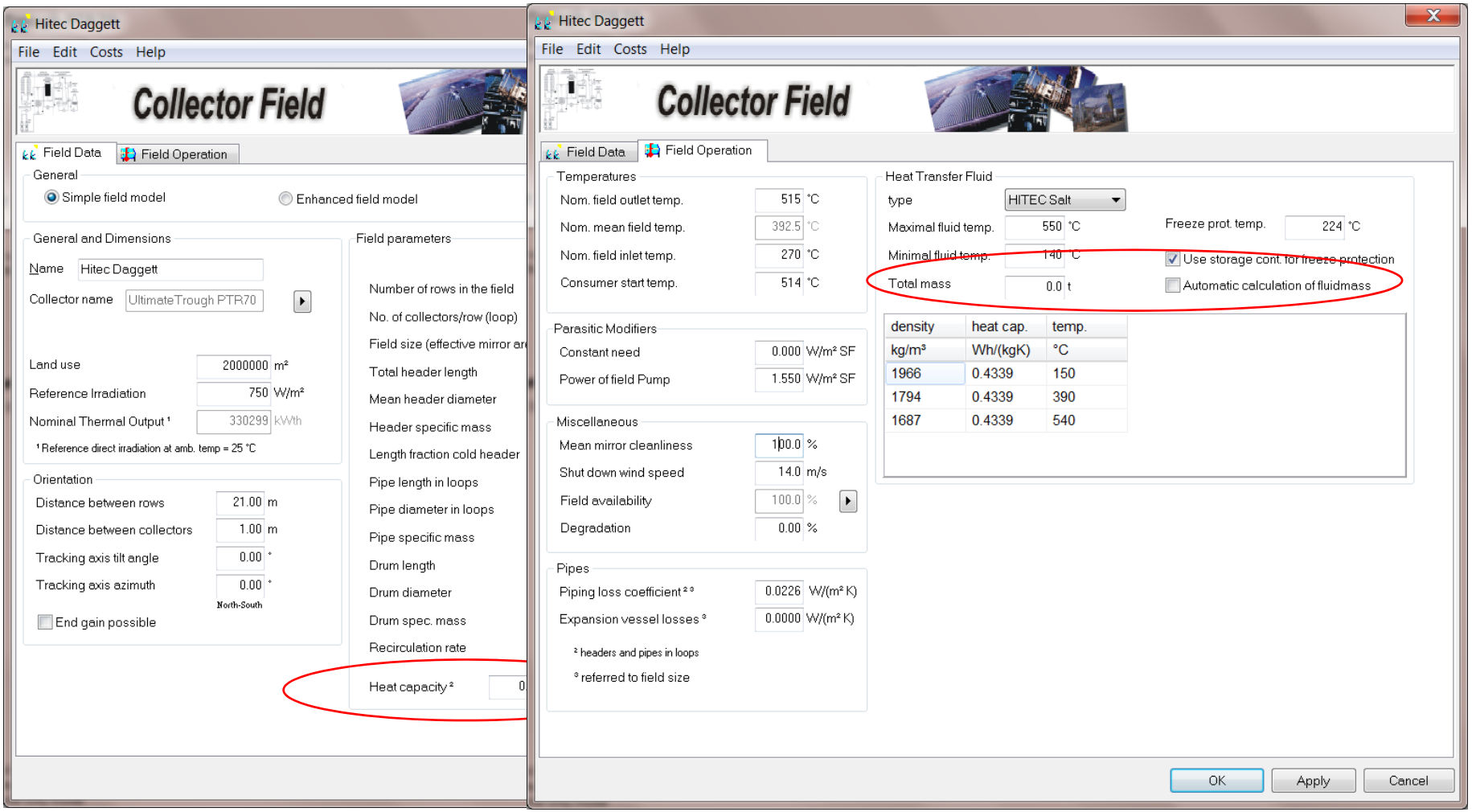
- Charge the TES to a certain level before starting the power block
- Once the power block is running, try to operate it at maximum load
- Keep a certain amount of the storage capacity for freeze protection
- Use the gas fired auxiliary burner only for freeze protection and only when the storage is totally empty



Additional code modifications

- Since greenius does consider the thermal inertia of the solar field this was switched off for the calculations in order to compare the greenius results with those from the EBSILON model
- “Normal users” don’t have access to the code, therefore this modification would not be possible for them
- They may get very close to this approximation by setting the Total mass of HTF and the heat capacity of the solar field piping to zero (on the on the „Collector Field“ form)

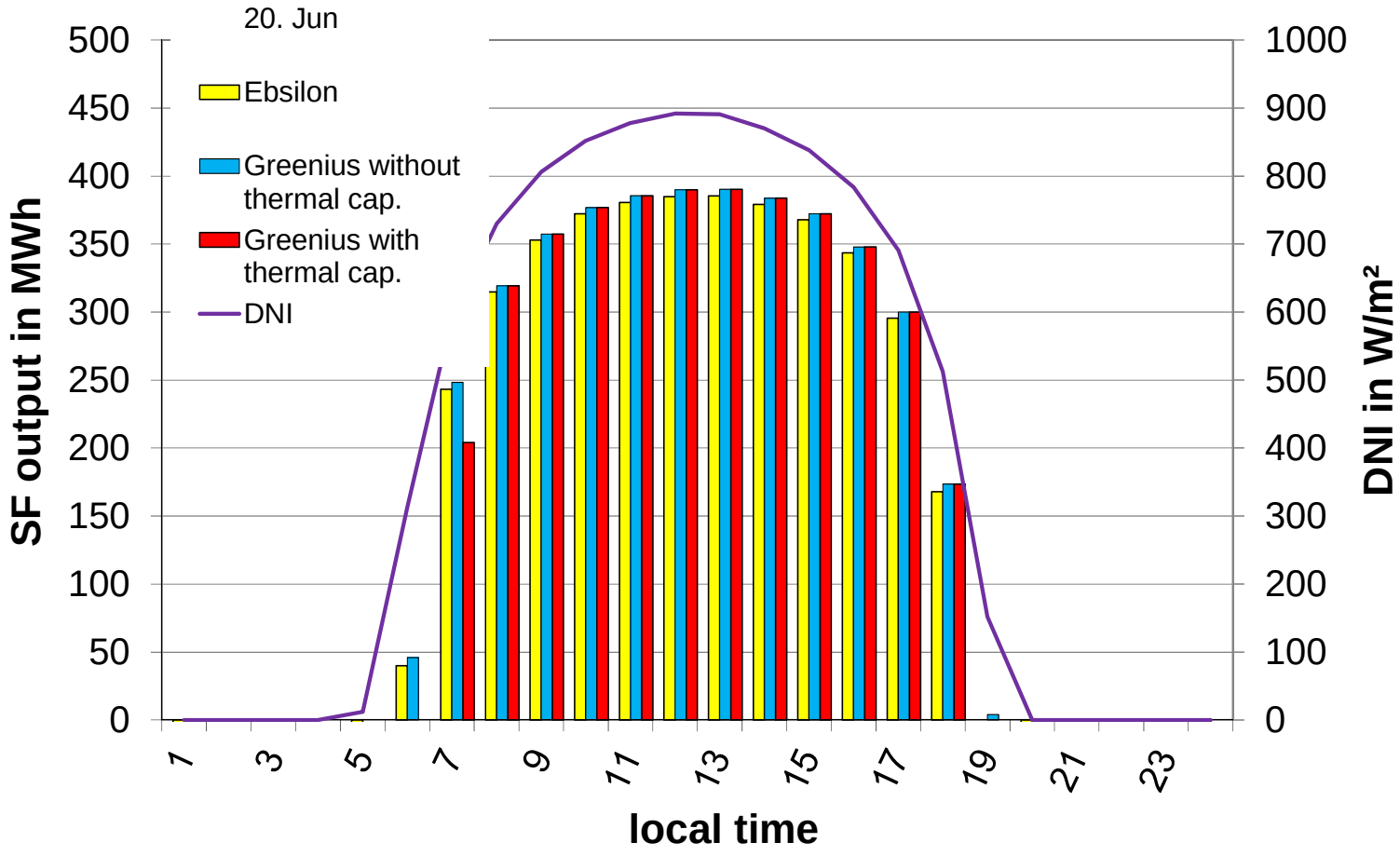
Switching off of thermal inertia



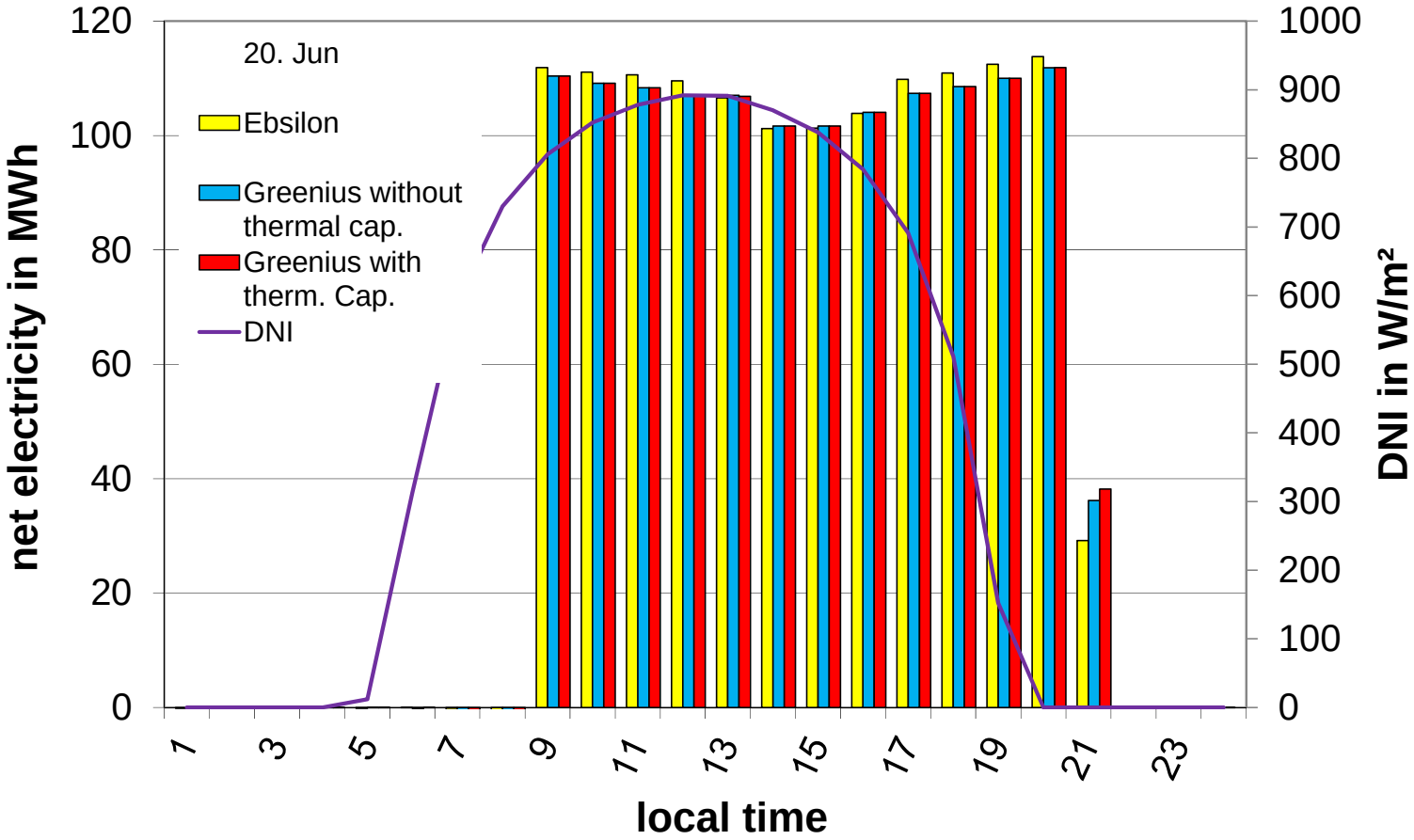
Comparison of annual output

Model	SF yield	Net electricity output	Gas used for freeze protection	Unit
EBSILON	923	305.7	0.4	GWh
greenius without thermal inertia	939.1	311.1	0.5	GWh
greenius with thermal inertia	905.1	306.6	0.1	GWh
Rel. difference greenius without inertia - Ebsilon	1.7	1.8		%
Rel. difference greenius wo - greenius with inertia	3.8	1.6		%

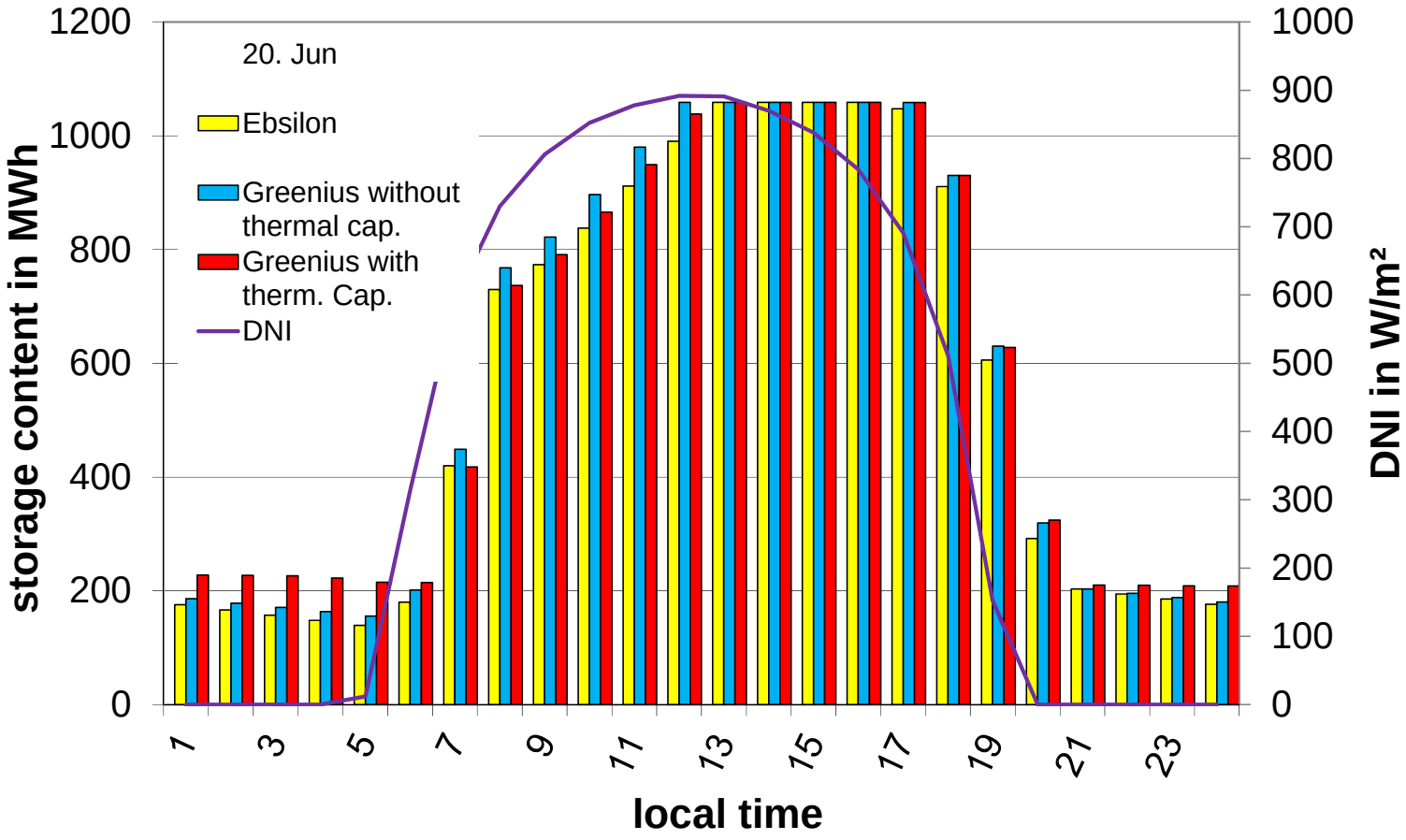
Comparison for a summer day: Solar field output



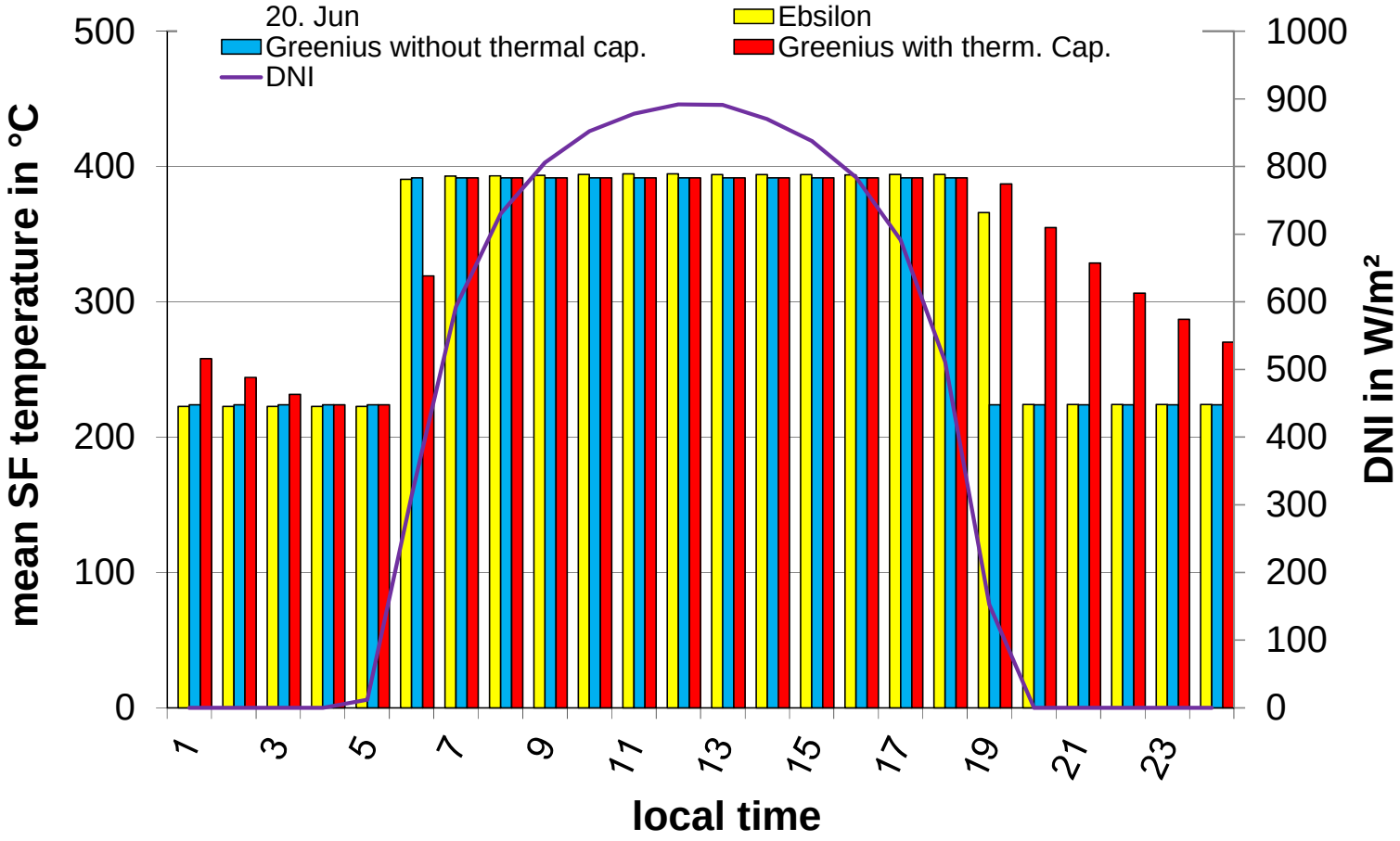
Comparison for a summer day: Net electricity



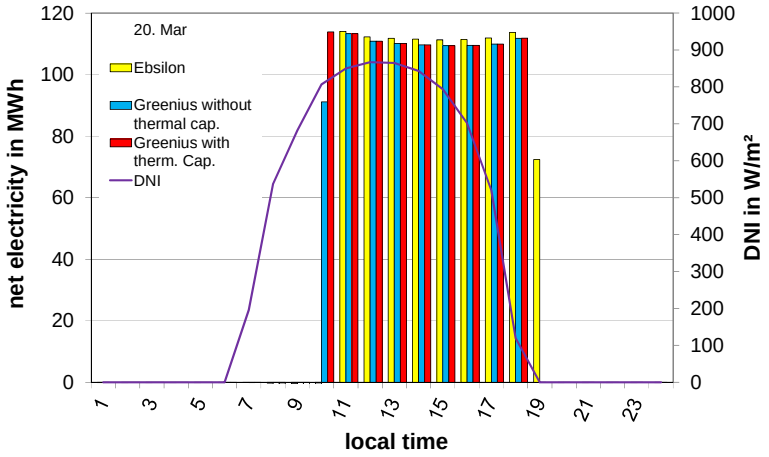
Comparison for a summer day: Storage content

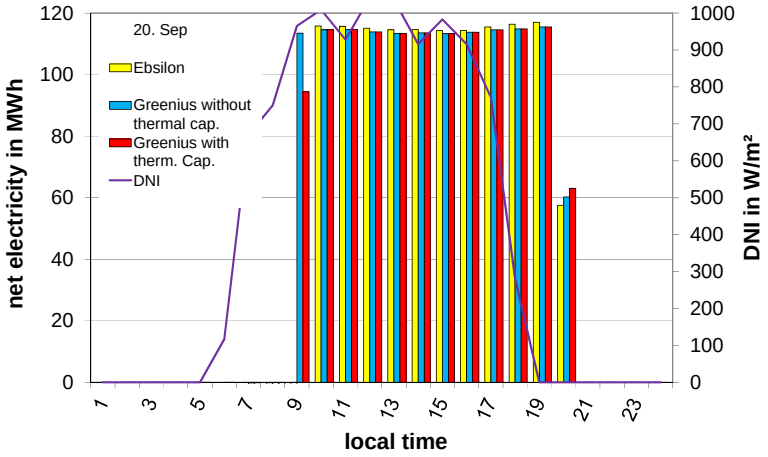


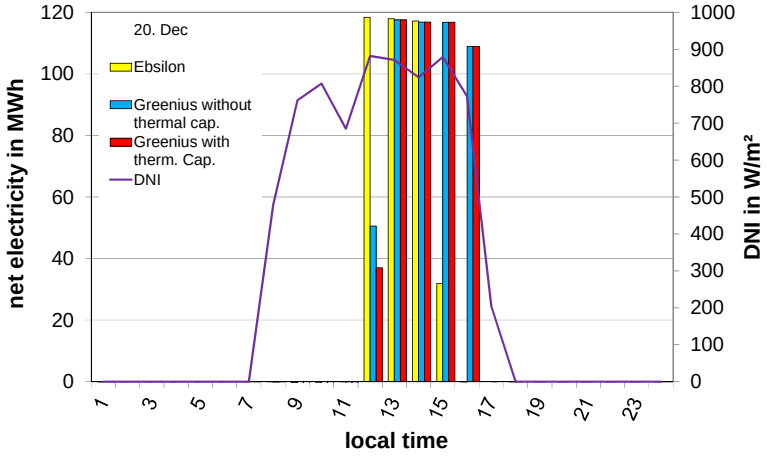
Mean solar field temperatures for the different cases

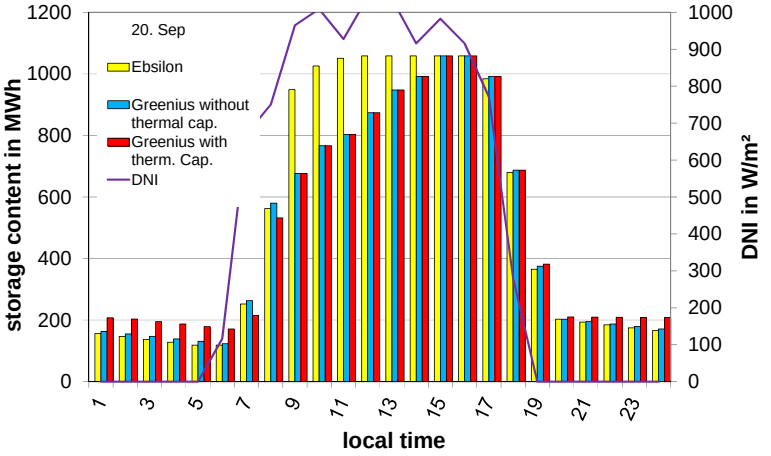


Other days


20. Mar
Ebsilon
Greenius without thermal cap.
Greenius with therm. Cap.
DNI
net electricity in MWh
DNI in W/m²
local time


20. Sep
Ebsilon
Greenius without thermal cap.
Greenius with therm. Cap.
DNI
net electricity in MWh
DNI in W/m²
local time


20. Dec
Ebsilon
Greenius without thermal cap.
Greenius with therm. Cap.
DNI
net electricity in MWh
DNI in W/m²
local time


20. Sep
Ebsilon
Greenius without thermal cap.
Greenius with therm. Cap.
DNI
storage content in MWh
DNI in W/m²
local time

Summary of the comparison

- Annual and daily performance figures from both tools show good agreement
- Differences in hourly values are caused by the fact that the operating strategies are not exactly the same and that EBSILON considers temperature variations of the TES
- Considering thermal inertia in greenius results in a decrease of about 1.5% for this molten salt system
- This is a lower value as the previously mentioned 7-12% for systems using thermal oil as HTF. The main reason for this lower impact is that the whole solar field is kept at a higher temperature level by freeze protection
- Since the major portion of the heat for freeze protection is taken from TES, this is also solar heat which must be collected by the solar field

Which tool for what purpose

Due do different model approaches EBSILON®Professional and greenius are suitable for different applications

- greenius
  - The power block configuration is fixed
  - Calculation of many SF/TES combinations
  - Pre-feasibility studies as long as no detailed information about the power block is available
- EBSILON®Professional
  - Optimization of power block in combination with SF
  - Integration of solar heat into existing fossil power plants