greenius – A free Software Tool for Simulating Electricity and Heat Generation Systems with Concentrating and Non-Concentrating Solar Collectors

Jürgen Dersch^{*1}, Javier Inigo Labairu¹, Tobias Hirsch¹,

¹Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institute of Solar Research, Köln ^{*}juergen.dersch@dlr.de

| eenius 4.11.0.2 - [Process heat 7 MW] | - 🗆 × | kk Process heat 21 MW | X File Edit View Visualize Help | - 14 - |
|--|--|--|--|---|
| e Project <u>C</u> ase <u>T</u> ools <u>W</u> indow <u>L</u> anguage <u>H</u> elp | _ <i>5</i> × | File Edit Costs Help | Typical Operation Year | |
| roject Summary a Project <u>S</u> ite 📝 <u>T</u> echnology | Y 딇 Economics 📈 Results | Collector Field | General Results General Results General Results Decletion (synchronic stress) Value Optimized and optimized stress Value Value Optimized stress Value Value Optimized stress Value | Hide Hide do Storage O Storage O Storage O Storage O Boiler O etct. O thitoticate solutions forsil Dialaux Diparticled DipartES SolSh Inc. and |
| Collector Assembly : SL4600+ Hui The collector has a length of 120.0 m | iyin70 2015 and an aperture width of 4.6 m. | kk Field Data | Graph Options Resolution Unit MW MW Average 5 Sum | MW |
| It has an effective mirror area of 529. The nominal optical efficiency is 77 % | 0 m ² and a focal length of 1.2 m. | General Simple field model General and Dimensions Field parameters | Single Restance Image: Single Restance | 0 0.000 0.0 |
| Collector Field : Process heat 21 M The field has 16 rows (loops) with 4 c It has an effective mirror area of 3385 The tracking axis has a tilt angle of 0.0 The thermal output of the field is 2095 | www Image: Collectors in each (total 64 collectors). 56 m². Load 0° and a tracking azimuth of 0.0°. Image: Collectors). 53 kWth at a DNI of 850 W/m². Edit | Name Process heat 21 MW Collector name SL4600 + Huiyin70 2015 Land use factor 3.73 Land use 126283 m² Reference Irradiation 850 W/m² | HeitO/Supernezter HeitOmand (Q load) 01.01 07:00 0.000 0.000 16 Dumed Solr Heat (Q Dump Cq) 01.01 09:00 0.000 0.000 16 HeitOrguration Dumper (Q out) 01.01 09:00 0.000 0.000 16 HeitOrguration Dumper (Q out) 01.01 09:00 0.005 01.41 4 HeitOrguration Dumper (Q out) 01.01 11:00 2.135 4.842 33856 m² Distorted V Collectors (H doc) 01.01 11:00 12.196 18.966 5torage Level (Q Storage) 01.01 13:00 3.172 5.766 5torage Level (Q Storage) 01.01 15:00 2.703 4.703 0.25545 m Storage Index (G storage) 01.01 16:00 0.237 1.157 0.2545 Description (R actified) Diver Company (R actified) 01.01 18:00 0.237 1.157 | 0 0.000 0.000 0.000 0.000 10.000 0.000 10.000 0.000 90.0 0.000 0.010 0.012 0.042 0.042 0.000 10.00 24.33 4 11.172 11.804 -0.373 </td |
| Thermal Storage : 50 MWh The storage net capacity is 50000 kWh The maximum input power is 11000 k The maximum output power is 11000 | h (5.0 full load hours). W. kW. Edit | Nominal Thermal Output 1 20953 kWth Header specific mass 1 At reference direct irradiation and amb. temp = 25 °C Length fraction cold header Orientation Pipe length in loops Distance between rows 13.00 m Distance between collectors 0.50 m | 00.29 kg/m Storage Paratics (P part Es) 01.01 20:00 0.000 0.000 0.50 Solar share Goldh) 01.01 20:00 0.000 0.000 0.50 Solar share Goldh) 01.01 20:00 0.000 0.000 504.0 m EtaOpt Tradking Error Pactor (etaOptTradk) 01.01 23:00 0.000 0.000 0.0525 m EtaOpt Tradking Error Pactor (etaOptTradk) 02.01 00:00 0.000 0.000 0.0525 m Steam Brow rate (modt St) 02.01 00:00 0.000 0.000 5.44 kg/m Kg/m DetaBut V (resel (Q Heat) Cellector theat Losses (Q Vessel) 02.01 03:00 0.000 0.000 5.44 kg/m Precesprotection from Storage (QP Stor) 02.01 06:00 0.000 0.000 | 0 0.000 0.0 |
| Boiler : 10 MW The nominal boiler output is 10000 kW The boiler efficiency is 90 %. | v. Load | Tracking axis tilt angle 0.00 ° Drum diameter Tracking axis azimuth 0.00 ° Drum spec. mass North-South Recirculation rate | Iteration count Parasitics (ItCountPar) 02.01 07:00 0.000 0.000 Iteration count Temperature (ItCountTemp) 02.01 07:00 0.000 0.000 Net Enthalpy FreshFeed (Q FFNet) 02.01 08:00 0.000 0.000 Refresh Graph View graph 02.01 10:00 2 89:3 6 574 | 0 0.000 0.0 |

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The software tool greenius has been developed at DLR for several years. It is designed to facilitate fast and simple performance calculations of concentrating solar technologies (CST) and other renewable energy systems based on hourly plant performance simulations for a typical operating year. Finer temporal resolutions can be used too, e.g., 30, 15, and 10 minutes.

Result presentation and analysis

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The results of the technical simulation are presented as a table containing one line for each time step of the typical operating year and one column for each output variable. Tables with daily, weekly and monthly sums are generated too.



A free version is available, and in a current project funded by the German Federal Ministry for Economic Affairs and Climate Action (Ref: 03EN6032A) the process heat simulation capabilities of greenius will be extended.

Utilization

greenius comes with several examples which may be used as starting points for own simulation projects. Users may modify the examples and load their own meteorological datasets as well as component datasets, e.g., for certain collector models.

Load curves can be defined and manipulated by users to adapt the simulated load to their needs. Import filters for common meteorological data formats are included to ease their utilization.

An economic calculation is also included in greenius which allows for detailed analysis of cash flows, etc. It should be mentioned that users must update the preliminary cost estimates delivered with greenius in order to get reliable costs. There is no up-to-date cost database included.

Complete simulation of a typical year needs only a few

The results can be plotted and users may zoom into the table to analyze the plant's operation and performance for single days. This is particularly useful to check whether the plant operates as expected and fulfills the defined load curve.

An example is given on the right-hand side. The 3rd figure from above is actually an enlarged section of the 2nd figure showing results for just 10 days. The blue line represents the load which is satisfied by the solar field, the thermal storage, or the auxiliary boiler. The green line represents solar heat provided either by the solar field or the thermal storage, and the red line shows the heat output of the solar field.

Potential users

greenius is particularly made for engineers who are planning such installations or are going to implement them for their own company. It might be used for comparing different thermal technologies and also PV installations. Typical use cases are feasibility studies and checks of proposals from different suppliers. The software comes with online help and a manual, but due to the large number of adjustable parameters, sometimes depending on others, some knowledge about the basics of these thermal systems is required to achieve meaningful results.

| Cash Fl | ow | | | 1000 | | | | | |
|------------------------|----------|-------------------|-----------------|--|------------|------------|------------|------------|-----|
| Summary Coperation | 👃 Constr | ruction 💧 Debt Se | ervice 🦂 Depred | ciation and Taxes | | | | | |
| | unit | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | |
| Total Revenues | € | Q | 5,256,000 | 5,256,000 | 5,256,000 | 5,256,000 | 5,256,000 | 5,256,000 | |
| Total Running Costs | € | 0 | 2,614,237 | 2,654,310 | 2,695,104 | 2,736,633 | 2,778,909 | 2,821,946 | |
| Net Operating CF | € | 0 | 2,641,763 | 2,601,690 | 2,560,896 | 2,519,367 | 2,477,091 | 2,434,054 | |
| Investment Costs | € | 12,657,045 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Pre-Finance CF | € | -12,657,045 | 2,641,763 | 2,601,690 | 2,560,896 | 2,519,367 | 2,477,091 | 2,434,054 | |
| Grant Funding | € | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Equity Funding | € | 3,797,114 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Debt Drawing | € | 8,859,931 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Debt Service | € | 0 | -1,308,308 | -1,262,517 | -1,216,727 | -1,170,936 | -1,125,146 | -1,079,355 | |
| Post Finance CF | € | 0 | 1,333,455 | 1,339,172 | 1,344,169 | 1,348,431 | 1,351,945 | 1,354,699 | |
| Tax Liability (Saving) | € | 0 | -431,777 | -433,493 | -434,992 | -436,270 | -437,324 | -438,150 | |
| Post Tax CF | € | 0 | 901,678 | 905,680 | 909,177 | 912,161 | 914,621 | 916,548 | |
| Dividends Paid | € | 0 | 901,678 | 905,680 | 909,177 | 912,161 | 914,621 | 916,548 | |
| Discounted CF | € | 0 | 850,639 | 806,052 | 763,363 | 722,517 | 683,458 | 646,130 | |
| Disc. Equity Inj. | € | 3,797,114 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Net Present Value | € | 10,329,052 | | | | | | | |
| Equity/Dividends | € | -3,797,114 | 901,678 | 905,680 | 909,177 | 912,161 | 914,621 | 916,548 | |
| IRR on equity | % | 25.34 | | | | | | | |
| ADSCR | | n/a | 1.69 | 1.72 | 1.75 | 1.78 | 1.81 | 1.85 | |
| min. ADSCR | | 1.69 | | | | | | | |
| Payback Period | yrs. | 4.18 | | | | | | | |
| Disc.Payback Period | yrs. | 4.96 | | | | | | | |
| | | | | | | | | | |
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|--|-----------------------|------------------|------------|
| 🔆 Key Results | | | (<u>)</u> |
| Technology 😪 Economics | | | Eil |
| Technical Key Results | | | |
| Meteorological Data: | | | - |
| Global horizontal irradiance (GHI) | kWh/(m²⋅a) | 1860.16 | |
| Direct normal irradiance (DNI) | kWh/(m²⋅a) | 2206.99 | - Mi |
| Direct irradiance on collector plane (DNc) | kWh/(m²⋅a) | 1918.98 | |
| Diffuse horizontal irradiance (Diff) | kWh/(m²⋅a) | 0.00 | |
| Mean annual ambient temperature | °C | 16.61 | H |
| Site Position and Orientation: | | | 0 |
| Site | | Spain - PSA | |
| Latitude | °N | 37.09 | A |
| Longitude | °E | -2.36 | |
| Tracking Axis: | | | Ir |
| Azimuth angle | ٥ | 0.00 | N |
| Tilt angle | ٥ | 0.00 | F |
| Trough Plant System Dimension: | | | |
| Collector: | | SL4600+ Huiyin70 | Т |
| Number of collectors | | 64 | N |
| Effective Collector Area | m² | 33856.0 | F |
| Land use | m² | 126292.9 | Ir |
| Nominal thermal output | kWth | 20952.99 | |
| Simulation Results: | | | L |
| Annual cooling energy generation | MWhth | 0 | Т |
| Annual solar heat generation | MWhth | 34,531 | A |
| Annual fossil heat generation | MWhth | 23,869 | N |
| Total annual heat generation | MWhth | 58,400 | A |
| Specific thermal field output | kWh_th/m ² | 1153.01 | |
| Mean annual field efficiency | % | 52.24 | |
| Mean system efficiency | % | 52.24 | |
| Solar share | % | 59.13 | |
| Annual electricity consumption | MWhel | 355 | J |

| Key Results 1 | | - 0 | Х |
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| 🧦 Key Results | | | |
| 🙀 Technology | | | |
| Economic Key Results | | | ^ |
| Financial Input Parameters: | | | |
| Heat Tariff | €/kWh_th | 0.0900 | |
| Grant Proportion (Renewable) | % | 0.00 | |
| Debt-Equity-Ratio | % | 70.00 | |
| Average Interest Rate | % | 5.64 | |
| Simulation Results: | | | |
| nternal Rate of Return (IRR) on Equity | % | 25.34 | |
| Net Present Value | € | 10,329,052 | |
| Payback Period | yrs. | 4.18 | |
| Discounted Payback Period | yrs. | 4.96 | |
| Fotal Incremental Costs | € | 51,331,049 | |
| Minimum ADSCR | | 1.69 | |
| Required Tariff for min. IRR | €/kWh | 0.0762 | |
| ncremental LHC | €/kWh_th | 0.0688 | |
| Calculation of LHC | | | |
| evelized Heat Costs (LHC) | €/kWh_th | 0.0688 | |
| Fotal Investment Costs (IC) | € | 12,657,045 | |
| Annuity of IC | | 0.0782 | |
| NPV of Running Costs (OC) | € | 38,674,004 | |
| Appuity of OC | | 0.0782 | |

seconds on a modern notebook or desktop computer. greeenius runs only on MS Windows systems.

Users may save their own projects in a single ASCII file for documentation purposes or to rerun it later if required. Result files can be exported to MS Excel, CSV, or plain text format. Availability

A free version of greenius is available for download. Currently, the DLR Solar Research website is being restructured and therefore the download link doesn't work. If you need a version immediately, please send an email request to juergen.dersch@dlr.de

The figures above show different windows with simulation results which are available in greenius after running a project.

Supported by:



on the basis of a decision by the German Bundestag

