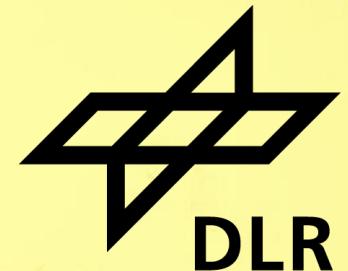


greenius: Simulationstool für schnelle Prognosen von Wärmeerträgen

Side Event der HEATEXPO 2025, Dekarbonisierung der Wärme: Hochtemperatur-Solarthermie bis 400 °C in Wärmenetzen und Prozesswärme

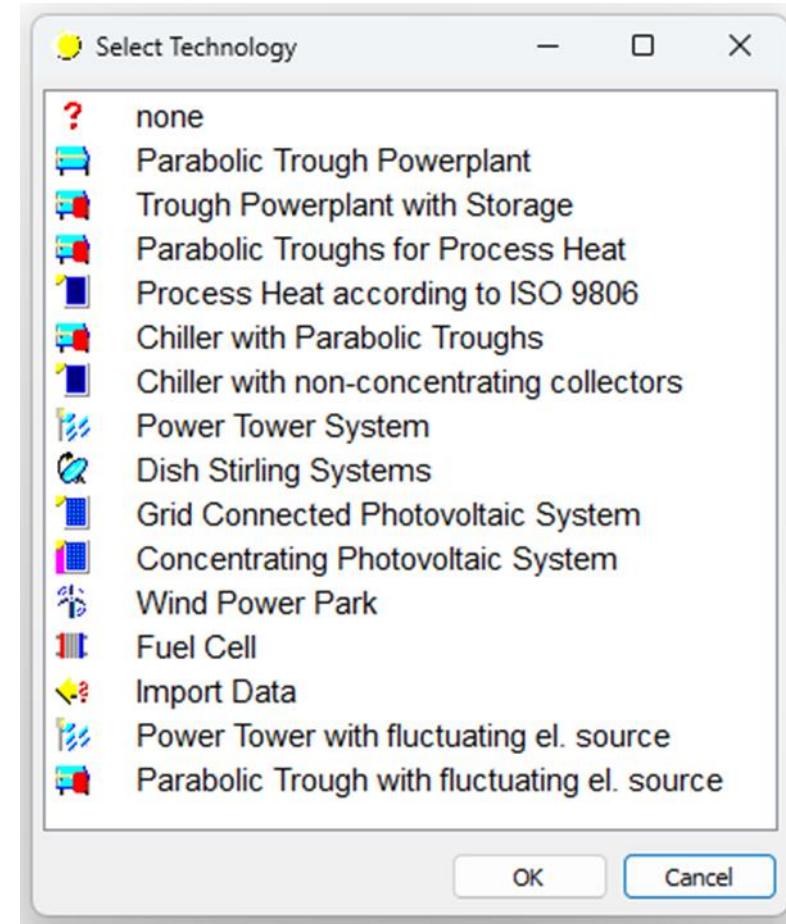
Javier Inigo Labairu und Jürgen Dersch



Die Software greenius



- Das Simulationstool **greenius** wird am DLR seit vielen Jahren entwickelt und gepflegt
- Es wurde zur einfachen und schnellen Ertragsberechnung von solarthermischen Kraftwerken mit konzentrierenden Systemen und anderen regenerativen Systemen zur Stromerzeugung entworfen
- Die Simulation erfolgt auf der Basis von Jahresrechnungen mit stündlicher Auflösung und die Berechnung eines typischen Jahres dauert nur wenige Sekunden
- Die aktuellen Erweiterungen beziehen sich auf Prozesswärmeerzeugung mit konzentrierenden und nichtkonzentrierenden Kollektoren
- Einsatzmöglichkeiten: z. B. Machbarkeitsstudien oder Technologievergleiche
- Kostenlos verfügbar unter: <http://freegreenius.dlr.de>

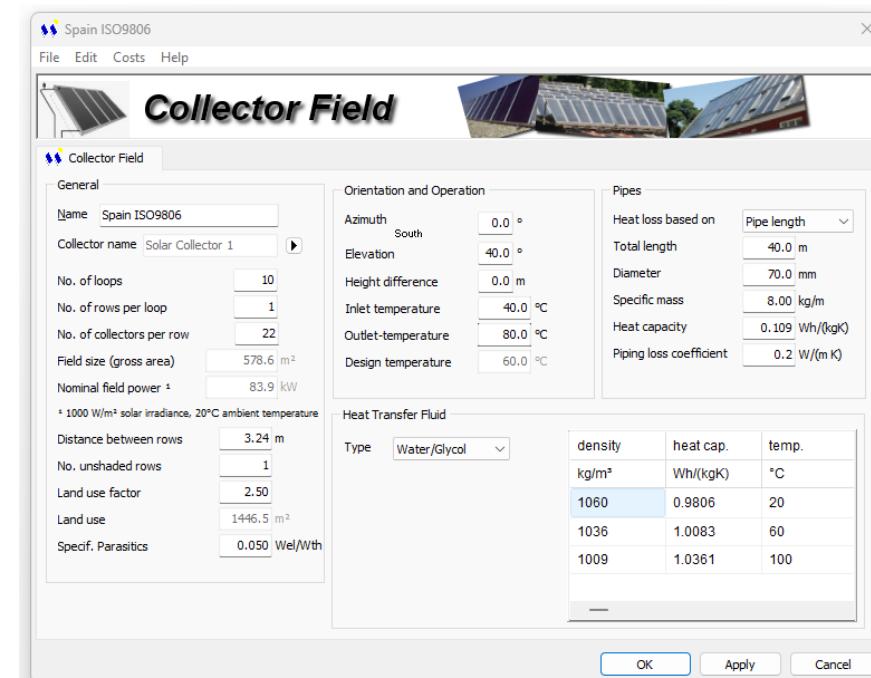
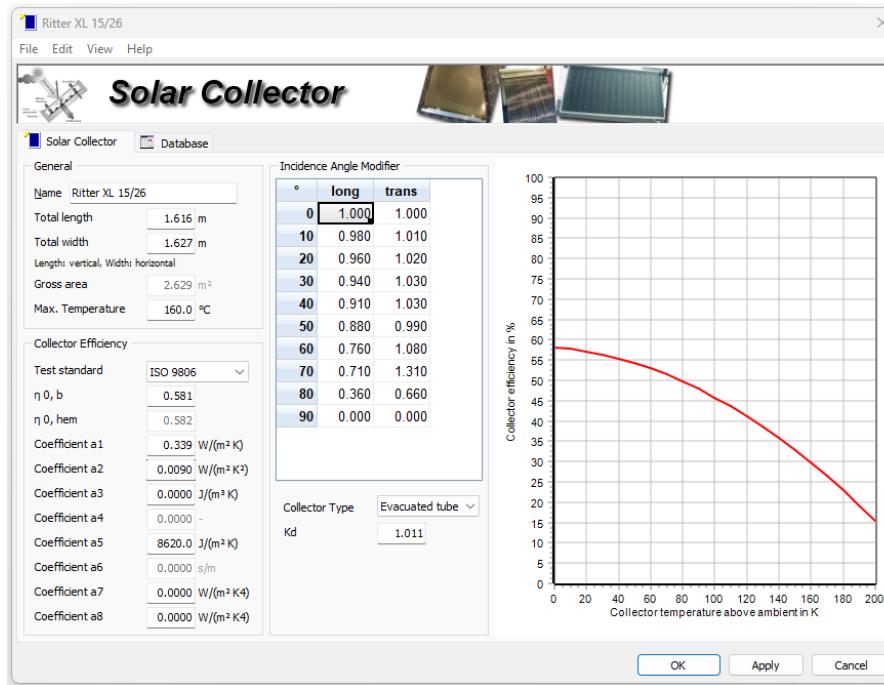


- Die Kombination aus schnellen technischen Ertragsberechnungen und wirtschaftlichen Analysen
 - Umfassende Visualisierungsoptionen zur grafischen Auswertung der Ergebnisse
 - Benutzeroberflächen zur Parametereingabe und Ergebnisanalyse
 - Integration von meteorologischen Daten und Ertragskennfeldern aus Drittsoftware
 - Export der Ergebnisdateien im Microsoft-Excel-Format zur weiteren Verarbeitung
 - Einbindung der Solar Keymark-Datenbank zur Nutzung zertifizierter Kollektordaten
-
- **Keine** detaillierte Berechnung von Wärmebilanzdiagrammen für Kraftwerksblöcke
 - **Keine** Auslegung von Rohrleitungen und Hydrauliksystemen der Anlage
 - **Keine** aktuellen Kostendatenbanken für Komponenten

Neueste Aktualisierungen



- Implementierung der ISO-9806-Norm für konzentrierende und nicht-konzentrierende Solarkollektoren
- Detaillierte Berechnung der Verschattungsverluste und verschiedene Methoden für Rohrwärmeverluste



Neueste Aktualisierungen



- Integration der Solar-Keymark-Datenbank zur Simulation von konzentrierenden und nicht-konzentrierenden Solarkollektoren gemäß ISO 9806

Ritter XL 15/26

File Edit View Help

Solar Collector



Solar Collector Database

Excerpt from the SolarKeymark. For details and the full list see: <https://solarkeymark.eu/database/>

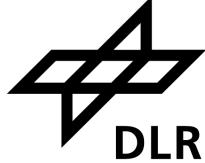
ID	Company	Type	Name	Standard	Tmax	Lcol
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 10	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 12	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 14	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 15	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 16	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 18	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 20	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 21	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 22	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 24	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 25	EN ISO 9806	230	19€
4217	2-Improve Energy	Evacuated tubular collector	Prisma Pro 28	EN ISO 9806	230	19€
489	3S Swiss Solar Solutions AG	Flat plate collector	ThermiePanel TS	EN ISO 9806	100	9€
731	Smith Water Products Company	Flat plate collector	AOSP 240 V	EN ISO 9806	199	20€

Find next Find previous

Load SolarKeymark Database Copy Selection to Collector Form

OK Apply Cancel

Voraussetzungen und erforderliche Eingabedaten



- Standort (Länge, Breite, Höhe)
- Anlagengröße (Nennleistung)
- Meteorologischer Datensatz
- Lastkurve
- Technologie

- greenius kann auch verwendet werden, um verschiedene Technologien und/oder Standorte miteinander zu vergleichen.

Definition des Projektstandorts (1)

greenius 5.1.0.1 - [Example_ISO9806]

File Project Case Tools Window Language Help

Project Summary Project Site Technology Economics Results

Nation : Default

The electricity tariff for injection from renewables is 0.17 €/kWh.
The fuel price is 0.05 €/kWh and the discount rate 6.0 %.
The income tax rate was defined to be 30.00 %.

Location : Spain - Almeria

The location of the project will be in Spain - Almeria.
It is located on 36.83°N -2.45°E, 5 m above sea level (timezone 1.0 h).
The specific grading and land costs are 1.2 €/m² and 1.0 €/m².

Load Curve and OS : 8_to_9_workingdays

The annual sum of the load is 678.40 MWh and the average load 77.44 kW,
whereas the annual load minimum is 0.00 kW and the maximum 200.00 kW.
January 1st of the typical reference year is a Monday.
Operating strategy is: 8_to_9_workingdays

Meteo : Almeria (Spain)

It is located at 36.83°N -2.45°E, 5 m (timezone 1.0 h).
Temperature min. is 3.8 °C, max. 36.9 °C, mean 17.6 °C.
The annual sum of global irradiation GHI is 1812 kWh/m² and the sum of direct normal irradiation DNI is 1918 kWh/m²
The annual sum of diffuse irradiation Diff is: 648 kWh/m²
There are no wind speed values available.

Load Edit Load Edit Load Edit Load Edit

Ready

Definition des Projektstandorts (2)

Spain

File Edit Help

Nation



National Economics

General

Name Spain

Remuneration Tariffs

Electricity 0.150 €/kWh

flat

variable

Heat/Cooling 0.080 €/kWht

Tariffs valid for 2024

Fix fossil fuel usage 0.0 %

Prices of Delivery

Fuel price 0.050 €/kWh

Water price 0.050 €/m³

Purchased from the grid 0.150 €/kWh

Prices valid for 2024

Specific Reference Values

Electricity 0.100 €/kWh

Heat

Levelized generation costs 0.000 €/kWh

CO₂ emissions 0.600 kg/kWh

0.300 kg/kWh

OK

Apply

Cancel

Spain - Almeria

File Edit Tools Help

Location



Location

Geographical Location

Name Spain - Almeria

Latitude 36.83 °N Altitude 5 m

Longitude -2.45 °E

Timezone +1 (Middle European Time)

Solar Angles for this Location

Date 24.07.2025 Day Length: 14:10 h

Sunrise at 06:10:37 (Azimuth 64.48°)

Sunset at 20:21:37 (Azimuth 295.35°)

Solar noon at 13:16:16 (Elevation 72.92°)

Properties of Ground

Ground structure Sand

Roughness length 0.03 m

Albedo factor 0.2 unspecified

Average slope 3 °

specific Land costs 1 €/m²

Image of Location



OK

Apply

Cancel

Definition der Technologie (1)

greenius 5.1.0.1 - [Example_ISO9806]

File Project Case Tools Window Language Help

Project Summary Project Site Technology Economics Results

Solar Collector : Absolicon Solar T160
The collector has a total area of 6.04 m².
The optical efficiency is 69.7 %.



NC Collector Field : Spain ISO9806
The collector field consists of 10 loops with 8 collectors and a total aperture area of 483.04 m².
The collectors have an elevation of 40.0° and azimuth angle of 0.0°.



Thermal Storage : 600 kWh Storage
The storage net capacity is 600 kWh (3.0 full load hours).
The maximum input power is 200 kW.
The maximum output power is 200 kW.



Boiler : Default
No boiler has been defined.
The plant is operated in solar-only mode!



Load Edit Load Edit Load Edit Load Edit

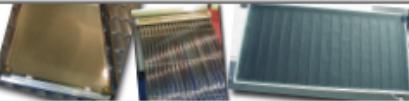
Ready

Definition der Technologie (2)

Absolicon Solar T160

File Edit View Help

Solar Collector



Solar Collector Database

General

Name	Absolicon Solar T160
Total length	1.095 m
Total width	5.514 m
Length: vertical, Width: horizontal	
Gross area	6.038 m ²
Max. Temperature	180.0 °C

Collector Efficiency

Test standard	ISO 9806
$\eta_{0,b}$	0.697
$\eta_{0,hem}$	
Coefficient a1	0.730 W/(m ² K)
Coefficient a2	0.0000 W/(m ² K ²)
Coefficient a3	0.0000 J/(m ³ K)
Coefficient a4	0.0000 -
Coefficient a5	1483.0 J/(m ² K)
Coefficient a6	0.0000 s/m
Coefficient a7	0.0000 W/(m ² K ⁴)
Coefficient a8	0.0000 W/(m ² K ⁴)

Incidence Angle Modifier

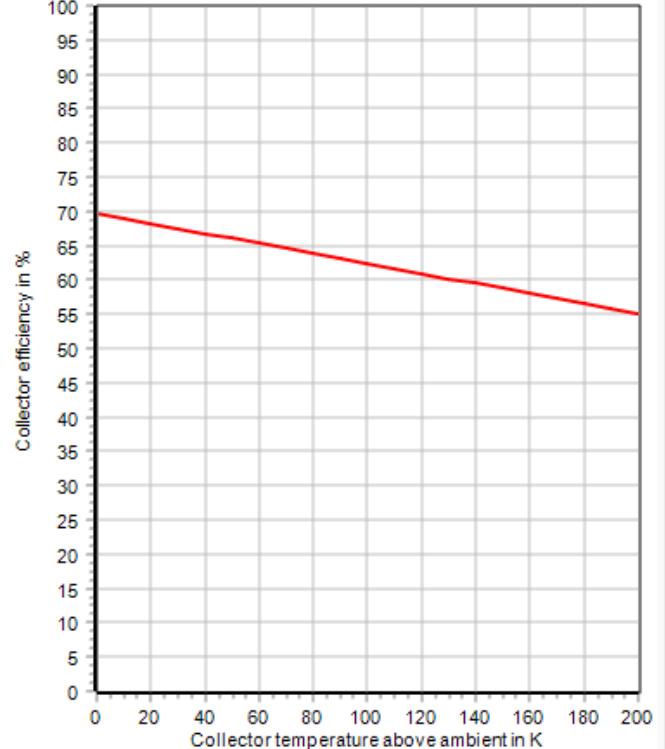
°	long	trans
0	1.000	1.000
10	0.990	1.000
20	0.990	1.000
30	0.980	1.000
40	0.960	1.000
50	0.910	1.000
60	0.770	1.000
70	0.530	1.000
80	0.180	1.000
90	0.000	0.000

Collector Type: Concentrating

Test method: quasi-dynam

Kd: 0.120

Collector efficiency in %



Collector efficiency in %

Collector temperature above ambient in K

OK Apply Cancel

Definition der Technologie (3)



Spain ISO9806

File Edit Costs Help

Collector Field

Collector Field

General		Orientation and Operation		Pipes	
Name	Spain ISO9806	Azimuth	South	Heat loss based on	Pipe length
Collector name	Solar Collector 15	Elevation	40.0 °	Total length	40.0 m
No. of loops	10	Height difference	0.0 m	Diameter	70.0 mm
No. of rows per loop	1	Inlet temperature	40.0 °C	Specific mass	8.00 kg/m
No. of collectors per row	8	Outlet-temperature	80.0 °C	Heat capacity	0.109 Wh/(kgK)
Field size (gross area)	483.0 m ²	Design temperature	60.0 °C	Piping loss coefficient	0.2 W/(m K)
Nominal field power ¹	324.3 kW				
¹ 1000 W/m ² solar irradiance, 20°C ambient temperature					
Distance between rows	3.24 m	Heat Transfer Fluid			
No. unshaded rows	1	Type	Water/Glycol	density	heat cap.
Land use factor	2.50			kg/m ³	Wh/(kgK)
Land use	1207.5 m ²			1060	0.9806
Specif. Parasitics	0.050 Wel/Wth			1036	1.0083
				1009	1.0361
				temp. °C	
				20	60
				100	

OK **Apply** **Cancel**

600 kWh Storage

File Edit Costs Help

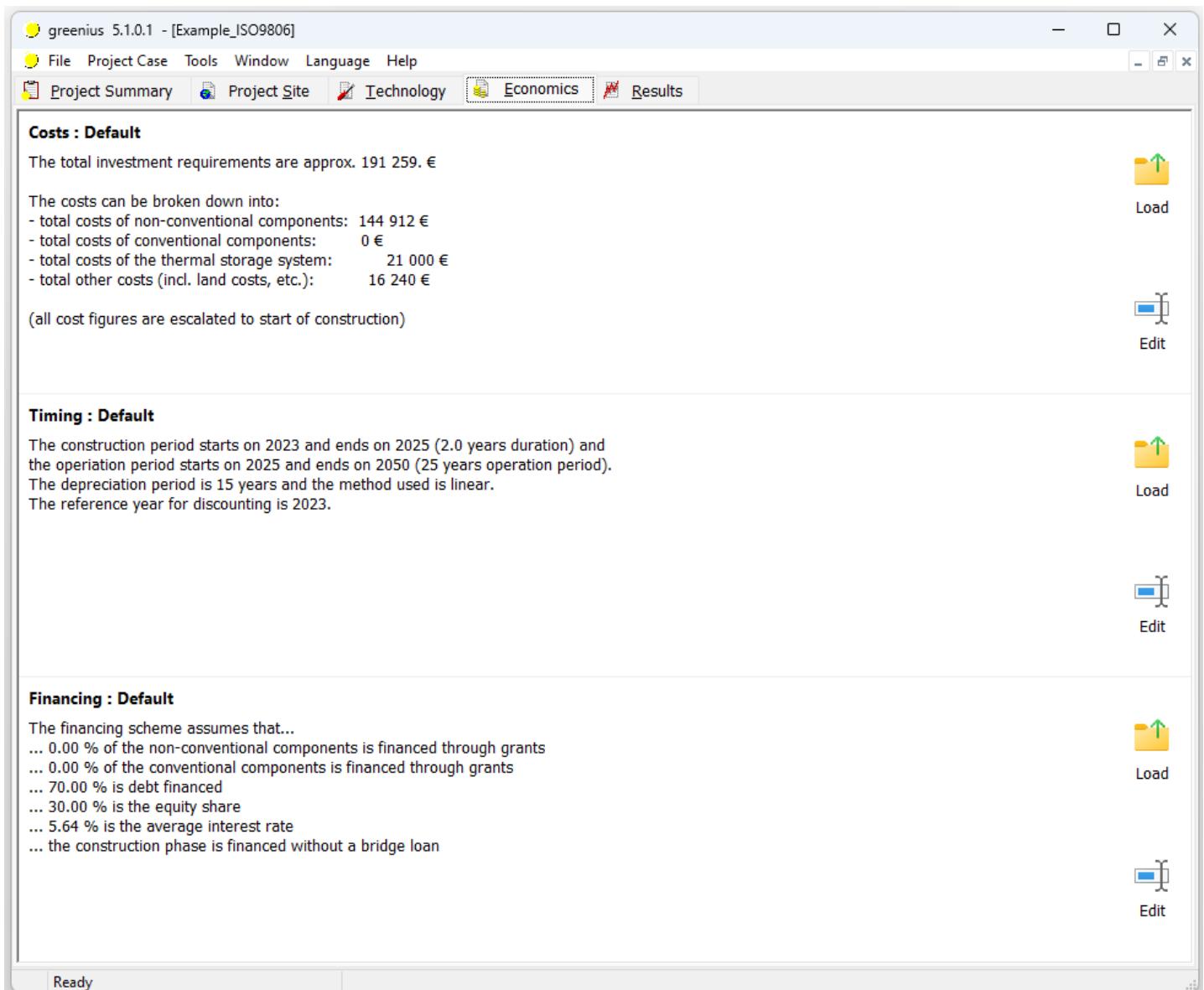
Storage

Storage

General Information	
Name	600 kWh Storage
Typ	Single Tank
Technical data	
Net Capacity	600 kWh
Consumer design demand	200 kW
Full load hours	3.0 h
Nominal field excess	138 kW
Maximal charging	200 kW
Maximal discharging	200 kW
Time constant	70.00 h
50 % loss in	48.5 h
Input temp. difference	11.0 °C
Output temp. difference	11.0 °C
Pumping parasitics	0.003 Wel/Wth

OK **Apply** **Cancel**

Definition der Wirtschaftlichkeit (1)



The screenshot shows the greenius 5.1.0.1 software interface with the following details:

- Costs : Default**

The total investment requirements are approx. 191 259, €
The costs can be broken down into:
 - total costs of non-conventional components: 144 912 €
 - total costs of conventional components: 0 €
 - total costs of the thermal storage system: 21 000 €
 - total other costs (incl. land costs, etc.): 16 240 €(all cost figures are escalated to start of construction)
- Timing : Default**

The construction period starts on 2023 and ends on 2025 (2.0 years duration) and the operation period starts on 2025 and ends on 2050 (25 years operation period). The depreciation period is 15 years and the method used is linear.
The reference year for discounting is 2023.
- Financing : Default**

The financing scheme assumes that...
 - ... 0.00 % of the non-conventional components is financed through grants
 - ... 0.00 % of the conventional components is financed through grants
 - ... 70.00 % is debt financed
 - ... 30.00 % is the equity share
 - ... 5.64 % is the average interest rate
 - ... the construction phase is financed without a bridge loan

On the right side of the window, there are two columns of icons with labels:

- Load (with a folder icon)
- Edit (with a document icon)
- Load (with a folder icon)
- Edit (with a document icon)
- Load (with a folder icon)
- Edit (with a document icon)

At the bottom left, it says "Ready".

Berechnung und Ergebnisanalyse



The screenshot shows the greenius 5.1.0.1 software interface with the following details:

- Top Bar:** File, Project Case, Tools, Window, Language, Help, Project Summary, Project Site, Technology, Economics, Results.
- Typical Operation Year:** The thermal output of the collector field is 581.43 MWh/a. The specific thermal output is 1204 kWh/m² collector area. The annual solar share (gross) is 64.5 %.
- Cash Flow:** The calculated project has an Internal Rate of Return (IRR) on Equity of 15.42 %. The Present Value (PV) of the investment is 0.089 million €, and the equity investment is amortized after 7.71 years. The required heat price is 0.0742 €/kWh to match the minimum required IRR of 12.0 %.
- Key Results:** The leveled heat costs (LHC) based on the nation discount rates are 0.062 €/kWh. The total incremental costs are 276 145 € (0.032 €/kWhe). 146.0 t CO₂ are avoided per year with costs of 148.0 €/tCO₂.
- Calculation Progress Dialog:** A separate window titled "Calculating..." is displayed, showing "Parabolic Trough Operation..." with a progress bar at 69%. It also displays "Passed calculation time: 1.92 s" and "Remaining calculation time: 0.88 s". A "Break Calculations" button is available.

Ergebnisanalyse (1): Tabelle



Typical Operation Year

File Edit View Visualize... Help

Typical Operation Year

General Results

Renewable Electricity Generation: 0 MWh
No Solution found: 0 out of 8760

Graph Options
Resolution: Hourly
Display Period: from Hour 1 to Hour 8760

Timeticks: Hours Days Weeks Months

Value	Q load	H col	Q abs	Q_hloss	Q_ploss	Q col	Q field	Q Cool	Q Dump	Q heatup	dQ Storage	Q Storage	Q Stor.loss	Q aux	Q s,tot	Q tot	W el aux	eta foss	eta sol
Unit	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	%	%
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90.0	109.7
Sum	678	887	639	57	1	583	581	0	120	0	24	1,674	24	241	438	678	26		
01.01 01:00	0.000	0.000	0.004	0.000	-0.004	0.000	0.000	0.000	-0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 02:00	0.000	0.000	0.001	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 05:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 06:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 07:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 08:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 09:00	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	158.6	
01.01 10:00	0.200	0.081	0.059	0.013	0.000	0.046	0.029	0.000	0.017	0.000	0.000	0.000	0.171	0.029	0.200	0.003	90.0	128.6	
01.01 11:00	0.200	0.000	0.003	0.013	0.000	-0.010	0.000	0.000	-0.011	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-27.1	
01.01 12:00	0.200	0.000	0.004	0.005	0.000	-0.002	0.000	0.000	-0.002	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-237.3	
01.01 13:00	0.200	0.000	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-8721.0	
01.01 14:00	0.200	0.000	0.005	0.004	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	488.5	
01.01 15:00	0.200	0.000	0.002	0.004	0.000	-0.002	0.000	0.000	-0.002	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-146.3	
01.01 16:00	0.200	0.000	0.002	0.002	0.000	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-228.5	
01.01 17:00	0.200	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-833.0	
01.01 18:00	0.200	0.000	0.000	0.002	0.000	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	-42.8	
01.01 19:00	0.200	0.000	0.000	0.001	0.000	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	0.0	
01.01 20:00	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	0.0	
01.01 21:00	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.200	0.002	90.0	0.0	
01.01 22:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
01.01 23:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 05:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 06:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	
02.01 07:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	

Cancel

Key Results 24

File Edit Help

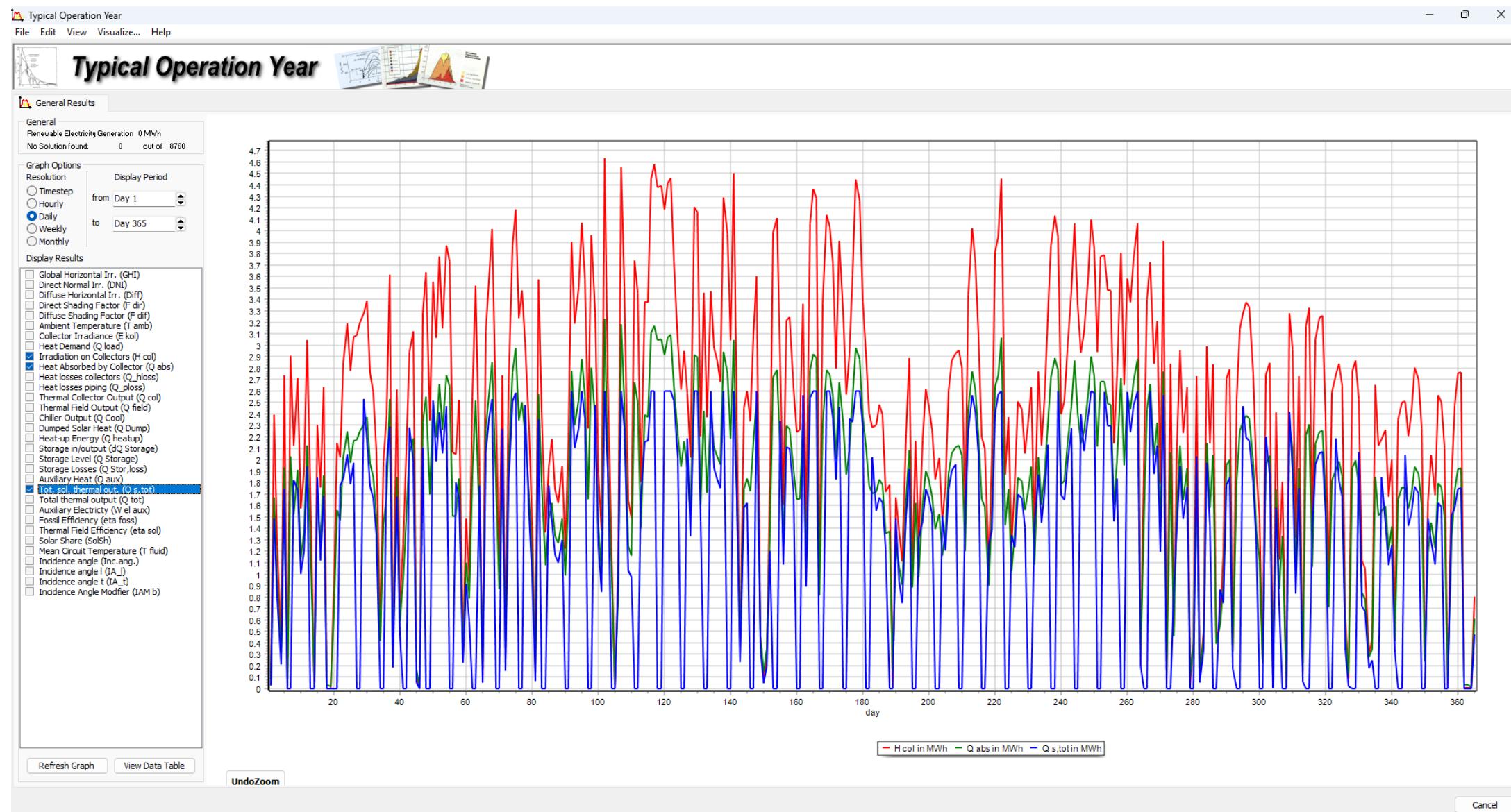
Key Results

Technology Economics

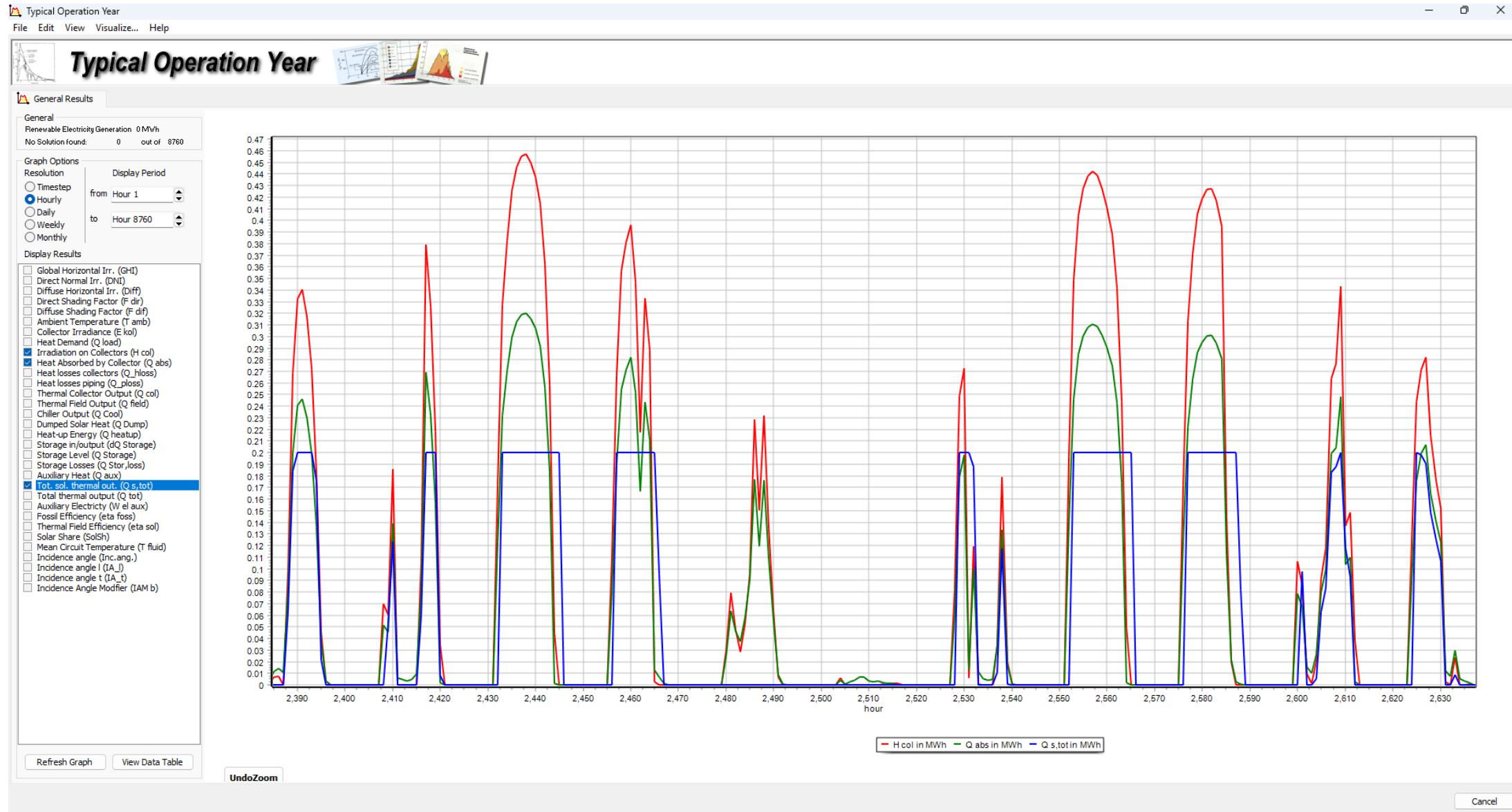
Economic Key Results		
Financial Input Parameters:		
Heat Tariff	€/kWh_th	0.0800
Grant Proportion (Renewable)	%	0.00
Debt-Equity-Ratio	%	70.00
Average Interest Rate	%	5.64
Simulation Results:		
Internal Rate of Return (IRR) on Equity	%	15.42
Net Present Value	€	89,191
Payback Period	yrs.	7.71
Discounted Payback Period	yrs.	10.33
Total Incremental Costs	€	276,145
Minimum ADSCR		1.32
Required Tariff for min. IRR	€/kWh	0.0742
Incremental LHC	€/kWh_th	0.0318
Calculation of LHC		
Leveled Heat Costs (LHC)	€/kWh_th	0.0618
Total Investment Costs (IC)	€	191,259
Annuity of IC		0.0782
NPV of Running Costs (OC)	€	345,053
Annuity of OC		0.0782
Environmental Aspects:		
Annual CO2 Reduction	t CO2	145.97

Cancel

Ergebnisanalyse (2): Jahresdiagramm mit täglicher Auflösung

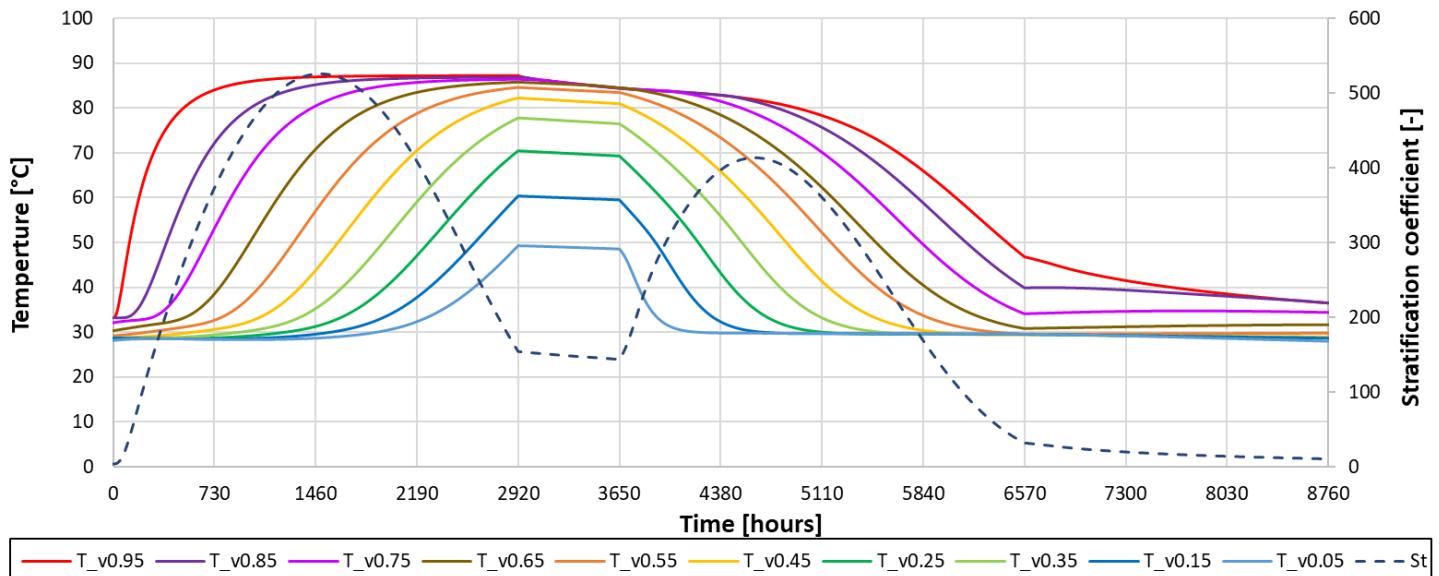
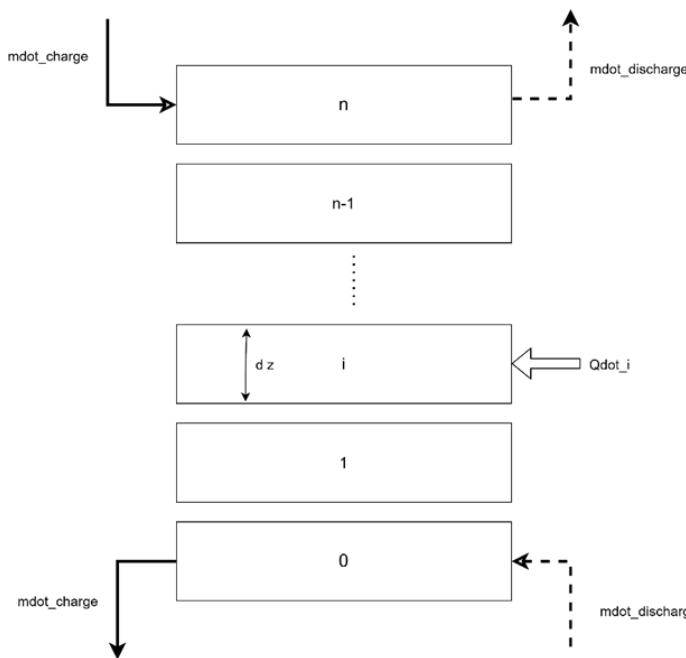


Ergebnisanalyse (3): Zoom auf die Stundenauflösung



Ausblick: Saisonale Speicher

- Implementierung saisonaler Speicher als Schichtspeicher
- Integration mit Wärmepumpen für Prozesswärme und Fernwärmesysteme

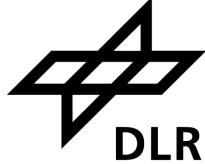


Ausblick: Strukturelle Verbesserungen



- Softwarestruktur-Update: Neue Energiesysteme integrieren, Benutzerfreundlichkeit verbessern
- Kraft-Wärme-Kopplungssimulation: Gleichzeitige Modellierung von Strom und Wärme
- Strompreisgestaltung: Stundenbasierte Preisverläufe und Netzintegration
- Parameter-Variationen: Automatisierte Sensitivitätsanalysen für schnellere Auslegung
- Verbreitung von greenius: Schulungen, Webinare, Workshops, Newsletter, Community-Building
- Modellierungsempfehlungen: Standardisierte Dokumentation und Parametersätze für solarthermische Prozesswärmesysteme

Ausblick: Technologieimplementierung



- Hybride CSP-Systeme mit Wärmespeicher, Power-to-Heat und Backup-Brennstoffen
- Power-to-Heat-Systeme: Elektrifizierung der Prozesswärme mit PV, Wärmepumpen oder Elektrohitzern
- Schichtspeicher & Rohrverluste: Simulation von Schichtspeichern und Wärmeverlusten in der Verteilung
- CO₂-Vermeidung: Direkte Emissionen und Minderungs-Potenzial bewerten
- Aktualisierte Komponentendatensätze: Neueste Technologieparameter für präzise techno-ökonomische Analysen
- Integration mit Industrie und internationalen Organisationen: Nutzerfeedback, Leitlinienbeiträge, Community-Building

VIELEN DANK!

Side Event der HEATEXPO 2025, Dekarbonisierung der Wärme: Hochtemperatur-Solarthermie bis 400 °C in Wärmenetzen und Prozesswärme

Javier Inigo Labairu und Jürgen Dersch

