Gemasolar
a Torresol Energy Company

Funcionamiento de Gemasolar
Gemasolar: how it works

1 Heliostatos / Heliostats

La luz solar incide sobre los heliostatos reflejándola hacia el receptor, situado en lo alto de la torre.
Solar light is refl ected by the heliostats towards the receiver, located on top of the tower.

2 Tanque 1 / Tank 1

Las sales, a 290ºC, son bombeadas desde el tanque frío hasta el receptor.
Molten salts, at 290ºC, are pumped from the cold molten salt tank to the receiver.

3 Torre / Tower

Dentro del receptor de torre, las sales son calentadas hasta 565ºC antes de ser almacenadas en el tanque de sales calientes.
Inside the receiver, molten salts are heated up to 565ºC before being stored in the hot molten salt tank.

4 Tanque 2 / Tank 2

En el tanque de sales calientes se almacenan las sales fundidas a muy alta temperatura.
The hot molten salt tank keeps the energy accumulated in form of molten salts at very high temperature.

5 Generador de vapor / Steam Generator

Desde el tanque caliente las sales son conducidas al sistema de generación de vapor donde ceden calor y se enfrían.
The hot molten salts are delivered to the steam generation system, where they transfer their heat to the water, reducing their temperature.

6 Turbina / Turbine

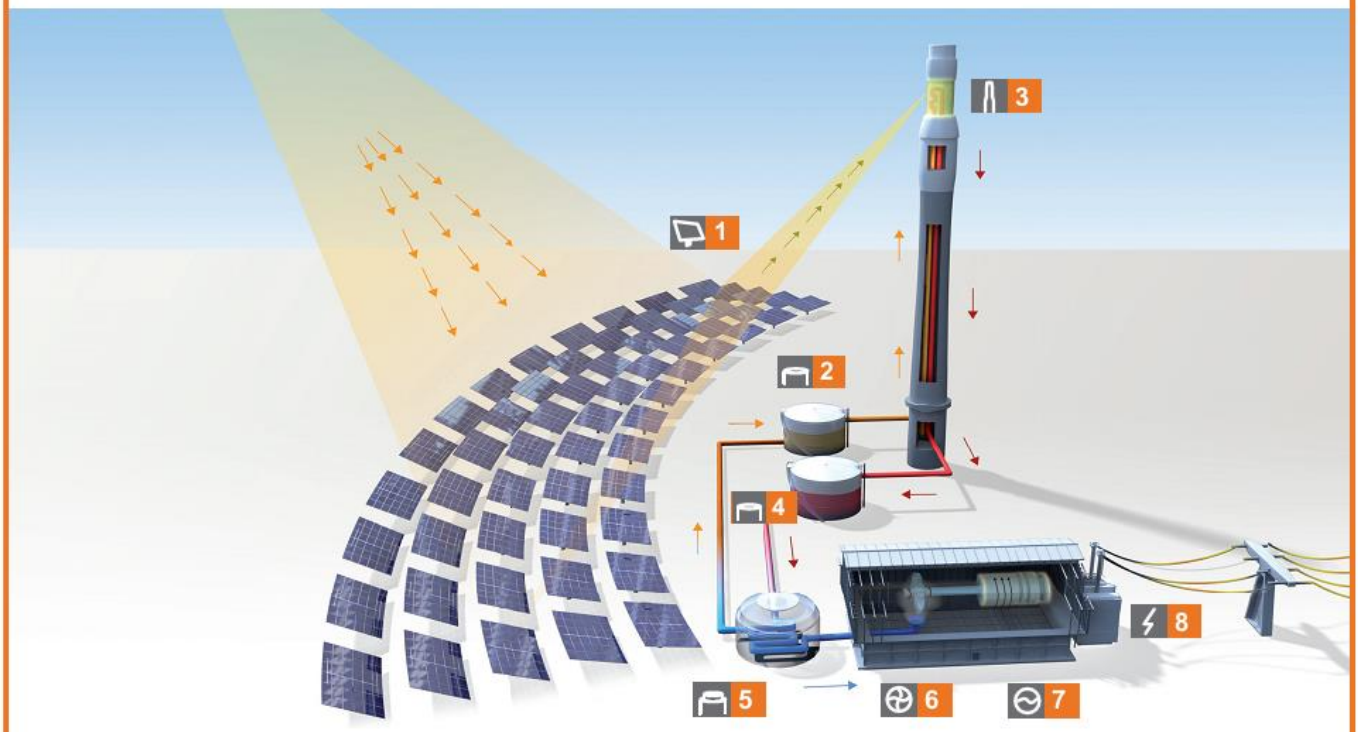
Las sales al enfriarse generan vapor de agua a alta presión para mover la turbina.
The heat transferred transforms the water into high pressure steam to move the turbine.

7 Generador eléctrico / Electric Generator

La turbina mueve un generador eléctrico produciendo energía.
The turbine powers the electric generator producing electrical energy.

8 Transformador / Electrical Transformer

La energía producida en el generador es conducida a un transformador eléctrico para ser inyectada a la red.
The electricity is delivered to a transformer to be injected into the distribution grid.



SENER
The way to see the future

Torresol Energy
reinventing solar power

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Gemasolar
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Gemasolar: Datos destacados
Gemasolar: key figures

Primera

First

- Primera planta comercial en el mundo con tecnología CSP
- Primer receptor solar de alta temperatura en sales fundidas
- Primera planta CSP con 15 horas de almacenamiento térmico

- First worldwide commercial application of this new CSP technology
- First high temperature solar receiver with molten salt
- First CSP plant with 15 hours of thermal storage

Altura de la Torre / Tower height: 140 m

Área reflectante total / Total reflective area: m2

Superficie del campo solar / Surface area of the solar field: Ha

Potencia nominal de la turbina / Turbine power capacity: MWe

Capacidad de utilización / Capacity factor: 75%

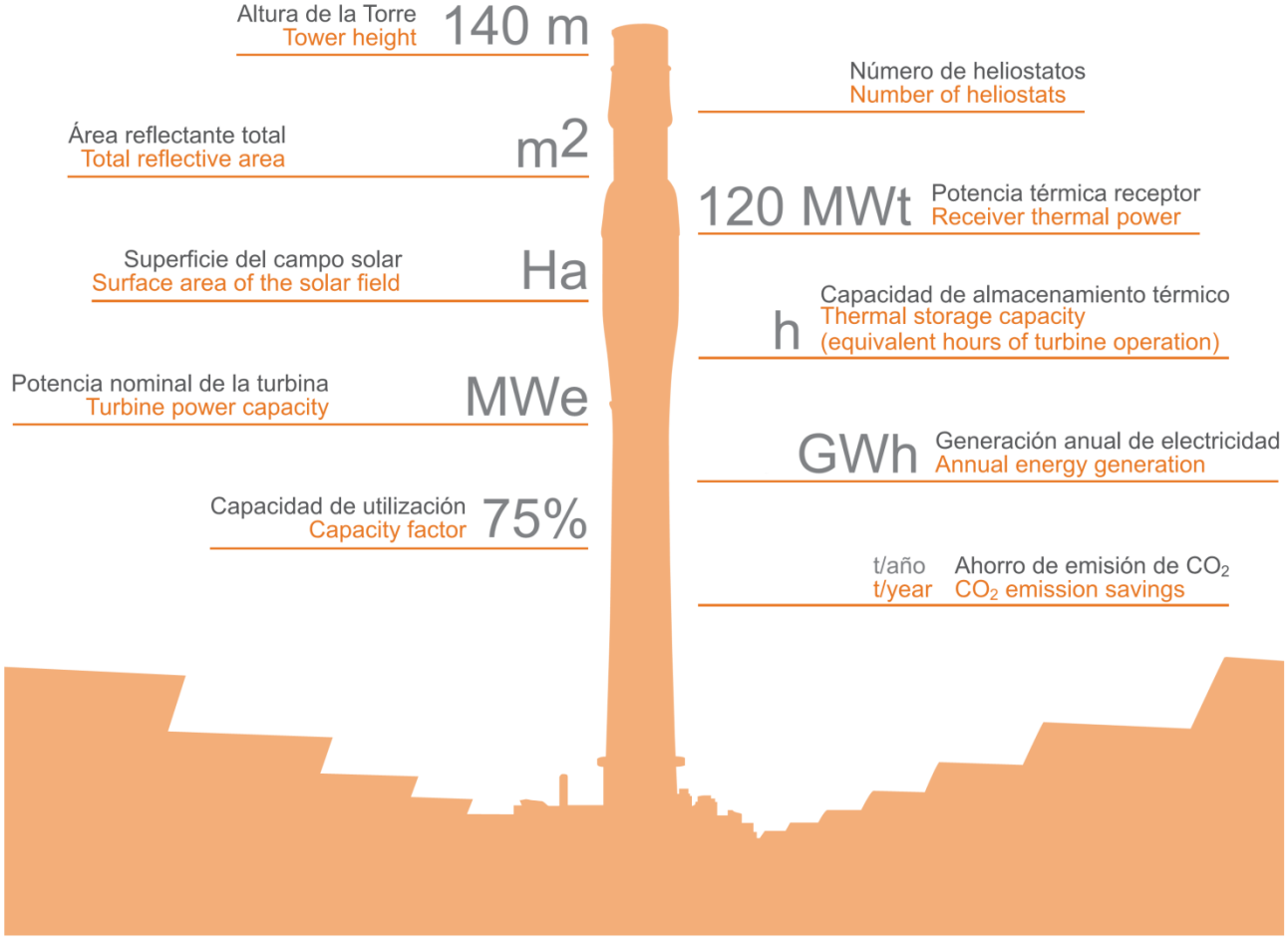
Número de heliostatos / Number of heliostats

120 MWt — Potencia térmica receptor / Receiver thermal power

h — Capacidad de almacenamiento térmico / Thermal storage capacity (equivalent hours of turbine operation)

GWh — Generación anual de electricidad / Annual energy generation

t/año / t/year — Ahorro de emisión de CO_2 / CO_2 emission savings



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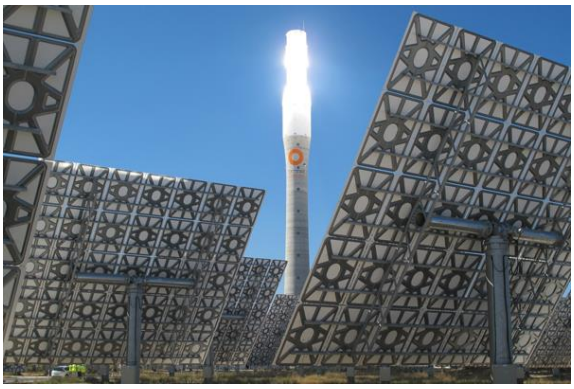
1

Heliostats and Receiver



Heliostat:

Mirror reflectivity: $r = 0.88$

Heliostat concentration:

$C = \frac{A_{Heliostat\ Field}}{A_{receiver}} = 1212$ suns

Size of single heliostat: $A_{mirror} = 115\ \mathrm{m}^2$

Receiver:

Absorption efficiency: $\eta_{ab} = 0.95$

Diameter = 8 m; Height = 10 m

2 4

Storage Tanks

Molten Salt: Sodium and potassium nitrates

$c_p = 1.55\,\frac{\mathrm{kJ}}{\mathrm{kgK}}$, $\rho_{salt} = 1750\ \mathrm{kg/m^3}$ at 565°C

Hot Tank: $T = 565°\mathrm{C}$, Diameter = 23 m, Height = 14 m

Cold Tank: $T = 290°\mathrm{C}$, Diameter = 23 m, Height = 14 m

5

Steam Generator

Heat Exchanger: efficiency: 0.8

Condenser: outlet temperature = 320 K, outlet steam quality = 0%;
no pressure drop through condenser

Pump: adiabatic, outlet temperature = 325 K

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6 7 8

PowerBlock

Turbine: Siemens SST-600

adiabatic, outlet steam quality = 92.5 %

SST-600

up to 150MW

The SST-600 is a single-casing turbine with front admission, geared or with direct drive; suited to both generator and mechanical drives. Used for tailor-made applications for most complex processes in industry and power generation.

Technical data

- Power output up to 150MW
- Inlet pressure up to 165bar/2,393psi
- Inlet temperature up to 565°C/1,049°F
- Rotational speed 3,000–18,000rpm
- Up to 2 controlled extraction with pressure up to 72bar/1,044psi
- Up to 7 bleeds at various pressure levels
- Exhaust pressure (back pressure) up to 72bar/1,044psi or condensing
- Exhaust area 0.2–8.0m²/1.9–38sq.ft.

"The plant Gemasolar uses a Siemens SST-600 Turbine with an inlet pressure of 100 bar and an inlet temperature of 542°C" (Fact sheet: "Steam turbines for CSP plants", Siemens)

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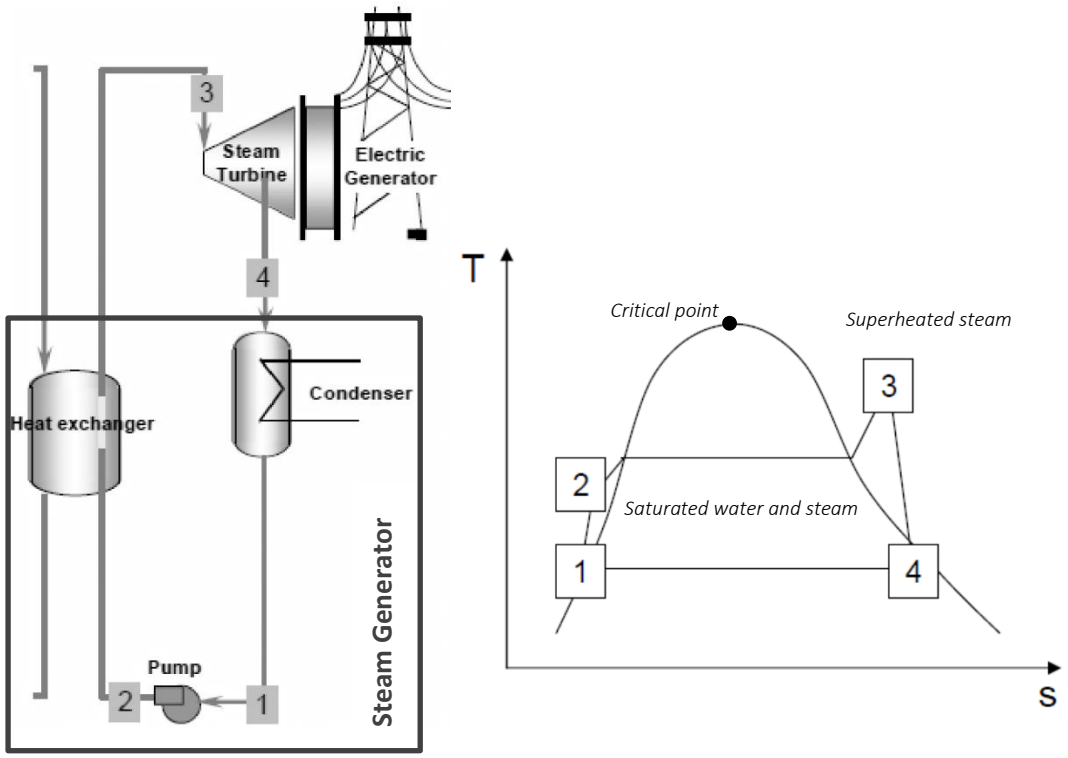
Rankine Cycle

The Rankine cycle, in the form of a steam engine is used to generate electric power in solar thermal, biomass, coal and nuclear power plants.



Process 1-2: The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage, the pump requires little input energy.

Process 2-3: The high pressure liquid enters a heat exchanger where it is heated at a constant pressure to become dry saturated vapor and then superheated steam.

Process 3-4: The superheated steam expands through a turbine, generating power. This decreases the temperature and pressure of the vapor, and some condensation occurs.

Process 4-1: The wet vapor then enters a condenser where it is condensed at a constant pressure to saturated water.

Table 5. Properties of Saturated Water and Steam (Pressure)

Press. MPa	Temp. t (°C)	Volume, m^3/kg v_L	v_V	Enthalpy, kJ/kg h_L	h_V	Entropy, kJ/(kg•K) s_L	s_V	Press. MPa
0.001	6.97	0.0010001	129.18	29.298	2513.7	0.1059	8.9749	**0.001**
0.002	17.50	0.0010014	66.990	73.435	2532.9	0.2606	8.7227	**0.002**
0.003	24.08	0.0010028	45.655	100.99	2544.9	0.3543	8.5766	**0.003**
0.004	28.96	0.0010041	34.792	121.40	2553.7	0.4224	8.4735	**0.004**
0.005	32.88	0.0010053	28.186	137.77	2560.8	0.4763	8.3939	**0.005**
0.006	36.16	0.0010064	23.734	151.49	2566.7	0.5209	8.3291	**0.006**
0.007	39.00	0.0010075	20.525	163.37	2571.8	0.5591	8.2746	**0.007**
0.008	41.51	0.0010085	18.099	173.85	2576.2	0.5925	8.2274	**0.008**
0.009	43.76	0.0010094	16.200	183.26	2580.3	0.6223	8.1859	**0.009**
0.010	45.81	0.0010103	14.671	191.81	2583.9	0.6492	8.1489	**0.010**
0.012	49.42	0.0010119	12.359	206.91	2590.3	0.6963	8.0850	**0.012**
0.014	52.55	0.0010133	10.691	219.99	2595.8	0.7366	8.0312	**0.014**
0.016	55.31	0.0010147	9.4309	231.55	2600.7	0.7720	7.9847	**0.016**
0.018	57.80	0.0010160	8.4433	241.95	2605.0	0.8035	7.9437	**0.018**
0.020	60.06	0.0010171	7.6482	251.40	2608.9	0.8320	7.9072	**0.020**
0.025	64.96	0.0010198	6.2034	271.93	2617.4	0.8931	7.8302	**0.025**
0.030	69.10	0.0010222	5.2286	289.23	2624.6	0.9439	7.7675	**0.030**
0.035	72.68	0.0010244	4.5252	304.25	2630.7	0.9876	7.7146	**0.035**
0.040	75.86	0.0010264	3.9931	317.57	2636.1	1.0259	7.6690	**0.040**
0.045	78.71	0.0010282	3.5761	329.55	2640.9	1.0601	7.6288	**0.045**
0.05	81.32	0.0010299	3.2401	340.48	2645.2	1.0910	7.5930	**0.05**
0.06	85.93	0.0010331	2.7318	359.84	2652.9	1.1452	7.5311	**0.06**
0.07	89.93	0.0010359	2.3649	376.68	2659.4	1.1919	7.4790	**0.07**
0.08	93.49	0.0010385	2.0872	391.64	2665.2	1.2328	7.4339	**0.08**
0.09	96.69	0.0010409	1.8695	405.13	2670.3	1.2694	7.3942	**0.09**
0.10	99.61	0.0010431	1.6940	417.44	2674.9	1.3026	7.3588	**0.10**
0.12	104.78	0.0010473	1.4284	439.30	2683.1	1.3608	7.2976	**0.12**
0.14	109.29	0.0010510	1.2366	458.37	2690.0	1.4109	7.2460	**0.14**
0.16	113.30	0.0010544	1.0914	475.34	2696.0	1.4549	7.2014	**0.16**
0.18	116.91	0.0010576	0.97753	490.67	2701.4	1.4944	7.1620	**0.18**
0.20	120.21	0.0010605	0.88574	504.68	2706.2	1.5301	7.1269	**0.20**
0.25	127.41	0.0010672	0.71870	535.35	2716.5	1.6072	7.0524	**0.25**
0.30	133.53	0.0010732	0.60579	561.46	2724.9	1.6718	6.9916	**0.30**
0.35	138.86	0.0010786	0.52420	584.31	2732.0	1.7275	6.9401	**0.35**
0.40	143.61	0.0010836	0.46239	604.72	2738.1	1.7766	6.8954	**0.40**
0.45	147.91	0.0010882	0.41390	623.22	2743.4	1.8206	6.8560	**0.45**
0.50	151.84	0.0010926	0.37480	640.19	2748.1	1.8606	6.8206	**0.50**
0.55	155.46	0.0010967	0.34259	655.88	2752.3	1.8972	6.7885	**0.55**
0.60	158.83	0.0011006	0.31558	670.50	2756.1	1.9311	6.7592	**0.60**
0.65	161.99	0.0011044	0.29258	684.22	2759.6	1.9626	6.7321	**0.65**
0.70	164.95	0.0011080	0.27276	697.14	2762.7	1.9921	6.7070	**0.70**
0.80	170.41	0.0011148	0.24033	721.02	2768.3	2.0460	6.6615	**0.80**
0.90	175.36	0.0011212	0.21487	742.72	2773.0	2.0944	6.6212	**0.90**
1.00	179.89	0.0011272	0.19435	762.68	2777.1	2.1384	6.5850	**1.00**
1.10	184.07	0.0011330	0.17744	781.20	2780.7	2.1789	6.5520	**1.10**

Table 6. Superheated Steam – SI Units

Pressure MPa (Sat. T)		Temperature—Degrees Celsius 300	325	350	375	400	450	500	550	600	650	700	750	800
7.0	*v*	0.0295	0.0326	0.0353	0.0377	0.0400	0.0442	0.0482	0.0520	0.0557	0.0593	0.0628	0.0664	0.0698
(285.83)	*h*	2839.8	2935.5	3016.8	3090.4	3159.1	3288.2	3411.3	3531.5	3650.6	3769.4	3888.5	4008.1	4128.6
	s	5.9335	6.0970	6.2303	6.3460	6.4501	6.6351	6.7997	6.9505	7.0909	7.2232	7.3488	7.4687	7.5837
7.5	*v*	0.0267	0.0298	0.0325	0.0348	0.0370	0.0410	0.0448	0.0483	0.0518	0.0552	0.0586	0.0619	0.0651
(290.54)	*h*	2814.3	2917.4	3002.7	3078.8	3149.3	3280.7	3405.3	3526.7	3646.5	3765.9	3885.4	4005.5	4126.3
	s	5.8644	6.0407	6.1805	6.3002	6.4070	6.5954	6.7620	6.9141	7.0555	7.1885	7.3145	7.4348	7.5501
8.0	*v*	0.0243	0.0274	0.0300	0.0323	0.0343	0.0382	0.0418	0.0452	0.0485	0.0517	0.0548	0.0579	0.0610
(295.01)	*h*	2786.4	2898.3	2988.1	3066.9	3139.3	3273.2	3399.4	3521.8	3642.4	3762.4	3882.4	4002.9	4124.0
	s	5.7935	5.9849	6.1319	6.2560	6.3657	6.5577	6.7264	6.8798	7.0221	7.1557	7.2823	7.4030	7.5186
8.5	*v*	0.0220	0.0252	0.0278	0.0300	0.0320	0.0357	0.0391	0.0424	0.0455	0.0485	0.0515	0.0545	0.0574
(299.27)	*h*	2755.4	2878.3	2972.9	3054.7	3129.1	3265.6	3393.4	3516.9	3638.3	3758.9	3879.4	4000.2	4121.7
	s	5.7193	5.9294	6.0845	6.2132	6.3259	6.5216	6.6925	6.8473	6.9905	7.1248	7.2519	7.3730	7.4889
9.0	*v*		0.0233	0.0258	0.0280	0.0300	0.0335	0.0368	0.0399	0.0429	0.0458	0.0486	0.0514	0.0541
(303.35)	*h*		2857.0	2957.2	3042.2	3118.8	3257.9	3387.3	3511.9	3634.2	3755.4	3876.4	3997.6	4119.4
	s		5.8736	6.0378	6.1716	6.2875	6.4871	6.6601	6.8163	6.9605	7.0955	7.2231	7.3446	7.4608
9.5	*v*		0.0215	0.0240	0.0262	0.0281	0.0316	0.0347	0.0377	0.0405	0.0433	0.0460	0.0486	0.0512
(307.25)	*h*		2834.4	2940.9	3029.4	3108.2	3250.2	3381.2	3506.9	3630.0	3751.9	3873.3	3994.9	4117.0
	s		5.8170	5.9917	6.1309	6.2502	6.4538	6.6291	6.7867	6.9319	7.0676	7.1957	7.3176	7.4341
10.0	*v*		0.0199	0.0224	0.0246	0.0264	0.0298	0.0328	0.0357	0.0384	0.0410	0.0436	0.0461	0.0486
(311.00)	*h*		2810.2	2924.0	3016.2	3097.4	3242.3	3375.1	3501.9	3625.8	3748.3	3870.3	3992.3	4114.7
	s		5.7593	5.9458	6.0910	6.2139	6.4217	6.5993	6.7584	6.9045	7.0409	7.1696	7.2918	7.4086
11.0	*v*		0.0170	0.0196	0.0217	0.0235	0.0267	0.0296	0.0322	0.0347	0.0371	0.0395	0.0418	0.0441
(318.08)	*h*		2755.6	2887.8	2988.7	3075.1	3226.2	3362.6	3491.9	3617.5	3741.2	3864.2	3987.0	4110.1
	s		5.6373	5.8541	6.0129	6.1438	6.3605	6.5430	6.7050	6.8531	6.9910	7.1207	7.2437	7.3612
12.0	*v*		0.0143	0.0172	0.0193	0.0211	0.0242	0.0268	0.0293	0.0317	0.0339	0.0361	0.0383	0.0404
(324.68)	*h*		2688.4	2848.0	2959.5	3051.9	3209.8	3350.0	3481.7	3609.0	3734.1	3858.0	3981.6	4105.4
	s		5.4988	5.7607	5.9362	6.0762	6.3027	6.4902	6.6553	6.8055	6.9448	7.0756	7.1994	7.3175
13.0	*v*			0.0151	0.0173	0.0190	0.0220	0.0245	0.0269	0.0291	0.0312	0.0332	0.0352	0.0372
(330.86)	*h*			2803.6	2928.3	3027.6	3192.9	3337.1	3471.4	3600.5	3726.9	3851.9	3976.3	4100.7
	s			5.6635	5.8600	6.0104	6.2475	6.4404	6.6087	6.7610	6.9018	7.0336	7.1583	7.2771
14.0	*v*			0.0132	0.0155	0.0172	0.0201	0.0225	0.0248	0.0268	0.0288	0.0308	0.0326	0.0345
(336.67)	*h*			2752.9	2894.9	3002.2	3175.6	3324.1	3461.0	3591.9	3719.7	3845.7	3970.9	4096.0
	s			5.5595	5.7832	5.9457	6.1945	6.3931	6.5648	6.7192	6.8615	6.9944	7.1200	7.2393
15.0	*v*			0.0115	0.0139	0.0157	0.0185	0.0208	0.0229	0.0249	0.0268	0.0286	0.0304	0.0321
(342.16)	*h*			2693.0	2858.9	2975.5	3157.8	3310.8	3450.5	3583.3	3712.4	3839.5	3965.6	4091.3
	s			5.4435	5.7049	5.8817	6.1433	6.3479	6.5230	6.6797	6.8235	6.9576	7.0839	7.2039
16.0	*v*			0.0098	0.0125	0.0143	0.0170	0.0193	0.0214	0.0232	0.0250	0.0267	0.0284	0.0301
(347.36)	*h*			2617.0	2819.5	2947.5	3139.6	3297.3	3439.8	3574.6	3705.1	3833.3	3960.2	4086.6
	s			5.3045	5.6238	5.8177	6.0935	6.3045	6.4832	6.6422	6.7876	6.9228	7.0499	7.1706
17.0	*v*				0.0112	0.0130	0.0158	0.0180	0.0199	0.0218	0.0235	0.0251	0.0267	0.0282
(352.29)	*h*				2775.9	2917.8	3120.9	3283.6	3429.1	3565.9	3697.8	3827.0	3954.8	4081.9
	s				5.5384	5.7533	6.0449	6.2627	6.4451	6.6064	6.7534	6.8897	7.0178	7.1391
18.0	*v*				0.0100	0.0119	0.0147	0.0168	0.0187	0.0204	0.0221	0.0236	0.0251	0.0266
(356.99)	*h*				2726.9	2886.3	3101.7	3269.7	3418.3	3557.0	3690.4	3820.7	3949.4	4077.2
	s				5.4465	5.6881	5.9973	6.2222	6.4085	6.5722	6.7208	6.8583	6.9872	7.1091

v = specific volume, m^3/kg *h* = enthalpy, kJ/kg *s* = entropy, kJ/(kg•K)

Table: Solar irradiance for an average day in June. Sevilla Spain

Site latitude 37.37; Site longitude -5.98; Elevation 13 m

Provider: MINES ParisTech; http://www.soda-is.com/eng/

Time [h]	Irradiance [W/m^2]
1	0
2	0
3	0
4	0
5	0
6	32
7	144
8	360
9	593
10	783
11	925
12	1007
13	885
14	671
15	816
16	664
17	550
18	311
19	100
20	16
21	0
22	0
23	0
24	0