SOLAIR
Increasing the Market Implementation of Solar Air-Conditioning Systems for Small and Medium Applications in Residential and Commercial Buildings
Intelligent Energy Europe

Solar Thermal Systems
in residences & swimming pools

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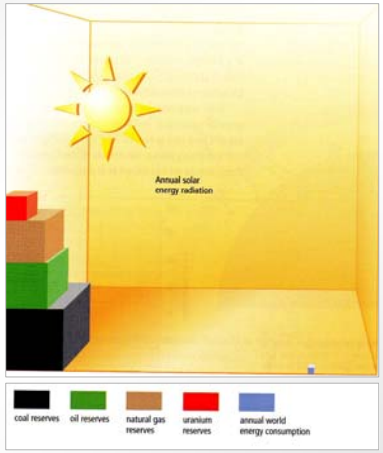
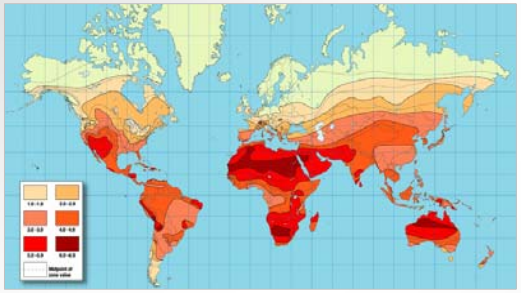
Energy resources

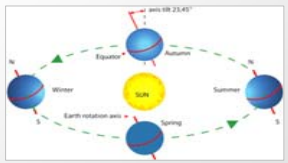
- Available resources of fossil fuels (coal, oil, natural gas and uranium) are being consumed at an ever-increasing rate
- **Stocks are finite**; thus rational use of energy is required.
- However, **radiation** supply from sun carries a **5 billion year guarantee**
- Annually, **the sun provides 1.5*10^{18} kWh**, that is more than 10,000 times the energy that human race needs.



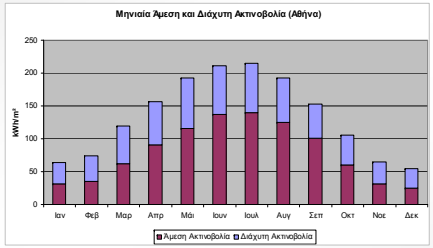
Average annual solar irradiance is an important value for designing a solar plant. It depends on the geographical location, i.e. Saharan desert has 2.2 times higher radiation that Europe.



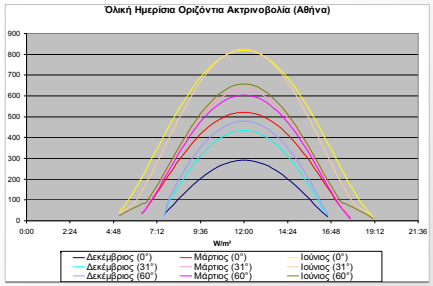
The **average solar irradiance is higher at lower latitudes**, since the rotation axis of the earth forms an angle of 23.45^0 with the perpendicular.



- Annual solar irradiance (sum of direct and diffuse) in Greece is approximately **1,600 kWh/m^2**.
- This amount of energy, corresponds to **160 lt oil.**



- Daily solar irradiance for 3 representative dates (in winter, summer and spring) is shown in the next diagram.
- The area that receives the biggest amount of radiation has an inclination of **60^0 in December** and **0^0 in June**.



Optimum collector angle

It depends on the geographical location and the system's type of use.

- **Winter use**: geographical latitude of area **+ 15⁰**
- **Summer use**: geographical latitude of area **- 15⁰**
- **Annual use**: collector angle **= geographical latitude**

RESULTS OF INCIDENT RADIATION ON COLLECTORS (FROM TSOL)
Place: Athens
Azimuth: 0

G Inclined, Specific[kWh/m²]
acording to collectors inclination (in degrees °)

From:	To:	0	10	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
1/ 1/	1/ 2/	66	80	91	96	100	104	107	109	111	112	113	112	111	109	107	104	100
1/ 2/	1/ 3/	75	84	91	93	96	97	99	99	99	99	98	96	94	91	88	84	80
1/ 3/	1/ 4/	104	112	116	118	119	119	119	118	116	114	111	108	104	99	94	89	83
1/ 4/	1/ 5/	146	151	152	152	151	149	147	143	139	134	129	123	116	108	101	92	84
1/ 5/	1/ 6/	182	183	181	178	175	170	165	159	153	145	137	128	119	109	100	90	79
1/ 6/	1/ 7/	200	200	195	191	185	180	173	166	158	149	139	128	118	108	96	85	75
1/ 7/	1/ 8/	213	214	210	205	199	194	187	180	171	162	151	139	128	117	105	91	80
1/ 8/	1/ 9/	200	206	206	204	202	199	194	188	182	174	165	155	144	132	121	109	96
1/ 9/	1/10/	156	168	176	179	180	181	180	178	175	171	166	161	154	146	138	128	118
1/10/	1/11/	106	120	130	134	138	140	142	143	142	142	140	137	134	130	125	119	113
1/11/	1/12/	66	77	86	90	94	96	99	100	101	102	102	101	99	97	95	92	88
1/12/	1/ 1/	53	63	72	76	79	82	85	87	88	89	89	89	88	87	85	83	80
	Sum YEAR	**1567**	**1658**	**1706**	**1716**	**1718**	**1711**	**1697**	**1670**	**1635**	**1593**	**1540**	**1477**	**1409**	**1334**	**1252**	**1165**	**1075**
hotels season:	**1/4 to 1/11**	**1203**	**1242**	**1250**	**1243**	**1230**	**1213**	**1188**	**1157**	**1120**	**1077**	**1027**	**971**	**913**	**850**	**784**	**714**	**645**
heating season:	**1/11 to 1/4**	**364**	**416**	**456**	**473**	**488**	**498**	**509**	**513**	**515**	**516**	**513**	**506**	**496**	**484**	**468**	**450**	**430**
"winter":	1/12 to 1/3	194	227	254	265	275	283	291	295	298	300	300	297	293	287	280	270	260

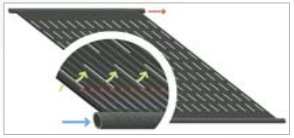
Collector type 1: Unglazed

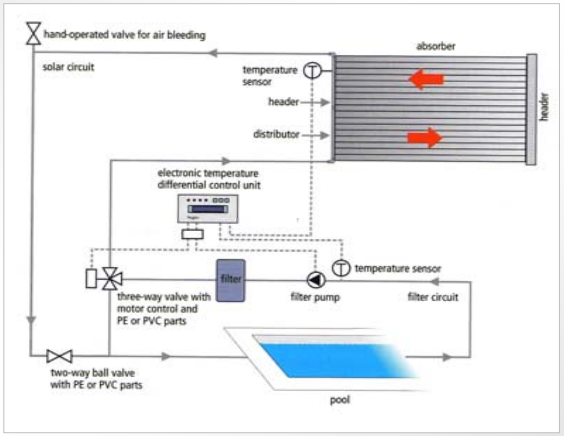
Properties

- No glazing, no insulation
- Low operation temperature
- Low cost, average payback time 1-5 years
- High thermal losses, low performance

Applications

- Pool heating only. Warm climates: to extend the swimming period from April-October.





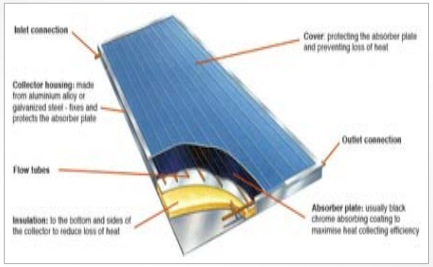
Collector type 2: Standard flat plate

Properties

- Middle cost: more expensive than unglazed, but cheaper than vacuum
- Higher operation temperature
- Thermal insulation on back & edges
- Fragile, heavier: 20-32 kg/m²
- Absorber: black paint or spectral-selective coating (black chrome, black nickel, blue titanium)
- Spectral-selective coating: conversion of short-wave solar radiation into heat (light absorption capacity) is optimized, while thermal emissions are kept low. Absorption rate: 90-95%, emission rate 5-15%
- Stagnation temperature: 160-200⁰C

Applications

- Space heating
- Solar air conditioning (selective coating)



Collector type 3: Vacuum

Properties

- High cost
- Almost zero convection thermal losses (tube pressure < 0.00001 bar)
- Low radiation losses
- High efficiency, even with low radiation
- Low weight
- Direct-flow: South-oriented,
- Heat-pipe: Dry connection (the heat transfer takes place from the condenser via the tube wall to the medium, so defective tubes are replaced without emptying the solar circuit) or Wet connection (the condenser is immersed in the medium, so defective tubes are replaced by emptying the solar circuit)
- Average annual efficiency 45-50% (with 1000kWh/m² irradiation, the energy yield is 450-500kWh/m²a
- Stagnation temperature: 200-350⁰C

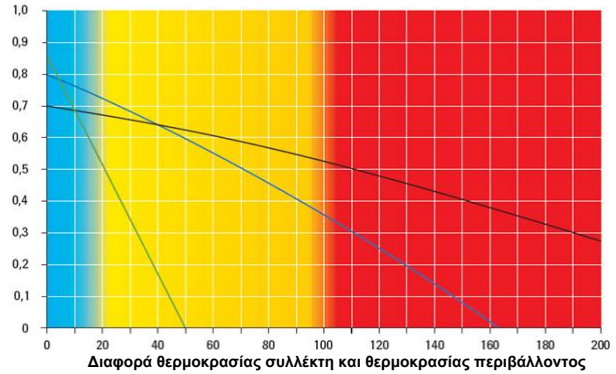
Applications

- Solar air conditioning
- Industrial applications (steam generation)

Collectors comparison

Collector type	Application	Performance (kWh/m²a)
Unglazed	Pool heating	300
Flat plate (black paint)	Pool heating, Hot water	650
Flat plate (selective coating)	Hot water, space heating, solar a/c	700
Vacuum	Solar a/c, industry	850

Performance



Solar Thermal systems

- **Thermosyphon**

No pumps, since gravity is used for liquid transport

- **Forced circulation**

Circulating pumps required, in Northern - Central Europe

- **Direct (drainback) system**

Direct circulation of domestic water through the collector, the heat transfer medium is pure water. When the collector pump is switched off, the collector drains completely.

- **Indirect (filled) system**

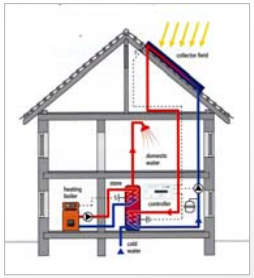
Solar circuit is separate from domestic water circuit, the heat transfer medium is water-glycol mixture. The collector circuit is partially or completely filled.

- **Open system**

Open container at the highest point of solar circuit, which absorbs the volumetric expansion of the liquid caused by T changes

- **Closed system**

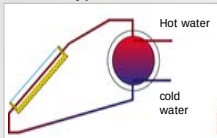
Operate at high pressures (1.5-10 bar), which influences the $T_{evaporation}$ of the liquid.



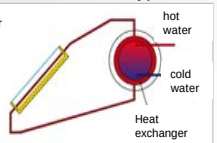
Environmental benefits

- 50-70kg savings in oil per m² collector.
- Reduction in CO_2 emissions > 750 kg/m² collector per year, when electricity is replaced.
- Reduction in CO_2 emissions > 250 kg/m² collector per year, when oil is replaced.

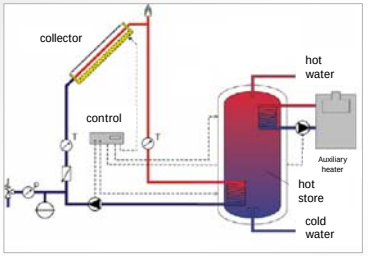
Thermosyphon direct



Thermosyphon Indirect

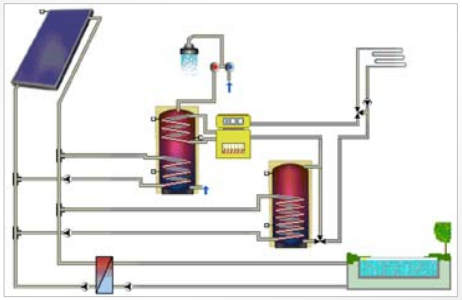


Forced circulation, indirect



Combi systems

- Pool heating, hot water and space heating
- Integration into existing fan coil units
- High energy saving potential
- Required collector field: 20% of space for 40-50% covering (i.e. 20m² flat plate selective for 100m² house).
- Applied in houses, hotels, hospitals, industry
- 100% covering with solar collectors & biomass



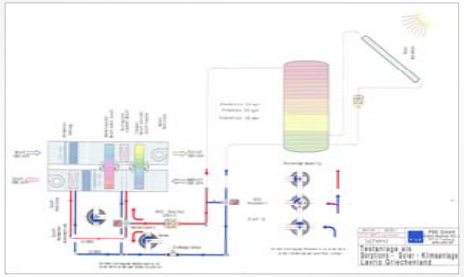
Solar air-conditioning systems

Method	Closed cycle		Open cycle	
Refrigereant cycle	Closed refrigerant cycle		Refrigerant (water) is in contact to the atmosphere	
Principle	Chilled water		Dehumidification of air and evaporative cooling	
Phase of sorbent	solid	liquid	solid	liquid
				
Typical material pairs	water - silica gel	water - lithium bromide ammonia - water	water - silica gel, water - lithium chloride	water - calcium chloride, water - lithium chloride
Market available technology	Adsorption chiller	Absorption chiller	Desiccant cooling	Close to market introduction
Typical cooling capacity (kW cold)	50 – 430 kW	15 kW – 5 MW	20 kW – 350 kW (per module)	
Typical COP	0.5 – 0.7	0.6 – 0.75 (single effect)	0.5 – >1	> 1
Driving temperature	60 – 90 °C	80 – 110 °C	45 – 95 °C	45 – 70 °C
Solar collectors	Vacuum tubes, flat plate collectors	Vacuum tubes	Flat plate collectors, solar air collectors	Flat plate collectors, solar air collectors

CRES Solar Cooling system in PENA

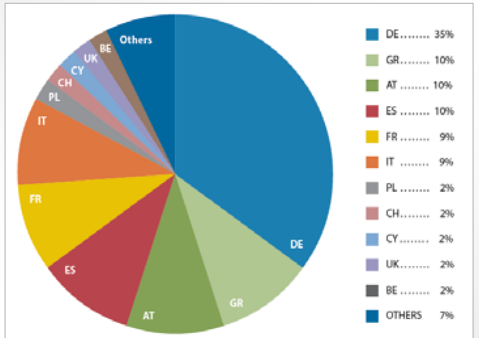
PENA, Lavrio
Solar cooling Solid DEC system
Demo & research application for CRES

In operation since	2007
Air conditioned area	84m²
Collector type	**10 m², Calpak flat-plate**
Collector fluid	water-glycol
Operation temperature	60°C
Nominal air flow rate	1100 m³/h
Min. air volume flow rate	373 m³/h
Desiccant cooling system	solid LiCl
Brand of desiccant unit	Klingenburg



Greek market share in Europe, 2007

- Concentration in the European market is decreasing
- **5 countries account for ¾ of the total** – just a few years ago the same share was held by Germany, Austria and Greece only
- **Greece accounts for 9-10%** of European sales.



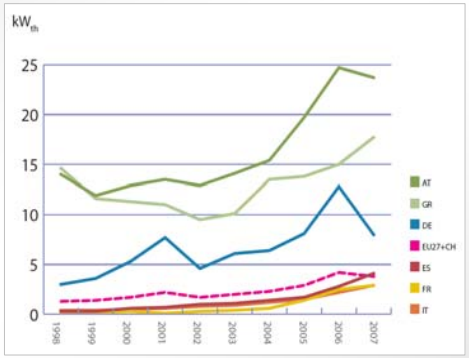
	In Operation²	Market (=Newly Installed)					Market Growth
	2007	2005	2006	2007			2007/2006
	Total Glazed m²	Total Glazed m²	Total Glazed m²	Total Glazed m²	Flat Plate m²	Vacuum Collectors m²	Total Glazed %
AT (Austria)	2 892 627	233 470	292 669	281 000	277 600	3 400	-4%
BE (Belgium)	146 118	20 234	35 636	42 000	37 000	5 000	18%
BG (Bulgaria)	25 100	2 000	2 200	2 500	-	-	14%
CH (Switzerland)	508 900	39 132	51 863	65 432	62 878	2 554	26%
CY (Cyprus)	625 200	50 000	60 000	65 000	-	-	8%
CZ (Czech Republic)	133 730	15 550	22 030	25 000	18 900	6 100	13%
DE (Germany)	8 994 000	950 000	1 500 000	940 000	840 000	100 000	-37%
DK (Denmark)	385 280	21 250	25 300	23 000	22 000	1 000	-9%
EE (Estonia)	1 470	250	300	350	-	-	17%
ES (Spain)	964 166	106 800	175 000	262 000	257 000	11 000	50%
FI (Finland)	28 493	2 383	3 200	4 000	3 000	1 000	25%
FR (France)	870 600	121 500	220 000	255 000	243 000	12 000	16%
GR (Greece)	3 570 200	220 500	240 000	283 000	279 000	4 000	18%
HU (Hungary)	14 250	1 000	1 000	8 000	6 000	2 000	700%
IE (Ireland)	30 790	3 500	5 000	15 000	10 000	5 000	200%
IT (Italy)	1 100 230	127 859	186 000	245 000	210 000	35 000	32%
LT (Lithuania)	3 450	500	600	700	-	-	17%
LU (Luxemburg)	18 900	1 900	2 500	3 000	-	-	20%
LV (Latvia)	5 350	1 000	1 200	1 500	-	-	25%
MT (Malta)	29 360	4 000	4 500	5 500	-	-	22%
NL (Netherlands)	338 341	20 248	14 685	19 900	17 900	2 000	36%
PL (Poland)	234 897	27 700	41 400	67 000	44 000	23 000	62%
PT (Portugal)	285 950	16 000	20 000	25 000	22 000	3 000	25%
RO (Romania)	69 600	400	400	500	-	-	25%
SE (Sweden)	262 394	22 621	28 539	25 465	15 554	9 911	-11%
SI (Slovenia)	121 100	4 800	6 900	12 000	10 300	1 700	74%
SK (Slovakia)	81 750	7 500	8 500	9 000	7 740	1 260	6%
UK (United Kingdom)	384 920	28 000	54 000	54 000	27 000	27 000	0%
EU27 + CH	21 957 446	2 049 297	3 003 422	2 739 847	-	-	-9%

Greece

- **3,570,200 m² in operation**
- **283,000 m² newly installed glazed**
  - 279,000 m² flat plates
  - 4,000 m² vacuum

Newly Installed Capacity per Capita in Europe, 2007

- **EU average:**
- **3.8 kWth** /1.000 capita.
- **Greece: steady increase**
- **17,7 kWth** /1.000 capita
- **4.5 times the EU average**.
- Austria: big advance
- 23,7 kWth /1.000 capita (6 times the EU average, 3 times the Germany)
- France and Italy: 2,9 kWth per 1.000 capita.



Solar Thermal Capacity in Operation per Capita in Europe, 2007

- **Cyprus is 1st: 562 kWth** in operation per 1.000 capita
- **Greece is 3rd** (in 2001 was first)
- **EU average: 30,7 kWth** /1.000 capita.
- Austria shows the rest what is possible: 244 kWth/1.000 capita, 8 times the EU average.

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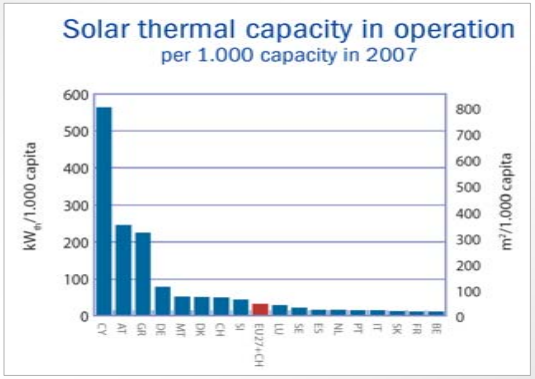
The figures relate to all installations built in the past and deemed to be still in operation (ESTIF assumes a life-time of 20 year for systems installed after 1989) and to today's size of the population.



Conclusions

- DHWS systems in small residential units are quite widespread
  - 80% of solar thermal market
- However, there is **large growth potential**, because
  - only 25% of the buildings are equipped with such a system
  - >90% of the owners are satisfied
- Instead of showing saturation, these developed market segments show **high level of new installations** per inhabitant, even in unfavourable times
- **Solar Cooling is not yet widespread**
  - 8% of the solar thermal market
  - lack of real incentives

Law modernization

solar thermal systems project study compulsory for every building

Financial incentives

to cover part of investment & construction costs

Thank you for your attention!

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SOLAIR Project Webpage
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SOLPOOL Project Webpage
http://www.solpool.info