

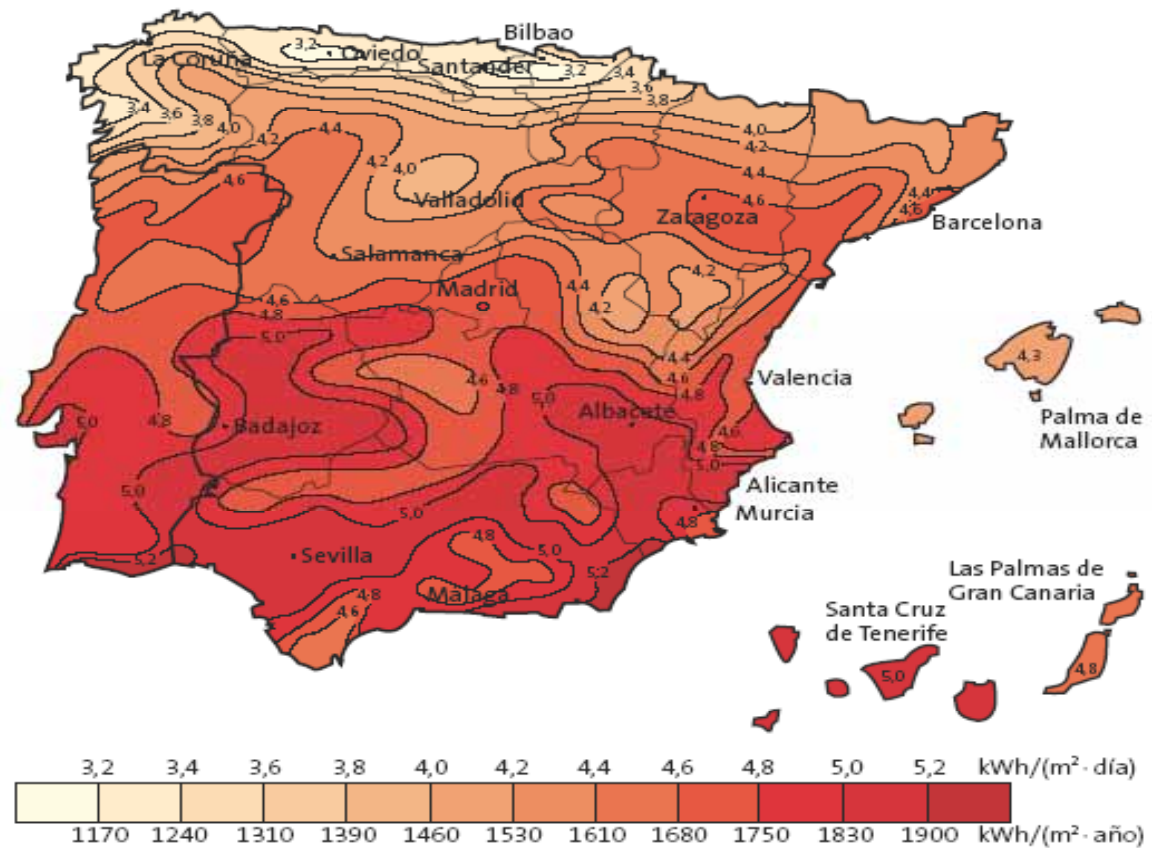
# SWH system sizing

Xavier Vallvé, TTA  
Spain

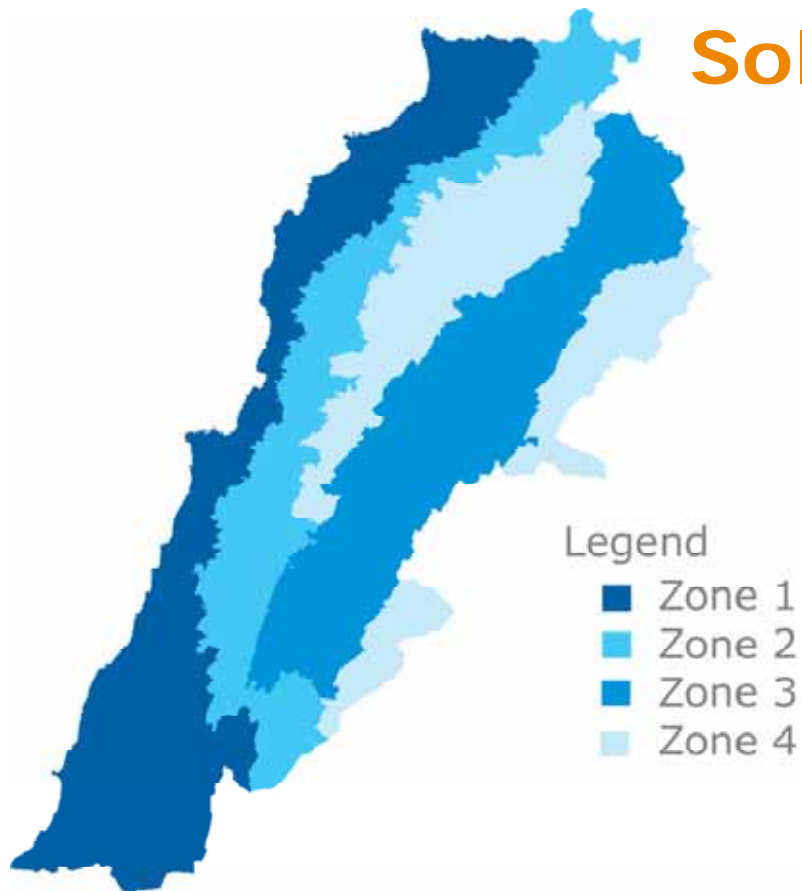


# Solar radiation

Example of a solar map:  
Spain (unit: kWh/m<sup>2</sup> day)



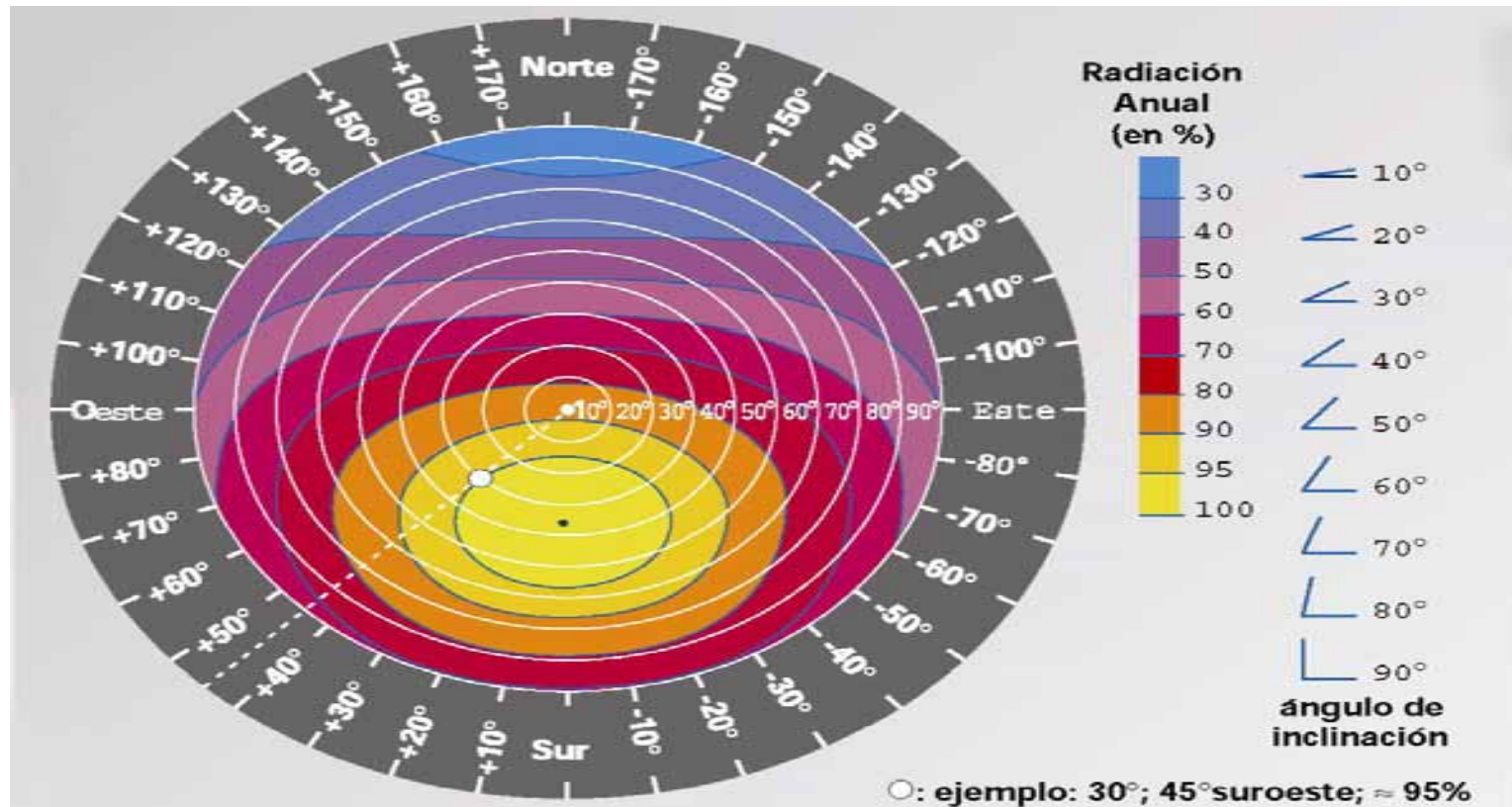
# Solar radiation



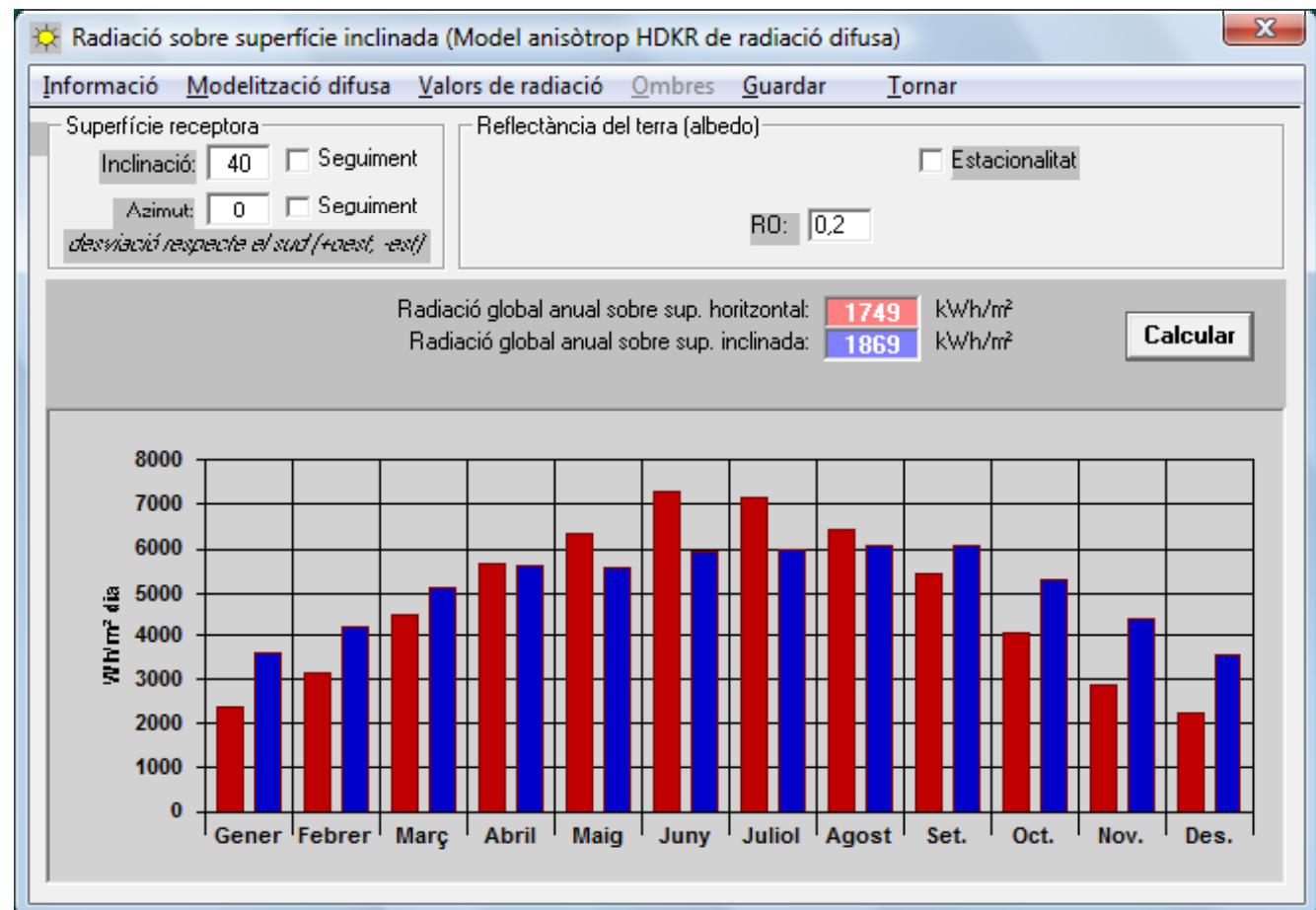
Climatic zones in Lebanon  
and solar radiation

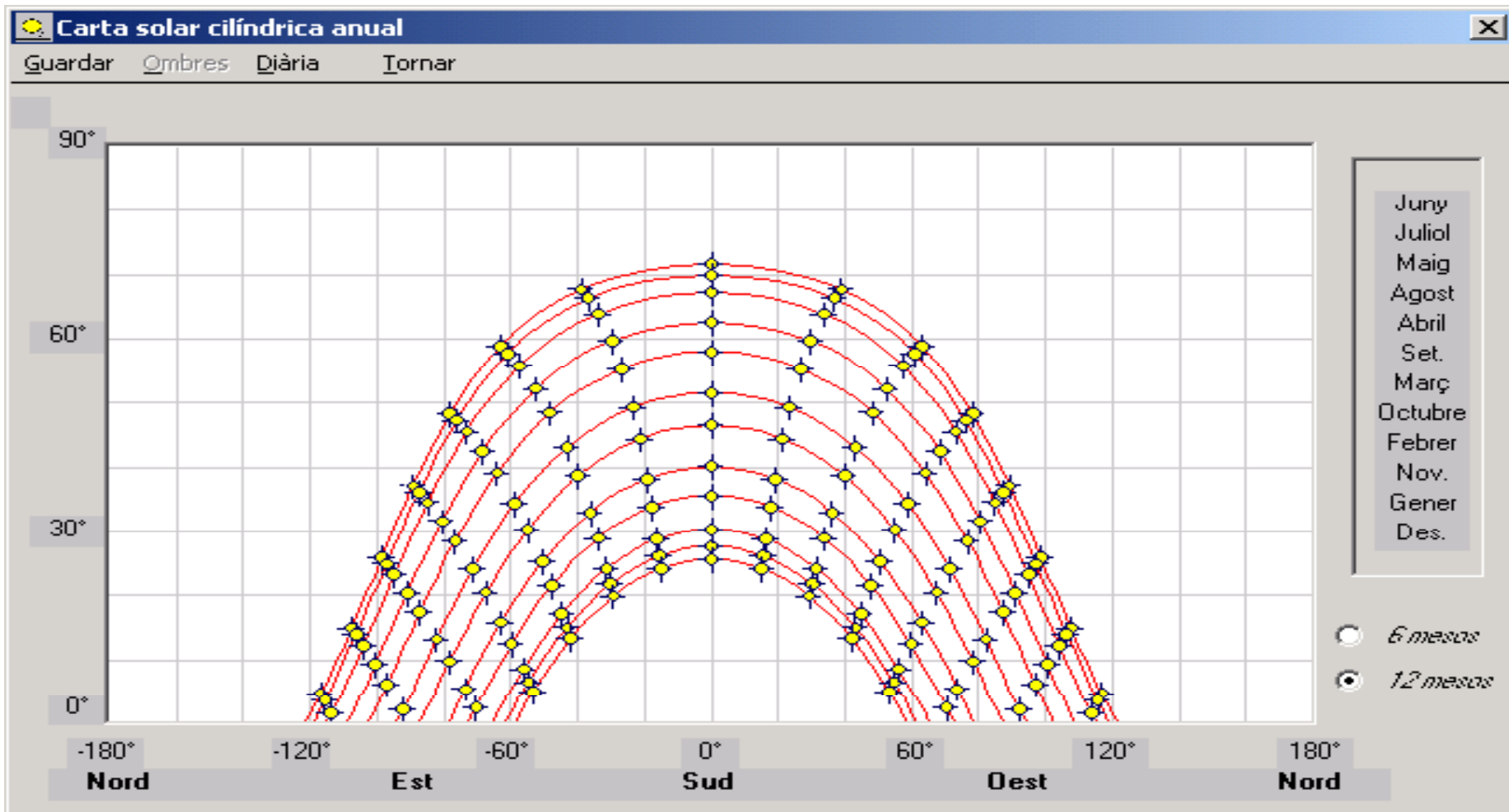
Solar radiation incident at 40° (kWh/m <sup>2</sup> mean average monthly day)				
	Tripoli	Nabatiye et Tahta	Zahlé	Beirut
	34°20'37" North, 36°0'25" East, Elevation: 1382 m.s.m	33°22'59" North, 35°26'59" East, Elevation: 403 m.s.m	33°50'34" North, 35°55'8" East, Elevation: 935 m.s.m	33°52'57" North, 35°30'46" East, Elevation: 61 m.s.m
Jan	3.536	3.598	3.809	3.488
Feb	4.225	4.230	4.484	4.117
Mar	5.162	5.204	5.250	5.057
Apr	5.552	5.716	5.925	5.544
May	5.661	5.697	5.713	5.537
Jun	6.194	6.094	6.151	5.917
Jul	6.258	6.162	6.243	5.998
Aug	6.299	6.194	6.313	6.033
Sep	6.170	6.129	6.354	5.895
Oct	5.219	5.282	5.383	5.055
Nov	4.002	4.314	4.240	4.091
Dec	3.213	3.532	3.600	3.309
Año	5.128	5.183	5.291	5.007
Hp year	5,13	5,18	5,29	5,01
HP average	5,15			

# SHWS orientation and tilt



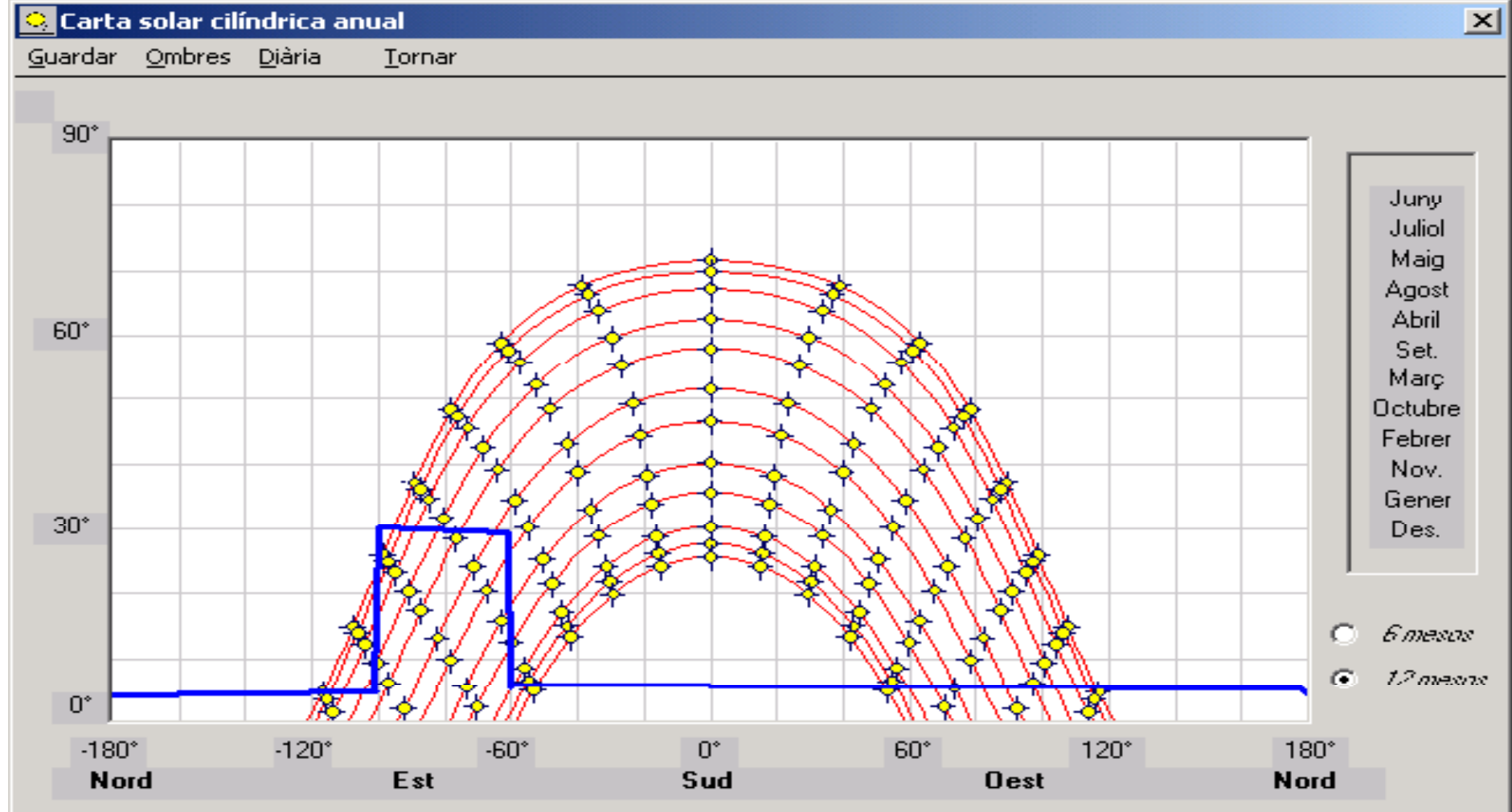
# Radiation incidence at horizontal and tilted surface





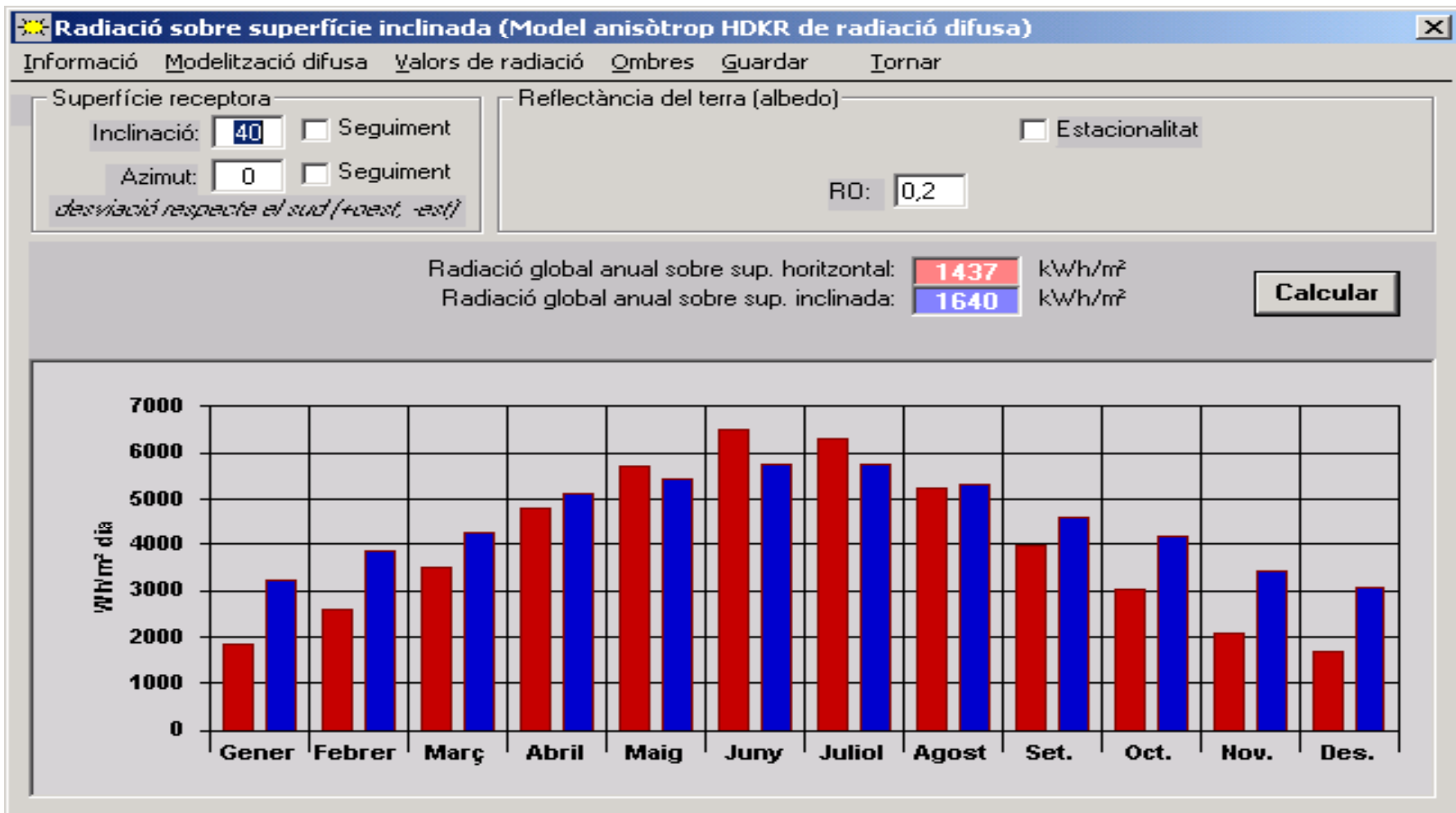
# Solar radiation: Shadow

CEDRO



# Solar radiation: Shadow

CEDRO





## Solar radiation: Shadow



# Dependence on orientation and tilt



<i>Radiación solar incidente sobre superficies inclinadas (Wh/m<sup>2</sup> x día)</i>													<i>Localidad: Barcelona</i>	<i>Latitud: 41,2°</i>
<i>Azimut: 0°</i>														
<b>Angulo</b>	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	ANUAL	
0°	2.190	2.824	3.744	4.806	5.470	6.163	6.446	5.551	4.139	3.067	2.153	1.643	1.468.329	
5°	2.476	3.081	3.941	4.919	5.498	6.147	6.453	5.641	4.306	3.302	2.408	1.871	1.524.265	
10°	2.764	3.320	4.116	5.007	5.501	6.105	6.431	5.702	4.474	3.518	2.650	2.088	1.573.746	
15°	3.035	3.540	4.268	5.067	5.478	6.038	6.380	5.734	4.566	3.713	2.876	2.293	1.613.490	
20°	3.288	3.739	4.395	5.101	5.430	5.944	6.298	5.736	4.658	3.888	3.085	2.484	1.645.370	
25°	3.520	3.916	4.496	5.106	5.355	5.822	6.187	5.707	4.724	4.038	3.275	2.660	1.668.322	
30°	3.730	4.068	4.572	5.084	5.253	5.674	6.046	5.647	4.762	4.165	3.445	2.820	1.682.096	
<b>35°</b>	3.916	4.196	4.621	5.034	5.127	5.501	5.875	5.557	4.773	4.267	3.593	2.962	1.686.608	
40°	4.076	4.298	4.643	4.957	4.977	5.303	5.677	5.438	4.756	4.342	3.719	3.085	1.681.750	
<b>45°</b>	4.210	4.372	4.637	4.853	4.803	5.081	5.453	5.289	4.713	4.391	3.821	3.189	1.667.566	
50°	4.316	4.420	4.604	4.723	4.606	4.838	5.203	5.114	4.642	4.414	3.898	3.272	1.644.210	
55°	4.394	4.440	4.544	4.568	4.390	4.576	4.931	4.912	4.544	4.409	3.951	3.334	1.611.802	
60°	4.442	4.432	4.457	4.390	4.154	4.296	4.639	4.685	4.421	4.377	3.978	3.374	1.570.673	
65°	4.461	4.396	4.345	4.188	3.903	4.003	4.329	4.436	4.273	4.319	3.980	3.392	1.521.154	
70°	4.451	4.333	4.208	3.967	3.636	3.696	4.004	4.166	4.102	4.234	3.956	3.369	1.463.679	
75°	4.411	4.243	4.046	3.726	3.358	3.382	3.667	3.879	3.908	4.123	3.906	3.363	1.398.756	
80°	4.342	4.126	3.862	3.468	3.071	3.063	3.323	3.575	3.694	3.988	3.832	3.316	1.327.021	
85°	4.245	3.984	3.656	3.196	2.779	2.743	2.976	3.259	3.460	3.829	3.733	3.247	1.249.186	
90°	4.119	3.818	3.431	2.912	2.484	2.428	2.630	2.933	3.208	3.647	3.610	3.157	1.166.107	

Yearly highest solar radiation

Optimal tilt for regular hot water consumptions

## Dependence on orientation and tilt

In Lebanon,

Optimal tilt for maximal year round production : around  $27^{\circ}$  to  $35^{\circ}$

Optimal tilt for regular hot water consumptions : around  $39^{\circ}$  to  $45^{\circ}$

---

## Hot water consumption

Hot water demand is the largest uncertainty in the design process!  
 Consumption values adopted for SHW CEDRO sizing (l/day):

Type of HW consumer	Liters of HW at 60°C	
Single-family house	30	person
Multifamily house	22	person
Hospitals and clinics	55	bed
Hotel ****	70	bed
Hotel ***	55	bed
Hotel **	40	bed
Residence (students/ old people)	55	bed
Shower room	15	service
Schools	3	pupil
Sport Arena	20	person
Restaurants	5 to 10	service

# Reference Data

**CEDRO**

 Natural Resources Canada / Ressources naturelles Canada

Canada



**RETScreen® International**  
www.retscreen.net

*Clean Energy Project Analysis Software*

## Project information

[See project database](#)

Project name   
Project location

Prepared for   
Prepared by

Project type

Technology

Analysis type

Heating value reference

Show settings

---

## Site reference conditions

[Select climate data location](#)

Climate data location

Show data

---

# Climatic Data



RETScreen ✖

Country - region: Lebanon | Province / State: n/a | Climate data location: Beirut (CivMil)

Latitude: 33,8 °N | Longitude: 35,5 °E | Elevation: 19 m | Heating design temperature: 8,8 °C | Cooling design temperature: 30,7 °C | Earth temperature amplitude: 17,1 °C

Source: NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	13,3	66,8%	2,31	101,6	3,1	12,1	146	102
Feb	13,7	65,1%	3,19	101,4	3,6	12,8	120	104
Mar	15,2	65,8%	4,38	101,3	3,3	15,6	87	161
Apr	18,0	66,0%	5,50	101,1	3,4	20,5	0	240
May	20,7	71,2%	6,46	101,0	3,1	24,8	0	332
Jun	23,5	70,9%	7,21	100,8	3,5	28,2	0	405
Jul	25,7	71,9%	7,02	100,5	3,9	30,9	0	487
Aug	26,6	70,2%	6,42	100,6	3,3	31,4	0	515
Sep	25,5	65,4%	5,38	100,9	3,1	29,3	0	465
Oct	22,7	62,3%	4,25	101,2	2,8	24,6	0	394
Nov	18,7	60,6%	3,00	101,4	3,1	18,6	0	261
Dec	15,1	65,1%	2,32	101,6	3,0	13,9	90	158
Annual	19,9	66,8%	4,79	101,1	3,3	21,9	443	3.623
Source	Ground	Ground	Ground	Ground	Ground	NASA	Ground	Ground

Measured at: m | 10 | 0

# HW production: required energy



## RETScreen Energy Model - Heating project

### Heating project

Technology

Solar water heater

#### Load characteristics

Application

- Swimming pool  
 Hot water

	Unit	Base case	Proposed case
Load type		Hospital	
Number of units	Bed	40	
Occupancy rate	%	100%	
Daily hot water use - estimated	L/d	7.874	
Daily hot water use	L/d	2.200	2.200
Temperature	°C	60	60
Operating days per week	d	7	7

#### Percent of month used

Supply temperature method

Formula

Water temperature - minimum

°C 17,8

Water temperature - maximum

°C 22,3

	Unit	Base case	Proposed case
Heating	MWh	37,5	37,5



# Solar collector characterisation



## Solar water heater

Type  
 Manufacturer  
 Model  
 Gross area per solar collector  
 Aperture area per solar collector  
 Fr (tau alpha) coefficient  
 Fr UL coefficient  
 Temperature coefficient for Fr UL  
 Number of collectors  
 Solar collector area  
 Capacity  
 Miscellaneous losses

Glazed		15
Reference		
m <sup>2</sup>	2,10	
m <sup>2</sup>	2,00	
	0,70	
(W/m <sup>2</sup> )/°C	5,50	
(W/m <sup>2</sup> )/°C <sup>2</sup>		
	30	
m <sup>2</sup>	63,00	
kW	42,00	
%	15,0%	

## Solar water heater

Type  
 Manufacturer  
 Model  
 Gross area per solar collector  
 Aperture area per solar collector  
 Fr (tau alpha) coefficient  
 Fr UL coefficient  
 Temperature coefficient for Fr UL  
 Number of collectors  
 Solar collector area  
 Capacity  
 Miscellaneous losses

Glazed		3
More efficient		
m <sup>2</sup>	9,10	
m <sup>2</sup>	9,00	
	0,79	
(W/m <sup>2</sup> )/°C	3,21	
(W/m <sup>2</sup> )/°C <sup>2</sup>		
	4	
m <sup>2</sup>	36,40	
kW	25,20	
%	15,0%	



# Sizing the solar collector array



## RETScreen Energy Model - Heating project

### Heating project

Technology

Solar water heater

#### Load characteristics

Application

- Swimming pool
- Hot water

Load type

Unit	Base case	Proposed
	Hospital	
Bed	40	
Occupancy rate	100%	
Daily hot water use - estimated	7.874	
Daily hot water use	2.200	2.200
Temperature	60	60
Operating days per week	7	7

Number of units

Occupancy rate

Daily hot water use - estimated

Daily hot water use

Temperature

Operating days per week

#### Percent of month used

Supply temperature method

Water temperature - minimum

Water temperature - maximum

Unit	Base case	Proposed case
	Formula	
°C	17,6	
°C	22,3	
Heating	37,5	37,5

Heating

#### Resource assessment

Solar tracking mode

Slope

Azimuth

	Fixed	
°	40,0	
°	0,0	

## Reference solar collector

### Show data

#### Solar water heater

Type

Manufacturer

Model

Gross area per solar collector

Aperture area per solar collector

Fr (tau alpha) coefficient

Fr UL coefficient

Temperature coefficient for Fr UL

Number of collectors

Solar collector area

Capacity

Miscellaneous losses

Glazed		
Reference		
m <sup>2</sup>	2,10	
m <sup>2</sup>	2,00	
	0,70	
(W/m <sup>2</sup> )/°C	5,50	
(W/m <sup>2</sup> )/°C <sup>2</sup>		
	30	15
m <sup>2</sup>	63,00	
kW	42,00	
%	15,0%	

#### Balance of system & miscellaneous

Storage

Storage capacity / solar collector area

Storage capacity

Heat exchanger

Heat exchanger efficiency

Miscellaneous losses

Pump power / solar collector area

Electricity rate

	Yes
L/m <sup>2</sup>	50
L	3.000,0
yes/no	Yes
%	90,0%
%	5,0%
W/m <sup>2</sup>	0,00
\$/kWh	

#### Summary

Electricity - pump

Heating delivered

Solar fraction

MWh	0,0
MWh	24,5
%	65%

# Sizing the solar collector array



## RETScreen Energy Model - Heating project

### Heating project

		Solar water heater	
<b>Technology</b>			
<b>Load characteristics</b>			
Application	<input type="checkbox"/>	Swimming pool	
	<input checked="" type="checkbox"/>	Hot water	
	<b>Unit</b>	<b>Base case</b>	<b>Proposed</b>
Load type		Hospital	
Number of units	Bed	40	
Occupancy rate	%	100%	
Daily hot water use - estimated	L/d	7.874	
Daily hot water use	L/d	2.200	2.200
Temperature	°C	60	60
Operating days per week	d	7	7
<b>Percent of month used</b>			
Supply temperature method		Formula	
Water temperature - minimum	°C	17,6	
Water temperature - maximum	°C	22,3	
	<b>Unit</b>	<b>Base case</b>	<b>Proposed case</b>
Heating	MWh	37,5	37,5
<b>Resource assessment</b>			
Solar tracking mode		Fixed	
Slope	°	40,0	
Azimuth	°	0,0	

## More efficient collector

### Show data

#### Solar water heater

Type  
 Manufacturer  
 Model  
 Gross area per solar collector  
 Aperture area per solar collector  
 Fr (tau alpha) coefficient  
 Fr UL coefficient  
 Temperature coefficient for Fr UL  
 Number of collectors  
 Solar collector area  
 Capacity  
 Miscellaneous losses

Glazed	
More efficient	
m <sup>2</sup>	9,10
m <sup>2</sup>	9,00
	0,79
(W/m <sup>2</sup> )/°C	3,21
(W/m <sup>2</sup> )/°C <sup>2</sup>	
	4
m <sup>2</sup>	36,40
kW	25,20
%	15,0%

3

#### Balance of system & miscellaneous

Storage  
 Storage capacity / solar collector area  
 Storage capacity  
 Heat exchanger  
 Heat exchanger efficiency  
 Miscellaneous losses  
 Pump power / solar collector area  
 Electricity rate

	Yes
L/m <sup>2</sup>	83
L	3.000,1
yes/no	Yes
%	90,0%
%	5,0%
W/m <sup>2</sup>	0,00
\$/kWh	

#### Summary

Electricity - pump MWh 0,0  
 Heating delivered MWh 25,2  
 Solar fraction % 67%

# Solar fraction – CEDRO projects



	Daily hot water consumption	Collector type	Collectors Area(m2)	Capacity (l)	Annual Consumption (MJ)	Annual Production (MJ)	Solar Fraction (%)
SHW 500	500	reference	18	1.000	32.572	22.857	70
		more efficient	9	1.000	32.572	21.180	65
SHW 2.000	2.000	reference	60	3.000	119.483	81.875	69
		more efficient	36	3.000	119.483	87.779	73
SHW 6.000	6.000	reference	144	8.000	351.244	225.868	64
		more efficient	90	8.000	351.244	240.235	68
SHW 12.000	12.000	reference	340	17.000	698.887	483.583	69
		more efficient	181	17.000	698.887	482.319	69

Hospital	Current Number of Equiped Beds	Rated daily hot water consumption	Collector type	Collector area	Capacity calculated	Number solar hot water tank	Annual Consumption	Annual Production	Yearly solar fraction
		(L/day)		(m2)	(L)	Ut. (capacity)	(MJ)	(MJ)	(%)
Ehden	10	550	reference	18	900	1000	35.469	23.901	67
			more efficient	9	450	1000	35.469	22.964	65
Sir El Donniah	40	2.200	reference	60	3.000	2000 + 1000	131.071	86.209	66
			more efficient	36	1.800	2000 + 1000	131.071	90.186	69
Kesrwan	100	5.500	reference	144	7.200	4 x 2000	322.274	216.366	67
			more efficient	90	4.515	4 x 2000	322.274	232.676	72
Seblina	50 + 50 (to be added)	5.500	reference	144	7.200	4 x 2000	322.274	216.366	67
			more efficient	90	4.515	4 x 2000	322.274	232.676	72
Tripoli	220	12.100	reference	340	17.000	4 x 4000 + 1000	704.681	486.992	69
			more efficient	181	9.030	4 x 4000 + 1000	704.681	483.732	69



**Thank you for your attention**

[xavier.vallve@tta.com.es](mailto:xavier.vallve@tta.com.es)