Description and Visual Representation of Most Promising Markets

Edited by: Juan Rodriguez, Roberto Fedrizzi

Version v5.0

Bolzano, 25.01.2010

Identification of most promising markets and promotion of standardised system configurations for the market entry of small scale combined solar heating & cooling applications
EIE/07/158/SI2.466793 09/2007 – 02/2010

Intelligent Energy Europe
The sole responsibility for the content of this publication lies within the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

Table of Contents

List of Figures

List of Tables

1 Introduction

The scope of the paper is the identification of the most promising markets in Europe for the installation of solar combi plus systems, on the basis of solar thermal collectors market and meteorological data.

The main idea of the work is the creation of maps that, in a graphical way, permit an easy evaluation of the locations that are suitable for this kind of application. Data of the solar thermal collectors market in Europe were studied as a first step of the analysis, in order to individuate which markets are the most sensitive to the solar energy exploitation for thermal applications (domestic hot water and heating production).

Then, energy prices were analyzed to identify countries where customers are mostly sensitive to energy consumption.

Finally, meteorological data were studied to evaluate the maximum amount of solar energy that can be obtained from a given collector technology (flat plate and evacuated tube collectors were considered) at different temperatures, relative to different distribution systems installed in the building. At the same time, the demand of heating and cooling of buildings in Europe, over the whole year, was evaluated. Comparing demand and availability of energy, the most promising markets were defined.

2 Methodology

The solar thermal collectors’ data for the preparation of the maps were retrieved from the “Solar Thermal Markets in Europe, Trends and Market Statistics 2007” document from ESTIF [¤], which information was elaborated from AEE-Intec, on the basis of the solar thermal market for heating and domestic hot water preparation. The data recovered were used without any elaboration.

For the elaboration of the meteorological data, the creation of an excel file with a visual basic macro was necessary. The hourly data used were written in the format TM2 (most of them come from the Meteonorm°6 data base), and proceed directly from the climate data series of 608 weather stations. It should be remarked that no one of the data files was interpolated from other weather stations. On the basis of a macro file obtained from the web page of the National Renewable Energy Laboratory (USA) [http://rredc.nrel.gov/solar/pubs/tmy2], the data from 608 locations were charged into an excel file and further elaborated. Some parameters can directly be taken from the original file, namely:

- Name of the City
- Country
- Latitude
- Longitude
- Altitude over the sea level
- Direct normal radiation
- Diffuse horizontal radiation
- Dry temperature

And some others, as HDD (Heating Degree Day), CDD (Cooling Degree Day), Critical Radiation, useful radiation, were computed. These parameters, defined in the next chapter, were calculated by means of the latter data and inputs introduced by the user (type and efficiency of collector, useful temperatures, etc.). All the information obtained was represented on Europe maps by means of a free GIS tool.

2.1 Building Indexes and Demands

The psychrometric diagram of Figure 1 delimitates into trapezoids the acceptable living conditions for winter and summer season. As can be seen, a humidity of 50%, temperatures of 21ºC in the heating season (blue trapezoid), and 25ºC in the cooling one (pink) assure the inside quality. Moving the red point to the left on the 50% relative humidity curve, the amount of energy that the building losses in winter time to the environment is lower. The contrary happens in summer time with the blue point. To

define parameters proportional to the building loads, it was decided to evaluate as internal conditions, 21°C in winter time, and 26°C in the summer season (see Figure 2).

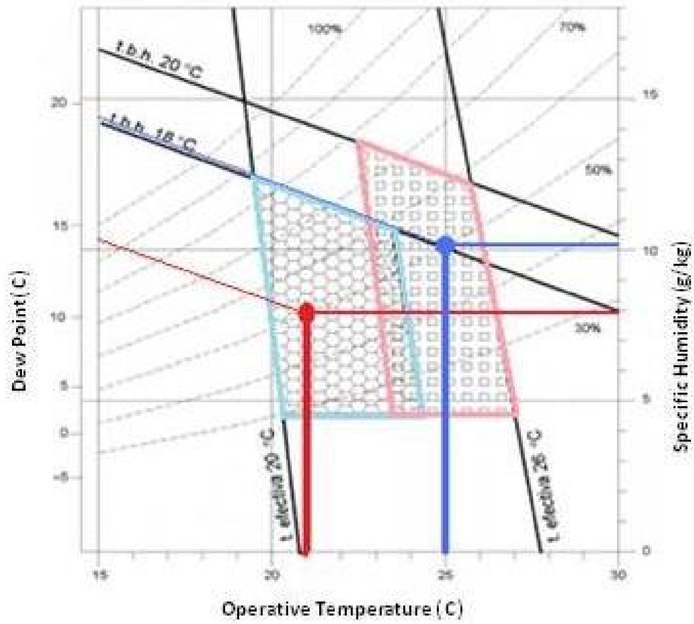

Figure 1 – Optimal comfort conditions on a psychrometric diagram.

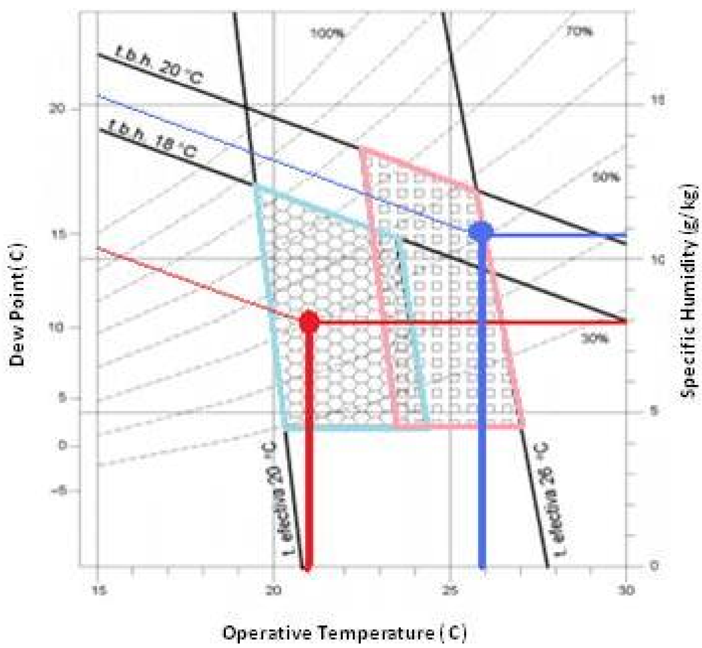

Figure 2 – Ambient conditions selected within the Solar Combi+ project.

The following two parameters (Heating Degree Days and Cooling Degree Days) serve as a first evaluation of the energy demand of a building, based only on the external temperatures. Both parameters compare the external temperatures with the in-house ones that always assure conditions perfectly acceptable inside the building all along the year (calculated for a relative humidity of 50%). While the winter parameter (HDD) is a good figure of the heating needs of the building, the summer factor (CDD) is a doubtful one, because it does not take into account humidity (latent heat) and the solar gains, that in some cases are the highest contributions. Nevertheless it can be used in an easy way, as a first approximation.

2.1.1 HDD (Heating Degree Days)

This parameter is a quantitative index designed to reflect the energy demand needed to heat a building. It is derived from daily temperature observations and calculated as the yearly sum of the difference in degrees between a base temperature that defines the internal building ambient temperature (typically 21ºC is the temperature where the loses with the environment do not exist) and the external dry temperature .

$$HDD = \sum_{h=1}^{8760} \frac{(21 - T_{amb,h})}{24} \approx \sum_{d=1}^{365} (21 - T_{amb,d})$$

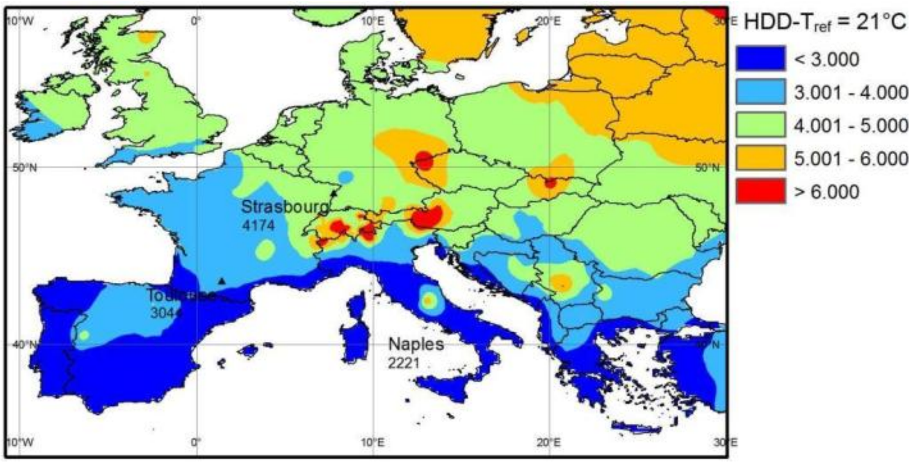

Figure 3 - Heating degree days in Europe

In the case of SC+, it can be seen how for a division of Europe in 5 zones, the studied cities belong to the three hottest ones. (Naples 2221, Toulouse 3040, Strasbourg 4174). The other two zones that correspond to HDD values over 5000 are not going to be studied, overall because as can be seen in the following figures, there will not be enough needed of cooling to be a case of interest for SC+ systems.

The comparison of the three cities shows a increment of CDD of 36% between Naples and Toulouse and 88% between Naples and Strasbourg.

2.1.2 CDD (Heating Degree Days)

The Cooling Degree Days parameter (CDD) is defined in a similar way to evaluate the gains obtained by the building due to the external temperatures (reference temperature taken is 26ºC).

$$CDD = \sum_{h=1}^{8760} \frac{(T_{amb,h} - 26)}{24} \approx \sum_{d=1}^{365} (T_{amb,d} - 26)$$

Again, as it can be seen in the figure 4, the correspondent values for CDD are highly different for the chosen cities. (70 for Naples, 26 for Toulouse and 9 for Strasbourg). Comparing to the value of Naples, Toulouse and Strasbourg are respectively 63% 87% lower.

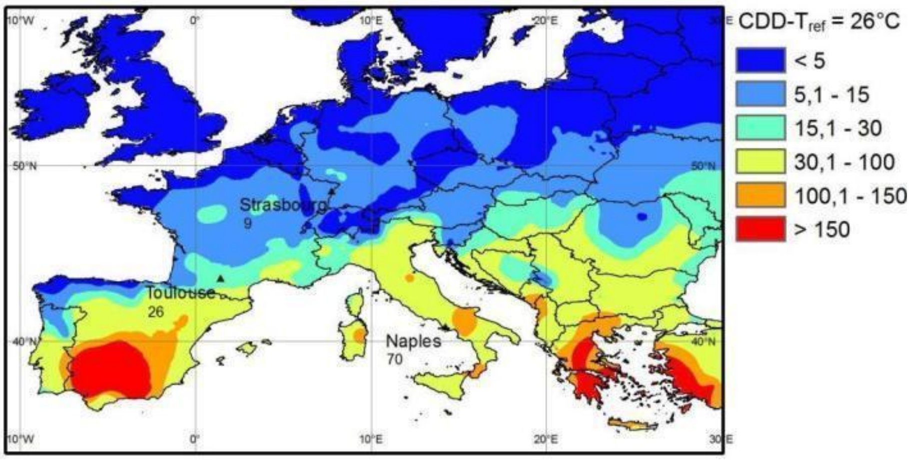

Figure 4 - Cooling degree days in Europe

2.1.3 Cooling and Heating Demands delivered by the Simulation of the building.

The total demands of cooling and heating of the buildings simulated into the SC+ program are shown in Table 1.

Table 1 - Building demands simulated [kWh/m^2/year]

kWh/m^2/y	Office		Typical House			Low consumption House		
	Heating	Cooling	Heating	Cooling	DHW	Heating	Cooling	DHW
Strasbourg	69.74	34.19						
Toulouse	34.13	50.28	46.05	5.69	12.66	24.58	6.12	12.66
Naples	9.22	80.75	21.11	18.45	11.43	9.37	17.45	11.43

Comparing Toulouse with Naples, it can be seen that the heating loads range between about 9 and 46 kWh/m^2/year. Cooling loads range between 6 an 20 kWh/m^2/year when residential buildings are regards, while much higher values are seen with regards to the office application (50-80 kWh/m^2/year).

If Naples is compared to Strasbourg (only the office application was simulated in this case), the heating loads are 7 times higher in Strasbourg, while the cooling loads are only three times higher in Naples.

2.2 Radiation parameters

The total radiation on a horizontal surface was calculated first from the direct normal and diffuse radiation of the meteorological files.

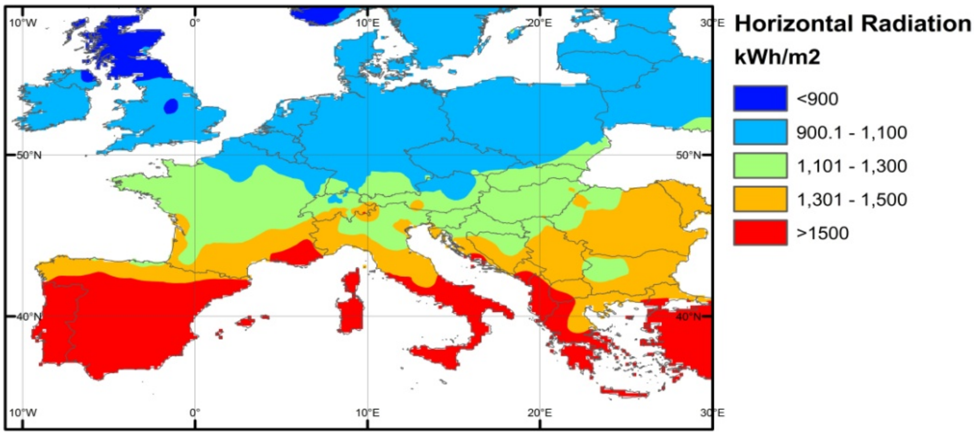

Figure 5 - Total radiation on horizontal

A delimitation of these data was needed to evaluate the suitable energy on a tilted surface oriented to the south. For comparison purposes, the tilt angle of the collectors chosen for all European countries was 40°, even though the best value varies with the latitude. Moreover, two different maps were created, one for the heating season and one for the cooling season (cooling season from 15th May to 15th September, heating season is the remaining part of the year).

The last two figures represent the maximum amount of energy that can be collected from the sun, independently of the type of collector and the temperature needed in the processes, so these graphs correspond to the upper limits in terms of possible energy collected. It is interesting to notice in table 2 that the total energy that can be captured in the eight months of heating and in the four months of cooling season is nearly identical for the three cities.

To produce more representative figures, two more parameters were introduced to take into consideration ambient temperature and collector's outlet temperatures: Critical and Useful Radiation.

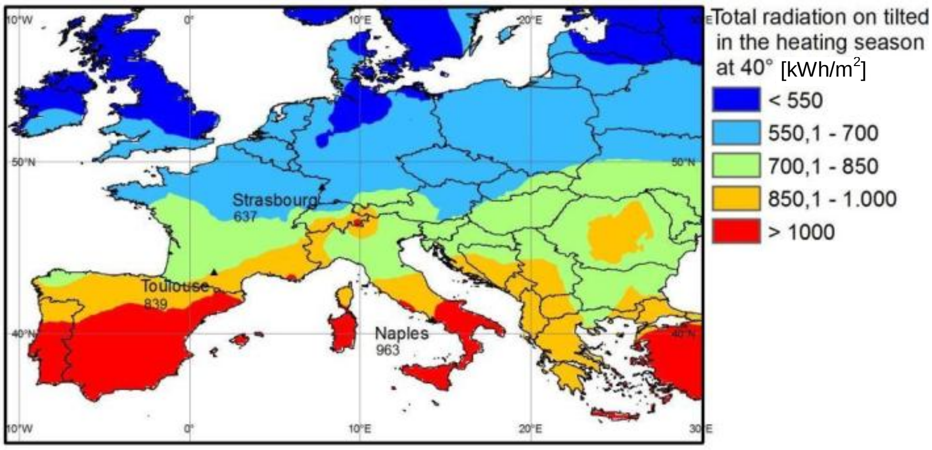

Figure 6 - Total radiation on tilted surface in the heating season (8 months).

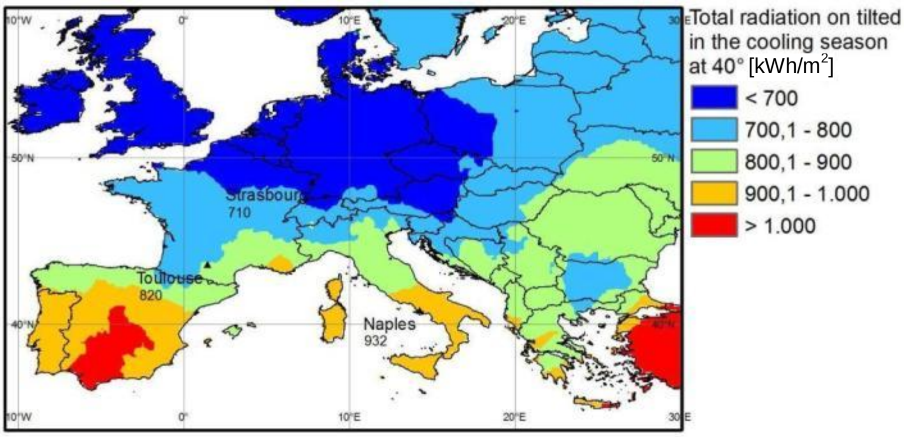

Figure 7 - Total radiation on tilted surface in the cooling season (4 months).

Table 2-Radiations on horizontal, Tilted angle 40º for Heating and Cooling Season

	Total Radiation Horizontal	Heating Season Radiation Tilted 40º, Faced South (8 months)	Cooling Season Radiation Tilted 40º, Faced South (4 months)
Strasbourg	1540	637	710
Toulouse	1897	839	820
Naples	2135	963	932

2.2.1 Critical radiation

A thermal collector is defined by its efficiency, that evaluates its performance as the ability of solar radiation harvested minus the thermal losses to the environment:

$$\eta = IAM \times k_0 \; - k_1 * \frac{(T_{avg} - T_{amb})}{G_\perp} - k_2 \frac{(T_{avg} - T_{amb})^2}{G_\perp}$$

- k_0 = optical efficiency angle (0.823 - flat plate, 0.601 – evacuated tubes, with respect to gross collectors' area)
- k_1 =linear loss coefficient (3.02 W/(m^2*K) - flat plate, 0.767 W/(m^2*K) – evacuated tubes, with respect to gross collectors' area)
- k_2 = quadratic loss coefficient (not used in this case, due to its secondary effects at temperatures up to 100 °C)
- T_{avg} = average temperature
- T_{amb} = ambient temperature
- IAM = Incident Angle Modifier, evaluates in percentages the amount of energy that arrives to the collector depending on the two angles (transversal and longitudinal) that the sun forms hourly with the tilted collector. IAM = $IAM_T \times IAM_L$

The Critical Radiation is defined as the level of radiation that creates the equilibrium between the losses from a collector and the energy harvested for a predetermined temperature. Developing the later equation for an efficiency equal to 0 and without taking into account the quadratic loss coefficient, the irradiation obtained is represented by:

$$I_{Critical}^{temp,coll} = \frac{k_1}{IAM \times k_0} * (T_{procces} - T_{amb})$$

As can be seen, to define the Critical Radiation it should be previously defined: the type of collector, the IAM angles (longitudinal and transversal) and the temperatures needed for the considered processes (temperature at the outlet of the collectors in a first attempt).

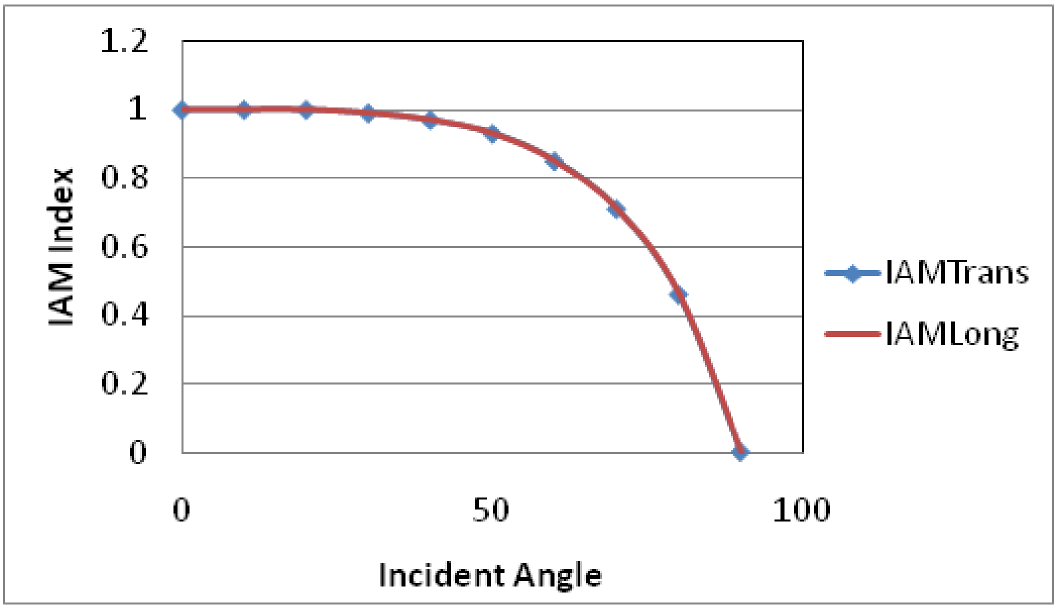

Figure 8 - Flat plate collector: k_0= 0.823 , k_1= 3.02 W/m^2K

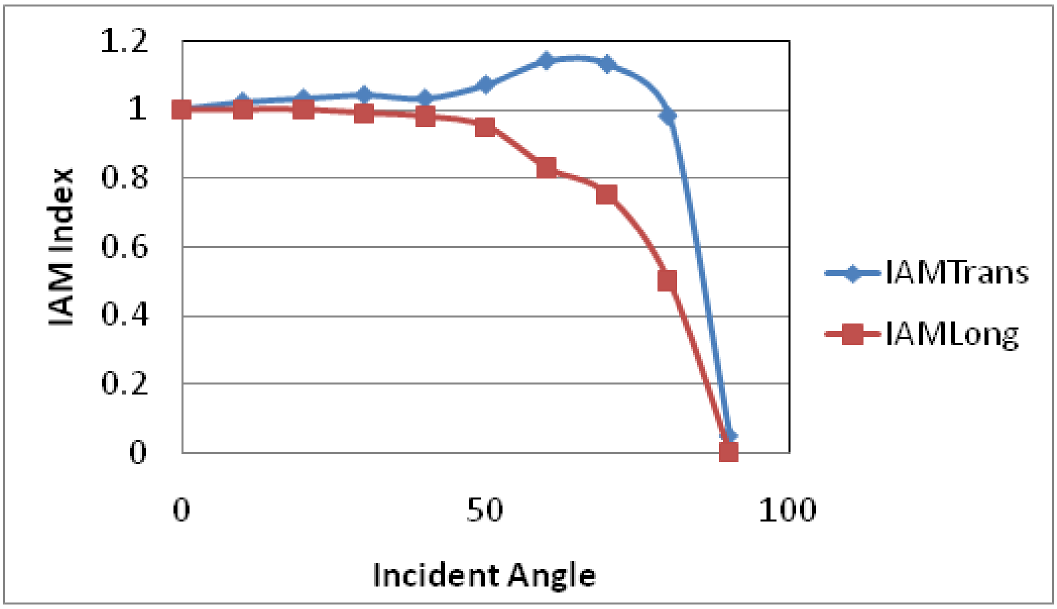

Figure 9 - Evacuated tube collector: k_0= 0.601 , k_1= 0.767 W/m^2K

2.2.2 Useful radiation

It is defined as the difference between Total Radiation received by a collector and its Critical Radiation. It represents the amount of energy for a given collector and climate conditions (radiation and ambient temperature) that can be used to warm the thermal fluid up to a given temperature:

$$I_{Useful}^{temp,coll} = I_{total} - I_{Critical}^{temp,coll}$$

Within this project, the process temperatures considered were dependent on the technologies of the sorption chillers used for the cold water production, on the needs to distribute domestic hot water and heating. Therefore, the temperatures considered for the computation of the Critical Radiation were:

- 40ºC for heating through direct feeding of radiant floors or fan coils.
- 60ºC for DHW all along the year.
- 70ºC for Adsorption chillers (summer time).
- 90ºC for Absorption chillers (summer time).

It should be remembered that the results are related to the maximum amount of harvested energy, at certain process and ambient temperatures; therefore, in the case of the chillers, the temperature evaluated is the minimum one that can drive the system. Moreover, the characteristic parameters of the collectors (k_0 and k_1) are taken constant for the calculations, which is only achievable if their inlet temperature is also retained constant. This is only possible if the demand and the useful radiation always overlap, which is not the case. As a result, the model used introduces some simplifications that result in somehow overestimated figures, when compared with actual energies available for heating, cooling and domestic hot water production. Nevertheless the model is well suited for the purpose of the most promising markets analysis, since it allows an easy comparison of the European regions in terms of offered solar energy at different year times.

3 Results

3.1 Solar Thermal Collectors Market

Figure 10 shows the European solar thermal market in terms of collectors' area sold up to the entire 2008. As it can be seen, the far largest market is Germany with about 11 Mm^2 installed; Greece, Austria, Italy, France and Spain follow with about 3.9, 3.2, 1.6, 1.6 and 1.4 Mm^2 sold. If the collectors' area per inhabitant is regarded, Austria, Greece and Germany again have the largest figures (388, 344 and 135 m^2/1000 inhabitants respectively).

Therefore, if the status quo is regarded, the last three countries seem to offer the best possibilities for the entry of the solar heating and cooling technologies on the market. Other countries like Cyprus and Malta present noteworthy values of collectors' area per inhabitant (873 and 75 m^2/1000 inhabitants respectively); however, they cannot be regarded as promising markets, as a whole, due to their limited absolute size. The other countries cited (Italy, Spain and France) follow by far.

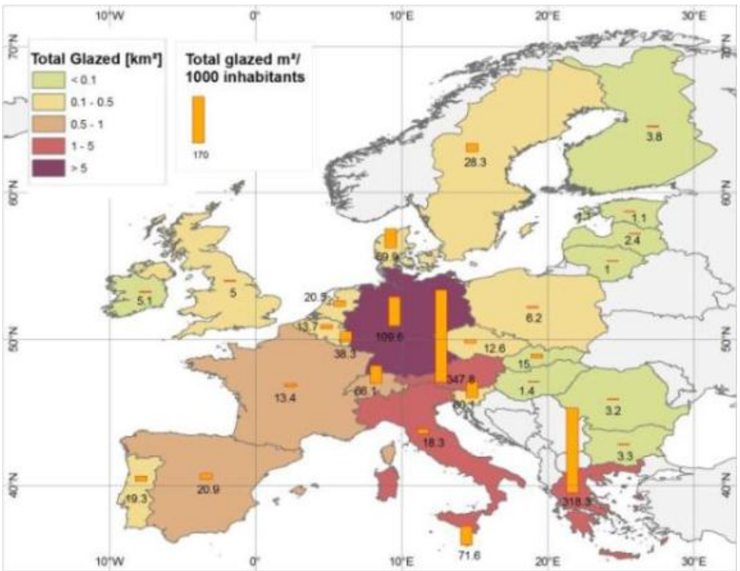

Figure 10 – Solar thermal market in Europe. Cumulative installed solar thermal fields at 2008.

If a "growth" approach is used to identify promising markets, the collectors installations of the last four years can be considered. The market increase in this time range shows clearly that also other countries can be taken into account; among the southern ones with a good potential of solar energy exploitation, Slovenia, Portugal, and again France, Spain and Italy show surprising rises of their solar thermal markets: +789%, +760%, +646%, +382%

and +260% respectively (see Figure 11, Figure 12). The three greatest markets (Germany, Austria and Greece) grow at slower rates, although still +34% is observed in Greece, +90% in Austria and +180% in Germany.

Therefore, all mentioned countries can be considered somehow suitable ones for solar thermal applications and promising for solar combi plus installations.

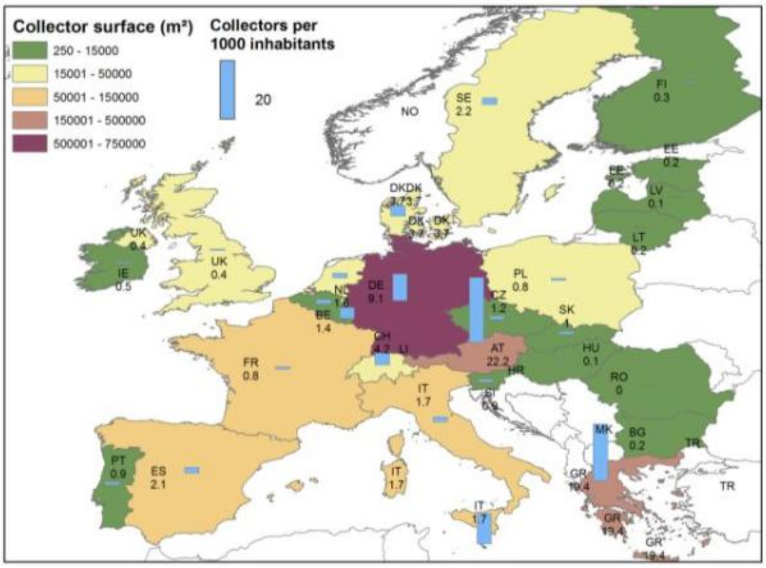

Figure 11 - Solar thermal market in Europe. Installations in 2004

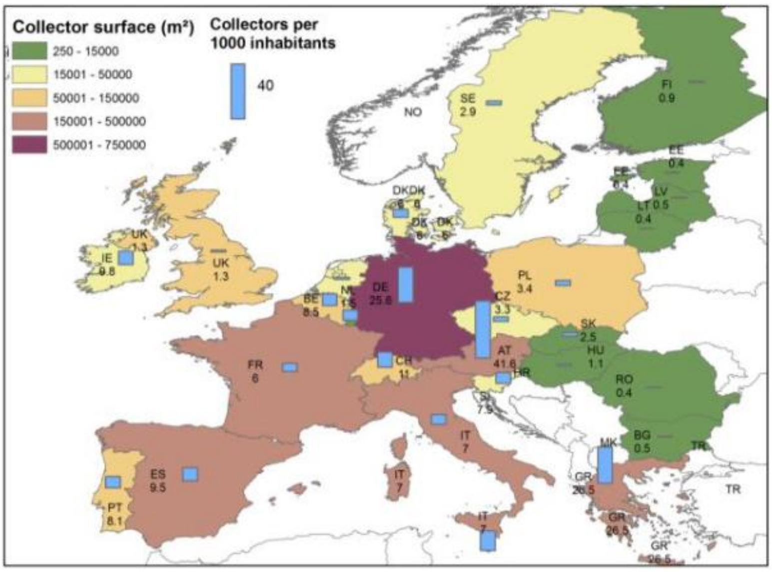

Figure 12 - Solar thermal market in Europe. Installations in 2008

Table 3 - Solar thermal collectors installations in Europe - Source ESTIF, AEE-Intec

	m^2				m^2/1000 inhabitants				
	2004	2006	2008	Cumulat at 2008	2004	2006	2008	Cumulat at 2008	Increase 04-08
AT	182594	292669	347703	3240330	22.2	35.3	41.6	387.8	187%
BE	14700	35636	91000	268947	1.4	3.4	8.5	25.0	607%
BG	1800	2200	4000	31600	0.2	0.3	0.5	4.2	250%
CH	31160	51863	85000	593980	4.2	6.9	11.0	77.1	261%
CY	30000	60000	68000	693200	40.0	77.1	85.6	873.1	214%
CZ	12250	22030	35000	165100	1.2	2.1	3.3	15.8	275%
DE	750000	1500000	2100000	11094000	9.1	18.2	25.6	135.3	281%
DK	20000	25300	33000	418280	3.7	4.6	6.0	75.9	162%
EE	250	300	500	1970	0.2	0.2	0.4	1.5	200%
ES	90000	175000	434000	1411166	2.1	3.9	9.5	30.8	452%
FI	1630	3200	4800	25293	0.3	0.6	0.9	4.7	300%
FR	52000	220000	388000	1624100	0.8	3.5	6.0	25.2	750%
GR	215000	240000	298000	3868200	19.4	21.5	26.5	343.6	136%
HU	1500	1000	11000	25250	0.1	0.1	1.1	2.5	1100%
IE	2000	5000	43610	74400	0.5	1.2	9.8	16.7	1960%
IT	97738	186000	421000	1606230	1.7	3.1	7.0	26.7	411%
LT	500	600	840	4290	0.2	0.3	0.4	1.9	200%
LU	1700	2500	3600	22500	3.7	5.3	7.3	45.6	197%
LV	500	1200	1800	7150	0.1	0.4	0.5	2.1	500%
MT	4215	4500	6000	35360	10.5	11.0	14.5	85.5	138%
NL	26300	14685	25000	363341	1.6	0.9	1.5	22.0	93%
PL	28900	41400	129632	365676	0.8	1.1	3.4	9.6	425%
PT	10000	20000	86000	318950	0.9	1.9	8.1	30.0	900%
RO	400	400	8000	94300	0.0	0.0	0.4	4.4	n.a.
SE	20058	28539	26813	289207	2.2	3.1	2.9	31.2	131%
SI	1800	6900	16000	137300	0.9	3.4	7.9	67.6	877%
SK	5500	8500	13500	95250	1.0	1.6	2.5	17.6	250%
UK	25000	54000	81000	385920	0.4	0.9	1.3	6.3	325%

3.2 Energy prices

Figure 13 and Figure 14 report the gas and electricity prices in Europe. Customers are most sensitive to their energy consumption, and therefore might be more sensitive to energy efficiency, in countries where large values are encountered for both prices. From the maps, those (southern) countries are namely Germany, Austria, Portugal, Czech Republic, Slovakia, Spain, Italy and France.

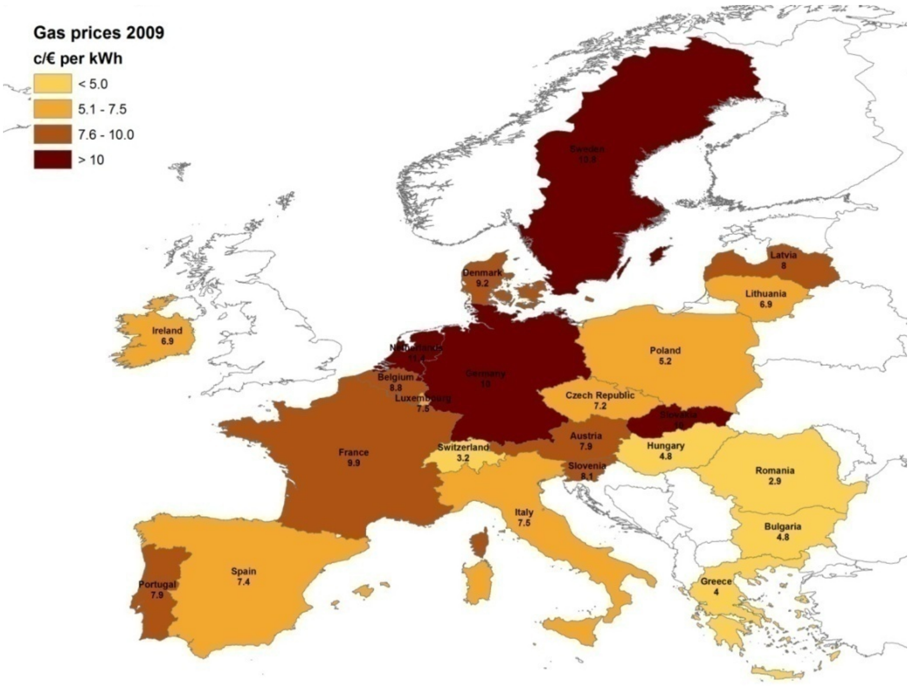

Figure 13 - Gas prices in Europe - Source Eurostat

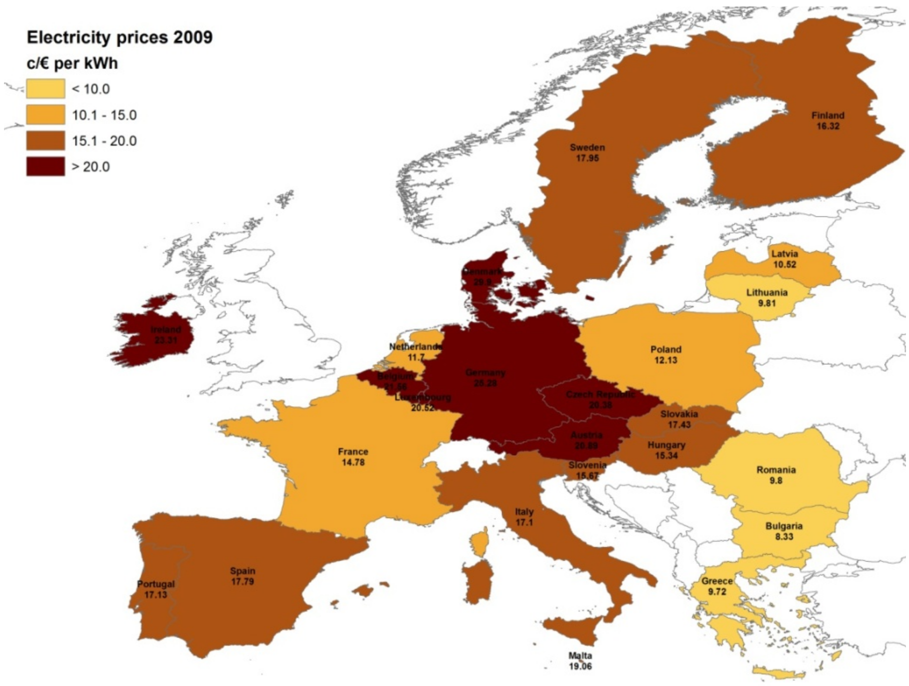

Figure 14 - Electricity prices in Europe - Source Eurostat

3.3 Heating and Cooling Loads

In the HDD map presented (Figure 3), it can be seen how much the HDD changes within Europe: the figure increases (the energy demand for heating rises proportionally) from about 2000°HDD in south Europe to more than 5000°HDD in the northern countries (compare also the data relative to the three cities studied within the project, Table 4). Comparing the latter map with the one in Figure 4 (CDD), it can be seen that the range of values is much narrower; this is due to the fact that only four months are taken instead of eight and to the lower average temperature differences between the inner and the outer temperatures that are reached in summer. Moreover, the latent and radiative loads are not considered in CDD definition. In any case, the cooling loads are about one order of magnitude lower than the heating loads in the worst cooling case (Naples). Nevertheless, the values might easily vary of a factor 8 moving from south to north Europe (Table 4).

Table 4 - HDD and CDD values for the cities studied in the project.

	HDD (21°C)	CDD (26°C)
Strasbourg	4174	9
Toulouse	3044	26
Naples	2221	70

On the base of these last numbers, Naples and Toulouse will fit better to solar combi plus systems due to high both heating and cooling demands, while Strasbourg's loads will point mainly on heating requirements.

3.4 Space Heating Useful Radiation (40ºC)

Looking at the useful energy at the collector outlet, the lowest process temperatures -useful for heating purposes through radiant floors- are analyzed first. It can be seen that, when fluid temperatures of 40°C are considered during the heating period, considerable amounts of energy can be elaborated both in southern and northern regions (see Table 5, Figure 15 and Figure 16). When looking at Figure 15 and Figure 16, relating to flat plate and evacuated tube collectors respectively, values range between about 300 kWh/m^2/year and 900 kWh/m^2/year. If the three cities are considered, the values of useful radiation change between 400 and 700 kWh/m^2/year in the case of flat plate collectors and 540 and 860 kWh/m^2/year in the case of evacuated tube ones.

Table 5 -Useful radiation [kWh/m²/year] at 40°C for heating (8 months)

	FP-Heating Season	ET-Heating Season	Relation FP/ET
Strasbourg	397	537	73.92%
Toulouse	568	735	77.28%
Naples	690	861	80.13%

The useful radiation for the evacuated tube collectors in Strasbourg is approaching the one for the flat plate collectors in Toulouse and the useful radiation in Toulouse exceeds the one in Naples. The effectiveness of the evacuated tubes is more significant in the northern countries: the relation between energy obtained by flat plate and evacuated tube is presented in the last column of Table 5 that shows values between 74 and 80%. Therefore, to cover an acceptable part of the demand in northern countries, the most efficient technology could be needed. However, the choice is left also to space availability and economical aspects.

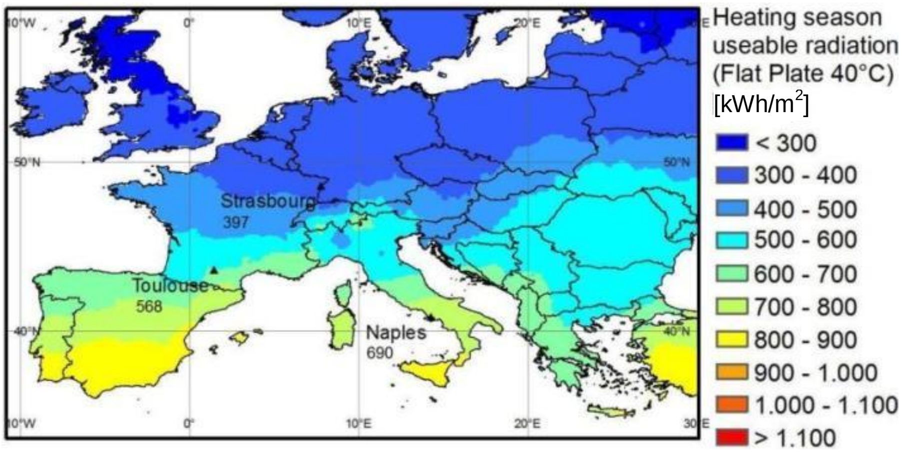

Figure 15 - Heating season (8 months) useable radiation for flat plate collectors at 40°C

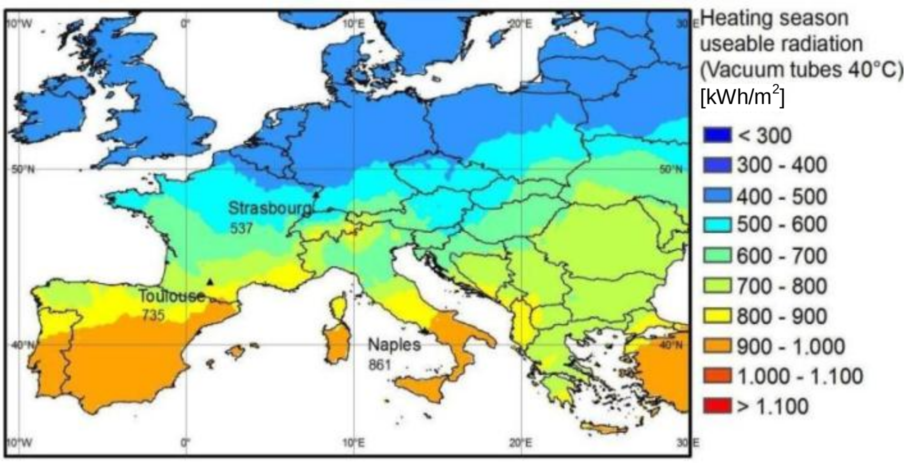

Figure 16 - Heating season (8 months) useable radiation for evacuated tube collectors at 40°C

3.5 DHW Preparation Useful Radiation (60ºC)

Comparable amounts of energy can be obtained during the summer season and the remaining part of the year (again, it must be remembered that summer season is half time the winter one.), if 60°C hot water is regarded.

In Figure 17 and Figure 18 (Heating season), values range again between about 300 kWh/m^2/year and 900 kWh/m^2/year. If the three cities are considered, the values of useful radiation change between 300 and 550 kWh/m^2/year in the case of flat plate collectors and 500 and 800 kWh/m^2/year in the case of evacuated tube ones. During the cooling season (Figure 19 and Figure 20), the useful radiation reaches for the three cities values between 450 and 650 kWh/m^2/year in the case of flat plate collectors and 600 and 850 kWh/m^2/year in the case of evacuated tube. Remarkable good results are seen in the top right corners of the maps; however, this is due to the low amount of data recorded in those places that produces interpolation mismatches.

Due to the higher temperatures needed when Domestic Hot Water preparation is considered, evacuated tubes increase the advantages seen in the previous chapter to an averaged 28% for the cooling season and 36% in winter time (see Table 6 and Table 7). Those differences can be explained by the relations between radiation and external temperatures, responsible for the thermal losses. More severe temperature differences are encountered on average in winter time, between solar collector and the surrounding environment.

Table 6 -Useful radiation [kWh/m^2/year] at 60°C for domestic hot water preparation

	FP-Cooling Season	ET-Cooling Season	FP-Heating Season	ET-Heating Season
Strasbourg	438	624	302	490
Toulouse	530	734	445	678
Naples	632	855	552	802

Also it can be calculated the relation among the three cities for a determined DHW demand (tap temperatures differ of some degrees along the year for the cities, but the total demand of energy to heat DHW is under the energy differences obtained for the three locations). From the point of view of DHW, the most promising market corresponds to Naples, due to the 20% bigger results compared with Toulouse and approximately 50% with Strasbourg. The election between flat plate and evacuated tube collectors depends again on the prices of the collectors for a given demand.

Table 7 - Relation between energies harvested by FP and ET in a determined season

	Relation FP/ET Cooling Season	Relation FP/ET Heating season
Strasbourg	70.20%	61.63%
Toulouse	72.21%	65.63%
Naples	73.91%	68.82%

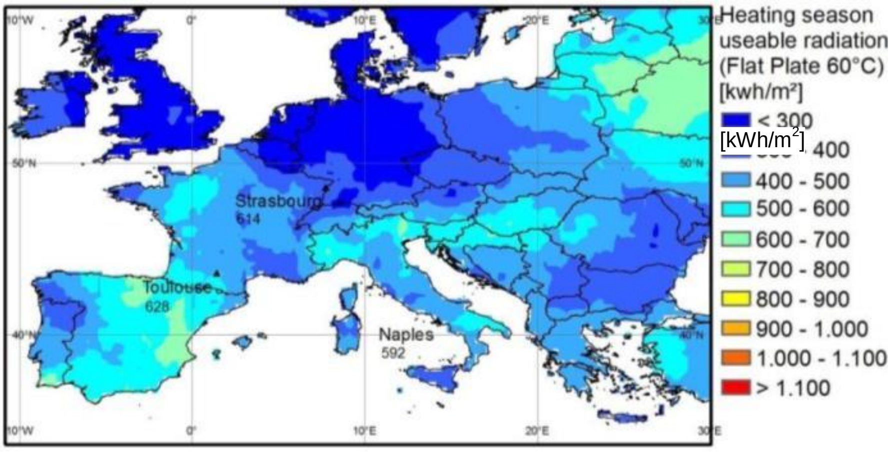

Figure 17 - Heating season (8 months) useable radiation for flat plate collectors at 60°C

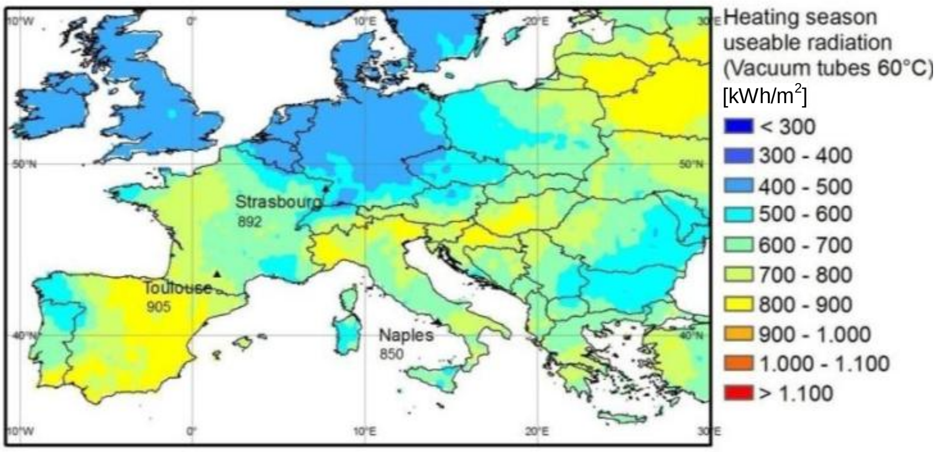

Figure 18 - Heating season (8 months) useable radiation. Evacuated tube collectors 60ºC

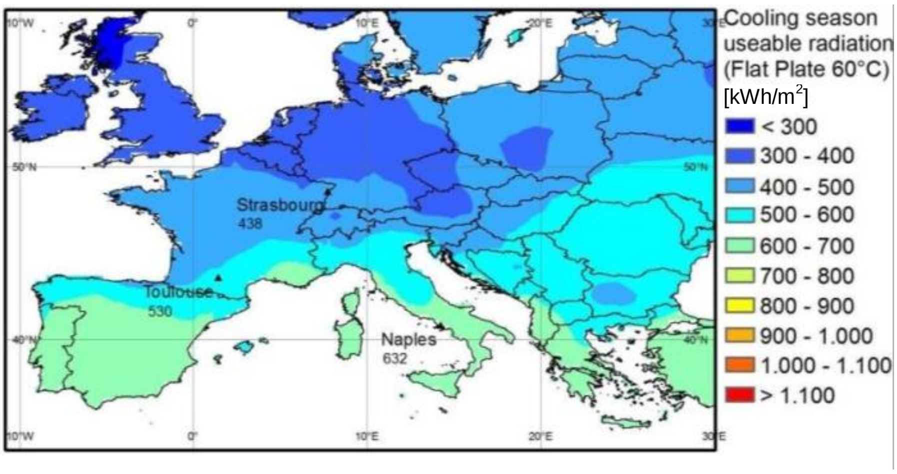

Figure 19 - Cooling season (4 months) useable radiation for flat plate collectors at 60°C

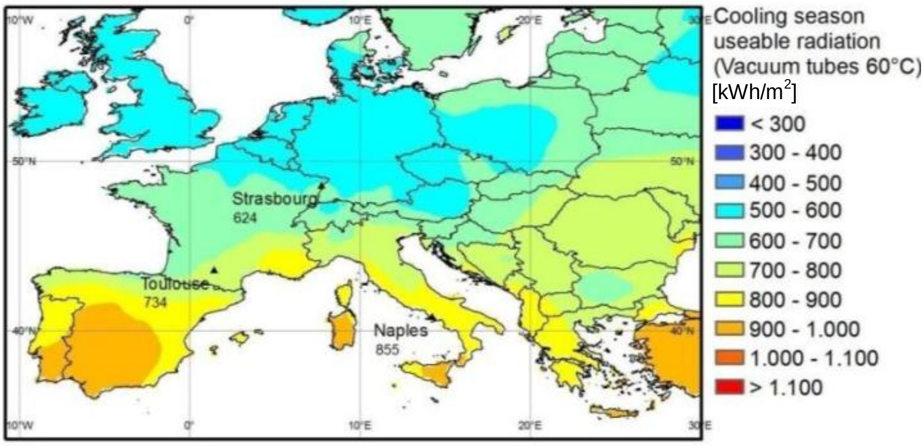

Figure 20 - Cooling season (4 months) useable radiation for evacuated tube collectors at 60°C

3.6 Sorption chillers driving Useful Radiation

In order to define the most promising markets, the definition of the demand for the building is needed: the decrease of available radiation in the northern countries could be counterbalanced by an equivalent, or even higher, drop on the cooling demand. As seen in Table 1, the cooling demands for Strasbourg and Toulouse are 60% and 40% lower than the one of Naples (Office Building case). For the domestic applications cases, 70% and 65% lower energy demanded in Toulouse is obtained if compared with Naples.

3.6.1 Adsorption chillers (70ºC - Cooling season)

If the available energy is regarded at a temperature useful for driving adsorption chillers (70°C), In Figure 21 and Figure 22, values range again between about 300 kWh/m^2/year and 850 kWh/m^2/year. If the three cities are considered, the values of useful radiation change between 400 and 600 kWh/m^2/year in the case of flat plate collectors and 600 and 850 kWh/m^2/year in the case of evacuated tube.

Taking Naples again as the reference location, the reduction of the useful radiation is in the order of 18% and 33% in Toulouse and Strasbourg respectively when flat plate collectors are taken, and in the order of 15% and 28% in Toulouse and Strasbourg respectively when evacuated tube are considered.

From this analysis it comes out that an easier cooling coverage (for given building and collectors area) can be provided in the northern countries. However, it has to be considered that as far as the cooling demand drops, the economics of the investment for cooling increases up to inacceptable values. Passive cooling can be contemplated when very low cooling loads are encountered. Comparing Table 7 (Cooling season) with Table 8 it turns out clearly also that the energy harvesting effectiveness of evacuated tube collectors becomes more and more significant as far as the needed temperature levels rise.

Table 8 -Useful radiation [kWh/m^2/year] for cooling (4 months)

	FP-70°C	ET-70°C	Relation FP/ET 70ºC
Strasbourg	390	604	64.57%
Toulouse	478	714	66.95%
Naples	577	834	69.18%

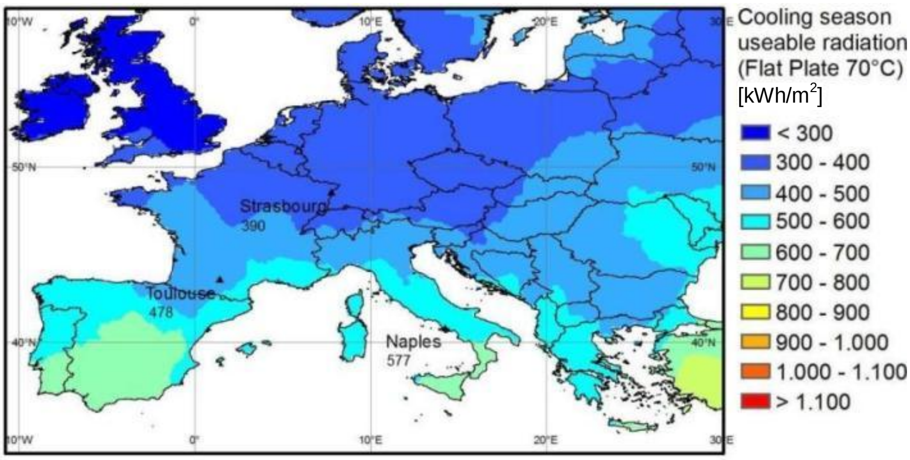

Figure 21 - Cooling season (4 months) useable radiation for flat plate collectors at 70°C

[kWh/m2]
EURAC research

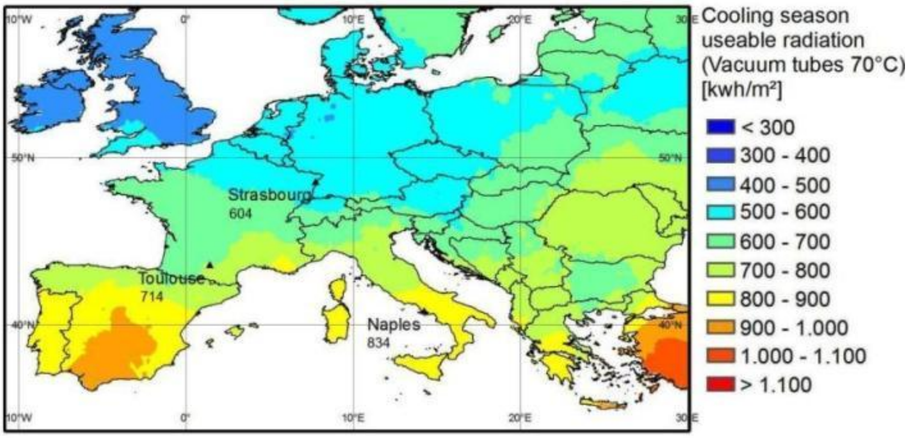

Figure 22 - Cooling season (4 months) useable radiation for evacuated tube collectors at 70°C

3.6.2 Absorption chillers (90ºC - Cooling season)

The comments made in the previous paragraph hold for the useful energy available at a 90°C temperature level. In Figure 23 and Figure 24, values range again between about 300 kWh/m^2/year and 800 kWh/m^2/year. The values of useful radiation for the three cities change between 300 and 500 kWh/m^2/year in the case of flat plate collectors and 550 and 800 kWh/m^2/year in the case of evacuated tube.

Comparing Table 7 (Cooling season) with Table 8 and Table 9 it is noticed once again that the energy harvesting effectiveness of evacuated tube is much more relevant than the one of the flat plate collectors as far as the temperatures needed increase and the location of the system moves to the north. As much as twice effectiveness is obtained with evacuated tube collectors when high temperatures are regarded.

The useful radiation reduction from Naples to Toulouse and to Strasbourg is comparable with the one shown in the previous paragraph: 20% and 36% in Toulouse and Strasbourg respectively when flat plate collectors are taken, and 16% and 29% when evacuated tube are considered.

Table 9 -Useful radiation [kWh/m^2/year] for cooling (4 months)

	FP-90°C	ET-90°C	Relation FP/ET 90ºC
Strasbourg	306	565	54.16%
Toulouse	383	674	56.82%
Naples	474	793	59.77%

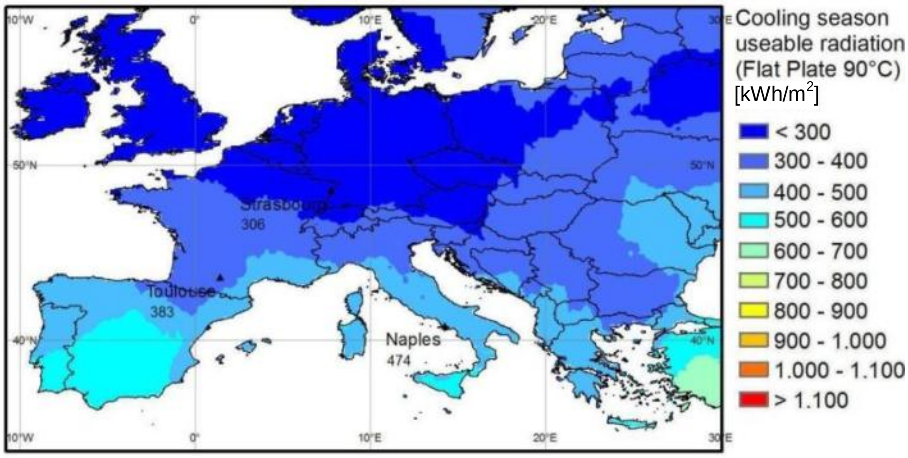

Figure 23 - Cooling season (4months) useable radiation for flat plate collectors at 90°C

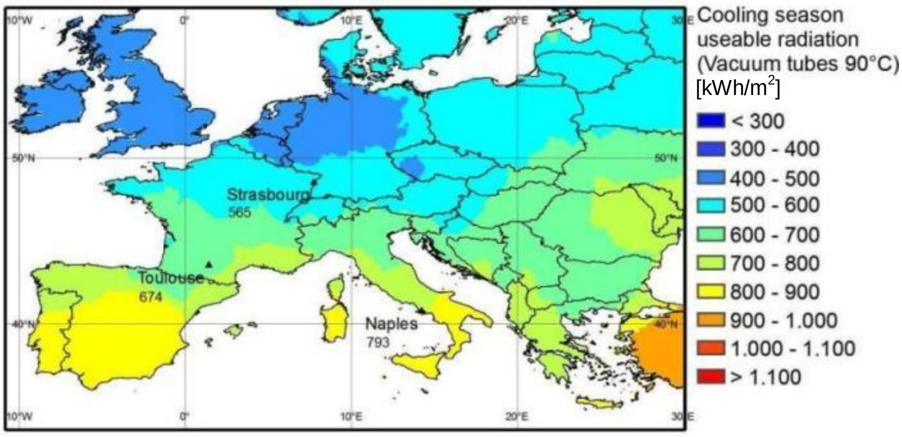

Figure 24 Cooling season (4 months) useable radiation for evacuated tube collectors at 90°C

4 Conclusions

The physical location of the system installed fixes the amount of solar energy provided and to some extent the domestic hot water, heating and cooling needs. The combination of useful energy possibly harvested and overall loads determines the most promising climates for the installation of a solar combi plus application.

All the investigated locations are suitable under the point of view of the heating needs and potential coverage of the loads through a high fraction of solar energy, due to the low temperatures needed (40°C were considered as heating temperature level). Southern countries are obviously more suitable for cooling applications due to the significantly higher radiation, which is available, while passive cooling could be a more adequate solution to cover northern countries requirements. However, cooling needs might result much higher too in southern regions, both during the days and the nights.

The technologies used for cooling (ab-/adsorption chillers) and for harvesting the solar energy have to be considered too: as far as the needed temperature levels go higher and the location moves northern, more effective solar collectors shall be adopted. The extra saving obtained with evacuated tube collectors should always be compared with the extra initial system costs. The seasonal demands are also important, i.e. cooling demands can be proportionally lower than the winter ones and the energy increase due to more expensive collectors not very significant.

Therefore, although the return of the investment is cut when combined high heating, cooling and DHW loads are encountered, a “most promising market” cannot be stated within the ones analyzed, since the selection of a good location is so much dependent on the technology employed (both for heating and cooling and for the construction of the buildings). The technology and the economics of the specific application have to be evaluated.

From a social point of view, only few countries seem to be more promising than others, since the penetration of the solar technologies for DHW preparation and heating -therefore the awareness of the population about those technologies- and energy prices -therefore the willing of the customers to install RES for heating and cooling- are higher.

5 References

- ESTIF, “Solar Thermal Markets in Europe, Trends and Market Statistics 2007”, Bruxelles, June 2007.
- ESTIF, “Solar Thermal Markets in Europe, Trends and Market Statistics 2008”, Bruxelles, May 2009.
- Henning, H.M., “Solar Assisted Air Conditioning in Buildings – A Handbook for Planners”, 2003.
- Duffie, J., “Solar Engineering of Thermal Process”, 2006.