SOLAR THERMAL COLLECTOR MARKET IN IEA MEMBER COUNTRIES

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

Werner Weiss and Gerhard Faninger

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Werner Weiss* and Gerhard Faninger**

*AEE INTEC
Arbeitsgemeinschaft ERNEUERBARE ENERGIE
Institute for Sustainable Technologies
A-8200 Gleisdorf, Austria

**University of Klagenfurt
A-9020 Klagenfurt, Austria

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1 Summary

This study was prepared within the framework of the Solar Heating and Cooling Programme (SHC) of the International Energy Agency (IEA). The goal of the study was to document the collector areas previously installed in the SHC Member countries and other IEA Member countries, and to ascertain the contribution of solar plants to the supply of energy and the CO_2 emissions avoided as a result of operating these plants. The collectors documented were unglazed collectors recorded used to warm swimming pools, flat-plate and vacuum tube collectors with water as the energy carrier, and air collectors.

The data was collected within the framework of a questionnaire survey of the national delegates of the Executive Committee of the SHC Programme. Since some countries have very detailed statistics and others could only provide estimates from experts, the data was checked for its plausibility on the basis of various publications, and if necessary, corrected. Starting with the collector area installed the contributions of solar plants towards the supply of energy and reduction of CO_2 were ascertained.

The most important results
The installed collector area in the 22 IEA Member countries equaled around 58 million square meters at the end of year 2000. Of this, 17 million square meters was accounted for by unglazed collectors, which are used mainly to heat swimming pools, and 40 million square meters of flat-plate and evacuated tube collectors, which are used to prepare hot water and for space heating. Air collectors were installed to an extent of 1.35 million square meters. These are used for drying agricultural products and to a lesser extent for space heating.

If one observes the use of solar thermal energy it becomes clear that it greatly varies in the different countries respective economic regions. In North America (USA and Canada) swimming pool heating is dominant with 15 million square meters of unglazed collectors while in Europe (9.7 million square meters) and Japan (11.7 million square meters) plants with flat-plate and evacuated tube collectors mainly used to prepare hot water and for space heating are dominant.

Focusing on the installed flat-plate and evacuated tube collectors through the year 2000, then Greece, Austria and Turkey are leading with 264 m², 195 m², 113 m² per 1000 inhabitants respectively. They are followed by Japan, Denmark and Germany with collector areas between 93 and 34 m² per 1000 inhabitants.

With regard to the heating of swimming pools with unglazed collectors, Austria leads with 73 m² ahead of the USA with 52 m² and Switzerland with 31 m² per 1000 inhabitants. In fourth to sixth place there is Canada, Germany and the Netherlands with collector areas between 6 and 16 m² per 1000 inhabitants.

Analyzing the market development from 1999 and 2000 in the field of plants for the preparation of hot water and space heating it can be seen that the market of flat plate and evacuated tube collectors grew from 2,025,384 m² in the year 1999 to 2,285,797 m² in the year 2000. This corresponds to a growth of 13%. The markets that underwent the greatest growth between 1999 and 2000 included Mexico at 226%, Sweden at 99%, Spain at 65%, Germany at 47% and France at 42%. The countries with stagnating markets were Japan, Italy, Norway and Turkey. Decreasing markets were recorded in Denmark at -16%, Switzerland at -11%, Portugal at -6%, and the USA and the Netherlands at -4%.

The market of unglazed collectors for swimming pool heating recorded a slight decrease from 915,378 m² in the year 1999 to 907,903 m² in the year 2000. This corresponds to a reduction of 0.8%. The markets that underwent the greatest growth in this sector between 1999 and 2000 included Mexico at 66%, New Zealand at 12% and France at 7%. Decreasing markets were recorded in Denmark at -73%, Switzerland at -16%, Austria at -13% and the Netherlands at -6%.

Until now there has been scarcely any information available on the contribution of solar collectors to the supply of energy, and the potential of this technology has been, for the greater part, underestimated. The calculated **annual collector yield** of all recorded systems[1] in the 20 Member countries of the IEA SHC Programme is approximately 24,367 GWh (87,721 TJ). This corresponds to an **oil equivalent** of 3.9 billion liter and an **annual avoidance of 10.7 million tons of CO_2**.

[1] All water based systems excl. air based systems. Since the database of the applications of air collectors is insufficient, the contribution of air collectors to the energy supply and CO_2 reduction was not calculated.

2 Total solar thermal collector area in operation by the year 2000

Since the beginning of the 1990s, the solar thermal market has undergone a favorable development. At the end of 2000, a total of 58.2 million square meters of collector area were installed in the IEA Member countries. As shown in Table 1, this collector area is divided in 16.97 million square meters of unglazed collectors for swimming pool heating; 36.69 million square meters of glazed flat plate collectors, and 3.16 million square meters of evacuated tube collectors (mainly used for domestic hot water preparation and space heating), and 1.35 million square meters of glazed and unglazed air collectors for space heating and drying applications. With regard to flat plate and evacuated tube water collectors, it has to be noted that in the US the majority was installed in the 1980s and about 70% was installed up to the year 1985. In comparison to that, most systems in Europe were installed in the 1990s.

Table 1: Total collector area in operation by the year 2000 in IEA Member countries

Total Collector Area in Operation in the Year 2000 in the IEA-Member Countries						
Country	Water collectors			AIR COLLECTOR		TOTAL
	unglazed	glazed	evacuated tube	unglazed	glazed	
Australia						
Austria	571,806	1,581,185	26,219		3,500	**2,182,710**
Belgium	21,875	19,400	1,700			**42,975**
Canada	493,000	72,000	509	41,000	0	**606,509**
Denmark	15,563	243,169				**258,732**
Finland		10,200	100			**10,300**
France	84,500	470,000				**554,500**
Germany	615,000	2,399,000	392,000		40,000	**3,446,000**
Greece		2,815,000				**2,815,000**
Italy	20,000	300,000	20,000	2,000	2,000	**344,000**
Japan		11,445,008	307,481			**11,752,489**
Mexico	283,800	94,600				**378,400**
The Netherlands	100,305	176,580		5,341		**282,226**
New Zealand		64,000				**64,000**
Norway	500	7,000	100		1,000	**8,600**
Portugal	1,000	238,000	500			**239,500**
Spain		399,922				**399,922**
Sweden	30,000	175,045	3,000			**208,045**
Switzerland	221,200	250,800	15,000	816,000		**1,303,000**
Turkey	0	7,500,000	0	0	0	**7,500,000**
United Kingdom	0	149,000	2,000			**151,000**
United States	14,513,000	8,277,000	2,390,000		439,000	**25,619,000**
TOTAL	**16,971,549**	**36,686,909**	**3,158,609**	**864,341**	**485,500**	**58,166,908**

2.1 Glazed flat plate and evacuated tube collectors in operation by the year 2000 in IEA Member countries

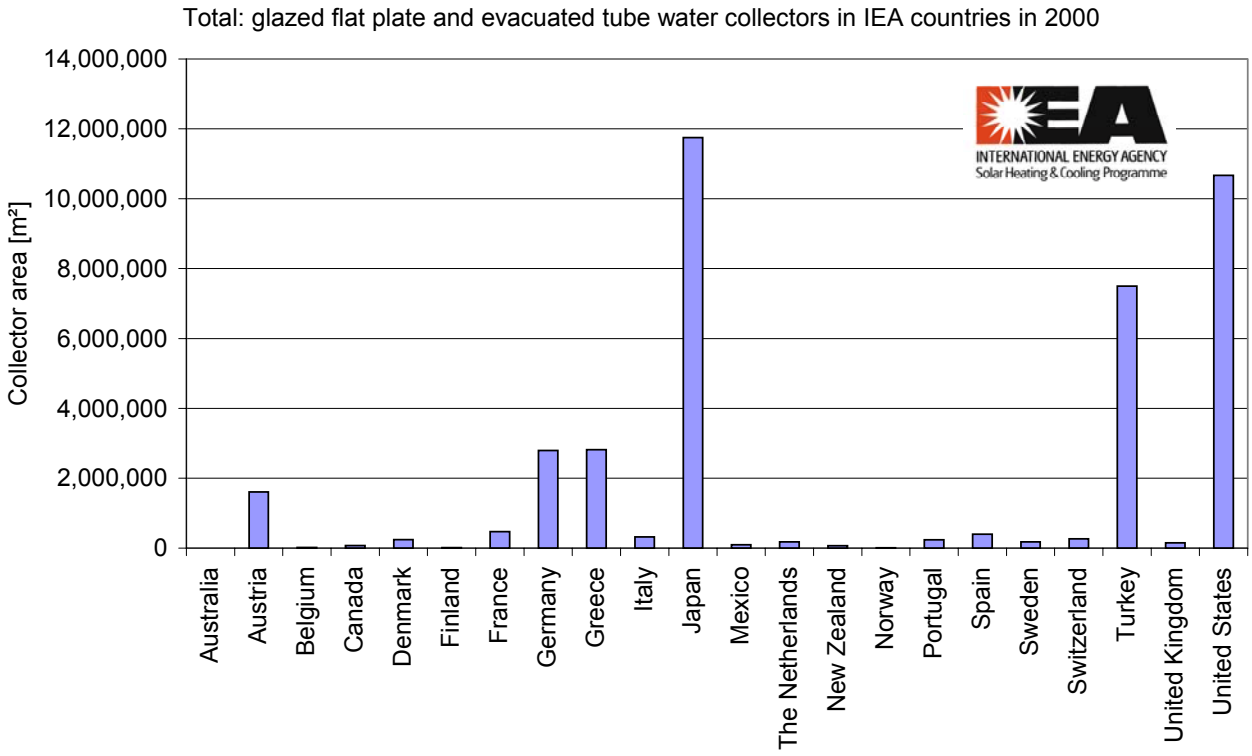

Figure 1: Glazed flat plate and evacuated tube collectors in operation in the year 2000.

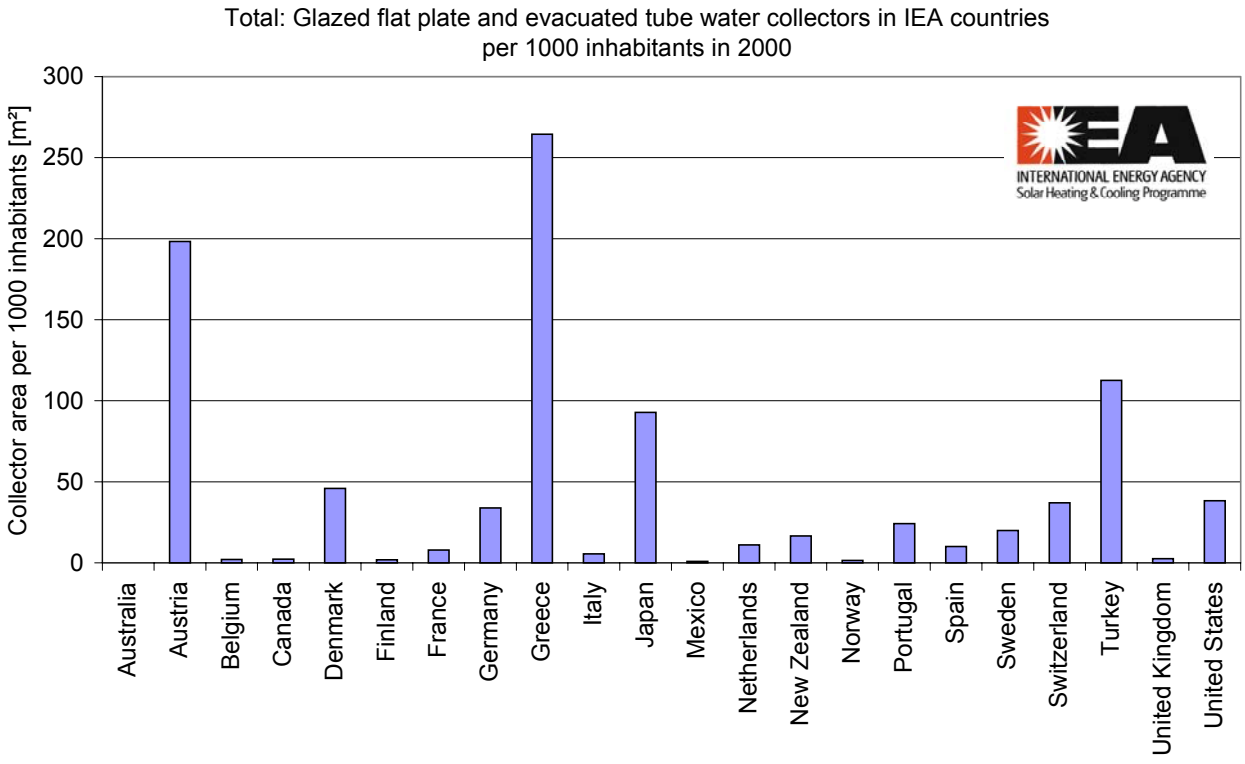

Figure 1: Glazed flat plate and evacuated tube collectors in operation in the year 2000 per 1000 inhabitants

2.2 Glazed flat plate and evacuated tube collectors in operation in 2000 by economic region

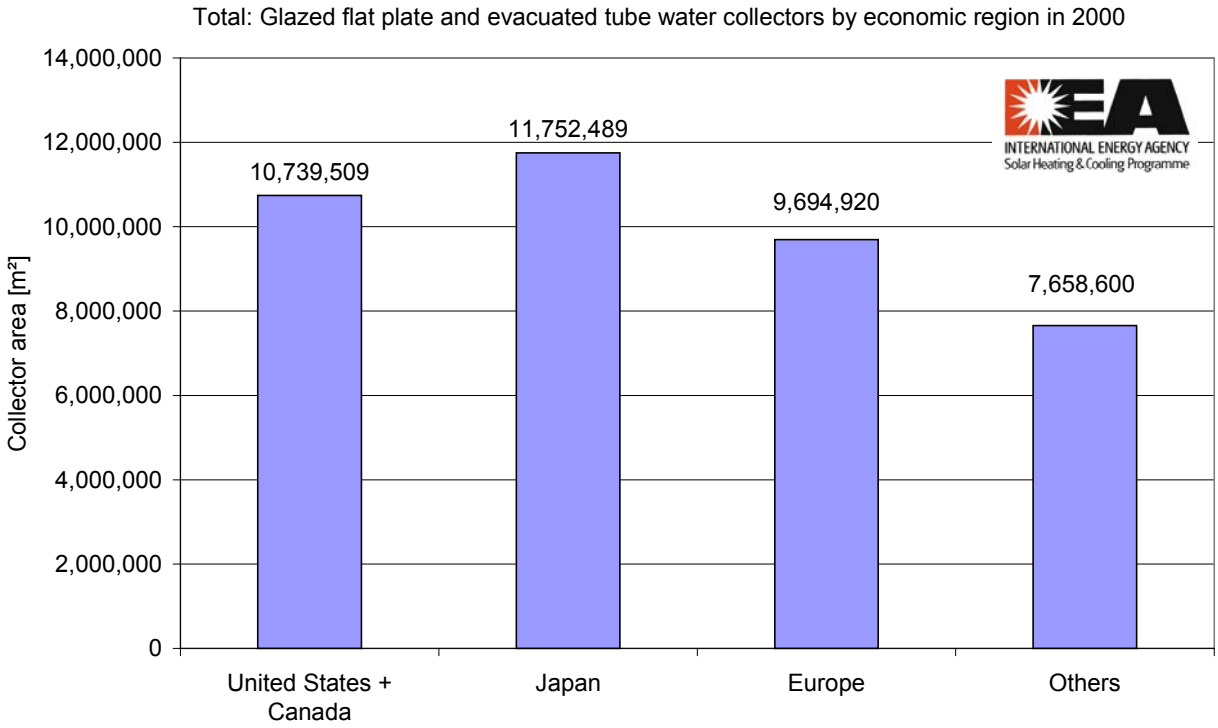

Figure 2: Glazed flat plate and evacuated tube collectors in operation by economic region[2] in the year 2000

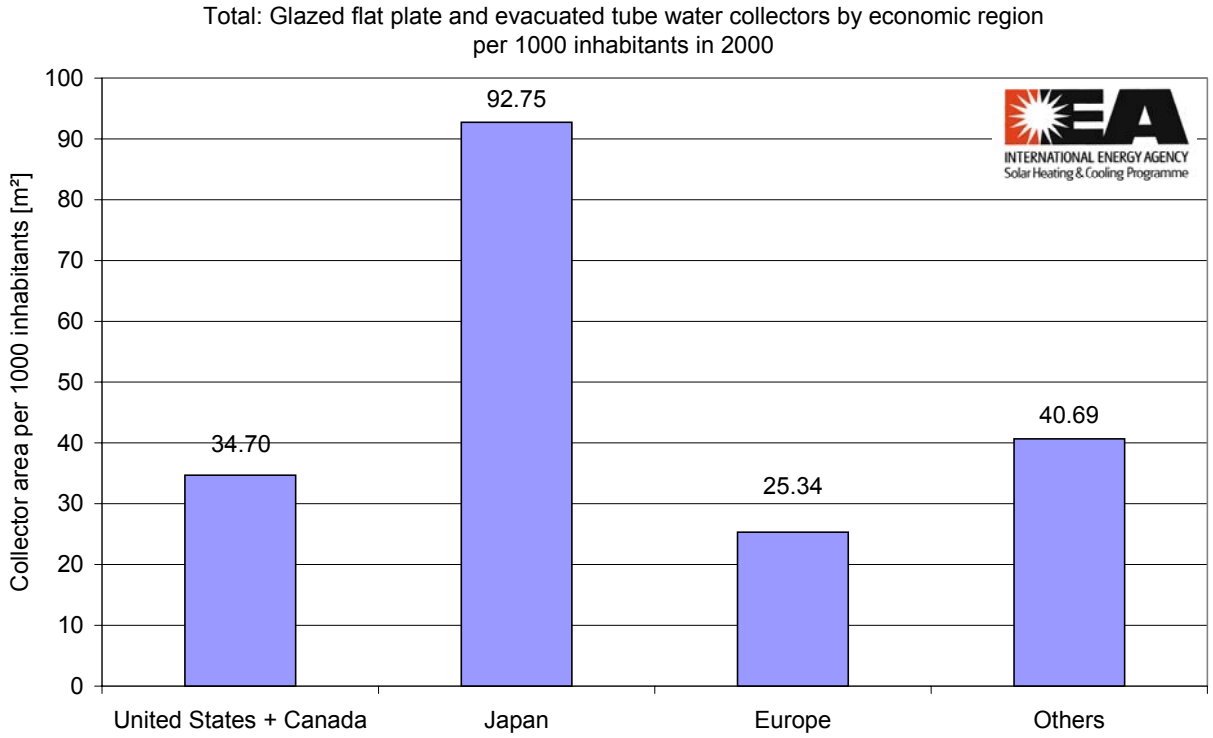

Figure 3: Glazed flat plate and evacuated tube collectors in operation by economic region in the year 2000 per 1000 inhabitants

[2] Europe: European Union (excl. Ireland and Luxemburg) + Switzerland and Norway
Others: Australia, Mexico, New Zealand, Turkey

2.3 Unglazed collectors in operation by the year 2000 in IEA-SHC member countries

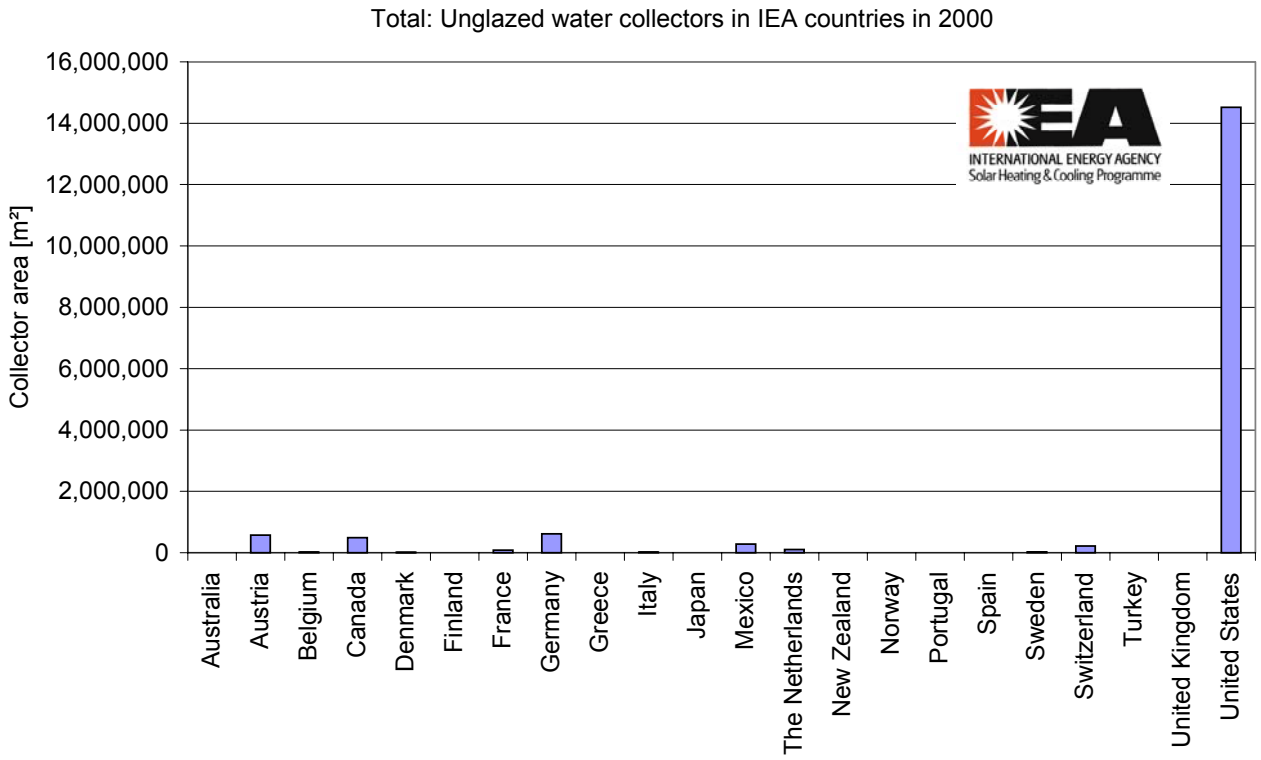

Figure 4: Unglazed collectors in operation in the year 2000

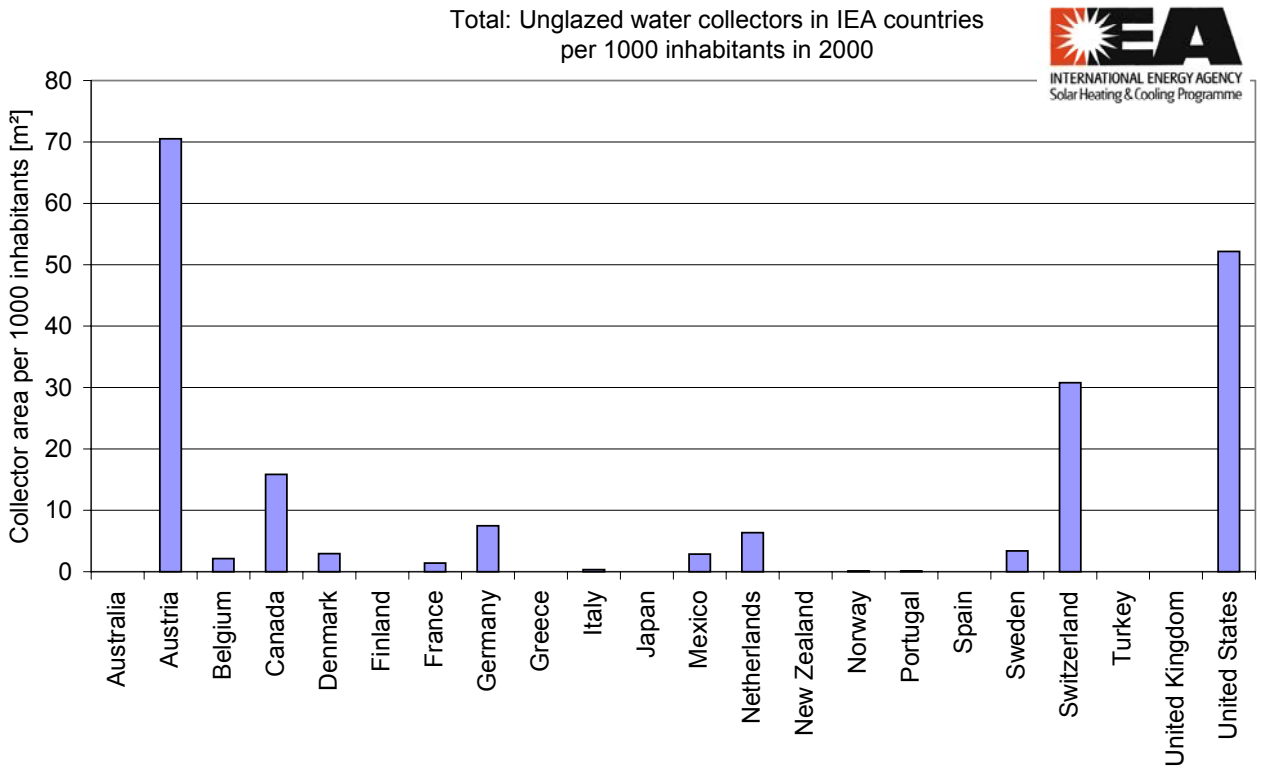

Figure 5: Unglazed collectors in operation in different countries in the year 2000 per 1000 inhabitants

2.4 Unglazed collectors in operation by economic region in 2000

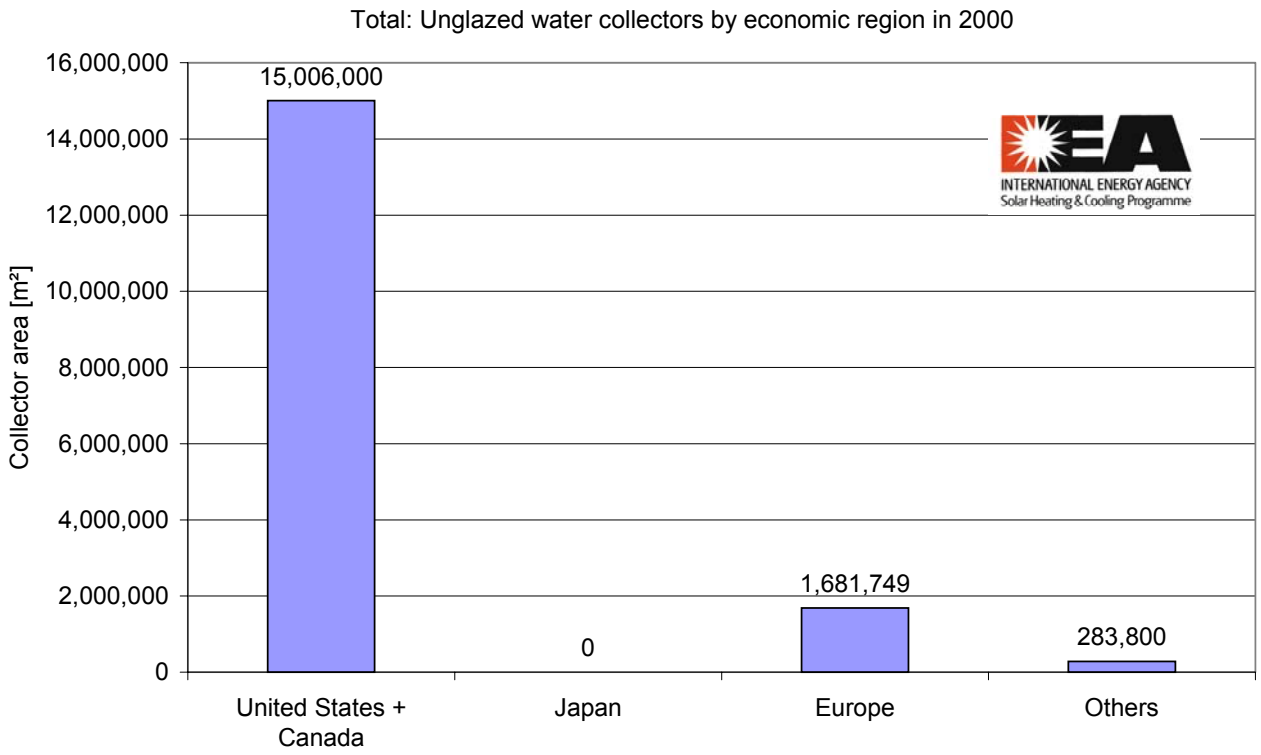

Figure 6: Unglazed collectors in operation by economic region[3] in the year 2000

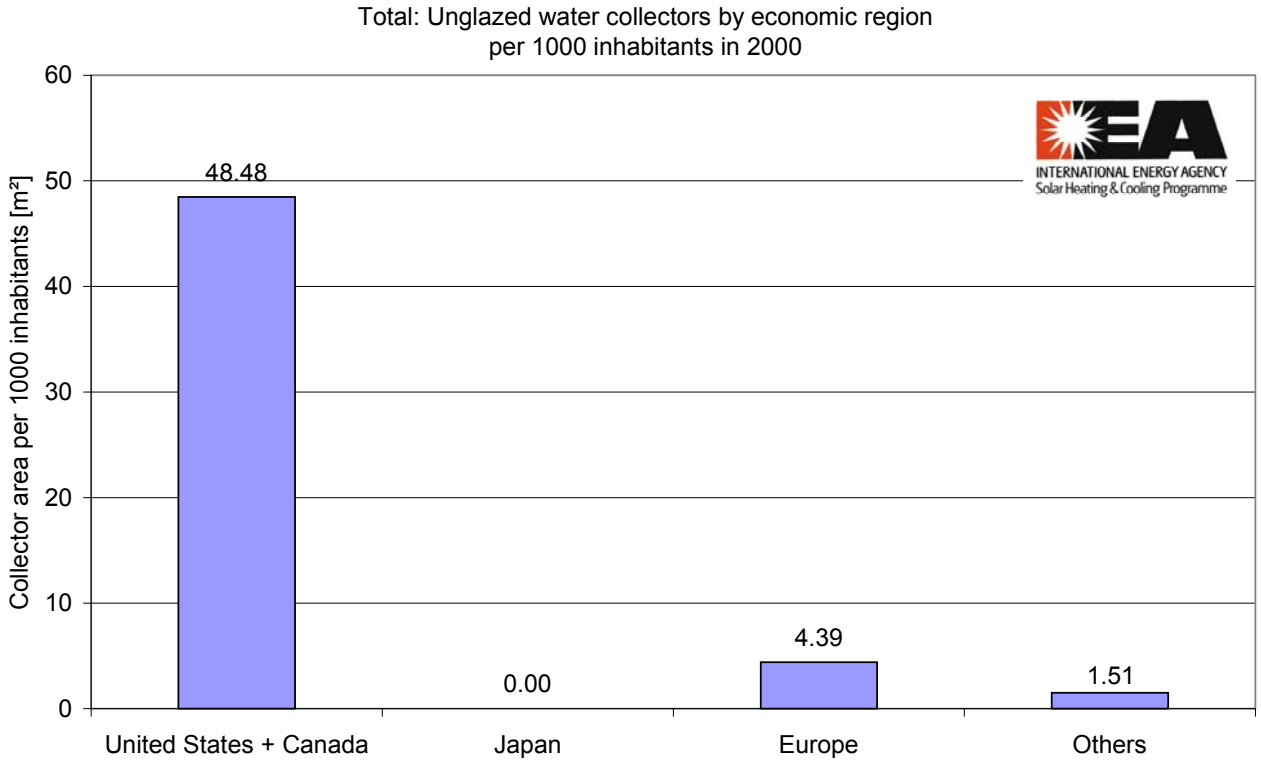

Figure 7: Unglazed collectors in operation by economic region in the year 2000 per 1000 inhabitants

[3] Europe: EU 15, Switzerland and Norway

3 Market development

The collector area installed yearly in the IEA Member countries in 1999 and 2000 was about 3 million square meters. The increase of the installed collector area from 1999 to the year 2000 was 254,827 m² or 8.7%.

3.1 Installed collector area in the year 1999

Table 2: Installed collector area in 1999 in IEA Member countries

Collector Area Installed in IEA-Member Countries in 1999, m2/yr						
Country	Water Collectors			AIR COLLECTOR		TOTAL
	unglazed	glazed	evacuated	unglazed	glazed	
Australia						n.a.
Austria	16,920	138,750	2,398		500	**158,568**
Belgium	1,250	1,300	200			**2,750**
Canada	25,000	234	30	1,982		**27,246**
Denmark	246	15,298	100			**15,644**
Finland		1,500	100	500		**2,100**
France	7,000	23,000	1,000			**31,000**
Germany	50,000	360,000	60,000		5,000	**475,000**
Greece		161,120				**161,120**
Italy	3,000	45,000	3,000	500	500	**52,000**
Japan		298,473	8,283			**306,756**
Mexico	21,560	5,390				**26,950**
Netherlands	8,000	28,000		300		**36,300**
New Zealand	4,000	4,000				**8,000**
Norway	100	1,000			100	**1,200**
Portugal	500	8,000	500			**9,000**
Spain		21,582				**21,582**
Sweden	2,932	9,357	145		80	**12,514**
Switzerland	17,524	28,450	1,155			**47,129**
Turkey		750,000				**750,000**
United Kingdom		3,000	6,000			**9,000**
United States	757,346	38,462	557		1,022	**797,387**
TOTAL	**915,378**	**1,941,916**	**83,468**	**3,282**	**7,202**	**2,951,246**

Installed collector area in the year 2000

Table 3: Installed collector area in 2000 in IEA Member countries

Collector Area Installed in IEA-Member Countries in 2000, m2/yr						
Country	Water Collectors			AIR COLLECTOR		TOTAL
	unglazed	glazed	evacuated	unglazed	glazed	
Australia						n.a.
Austria	14,738	150,543	2,401		550	**168,232**
Belgium	1,250	1,400	200			**2,850**
Canada	27,000	626	161	3,366	0	**31,153**
Denmark	67	12,874	50			**12,991**
Finland		2,000		500		**2,500**
France	7,500	34,000				**41,500**
Germany	50,000	510,000	110,000		7,000	**677,000**
Greece		170,000				**170,000**
Italy	3,000	45,000	3,000	500	500	**52,000**
Japan		301,620	5,891			**307,511**
Mexico	35,778	17,622				**53,400**
Netherlands	7,500	27,000		300		**34,800**
New Zealand	4,500	4,500				**9,000**
Norway	100	1,000			100	**1,200**
Portugal	500	7,500	500			**8,500**
Spain		35,667				**35,667**
Sweden	2,983	18,045	872			**21,900**
Switzerland	14,779	24,701	1,555			**41,035**
Turkey	0	750,000	0	0	0	**750,000**
United Kingdom		9,000	1,000			**10,000**
United States	738,208	35,675	1,394		557	**775,834**
TOTAL	**907,903**	**2,158,773**	**127,024**	**4,666**	**8,707**	**3,207,073**

3.2 Market development of glazed flat plate and evacuated tube collectors by country

The market for flat plate and evacuated tube collectors grew from 2,025,384 m² in the year 1999 to 2,285,797 m² in the year 2000. This corresponds to a growth of 13%. The markets that underwent the greatest growth between 1999 and 2000 included Mexico at 226%, Sweden at 99%, Spain at 65%, Germany at 47% and France at 42%. The countries with stagnating markets were Japan, Italy, Norway and Turkey. Decreasing markets were recorded in Denmark at -16%, Switzerland at -11%, Portugal at -6% and the USA and the Netherlands at -4%.

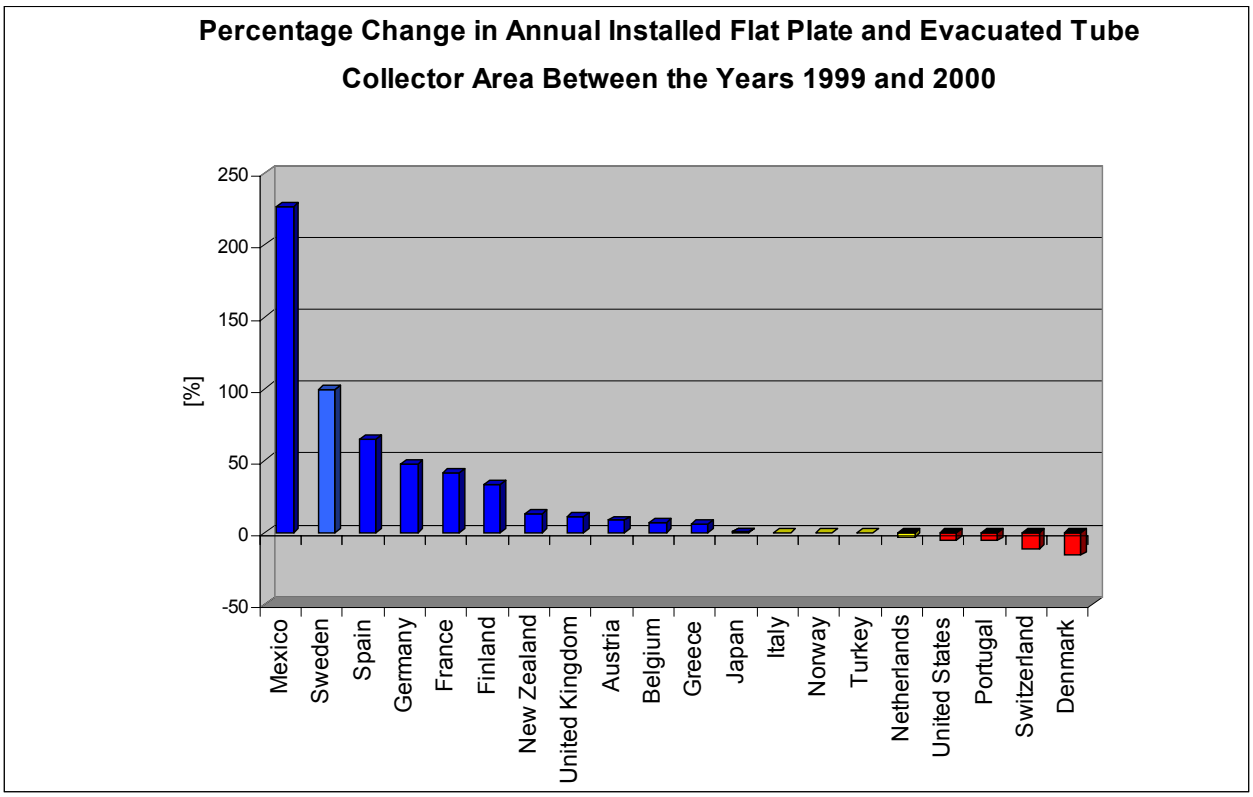

Figure 8: Percentage Change in Annual Installed Flat Plate and Evacuated Tube Collector Area Between the Years 1999 and 2000

3.3 Market development of unglazed collectors for swimming pool heating by country

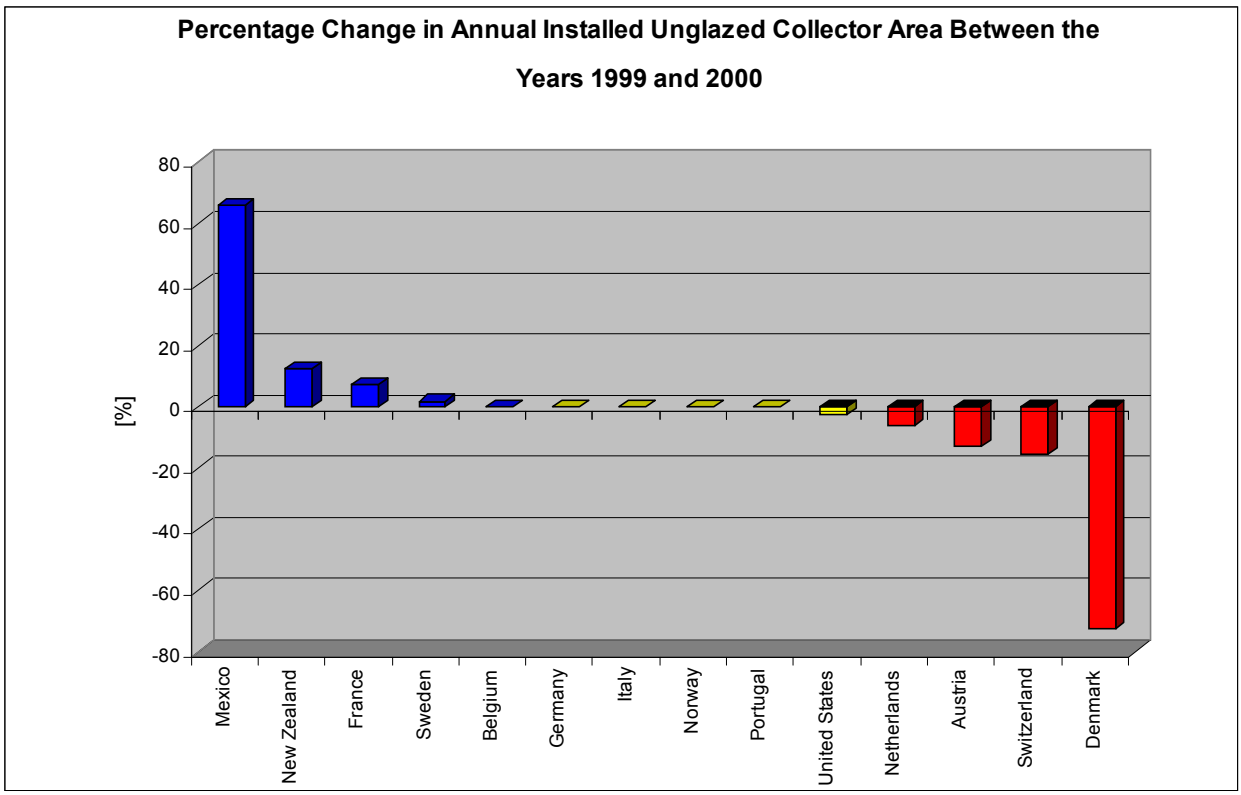

Figure 9: Percentage Change in Annual Installed Unglazed Collector Area Between the Years 1999 and 2000

The market for unglazed collectors recorded a slight decrease from 915,378 m² in the year 1999 to 907,903 m² in the year 2000. This corresponds to a reduction of 0.8%. The markets that underwent the greatest growth between 1999 and 2000 included Mexico at 66%, New Zealand at 12% and France at 7%. Decreasing markets were recorded in Denmark at -73%, Switzerland at -16%, Austria at -13% and the Netherlands at -6%.

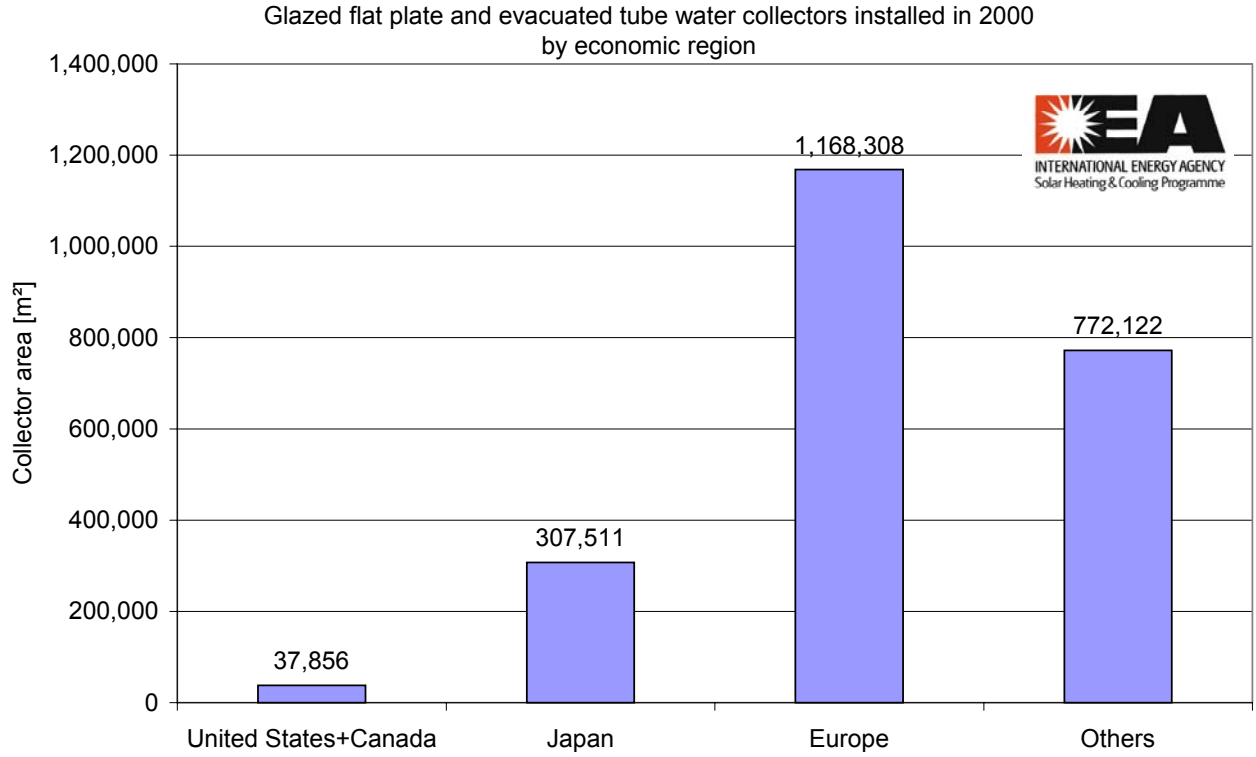

Figure 10: Glazed flat plate and evacuated tube water collectors installed in 2000

4 Contribution to the energy supply and CO_2 reduction

Until now there has been scarcely any information available on the contribution of solar collectors to the supply of energy, the potential of this technology has been, for the greater part, under-estimated.

In this section, the contribution of the installed water collectors to the energy supply and CO_2 reduction is shown. The data for air collector applications was insufficient, therefore,
the contribution of air collectors to the energy supply and CO_2 reduction was not calculated.

As shown in Table 1, around 56,82 million square meters of unglazed, flat plate and evacuated tube collectors were installed by the end of the year 2000 in the IEA Member countries. The annual yield of these collector areas is calculated to be 24,367 GWh (87,721 TJ). This corresponds to a calculated oil equivalent of 3.9 billion liter and an annual CO_2 reduction of 10.7 million tons of CO_2.

Basis for calculation

In order to ascertain the energy yield of thermal solar plants, the oil equivalent saved and the CO_2 emissions avoided, the following procedure was used:

- Only water collectors were used for the calculations (unglazed, flat plate and evacuated tube collectors). Air collector plants were not considered.

- For each country, the overall collector area installed (water collectors) was allocated to the four plant types:

  Collector area for: - swimming pool heating
  - domestic hot water systems for single family houses
  - domestic hot water systems for multi-family houses and district heating
  - solar combisystems for domestic hot water and space heating

- Reference plants were defined for each country for each type of plant.

- The number of plants for each country was ascertained from the share of collector area for each plant type and the collector area per reference system.

Reference collectors and a reference climate were determined for each country apart from the reference plants. On the basis of these reference conditions simulations were performed with the simulation program T-Sol[4] and in this way the solar yields, energy savings and CO_2 emissions were ascertained.

The reference conditions, which formed the basis for the simulation, can be found in the appendix.

Results

The annual collector yield per square meter of collector area lies, depending on the application (domestic hot water preparation, space heating...), the local climatic conditions and the plant dimensioning (high or low solar fraction), between 250 kWh/m² for solar combisystems for hot water and space heating in northern climate zones and 600 kWh/m² for plants used to prepare hot water in southern climate zones.

The energy savings were ascertained from the energy equivalent of the fuel used and the rate of efficiency of the auxiliary heating system. For the auxiliary heating system oil was taken as the fuel for all plants and the energy equivalent per liter of oil 36.700 kJ respectively 10.2 kWh was used in all countries.

To obtain an exact statement about the CO_2 emissions avoided the substituted energy medium would have to be ascertained for each country. Since this could only be done in a very detailed survey which goes beyond the scope of this study, the energy savings and the CO_2 emissions avoided relate to oil. This represents a simplification since gas, coal, biomass or electricity can be used as the energy medium for the auxiliary heating system instead of oil.

The CO_2 emissions avoided by solar plants were ascertained from the energy savings (oil equivalent). 2.73 kg CO_2 per liter of oil was used as the emission factor.

[4] T-Sol, Version 4.03, dynamic simulation program to design and optimize thermal solar plants, Valentin Energiesoftware, www.valentin.de

Table 4: Calculated collector yield and corresponding oil equivalent as well as CO_2-reduction of all solar thermal systems (systems for hot water, space heating and swimming pool heating)

Country	total collector area* [m²]	calculated number of systems	collector yield [GWh/a]	collector yield [TJ/a]	energy savings - oil equivalent [l/a]	CO2 reduction [t/a]
Australia	0	0	0	0	0	0
Austria	2,179,210	226,181	700	2,519	100,613,156	274,545
Belgium	42,975	4,329	10	37	1,536,165	4,191
Canada	565,000	13,937	139	501	22,712,002	61,969
Denmark	258,732	55,277	86	311	12,194,644	33,271
Finland	10,200	2,433	3	12	426,858	1,165
France	554,500	113,395	190	684	28,058,629	76,552
Germany	3,406,000	407,584	1,146	4,127	168,838,020	460,646
Greece	2,815,000	703,750	1,640	5,903	262,498,750	717,051
Italy	340,000	80,100	141	509	22,405,910	61,126
Japan	11,752,489	2,840,968	5,483	19,737	824,679,205	2,249,944
Mexico	378,400	9,403	146	527	27,124,380	74,008
Netherlands	276,885	81,128	80	288	11,531,493	31,471
New Zealand	64,000	15,264	19	69	3,050,342	8,325
Norway	7,600	1,164	2	9	322,509	880
Portugal	239,500	56,887	150	540	24,504,613	66,858
Spain	399,922	95,381	244	879	36,789,585	100,384
Sweden	208,045	26,026	60	214	7,943,550	21,678
Switzerland	487,000	39,470	128	461	18,883,244	51,519
Turkey	7,500,000	1,702,500	3,932	14,155	629,437,500	1,719,394
United Kingdom	151,000	37,750	50	181	7,198,925	19,645
United States	25,180,000	1,850,398	10,016	36,058	1,692,620,535	4,618,469
Total	**56,816,458**	**8,363,326**	**24,367**	**87,722**	**3,903,370,016**	**10,653,089**

* Unglazed, glazed flat plate and evacuated tube collectors

Table 5: Calculated collector yield and corresponding oil equivalent as well as CO_2-reduction of solar thermal systems for hot water preparation and space heating with flat plate and evacuated tube collectors

Country	total collector area [m²]	number of systems	collector yield [GWh/a]	collector yield [Tera J /a]	energy savings - oil equivalent [l/a]	CO2 reduction [t/a]
Australia						
Austria	1,607,404	223,322	607	2,186	84,954,248	231,820
Belgium	21,100	4,220	7	24	916,162	2,500
Canada	72,000	11,472	33	119	4,643,059	12,669
Denmark	243,169	55,199	84	303	11,790,730	32,169
Finland	10,200	2,433	3	12	426,858	1,165
France	470,000	112,972	173	624	25,181,953	68,704
Germany	2,791,000	404,509	1,014	3,651	145,951,103	398,201
Greece	2,815,000	703,750	1,640	5,903	262,498,750	717,051
Italy	320,000	80,000	137	494	21,656,000	59,080
Japan	11,752,489	2,840,968	5,483	19,737	824,679,205	2,249,944
Mexico	94,600	7,984	64	230	12,450,075	33,970
Netherlands	176,580	80,626	65	234	9,034,500	24,658
New Zealand	64,000	15,264	19	69	3,050,342	8,325
Norway	7,100	1,161	2	9	311,259	849
Portugal	238,500	56,882	150	539	24,462,074	66,742
Spain	399,922	95,381	244	879	36,789,585	100,384
Sweden	178,045	25,876	56	200	7,322,670	19,984
Switzerland	265,800	38,364	90	323	12,560,795	34,269
Turkey	7,500,000	1,702,500	3,932	14,155	629,437,500	1,719,394
United Kingdom	151,000	37,750	50	181	7,198,925	19,645
United States	10,667,000	1,777,833	6,116	22,017	1,019,587,417	2,782,131
Total	**39,844,909**	**8,278,468**	**19,969**		**3,144,903,211**	**8,583,651**

Table 6: Calculated collector yield and corresponding oil equivalent as well as CO_2-reduction of solar thermal systems for swimming pool heating with unglazed collectors

Country	total collector area [m²]	calculated number of systems	collector yield [GWh/a]	energy savings - oil equivalent [l/a]	CO2 reduction [t/a]
Australia					
Austria	571,806	2,859	93	15,658,907	42,724
Belgium	21,875	109	4	620,003	1,692
Canada	493,000	2,465	106	18,068,943	49,300
Denmark	15,563	78	2	403,914	1,102
Finland	0	0	0	0	0
France	84,500	423	17	2,876,676	7,849
Germany	615,000	3,075	132	22,886,918	62,446
Greece	0	0	0	0	0
Italy	20,000	100	4	749,910	2,046
Japan		0	0	0	0
Mexico	283,800	1,419	82	14,674,305	40,038
Netherlands	100,305	502	15	2,496,993	6,813
New Zealand		0	0	0	0
Norway	500	3	0	11,250	31
Portugal	1,000	5	0	42,539	116
Spain		0	0	0	0
Sweden	30,000	150	4	620,880	1,694
Switzerland	221,200	1,106	38	6,322,449	17,250
Turkey	0	0	0	0	0
United Kingdom	0	0	0	0	0
United States	14,513,000	72,565	3,900	673,033,119	1,836,337
Total	**16,971,549**	**84,858**	**4,398**	**758,466,804**	**2,069,438**

4.1 Calculated collector yield

4.1.1 Collector yield of glazed flat plate and evacuated tube collectors

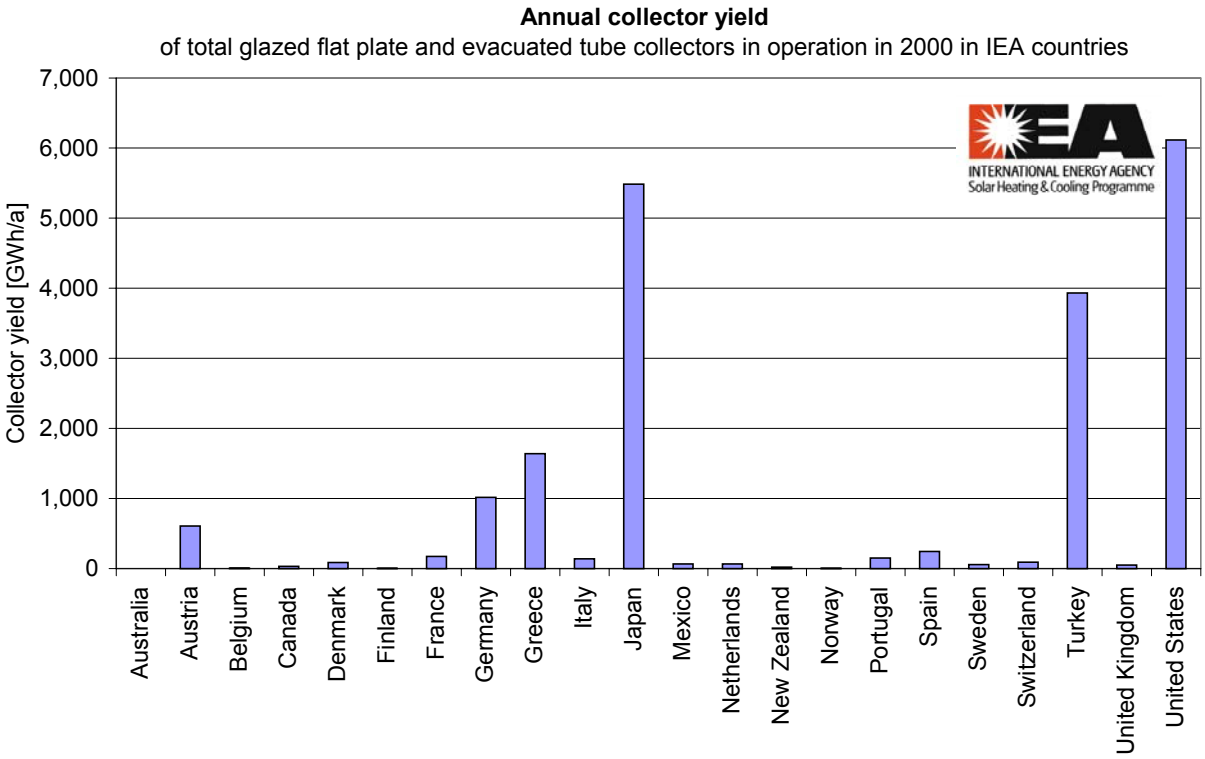

Figure 12: Annual collector yield of glazed flat plate and evacuated tube collectors in operation in the year 2000

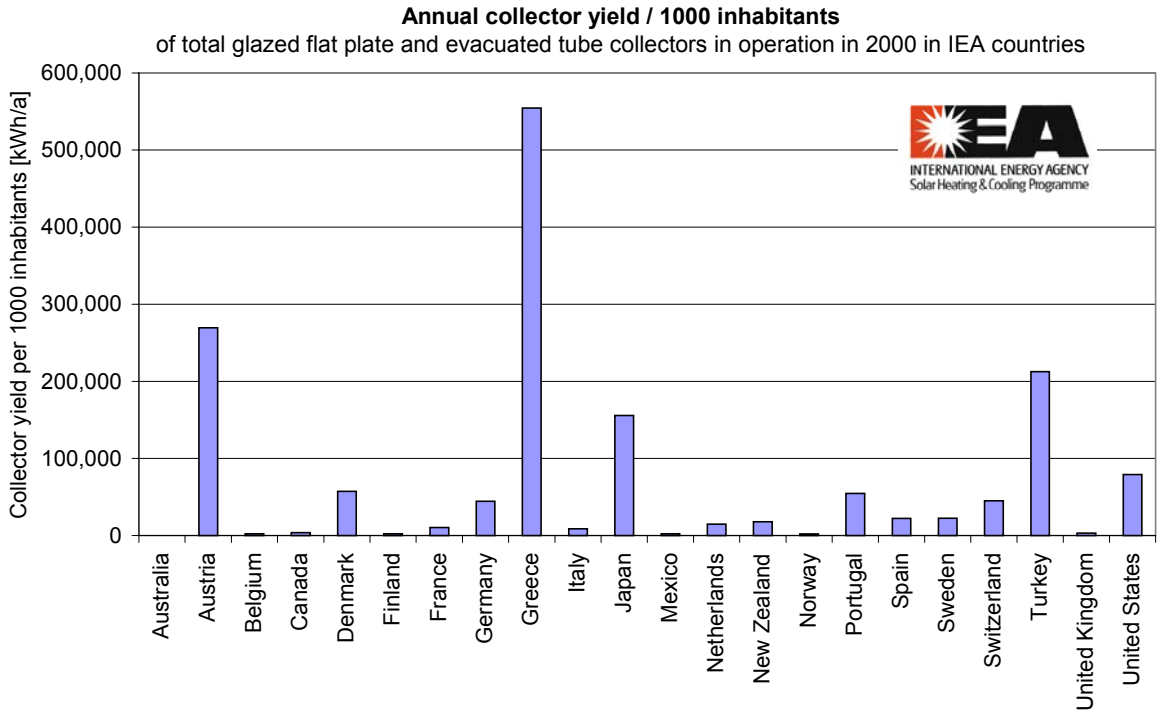

Figure 13: Annual collector yield of glazed flat plate and evacuated tube collectors in operation in the year 2000 per 1000 inhabitants

4.1.2 Collector yield of unglazed collectors

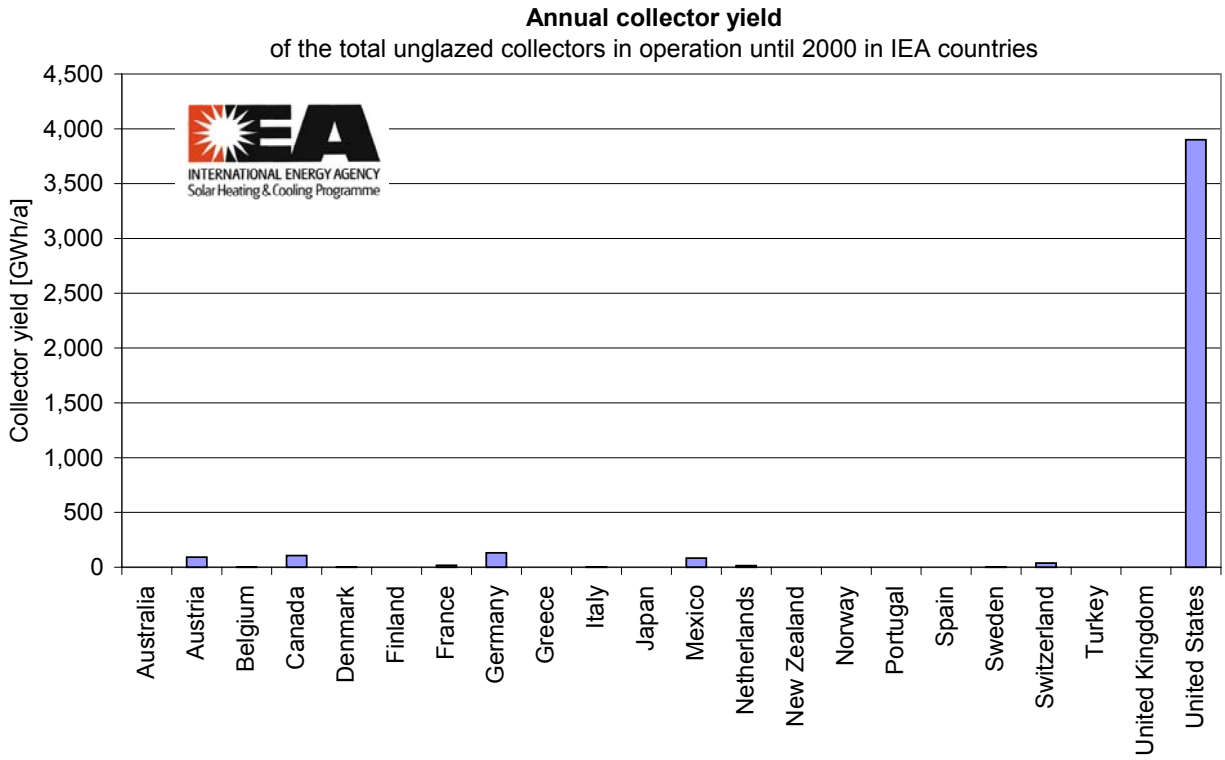

Figure 14: Annual collector yield of unglazed collectors in operation in the year 2000

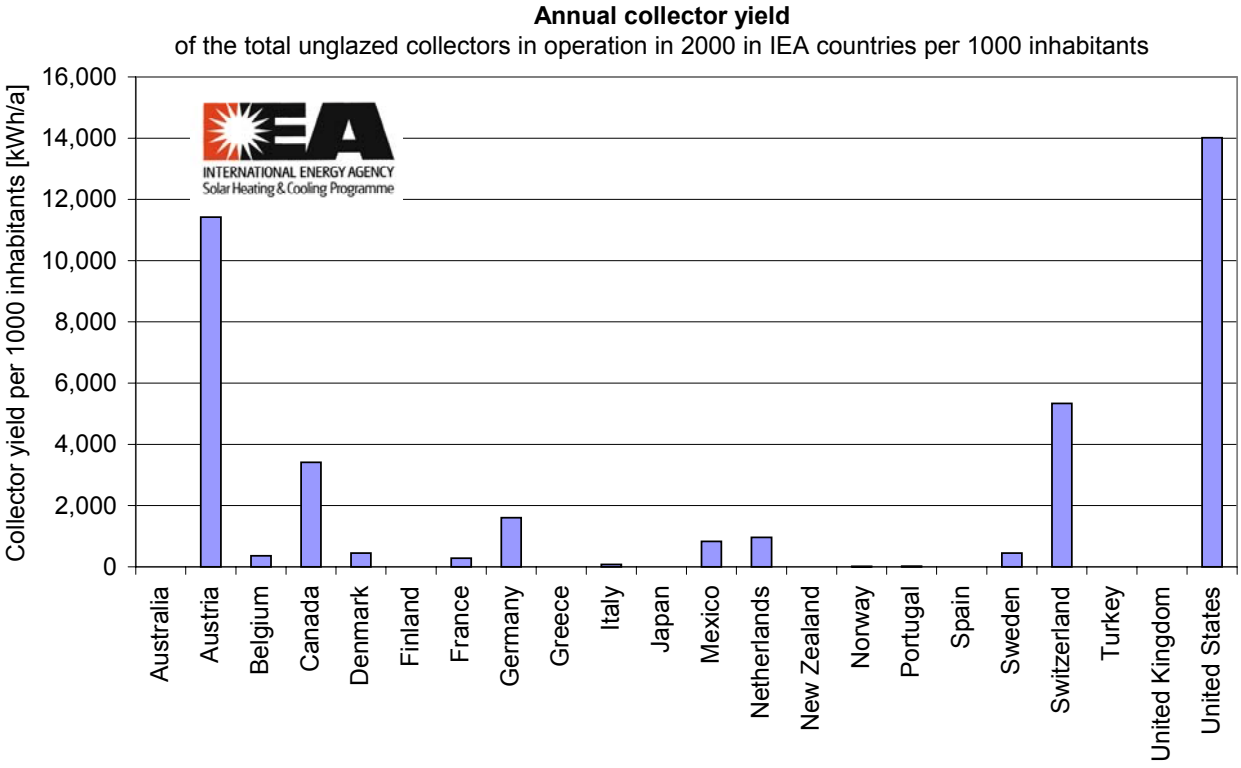

Figure 15: Annual collector yield of unglazed collectors in operation in the year 2000 per 1000 inhabitants

4.2 Calculated energy savings

4.2.1 Energy savings in oil equivalent - glazed flat plate and evacuated tube collectors

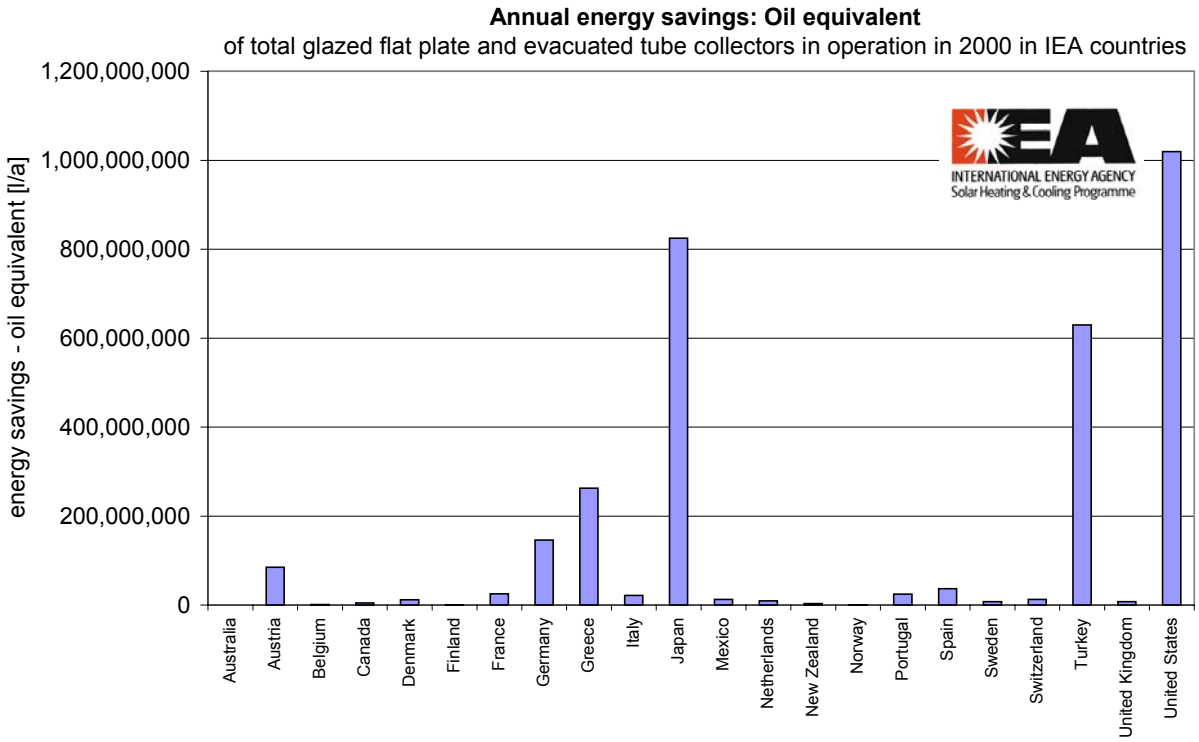

Figure 16: Annual energy savings in oil equivalent - glazed flat plate and evacuated tube collectors

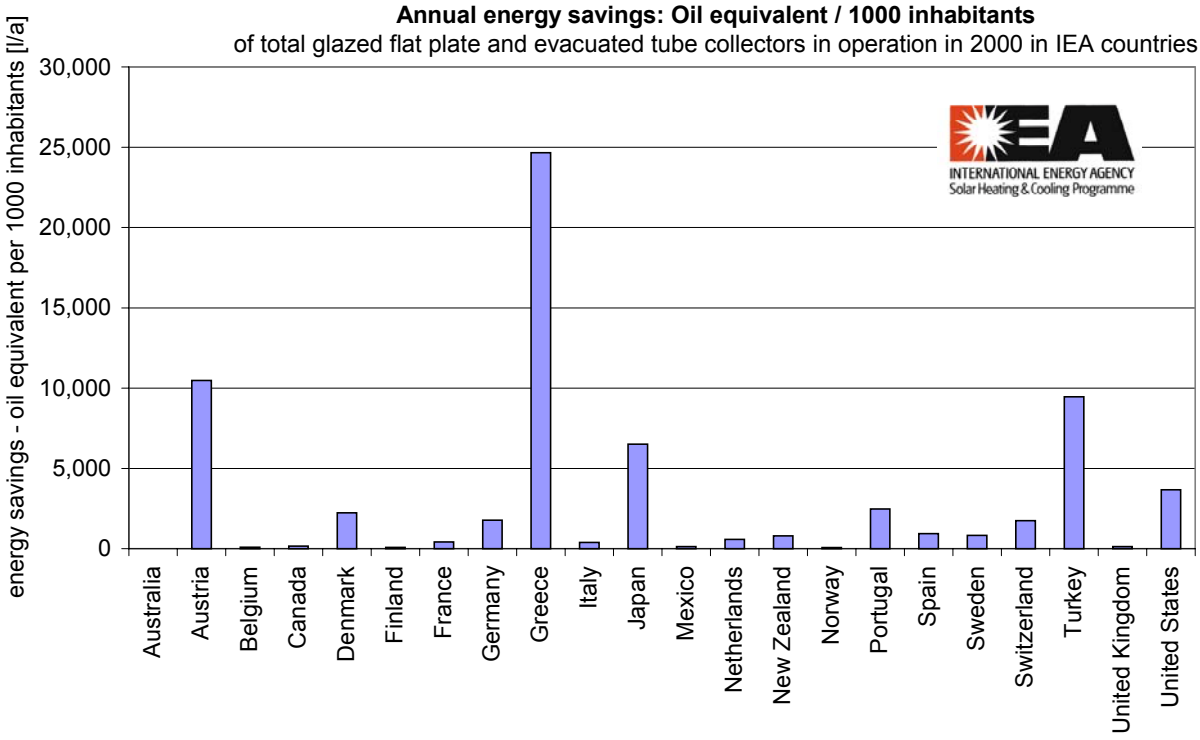

Figure 17: Annual energy savings in oil equivalent - glazed flat plate and evacuated tube collectors per 1000 inhabitants

4.2.2 Energy savings in oil equivalent - unglazed collectors

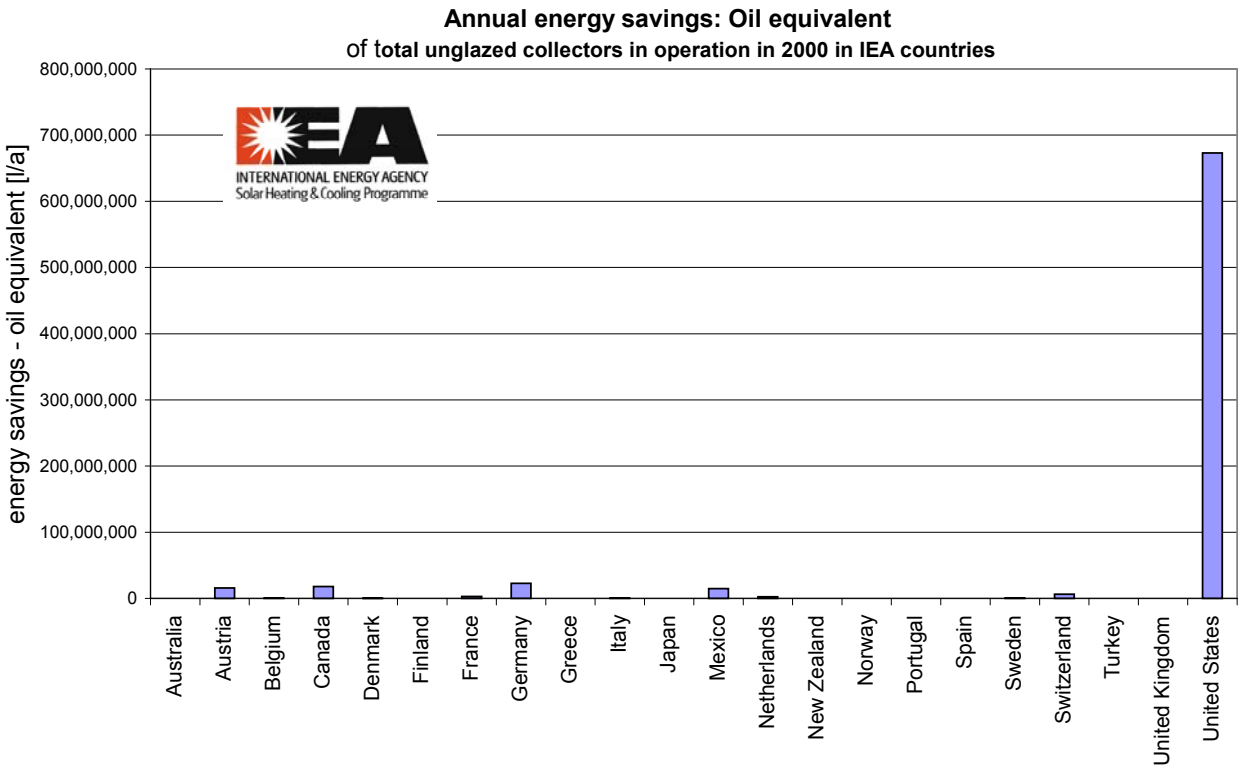

Figure 18: Annual energy savings in oil equivalent - unglazed collectors

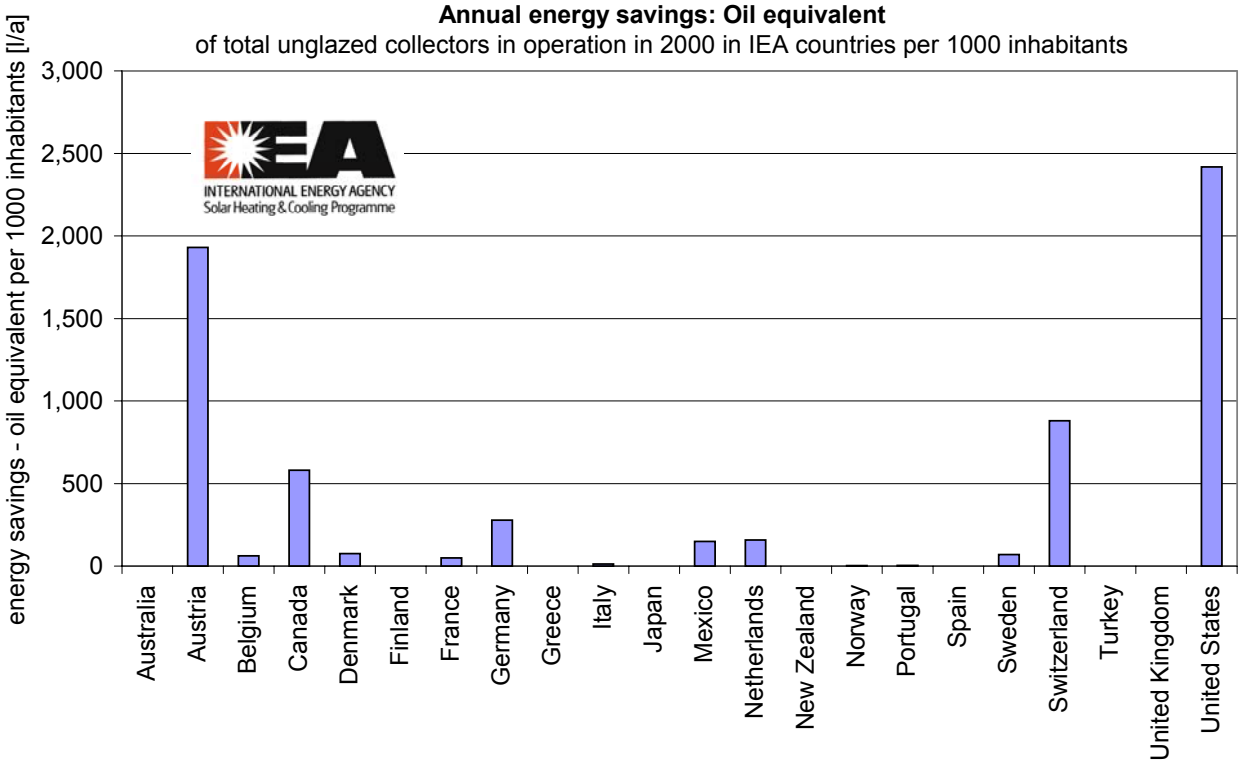

Figure 19: Annual energy savings per 1000 inhabitants in oil equivalent - unglazed collectors

4.3 Calculated contribution to CO_2 reduction

4.3.1 Contribution to CO_2 reduction: Flat plate and evacuated tube collectors

Figure 20: Annual contribution to CO_2 reduction – flat plate and evacuated tube collectors

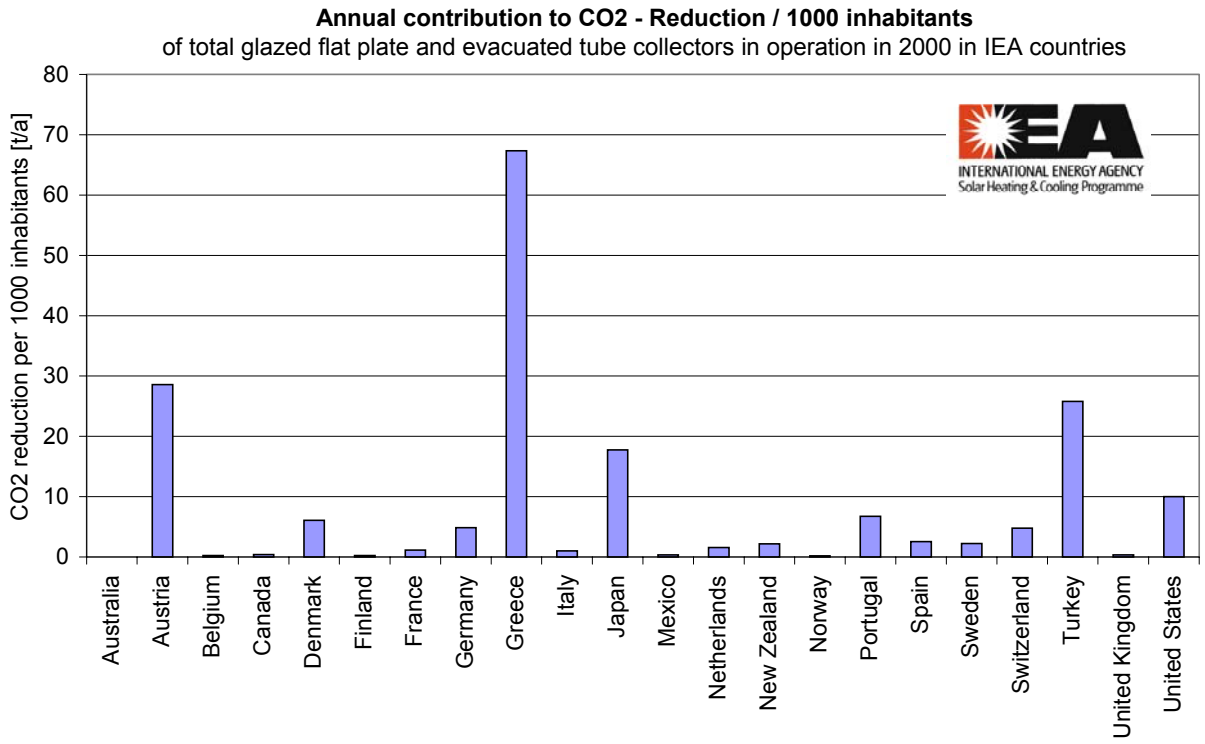

Figure 21: Annual contribution to CO_2 reduction per 1000 inhabitants– flat plate and evacuated tube collectors

4.3.2 Contribution to CO_2 reduction: Unglazed collectors

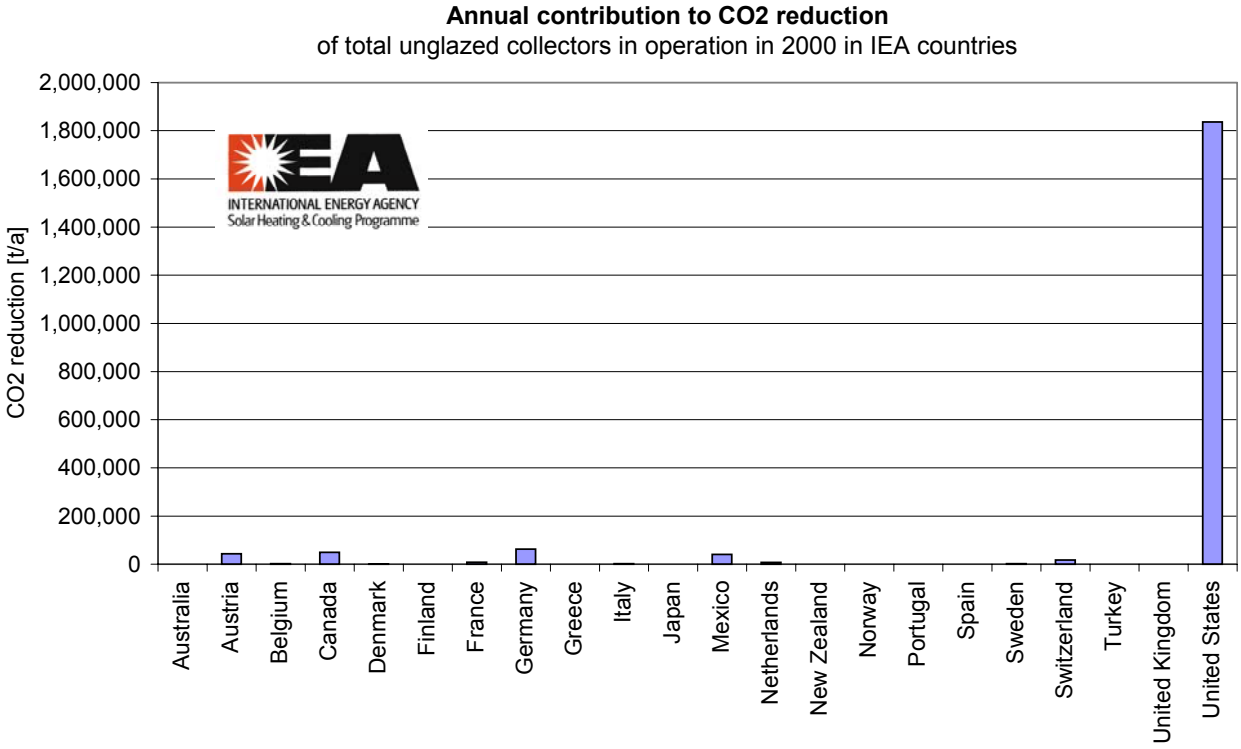

Figure 22: Annual contribution to CO_2 reduction – unglazed collectors

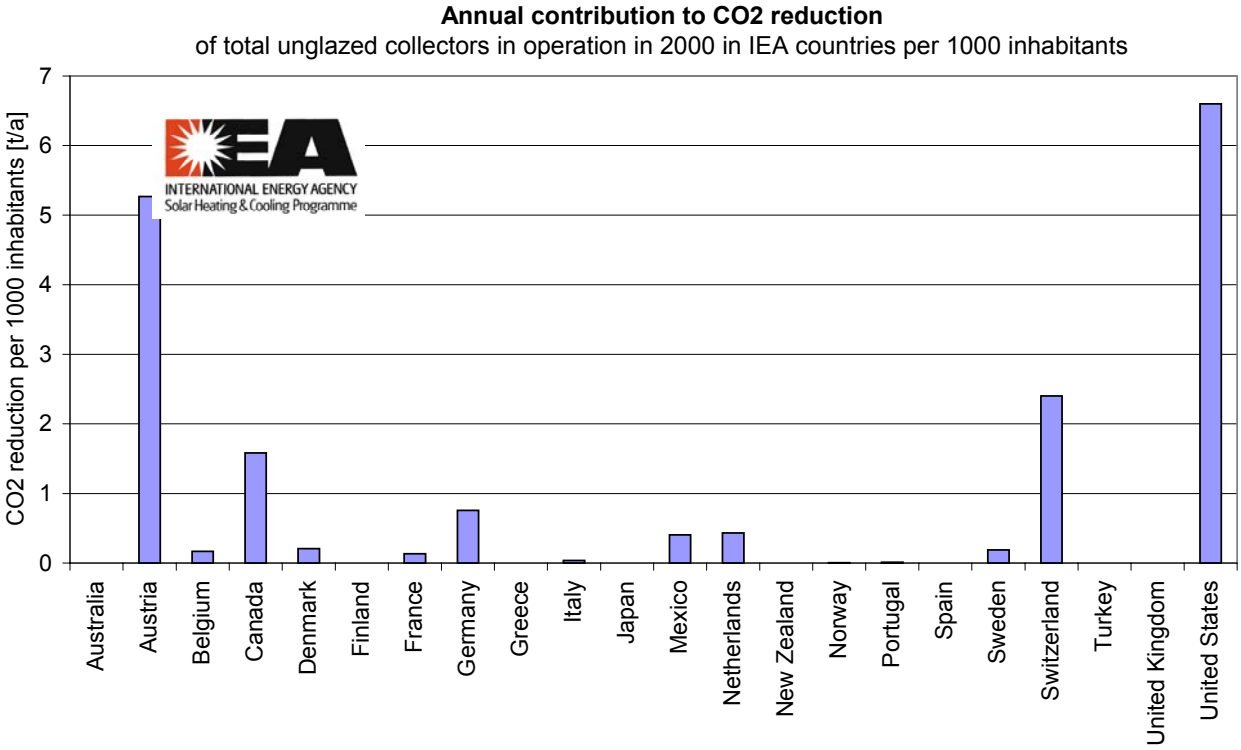

Figure 23: Annual contribution to CO_2 reduction per 1000 inhabitants – unglazed collectors

4.4 Contribution of solar thermal collectors to CO_2 reduction by economic region

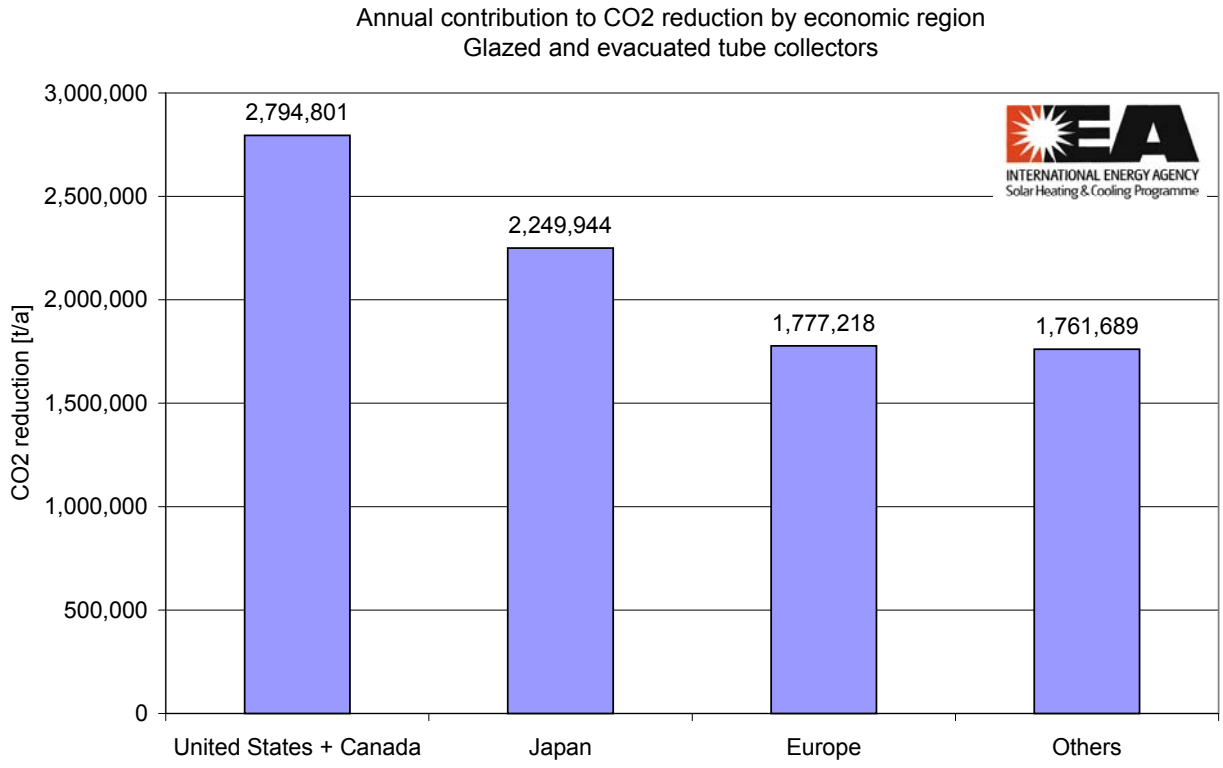

Figure 24: Annual contribution of glazed and evacuated tube collectors to CO_2-reduction

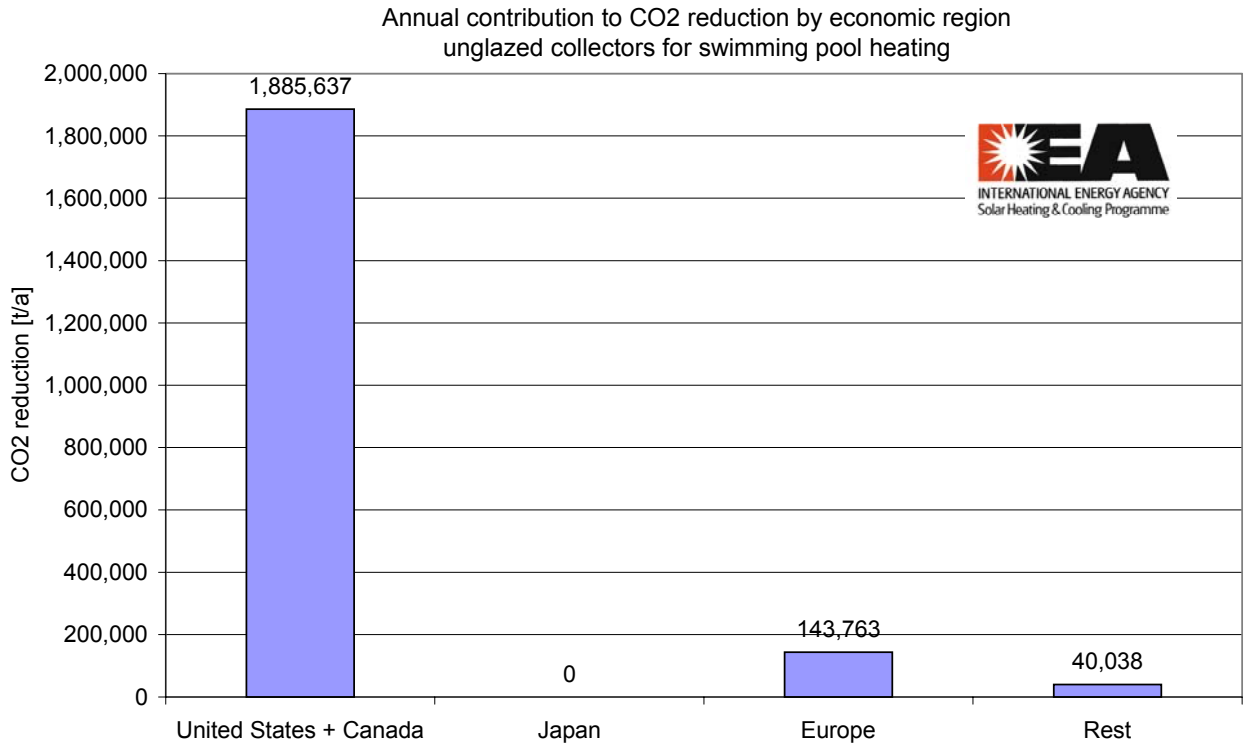

Figure 25: Annual contribution of unglazed collectors to CO_2 reduction

5 APPENDIX

5.1 Reference systems

To make the simulations to determine the energy output of a solar thermal heating system, it was necessary to define reference systems for different applications and countries (regions).
Based on the reference systems, hot water demand, heat load (only for solar combisystems[5]) and weather data, the energy output of the systems and the resulting energy savings in oil equivalent were calculated.

For the simulations, four major applications and reference systems—described in section 4—were chosen. For these reference systems, the daily hot water demand, the heat demand (only for solar combisystems) and the weather data (location) were defined. The reference systems, are those systems most common in the respective country.

The following tables describe the key data of the reference systems in different countries, the location of the reference climate used and the share of the total collector area[6] in use for the respective application. Furthermore, a hydraulic scheme is shown for each reference system.

[5] Solar combisystems are solar heating installations providing space heating as well as domestic hot water for the inhabitants of the building. The primary energy sources are solar energy as well as an auxiliary source such as biomass, gas, oil and electricity.
[6] Glazed flat plate and evacuated tube collector

5.1.1 Solar thermal systems for swimming pool heating with unglazed plastic absorbers

Country	reference system	Total collector area [m²]	number of systems	reference climate
Australia	C: 200 m² unglazed plastic absorber	n.a.	n.a.	Sydney
Austria	C: 200 m² unglazed plastic absorber	571,806	2,859	Graz
Belgium	C: 200 m² unglazed plastic absorber	21,875	109	Brussels
Canada	C: 200 m² unglazed plastic absorber	493,000	2,465	Montreal
Denmark	C: 200 m² unglazed plastic absorber	15,563	78	Copenhagen
Finland	C: 200 m² unglazed plastic absorber	0	0	Helsinki
France	C: 200 m² unglazed plastic absorber	84,500	423	Paris
Germany	C: 200 m² unglazed plastic absorber	615,000	3,075	Würzburg
Italy	C: 200 m² unglazed plastic absorber	20,000	100	Bologna
Japan	C: 200 m² unglazed plastic absorber	n.a.	n.a.	Tokyo
Mexico	C: 200 m² unglazed plastic absorber	283,800	1,419	Mexico City
Netherlands	C: 200 m² unglazed plastic absorber	100,305	502	Amsterdam
New Zealand	C: 200 m² unglazed plastic absorber	n.a.	n.a.	Wellington
Norway	C: 200 m² unglazed plastic absorber	500	3	Oslo
Portugal	C: 200 m² unglazed plastic absorber	1,000	5	Lisbon
Spain	C: 200 m² unglazed plastic absorber	n.a.	n.a.	Madrid
Sweden	C: 200 m² unglazed plastic absorber	30,000	150	Gothenburg
Switzerland	C: 200 m² unglazed plastic absorber	221,200	1,106	Zurich
United Kingdom	C: 200 m² unglazed plastic absorber	0	0	London
United States	C: 200 m² unglazed plastic absorber	14,513,000	72,565	Denver Los Angeles

C: collector area

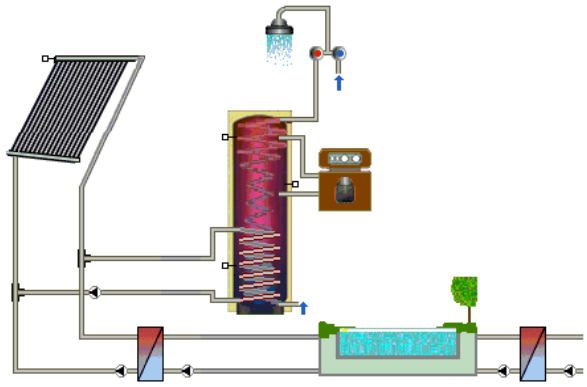

Figure 1: Hydraulic scheme of the swimming pool reference system

5.1.2 Solar domestic hot water systems for single family houses

Country	reference system	reference climate	% of total market[7]
Australia	C: 4 m² / ST: 300 l / HWD: 150 l/d / TS	Sydney	90
Austria	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Graz	77
Belgium	C: 4 m² / ST: 200 l / HWD: 150 l/d / PDS	Brussels	100
Canada	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Montreal	95
Denmark	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Copenhagen	90
Finland	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Helsinki	95
France	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Paris	95
Germany	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Würzburg	80
Greece	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Athens	100
Italy	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Bologna	100
Japan	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Tokyo	96
Mexico	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Mexico City	28
Netherlands	C: 2 m² / ST: 150 l / HWD: 150 l/d / PDS	Amsterdam	90
New Zealand	C: 4 m² / ST: 300 l / HWD: 150 l/d / TS	Wellington	95
Norway	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Oslo	98
Portugal	C: 4 m² / ST: 200 l / HWD: 150 l/d / TS	Lisbon	95
Spain	C: 4 m² / ST: 200 l / HWD: 150 l/d / TS	Madrid	95
Sweden	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Gothenburg	25
Switzerland	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Zurich	80
Turkey	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Istanbul	90
United Kingdom	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	London	100
United States	C: 6 m² / ST: 300 l / HWD: 150 l/d / PS	Denver Los Angeles	100

C	collector area
ST	hot water storage
HWD	hot water demand / day with 60°C
TS	thermosiphon system
PS	pumped system
PDS	pumped, drain back system

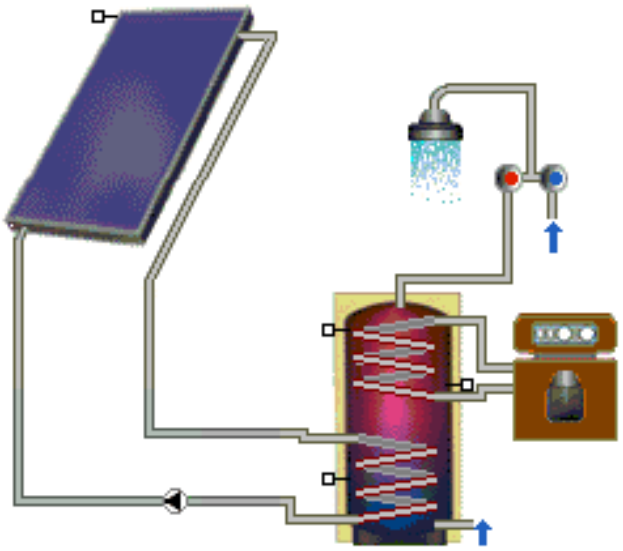

Figure 2: Hydraulic scheme of the DHW reference system

[7] percentage of total installed collector area (flat plate and vacuum tube) by the year 2000 for DHW systems for single family houses

5.1.3 Solar domestic hot water systems for multi-family houses and district heating

Country	reference system	reference climate	% of total market [8]
Australia	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Sydney	10
Austria	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Graz	3
Belgium		Brussels	0
Canada	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Montreal	5
Denmark	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Copenhagen	9
Finland	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Helsinki	5
France	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Paris	1
Germany	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Würzburg	8
Greece		Athens	0
Italy		Bologna	0
Japan	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Tokyo	2
Mexico*	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Mexico City	72
Netherlands	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PDS	Amsterdam	8
New Zealand	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Wellington	5
Norway	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Oslo	1
Portugal	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Lisbon	5
Spain	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Madrid	5
Sweden	C: 1000 m² / ST: 50000 l / HWD: 40000 l/d / PS	Gothenburg	65
Switzerland	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Zurich	5
Turkey	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Istanbul	10
United Kingdom		London	0
United States		Denver Los Angeles	0

* Industry

C	collector area
ST	hot water storage
HWD	hot water demand / day with 60°C
TS	thermosiphon system
PS	pumped system
PDS	pumped, drain back system

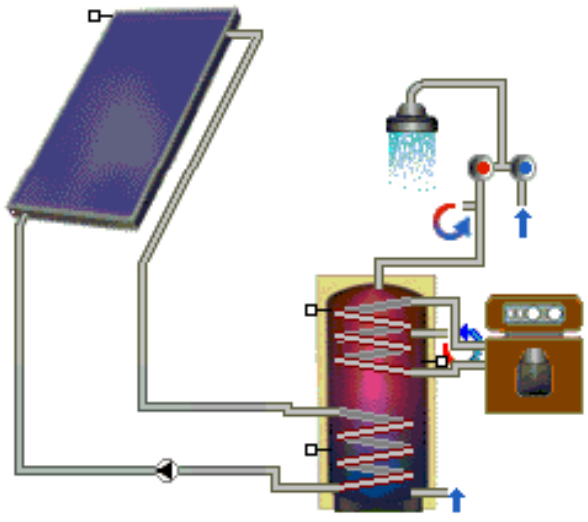

Figure 3: Hydraulic scheme of the DHW system for muli-family houses

[8] percentage of total installed collector area (flat plate and vacuum tube) until 2000 for DHW systems for multi-family houses and district heating systems

5.1.4 Solar combisystems for domestic hot water and space heating

(one family house with 140 m² gross area)

Country	reference system	reference climate	% of total market[9]
Australia		Sydney	0
Austria	C: 20 m² / ST: 2000 l / HWD: 160 l/d / SHD: 80 kWh/m² / PS	Graz	20
Belgium	C: 4 m² / ST 240 l / HWD: 160 l/d SHD: 80 kWh/m² / PDS	Brussels	0
Canada		Montreal	0
Denmark	C: 15 m² / ST: 800 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Copenhagen	1
Finland	C: 8m² / ST: 300 l / HWD: 160 l/d SHD: 100 kWh/m² / PS	Helsinki	0
France	C: 15 m² / ST: 250 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Paris	4
Germany	C: 12 m² / ST: 750 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Würzburg	12
Greece		Athens	0
Italy		Bologna	0
Japan		Tokyo	2
Mexico		Mexico City	0
Netherlands	C: 4 m² / ST 240 l / HWD: 160 l/d SHD: 80 kWh/m² / PDS	Amsterdam	2
New Zealand		Wellington	0
Norway	C: 10 m² / ST: 1500 l / HWD: 160 l/d SHD: 100 kWh/m² / PS	Oslo	1
Portugal		Lisbon	0
Spain		Madrid	0
Sweden	C: 12 m² / ST: 1000 l / HWD: 160 l/d SHD: 100 kWh/m² / PS	Gothenburg	10
Switzerland	C: 15 m² / ST: 1000 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Zurich	15
Turkey		Instanbul	0
United Kingdom		London	0
United States		Denver Los Angeles	0

C collector area
ST hot water storage
TS thermosiphon system
PS pumped system
PDS pumped, drain back system
HWD hot water demand / day with 60°C
SHD space heat demand [kWh/m² a]

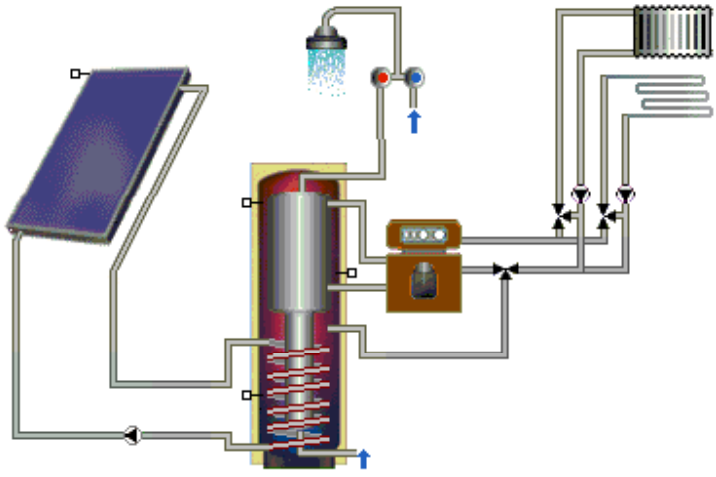

Figure 4: Hydraulic scheme of the solar combi reference system

[9] percentage of total installed collector area (flat plate and vacuum tube) until 2000 for solar combisystems

5.2 Reference collector

Data of the reference absorber for swimming pool heating

$\eta = 0.85$
a1 = 20 [W/m²K]
a2 = 0.1 [W/m² K²]

Data of the reference collector for all other applications:

$\eta = 0.8$
a1 = 3.69 [W/m²K]
a2 = 0.007 [W/m² K²]

5.3 Reference climates

Country	Used reference climate[10]
Australia	Sydney
Austria	Graz
Belgium	Brussels
Canada	Montreal
Denmark	Copenhagen
Finland	Helsinki
France	Paris
Germany	Würzburg
Italy	Bologna
Japan	Tokyo
Mexico	Mexico City
Netherlands	Amsterdam
New Zealand	Wellington
Norway	Oslo
Portugal	Lisbon
Spain	Madrid
Sweden	Gothenburg
Switzerland	Zurich
United Kingdom	London
United States	Denver Los Angeles

[10] Meteonorm

5.4 Population data

Country	Inhabitants in 2000
Australia	18,886,000
Austria	8,109,000
Belgium	10,161,000
Canada	31,147,000
Denmark	5,293,000
Finland	5,176,000
France	59,080,000
Germany	82,220,000
Greece	10,645,000
Italy	57,298,000
Japan	126,714,000
Mexico	98,881,000
Netherlands	15,786,000
New Zealand	3,862,000
Norway	4,465,000
Portugal	9,875,000
Spain	39,630,000
Sweden	8,910,000
Switzerland	7,184,000
Turkey	66,591,000
United Kingdom	58,830,000
United States	278,357,000
Total	**1,007,100,000**

Economic Region	Inhabitants
United States	309,504,000
Japan	126,714,000
Europe	382,662,000
Rest	219,367,000
Total	**1,038,247,000**

Source: Statistisches Jahrbuch 2002 (http://www.statistik.at/index.htm)

5.5 References to reports or persons that have supplied the market data

The following persons and members of the Executive Committee of the IEA Solar Heating and Cooling Programme supplied the market data (installed collector area) and the reference systems for their respective countries:

Australia	Ballinger, John Solar Efficient Architecture, Kanogroo Valley
Austria	Faninger, Gerhard IFF-University of Klagenfurt, Klagenfurt
Belgium	De Herde, André Université Catholique de Louvain, Lauvain-la-Neuve
Canada	Mc Clenahan, Doug CANMET - Natural resources Canada, Ottawa
Denmark	Kristensen, Poul E. Virum
Finland	Lund, Peter Helsinki University of Technology, Espoo
France	Loyen, Richard ASSOCIATION DE PROFESSIONNELS POUR LE DEVELOPPEMENT DES ÉNERGIES RENOUVELABLES, CASTELLET
Germany	Stry-Hipp, Gerhard German Solar Industry Association – DFS, Freiburg
Greece	Stry-Hipp, Gerhard German Solar Industry Association – DFS, Freiburg
Italy	Zampetti, Paolo ENEA, Rome
Japan	Yoshimura, Kazuki National Institute of Advanced Industrial Science and Technology, Nagoya
Mexico	Pilatowsky, Isaac Centro de Investigacion en Energia, Temixco, Morelos
Netherlands	Bosselaar, Lex NOVEM, Utrecht
New Zealand	Donn, Michael School of Architecture, Wellington
Norway	Salvesen, Fritjof KanEnergi AS, 1351 Rud
Portugal	Farinha Mendes, João INETI - Edificio G, Lisbon
Spain	Delgado, Maria Luisa CIEMAT, Madrid
Sweden	Dalenbäck, Jan-Olof Chalmers University of Technology, Göteborg

Switzerland	Wolfer, Urs Bundesamt für Energie, Bern
Turkey	Erkul, Gulsun First Secretary (Energy Adviser), Permanent Delegation of Turkey to the OECD
United Kingdom	Stry-Hipp, Gerhard German Solar Industry Association – DFS, Freiburg
United States	Crawley, Drury U.S. Department of Energy, EE-41, Washington D.C.

Reports

Active Solar Thermal Industry Group (ASTIG): Solar Thermal Markets in Europe, Brussels, March, 2002

European Solar Industry Federation (ESIF)/European Commission: Sun in action - The solar thermal market - A strategic plan for action in Europe, Office for Official Publications of the European Communities, Luxembourg, 1996

Faninger, Gerhard.: Der Solarmarkt in Österreich 2001, Bundesverband SOLAR in WKO and IFF-Universität Klagenfurt, Klagenfurt, 2002

Stry-Hipp, Gerhard: Der europäische Solarthermiemarkt, German Solar Industry Association – DFS, Freiburg, published at the 5th international symposium Gleisdorf SOLAR , Gleisdorf, Austria, September 2000

SOFAS: Markterhebung Sonnenenergie 2001, Teilstatistik der Schweizerischen Statistik der erneuerbaren Energien, Bundesamt für Energie, Bern, Mai, 2002

U.S. Department of Energy: Renewable Energy Annuals 1995-2001, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Washington D.C., March 2001