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Solar Heating Worldwide

Markets and Contribution to the Energy Supply 2001

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Markets and contribution to the energy supply 2001

IEA Solar Heating & Cooling Programme

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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 important markets worldwide, 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 are unglazed collectors, glazed flat-plate and vacuum tube collectors with water as the energy carrier as well as glazed and unglazed 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 and other national experts active in the field of solar thermal energy. Since some of the 26 countries included in this study 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 26 countries included in this study represent 3.3 billion people which is about 50% of the world´s population. The collector area installed in these countries is estimated to represent 85-90% of the solar thermal market worldwide.

The most important results

The installed collector area in the 26 countries represented in this study equaled around 100 million square meters at the end of year 2001. Of this, 27.7 million square meters were accounted for by unglazed plastic collectors, which are used mainly to heat swimming pools, and 71.3 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 1.6 million square meters. These are used for drying agricultural products and to a lesser extent for space heating of houses and production halls.

Total collector area by economic region

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 23.4 million square meters of unglazed plastic collectors while in China (32.0 million square meters), Europe (11.2 million square meters) and Japan (12.1 million square meters) plants with flat-plate and evacuated tube collectors mainly used to prepare hot water and for space heating are dominant.

Leading countries - flat-plate and evacuated tube collectors

Focusing on the total of flat-plate and evacuated tube collectors installed by the year 2001, then Israel, Greece and Austria are leading with 608 m², 298 m², 220 m² per 1000 inhabitants respectively. They are followed by Turkey, Japan, Australia, Denmark and Germany with collector areas between 118 and 45 m² per 1000 inhabitants.

Leading countries - unglazed plastic collectors

With regard to the heating of swimming pools with unglazed plastic collectors, Australia leads with 103 m² ahead of the USA with 81 m² and Austria with 72 m² per 1000 inhabitants. In fourth to sixth place there are Switzerland, Canada, and the Netherlands with collector areas between 28 and 10 m² per 1000 inhabitants.

Market development

Analyzing the market development from 2000 to 2001 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 8.9 million square meters in the year 2000 to 11.3 million square meters in the year 2001. This corresponds to a remarkable growth of 26%.
The most dynamic markets worldwide are in China and Europe. In 2001 the installed flat-plate and evacuated tube collectors per 1000 inhabitants was 6.4 m² in China and 3.9 m² in Europe whereas in Japan only 2.5 m² and in the USA and Canada just 0.08 m² were installed.

The market of unglazed collectors for swimming pool heating recorded also an increase from 1.3 million square meters in the year 2000 to 1.6 million square meters in the year 2001. This corresponds to a growth of 23%. The markets that underwent the greatest growth in this sector between 2000 and 2001 included the USA, Spain and France.

Contribution of solar collectors to the supply of energy

The **annual collector yield** of all solar thermal systems[1] installed by the end of 2001 in the 26 recorded countries is 41,795 GWh (150,463 TJ). This corresponds to an **oil equivalent** of 6.7 billion liter and an **annual avoidance of 18.2 million tons of CO_2.**

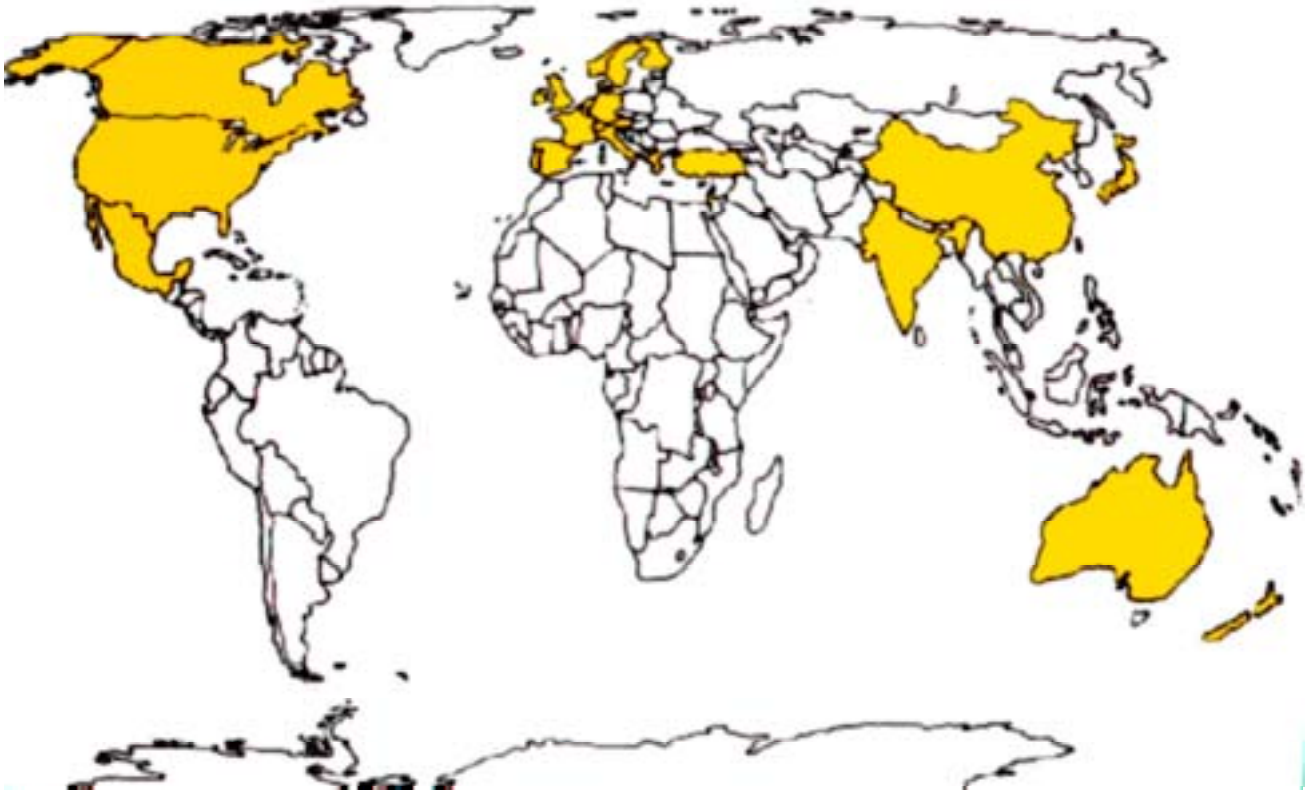

Figure 1: Countries represented in this document (yellow)

[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 2001

Since the beginning of the 1990s, the solar thermal market has undergone a favorable development. At the end of 2001, a total of 100 million square meters of collector area were installed in the 26 recorded countries. These 26 countries represent 3.3 billion people which is about 50% of the worlds population. The collector area installed in these countries represent approximately 85 - 90% of the solar thermal market worldwide.

As shown in Table 1, this collector area is divided in 27.68 million square meters of unglazed collectors for swimming pool heating; 49.05 million square meters of glazed flat plate collectors, and 22.30 million square meters of evacuated tube collectors (mainly used for domestic hot water preparation and space heating), and 1.62 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 should be noted that in the US the majority was installed in the 1980s and about 70% was installed up to the year 1985. This means, that these collector arrays will be taken out of operation in the upcoming 10 years, because they reach the end of their lifespan of 20 to 25 years.
In comparison to that, most systems in Europe and China were installed in the last 10 years.

Table 1: Total collector area in operation by the year 2001

Total Collector Area in Operation in the Year 2001						
Country	Water collectors			AIR COLLECTOR		TOTAL
	unglazed	glazed	evacuated tube	unglazed	glazed	
Australia	2.000.000	1.198.000				**3.198.000**
Austria	580.873	1.739.045	28.439			**2.348.357**
Belgium	22.612	23.578	2.003			**48.193**
Canada	516.000	72.997	675	45.112		**634.784**
China		11.200.000	20.800.000			**32.000.000**
Denmark	21.870	270.570	550			**292.990**
Finland		12.000	100	70.000		**82.100**
France	98.500	508.500				**607.000**
Germany	665.000	3.149.000	542.000		40.000	**4.396.000**
Greece		2.990.000				**2.990.000**
India		600.000				**600.000**
Ireland		2.645	690			**3.335**
Israel		3.920.000				**3.920.000**
Italy	23.000	339.700	23.750	2.500	2.500	**391.450**
Japan		11.755.008	311.481			**12.066.489**
Mexico	320.000	110.490				**430.490**
The Netherlands	154.099	206.464	2.462	4.794		**367.819**
New Zealand	1.200	66.700	10			**67.910**
Norway	599	7.250	100	400.000	1.000	**408.949**
Portugal	1.000	244.000	500			**245.500**
Spain	5.000	452.067	5.000			**462.067**
Sweden	33.386	196.593	3.422			**233.401**
Switzerland	201.470	249.150	23.160	825.000		**1.298.780**
Turkey		8.130.000				**8.130.000**
United Kingdom	89.000	157.000	9.230			**255.230**
United States	22.944.375	1.445.340	551.372		226.557	**25.167.644**
TOTAL	**27.677.984**	**49.046.097**	**22.304.944**	**1.347.406**	**270.057**	**100.646.488**

2.1 Glazed flat plate and evacuated tube collectors in operation by the year 2001

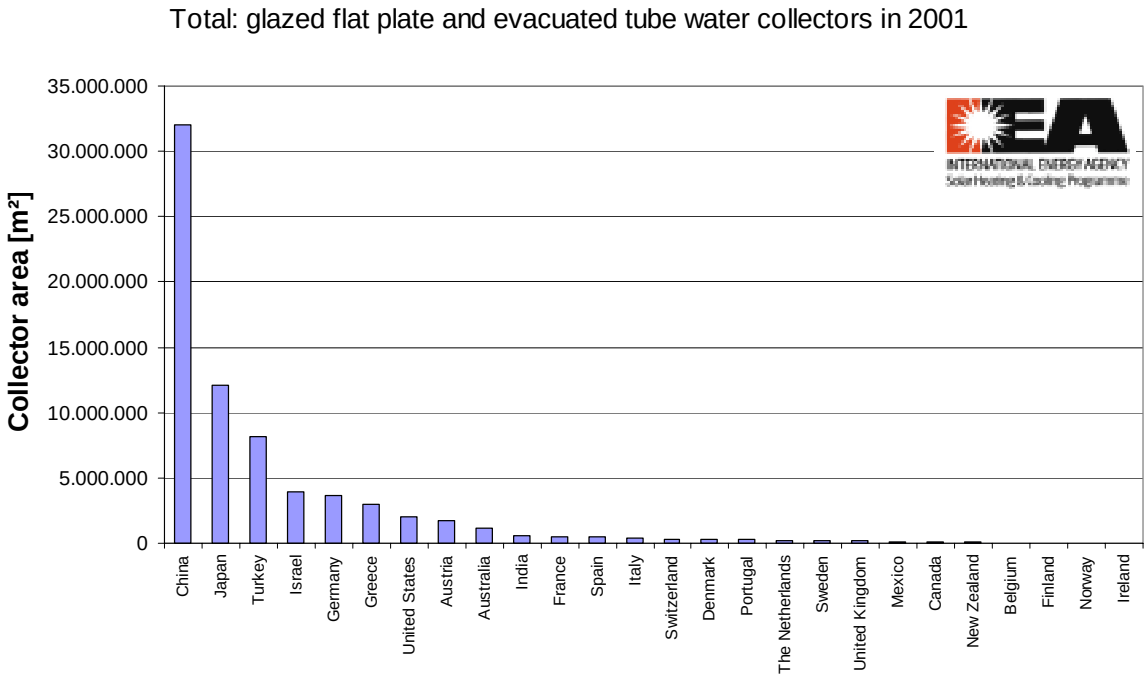

Figure 2: Glazed flat plate and evacuated tube collectors in operation in the year 2001

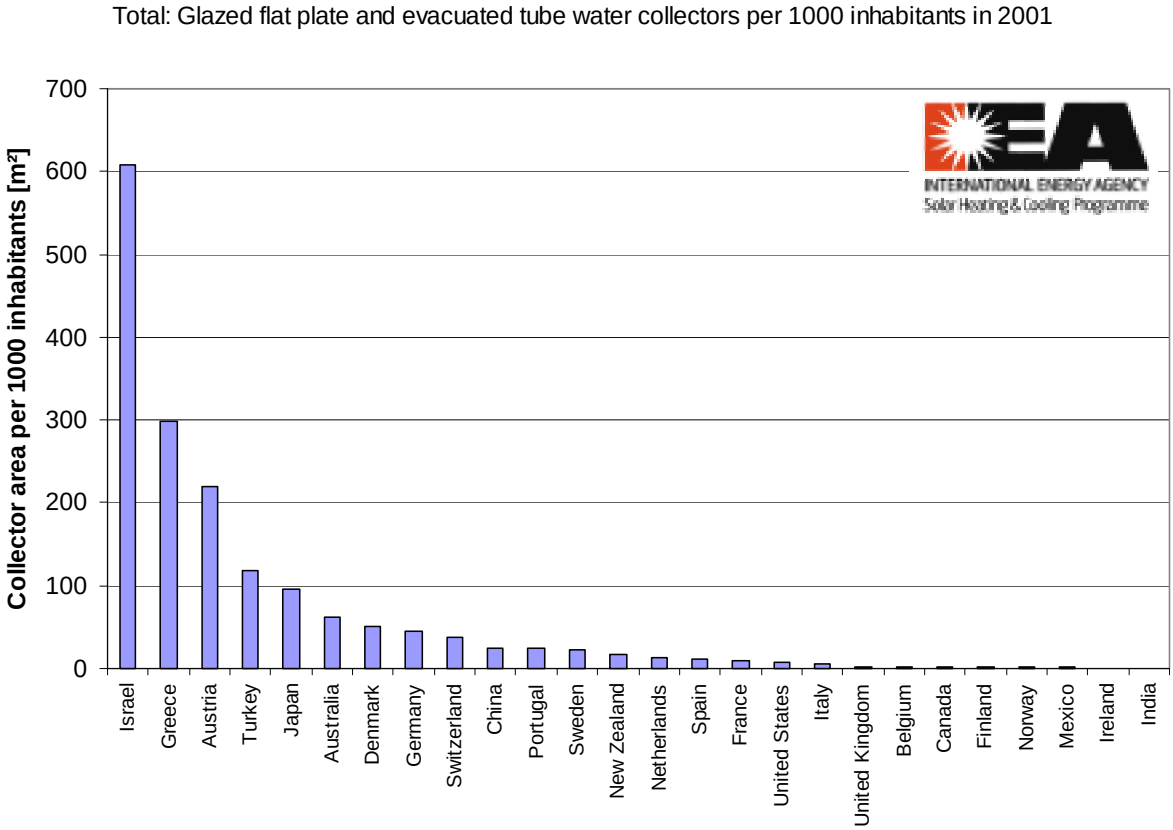

Figure 3: Glazed flat plate and evacuated tube collectors in operation in the year 2001 per 1000 inhabitants

2.2 Glazed flat plate and evacuated tube collectors in operation in 2001 by economic region

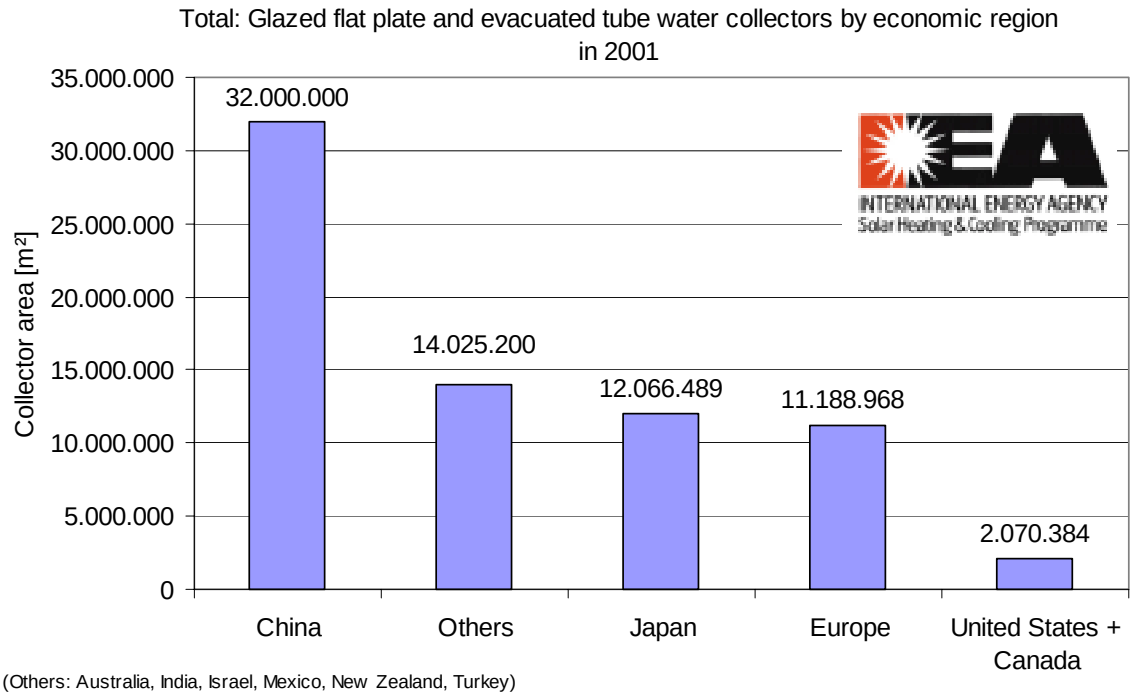

Figure 4: Glazed flat plate and evacuated tube collectors in operation by economic region[2] in the year 2001

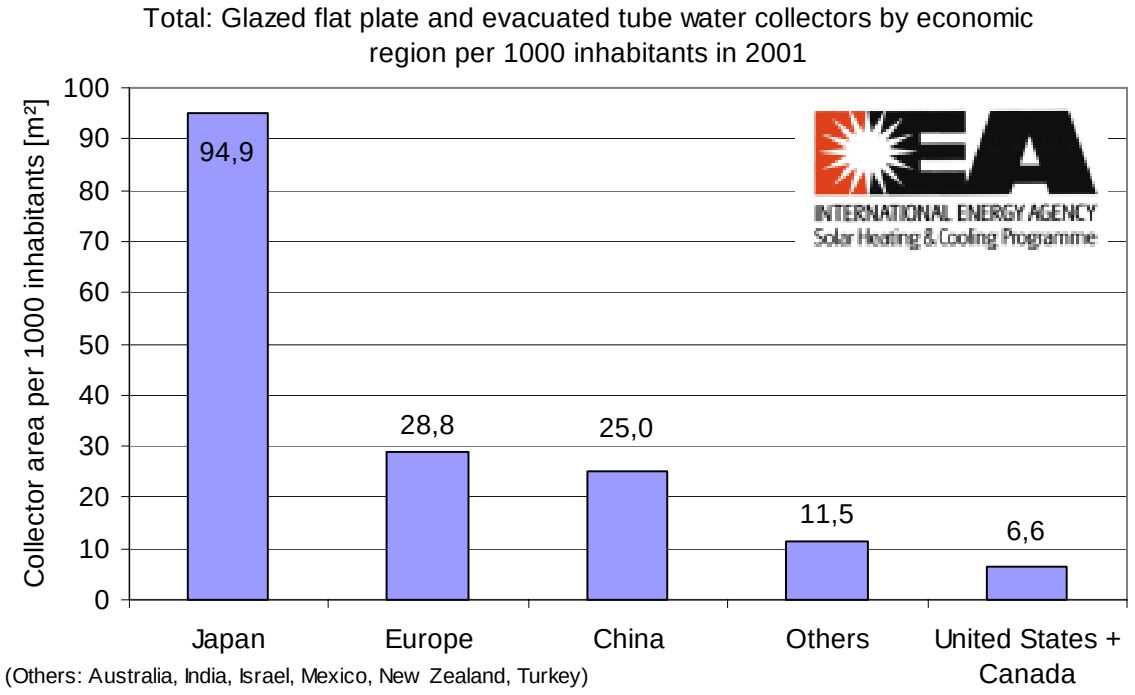

Figure 5: Glazed flat plate and evacuated tube collectors in operation by economic region in the year 2001 per 1000 inhabitants

[2] Europe: EU 15 (excl. Luxemburg) + Switzerland and Norway

2.3 Unglazed collectors in operation by the year 2001

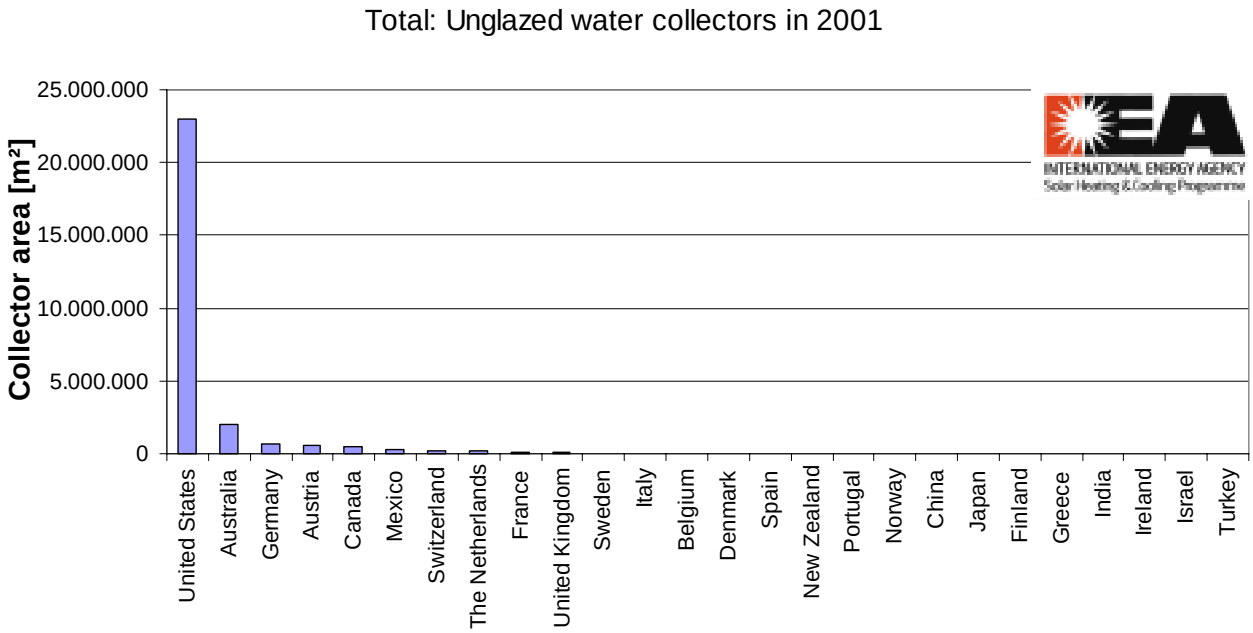

Figure 6: Unglazed collectors in operation in the year 2001

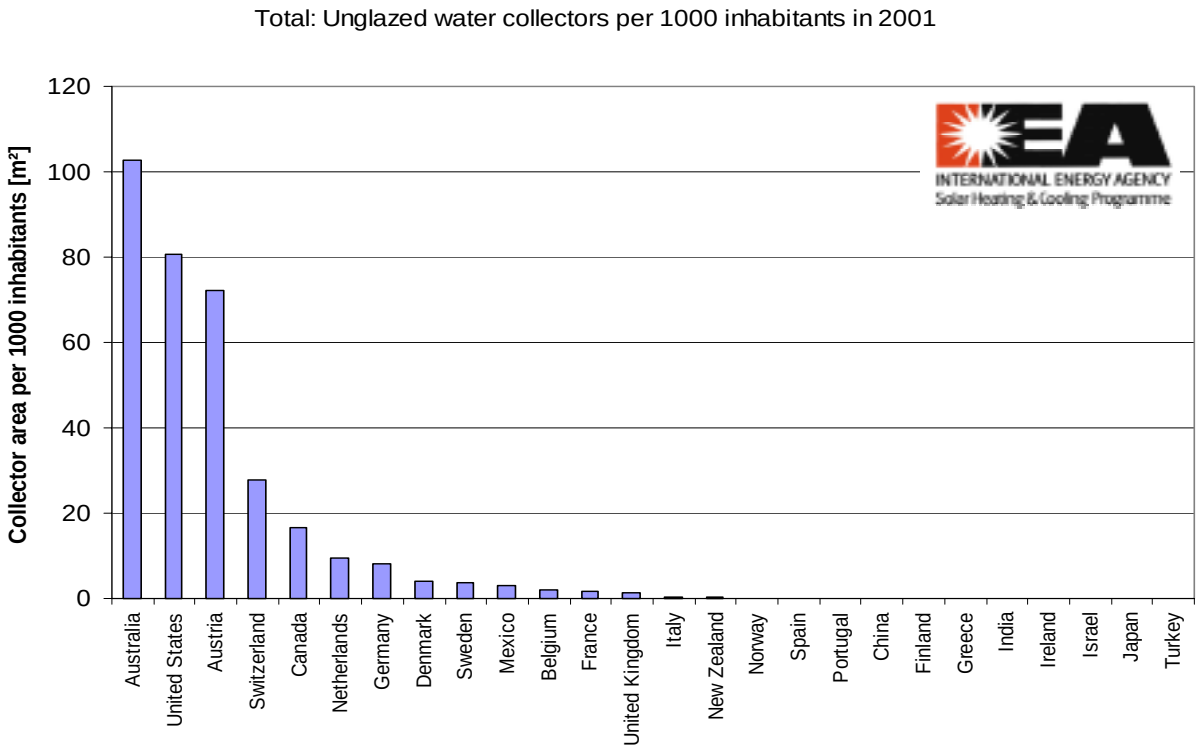

Figure 7: Unglazed collectors in operation in different countries in the year 2001 per 1000 inhabitants

2.4 Unglazed collectors in operation by economic region in 2001

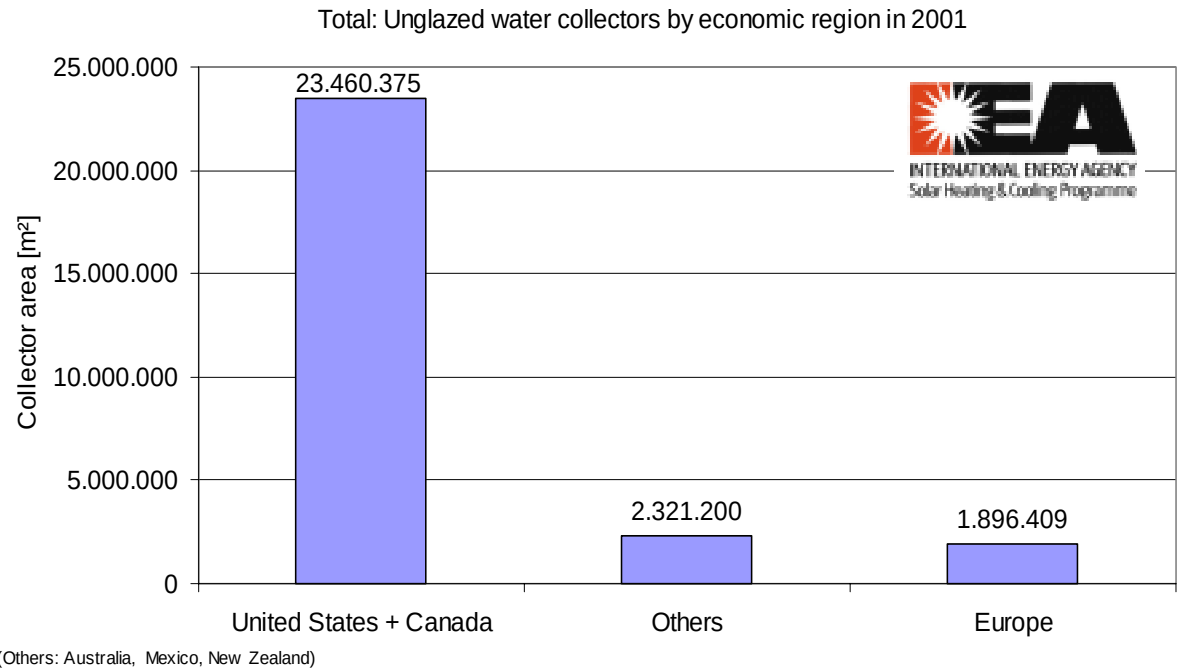

Figure 8: Unglazed collectors in operation by economic region[3] in the year 2001

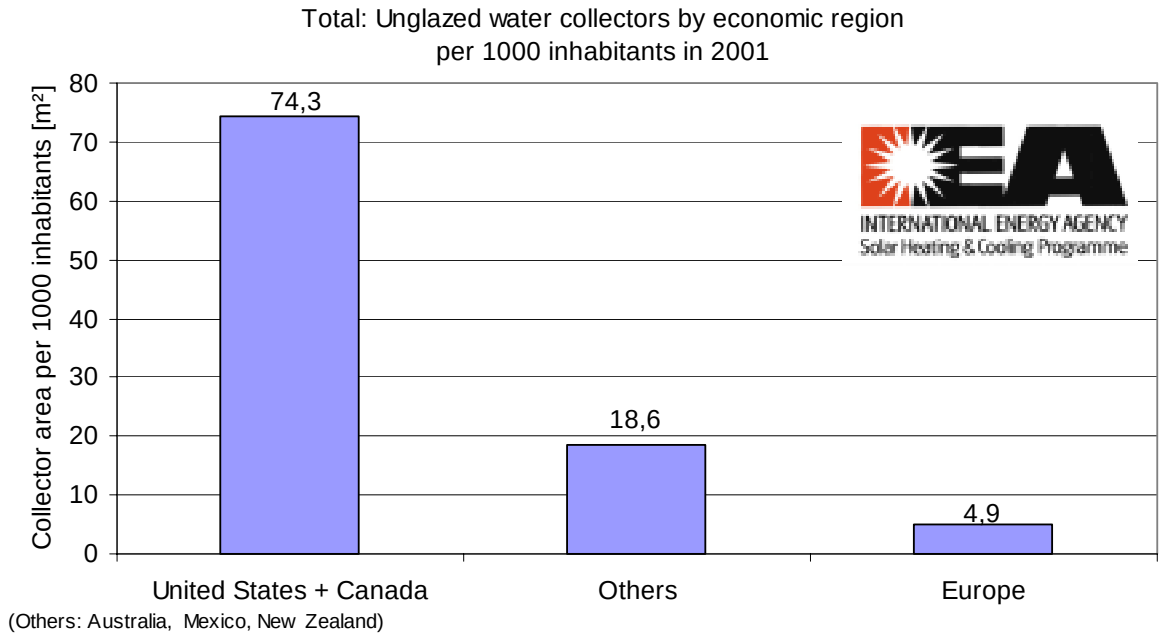

Figure 9: Unglazed collectors in operation by economic region in the year 2001 per 1000 inhabitants

[3] Europe: EU 15 (excl. Luxemburg) + Switzerland and Norway

3 Market development

The following tables show the collector area installed yearly in the recorded countries in 1999, 2000 and 2001. It has to be mentioned here, that the number of countries who made data available increased from 21 countries in 1999 to 26 countries in 2001 and 2002. Therefore the total numbers can not be compared directly.

Analyzing the market development from 2000 to 2001 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 8.9 million square meters in the year 2000 to 11.3 million square meters in the year 2001. This corresponds to a remarkable growth of 26%.
The market of unglazed collectors for swimming pool heating recorded also an increase from 1.3 million square meters in the year 2000 to 1.6 million square meters in the year 2001.

3.1 Installed collector area in the year 1999

Table 2: Installed collector area in 1999

Collector Area Installed in 1999, m2/yr						
Country	Water Collectors			Air Collectors		TOTAL
	unglazed	glazed	evacuated	unglazed	glazed	
Australia						
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**

3.2 Installed collector area in the year 2000

Table 3: Installed collector area in 2000

Collector Area Installed in 2000, m2/yr						
Country	Water Collectors			Air Collectors		TOTAL
	unglazed	glazed	evacuated	unglazed	glazed	
Australia	380.000	71.000				**451.000**
Austria	14.738	150.543	2.401	3.000	550	**171.232**
Belgium	1.250	1.400	200			**2.850**
Canada	27.000	626	161	3.366		**31.153**
China		2.140.000	3.960.000			**6.100.000**
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**
India		70.000				**70.000**
Ireland		340	40			**380**
Israel		390.000	422			**390.422**
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	53	300		**34.853**
New Zealand	4.500	4.500				**9.000**
Norway	100	1.000		20.000	100	**21.200**
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	9.000		**50.035**
Turkey		750.000				**750.000**
United Kingdom	10.000	9.000	1.000			**20.000**
United States	738.369	35.674	1.394		557	**775.994**
TOTAL	**1.298.064**	**4.830.112**	**4.087.539**	**36.666**	**8.707**	**10.261.088**

3.3 Installed collector area in the year 2001

Table 4: Installed collector area in 2001

Collector Area Installed in 2001, m2/yr						
Country	Water Collectors			Air Collectors		TOTAL
	unglazed	glazed	evacuated	unglazed	glazed	
Australia	380.000	75.000				**455.000**
Austria	9.067	157.860	2.220			**169.147**
Belgium	737	4.178	303			**5.218**
Canada	23.000	997	166	4.112		**28.275**
China		2.870.000	5.330.000			**8.200.000**
Denmark	600	26.000	150			**26.750**
Finland		1.500	50			**1.550**
France	14.000	38.500				**52.500**
Germany	50.000	750.000	150.000			**950.000**
Greece		175.000				**175.000**
India		80.000				**80.000**
Ireland		160	110			**270**
Israel		420.000				**420.000**
Italy	3.000	39.700	3.750	500	500	**47.450**
Japan		310.000	4.000			**314.000**
Mexico	36.200	15.890				**52.090**
Netherlands	7.500	30.671				**38.171**
New Zealand	1.200	2.700	10			**3.910**
Norway	99	250				**349**
Portugal		6.000				**6.000**
Spain	5.000	52.145	5.000			**62.145**
Sweden	3.386	21.548	422			**25.356**
Switzerland	6.070	21.870	860	9.000		**37.800**
Turkey		630.000				**630.000**
United Kingdom	10.000	8.000	7.230			**25.230**
United States	1.014.375	24.340	372		557	**1.039.644**
TOTAL	**1.564.234**	**5.762.309**	**5.504.643**	**13.612**	**1.057**	**12.845.855**

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

3.4.1 Market development 1999 - 2000

The market for flat plate and evacuated tube collectors grew in the 22 recorded countries 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 227%, Sweden at 99%, Spain at 65%, Germany at 48% 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%.

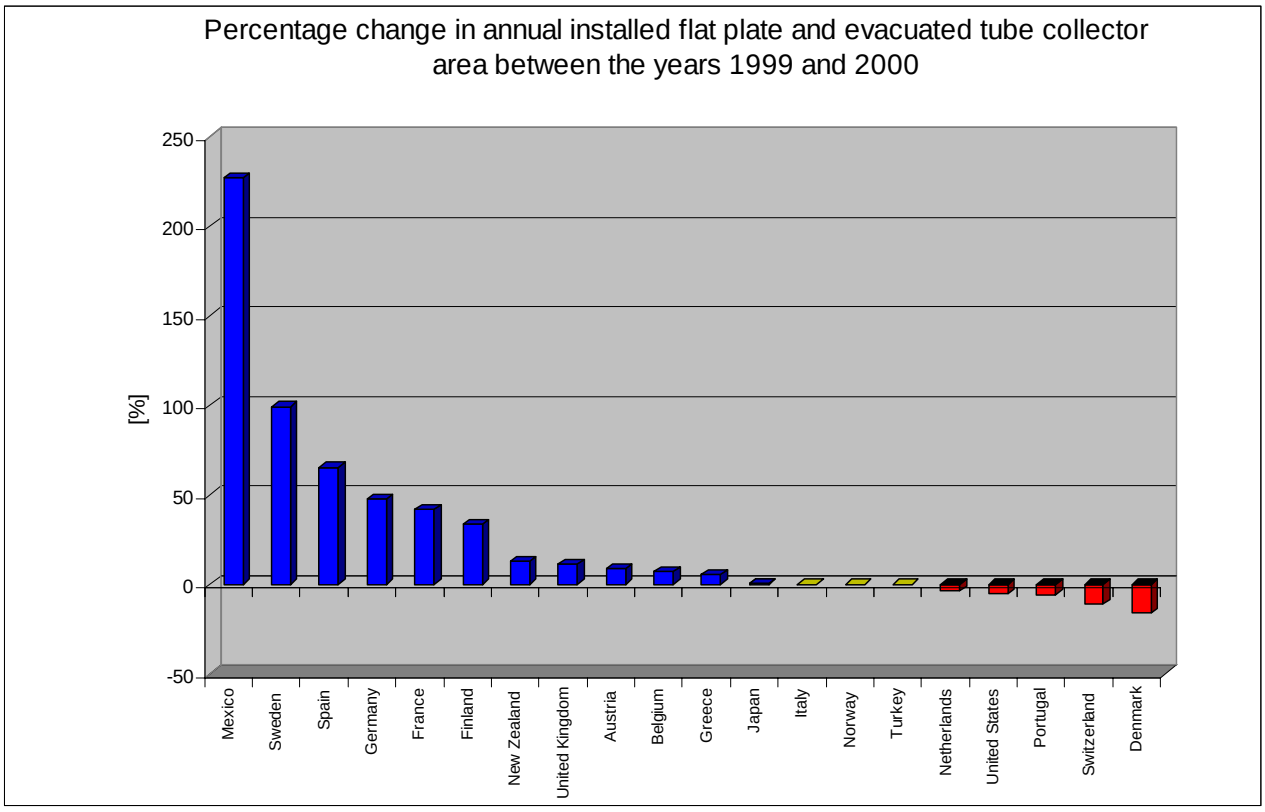

Figure 10: Percentage change in annual installed flat plate and evacuated tube collector area between the years 1999 and 2000

3.4.2 Market development 2000 – 2001

The market for flat plate and evacuated tube collectors grew in the 26 recorded countries from 8,917,651 m² in the year 2000 to 11,266,952 m² in the year 2001. This corresponds to a growth of 26 %. The markets that underwent the greatest growth between 2000 and 2001 included Belgium at 180%, Denmark at 102% and Spain at 60%. The largest decreases in markets were recorded in Norway at -75%, New Zealand at -40% and the USA at -33%.

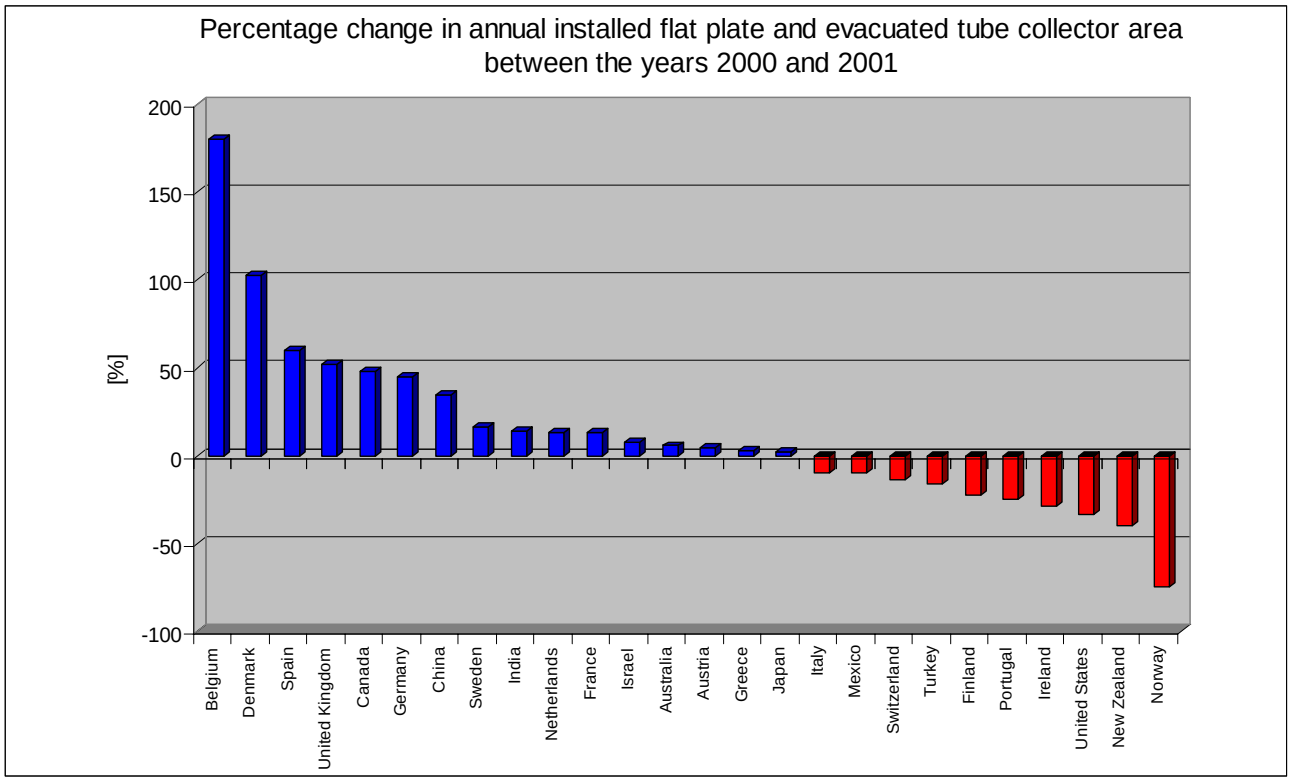

Figure 11: Percentage change in annual installed flat plate and evacuated tube collector area between the years 2000 and 2001

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

3.5.1 Market development 1999 - 2000

The market for unglazed collectors in the 22 recorded countries grew from 915,378 m² in the year 1999 to 1,298,064 m² in the year 2000. This corresponds to an increase of 41%. 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%, the Netherlands at -6% and the USA at –2,5%.

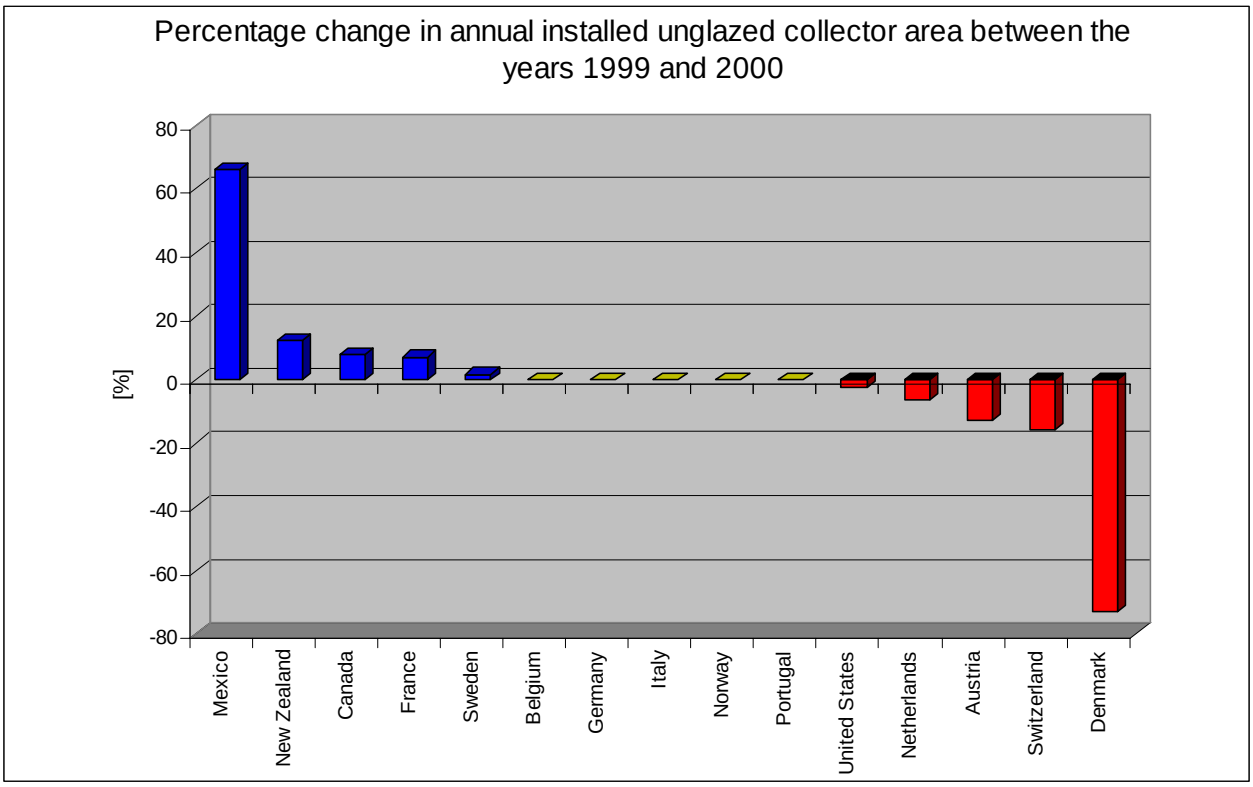

Figure 12: Percentage change in annual installed unglazed collector area between the years 1999 and 2000

3.5.2 Market development 2000 – 2001

The market for unglazed collectors in the 26 recorded countries grew from 1,298,064 m² in the year 2000 to 1,564,234 m² in the year 2001. This corresponds to an increase of 20%. The markets that underwent the greatest growth between 2000 and 2001 included Denmark at 795%, France at 87% and the United States at 37%. Decreasing markets were recorded in New Zealand at -73%, Switzerland at -59%, Belgium at -41%, Austria at -38%, Canada at -15% and Norway at -1%.

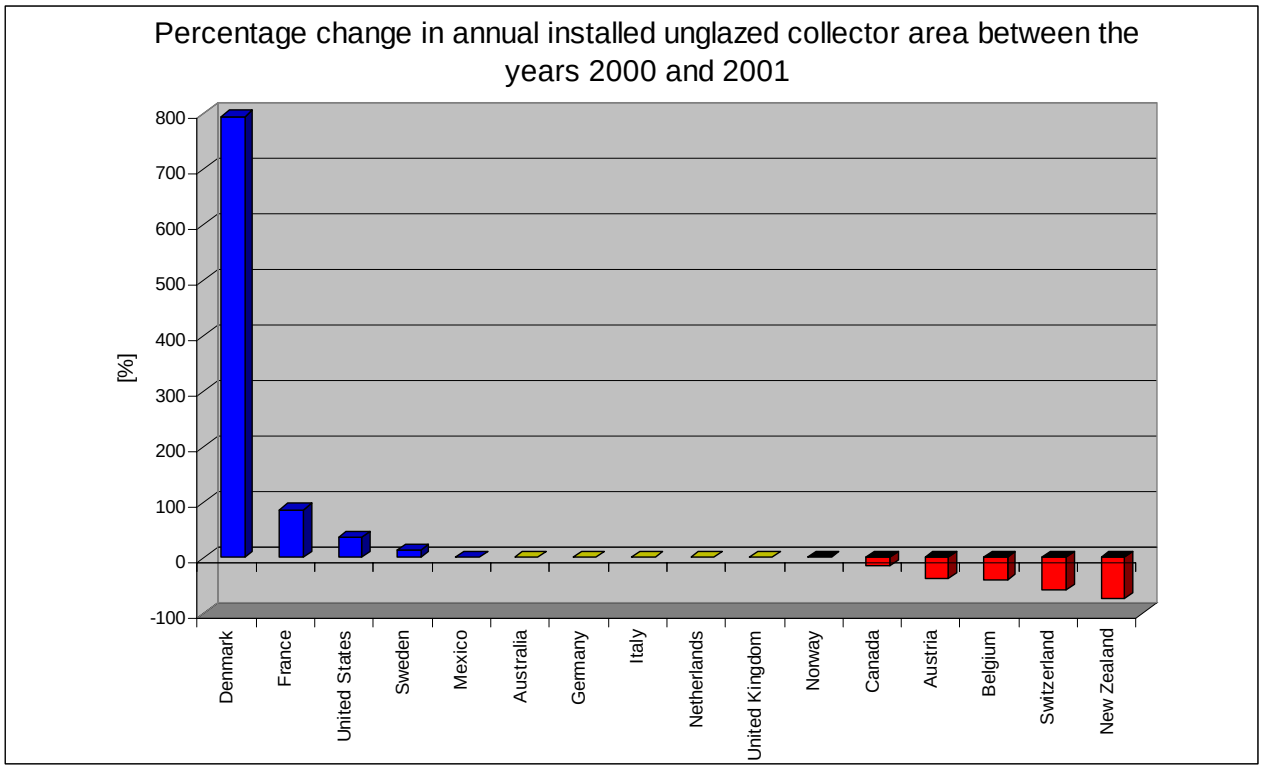

Figure 13: Percentage change in annual installed unglazed collector area between the years 2000 and 2001

4 Contribution to the energy supply and CO_2 reduction

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 99 million square meters of unglazed, flat plate and evacuated tube collectors were installed by the end of the year 2001 in the recorded countries. The annual yield of these collector areas is calculated to be 41,795 GWh (150,463 TJ). This corresponds to a calculated oil equivalent of 6.7 billion liter and an annual CO_2 reduction of 18.2 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.

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

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 source 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.

Table 5: 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) in 2001

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	3.198.000	281.946	1.226	4.414	216.683.765	591.235
Austria	2.348.357	248.467	762	2.742	109.321.977	298.309
Belgium	48.193	5.229	12	42	1.751.619	4.779
Canada	589.672	14.318	145	522	23.662.797	64.563
China	32.000.000	8.000.000	13.968	50.285	2.200.000.000	6.008.000
Denmark	292.990	61.780	97	349	13.670.793	37.299
Finland	12.100	2.886	4	14	506.370	1.381
France	607.000	122.719	207	745	30.598.015	83.481
Germany	4.356.000	538.274	1.484	5.343	217.762.877	594.129
Greece	2.990.000	747.500	1.742	6.270	278.817.500	761.628
India	600.000	150.000	262	943	41.250.000	112.650
Ireland	3.335	834	1	4	145.073	395
Israel	3.920.000	980.000	2.873	10.344	458.640.000	1.250.480
Italy	386.450	90.978	161	578	25.458.875	69.455
Japan	12.066.489	2.916.873	5.707	20.547	857.818.769	2.340.358
Mexico	430.490	10.925	168	603	31.087.399	84.820
Netherlands	363.025	96.166	100	360	14.525.584	39.641
New Zealand	67.910	15.916	20	73	3.225.638	8.804
Norway	7.949	1.209	3	9	337.511	921
Portugal	245.500	58.318	154	554	25.120.011	68.537
Spain	462.067	109.035	281	1.010	42.308.407	115.442
Sweden	233.401	29.236	67	241	8.917.214	24.335
Switzerland	473.780	40.311	127	457	18.626.952	50.820
Turkey	8.130.000	1.845.510	4.846	17.447	770.179.290	2.103.577
United Kingdom	255.230	42.003	69	248	10.213.517	27.871
United States	24.941.087	447.507	7.311	26.320	1.254.886.307	3.423.939
Total	**99.029.025**	**16.857.940**	**41.795**	**150.463**	**6.655.516.261**	**18.166.848**

*) Unglazed, glazed flat plate and evacuated tube collectors

Table 6: 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 in 2001

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	1.198.000	271.946	489	1.762	86.252.765	235.361
Austria	1.767.484	245.562	668	2.403	93.414.770	254.907
Belgium	25.581	5.116	8	29	1.110.727	3.030
Canada	73.672	11.738	34	121	4.750.881	12.963
China	32.000.000	8.000.000	13.968	50.285	2.200.000.000	6.008.000
Denmark	271.120	61.671	94	337	13.103.190	35.750
Finland	12.100	2.886	4	14	506.370	1.381
France	508.500	122.226	187	675	27.244.730	74.331
Germany	3.691.000	534.949	1.341	4.829	193.015.235	526.607
Greece	2.990.000	747.500	1.742	6.270	278.817.500	761.628
India	600.000	150.000	262	943	41.250.000	112.650
Ireland	3.335	834	1	4	145.073	395
Israel	3.920.000	980.000	2.873	10.344	458.640.000	1.250.480
Italy	363.450	90.863	156	561	24.596.479	67.102
Japan	12.066.489	2.916.873	5.707	20.547	857.818.769	2.340.358
Mexico	110.490	9.325	75	269	14.541.319	39.676
Netherlands	208.926	95.396	77	277	10.689.444	29.175
New Zealand	66.710	15.910	20	72	3.179.505	8.678
Norway	7.350	1.206	2	9	324.034	884
Portugal	244.500	58.313	154	553	25.077.473	68.421
Spain	457.067	109.010	279	1.005	42.046.462	114.727
Sweden	200.015	29.069	62	225	8.226.257	22.449
Switzerland	272.310	39.303	92	331	12.868.436	35.108
Turkey	8.130.000	1.845.510	4.846	17.447	770.179.290	2.103.577
United Kingdom	166.230	41.558	55	199	7.925.015	21.627
United States	1.996.712	332.785	1.145	4.121	190.852.389	520.776
Total	**71.351.041**	**16.719.550**	**34.342**	**123.630**	**5.366.576.112**	**14.650.041**

*)Glazed flat plate and evacuated tube collectors

Table 7: Calculated collector yield and corresponding oil equivalent as well as CO_2-reduction of solar thermal systems for swimming pool heating with unglazed collectors in 2001

Country	total collector area [m²]	calculated number of systems	collector yield [GWh/a]	collector yield [Tera J/a]	energy savings - oil equivalent [l/a]	CO2 reduction [t/a]
Australia	2.000.000	10.000	737	2.652,1	130.431.000	355.874
Austria	580.873	2.904	94	338,6	15.907.207	43.402
Belgium	22.612	113	4	13,6	640.892	1.749
Canada	516.000	2.580	111	400,5	18.911.916	51.600
China	n.a.					
Denmark	21.870	109	3	12,1	567.603	1.549
Finland	n.a.					
France	98.500	493	19	69,7	3.353.285	9.149
Germany	665.000	3.325	143	514,6	24.747.643	67.522
Greece	n.a.					
India	n.a.					
Ireland	n.a.					
Israel	n.a.					
Italy	23.000	115	5	17,4	862.397	2.353
Japan	n.a.					
Mexico	320.000	1.600	93	334,2	16.546.080	45.145
Netherlands	154.099	770	23	83,8	3.836.141	10.467
New Zealand	1.200	6	0,3	1,0	46.133	126
Norway	599	3	0,1	0,3	13.478	37
Portugal	1.000	5	0,2	0,9	42.539	116
Spain	5.000	25	1	5,4	261.945	715
Sweden	33.386	167	4	16,0	690.957	1.885
Switzerland	201.470	1.007	35	125,7	5.758.516	15.712
Turkey	n.a.					
United Kingdom	89.000	445	13	48,5	2.288.502	6.244
United States	22.944.375	114.722	6.166	22.198,7	1.064.033.918	2.903.163
Total	**27.677.984**	**138.390**	**7.454**		**1.288.940.149**	**3.516.807**

4.1 Collector yield by economic region in 2001

4.1.1 Collector yield of glazed flat plate and evacuated tube collectors by economic region in 2001

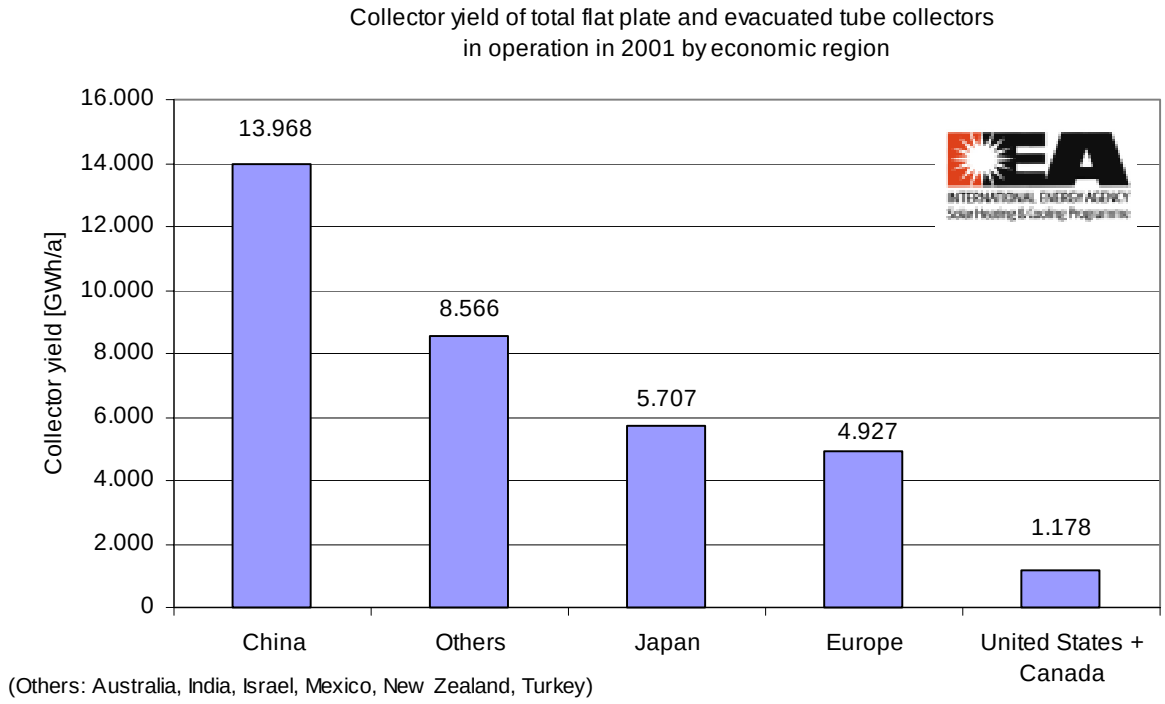

Figure 14: Annual collector yield of glazed flat plate and evacuated tube collectors in operation by economic region[5] in the year 2001

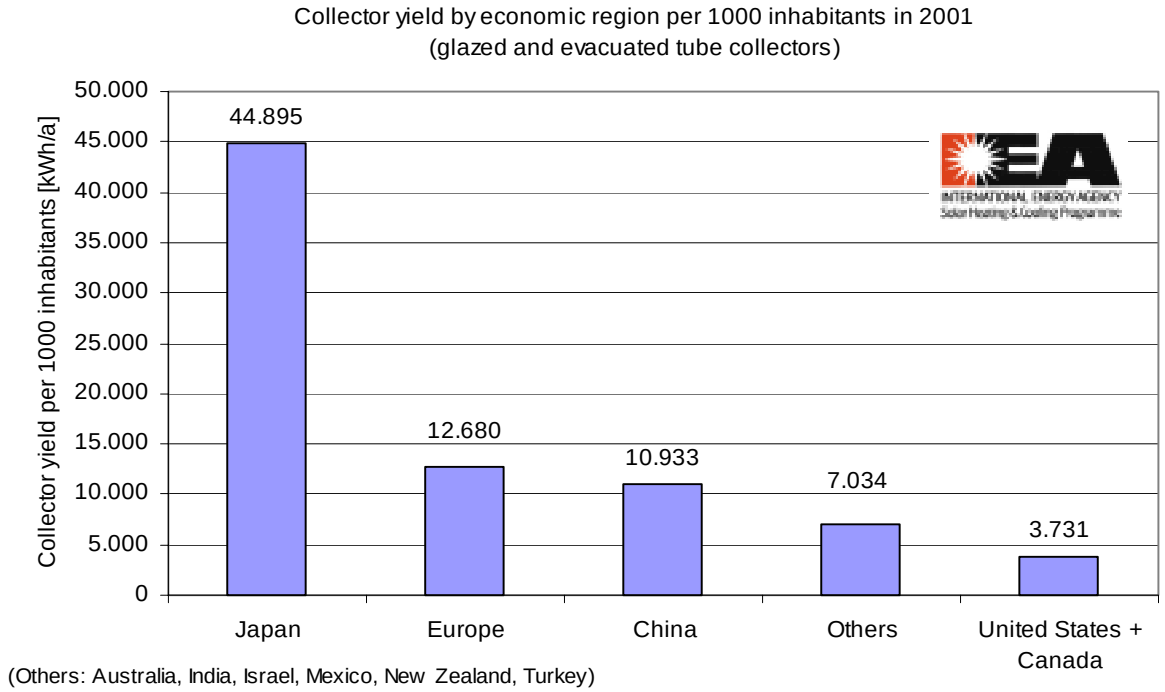

Figure 15: Annual collector yield of glazed flat plate and evacuated tube collectors in operation by economic region in the year 2001 per 1000 inhabitants

[5] Europe: EU 15 (excl. Luxemburg) + Switzerland and Norway

4.1.2 Collector yield of unglazed collectors by economic region in 2001

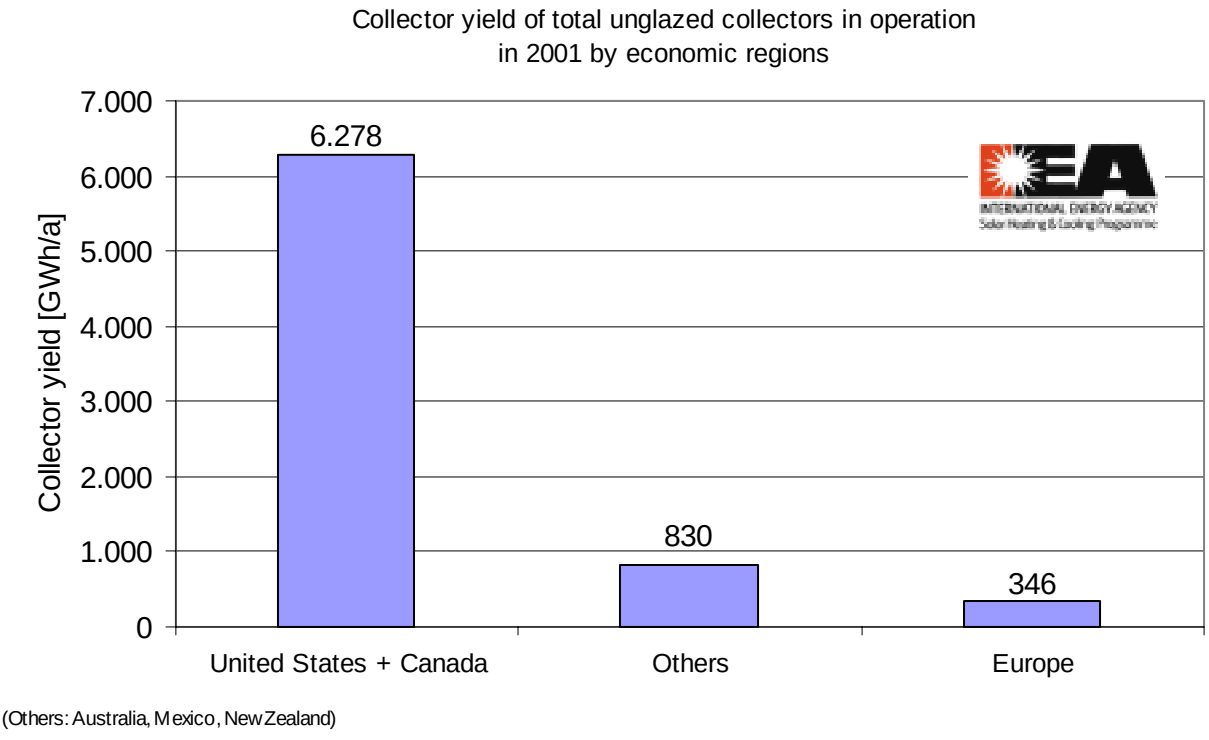

Figure 16: Annual collector yield of unglazed collectors in operation by economic region in the year 2001

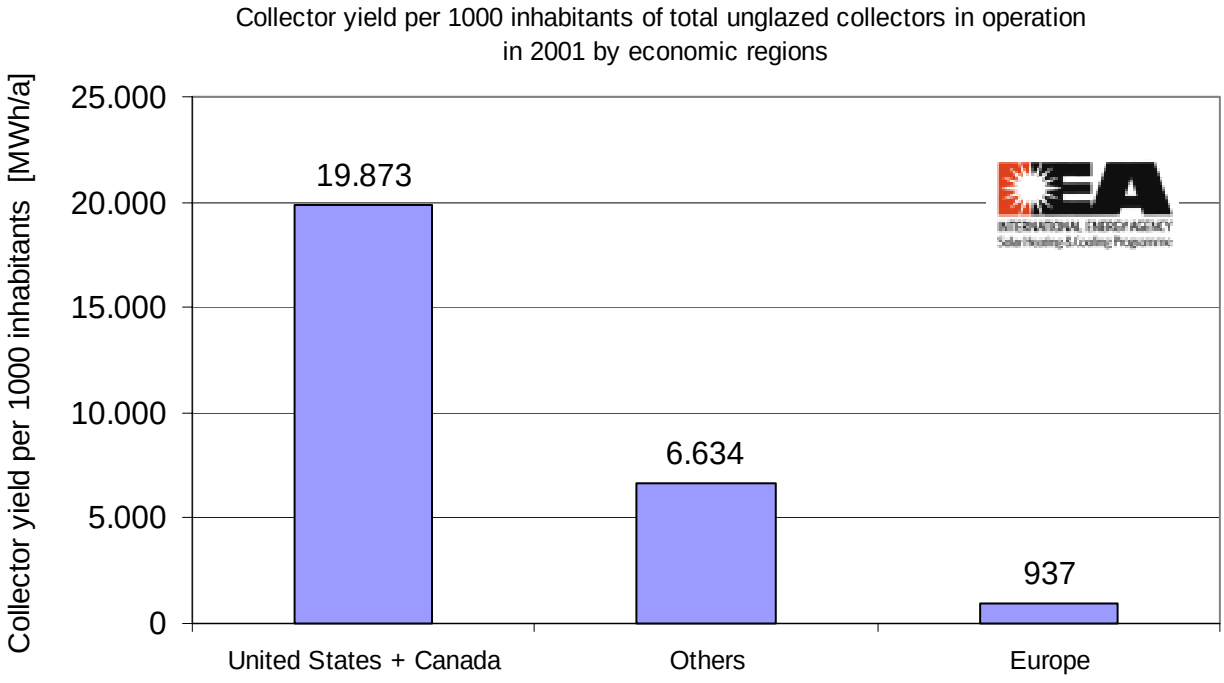

Figure 17: Annual collector yield of unglazed collectors in operation by economic region in the year 2001 per 1000 inhabitants

4.2 Energy savings by economic region in 2001

4.2.1 Energy savings in oil equivalent - glazed flat plate and evacuated tube collectors by economic region in 2001

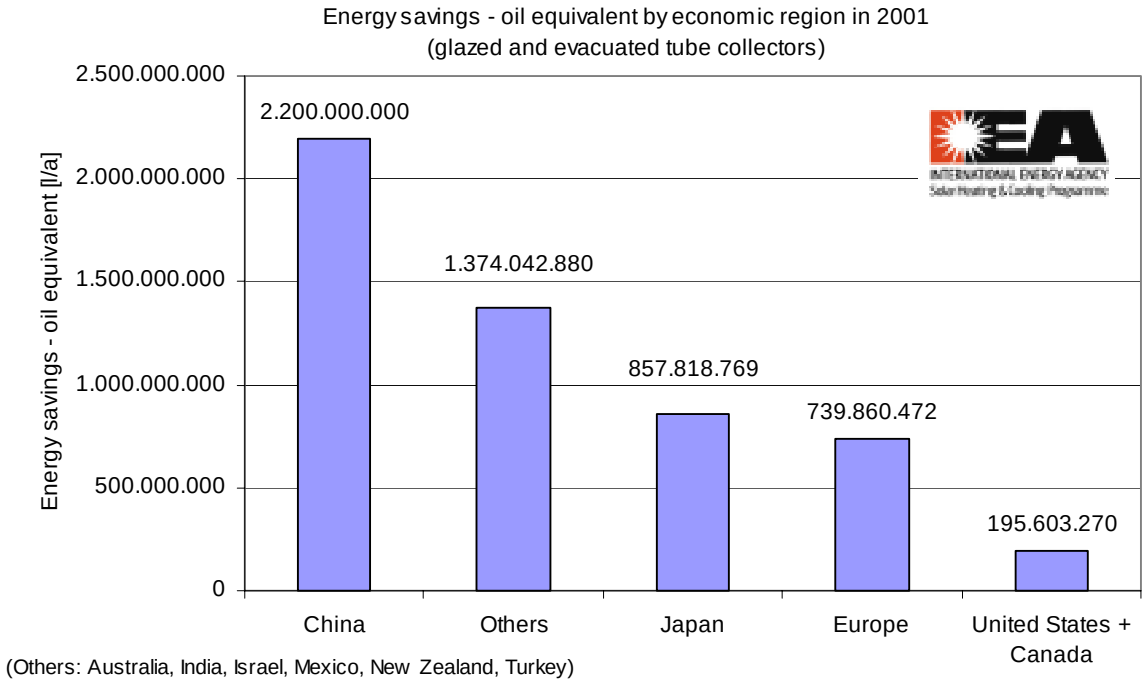

Figure 18: Annual energy savings in oil equivalent - glazed flat plate and evacuated tube collectors by economic region in the year 2001

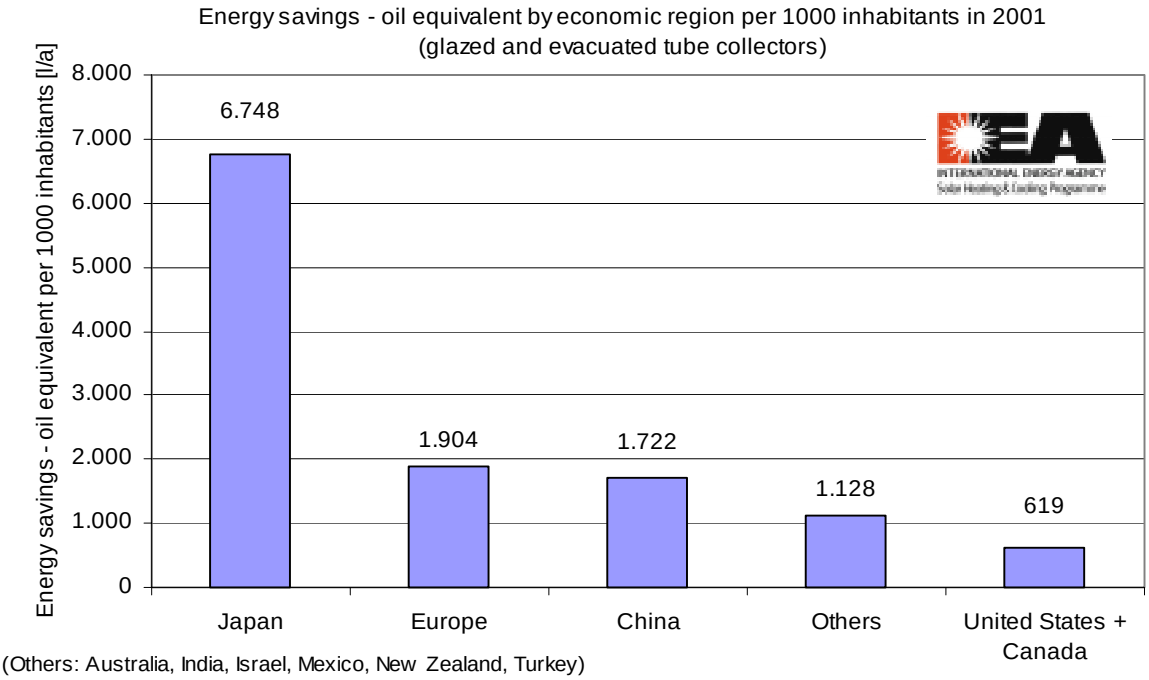

Figure 19: Annual energy savings in oil equivalent - glazed flat plate and evacuated tube collectors operation by economic region in the year 2001per 1000 inhabitants

4.2.2 Energy savings in oil equivalent - unglazed collectors by economic region in 2001

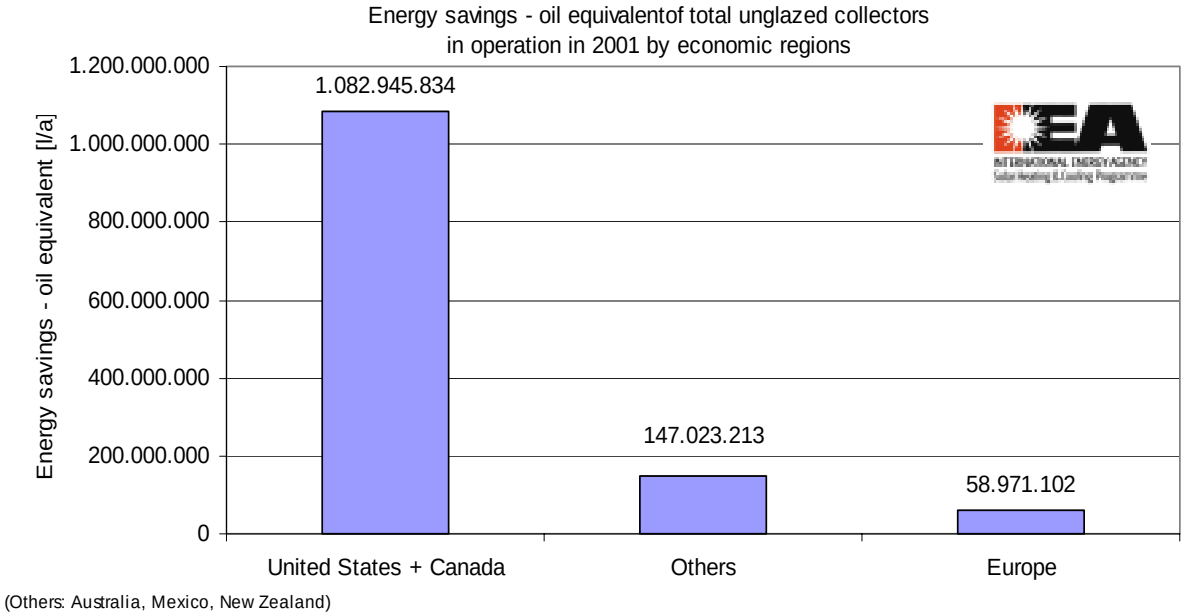

Figure 20: Annual energy savings in oil equivalent - unglazed collectors by economic region in the year 2001

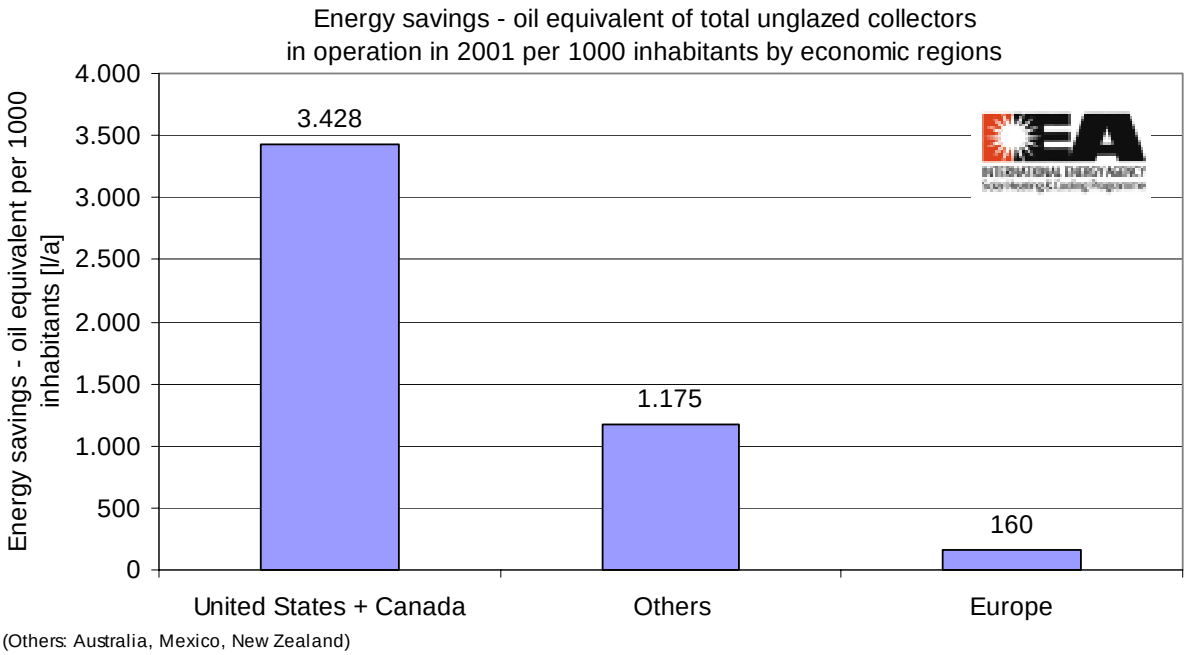

Figure 21: Annual energy savings by economic region in the year 2001 per 1000 inhabitants in oil equivalent - unglazed collectors

4.3 Contribution to CO_2 reduction by economic region in 2001

4.3.1 Contribution to CO_2 reduction: Flat plate and evacuated tube collectors by economic region in 2001

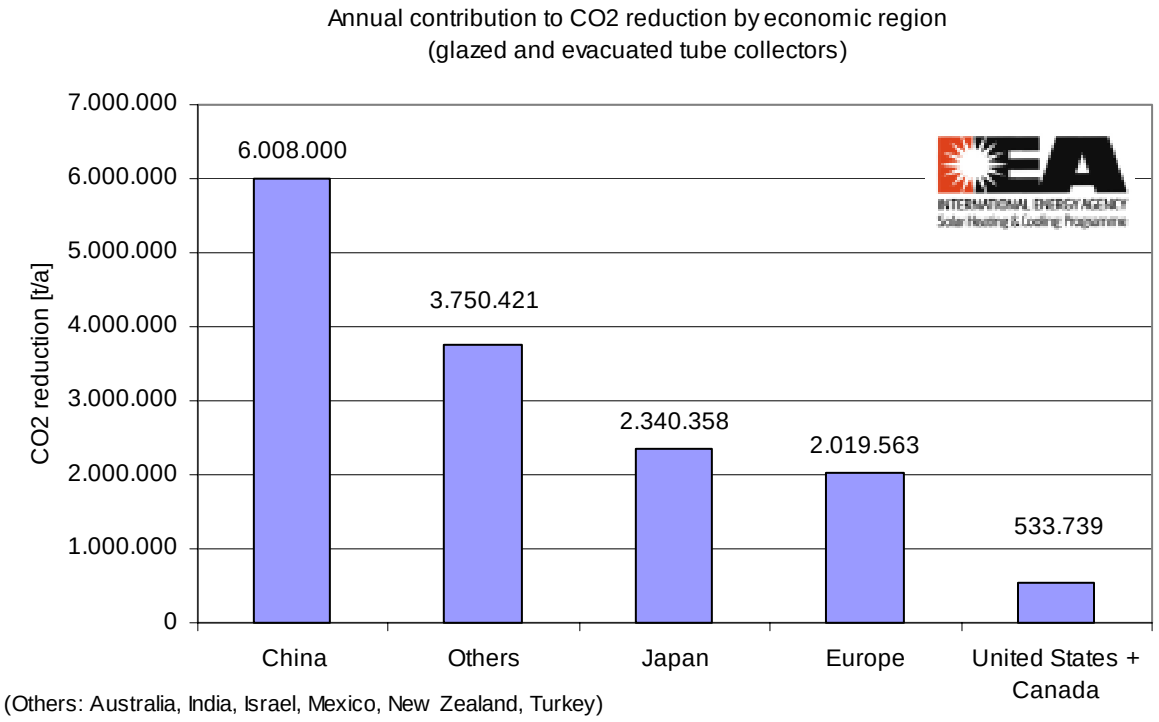

Figure 22: Annual contribution to CO_2 reduction – flat plate and evacuated tube collectors by economic region in the year 2001

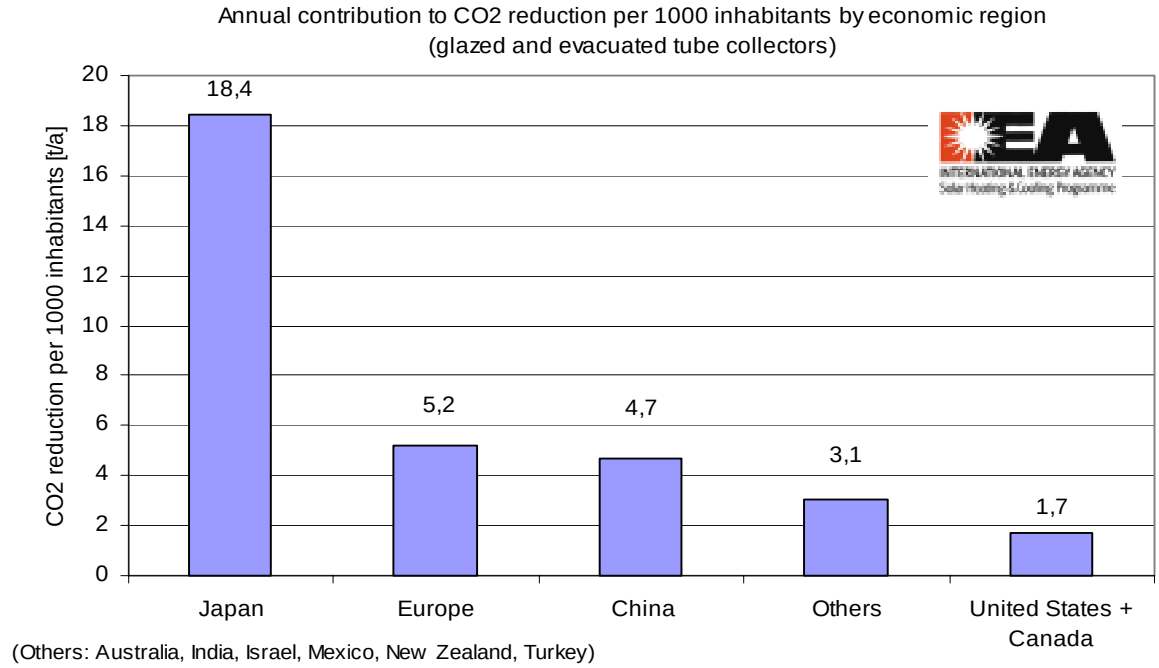

Figure 23: Annual contribution to CO_2 reduction by economic region in the year 2001 per 1000 inhabitants– flat plate and evacuated tube collectors

4.3.2 Contribution to CO_2 reduction: Unglazed collectors by economic region in 2001

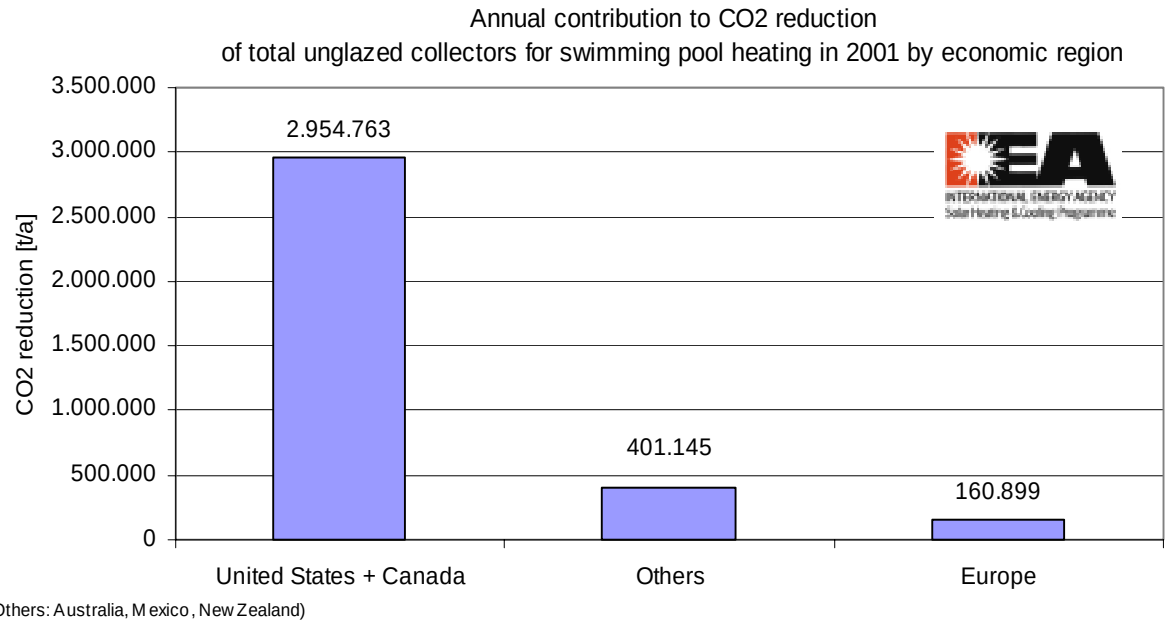

Figure 24: Annual contribution to CO_2 reduction – unglazed collectors by economic region in the year 2001

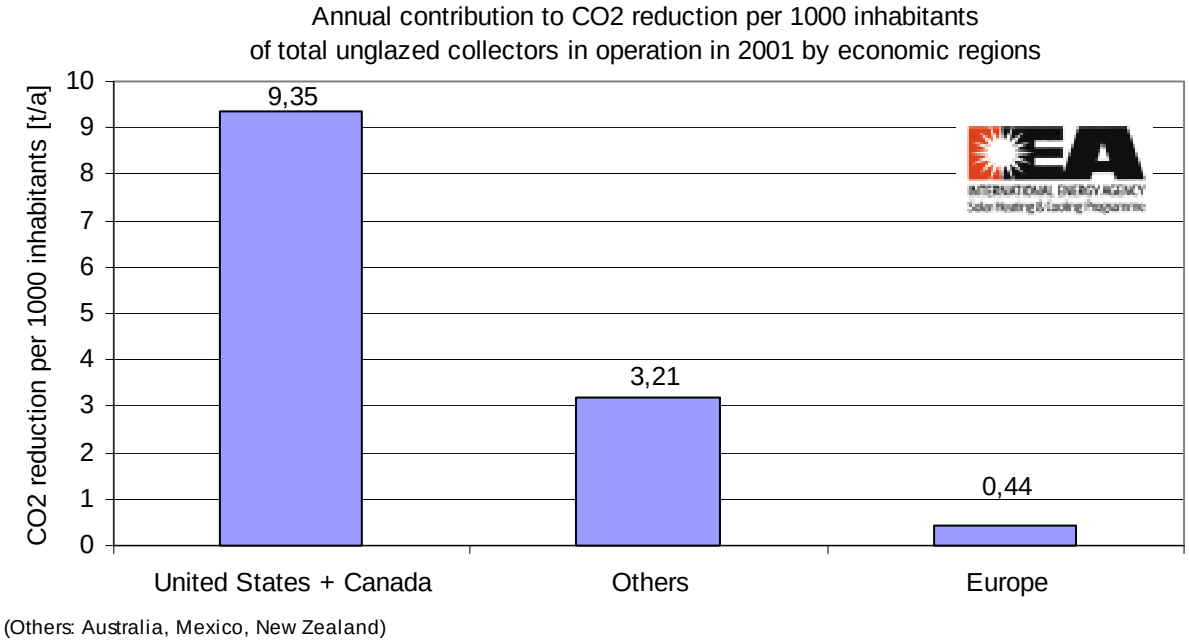

Figure 25: Annual contribution to CO_2 reduction by economic region in the year 2001 per 1000 inhabitants – unglazed collectors

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[6]) 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[7] in use for the respective application. Furthermore, a hydraulic scheme is shown for each reference system.

[6] 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.
[7] 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	2,000,000	10,000	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
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
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	1,200	6	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	5,000	25	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	89,000	445	London
United States	C: 200 m² unglazed plastic absorber	14,513,000	72,565	Denver Los Angeles

C: collector area

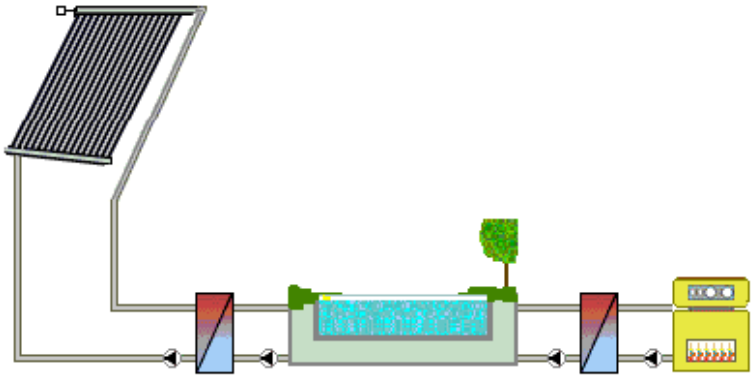

Figure A1: Hydraulic scheme of the swimming pool reference system

5.1.2 Solar domestic hot water systems for single family houses

Country	reference system	reference climate	% of total market[8]
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
China	C: 4 m² / ST: 200 l / HWD: 150 l/d / TS	Shanghai	100
Denmark	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Copenhagen	86
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
Indien	C: 4 m² / ST: 200 l / HWD: 150 l/d / TS	Bombay	100
Irland	C: 4 m² / ST: 200 l / HWD: 150 l/d / PS	Dublin	100
Israel	C: 4 m² / ST: 200 l / HWD: 150 l/d / TS	Jerusalem	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	10
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

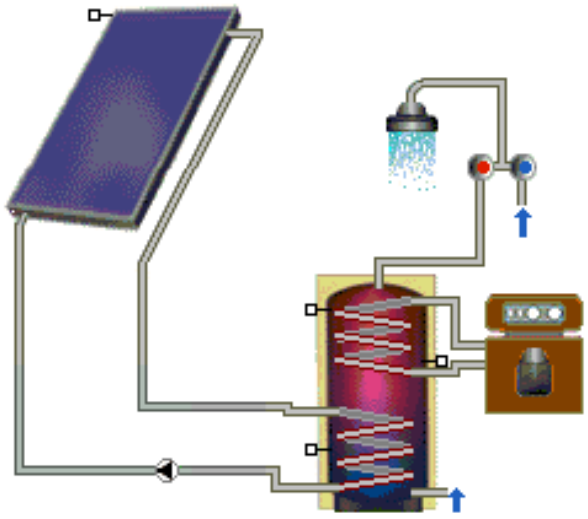

Figure A2: Hydraulic scheme of the DHW reference system

[8] 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 [9]
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	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	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	13
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	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	Athens	0
Italy	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	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	25
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	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	London	0
United States	C: 50 m² / ST: 2500 l / HWD: 2000 l/d / PS	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

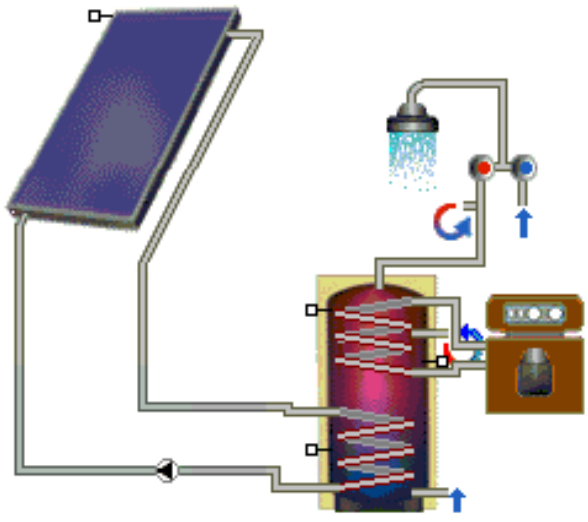

Figure A3: Hydraulic scheme of the DHW system for muli-family houses

[9] 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[10]
Austria	C: 20 m² / ST: 2000 l / HWD: 160 l/d / SHD: 80 kWh/m² / PS	Graz	20
Denmark	C: 15 m² / ST: 800 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Copenhagen	1
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
Japan	C: 12 m² / ST: 750 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Tokyo	2
Netherlands	C: 4 m² / ST 240 l / HWD: 160 l/d SHD: 80 kWh/m² / PDS	Amsterdam	2
Norway	C: 10 m² / ST: 1500 l / HWD: 160 l/d SHD: 100 kWh/m² / PS	Oslo	1
Sweden	C: 12 m² / ST: 1000 l / HWD: 160 l/d SHD: 100 kWh/m² / PS	Gothenburg	65
Switzerland	C: 15 m² / ST: 1000 l / HWD: 160 l/d SHD: 80 kWh/m² / PS	Zurich	15

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]

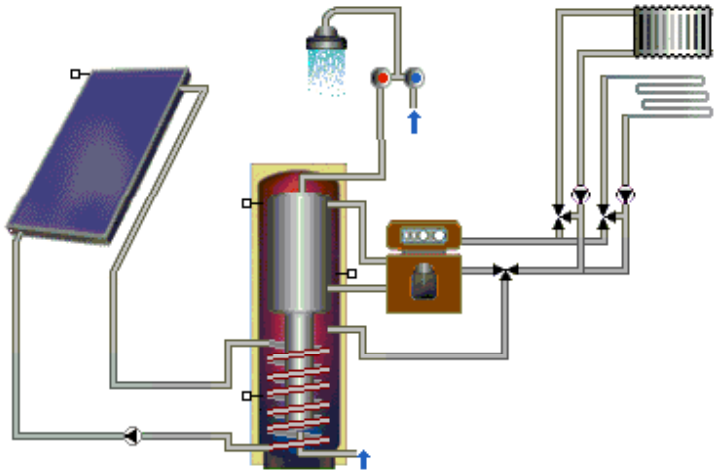

Figure A4: Hydraulic scheme of the solar combi reference system

[10] percentage of total installed collector area (flat plate and vacuum tube) until 2000 for solar combi systems

5.2 Reference collector

Data of the reference absorber for swimming pool heating

$\xi = 0.85$
$a1 = 20\ [W/m^2K]$
$a2 = 0.1\ [W/m^2\ K^2]$

Data of the reference collector for all other applications:

$\xi = 0.8$
$a1 = 3.69\ [W/m^2K]$
$a2 = 0.007\ [W/m^2\ K^2]$

5.3 Reference climates

Country	Used reference climate[11]
Australia	Sydney
Austria	Graz
Belgium	Brussels
Canada	Montreal
China	Shanghai
Denmark	Copenhagen
Finland	Helsinki
France	Paris
Germany	Würzburg
Greece	Athens
India	Bombay
Ireland	Dublin
Israel	Jerusalem
Italy	Bologna
Japan	Tokyo
Mexico	Mexico City
Netherlands	Amsterdam
New Zealand	Wellington
Norway	Oslo
Portugal	Lisbon
Spain	Madrid
Sweden	Gothenburg
Switzerland	Zurich
Turkey	Istanbul
United Kingdom	London
United States	Denver Los Angeles

[11] Meteonorm

5.4 Population data

Country	Inhabitants in 2001
Australia	19.485.000
Austria	8.032.000
Belgium	10.264.000
Canada	31.082.000
China	1.277.558.000
Denmark	5.333.000
Finland	5.188.000
France	59.191.000
Germany	82.335.000
Greece	10.020.000
India	1.017.544.000
Ireland	3.839.000
Israel	6.445.000
Italy	57.948.000
Japan	127.130.000
Mexico	101.754.000
The Netherlands	16.044.000
New Zealand	3.850.000
Norway	4.513.000
Portugal	10.024.000
Spain	40.266.000
Sweden	8.833.000
Switzerland	7.231.000
Turkey	68.610.000
United Kingdom	59.542.000
United States	284.797.000
Total	**3.326.858.000**

Economic Region	Inhabitants in 2001
United States + Canada	315.879.000
Japan	127.130.000
China	1.277.558.000
Europe	388.603.000
Others	1.217.688.000
Total	**3.326.858.000**

Others: Australia, India, Israel, Mexico, New Zealand, Turkey
Europe: EU 15 (excl. Luxemburg) + Switzerland and Norway

Source: Statistisches Jahrbuch 2004 (http://www.statistik.at/jahrbuch/pdf/k37.pdf)

5.5 References to reports and persons that have supplied the data

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

Australia	John Ballinger Solar Efficient Architecture, Kangaroo Valley
	Ken Guthrie Sustainable Energy Authority Victoria, Melbourne
Austria	Gerhard Faninger IFF-University of Klagenfurt, Klagenfurt
Belgium	André De Herde Université Catholique de Louvain, Lauvain-la-Neuve
Canada	Doug McClenahan CANMET - Natural Resources Canada, Ottawa
China	Jiang Xinian Guangzhou Institute of Energy Conservation Chinese Academy of Sciences Beijing
Denmark	Poul E. Kristensen Virum
Finland	Peter Lund Helsinki University of Technology, Espoo
France	Richard Loyen Association de Professionnels pour le Developpement des Énergies Renouvelables, Castellet
Germany	Gerhard Stry-Hipp Bundesverband Solarindustrie e.V. – Bsi, Berlin
Greece	Aris Aidonis Center for Renewable Energy Sources (CRES), Pikermi
Israel	Asher Vaturi ICTAF, Tel Aviv University
	Ministry of National Infrastructures
	Solel and Israel Manufacturing Association
Italy	Paolo Zampetti ENEA, Rome

Japan	Yoshimura, Kazuki National Institute of Advanced Industrial Science and Technology, Nagoya
Mexico	Isaac Pilatowsky and Claudio Estrada Centro de Investigacion en Energia, Temixco, Morelos
Netherlands	Lex Bosselaar NOVEM, Utrecht
	Ecofys, BIJDRAGE THERMISCHE ZONNE-ENERGIE 2002
New Zealand	Michael Donn, School of Architecture, Wellington
	Brian Cox Solar Industries Association New Zealand
Norway	Fritjof Salvesen KanEnergi AS, 1351 Rud
Portugal	João Farinha Mendes INETI - Edificio G, Lisbon
Spain	Maria Luisa Delgado CIEMAT, Madrid
Sweden	Jan-Olof Dalenbäck Chalmers University of Technology, Göteborg
Switzerland	Urs Wolfer Bundesamt für Energie, Bern SOFAS, "Markterhebung Sonnenenergie 2001", August 2003
Turkey	Gulsun Erkul First Secretary (Energy Adviser), Permanent Delegation of Turkey to the OECD
United States	Drury Crawley U.S. Department of Energy, EE-41, Washington D.C.

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