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WERNER WEISS | MONIKA SPÖRK-DÜR

SOLAR HEAT WORLDWIDE

Global Market Development and Trends in 2018 | Detailed Market Figures 2017

Federal Ministry
Transport, Innovation
and Technology

SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Solar Heat Worldwide

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Detailed Market Figures 2017

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1 Background

The Solar Heat Worldwide report has been published annually since 2005 within the framework of the Solar Heating and Cooling Technology Collaboration Programme (SHC TCP) of the International Energy Agency (IEA).
The first edition of the report included data from 35 countries. The database has been extended to 68 countries over the past 15 years. In addition to the increased number of countries, also the degree of detail of the data was significantly improved.
The 2019 edition and all past issues of the report can be downloaded from the following website:
http://www.iea-shc.org/solar-heat-worldwide

The goal of the report is to give an overview of the general trends, to highlight special applications and outstanding projects and to document the solar thermal capacity installed in the important markets worldwide. Furthermore, it is the goal to ascertain the contribution of solar thermal systems to the supply of energy and the CO_2 emissions avoided as a result of operating these systems. The collectors documented in detail are unglazed collectors, glazed flat-plate collectors (FPC) and evacuated tube collectors (ETC) with water as the energy carrier as well as glazed and unglazed air collectors.
In this edition of Solar Heat Worldwide for the first time also hybrid Photovoltaic-Thermal (PVT) collectors are included, as PVT collectors got more market relevance in recent years.
PVT collectors convert in a single device solar radiation in electricity and heat and could thus play an important role in the energy supply of the future.

The data were collected from a survey of the national delegates of the SHC TCP Executive Committee and other national experts active in the field of solar thermal energy. As some of the 68 countries included in this report have very detailed statistics and others have only estimates from experts, the data was checked for its plausibility on the basis of various publications.

The collector area, also referenced as the installed capacity, served as the basis for estimating the contributions of solar thermal systems to the energy supply and reductions of CO_2 emissions.

The 68 countries included in this report represent 4.9 billion people, or about 66 % of the world's population. The installed capacity in these countries is estimated to represent 95 % of the solar thermal market worldwide.

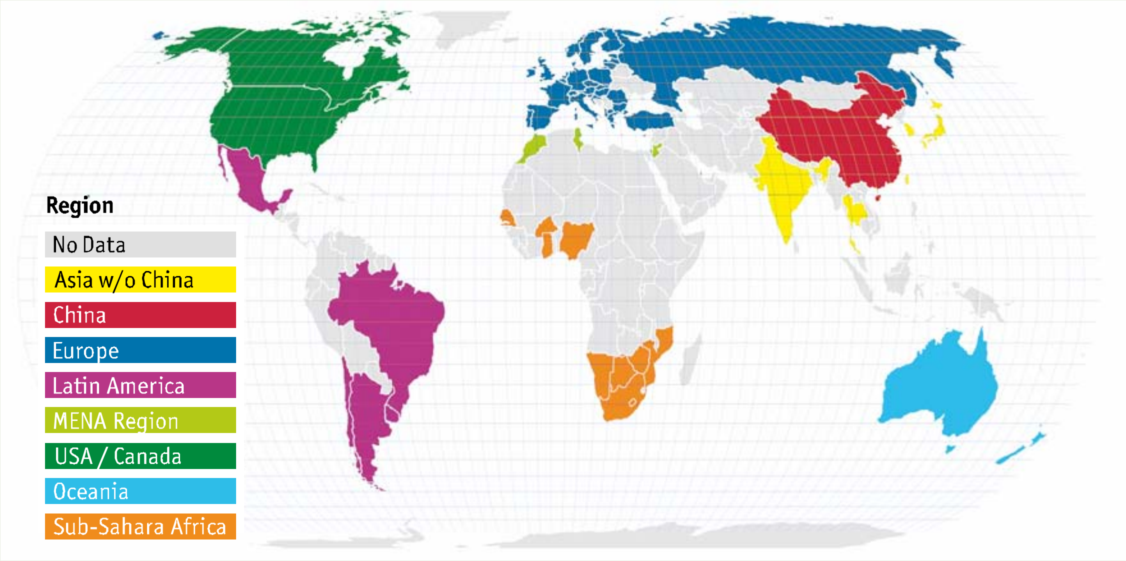

Figure 1: *Countries shown in color have detailed market data. Countries shown in grey have estimated market data. (Source: Natural Earth 2019 / AEE INTEC http://www.naturalearthdata.com/downloads/10m-cultural-vectors/10m-admin-0-countries/)*

2 Summary

This report is split into two parts. The first part (Chapters 3 - 4) gives an overall overview of the global solar thermal market development in 2018. In addition, general trends are described and detailed 2018 data on successful applications, such as solar assisted district heating, solar heat for industrial processes and hybrid photovoltaic-thermal systems, are documented.

The second part (Chapters 5 - 8) presents detailed market figures for the year 2017 from 68 countries around the globe. The concluding chapter of the second part gives an overview of the levelized cost of solar heat for different applications.

Global solar thermal market developments and status in 2018

Although the global solar thermal market fell again by 3.9 % in 2018, the significant slowdown in the market decline in some countries and the very positive growth figures in nine of the top 20 countries worldwide point to a turnaround in the market for solar thermal energy. If this trend continues, global market growth can again be expected in 2019.

The cumulated solar thermal capacity in operation by end of 2018 was 480 GW_{th} (686 million square meters). Compared to the year 2000 the installed capacity grew by a factor of 7.7.
The corresponding annual solar thermal energy yield in 2018 amounted to 396 TWh, which correlates to savings of 42.6 million tons of oil and 137.5 million tons of CO_2.

Despite these achievements, the global solar thermal market has faced challenging times in recent years. This is especially evident in the large markets in China and Europe where the traditional mass markets for small-scale solar water heating systems for single-family houses and apartment buildings are under market pressure from heat pumps and photovoltaic systems. The applications mentioned above still represent more than 90 % of the worldwide annual installations, even if the number of megawatt-scale systems for district heating as well as for industrial applications are increasing from year to year.

By the end of 2018 about 339 large-scale solar thermal systems (>350 kW_{th}; 500 m²) connected to district heating networks and in residential buildings were in operation. The total installed capacity of these systems equaled 1,200 MW_{th} (1,747,200 m²), excluding concentrating systems that add 177,950 m². Denmark is still the leading European country for large-scale systems for district heating, adding 54 % of the new installed collector area worldwide (excluding parabolic trough collectors). About 87 % of the installed collector area for large scale systems added outside Europe in 2018 is installed in China.

In 2018, seventeen large-scale solar thermal systems with about 85,100 m² (60 MW_{th}) were installed in Europe. Of these installations in 2018, six are in Denmark (66,800 m²), six in Germany (9,380 m²), two in Austria (3,010 m²) and one in Turkey (4,575 m²).

Outside Europe, 27 MW_{th} (38,260 m²) were installed, excluding seven concentrating systems in China and two in Mexico respectively, that added a collector area of 20,490 m².

In China most of the installed systems for district heating have been installed in Tibet including the 2018 extension of an existing system with 9,000 m² parabolic trough collectors in Shenza and the second largest system installed for district heating in 2018 in Langkasi with a collector area of 22,275 m². In South Africa, the first solar district heating network was installed in 2018 with a collector area of 557 m². In Mexico, Denmark and China parabolic trough collector fields have been installed in the last few years for district heating (China and Denmark) as well as for large buildings (Mexico). These parabolic trough systems add to a total collector area of 177,950 m².

Solar heat for industrial processes (SHIP) continues to be a growing niche market worldwide. A number of promising projects have been implemented in the last couple of years ranging from small-scale demonstration plants to very large systems with 100 MW_{th} capacity. At least 741 SHIP systems, totaling 662,648 m^2 collector area (567 MW_{th}), were in operation at the end of the year 2018.

In 2018, suppliers of industrial solar heat technology commissioned 108 new systems. In 2017, 107 units with a collector area of 190,700 m² were installed. If the exceptionally large Miraah plant[1] (148,000 m², 100 MW_{th}) constructed in Oman in 2017 is excluded then the newly installed collector area of SHIP plants increased from 44,580 m² (31.2 MW_{th}) in 2017 to 53,654 m² (37.6 MW_{th}) in 2018.

Photovoltaic Thermal (PVT) collectors and systems have been included for the first time in this edition of the Solar Heat Worldwide report. This chapter takes a look at the PVT market worldwide with a special focus on Europe.
By the end of the year 2018 a cumulated PVT collector area of 1,075,247 m² was installed. In the European Market, France is the market leader with an installed collector area of 442,504 m² followed by Germany with 109,380 m². Outside of Europe the main PVT-manufacturer in Israel reported a cumulated manufactured collector area of 575,000 m² by the end of 2018.

Market status worldwide in 2017

By the end of 2017, an installed capacity of 473.5 GW_{th} corresponding to a total of 676 million square meters of collector area was in operation in the recorded 68 countries. These figures include unglazed water collectors, flat plate collectors, evacuated tube collectors, and unglazed and glazed air collectors.

The vast majority of the total capacity in operation was installed in China (334.5 GW_{th}) and Europe (54.3 GW_{th}), which together accounted for 82.1 % of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (18.9 GW_{th}), Asia excluding China (13.3 GW_{th}), Latin America (13.6 GW_{th}), the MENA[2] countries (Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia) (7.0 GW_{th}), Australia and New Zealand (6.7 GW_{th}), and Sub-Sahara African countries Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa and Zimbabwe (1.6 GW_{th}). The market volume in the 68 documented countries is estimated to account for 95 % of the total installations.

With a global share of 71 %, evacuated tube collectors were the predominant solar thermal collector technology followed by flat plate collectors with 22.6 %, unglazed water collectors with 6.1 % and glazed and unglazed air collectors with 0.3 %.

The top 10 countries – those with the highest market penetration per capita – were China, the United States, Turkey, Germany, Brazil, India, Australia, Austria, Israel and Greece.
The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2017 per 1,000 inhabitants were Barbados (540 kW_{th} / 1,000 inhabitants), Cyprus (440 kWth / 1,000 inhabitants), Austria (413 kW_{th} / 1,000 inhabitants), Israel (397 kW_{th} / 1,000 inhabitants), Greece (300 kW_{th} / 1,000 inhabitants), Australia (276 kW_{th} / 1,000 inhabitants), the Palestinian Territories (269 kW_{th} / 1,000 inhabitants), China (242 kW_{th} / 1,000 inhabitants), Turkey (201 kW_{th} / 1,000 inhabitants) and Denmark (199 kW_{th} / 1,000 inhabitants).

Newly installed capacity worldwide in 2017

By the end of 2017 a capacity of 34.6 GW_{th}, corresponding to 49.5 million m² of solar collectors, was installed worldwide. This means a decrease in new collector installations of 5.1 % compared to the year 2016. This downward trend, however, is less than the 13.6 %

1 For details of this plant see the 2018 edition of Solar Heat Worldwide at http://www.iea-shc.org/solar-heat-worldwide

2 Middle East and North Africa

in the year 2015 / 16 and initial 2018 data show a continued slowing of this downward trend as markets rebound driven mainly by the growth in large-scale and solar process heat installations and the recovering market in China.

The main markets in 2017 were again China (26.1 GW_{th}) and Europe (2.8 GW_{th}), which together accounted for 83.3 % of the overall new collector installations. The rest of the market was shared between Latin America (1.2 GW_{th}), Asia excluding China (1.2 GW_{th}), the United States and Canada (0.7 GW_{th}), the MENA countries (0.4 GW_{th}), Australia (0.4 GW_{th}), and the Sub-Sahara African countries (0.1 GW_{th}). The market volume of “all other countries” is estimated to amount for 5 % of the new installations (1.7 GW_{th}).

Of the top 10 markets in 2017, positive market growth was reported from India, Australia, Israel and Mexico.

With a share of 71.8 % of the newly installed capacity in 2017, evacuated tube collectors are still by far the most important solar thermal collector technology worldwide. In a global context, this breakdown is mainly driven by the dominance of the Chinese market where around 83.6 % of all newly installed collectors in 2017 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82 % in 2011 to 71.8 % in 2017, and in the same time frame flat plate collectors increased the share from 14.7 % to 23.7 %.

In Europe, the situation is almost the opposite compared to China with 71 % of all solar thermal systems installed in 2017 being flat plate collectors. In the medium-term, the share of flat plate collectors, however, has decreased from 81.5% in 2011 to 71.0% in 2017 due to growth of the evacuated tube collector markets in Turkey, Poland, Switzerland and Germany. Overall, the share of evacuated tube collectors in Europe increased the share in Europe from 15.6% in 2011 to 28% in 2017.

In terms of newly installed solar thermal capacity per 1,000 inhabitants in 2017, Israel took the lead followed by Cyprus, Barbados and Greece. China ranked fifth followed by Australia, Turkey, Austria, the Palestinian Territories and Switzerland.

Distribution by system type and application

The thermal use of the sun’s energy varies greatly from region to region and can be roughly distinguished by the type of solar thermal collector used, the type of system operation (pumped solar thermal systems, thermosiphon systems) and the main type of application (swimming pool heating, domestic hot water preparation, space heating, others such as heating of industrial processes, solar district heating and solar thermal cooling).

Worldwide, more than three quarters of all solar thermal systems installed are thermosiphon systems, and the rest are pumped solar heating systems. Similar to the distribution by type of solar thermal collector in total numbers, the Chinese market and Asia excluding China influenced the overall figures the most.

In general, thermosiphon systems are more common in warm climates, such as in Africa, South America, southern Europe and the MENA countries. In these regions thermosiphon systems are more often equipped with flat plate collectors, while in China the typical thermosiphon system for domestic hot water preparation is equipped with evacuated tubes.

The calculated number of water-based solar thermal systems in operation was approximately 118 million by the end of 2017. The breakdown is 63 % used for domestic hot water preparation in single-family houses, 28 % attached to larger domestic hot water systems for multifamily houses, hotels, hospitals, schools, etc., and 6 % used for swimming pool heating. Around 2 % of the worldwide installed capacity supplied heat for both domestic hot water and space heating (solar combi-systems). The remaining systems ac-

A 0.7 MW_{th} solar thermal system supplies heat to the Berlin district heating network. *Photo: Arcon-Sunmark*

counted for around 1 % and delivered heat to other applications, including district heating networks, industrial processes and thermally driven solar cooling applications.

Compared to the cumulated installed capacity, the share of swimming pool heating was less for new installations (6 % of total capacity and 3 % of newly installed capacity). A similar trend can be seen for several years now for domestic hot water systems in single-family homes: 63 % of total capacity in operation and 44 % of new installations in 2017 make this kind of system the most common application worldwide, but it is showing a decreasing trend.

By contrast, the share of large-scale domestic hot water applications is increasing (28 % of total capacity and 51 % of newly installed capacity). It can be assumed that this market segment took over some of the market shares from both swimming pool heating and domestic hot water systems in single-family homes.

The share of solar district heating and solar process heat applications is steadily increasing despite it still only representing 3 % of the global market.

Employment and turnover

Based on a comprehensive literature survey and data collected from detailed country reports, the number of jobs in the fields of production, installation and maintenance of solar thermal systems is estimated to be 672,000 worldwide in 2017.[3]

The worldwide turnover of the solar thermal industry in 2017 is estimated at € 15.2 billion (US$ 16.9 billion).

3 Background information on the methodology used can be found in the Appendix, Chapter 9.4

3 Worldwide solar thermal capacity in 2018

After a period of significant growth between 2005 and 2016, the growth rate has decelerated in recent years globally. Despite this trend, some countries still show a notable increase in their installed solar thermal capacity.
As shown in the figure below, the global solar thermal capacity of unglazed and glazed water collectors in operation grew from 62 GW_{th} (89 million square meters) in 2000 to 480 GW_{th} (686 million square meters) in 2018.

The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 396 TWh in 2018 (**Figure 2**).

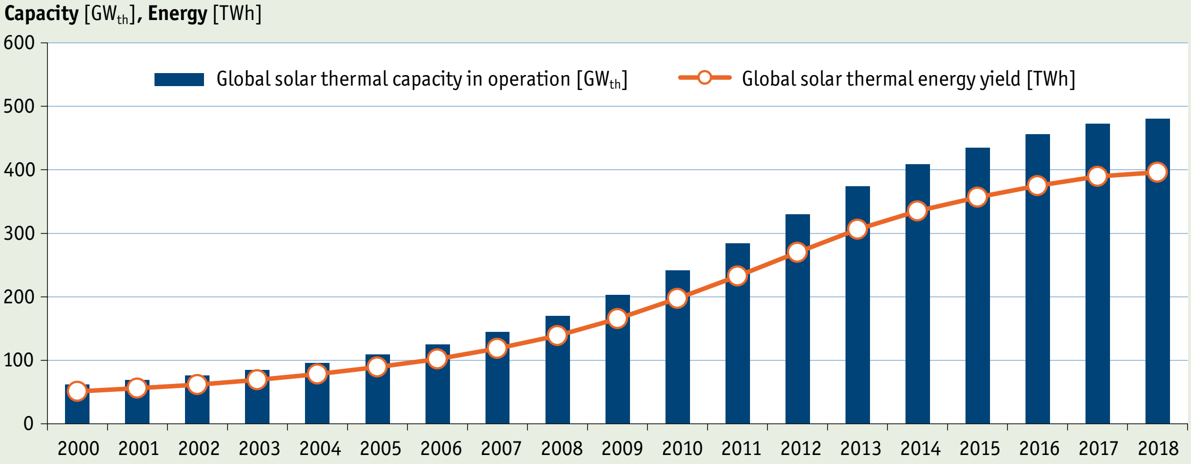

Figure 2: Global solar thermal capacity in operation and annual energy yields 2000 – 2018

Environmental effects and contribution to climate goals

The global solar thermal energy yields of all installed solar thermal systems in 2018 corresponded to savings of 42.6 million tons of oil and 137.5 million tons of CO_2. This shows the significant contribution of this technology to the effort in reducing the global greenhouse gas emissions.

3.1 Solar thermal capacity in relation to the capacity of other renewable energy technologies

Solar thermal was the leading new renewable energy technology in terms of cumulated installed capacity in operation for many years. In 2015 wind energy caught up to a level equal to solar thermal and has been ahead of solar thermal since 2016. In 2018 photovoltaics overtook solar thermal in terms of installed capacity.

Compared with other forms of renewable energy, solar thermal's contribution in meeting global energy demand is now, besides the traditional renewable energies like biomass and hydropower, third behind wind power and PV (**Figure 3**).

The cumulated solar thermal capacity in operation by the end of 2018 was 480 GW_{th}[4], which trailed behind wind power's installed capacity of 590 GW_{el} and photovoltaics' 502 GW_{el} of installed capacity. The total capacity of concentrating solar thermal power (CSP) systems was about 5.5 GW_{el}, which is in the range of 0.6 % of the capacity of solar heating and cooling technologies.
In terms of energy, solar thermal systems supplied a total of 396 TWh of heat, whereas wind turbines supplied 1470 TWh and photovoltaic systems 640 TWh of electricity.

4 The figures for 2018 are based on the latest market data from Australia, Austria, Brazil, China, Germany, India, Israel, Mexico, South Africa, Turkey and the United States, which represented about 88 % of the cumulated installed capacity in operation in the year 2017.

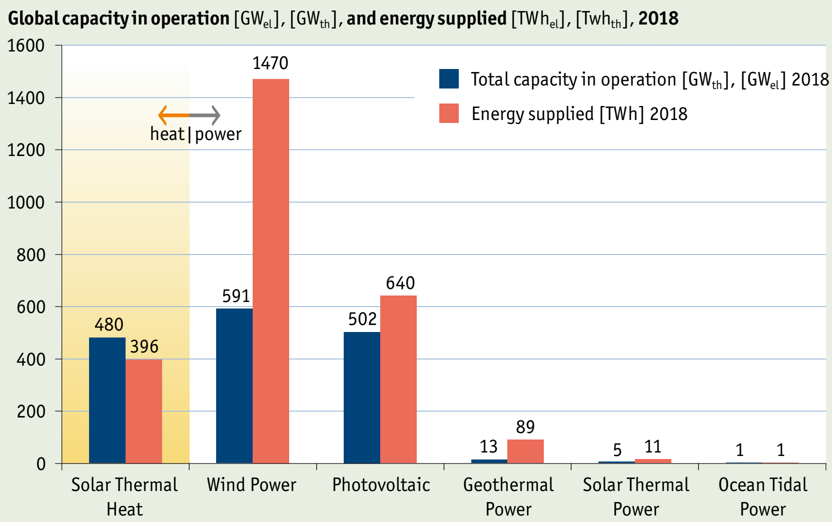

Figure 3: *Global capacity in operation [GW_{el}], [GW_{th}] 2018 and annual energy yields [TWh_{el}], [TWh_{th}].*
(Sources: AEE INTEC, Global Wind Energy Council (GWEC), European PV Industry Association (EPIA), REN21 - Global Status Report 2019)

The development of global installed capacity of solar thermal heat, wind and photovoltaics between 2010 and 2018 is shown in Figure 4. It can be highlighted that all mentioned renewable technologies show positive growth rates in terms of cumulated installed capacities.

In 2018, photovoltaics had the highest global growth rate with 25 % added capacity and was followed by wind, which increased its installed capacity by 10 %. With 2 % added capacity, solar thermal was significantly behind the other two technologies as shown in Figure 4.

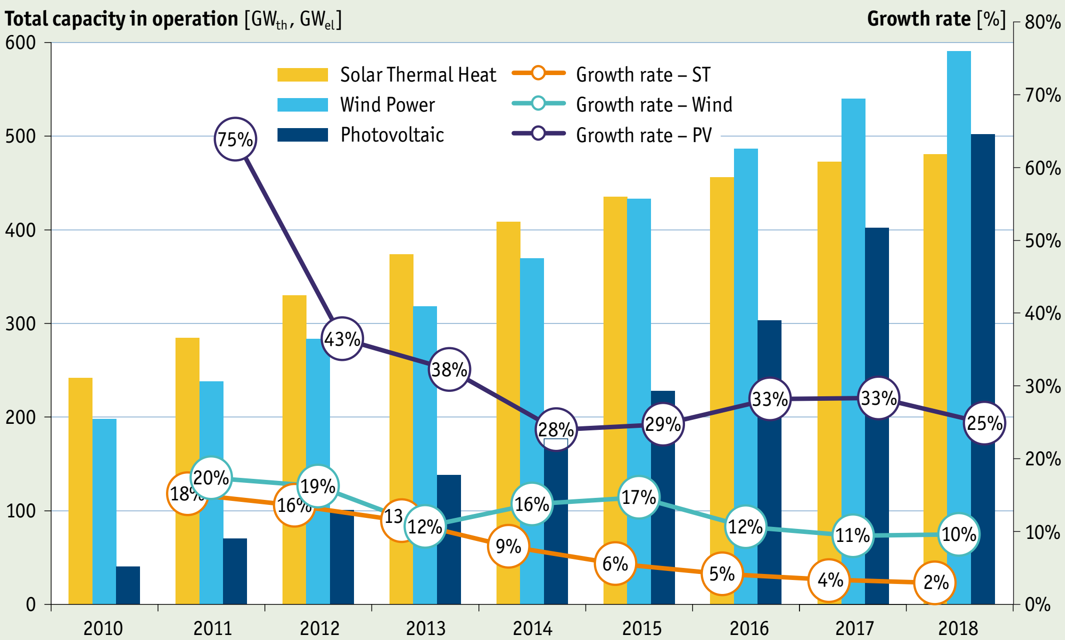

Figure 4: *Global capacity in operation and market growth rates between 2010 and 2018*
(Sources: AEE INTEC, Global Wind Energy Council (GWEC), European PV Industry Association (EPIA), REN21 - Global Status Reports 2011-2019)

4 Solar thermal market development and trends in 2018

The global solar thermal market has faced challenging times in the recent years as reflected in the shrinking of annual collector capacity (18 % in 2010 / 2011 to 2 % in 2017 / 2018).

Compared to 2017, the global new installations declined again by 3.9 % in 2018. This was mainly due to China, where for the fifth year in a row the market declined. After a 17 % decline in 2014 and 2015 and a 9 % decline in 2016, the downtrend slowed to a level of 5 % in 2018. This is important to note because the Chinese is by far the largest market worldwide, what has a major impact on the worldwide figures, as shown above in **Figure 4**.

The market dominance of China overlooks the fact that in 2018 ten out of the top 20 countries saw market growth again. Positive market growth was recorded in Poland (179 %), Denmark (128 %), India (17 %), Cyprus (5 %), Greece (4 %), Mexico (4 %), Australia (2 %), Spain (2 %), France (2 %) and South Africa (2 %). For other detailed country trends please refer to **Chapter 5**.

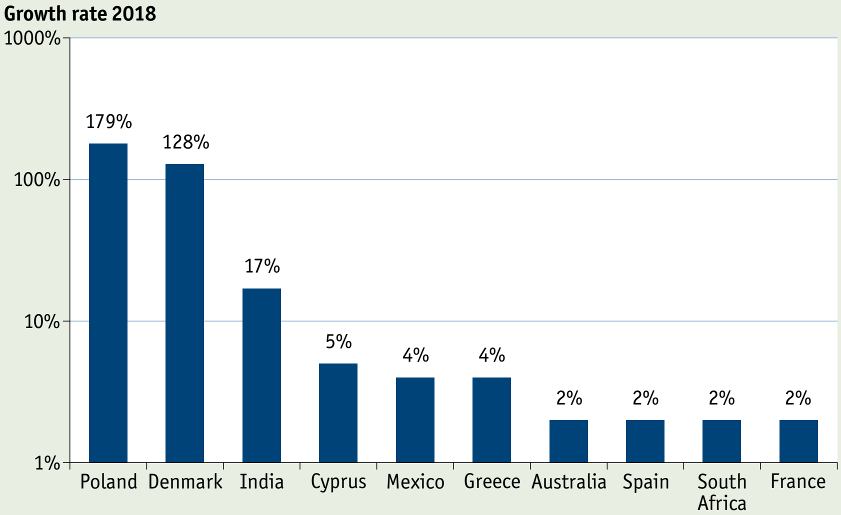

Figure 5: *Solar thermal market growth rates in the most successful countries in 2018*

Megawatt-scale solar supported district heating systems and solar heating and cooling applications in the commercial and industrial sector have gained increasing interest all over the world in recent years, and several ambitious projects have been successfully implemented. New installations for these applications were installed all over the globe in 2018. This positive trend is expected to continue, but it should be mentioned that Megawatt-scale plants still represent only about 1 % of the overall global installed capacity.

The significant slowdown in the market downturn in some countries and the very positive growth figures in ten out of the top 20 countries worldwide point to a turnaround in the solar thermal market. If this trend continues, global market growth can be expected again in 2019.

Large-scale system for multi-family houses. *Photo: SOLID GmbH*

4.1 Small-scale solar thermal heating systems

Small-scale solar water heating systems and to a certain extent solar combi-systems for combined hot water preparation and space heating for detached single-family houses and apartment buildings, for multifamily houses, for the hotels as well as for public buildings represent still more than 90 % of the worldwide annual installations.
This traditional mass market has come under considerable pressure in Europe and China over the past few years and has experienced significant market declines but seems to recover.

4.2 Large-scale solar thermal heating systems

In the Scandinavian countries Denmark and Sweden, as well as in Austria, Germany, Spain and Greece, large-scale solar thermal plants connected to local or district heating grids, or installed on large residential, commercial and public buildings have been in use since the early 1980s. In recent years, China and other countries have also installed a number of large-scale systems.

By the end of 2018, 339 large-scale solar thermal systems (>350 kW_{th}; 500 m²) were in operation (**Figure 6**). The total installed collector area of these systems equaled 1,747,200 m² (1,200 MW_{th}, excluding concentrating solar thermal systems that add up to 177,950 m²).

The biggest sub-sector of the systems described above is solar assisted district heating. And, Denmark is the leader by far not only in Europe but worldwide, in the number of systems and in the installed capacity.

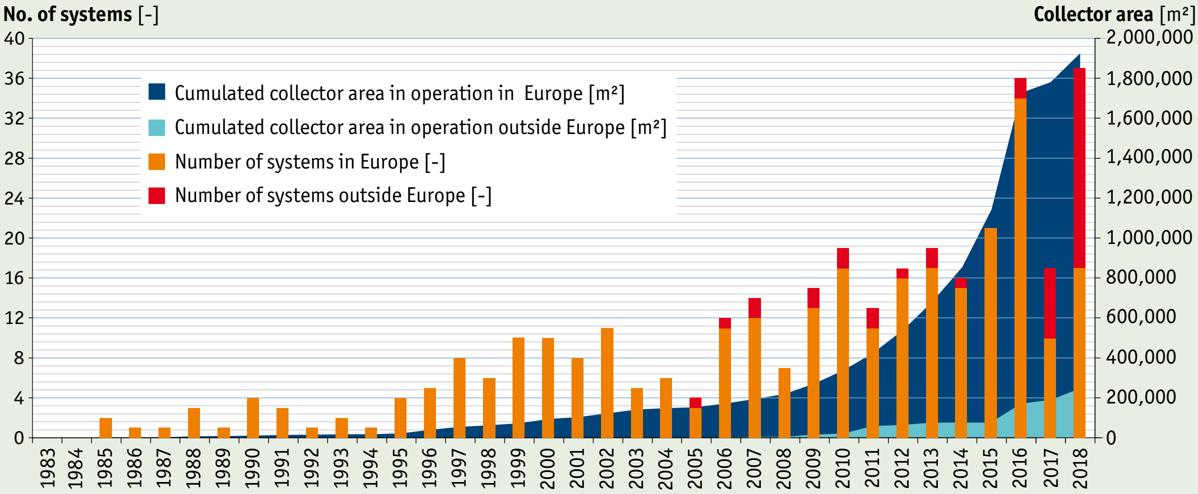

Figure 6: *Large-scale systems for solar district heating and large residential, commercial and public buildings worldwide – annual achievements and cumulated area in operation in 2018*
(Data source: Daniel Trier - PlanEnergi, DK, Jan-Olof Dalenbäck - Chalmers University of Technology, SE, Sabine Putz - IEA SHC Task 45, AT, Bärbel Epp - solarthermalworld.org, DE)

The first of these solar assisted district heating systems was installed in the small town of Saltum already in 1988. It has a collector area of 1.005 m² (0.7 MW_{th}). By the end of 2018 a total number of 117 systems with 1,366,550 collector area related to an installed capacity of 956.6 MW_{th} (including extensions of existing systems but excluding parabolic troughs) was installed in Denmark[5].

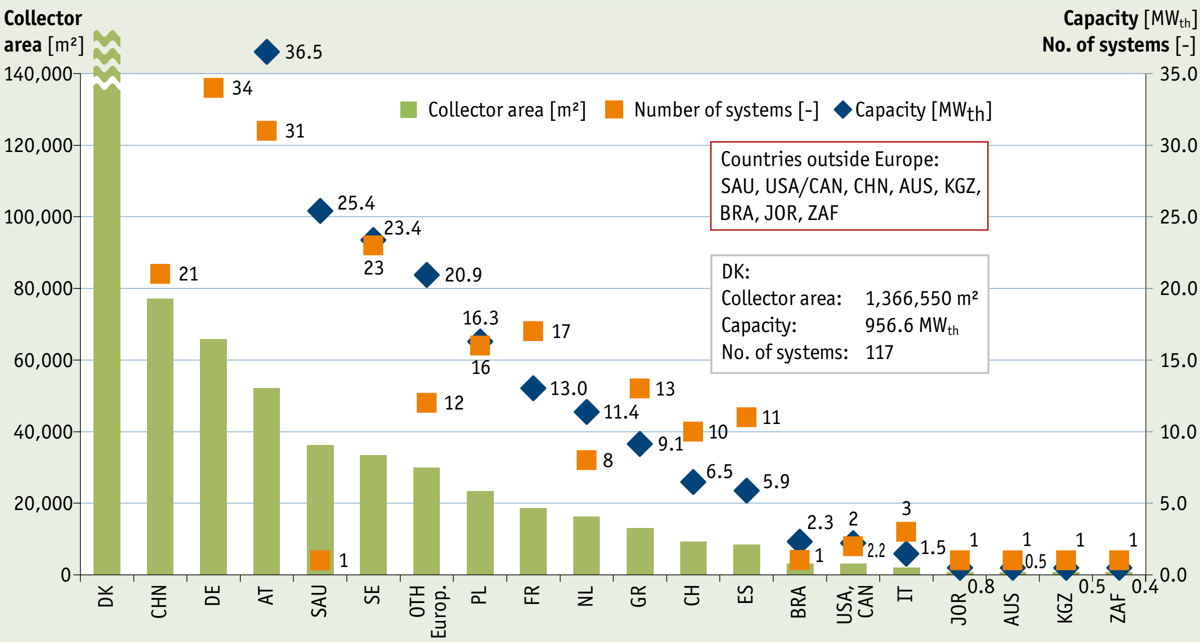

Figure 7: *Large-scale systems (with evacuated tube collectors and flat plate collectors included in the diagram, concentrating solar thermal systems add with 177,950 m²) for solar district heating and residential buildings – capacities and collector area installed and number of systems in 2018*
(Data source: Daniel Trier - PlanEnergi, DK, Jan-Olof Dalenbäck - Chalmers University of Technology, SE, Sabine Putz - IEA SHC Task 45, AT, Bärbel Epp - solarthermalworld.org, DE)

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5 Daniel Trier, PlanEnergi, Arcon Sunmark Reference List http://arcon-sunmark.com/brochures, Jan-Olof Dalenbäck SDH – www.solar-district-heating.eu.

The Aabybro solar district heating system. *Photo: Arcon-Sunmark*

Most of the Danish installations are ground mounted flat plate collector fields hydraulically connected to load-balancing storages in close distance to the district heating main distribution line.

Six new solar district heating systems with collector areas between 900 m² (Jerslev, stage 2) and 26,195 m² (Aabybro) were built in 2018.

The largest plants in operation were installed already in 2016 in Silkeborg (110 MW_{th}), in 2011 in Vojens (50 MW_{th}; 69,991 m²), 2009 in Gram (31.4 MW_{th}; 44,836 m²) and 2014 in Dronninglund (26.3 MW_{th}; 37,500 m²). These systems are equipped with seasonal pit heat storages for solar fractions of around 50 %.

In addition to Denmark, a number of other countries are showing an increasing interest in this type of plants as they offer an excellent opportunity for decarbonizing the heat sector in neighborhoods and entire cities. Countries to note are Germany with 34 large-scale systems (some of these with seasonal storage), Austria (31 systems), Sweden (23 systems), China (21 systems), France (17 systems), Poland (16 systems), Greece (13 systems) Spain (11 systems) and Switzerland (10 systems).

4.2.1 Large-scale systems connected to district heating in 2018

In 2018, 15 large-scale solar thermal systems connected to district heating (> 500 m²) were added in Europe. Of these installations, six in Denmark[6] (66,800 m²), six in Germany (9,380 m²), two in Austria[7] (3,010 m²) and one in Turkey (4,575 m²).

In China most of the installed collector area for district heating has been installed in Tibet including the addition of 9,000 m² parabolic trough collectors added to an existing system in Shenza, and the second largest system installed for district heating in 2018 in Langkasi with a collector area of 22,275 m² (flat plate collectors).

6 This includes two extensions of already existing systems in Jerslev and Hjallerup

7 Including one extension with 504 m²

22,275 m² (15.6 MW_{th}) solar collector field covers more than 90 % of Langkazi's heating needs in Tibet. Photo: Arcon-Sunmark

In South Africa, the first solar district heating network was installed in 2018 with a collector area of 557 m².

In Europe, all large-scale systems for solar district heating added in 2018 totaled for 83,760 m² (58.6 MW_{th}) of solar collectors. In China about 32,000 m² collector area (22.4 MW_{th}) for district heating were added in 2018, excluding 18,615 m² parabolic trough collector area.

Highlighted below are a few of the solar district heating systems installed in 2018.

The largest plant built in 2018 is in the Danish city of Aabybro. The installed capacity of the system is 18.3 MW_{th} (26,195 m²).

Since December 2018, the solar district heating plant of Langkazi in Tibet has been supplying energy to the citizens. The 15.6 MW_{th} (22,275 m²) solar collector field covers more than 90 % of Langkazi's heating needs. The system includes a 15,000 m^3 seasonal storage that allows the energy to be stored and used as needed. As part of the project, 25 kilometers of district heating pipes were laid in the city to connect the homes with the district heating plant. The majority of households did not have proper heaters to access heat throughout the year.

In Germany, 2018 was a good year for solar heating networks. Six new large solar collector fields were connected to heating networks. One example is the commissioning of Berlin's largest solar thermal system with a collector surface area of 983 m² (0.7 MW_{th}) in the spring of 2018 at the Berlin-Köpenick heating plant for the district heating network.

In Austria, a solar system was installed in 2018, that provides heat for the boiler feed water for district heat supply of the city of Vienna. The collectors with an installed capacity of 0.46 MW_{th} (656 m²) were installed on the roof of a boiler house.

The WITS Junction system in the South African city of Johannesburg is the first solar district heating system in Sub Sahara Africa. *Photo: BlackDot Energy / SOLTRAIN*

The first solar district heating system in Sub Sahara Africa was built on the university campus of the University of the Witwatersrand in Johannesburg. The system with a capacity of 0.39 MW_{th} (557 m²) in combination with a 60 m³ storage tank supplies student residences in 27 buildings on the 4.5-hectare-site.

4.3 Solar heat for industrial processes

A variety of industrial processes demand vast amounts of thermal energy, which makes the industrial sector a promising market for solar thermal applications. Depending on the temperature level of the needed heat, different types of solar thermal collectors are used from air collectors, flat plate and evacuated tube collectors for temperatures up to 100°C to concentrating solar thermal collectors, such as Scheffler dishes, Fresnel collectors and parabolic troughs for temperatures up to 400°C.

Solar heat for industrial processes (SHIP) is a growing market. A number of promising projects have been implemented in the last couple of years ranging from small-scale demonstration plants to very large systems in the 100 MW_{th} sector.

Based on the data published in the AEE INTEC SHIP database[8] and a SHIP supplier survey carried out by the German consulting company SOLRICO[9] at least 741 SHIP plants with an overall collector area of 662,648 m² (567 MW_{th}) were installed worldwide by the end of the year 2018.

In 2018, suppliers of industrial solar heat technology commissioned 108 new systems. In 2017, 107 units with a collector area of 190,708 m² were installed. Taking into account the exceptionally large Miraah plant[10] with 148,000 m² (100MW_{th}) constructed in Oman in 2017, the newly installed collector area of SHIP plants has increased from 42.708 m² to 53.654 m² (37.6 MW_{th}) in 2018.

8 http://ship-plants.info/
9 https://www.solarthermalworld.org/content/mexico-china-and-india-lead-global-ship-market
10 For details of this plant see the 2018 edition of Solar Heat Worldwide at http://www.iea-shc.org/solar-heat-worldwide

In Vienna 656 m² flat plate collectors were installed on the roof of a boiler house at a height of 70 meters. *Photo: Greenonetec Solarindustrie GmbH*

	No. of systems put up in 2018	Collector area added in 2018 [m²]	Average system size [m²]
China	15	28,813	1,921
Mexico	51	6,898	135
France	2	5,543	2,772
India	10	3,964	396
Germany	9	1,589	177
Spain	3	1,218	406
Austria	3	435	145
Other countries	15	5,194	346
TOTAL	108		53,654

Table 1: *Number and size of SHIP plants commissioned in key countries in 2018. Source: SOLRICO; AEE INTEC*

Besides the countries listed in the table above solar thermal systems for industrial applications were also installed in Argentina, Cyprus, Greece, Israel, Italy, Malaysia, South Korea, South Africa, Turkey, the UAE and the USA.

4.3.1 Detailed analysis of 308 SHIP systems

Out of the 741 documented SHIP plants, detailed information on the collector area and installed capacity as well as type of application and type of collector are available for 308 plants. This information can be found in the SHIP database, which is an online portal operated by AEE INTEC in Austria.

The following graphs present an analysis of the systems with detailed information available.

Flat plate collectors with transparent insulation used for a cleaning process in an Israeli dairy. *Photo: Tigi Ltd.*

It is important to note that the figures are dominated by the world's largest solar process heat application in Oman, which was commissioned in early 2018. With a thermal capacity of 100 MW_{th} it accounts for 48 % of the total installed thermal capacity of all 308 documented solar process heat applications worldwide. The second largest system is installed near a copper mine in Chile with a thermal capacity of 27.5 MW_{th}.

Figure 8 shows the distribution of the 308 systems in terms of size. The two mentioned systems in Oman and Chile exceed 21 MW_{th} of thermal capacity, 33 systems have installed capacities between 0.7 MW_{th} and 21 MW_{th} (1,000 m² – 30,000 m²) of thermal capacity, 57 systems have installed capacities between 0.35 and 0.7 MW_{th} (500 – 1,000 m²) and 216 systems are below 0.35 MW_{th} (<500 m²).

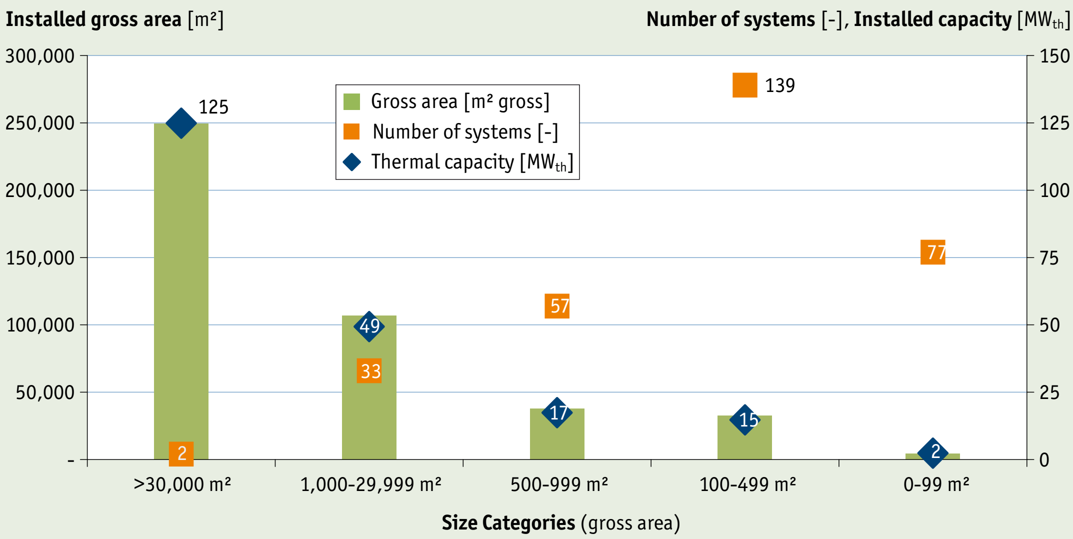


Figure 8: *Global solar process heat systems in operation by end of March 2019 – capacity and collector area (Source: IEA SHC Task49 / IV SHIP database)*

556 m² collector area provides solar process heat for Klein Karoo International Tannery in South Africa. *Photo: E3 Energy / SOLTRAIN*

Figure 9 shows the analyzed process heat systems in respect to the used collector technology. The majority of the systems use flat plate collectors to produce solar process heat followed by parabolic trough collectors and evacuated tube collectors. Parabolic trough collectors have the largest installed collector area.

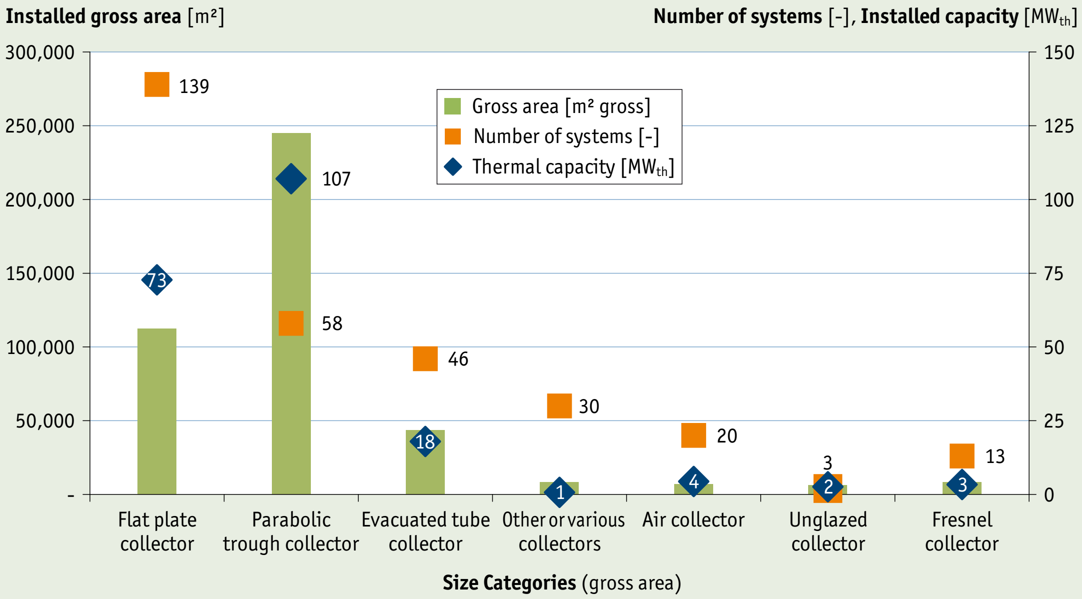


Figure 9: *Global solar process heat systems in operation by end of March 2019 – type of collector (Source: IEA SHC Task49 / IV SHIP database)*

The food-processing plant of the company Papes Safor in Spain uses parabolic trough collectors. *Photo: Rackam*

The following diagram shows the industry sectors of the 308 systems analyzed in detailed. The main sectors remain to be mining, food and textile.

The combined food and beverage industry account for 46 % of all installed systems, however, they tend to be small to medium-sized, thus only representing 16 % of the installed thermal capacity. Another important sector is the textile industry with 24 installations and 22 MW_{th} (11 %) of installed thermal capacity. The mining industry includes the above mentioned 2 biggest systems and are thus the dominant sector in terms of installed thermal capacity. The 14 systems account for 63 % of the total installed thermal capacity.

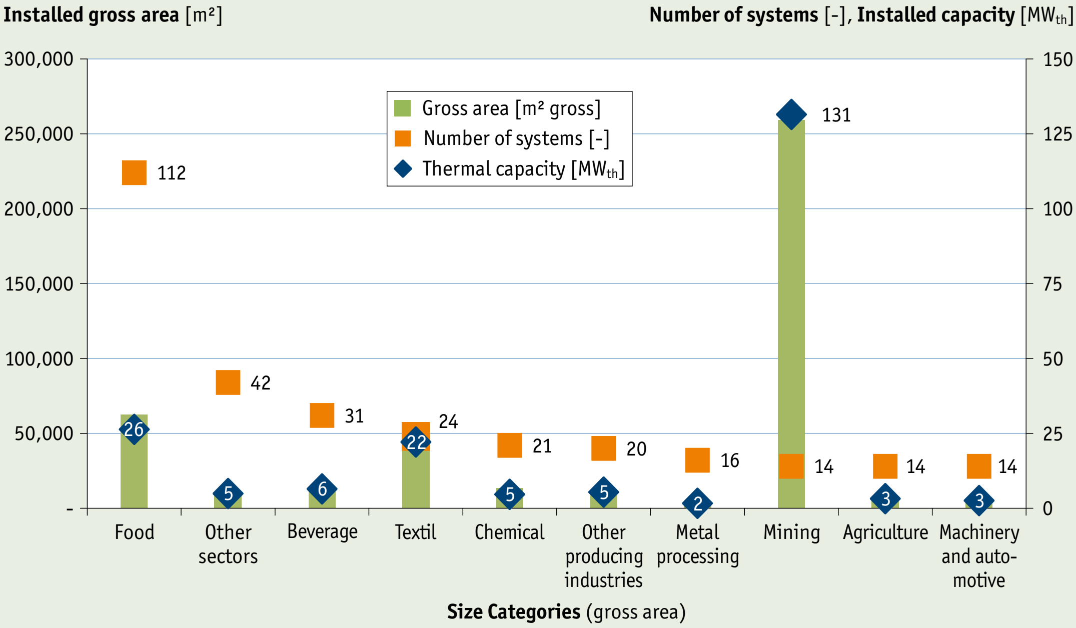


Figure 10: *Global solar process heat systems in operation by end of March 2019 – industry sector (Source: IEA SHC Task49 / IV SHIP database)*

Flat-plate collectors for the food and beverage industry in Mexico. *Photo: Módulo Solar*

Noteworthy is also the combined metal processing, machinery and automotive industry that is represented with 30 plants (10 %) with rather small systems (in average 315 m^2_{gross}) thus currently account for 2 % of the total installed thermal capacity.

Figure 11 shows the global installed solar process heat systems by country. Mexico and India have the highest number of installed systems, followed by Austria, Germany, USA and Spain. China has 12 systems with a large average system size leading to the second highest installed capacity. Oman is leading in terms of installed thermal capacity with its single installed system. Similar to that is Chile with two systems accounting for the third highest installed thermal capacity.

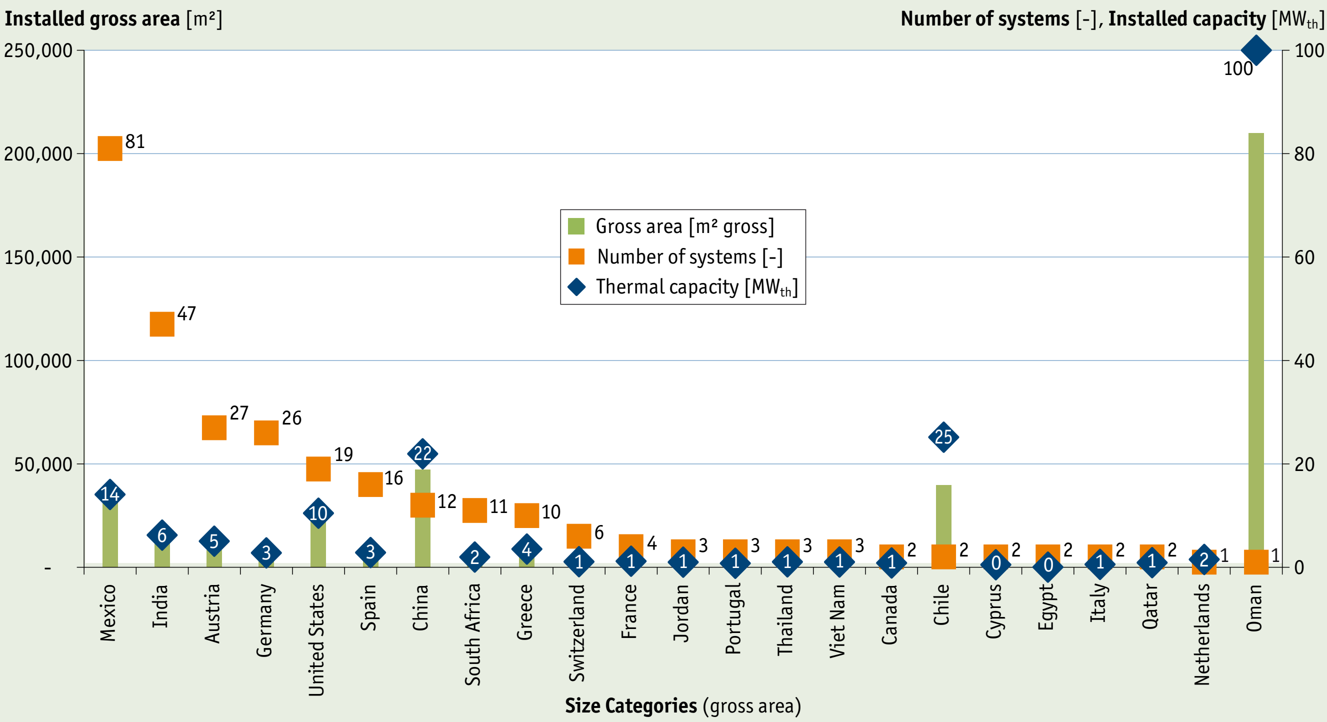


Figure 11: *Global solar process heat systems in operation by end of March 2019 – countries. Only countries with at least 0.7 MW_{th} (1,000 m² gross area) are shown (285 of 308 systems accounting for 98 % of installed thermal capacity)*
(Source: IEA SHC Task49 / IV SHIP database)

Figure 12 shows heat delivery by latitude, heat delivery depends on the solar radiation, ambient temperature, process integration and the process temperature level. Therefore, it has a wide range between 0.2 and about 1.5 for all regions.

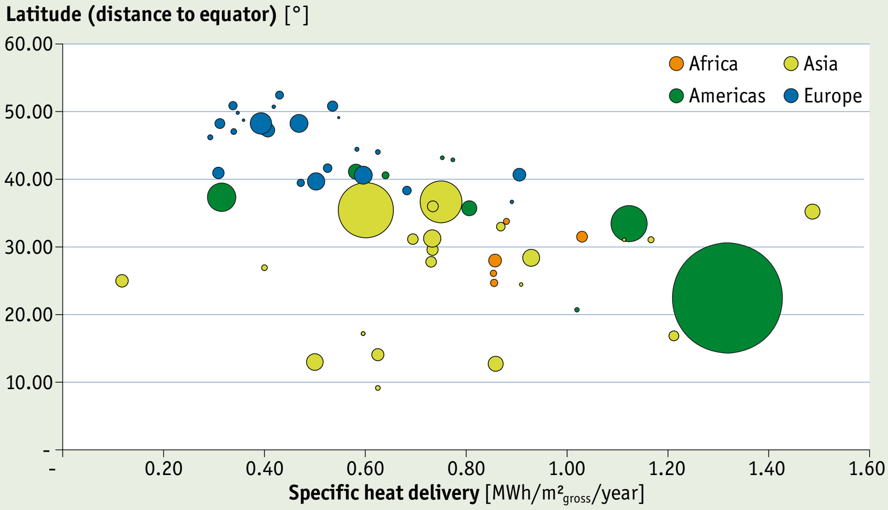


Figure 12: *Specific heat delivery and latitude of installed systems (Source: IEA SHC Task49 / IV SHIP database)*

4.3.2 Process and collector temperatures for different collector technologies

Figure 13 shows an analysis of the process and collector temperatures for different collector types. The SHIP database contains detailed information on collector and process temperatures for 89 of the total 308 plants.

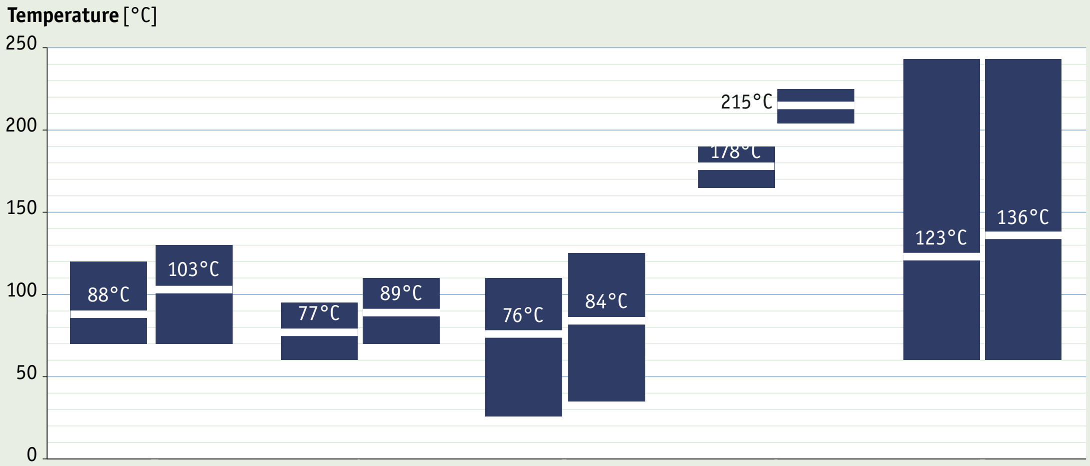
In the graph below, the target process temperatures are compared with the target collector temperatures. Of interest in this comparison are (1) the temperature difference between the target temperature on the process side and the target temperature in the solar loop and (2) the information it provides about the choice of the collector for different target temperatures. The evaluation shows that air collectors were used in three drying systems and that the collector temperature was an average of 103°C and the process temperature an average of 88°C. Two of these plants used Fresnel collectors, which reached significantly higher temperatures in the collector loop compared to the actual temperature requirement.

The systems with evacuated tube collectors (13 systems) have an average temperature difference of 12 Kelvin. In the solar loop the maximum temperature was 110°C. The maximum process target temperatures of the systems were between 60 and 95°C.

Most of the documented solar process heat plants are equipped with flat-plate collectors (58 systems). The fluctuation range of the operating temperatures is much higher than that of the air, vacuum or Fresnel collectors. It is not surprising that flat-plate collectors are used at relatively low process target temperatures since they have very good efficiency in this temperature range. However, the vacuum flat-plate collectors analyzed had relatively high solar target temperatures (maximum 125°C). The average temperature difference between the collector and process side is 8 Kelvin for the flat-plate systems. The average process target temperature of the vacuum tube and flat plate collector systems is 89°C and 84°C respectively so in a similar temperature range.

The largest fluctuation range was in the systems with parabolic trough collectors (13 systems). Here, the minimal process temperatures were particularly surprising because for use at 60°C, vacuum tube and flat plate collectors have a much better price / performance ratio than parabolic trough collectors. The mean temperature difference between the collector and process side was 13 Kelvin for the parabolic trough systems.

In Figure 13, the left bar shows the highest targeted process temperature and the right bar shows the highest targeted collector temperature for the different collector types (under normal operation thus excluding overheating or stagnation situations).



	Air collector		Evacuated tube collector		Flat plate collector		Fresnel collector		Parabolic trough collector	
Avg	88	103	77	89	76	84	178	215	123	136
Min	70	70	60	70	26	35	165	204	60	60
Max	120	130	95	110	110	125	190	225	243	243

Figure 13: *Temperature range of targeted process (left bar) and collector (right bar) for different collector technologies (Source: IEA SHC Task49/IV SHIP database)*

4.4 Photovoltaic-Thermal Systems (PVT)

New to this report this year is detailed data on PVT systems.

Photovoltaic-Thermal (PVT) collectors integrate photovoltaic and thermal solar energy conversion in a single device and reach higher yields per area. Regular photovoltaic systems convert 15–20 % of the incoming radiation to electricity, while the rest remains unused. In hybrid PVT systems, a part of this energy is transferred to a liquid or air, and harvested as (useful) heat. This way, PVT systems can play an important role in the supply of local renewable energy, both in the form of electricity and heat, and use up to 70 % of the incident solar radiation.

4.4.1 General market overview

This chapter takes a look at the worldwide PVT market with a special focus on Europe. The market for Photovoltaic-Thermal systems and the number of PVT module producers is growing. IEA SHC Task 60 PVT systems[11] conducted a market survey of 26 PVT collector manufacturers and PVT system suppliers in 11 countries (see **Figure 14**). The large majority of manufacturers focus on liquid PVT collectors (48 % uncovered flat plate collectors, 28 % covered flat plate collectors, 4 % vacuum tube collectors), 12 % produce air collectors and 8 % concentrating collectors.

11 http://task60.iea-shc.org/

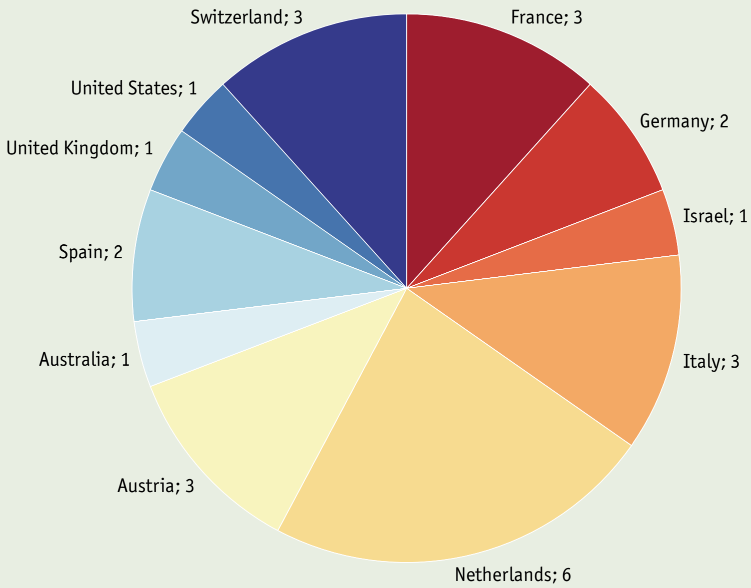


Figure 14: *PVT manufacturers by country (Source: IEA SHC Task 60 survey, AEE INTEC)*

Figure 15 shows the distribution of PVT manufacturers by collector type.

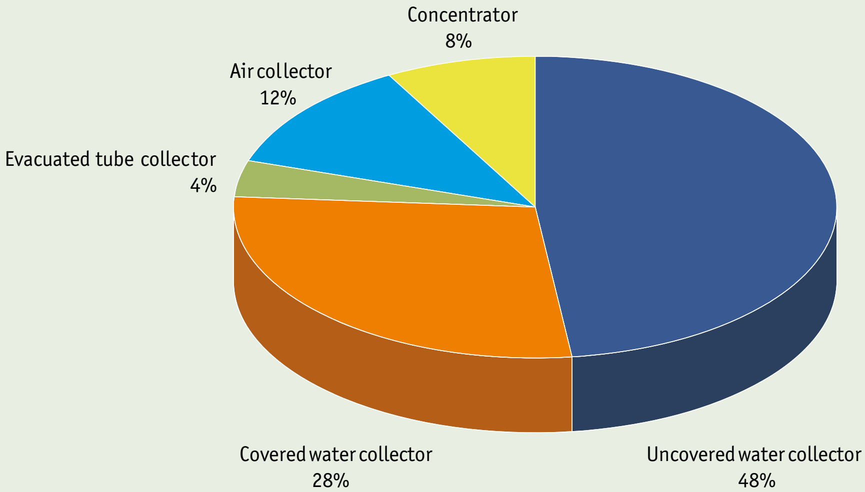


Figure 15: *Distribution of PVT manufacturer by collector type (Source: IEA SHC Task 60 survey, AEE INTEC)*

Technical benchmark figures for PVT collectors from the 26 PVT manufacturers were collected from the comprehensive market survey. In Figure 16, the specific solar thermal power output in W_{th} / $m^2_{gross\ areas}$ is highlighted in the blue boxes for different collector types (a blue diamond equals the average value). The nominal PV power in W_{peak} / $m^2_{gross\ area}$ is shown as green bars (a green diamond equals the average value). To derive the thermal and electrical capacity from the area of installed PVT-collectors, the average values of each collector type were used.

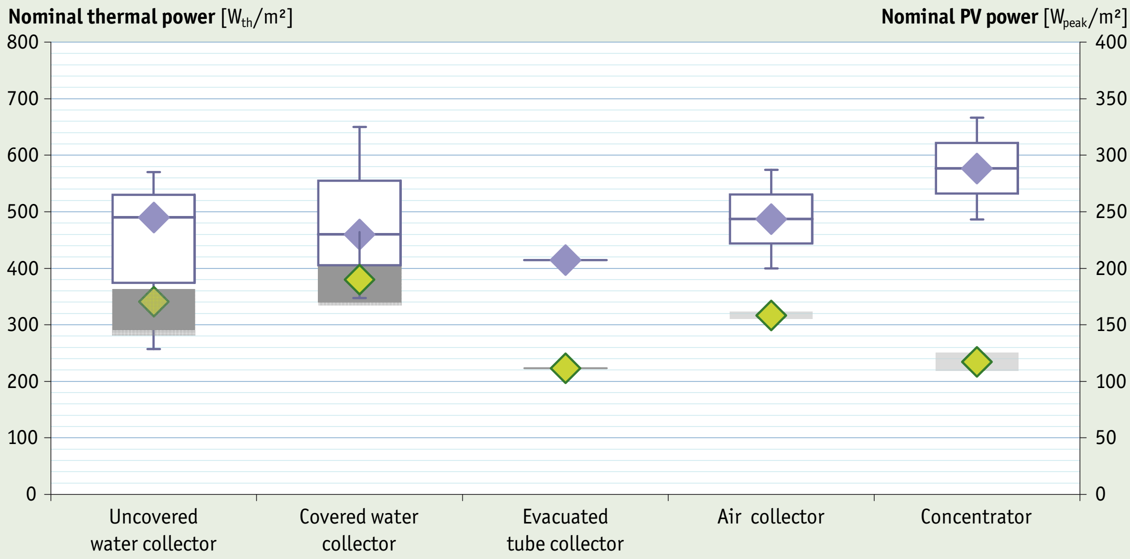


Figure 16: *Thermal and electrical nominal power of PVT collectors of a 26 manufacturers survey*

4.4.2 Total installed area and capacity of PVT-collectors

By the end of the year 2018, a cumulated PVT collector area of 1,075,247 m² was manufactured according to the IEA SHC Task 60 survey. In terms of trade (export and import), Table 2 shows the cumulated installed collector area by collector type at the end of 2018. In the European Market, France is the market leader with an installed collector area of 442,504 m² followed by Germany with 109,380 m². In Italy, The Netherlands and Switzerland collector areas range between 5,000 and 15,000 m². In the remaining European countries collector areas smaller than 5,000 m² were reported.
Outside of Europe, the main PVT manufacturer in Israel reported a cumulated manufactured collector area of 575,000 m² by the end of 2018 with a high export rate to Korea, China and Germany.

Country	Water Collectors [m²]			Air Collectors [m²]	Concentators [m²]	TOTAL [m²]
	unglazed	glazed	evacuated tube			
Australia	0	0	0	8	0	8
Austria	300	573	0	0	0	873
Belgium	524	0	0	290	15	829
Chile	0	0	0	0	10	10
China	133,721	25	0	0	171	133,916
Denmark	73	0	0	0	0	73
Egypt	0	0	0	0	21	21
France	9,204	0	0	433,300	0	442,504
Germany	107,927	1,232	0	87	135	109,380
India	0	4	0	0	240	244
Israel	53,488	0	0	0	0	53,488
Italy	9,038	6,400	0	0	0	15,438
Korea	280,814	0	0	0	0	280,814
Luxembourg	635	0	0	145	0	780
Maldive	0	0	0	0	21	21
Netherlands	5,588	7,579	0	0	1,773	14,940
Norway	200	0	0	0	0	200
Pakistan	0	4	0	0	0	4
Paraguay	0	0	0	0	51	51
South Africa	0	0	0	0	750	750
Spain	0	3,334	0	0	0	3,334
Sri Lanka	0	0	0	0	31	31
Switzerland	6,846	0	0	2,030	0	8,876
United Kingdom	15	0	38	348	0	400
United States	4,800	0	0	0	0	4,800
Others	162	3,300	0	0	0	3,462
TOTAL	613,334	22,449	38	436,208	3,218	1,075,247

Table 2: *Total installed PVT collector area worldwide. (Source: IEA SHC Task 60 survey, AEE INTEC)*

The following figure shows the total installed collector area and the distribution of the PVT technologies by country in 2018 in Europe.

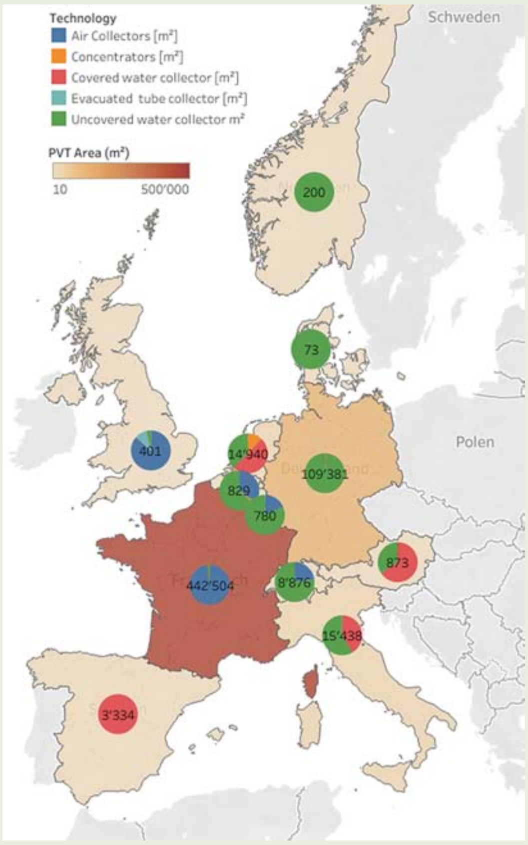


Figure 17: *Total installed collector area and PVT technologies in Europe by end of 2018 (Source: IEA SHC Task 60 survey, AEE INTEC)*

By the end of 2018, a total cumulated thermal capacity of PVT modules of 524.2 MW_{th} and a nominal PV power of 178.2 MW_{peak} were installed worldwide.

The total installed capacity in operation was divided into uncovered water collectors: 298.1 MW_{th} and 103.6 MW_{peak}, covered water collectors: 10.3 MW_{th} and 4.3 MW_{peak}, evacuated tube collectors: 0.02 MW_{th} and 0.04 MW_{peak}, air collectors: 212.5 MW_{th} and 69.1 MW_{peak} and concentrators: 1.9 MW_{th} and 0.4 MW_{peak}.

Country	Water Collectors						Air Collectors		Concentrators		TOTAL	
	uncovered		covered		evacuated tube							
	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]
Australia	0	0	0	0	0	0	4	1	0	0	4	1
Austria	147	51	264	109	0	0	0	0	0	0	411	160
Belgium	257	89	0	0	0	0	141	46	9	2	406	137
Chile	0	0	0	0	0	0	0	0	6	1	6	1
China	65,523	22,775	12	5	0	0	0	0	98	20	65,633	22,800
Denmark	36	12	0	0	0	0	0	0	0	0	36	12
Egypt	0	0	0	0	0	0	0	0	12	2	12	2
France	4,510	1,568	0	0	0	0	211,060	68,609	0	0	215,570	70,176
Germany	52,884	18,382	567	234	0	0	42	14	78	16	53,571	18,646
India	0	0	2	1	0	0	0	0	139	28	140	29
Israel	26,209	9,110	0	0	0	0	0	0	0	0	26,209	9,110
Italy	4,429	1,539	2,944	1,215	0	0	0	0	0	0	7,373	2,755
Korea	137,599	47,828	0	0	0	0	0	0	0	0	137,599	47,828
Luxembourg	311	108	0	0	0	0	71	23	0	0	382	131
Maldive	0	0	0	0	0	0	0	0	12	2	12	2
Netherlands	2,738	952	3,486	1,439	0	0	0	0	1,022	208	7,247	2,599
Norway	98	34	0	0	0	0	0	0	0	0	98	34
Pakistan	0	0	2	1	0	0	0	0	0	0	2	1
Paraguay	0	0	0	0	0	0	0	0	30	6	30	6
South Africa	0	0	0	0	0	0	0	0	433	88	433	88
Spain	0	0	1,534	633	0	0	0	0	0	0	1,534	633
Sri Lanka	0	0	0	0	0	0	0	0	18	4	18	4
Switzerland	3,354	1,166	0	0	0	0	989	321	0	0	4,343	1,487
UK	7	2	0	0	16	4	170	55	0	0	192	62
United States	2,352	818	0	0	0	0	0	0	0	0	2,352	818
Others	79	28	1,518	627	0	0	0	0	0	0	1,597	654
TOTAL	298,182	103,645	10,327	4,263	16	4	212,477	69,069	1,855	377	525,208	178,177

Table 3: *Total installed thermal and electrical capacity in operation 2018. (Source: IEA SHC Task 60 survey, AEE INTEC)*

With a global share of 57 % of the installed thermal capacity, uncovered water collectors were the dominating PVT-technology produced, followed by air collectors with 41 % and covered water collectors with 2 %. Evacuated tube collectors and concentrators play only a minor role in the total numbers (Figure 18).

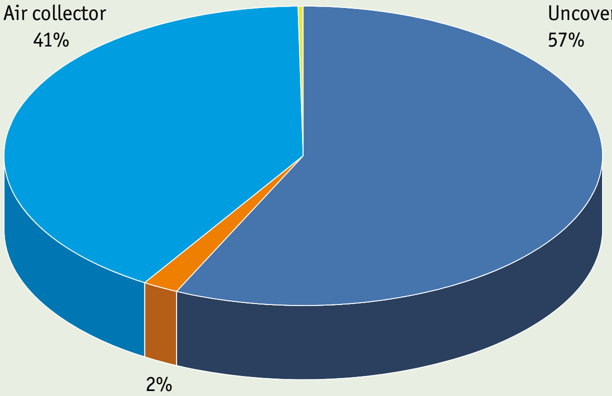


Figure 18: *Distribution of the total installed thermal capacity in operation by collector type in 2018 (Source: IEA SHC Task 60 survey, AEE INTEC)*

4.4.3 Distribution by type of application

A number of promising projects have been implemented in the last couple of years ranging from small-scale plants to very large systems with a capacity of 21 MW_{th} in Israel[12]. More than 22,900 systems totalling approximately 1,075,247 m² are documented. Table 4 shows PVT systems by application. The majority of the systems are used for solar air (pre)heating / cooling of buildings followed by domestic hot water preparation for single family houses.

PVT-Applications	Number of installations [#]	Total collector area [m²]
Swimming pool heating	82	8,360
Domestic hot water systems SFH	1,662	34,561
Large domestic hot water systems	165	20,851
Solar combi systems for SFH	633	17,758
Large solar combi systems	201	39,684
Solar air systems	20,121	441,674
Solar district heating systems	6	10,081
Solar heat for industrial applications	33	8,049
Not specified	17	494,229
TOTAL	22,920	1,075,247

Table 4: *PVT systems by application. (Source: IEA SHC Task 60 survey, AEE INTEC)*

As shown in Figure 19, solar air systems dominate the PVT market. A collector area of 494,229 m² cannot be classified. In a global context, this breakdown is mainly driven by the dominance of the French market where almost all of the manufactured PVT collectors were air collectors. Nevertheless, uncovered PVT collectors were the most common technology. By the end of 2018, 2,169 systems of uncovered PVT collectors corresponding to a gross area of 613,334 m² were in operation. Out of these systems, 75 % were used for domestic hot water preparation in single and multifamily houses, hotels, and hospitals. Around 21 % of the systems supplied electricity to households and to electric heating elements for domestic hot water and space heating (combi systems). The remaining systems accounted for around 4 % and delivered energy to other applications, such as industrial processes, district heating networks and swimming pools. Covered PVT collectors were mainly used in combi systems.

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12 www.millenniumsolar.com

672 m² uncovered PVT collectors in Switzerland. *Photo: Swiss Travel Fund Cooperative (Reka)*

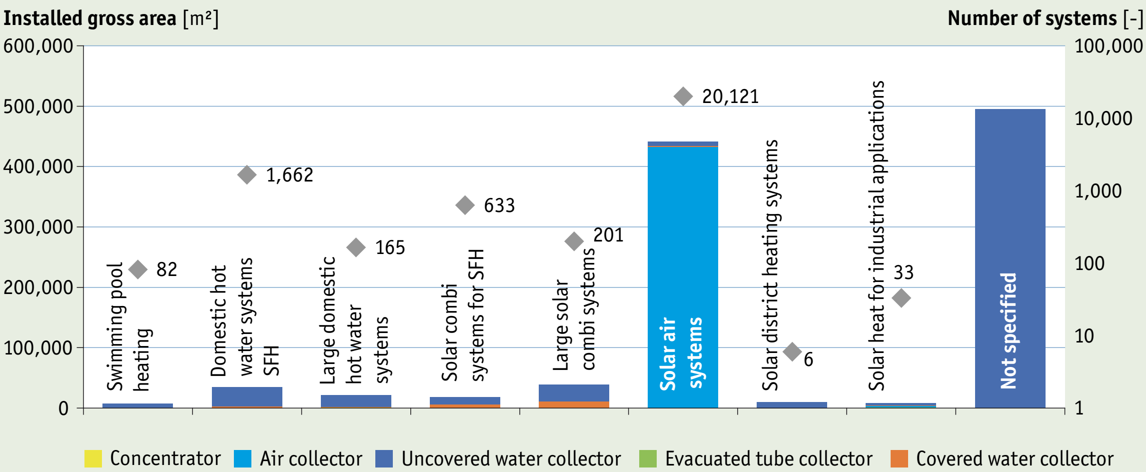

Figure 19: *PVT systems in operation worldwide by type of application, collector types and collector area at the end of 2018. (Source: IEA SHC Task 60 survey, AEE INTEC)*

4.4.4 Examples of PVT systems in operation

Uncovered, uninsulated PVT system delivers energy to multi-family buildings in Switzerland[13]

In December 2014 the vacation village Blatten in Switzerland with seven apartment houses, a reception center with swimming pool and a communication center was opened. The roofs of the seven apartment houses have an east-west orientation and have solar systems on both sides. The PVT system with a total of 672 m² (102.3 kW_{peak} electricity) is installed on four of the buildings. The system is comprised of uncovered uninsulated PVT water collectors integrated into the roof.

The heat supply is based on four ground source heat pumps with 31 boreholes. The heat from the PVT collectors is primarily used for the regeneration of the borehole field, but it can also be used as source for the heat pumps or can be stored in a low-temperature storage unit. In 2016, the solar thermal output was 400 kWh / m² (total: 268 MWh). The DC electricity yield of the PVT system was 130 kWh / (m²a) (87 MWh / a).

13 https://www.aramis.admin.ch/Default.aspx?DocumentID=34977&Load=true

150 m² covered PVT collectors in Spain.
Photo: EndeF (www.endef.com)

131 m² of uncovered PVT collectors in the south of Spain.
Photo: Setolazar (www.setolazar.es)

Glass covered PVT collector system delivers energy to a hotel in Spain

This installation was set up at the end of 2017 in a luxury resort in Ibiza (Balearic Islands). A total of 90 glass covered PVT panels were installed on the roof of a hotel, covering a surface of 147.6 m².

The panels are used for preheating of domestic hot water and for self-consumption of electricity without feed-in to the public electricity grid. The PVT system generated 112,814 kWh / year of thermal energy, which represents a contribution of 23.5 % of the total hot water demand of the hotel. In addition, around 34,600 kWh / year of electricity was generated.

Uncovered PVT system delivers energy to a fish farm in Spain

This system was installed in early 2018. A total of 80 uncovered PVT collectors were installed on the roof of the Marine Studies Center of Cádiz in Spain. The system is coupled to a reversible heat pump unit to complement the energy needs of the fish farm. The annual energy generation of the PVT system is calculated to reach 47,418 kWh of electricity and 67,240 kWh of thermal energy.

Low concentrating PVT systems delivers energy to a cheese factory in The Netherlands

In a cheese factory in The Netherlands, 88 low concentrating PVT collectors with a thermal capacity of 110 kW_{th} and an electrical power of 22 kW_{peak} are operational since July 2017. The generated heat is used to pre-heat a 8 m^3 tank up to 30 °C in winter and 75 °C in summer time.

The electricity gained contributes to the electric consumption of the factory building.

In 2018, the collectors delivered close to 450 MWh of heat and 15 MWh of electricity.

Low concentrating PVT collectors in the food industry in North Holland.
Photo: Solarus (www.solarus.com)

4.5 Solar air conditioning and cooling

4.5.1 Small and medium size applications

There is huge potential for solar cooling systems in the growing global market for cooling and refrigeration, particularly in emerging countries as their economies grow. By 2050, air conditioning will account for 37% of the world's total electricity demand growth[14]. A major argument for using solar driven systems is that they consume less conventional energy and use natural refrigerants, such as water and ammonia. In Europe, their application is also pushed by the European F-gas regulation No. 517/2014. Another driver of demand for solar cooling technology is its potential to reduce peak electricity demand, particularly in countries with significant cooling needs and grid constraints. Both solar thermal and PV driven solar cooling and air conditioning systems have a role to play[15].

By the end of 2018, an estimated 1,800 solar cooling systems were installed worldwide. Of these, 70 % were small and medium capacity (< 350 kW) solar cooling systems installed in Europe. According to a survey carried out in early 2019 by SOLRICO for REN21[16], in 2018 only a small number of new solar cooling systems in the small and medium range were installed, mainly in Italy and Germany.

4.5.2 Solar cooling with a cooling capacity larger than 350 kW

Thermal absorption chillers with a cooling capacity larger than 350 kW / 100 RT continue to improve in performance and decrease in cost. The significant improvements in the performance of large flat plate collectors at temperatures up to 120 °C and system adjustments have been key in the overall performance improvements. In addition, economies of scale have played an important role in the cost competitiveness of solar cooling applications for large office buildings, hotels, hospitals, and commercial and industrial applications.

The advantage of solar energy for cooling is the match in time between solar radiation (supply) and demand. Expensive electricity in peak times can be saved. Furthermore, solar thermal energy is an outstanding option for storing solar heat to meet cooling demands in the evenings, nights and mornings.

The electricity needed by a system, e.g. running pumps and the cooling tower, is quite low. Depending on the climate, it may give electric COPs (kW_{th} / kW_{el}) of 20 to 40 in systems with optimized variable speed drive performances. Thus, the electric demand for air conditioning in a building is cut down by more than 80 % compared to conventional HVAC equipment.

Even though the technical and economic conditions for solar cooling and air conditioning have improved significantly in recent years, this remains a challenging market, which is reflected in the comparatively low number of solar cooling systems built in recent years.

The world's largest solar cooling application is located in Arizona, USA and was commissioned in May 2014. The installation covers a roof-mounted solar thermal collector field with a capacity of 3.4 MW_{th} (4,865 m²) that supplies heat to a single-effect lithium bromide absorption chiller with a cooling capacity of 1.75 MW.

Three large solar cooling systems were installed in 2018. These include two systems in Italy, which are using evacuated tube collectors and one system in Jordan, were Fresnel collectors are used to provide the heat for the chiller.

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14 https://www.iea.org/futureofcooling/

15 http://task53.iea-shc.org/Data/Sites/53/media/events/meeting-09/workshop/09-jakob_results-from-feasibility-studies-of-solar-cooling-systems-in-mexico-and-the-arab-region.pdf

16 Not published internal communication

Linear Fresnel collectors used for direct steam generation for the solar cooling system at the Japan Tobacco International factory in Jordan.
Photo: Industrial Solar GmbH

In 2019, the completion of several new plants is expected. Two solar thermal cooling and process heat systems will be commissioned for a chemical industry and a food production site both located in Barcelona, Spain. One more system with 650 kW for industrial cooling and heating will be commissioned in Graz, Austria and in Singapore, the Land Transport Authority has awarded the installation of an Environment Control System for 4-in-1 Rail & Bus Depot, which will include the world's largest solar thermal cooling system (approximately 6,500 m² of solar collector field and 1,794 kW absorption chiller).

Country	Site	Commissioned	Installed capacity [kW_{th}]	Collector size [m²]	Collector type	Cooling capacity [kW_{cold}]
Italy	Borgoricco	2018	1,046	1,494	Evac. tube	700
Italy	Laives	2018	n.a.	n.a.	Evac. tube	176
Jordan	Japan Tobacco International factory	2018	700	1,254	Fresnel	n.a.
Singapore	IKEA Alexandra	2017	1,730	2,472	Flat plate	880
Nicaragua	Hospital Militar Escuela, Dr. Alejandro Dávila Bolaños	2017	3,115	4,450	Flat plate	1,023
India	Office, Gujarat State Electricity Corporation	2017	1,102	1,575	Evac. tube	528
India	Swiss Embassy, New Delhi	2017	630	441	Parabolic trough	210
China	Tianjin Zhongbei	2015	n.a.	n.a.	Evac. tubes	698
Arizona, USA	Desert Mountain High School Scottsdale	2014	3,407	4,865	Flat plate	1,750
Johannesburg, S.A.	MTN Headquarter	2014	272	484	Fresnel	330
China	Dezhou Institute	2014	n.a.	720	Parabolic trough	n.a.
Unitad Arab Emirates	Sheikh Zayed Desert Learning Center	2012	794	1,134	Flat plate	352
Jamaika	Digicel, Kingston		687	982	Flat plate	600
Singapore	United World College	2011	2,710	3,872	Flat plate	1,500
Qatar, Doha	Showcase football stadium	2010	700	1,408	Fresnel	n.a
Istanbul, Turkey	Metro shopping center	2009	840	1,200	Evac. tube	n.a.
Spain, Sevilla	Sevilla University, Escuela Superior de Ingenieros	2009		352	Fresnel	n.a.
Lisbon, Portugal	CGD Lisbon	2008	1,105	1,579	Flat plate	585
Rome, Italy	Metro Cash&Carry	2008	2,100	3,000	Flat plate	700

Table 5: *Large-scale solar cooling systems installed between 2008 and 2018*

Sources: Blackdot Energy, Industrial Solar GmbH, Ritter XL Solar, SOLID GmbH, SOLRICO, Vicot Solar Energy

A 224 m² solar air collector field is used for commercial woodchips drying in Edlbach, Austria. Photo: CONA SOLAR AUSTRIA

4.6 Solar air heating systems

Solar air heating systems have been used mainly in North America and Japan for the past 30 years by schools, municipalities, military, commercial and industrial entities as well as in in agricultural and in residential buildings. Wall mounted systems are common to take advantage of the low winter sun angles and to avoid snow accumulation on the collectors. Storage of the heat is possible, but most solar air systems do not include storage to minimize costs.

Solar air heating systems in North America are typically designed to cover between 20 and 30 % of the annual space heating demand of a building. The air is generally taken off the top of the collector (since hot air rises) and the heated or pre-heated fresh air is then connected to fans and ducted into the building via the ventilation system.

Solar air heaters are also common in agricultural applications, primarily for drying.

By end of 2017, a total of 1,190 MW_{th} (1,697,233 m²) of glazed and unglazed air collectors were installed worldwide. The new installations in 2017 were at a range of 24.9 MW_{th} (35,500 m²).

The leading countries in air collector installations are Australia, Canada, Japan and the United States. The other markets are nearly negligible.

5 Detailed global market data 2017 and country figures

The following chapters of the report show detailed solar thermal market figures for the year 2017 and country figures for 68 countries.

Background of the presented data

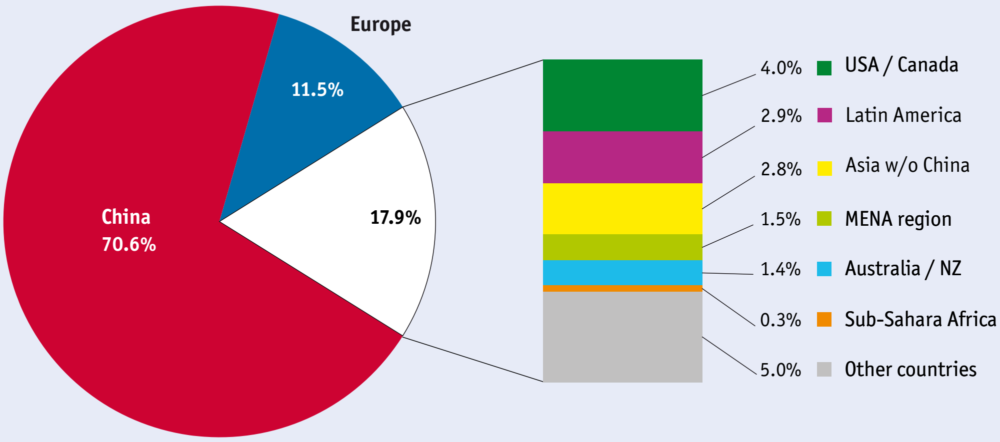
The following chapters of the report show figures of the actual collector area in operation in 2017 and not the cumulated collector area installed in a country. To determine the collector area (and respective capacity) in operation, either official country reports on the lifetime were used or, if such reports were not available, a 25-year lifetime for a system was calculated. The collector area in operation was then calculated using a linear equation. For China, the methodology of the Chinese Solar Thermal Industry Federation (CSTIF) was used. According to the CSTIF approach the operation lifetime is considered to be 10 years. For Germany a lifetime of 20 years is used.

The analysis further distinguishes between different types of solar thermal collectors, such as unglazed water collectors, glazed water collectors including flat plate collectors (FPC) and evacuated tube collectors (ETC) as well as unglazed and glazed air collectors. Concentrating collectors are not within the scope of this report.

5.1 General market overview of the total installed capacity in operation

By the end of 2017, an installed capacity of 473.5 GW_{th} corresponding to a total of 676.4 million square meters of collector area was in operation worldwide.

The vast majority of the total capacity in operation was installed in China (334.5 GW_{th}) and Europe (54.3 GW_{th}), which together accounted for 82.1 % of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (18.9 GW_{th}), Latin America (13.6 GW_{th}), Asia excluding China (13.3 GW_{th}), the MENA countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (7.0 GW_{th}), Australia and New Zealand (6.7 GW_{th}), and Sub-Sahara African countries Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa and Zimbabwe (1.6 GW_{th}). The market volume of "*all other countries*" is estimated to amount for 5 % of the total installations (23.7 GW_{th}).



Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan, Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Figure 20: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2017

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		158.9	3.7			163
Argentina	6.5	7.3	17.3			31
Australia	3,798.9	2,386.3	135.1	255.5	8.3	6,584
Austria	264.8	3,292.9	60.0		2.8	3,621
Barbados		158.0				158
Belgium	31.5	366.0	66.1			464
Botswana		7.4	1.3			9
Brazil	3,759.7	6,580.6	71.1			10,411
Bulgaria		94.9	3.1			98
Burkina Faso		2.1	0.3			2
Canada	564.3	49.5	34.7	288.8	34.3	972
Cape Verde		1.2				1
Chile	45.9	149.3	37.7	0.0	0.2	233
China		29,972.6	304,543.4	2.8	1.4	334,520
Croatia		139.3	8.0			147
Cyprus	1.5	519.7	16.5			538
Czech Republic	418.6	311.0	95.8			825
Denmark	14.4	1,127.6	6.4	3.0	12.6	1,164
Estonia		6.2	5.0			11
Finland	8.3	24.1	13.5			46
France (mainland)+	88.0	1,708.0	130.1	6.1	0.8	1,933
Germany	381.9	11,900.7	1,455.3		15.7	13,754
Ghana		1.2	0.4			2
Greece		3,217.2	15.4			3,233
Hungary	12.5	155.9	51.2	1.9	1.5	223
India	0.0	2,825.4	5,184.1	0.0	8.3	8,018
Ireland		163.6	90.9			254
Israel	26.6	3,271.4				3,298
Italy	30.7	2,742.3	429.2			3,202
Japan		2,495.0	48.0		367.6	2,911
Jordan*	4.2	687.7	190.5			882
Korea, South		1,188.0	121.4			1,309
Latvia		7.8	1.9			10
Lebanon		236.2	315.4			552
Lesotho		1.0	0.4			1
Lithuania		5.0	6.7			12
Luxembourg		37.6	6.2			44
Malta		29.3	7.3			37
Mauritius**		93.0				93
Mexico	909.5	1,023.6	810.0	0.5	6.1	2,750
Morocco*		315.7				316
Mozambique	0.1	0.3	1.2			2
Namibia	1.1	27.7	0.9			30
Netherlands	66.8	360.6	27.9			455
New Zealand***	4.9	100.1	6.8			112
Nigeria	0.0	0.5	0.2	0.0	0.0	0.7
Northern Macedonia		38.6	17.5			56
Norway	1.3	26.8	2.9	0.1	2.9	34
Palestinian Territories		1,216.9	5.8			1,223
Poland		1,237.9	336.4			1,574
Portugal	1.5	720.2	19.8			742
Romania	0.2	71.7	60.7	0.6		133
Russia	0.1	14.4	2.3	0.0	0.0	17
Senegal		0.1	1.2	0.0	0.8	2.1
Slovakia	0.7	98.4	17.6			117
Slovenia		87.2	16.4			104
South Africa	818.2	423.4	185.8	0.0	0.0	1,427
Spain	106.5	2,616.8	150.4	1.2	0.9	2,876
Sweden	119.3	211.4	50.7			381
Switzerland	134.8	933.3	92.8			1,161
Taiwan	1.4	1,100.3	93.3			1,195
Thailand****		110.3				110
Tunisia		630.0	49.1			679
Turkey		11,835.7	4,444.6	6.7		16,287
United Kingdom		437.0	122.8	16.2		576
United States	15,615.6	2,033.5	114.3	81.9	45.9	17,891
Uruguay		48.6				49
Zimbabwe		15.3	13.9			29
All other countries (5%)	1,433.7	5,360.9	16,832.6	35.0	26.9	23,689
TOTAL	28,674	107,218	336,652	700	537	473,781

Note: If no data is given: no reliable database for this collector type is available

* Total capacity in operation refers to the year 2014

** Total capacity in operation refers to the year 2015

*** Total capacity in operation refers to the year 2009

**** Total capacity in operation refers to the year 2016

\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered

Table 6: *Total capacity in operation in 2017 [MW_{th}]*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		226,969	5,246			232,215
Argentina	9,318	10,393	24,748			44,459
Australia	5,427,000	3,409,000	193,000	365,000	11,800	9,405,800
Austria	378,291	4,704,139	85,727		4,028	5,172,185
Barbados		225,720				225,720
Belgium	45,000	522,883	94,450			662,333
Botswana		10,500	1,800			12,300
Brazil	5,370,961	9,400,875	101,565			14,873,401
Bulgaria		135,580	4,470			140,050
Burkina Faso		2,982	469			3,450
Canada	806,144	70,714	49,512	412,609	48,994	1,387,973
Cape Verde		1,783				1,783
Chile	65,550	213,300	53,878	0	300	333,028
China		42,818,000	435,062,000	4,000	2,000	477,886,000
Croatia		199,041	11,475			210,516
Cyprus	2,213	742,482	23,567			768,262
Czech Republic	598,000	444,305	136,798			1,179,103
Denmark	20,500	1,610,870	9,197	4,300	18,000	1,662,867
Estonia		8,830	7,190			16,020
Finland	11,800	34,490	19,233			65,523
France (mainland)+	125,780	2,439,996	185,880	8,653	1,100	2,761,409
Germany	545,580	17,001,000	2,079,000		22,400	19,647,980
Ghana		1,744	637			2,381
Greece		4,596,000	22,000			4,618,000
Hungary	17,800	222,700	73,100	2,750	2,200	318,550
India	0	4,036,219	7,405,856	0	11,900	11,453,975
Ireland		233,670	129,881			363,551
Israel	38,000	4,673,434				4,711,434
Italy	43,800	3,917,526	613,203			4,574,529
Japan		3,564,250	68,607		525,149	4,158,006
Jordan*	5,940	982,482	272,084			1,260,506
Korea, South		1,697,189	173,496			1,870,685
Latvia		11,142	2,740			13,882
Lebanon		337,461	450,541			788,002
Lesotho		1,449	598			2,047
Lithuania		7,200	9,550			16,750
Luxembourg		53,745	8,900			62,645
Malta		41,855	10,464			52,319
Mauritius**		132,793				132,793
Mexico	1,299,253	1,462,282	1,157,142	752	8,773	3,928,202
Morocco*		451,000				451,000
Mozambique	144	361	1,781			2,286
Namibia	1,560	39,520	1,355			42,435
Netherlands	95,370	515,090	39,810			650,270
New Zealand***	7,025	142,975	9,644			159,645
Nigeria	0	688	237	0	70	994
Northern Macedonia		55,119	25,054			80,173
Norway	1,849	38,220	4,130	200	4,106	48,505
Palestinian Territories		1,738,369	8,225			1,746,594
Poland		1,768,490	480,600			2,249,090
Portugal	2,130	1,028,905	28,330			1,059,365
Romania	340	102,400	86,750	800		190,290
Russia	137	20,596	3,317	2	64	24,115
Senegal		91	1,733	0	1,203	3,027
Slovakia	1,000	140,550	25,150			166,700
Slovenia		124,500	23,400			147,900
South Africa	1,168,918	604,789	265,475	0	0	2,039,182
Spain	152,172	3,738,295	214,826	1,750	1,250	4,108,293
Sweden	170,410	301,993	72,411			544,814
Switzerland	192,580	1,333,290	132,590			1,658,460
Taiwan	1,937	1,571,874	133,244			1,707,055
Thailand****		157,536				157,536
Tunisia		900,038	70,104			970,142
Turkey		16,908,182	6,349,454	9,570		23,267,206
United Kingdom		624,266	175,453	23,100		822,819
United States	22,308,019	2,904,951	163,307	116,975	65,500	25,558,752
Uruguay		69,393				69,393
Zimbabwe		21,811	19,914			41,725
All other countries (5%)	2,048,133	7,658,436	24,046,542	50,024	38,360	33,841,495
TOTAL	40,962,655	153,168,718	480,930,839	1,000,485	767,197	676,829,894

Note: If no data is given: no reliable database for this collector type is available
* Total collector area in operation refers to the year 2014
** Total collector area in operation refers to the year 2015
*** Total collector area in operation refers to the year 2009
**** Total collector area in operation refers to the year 2016
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered

Table 7: *Total installed collector area in operation in 2017 [m²]*

The total installed capacity in operation in 2017 was divided into flat plate collectors (FPC): 107.2 GW_{th} (153.1 million square meters), evacuated tube collectors (ETC): 336.4 GW_{th} (480.6 million square meters), unglazed water collectors 28.7 GW_{th} (41.0 million square meters), and glazed and unglazed air collectors: 1.2 GW_{th} (1.8 million square meters).

With a global share of 71 %, evacuated tube collectors were the predominant solar thermal collector technology, followed by flat plate collectors with 22.6 % and unglazed water collectors with 6.1 %. Air collectors play only a minor role in the total numbers (Figure 21).

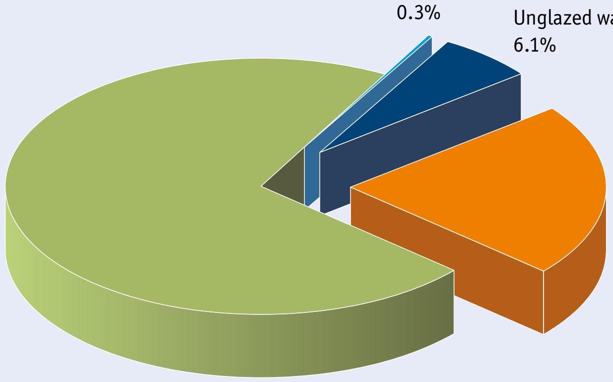


Figure 21: *Distribution of the total installed capacity in operation by collector type in 2017 – WORLD*

By contrast in Europe, the second largest market to China, flat plate collectors were the dominant collector type (Figure 22). Compared to 2016 the share of evacuated tube collectors increased in Europe by 0.7 % and the share of unglazed water collectors decreased to 3.1 %.

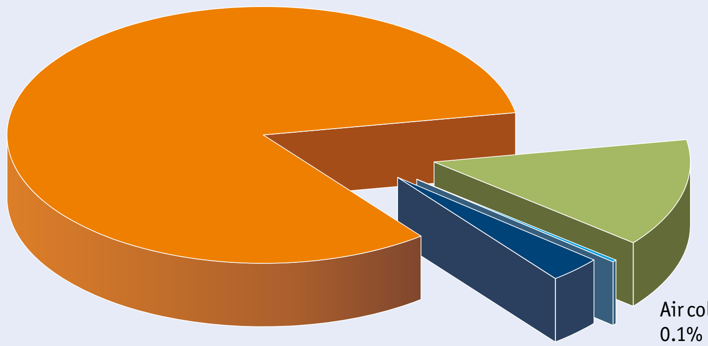


Figure 22: *Distribution of the total installed capacity in operation by collector type in 2017 - EUROPE*

Figure 23 shows the cumulated installed capacity of glazed and unglazed water collectors in operation for the 10 leading markets in 2017 in total numbers.

Compared to the year 2016, the top 10 countries remained unchanged in the ranking. However, in 2015, Turkey overtook Germany for the number three position and India overtook Australia for the number six position. Both countries still hold this position showing the market shift from historically dominated OECD to non-OECD countries.

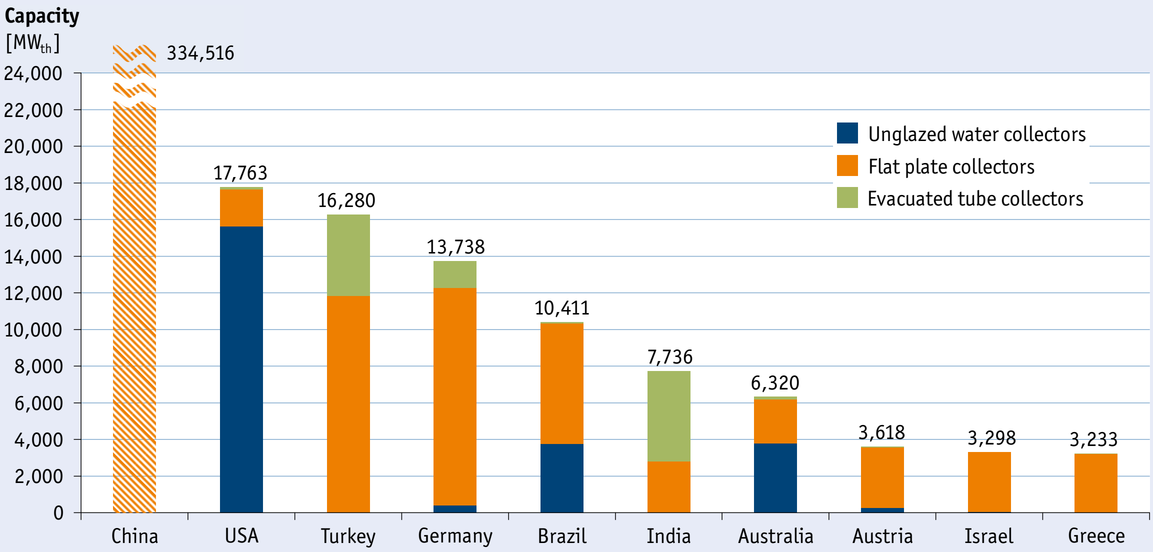


Figure 23: *Top 10 countries of cumulated water collector installations (absolute figures in MW$_{th}$) 2017*

China remained the world leader in total capacity, and its market is dominated by evacuated tube collectors. The United States held its second position due to the high number of installed unglazed water collectors. Only Australia, and to some extent Brazil, play an important role with respect to unglazed water collectors besides the United States. In the large European markets in Germany, Austria and Greece flat plate collectors were the most important collector technology. A strong trend towards evacuated tube collector technology can be seen in Turkey and India over the past few years.

The top 10 countries with the highest market penetration per capita are shown in Figure 24. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2017 per 1,000 inhabitants were Barbados (540 kW$_{th}$ / 1,000 inhabitants), Cyprus (440 kW$_{th}$ / 1,000 inhabitants), Austria (413 kW$_{th}$ / 1,000 inhabitants), Israel (397 kW$_{th}$ / 1,000 inhabitants), Greece (300 kW$_{th}$ / 1,000 inhabitants), Australia (276 kW$_{th}$ / 1,000 inhabitants), the Palestinian territories (269 kW$_{th}$ / 1,000 inhabitants), China (243 kW$_{th}$ / 1,000 inhabitants), Turkey (201 kW$_{th}$ / 1,000 inhabitants) and Denmark (199 kW$_{th}$ / 1,000 inhabitants).

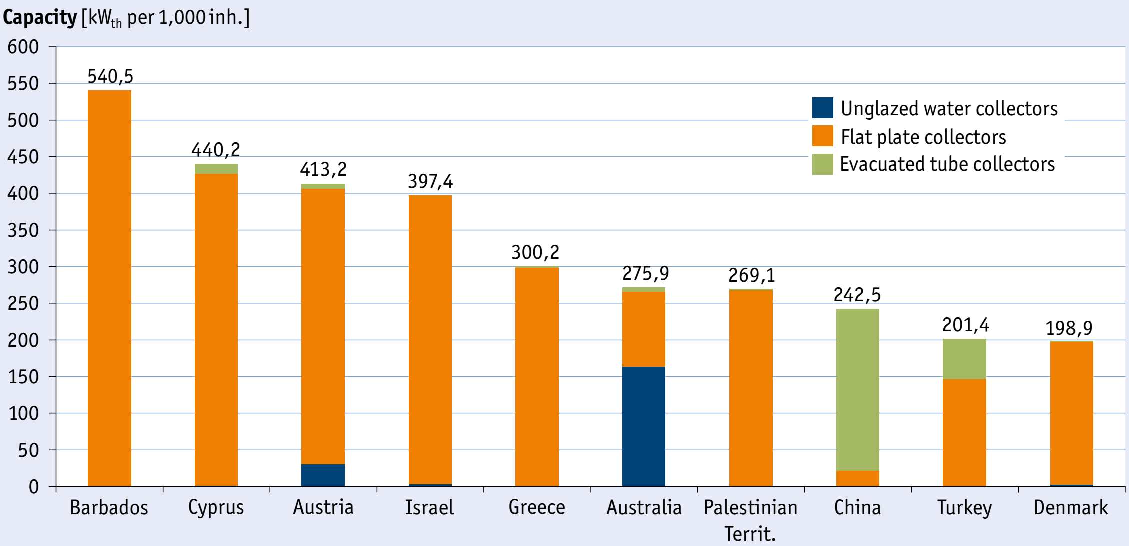


Figure 24: *Top 10 countries of cumulated water collector installations (relative figures in kW$_{th}$ per 1,000 inhabitants) 2017*

5.2 Total capacity of glazed water collectors in operation

With 334.5 GW_{th}, China was once again by far the leader in terms of total installed capacity of glazed water collectors in 2017. With >10 GW_{th} of installed capacity, Turkey and Germany were next. Several countries, namely India, Brazil, Austria, Israel, Greece, Italy, Spain, Australia, Japan, the United States, Mexico, Poland, France, South Korea, the Palestinian Territories, Taiwan, Denmark and Switzerland had more than 1 GW_{th} of water collectors installed by the end of 2017 (**Figure 25**).

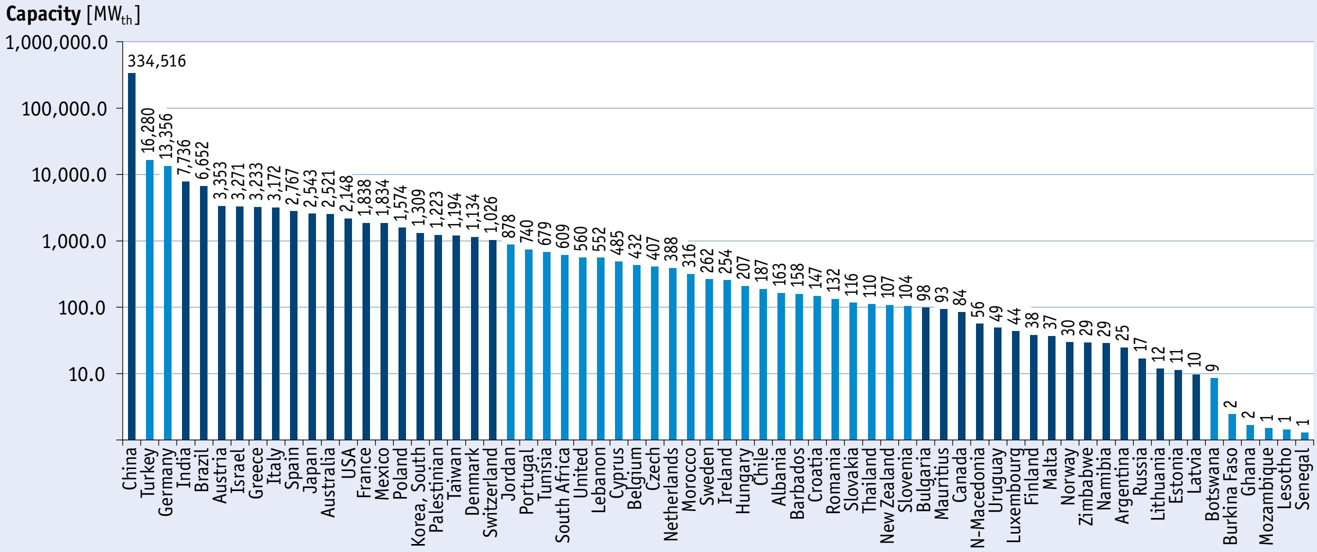


Figure 25: *Total capacity of glazed water collectors in operation by the end of 2017*

In terms of total installed capacity of glazed water collectors in operation per 1,000 inhabitants, there was a continued dominance by five countries: Barbados, Cyprus, Israel, Austria and Greece. China ranks seventh in terms of market penetration. Nevertheless, it is remarkable that China with its 1.37 billion inhabitants exceeds solar thermal per capacity levels of the large European markets in Germany, Turkey, Denmark and Spain (**Figure 26**).

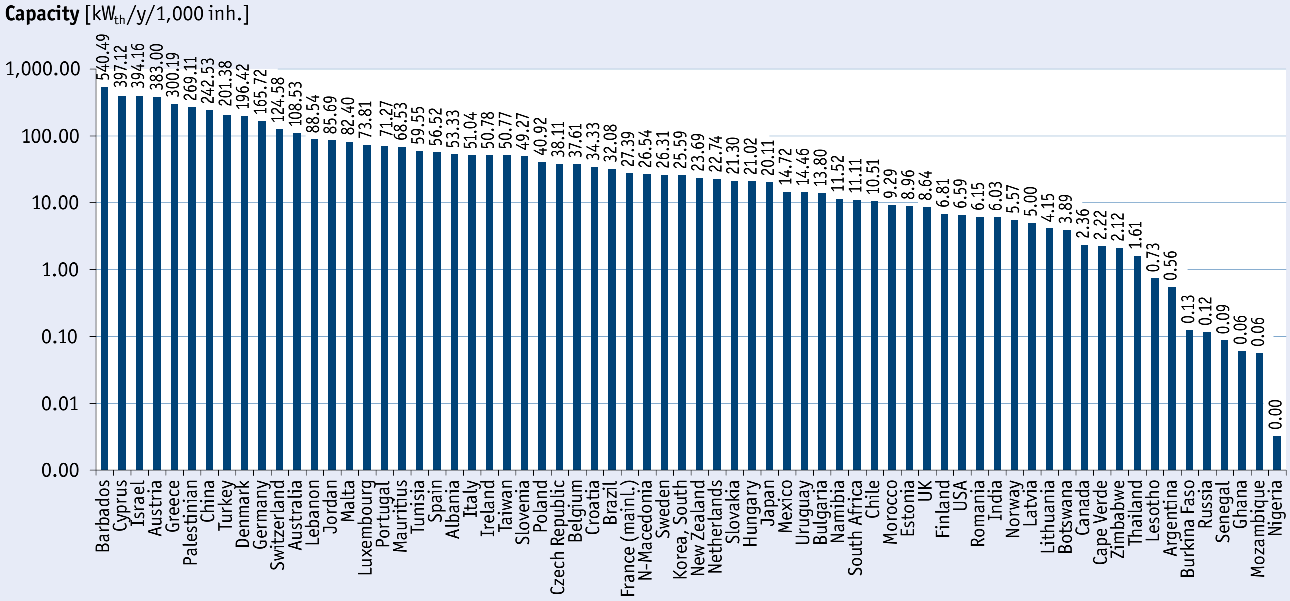


Figure 26: *Total Capacity of glazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2017*

The following figures show the solar thermal market penetration per capita worldwide and in Europe.

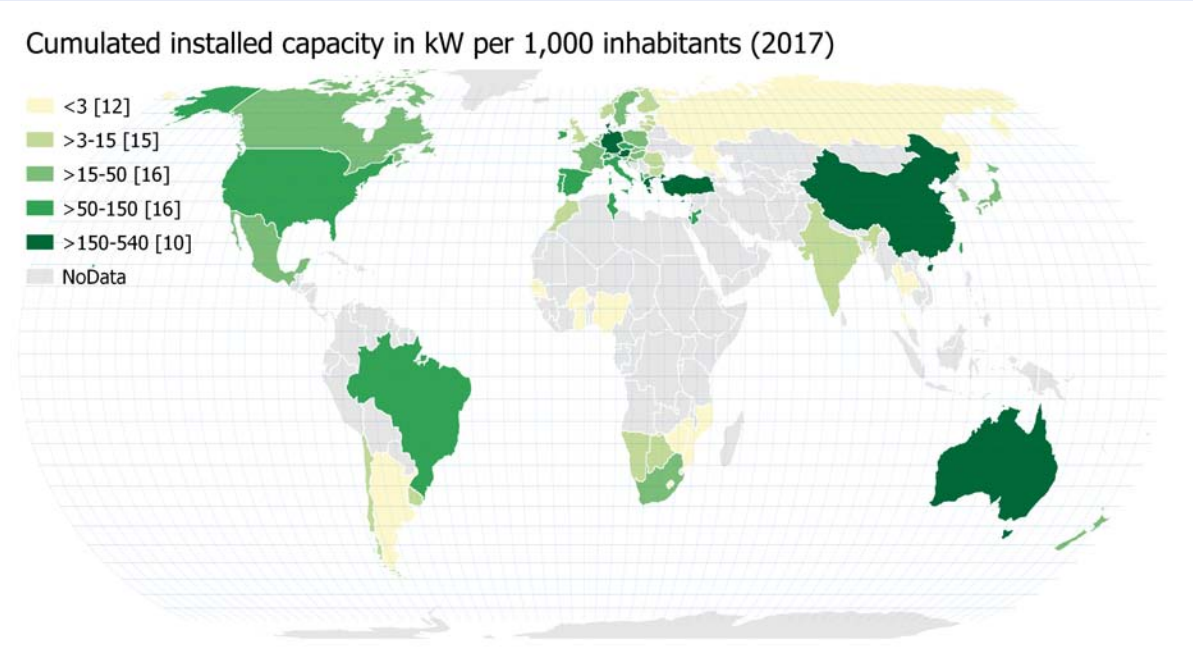


Figure 27: *Solar thermal market penetration per capita worldwide in kW_{th} per 1,000 inhabitants*

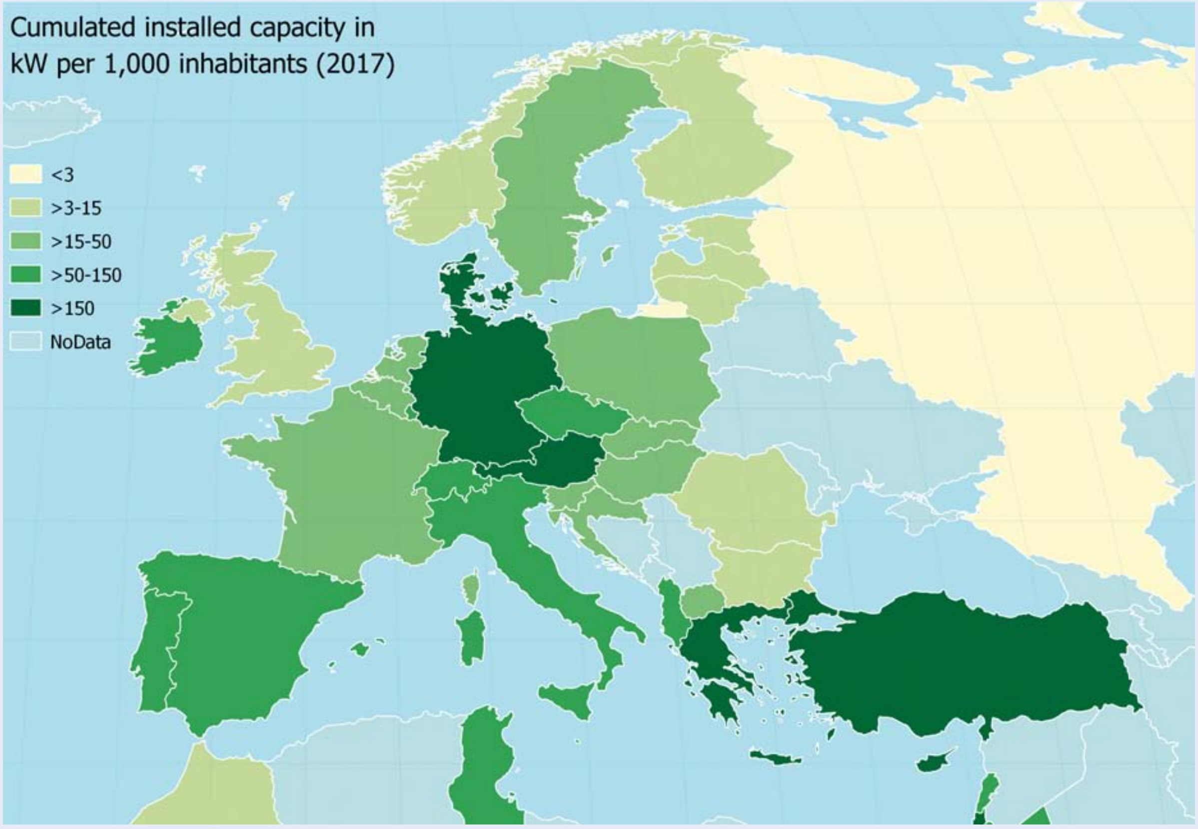
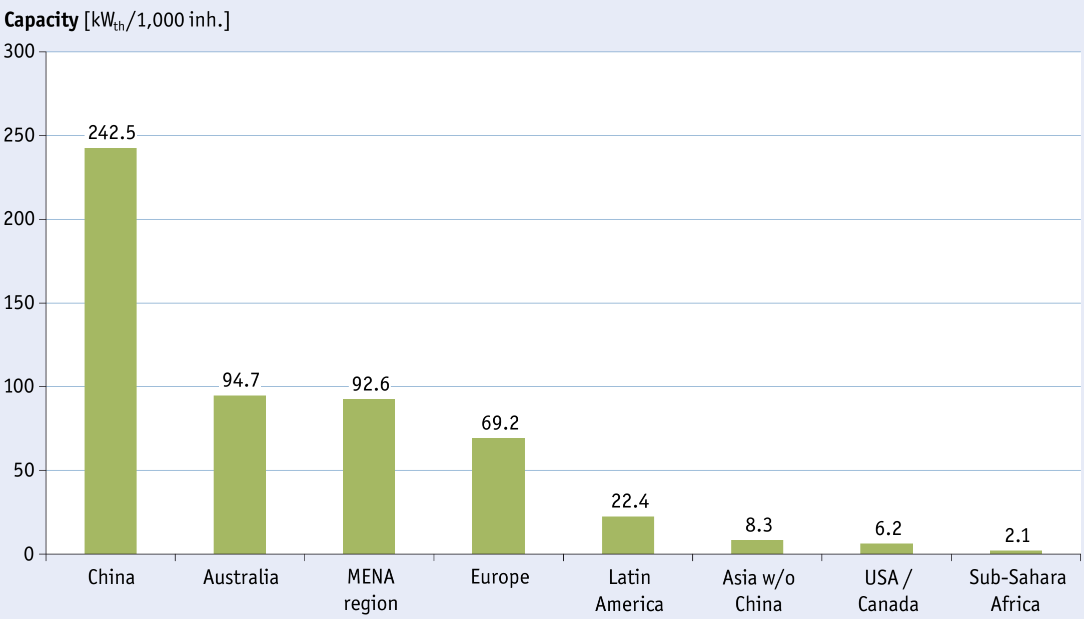


Figure 28: *Solar thermal market penetration per capita in Europe in kW_{th} per 1,000 inhabitants*

5.3 Total capacity of glazed water collectors in operation by economic region

Figure 29: *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2017*

In terms of market penetration per capita by economic region, China again takes the lead. It is notable that the MENA countries and also Australia are ahead of Europe (**Figure 30**) and shows the very unbalanced market penetration in Europe. Whereas some European countries like Cyprus, Austria and Greece belong to the world market leaders in terms of high market penetration, others like the Baltic countries have negligible solar thermal market penetrations.



Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia excluding China:	India, Japan, South Korea, Taiwan, Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Figure 30: *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in kW_{th} per 1,000 inhabitants in 2017*

5.4 Total capacity of unglazed water collectors in operation

Unglazed water collectors are mainly used for swimming pool heating. This type of collector has lost a significant market share over the past decade. The share of unglazed water collectors in the total installed collector capacity was reduced from 21 %[17] in 2005 to just 6 % in 2017. Figure 31 and Figure 32 show the total installed capacity of unglazed water collectors and total installed capacity of unglazed water collectors per 1,000 inhabitants by end of the year 2017.

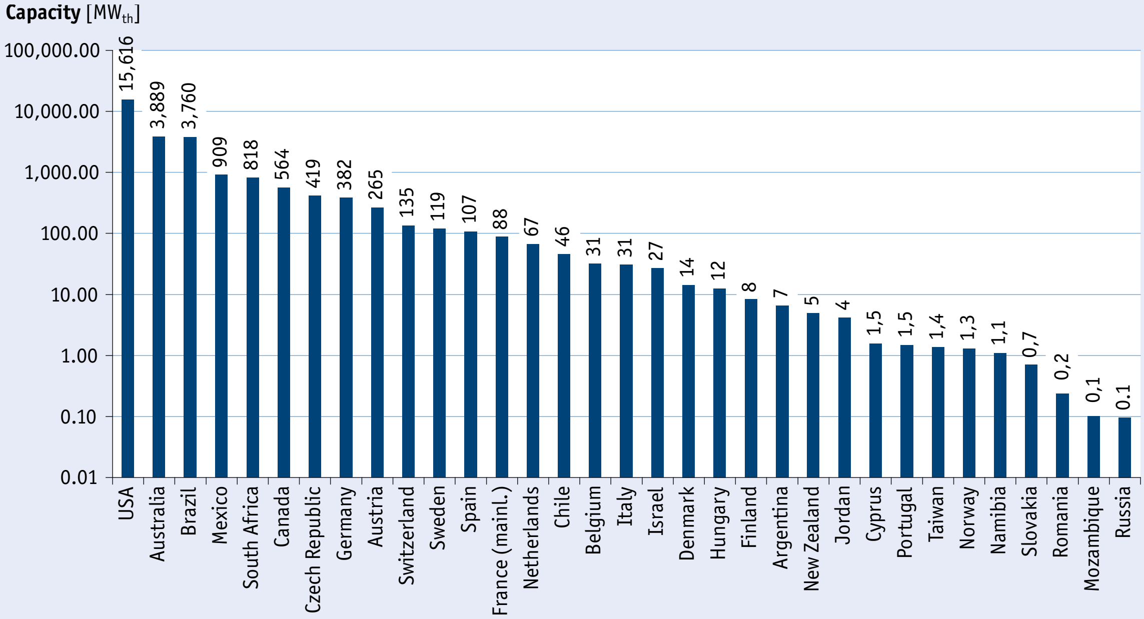


Figure 31: *Total capacity of unglazed water collectors in operation in 2017*

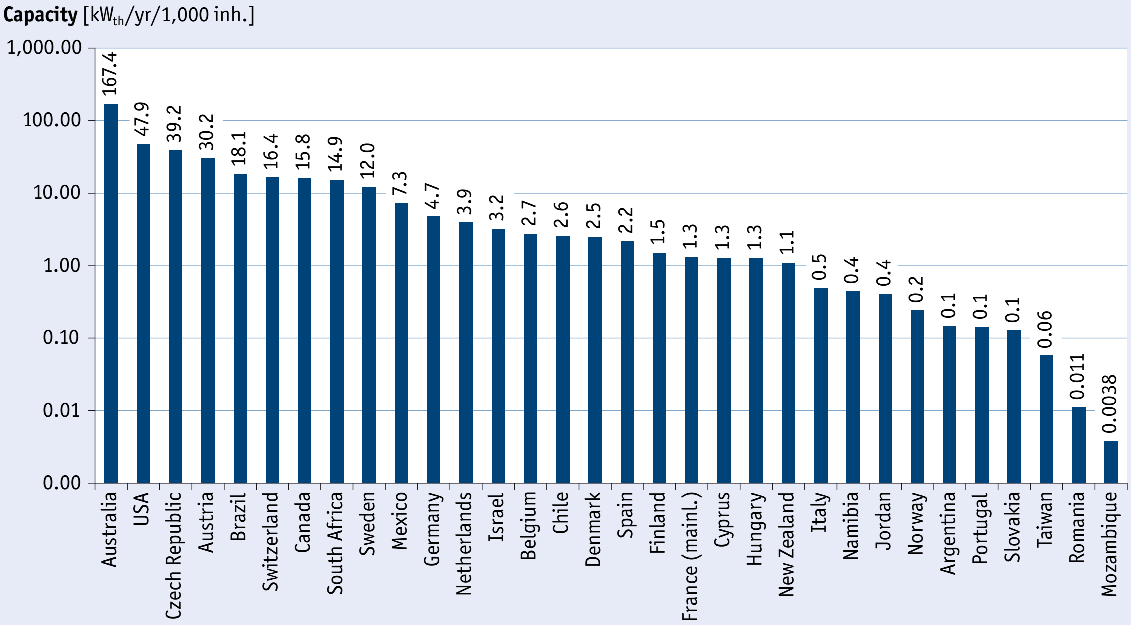


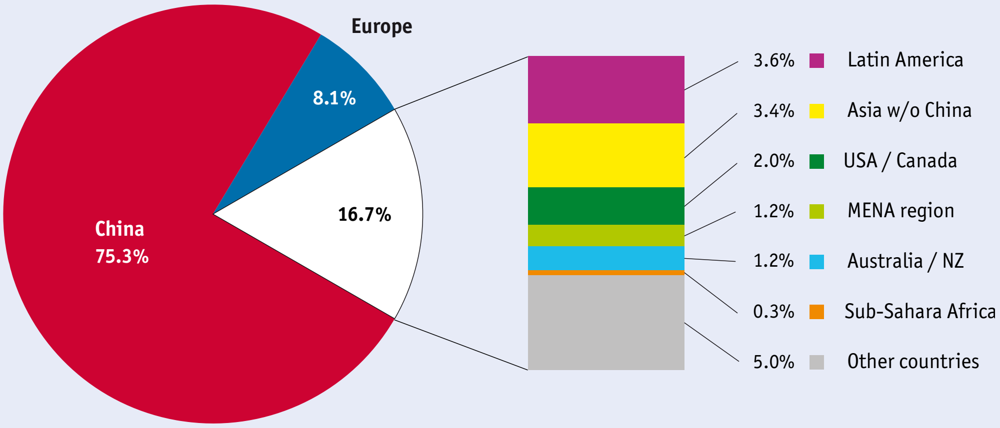
Figure 32: *Total capacity of unglazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2017*

17 Solar Heat Worldwide (Ed.2008), Figure 3

5.5 Newly installed capacity in 2017 and market development

In the year 2017, a total capacity of 34.6 GW_{th}, corresponding to 49.5 million square meters of solar collectors was installed worldwide. This means a decrease in new collector installations by 5 % compared to the year 2016.

The main markets were in China (26.1 GW_{th}) and Europe (2.8 GW_{th}), which together accounted for 83.3 % of the overall new collector installations in 2017. The rest of the market was shared between Latin America (1.2 GW_{th}), Asia excluding China (1.2 GW_{th}), the United States and Canada (0.7 GW_{th}), the MENA countries (0.4 GW_{th}), Australia (0.4 GW_{th}), and the Sub-Sahara African countries (0.1 GW_{th}). The market volume of "all other countries" is estimated to amount to 5 % of the new installations (1.7 GW_{th}).



Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia excluding China:	India, Japan, Korea South, Taiwan, Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Lebanon, Palestinian Territories, Tunisia

Figure 33: *Share of newly installed capacity (glazed and unglazed water and air collectors) by economic regions in 2017*

Of the top 10 markets in 2017, a positive market development was reported from India (26 %), Greece (16 %), Mexico (7 %), Australia (5 %), Turkey (4 %) and Israel (1 %). The other major solar thermal markets within the top 10 countries saw declines in their markets.

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		15.7	1.7			17.5
Argentina	6.5	7.3	17.3			31.1
Australia	297.5	108.6	12.1	3.5	0.7	422.4
Austria	0.4	69.8	0.7		0.2	71.2
Barbados*		8.0	0.0			8.0
Belgium		21.1	3.6			24.8
Botswana**		0.7	0.0			0.7
Brazil	442.7	422.0	19.8			884.5
Bulgaria		3.2	0.3			3.5
Burkina Faso**		0.7	0.1			0.9
Canada	11.5	0.5	0.8	4.7	0.0	17.5
Cape Verde**		0.1				0.1
Chile	0.0	20.5	8.3	0.0	0.0	28.8
China		4,219.6	21,862.4	0.7		26,082.7
Croatia		13.5	1.0			14.5
Cyprus		37.6	0.0			37.6
Czech Republic	0.0	11.6	5.3			16.8
Denmark		22.1	0.0	0.0		22.1
Estonia		0.6	0.4			1.1
Finland		2.0	0.5			2.5
France (mainland)+	3.9	32.0	1.6	0.6		38.0
Germany	14.0	391.3	46.2			451.5
Ghana**		0.1	0.0			0.1
Greece		221.2	0.4			221.6
Hungary	0.4	8.4	2.1	0.2	0.1	11.1
India		278.1	784.7		0.4	1,063.1
Ireland		7.9	6.3			14.2
Israel	0.7	298.2	0.0			298.9
Italy		120.1	16.4			136.5
Japan		41.9	1.1		4.5	47.5
Korea, South		7.4	5.9			13.3
Latvia		0.9	0.2			1.1
Lebanon		18.8	16.1			34.9
Lesotho		0.0	0.1			0.1
Lithuania		0.5	0.9			1.4
Luxembourg		2.5	0.0			2.5
Malta		0.4	0.1			0.5
Mexico	80.4	104.4	89.0			273.8
Mozambique**		0.2	0.4			0.6
Netherlands	1.8	15.6	4.3			21.7
Nigeria	0.0	0.3	0.0	0.0		0.3
Northern Macedonia		4.8	5.8			10.6
Norway		1.6	0.1			1.6
Palestinian Territories		30.8	0.0			30.8
Poland		75.0	2.7			77.8
Portugal		31.7	0.6			32.3
Romania	0.0	5.0	6.7			11.8
Russia		0.3	0.0			0.3
Senegal**		0.0	0.1	0.0	0.0	0.1
Slovakia	0.0	5.6	1.1			6.7
Slovenia		0.9	0.2			1.1
South Africa	41.9	22.4	27.6			91.8
Spain	2.6	133.5	5.0			141.1
Sweden	0.0	2.0	0.2			2.2
Switzerland	3.5	40.4	4.6			48.5
Taiwan		62.0	3.9			65.9
Tunisia		44.3	0.0			44.3
Turkey		682.5	665.0	0.7		1,348.2
United Kingdom		6.3	1.9	0.4		8.5
United States	536.3	116.1	6.0	4.2	2.8	665.4
Uruguay		7.4	0.0			7.4
Zimbabwe		0.0	3.3			3.3
All other countries (5%)	76.0	411.1	1,244.5	0.8	0.5	1,732.8
TOTAL	1,520.1	8,219.3	24,889.3	15.7	9.2	34,653.6

Note: If no data is given: no reliable database for this collector type is available
* 0% growth rate assume
** Country market data for new installations in 2017 estimated by AEE INTEC
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered

Table 8: *Newly installed capacity in 2017 [MW_{th}/a]*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		22,471	2,486			24,957
Argentina	9,318	10,393	24,748			44,459
Australia	425,000	155,185	17,243	5,000	1,000	603,428
Austria	630	99,770	1,060		320	101,780
Barbados*		11,430				11,430
Belgium		30,200	5,200			35,400
Botswana**		1,000	1,800			2,800
Brazil	632,451	602,803	28,260			1,263,514
Bulgaria		4,600	450			5,050
Burkina Faso**		1,050	180			1,230
Canada	16,478	651	1,129	6,688	8	24,954
Cape Verde**		180				180
Chile		29,300	11,878			41,178
China		6,028,000	31,232,000	1,000		37,261,000
Croatia		19,300	1,400			20,700
Cyprus		53,718	0			53,718
Czech Republic		16,500	7,500			24,000
Denmark		31,500				31,500
Estonia		900	600			1,500
Finland		2,900	700			3,600
France (mainland)+	5,500	45,740	2,260	800		54,300
Germany	20,000	559,000	66,000			645,000
Ghana**		81	26			107
Greece		316,000	500			316,500
Hungary	500	12,000	3,000	300	100	15,900
India		397,286	1,120,963		500	1,518,749
Ireland		11,250	9,050			20,300
Israel	1,000	426,000				427,000
Italy		171,600	23,400			195,000
Japan		59,847	1,582		6,435	67,864
Korea, South		10,631	8,436			19,067
Latvia		1,350	250			1,600
Lebanon		26,842	22,957			49,799
Lesotho		34	123			157
Lithuania		750	1,250			2,000
Luxembourg		3,600	0			3,600
Malta		614	154			768
Mexico	114,900	149,200	127,100			391,200
Mozambique		300	600			900
Namibia		4,525	12			4,537
Netherlands	2,620	22,220	6,160			31,000
Nigeria		400	68			468
Northern Macedonia		6,886	8,225			15,111
Norway		2,241	78			2,319
Palestinian Territories		44,052	0			44,052
Poland		107,200	3,900			111,100
Portugal		45,250	850			46,100
Romania		7,200	9,600			16,800
Russia		393	66			459
Senegal**		4	86		58	148
Slovakia		8,000	1,600			9,600
Slovenia		1,300	250			1,550
South Africa	59,825	31,953	39,405			131,183
Spain	3,652	190,666	7,187			201,505
Sweden	0	2,867	341			3,208
Switzerland	4,931	57,774	6,626			69,331
Taiwan		88,623	5,544			94,168
Tunisia		63,246				63,246
Turkey		975,000	950,000	1,000		1,926,000
United Kingdom		8,960	2,659	500		12,120
United States	766,210	165,800	8,596	6,000	4,000	950,606
Uruguay		10,551				10,551
Zimbabwe			4,665			4,665
All other countries (5%)	108,580	587,320	1,777,905	1,120	654	2,475,580
TOTAL	2,171,595	11,746,408	35,558,107	22,408	13,075	49,511,593

Note: If no data is given: no reliable database for this collector type is available
* 0% growth rate assume
** Country market data for new installations in 2017 estimated by AEE INTEC
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered

Table 9: *Newly installed collector area in 2017 [m²/a]*

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New installations in 2017 are divided into flat plate collectors: 8.2 GW_{th} (11.8 million square meters), evacuated tube collectors: 24.9 GW_{th} (35.6 million square meters), unglazed water collectors: 1.5 GW_{th} (2.2 million square meters), and glazed and unglazed air collectors: 0.02 GW_{th} (0.04 million square meters).

With a share of 71.8 %, evacuated tube collectors remain by far the most important solar thermal collector technology worldwide (**Figure 34**). In a global context, this breakdown is mainly driven by the dominance of the Chinese market where around 84 % of all newly installed collectors in 2017 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82 % in 2011 to 71.8 % in 2017 and in the same time frame flat plate collectors increased their share from 14.7 % to 23.7 %.

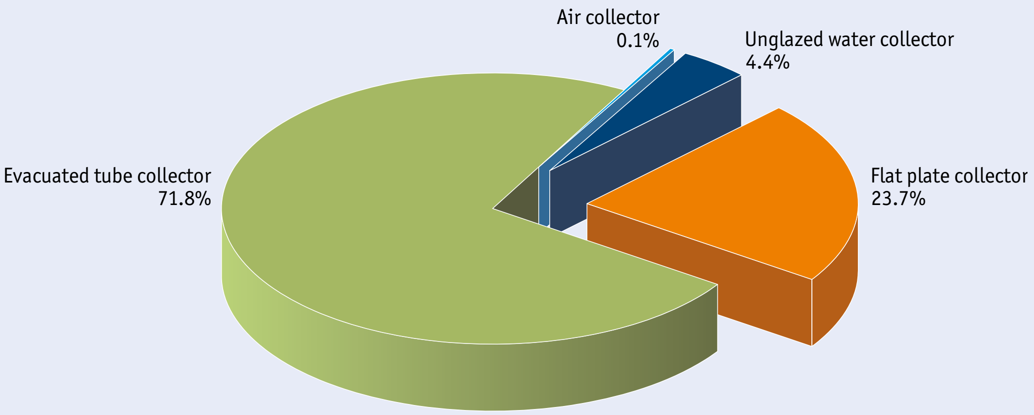
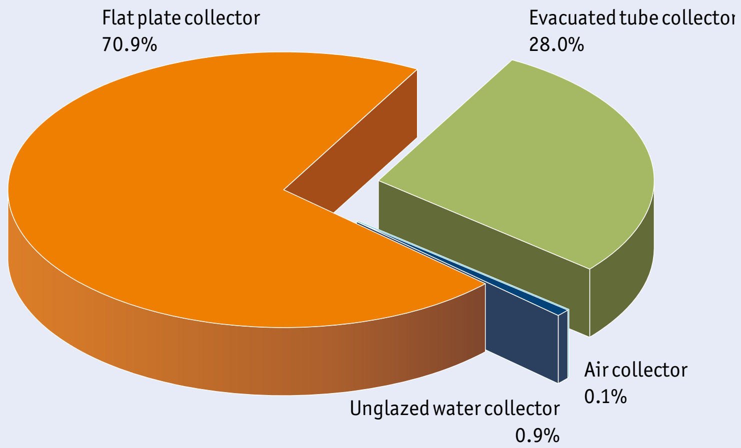


Figure 34: *Distribution of the newly installed capacity by collector type in 2017 - WORLD*

In Europe, the situation is almost the opposite compared to China with 71 % of all solar thermal collectors installed in 2017 being flat plate collectors (**Figure 35**). In the medium-term perspective, the share of flat plate collectors decreased in Europe from 81.5 % in 2011 to 71 % in 2017. While driven mainly by the markets in Turkey, Poland, Switzerland and Germany, evacuated tube collectors increased their share in Europe between 2011 and 2017 from 15.6 % to 28 %. In the year 2017 the share of evacuated tube collectors increased compared to the year 2016 from 23.5 % in 2016 to 28 % in 2017.



Europe: EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey

Figure 35: *Distribution of the newly installed capacity by collector type in 2017 – EUROPE*

Figure 36 shows the newly installed capacity of glazed and unglazed water collectors in total numbers for the 10 leading markets in 2017. China remained the market leader in absolute terms followed by Turkey. India overtook Brazil and ranks in the third position in 2017. Greece pushed Denmark out of the top 10 as there was a smaller number of solar district heating systems installed in 2017. Germany faced a market decline the fifth year in a row, but held on to its sixth position rank.

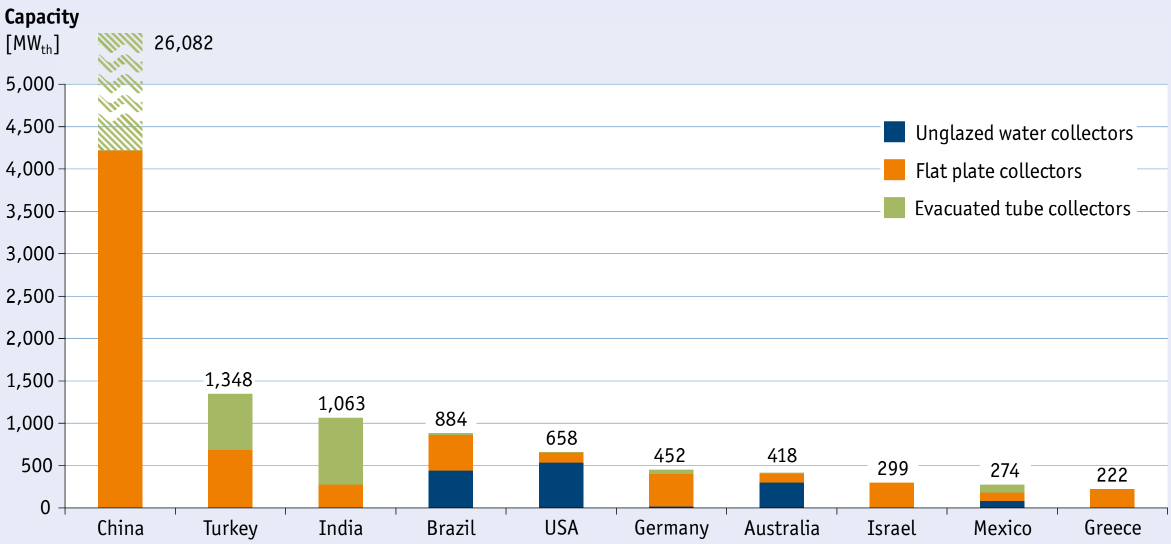


Figure 36: *Top 10 markets for glazed and unglazed water collectors in 2017 (absolute figures in MW_{th})*

In terms of newly installed solar thermal capacity per 1,000 inhabitants in 2017, the top 10 countries are shown in Figure 37. Israel took the lead while Cyprus held the second position once again. Greece overtook China and Denmark was pushed out of the top 10 because of a reduction in the installed collector area for solar district heating. Switzerland joined the top 10 list with 5.9 kW_{th} installed collector area per 1,000 inhabitants..

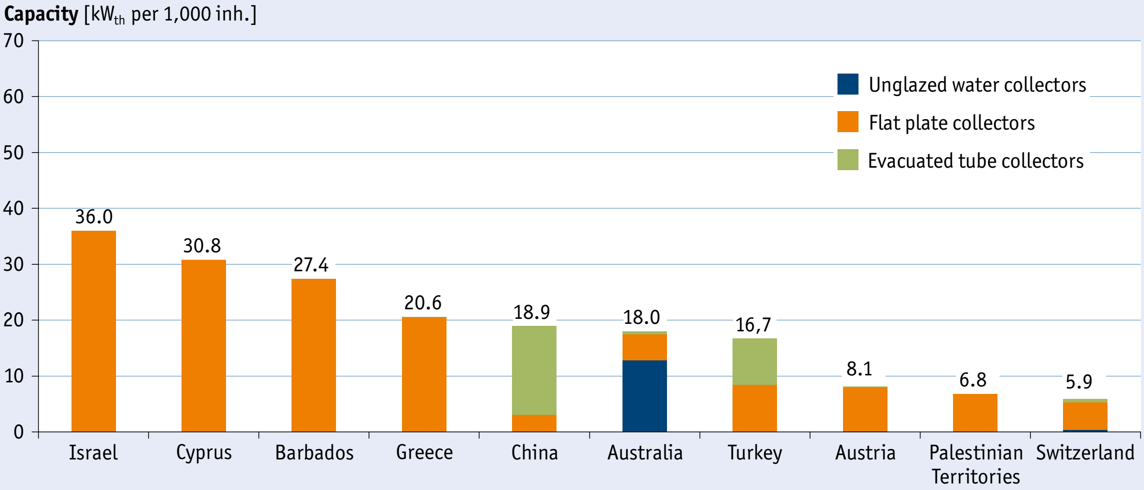


Figure 37: *Top 10 markets for glazed and unglazed water collectors in 2017 (in kW_{th} per 1,000 inhabitants)*

5.6 Newly installed capacity of glazed water collectors

In 2017 glazed water collectors accounted for 95.5 % of the total newly installed capacity. China was the most influential market in the global context (Figure 38).

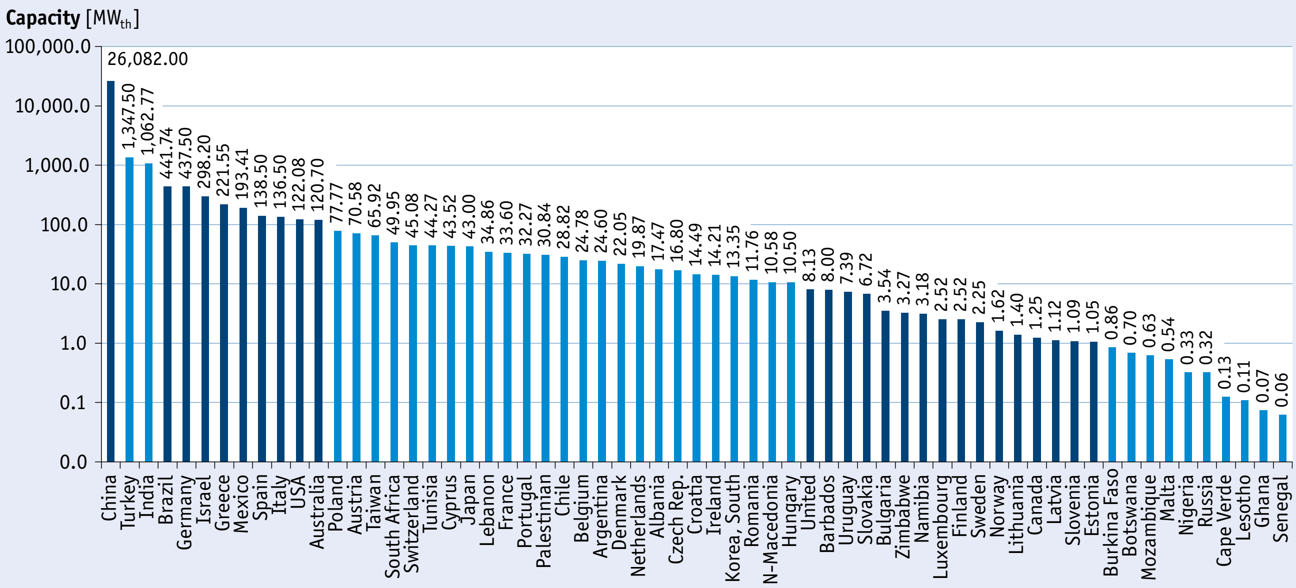


Figure 38: *Newly installed capacity of glazed water collectors in 2017*

In terms of newly installed glazed water collector capacity per 1,000 inhabitants, Israel is the leader ahead of Cyprus and Barbados. In this respect China ranks in the fifth place (Figure 39).

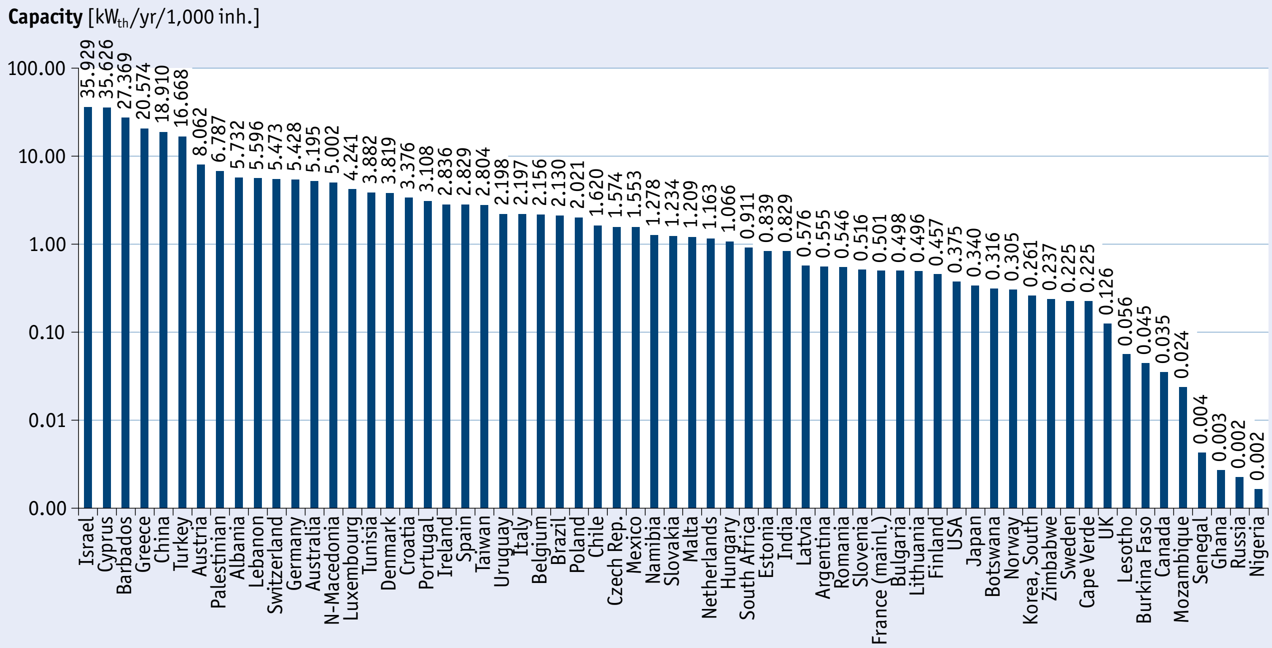


Figure 39: *Newly installed capacity of glazed water collectors in 2017 in kW$_{th}$ per 1,000 inhabitants*

The following figures show the solar thermal market penetration per capita of the newly installed capacity in 2017 worldwide and in Europe.

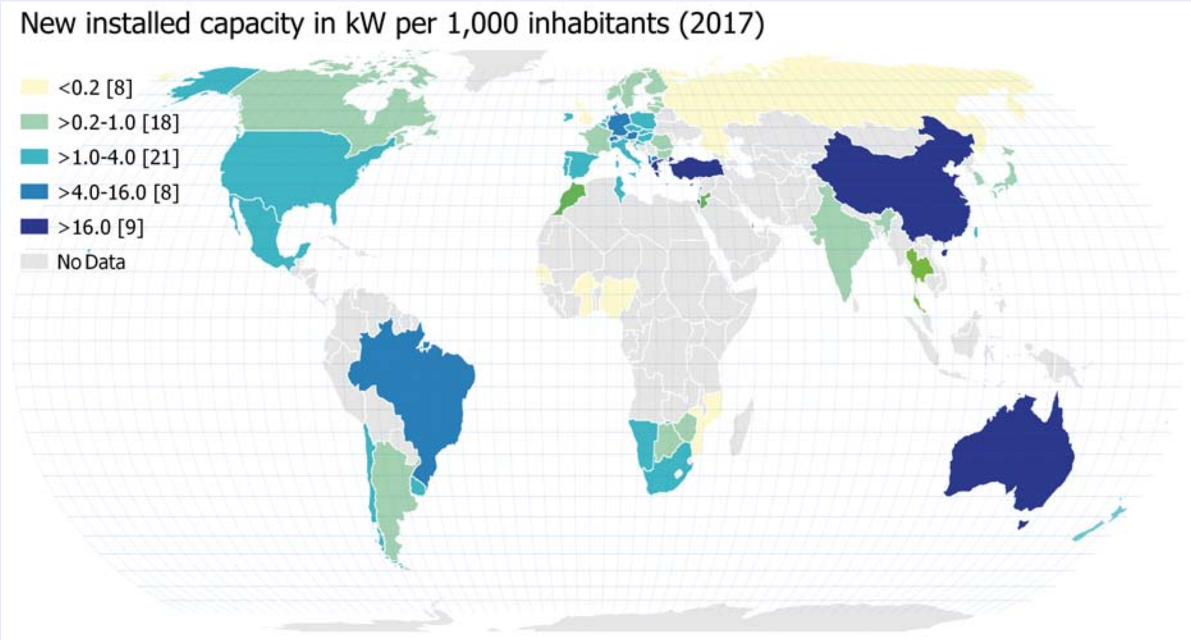


Figure 40: *Installed capacity worldwide in 2017 in kW_{th} per 1,000 inhabitants*

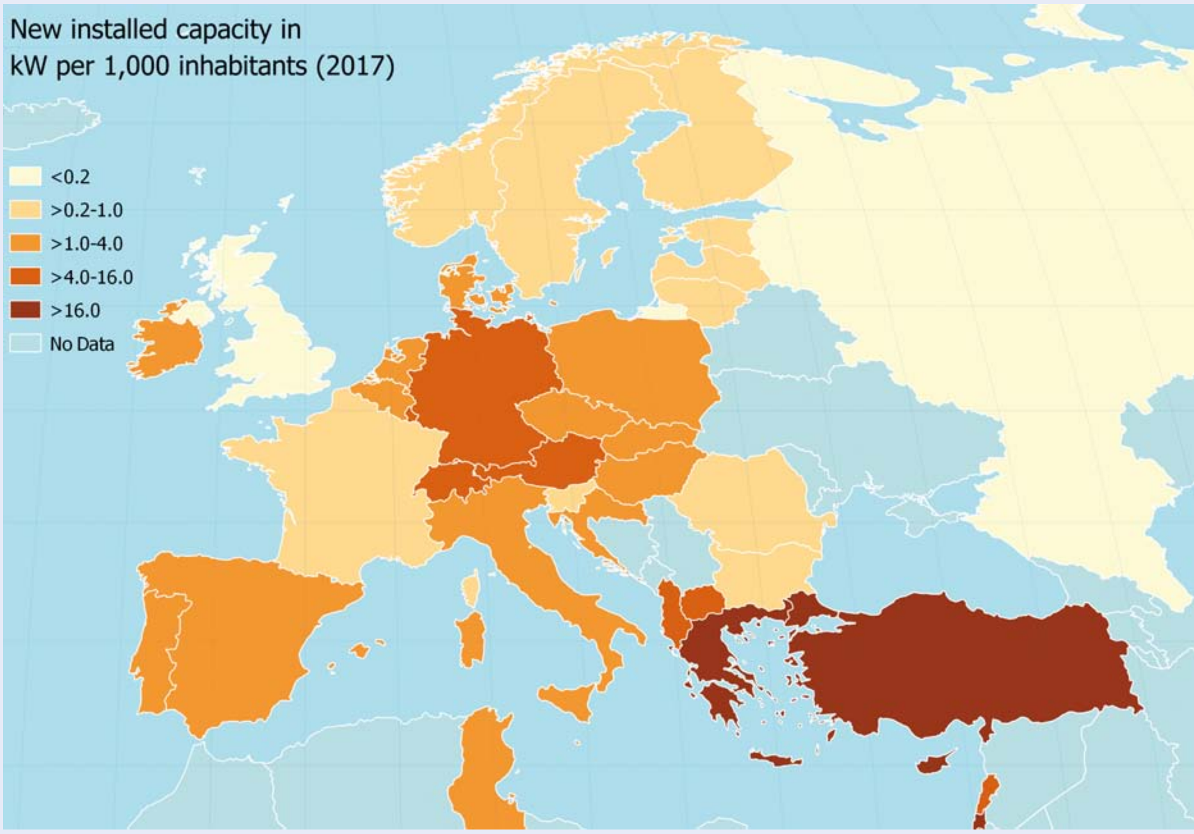


Figure 41: *Installed capacity in Europe in 2017 in kW_{th} per 1,000 inhabitants*

5.7 Market development of glazed water collectors between 2000 and 2017

The worldwide market of glazed water collectors was characterized by a steady upwards trend between 2000 and 2011 and showed a leveling trend in 2012 and 2013 at around 53 GW_{th}. In 2014, a significant market decline of –15.6 % was reported for the first time since the year 2000. This trend continued in 2015, 2016 and 2017 but the markets seem to have recovered slightly as the decline slowed down and six of the top ten markets reported growth in 2017.

The newly installed glazed water collector capacity in 2017 amounted to 33 GW_{th} (Figure 42).

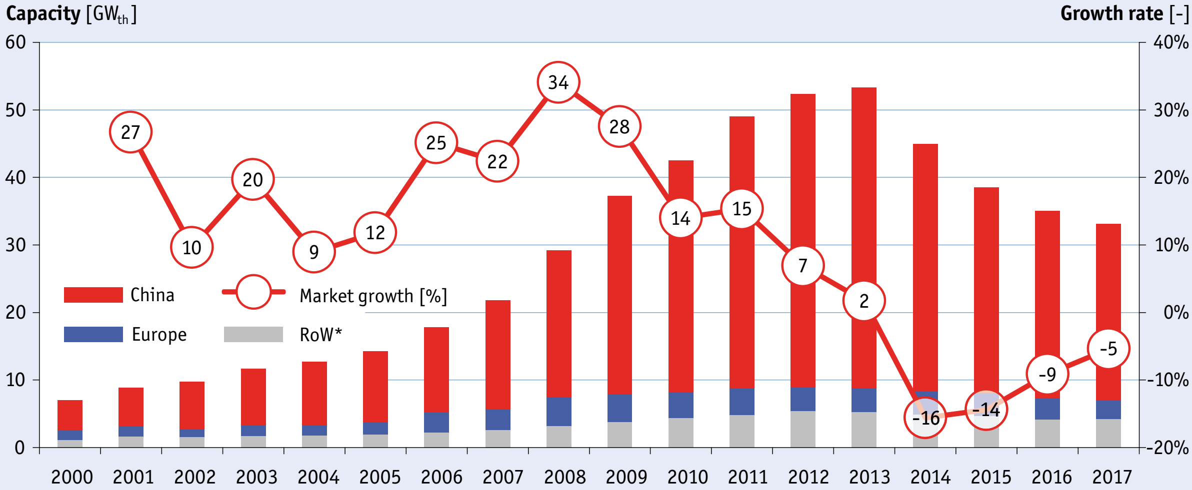


Figure 42: *Global market development of glazed water collectors from 2000 to 2017*

In 2000, the Chinese market was about three times as large as the European market while in 2017, the Chinese market exceeded the European market more than nine-fold (Figure 43). It can also be seen in Figure 43 that after years of very high growth rates in China this trend has changed in the past four years. Compared to the years before, the Chinese market began to experience low growth rates in 2012 and 2013 and then shrank significantly in 2014 and 2015. The downwards trend, however, became less dramatic in 2016 and 2017.

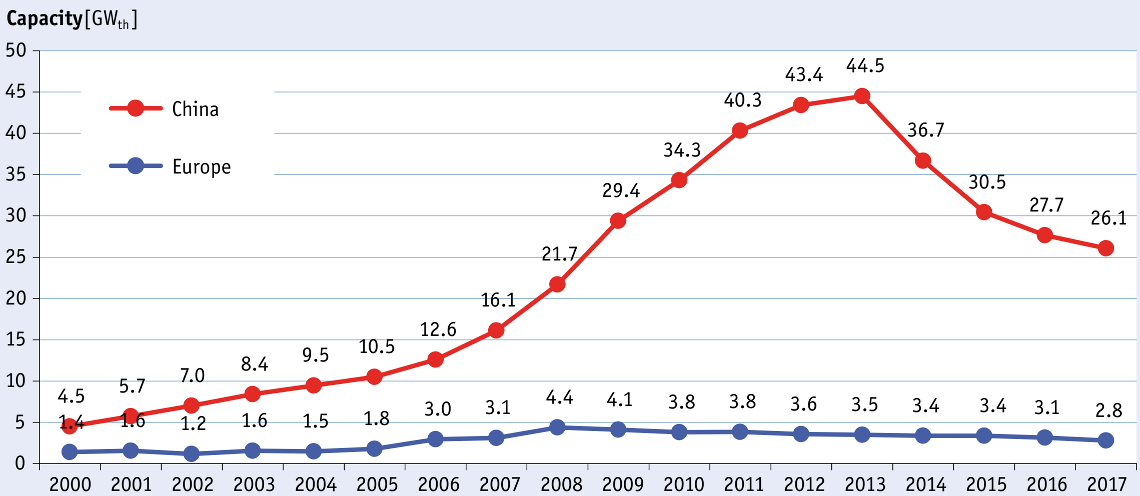
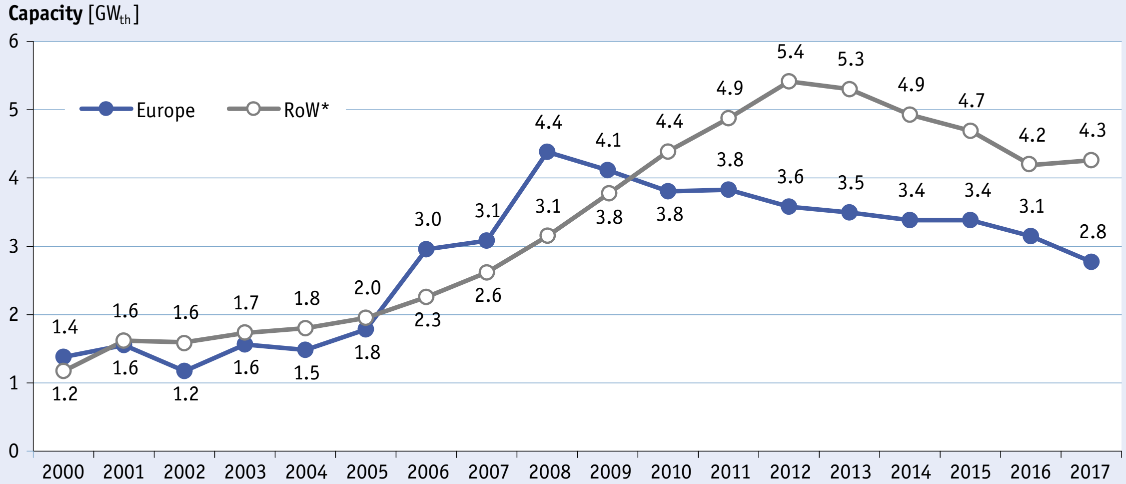


Figure 43: *Market development of glazed water collectors in China and Europe 2000 – 2017*

The European market peaked at 4.4 GW_{th} installed capacity in 2008 and has decreased steadily down to 3.1 GW_{th} in 2016 and 2.8 GW_{th} in 2017. In the "remaining markets worldwide" (RoW) an upward trend could be observed between 2002 and 2012 and a falling trend in the years from 2013 to 2016. Between 2016 and 2017 a slight upward trend is noticeable (**Figure 44**).



Europe: EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
Rest of World (RoW): Asia (India, Japan, Korea South, Taiwan, Thailand), Australia, Canada, United States
Latin America (Argentina, Brazil, Chile, Mexico, Uruguay)
MENA countries (Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia)
Sub-Sahara Africa (Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe),
"All other countries" see figures for 2017 in Tables 4 and 5

Figure 44: *Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2017*

RoW includes all economic regions other than China and Europe. Of these regions, besides "all other countries", Asia (excluding China), Latin America and the MENA countries hold the largest market shares (see **Figure 45**).

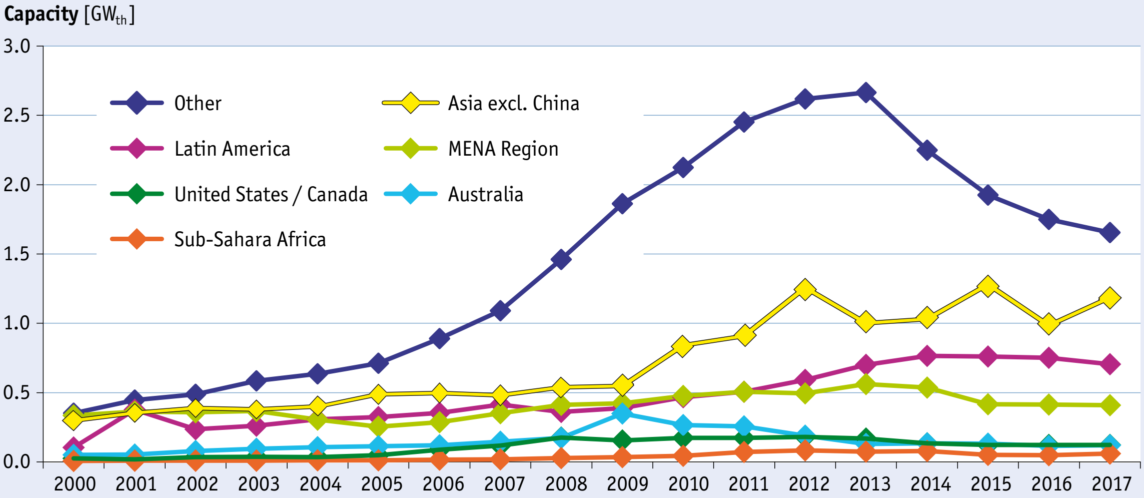
"Asia excl. China" is mainly influenced by the large Indian market. Other markets covered within this economic region (Japan, South Korea) reported a market decrease in 2017.

Latin America shows the most steady and dynamic upward trend of all the economic regions. The dominant Brazilian, but also the large Mexican market as well as the evolving markets, for example in Chile, are responsible for the positive growth rates that have lasted 6 years in a row. Since 2015 the market in the region is about stable with a slight decrease.

Glazed water collector markets in the MENA countries were characterized by steady growth from 2000 to 2013. The market decline since 2014, which is shown in **Figure 45**, is explained by the fact that from 2015 on no data were received from two major markets in Morocco and Jordan. The sales numbers in the most important market, Israel, slightly increased by 1 % in 2017.

The market volume for glazed water collectors in Australia was similar to the volume in Latin America and the MENA countries in 2009 and continued to shrink more or less through 2015. In 2017, the market stayed nearly the same (0.5 % increase).

Sub-Sahara African markets showed a stable market in 2017. In the United States and Canada the decreasing trend continued for the third year in a row but with – 5 % in 2017.



Asia excl. China:	India, Japan, Korea South, Taiwan, Thailand
Latin America:	Argentina, Brazil, Chile, Mexico, Uruguay
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia
Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe

Figure 45: *Market development of glazed water collectors in the Latin America, United States / Canada, Sub-Sahara Africa, Asia, the MENA Region and Australia (excluding China and Europe) from 2000 to 2017*

In relative figures, the annual global market volume for glazed water collectors grew from 1.2 kW_{th} per 1,000 inhabitants in 2000 to 7.5 kW_{th} per 1,000 inhabitants in 2013 and dropped down to 4.5 kW_{th} per 1,000 inhabitants in 2017 (Figure 46).

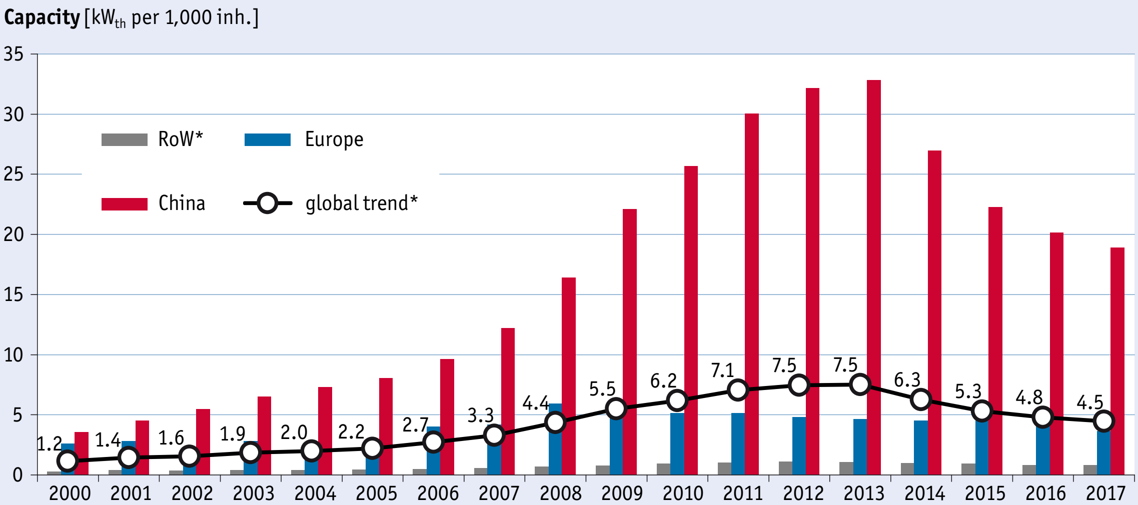


Figure 46: *Annual installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2017*

The fact that China suffered major market declines from 2014 to 2017 is also reflected in the market penetration of glazed water collector installations per capita. The annually installed capacity rose from 3.5 kW_{th} per 1,000 inhabitants in 2000 and peaked at 32.8 kW_{th} per 1,000 inhabitants in 2013 and fell down to 18.9 kW_{th} per 1,000 inhabitants in 2017.

In Europe, market penetration peaked in 2008 with 5.9 kW_{th} per 1,000 inhabitants. The downward trend between 2009 and 2013 seems to have stabilized from 2014 on and lies at 3.7 kW_{th} per 1,000 inhabitants in 2017.

5.8 Market development of unglazed water collectors between 2000 and 2017

With a newly installed capacity of 1.5 GW_{th} in 2017, unglazed water collectors accounted for 4.4 % of the total installed solar thermal capacity (Figure 34). Compared to the year 2016 the market increased slightly by 3.3 %.

The most important markets for unglazed water collectors in 2017 were the United States (536 MW_{th}), Brazil (443 MW_{th}), Australia (298 MW_{th}), Mexico (80 MW_{th}) and South Africa (42 MW_{th}), which accounted for 92 % of the recorded unglazed water collector installations worldwide. Another 2 % were installed in Canada (12 MW_{th}), Germany (14 MW_{th}) and Argentina (7 MW_{th}).

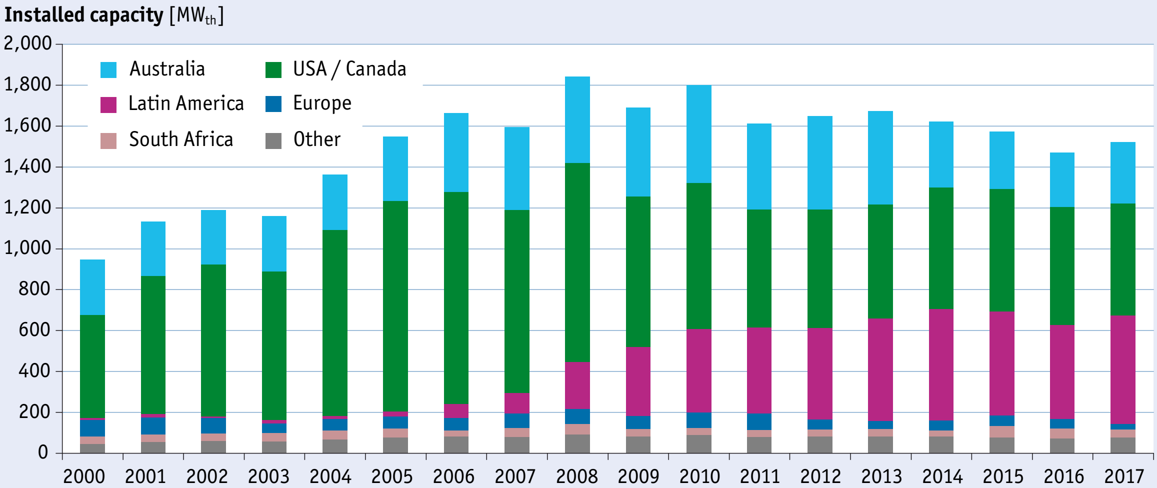


Figure 47: *Global market development of unglazed water collectors from 2000 to 2017*

The unglazed water collector market in the United States peaked in 2006 (1.01 GW_{th}) and has almost halved since then (0.54 GW_{th} in 2017). Nevertheless, the annual global market volume for unglazed water collectors has remained at a nearly constant level because of the Brazilian market, which entered in 2007 and peaked in 2014 with 0.45 GW_{th}. Australia has faced a market decrease since 2010 and is now the third largest market for unglazed water collectors behind that of the United States and Brazil.

6 Contribution to the energy supply and CO_2 reduction in 2017

In this section, the contribution of the total installed glazed and unglazed water collectors in operation to the thermal energy supply and CO_2 reduction is shown.

The basis for these calculations is the total glazed and unglazed water collector area in operation in each country as shown in **Table 6**. The contribution of the total installed air collector capacity in operation in 2017 of 1.2 GW_{th} was not taken into consideration – with a share of around 0.3% of the total installed collector capacity these collectors were omitted from the calculation.

The results are based on calculations using the simulation tool T-SOL expert 4.5, for each country. For the simulations, different types of collectors and applications as well as the characteristic climatic conditions were considered for each country. A more detailed description of the methodology can be found in the appendix (see **Chapter 9**).

The annual collector yield of all water-based solar thermal systems for the simulated applications (swimming pool, DHW for single family houses, DHW for multi-family houses and solar combi systems) in operation by the end of 2017 in the 68 recorded countries was 389,7 TWh (= 1,403 PJ). This corresponds to a final energy savings equivalent of 41.9 million tons of oil and 135 million tons of CO_2. The calculated number of different types of solar thermal systems in operation was around 118 million (**Table 10**).

The most important application for solar thermal systems is domestic hot water heating (see section 7.3), and therefore, this type of application accounted for the highest savings in terms of oil equivalent and CO_2. In 2017, 94% of the energy provided by solar thermal systems worldwide was used for heating domestic hot water, mainly by small-scale systems in single-family houses (68%) and larger applications attached to multi-family houses, hotels, schools, etc. (26%). Swimming pool heating held a share of 4% in the contribution to the energy supply and CO_2 reduction and the remaining 2% was met by solar combi-systems.

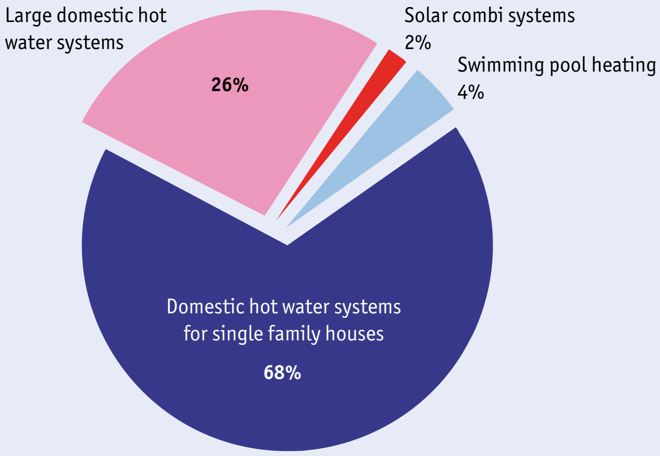


Figure 48: Share of energy savings and CO_2 reduction by type of application of glazed and unglazed water collectors in operation in 2017

Table 10 summarizes the calculated annual collector yields and the corresponding oil equivalents and CO_2 reductions of all water-based solar thermal systems by the end of 2017.

Country	Total collector area [m²]	Total capacity [MW_{th}]	Calculated number of systems	Collector yield [GWh/a]	Collector yield [TJ/a]	Energy savings [t_{oe}/a]	CO_2 reduction [t_{CO2e}/a]
Albania	232,215	163	49,247	164	590	17,613	56,853
Argentina	44,459	31	5,862	31	112	3,341	10,785
Australia	9,029,000	6,320	1,146,580	5,608	20,189	602,754	1,945,690
Austria	5,168,157	3,618	514,504	2,090	7,522	224,585	724,962
Barbados	225,720	158	56,430	199	717	21,409	69,110
Belgium	662,333	464	115,264	263	948	28,299	91,350
Botswana	12,300	9	2,009	12	42	1,239	4,000
Brazil	14,873,401	10,411	4,453,502	9,705	34,938	1,043,096	3,367,115
Bulgaria	140,050	98	24,372	69	248	7,416	23,940
Burkina Faso	3,450	2	218	3	12	345	1,115
Canada	926,370	648	35,330	446	1,605	47,918	154,680
Cape Verde	1,783	1	159	2	6	171	552
Chile	332,728	233	69,039	230	828	24,718	79,789
China	477,880,000	334,516	81,000,660	267,870	964,331	28,790,825	92,936,784
Croatia	210,516	147	36,635	106	381	11,372	36,710
Cyprus	768,262	538	335,799	683	2,458	73,395	236,919
Czech Republic	1,179,103	825	82,891	393	1,415	42,241	136,354
Denmark	1,640,567	1,148	98,081	684	2,463	73,548	237,414
Estonia	16,020	11	2,788	6	23	691	2,231
Finland	65,523	46	11,403	27	96	2,854	9,211
France (mainland)+	2,751,851	1,926	601,852	1,333	4,800	143,312	462,612
Germany	19,625,580	13,738	2,304,796	7,991	28,768	858,886	2,772,484
Ghana	2,381	2	125	2	8	231	744
Greece	4,618,000	3,233	1,232,867	3,217	11,580	345,733	1,116,027
Hungary	313,600	220	46,084	142	512	15,273	49,301
India	11,442,075	8,009	5,039,376	9,880	35,569	1,061,931	3,427,912
Ireland	363,551	254	84,138	152	548	16,360	52,810
Israel	4,711,434	3,298	1,508,601	4,347	15,649	467,210	1,508,153
Italy	4,574,529	3,202	796,092	2,791	10,046	299,937	968,196
Japan	3,633,220	2,543	882,937	2,105	7,579	226,288	730,458
Jordan*	1,260,506	882	223,109	1,194	4,297	128,286	414,108
Korea, South	1,870,685	1,309	428,574	971	3,495	104,334	336,789
Latvia	13,882	10	2,416	6	21	633	2,042
Lebanon	788,002	552	125,474	659	2,371	70,794	228,525
Lesotho	2,047	1	461	2	6	192	620
Lithuania	16,750	12	2,915	7	25	753	2,432
Luxembourg	62,645	44	10,902	27	95	2,848	9,195
Malta	52,319	37	20,928	45	163	4,880	15,754
Mauritius**	132,793	93	88,529	113	408	12,183	39,325
Mexico	3,918,677	2,743	462,964	2,242	8,070	240,945	777,771
Morocco*	451,000	316	60,900	383	1,378	41,146	132,821
Mozambique	2,286	2	349	2	7	203	656
Namibia	42,435	30	5,241	39	139	4,160	13,430
Netherlands	650,270	455	156,932	261	938	28,007	90,407
New Zealand***	159,645	112	32,703	99	355	10,592	34,191
Nigeria	924	1	353	1	3	87	281
Northern Macedonia	80,173	56	18,287	50	179	5,331	17,207
Norway	44,199	31	2,203	16	59	1,749	5,645
Palestine	1,746,594	1,223	599,722	1,629	5,866	175,124	565,301
Poland	2,249,090	1,574	283,010	918	3,306	98,713	318,647
Portugal	1,059,365	742	192,036	818	2,944	87,907	283,762
Romania	189,490	133	32,976	105	377	11,247	36,306
Russia	24,049	17	1,297	10	36	1,075	3,469
Senegal	1,824	1	455	2	6	191	617
Slovakia	166,700	117	20,403	78	280	8,365	27,001
Slovenia	147,900	104	23,578	62	224	6,685	21,580
South Africa	2,038,407	1,427	472,652	1,465	5,274	157,445	508,234
Spain	4,105,293	2,874	482,988	2,863	10,306	307,700	993,256
Sweden	544,814	381	41,365	199	717	21,402	69,085
Switzerland	1,658,460	1,161	200,658	655	2,358	70,389	227,215
Taiwan	1,707,055	1,195	336,923	1,038	3,738	111,615	360,293
Thailand****	157,536	110	36,001	132	476	14,212	45,876
Tunisia	970,142	679	286,020	871	3,135	93,609	302,171
Turkey	23,257,636	16,280	5,372,514	20,864	75,111	2,242,501	7,238,794
United Kingdom	799,719	560	129,590	286	1,029	30,721	99,168
United States	25,376,277	17,763	426,321	11,285	40,625	1,212,885	3,915,193
Uruguay	69,393	49	17,348	47	170	5,083	16,410
Zimbabwe	41,725	29	17,761	36	128	3,822	12,337
All other countries (5%)	33,753,128	23,627	6,952,282	20,026	72,092	2,152,372	6,947,857
TOTAL	675,062,012	472,543	118,106,778	390,053	1,404,192	41,923,182	135,328,030

* Total capacity in operation refers to the year 2014

** Total capacity in operation refers to the year 2015

*** Total capacity in operation refers to the year 2009

**** Total capacity in operation refers to the year 2016

+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered

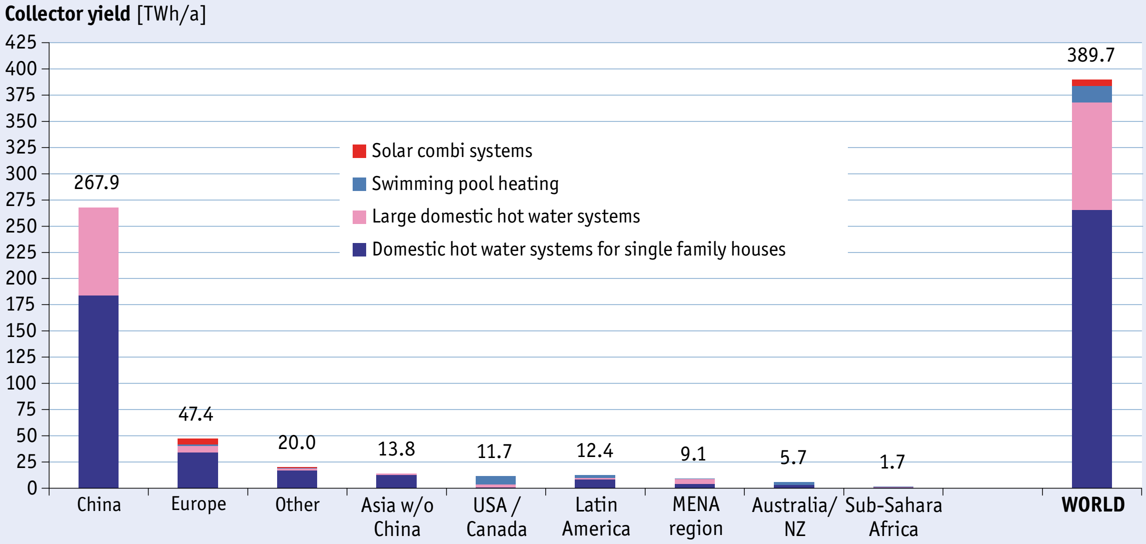
Table 10: *Calculated annual collector yield and corresponding oil equivalent and CO_2 reduction of glazed and unglazed water collectors in operation by the end of 2017*

In Chapters 6.1 to 6.3, the annual collector yield, energy savings and CO_2 savings by economic regions and worldwide are graphed.

6.1 Annual collector yield by economic region

In 2017, gross solar thermal collector yields amounted to 389.7 TWh worldwide (Table 10) and the major share, 68 %, was contributed by domestic hot water applications for single-family houses (Figure 48).

China accounted for 69 % of the thermal energy gains (267.9 TWh), Europe for 12 % (47.3 TWh) and the Rest of the World for 19 % (74.5 TWh) (Figure 49).



Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

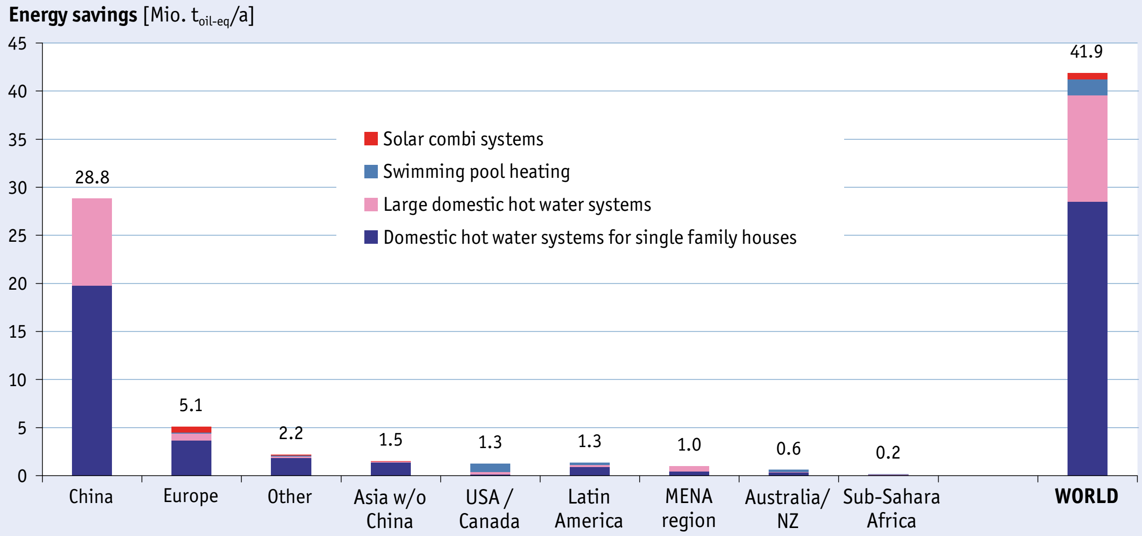
Figure 49: *Annual collector yield of unglazed and glazed water collectors in operation in 2017*

6.2 Annual energy savings by economic region

The annual final energy savings amounted to 389.7 TWh or 41.9 million tons of oil equivalent in 2017[18]. This is calculated using a utilization ratio of 0.8 for the reference oil boiler, which is assumed to be partially replaced by a solar thermal system (see methodology Chapter 9.1)

The breakdown shows that China accounted for 28.8 million tons oil equivalent, Europe for 5.1 million tons oil equivalent, and the Rest of World for 8.0 million tons oil equivalent (Figure 50).

18 1 toe = 1.163 x 10^4 kWh (Defra / DECC 2013), for the simulated applications

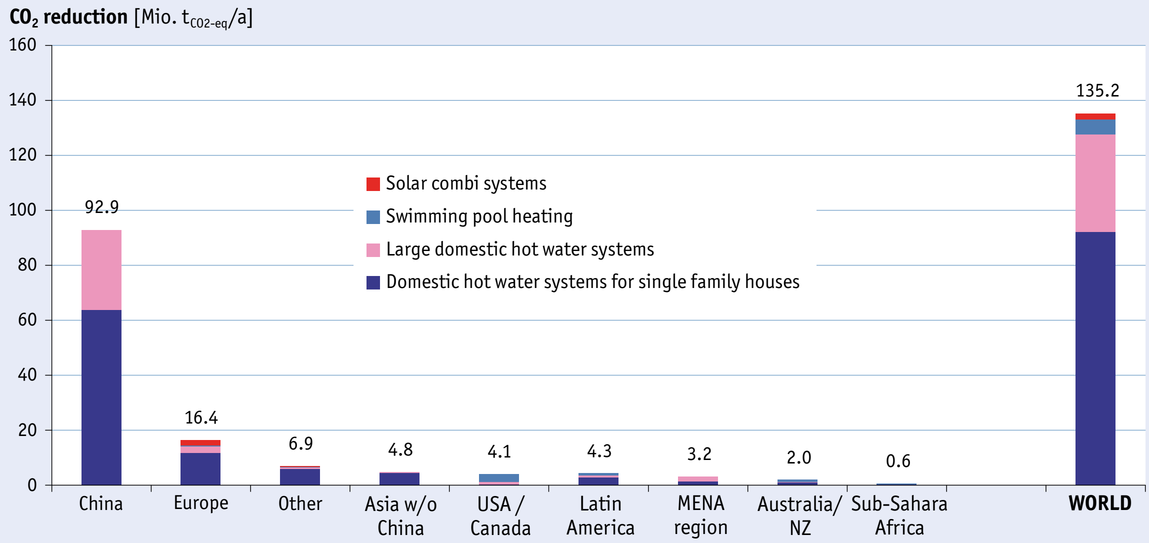


Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 50: *Annual energy savings in oil equivalent by unglazed and glazed water collectors in operation in 2017*

6.3 Annual contribution to CO_2 reduction by economic region

41.9 million tons of oil equivalent correspond to an annual CO_2 emission reduction of 135.2 million tons[19]. The breakdown shows that China accounted for 92.9 million tons of CO_2 equivalent, Europe 16.4 million tons of CO_2 equivalent, and the Rest of World 25.9 million tons of CO_2 equivalent (see **Figure 51**).



Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 51: *Contribution to CO_2 reduction by unglazed and glazed water collectors in operation in 2017*

19 1 toe (fuel oil) = 3,228 tCO_2e *(Source: Defra / DECC 2013)*

7 Distribution of systems by type and application in 2017

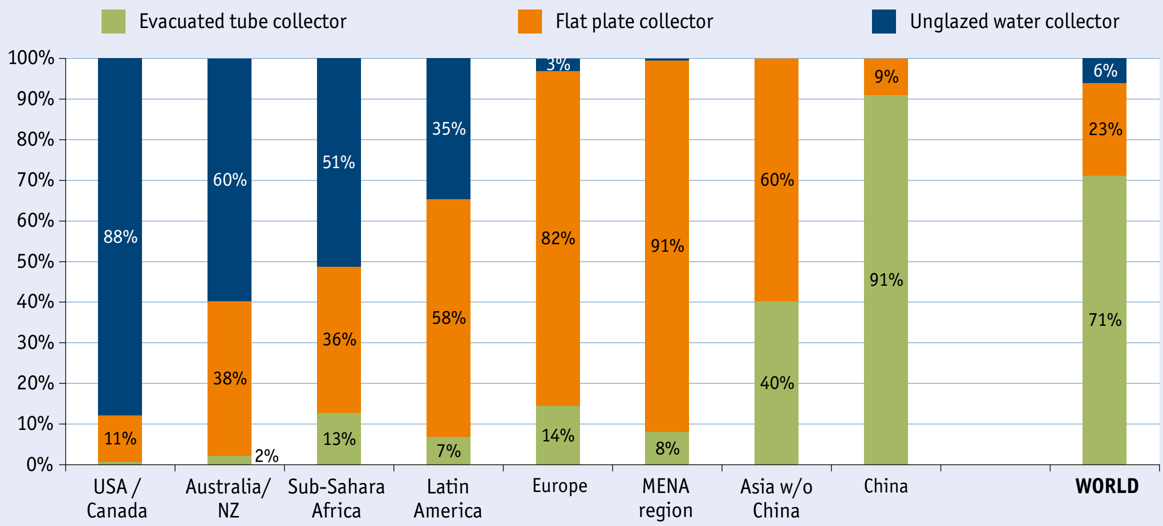
The use of solar thermal energy varies greatly from region to region and can be roughly distinguished by the type of solar thermal collector used (unglazed water collectors, evacuated tube collectors, flat plate collectors, glazed and unglazed air collectors, concentrating collectors), the type of system operation (pumped solar thermal systems, thermosiphon systems), and the main type of application (swimming pool heating, domestic hot water preparation, space heating, others such as heating of industrial processes, solar district heating or solar thermal cooling).

In Chapters 7.1 to 7.3, the distribution of these system types and applications are shown by different economic regions for both the cumulated capacity in operation in 2017 and the newly installed capacity in 2017[20].

7.1 Distribution by type of solar thermal collector

In terms of the total water collector area worldwide, evacuated tube collectors dominated with a share of 71 % of the cumulated capacity in operation (Figure 52) and a share of 72 % of the newly installed capacity (Figure 53). Worldwide flat plate collectors accounted for 23 % of the cumulated capacity in operation (Figure 52) and 24 % of the newly installed capacity (Figure 53). Unglazed water collectors accounted for 6 % of the cumulated water collectors installed worldwide and for 4 % of the newly installed capacity.

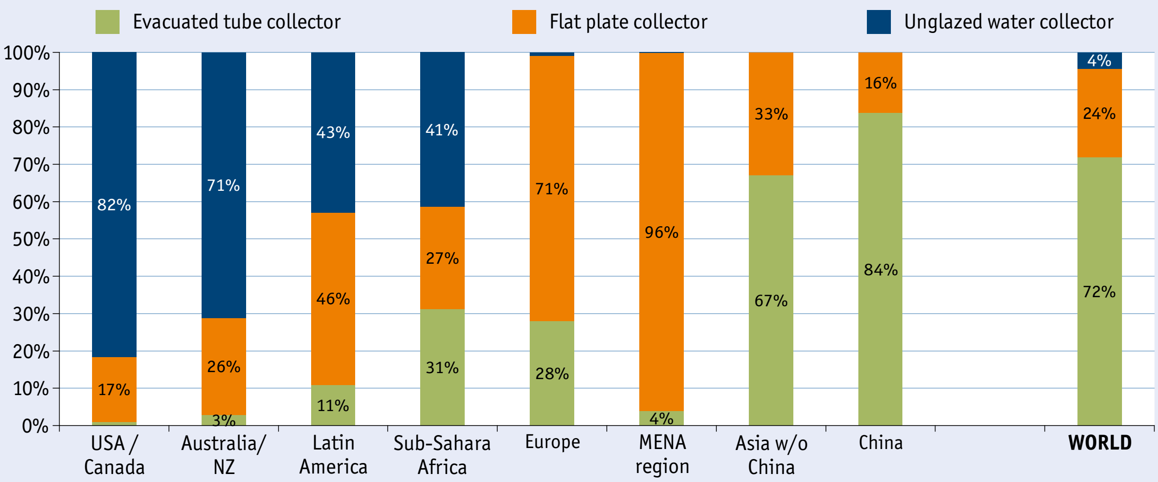
In all economic regions besides China (evacuated tube collectors) and North America (unglazed water collectors) flat plate collectors are dominant.



Sub-Sahara Africa:	Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 52: Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2017

20 It is important to note that the statistical information summarized in Chapters 6.1 to 6.4 is sometimes only based on rough expert estimations by country representatives, and therefore, figures may deviate from those published in previous editions of this report, particularly in reference to the cumulated installed capacity in operation by system type and application.



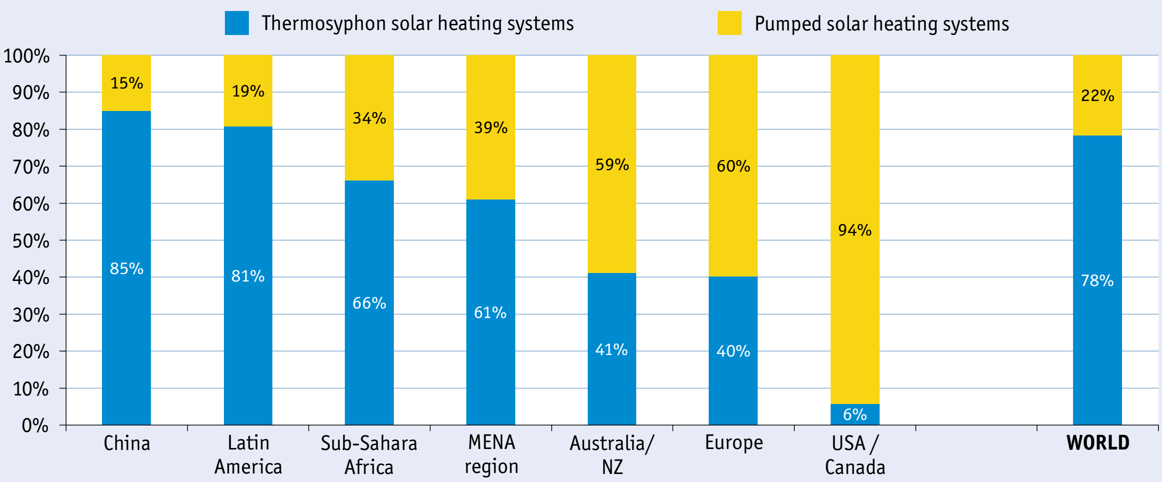
Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China: India, Japan, South Korea, Taiwan Thailand
Latin America: Argentona, Brazil, Chile, Mexico, Uruguay
Europe: EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 53: *Distribution by type of solar thermal collector for the newly installed water collector capacity in 2017*

7.2 Distribution by type of system

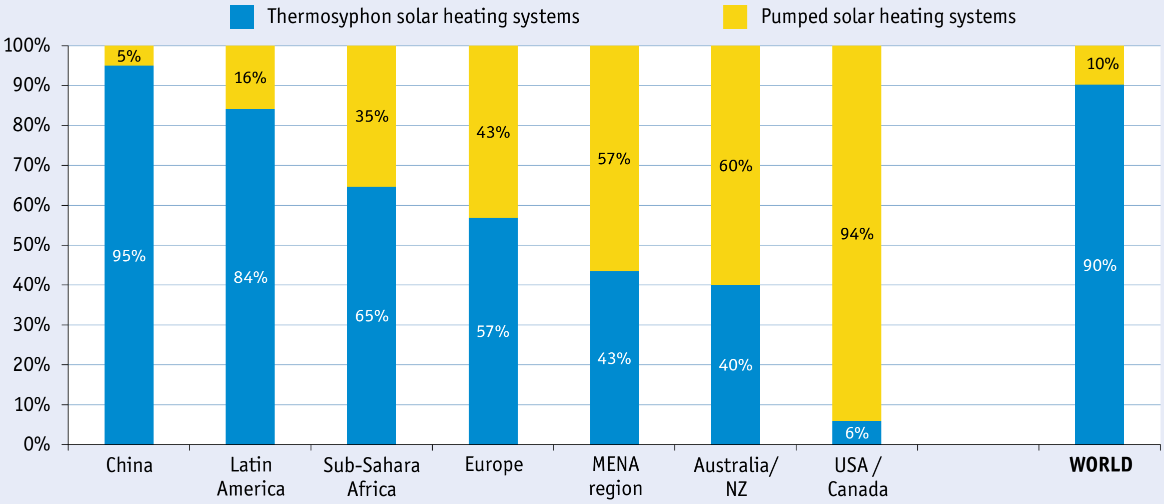
Worldwide, more than three quarters of all solar thermal systems installed are thermosiphon systems and the rest are pumped solar heating systems (**Figure 54**). Similar to the distribution by type of solar thermal collector in total numbers, the Chinese market influenced the overall figures the most. In 2017, 90 % of the newly installed systems were estimated to be thermosiphon systems while pumped systems only accounted for 10 % (**Figure 55**).

In general, thermosiphon systems are more common in warm climates such as in Africa, South America, southern Europe and the MENA countries. In these regions thermosiphon systems are more often equipped with flat plate collectors, while in China the typical thermosiphon system for domestic hot water preparation is equipped with evacuated tubes.



Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China: India, Japan, South Korea, Taiwan Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 54: *Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2017*

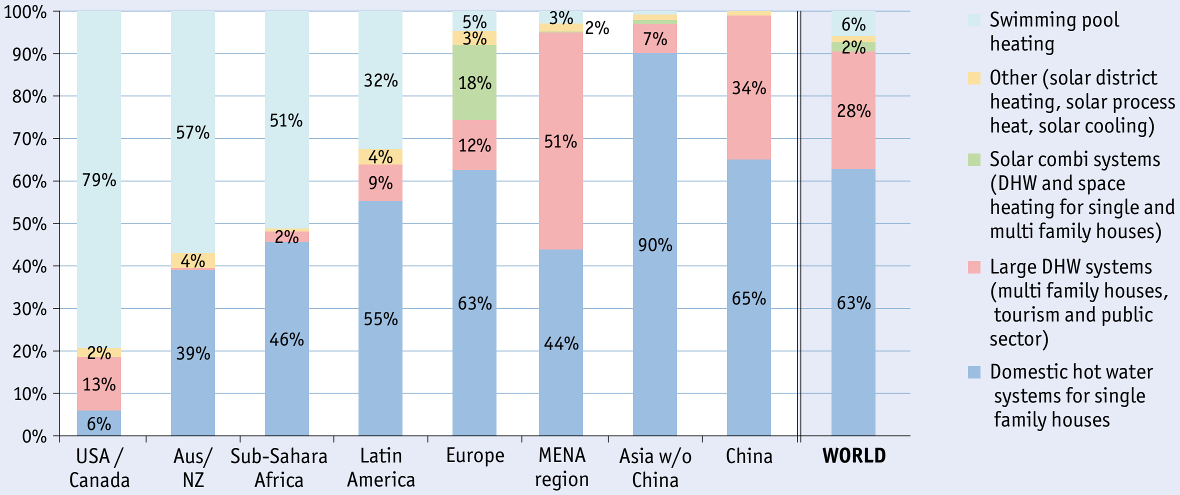


Sub-Sahara Africa:	Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 55: Distribution by type of system for the newly installed glazed water collector capacity in 2017

7.3 Distribution by type of application

By the end of 2017, 675 million square meters of water-based solar thermal collectors, corresponding to a thermal peak capacity of 472 GW_{th}, were in operation worldwide (Table 6). Out of these, 6 % were used for swimming pool heating, 63 % were used for domestic hot water preparation in single-family houses and 28 % were attached to larger domestic hot water systems for multifamily houses, hotels, hospitals, schools, etc. Around 2 % of the worldwide installed capacity supplied heat for both domestic hot water and space heating (solar combi-systems). The remaining systems accounted for around 1 % and delivered heat to other applications such as district heating networks, industrial processes or thermally driven solar cooling applications (Figure 56). Considering typical solar thermal system sizes for the mentioned applications in the different countries covered in this report the number of systems in operation worldwide is calculated to be around 118 million.



For an explanation of the regional units please see figure 55

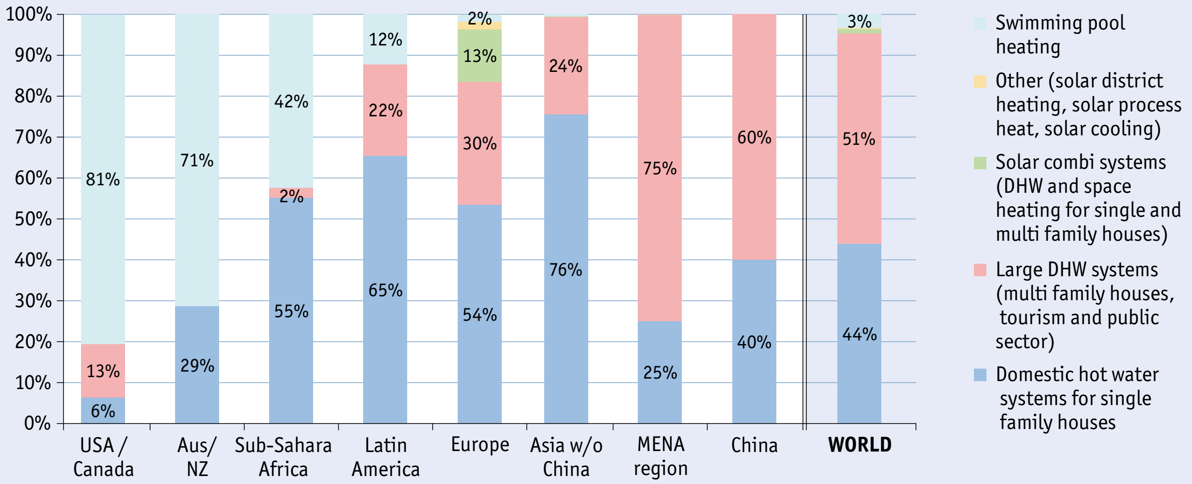
Figure 56: Distribution of solar thermal systems by application for the total installed water collector capacity by economic region in operation by the end of 2017

The newly installed water-based solar thermal collector area amounted to 49.5 million square meters, which corresponds to 34.6 GW of thermal peak capacity (Table 8).

Compared to the cumulated installed capacity, the share of swimming pool heating was less for new installations (6 % of total capacity and 3 % of newly installed capacity). A similar trend can be seen for several years now for domestic hot water systems in single-family homes: 63 % of total capacity in operation and 44 % of new installations in 2017 make this system the most common application worldwide but is showing a downward trend.

By contrast, the share of large-scale domestic hot water applications basically tends to increase (28 % of total capacity and 51 % of newly installed capacity). It can be assumed that this market segment took over some of the market shares from both swimming pool heating and domestic hot water systems in single-family homes.

The share of applications such as solar district heating and solar process heat is still on a low level of 1 % globally (Figure 57).



Sub-Sahara Africa:	Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w / o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA countries:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 57: *Distribution of solar thermal systems by application for the newly installed water collector capacity by economic region in 2017*

8 Levelized cost of solar thermal generated heat

In this chapter Levelized Cost of solar thermal generated heat for different solar thermal systems and applications are summarized. The costs of solar heat presented are based on a data collected in 12 countries in 2016: Australia, Austria, Brazil, Canada, China, Denmark, France, Germany, India, Israel, South Africa and Turkey.

Since system costs have not changed significantly in the past three years, the costs presented below still provide a good indication. The Levelized Cost of Heat ($LCOH_{Coll}$[21]) shown here refer to the energy yield of the collector, but taking into account the total costs of the respective solar thermal system[22].

System type	Typical collector size [m²]	$LCOH_{Coll}$ €-ct/kWh
Pool heating systems	30 – 300	1
Thermosiphon domestic hot water systems	2 – 4	7
Pumped domestic hot water systems	4 – 6	12
Pumped domestic hot water systems in multi-family homes	50	8
Solar combi systems for hot water preparation and space heating	15 – 40	14
Solar district heating systems	10,000	4

Table 11: *Levelized Cost of solar thermal generated heat for different applications*

Demonstration system at Matopo Highschool in Zimbabwe with a collector area of 13 m². *Photo: SOLTRAIN / AEE INTEC*

21 $LCOH_{coll}$: Levelized cost of heat based on the collector output and the system cost including operation and maintenance cost. For detailed information please see former editions of this report.

22 For a detailed analysis and presentation of costs, see the editions 2017 and 2018 of Solar Heat Worldwide: http://www.iea-shc.org/solar-heat-worldwide-past

9 Appendix

9.1 Methodological approach for the energy calculation

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

- Only water collectors were used in the calculations (unglazed water collectors, flat-plate collectors and evacuated tube collectors). Air collectors were not included.
- For each country, the cumulated water collector area was allocated to the following applications (based on available country market data):
  - Solar thermal systems for swimming pool heating
  - Solar domestic hot water systems for single-family houses,
  - Solar domestic hot water systems for multifamily houses including the tourism sector as well as the public sector (to simplify the analysis solar district heating systems, solar process heat and solar cooling applications were also allocated here), and
  - Solar combi-systems for domestic hot water and space heating for single- and multi-family houses.
- Reference systems were defined for each country and for each type of application (pumped or thermosiphon solar thermal system).
- The number of systems per country was determined from the share of collector area for each application and the collector area defined for the reference system.

Apart from the reference applications and systems mentioned above, reference collectors and reference climates were determined. On the basis of these boundary conditions, simulations were performed with the simulation program T-Sol [T-Sol, Version 4.5 Expert, Valentin Energiesoftware, www.valentin-software.com] and gross solar yields for each country and each system were obtained. The gross solar yields refer to the solar collector heat output and do not include heat losses through transmission piping or storage heat losses[23].

The amount of final energy saved is calculated from the gross solar yields considering a utilization rate of the auxiliary heating system of 0.8. Final energy savings are expressed in tons of oil equivalent (toe): 1 toe = 11,630 kWh.

Finally, the CO_2 emissions avoided by the different solar thermal applications are quoted as kilograms carbon dioxide equivalent ($kgCO_2e$) per tons of oil equivalent: 1 toe = 3.228 t CO_2e[24]. The emission factor only account for direct emissions.

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 report, the energy savings and the CO_2 emissions avoided therefore relate to fuel oil. It is obvious that not all solar thermal systems just replace systems running on oil. This represents a simplification since gas, coal, biomass or electricity can be used as an energy source for the auxiliary heating system instead of oil.

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

23 Using gross solar yields for the energy calculations is based on a definition for Renewable Heat by EUROSTAT and IEA SHC. In editions of this report prior to 2011 solar yields calculated included heat losses through transmission piping and hence energy savings considered were about 5 to 15 % less depending on the system, the application and the climate.

24 Source: Defra / DECC 2013

9.1.1 Reference systems for swimming pool heating

The information in Table 12 refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2017.

Country*	Reference climate	Horizontal irradiation [kWh/m²·a]	Total collector area (swimming pool) [m²]	Collector area per system [m²]	Total number of systems	Specific solar yield (swimming pool) [kWh/m²·a]
Argentina	Buenos Aires	1,748	9,318	200	47	471
Australia	Sydney	1,674	5,218,762	35	149,107	466
Austria	Graz	1,126	585,853	200	2,929	283
Belgium	Brussels	971	30,889	200	154	262
Brazil	Brasília	1,793	4,833,323	32	151,041	375
Bulgaria	Sofia	1,188	6,531	200	33	320
Canada	Montreal	1,351	540,907	25	21,636	386
Chile	Santiago de Chile	1,753	70,538	15	4,703	473
Croatia	Zagreb	1,212	9,818	200	49	327
Cyprus	Nicosia	1,886	1,852	200	9	508
Czech Republic	Praha	998	678,456	200	3,392	303
Estonia	Tallin	960	747	200	4	259
Finland	Helsinki	948	3,056	200	15	256
France (mainland)	Paris	1,112	148,589	200	743	328
Germany	Würzburg	1,091	601,666	30	20,056	314
Greece	Athens	1,585	215,365	200	1,077	427
Hungary	Budapest	1,199	35,217	10	3,522	344
India	Neu-Delhi	1,961	114,421	16	7,151	529
Israel	Jerusalem	2,198	188,457	200	942	568
Italy	Bologna	1,419	213,338	200	1,067	442
Jordan	Amman	2,145	6,661	200	33	578
Korea, South	Seoul	1,161	15,072	200	75	313
Latvia	Riga	991	647	200	3	267
Lebanon	Beirut	1,935	7,880	17	478	522
Lithuania	Vilnius	1,001	781	200	4	270
Luxembourg	Luxembourg	1,037	2,922	200	15	280
Mexico	Mexico City	1,706	1,399,528	200	6,998	311
Morocco	Rabat	2,000	18,040	200	90	539
Netherlands	Amsterdam	999	104,043	40	2,601	272
New Zealand	Wellington	1,401	11,175	200	56	378
Northern Macedonia	Skopje	1,381	802	20	40	372
Norway	Oslo	971	1,847	200	9	316
Palestine	Jerusalem	2,198	69,864	200	349	593
Portugal	Lisbon	1,686	5,297	200	26	421
Romania	Bucharest	1,324	8,837	200	44	357
Russia	Moscow	996	96	200	0	269
Slovakia	Bratislava	1,214	7,774	200	39	327
Slovenia	Ljubjana	1,115	1,479	200	7	301
South Africa	Johannesburg	2,075	1,166,412	40	29,160	505
Spain	Madrid	1,644	205,265	200	1,026	472
Sweden	Gothenburg	934	156,004	200	780	295
Switzerland	Zürich	1,094	277,229	200	1,386	277
Taiwan	Taipei	1,372	14,510	175	83	319
Thailand	Bangkok	1,765	1,269	300	4	476
United Kingdom	London	943	287,099	200	1,435	254
United States	LA, Indianapolis	1,646	20,301,021	200	101,505	387
Other (5%)		1,458	2,047,600	200	10,238	393
	TOTAL		39,626,260		524,165	
	AVERAGE	1,411		161		393

*Countries not listed in this table did not report any share of collectors used for swimming pool heating.

Table 12: Solar thermal systems for swimming pool heating in 2017

Figure 58 shows the hydraulic scheme of the swimming pool reference system as used for the simulations of the solar energy yields.

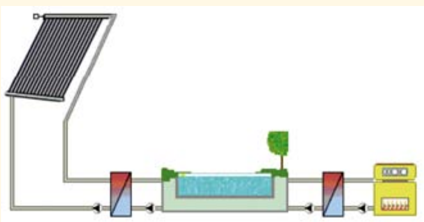


Figure 58: Hydraulic scheme of the swimming pool reference system

9.1.2 Reference systems for domestic hot water preparation in single-family houses

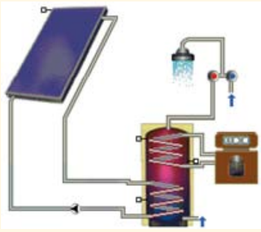
The information in Table 13 refers to the total capacity of water collectors in operation used for domestic hot water heating in single-family houses at the end of 2017 as reported by each country.

Country	Reference climate	Horizontal irradiation [kWh/m²·a]	Total coll. area (DHW-SFH) [m²]	Coll. area per system [m²]	Total number of systems	Specific solar yield (DHW-SFH) [kWh/m²·a]
Albania	Tirana	1,604	142,348	3	47,449	713
Argentina	Buenos Aires	1,748	22,230	4	5,557	777
Australia	Sydney	1,674	3,467,136	4	990,610	844
Austria	Graz	1,126	2,151,494	6	358,582	451
Barbados	Grantley Adams	2,016	225,720	4	56,430	882
Belgium	Brussels	971	410,394	4	102,599	423
Botswana	Gaborone	2,161	7,380	4	1,845	961
Brazil	Brasília	1,793	8,555,434	2	4,277,717	809
Bulgaria	Sofia	1,188	86,778	4	21,694	524
Burkina Faso	Ougadougou	2,212	477	4	119	983
Canada	Montreal	1,351	40,760	6	6,793	556
Cape Verde	Praia	2,096	535	4	134	932
Chile	Santiago de Chile	1,753	123,109	2	61,555	771
China	Shanghai	1,282	310,622,000	4	77,655,500	592
Croatia	Zagreb	1,212	130,440	4	32,610	539
Cyprus	Nicosia	1,886	666,010	2	333,005	912
Czech Republic	Praha	998	255,040	5	54,264	385
Denmark	Copenhagen	989	257,569	4	64,392	454
Estonia	Tallin	960	9,926	4	2,482	432
Finland	Helsinki	948	40,599	4	10,150	441
France	Paris	1,112	1,794,080	3	560,650	496
Germany	Würzburg	1,091	8,575,734	6	1,531,381	424
Ghana	Accra	2,146	210	4	52	954
Greece	Athens	1,585	2,861,401	3	1,144,560	772
Hungary	Budapest	1,199	175,491	5	35,098	473
India	Neu-Delhi	1,961	10,011,816	2	5,005,908	882
Ireland	Dublin	949	327,195	4	81,799	423
Israel	Jerusalem	2,198	848,058	3	282,686	1,024
Italy	Bologna	1,419	2,834,466	4	708,616	661
Japan	Tokyo	1,175	3,483,910	4	870,977	586
Jordan	Amman	2,145	1,003,076	5	218,060	986
Korea, South	Seoul	1,161	1,696,093	4	424,023	525
Latvia	Riga	991	8,602	4	2,150	462
Lebanon	Beirut	1,935	468,861	4	117,215	860
Lesotho	Maseru	2,050	641	2	320	911
Lithuania	Vilnius	1,001	10,379	4	2,595	450
Luxembourg	Luxembourg	1,037	38,816	4	9,704	450
Malta	Luqa	1,902	52,319	3	20,928	868
Mauritius	Port Louis	1,920	132,793	2	88,529	854
Mexico	Mexico City	1,706	1,763,405	4	440,851	718
Morocco	Rabat	2,000	225,500	4	56,375	889
Mozambique	Maputo	1,910	1,317	4	329	849
Namibia	Windhoek	2,363	19,096	4	4,774	1,032
Netherlands	Amsterdam	999	409,670	3	146,311	433
New Zealand	Wellington	1,401	127,716	4	31,929	647
Nigeria	Abuja	2,007	661	4	165	892
Northern Macedonia	Skopje	1,381	72,156	4	18,039	627
Norway	Oslo	971	1,535	6	256	430
Palestine	Jerusalem	2,198	873,297	2	582,198	977
Poland	Warsaw	1,024	1,574,363	6	262,394	397
Portugal	Lisbon	1,686	736,259	4	184,065	804
Romania	Bucharest	1,324	117,412	4	29,353	594
Russia	Moscow	996	3,319	4	830	443
Senegal	Dakar	2,197	1,769	4	442	977
Slovakia	Bratislava	1,214	103,291	6	17,215	481
Slovenia	Ljubljana	1,115	137,547	6	22,925	424
South Africa	Johannesburg	2,075	841,978	2	443,146	1,009
Spain	Madrid	1,644	1,642,117	4	410,529	766
Sweden	Gothenburg	934	40,801	4	10,200	383
Switzerland	Zürich	1,094	925,425	6	162,355	426
Taiwan	Taipei	1,372	1,602,412	5	333,836	616
Thailand	Bangkok	1,765	142,833	4	35,708	854
Tunisia	Tunis	1,808	942,008	3	285,457	902
Turkey	Antalya	1,795	21,397,025	4	5,349,256	910
United Kingdom	London	943	512,620	4	128,155	415
United States	LA, Indianapolis	1,646	1,522,577	6	253,763	646
Uruguay	Montevideo	1,534	69,393	4	17,348	682
Zimbabwe	Harare	2,017	35,107	2	17,554	854
All other countries (5%)		1,407	27,097,102	4	6,774,275	626
	TOTAL		424,479,028		111,208,774	
	AVERAGE	1,530		4		684

PS: pumped system   TS: thermosiphon system   PDS: pumped drain back system

Table 13: Solar thermal systems for domestic hot water heating in single-family houses by the end of 2017

Figure 59 shows the hydraulic scheme used for the energy calculation for all pumped solar thermal systems and **Figure 60** refers to the thermosiphon systems.



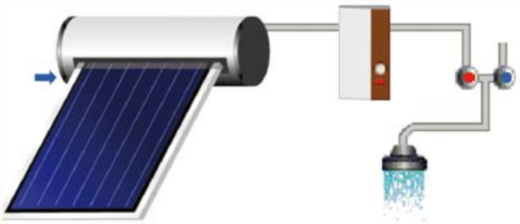


Figure 59, 60: *Hydraulic scheme of the domestic hot water pumped reference system for single-family houses and hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses*

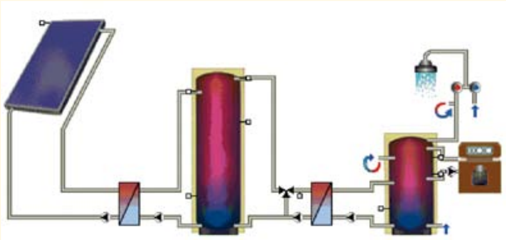
For the Chinese thermosiphon systems the reference system above was used, but instead of a flat plate collector as shown in **Figure 60** a representative Chinese vacuum tube collector was used for the simulation.

9.1.3 Reference systems for domestic hot water preparation in multifamily houses

The information in **Table 14** refers to the total capacity of water collectors in operation used for domestic hot water heating in multi-family houses at the end of 2017 as reported by each country.

Figure 61 shows the hydraulic scheme of domestic hot water reference system for multifamily houses as used for the simulations of the solar energy yields. As opposed to small-scale domestic hot water systems, all large-scale systems are assumed to be pumped solar thermal systems.

Figure 62 shows the hydraulic scheme of domestic hot water reference system for multifamily houses as used for the simulations of the solar energy yields.



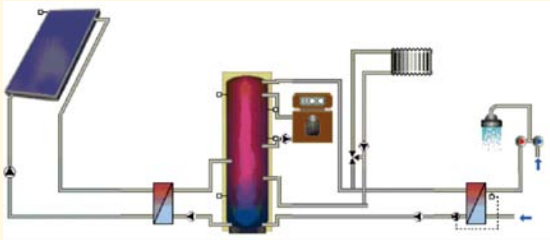


Figure 61, 62: *Hydraulic scheme of the domestic hot water pumped reference system for multifamily houses and hydraulic scheme of the solar-combi reference system for single and multifamily houses*

Country	Reference climate	Horizontal irradiation [kWh/m²·a]	Total collector area (DHW-MFH) [m²]	Collector area per system [m²]	Total number of systems	Specific solar yield (DHW-MFH) [kWh/m²·a]
Albania	Tirana	1,604	89,867	50	1,797	694
Argentina	Buenos Aires	1,748	12,912	50	258	730
Australia	Sydney	1,674	343,102	50	6,862	725
Austria	Graz	1,126	401,281	50	8,026	505
Belgium	Brussels	971	93,316	50	1,866	405
Botswana	Gaborone	2,161	4,920	30	164	902
Brazil	Brasília	1,793	1,484,644	60	24,744	658
Bulgaria	Sofia	1,188	19,732	50	395	515
Burkina Faso	Ougadougou	2,212	2,973	30	99	923
Canada	Montreal	1,351	344,610	50	6,892	621
Cape Verde	Praia	2,096	1,248	50	25	875
Chile	Santiago de Chile	1,753	139,080	50	2,782	732
China	Shanghai	1,282	167,258,000	50	3,345,160	502
Croatia	Zagreb	1,212	29,660	50	593	506
Cyprus	Nicosia	1,886	88,137	50	1,763	750
Czech Republic	Praha	998	38,910	42	918	436
Denmark	Copenhagen	989	1,325,578	50	26,512	413
Estonia	Tallin	960	2,257	50	45	401
Finland	Helsinki	948	9,232	50	185	396
France	Paris	1,112	809,182	20	40,459	489
Germany	Würzburg	1,091	2,317,596	50	46,352	472
Ghana	Accra	2,146	2,171	30	72	896
Greece	Athens	1,585	650,630	50	13,013	642
Hungary	Budapest	1,199	35,311	50	706	522
India	Neu-Delhi	1,961	1,315,839	50	26,317	749
Ireland	Dublin	949	10,907	50	218	425
Israel	Jerusalem	2,198	3,674,919	3	1,224,973	917
Italy	Bologna	1,419	644,506	50	12,890	592
Japan	Tokyo	1,175	7,629	50	153	516
Jordan	Amman	2,145	250,769	50	5,015	801
Korea, South	Seoul	1,161	139,236	50	2,785	485
Latvia	Riga	991	1,956	50	39	414
Lebanon	Beirut	1,935	311,261	40	7,782	807
Lesotho	Maseru	2,050	1,398	10	140	856
Lithuania	Vilnius	1,001	2,360	50	47	418
Luxembourg	Luxembourg	1,037	8,826	50	177	433
Mexico	Mexico City	1,706	755,745	50	15,115	713
Morocco	Rabat	2,000	202,950	50	4,059	835
Mozambique	Maputo	1,910	969	50	19	797
Namibia	Windhoek	2,363	23,339	50	467	814
Netherlands	Amsterdam	999	104,043	40	2,601	418
New Zealand	Wellington	1,401	15,965	50	319	585
Nigeria	Abuja	2,007	263	1	188	838
Northern Macedonia	Skopje	1,381	6,414	50	128	577
Norway	Oslo	971	16,791	50	336	406
Palestine	Jerusalem	2,198	785,967	50	15,719	917
Poland	Warsaw	1,024	562,273	50	11,245	447
Portugal	Lisbon	1,686	317,810	40	7,945	705
Romania	Bucharest	1,324	26,697	50	534	553
Russia	Moscow	996	19,480	50	390	416
Senegal	Dakar	2,197	55	5	12	917
Slovakia	Bratislava	1,214	23,486	50	470	507
Slovenia	Ljubljana	1,115	1,479	50	30	477
South Africa	Johannesburg	2,075	30,017	87	345	866
Spain	Madrid	1,644	1,929,488	50	38,590	676
Sweden	Gothenburg	934	55,201	50	1,104	430
Switzerland	Zürich	1,094	110,498	20	5,525	457
Taiwan	Taipei	1,372	90,132	30	3,004	518
Thailand	Bangkok	1,765	11,726	80	147	737
Tunisia	Tunis	1,808	28,134	50	563	755
Turkey	Antalya	1,795	1,860,611	80	23,258	749
United States	LA, Indianapolis	1,646	3,552,679	50	71,054	687
Zimbabwe	Harare	2,017	6,618	32	207	842
All other countries (5%)		1,407	3,414,741	50	68,295	525
	TOTAL		195,827,523		5,081,890	
	AVERAGE	1,520		46		631

Table 14: *Solar thermal systems for domestic hot water heating in multifamily houses by the end of 2017*

9.1.4 Reference systems for domestic hot water preparation and space heating in single and multifamily houses (solar combi-systems)

The information in Table 15 refers to the total capacity of water collectors in operation used for solar combi systems in single and in multifamily houses at the end of 2017 as reported by each country.

Country	Reference climate	Horizontal irradiation [kWh/m²·a]	Total collector area (Combi systems) [m²]	Collector area per system [m²]	Total number of systems	Spec. solar yield (Combi systems) [kWh/m²·a]
Austria	Graz	1,126	2,029,529	14	144,966	369
Belgium	Brussels	2,016	127,734	12	10,645	342
Bulgaria	Sofia	1,793	27,009	12	2,251	418
Canada	Montreal	2,212	93	12	8	476
Croatia	Zagreb	1,282	40,599	12	3,383	426
Cyprus	Nicosia	1,212	12,263	12	1,022	663
Czech Republic	Praha	1,886	206,697	9	24,317	351
Denmark	Copenhagen	998	57,420	8	7,177	348
Estonia	Tallin	989	3,090	12	257	338
Finland	Helsinki	960	12,636	12	1,053	334
Germany	Würzburg	1,112	8,130,583	12	707,007	378
Greece	Athens	2,146	890,603	12	74,217	558
Hungary	Budapest	1,585	67,581	10	6,758	422
Ireland	Dublin	1,961	25,449	12	2,121	364
Italy	Bologna	2,198	882,220	12	73,518	499
Japan	Tokyo	1,419	141,681	12	11,807	414
Korea, South	Seoul	2,145	20,283	12	1,690	409
Latvia	Riga	1,161	2,677	12	223	349
Lesotho	Maseru	1,935	8	12	1	721
Lithuania	Vilnius	2,050	3,230	12	269	352
Luxembourg	Luxembourg	1,001	12,081	12	1,007	365
Morocco	Rabat	2,000	4,510	12	376	704
Netherlands	Amsterdam	1,706	32,514	6	5,419	352
New Zealand	Wellington	2,000	4,789	12	399	493
Northern Macedonia	Skopje	1,037	802	10	80	486
Norway	Oslo	2,363	24,026	15	1,602	342
Palestine	Jerusalem	999	17,466	12	1,455	773
Poland	Warsaw	1,401	112,455	12	9,371	365
Romania	Bucharest	971	36,544	12	3,045	466
Russia	Moscow	2,198	1,154	15	77	350
Slovakia	Bratislava	1,686	32,149	12	2,679	427
Spain	Madrid	996	328,423	10	32,842	619
Sweden	Gothenburg	2,197	292,808	10	29,281	389
Switzerland	Zürich	1,214	345,308	11	31,392	385
Thailand	Bangkok	2,075	1,708	12	142	621
All other countries (5%)		1,145	1,193,684	12	99,474	403
	TOTAL		15121806		1291332	
	AVERAGE	1588		12		448

Combi-system: system for the supply of domestic hot water and space heating

Table 15: Solar combi system reference for single and multifamily houses and the total collector area in operation in 2017

9.2 Reference collectors

9.2.1 Data of the reference unglazed water collector for swimming pool heating

$\eta = 0.85$ $a_1 = 20$ [W/m²K] $a_2 = 0.1$ [W/m² K²]

9.2.2 Data of the reference collector for all other applications except for China

$\eta = 0.8$ $a_1 = 3.69$ [W/m²K] $a_2 = 0.007$ [W/m² K²]

9.2.3 Data of the Chinese reference vacuum tube collector

$\eta = 0.74$ $a_1 = 2.5$ [W/m²K] $a_2 = 0.013$ [W/m² K²]

9.3 Methodological approach for the cost calculation

The economic performance of the investigated solar thermal systems in **Chapter 8** is quantified using the levelized cost of energy *(LCOE)* approach (e.g., acc. to /[25]/). The idea of this approach is to compare the total costs *(C)* related to an energy supply system with the resulting energy supplied by this system *(E)*. Since both the costs as well as the energy supplied are subject to the time preference of the investors, both terms are discounted at the interest rate *r* with an economic assessment period of *t*. *LCOE* are calculated according to Eq. 1.

$$LCOE = \frac{\sum_{t=1}^{t_{ges}} C_t \cdot (1+r)^{-t}}{\sum_{t=1}^{t_{ges}} E_t \cdot (1+r)^{-t}} \qquad \text{(Eq. 1)}$$

The calculation of levelized cost of solar thermal generated heat *LCOH* in this report is derived from Equation 1 and may be expressed as the following:

$$LCOE = \frac{I_0 + \sum_{t=1}^{t_{ges}} A_t \cdot (1+r)^{-t}}{\sum_{t=1}^{t_{ges}} SE \cdot (1+r)^{-t}} \qquad \text{(Eq. 2)}$$

LCOH	levelized cost of solar thermal generated heat [€/kWh]
A_t	fixed and variable O&M expenditures in the year *t* [€/m²$_{gross}$]
r	discount (interest) rate [%]
t	year within the period of use (1,2,... t_{ges})
I_0	specific solar thermal system costs incl. installation (excl. VAT and subsidies) [€/m²$_{gross}$]
SE	solar energy yield in the year *t* [kWh/m²$_{gross}$]
t_{ges}	period of use (solar thermal system life time in years) [a]

All technical and economical parameters of the investigated solar thermal systems are elaborated for both the solar loop and solar energy storage. Conventional heat supply is not considered.

All specific benchmark figures are referred to gross collector area installed (e.g., € / m²$_{gross}$, kWh / m²$_{gross}$).

Cost data refer to end-user (customer) prices excluding value added taxes or subsidies. Solar energy yield *SE* is referred to as *specific* annual thermal energy delivered by the solar thermal collector in kWh per m² gross collector area installed (thermal losses in solar loop piping and thermal energy storage not considered).

Calculation of levelized cost of solar thermal generated heat *LCOH* in this report is based on following assumptions for all systems:

- Discount (interest) rate r = 3 %
- Annual O&M expenditures A_t = 0.5 % of specific costs incl. installation I_0 in case of pumped systems
- Annual O&M expenditures A_t = 0.25 % of specific costs incl. installation I_0 in case of thermosiphon systems
- Period of use (solar thermal system life time) t_{ges} = 25 years for all pumped systems (except China: 15 years) and 10 years for all thermosiphon systems (except Australia: 15 years).

25 Branker, K., Pathak, M.J.M., Pearce, J.M., 2011. A review of solar photovoltaic levelized cost of electricity. Renewable and Sustainable Energy Reviews 15, 4470–4482.

9.4 Methodological approach for the job calculation

The job calculation is based on a comprehensive literature study, information provided by the China National Renewable Energy Centre and IRENA as well as data collected from different country market reports. Based on this information the following assumptions were taken to calculate the number of full-time jobs:

In countries with high labor cost, advanced automated production of flat plate or evacuated tube collectors and heat storages – pumped systems with a total of 133 m² solar collector area have to be installed on average per full time job. In countries with low labor cost and advanced automated production of evacuated tube collectors and heat storages – thermosiphon systems with a total of 87 m² solar collector area have to be installed per full time job on average. The same collector area has to be installed per full time job in countries with mainly manual flat plate collector production and low labor cost. For swimming pool systems with unglazed polymeric collectors or air collectors around 200 m² solar collector area have to be installed per full time job.

The numbers presented are full time jobs and consider production, installation and maintenance of solar thermal systems.

144 m² collector area at Barnato Hall student residences at the University of the Witwatersrand, South Africa.

Photo: SOLTRAIN / AEE INTEC

9.5 Reference climates

No.	Country	Reference climate	Horizontal irradiation [kWh/m²·a]	Inclined irradiation [kWh/m²·a]	Avg. Outside air temp. [°C]
1	Albania	Tirana	1,604	1,835	13.5
2	Argentina	Buenos Aires	1,748	1,971	17.5
3	Australia	Sydney	1,674	1,841	18.1
4	Austria	Graz	1,126	1,280	9.2
5	Barbados	Grantley Adams	2,016	2,048	27.4
6	Belgium	Brussels	971	1,095	10.0
7	Botswana	Gaborone	2,161	2,365	18.0
8	Brazil	Brasília	1,793	1,838	22.0
9	Bulgaria	Sofia	1,188	1,304	10.1
10	Burkina Faso	Ouagadougou	2,212	2,270	25.0
11	Canada	Montreal	1,351	1,568	6.9
12	Cape Verde	Praia	2,096	2,168	23.6
13	Chile	Santiago de Chile	1,753	1,850	14.5
14	China	Shanghai	1,282	1,343	17.1
15	Croatia	Zagreb	1,212	1,352	11.3
16	Cyprus	Nicosia	1,886	2,098	19.9
17	Czech Republic	Praha	998	1,111	7.9
18	Denmark	Copenhagen	989	1,164	8.1
19	Estonia	Tallin	960	1,126	5.3
20	Finland	Helsinki	948	1,134	4.6
21	France	Paris	1,112	1,246	11.0
22	Germany	Würzburg	1,091	1,225	9.5
23	Ghana	Accra	2,146	2,161	23.7
24	Greece	Athens	1,585	1,744	18.5
25	Hungary	Budapest	1,199	1,346	11.0
26	India	Neu-Delhi	1,961	2,275	24.7
27	Ireland	Dublin	949	1,091	9.5
28	Israel	Jerusalem	2,198	2,400	17.3
29	Italy	Bologna	1,419	1,592	14.3
30	Japan	Tokyo	1,175	1,287	16.7
31	Jordan	Amman	2,145	2,341	17.9
32	Korea, South	Seoul	1,161	1,280	12.7
33	Latvia	Riga	991	1,187	6.3
34	Lebanon	Beirut	1,935	2,132	19.9
35	Lesotho	Maseru	2,050	2,290	15.2
36	Lithuania	Vilnius	1,001	1,161	6.2
37	Luxembourg	Luxembourg	1,037	1,158	8.4
38	Malta	Luqa	1,902	2,115	18.7
39	Mauritius	Port Louis	1,920	2,010	23.3
40	Mexico	Mexico City	1,706	1,759	16.6
41	Morocco	Rabat	2,000	2,250	17.2
42	Mozambique	Maputo	1,910	2,100	22.8
43	Namibia	Windhoek	2,363	2,499	21.0
44	Netherlands	Amsterdam	999	1,131	10.0
45	New Zealand	Wellington	1,401	1,542	13.6
46	Nigeria	Abuja	2,007	2,051	25.7
47	Northern Macedonia	Skopje	1,381	1,521	12.5
48	Norway	Oslo	971	1,208	5.8
49	Palestine	Jerusalem	2,198	2,400	17.3
50	Poland	Warsaw	1,024	1,156	8.1
51	Portugal	Lisbon	1,686	1,875	17.4
52	Romania	Bucharest	1,324	1,473	10.6
53	Russia	Moscow	996	1,181	5.9
54	Senegal	Dakar	2,197	2,259	24.9
55	Slovakia	Bratislava	1,214	1,374	10.3
56	Slovenia	Ljubjana	1,115	1,231	9.8
57	South Africa	Johannesburg	2,075	2,232	15.6
58	Spain	Madrid	1,644	1,844	15.5
59	Sweden	Gothenburg	934	1,105	7.2
60	Switzerland	Zürich	1,094	1,218	9.6
61	Taiwan	Taipei	1,372	1,398	20.8
62	Thailand	Bangkok	1,765	1,898	29.1
63	Tunisia	Tunis	1,808	2,038	19.3
64	Turkey	Antalya	1,795	1,958	18.4
65	United Kingdom	London	943	1,062	12.0
66	United States	LA, Indianapolis	1,646	1,816	14.3
67	Uruguay	Montevideo	1,534	1,647	15.9
68	Zimbabwe	Harare	2,017	2,087	18.9

Table 16: *Reference climates for the 68 countries surveyed*

Source: T-Sol expert version 4.5 and Meteonorm version 6.1 and Global Solar Atlas (The Worldbank Group 2016).

9.6 Population data

No	Country	2017	Reg. code
1	Albania	3,047,987	6
2	Argentina	44,293,293	4
3	Australia	23,232,413	3
4	Austria	8,754,413	6
5	Barbados	292,336	4
6	Belgium	11,491,346	6
7	Botswana	2,214,858	1
8	Brazil	207,353,391	4
9	Bulgaria	7,101,510	6
10	Burkina Faso	19,199,732	1
11	Canada	35,623,680	8
12	Cape Verde	560,899	1
13	Chile	17,789,267	4
14	China	1,379,302,771	5
15	Croatia	4,292,095	6
16	Cyprus	1,221,549	6
17	Czech Republic	10,674,723	6
18	Denmark	5,773,437	6
19	Estonia	1,251,581	6
20	Finland	5,518,371	6
21	France	67,106,161	6
22	Germany	80,594,017	6
23	Ghana	27,500,000	1
24	Greece	10,768,477	6
25	Hungary	9,850,845	6
26	India	1,281,935,911	2
27	Ireland	5,011,102	6
28	Israel	8,299,706	7
29	Italy	62,137,802	6
30	Japan	126,451,398	2
31	Jordan	10,248,069	7
32	Korea, South	51,181,299	2
33	Latvia	1,944,643	6
34	Lebanon	6,229,794	7
35	Lesotho	1,958,042	1
36	Lithuania	2,823,859	6
37	Luxembourg	594,130	6

No	Country	2017	Reg. code
38	Malta	444,457	6
39	Mauritius	1,356,388	1
40	Mexico	124,574,795	4
41	Morocco	33,986,655	7
42	Mozambique	26,573,706	1
43	Namibia	2,484,780	1
44	Netherlands	17,084,719	6
45	New Zealand	4,510,327	3
46	Nigeria	198,346,055	1
47	Northern Macedonia	2,114,760	6
48	Norway	5,320,045	6
49	Palestine	4,543,126	7
50	Poland	38,476,269	6
51	Portugal	10,383,790	6
52	Romania	21,529,967	6
53	Russia	142,257,519	6
54	Senegal	14,668,522	1
55	Slovakia	5,445,829	6
56	Slovenia	2,101,416	6
57	South Africa	54,841,552	1
58	Spain	48,958,159	6
59	Sweden	9,960,487	6
60	Switzerland	8,236,303	6
61	Taiwan	23,508,428	2
62	Thailand	68,414,135	2
63	Tunisia	11,403,800	7
64	Turkey	80,845,215	6
65	United Kingdom	64,769,452	6
66	United States	325,719,178	8
67	Uruguay	3,360,148	4
68	Zimbabwe	13,805,084	1
	All other countries (5%)	2,510,522,254	9
Σ Solar Thermal World Statistics		4,913,649,973	66%
Σ Inhabitants world		7,424,172,227	

Table 17: *Inhabitants by the end of 2017 of the 68 surveyed countries in alphabetical order*

Data source: International Data Base of the U.S. Census Bureau

Region Code / Region		Σ Inhabitants	Share
1	Sub-Sahara Africa	363,509,618	5%
2	Asia excl. China	1,551,491,171	21%
3	Australia / New Zealand	27,742,740	0%
4	Latin America	397,663,230	5%
5	China	1,379,302,771	19%
6	Europe	757,886,435	10%
7	MENA Region	74,711,150	1%
8	United States / Canada	361,342,858	5%
9	Other countries	2,510,522,254	34%
TOTAL		7,424,172,227	100%

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde Ghana, Namibia, Nigeria, Mozambique, Senegal, South Africa, Zimbabwe
Asia excluding China: India, Japan, Korea South, Taiwan, Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: Albania, EU 28, Northern Macedonia, Norway, Russia, Switzerland, Turkey
MENA Region: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Table 18: *Inhabitants per economic region by the end of 2017*

Data source: International Data Base of the U.S. Census Bureau

9.7 Market data of the previous years

The data presented in Chapters 5 to 8 were originally collected in square meters. Through an agreement of international experts the collector areas of these solar thermal applications have been converted and are shown in installed capacity as well.

Making the installed capacity of solar thermal collectors comparable with that of other energy sources, solar thermal experts from seven countries agreed upon a methodology to convert installed collector area into solar thermal capacity.

The methodology was developed during a meeting with IEA SHC Programme officials and major solar thermal trade associations in Gleisdorf, Austria in September 2004. The represented associations from Austria, Canada, Germany, the Netherlands, Sweden and the United States as well as the European Solar Thermal Industry Federation (ESTIF) and the IEA SHC Programme agreed to use a factor of 0.7 kW_{th} / m² to derive the nominal capacity from the area of installed collectors.

In order to ensure consistency of the calculations within this report the following tables provide data from the previous years. If necessary, the numbers have been revised in 2014 compared to the data originally published in earlier editions of this report due to changes in methodology or the origin of the data for each country.

In the following Table 19, Table 20 and Table 21 these countries are marked accordingly and in Chapter 9.8 (References) the respective data source is cited.

Thermosyphon systems at a hotel in Namibia. *Photo: SOLTRAIN / AEE INTEC*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		20,574	544			21,118
Australia	400,000	169,000	18,700	30,000	1,000	618,700
Austria	890	134,260	2,320		270	137,740
Barbados**		11,430				11,430
Belgium		38,250	6,750			45,000
Botswana		2,500				2,500
Brazil	610,066	767,311	25,055			1,402,432
Bulgaria		5,100	500			5,600
Burkina Faso		932	139			1,070
Canada	22,593	2,684	3,384	14,583	13,981	57,225
Cape Verde		160				160
Chile	10,045	25,114	10,502		80	45,741
China		5,500,000	38,000,000	200		43,500,200
Croatia		19,000	2,500			21,500
Cyprus		18,800	600			19,400
Czech Republic	30,000	22,000	9,000			61,000
Denmark		250,000		1,000		251,000
Estonia		1,000	1,000			2,000
Finland		3,300	1,700			5,000
France (mainland)	2,000	91,600	4,850	700		99,150
Germany	25,000	731,000	75,000			831,000
Ghana		76	24			100
Greece		271,000	600			271,600
Hungary	1,000	11,000	4,000	150	150	16,300
India+		172,267	1,379,550		1,000	1,552,817
Ireland		12,716	9,951			22,667
Israel	1,000	428,350				429,350
Italy		201,810	27,520			229,330
Japan		98,608	2,163		6,435	107,206
Korea, South		9,888	19,145			29,033
Latvia		1,580	330			1,910
Lebanon		21,348	32,628			53,976
Lesotho		70	140			210
Lithuania		800	1,400			2,200
Luxembourg		4,700	750			5,450
Malta		800	200			1,000
Mauritius		8,880				8,880
Mexico	104,000	130,000	111,000			345,000
Mozambique	136	48	32			216
Namibia	780	4,802	3			5,585
Netherlands	2,621	17,548	3,971			24,140
Nigeria		58	90		35	184
Northern Macedonia		5,955	4,936			10,891
Norway		516	80			596
Palestine		49,000	225			49,225
Poland		225,000	52,000			277,000
Portugal		45,304	830			46,134
Romania	170	6,800	11,000			17,970
Russia		716	32			748
Senegal		4	80		55	139
Slovakia	500	4,500	800			5,800
Slovenia		2,200	600			2,800
South Africa	78,940	29,016	24,000			131,956
Spain	3,375	226,669	11,121			241,165
Sweden	82	5,036	1,535			6,653
Switzerland	6,676	76,275	15,485			98,436
Taiwan		119,015	8,969			127,985
Thailand*		6,700				6,700
Tunisia		63,223				63,223
Turkey		1,071,070	1,024,665	1,000		2,096,735
United Kingdom		20,322	3,967	500		24,789
United States	835,744	162,189	8,361	10,500	11,000	1,027,794
Uruguay		6,003				6,003
Zimbabwe		353	2,898			3,251
All other countries (5%)	112,401	596,644	2,154,086	3,086	1,790	2,868,006
TOTAL	2,248,019	11,932,872	43,081,712	61,719	35,795	57,360,117

* Revised due to new / adapted database in 2018.
** Based on Solar Water Heating Techscope Market Readiness Assessment - Reports UNEP 2015.
\+ The figures for India refer to the fiscal year April 2015 to March 2016.

Table 19: *Newly installed collector area in 2015 [m²]*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		21,714	784			22,498
Australia	380,000	148,200	16,470	30,000	1,000	575,670
Austria	760	109,600	1,440		130	111,930
Barbados**		11,430				11,430
Belgium		39,000	7,500			46,500
Botswana		2,500				2,500
Brazil	548,205	734,240	22,477			1,304,922
Bulgaria		5,100	500			5,600
Burkina Faso		1,000	150			1,150
Canada	22,008	1,303	2,367	10,438	100	36,216
Cape Verde		120				120
Chile		29,300	11,878			41,178
China		5,340,000	34,180,000	500		39,520,500
Croatia		19,000	2,500			21,500
Cyprus		62,170				62,170
Czech Republic	30,000	22,000	9,000			61,000
Denmark		478,297				478,297
Estonia		1,000	1,000			2,000
Finland		3,333	1,667			5,000
France (mainland)	2,000	64,530	2,580	800		69,910
Germany	22,000	677,000	67,000			766,000
Ghana		76	24			100
Greece		272,000	600			272,600
Hungary	1,000	9,000	3,000	100	100	13,200
India+		150,476	1,050,383		1,200	1,202,059
Ireland		13,594	10,783			24,377
Israel	1,000	420,000				421,000
Italy		183,647	25,043			208,690
Japan		70,559	1,582		6,435	78,576
Korea, South		10,686	18,286			28,972
Latvia		1,500	300			1,800
Lebanon		23,900	31,170			55,070
Lesotho		46	151			197
Lithuania		800	1,400			2,200
Luxembourg		4,200	700			4,900
Malta		614	154			768
Mexico	108,300	139,100	118,800			366,200
Mozambique	8	13	7			28
Namibia	780	5,370	30			6,180
Netherlands	2,620	20,137	5,179			27,936
Nigeria		229	79		35	343
Northern Macedonia		6,466	5,993			12,459
Norway		1,660	110			1,770
Palestine		49,000	225			49,225
Poland		111,700	3,700			115,400
Portugal		45,300	800			46,100
Romania		6,800	11,000			17,800
Russia	22	1,820	172	2	14	2,030
Senegal		4	80		55	139
Slovakia		8,000	1,600			9,600
Slovenia		2,300	400			2,700
South Africa	67,428	32,207	26,640			126,275
Spain	3,321	201,793	7,076	1,250	1,250	214,690
Sweden		2,487	336			2,823
Switzerland	5,654	51,150	9,895			66,699
Taiwan		94,370	5,784			100,154
Thailand*		2,680				2,680
Tunisia		67,738				67,738
Turkey		964,000	887,000	3,000		1,854,000
United Kingdom		10,920	3,011	500		14,431
United States	802,314	164,135	8,528	12,000	9,000	995,977
Uruguay		6,598				6,598
Zimbabwe		32	8,954			8,986
All other countries (5%)	105,127	575,155	1,925,068	3,084	1,017	2,609,451
TOTAL	2,102,548	11,503,100	38,501,354	61,674	20,335	52,189,011

* Revised due to new / adapted database in 2018.
** Based on Solar Water Heating Techscope Market Readiness Assessment - Reports UNEP 2015, 0 % growth assumed in 2016.
\+ In 2016 change from fiscal year to calendar year. Data refer to April 2016 – December 2016

Table 20: *Newly installed collector area in 2016 [m²]*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		204,498	2,760			207,258
Australia	5,270,000	3,386,000	174,000	360,000	10,800	9,200,800
Austria	418,221	4,702,535	85,738		3,708	5,210,202
Barbados**		214,290				214,290
Belgium	45,000	494,083	89,250			628,333
Botswana		9,500				9,500
Brazil	4,738,510	8,838,072	73,305			13,649,887
Bulgaria		133,480	4,020			137,500
Burkino Faso		1,932	289			2,220
Canada	806,664	70,365	48,436	406,579	48,985	1,381,029
Cape Verde		1,603				1,603
Chile	65,550	184,000	42,000		300	291,850
China		38,637,613	424,942,386	3,000	2,000	463,584,999
Croatia		200,017	10,075			210,092
Cyprus	2,213	660,120	24,800			687,133
Czech Republic	598,000	439,214	129,298			1,166,512
Denmark	20,500	1,603,120	9,197	4,300	18,000	1,655,117
Estonia		7,930	6,590			14,520
Finland	11,800	36,667	18,333			66,800
France (mainland)	120,280	1,914,750	183,620	6,600	1,100	2,226,350
Germany	551,070	16,734,000	2,051,000		24,000	19,360,070
Ghana		1,663	611			2,274
Greece		4,476,000	21,600			4,497,600
Hungary	17,300	210,700	70,100	2,450	2,100	302,650
India+		3,638,933	6,284,893		11,400	9,935,226
Ireland		222,420	120,831			343,251
Israel	37,000	4,597,434				4,634,434
Italy	43,800	3,775,766	589,803			4,409,369
Japan		3,436,185	67,025		525,149	4,028,359
Jordan	5,940	982,482	272,084			1,260,506
Korea, South		1,686,558	165,060			1,851,618
Latvia		9,592	2,740			12,332
Lebanon		286,719	396,414			683,133
Lesotho		1,403	447			1,850
Lithuania		6,500	8,300			14,800
Luxembourg		51,936	8,200			60,136
Malta		41,337	10,334			51,671
Mauritius		132,793				132,793
Mexico	1,184,353	1,313,082	1,030,042	752	8,773	3,537,002
Morocco		451,000				451,000
Mozambique	144	61	1,181			1,386
Namibia	1,560	34,995	1,343			37,898
Netherlands	100,564	517,991	33,650			652,205
New Zealand	7,025	142,975	9,644			159,645
Nigeria		288	169		70	527
Northern Macedonia		48,233	16,829			65,062
Norway	1,849	37,478	4,052	200	4,106	47,686
Palestine		1,694,317	8,225			1,702,542
Poland		1,660,500	476,700			2,137,200
Portugal	2,130	990,522	27,480			1,020,132
Romania	340	97,000	77,150	800		175,290
Russia	137	20,203	3,251	2	64	23,657
Senegal		87	1,648		1,145	2,879
Slovakia	1,000	136,550	23,550			161,100
Slovenia		123,650	23,150			146,800
South Africa	1,109,093	572,836	226,070			1,907,999
Spain	148,520	3,547,629	207,639	1,750	1,250	3,906,788
Sweden	170,410	301,674	72,070			544,154
Switzerland	198,050	1,296,480	125,620			1,620,150
Taiwan	1,937	1,555,672	131,539			1,689,148
Thailand*		157,536				157,536
Tunisia		836,792	70,104			906,896
Turkey		15,933,182	5,399,454	8,570		21,341,206
United Kingdom		625,375	172,794	22,600		820,769
United States	22,116,619	2,821,556	154,711	111,068	61,500	25,265,453
Uruguay		58,842				58,842
Zimbabwe		21,811	15,249			37,060
All other countries (5%)	1,989,241	7,210,795	23,361,151	48,877	38,118	32,648,182
TOTAL	39,784,821	144,241,319	467,588,003	977,548	762,569	653,354,261

* Revised due to new / adapted database in 2018.
** Based on Solar Water Heating Techscope Market Readiness Assessment - Reports UNEP 2015.
\+ In 2016 change from fiscal year to calendar year.

Table 21: *Total collector area in operation by the end of 2016 [m²]*

9.8 References to reports and persons who have supplied the data

The production of the report, *Solar Heat Worldwide – Edition 2019* was kindly supported by national representatives of the recorded countries or other official sources of information as cited below.

COUNTRY	CONTACT	SOURCE REMARKS
Albania	**Dr. Eng. Edmond M. HIDO** EEC - Albania-EU Energy Efficiency Centre (EEC)	EEC - Albania-EU Energy Efficiency Centre
Argentina	**Federico Pescio** ENERGÍA SOLAR TÉRMICA Instituto Nacional de Tecnología Industrial (INTI) Energías Renovables Centro de Investigación y Desarrollo en Energías Renovables	Censo Nacional de Energía Solar Térmica (baja temperatura) Instituto Nacional de Tecnología Industrial (INTI)
Australia	**Dr. David Ferrari** Technical Supervisor, Victorian Energy Upgrades Essential Services Commission, Victoria	Essential Services Commission, with data from the Clean Energy Regulator and industry surveys / interviews Out of operation systems calculated by Essential Services Commission
Austria	**Werner Weiss** AEE - Institute for Sustainable Technologies	Biermayr et al, 2018: Innovative Energie-technologien in Österreich – Marktentwicklung 2017 (Report in German) Out of operation systems calculated by AEE INTEC
Barbados		Based on Solar Water Heating Techscope Market Readiness Assessment – Reports, UNEP 2015 0% growth assumed in 2017
Belgium	**ESTIF** European Solar Thermal Industry Federation **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 Unglazed water collectors: AEE INTEC recordings
Botswana	**Dr. Edwin Matlotse** Botswana University	Estimation for new installed collector area 2017 AEE INTEC
Brazil	**Marcelo Mesquita** Depto. Nac. de Aquecimento Solar da ABRAVA	DASOL ABRAVA Out of operation systems calculated based on DASOL ABRAVA long time recordings
Bulgaria	**ESTIF** European Solar Thermal Industry Federation **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 Unglazed water collectors: AEE INTEC recordings
Burkina Faso	**Kokouvi Edem N'Tsoukpoe** International Institute for Water and Environmental Engineering Ouagadougou, Burkina Faso	Rapport de l'étude de marché du solaire thermique: production d'eau chaude et de séchage de produits agricoles, 2015 Estimation for new installed collector area 2017 AEE INTEC
Canada	**Reda Djebbar, Ph.D., P.Eng.** Natural Resources Canada	Clear Sky Advisors, April 2018 Report „Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2017)" Out of operation systems considered by NRC
Cape Verde	**Antúnio Barbosa**	Country Market Report on solar thermal heating systems, solar drying and solar cooling, September 2015 Integrated 2019, new collector area 2017 estimation AEE INTEC

Chile	**Sven Harfagar Mandiola** División Energías Renovables Ministerio de Energía / Gobierno de Chile	www.minenergia.cl/sst/ 0 % growth assumed in 2017
China	**Hu Runqing** Center for Renewable Energy Development - Energy Research Institute (NDRC)	CSTIF - Chinese Solar Thermal Industry Federation Out of operation systems calculated by CSTIF
Croatia	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018
Cyprus	**Panayiotis Kastanias** Cyprus Employers and Industrialists Federation	EBHEK Solar Thermal Market Analysis 2017-2018
Czech Republic	**Ales Bufka** Ministry of Industry and Trade	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 Unglazed water collectors: AEE INTEC recordings
Denmark	**ESTIF** European Solar Thermal Industry Federation **AEE INTEC** Jan-Erik Nielsen, Daniel Trier, Planenergi	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Unglazed water collectors: AEE INTEC recordings
Estonia	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Finland	**Ville Maljanen** Solar Energy Statistics Finland	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
France (mainland)	**Solar Thermal Markets in Europe -** Trends and Market Statistics 2017, ESTIF 2018 **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018; air collectors: John Hollick Unglazed ObservER' 2018; Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018; air collectors: John Hollick
Germany	**Marco Tepper** BSW - Bundesverband Solarwirtschaft e.V., data Bärbel Epp solrico **John Hollick** SAHWIA - Solar Air Heating World Industry Association	BSW - Bundesverband Solarwirtschaft e.V. Air collectors: SAHWIA FPC / ETC: BSW solar long time recordings; unglazed water collectors & glazed air collectors: recordings AEE INTEC
Ghana	**Divine Atsu** Koforidua Polytechnic / Department of Energy Systems Engineering	7 % growth assumed in 2017 (estimation AEE INTEC)
Greece	**Costas Travasoras (EBHE)** AEE INTEC, Dr Vassiliki Drosou (CRES)	Costas Travasaros (EBHE) Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018
Hungary	**Pál Varga** MÉGNAP- Hungarian Solar Thermal Industry Federation	MÉGNAP- Hungarian Solar Thermal Industry Federation New and cumulated installations: Hungarian Solar Thermal Industry Federation (MÉGNAP); provided by Pál Varga (personal estimation)
India	**Jaideep N. Malaviya** Malaviya Solar Energy Consultancy	Malaviya Solar Energy Consultancy (based on market survey) New and cumulated installations based on survey from Malaviya Solar Energy Consultancy; out of operation systems considered, in 2016 re-corded data changed from fiscal year to calendar year

Ireland	**Mary Holland** Sustainable Energy Authority of Ireland	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Cumulated calculated by AEE INTEC based on new installed collector areas (Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018)
Israel	**Eli Shilton** / ELSOL **Bärbel Epp** - solrico	ELSOL (Eli Shilton), data provided by Bärbel Epp Cumulated collector area calculated by AEE INTEC based on new installation and replacement figures from Eli Shilton (ELSOL)
Italy	**ESTIF** European Solar Thermal Industry Federation **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Cumulated area: ESTIF 2018 / share FPC-ETC: AEE INTEC / unglazed water collectors: AEE INTEC
Japan		EurObservEr 2018 Solar System Development Association (SSDA) Share FPC / ETC AEE INTEC
Jordan	**AEE INTEC**	AEE INTEC New installations: no new collectors for 2017 reported Cumulated installations by end of 2014
Korea, South	**Eunhee Jeong** Korea Energy Management Corporation (KEMCO) **Kyoung-ho Lee** Solar Thermal and Geothermal Research Center New and Renewable Energy Research Division Korea Institute of Energy Research (KIER)	2017 New & Renewable Energy Statistics by the Korea New & Renewable Energy Center, 2018
Latvia	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Lebanon	**Tony Gebrayel, Rani Al Achkar** Lebanese Center for Energy Conservation (LCEC)	Lebanese Center for Energy Conservation (LCEC) Cumulated calculated by AEE INTEC
Lesotho	**Bethel Business** and Community Development Center (BBCDC)	SOLTRAIN Study, Data provided by Puleng Mosothoane
Lithuania	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Luxembourg	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Northern Macedonia	**Prof. Dr. Ilja Nasov** National University St. Kiril and Metodij, Faculty for Natural Science, Institute of Physics, Solar Energy Department	2017 data estimation of Ilya Nasov and other solar experts New installations: estimation of Ilya Nasov and other solar experts; Cumulated installations: calculated by AEE INTEC based on new installation figures
Malta	**Ing. Therese Galea** Sustainable Energy and Water Conservation Unit (SEWCU) Ministry for Energy and Health	Sustainable Energy and Water Conservation Unit (SEWCU) based on data provided by the Regulator for Energy and Water Services (REWS)
Mauritius	**Mrs Devika Balgobin** Statistician Environment Statistics Unit Ministry of Environment and Sustainable Development	Statistics Mauritius No new collector area 2017; cumulated collector area by end of 2015

Mexico	**David Garcia** / FAMERAC **Bärbel Epp** Solrico – Solar market research (http://www.solrico.com/)	Glazed and unglazed water collectors: FAMERAC - Renewable Energy Industry Associationdata provided by Bärbel Epp Air collectors: SAHWIA - Solar Air Heating World Industry Association Cumulated installations: calculated by AEE INTEC
Morocco	**Ashraf Kraidy** / RECREEE - Regional Center for Renewable Energy and Energy Efficiency	No new collector area 2017; cumulated collector area by end of 2014
Mozambique	**Fabião Cumbe** / ENPCT, E.P. **AEE INTEC**	estimation AEE INTEC Cumulated installations calculated by AEE INTEC based on new installation figures for 2017 estimated by AEE INTEC
Namibia	**Fenni Shidhika** Namibia Energy Institute Namibia University of Science and Technology	Namibia Energy Institute Solar Water Heaters-Survey 2017
Netherlands	**André Meurink, Reinoud Segers** Statistics Netherlands (CBS)	Statistics Netherlands (CBS) Newly installed areas: Statistics Netherlands based on survey of sales. Market Shares: Expert estimates Netherlands Enterprise Agency and Holland Solar.
New Zealand		No data available since 2010 Cumulated area in 2009
Nigeria	**Okala Nwoke** National Centre for Energy Research and Development, University of Nigeria, Nsukka	National Centre for Energy Research and Development, University of Nigeria 2017 data provided by Okala Nwoke plus 30 % additional installed area assumed by AEE INTEC
Norway	**Michaela Meir** Aventasolar	Solvarmeanlegg i Norge 2018 commissioned by The Norwegian Solar Energy Cluster (Solenergiklyngen), provided by Michaela Meir Calculated by AEE INTEC based on new installed 2017 (flat plate collectors: 4 % out of operation considered
Palestinian Territories	**Mohammed Mobayyed** EEU Director / Palestinian Energy Authority **Abdallah Azzam** Palestinian Central Bureau of Statics / Natural Resource Statistics	Palestinian Energy Authority Cumulated area calculated by AEE INTEC (replacements not considered)
Poland	**Janusz Staroscik - President** Association of Heating Appliances manufacturers and Importers in Poland	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018
Portugal	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Romania	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Russia	**Dr. Semen Frid, Dr. Sophia Kiseleva** Moscow State University **Prof. Vitaly Butuzov** Yuzhgeoteplo corporation, Krasnodar	Joint Institute for High Temperatures of Russian Academy of Sciences (JIHT RAS) Dr. Semen Frid, Sophia Kiseleva - Moscow State University, Vitaly Butuzov - Energytechnologies Ltd. (Krasnodar); the source of information - JIHT RAS.
Senegal	**Université Cheikh Anta DIOP**	Rapport de Marché du Solaire Thermique: Production d' Eau Chaude et Séchage de Produits Agricoles: provided by T. Ababacar 7 % growth assumed 2017 (estimation AEE INTEC)

Slovakia	**ESTIF** European Solar Thermal Industry Federation	Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018 Glazed water collectors: ESTIF, 2018 (estimation)
Slovenia	**University of Ljubljana** Faculty of Mechanical Engineering **ESTIF** – European Solar Thermal Industry Federation	University of Ljubljana, Faculty of Mechanical Engineering; Eco Fund, Slovenian Environmental Public Fund; provided by Ciril Arkar
South Africa	**Karin Kritzinger** Centre of Renewable and Sustainable Energy Studies University of Stellenbosch	Department of Energy, SESSA, Stellenbosch University, Solco, GIZ, Sanedi, City of Cape Town Metro; provided by Karin Kritzinger
Spain	**Pascual Polo** ASIT - Asociación Solar de la Industria Térmica	ASIT (Solar Energy Industry Association of Spain) Out of operation systems calculated by ASIT
Sweden	**Prof. Jan-Olof Dalenbäck** Svensk Solenergi / CHALMERS	Svensk solenergi (Solar Energy Association of Sweden) Solar Thermal Markets in Europe - Trends and Market Statistics 2017, ESTIF 2018
Switzerland	http://www.swissolar.ch/	SWISSOLAR - Markterhebung Sonnenenergie 2017, Bundesamt für Energie 2018 Out of operation systems calculated by SWISSOLAR
Taiwan	**K.M. Chung** Energy Research Center - National Cheng Kung University	Bureau of Energy, Ministry of Economic Affairs, R.O.C. Out of operation systems calculated by Bureau of Energy, Ministry of Economic Affairs, R.O.C.
Thailand	**Charuwan Phipatana-phuttapanta** Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy	GIZ study, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy (Subsidized systems) Data for subsidized systems, provided by Charuwan Phipatana-phuttapanta, single-family houses estimated by AEE INTEC based on GIZ study, no new collector area in 2017
Tunisia	**Abdelkader Baccouche** Agence Nationale pour la Maîtrise de l'Energie (ANME)	ANME (National Agency of Energy Conservation)
Turkey	**A. Kutay Ulke** Bural Heating Corporation Ltd. **John Hollick** SAHWIA - Solar Air Heating World Industry Association **Prof. Bulent Yesilata** GAP Renewable Energy and Energy Efficiency Center Harran University	Water collectors: A. Kutay Ulke, personal studies Air collectors: SAHWIA New installations: A. Kutay Ulke cumulated installations: calculated by AEE INTEC considering 14 years lifetime shares provided by Bulent Yesilata (2016)
United Kingdom	**Lethbridge Yehuda** Department of Energy and Climate Change **Karl Sample** SICE / UK IEA Solar delegate **John Hollick** SAHWIA - Solar Air Heating World Industry Association	UK Solar Trade Association and ESTIF Reports collated in BEIS annual survey Active Solar 2017 survey, Provided by Karl Sample, air collectors provided by John Hollick Cumulated ESTIF 2018; FPC / ETC calculated by AEE INTEC; air collectors provided by John Hollick

United States	**Les Nelson** IAPMO Solar Heating & Cooling Programs **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Water Collectors and air collectors: IAPMO Solar Heating & Cooling Programs; Air collectors: SAHWIA New installations: DOE / SEIA / IAPMO; Totals: calculated by AEE INTEC considering 25 years lifetime
Uruguay	**Ministry of Industry, Energy and Mining**	Ministry of Industry, Energy and Mining, provided by Martín Scarone
Zimbabwe	**Samson Mhlanga** National University of Science and Technology, Bulawayo	Dr. Anton Schwarzlmüller Domestic Solar Heating unpublished statistics SOLTRAIN survey (unpublished sources) Cumulated 2017 calculated by AEE INTEC

9.9 Additional literature and web sources used

The following reports and statistics were used in this report.

- Bundesamt für Energie (BFE): Markterhebung Sonnenenergie 2017 - Teilstatistik der Schweizerischen Statistik der erneuerbaren Energien; prepared by SWISSOLAR, Thomas Hostettler, Bern, Switzerland July 2018
- Bundesministerium für Verkehr, Innovation und Technologie (BMVIT): Innovative Energy Technologies in Austria - Market Development 2017; prepared by Peter Biermayr et al, Vienna, Austria June 2018
- Bundesverband Solarwirtschaft e.V. (BSW-Solar): Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) 2017; accessed December 2018
- ClearSky Advisors Inc.: Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2017); Prepared by ClearSky Advisors Inc., Dr. Reda Djebbar, Natural Resources Canada, March 2018
- European Solar Thermal Industry Federation (ESTIF): Solar Thermal Markets in Europe, Trends and Market Statistics 2017; Belgium - Brussels; November 2018
- IRENA: Renewable Energy and Jobs: Annual Review 2018
- Weiss, W. (2003) Wirtschaftsfaktor Solarenergie, Wien
- Weiss, W., Biermayr, P. (2006) Potential of Solar Thermal in Europe, published by ESTIF
- Lehr, U. et.al (2015) Beschäftigung durch erneuerbare Energien in Deutschland: Ausbau und Betrieb, heute und morgen

The following online sources were used in this report:

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http://www.asit-solar.com/
http://www.solarpowereurope.org/home/
http://www.iea-shc.org/
http://www.mnre.gov.in/
http://www.olade.org/
http://sahwia.org/
http://www.solarwirtschaft.de/
http://www.solarthermalworld.org/
http://www.aderee.ma/
http://www.dasolabrava.org.br/
http://www.giz.de/
http://www.irena.org/
http://www.ome.org/
http://www.ren21.net/
http://www.solar-district-heating.eu/
http://www.solrico.com/
http://www.swissolar.ch/

9.10 List of Figures

9.11 List of Tables