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WERNER WEISS | MONIKA SPÖRK-DÜR

# SOLAR HEAT WORLDWIDE

Global Market Development and Trends in 2017 | Detailed Market Figures 2016

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SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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**Global Market Development and Trends in 2017**
**Detailed Market Figures 2016**

**2018 EDITION**

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# Table of Contents

# 1 Background

The report was prepared within the framework of the Solar Heating and Cooling Programme (SHC) of the International Energy Agency (IEA). 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.

This edition of Solar Heat Worldwide includes for the first time an overview of concentrating solar collectors, which are applied in district heating and for industrial processes.

The data were collected from a survey of the national delegates of the IEA SHC Executive Committee and other national experts active in the field of solar thermal energy. As some of the 66 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 66 countries included in this report represent 4.8 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.

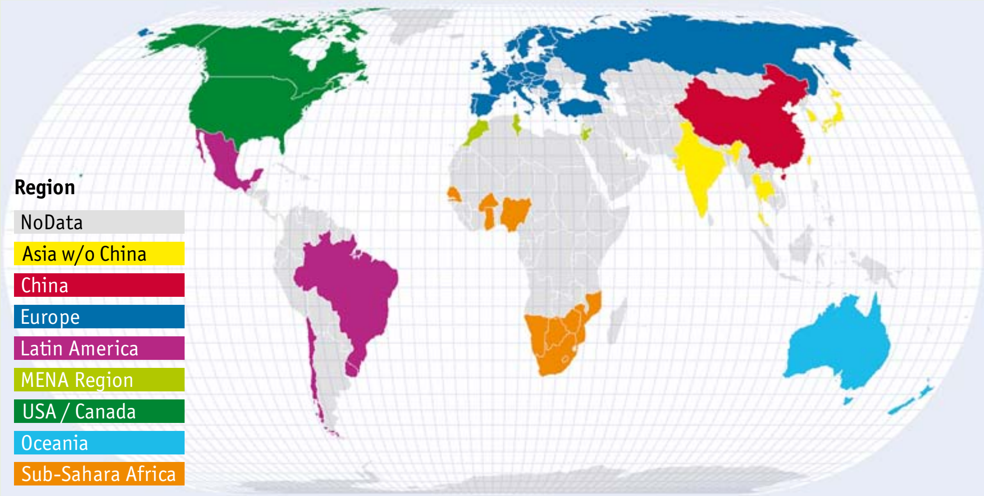



*Figure 1:* *Countries shown in color have detailed market data. Countries shown in grey have estimated market data.*

# 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 2017. In addition, general trends are described and detailed 2017 data on successful applications, such as solar assisted district heating and solar heat for industrial processes, are documented.

The second part (Chapters 5 – 8) presents detailed market figures for the year 2016 from 66 countries around the globe. The concluding chapter of the second part is focused on solar thermal system cost and levelized cost of solar heat for different applications and regions worldwide.

## Global solar thermal market developments and status in 2017

The cumulated solar thermal capacity in operation by end of 2017 was 472 $GW_{th}$ (675 million square meters). Compared to the year 2000 the installed capacity grew by the factor 7.6.

The corresponding annual solar thermal energy yield in 2017 amounted to 388 TWh, which correlates to savings of 41.7 million tons of oil and 134.7 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.

In total, the global market declined by 4.2 % in 2017. Positive market developments were recorded in India (26 %), Mexico (7 %), and in Turkey (4 %).

In contrast to the small-scale solar water heating systems, the megawatt-scale solar supported district heating systems and industrial applications have gained increasing interest all over the world in recent years and several ambitious projects have been successfully implemented.

By the end of 2017 about 300 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 1,140 $MW_{th}$ (1,630,415 m²), excluding concentrating systems that add 110,929 m².

In 2017, nine large-scale solar thermal systems with about 35,000 m² (24.5 $MW_{th}$) were installed in Europe. Outside Europe, 5.9 $MW_{th}$ (8,444 m²) were installed and one concentrating system in Tibet with a collector area of 9,000 m². About 75 % of the new collector area installed in Europe is from two new large systems in Denmark and three extensions added to Danish systems. About 92 % of the installed capacity installed outside Europe has been installed in China.

The world's largest plant for solar district heating is located in Silkeborg, Denmark and has an installed capacity of 110 $MW_{th}$ (156,694 m² flat plate collectors). The start of operation of this plant was in December 2016.

Important to note is that in 2016 and 2017 three parabolic trough collector fields were installed for feeding into district heating networks in Denmark and China. The concentrating collector area of these three systems installed adds up to 110,929 m².

Solar heat for industrial processes (SHIP) continues to be 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 with 100 $MW_{th}$ capacity. At least 624 SHIP systems, totalling 608,994 m² collector area, were in operation at the end of the year 2017.

2017 was a record year for SHIP installations – 124 new larger systems, totalling 192,580 m² collector area, started operating. With this, the documented world total grew in 2017 by 25 % in number of installed plants and by 46 % by installed collector area. The world's largest solar process heat application began operation in February 2018 at the Amal oilfield located in the south of the Sultanate of Oman. The Miraah parabolic trough plant with a total capacity of over 100 $MW_{th}$ delivers 660 tons of steam per day for the extraction of viscous or heavy oil as an alternative to steam generated from natural gas.

## Detailed market analyses for 66 countries based on 2016 data

By the end of 2016, an installed capacity of 457 $GW_{th}$ corresponding to a total of 653 million square meters of collector area was in operation in the recorded 66 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 (324.5 $GW_{th}$) and Europe (51.8 $GW_{th}$), which together accounted for 82.3 % of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (18.6 $GW_{th}$), Asia excluding China (12.1 $GW_{th}$), Latin America (12.3 $GW_{th}$), the MENA[1] countries, Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (6.8 $GW_{th}$), Australia and New Zealand (6.5 $GW_{th}$), and Sub-Sahara African countries Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa and Zimbabwe (1.5 $GW_{th}$). The market volume of "all other countries" is estimated to amount for 5 % of the total installations (22.8 $GW_{th}$).

With a global share of 71.6 %, evacuated tube collectors were the predominant solar thermal collector technology followed by flat plate collectors with 22.1 %, 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 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 2016 per 1,000 inhabitants were Barbados (515 $kW_{th}$/1,000 inhabitants), Austria (418 $kW_{th}$/1,000 inhabitants), Cyprus (399 $kW_{th}$/1,000 inhabitants), Israel (397 $kW_{th}$/1,000 inhabitants), Greece (292 $kW_{th}$/1,000 inhabitants), the Palestinian Territories (289 $kW_{th}$/1,000 inhabitants), Australia (269 $kW_{th}$/1,000 inhabitants), China (236 $kW_{th}$/1,000 inhabitants), Denmark (204 $kW_{th}$/1,000 inhabitants) and Turkey (186 $kW_{th}$/1,000 inhabitants).

1 Middle East and North Africa

## Newly installed capacity worldwide in 2016

By the end of 2016 a capacity of 36.5 $GW_{th}$, corresponding to 52.2 million m² of solar collectors, were installed worldwide. This means a decrease in new collector installations of 9 % compared to the year 2015. This downward trend however is less than the 14 % in the year 2014/15 and seems to continue in 2017 with recovering markets mainly driven by the growth in large-scale and solar process heat installations and the recovering market in China.

The main markets in 2016 were again China (27.7 $GW_{th}$) and Europe (3.2 $GW_{th}$), which together accounted for 84.5 % of the overall new collector installations in 2016. The rest of the market was shared between Latin America (1.2 $GW_{th}$), Asia excluding China (1.0 $GW_{th}$), 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 (1.8 $GW_{th}$).

Of the top 10 markets in 2016, positive market growth was reported from Denmark due to 31 large-scale installations and 5 extensions of existing plants in 2016 and from Mexico, where a strong committed supply chain and cost-effective residential market exists and the construction market with a wide range of applications (residential solar hot water collectors, residential and commercial swimming pools, agricultural drying systems, and an increased number of larger commercial SHIP and public building installations) is a growing sector.

With a share of 73.8 % of the newly installed capacity in 2016, 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 86 % of all newly installed collectors in 2016 were evacuated tube collectors. Nevertheless, it is noteable that the share of evacuated tube collectors decreased from about 82 % in 2011 to 73.8 % in 2016, and in the same time frame flat plate collectors increased the share from 14.7 % to 22.1 %.

In Europe, the situation is almost the opposite compared to China with 74.9 % of all solar thermal systems installed in 2016 being flat plate collectors. In the medium-term perspective, the share of flat plate collectors decreased in Europe from 81.5 % in 2011 to 74.9 % in 2016. Driven mainly by the markets in Turkey, Poland, Switzerland and Germany the evacuated tube collectors did increase their share in Europe between 2011 and 2016 from 15.6 % to 23.5 %.

In terms of newly installed solar thermal capacity per 1,000 inhabitants in 2016, Denmark took the lead followed by Israel and Cyprus in second position. China ranks fifth followed by Greece, Australia, Turkey, Austria and the Palestinian Territories.

## Distribution of systems 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 2016, 89 % of the newly installed systems were thermosiphon systems while pumped systems only accounted for 11 %.

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 113 million by the end of 2016. The breakdown is 6% used for swimming pool heating, 63% used for domestic hot water preparation in single-family houses and 28% 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, 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 42% of new installations in 2016 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 50% 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 708,000 worldwide in 2016.[2]

The worldwide turnover of the solar thermal industry in 2016 is estimated at € 16 billion (US$ 19.2 billion).

## Levelized cost of solar thermal generated heat (LCOH)

Solar thermal markets are facing challenging times, which is partly due to increasing economic pressure from other renewable technologies. To address this, a special focus is being given to the economics of solar thermal systems in Chapter 8 of this year's report.

The economic analysis based on 2016 cost shows that there is a very broad range in system costs, and subsequently, the levelized cost of solar heat. The cost data shown below refer to end-user (customer) prices excluding VAT and subsidies. These costs are dependent on the system type (thermosyphon or pumped) and the application, such as small domestic hot water systems for single-family homes, large domestic hot water systems for multi-family homes, small combined hot water and space heating systems and

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

*156,694 m² solar collector field at Silkeborg, Denmark* Photo: Arcon-Sunmark AS

swimming pool heating systems with unglazed water collectors. Furthermore, the solar fraction and the climatic conditions play an important role.

For domestic applications, the lowest LCOH range is between ~1 €-ct / kWh for pool heating systems (Australia, Brazil), 2 – 4 €-ct / kWh for small thermosiphon domestic hot water systems (Brazil, India, Turkey) and 7 – 8 €-ct / kWh for small pumped domestic hot water systems (Australia, China).

For larger pumped systems in multi-family homes LCOH is lowest in Brazil and India (2 – 3 €-ct / kWh).

Small combined hot water and space heating systems are cheapest in Brazil (3 €-ct / kWh).

By contrast, the highest LCOH range is between ~2 €-ct / kWh for pool heating systems (Canada, Israel), 7 – 12 €-ct / kWh for small thermosiphon systems (Australia, China, South Africa), 12 – 20 €-ct / kWh for small pumped systems (Australia, Austria, Canada, Denmark, France), 8 – 14 €-ct / kWh for larger pumped systems in multi-family homes (Austria, Canada, Denmark, France) and 11 – 19 €-ct / kWh for small combi-systems (Austria, China, Denmark, Germany, South Africa).

For large-scale systems in Denmark (>10,000 m²), the average LCOH for diurnal storage is 3.6 €-ct / kWh. And for even larger systems (>50,000 m²) with seasonal storage attached, the average LCOH is 4.9 €-ct / kWh.

# 3 Worldwide solar thermal capacity in 2017

Global solar thermal capacity of unglazed and glazed water collectors in operation grew from 62 $GW_{th}$ (89 million square meters) in 2000 to 472 $GW_{th}$ (675 million square meters) in 2017.

The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 388 TWh in 2017 (**Figure 2**).

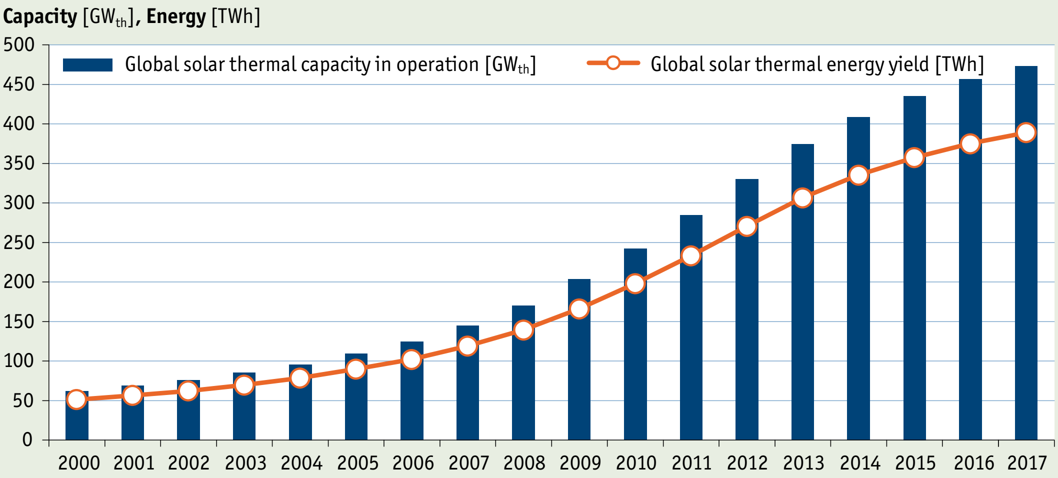



***Figure 2:*** *Global solar thermal capacity in operation and annual energy yields 2000 – 2017*

**Environmental effects and contribution to climate goals**

The global solar thermal energy yields in 2017 corresponded to savings of 41.7 million tons of oil and 134.7 million tons of $CO_2$. This shows the significant contribution of this technology to the global climate goals.

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

Compared with other forms of renewable energy, solar heating's contribution in meeting global energy demand is, besides the traditional renewable energies like biomass and hydropower, second only to wind power (**Figure 3**).

The cumulated solar thermal capacity in operation by the end of 2017 was 472 $GW_{th}$[3], which trailed behind wind power's installed capacity of 540 $GW_{el}$, but ahead of photovoltaics' 402 $GW_{el}$ of installed capacity. The total capacity of concentrating solar thermal power (CSP) systems was about 5 $GW_{el}$, which is in the range of 1 % of the capacity of solar heating and cooling technologies.

In terms of energy, solar thermal systems supplied a total of 388 TWh of heat, whereas wind turbines supplied 1,430 TWh and photovoltaic systems 494 TWh of electricity.

**Global capacity in operation** [$GW_{el}$], [$GW_{th}$], **and energy supplied** [$TWh_{el}$], [$Twh_{th}$], **2017**

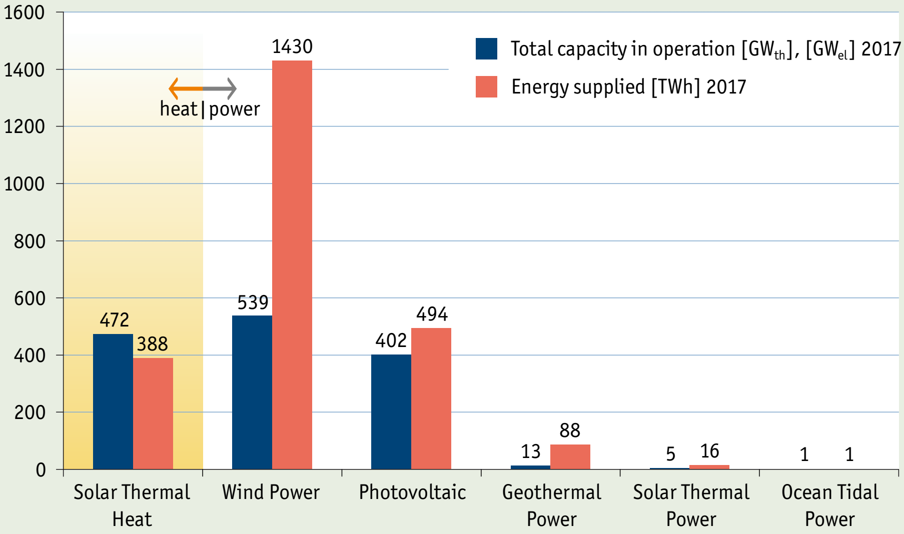



***Figure 3:*** *Global capacity in operation [$GW_{el}$], [$GW_{th}$] 2017 and annual energy yields [$TWh_{el}$], [$TWh_{th}$].*
*(Sources: AEE INTEC, Global Wind Energy Council (GWEC), SolarPower Europe, REN21 – Global Status Report 2018)*

The development of global installed capacity of solar thermal heat, wind and photovoltaics between 2010 and 2017 is shown in **Figure 4**. It can be highlighted that all mentioned renewable technologies show positive growth rates in terms of cumulated installed capacities.

Solar thermal was the leading 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.

3 The figures for 2017 are based on the latest market data from Australia, Austria, Brazil, China, Germany, India, Israel, Mexico, Turkey and the United States, which represented about 87 % of the cumulated installed capacity in operation in the year 2016. The other countries were estimated according to their trend over the past two years.

*Collector assembling at Hospital Militar Escuela Dr. Alejandro Dávila Bolaños, Nicaragua* *Photo: SOLID*

In 2017, photovoltaics had the highest global growth rate with 33 % added capacity and was followed by wind, which increased its installed capacity by 11 %. With 4 % added capacity, solar thermal was significantly behind the other two technologies as shown in **Figure 4**.

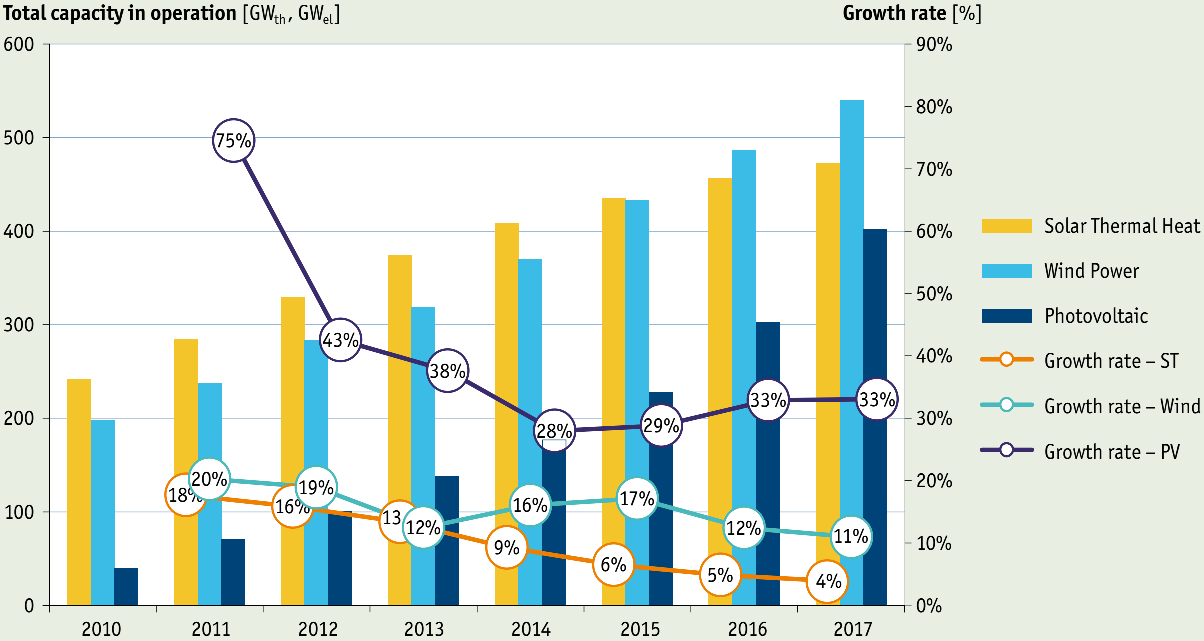



***Figure 4:*** *Global capacity in operation and market growth rates between 2010 and 2017 (Sources: AEE INTEC, Global Wind Energy Council (GWEC), SolarPower Europe, REN21 – Global Status Reports 2011 – 2018)*

# 4 Solar thermal market development and trends in 2017

Solar thermal systems are facing challenging times. This is reflected in the continuous shrinking of the annual added collector capacity, which declined from 18 % in the period 2010/2011 to 4 % in the period 2016 / 2017.

Compared to the year 2016, new installations declined by 4.2% in 2017. The most dramatic development were in China where for the fourth year in a row the market declined. After a –17 % decline in 2014 and 2015 and a 9 % decline in 2016, this trend continued 2017 with a 6 % decline. For detailed country trends please refer to Chapter 5. Besides this general trend in China it is remarkable that 2017 saw an increase of 8 % in newly installed flat plate capacity in China, whereas vacuum tube capacity declined by 8 %. Positive market growth were recorded in India (26 %), Mexico (7 %), and in Turkey (4 %).

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.

Although the share of these types of systems is increasing steadily, it still only represents about 3 % of the overall global installed capacity and only a few countries have installations up to now.

## 4.1 Solar thermal heating systems in the building sector

Small-scale solar water heating systems for detached single-family houses and apartment buildings represent approximately 90 % of the worldwide annual installations, therefore a declining interest in these systems would have a significant impact, particularly in the large markets of China and Europe. These two markets are the traditional mass markets for small-scale solar water heating and to a certain extent for solar space heating systems for detached single-family houses and apartment buildings and both are under market pressure from heat pumps and photovoltaic systems.

## 4.2 Large-scale systems for the supply of residential, commercial and public buildings

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 installed a number of large-scale systems.

By the end of 2017, 296 large-scale solar thermal systems (>350 $kW_{th}$; 500 m²) were in operation (**Figure 5**). The total installed collector area of these systems equaled 1,741,344 m². The capacity of these systems (excluding concentrating solar thermal systems) was 1,140 $MW_{th}$.

In 2017, 15 large-scale solar thermal systems were added worldwide. Of these installations, two installations each in Austria, Denmark and Germany and one large-scale system each in Sweden, France and in the Republic of Serbia were installed. In addition, the collector area of three existing Danish plants was extended.

Outside Europe in 2017 one large-scale system for district heating was installed in Australia, one in Kyrgyzstan and four in China. The total capacity of these systems is 5.9 $MW_{th}$ (8,444 m², excluding one concentrating solar thermal system with 9,000 m² in Tibet).

The nine large-scale systems added in Europe in 2017 account for about 35,000 m² (24.5 $MW_{th}$) of solar collectors. Of the new collector area, 46 % was installed in Denmark..

Denmark is the European frontrunner for large-scale solar district heating system installations, but in 2017 the market dipped. After a record high in 2016, with 31 new installations equalling 400,000 m² of large-scale collector fields across the country, Denmark was down to only two new installations and three extensions of existing solar district heating systems with a total capacity of 18.6 $MW_{th}$ (26,536 m²) in 2017.

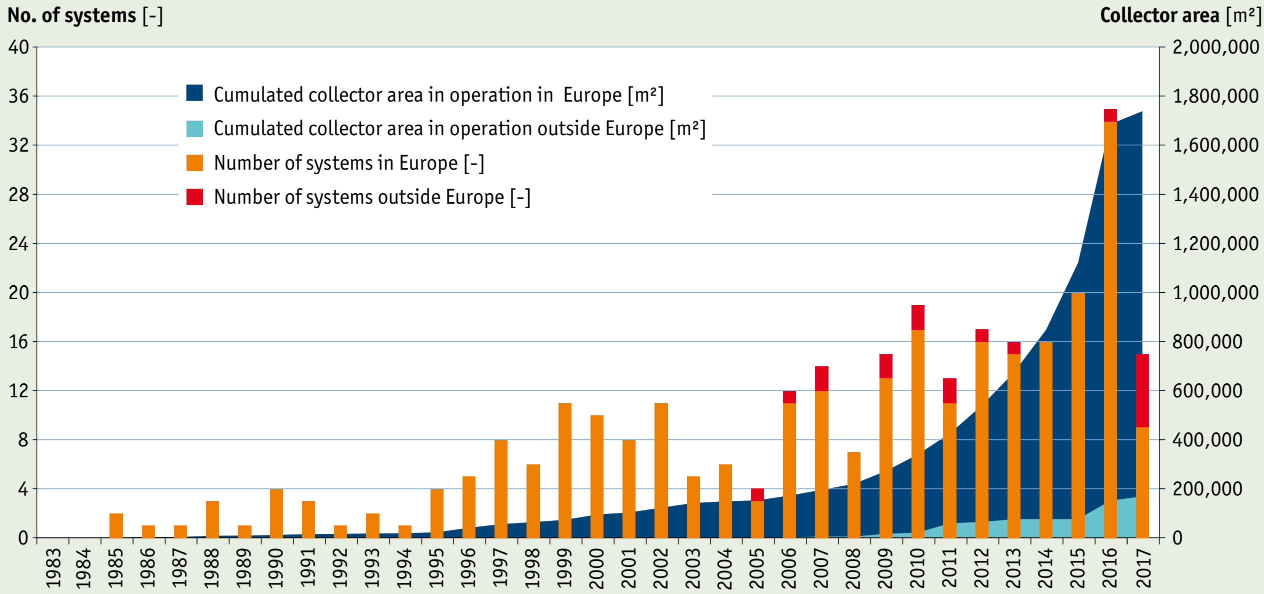
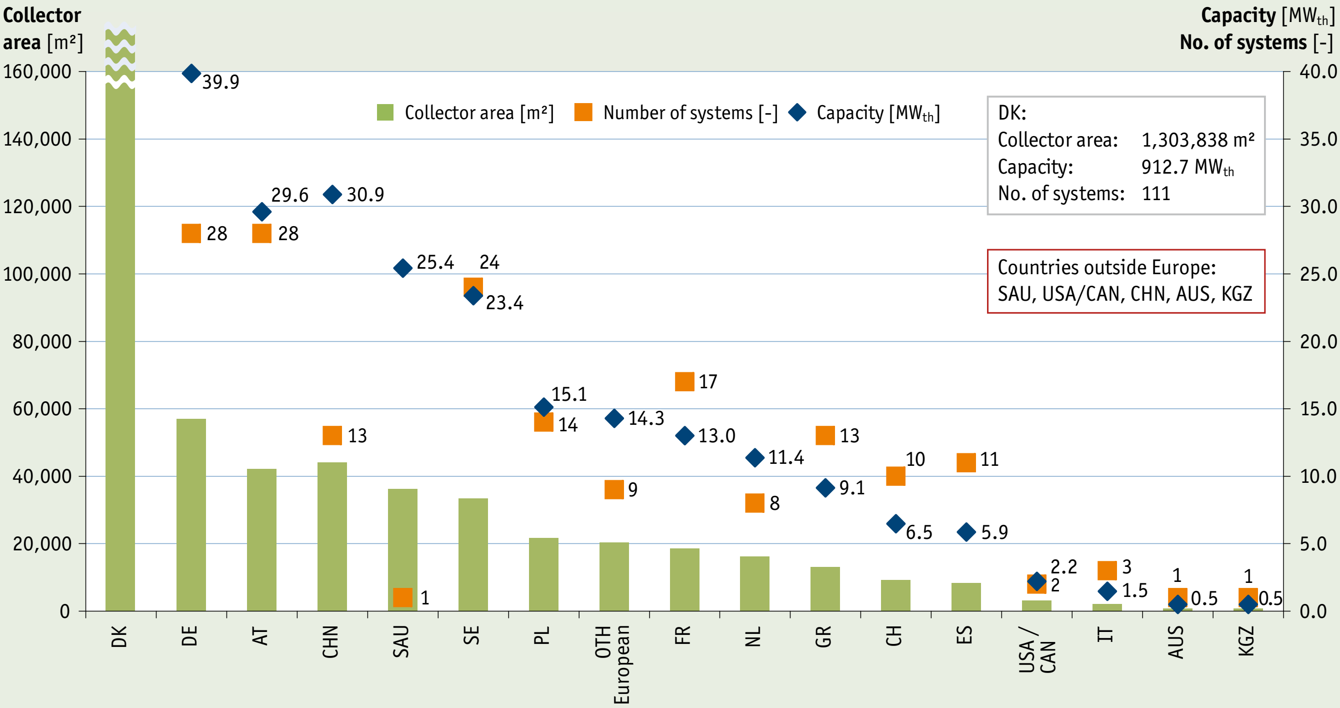



***Figure 5:*** *Large-scale systems for solar district heating and large residential, commercial and public buildings worldwide – annual achievements and cumulated area in operation in 2017 (Data source: Jan-Olof Dalenbäck – Chalmers University of Technology, SE and Sabine Putz – IEA SHC Task 55, Bärbel Epp solarthermalworld.org)*

*Solar thermal systems on multi-family houses in Salzburg, Austria* Photo: AEE INTEC

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 also worldwide, in the number of systems as well as in the installed capacity. The collector area for solar district heating in Denmark adds up to 1,327,451 m² with an installed capacity of 910.4 $MW_{th}$ by end of 2017.[4] The average system size of these plants calculates to be 8.2 $MW_{th}$ (11,746 m²). 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. The largest plants in operation are located in Silkeborg (110 $MW_{th}$), Vojens (50 $MW_{th}$; 69,991 m²), Gram (31.4 $MW_{th}$; 44,836 m²) and Dronninglund (26.3 $MW_{th}$; 37,500 m²) and are equipped with seasonal pit heat storages for solar fractions of around 50 % (see also **Chapter 4.2.1**).




Systems with concentrating solar thermal collectors >500 m² excluded; worldwide this type of system added with 110,929 m² to large-scale systems for solar district heating and large residential, commercial and public buildings.

**Figure 6:** *Large-scale systems for solar district heating and residential buildings – capacities and collector area installed and number of systems in 2017 (Data source: Jan-Olof Dalenbäck – Chalmers University of Technology, SE, Sabine Putz – IEA SHC Task 55, Bärbel Epp, solarthermalworld.org)*

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4 For the calculation of the installed capacity of solar district heating in Denmark by end of 2017 the system of Brønderslev with an installed collector area of 26,929 m² has been excluded because it is a concentrating solar thermal system.

*Solar district heating system in Vojens with load-balancing pit storage, Denmark.* *Photo: Arcon-Sunmark A/S*

Figure 6 shows solar district heating systems and large-scale systems for large residential, commercial and public buildings (excluding concentrating solar thermal systems) in Europe and worldwide. In Denmark, the share of large-scale systems for large residential, commercial and public buildings is less than 1 % (a collector area of about 3,300 m²).

Worldwide, Denmark is a good example for a mature and commercial solar district heating market but other markets are catching up, especially China. In several other countries smaller niche markets exist, such as in Austria where 28 systems >500 m² are installed to feed into district heating networks, smaller micro grids in urban quarters or local biomass heating networks and to supply large residential, commercial and public buildings. Other countries to note are Germany with 28 large-scale systems (some of these with seasonal storage), Sweden (24 systems), France (17 systems), Poland (14 systems), Greece (13 systems) and Switzerland (10 systems).

### 4.2.1 Selected large-scale systems connected to district heating in different countries

The world's largest plant for solar district heating is located in Denmark. Silkeborg has an installed capacity of 110 $MW_{th}$ (156,694 m² flat plate collectors)[5]. The start of operation of this plant was in December 2016.

Besides the system in Silkeborg, a substantial number of the other largest solar thermal systems are also located in Denmark and supply heat to district heating networks. The second largest system was commissioned in the city of Vojens in 2015 with a thermal capacity of 50 $MW_{th}$ (69,991 m²) and delivers 55 – 60 % of the thermal energy demand of 2,000 households[6];[7]. It is connected to a huge seasonal pit heat storage with a volume of 203,000 m³.

In Riyadh, Saudi Arabia a large-scale solar district heating plant was commissioned in July 2011. The solar thermal plant with a total capacity of 25.4 $MW_{th}$ (36,305 m²) is connected to a heating network for the supply of space heating and domestic hot water at a university campus.

One of the large solar district heating systems in China was installed already in 2013 at the Hebei University of Economics and Business in Shijiazhuang and supplies heat for space heating and hot water for the students' apartments. A vacuum collector field of 8.1 $MW_{th}$ (11,592 m²) is connected to 20,000 m³ heat storage. The overall storage comprises of 228 steel tanks that are integrated into a building. Another large system in similar size, 7.9 $MW_{th}$ (11,310 m²) was installed in 2008 in the new city in the resettlement district in Shenzhen.

As mentioned above, in 2017 four large-scale solar thermal plants for district heating were installed in China. Two of these systems are using concentrating solar collectors and are described in the following chapter.

The other two systems use flat-plate collectors. One of these systems is located in Lhasa, Tibet. It has a capacity of 2.24 $MW_{th}$ (3,200 m²) and is used for space heating of military barracks. The second system with a capacity of 2.17 $MW_{th}$ (3,100 m²) is installed in Inner Mongolia and supplies a residential area of the Hohehot Municipality[8].

*3,200 m² solar space heating project in Lhasa, Tibet.* Photo: FIVESTAR SOLAR ENERGY CO., LTD.

5 http://solar-district-heating.eu/ServicesTools/Plantdatabase.aspx
6 http://www.solarthermalworld.org/content/denmark-37-mw-field-203000-m3-storage-underway
7 http://www.arcon.dk/NY_Referencer.aspx
8 Information from Bärbel Epp - solrico

*Multi-family buildings in Crailsheim, Germany. Large-scale system with 5.1 $MW_{th}$ installed capacity.* *Photo: ITW / TZS University of Stuttgart, Germany.*

Germany and Austria also installed several MW-scale solar assisted district heating systems. At the end of August 2016, the biggest solar thermal installation in Germany with 5.8 $MW_{th}$ (8,300 m²) and about 4,000 MWh annual heat yield went into operation in Senftenberg in the Lausitz region of eastern Germany. This is one of the biggest installations with vacuum tube collectors worldwide.

Other large-scale German plants are located in Crailsheim with an installed capacity of 5.1 $MW_{th}$ and in Neckarsulm (3.9 $MW_{th}$).

The largest Austrian system in the MW-scale was commissioned in 2014 (extension) in the city of Graz and has a total capacity of 5.2 $MW_{th}$.

Canada also has a successful solar supported district heating network in Alberta. The Drake Landing Solar Community uses a 1.6 $MW_{th}$ (2,293 m²) centralized solar thermal plant connected to a seasonal borehole thermal energy storage to supply more than 90% of the energy needed for space heating of 52 energy efficient single-family homes.

*Parabolic trough collector field in Brønderslev, Denmark with an installed capacity of 16.6 $MW_{th}$ supplies not only heat to the district heating network, but also to power production as an add-on to a biomass-fuelled ORC system.* *Photo: Aalborg CSP*

## 4.2.2 Concentrating solar collectors for district heating

In 2016 and 2017 three concentrating solar collector fields were installed for feeding in district heating networks in Denmark and China[9],[10],[11]. The concentrating collector area of these three installed systems adds up to 110,929 m².

One of these concentrating solar thermal systems has been installed in northern Denmark in the municipality of Brønderslev. Its 26,929 m² parabolic trough collector field with an installed capacity of 16.6 $MW_{th}$ supplies not only heat to the district heating network, but also contributes to power production as an add-on to a biomass-fuelled organic rankine cycle (ORC) system. This combined solution is the first large-scale system in the world to demonstrate how concentrating solar collectors with an integrated energy system design can optimize efficiency of ORC even in regions with low direct solar radiation. The expected annual solar yield is 16,000 MWh or 590 kWh / m² collector area. The parabolic trough collector field has been operating since early 2017 but is going to be connected to the ORC plant in 2018.

In China two large-scale parabolic trough collector fields have been installed and connected to district heating systems. One system was installed in Inner Mongolia in October 2016 with a parabolic trough collector area of 75,000 m², the second one in Tibet with a collector area of 9,000 m² (in a second phase another 9,000 m² collector area is planned to be finished in 2018). This collector field will run on thermal oil and will be connected to a molten salt storage tank.

9 http://www.solarthermalworld.org/content/denmark-concentrating-solar-collectors-district-heat-northern-europe
10 http://www.solarthermalworld.org/content/second-winter-75000-m²-sdh-heating-system-inner-mongolia
11 http://www.solarthermalworld.org/content/tibets-highly-subsidised-solar-heating-market


*Figure 7:* *Solar district heating systems >500 m² (350 $kW_{th}$) in Europe. (Source: Heat Roadmap Europe)*

## 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 with 100 $MW_{th}$ capacity.

*1 $MW_{th}$ solar process heat plant at the Goess Brewery in Austria.* *Photo: Brauunion*

Based on the data published in the AEE INTEC SHIP database[12] and by SOLRICO[13] and the project, Solar Payback[14] at least 624 SHIP systems totalling 608,994 m² collector area were in operation at the end of the year 2017.

2017 was a record year for SHIP installations with 124 new documented systems, totalling 192,580 m² collector area, starting operation. With this the documented world total raised in 2017 by 25 % in terms of the number of the installed plants and by 46 % in terms of installed collector area. A select number of these plants are described in the following chapter.
The table below gives an overview by country of the SHIP plants installed in 2017.

| | No. of systems installed in 2017 | Total collector area [m²] | Average collector system size [m²] |
|---|---|---|---|
| Oman | 1 | 148,000 | 148,000 |
| Mexico | 36 | 6,411 | 178 |
| India | 36 | 15,313 | 425 |
| China | 19 | 11,534 | 607 |
| Austria | 2 | 1,785 | 893 |
| France | 2 | 2,052 | 1,026 |
| Afghanistan | 1 | 3,260 | 3,260 |
| Jordan | 1 | 1,254 | 1,254 |
| Other countries | 12 | 2,971 | 114 |
| **TOTAL** | 124 | 192,580 | |

**Table 1:** *Solar heat for industrial processes (SHIP) plants installed in 2017. Sources: Solar Payback SHIP Supplier Survey 2017, AEE INTEC*

Not included in the table's figures are the 378 small preheating units (totalling at 1.6 $MW_{th}$; 2,234 m²) that were newly installed in 2017 in the silk production center of Sidlaghatta[15], in southern India used to replace wood and briquettes for preheating the traditional stoves.

12 http://ship-plants.info/
13 http://www.sunwindenergy.com/content/solar-process-heat-surprisingly-popular
14 https://www.solar-payback.com/suppliers/
15 http://www.solarthermalworld.org/content/1500-preheating-systems-indias-silk-region

*Indoor parabolic trough collectors at the Miraah plant in Oman.* Photo: Barbara Soldera, GlassPoint Solar, Inc.

## 4.3.1 2017 industrial process heat installation highlights

**Solar plant for enhanced oil recovery in Oman**

In February 2018 four blocks of the Miraah solar plant with a total capacity of over 100 $MW_{th}$ began operation. The plant delivers 660 tons of steam per day to the Amal oilfield located in the south of the Sultanate of Oman. The steam is used for the extraction of viscous or heavy oil as an alternative to steam generated from natural gas.

The installation of these four blocks was just the first step. Once complete the plant will be the world's largest solar process heat system. The 1 $GW_{th}$ installation will consist of 36 blocks built in a sequence. It is planned that additional eight blocks with 200 $MW_{th}$ are operational in early 2019.

At this plant the parabolic trough collectors and other system components are indoors, using a greenhouse structure to protect from wind and sand, which is common in remote oilfields like Amal. The greenhouse enables major cost and performance advantages compared to exposed solar designs, from reducing overall material usage to automated washing operations[16].

16 https://www.glasspoint.com/

*Four blocks of the Miraah solar plant with a total capacity of 100 $MW_{th}$.* *Photo: Barbara Soldera, GlassPoint Solar, Inc.*

**China**

The largest SHIP installation completed in China in 2017 was a 2.3 $MW_{th}$ (3,300 m²) vacuum tube collector field that supplies heat to the company Heli Lithium Industry in Tibet.

Another big plant installed in 2017 uses a 1.5 $MW_{th}$ (2,200 m²) vacuum tube collector field to supply heat to the sea vegetable processer Polyocean Algal Industry Group in the city of Quingdao, Shandong Province.

**Afghanistan**

A German parabolic trough collector manufacturer delivered and installed a 3,260 m² collector field in Afghanistan at a meat production factory.

**Jordan**

A Fresnel collector field with a capacity of 700 $kW_{th}$ (aperture area of 1,254 m²) for direct steam generation for solar process heating and solar thermal cooling with an absorption chiller has been installed at the Japan Tobacco International factory in Jordan.

*Fresnel collector field for direct steam generation in Jordan.* *Photo: Industrial Solar GmbH, Copyright: Anders*

**India and Mexico**

Apart from the large plants mentioned above, two countries show particular dynamic growth in recent years.

As shown in **Figure 16**, India and Mexico have the highest number of solar process heat applications. Together they account for 41 % of the installed solar process heat systems worldwide. They share a couple of similarities: a strong local solar industry and an ability to provide affordable system solutions to end-users. High solar radiation and strong industrial production are key ingredients for strong solar process heat market, and these countries have both. They also have a high share of concentrating solar thermal collectors. **Figure 8** shows that almost three quarters of all concentrating systems worldwide are installed in Mexico (40 %) and India (33 %). Their share of non-concentrating systems is significantly lower, accounting for 28 % of all systems.

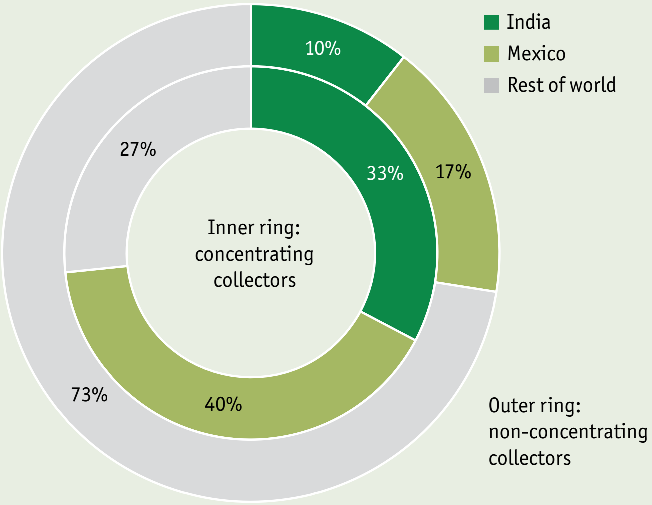


***Figure 8:***

*Share of concentrating and non-concentrating solar thermal collector systems in India, Mexico and the rest of the world by end of March 2018. The inner ring shows the share of concentrating solar thermal (CST) collector systems. The outer ring shows the share of non-concentrating solar thermal collector systems. (Source: IEA SHC Task49 / IV SHIP database)*

As **Figure 9** shows, the growth for Indian systems with concentrating solar collectors (mainly Scheffler dish systems) has been steady over the years with 1 to 4 new systems every year over the last 9 years. While in Mexico, the first system with concentrating solar thermal collectors was installed in 2012 and since then have commissioned more and larger systems every year with the exception of 2016. In 2017, 11 new systems with concentrating solar thermal collectors (mainly parabolic trough) with a total area of around 4,700 m² were installed in Mexico.

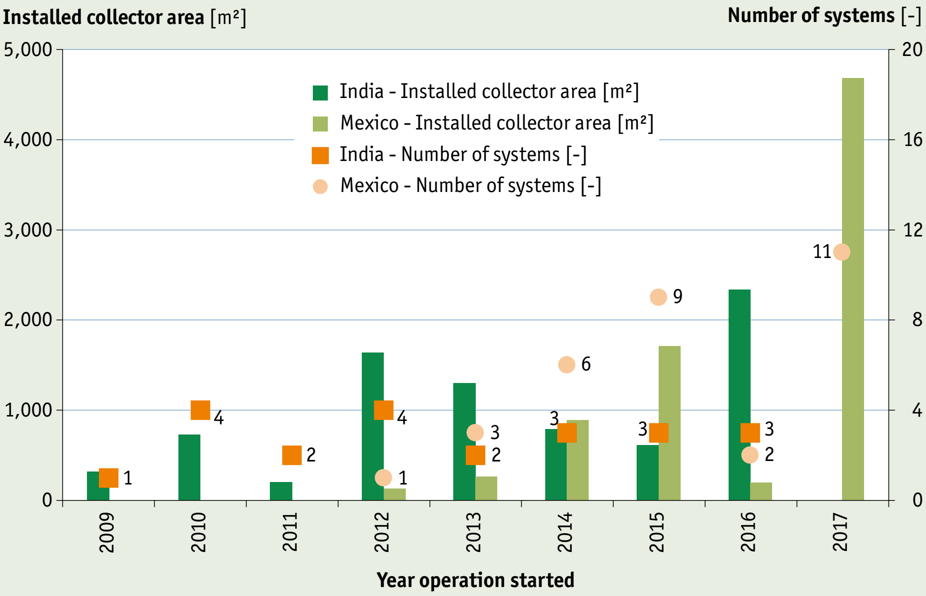


*Figure 9:* *Number and gross area of installed plants with concentrating solar thermal (CST) collector systems in India and Mexico by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

The targeted industrial sectors in **Figure 10** shows that both countries have installed the majority of their systems in the food industry sectors. While Mexico has focused almost entirely on the food and beverage sectors; India also has a significant number of plants in the chemical, textile, agriculture and other industries sectors.

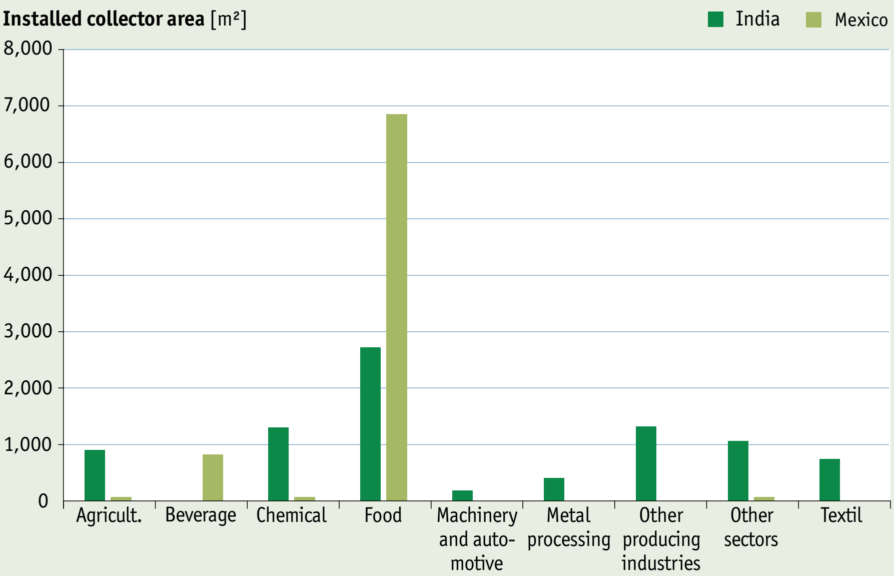


*Figure 10:* *Application of concentrating solar thermal (CST) collector systems to various industrial sectors in India and Mexico by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

**Figure 11** and **Figure 12** show the number, gross area and thermal capacity of the installed plants with concentrating collectors in Mexico and India respectively. Both countries have most systems with the highest total gross area in the range of 100 – 999 m². India also has one application with a gross area >1000 m².

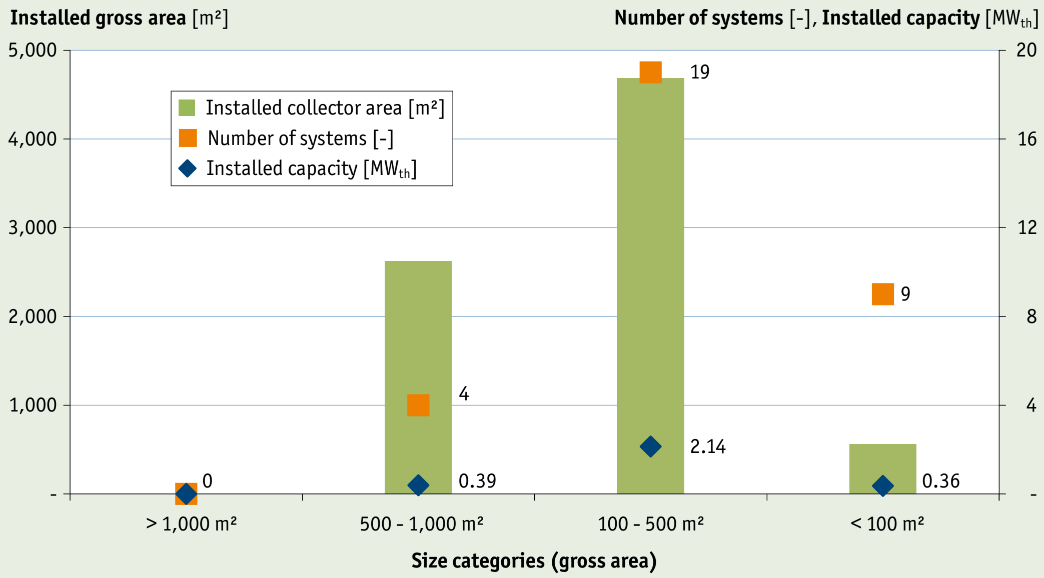


***Figure 11:*** *Number, gross area and thermal capacity of installed plants with concentrating collector types in different size categories in Mexico by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

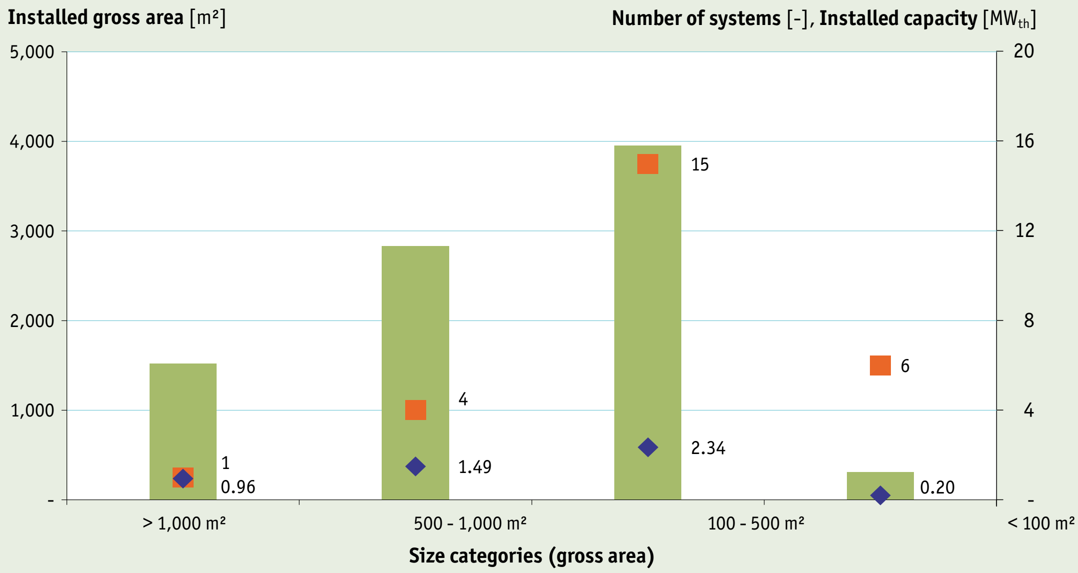


***Figure 12:*** *Number, gross area and thermal capacity of installed plants with concentrating collector types in different size categories in India by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

*Photo: Inventive Power S.A.P.I. de C.V.*

### 4.3.2 Detailed analysis of 271 systems

Of the 635 documented SHIP plants, 271 have more detailed information on the collector area and installed capacity as well as type of application and type of collector that can be found in the IEA SHC Task49 / IV SHIP database, which is an online portal operated by AEE INTEC in Austria[17].

The following figures show the analysis of the systems where detailed information was available.

As described above, a 100 $MW_{th}$ solar process heat application was commissioned in Oman in 2017 for enhanced oil recovery. The first four blocks of this system surpass the so far largest solar process heat application in Chile, which has a thermal capacity of 27.5 $MW_{th}$. Together the two systems account for 62 % of the total installed thermal capacity of the 271 solar process heat plants worldwide analyzed in this chapter in detail.

**Figure 13** shows the distribution of the 271 systems in terms of size. The two systems mentioned above exceed 21 $MW_{th}$ of thermal capacity, 26 systems have installed capacities between 0.7 $MW_{th}$ and 21 $MW_{th}$ (1,000 m² – 30,000 m²), 45 systems have installed capacities between 0.35 and 0.7 $MW_{th}$ (500 – 1,000 m²) and 198 systems are below 0.35 $MW_{th}$ (<500 m²).

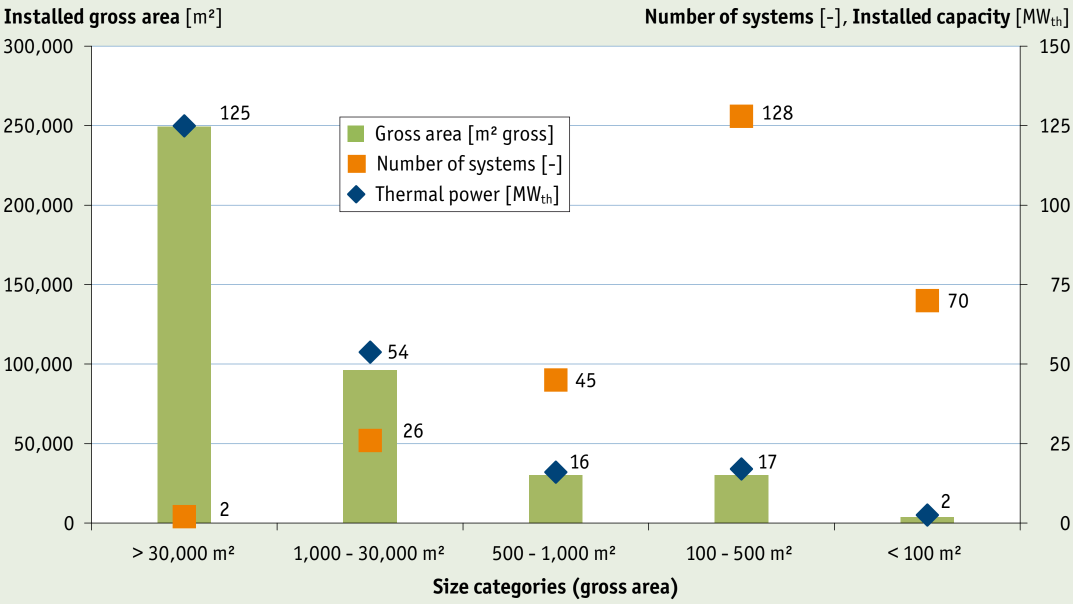


***Figure 13:*** *Global solar process heat plants in operation by capacity and collector area by end of March 2018 (Source: IEA SHC Task49 / IV SHIP database)*

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17 http://ship-plants.info/

**Figure 14** 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. In terms of installed collector area parabolic trough collectors are ahead of flat plate collectors. Compared to the year 2016 parabolic trough collectors took over 2nd place in regard to the number of installed systems from evacuated tube collectors.

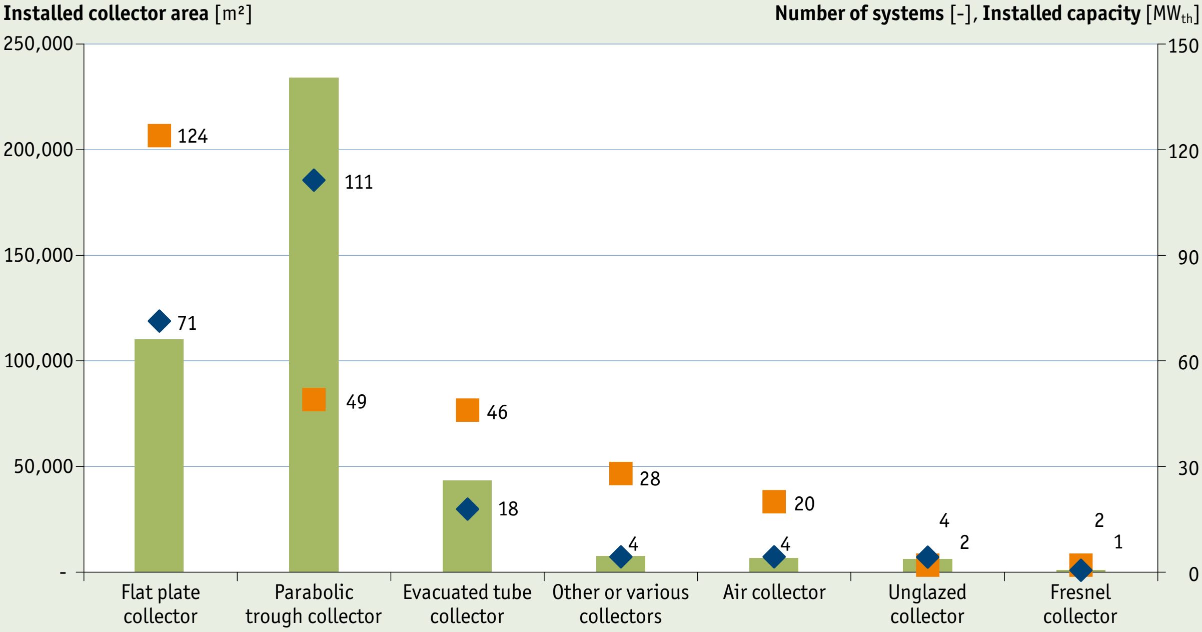



***Figure 14:*** *Global solar process heat applications in operation by type of collector by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

The following figure shows the industry sectors of the 271 systems analyzed in detail. The main sectors are mining, food and textile. While the food sector accounts for 104 systems (38 %) these systems tend to be small to medium-sized systems and thus represent in total 25.6 $MW_{th}$ (13 %) of the total installed thermal capacity. On the other side, the mining sector accounts for the two largest systems (Codelco copper mine in Chile and Miraah oil field in Oman) and 12 smaller systems (5 % of total number installed systems). The installed thermal capacity in the mining sector is 131 $MW_{th}$ and represents 65 % of the total installed thermal capacity.

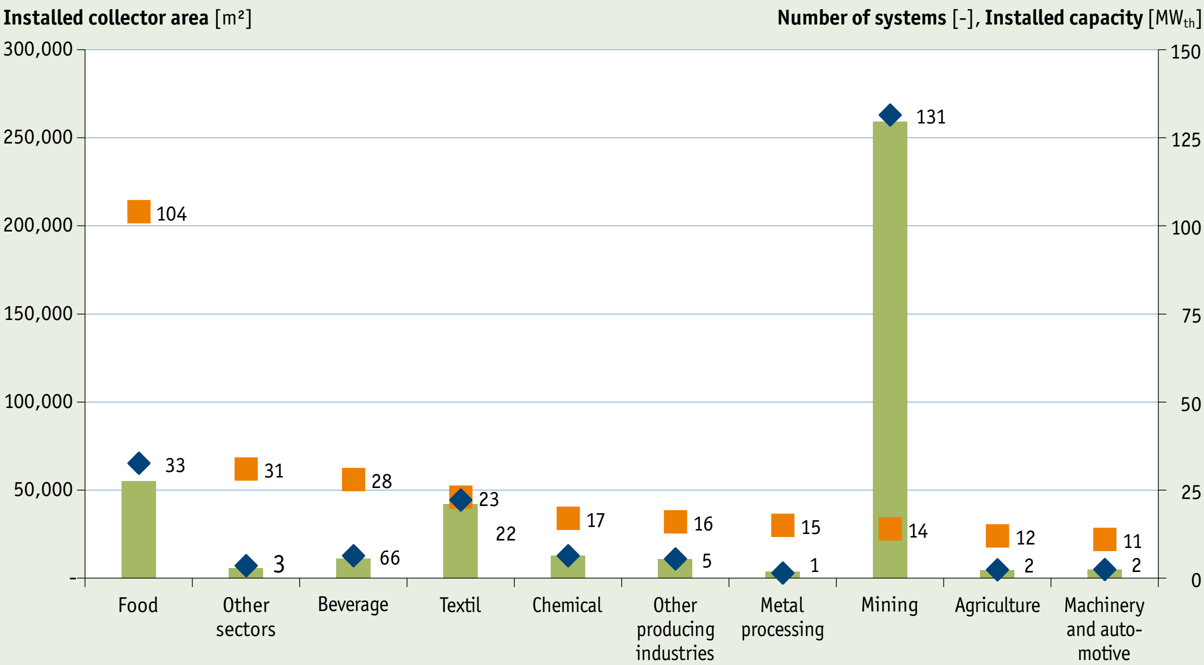



***Figure 15:*** *Global solar process heat installations in operation by industry sector by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

**Figure 16** shows the global installed solar process heat systems by country. Mexico and India have the highest number of installed systems, followed by Austria, Germany, United States and Spain. In terms of solar capacity, Oman is the leader with only one system installed followed by China generated from 12 systems, and then Chile generated from two systems.

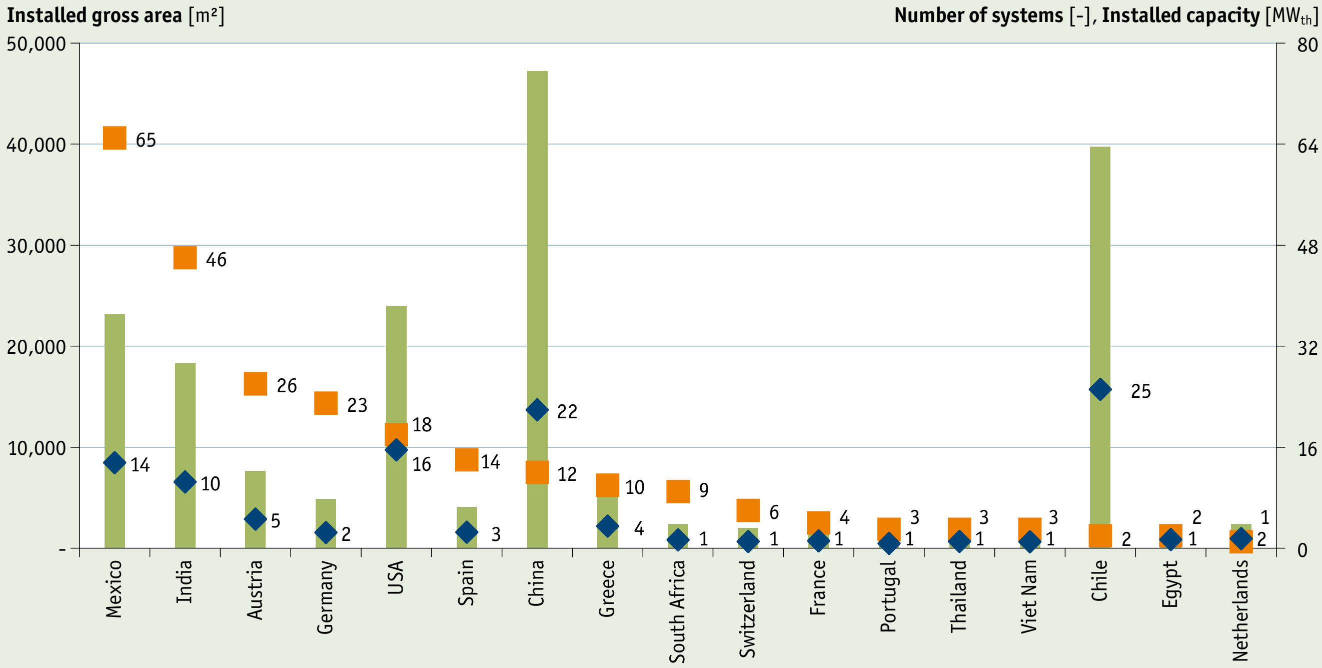



**Figure 16:** *Global solar process heat installations in operation by country by end of March 2018. Only countries with at least 0.7 MW$_{th}$ (1,000 m² gross area) are shown (248 of 271 systems accounting for 98 % of installed thermal capacity) (Source: IEA SHC Task49 / IV SHIP database)*

Looking at the specific useful heat delivery in respect to the latitude, **Figure 17** illustrates the range. The specific 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 countries.

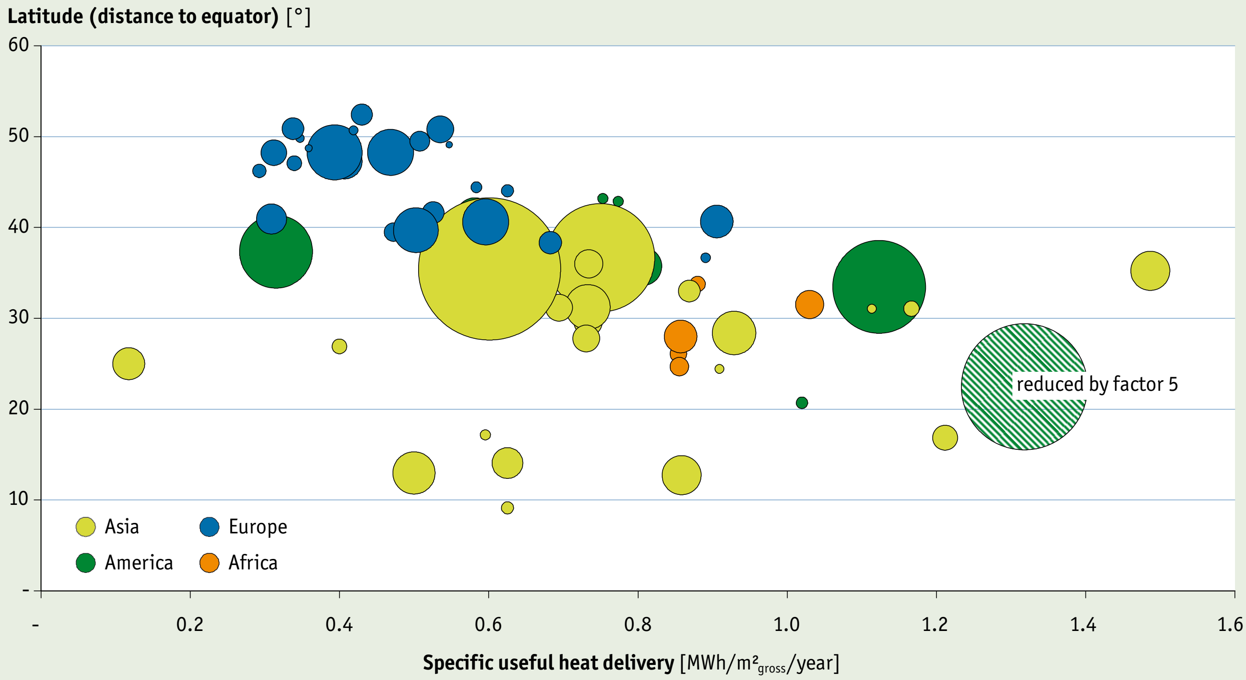



**Figure 17:** *Specific useful heat delivery and latitude of installed systems by end of March 2018 (Source: IEA SHC Task49 / IV SHIP database)*

## 4.4 Solar air conditioning and cooling

### 4.4.1 Small and medium size applications

In a global market for cooling and refrigeration, which will keep growing especially in emerging countries worldwide due to their economic growth, there is a huge potential for cooling systems that use solar energy. This is related to thermal as well as PV driven solar cooling and air conditioning systems. 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 with grid constraints.

By the end of 2015, an estimated 1,350 solar cooling systems were installed worldwide. More recent global data are not available as data collection is difficult with more and more players entering the market, especially in Asia and the Middle East. Approximately 70 % of the small and medium capacity (<350 kW) solar cooling systems worldwide are installed in Europe.


*Figure 18:* *Market development 2004 – 2015 of small to large-scale solar air conditioning and cooling systems (Source: Solem Consulting, Tecsol)*

In the segment of small and medium size applications, a new generation of solar cooling systems, either PV or thermally driven, has appeared among existing solar thermal cooling solutions. Unfortunately, a real and significant market has not yet emerged from these innovations. Nevertheless, several SME's[18,19,20] are working on solutions to reduce the relatively high system costs, space requirements and the complexity of solar thermal-based cooling, especially for small-capacity systems.

Already, several Chinese manufacturers are including a PV option on their units as a support to the main grid supply even if this add on positions the overall system as an expensive air conditioner.

18 http://pvcooling.atisys.fr/
19 https://www.sunoyster.com/socool/
20 http://www.freescoo.com/en/

## 4.4.2 Solar cooling with a cooling capacity larger than 350 kW

Solar cooling with thermal absorption chillers with a cooling capacity larger than 350kW / 100RT has improved significantly in performance and at the same time decreased in costs recently. Economy of scale plays an important role: Therefore, solar cooling for larger office buildings, hotels, hospitals or commercial and industrial applications have become cost competitive.

Solar thermal systems, which combine at the same time the demand of low temperature heat (for domestic hot water) and high temperature heat (for air conditioning) are even more competitive. Those combinations are very favorable especially in moderate climates because they give a very good balance of the solar energy use over the year.

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 outstanding by the easy way of storing the solar heat and shifting it for cooling demands in the evenings and nights, and moreover keeping remaining energy for morning cooling.

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.

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 $m^2$) that supplies heat to a single-effect lithium bromide absorption chiller with a cooling capacity of 1.75 MW.

Several larger solar cooling systems were also installed between 2015 and 2017. These include systems for the European companies Wipotec (Germany) and for the Sheikh Zayed Desert Learning Center in Abu Dhabi[21].

In 2017, large-scale solar cooling installations were realized for IKEA Alexandra in Singapore and for Hospital Militar Escuela, Dr. Alejandro Dávila Bolaños in Managua, Nicaragua.

The solar thermal cooling system at IKEA Alexandra in Singapore has a collector area of 2,472 $m^2$. The cooling capacity of the absorption chiller is 880 kW (250 tons).

The system in Managua has a total capacity of 3.1 $MW_{th}$ (4,450 $m^2$ collector area). The roof mounted flat plate collector field is hydraulically connected to a 1.023 $MW_{th}$ absorption chiller with a cooling capacity of 1,023 kW and supplies hot water and cooling to Nicaragua's largest and most modern hospital with approximately 400 beds.

21 Dr. Jakob energy research, 2016

*2,472 m² solar cooling system at IKEA Singapore delivers 1,587 MWh for an 880 kW absorption chiller.* *Photo: SOLID GmbH*

| Country | Site | Commis-sioned | Installed capacity [kWth] | Collector size [m²] | Collector type | Cooling capacity [kWcold] |
|---|---|---|---|---|---|---|
| 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 | Evacuated tube | 528 |
| Arizona, USA | Desert Mountain High School, Scottsdale | 2014 | 3,407 | 4,865 | Flat plate | 1,750 |
| Johannesburg, South Africa | MTN Headquarter | 2014 | 272 | 484 | Fresnel | 330 |
| 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 | Evacuated 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 2:*** *Large-scale solar cooling systems installed between 2007 and 2017*

*Sources: Blackdot Energy, Industrial Solar GmbH, Ritter XL Solar, SOLID GmbH, **www.solarthermalworld.org***

As can be seen in the table above, the majority of these systems are equipped with flat plate or evacuated tube collectors. By contrast, some thermal cooling machines are driven by concentrating solar thermal collectors, such as Fresnel collectors.

*Solar air collector system in Uzbekistan.* *Photo: CONA SOLAR AUSTRIA*

## 4.5 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 and take advantage of the lower winter sun angles and avoid snow accumulation as is typical of roof mounted systems. 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 or in some cases for wood chip drying.

By end of 2016 a total of 1.22 $MW_{th}$ (1,742,942 $m^2$) of glazed and unglazed air collectors were installed worldwide. The annual worldwide market 2016 was at a range of 57 $MW_{th}$ (82,000 $m^2$).

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 2016 and country figures

The following chapters of the report show detailed solar thermal market figures for the year 2016 and country figures for 66 countries.

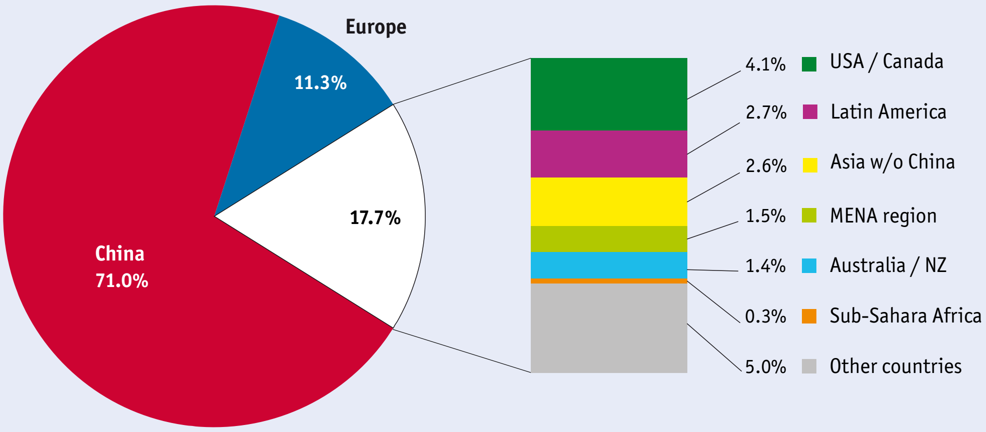
**Background of the presented data:** The following chapters of the report show figures of the actual collector area in operation in 2016 and not the cumulated collector area installed in a country. To determine the collector area (and respective capacity) in operation, either official country reports 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 2016, an installed capacity of 457 $GW_{th}$ corresponding to a total of 652.9 million square meters of collector area was in operation worldwide.

The vast majority of the total capacity in operation was installed in China (324.5 $GW_{th}$) and Europe (51.8 $GW_{th}$), which together accounted for 82.3 % of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (18.6 $GW_{th}$), Asia excluding China (12.1 $GW_{th}$), Latin America (12.3 $GW_{th}$), the MENA countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (6.8 $GW_{th}$), Australia and New Zealand (6.5 $GW_{th}$), and Sub-Sahara African countries Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa and Zimbabwe (1.5 $GW_{th}$). The market volume of “all other countries” is estimated to amount for 5 % of the total installations (22.9 $GW_{th}$).




| | |
|---|---|
| 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, Macedonia, Norway, Russia, Switzerland, Turkey |
| MENA countries: | Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia |

*Figure 19: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2016*

| Country | Water Collectors [$MW_{th}$] | | | Air Collectors [$MW_{th}$] | | TOTAL [$MW_{th}$] |
|---|---|---|---|---|---|---|
| | unglazed | FPC | ETC | unglazed | glazed | |
| Albania | | 143.1 | 1.9 | | | 145.0 |
| Australia | 3,689.0 | 2,370.2 | 121.8 | 252.0 | 7.6 | 6,440.6 |
| Austria | 292.8 | 3,291.8 | 60.0 | | 2.6 | 3,647.1 |
| Barbados | | 150.0 | 0.0 | | | 150.0 |
| Belgium | 31.5 | 345.9 | 62.5 | | | 439.9 |
| Botswana**** | | 6.7 | 0.0 | | | 6.7 |
| Brazil | 3,317.0 | 6,186.7 | 51.3 | | | 9,555.0 |
| Bulgaria | | 93.4 | 2.8 | | | 96.2 |
| Burkina Faso** | | 0.7 | 0.1 | | | 0.8 |
| Canada | 564.7 | 49.3 | 33.9 | 284.6 | 34.3 | 966.6 |
| Chile | 45.9 | 128.8 | 29.4 | 0.0 | 0.2 | 204.3 |
| China | | 27,046.3 | 297,459.7 | 2.1 | 1.4 | 324,509.5 |
| Croatia | | 140.0 | 7.1 | | | 147.1 |
| Cyprus | 1.5 | 462.1 | 17.4 | | | 481.0 |
| Czech Republic | 418.6 | 307.4 | 90.5 | | | 816.5 |
| Denmark | 14.4 | 1,122.2 | 6.4 | 3.0 | 12.6 | 1,158.6 |
| Estonia | | 5.6 | 4.6 | | | 10.2 |
| Finland | 8.3 | 25.7 | 12.8 | | | 46.8 |
| France (mainland)+ | 84.2 | 1,340.3 | 128.5 | 4.6 | 0.8 | 1,558.4 |
| Germany | 385.8 | 11,713.8 | 1,435.7 | | 18.3 | 13,553.6 |
| Ghana**** | | 1.2 | 0.4 | | | 1.6 |
| Greece | | 3,133.2 | 15.1 | | | 3,148.3 |
| Hungary | 12.1 | 147.5 | 49.1 | 1.7 | 1.5 | 211.9 |
| India++ | | 2,529.5 | 4,143.9 | | 8.3 | 6,681.7 |
| Ireland | | 155.7 | 84.6 | | | 240.3 |
| Israel | 25.9 | 3,218.2 | 0.0 | | | 3,244.1 |
| Italy | 30.7 | 2,643.0 | 412.9 | | | 3,086.6 |
| Japan | | 2,405.3 | 46.9 | | 367.6 | 2,819.8 |
| Jordan* | 4.2 | 687.7 | 190.5 | | | 882.4 |
| Korea, South | | 1,180.6 | 115.5 | | | 1,296.1 |
| Latvia | | 6.7 | 1.9 | | | 8.6 |
| Lebanon | | 200.7 | 277.5 | | | 478.2 |
| Lesotho | | 1.0 | 0.3 | | | 1.3 |
| Lithuania | | 4.6 | 5.8 | | | 10.4 |
| Luxembourg | | 36.4 | 5.7 | | | 42.1 |
| Macedonia | | 33.8 | 11.8 | | | 45.6 |
| Malta | | 28.9 | 7.2 | | | 36.1 |
| Mauritius** | | 93.0 | 0.0 | | | 93.0 |
| Mexico | 722.9 | 919.2 | 721.0 | 0.5 | 6.1 | 2,369.7 |
| Morocco* | | 315.7 | 0.0 | | | 315.7 |
| Mozambique | 0.1 | 0.0 | 0.8 | | | 0.9 |
| Namibia | 1.1 | 24.5 | 0.9 | | | 26.5 |
| Netherlands | 70.4 | 362.6 | 23.6 | | | 456.6 |
| New Zealand*** | 4.9 | 100.1 | 6.8 | | | 111.8 |
| Nigeria | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 | 0.3 |
| Norway**** | 1.3 | 30.5 | 3.5 | 0.1 | 2.9 | 38.3 |
| Palestinian Ter.**** | | 1,278.6 | 5.8 | | | 1,284.4 |
| Poland | | 1,162.4 | 333.7 | | | 1,496.1 |
| Portugal | 1.5 | 693.4 | 19.2 | | | 714.1 |
| Romania | 0.2 | 67.9 | 54.0 | 0.6 | | 122.7 |
| Russia | 0.1 | 14.1 | 2.3 | 0.0 | 0.0 | 16.5 |
| Senegal**** | 0.0 | 0.1 | 1.2 | 0.0 | 0.8 | 2.1 |
| Slovakia | 0.7 | 96.1 | 15.9 | | | 112.7 |
| Slovenia | | 86.6 | 16.2 | | | 102.8 |
| South Africa | 776.4 | 401.0 | 158.2 | 0.0 | 0.0 | 1,335.6 |
| Spain | 104.0 | 2,483.3 | 145.3 | 1.2 | 0.9 | 2,734.7 |
| Sweden | 119.3 | 211.2 | 50.4 | | | 380.9 |
| Switzerland | 138.6 | 907.5 | 87.9 | | | 1,134.0 |
| Taiwan | 1.4 | 1,089.0 | 92.1 | | | 1,182.5 |
| Thailand**** | | 110.3 | 0.0 | | | 110.3 |
| Tunisia | | 585.8 | 49.1 | | | 634.9 |
| Turkey | | 11,153.2 | 3,779.6 | 6.0 | | 14,938.8 |
| United Kingdom | | 437.8 | 121.0 | 15.8 | | 574.6 |
| United States | 15,481.6 | 1,975.1 | 108.3 | 77.7 | 43.1 | 17,685.8 |
| Uruguay**** | | 40.8 | 0.0 | | | 40.8 |
| Zimbabwe | | 15.3 | 10.7 | | | 26.0 |
| All other countries (5%) | 1,386.9 | 5,052.6 | 16,352.8 | 34.2 | 26.8 | 22,853.3 |
| **TOTAL** | 27,738 | 101,051 | 327,056 | 684 | 536 | 457,065 |

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 is based on estimations for new installations in 2016

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

***Table 3:*** *Total capacity in operation in 2016 [$MW_{th}$]*

| Country | Water Collectors [m²] | | | Air Collectors [m²] | | TOTAL (excl. concentrators) [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 |
| Burkina Faso**** | | 932 | 139 | | | 1,071 |
| Canada | 806,664 | 70,365 | 48,436 | 406,579 | 48,985 | 1,381,029 |
| Chile | 65,550 | 184,000 | 42,000 | 0 | 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 | 551,110 | 16,734,000 | 2,051,000 | | 26,100 | 19,362,210 |
| 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++ | | 3,613,504 | 5,919,907 | | 11,900 | 9,545,311 |
| 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 |
| Macedonia | | 48,233 | 16,829 | | | 65,062 |
| Malta | | 41,337 | 10,334 | | | 51,671 |
| Mauritius** | | 132,793 | | | | 132,793 |
| Mexico | 1,032,677 | 1,313,082 | 1,030,042 | 752 | 8,773 | 3,385,326 |
| 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 | 0 | 120 | 235 | 0 | 70 | 425 |
| Norway**** | 1,849 | 43,624 | 5,032 | 200 | 4,106 | 54,812 |
| Palestinian Ter.**** | | 1,826,625 | 8,225 | | | 1,834,850 |
| 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**** | 0 | 87 | 1,648 | 0 | 1,145 | 2,879 |
| Slovakia | 1,000 | 137,350 | 22,750 | | | 161,100 |
| Slovenia | | 123,650 | 23,150 | | | 146,800 |
| South Africa | 1,109,093 | 572,836 | 226,070 | 0 | 0 | 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**** | | 58,247 | | | | 58,247 |
| Zimbabwe | | 21,811 | 15,249 | | | 37,060 |
| All other countries (5%) | 1,981,260 | 7,217,947 | 23,361,156 | 48,877 | 38,266 | 32,647,506 |
| **TOTAL** | 39,625,204 | 144,358,932 | 467,223,119 | 977,548 | 765,316 | 652,950,119 |

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

*Table 4:* *Total installed collector area in operation in 2016 [m²]*

The total installed capacity in operation in 2016 was divided into flat plate collectors (FPC): 101.1 $GW_{th}$ (144.4 million square meters), evacuated tube collectors (ETC): 327.1 $GW_{th}$ (467.2 million square meters), unglazed water collectors 27.7 $GW_{th}$ (39.6 million square meters), and glazed and unglazed air collectors: 1.2 $GW_{th}$ (1.7 million square meters)[22].

With a global share of 71.5 %, evacuated tube collectors were the predominant solar thermal collector technology, followed by flat plate collectors with 22.1 % and unglazed water collectors with 6.1 %. Air collectors play only a minor role in the total numbers (**Figure 20**).

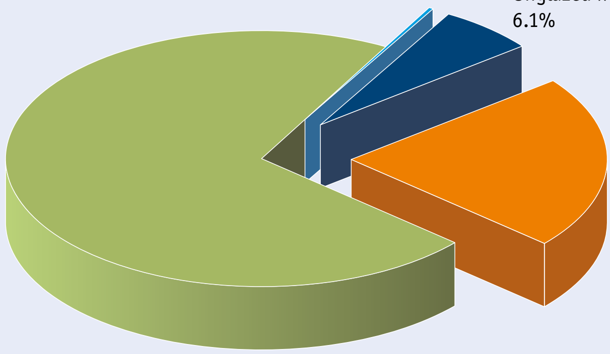



***Figure 20:*** *Distribution of the total installed capacity in operation by collector type in 2016 – WORLD*

By contrast in Europe, the second largest market to China, flat plate collectors were the dominant collector type (**Figure 21**). Compared to 2015 the share of evacuated tube collectors increased in Europe by 1.8 %.

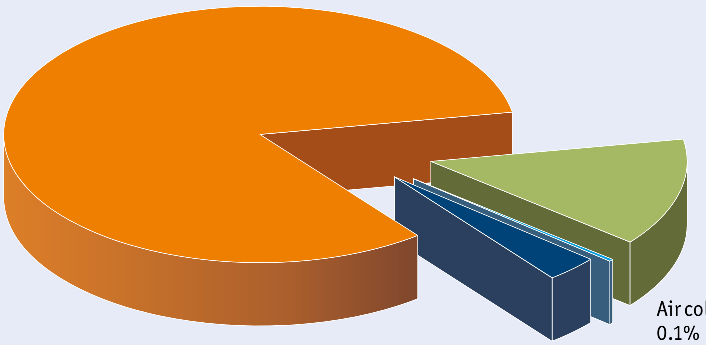



***Figure 21:*** *Distribution of the total installed capacity in operation by collector type in 2016 – EUROPE*

22 In 2014 glazed air collectors in Switzerland reached the end of the service life time. The majority of these systems were used for agricultural hay drying.

**Figure 22** shows the cumulated installed capacity of glazed and unglazed water collectors in operation for the 10 leading markets in 2016 in total numbers.

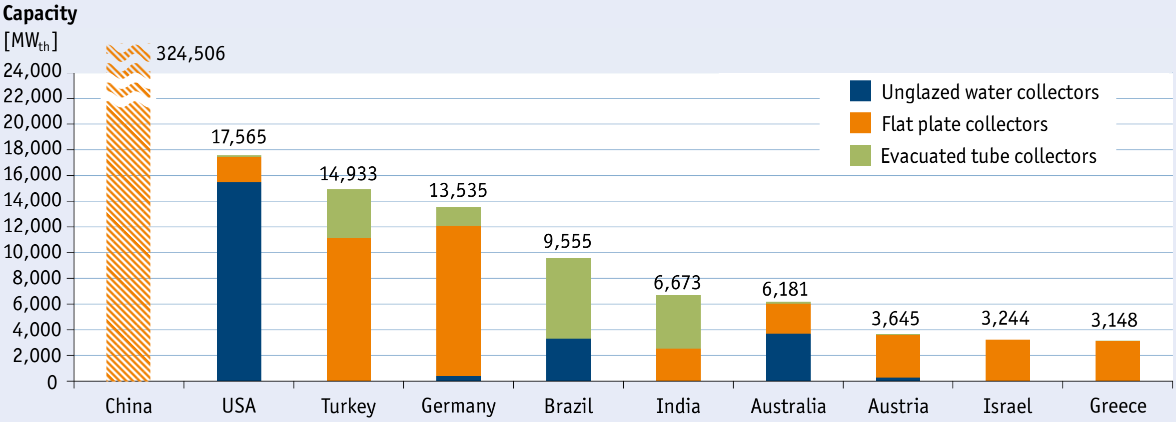



***Figure 22:*** *Top 10 countries of cumulated water collector installations (absolute figures in $MW_{th}$) 2016*

Compared to the year 2015, the top 10 countries remained unchanged. However, Turkey overtook Germany in 2015 and now holds the number three position and India overtook Australia in 2015 and improved its position from seventh position to position six. This shows the trend of the last years that non-OECD countries are taking over more and more the top positions.

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 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 Israel over the past several years.

The top 10 countries with the highest market penetration per capita changed compared to 2015. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2016 per 1,000 inhabitants were Barbados (515 $kW_{th}$ / 1,000 inhabitants), Austria (418 $kW_{th}$ / 1,000 inhabitants), Cyprus (399 $kW_{th}$ / 1,000 inhabitants), Israel (397 $kW_{th}$ / 1,000 inhabitants), Greece (292 $kW_{th}$ / 1,000 inhabitants), the Palestinian territories (289 $kW_{th}$ / 1,000 inhabitants), Australia (269 $kW_{th}$ / 1,000 inhabitants), China (236 $kW_{th}$ / 1,000 inhabitants), Denmark (204 $kW_{th}$ / 1,000 inhabitants) and Turkey (186 $kW_{th}$ / 1,000 inhabitants). Denmark overtook Turkey due to a lot of large district heating systems installed in 2016.

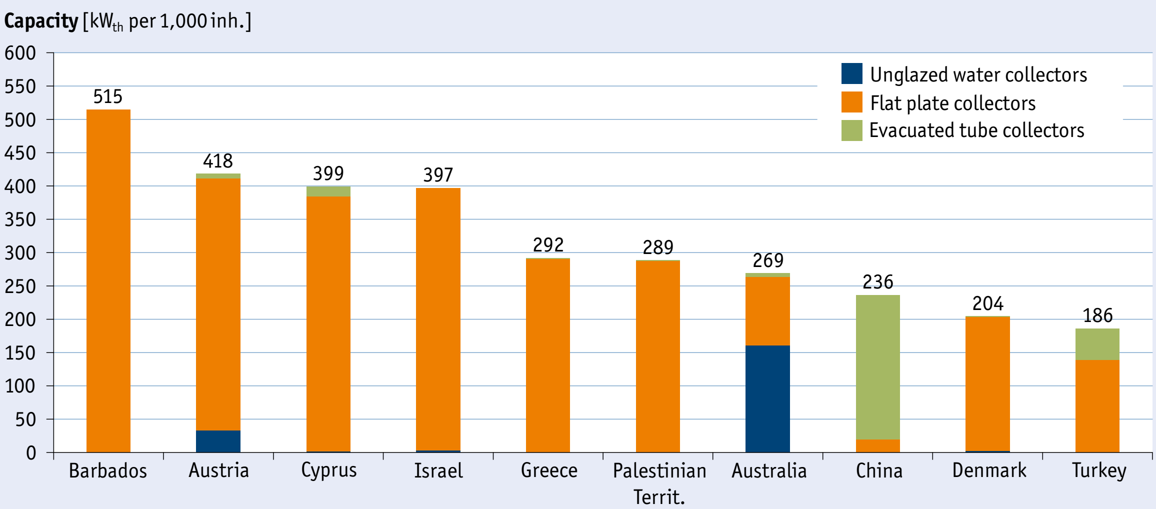



***Figure 23:*** *Top 10 countries of cumulated water collector installations (relative figures in $kW_{th}$ per 1,000 inhabitants) 2016*

## 5.2 Total capacity of glazed water collectors in operation

With 324.5 $GW_{th}$, China was still by far the leader in terms of total installed capacity of glazed water collectors in 2016. 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, and Taiwan had more than 1 $GW_{th}$ of water collectors installed by the end of 2016 (**Figure 24**).

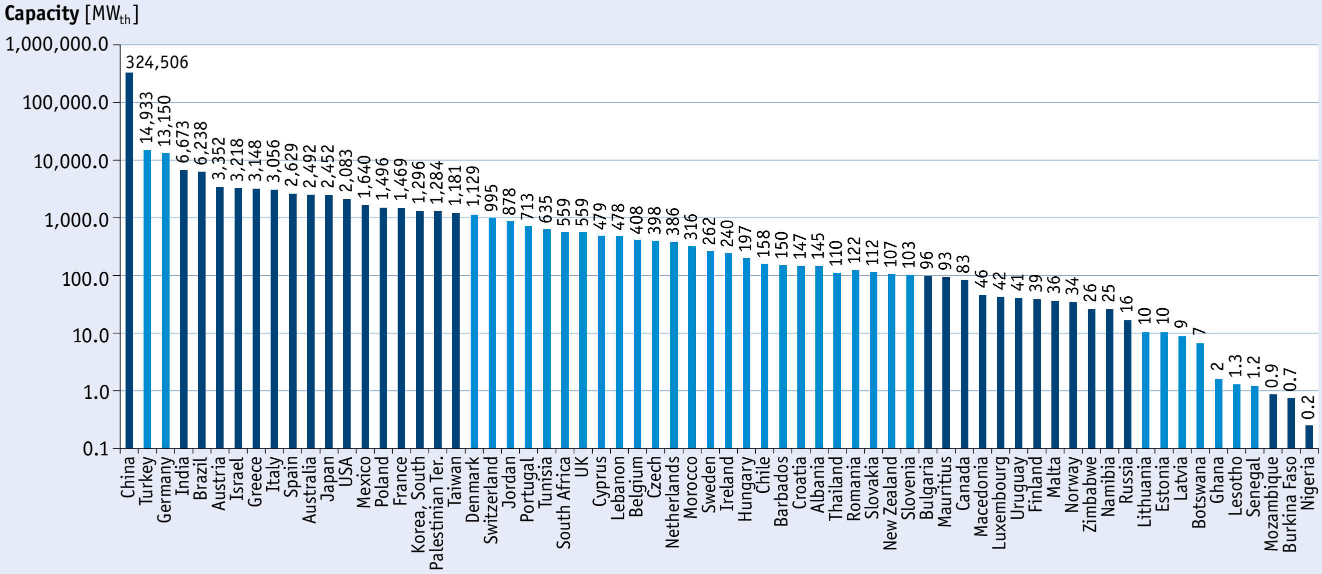



***Figure 24:*** *Total capacity of glazed water collectors in operation by the end of 2016*

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 25**).

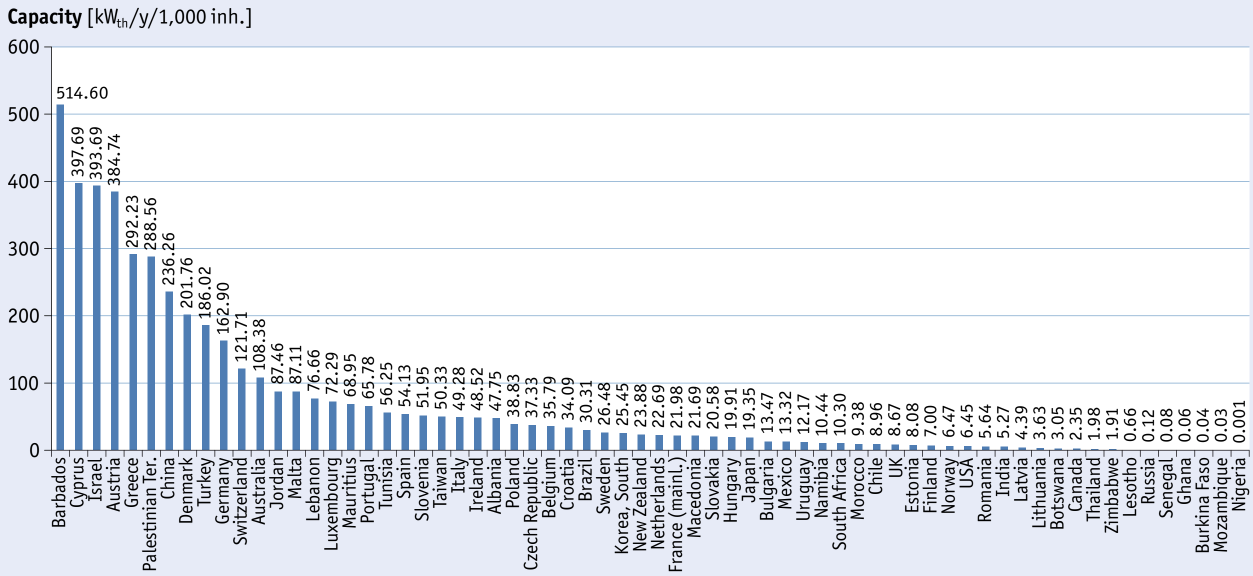



***Figure 25:*** *Total capacity of glazed water collectors in operation in $kW_{th}$ per 1,000 inhabitants in 2016*

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

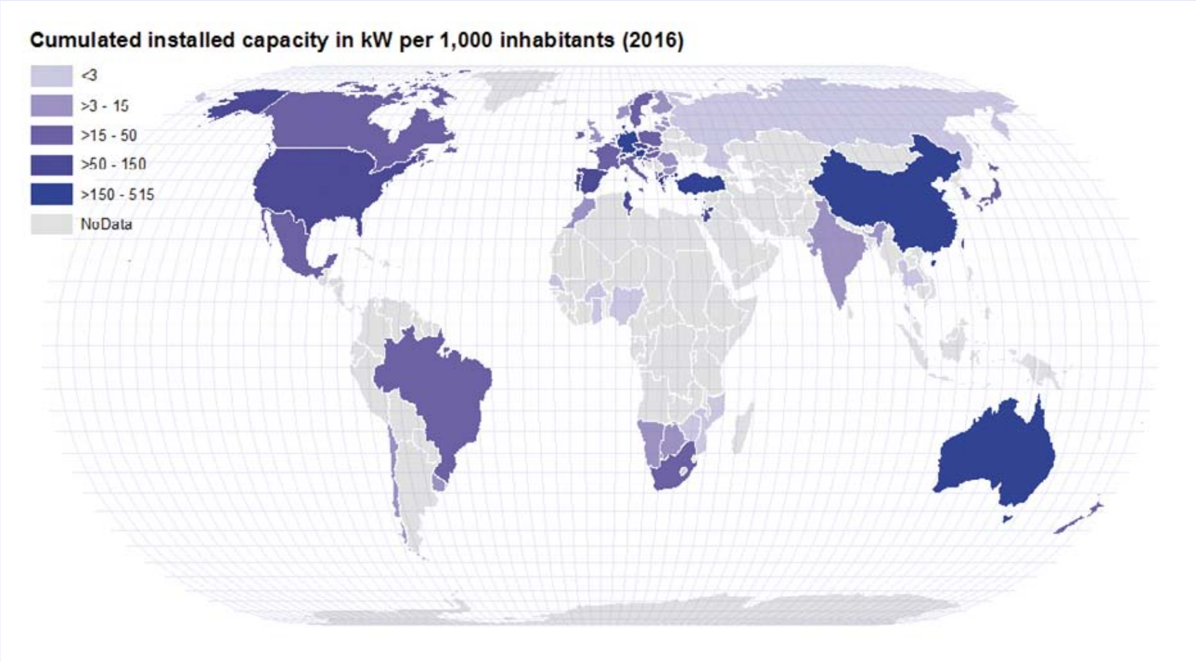



***Figure 26:*** *Solar thermal market penetration per capita worldwide in $kW_{th}$ per 1,000 inhabitants*

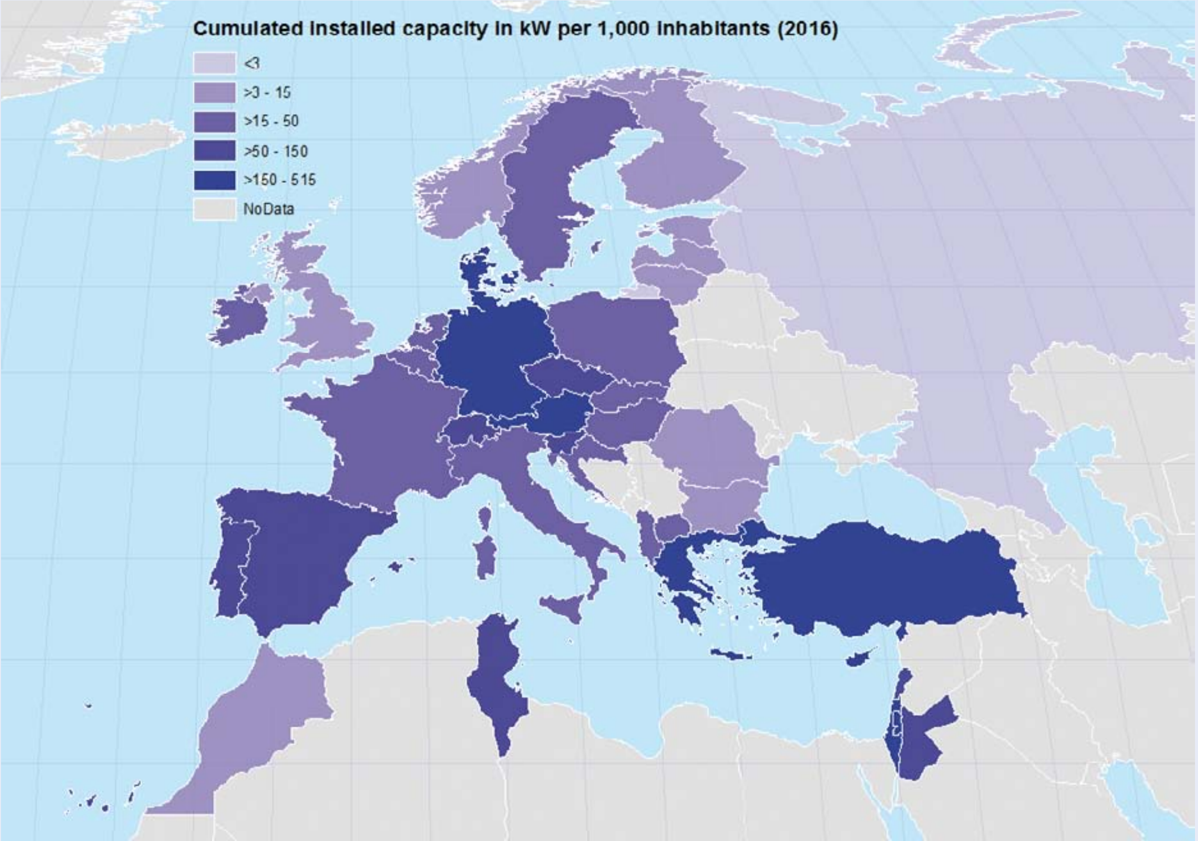



***Figure 27:*** *Solar thermal market penetration per capita in Europe in $kW_{th}$ per 1,000 inhabitants*

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

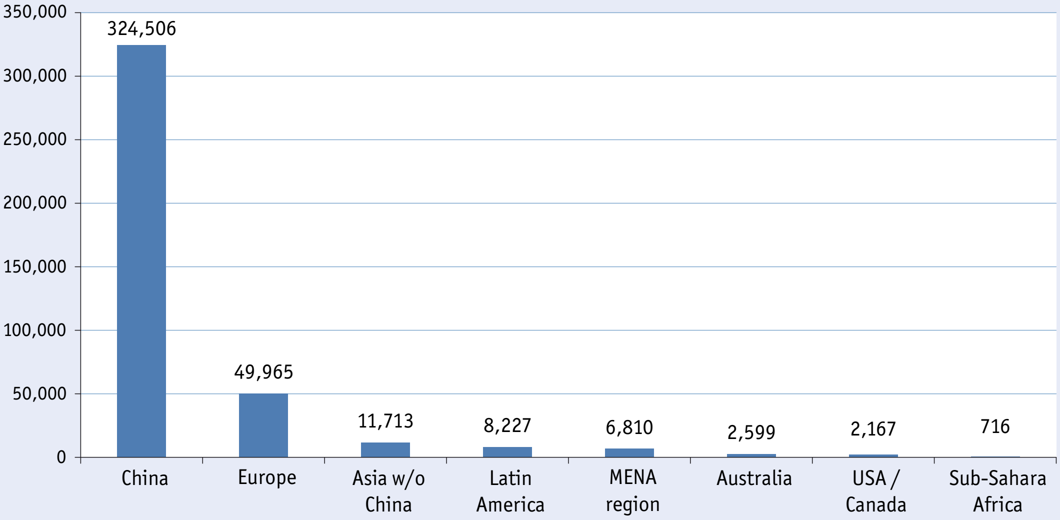
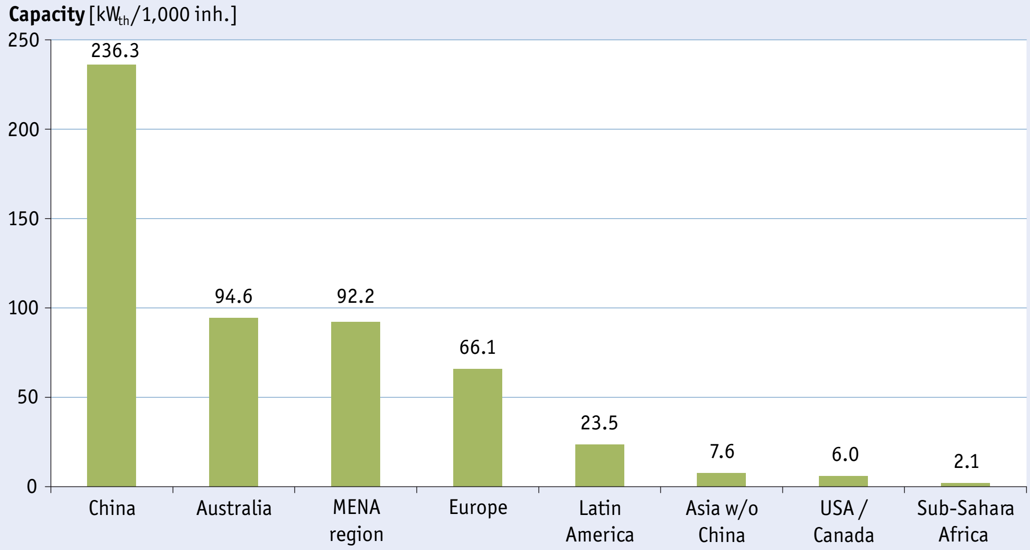



***Figure 28:*** *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2016*

In terms of market penetration per capita by economic region, China again takes the lead. It is remarkable that the MENA countries and also Australia are ahead of Europe (**Figure 29**) and shows the very unbalanced market distribution 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, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
| Asia excluding China: | India, Japan, South Korea, Taiwan, Thailand |
| Latin America: | Barbados, Brazil, Chile, Mexico, Uruguay |
| Europe: | EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey |
| MENA countries: | Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia |

***Figure 29:*** *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in $kW_{th}$ per 1,000 inhabitants in 2016*

## 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 %[23] in 2005 to just 6 % in 2016. **Figure 30** and **Figure 31** 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 2016.

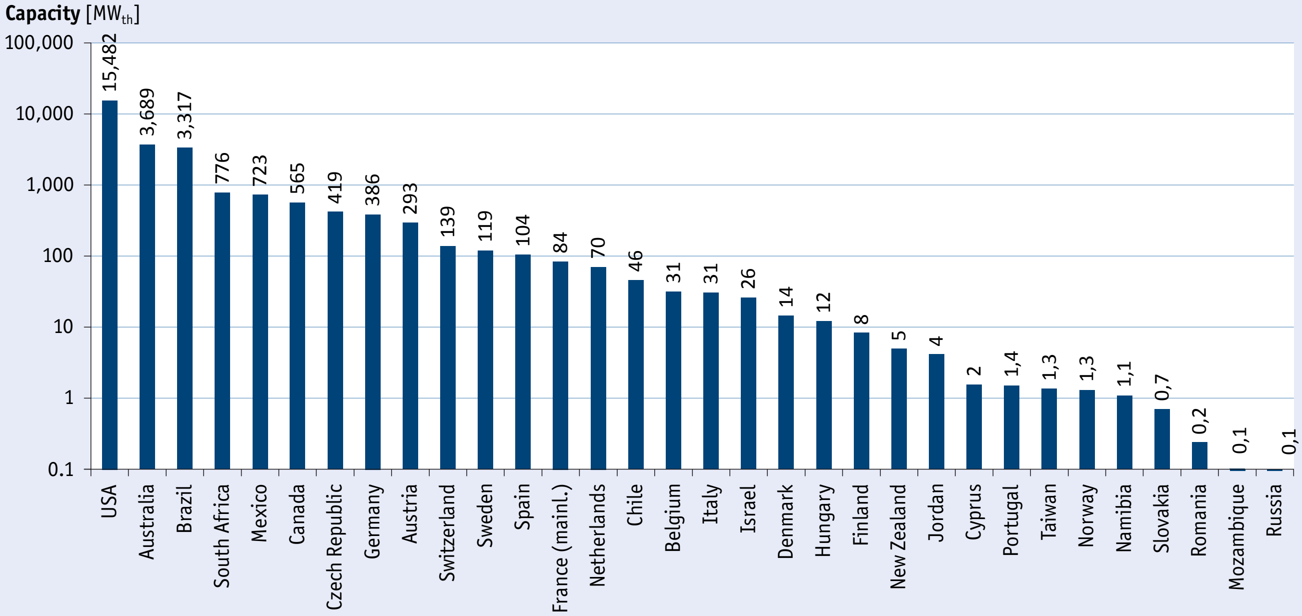



***Figure 30:*** *Total capacity of unglazed water collectors in operation in 2016*

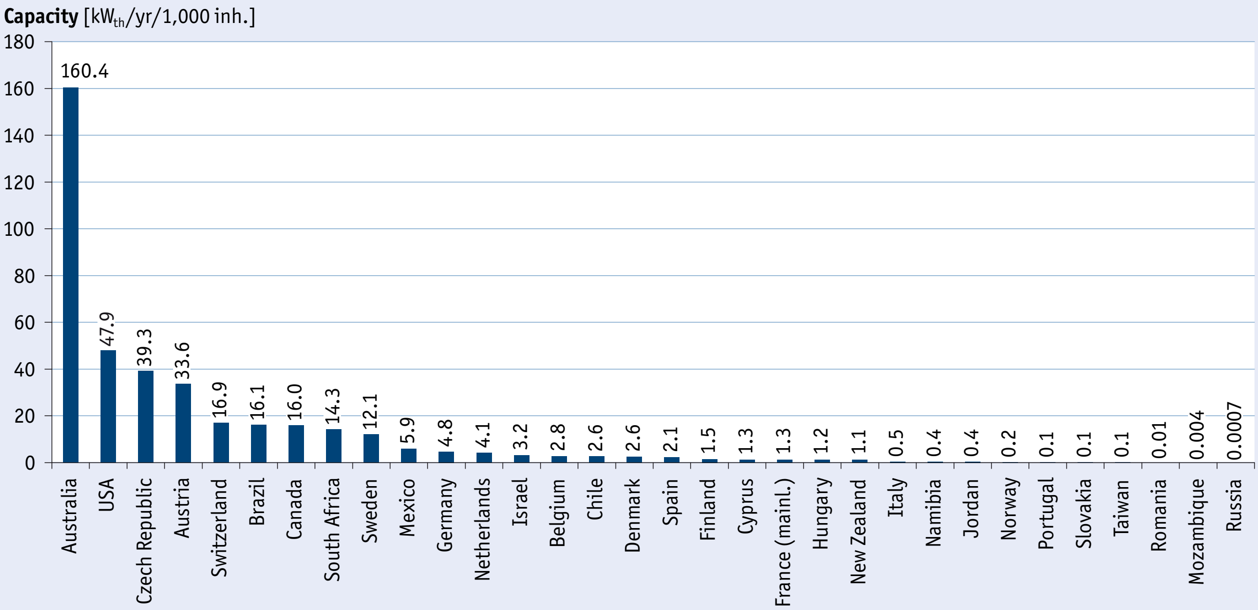


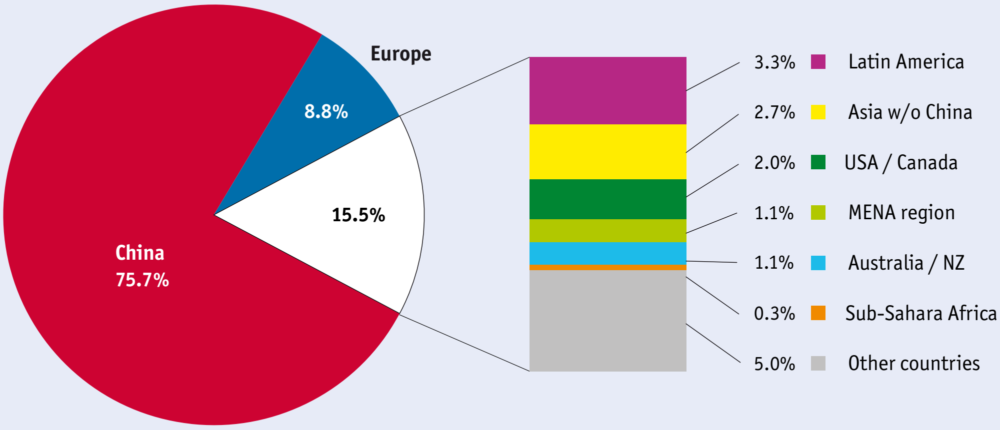

***Figure 31:*** *Total capacity of unglazed water collectors in operation in $kW_{th}$ per 1,000 inhabitants in 2016*

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

## 5.5 Newly installed capacity in 2016 and market development

In the year 2016, a total capacity of 36.5 $GW_{th}$, corresponding to 52.2 million square meters of solar collectors was installed worldwide. This means a decrease in new collector installations by 9 % compared to the year 2015.

The main markets were in China (27.7 $GW_{th}$) and Europe (3.2 $GW_{th}$), which together accounted for 85 % of the overall new collector installations in 2016. The rest of the market was shared between Latin America (1.2 $GW_{th}$), Asia excluding China (1.0 $GW_{th}$), 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 (1.8 $GW_{th}$).




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

**Figure 32:** *Share of newly installed capacity (glazed and unglazed water and air collectors) by economic regions in 2016*

From the top 10 markets in 2016 a positive market development was reported only from Denmark (90 % compared to 2015 due to large solar district heating systems installed in 2016) and Mexico (6 %). The other major solar thermal markets within the top 10 countries suffered market declines.

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

| Country | Water Collectors [MW$_{th}$] | | | Air Collectors [MW$_{th}$] | | TOTAL [MW$_{th}$] |
|---|---|---|---|---|---|---|
| | unglazed | FPC | ETC | unglazed | glazed | |
| Albania | | 15.2 | 0.5 | | | 15.7 |
| Australia | 266.0 | 103.7 | 11.5 | 21 | 0.7 | 402.9 |
| Austria | 0.5 | 76.7 | 1.0 | | 0.1 | 78.3 |
| Barbados | | 8 | 0 | | | 8.0 |
| Belgium | | 27.3 | 5.3 | | | 32.6 |
| Botswana* | | 1.8 | 0 | | | 1.8 |
| Brazil | 383.7 | 514.0 | 15.7 | | | 913.4 |
| Bulgaria | | 3.6 | 0.30 | | | 3.9 |
| Canada | 15.4 | 0.9 | 1.7 | 7.3 | 0 | 25.3 |
| Chile | 0 | 20.5 | 8.3 | 0 | 0 | 28.8 |
| China | | 3,738 | 23,926 | 0 | | 27,664 |
| Croatia | | 13.3 | 1.8 | | | 15.1 |
| Cyprus | | 43.5 | 0.0 | | | 43.5 |
| Czech Republic | 21.0 | 15.4 | 6.3 | | | 42.7 |
| Denmark | | 334.8 | 0.0 | 0 | | 334.8 |
| Estonia | | 0.7 | 0.7 | | | 1.4 |
| Finland | | 2.3 | 1.2 | | | 3.5 |
| France (mainland)+ | 1.4 | 45.2 | 1.8 | 0.5 | | 48.9 |
| Germany | 15.4 | 473.9 | 46.9 | | | 536.2 |
| Ghana* | | 0.1 | 0.0 | | | 0.1 |
| Greece | | 190.4 | 0.4 | | | 190.8 |
| Hungary | 0.7 | 6.3 | 2.1 | 0.1 | 0.1 | 9.3 |
| India++ | | 105 | 735 | | 1 | 841 |
| Ireland | | 9.5 | 7.5 | | | 17.0 |
| Israel | 0.7 | 294.0 | 0.0 | | | 294.7 |
| Italy | | 128.6 | 17.5 | | | 146.1 |
| Japan | | 49.4 | 1.1 | | 4.5 | 55.0 |
| Korea, South | | 7.5 | 12.8 | | | 20.3 |
| Latvia | | 1.1 | 0.2 | | | 1.3 |
| Lebanon | | 16.7 | 21.8 | | | 38.5 |
| Lesotho | | 0.03 | 0.11 | | | 0.14 |
| Lithuania | | 0.5 | 1.0 | | | 1.5 |
| Luxembourg | | 2.9 | 0.5 | | | 3.4 |
| Macedonia | | 4.5 | 4.2 | | | 8.7 |
| Malta | | 0.4 | 0.1 | | | 0.5 |
| Mexico | 75.8 | 97.4 | 83.2 | | | 256.4 |
| Mozambique | 0 | 0.01 | 0.01 | | | 0.02 |
| Namibia | 0.5 | 3.8 | 0.02 | | | 4.32 |
| Netherlands | 1.8 | 14.1 | 3.6 | | | 19.5 |
| Nigeria | 0 | 0.04 | 0.17 | 0 | 0 | 0.21 |
| Norway* | | 2.4 | 0.4 | | | 2.8 |
| Palestinian Territories* | | 34.3 | 0.2 | | | 34.5 |
| Poland | | 78.2 | 2.6 | | | 80.8 |
| Portugal | | 31.7 | 0.6 | | | 32.3 |
| Romania | 0 | 4.8 | 7.7 | | | 12.5 |
| Russia | 0 | 1.3 | 0.1 | 0 | 0 | 1.4 |
| Senegal | 0 | 0.0 | 0.1 | 0 | 0 | 0.1 |
| Slovakia | 0 | 5.6 | 1.1 | | | 6.7 |
| Slovenia | | 1.6 | 0.3 | | | 1.9 |
| South Africa | 47.2 | 22.5 | 18.7 | | | 88.4 |
| Spain | 2.3 | 141.3 | 4.9 | 0.9 | 0.9 | 150.3 |
| Sweden | 0 | 1.7 | 0 | | | 2.0 |
| Switzerland | 4.0 | 35.8 | 6.9 | | | 46.7 |
| Taiwan | | 66.1 | 4.0 | | | 70.1 |
| Thailand* | | 2.0 | | | 0 | 2.0 |
| Tunisia | | 47.4 | 0.0 | | | 47.4 |
| Turkey | | 674.8 | 620.9 | 2.1 | | 1,297.8 |
| United Kingdom | | 7.6 | 2.1 | 0.4 | | 10.1 |
| United States | 561.6 | 114.9 | 6.0 | 8.4 | 6.3 | 697.2 |
| Uruguay* | | 4.2 | 0 | | | 4.2 |
| Zimbabwe | | 0.2 | 2.0 | | | 2.3 |
| Other (5%) | 73.6 | 402.6 | 1,347.3 | 2.2 | 0.7 | 1,826.4 |
| **TOTAL** | 1,472 | 8,052 | 26,947 | 43 | 14 | 36,528 |

Note: If no data is given: no reliable database for this collector type is available.
* Country market data for new installations in 2016 estimated by AEE INTEC (0 % growth rate assumed)
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
++ Since 2016 the figures for India refer to calendar year

*Table 5:* *Newly installed capacity in 2016 [$MW_{th}$ / a]*

| 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 |
| Canada | 22,008 | 1,303 | 2,367 | 10,438 | 100 | 36,216 |
| Chile | 0 | 29,300 | 11,878 | 0 | 0 | 41,178 |
| China | | 5,340,000 | 34,180,000 | 500 | | 39,520,500 |
| Croatia | | 19,000 | 2,500 | | | 21,500 |
| Cyprus | | 62,170 | 0 | | | 62,170 |
| Czech Republic | 30,000 | 22,000 | 9,000 | | | 61,000 |
| Denmark | | 478,297 | | 0 | | 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 |
| Macedonia | | 6,466 | 5,993 | | | 12,459 |
| 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 | 0 | 62 | 245 | 0 | 35 | 342 |
| Norway* | | 3,415 | 585 | | | 4,000 |
| Palestinian Territories* | | 49,000 | 225 | | | 49,225 |
| Poland | | 111,700 | 3,700 | | | 115,400 |
| Portugal | | 45,300 | 800 | | | 46,100 |
| Romania | 0 | 6,800 | 11,000 | | | 17,800 |
| Russia | 22 | 1,820 | 172 | 2 | 14 | 2,030 |
| Senegal* | 0 | 4 | 80 | 0 | 55 | 139 |
| Slovakia | 0 | 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 | 0 | 2,487 | 336 | | | 2,823 |
| Switzerland | 5,654 | 51,150 | 9,895 | | | 66,699 |
| Taiwan | | 94,370 | 5,784 | | | 100,154 |
| Thailand* | | 2,860 | | | | 2,860 |
| 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* | | 6,003 | | | | 6,003 |
| Zimbabwe | | 353 | 2,898 | | | 3,251 |
| Other (5%) | 105,127 | 575,175 | 1,924,775 | 3,084 | 1,017 | 2,609,177 |
| **TOTAL** | 2,102,548 | 11,503,494 | 38,495,496 | 61,674 | 20,335 | 52,183,546 |

Note: If no data is given: no reliable database for this collector type is available.
* Country market data for new installations in 2015 estimated by AEE INTEC (0 % growth rate assumed)
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
++ Since 2016 the figures for India refer to calendar year

***Table 6:*** *Newly installed collector area in 2016 [m² / a]*

New installations in 2016 are divided into flat plate collectors: 8.1 $GW_{th}$ (11.5 million square meters), evacuated tube collectors: 26.9 $GW_{th}$ (38.5 million square meters), unglazed water collectors: 1.5 $GW_{th}$ (2.1 million square meters), and glazed and unglazed air collectors: 0.06 $GW_{th}$ (0.1 million square meters).

With a share of 73.8 %, evacuated tube collectors remain by far the most important solar thermal collector technology worldwide (**Figure 33**). In a global context, this breakdown is mainly driven by the dominance of the Chinese market where around 87 % of all newly installed collectors in 2016 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82 % in 2011 to 73.8 % in 2016 and in the same time frame flat plate collectors increased their share from 14.7 % to 22 %.

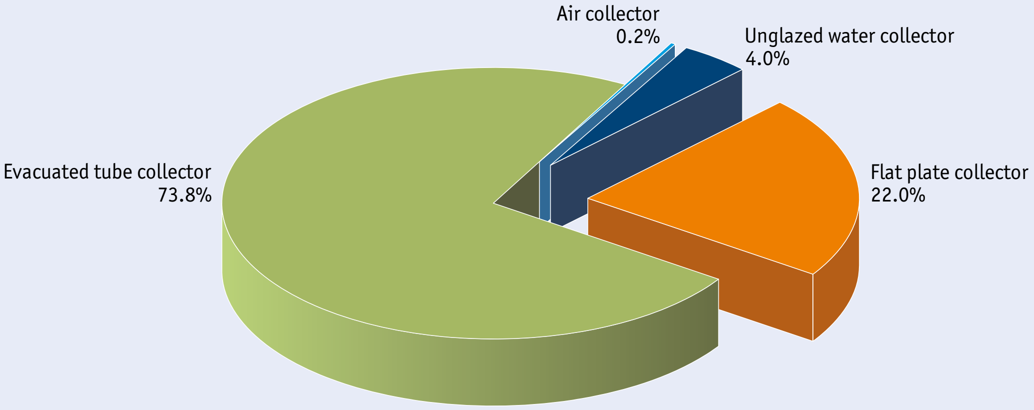
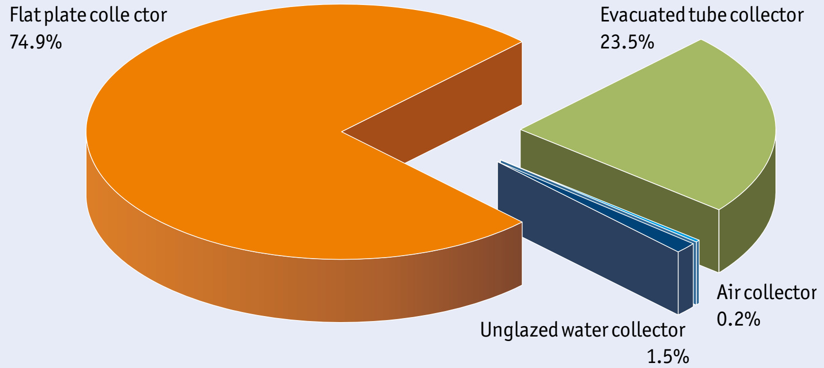



***Figure 33:*** *Distribution of the newly installed capacity by collector type in 2016 – WORLD*

In Europe, the situation is almost the opposite compared to China with 74.9 % of all solar thermal collectors installed in 2016 being flat plate collectors (**Figure 34**). In the medium term perspective, the share of flat plate collectors decreased in Europe from 81.5 % in 2011 to 74.9 % in 2016. While driven mainly by the markets in Turkey, Poland, Switzerland and Germany, evacuated tube collectors increased their share in Europe between 2011 and 2016 from 15.6 % to 23.5 %. In the year 2016 the share of evacuated tube collectors decreased again compared to the year 2015 from 26.1 % in 2015 to 23.5 % in 2016.




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

***Figure 34:*** *Distribution of the newly installed capacity by collector type in 2016 – EUROPE*

**Figure 35** shows the newly installed capacity of glazed and unglazed water collectors for the 10 leading markets in 2016 in total numbers. China remained the market leader in absolute terms followed by Turkey. Brazil overtook India and ranks in the third position in 2016. Denmark pushed Poland out of the top 10 due to the large number of solar district heating systems installed in 2016. Germany faced a significant market decline the fourth year in a row, but held on to its sixth position rank.

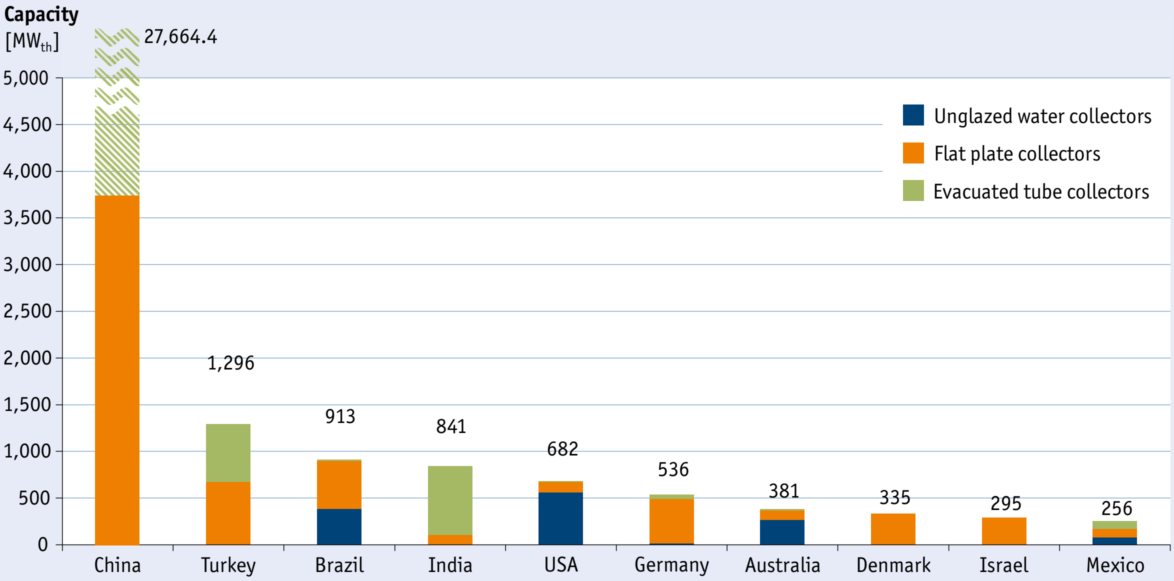



**Figure 35:** *Top 10 markets for glazed and unglazed water collectors in 2016 (absolute figures in $MW_{th}$)*

In terms of newly installed solar thermal capacity per 1,000 inhabitants in 2016, the top 10 countries are shown in **Figure 40**. The fast climber in 2016 was Denmark, which took the lead. Israel and Cyprus were second. The other rankings stayed unchanged compared to 2015.

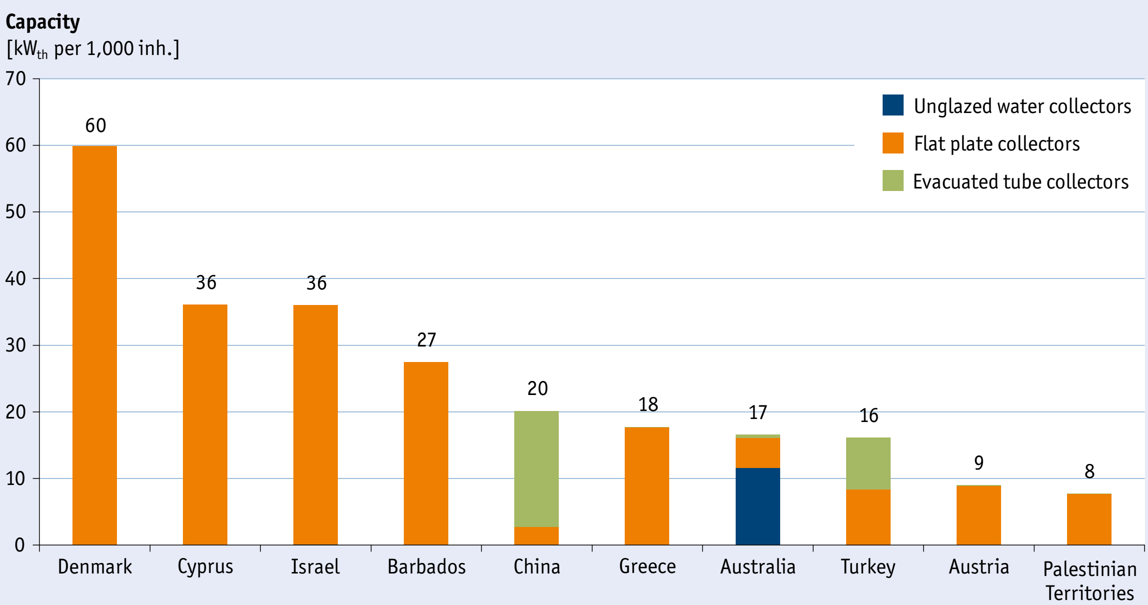



**Figure 36:** *Top 10 markets for glazed and unglazed water collectors in 2016 (in $kW_{th}$ per 1,000 inhabitants)*

## 5.6 Newly installed capacity of glazed water collectors

In 2016 glazed water collectors accounted for 95.9 % of the total newly installed capacity and with a market share of 79 %. China was the most influential market in the global context (**Figure 37**).

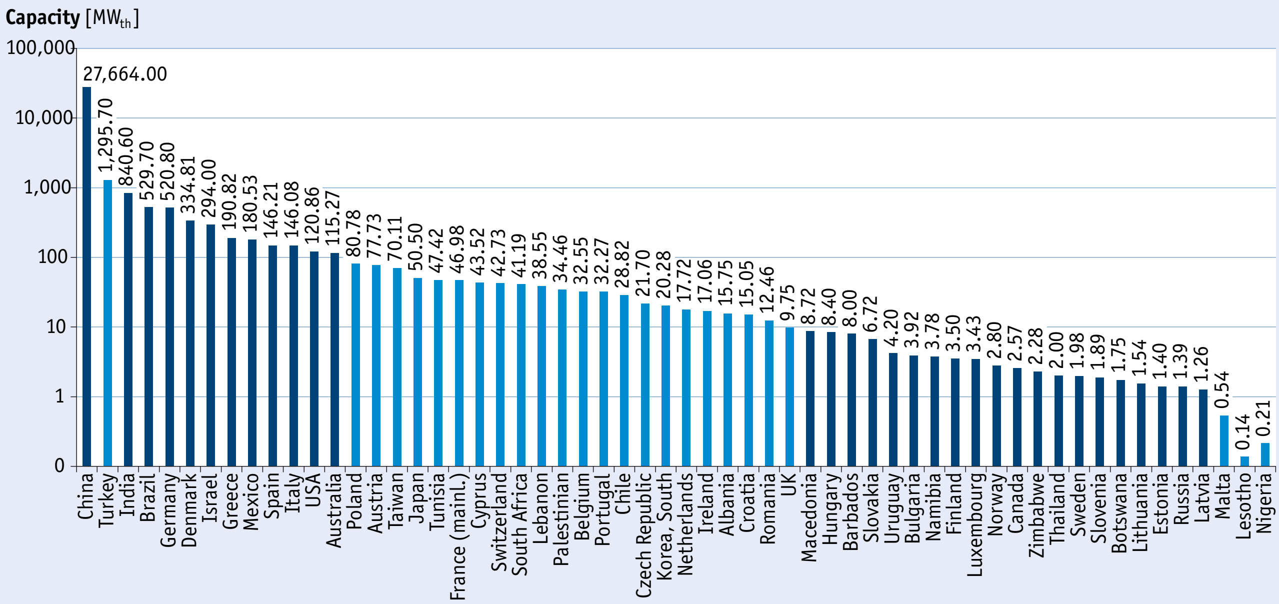



*Figure 37:* *Newly installed capacity of glazed water collectors in 2016*

In terms of newly installed glazed water collector capacity per 1,000 inhabitants, Denmark is the leader ahead of Cyprus and Israel. In this respect China ranks in the place (**Figure 38**).

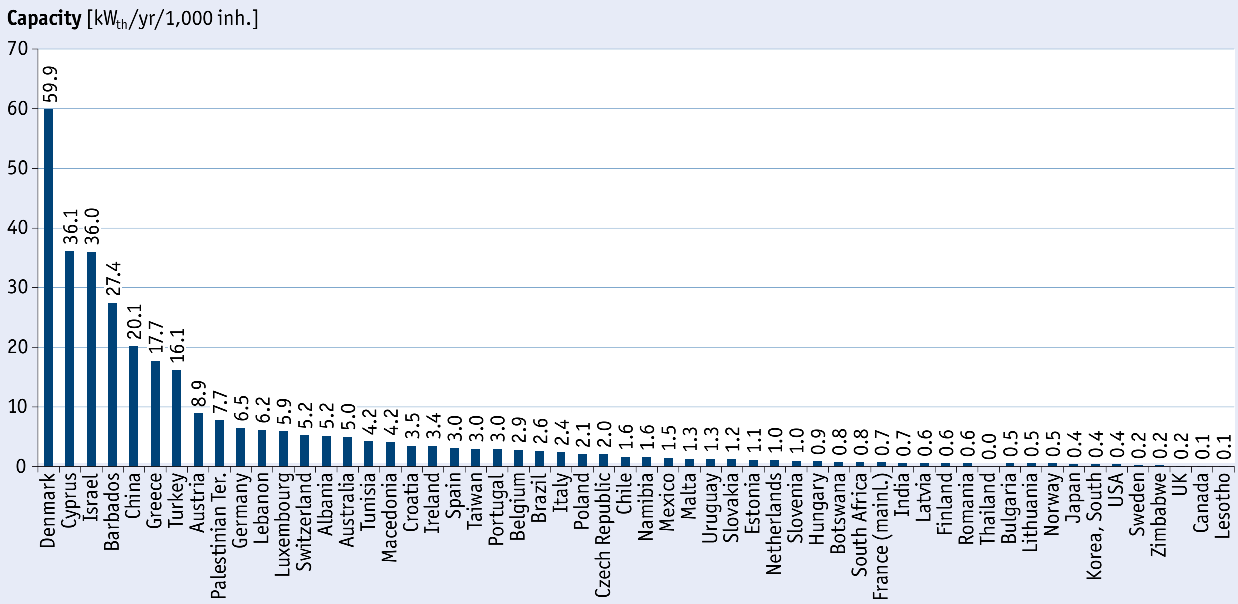



*Figure 38:* *Newly installed capacity of glazed water collectors in 2016 in $kW_{th}$ per 1,000 inhabitants*

The following figures show the solar thermal market penetration per capita of the newly installed capacity in 2016 worldwide and in Europe.

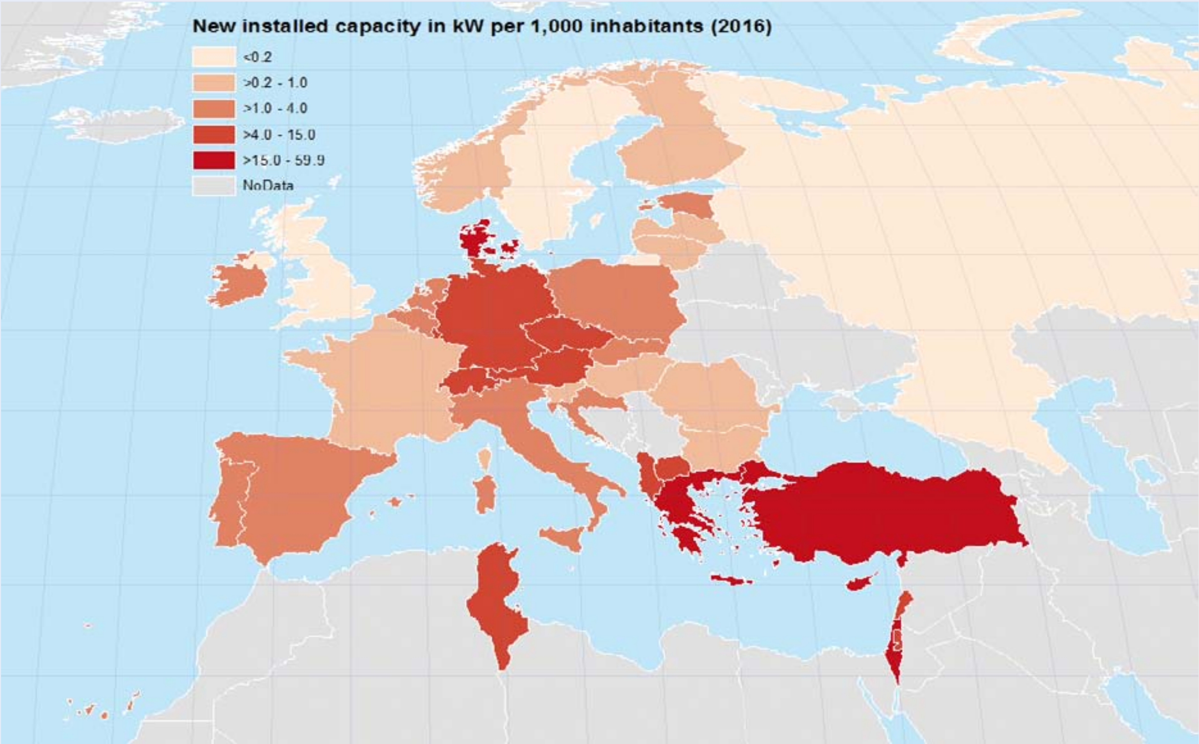



***Figure 39:*** *Installed capacity in Europe in 2016 in $kW_{th}$ per 1,000 inhabitants*

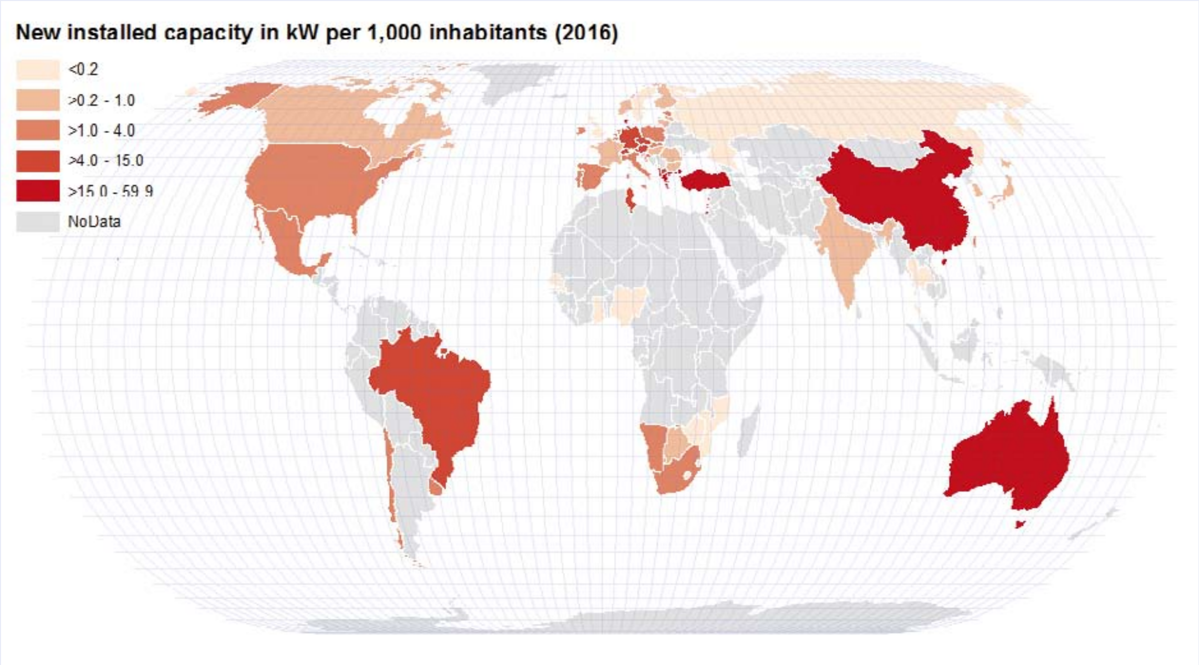



***Figure 40:*** *Installed capacity worldwide in 2016 in $kW_{th}$ per 1,000 inhabitants*

## 5.7 Market development of glazed water collectors between 2000 and 2016

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 and 2016, but the markets seem to have recovered slightly as the decline slowed down.

The newly installed glazed water collector capacity in 2016 amounted to 35 $GW_{th}$ (**Figure 41**).

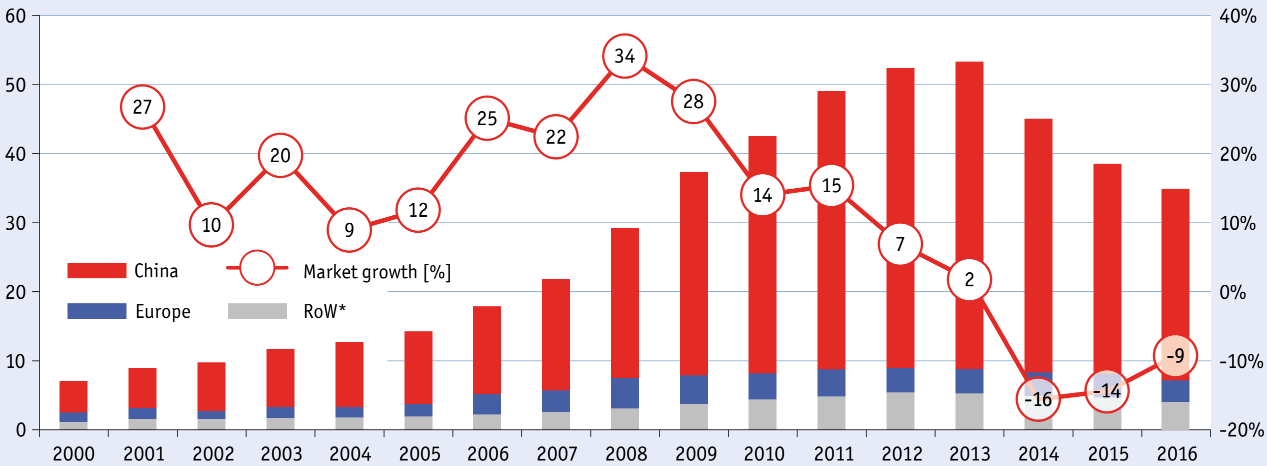



*Figure 41:* *Global market development of glazed water collectors from 2000 to 2016*

In 2000 the Chinese market was about three times as large as the European market while in 2016 the Chinese market exceeded the European market nine-fold (**Figure 42**).

It can also be seen in **Figure 42** that after years of very high growth rates in China this trend has changed in the past three years. Compared to the years before, the Chinese market began to experience low growth rates in 2012 and 2013 and continued to shrink significantly in 2014 and 2015.

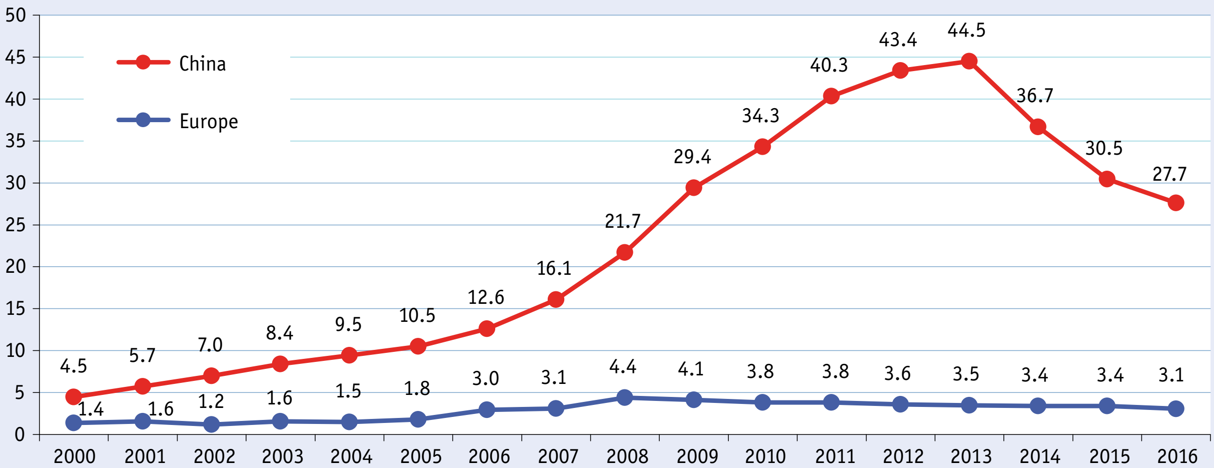
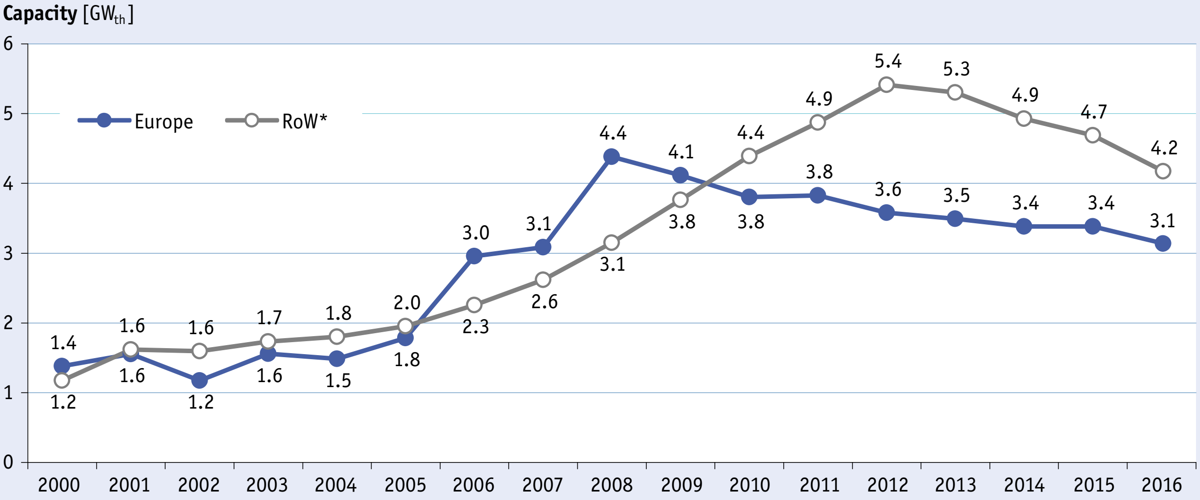



*Figure 42:* *Market development of glazed water collectors in China and Europe 2000 – 2016*

The European market peaked at 4.4 $GW_{th}$ installed capacity in 2008 and has decreased steadily down to 3.4 $GW_{th}$ in 2015 and 3.1 $GW_{th}$ in 2016. In the remaining markets worldwide (RoW) an upward trend could be observed between 2002 and 2012 and a falling trend since 2013 (**Figure 43**).




Europe: EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey
Rest of World (RoW): Asia (India, Japan, Korea South, Taiwan, Thailand), Australia, Canada, UNITED STATES, Latin America (Brazil, Chile, Mexico, Uruguay), MENA countries (Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia), Sub-Sahara Africa (Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe),
"All other countries": See figures for 2015 in **Tables 4** and **5**

***Figure 43:*** *Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2016*

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 44**).

"Asia excl. China" is mainly influenced by the large Indian market, which dropped in 2013 but recovered significantly in 2014 and 2015. Other markets covered within this economic region (Japan, South Korea and Thailand) reported a market decrease in 2016.

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.

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 44**, is explained by the fact that from 2015 on no data were received from two major markets namely Morocco and Jordan. The sales numbers in the most important market, Israel, slightly decreased in 2016.

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 2016, a decrease of –7 % was reported.

Sub-Sahara African markets showed a decrease of 7 % in 2016. Also in the United States and Canada the decreasing trend continued for the third year in a row but slowed down to –3 % in 2016.

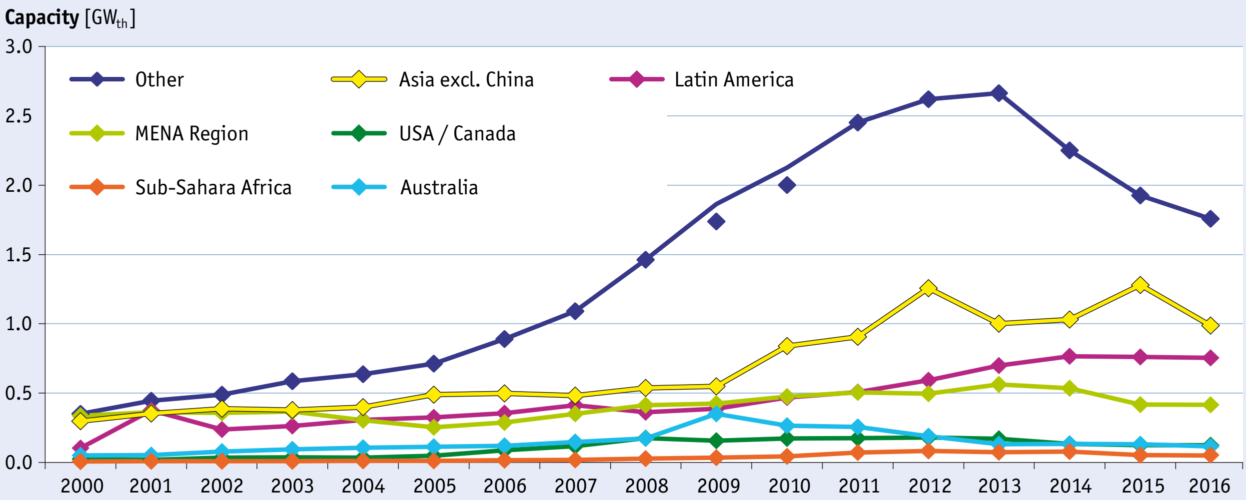



**Figure 44:** *Market development of glazed water collectors in Rest of World (excluding China and Europe) from 2000 to 2016*

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 4.8 $kW_{th}$ per 1,000 inhabitants in 2016 (**Figure 45**).

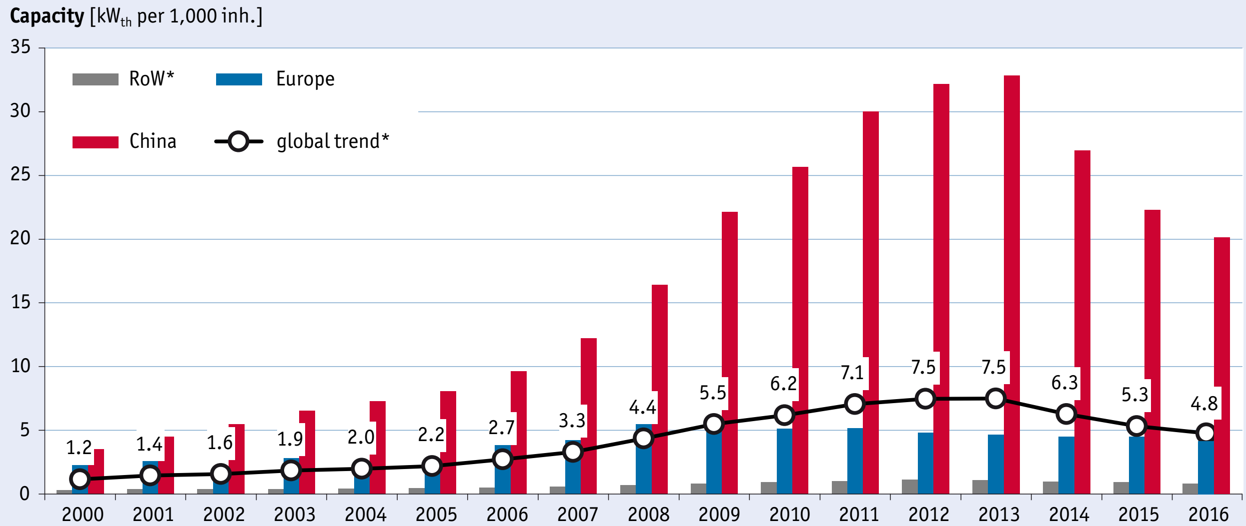



**Figure 45:** *Annual installed capacity of glazed water collectors in $kW_{th}$ per 1,000 inhabitants from 2000 to 2016*

The fact that China suffered major market declines from 2014 to 2016 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 20.1 $kW_{th}$ per 1,000 inhabitants in 2016.

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 4.2 $kW_{th}$ per 1,000 inhabitants in 2016.

## 5.8 Market development of unglazed water collectors between 2000 and 2016

With a newly installed capacity of 1.5 $GW_{th}$ in 2016, unglazed water collectors accounted for 4 % of the total installed solar thermal capacity (Figure 33). Compared to the year 2015 the market decreased by −6.5 %.

The most important markets for unglazed water collectors in 2016 were the United States (577 $MW_{th}$), Brazil (384 $MW_{th}$), Australia (266 $MW_{th}$), Mexico (75.8 $MW_{th}$) and South Africa (47.2 $MW_{th}$), which accounted for 91 % of the recorded unglazed water collector installations worldwide. Another 4 % were installed in the Czech Republic (21 $MW_{th}$), Canada (15 $MW_{th}$) and Germany (15 $MW_{th}$).

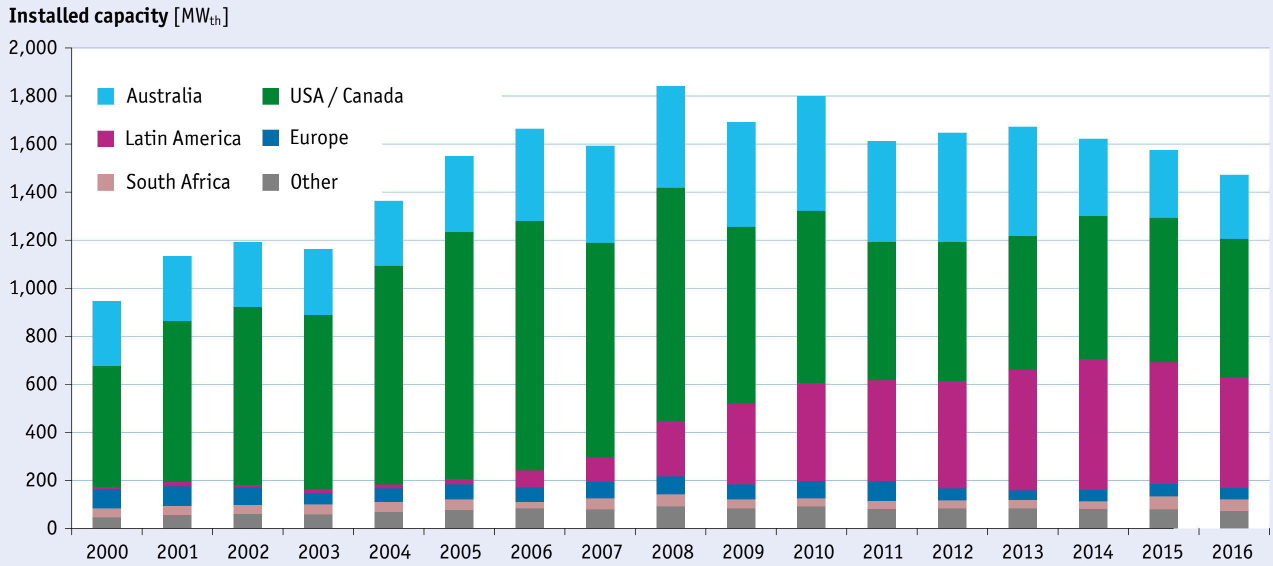



*Figure 46:* *Global market development of unglazed water collectors from 2000 to 2016*

The unglazed water collector market in the United States peaked in 2006 (1.01 $GW_{th}$) and has almost halved since then (0.56 $GW_{th}$ in 2016). 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 energy supply and $CO_2$ reduction in 2016

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 3**. The contribution of the total installed air collector capacity in operation in 2016 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 in operation by the end of 2016 in the 66 recorded countries was 375 TWh (= 1,350 PJ). This corresponds to a final energy savings equivalent of 40.3 million tons of oil and 130 million tons of $CO_2$. The calculated number of different types of solar thermal systems in operation was around 113 million (**Table 7**).

The most important application for solar thermal systems is domestic hot water heating (see section 7.3), and therefore, this type of application ccounted for the highest savings in terms of oil equivalent and $CO_2$. In 2016, 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 (67 %) and larger applications attached to multi-family houses, hotels, schools, etc. (27 %). Swimming pool heating held a share of 4 % in the contribution to the energy supply and $CO_2$ reduction and the remaining 1 % was met by solar combi-systems.

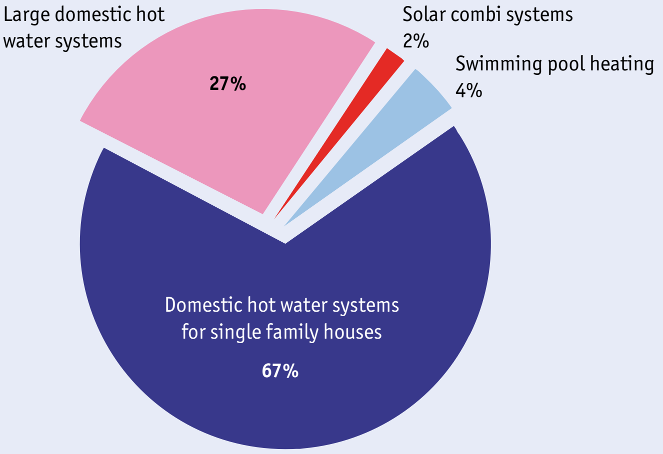



*Figure 47:* *Share of energy savings and $CO_2$ reduction by type of application of glazed and unglazed water collectors in operation in 2016*

**Table 7** summarizes the calculated annual collector yields and the corresponding oil equivalents and $CO_2$ reductions of all water-based solar thermal systems (systems for hot water, space heating and swimming pool heating) in operation by the end of 2016.

| Country | Total collector area [m²] | Total capacity [$MW_{th}$] | Calculated number of systems | Collector yield [GWh/a] | Energy savings [$t_{oe}$/a] | $CO_2$ reduction [$t_{CO2e}$/a] |
|---|---|---|---|---|---|---|
| Albania | 207,258 | 145 | 43,110 | 146 | 15,714 | 50,725 |
| Australia | 8,830,000 | 6,181 | 1,121,309 | 5,484 | 589,469 | 1,902,806 |
| Austria | 5,206,494 | 3,645 | 518,320 | 2,105 | 226,251 | 730,340 |
| Barbados | 214,290 | 150 | 53,573 | 189 | 20,325 | 65,610 |
| Belgium | 628,333 | 440 | 109,347 | 250 | 26,847 | 86,661 |
| Botswana**** | 9,500 | 7 | 1,552 | 9 | 957 | 3,089 |
| Brazil | 13,649,887 | 9,555 | 4,087,149 | 8,907 | 957,289 | 3,090,130 |
| Bulgaria | 137,500 | 96 | 23,929 | 68 | 7,281 | 23,504 |
| Burkina Faso** | 1,071 | 1 | 68 | 1 | 107 | 346 |
| Canada | 925,465 | 648 | 35,295 | 445 | 47,871 | 154,529 |
| Chile | 291,550 | 204 | 60,495 | 202 | 21,659 | 69,914 |
| China | 463,579,999 | 324,506 | 78,576,810 | 259,854 | 27,929,294 | 90,155,760 |
| Croatia | 210,092 | 147 | 36,562 | 106 | 11,350 | 36,636 |
| Cyprus | 687,133 | 481 | 300,338 | 611 | 65,644 | 211,900 |
| Czech Republic | 1,166,512 | 817 | 82,006 | 389 | 41,790 | 134,898 |
| Denmark | 1,632,817 | 1,143 | 97,618 | 681 | 73,201 | 236,293 |
| Estonia | 14,520 | 10 | 2,527 | 6 | 626 | 2,022 |
| Finland | 66,800 | 47 | 11,625 | 27 | 2,909 | 9,391 |
| France (mainland)+ | 2,218,807 | 1,553 | 485,271 | 1,075 | 115,552 | 373,002 |
| Germany | 19,336,110 | 13,535 | 2,270,801 | 7,873 | 846,218 | 2,731,591 |
| Ghana* | 2,274 | 2 | 119 | 2 | 220 | 711 |
| Greece | 4,497,600 | 3,148 | 1,200,724 | 3,133 | 336,719 | 1,086,930 |
| Hungary | 298,100 | 209 | 44,624 | 135 | 14,489 | 46,771 |
| India++ | 9,533,411 | 6,673 | 4,198,753 | 8,232 | 884,789 | 2,856,099 |
| Ireland | 343,251 | 240 | 79,440 | 144 | 15,447 | 49,861 |
| Israel | 4,634,434 | 3,244 | 1,483,946 | 4,276 | 459,574 | 1,483,505 |
| Italy | 4,409,369 | 3,087 | 767,349 | 2,690 | 289,108 | 933,240 |
| Japan | 3,503,560 | 2,452 | 851,427 | 2,030 | 218,212 | 704,390 |
| Jordan* | 1,260,506 | 882 | 223,109 | 1,194 | 128,286 | 414,108 |
| Korea, South | 1,851,618 | 1,296 | 424,205 | 961 | 103,270 | 333,356 |
| Latvia | 12,332 | 9 | 2,146 | 5 | 562 | 1,814 |
| Lebanon | 683,133 | 478 | 108,737 | 565 | 60,724 | 196,017 |
| Lesotho | 1,850 | 1 | 384 | 2 | 172 | 557 |
| Lithuania | 14,800 | 10 | 2,576 | 6 | 666 | 2,149 |
| Luxembourg | 60,136 | 42 | 10,465 | 25 | 2,734 | 8,826 |
| Macedonia | 65,062 | 46 | 14,841 | 40 | 4,326 | 13,964 |
| Malta | 51,671 | 36 | 13,795 | 41 | 4,457 | 14,388 |
| Mauritius** | 132,793 | 93 | 88,529 | 113 | 12,183 | 39,325 |
| Mexico | 3,375,801 | 2,363 | 398,827 | 1,931 | 207,566 | 670,022 |
| Morocco* | 451,000 | 316 | 60,900 | 383 | 41,146 | 132,821 |
| Mozambique | 1,386 | 1 | 347 | 1 | 127 | 408 |
| Namibia | 37,898 | 27 | 4,680 | 35 | 3,716 | 11,994 |
| Netherlands | 652,205 | 457 | 155,233 | 260 | 27,978 | 90,312 |
| New Zealand*** | 159,645 | 112 | 32,703 | 99 | 10,592 | 34,191 |
| Nigeria | 355 | 0 | 136 | 0 | 33 | 108 |
| Norway** | 50,506 | 35 | 2,517 | 19 | 1,998 | 6,450 |
| Palestine**** | 1,834,850 | 1,284 | 630,026 | 1,712 | 183,973 | 593,865 |
| Poland | 2,137,200 | 1,496 | 268,931 | 873 | 93,802 | 302,794 |
| Portugal | 1,020,132 | 714 | 184,924 | 788 | 84,651 | 273,253 |
| Romania | 174,490 | 122 | 30,366 | 96 | 10,357 | 33,432 |
| Russia | 23,591 | 17 | 1,264 | 10 | 1,053 | 3,398 |
| Senegal**** | 1,734 | 1 | 432 | 2 | 182 | 587 |
| Slovakia | 161,100 | 113 | 19,717 | 75 | 8,084 | 26,094 |
| Slovenia | 146,800 | 103 | 22,849 | 62 | 6,642 | 21,442 |
| South Africa | 1,908,419 | 1,336 | 433,952 | 1,363 | 146,480 | 472,837 |
| Spain | 3,903,788 | 2,733 | 459,281 | 2,722 | 292,597 | 944,503 |
| Sweden | 544,154 | 381 | 41,315 | 199 | 21,376 | 69,001 |
| Switzerland | 1,620,150 | 1,134 | 196,023 | 640 | 68,763 | 221,966 |
| Taiwan | 1,689,148 | 1,182 | 333,501 | 1,028 | 110,468 | 356,589 |
| Thailand**** | 157,536 | 110 | 36,001 | 132 | 14,212 | 45,875 |
| Tunisia | 906,896 | 635 | 274,560 | 818 | 87,909 | 283,769 |
| Turkey | 21,332,636 | 14,933 | 4,927,839 | 19,137 | 2,056,893 | 6,639,650 |
| United Kingdom | 798,169 | 559 | 138,903 | 310 | 33,333 | 107,598 |
| United States | 25,092,885 | 17,565 | 421,560 | 11,159 | 1,199,340 | 3,871,470 |
| Uruguay**** | 58,247 | 41 | 14,562 | 40 | 4,267 | 13,774 |
| Zimbabwe | 37,060 | 26 | 14,187 | 32 | 3,390 | 10,944 |
| Other (5%) | 32,560,379 | 22,792 | 6,706,606 | 19,272 | 2,071,397 | 6,686,469 |
| **TOTAL** | 651,208,198 | 455,846 | 113,245,014 | 375,217 | 40,328,617 | 130,180,774 |

* 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 is based on estimations for new installations in 2016
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
\++ Since 2016 the figures for India refer to calendar year

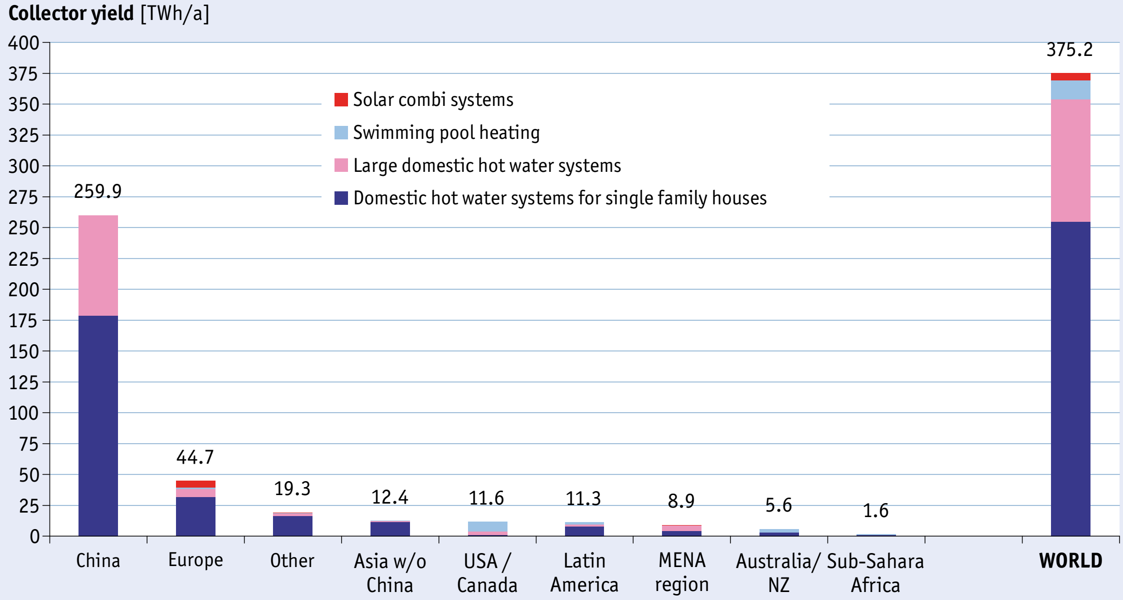
***Table 7:*** *Calculated annual collector yield and corresponding oil equivalent and $CO_2$ reduction of glazed and unglazed water collectors in operation by the end of 2016*

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 2016, gross solar thermal collector yields amounted to 375 TWh worldwide (**Table 7**) and the major share, 65 %, was contributed by domestic hot water applications for single-family houses (**Figure 47**).

China accounted for 69 % of the thermal energy gains (259.9 TWh), Europe for 12 % (44.7 TWh) and the Rest of the World for 19 % (70.6 TWh) (**Figure 48**).

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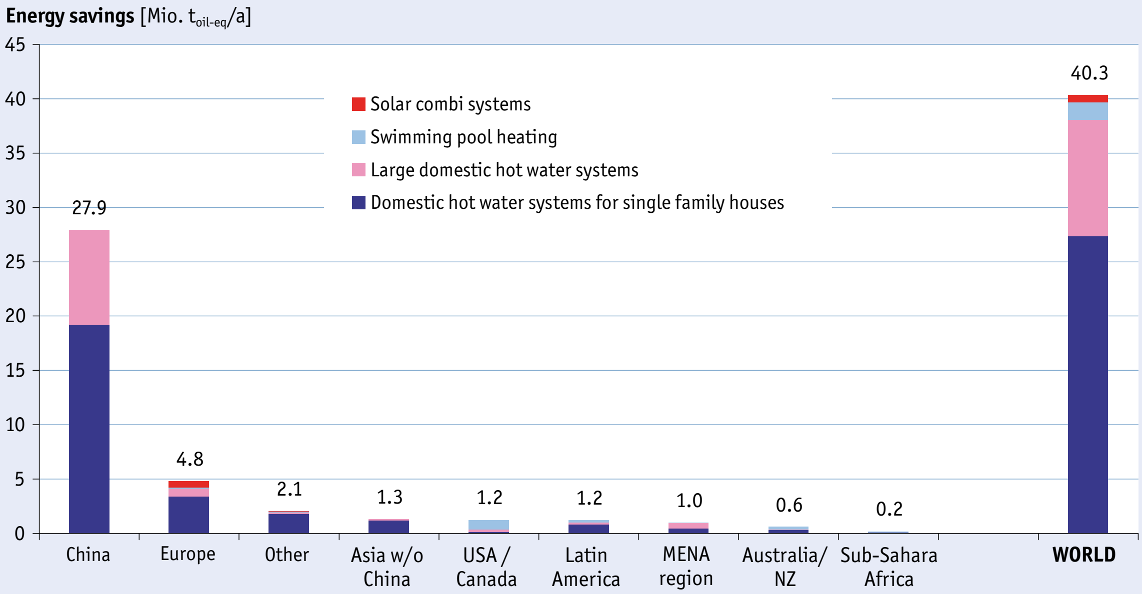
|---|---|
| Sub-Sahara Africa: | Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
| Asia w/o China: | India, Japan, South Korea, Taiwan Thailand |
| Latin America: | Barbados, Brazil, Chile, Mexico, Uruguay |
| Europe: | EU 28, Albania, Macedonia,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

***Figure 48:*** *Annual collector yield of unglazed and glazed water collectors in operation in 2016*

## 6.2 Annual energy savings by economic region

Considering a utilization ratio of 0.8 for the reference oil boiler, which is assumed to be partially replaced by the solar thermal system (see methodology Chapter 9.1), the annual final energy savings amounted to 469 TWh or 40.3 million tons of oil equivalent in 2016[24].

The breakdown shows that China accounted for 27.9 million tons oil equivalent, Europe for 4.8 million tons oil equivalent, and the Rest of World for 7.6 million tons oil equivalent (Figure 49).

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| Sub-Sahara Africa: | Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
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| Latin America: | Barbados, Brazil, Chile, Mexico, Uruguay |
| Europe: | EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey |
| MENA countries: | Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia |

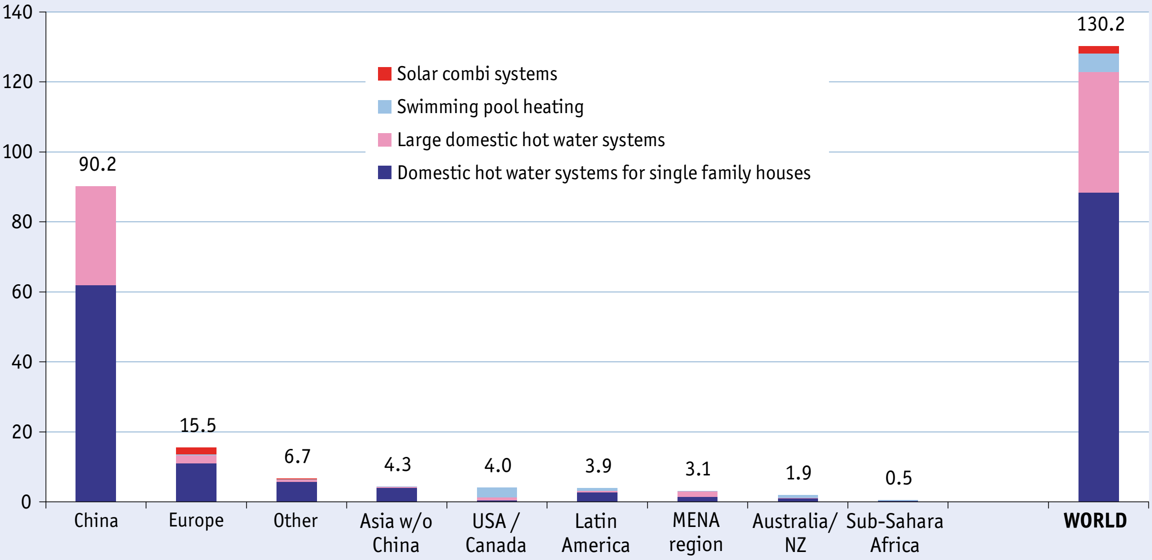
***Figure 49:*** *Annual energy savings in oil equivalent by unglazed and glazed water collectors in operation in 2016*

24 1 toe = 1.163 x $10^4$ kWh (Defra/DECC 2013)

*Solcrafte System* — *Photo: GREENoneTEC*

## 6.3 Annual contribution to $CO_2$ reduction by economic region

40.3 million tons of oil equivalent correspond to an annual $CO_2$ emission reduction of 130.2 million tons[25]. Here, the breakdown was China 90.2 million tons of $CO_2$ equivalent, Europe 15.5 million tons of $CO_2$ equivalent, and the Rest of World 24.5 million tons of $CO_2$ equivalent (see **Figure 50**).

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| Sub-Sahara Africa: | Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
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| Latin America: | Barbados, Brazil, Chile, Mexico, Uruguay |
| Europe: | EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey |
| MENA countries: | Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia |

**Figure 50:** *Contribution to $CO_2$ reduction by unglazed and glazed water collectors in operation in 2016*

25 1 toe (fuel oil) = 3,228 $tCO_2e$ (Defra/DECC 2013)

# 7 Distribution of systems by type and application in 2016

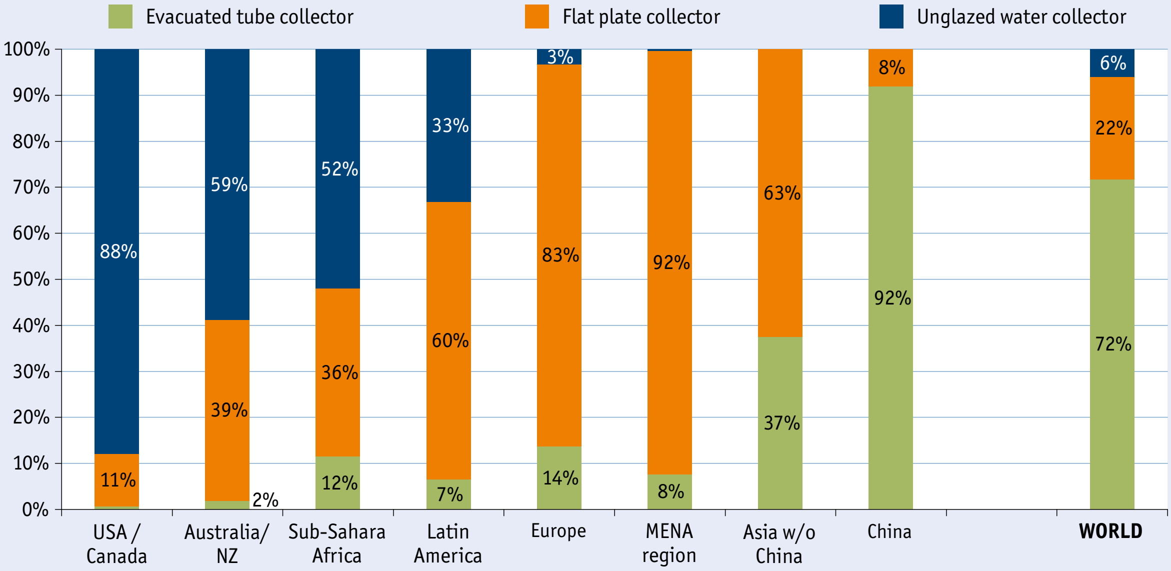
The use of solar thermal energy varies greatly from region to region and can be roughly distinguished by the type of solar thermal collector used (unglazed water collectors, evacuated tube collectors, flat plate collectors, glazed and unglazed air collectors, concentrating collectors), the type of system 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 share of these system types and applications are shown by different economic regions for both the cumulated capacity in operation in 2016 and the newly installed capacity in 2016[26].

## 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 72 % of the cumulated capacity in operation (**Figure 51**) and a share of 74 % of the newly installed capacity (**Figure 52**). Worldwide flat plate collectors accounted for 22 % of the cumulated capacity in operation (**Figure 51**) and a 22 % share of the newly installed capacity (**Figure 52**). 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.

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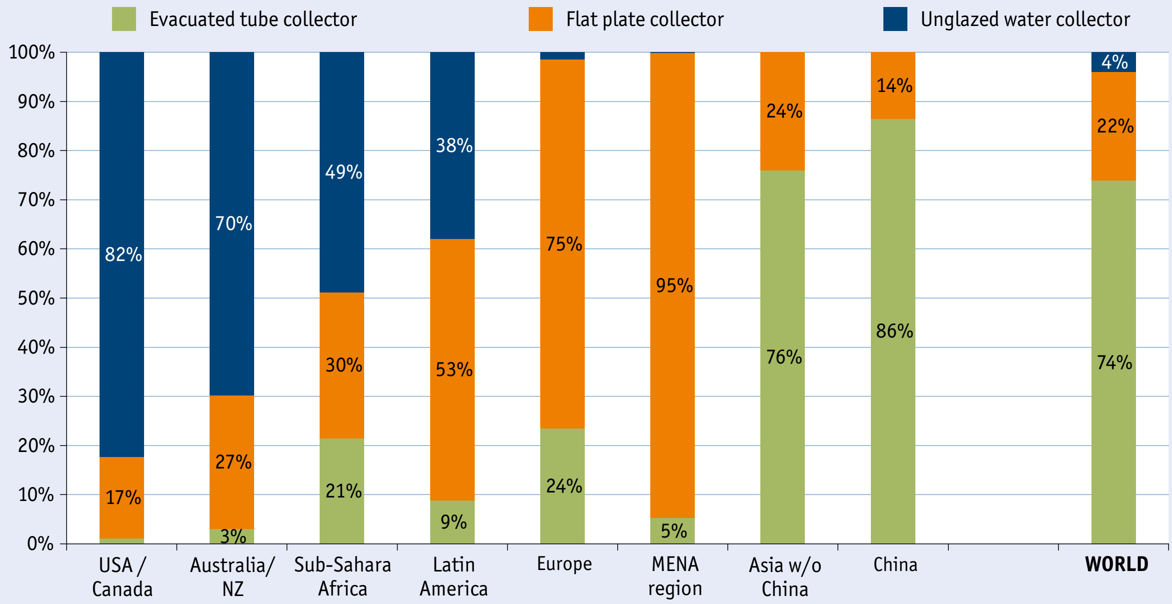
| Sub-Sahara Africa: | Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
| Asia w/o China: | India, Japan, South Korea, Taiwan Thailand |
| Latin America: | Barbados, Brazil, Chile, Mexico, Uruguay |
| Europe: | EU 28, Albania, Macedonia, Norway,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

*Figure 51:* *Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2016*

26 It has to be considered that statistical information summarized in Chapters 5.1 to 5.4 is sometimes based on rough expert estimations by country representatives only and hence especially the share by type of system and application of the cumulated installed capacity in operation may deviate from figures published in previous editions of this report.

*85 m² evacuated tubes at Centurion Building, CapeTown* *Photo: SOLTRAIN/AEE INTEC*

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

**Figure 52:** *Distribution by type of solar thermal collector for the newly installed water collector capacity in 2016*

## 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 53**). Similar to the distribution by type of solar thermal collector in total numbers, the Chinese market influenced the overall figures the most. In 2016, 89 % of the newly installed systems were estimated to be thermosiphon systems while pumped systems only accounted for 11 % (**Figure 54**).

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.

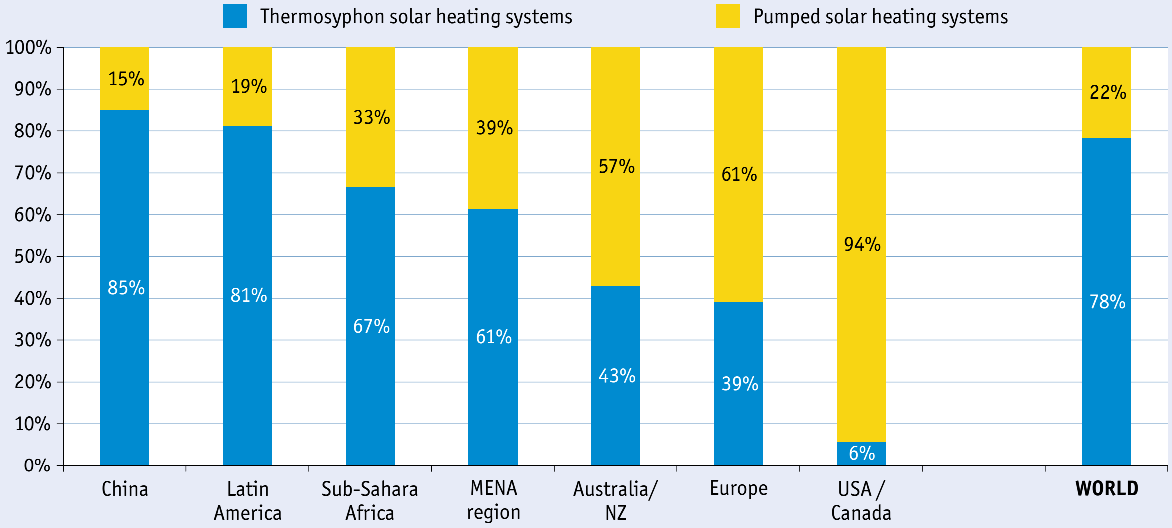
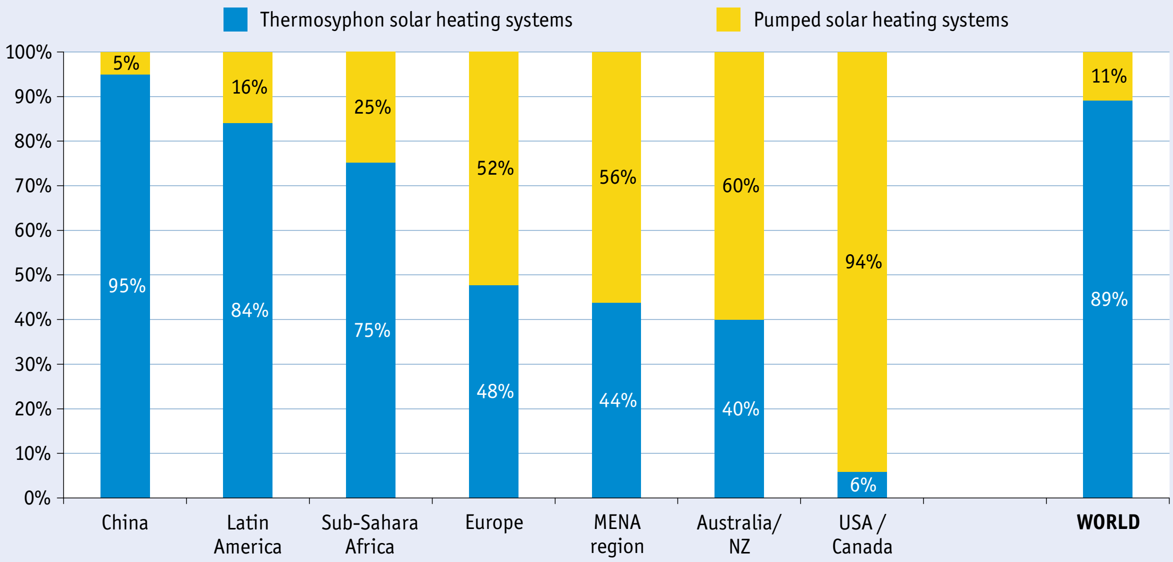



*Figure 53:* *Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2016*

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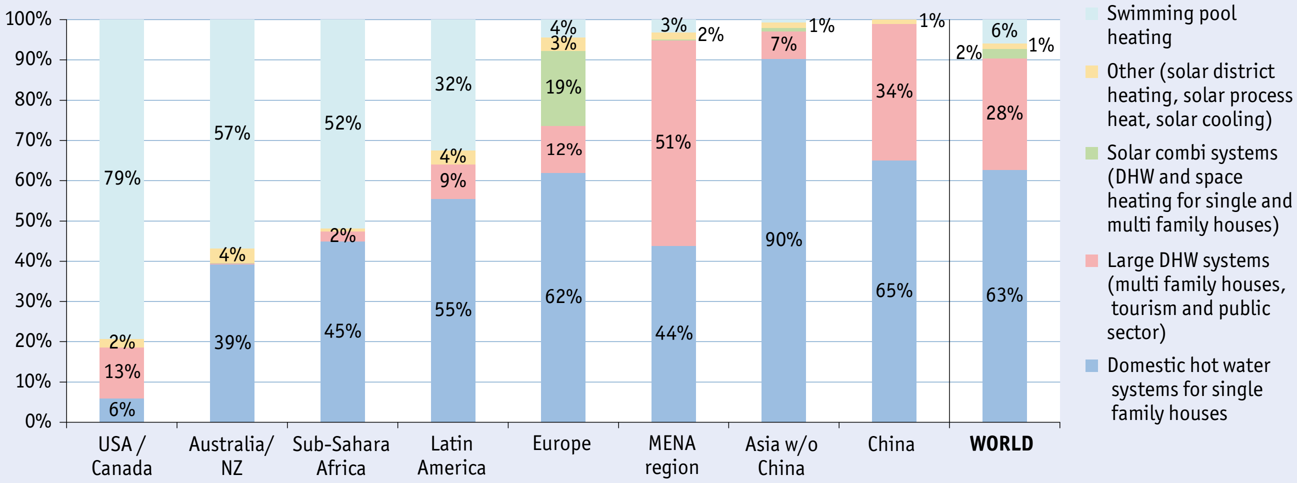
| Sub-Sahara Africa: | Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
| Asia w/o China: | India, Japan, South Korea, Taiwan Thailand |
| Latin America: | Barbados, Brazil, Chile, Mexico, Uruguay |
| Europe: | EU 28, Albania, Macedonia, Norway,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

*Figure 54:* *Distribution by type of system for the newly installed glazed water collector capacity in 2016*

## 7.3 Distribution by type of application

By the end of 2016, 651 million square meters of water-based solar thermal collectors corresponding to a thermal peak capacity of 456 $GW_{th}$ were in operation worldwide (**Table 3**). 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 55**). 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 113 million.

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| Sub-Sahara Africa: | Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe |
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| Europe: | EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey |
| MENA countries: | Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia |

**Figure 55:** *Distribution of solar thermal systems by application for the total installed water collector capacity by economic region in operation by the end of 2016*

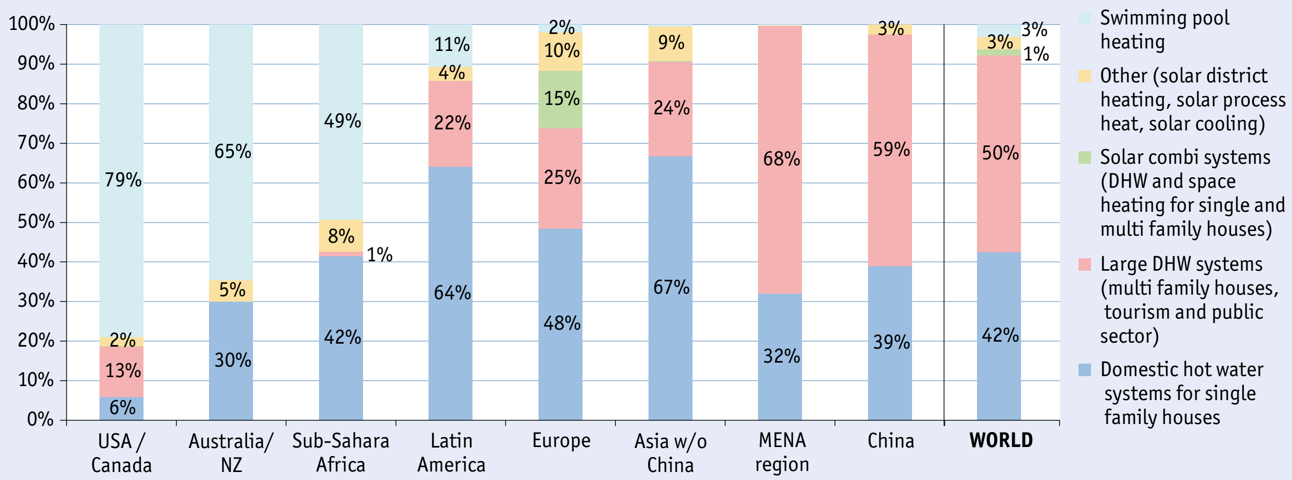
The newly installed water-based solar thermal collector area amounted to 52.1 million square meters, which corresponds to 36.4 GW of thermal peak capacity (**Table 5**).

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 42 % of new installations in 2016 make this kind of systems the most common application worldwide but with a decreasing tendency.

By contrast, the share of large-scale domestic hot water applications basically tends to increase (28 % of total capacity and 50 % 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.

*30 m² flat plate collectors at Pitseng Highschool, Lesotho* *Photo: SOLTRAIN/AEE INTEC*

The share of applications, such as solar district heating and solar process heat are increasing the share steadily even if it is still on a low level of 3 % globally (**Figure 56**).

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| 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, Macedonia, Norway, Russia, Switzerland, Turkey |
| MENA countries: | Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia |

***Figure 56:*** *Distribution of solar thermal systems by application for the newly installed water collector capacity by economic region in 2016*

# 8 Solar thermal system cost and levelized cost of heat

In this chapter, economic performance indicators for major solar thermal markets worldwide are analyzed. In total, technical and economic benchmark figures for solar thermal systems from 12 countries (Australia, Austria, Brazil, Canada, China, Denmark, France, Germany, India, Israel, South Africa and Turkey) were collected from a comprehensive questionnaire. Solar thermal experts, solar trade associations, technology providers and installation companies from these countries were asked to provide cost information on solar thermal applications most commonly applied in their countries, including small domestic hot water systems for single-family homes (DHW-SFH), large domestic hot water systems for multi-family homes (DHW-MFH), small combined hot water and space heating systems (COMBI-SFH) and swimming pool heating systems with unglazed water collectors (POOL HEATING). Moreover, cost information on 12 Danish large-scale solar district heating systems (SDH) was collected. All cost figures and the related exchange rates to Euro refer to the year 2016.

In Chapters 8.1 to 8.4 the results are summarized in bar charts that show both the range of investment costs as well as the range of the corresponding **L**evelized **C**ost **o**f Solar Thermal Generated **H**eat *(LCOH)* for each solar thermal application available in the respective country. Cost data are expressed as specific values in Euro per square meter gross collector area [€/m²$_{gross}$] and refer to end-user (customer) prices excluding value added tax and subsidies. The LCOH is expressed as €-cents[27] per kWh thermal end energy provided by the solar thermal system. The methodology applied for the LCOH calculation as well as all relevant techno-economic benchmark figures and assumptions are documented in the appendix (Chapter 9.3).

## Summary of results

The lowest LCOH for domestic applications were:

- ~1 €-ct/kWh for pool heating systems (Australia, Brazil)
- 2 – 4 €-ct/kWh for small thermosiphon domestic hot water systems (Brazil, India, Turkey) and 7 – 8 €-ct/kWh for small pumped domestic hot water systems (Australia, China)
- 2 – 3 €-ct/kWh for larger pumped systems in multi-family homes (Brazil and India)
- 3 €-ct/kWh for small combined hot water and space heating systems (Brazil)

The highest LCOH for domestic applications were:

- ~2 €-ct/kWh for pool heating systems (Canada, Israel)
- 7 – 12 €-ct/kWh for small thermosiphon systems (Australia, China, South Africa)
- 12 – 20 €-ct/kWh for small pumped systems (Australia, Austria, Canada, Denmark, France)
- 8 – 14 €-ct/kWh for larger pumped systems in multi-family homes (Austria, Canada, Denmark, France)
- 11 – 19 €-ct/kWh for small combined hot water and space heating systems (Austria, China, Denmark, Germany, South Africa).

Analysis of Danish large-scale solar district heating (SDH) systems shows that economies of scale enable a huge potential for cost reduction: while the average LCOH for small domestic applications in Denmark ranges between 18.5 €-ct/kWh for COMBI-SFH and 12.1 €-ct/kWh for DHW-MFH, the average LCOH for large-scale systems (>10,000 m²) including the cost for a diurnal storage goes

27 Respective currency exchange rates by January 2016 (https://www.oanda.com/currency/converter)

*14 m² flat plate collectors at Thatch View Lodge, South Africa* *Photo: SOLTRAIN/AEE INTEC*

down to 3.6 €-ct/kWh. For even larger systems (>50,000 m²) with seasonal storage attached a LCOH of 4.9 €-ct/kWh is achieved. The low LCOH in combination with a tax on natural gas makes large-scale solar thermal a commercial business case for district heating (consumer) co-operatives all over Denmark. (See **Chapter 4.2** for further information.)

In **Figure 57**, specific solar thermal system costs in €/m$^2_{gross}$ are highlighted in blue boxplots for (small-scale) domestic as well as for (large-scale) commercial solar thermal applications in Denmark. The corresponding levelized cost of solar thermal generated heat (LCOH) in €-ct/kWh is shown as green bars (a green diamond equals the average value).

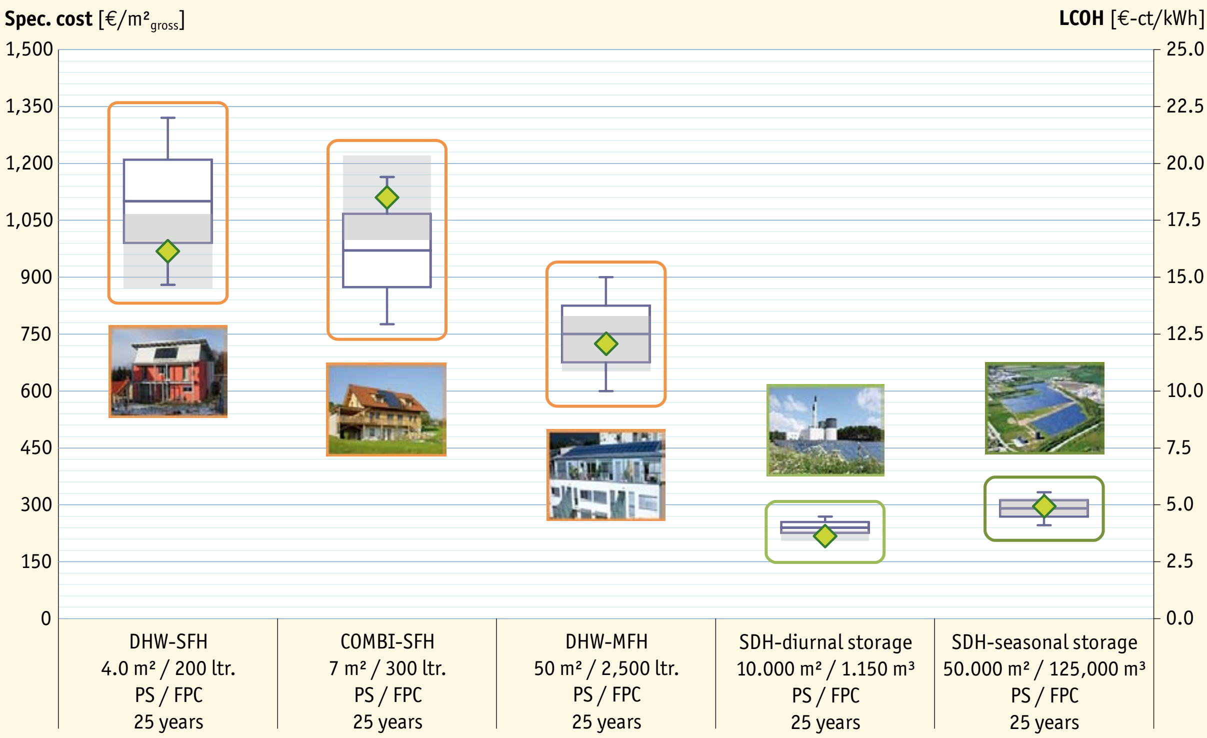



**Figure 57:** *Specific investment costs and levelized costs of heat for different solar thermal applications in Denmark (orange: small-scale domestic systems, green: large-scale commercial applications)*

## 8.1 Small domestic hot water systems

The majority of solar thermal systems installed worldwide are for domestic hot water preparation. Small domestic hot water systems for single-family homes as investigated in this chapter may differ by type of system (pumped systems, PS, or thermosiphon systems, TS) and/or by type of collector technology used (flat plate collector, FPC, or evacuated tube collector, ETC). Pumped systems are common in central and northern Europe as well as in North America and Australia, whereas thermosiphon systems are more common in warm climates, such as in Africa, Latin America, southern Europe and the MENA region. In Australia, both types of systems are about evenly present. In China, evacuated tube collectors in combination with thermosiphon systems are dominant, but the share of pumped systems with either flat plate or evacuated tube collectors is increasing. Other countries analyzed in this chapter are dominated by systems with flat plate collectors.

In **Figure 58**, specific solar thermal system costs in €/m²$_{gross}$ are highlighted for small pumped DHW systems in different countries within a typical price range (the blue boxplots). The corresponding levelized cost of solar thermal generated heat *(LCOH)* in €-ct/kWh is shown as green bars (a green diamond equals the average value).

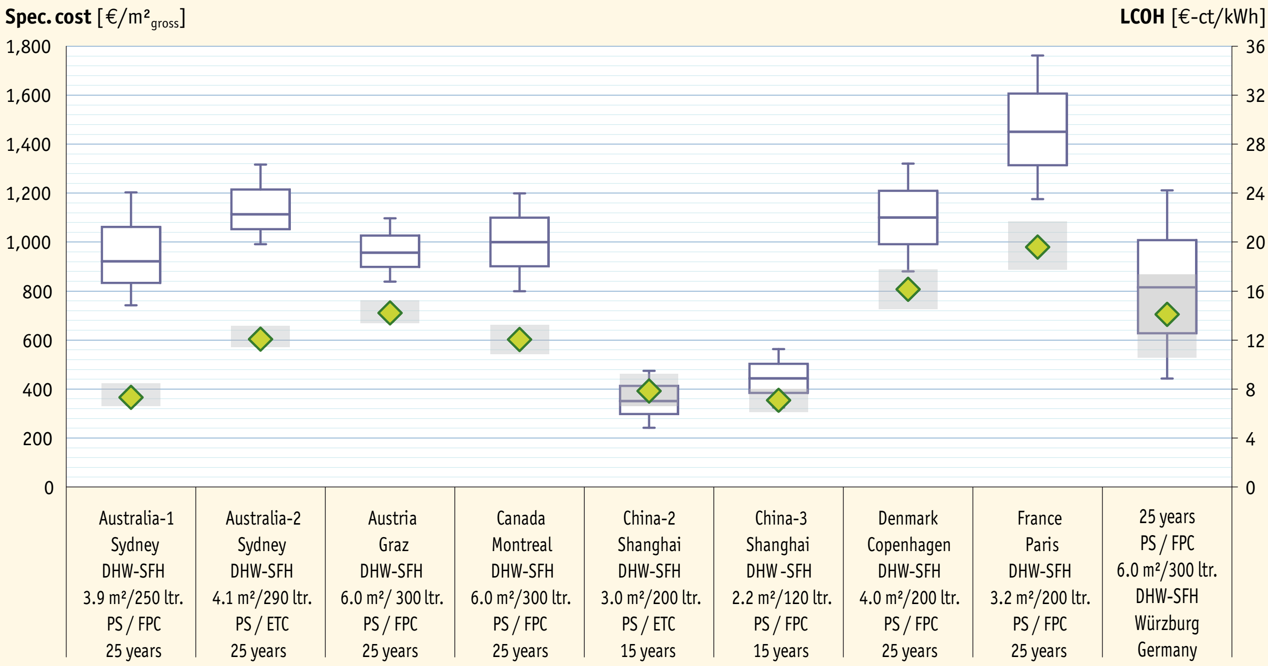



*Figure 58: Specific investment costs and levelized costs of solar thermal generated heat for small pumped domestic hot water systems*

The pumped solar water heating systems for single-family homes presented above have a collector area in the range between 2.2 m² (China) and 6 m² (Austria, Canada, Germany) and corresponding hot water storages between 120 liter and 300 liter. Flat plate collectors as well as evacuated tube collectors are used for this type of system.

Based on long-term experiences, service lifetime of the systems of between 15 years (China) and 25 years (all other countries) were taken as a basis for the calculation of the LCOH. Depending on the lifetime above as well as the end consumer cost and the respective climatic conditions the LCOH for small pumped hot water systems is between 7 – 19 €-ct/kWh. The lowest cost for solar heat is in

Australia and China. In central and northern Europe (Austria, Denmark, France and Germany) and Canada the cost of solar heat is about twice as high. The type of collector used seems not to have a significant influence on the cost of solar heat.

In **Figure 59**, specific solar thermal system costs in €/m²$_{gross}$ are highlighted for small thermosiphon DHW systems in different countries within a typical price range (blue boxplots). The corresponding levelized cost of solar thermal generated heat (LCOH) in €-ct/kWh is shown as green bars (a green diamond equals the average value).

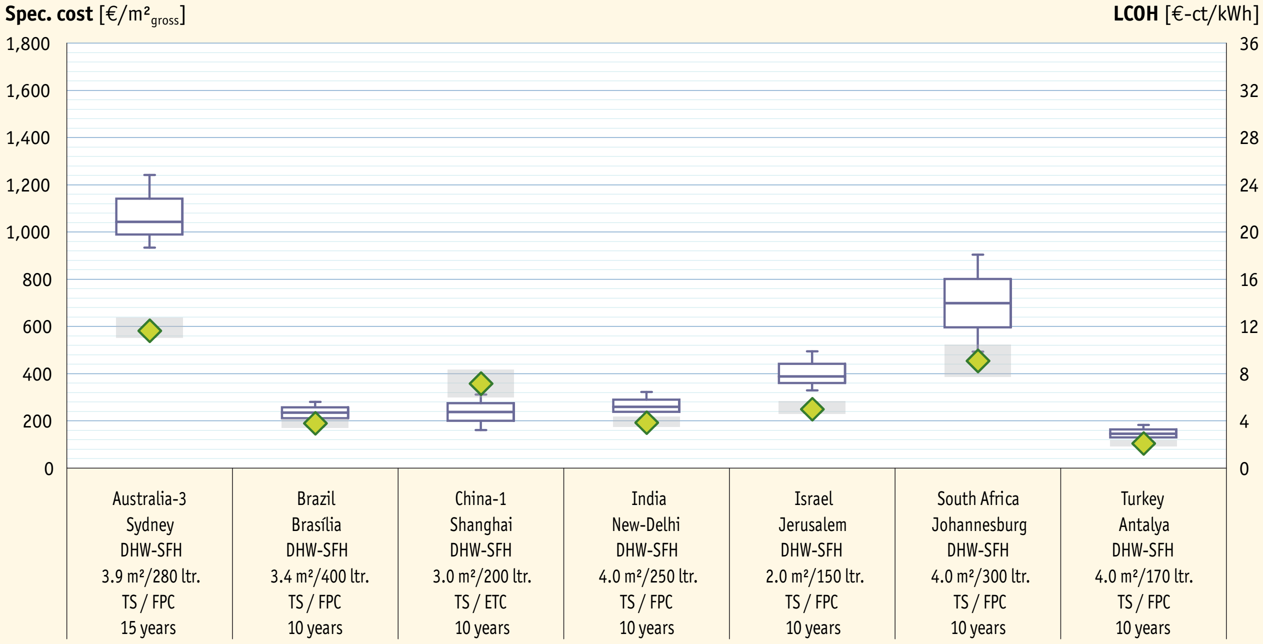



***Figure 59:*** *Specific investment costs and levelized costs of solar thermal generated heat for small thermosiphon domestic hot water systems*

The thermosiphon solar water heating systems for single-family homes presented above have a collector area in the range between 2 m² (Israel) and 4 m² (India, South Africa, Turkey) and corresponding hot water storages between 150 liter and 400 liter. Flat-plate as well as evacuated tube collectors are also used for thermosiphon systems.

Service lifetimes of these systems are between 10 and 15 years depending on the system quality. Depending on the lifetime defined above as well as the end consumer cost and the respective climatic conditions the LCOH for thermosiphon hot water systems are between 2.1 €-ct/kWh (Turkey) and 11.6 €-ct/kWh (Australia).

## 8.2 Large domestic hot water systems

In **Figure 60**, specific solar thermal system costs in €/m²gross are highlighted for large pumped DHW systems and for different countries within a typical price range (blue boxplots). The corresponding levelized cost of solar thermal generated heat (LCOH) in €-ct/kWh is shown as green bars (a green diamond equals the average value).

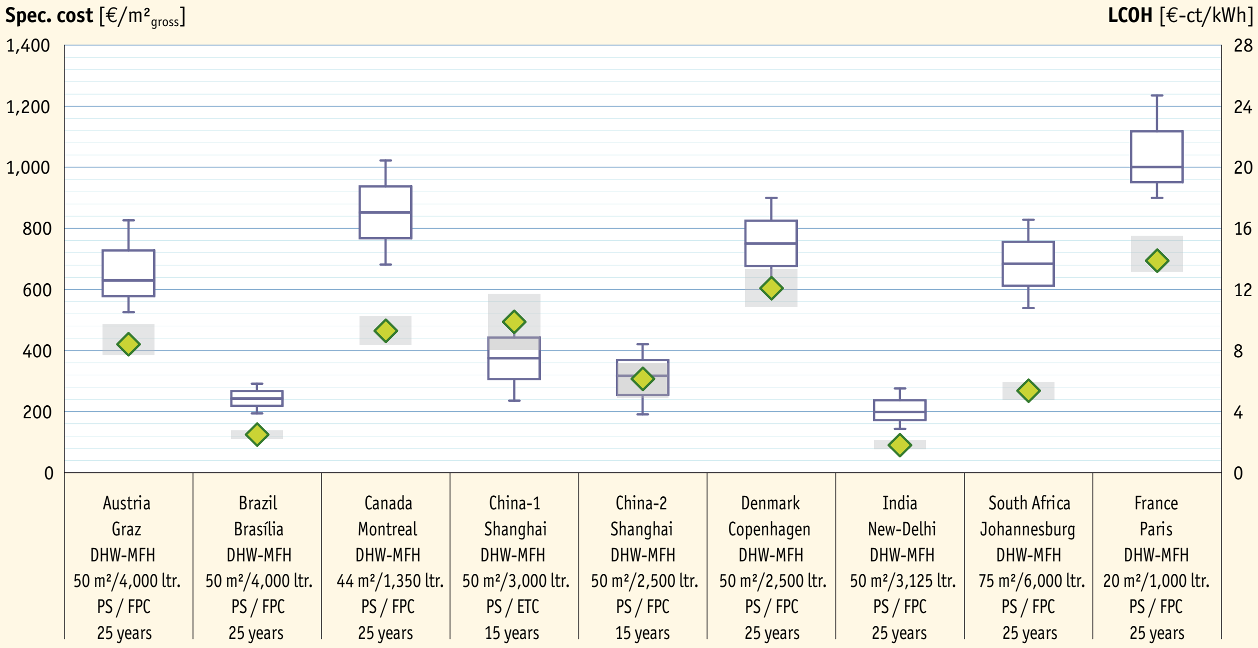



***Figure 60:*** *Specific investment costs and levelized costs of solar thermal generated heat for large pumped domestic hot water systems*

Larger pumped solar water heating systems for multi-family homes, hotels and hospitals presented above have a collector area in the range between 20 m² (France) and 75 m² (South Africa) and corresponding hot water storages between 1,000 liter and 6,000 liter. Flat plate collectors as well as evacuated tube collectors are used for this type of systems.

Based on long-term experiences the service lifetime of the systems is between 15 years (China) and 25 years (all other countries) and served as a basis for the calculation of the LCOH. Depending on the lifetime defined above as well as the end consumer cost and the respective climatic conditions, the LCOH for larger pumped hot water systems is in the range between 2 – 14 €-ct/kWh. The lowest cost for solar heat is achieved in India and Brazil. In Denmark and France, the highest cost of solar heat is 12€-ct/kWh and 14€-ct/kWh, respectively.

## 8.3 Combined hot water and space heating systems

In **Figure 61**, specific solar thermal system costs in €/m²$_{gross}$ are highlighted for small combined hot water and space heating systems in different countries within a typical price range (blue boxplots). The corresponding levelized cost of solar thermal generated heat (LCOH) in €-ct/kWh is shown as green bars (a green diamond equals the average value).

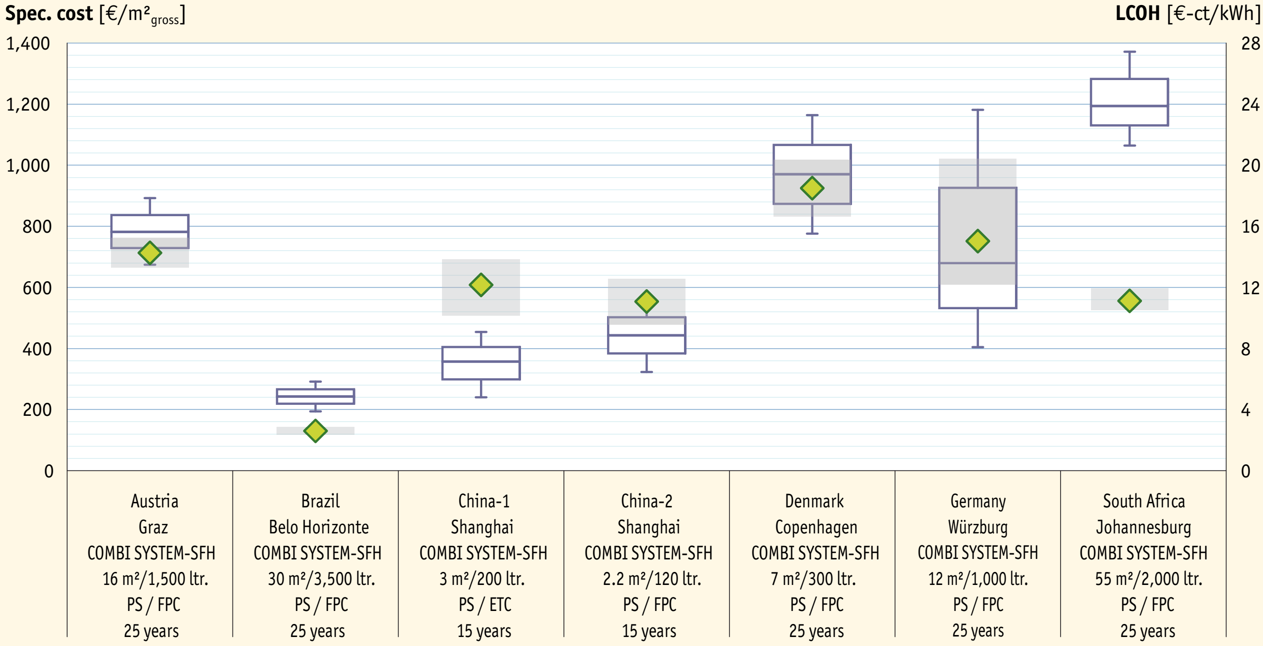



**Figure 61:** *Specific investment costs and levelized costs of solar thermal generated heat for small combined hot water and space heating systems*

The investigated solar combi-systems (used in single-family homes for hot water preparation and for space heating in the winter) have collector areas in the range between 2.2 m² (China) and 55 m² (South Africa) and corresponding hot water storages between 120 liter and 2,000 liter. Flat plate collectors are used predominantly for these applications.

Depending on the collector size of the systems and the climatic conditions the corresponding solar fraction of these systems has quite a broad variation. The service lifetime of the systems is between 15 years (China) and 25 years (all other countries[28]).

Depending on the lifetime defined above as well as the end consumer cost and the respective climatic conditions the LCOH for solar combi-systems is lowest in Brazil (3 €-ct/kWh). In the other countries investigated the LCOH is between 11 and 18.5 €-ct/kWh.

28 System investigated in South Africa is imported from Europe

## 8.4 Swimming pool heating systems

In **Figure 62**, specific solar thermal system costs in €/m²$_{gross}$ are highlighted for swimming pool heating systems with unglazed water collectors in different countries within a typical price range (blue boxplots). The corresponding levelized cost of solar thermal generated heat (LCOH) in €-ct/kWh is shown as green bars (a green diamond equals the average value).

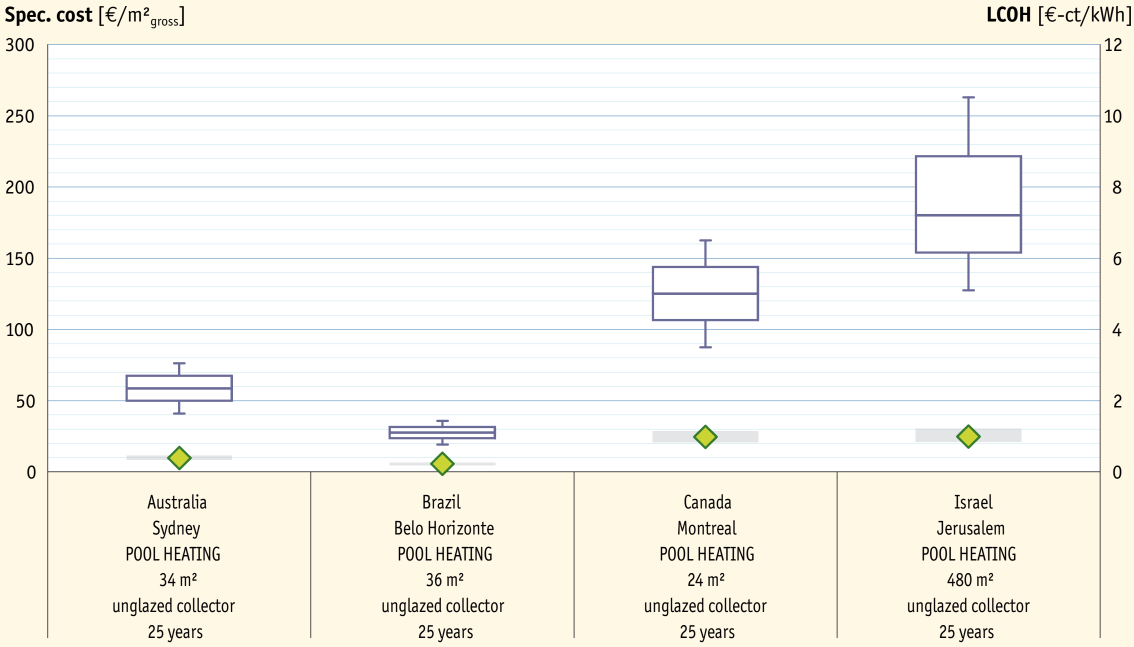



*Figure 62: Specific investment costs and levelized costs of solar thermal generated heat for swimming pool heating systems*

Swimming pool heating is the most economical solar water heating system. The LCOH has a range of 1 – 2 €-ct/kWh.

# 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[29].

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 $CO_2e$[30]. 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.

29 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.

30 Source: Defra / DECC 2013

### 9.1.1 Reference systems for swimming pool heating

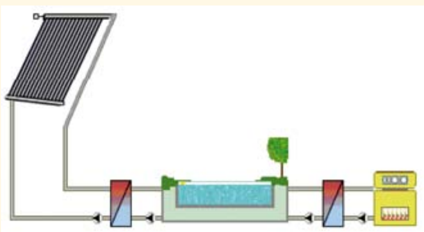
The information in **Table 8** refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2016.

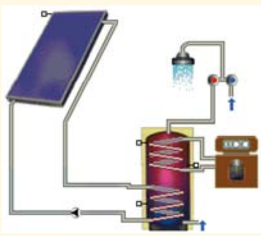
| Country* | Reference climate | Horizontal irradiation [kWh/m²·a] | Total collector area (swimming pool) [m²] | Collector area per system [m²] | Total number of systems | Specific solar yield (swimming pool) [kWh/m²·a] |
|---|---|---|---|---|---|---|
| Australia | Sydney | 1,674.0 | 5,103,740 | 35 | 145,821 | 466 |
| Austria | Graz | 1,126.0 | 590,199 | 200 | 2,951 | 283 |
| Belgium | Brussels | 971.1 | 29,303 | 200 | 147 | 262 |
| Brazil | Brasília | 1,792.5 | 4,435,725 | 32 | 138,616 | 375 |
| Bulgaria | Sofia | 1,187.5 | 6,412 | 200 | 32 | 320 |
| Canada | Montreal | 1,351.4 | 540,379 | 25 | 21,615 | 386 |
| Chile | Santiago de Chile | 1,752.7 | 61,809 | 15 | 4,121 | 473 |
| Croatia | Zagreb | 1,212.0 | 9,798 | 200 | 49 | 327 |
| Cyprus | Nicosia | 1,885.5 | 1,657 | 200 | 8 | 508 |
| Czech Republic | Praha | 998.4 | 671,211 | 200 | 3,356 | 303 |
| Estonia | Tallin | 960.2 | 677 | 200 | 3 | 259 |
| Finland | Helsinki | 948.0 | 3,115 | 200 | 16 | 256 |
| France (mainland) | Paris | 1,112.4 | 119,807 | 200 | 599 | 328 |
| Germany | Würzburg | 1,091.3 | 592,792 | 30 | 19,760 | 314 |
| Greece | Athens | 1,584.6 | 209,750 | 200 | 1,049 | 427 |
| Hungary | Budapest | 1,198.7 | 34,252 | 10 | 3,425 | 344 |
| India | Neu-Delhi | 1,960.5 | 95,334 | 16 | 5,958 | 529 |
| Israel | Jerusalem | 2,198.0 | 185,377 | 200 | 927 | 568 |
| Italy | Bologna | 1,419.0 | 205,636 | 200 | 1,028 | 442 |
| Jordan | Amman | 2,145.4 | 6,661 | 200 | 33 | 578 |
| Korea, South | Seoul | 1,161.1 | 14,919 | 200 | 75 | 313 |
| Latvia | Riga | 991.2 | 575 | 200 | 3 | 267 |
| Lebanon | Beirut | 1,934.5 | 27,325 | 17 | 1,656 | 522 |
| Lithuania | Vilnius | 1,001.2 | 690 | 200 | 3 | 270 |
| Luxembourg | Luxembourg | 1,037.4 | 2,805 | 200 | 14 | 280 |
| Macedonia | Skopje | 1,380.8 | 651 | 20 | 33 | 372 |
| Malta | Luqa | 1,901.9 | 2,410 | 200 | 12 | 513 |
| Mexico | Mexico City | 1,706.3 | 1,205,643 | 200 | 6,028 | 311 |
| Morocco | Rabat | 2,000.0 | 18,040 | 200 | 90 | 539 |
| Netherlands | Amsterdam | 999.0 | 110,875 | 40 | 2,772 | 272 |
| New Zealand | Wellington | 1,401.2 | 11,175 | 200 | 56 | 378 |
| Norway | Oslo | 971.1 | 2,111 | 200 | 11 | 316 |
| Palestinian Territories | Jerusalem | 2,198.0 | 73,394 | 200 | 367 | 593 |
| Portugal | Lisbon | 1,686.4 | 5,101 | 200 | 26 | 421 |
| Romania | Bucharest | 1,324.3 | 8,138 | 200 | 41 | 357 |
| Russia | Moscow | 996.0 | 189 | 200 | 1 | 269 |
| Slovakia | Bratislava | 1,213.8 | 7,513 | 200 | 38 | 327 |
| Slovenia | Ljubjana | 1,114.6 | 1,468 | 200 | 7 | 301 |
| South Africa | Johannesburg | 2,075.1 | 1,109,120 | 40 | 27,728 | 505 |
| Spain | Madrid | 1,643.5 | 195,189 | 200 | 976 | 472 |
| Sweden | Gothenburg | 933.9 | 155,815 | 200 | 779 | 295 |
| Switzerland | Zürich | 1,093.8 | 270,825 | 200 | 1,354 | 277 |
| Taiwan | Taipei | 1,372.2 | 13,513 | 175 | 77 | 319 |
| Thailand | Bangkok | 1,764.8 | 1,804 | 300 | 4 | 476 |
| United Kingdom | London | 942.6 | 37,223 | 200 | 186 | 254 |
| United States | LA, Indianapolis | 1,646.1 | 20,074,308 | 200 | 100,372 | 387 |
| All other countries (5%) | | 1,460.8 | 1,975,458 | 200 | 9,876 | 394 |
| | **TOTAL** | | 38,229,911 | | 502,098 | |
| | **AVERAGE** | 1,415 | | 161 | | 394 |

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

***Table 8:*** *Solar thermal systems for swimming pool heating in 2016*

**Figure 63** shows the hydraulic scheme of the swimming pool reference system as used for the simulations of the solar energy yields. **Figure 64** shows the hydraulic scheme used for the energy calculation for all pumped solar thermal systems and **Figure 65** refers to the thermosiphon systems. For the Chinese thermosiphon systems the reference system above was used, but instead of a flat plate collector as shown in **Figure 65** a representative Chinese vacuum tube collector was used for the simulation.





***Figures 63, 64, 65:*** *Hydraulic scheme of the swimming pool reference system system for single-family houses* — *Hydraulic scheme of the domestic hot water pumped reference* — *Hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses*

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

The information in **Table 9** refers to the total capacity of water collectors in operation used for domestic hot water heating in single-family houses at the end of 2016 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] | Type of system |
|---|---|---|---|---|---|---|---|
| Albania | Tirana | 1,604 | 124,355 | 3.0 | 41,452 | 713 | TS |
| Australia | Sydney | 1,674 | 3,390,720 | 3.5 | 968,777 | 844 | PS |
| Austria | Graz | 1,126 | 2,167,454 | 6.0 | 361,242 | 451 | PS |
| Barbados | Grantley Adams | 2,016 | 214,290 | 4.0 | 53,573 | 882 | TS |
| Belgium | Brussels | 971 | 389,327 | 4.0 | 97,332 | 423 | PDS / PS |
| Botswana | Gaborone | 2,161 | 5,700 | 4.0 | 1,425 | 961 | TS |
| Brazil | Brasília | 1,793 | 7,851,648 | 2.0 | 3,925,824 | 809 | TS |
| Bulgaria | Sofia | 1,188 | 85,198 | 4.0 | 21,299 | 524 | PS |
| Burkina Faso | Ouagadougou | 2,212 | 148 | 4.0 | 37 | 983 | TS |
| Canada | Montreal | 1,351 | 40,720 | 6.0 | 6,787 | 556 | PS |
| Chile | Santiago de Chile | 1,753 | 107,874 | 2.0 | 53,937 | 771 | PS |
| China | Shanghai | 1,282 | 301,326,999 | 4.0 | 75,331,750 | 592 | TS |
| Croatia | Zagreb | 1,212 | 130,177 | 4.0 | 32,544 | 539 | PS |
| Cyprus | Nicosia | 1,886 | 595,679 | 2.0 | 297,840 | 912 | TS |
| Czech Republic | Praha | 998 | 252,317 | 4.7 | 53,684 | 385 | PS |
| Denmark | Copenhagen | 989 | 256,352 | 4.0 | 64,088 | 454 | PS |
| Estonia | Tallin | 960 | 8,997 | 4.0 | 2,249 | 432 | PS |
| Finland | Helsinki | 948 | 41,391 | 4.0 | 10,348 | 441 | PS |
| France | Paris | 1,112 | 1,446,560 | 3.2 | 452,050 | 496 | PS |
| Germany | Würzburg | 1,091 | 8,449,245 | 5.6 | 1,508,794 | 424 | PS |
| Ghana | Accra | 2,146 | 200 | 4.0 | 50 | 954 | TS |
| Greece | Athens | 1,585 | 2,786,799 | 2.5 | 1,114,720 | 772 | TS |
| Hungary | Budapest | 1,199 | 171,437 | 5.0 | 34,287 | 473 | PS |
| India | Neu-Delhi | 1,961 | 8,341,735 | 2.0 | 4,170,867 | 882 | TS |
| Ireland | Dublin | 949 | 308,926 | 4.0 | 77,231 | 423 | PS |
| Israel | Jerusalem | 2,198 | 834,198 | 3.0 | 278,066 | 1,024 | TS |
| Italy | Bologna | 1,419 | 2,732,129 | 4.0 | 683,032 | 661 | PS |
| Japan | Tokyo | 1,175 | 3,359,578 | 4.0 | 839,895 | 586 | TS |
| Jordan | Amman | 2,145 | 1,003,076 | 4.6 | 218,060 | 986 | TS |
| Korea, South | Seoul | 1,161 | 1,678,805 | 4.0 | 419,701 | 525 | PS |
| Latvia | Riga | 991 | 7,641 | 4.0 | 1,910 | 462 | PS |
| Lebanon | Beirut | 1,935 | 403,048 | 4.0 | 100,762 | 860 | TS |
| Lesotho | Maseru | 2,050 | 500 | 2.0 | 250 | 911 | TS |
| Lithuania | Vilnius | 1,001 | 9,170 | 4.0 | 2,293 | 450 | PS |
| Luxembourg | Luxembourg | 1,037 | 37,261 | 4.0 | 9,315 | 450 | PS |
| Macedonia | Skopje | 1,381 | 58,556 | 4.0 | 14,639 | 627 | PS |
| Malta | Luqa | 1,902 | 32,016 | 2.5 | 12,807 | 868 | PS |
| Mauritius | Port Louis | 1,920 | 132,793 | 1.5 | 88,529 | 854 | TS |
| Mexico | Mexico City | 1,706 | 1,519,110 | 4.0 | 379,778 | 718 | PS |
| Morocco | Rabat | 2,000 | 225,500 | 4.0 | 56,375 | 889 | TS |
| Mozambique | Maputo | 1,910 | 1,386 | 4.0 | 347 | 849 | TS |
| Namibia | Windhoek | 2,363 | 17,054 | 4.0 | 4,264 | 1,032 | TS |
| Netherlands | Amsterdam | 999 | 404,367 | 2.8 | 144,417 | 433 | PDS / PS |
| New Zealand | Wellington | 1,401 | 127,716 | 4.0 | 31,929 | 647 | PS |
| Nigeria | Abuja | 2,007 | 254 | 4.0 | 63 | 892 | TS |
| Norway | Oslo | 971 | 1,754 | 6.0 | 292 | 430 | PS |
| Palestinian Ter. | Jerusalem | 2,198 | 917,425 | 1.5 | 611,617 | 977 | TS |
| Poland | Warsaw | 1,024 | 1,496,040 | 6.0 | 249,340 | 397 | PS |
| Portugal | Lisbon | 1,686 | 708,992 | 4.0 | 177,248 | 804 | PS |
| Romania | Bucharest | 1,324 | 108,117 | 4.0 | 27,029 | 594 | PS |
| Russia | Moscow | 996 | 3,232 | 4.0 | 808 | 443 | PS |
| Senegal | Dakar | 2,197 | 1,682 | 4.0 | 420 | 977 | TS |
| Slovakia | Bratislava | 1,214 | 99,821 | 6.0 | 16,637 | 481 | PS |
| Slovenia | Ljubjana | 1,115 | 132,120 | 6.0 | 22,020 | 424 | PS |
| South Africa | Johannesburg | 2,075 | 771,213 | 1.9 | 405,902 | 1,009 | TS |
| Spain | Madrid | 1,644 | 1,561,515 | 4.0 | 390,379 | 766 | PS |
| Sweden | Gothenburg | 934 | 40,752 | 4.0 | 10,188 | 383 | PS |
| Switzerland | Zürich | 1,094 | 904,048 | 5.7 | 158,605 | 426 | PS |
| Taiwan | Taipei | 1,372 | 1,586,110 | 4.8 | 330,440 | 616 | PS |
| Thailand | Bangkok | 1,765 | 142,833 | 4.0 | 35,708 | 854 | TS |
| Tunisia | Tunis | 1,808 | 905,989 | 3.3 | 274,542 | 902 | TS |
| Turkey | Antalya | 1,795 | 19,626,025 | 4.0 | 4,906,506 | 910 | TS |
| United Kingdom | London | 943 | 494,561 | 4.0 | 123,640 | 415 | PS |
| United States | LA, Indianapolis | 1,646 | 1,505,573 | 6.0 | 250,929 | 646 | PS |
| Uruguay | Montevideo | 1,534 | 58,247 | 4.0 | 14,562 | 682 | TS |
| Zimbabwe | Harare | 2,017 | 27,795 | 2.0 | 13,898 | 854 | TS |
| All other countries (5%) | | 1,403 | 26,139,560 | 4.0 | 6,534,890 | 624 | TS/PS |
| | **TOTAL** | | 408,311,812 | | 106,524,217 | | |
| | **AVERAGE** | 1,517 | | 4 | | 624 | |

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

***Table 9:*** *Solar thermal systems for domestic hot water heating in single-family houses by the end of 2016*

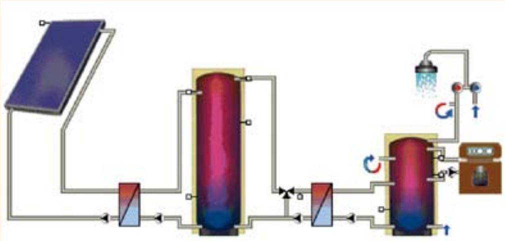
## 9.1.3 Reference systems for domestic hot water preparation in multifamily houses

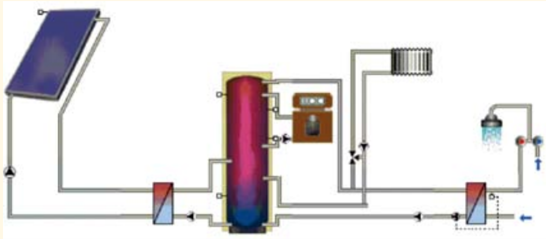
The information in **Table 10** refers to the total capacity of water collectors in operation used for domestic hot water heating in multi-family houses at the end of 2016 as reported by each country.

| 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 | 82,903 | 50.0 | 1,658 | 694 |
| Australia | Sydney | 1,674 | 335,540 | 50.0 | 6,711 | 725 |
| Austria | Graz | 1,126 | 404,257 | 50.0 | 8,085 | 505 |
| Belgium | Brussels | 971 | 88,526 | 50.0 | 1,771 | 405 |
| Botswana | Gaborone | 2,161 | 3,800 | 30.0 | 127 | 902 |
| Brazil | Brasília | 1,793 | 1,362,514 | 60.0 | 22,709 | 658 |
| Bulgaria | Sofia | 1,188 | 19,372 | 50.0 | 387 | 515 |
| Burkina Faso | Ouagadougou | 2,212 | 923 | 30.0 | 31 | 923 |
| Canada | Montreal | 1,351 | 344,273 | 50.0 | 6,885 | 621 |
| Chile | Santiago de Chile | 1,753 | 121,868 | 50.0 | 2,437 | 732 |
| China | Shanghai | 1,282 | 162,253,000 | 50.0 | 3,245,060 | 502 |
| Croatia | Zagreb | 1,212 | 29,600 | 50.0 | 592 | 506 |
| Cyprus | Nicosia | 1,886 | 78,830 | 50.0 | 1,577 | 750 |
| Czech Republic | Praha | 998 | 38,495 | 42.4 | 908 | 436 |
| Denmark | Copenhagen | 989 | 1,319,316 | 50.0 | 26,386 | 413 |
| Estonia | Tallin | 960 | 2,046 | 50.0 | 41 | 401 |
| Finland | Helsinki | 948 | 9,411 | 50.0 | 188 | 396 |
| France | Paris | 1,112 | 652,440 | 20.0 | 32,622 | 489 |
| Germany | Würzburg | 1,091 | 2,283,413 | 50.0 | 45,668 | 472 |
| Ghana | Accra | 2,146 | 2,074 | 30.0 | 69 | 896 |
| Greece | Athens | 1,585 | 633,667 | 50.0 | 12,673 | 642 |
| Hungary | Budapest | 1,199 | 29,124 | 50.0 | 582 | 522 |
| India | Neu-Delhi | 1,961 | 1,096,342 | 50.0 | 21,927 | 749 |
| Ireland | Dublin | 949 | 10,298 | 50.0 | 206 | 425 |
| Israel | Jerusalem | 2,198 | 3,614,859 | 3.0 | 1,204,953 | 917 |
| Italy | Bologna | 1,419 | 621,236 | 50.0 | 12,425 | 592 |
| Japan | Tokyo | 1,175 | 7,357 | 50.0 | 147 | 516 |
| Jordan | Amman | 2,145 | 250,769 | 50.0 | 5,015 | 801 |
| Korea, South | Seoul | 1,161 | 137,817 | 50.0 | 2,756 | 485 |
| Latvia | Riga | 991 | 1,737 | 50.0 | 35 | 414 |
| Lebanon | Beirut | 1,935 | 252,759 | 40.0 | 6,319 | 807 |
| Lesotho | Maseru | 2,050 | 1,343 | 10.0 | 134 | 856 |
| Lithuania | Vilnius | 1,001 | 2,085 | 50.0 | 42 | 418 |
| Luxembourg | Luxembourg | 1,037 | 8,473 | 50.0 | 169 | 433 |
| Macedonia | Skopje | 1,381 | 5,205 | 50.0 | 104 | 577 |
| Malta | Luqa | 1,902 | 7,280 | 50.0 | 146 | 794 |
| Mexico | Mexico City | 1,706 | 651,047 | 50.0 | 13,021 | 713 |
| Morocco | Rabat | 2,000 | 202,950 | 50.0 | 4,059 | 835 |
| Namibia | Windhoek | 2,363 | 20,844 | 50.0 | 417 | 814 |
| Netherlands | Amsterdam | 999 | 104,353 | 40.0 | 2,609 | 418 |
| New Zealand | Wellington | 1,401 | 15,965 | 50.0 | 319 | 585 |
| Nigeria | Abuja | 2,007 | 101 | 1.4 | 72 | 838 |
| Norway | Oslo | 971 | 19,187 | 50.0 | 384 | 406 |
| Palestinian Territories | Jerusalem | 2,198 | 825,683 | 50.0 | 16,514 | 917 |
| Poland | Warsaw | 1,024 | 534,300 | 50.0 | 10,686 | 447 |
| Portugal | Lisbon | 1,686 | 306,040 | 40.0 | 7,651 | 705 |
| Romania | Bucharest | 1,324 | 24,584 | 50.0 | 492 | 553 |
| Russia | Moscow | 996 | 19,061 | 50.0 | 381 | 416 |
| Senegal | Dakar | 2,197 | 52 | 4.5 | 12 | 917 |
| Slovakia | Bratislava | 1,214 | 22,697 | 50.0 | 454 | 507 |
| Slovenia | Ljubjana | 1,115 | 4,404 | 50.0 | 88 | 477 |
| South Africa | Johannesburg | 2,075 | 28,086 | 87.0 | 323 | 866 |
| Spain | Madrid | 1,644 | 1,834,780 | 50.0 | 36,696 | 676 |
| Sweden | Gothenburg | 934 | 55,135 | 50.0 | 1,103 | 430 |
| Switzerland | Zürich | 1,094 | 107,946 | 20.0 | 5,397 | 457 |
| Taiwan | Taipei | 1,372 | 89,525 | 30.0 | 2,984 | 518 |
| Thailand | Bangkok | 1,765 | 11,726 | 80.0 | 147 | 737 |
| Tunisia | Tunis | 1,808 | 907 | 50.0 | 18 | 755 |
| Turkey | Antalya | 1,795 | 1,706,611 | 80.0 | 21,333 | 749 |
| United Kingdom | London | 943 | 112,454 | 50.0 | 2,249 | 393 |
| United States | LA, Indianapolis | 1,646 | 3,513,004 | 50.0 | 70,260 | 687 |
| Zimbabwe | Harare | 2,017 | 9,265 | 32.0 | 290 | 842 |
| All other countries (5%) | | 1,256 | 3,294,073 | 50.0 | 65,881 | 524 |
| | **TOTAL** | | 189,627,730 | | 4,935,384 | |
| | **AVERAGE** | 1,494 | | 46 | | 524 |

*Table 10: Solar thermal systems for domestic hot water heating in multifamily houses by the end of 2016*

**Figure 66** 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 67** shows the hydraulic scheme of domestic hot water reference system for multifamily houses as used for the simulations of the solar energy yields.





**Figures 66, 67:** *Hydraulic scheme of the domestic hot water pumped reference system for multifamily houses* — *Hydraulic scheme of the solar-combi reference system for single and multifamily houses*

## 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 11** refers to the total capacity of water collectors in operation used for domestic hot water heating in multi-family houses at the end of 2016 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 | 2,044,584 | 14.0 | 146,042 | 369 |
| Belgium | Brussels | 971 | 121,177 | 12.0 | 10,098 | 342 |
| Bulgaria | Sofia | 1,188 | 26,518 | 12.0 | 2,210 | 418 |
| Canada | Montreal | 1,351 | 93 | 12.0 | 8 | 476 |
| Croatia | Zagreb | 1,212 | 40,517 | 12.0 | 3,376 | 426 |
| Cyprus | Nicosia | 1,886 | 10,968 | 12.0 | 914 | 663 |
| Czech Republic | Praha | 998 | 204,490 | 8.5 | 24,058 | 351 |
| Denmark | Copenhagen | 989 | 57,149 | 8.0 | 7,144 | 348 |
| Estonia | Tallin | 960 | 2,800 | 12.0 | 233 | 338 |
| Finland | Helsinki | 948 | 12,883 | 12.0 | 1,074 | 334 |
| Germany | Würzburg | 1,091 | 8,010,660 | 11.5 | 696,579 | 378 |
| Greece | Athens | 1,585 | 867,384 | 12.0 | 72,282 | 558 |
| Hungary | Budapest | 1,199 | 63,287 | 10.0 | 6,329 | 422 |
| Ireland | Dublin | 949 | 24,028 | 12.0 | 2,002 | 364 |
| Italy | Bologna | 1,419 | 850,368 | 12.0 | 70,864 | 499 |
| Japan | Tokyo | 1,175 | 136,625 | 12.0 | 11,385 | 414 |
| Korea, South | Seoul | 1,161 | 20,077 | 12.0 | 1,673 | 409 |
| Latvia | Riga | 991 | 2,378 | 12.0 | 198 | 349 |
| Lesotho | Maseru | 2,050 | 7 | 12.0 | 1 | 721 |
| Lithuania | Vilnius | 1,001 | 2,854 | 12.0 | 238 | 352 |
| Luxembourg | Luxembourg | 1,037 | 11,598 | 12.0 | 966 | 365 |
| Macedonia | Skopje | 1,381 | 651 | 10.0 | 65 | 486 |
| Malta | Luqa | 1,902 | 9,965 | 12.0 | 830 | 669 |
| Morocco | Rabat | 2,000 | 4,510 | 12.0 | 376 | 704 |
| Netherlands | Amsterdam | 999 | 32,610 | 6.0 | 5,435 | 352 |
| New Zealand | Wellington | 1,401 | 4,789 | 12.0 | 399 | 493 |
| Norway | Oslo | 971 | 27,454 | 15.0 | 1,830 | 342 |
| Palestinian Territories | Jerusalem | 2,198 | 18,349 | 12.0 | 1,529 | 773 |
| Poland | Warsaw | 1,024 | 106,860 | 12.0 | 8,905 | 365 |
| Romania | Bucharest | 1,324 | 33,651 | 12.0 | 2,804 | 466 |
| Russia | Moscow | 996 | 1,109 | 15.0 | 74 | 350 |
| Slovakia | Bratislava | 1,214 | 31,069 | 12.0 | 2,589 | 427 |
| Slovenia | Ljubjana | 1,115 | 8,808 | 12.0 | 734 | 362 |
| Spain | Madrid | 1,644 | 312,303 | 10.0 | 31,230 | 619 |
| Sweden | Gothenburg | 934 | 292,453 | 10.0 | 29,245 | 389 |
| Switzerland | Zürich | 1,094 | 337,331 | 11.0 | 30,666 | 385 |
| Thailand | Bangkok | 1,765 | 1,708 | 12.0 | 142 | 621 |
| United Kingdom | London | 943 | 153,931 | 12.0 | 12,828 | 332 |
| All other countries (5%) | | 1,140 | 1,151,503 | 12.0 | 95,959 | 401 |
| | **TOTAL** | | 15,039,495 | | 1,283,315 | |
| | **AVERAGE** | 1,265 | | 12 | | 401 |

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

**Table 11:** *Solar combi system reference for single and multifamily houses and the total collector area in operation in 2016*

## 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 /[31]/). 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

31 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.

- 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).

In **Table 12**, techno-economic benchmark figures of the investigated solar thermal systems are summarized for all countries and all kinds of applications.

| Country | Type of system | Global horizontal irradiation | Kind of system / Kind of collector | Gross coll. area / storage volume | Annual solar energy yield* | Net spec. solar thermal system costs incl. labour | | Levelized cost of heat | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | MIN | MAX | MIN | MAX |
| [-] | [-] | kWh/(m²·a) | [-] | m² / liter | kWh/(m²·a) | €/(m²gross) | | €-ct/kWh | |
| Economies of Scale - Example Denmark (Figure 57) | | | | | | | | | |
| Denmark | DHW-SFH | 989 | PS / FPC | 4.0m²/200ltr. | 454 | 880 | 1,320 | 12.9 | 19.4 |
| Denmark | COMBI-SFH | 989 | PS / FPC | 7.0m²/300ltr. | 348 | 776 | 1,164 | 14.8 | 22.2 |
| Denmark | DHW-MFH | 989 | PS / FPC | 50m²/2,500ltr. | 414 | 600 | 900 | 9.7 | 14.5 |
| Denmark | SDH (diurnal storage) | 989 | PS / FPC | 10.000m²/ 1.150m³ | 451 | 211 | 269 | 3.2 | 4.1 |
| Denmark | SDH (seasonal storage) | 989 | PS / FPC | 50.000m²/125,000m³ | 402 | 247 | 334 | 4.2 | 5.7 |
| **Country** | **Reference climate** | **Global horizontal irradiation** | **Kind of system / Kind of collector** | **Gross coll. area / storage volume** | **Annual solar energy yield*** | **Net spec. solar thermal system costs incl. labour** | | **Levelized Cost of Heat** | |
| | | | | | | MIN | MAX | MIN | MAX |
| [-] | [-] | kWh/(m²·a) | [-] | m² / liter | kWh/(m²·a) | €/(m²gross) | | €-ct/kWh | |
| Small domestic hot water systems (e.g. in single family homes) - A) Pumped systems (Figure 58) | | | | | | | | | |
| Australia-1 | Sydney | 1,674 | PS / FPC | 3.9m²/250ltr. | 844 | 740 | 1,200 | 5.9 | 9.6 |
| Australia-2 | Sydney | 1,674 | PS / ETC | 4.1m²/290ltr. | 844 | 990 | 1,320 | 10.7 | 14.3 |
| Austria | Graz | 1,126 | PS / FPC | 6.0m²/300ltr. | 451 | 840 | 1,100 | 12.5 | 16.2 |
| Canada | Montreal | 1,351 | PS / FPC | 6.0m²/300ltr. | 556 | 800 | 1,200 | 9.6 | 14.5 |
| China-2 | Shanghai | 1,282 | PS / ETC | 3.0m²/200ltr. | 592 | 240 | 470 | 5.4 | 10.6 |
| China-3 | Shanghai | 1,282 | PS / FPC | 2.2m²/120ltr. | 592 | 320 | 560 | 5.2 | 9.0 |
| Denmark | Copenhagen | 989 | PS / FPC | 4.0m²/200ltr. | 454 | 880 | 1,320 | 12.9 | 19.4 |
| Germany | Wurzburg | 1,091 | PS / FPC | 6.0m²/300ltr. | 424 | 440 | 1,210 | 7.8 | 20.6 |
| France | Paris | 1,112 | PS / FPC | 3.2m²/200ltr. | 496 | 1,180 | 1,760 | 15.9 | 23.8 |
| Small domestic hot water systems (e.g. in single family homes) - B) Thermosiphon systems (Figure 59) | | | | | | | | | |
| Australia-3 | Sydney | 1,674 | TS / FPC | 3.9m²/280ltr. | 844 | 930 | 1,240 | 10.4 | 13.9 |
| Brazil | Brasília | 1,793 | TS / FPC | 3.4m²/400ltr. | 809 | 190 | 280 | 3.0 | 4.6 |
| China-1 | Shanghai | 1,282 | TS / ETC | 3.0m²/200ltr. | 592 | 160 | 310 | 4.9 | 9.5 |
| India | New-Delhi | 1,961 | TS / FPC | 4.0m²/250ltr. | 882 | 220 | 320 | 3.2 | 4.8 |
| Israel | Jerusalem | 2,198 | TS / FPC | 2.0m²/150ltr. | 1,024 | 330 | 500 | 4.2 | 6.4 |
| South Africa | Johannesbg. | 2,075 | TS / FPC | 4.0m²/300ltr. | 1,009 | 490 | 900 | 6.4 | 11.8 |
| Turkey | Antalya | 1,795 | TS / FPC | 4.0m²/170ltr. | 910 | 110 | 180 | 1.6 | 2.6 |
| Large domestic hot water and/or space heating systems (e.g. in multi family homes, hotels, etc.) (Figure 60) | | | | | | | | | |
| Austria | Graz | 1,126 | PS / FPC | 50m²/4000ltr. | 505 | 530 | 830 | 7.0 | 11.1 |
| Brazil | Brasília | 1,793 | PS / FPC | 50m²/4000ltr. | 658 | 190 | 290 | 2.0 | 3.0 |
| Canada | Montreal | 1,351 | PS / FPC | 44m²/1350ltr. | 621 | 680 | 1,020 | 7.4 | 11.1 |
| China-1 | Shanghai | 1,282 | PS / ETC | 50m²/3000ltr. | 502 | 240 | 510 | 6.2 | 13.5 |
| China-2 | Shanghai | 1,282 | PS / FPC | 50m²/2500ltr. | 502 | 190 | 420 | 3.7 | 8.1 |
| Denmark | Copenhagen | 989 | PS / FPC | 50m²/2500ltr. | 414 | 600 | 900 | 9.7 | 14.5 |
| France | Paris | 1,112 | PS / FPC | 20m²/1000ltr. | 489 | 900 | 1,240 | 12.5 | 17.1 |
| India | New-Delhi | 1,961 | PS / FPC | 50m²/3125ltr. | 749 | 140 | 280 | 1.3 | 2.5 |
| South Africa | Johannesbg. | 2,075 | PS / FPC | 75m²/6000ltr. | 867 | 540 | 830 | 4.2 | 6.5 |
| Combined hot water and space heating systems (Figure 61) | | | | | | | | | |
| Austria | Graz | 1,126 | PS / FPC | 16m²/1500ltr. | 369 | 670 | 890 | 12.4 | 16.2 |
| Brazil | Belo Horizonte | 1,789 | PS / FPC | 30m²/3500ltr. | 631 | 190 | 290 | 2.1 | 3.1 |
| China-1 | Shanghai | 1,282 | PS / ETC | 3m²/200ltr. | 388 | 240 | 450 | 8.2 | 15.5 |
| China-2 | Shanghai | 1,282 | PS / FPC | 2.2m²/120ltr. | 388 | 320 | 560 | 8.1 | 14.1 |
| Denmark | Copenhagen | 989 | PS / FPC | 7m²/300ltr. | 348 | 780 | 1,160 | 14.8 | 22.2 |
| Germany | Wurzburg | 1,091 | PS / FPC | 12m²/1000ltr. | 378 | 410 | 1,180 | 8.1 | 22.6 |
| South Africa | Johannesbg. | 2,075 | PS / FPC | 55m²/2000ltr. | 730 | 1,060 | 1,370 | 9.9 | 12.7 |
| Pool heating systems with unglazed water collectors (Figure 62) | | | | | | | | | |
| Australia | Sydney | 1,674 | PS / unglazed | 34m² / - | 466 | 40 | 80 | 0.5 | 1.0 |
| Brazil | Belo Horiz. | 1,789 | PS / unglazed | 36m² / - | 375 | 20 | 40 | 0.3 | 0.6 |
| Canada | Montreal | 1,351 | PS / unglazed | 24m² / - | 386 | 90 | 160 | 1.4 | 2.6 |
| Israel | Jerusalem | 2,198 | PS / unglazed | 480m² / - | 568 | 130 | 260 | 1.4 | 2.9 |

* Annual solar energy yields in Table 12 are referred to aperture collector area. For LCOH calculation annual solar energy yields referring to gross collector area were used (conversion factors of 1 / 1.1 for flat plate collectors and 1 / 1.5 for evacuated tube collectors were assumed)

***Table 12:*** *Country-specific techno-economic benchmark figures of the investigated solar thermal systems*

## 9.4 Methodological approach for job the 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.

## 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 | Australia | Sydney | 1,674 | 1,841 | 18.1 |
| 3 | Austria | Graz | 1,126 | 1,280 | 9.2 |
| 4 | Barbados | Grantley Adams | 2,016 | 2,048 | 27.4 |
| 5 | Belgium | Brussels | 971 | 1,095 | 10.0 |
| 6 | Botswana | Gaborone | 2,161 | 2,365 | 18.0 |
| 7 | Brazil | Brasília | 1,793 | 1,838 | 22.0 |
| 8 | Bulgaria | Sofia | 1,188 | 1,304 | 10.1 |
| 9 | Burkina Faso | Ouagadougou | 2,212 | 2,270 | 25.0 |
| 10 | Canada | Montreal | 1,351 | 1,568 | 6.9 |
| 11 | Chile | Santiago de Chile | 1,753 | 1,850 | 14.5 |
| 12 | China | Shanghai | 1,282 | 1,343 | 17.1 |
| 13 | Croatia | Zagreb | 1,212 | 1,352 | 11.3 |
| 14 | Cyprus | Nicosia | 1,886 | 2,098 | 19.9 |
| 15 | Czech Republic | Praha | 998 | 1,111 | 7.9 |
| 16 | Denmark | Copenhagen | 989 | 1,164 | 8.1 |
| 17 | Estonia | Tallin | 960 | 1,126 | 5.3 |
| 18 | Finland | Helsinki | 948 | 1,134 | 4.6 |
| 19 | France | Paris | 1,112 | 1,246 | 11.0 |
| 20 | Germany | Würzburg | 1,091 | 1,225 | 9.5 |
| 21 | Ghana | Accra | 2,146 | 2,161 | 23.7 |
| 22 | Greece | Athens | 1,585 | 1,744 | 18.5 |
| 23 | Hungary | Budapest | 1,199 | 1,346 | 11.0 |
| 24 | India | Neu-Delhi | 1,961 | 2,275 | 24.7 |
| 25 | Ireland | Dublin | 949 | 1,091 | 9.5 |
| 26 | Israel | Jerusalem | 2,198 | 2,400 | 17.3 |
| 27 | Italy | Bologna | 1,419 | 1,592 | 14.3 |
| 28 | Japan | Tokyo | 1,175 | 1,287 | 16.7 |
| 29 | Jordan | Amman | 2,145 | 2,341 | 17.9 |
| 30 | Korea, South | Seoul | 1,161 | 1,280 | 12.7 |
| 31 | Latvia | Riga | 991 | 1,187 | 6.3 |
| 32 | Lebanon | Beirut | 1,935 | 2,132 | 19.9 |
| 33 | Lesotho | Maseru | 2,050 | 2,290 | 15.2 |
| 34 | Lithuania | Vilnius | 1,001 | 1,161 | 6.2 |
| 35 | Luxembourg | Luxembourg | 1,037 | 1,158 | 8.4 |
| 36 | Macedonia | Skopje | 1,381 | 1,521 | 12.5 |
| 37 | Malta | Luqa | 1,902 | 2,115 | 18.7 |
| 38 | Mauritius | Port Louis | 1,920 | 2,010 | 23.3 |
| 39 | Mexico | Mexico City | 1,706 | 1,759 | 16.6 |
| 40 | Morocco | Rabat | 2,000 | 2,250 | 17.2 |
| 41 | Mozambique | Maputo | 1,910 | 2,100 | 22.8 |
| 42 | Namibia | Windhoek | 2,363 | 2,499 | 21.0 |

| No. | Country | Reference climate | Horizontal irradiation | Inclined irradiation | Avg. outside air temp. |
|---|---|---|---|---|---|
| | | | [kWh/m²·a] | [kWh/m²·a] | [°C] |
| 43 | Netherlands | Amsterdam | 999 | 1,131 | 10.0 |
| 44 | New Zealand | Wellington | 1,401 | 1,542 | 13.6 |
| 45 | Nigeria | Abuja | 2,007 | 2,051 | 25.7 |
| 46 | Norway | Oslo | 971 | 1,208 | 5.8 |
| 47 | Palestinian Territories | Jerusalem | 2,198 | 2,400 | 17.3 |
| 48 | Poland | Warsaw | 1,024 | 1,156 | 8.1 |
| 49 | Portugal | Lisbon | 1,686 | 1,875 | 17.4 |
| 50 | Romania | Bucharest | 1,324 | 1,473 | 10.6 |
| 51 | Russia | Moscow | 996 | 1,181 | 5.9 |
| 52 | Senegal | Dakar | 2,197 | 2,259 | 24.9 |
| 53 | Slovakia | Bratislava | 1,214 | 1,374 | 10.3 |
| 54 | Slovenia | Ljubjana | 1,115 | 1,231 | 9.8 |
| 55 | South Africa | Johannesburg | 2,075 | 2,232 | 15.6 |
| 56 | Spain | Madrid | 1,644 | 1,844 | 15.5 |
| 57 | Sweden | Gothenburg | 934 | 1,105 | 7.2 |
| 58 | Switzerland | Zürich | 1,094 | 1,218 | 9.6 |
| 59 | Taiwan | Taipei | 1,372 | 1,398 | 20.8 |
| 60 | Thailand | Bangkok | 1,765 | 1,898 | 29.1 |
| 61 | Tunisia | Tunis | 1,808 | 2,038 | 19.3 |
| 62 | Turkey | Antalya | 1,795 | 1,958 | 18.4 |
| 63 | United Kingdom | London | 943 | 1,062 | 12.0 |
| 64 | United States | LA, Indianapolis | 1,646 | 1,816 | 14.3 |
| 65 | Uruguay | Montevideo | 1,534 | 1,647 | 15.9 |
| 66 | Zimbabwe | Harare | 2,017 | 2,087 | 18.9 |

Source: T-Sol expert version 4.5 and Meteonorm version 6.1.

***Table 13:*** *Reference climates for the 66 countries surveyed*

## 9.6 Population data

| No | Country | 2016 | Reg. code |
|---|---|---|---|
| 1 | Albania | 3,038,594 | 6 |
| 2 | Australia | 22,992,654 | 3 |
| 3 | Austria | 8,711,770 | 6 |
| 4 | Barbados | 291,495 | 4 |
| 5 | Belgium | 11,409,477 | 6 |
| 6 | Botswana | 2,180,597 | 1 |
| 7 | Brazil | 205,823,665 | 4 |
| 8 | Bulgaria | 7,144,653 | 6 |
| 9 | Burkina Faso | 19,512,533 | 1 |
| 10 | Canada | 35,362,905 | 8 |
| 11 | Chile | 17,650,114 | 4 |
| 12 | China | 1,373,541,278 | 5 |
| 13 | Croatia | 4,313,707 | 6 |
| 14 | Cyprus | 1,205,575 | 6 |
| 15 | Czech Republic | 10,660,932 | 6 |
| 16 | Denmark | 5,593,785 | 6 |
| 17 | Estonia | 1,258,545 | 6 |
| 18 | Finland | 5,498,211 | 6 |
| 19 | France | 66,836,154 | 6 |
| 20 | Germany | 80,722,792 | 6 |
| 21 | Ghana | 26,908,262 | 1 |
| 22 | Greece | 10,773,253 | 6 |
| 23 | Hungary | 9,874,784 | 6 |
| 24 | India | 1,266,883,598 | 2 |
| 25 | Ireland | 4,952,473 | 6 |
| 26 | Israel | 8,174,527 | 7 |
| 27 | Italy | 62,007,540 | 6 |
| 28 | Japan | 126,702,133 | 2 |
| 29 | Jordan | 10,041,098 | 7 |
| 30 | Korea, South | 50,924,172 | 2 |
| 31 | Latvia | 1,965,686 | 6 |
| 32 | Lebanon | 6,237,738 | 7 |
| 33 | Lesotho | 1,953,070 | 1 |
| 34 | Lithuania | 2,854,235 | 6 |
| 35 | Luxembourg | 582,291 | 6 |
| 36 | Macedonia | 2,100,025 | 6 |

| No | Country | 2016 | Reg. code |
|---|---|---|---|
| 37 | Malta | 415,196 | 6 |
| 38 | Mauritius | 1,348,242 | 1 |
| 39 | Mexico | 123,166,749 | 4 |
| 40 | Morocco | 33,655,786 | 7 |
| 41 | Mozambique | 25,930,150 | 1 |
| 42 | Namibia | 2,436,469 | 1 |
| 43 | Netherlands | 17,016,967 | 6 |
| 44 | New Zealand | 4,474,549 | 3 |
| 45 | Nigeria | 186,053,386 | 1 |
| 46 | Norway | 5,265,158 | 6 |
| 47 | Palestinian Territories | 4,451,014 | 7 |
| 48 | Poland | 38,523,261 | 6 |
| 49 | Portugal | 10,833,816 | 6 |
| 50 | Romania | 21,599,736 | 6 |
| 51 | Russia | 142,355,415 | 6 |
| 52 | Senegal | 14,320,055 | 1 |
| 53 | Slovakia | 5,445,802 | 6 |
| 54 | Slovenia | 1,978,029 | 6 |
| 55 | South Africa | 54,300,704 | 1 |
| 56 | Spain | 48,563,476 | 6 |
| 57 | Sweden | 9,880,604 | 6 |
| 58 | Switzerland | 8,179,294 | 6 |
| 59 | Taiwan | 23,464,787 | 2 |
| 60 | Thailand | 68,200,824 | 2 |
| 61 | Tunisia | 11,285,452 | 7 |
| 62 | Turkey | 80,274,604 | 6 |
| 63 | United Kingdom | 64,430,428 | 6 |
| 64 | United States | 323,127,513 | 8 |
| 65 | Uruguay | 3,351,016 | 4 |
| 66 | Zimbabwe | 13,600,580 | 1 |
| | All other countries | 2,501,383,326 | 9 |
| **Σ Solar Thermal World Statistics** | | 4,824,613,383 | 66% |
| **Σ Inhabitants world** | | 7,325,996,709 | 100% |

*Data source: International Data Base of the U.S. Census Bureau* http://www.census.gov/ipc/www/idb/country.php

***Table 14:*** *Inhabitants by the end of 2016 of the 66 surveyed countries in alphabetical order*

| Region Code / Region | | Σ Inhabitants 2016 | Share 2016 |
|---|---|---|---|
| 1 | Sub-Sahara Africa | 348,544,048 | 5% |
| 2 | Asia excl. China | 1,536,175,514 | 21% |
| 3 | Australia / New Zealand | 27,467,203 | 0% |
| 4 | Latin America | 350,283,039 | 5% |
| 5 | China | 1,373,541,278 | 19% |
| 6 | Europe | 756,266,268 | 10% |
| 7 | MENA Region | 73,845,615 | 1% |
| 8 | United States / Canada | 358,490,418 | 5% |
| 9 | Other countries | 2,501,383,326 | 34% |
| TOTAL | | 7,325,996,709 | 100% |

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

*Data source: International Data Base of the U.S. Census Bureau* **http://www.census.gov/ipc/www/idb/country.php**

***Table 15:*** *Inhabitants per economic region by the end of 2016*

## 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 2018 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 16**, **Table 17** and **Table 18** these countries are marked accordingly and in **Chapter 9.8** (References) the respective data source is cited.

| Country | Water Collectors [m²] | | | Air Collectors [m²] | | TOTAL (excl. concentrators) [m²] |
|---|---|---|---|---|---|---|
| | unglazed | glazed | evacuated tube | unglazed | glazed | |
| Albania | | 20,450 | 362 | | | 20,812 |
| Australia | 460,000 | 173,000 | 19,200 | 35,000 | 1,000 | 688,200 |
| Austria | 1,340 | 150,530 | 2,910 | | 390 | 155,170 |
| Barbados** | | 11,430 | | | | 11,430 |
| Belgium | | 42,500 | 9,500 | | | 52,000 |
| Brazil | 643,888 | 781,118 | 15,864 | | | 1,440,870 |
| Bulgaria | | 5,100 | 500 | | | 5,600 |
| Canada | 23,661 | 3,553 | 3,498 | 21,753 | 5,223 | 57,688 |
| Chile | 16,542 | 53,302 | 22,056 | | | 91,900 |
| China | | 5,400,000 | 47,000,000 | 2,300 | 2,000 | 52,404,300 |
| Croatia | | 18,952 | 2,575 | | | 21,527 |
| Cyprus | | 18,834 | 633 | | | 19,467 |
| Czech Republic | 35,000 | 27,095 | 11,148 | | | 73,243 |
| Denmark | | 179,186 | | | | 179,186 |
| Estonia | | 1,000 | 1,000 | | | 2,000 |
| Finland | | 3,000 | 1,000 | | | 4,000 |
| France (mainland) | | 150,500 | | 800 | | 151,300 |
| Germany | 20,000 | 814,800 | 85,200 | | | 920,000 |
| Ghana | | 756 | 281 | | | 1,037 |
| Greece | | 270,000 | 600 | | | 270,600 |
| Hungary | 1,000 | 11,500 | 4,500 | 200 | 200 | 17,400 |
| India+ | | 236,000 | 944,000 | | 1,000 | 1,181,000 |
| Ireland | | 14,760 | 10,674 | | | 25,434 |
| Israel | 2,200 | 390,000 | | | | 392,200 |
| Italy | | 236,280 | 32,220 | | | 268,500 |
| Japan | | 124,773 | 2,760 | | 6,495 | 134,028 |
| Jordan | | | 54,531 | | | 54,531 |
| Korea, South | | 13,108 | 18,935 | | | 32,043 |
| Latvia | | 1,940 | 420 | | | 2,360 |
| Lebanon | | 21,623 | 31,105 | | | 52,728 |
| Lesotho | | 250 | 150 | | | 400 |
| Lithuania | | 800 | 1,400 | | | 2,200 |
| Luxembourg | | 5,000 | 1,000 | | | 6,000 |
| Macedonia | | 5,672 | 4,723 | | | 10,395 |
| Malta | | 1,216 | 304 | | | 1,520 |
| Mexico | 116,800 | 101,600 | 101,600 | | | 320,000 |
| Morocco | | | 36,000 | | | 36,000 |
| Mozambique | | | 727 | | | 727 |
| Namibia | | 4,123 | 10 | | | 4,133 |
| Netherlands | 2,621 | 17,548 | 3,971 | | | 24,140 |
| New Zealand | | | | | | |
| Norway | | 3,415 | 585 | 200 | 202 | 4,402 |
| Palestine | | 157,625 | 1,000 | | | 158,625 |
| Poland | | 208,100 | 52,000 | | | 260,100 |
| Portugal | | 50,065 | 902 | | | 50,967 |
| Romania | 170 | 6,200 | 12,300 | | | 18,670 |
| Russia | | 75 | 177 | | | 251 |
| Slovakia | 500 | 4,600 | 900 | | | 6,000 |
| Slovenia | | 3,500 | 1,000 | | | 4,500 |
| South Africa | 45,844 | 78,667 | 18,646 | | | 143,157 |
| Spain | 3,839 | 235,355 | 15,900 | 500 | | 255,594 |
| Sweden | 320 | 5,024 | 1,649 | | | 6,993 |
| Switzerland | 4,487 | 98,744 | 14,403 | | | 117,634 |
| Taiwan | | 107,179 | 9,682 | | | 116,861 |
| Thailand* | | 14,032 | | | | 14,032 |
| Tunisia | | 69,555 | | | | 69,555 |
| Turkey | | 1,065,063 | 838,280 | 2,500 | | 1,905,843 |
| United Kingdom | | 29,508 | 7,044 | 1,600 | | 38,152 |
| United States | 826,651 | 174,375 | 8,990 | 11,000 | 13,700 | 1,034,716 |
| Uruguay | | 5,441 | | | | 5,441 |
| Zimbabwe | | 670 | 1,175 | | | 1,845 |
| Other (5%) | 116,045 | 612,026 | 2,600,526 | 3,992 | 1,590 | 3,334,179 |
| **TOTAL** | 2,320,908 | 12,240,518 | 52,010,516 | 79,845 | 31,800 | 66,683,587 |

* 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 2014 to March 2015.

***Table 16:*** *Newly installed collector area in 2014 [m²]*

SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

| Country | Water Collectors [m²] | | | Air Collectors [m²] | | TOTAL (excl. concentrators) [m²] |
|---|---|---|---|---|---|---|
| | unglazed | glazed | evacuated tube | 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 |
| Chile | 10,045 | 25,114 | 10,502 | 0 | 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 |
| Macedonia | | 5,955 | 4,936 | | | 10,891 |
| Malta | | 800 | 200 | | | 1,000 |
| 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 |
| Norway | | 0 | 3,415 | | | 3,415 |
| 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 |
| Other (5%) | 112,401 | 596,141 | 2,154,261 | 3,086 | 1,790 | 2,867,678 |
| TOTAL | 2,248,019 | 11,922,813 | 43,085,223 | 61,719 | 35,795 | 57,353,569 |

* 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 17:* *Newly installed collector area in 2015 [m²]*

| Country | Water Collectors [m²] | | | Air Collectors [m²] | | TOTAL (excl. con-centrators) [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 | | 932 | 139 | | | 1,070 |
| Canada | 806,664 | 70,365 | 48,436 | 406,579 | 48,985 | 1,381,029 |
| Chile | 65,550 | 184,000 | 42,000 | 0 | 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* | 551,110 | 16,734,000 | 2,051,000 | | 26,100 | 19,362,210 |
| 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+ | | 3,613,504 | 5,919,907 | | 11,900 | 9,545,311 |
| 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 |
| Macedonia | | 48,233 | 16,829 | | | 65,062 |
| Maldives | | | | | | |
| Malta | | 41,337 | 10,334 | | | 51,671 |
| Mauritius | | 132,793 | | | | 132,793 |
| Mexico | 1,032,677 | 1,313,082 | 1,030,042 | 752 | 8,773 | 3,385,326 |
| 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 | 0 | 120 | 335 | 0 | 70 | 526 |
| Norway | 1,849 | 43,624 | 5,032 | 200 | 4,106 | 54,812 |
| Palestine | | 1,826,625 | 8,225 | | | 1,834,850 |
| 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 | 0 | 87 | 1,648 | 0 | 1,145 | 2,879 |
| Slovakia | 1,000 | 137,350 | 22,750 | | | 161,100 |
| Slovenia | | 123,650 | 23,150 | | | 146,800 |
| South Africa | 1,109,093 | 572,836 | 226,070 | 0 | 0 | 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 | | 58,247 | | | | 58,247 |
| Zimbabwe | | 21,811 | 15,249 | | | 37,060 |
| Other (5%) | 1,981,260 | 7,217,947 | 23,361,161 | 48,877 | 38,266 | 32,647,511 |
| **TOTAL** | 39,625,204 | 144,358,932 | 467,223,224 | 977,548 | 765,316 | 652,950,224 |

* 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 18:*** *Total collector area in operation by the end of 2015 [m²]*

## 9.8 References to reports and persons that have supplied the data

The production of the report, *Solar Heat Worldwide – Edition 2018* was kindly supported by national representatives of the recorded countries or other official sources of information as cited below.

| COUNTRY | CONTACT | SOURCE<br>REMARKS |
|---|---|---|
| Albania | **Dr. Eng. Edmond M. HIDO**<br>EEC – Albania-EU Energy Efficiency Centre (EEC) | EEC – Albania-EU Energy Efficiency Centre |
| Australia | **Dr. David Ferrari**<br>Sustainability Victoria | Sustainability Victoria<br>Out of operation systems calculated by Sustainability Victoria |
| Austria | **Werner Weiss**<br>AEE - Institute for Sustainable Technologies | Biermayr et al, 2017: Innovative Energietechnologien in Österreich – Marktentwicklung 2016 (Report in German)<br>Out of operation systems calculated by AEE INTEC |
| Barbados | | Based on Solar Water Heating Techscope Market Readiness Assessment – Reports, UNEP 2015<br>0% growth assumed in 2016 |
| Belgium | **ESTIF – European Solar Thermal Industry Federation**<br>**AEE INTEC** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017<br>Unglazed water collectors: AEE INTEC recordings |
| Botswana | **Dr. Edwin Matlotse**<br>Botswana University | 0% growth assumed in 2016 |
| Brazil | **Marcelo Mesquita**<br>Depto. Nac. de Aquecimento Solar da ABRAVA | DASOL ABRAVA<br>Out of operation systems calculated based on DASOL ABRAVA long time recordings |
| Bulgaria | **ESTIF – European Solar Thermal Industry Federation**<br>**AEE INTEC** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017<br>Unglazed water collectors: AEE INTEC recordings |
| Burkina Faso | **Kokouvi Edem N'Tsoukpoe**<br>International Institute for Water and Environmental Engineering<br>Ouagadougou, Burkina Faso | Rapport de l'étude de marché du solaire thermique: production d'eau chaude et de séchage de produits agricoles, 2015<br>0% growth assumed in 2016 |
| Canada | **Reda Djebbar, Ph.D., P.Eng.**<br>Natural Resources Canada | Clear Sky Advisors, April 2017 Report – „Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2016)"<br>Out of operation systems considered by NRC |
| Chile | **Prof. Asistente José Miguel Cardemil**<br>Departamento de Ing. Mecánica, Fac. de Ciencias Físicas y Matemáticas, Universidad de Chile | www.minenergia.cl/sst/ |
| China | **Hu Runqing**<br>Center for Renewable Energy Development – Energy Research Institute (NDRC) | CSTIF – Chinese Solar Thermal Industry Federation<br>Out of operation systems calculated by CSTIF |
| Croatia | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 |

| | | |
|---|---|---|
| **Cyprus** | **Panayiotis Kastania**<br>Cyprus Employers and Industrialists Federation<br><br>**Soteris Kalogirou**<br>Cyprus University of Technlolgy | http://www.ebhek.org.cy/wp-content/uploads/2018/01/Cyprus-Solar-Thermal-Market-Analysis-EBHEK-2014-2015-2016.pdf<br>New installations 2016: EBHEK Solar Thermal Market Analysis 2014 – 2016<br>Cumulated calculated by AEE INTEC |
| **Czech Republic** | **Ales Bufka**<br>Ministry of Industry and Trade | Ministry of Industry and Trade |
| **Denmark** | **ESTIF – European Solar Thermal Industry Federation**<br><br>**AEE INTEC**<br><br>**Jan-Erik Nielsen**<br>Planenergi | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Unglazed water collectors: AEE INTEC recordings |
| **Estonia** | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Finland** | **Ville Maljanen**<br>Solar Energy Statistics Finland | Solar Energy Statistics Finland<br>Expert Estimation |
| **France (mainland)** | **Frédéric Tuillé**<br>Observ'ER – Observatoire des énergies renouvelables<br><br>**Paul KAAIJK**<br>Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME)<br><br>**John Hollick**<br>SAHWIA – Solar Air Heating World Industry Association | Observ'ER 2017, data provided by Frédéric Tuillé<br>Air collectors: John Hollick |
| **Germany** | **Marco Tepper**<br>BSW – Bundesverband Solarwirtschaft e.V.<br><br>**John Hollick**<br>SAHWIA – Solar Air Heating World Industry Association | BSW – Bundesverband Solarwirtschaft e.V.<br>Air collectors: SAHWIA<br>FPC/ETC: BSW solar long time recordings; unglazed water collectors & glazed air collectors: recordings AEE INTEC |
| **Ghana** | **Divine Atsu**<br>Koforidua Polytechnic, Department of Energy Systems Engineering | Data provided by Divine Atsu<br>0% growth assumed in 2016 |
| **Greece** | **Costas Travasoras (EBHE)**<br><br>**AEE INTEC** | Costas Travasoras (EBHE)<br>Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>New installations: ETC/FPC by ESTIF; Costas TRAVASAROS (EBHE)<br>Cumulated installations: cumulated area: ESTIF 2017 / share FPC-ETC: AEE INTEC |
| **Hungary** | **Pál Varga**<br>MÉGNAP - Hungarian Solar Thermal Industry Federation | MÉGNAP - Hungarian Solar Thermal Industry Federation<br>New and cumulated installations: Hungarian Solar Thermal Industry Federation (MÉGNAP); provided by Pál Varga (personal estimation) |
| **India** | **Jaideep N. Malaviya**<br>Malaviya Solar Energy Consultancy | Malaviya Solar Energy Consultancy (based on market survey)<br>New and cumulated installations based on survey from Malaviya Solar Energy Consultancy; out of operation systems considered in 2016 recorded data changed from fiscal to calendar year |

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|---|---|---|
| **Ireland** | **Mary Holland**<br>Sustainable Energy Authority of Ireland | Energy policy statistical support unit of Sustainable Energy Authority of Ireland<br>Grant scheme data; BER database: Source: Energy policy statistical support unit of Sustainable Energy Authority of Ireland; provided by Mary Holland |
| **Israel** | **Eli Shilton**<br>ELSOL<br><br>**Bärbel Epp**<br>Solrico – Solar market research, http://www.solrico.com/ | ELSOL (Eli Shilton), data provided by Bärbel Epp<br>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**<br><br>**AEE INTEC** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Cumulated area: ESTIF 2017 / share FPC-ETC: AEE INTEC / unglazed water collectors: AEE INTEC |
| **Japan** | | EurObservEr 2017<br>Solar System Development Association (SSDA)<br>Share FPC / ETC AEE INTEC |
| **Jordan** | **AEE INTEC** | AEE INTEC<br>New installations: no new collectors for 2016<br>Cumulated installations by end of 2014 |
| **Korea, South** | **Eunhee Jeong**<br>Korea Energy Management Corporation (KEMCO) | 2016 New & Renewable Energy Statistics by the Korea New & Renewable Energy Center, 2017 |
| **Latvia** | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Lebanon** | **Tony Gebrayel**<br>Lebanese Center for Energy Conservation (LCEC) | Lebanese Center for Energy Conservation (LCEC)<br>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 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Luxembourg** | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Macedonia** | **Prof. Dr. Ilja Nasov**<br>National University St. Kiril and Metodij,<br>Faculty for Natural Science, Institute of Physics,<br>Solar Energy Department | 2016 data estimation of Ilya Nasov and other solar experts<br>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**<br>Sustainable Energy and Water Conservation Unit (SEWCU)<br>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**<br>Statistician<br>Environment Statistics Unit, Ministry of Environment and Sustainable Development | Statistics Mauritius<br>No new collector area 2016; cumulated collector area by end of 2015 |
| **Mexico** | **David Garcia**<br>FAMERAC<br><br>**Bärbel Epp**<br>Solrico – Solar market research, http://www.solrico.com/ | Glazed and unglazed water collectors:<br>FAMERAC – Renewable Energy Industry Associationdata provided by Bärbel Epp<br>Air collectors: SAHWIA – Solar Air Heating World Industry Association<br>Cumulated installations: calculated by AEE INTEC |

| | | |
|---|---|---|
| **Morocco** | **Ashraf Kraidy**<br>RECREEE – Regional Center for Renewable Energy and Energy Efficiency | No new collector area 2016; cumulated collector area by end of 2014 |
| **Mozambique** | **Fabião Cumbe**<br>ENPCT, E.P.<br><br>**AEE INTEC** | Estimation provided by Fabião Cumbe<br>Cumulated installations calculated by AEE INTEC based on new installation figures for 2016 |
| **Namibia** | **Zivayi Chiguvare**<br>Namibian Energy Institute, Namibia University of Science and Technology | 2014 – 2016 survey provided by Zivayi Chiguvare |
| **Netherlands** | **André Meurink, Reinoud Segers**<br>Statistics Netherlands (CBS) | Statistics Netherlands (CBS)<br>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<br>Cumulated area in 2009 |
| **Nigeria** | **National Centre for Energy Research and Development, University of Nigeria, Nsukka** | National Centre for Energy Research and Development, University of Nigeria, provided by Okala Nwoke |
| **Norway** | | 2015 data projected by AEE INTEC<br>(0% growth rate 2015 / 2016 assumed) |
| **Palestinian Territories** | **Mohammed Mobayyed**<br>EEU Director, Palestinian Energy Authority | Palestinian Energy Authority<br>0% growth assumed in 2016, Cumulated area calculated by AEE INTEC (replacements not considered) |
| **Poland** | **Janusz Staroscik – President**<br>Association of Heating Appliances manufacturers and Importers in Poland | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017 |
| **Portugal** | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Romania** | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Russia** | **Dr. Semen Frid, Dr. Sophia Kiseleva**<br>Moscow State University<br><br>**Prof. Vitaly Butuzov**<br>Yuzhgeoteplo corporation, Krasnodar | Joint Institute for High Temperatures of Russian Academy of Scienses (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 Merché du Solaire Thermique: Production d'Eau Chaude et Séchage de Produits Agricoles: provided by T. Ababacar<br>0% growth assumed 2016 |
| **Slovakia** | **ESTIF – European Solar Thermal Industry Federation** | Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017<br>Glazed water collectors: ESTIF, 2017 (estimation) |
| **Slovenia** | **University of Ljubljana, Faculty of Mechanical Engineering**<br><br>**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**<br>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 |

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|---|---|---|
| **Spain** | **Pascual Polo**<br>ASIT – Asociación Solar de la Industria Térmica | ASIT (Solar Energy Industry Association of Spain)<br>Out of operation systems calculated by ASIT |
| **Sweden** | **Prof. Jan-Olof Dalenbäck**<br>Svensk Solenergi / CHALMERS | Svensk solenergi (Solar Energy Association of Sweden) |
| **Switzerland** | http://www.swissolar.ch/ | SWISSOLAR – Markterhebung Sonnenenergie 2016, Bundesamt für Energie 2017<br>Out of operation systems calculated by SWISSOLAR |
| **Taiwan** | **K.M. Chung**<br>Energy Research Center – National Cheng Kung University | Bureau of Energy, Ministry of Economic Affairs, R.O.C.<br>Out of operation systems calculated by Bureau of Energy, Ministry of Economic Affairs, R.O.C. |
| **Thailand** | **Charuwan Phipatana-phuttapanta**<br>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)<br>Data for subsidized systems, provided by Charuwan Phipatana-phuttapanta, single-family houses estimated by AEE INTEC based on GIZ study |
| **Tunisia** | **Abdelkader Baccouche**<br>Agence Nationale pour la Maîtrise de l'Energie (ANME) | ANME (National Agency of Energy Conservation) |
| **Turkey** | **A. Kutay Ulke**<br>Bural Heating Corporation Ltd.<br><br>**John Hollick**<br>SAHWIA – Solar Air Heating World Industry Association<br><br>**Prof. Bulent Yesilata**<br>GAP Renewable Energy and Energy Efficiency Center Harran University | Water collectors: A. Kutay Ulke, personal studies<br>Air collectors: SAHWIA<br>New installations: A. Kutay Ulke<br>Cumulated installations: calculated by AEE INTEC considering 14 years lifetime<br>Shares provided by Bulent Yesilata (2016) |
| **United Kingdom** | **Lethbridge Yehuda**<br>Department of Energy and Climate Change<br><br>**John Hollick**<br>SAHWIA – Solar Air Heating World Industry Association | UK Solar Trade Association and ESTIF Reports collated in BEIS annual survey Active Solar 2016 survey, provided by Yehuda Lethbridge, air collectors provided by John Hollick<br>Cumulated ESTIF 2017; FPC/ETC calculated by AEE INTEC; air collectors provided by John Hollick |
| **United States** | **Les Nelson**<br>IAPMO Solar Heating & Cooling Programs<br><br>**John Hollick**<br>SAHWIA – Solar Air Heating World Industry Association | Water Collectors and air collectors: IAPMO Solar Heating & Cooling Programs;<br>Air collectors: SAHWIA<br>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<br>0 % growth rate assumed 2015 / 2016 |
| **Zimbabwe** | **Samson Mhlanga**<br>National University of Science and Technology, Bulawayo | Dr. Anton Schwarzlmüller<br>Domestic Solar Heating unpublished statistics<br>SOLTRAIN survey (unpublished sources)<br>cumulated 2016 calculated by AEE INTEC |

### 9.8.1 Additional literature and web sources used

**The following reports and statistics were used in this report:**


- Bundesamt für Energie (BFE): Markterhebung Sonnenenergie 2016 – Teilstatistik der Schweizerischen Statistik der erneuerbaren Energien; prepared by SWISSOLAR, Thomas Hostettler, Bern, Switzerland July 2017
- Bundesministerium für Verkehr, Innovation und Technologie (BMVIT): Innovative Energy Technologies in Austria – Market Development 2016; prepared by Peter Biermayr et al, Vienna, Austria June 2017
- Bundesverband Solarwirtschaft e.V. (BSW-Solar): Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) 2016; accessed October 2017
- ClearSky Advisors Inc.: Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2016); Prepared by ClearSky Advisors Inc., Dr. Reda Djebbar, Natural Resources Canada, March 2017
- European Solar Thermal Industry Federation (ESTIF): Solar Thermal Markets in Europe, Trends and Market Statistics 2016; Belgium – Brussels; November 2017
- IRENA: Renewable Energy and Jobs: Annual Review 2016
- 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:**


- http://www.anes.org/anes/index.php
- 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/


## 9.9 List of Figures

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