EDITION 2018

WERNER WEISS | MONIKA SPÖRK-DÜR

SOLAR HEAT WORLDWIDE

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

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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Werner Weiss, Monika Spörk-Dür

AEE INTEC
AEE - Institute for Sustainable Technologies
8200 Gleisdorf, Austria

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Chapter 4.2: Large-scale Systems for Solar District Heating and Large Residential, Commercial and Public Buildings

Prof. Jan-Olof Dalenbäck
Chalmers University of Technology, Sweden

Bärbel Epp
Solrico, Germany

Chapter 4.3: Solar Heat for Industrial Applications

Bärbel Epp
Solrico, Germany

Wolfgang Glatzl
AEE INTEC, Austria

Barbara Soldera
GlassPoint Solar, Inc, USA

Chapter 4.4: Solar Air Conditioning and Cooling

Dr. Christian Holter
S.O.L.I.D. GmbH, Austria

Dr. Daniel Mugnier
TECSOL SA., France

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SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

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**).

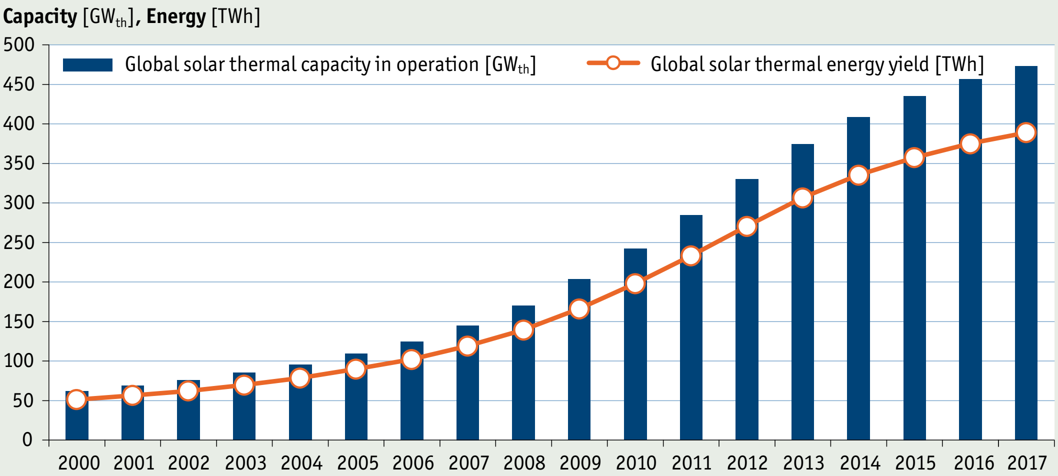


Figure 2: *Global solar thermal capacity in operation and annual energy yields 2000 – 2017*

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**

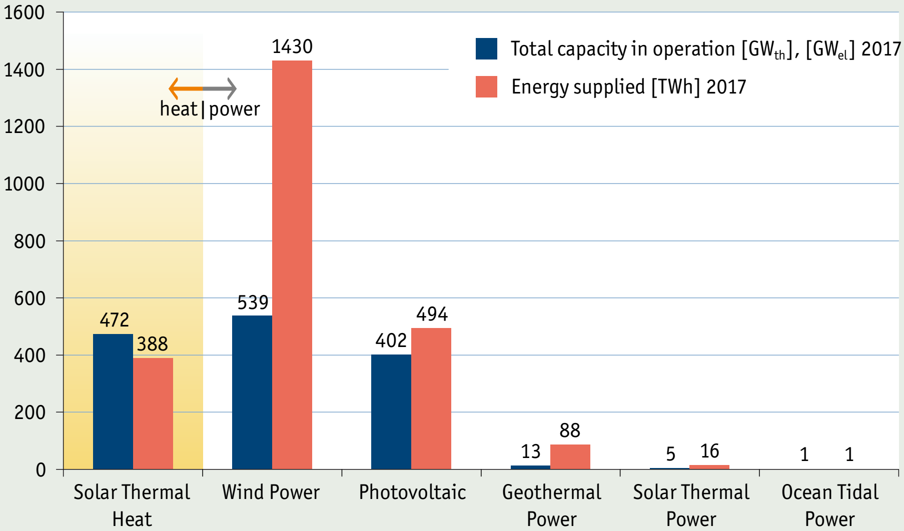


Figure 3: *Global capacity in operation [GW_{el}], [GW_{th}] 2017 and annual energy yields [TWh_{el}], [TWh_{th}].*
(Sources: AEE INTEC, Global Wind Energy Council (GWEC), SolarPower Europe, REN21 – Global Status Report 2018)

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**.

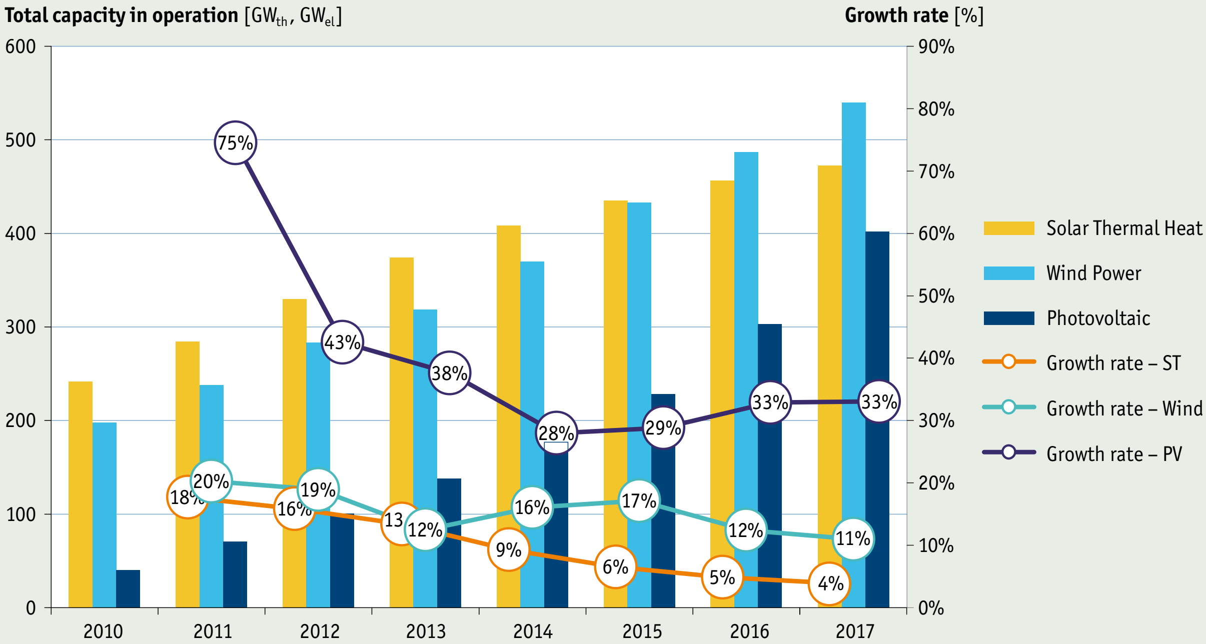


Figure 4: *Global capacity in operation and market growth rates between 2010 and 2017 (Sources: AEE INTEC, Global Wind Energy Council (GWEC), SolarPower Europe, REN21 – Global Status Reports 2011 – 2018)*

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.

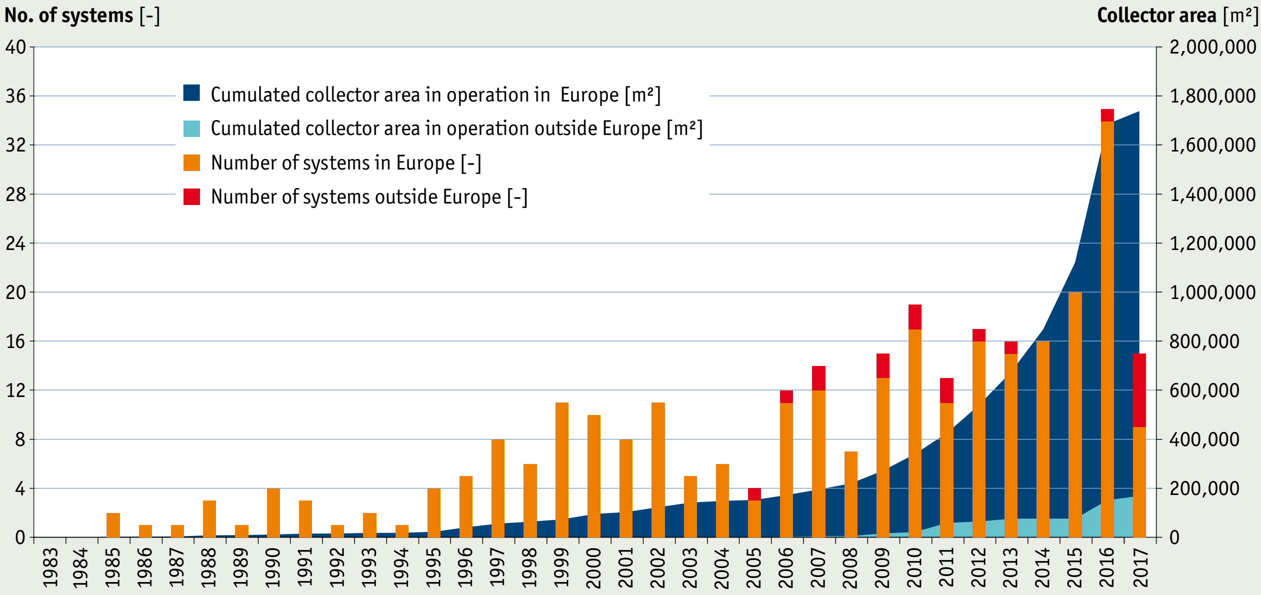
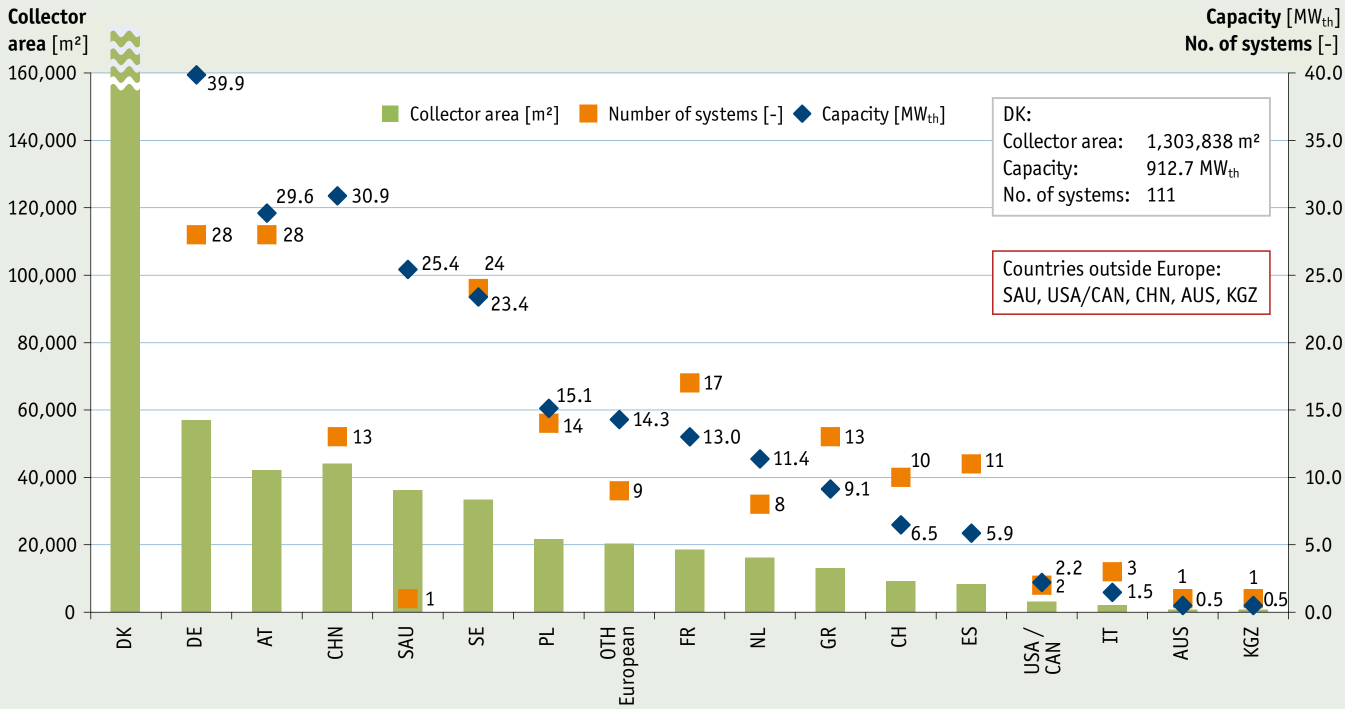


Figure 5: *Large-scale systems for solar district heating and large residential, commercial and public buildings worldwide – annual achievements and cumulated area in operation in 2017 (Data source: Jan-Olof Dalenbäck – Chalmers University of Technology, SE and Sabine Putz – IEA SHC Task 55, Bärbel Epp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

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.

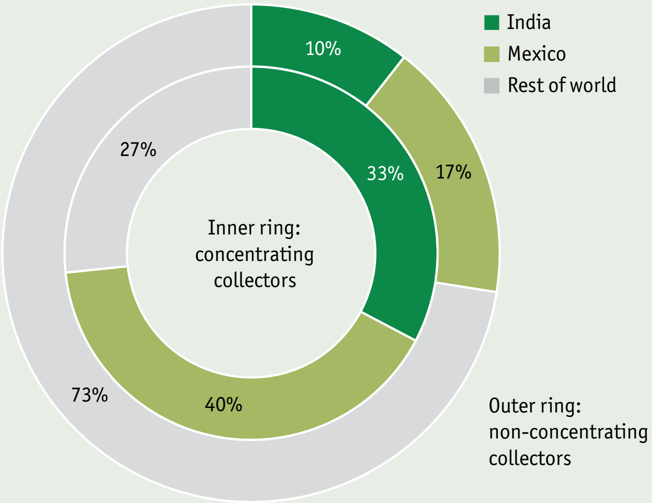


Figure 8:

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.

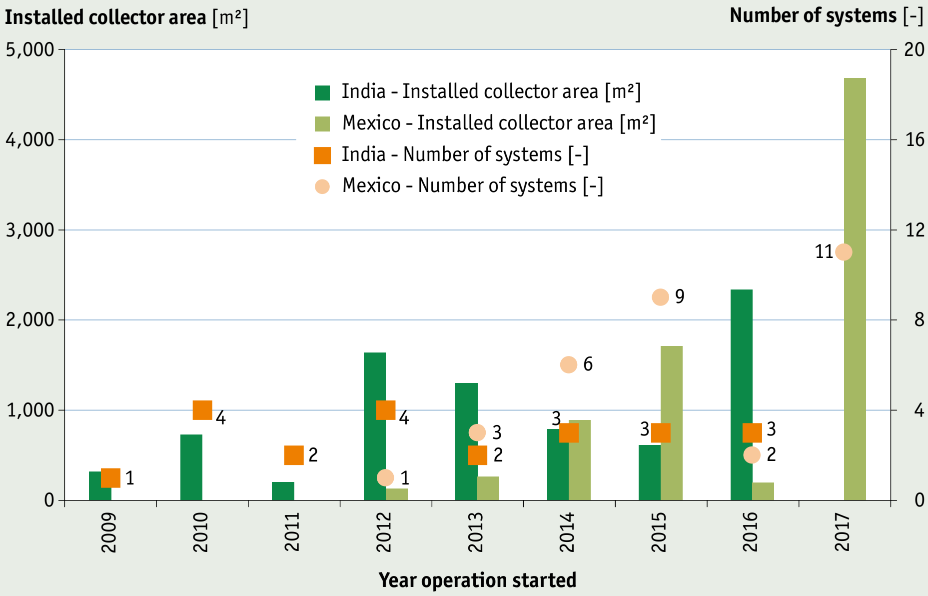


Figure 9: *Number and gross area of installed plants with concentrating solar thermal (CST) collector systems in India and Mexico by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

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.

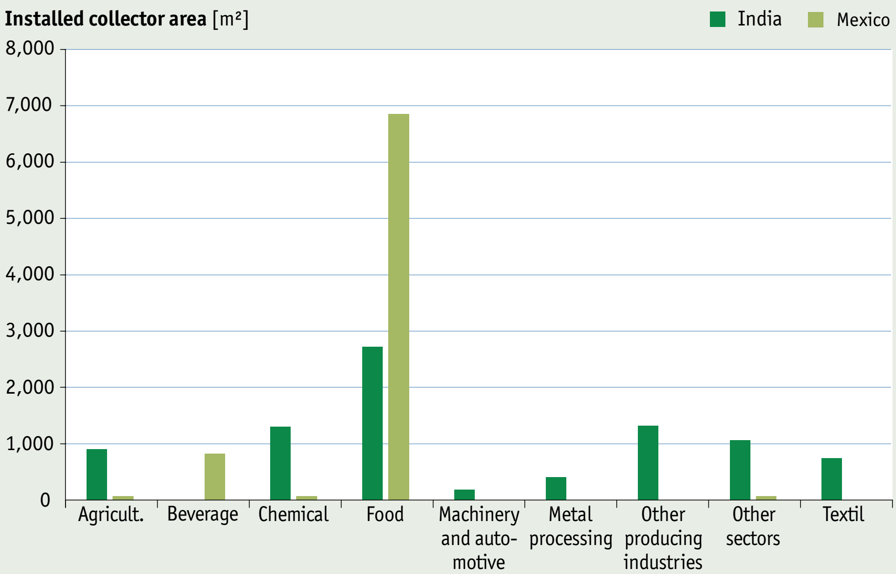


Figure 10: *Application of concentrating solar thermal (CST) collector systems to various industrial sectors in India and Mexico by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

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.

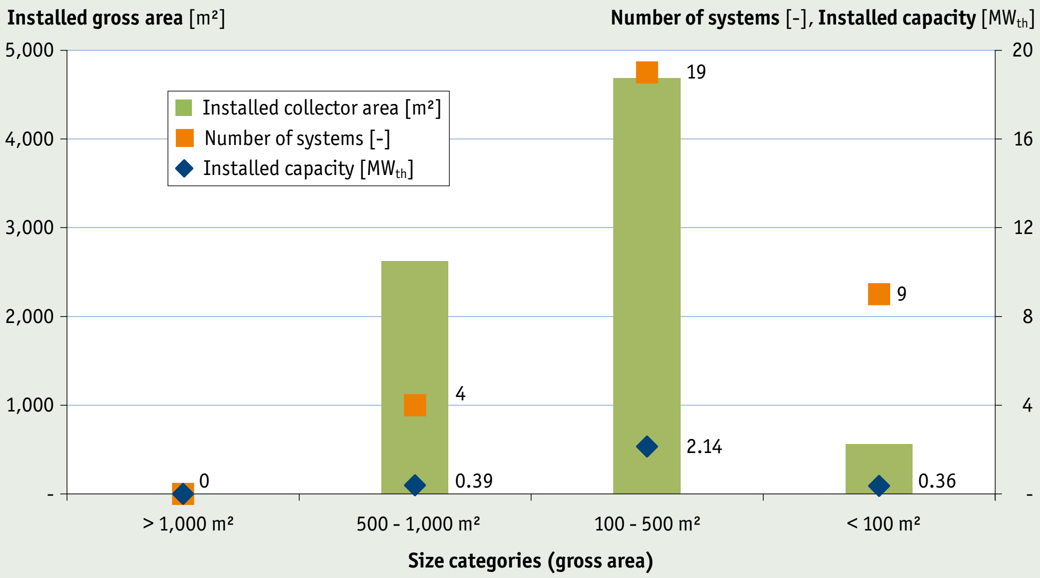


Figure 11: *Number, gross area and thermal capacity of installed plants with concentrating collector types in different size categories in Mexico by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

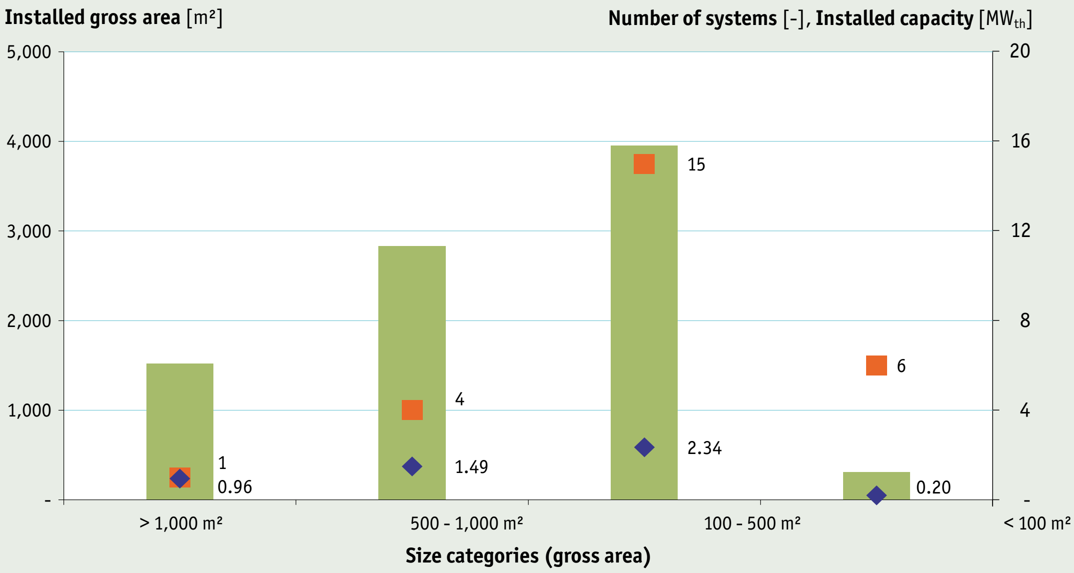


Figure 12: *Number, gross area and thermal capacity of installed plants with concentrating collector types in different size categories in India by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

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).

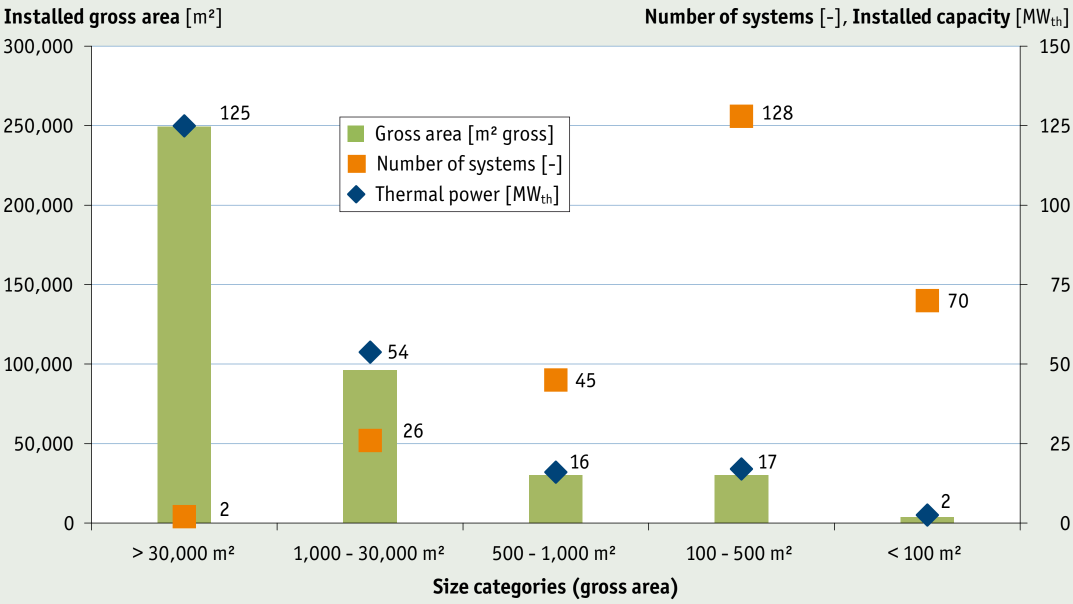


Figure 13: *Global solar process heat plants in operation by capacity and collector area by end of March 2018 (Source: IEA SHC Task49 / IV SHIP database)*

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.

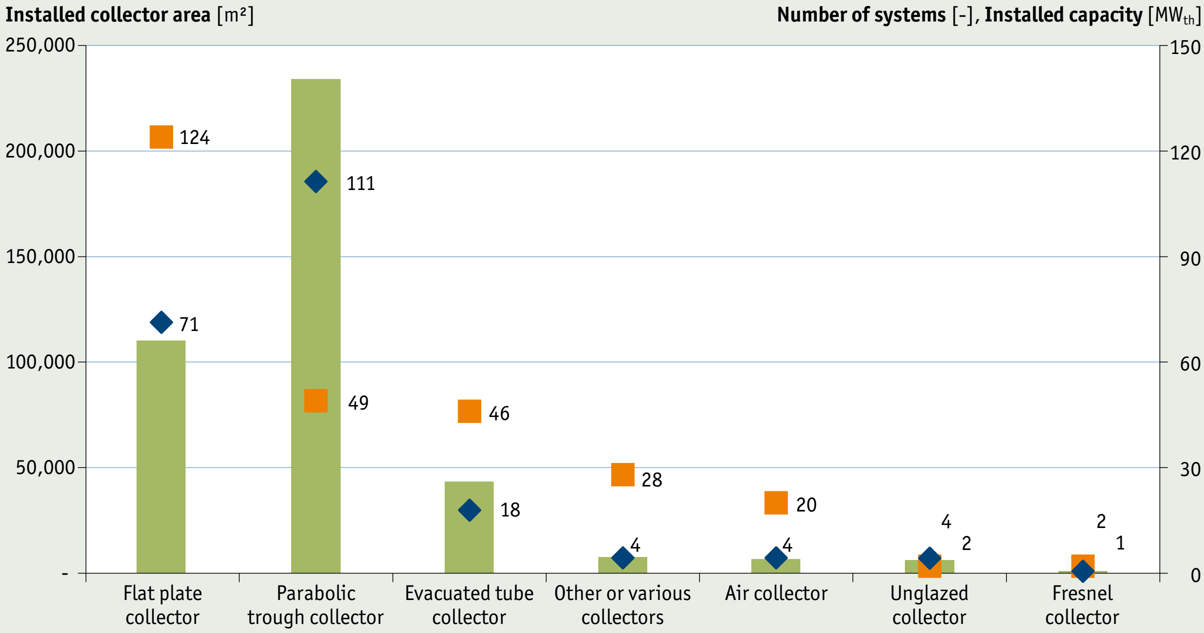


Figure 14: *Global solar process heat applications in operation by type of collector by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

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.

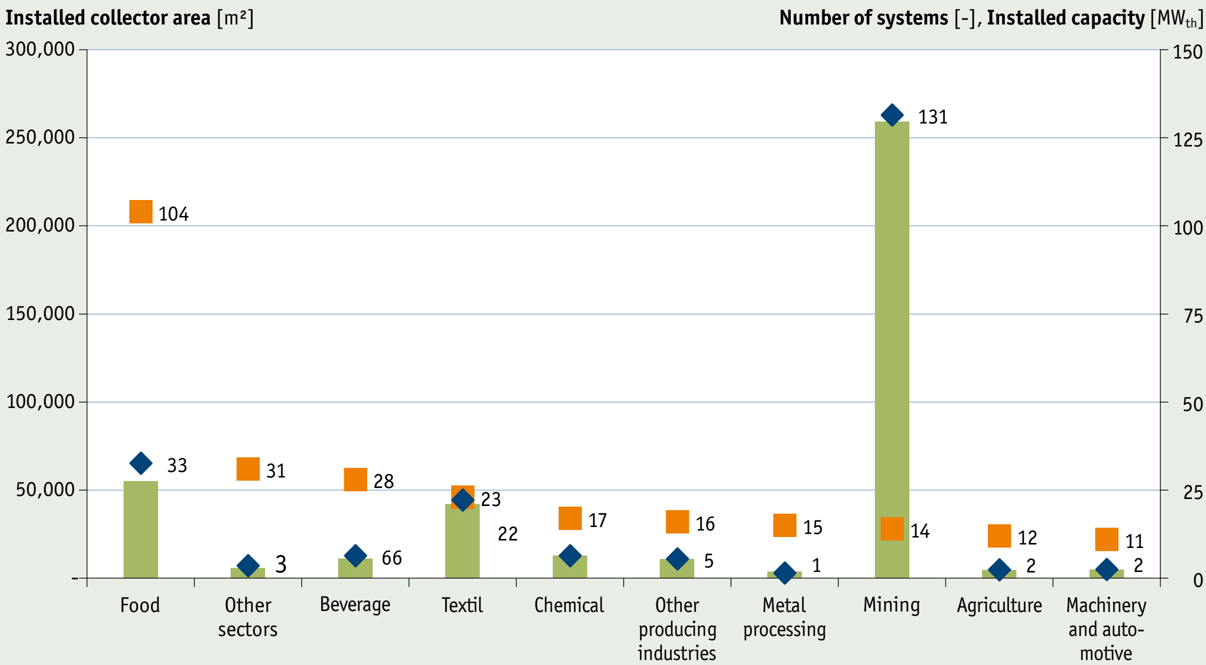


Figure 15: *Global solar process heat installations in operation by industry sector by end of March 2018. (Source: IEA SHC Task49 / IV SHIP database)*

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.

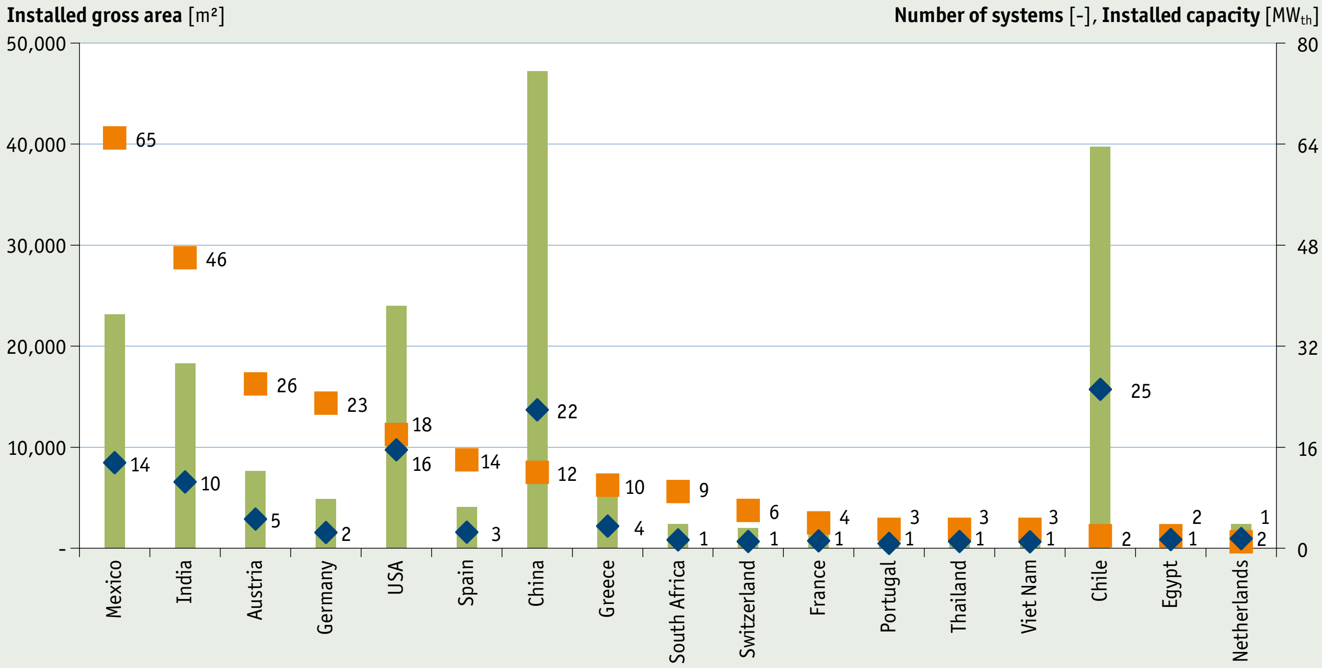


Figure 16: *Global solar process heat installations in operation by country by end of March 2018. Only countries with at least 0.7 MW_{th} (1,000 m² gross area) are shown (248 of 271 systems accounting for 98 % of installed thermal capacity) (Source: IEA SHC Task49 / IV SHIP database)*

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.

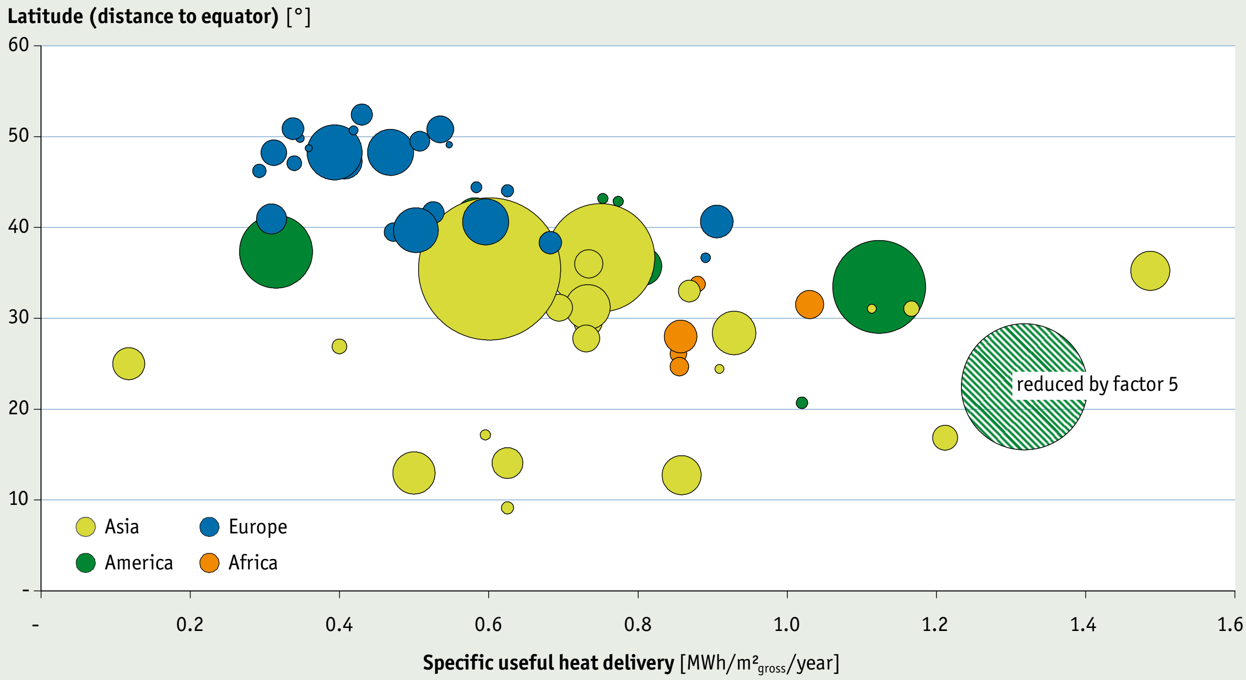


Figure 17: *Specific useful heat delivery and latitude of installed systems by end of March 2018 (Source: IEA SHC Task49 / IV SHIP database)*

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 m²) 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 m². 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 m² 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 m²) of glazed and unglazed air collectors were installed worldwide. The annual worldwide market 2016 was at a range of 57 MW_{th} (82,000 m²).

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

5 Detailed global market data 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.

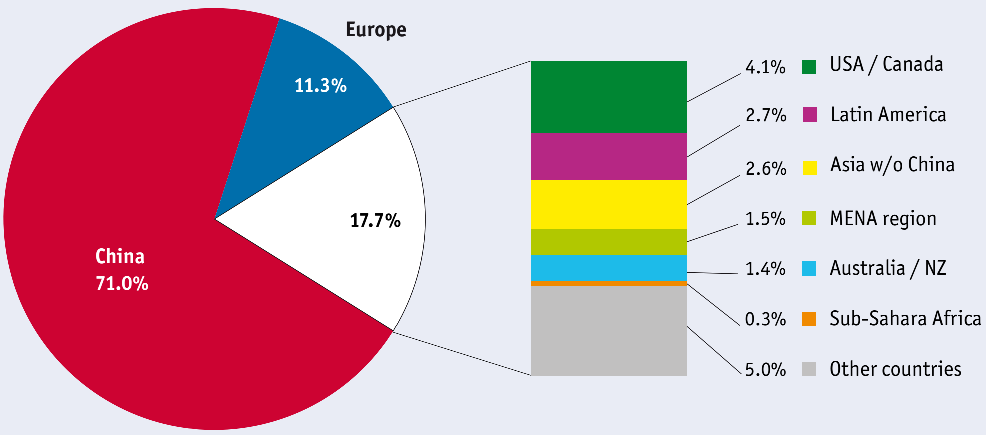
Background of the presented data: The following chapters of the report show figures of the actual collector area in operation in 2016 and not the cumulated collector area installed in a country. To determine the collector area (and respective capacity) in operation, either official country reports on 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 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 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**).

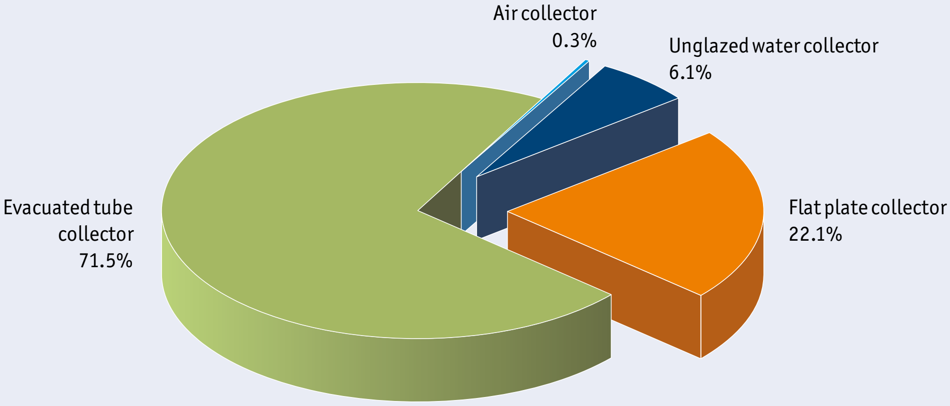


Figure 20: *Distribution of the total installed capacity in operation by collector type in 2016 – WORLD*

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 %.

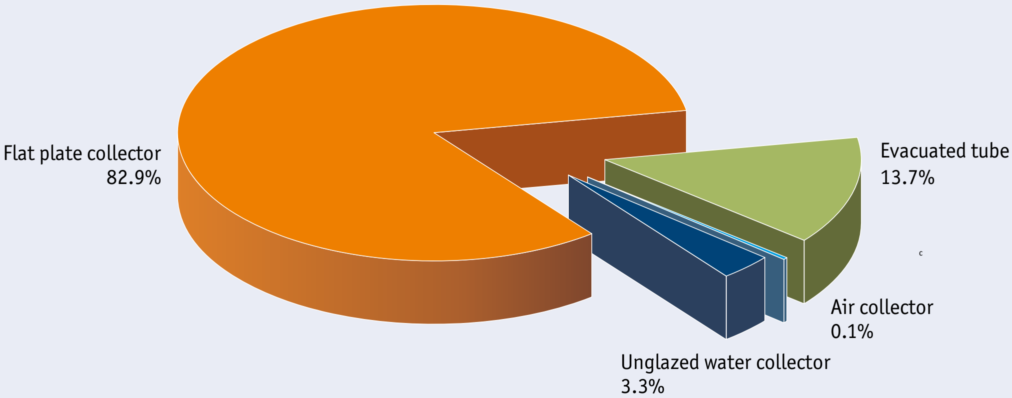


Figure 21: *Distribution of the total installed capacity in operation by collector type in 2016 – EUROPE*

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.

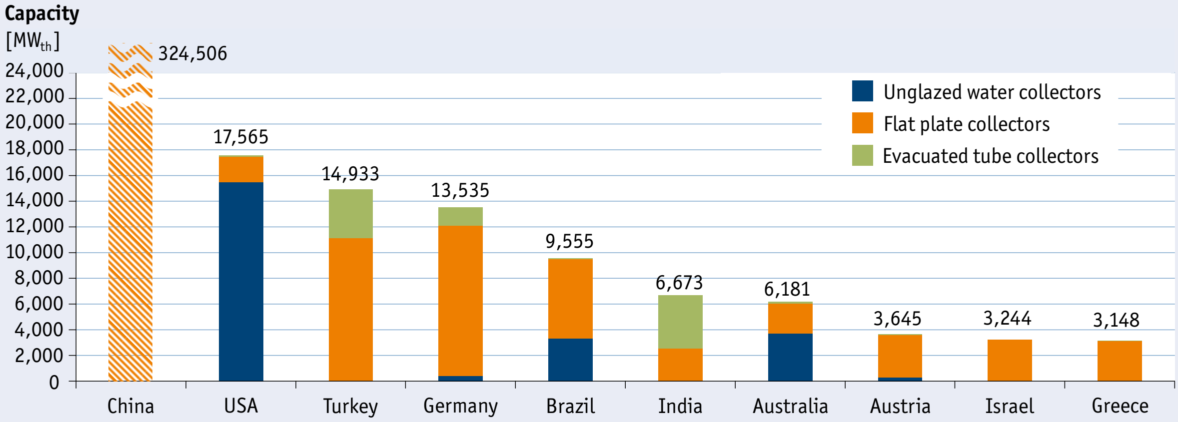


Figure 22: *Top 10 countries of cumulated water collector installations (absolute figures in MW_{th}) 2016*

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.

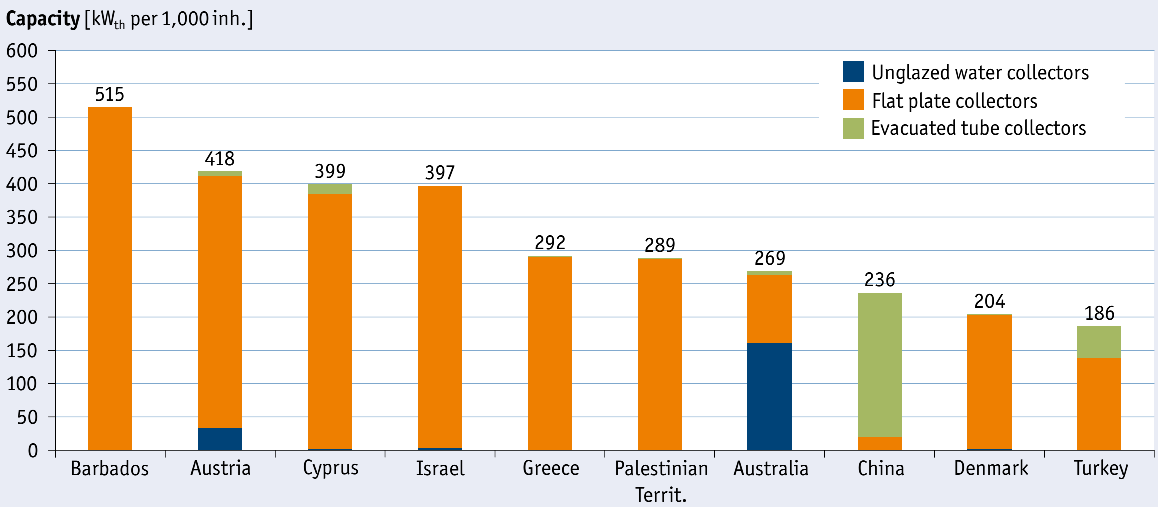


Figure 23: *Top 10 countries of cumulated water collector installations (relative figures in kW_{th} per 1,000 inhabitants) 2016*

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**).

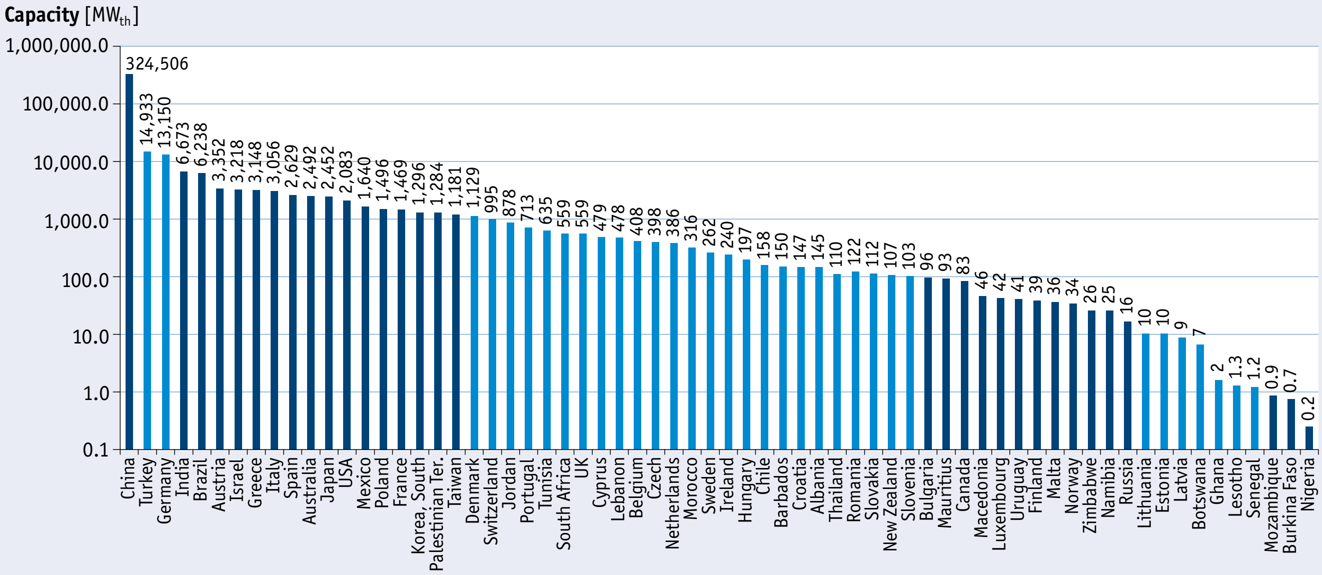


Figure 24: *Total capacity of glazed water collectors in operation by the end of 2016*

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**).

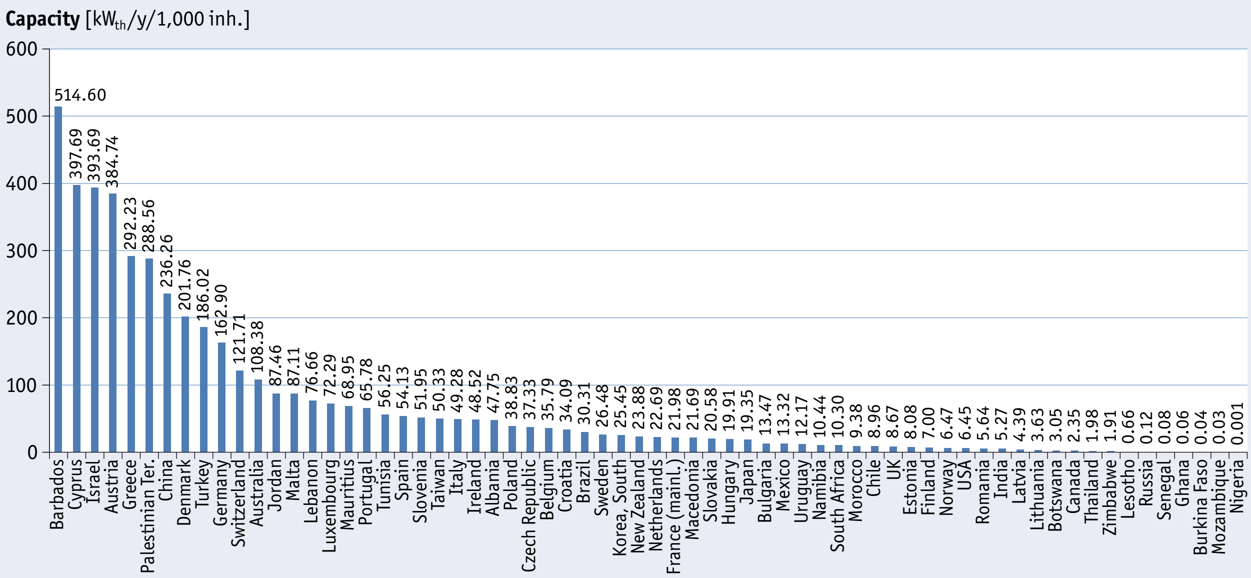


Figure 25: *Total capacity of glazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2016*

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

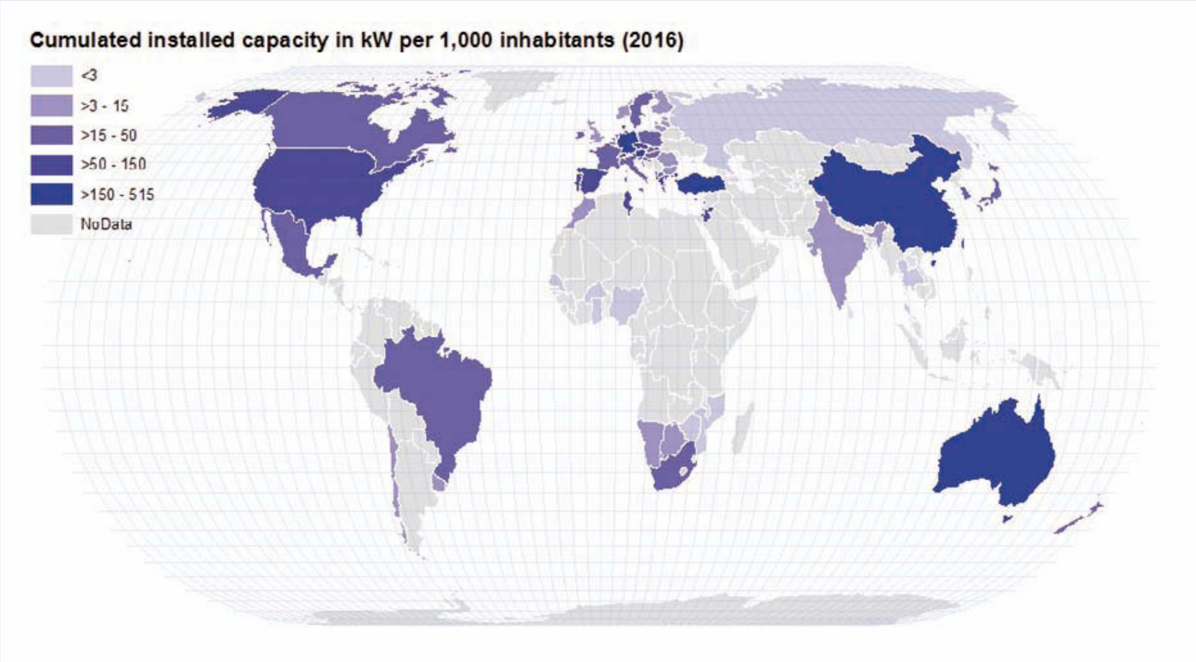


Figure 26: *Solar thermal market penetration per capita worldwide in kW_{th} per 1,000 inhabitants*

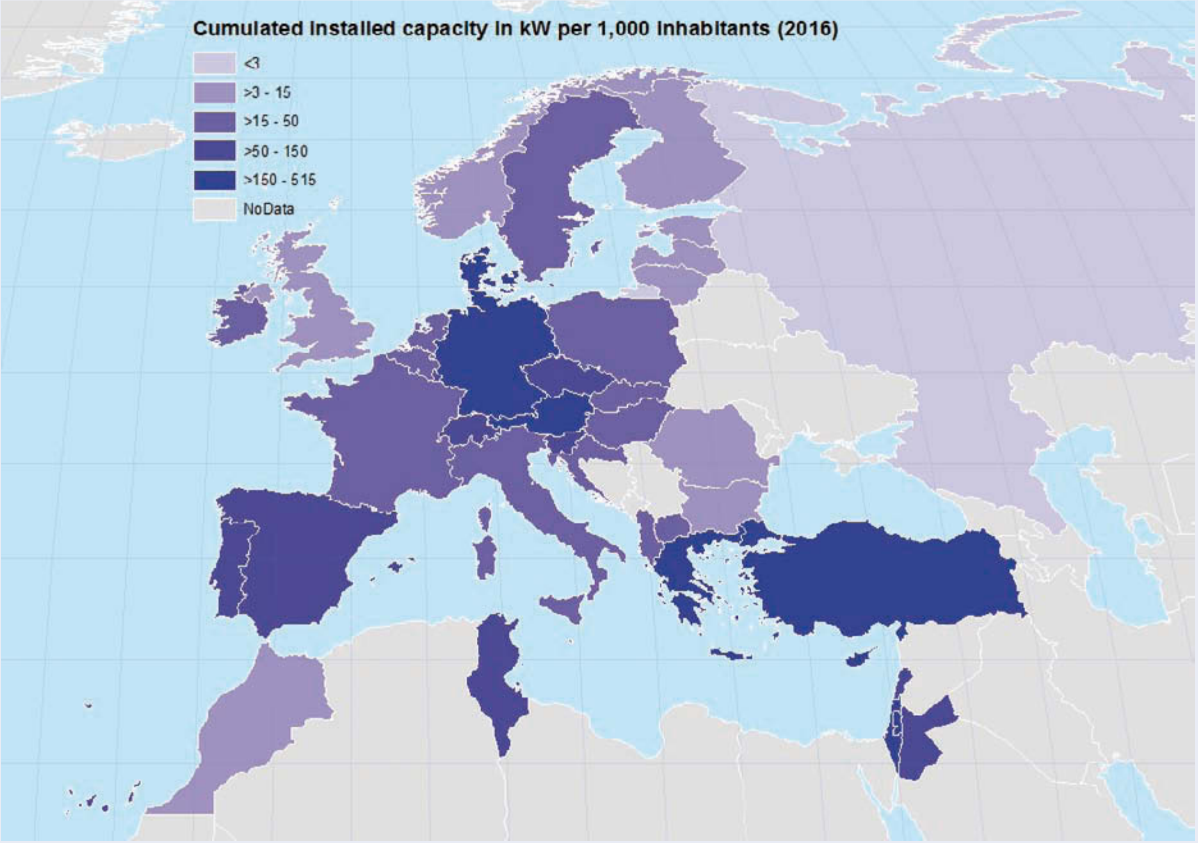


Figure 27: *Solar thermal market penetration per capita in Europe in kW_{th} per 1,000 inhabitants*

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

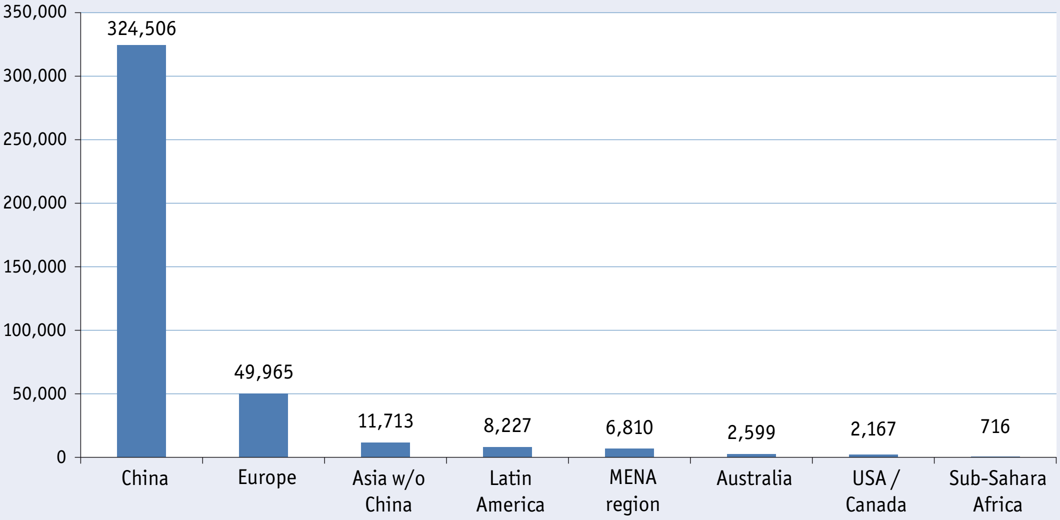
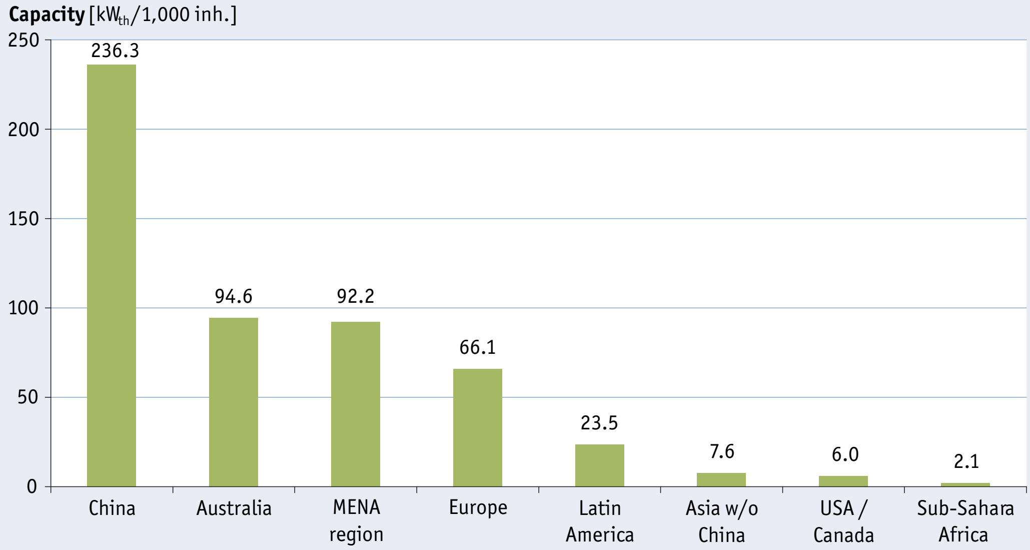


Figure 28: *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2016*

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.

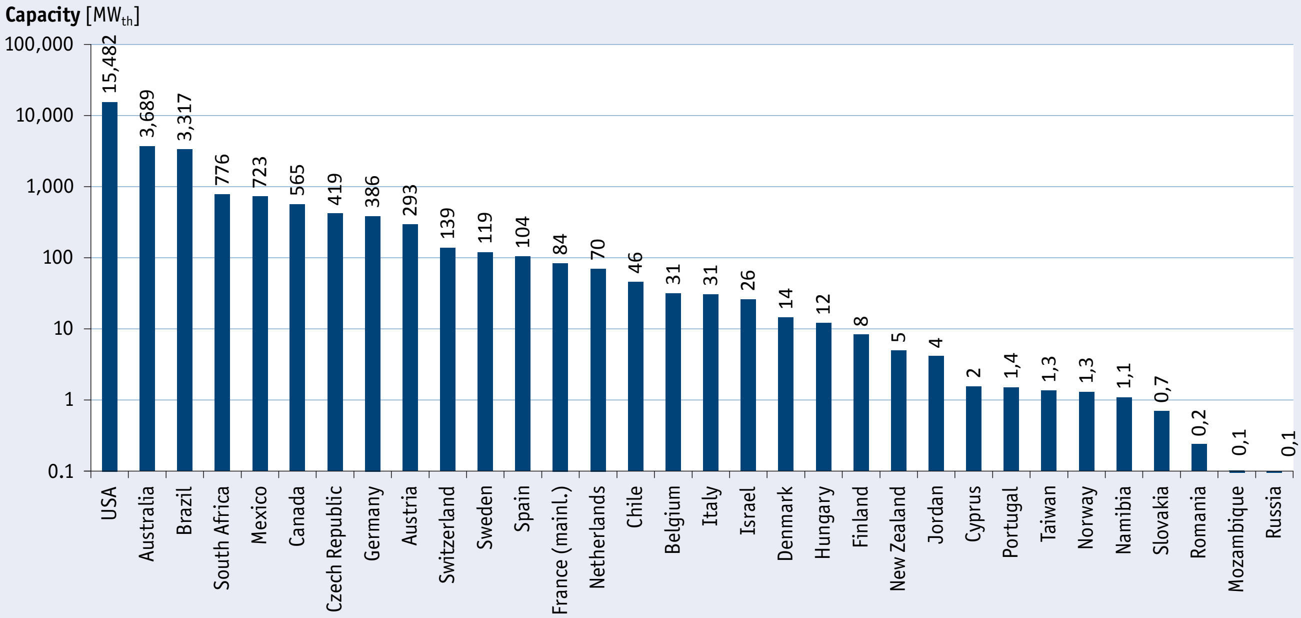


Figure 30: *Total capacity of unglazed water collectors in operation in 2016*

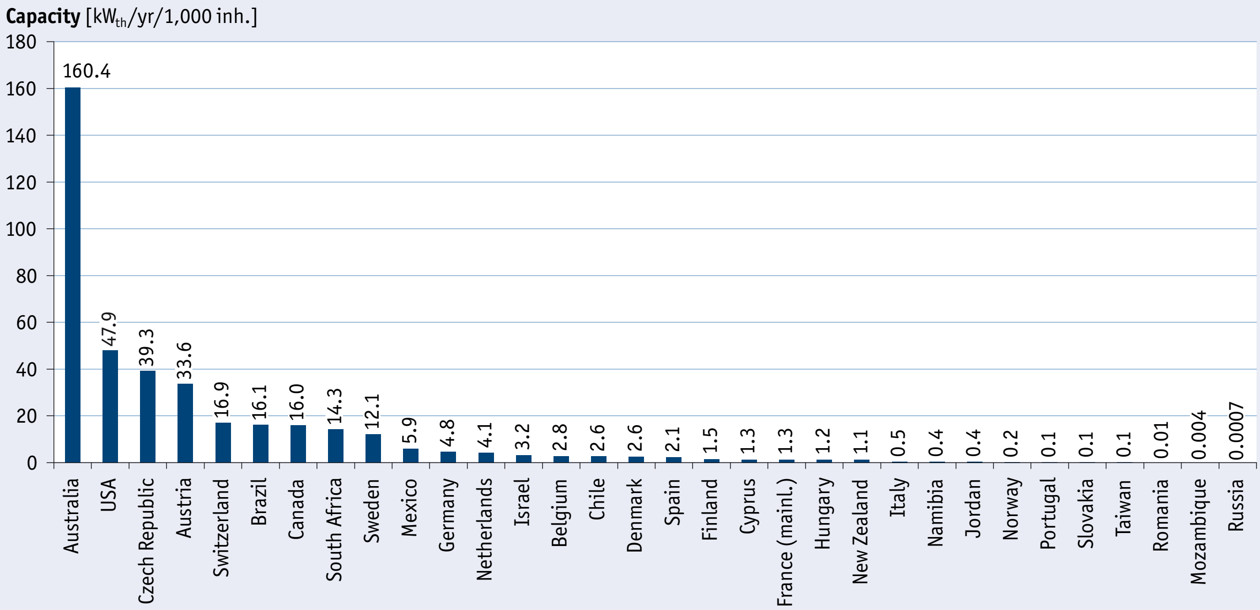


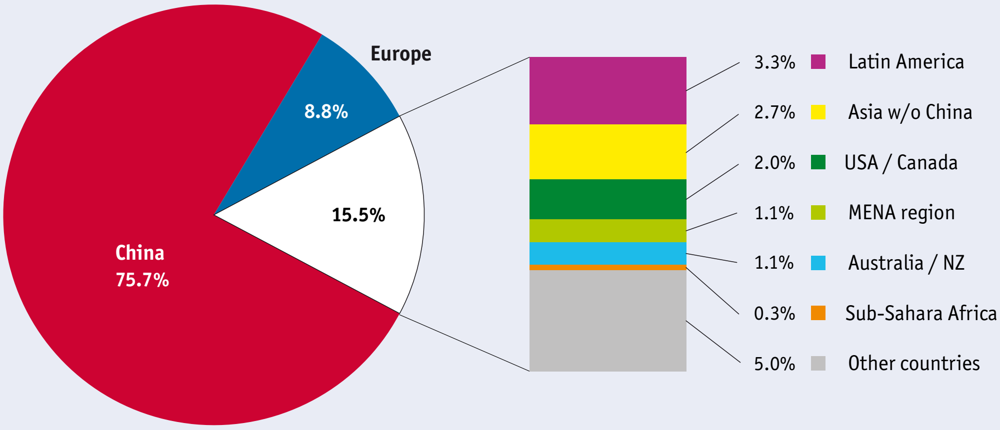
Figure 31: *Total capacity of unglazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2016*

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.

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 %.

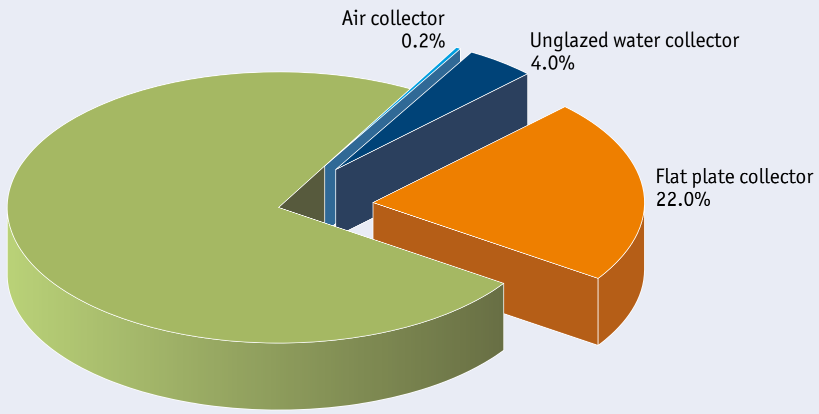
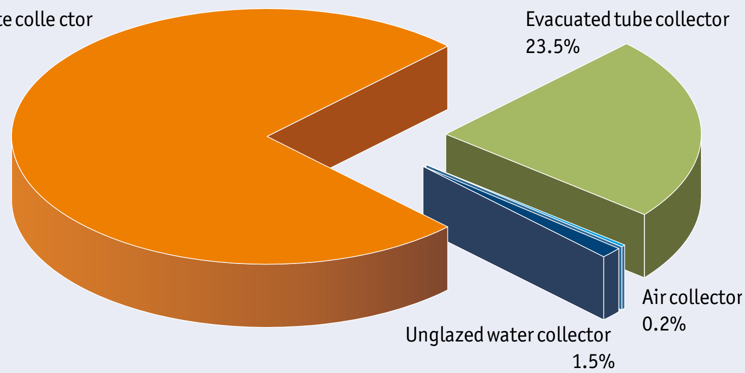


Figure 33: *Distribution of the newly installed capacity by collector type in 2016 – WORLD*

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.

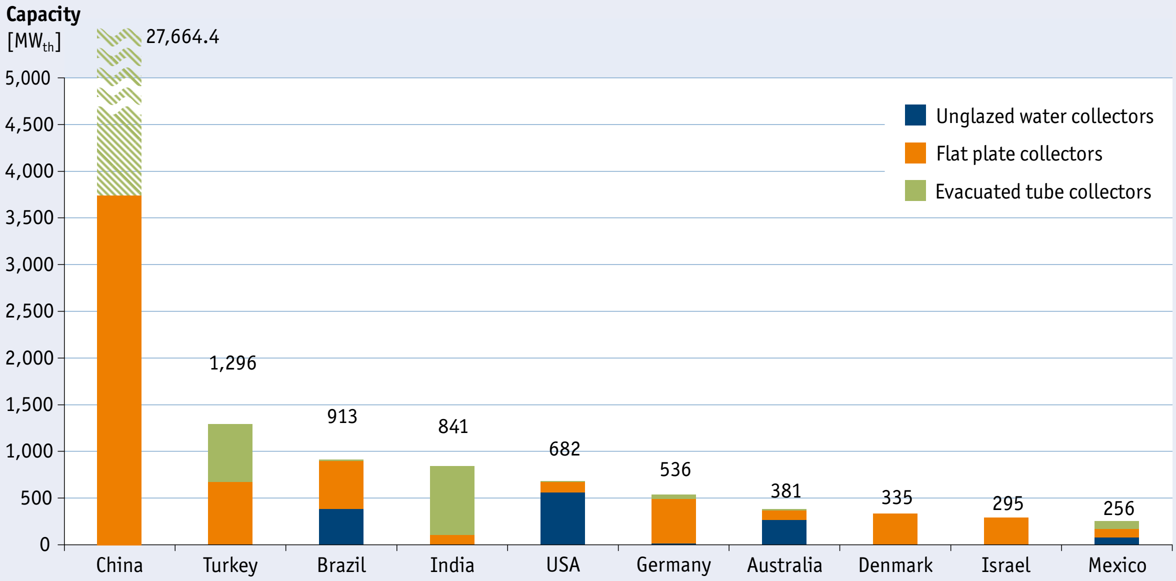


Figure 35: *Top 10 markets for glazed and unglazed water collectors in 2016 (absolute figures in MW_{th})*

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.

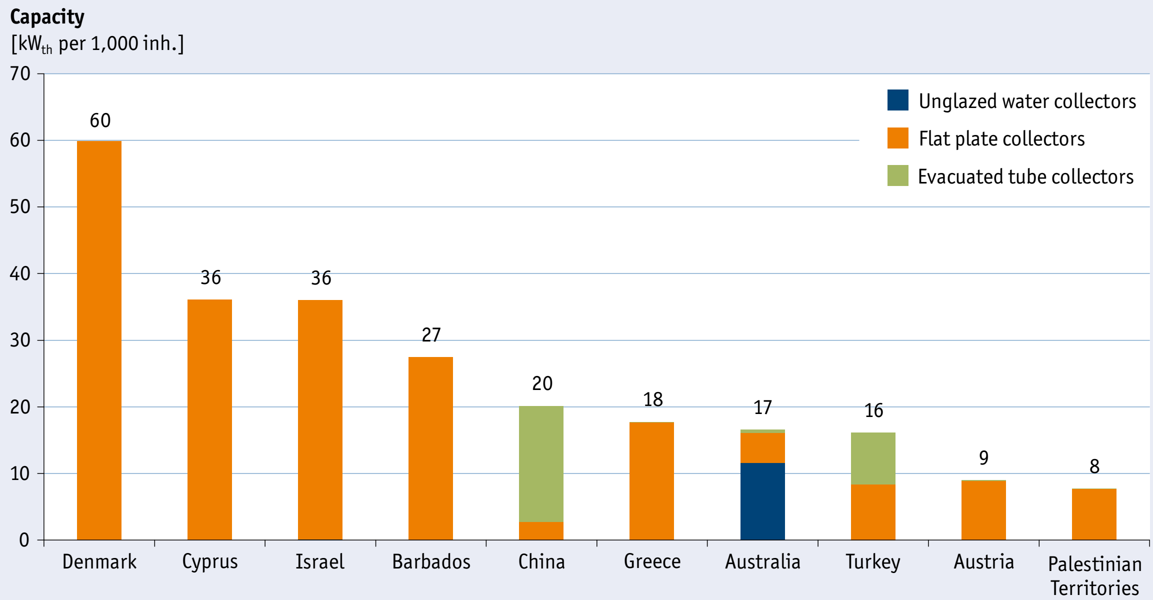


Figure 36: *Top 10 markets for glazed and unglazed water collectors in 2016 (in kW_{th} per 1,000 inhabitants)*

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**).

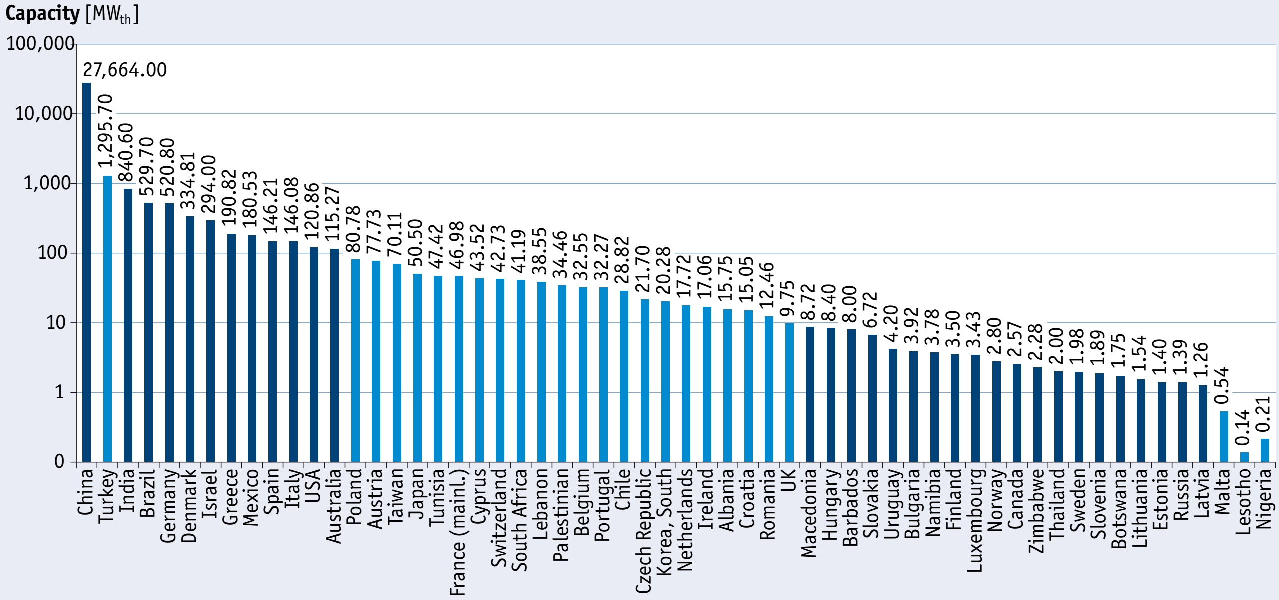


Figure 37: *Newly installed capacity of glazed water collectors in 2016*

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**).

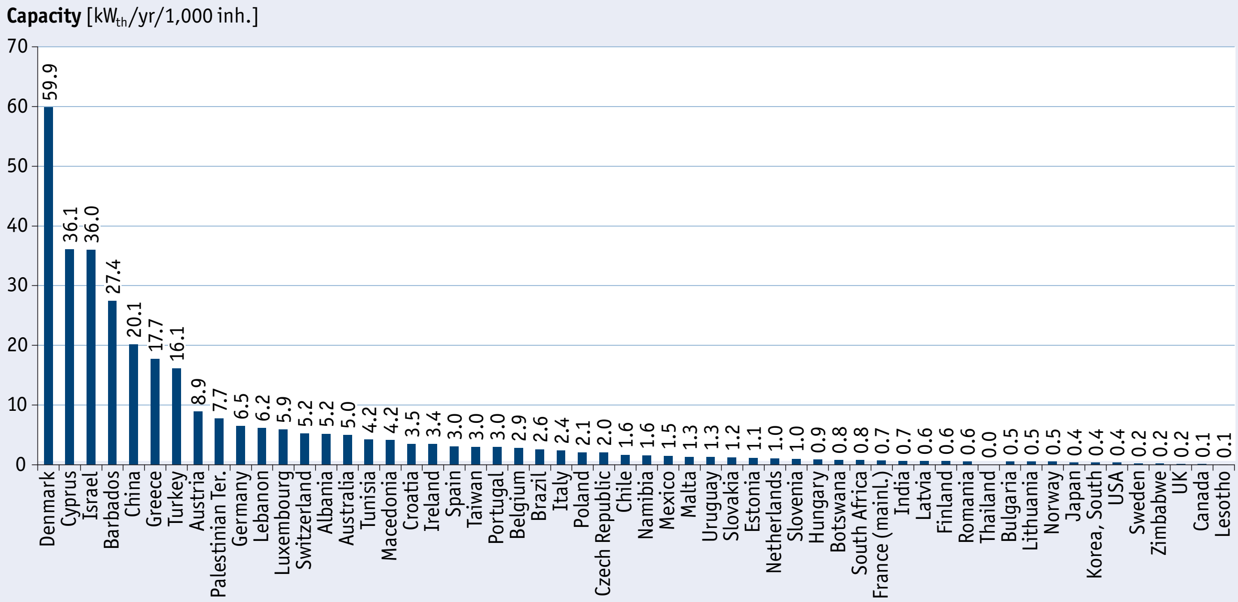


Figure 38: *Newly installed capacity of glazed water collectors in 2016 in kW$_{th}$ per 1,000 inhabitants*

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

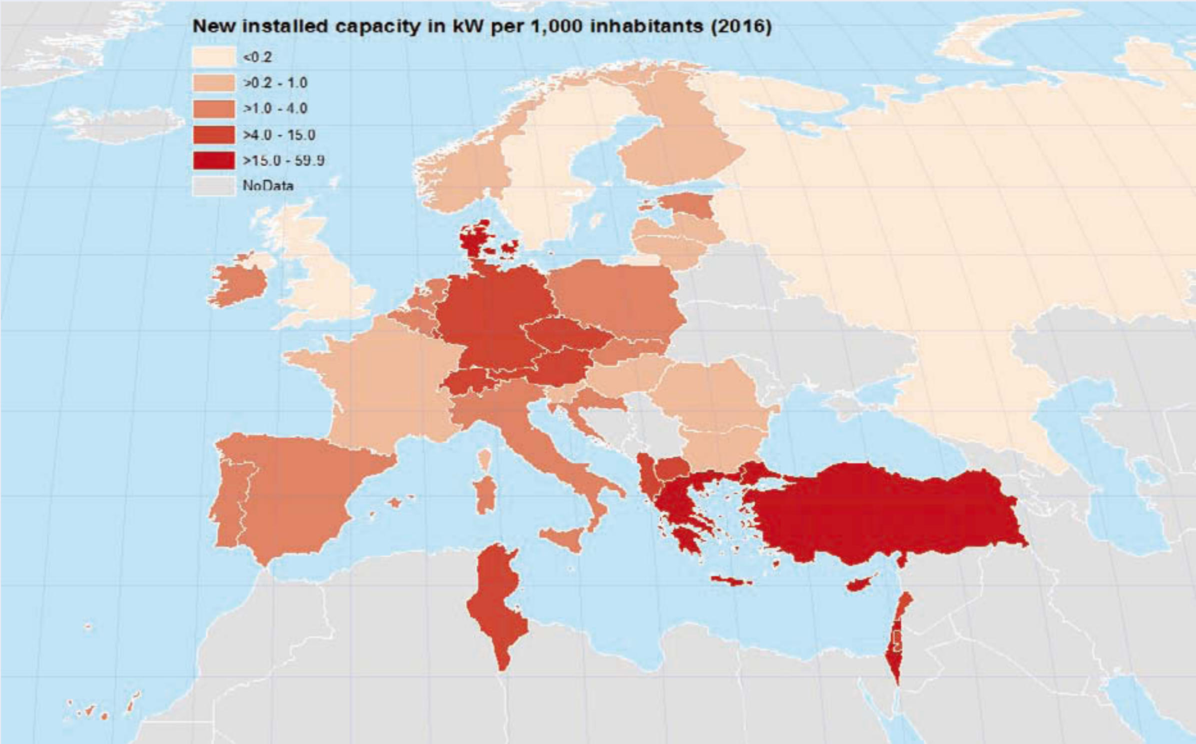


Figure 39: *Installed capacity in Europe in 2016 in kW_{th} per 1,000 inhabitants*

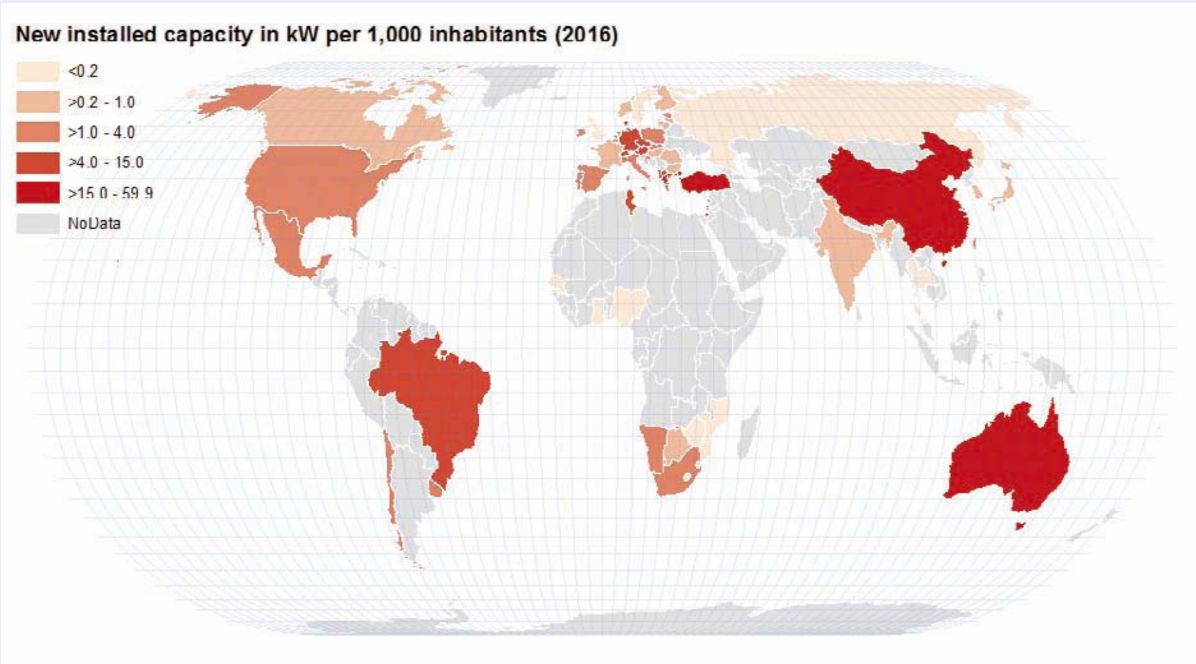


Figure 40: *Installed capacity worldwide in 2016 in kW_{th} per 1,000 inhabitants*

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**).

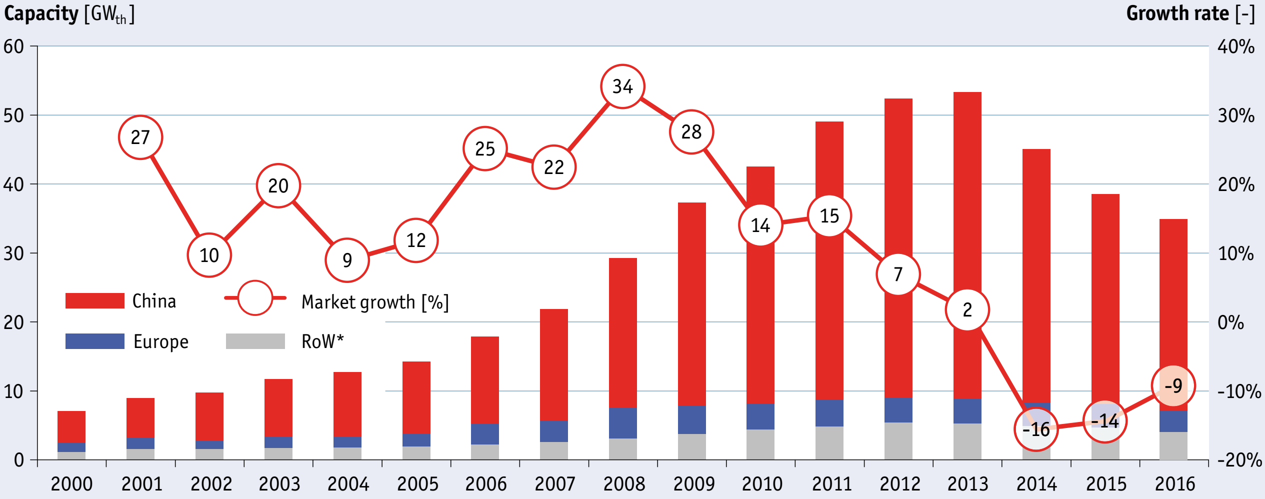


Figure 41: *Global market development of glazed water collectors from 2000 to 2016*

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.

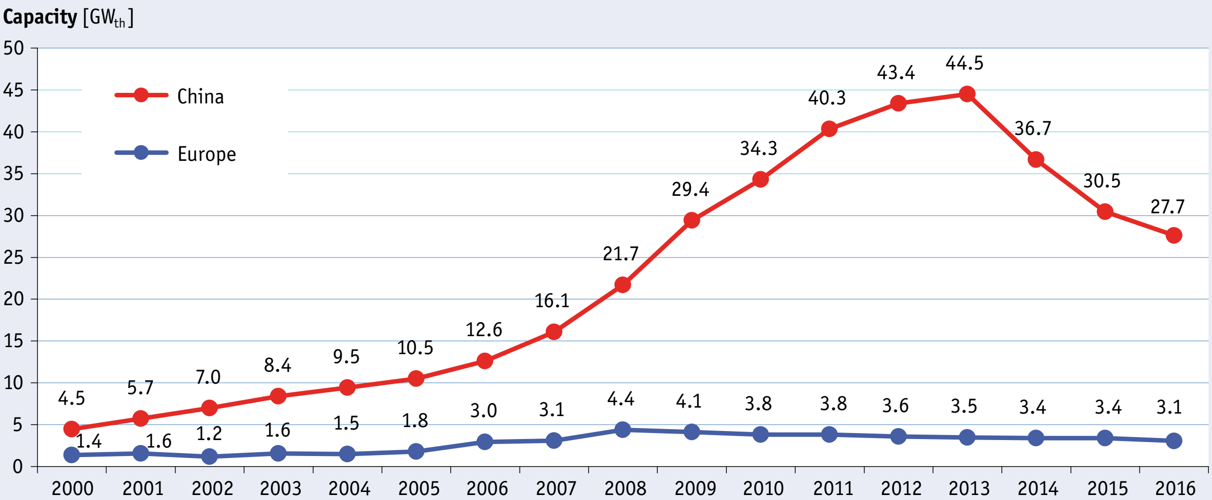
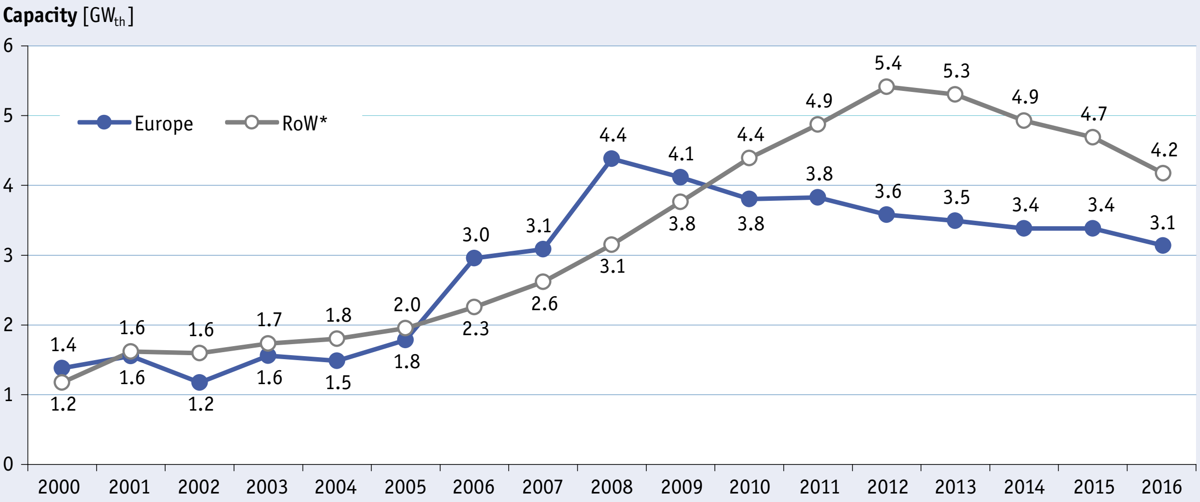


Figure 42: *Market development of glazed water collectors in China and Europe 2000 – 2016*

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.

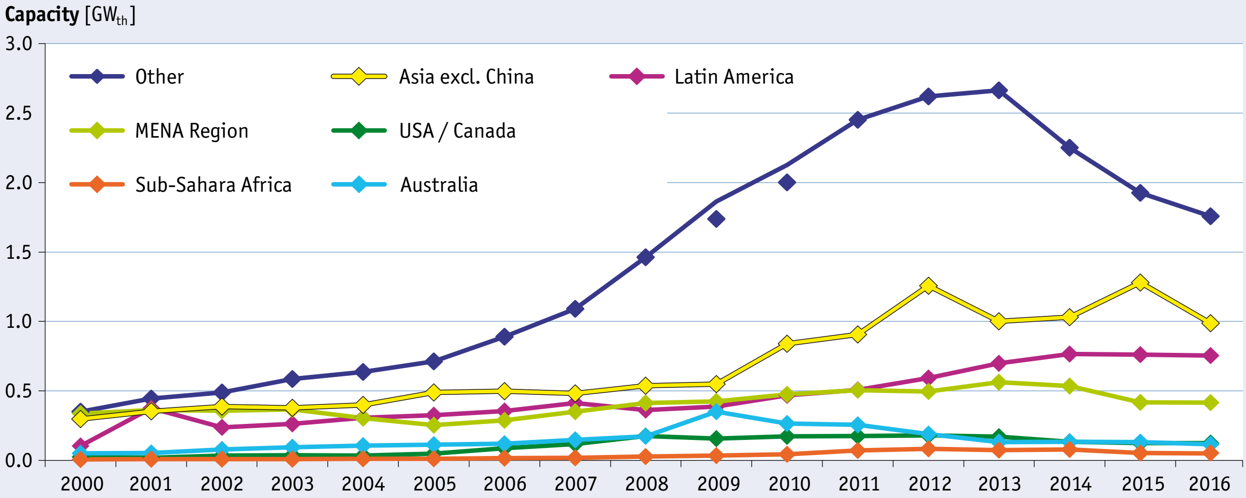


Figure 44: *Market development of glazed water collectors in Rest of World (excluding China and Europe) from 2000 to 2016*

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**).

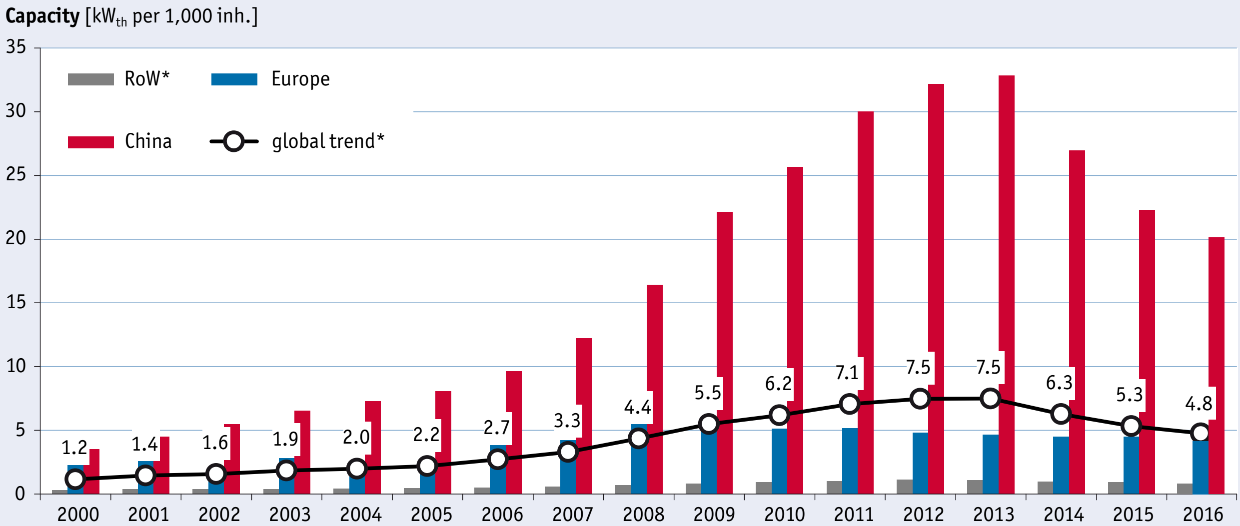


Figure 45: *Annual installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2016*

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}).

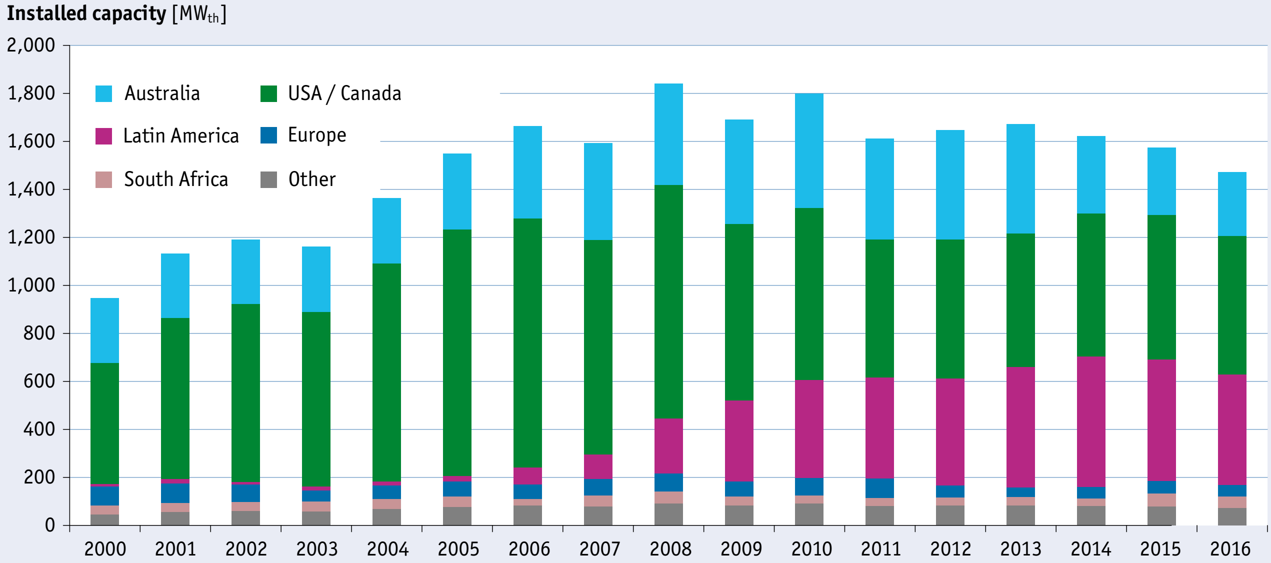


Figure 46: *Global market development of unglazed water collectors from 2000 to 2016*

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.

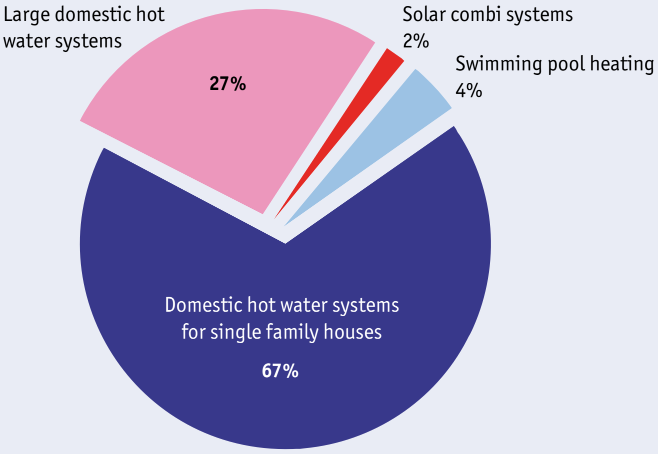


Figure 47: Share of energy savings and CO_2 reduction by type of application of glazed and unglazed water collectors in operation in 2016

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*

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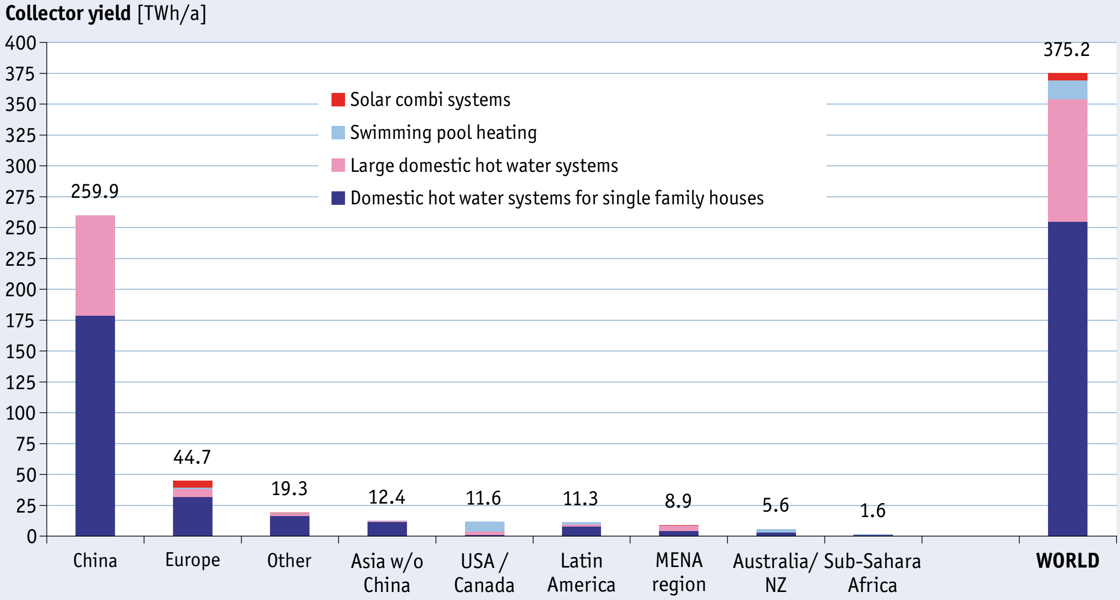
In **Chapters 6.1** to **6.3**, the annual collector yield, energy savings and CO_2 savings by economic regions and worldwide are graphed.

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**).



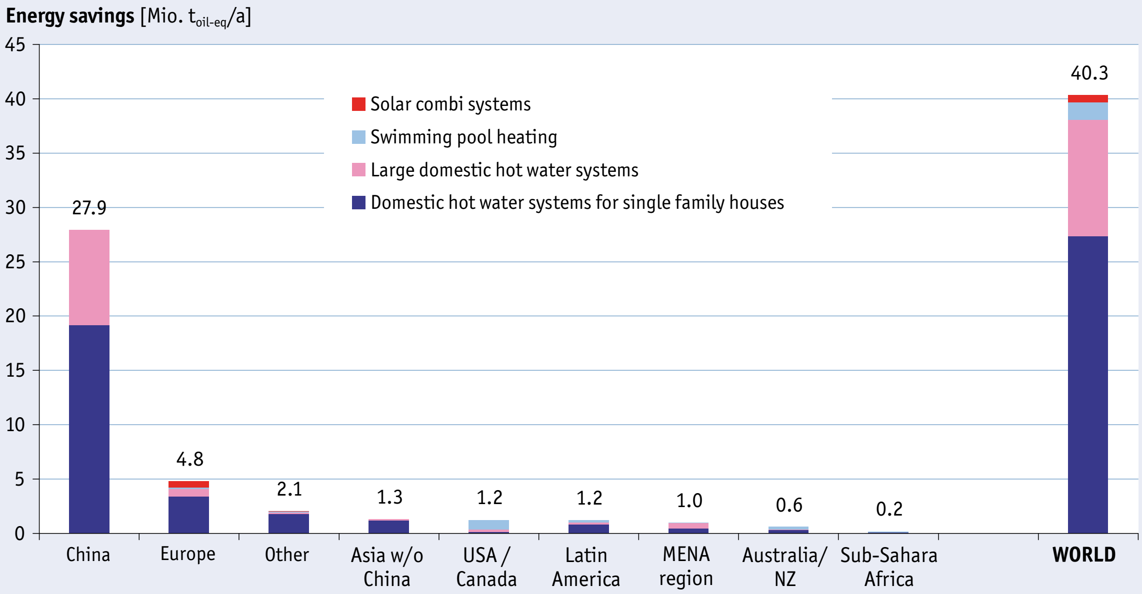
Sub-Sahara Africa:	Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Macedonia, Norway, Russia, Switzerland, 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**).



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

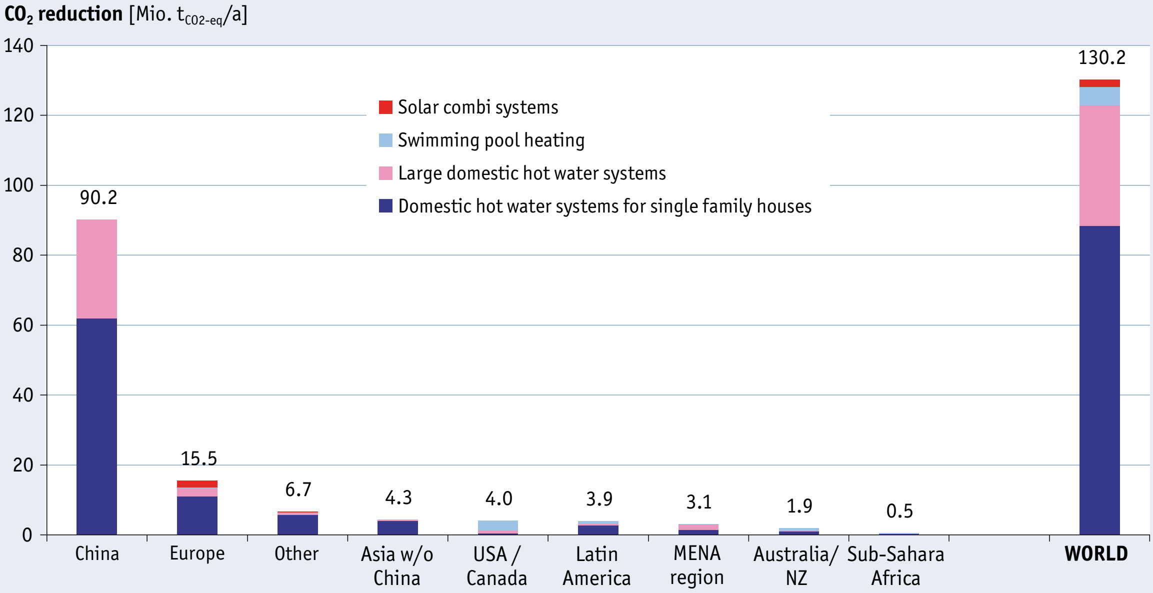
Figure 49: *Annual energy savings in oil equivalent by unglazed and glazed water collectors in operation in 2016*

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**).



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 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

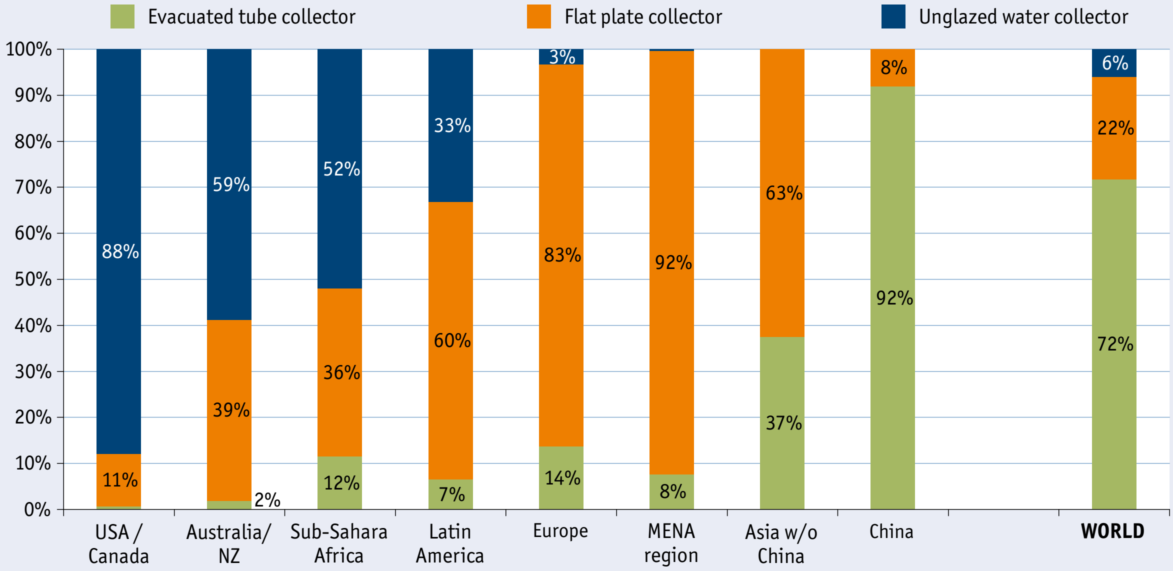
The use of solar thermal energy varies greatly from region to region and can be roughly distinguished by the type of solar thermal collector used (unglazed water collectors, evacuated tube collectors, flat plate collectors, glazed and unglazed air collectors, concentrating collectors), the type of system 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.

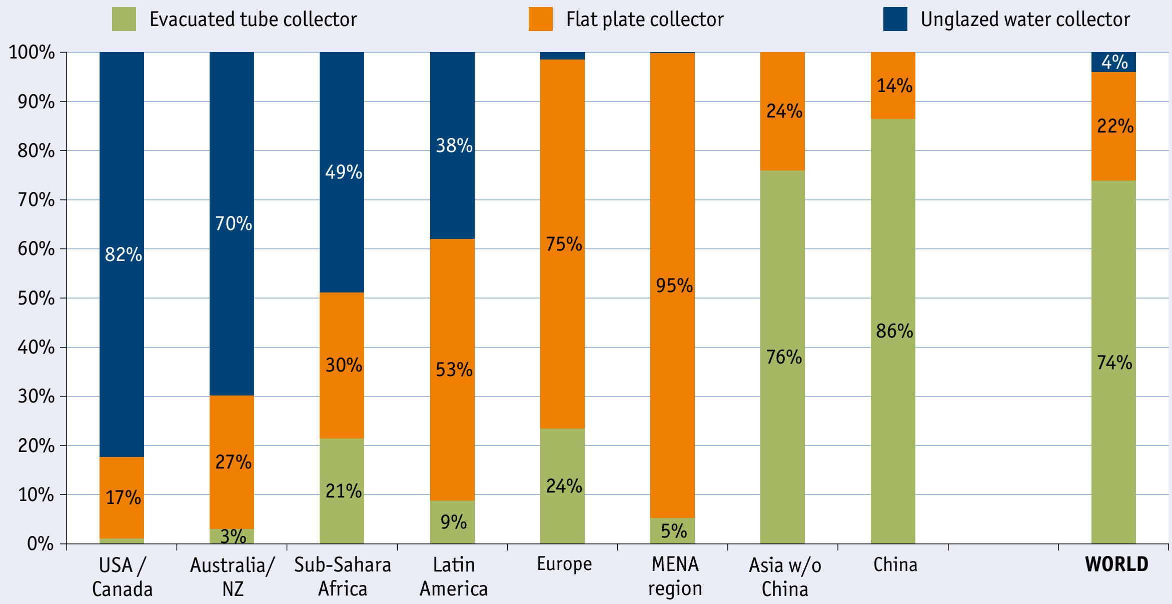


Sub-Sahara Africa:	Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Macedonia, Norway, Russia, Switzerland, 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*



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.

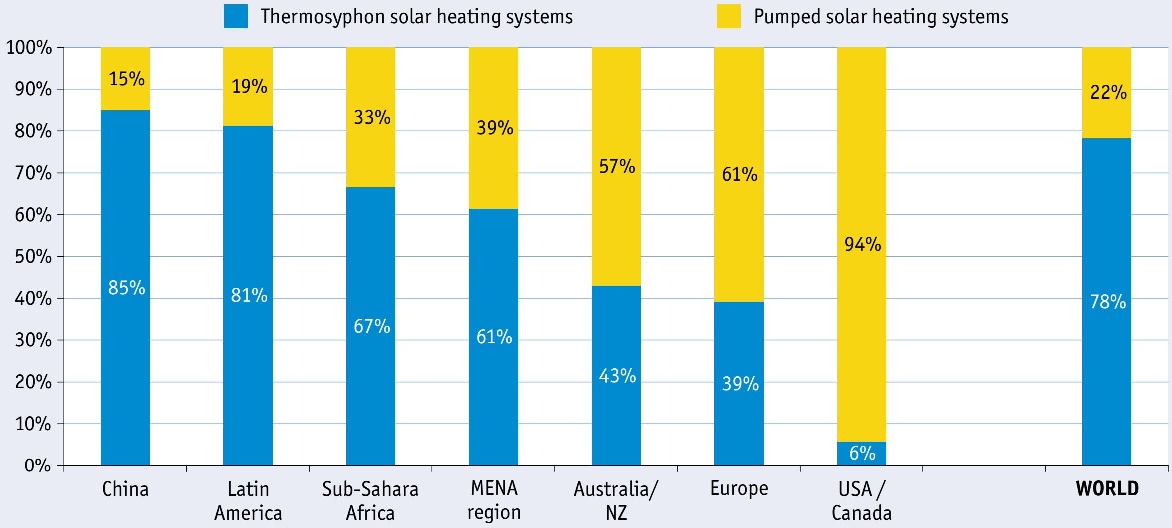
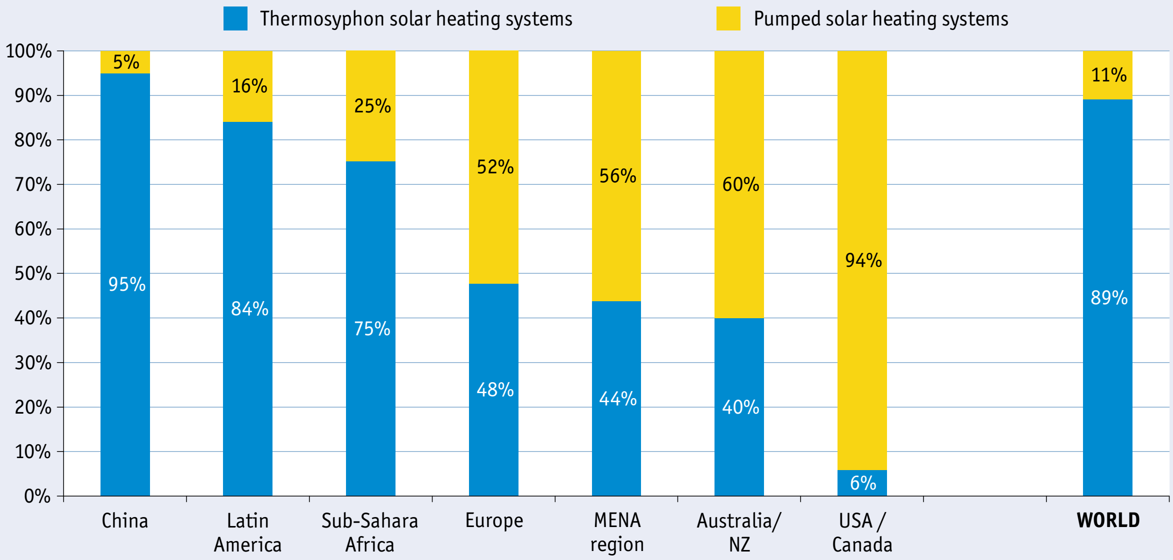


Figure 53: *Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2016*

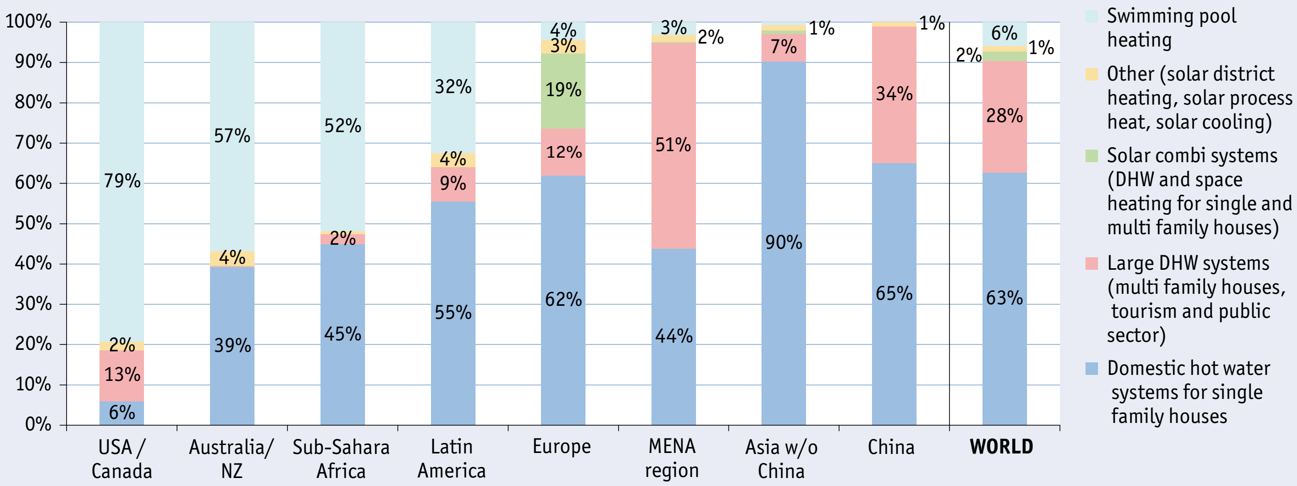


Sub-Sahara Africa:	Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China:	India, Japan, South Korea, Taiwan Thailand
Latin America:	Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Macedonia, Norway, Russia, Switzerland, 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.



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 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*

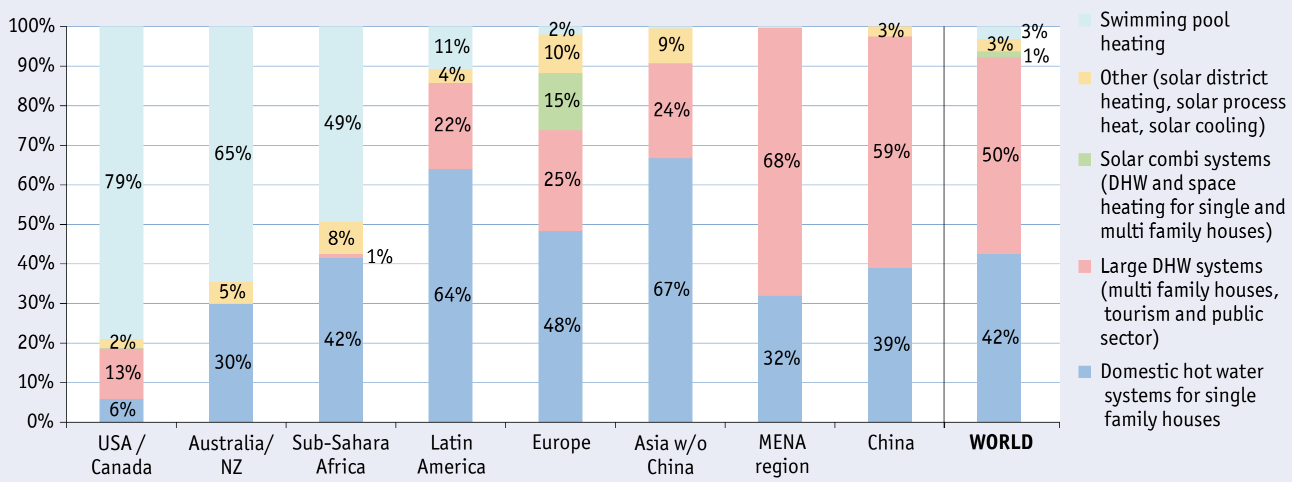
The newly installed water-based solar thermal collector area amounted to 52.1 million square meters, which corresponds to 36.4 GW of thermal peak capacity (Table 5).

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**).



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 €/m²$_{gross}$ 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).

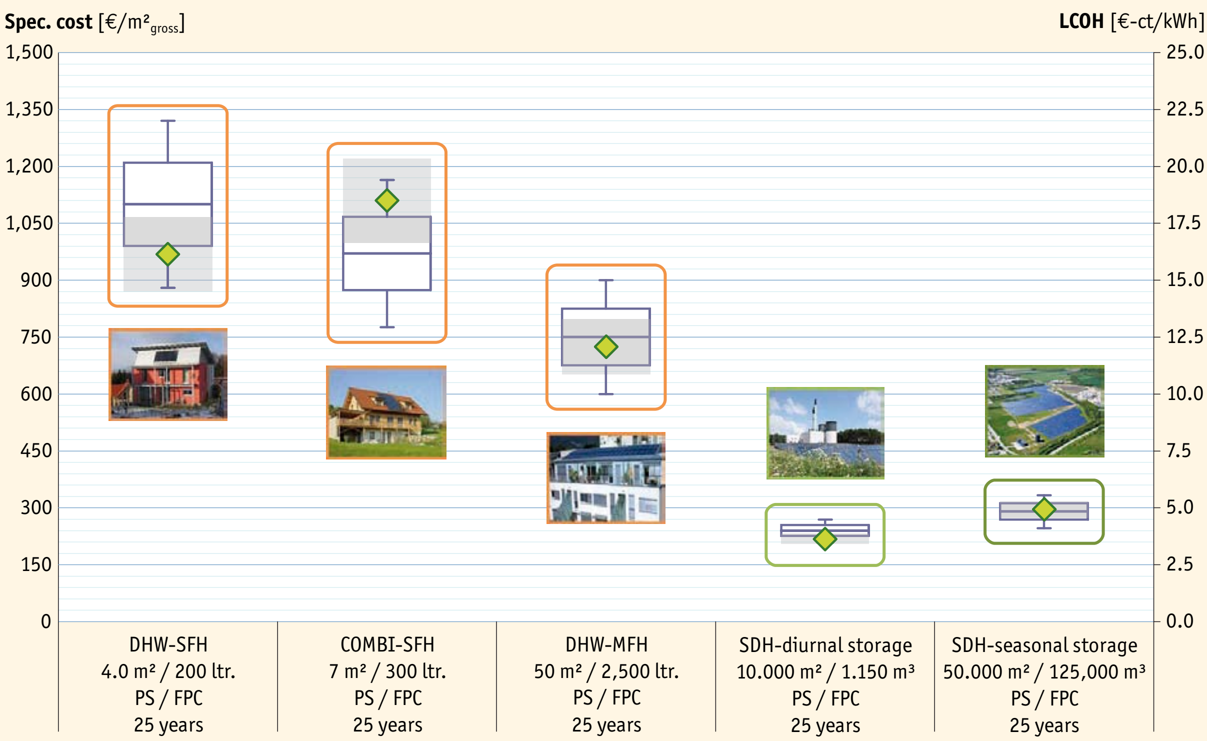


Figure 57: *Specific investment costs and levelized costs of heat for different solar thermal applications in Denmark (orange: small-scale domestic systems, green: large-scale commercial applications)*

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).

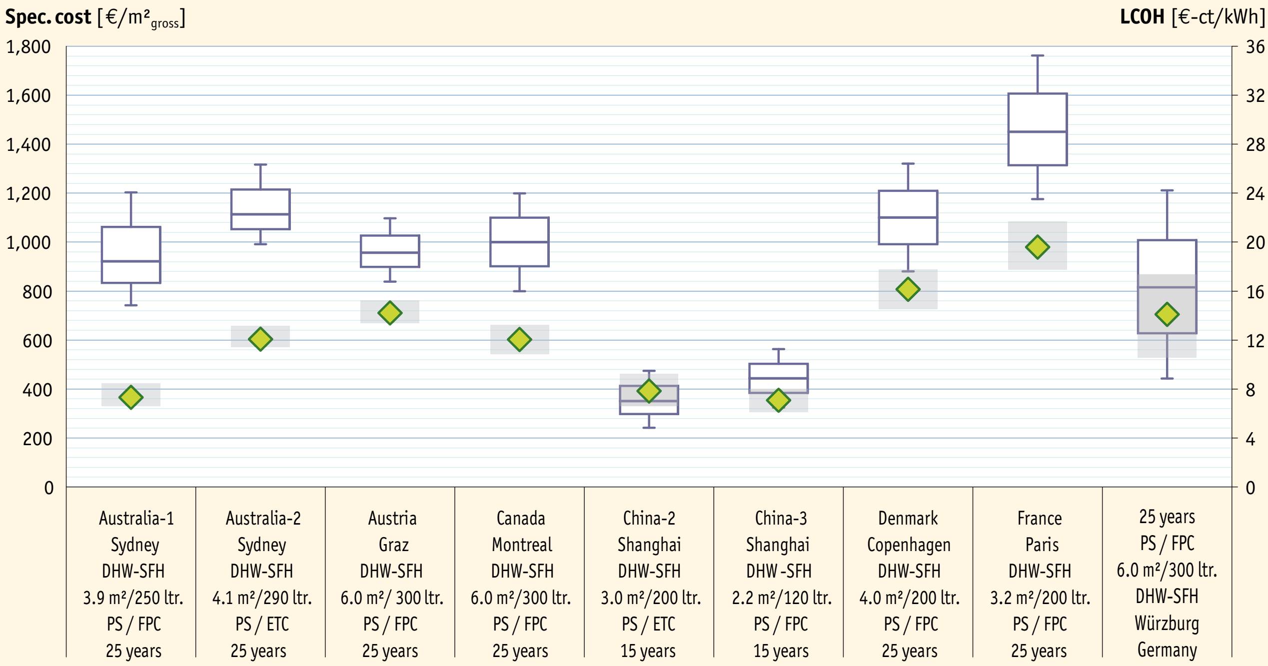


Figure 58: *Specific investment costs and levelized costs of solar thermal generated heat for small pumped domestic hot water systems*

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).

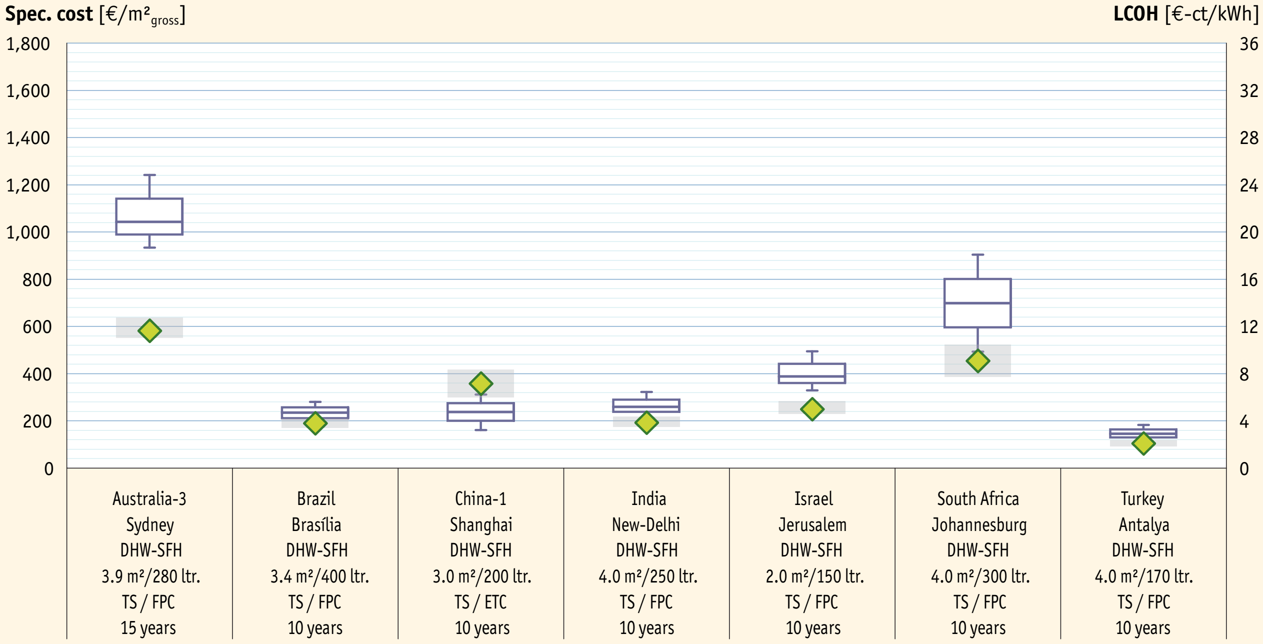


Figure 59: *Specific investment costs and levelized costs of solar thermal generated heat for small thermosiphon domestic hot water systems*

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).

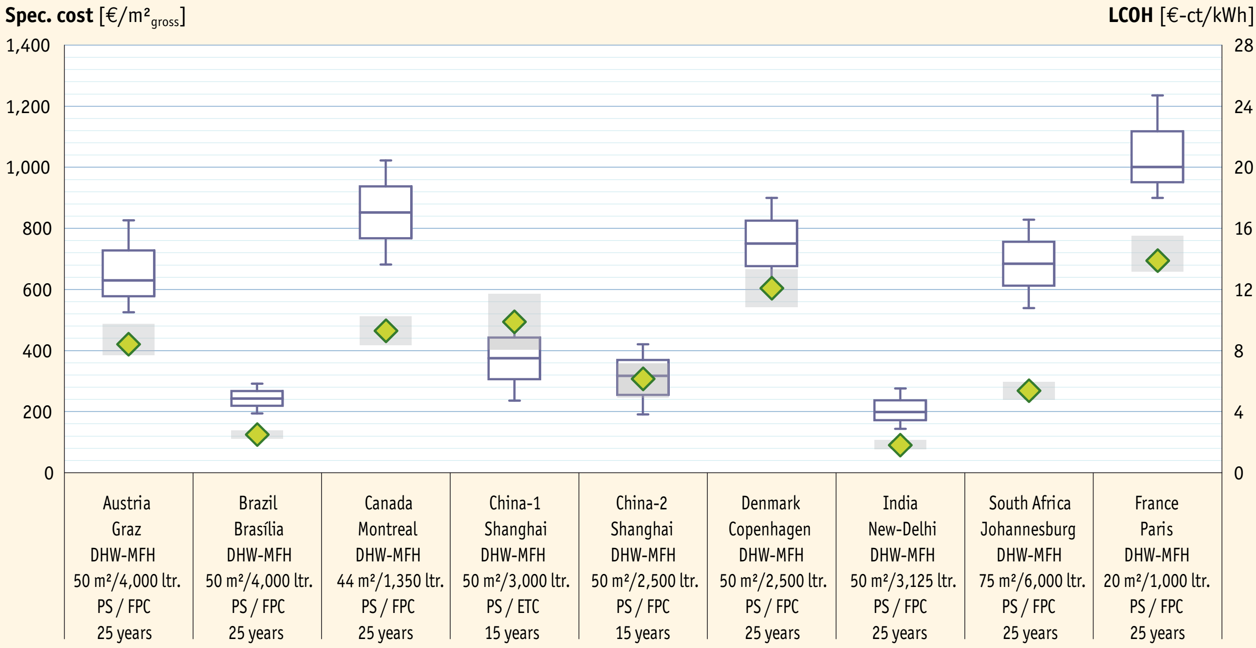


Figure 60: *Specific investment costs and levelized costs of solar thermal generated heat for large pumped domestic hot water systems*

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).

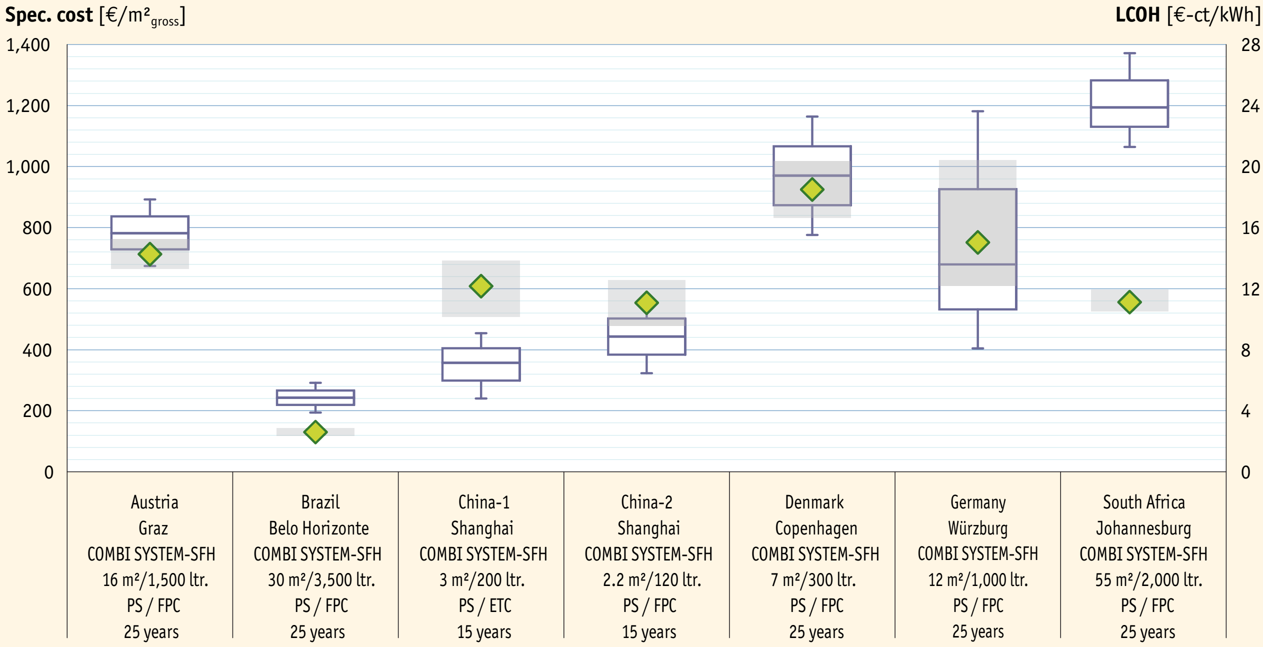


Figure 61: *Specific investment costs and levelized costs of solar thermal generated heat for small combined hot water and space heating systems*

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).

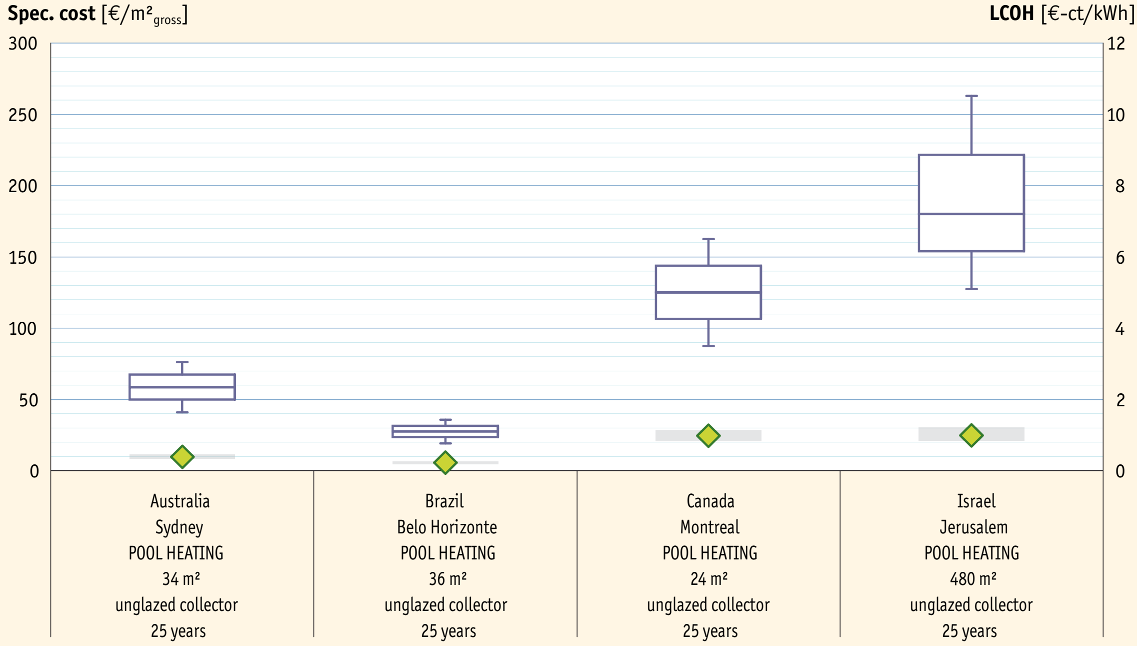


Figure 62: *Specific investment costs and levelized costs of solar thermal generated heat for swimming pool heating systems*

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

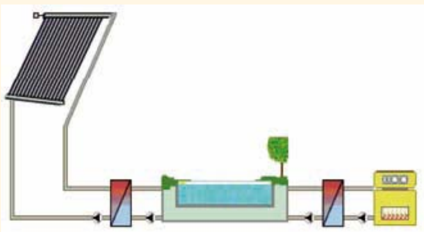
The information in **Table 8** refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2016.

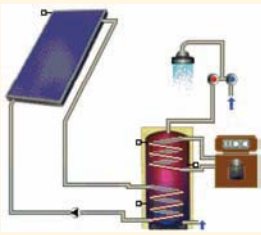
Country*	Reference climate	Horizontal irradiation [kWh/m²·a]	Total collector area (swimming pool) [m²]	Collector area per system [m²]	Total number of systems	Specific solar yield (swimming pool) [kWh/m²·a]
Australia	Sydney	1,674.0	5,103,740	35	145,821	466
Austria	Graz	1,126.0	590,199	200	2,951	283
Belgium	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*

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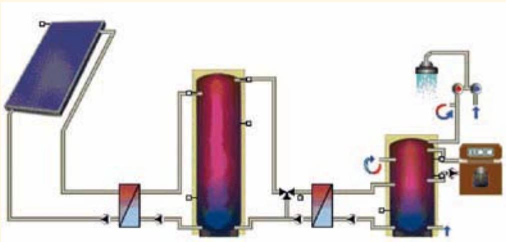
9.1.3 Reference systems for domestic hot water preparation in multifamily houses

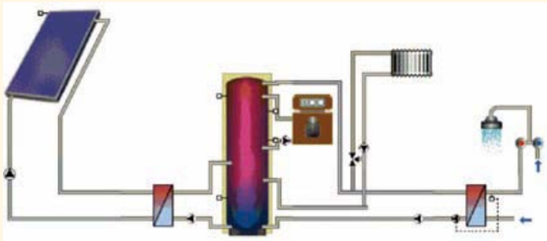
The information in **Table 10** refers to the total capacity of water collectors in operation used for domestic hot water heating in multi-family houses at the end of 2016 as reported by each country.

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

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	
[-]	[-]	kWh/(m²·a)	[-]	m² / liter	kWh/(m²·a)	MIN	MAX	MIN	MAX
						€/(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**	
[-]	[-]	kWh/(m²·a)	[-]	m² / liter	kWh/(m²·a)	MIN	MAX	MIN	MAX
						€/(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]*

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

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

Ireland	**Mary Holland** Sustainable Energy Authority of Ireland	Energy policy statistical support unit of Sustainable Energy Authority of Ireland Grant scheme data; BER database: Source: Energy policy statistical support unit of Sustainable Energy Authority of Ireland; provided by Mary Holland
Israel	**Eli Shilton** ELSOL **Bärbel Epp** Solrico – Solar market research, http://www.solrico.com/	ELSOL (Eli Shilton), data provided by Bärbel Epp Cumulated collector area calculated by AEE INTEC based on new installation and replacement figures from Eli Shilton (ELSOL)
Italy	**ESTIF – European Solar Thermal Industry Federation** **AEE INTEC**	Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017 Cumulated area: ESTIF 2017 / share FPC-ETC: AEE INTEC / unglazed water collectors: AEE INTEC
Japan		EurObservEr 2017 Solar System Development Association (SSDA) Share FPC / ETC AEE INTEC
Jordan	**AEE INTEC**	AEE INTEC New installations: no new collectors for 2016 Cumulated installations by end of 2014
Korea, South	**Eunhee Jeong** 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 Glazed water collectors: ESTIF, 2017 (estimation)
Lebanon	**Tony Gebrayel** Lebanese Center for Energy Conservation (LCEC)	Lebanese Center for Energy Conservation (LCEC) Cumulated calculated by AEE INTEC
Lesotho	**Bethel Business and Community Development Center (BBCDC)**	SOLTRAIN Study, Data provided by Puleng Mosothoane
Lithuania	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017 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 Glazed water collectors: ESTIF, 2017 (estimation)
Macedonia	**Prof. Dr. Ilja Nasov** National University St. Kiril and Metodij, Faculty for Natural Science, Institute of Physics, Solar Energy Department	2016 data estimation of Ilya Nasov and other solar experts New installations: estimation of Ilya Nasov and other solar experts; Cumulated installations: calculated by AEE INTEC based on new installation figures
Malta	**Ing. Therese Galea** Sustainable Energy and Water Conservation Unit (SEWCU) Ministry for Energy and Health	Sustainable Energy and Water Conservation Unit (SEWCU) based on data provided by the Regulator for Energy and Water Services (REWS)
Mauritius	**Mrs Devika Balgobin** Statistician Environment Statistics Unit, Ministry of Environment and Sustainable Development	Statistics Mauritius No new collector area 2016; cumulated collector area by end of 2015
Mexico	**David Garcia** FAMERAC **Bärbel Epp** Solrico – Solar market research, http://www.solrico.com/	Glazed and unglazed water collectors: FAMERAC – Renewable Energy Industry Associationdata provided by Bärbel Epp Air collectors: SAHWIA – Solar Air Heating World Industry Association Cumulated installations: calculated by AEE INTEC

Morocco	**Ashraf Kraidy** RECREEE – Regional Center for Renewable Energy and Energy Efficiency	No new collector area 2016; cumulated collector area by end of 2014
Mozambique	**Fabião Cumbe** ENPCT, E.P. **AEE INTEC**	Estimation provided by Fabião Cumbe Cumulated installations calculated by AEE INTEC based on new installation figures for 2016
Namibia	**Zivayi Chiguvare** Namibian Energy Institute, Namibia University of Science and Technology	2014 – 2016 survey provided by Zivayi Chiguvare
Netherlands	**André Meurink, Reinoud Segers** Statistics Netherlands (CBS)	Statistics Netherlands (CBS) Newly installed areas: Statistics Netherlands based on survey of sales. Market Shares: Expert estimates Netherlands Enterprise Agency and Holland Solar.
New Zealand		No data available since 2010 Cumulated area in 2009
Nigeria	**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 (0% growth rate 2015 / 2016 assumed)
Palestinian Territories	**Mohammed Mobayyed** EEU Director, Palestinian Energy Authority	Palestinian Energy Authority 0% growth assumed in 2016, Cumulated area calculated by AEE INTEC (replacements not considered)
Poland	**Janusz Staroscik – President** Association of Heating Appliances manufacturers and Importers in Poland	Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017
Portugal	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017 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 Glazed water collectors: ESTIF, 2017 (estimation)
Russia	**Dr. Semen Frid, Dr. Sophia Kiseleva** Moscow State University **Prof. Vitaly Butuzov** Yuzhgeoteplo corporation, Krasnodar	Joint Institute for High Temperatures of Russian Academy of Sciences (JIHT RAS) Dr. Semen Frid, Sophia Kiseleva – Moscow State University, Vitaly Butuzov – Energytechnologies Ltd. (Krasnodar); the source of information – JIHT RAS
Senegal	**Université Cheikh Anta DIOP**	Rapport de Merché du Solaire Thermique: Production d'Eau Chaude et Séchage de Produits Agricoles: provided by T. Ababacar 0% growth assumed 2016
Slovakia	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe – Trends and Market Statistics 2016, ESTIF 2017 Glazed water collectors: ESTIF, 2017 (estimation)
Slovenia	**University of Ljubljana, Faculty of Mechanical Engineering** **ESTIF – European Solar Thermal Industry Federation**	University of Ljubljana, Faculty of Mechanical Engineering;Eco Fund, Slovenian Environmental Public Fund; provided by Ciril Arkar
South Africa	**Karin Kritzinger** Centre of Renewable and Sustainable Energy Studies University of Stellenbosch	Department of Energy, SESSA, Stellenbosch University, Solco, GIZ, Sanedi, City of Cape Town Metro; provided by Karin Kritzinger

Spain	**Pascual Polo** ASIT – Asociación Solar de la Industria Térmica	ASIT (Solar Energy Industry Association of Spain) Out of operation systems calculated by ASIT
Sweden	**Prof. Jan-Olof Dalenbäck** Svensk Solenergi / CHALMERS	Svensk solenergi (Solar Energy Association of Sweden)
Switzerland	http://www.swissolar.ch/	SWISSOLAR – Markterhebung Sonnenenergie 2016, Bundesamt für Energie 2017 Out of operation systems calculated by SWISSOLAR
Taiwan	**K.M. Chung** Energy Research Center – National Cheng Kung University	Bureau of Energy, Ministry of Economic Affairs, R.O.C. Out of operation systems calculated by Bureau of Energy, Ministry of Economic Affairs, R.O.C.
Thailand	**Charuwan Phipatana-phuttapanta** Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy	GIZ study, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy (Subsidized systems) Data for subsidized systems, provided by Charuwan Phipatana-phuttapanta, single-family houses estimated by AEE INTEC based on GIZ study
Tunisia	**Abdelkader Baccouche** Agence Nationale pour la Maîtrise de l'Energie (ANME)	ANME (National Agency of Energy Conservation)
Turkey	**A. Kutay Ulke** Bural Heating Corporation Ltd. **John Hollick** SAHWIA – Solar Air Heating World Industry Association **Prof. Bulent Yesilata** GAP Renewable Energy and Energy Efficiency Center Harran University	Water collectors: A. Kutay Ulke, personal studies Air collectors: SAHWIA New installations: A. Kutay Ulke Cumulated installations: calculated by AEE INTEC considering 14 years lifetime Shares provided by Bulent Yesilata (2016)
United Kingdom	**Lethbridge Yehuda** Department of Energy and Climate Change **John Hollick** 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 Cumulated ESTIF 2017; FPC/ETC calculated by AEE INTEC; air collectors provided by John Hollick
United States	**Les Nelson** IAPMO Solar Heating & Cooling Programs **John Hollick** SAHWIA – Solar Air Heating World Industry Association	Water Collectors and air collectors: IAPMO Solar Heating & Cooling Programs; Air collectors: SAHWIA New installations: DOE/SEIA/IAPMO; Totals: calculated by AEE INTEC considering 25 years lifetime
Uruguay	**Ministry of Industry, Energy and Mining**	Ministry of Industry, Energy and Mining, provided by Martín Scarone 0% growth rate assumed 2015 / 2016
Zimbabwe	**Samson Mhlanga** National University of Science and Technology, Bulawayo	Dr. Anton Schwarzlmüller Domestic Solar Heating unpublished statistics SOLTRAIN survey (unpublished sources) 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

9.10 List of Tables