EDITION 2017

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SOLAR HEAT WORLDWIDE

Global Market Development and Trends in 2016 | Detailed Market Figures 2015

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SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Solar Heat Worldwide

Global Market Development and Trends in 2016
Detailed Market Figures 2015

2017 EDITION

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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 document the solar thermal capacity installed in the important markets worldwide and 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 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. Concentrating solar collectors are not in the scope of this report.

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.

Starting with the collector area, respectively the capacity installed, the contributions of solar thermal systems towards the supply of energy and the reduction of CO_2 were ascertained.

The 66 countries included in this report represent 4.7 billion people, or about 65% of the world's population. The installed capacity in these countries is estimated to represent 95% of the solar thermal market worldwide.

Figure 1: *From countries shown in color detailed market data are available. The market data from countries shown in grey the data are estimated.*

2 Summary

This report is split into two parts. The first part (Chapters 3 – 5) gives an overall overview of the global solar thermal market development in 2016. In addition, general trends are described and detailed 2016 data on successful applications, such as solar assisted district heating and solar heat for industrial processes are documented. The concluding chapter of the first part is focused on solar thermal system cost and levelized cost of solar heat for different applications and regions worldwide.

The second part comprising Chapters 6 – 8 presents detailed market figures for the year 2015 from 66 countries around the globe.

Global solar thermal market developments and status in 2016

The cumulated solar thermal capacity in operation by end of 2016 was 456 GW_{th} (652 million square meters). Compared to the year 2000 the installed capacity grew by a factor of 7.4.
The corresponding annual solar thermal energy yield in 2016 amounted to 375 TWh, which correlates to savings of 40.3 million tons of oil and 130 million tons of CO_2.

Despite these achievements, the global solar thermal market has faced challenging times in recent years. Especially in the large markets in China and Europe the traditional mass markets of small-scale solar water heating systems for detached single family houses and apartment buildings are under market pressure from heat pumps and photovoltaic systems.
The most dramatic development was observed in China. For the third year in a row, the 2016 market declined. After –17% in 2014 and also in 2015 the year 2016 continued this trend with –9%.
Positive market developments were seen in small markets in some Latin American countries, India and to a certain extent in Sub-Sahara Africa.

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 2016, 300 large-scale solar thermal systems >350 kW_{th} (500 m²) connected to district heating networks and 18 systems connected to cooling networks were in operation. The total installed capacity of these systems equaled 1,154 MW_{th} (1,648,383 m²). In 2016, 37 large-scale solar thermal systems with close to 500,000 m² (350 MW_{th}) were installed.
About 30% of this new collector area is from the world's largest plant in Silkeborg, Denmark, which has an installed capacity of 110 MW_{th} (156,694 m² flat plate collectors).

Solar heat for industrial processes is as well a growing market. A number of promising projects have been implemented in the last couple of years ranging from small-scale demonstration plants to very large systems in the several MW range. According to a study published by SOLRICO in early 2017, system designers and collector manufacturers reported more than 500 plants with an overall installed collector area of 416,414 m² for solar process heat worldwide[1].

The world's largest solar process heat application in operation was installed in Chile in June 2013. The installation has a thermal peak capacity of 27.5 MW_{th} and covers a total of 39,300 m² of flat plate collector area connected to 4,000 m³ thermal energy stor-

1 http://www.sunwindenergy.com/content/solar-process-heat-surprisingly-popular

age. The solar thermal system is designed to cover 85% of the process heat demand needed to refine copper at the Gaby copper mine of state-owned mining company Codelco.

Levelized cost of solar thermal generated heat

As noted above, solar thermal markets are facing challenging times partly caused by an increasing economic pressure from other renewable technologies. To address this, a special focus is being given to the economics of solar thermal systems in 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 (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). 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 (DHW-MFH) LCOH is lowest in Brazil and India (2 – 3 €-ct/kWh).

Small combined hot water and space heating systems (COMBI-SFH) 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).

Average LCOH for large-scale systems in Denmark (>10,000 m²) including cost for a diurnal storage goes 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.

Detailed market analysis for 66 countries based on 2015 data

By the end of 2015, an installed capacity of 435.9 GW_{th} corresponding to a total of 622.7 million square meters of collector area was in operation in the 66 countries analyzed in detail.

The vast majority of the total capacity in operation was installed in China (309.5 GW_{th}) and Europe (49.2 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 (18.4 GW_{th}), Asia excluding China (11.6 GW_{th}), Latin America (11.0 GW_{th}), the MENA[2] countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (6.7 GW_{th}), Australia and New Zealand (6.4 GW_{th}), and Sub-Sahara African coun-

2 Middle East and North Africa

Photo: AEE INTEC

tries Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa and Zimbabwe (1.4 GW_{th}). The market volume of "all other countries" is estimated to amount for 5% of the total installations (21.8 GW_{th}).

With a global share of 71.5%, evacuated tube collectors were the predominant solar thermal collector technology followed by flat plate collectors with 22.0%, unglazed water collectors with 6.2% and glazed and unglazed air collectors with 0.3%

The top 10 countries – those with the highest market penetration per capita remained unchanged compared to 2014. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2015 per 1,000 inhabitants were Barbados (489 kW_{th}/1,000 inhabitants), Austria (421 kW_{th}/1,000 inhabitants), Cyprus (400 kW_{th}/1,000 inhabitants), Israel (397 kW_{th}/1,000 inhabitants), Greece (287 kW_{th}/1,000 inhabitants), the Palestinian Territories (276 kW_{th}/1,000 inhabitants), Australia (265 kW_{th}/1,000 inhabitants), China (226 kW_{th}/1,000 inhabitants), Turkey (172 kW_{th}/1,000 inhabitants) and Germany (164 kW_{th}/1,000 inhabitants).

Installed capacity worldwide in 2015

By the end of 2015, a total capacity of 40.2 GW_{th}, corresponding to 57.4 million square meters of solar collectors, was installed worldwide. This means a decrease in new collector installations of 14% compared to the year 2014. This was the second year in a row that a shrinking world market has been observed. Based on data available for 2016 this trend seems to continue.

The main markets in 2015 were again in China (30.5 GW_{th}) and Europe (3.4 GW_{th}), which together accounted for 84% of the overall new collector installations in 2015. The rest of the market was shared between Latin America (1.3 GW_{th}), Asia excluding China (1.3 GW_{th}), the United States and Canada (0.8 GW_{th}), the MENA region (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 (2.0 GW_{th}).

From the top 10 markets in 2015 positive market development was reported from India (+31.8%), Turkey (+10.0%), Israel (+9.5%), Mexico (+7.8%) and Poland (+6.5%). The other major solar thermal markets within these top 10 countries namely China (–17.0%), Australia (–10.1%), Germany (–9.7%), Brazil (–2.7%) and the United States (–0.7%) suffered market declines.

In terms of economic regions, there was positive market growth in the period 2014/2015 in Asia (excluding China) and Sub-Sahara Africa. In Europe, the market stagnated and in all other economic regions solar thermal system installations dropped.

With a share of 72.3% of the new installed capacity in 2015, 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 87% of all new installed collectors in 2015 were evacuated tube collectors. Nevertheless it is remarkable that the share of evacuated tube collectors decreased from about 82% in 2011 to 75.1% in 2015, and in the same time frame flat plate collectors increased the share from 14.7% to 20.8%.

In Europe, the situation is almost the opposite compared to China with 72.3% of all solar thermal systems installed in 2015 being flat plate collectors. In the medium term perspective, the share of flat plate collectors decreased in Europe from 81.5% in 2011 to 72.3% in 2015. Driven mainly by the markets in Turkey, Poland, Switzerland and Germany the evacuated tube collectors did increase their share in Europe between 2011 and 2015 from 15.6% to 26.1%.

In terms of new installed solar thermal capacity per 1,000 inhabitants in 2015 the top 10 countries remained the same as in 2014, and Israel kept the leading position. Fast climbers in 2015 were Denmark, which overtook China and the Palestinian Territories (West Bank and Gaza Strip) and now ranks second behind Israel, and Turkey also jumped from seventh in 2014 to fifth place. China slipped from second place in 2014 to fourth.

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 influenced the overall figures the most. In 2015, 89% of the new 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 region. 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 108 million by the end of 2015. 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 ac-

Photo: ARCON SUNMARK

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

Compared to the cumulated installed capacity, the share of swimming pool heating was less for new installations (6% of total capacity and 4% of new 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 41% of new installations in 2015 make this kind of system the most common application worldwide, but it is showing a decreasing trend.

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

The share of applications, such as solar district heating and solar process heat are increasing the share steadily even if it is still only 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 714,000 worldwide in 2015.[3]

The worldwide turnover of the solar thermal industry in 2015 is estimated at € 18 billion (US$ 19.4 billion).

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

3 Worldwide solar thermal capacity in 2016

Global solar thermal capacity of unglazed and glazed water collectors in operation grew from 62 GW_{th} (89 million square meters) in 2000 to 456 GW_{th} (652 million square meters) in 2016.

The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 375 TWh in 2016 (**Figure 2**).

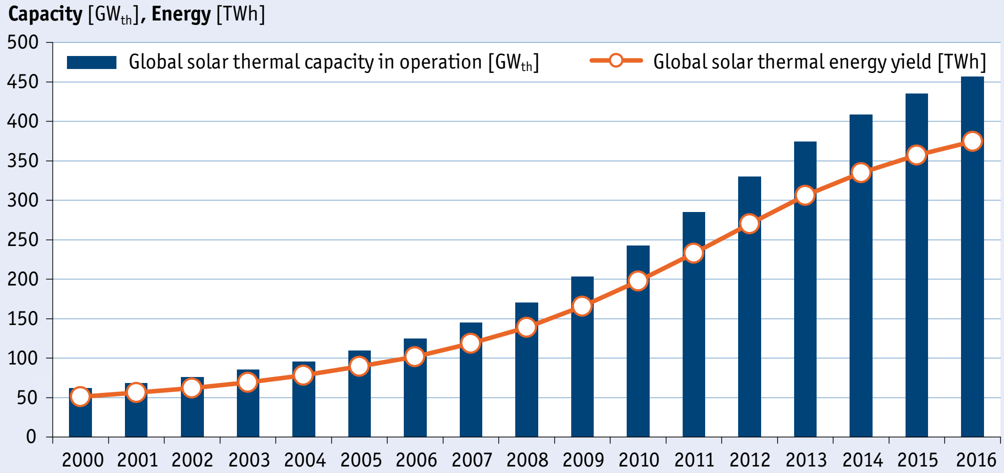


Figure 2: *Global solar thermal capacity in operation and annual energy yields 2000 – 2016*

Environmental effects and contribution to climate goals

The global solar thermal energy yields in 2016 corresponded to savings of 40.3 million tons of oil and 130 million tons of CO_2. This shows the significant contribution of this technology to the global climate goals.

Photo: AEE INTEC

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 end of 2016 was 456 GW_{th}[4], slightly behind wind power 487 GW_{el}, but still significantly ahead of photovoltaic, which has an installed capacity of 303 GW_{el}. The total capacity of Concentrating Solar Thermal Power (CSP) systems was 5 GW_{el}, which is in the range of 1.1% of the capacity of solar heating and cooling technologies.

In terms of energy, solar thermal systems supplied a total of 375 TWh of heat, whereas wind turbines supplied 900 TWh and photovoltaic systems 375 TWh of electricity.

Global capacity in operation [GW_{el}], [GW_{th}], **and energy supplied** [TWh_{el}], [Twh_{th}], **2016**

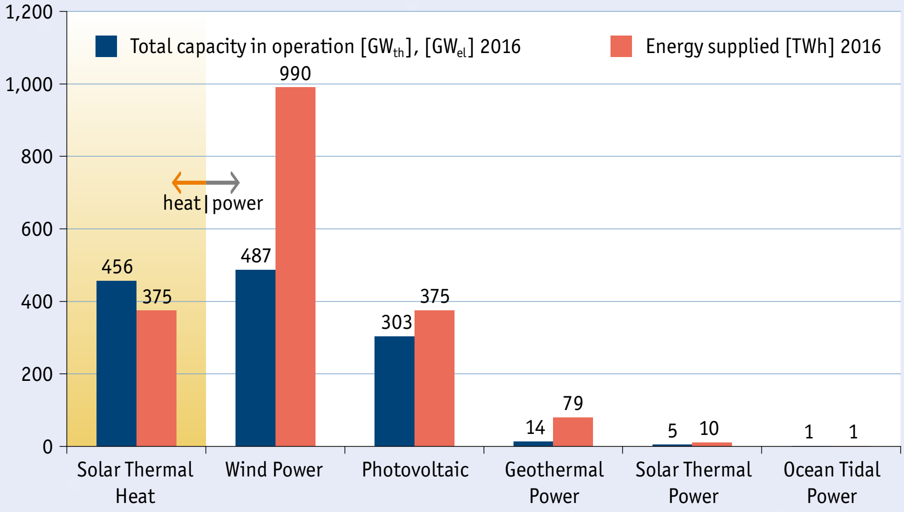


Figure 3: *Global capacity in operation [GW_{el}], [GW_{th}] 2016 and annual energy yields [TWh_{el}], [TWh_{th}] (Sources: AEE INTEC, Global Wind Energy Council (GWEC), European PV Industry Association (EPIA), REN21 - Global Status Report 2017)*

The development of global installed capacity of solar thermal heat, wind and photovoltaics between 2010 and 2016 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 and in recent years wind energy has caught up to a level equal to solar thermal in 2015 and higher than solar thermal in 2016.

4 The figures for 2016 are based on the latest market data from Australia, Austria, Brazil, China, Germany, 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.

In 2016, the highest global growth rate was observed by photovoltaics with 33% added capacity, followed by wind, which increased its installed capacity by 12%. With 5% added capacity, solar thermal was significantly behind the other two technologies as shown in **Figure 4**.

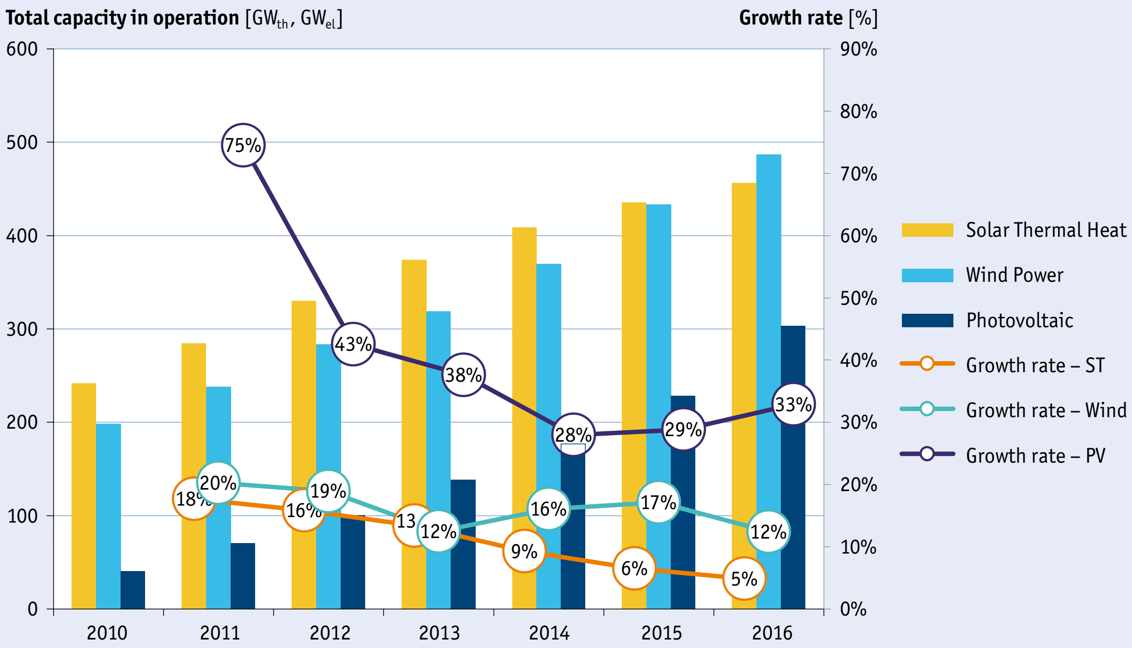


Figure 4: *Global solar thermal heat, wind power and photovoltaic capacity in operation and market growth rates between 2010 and 2016 (Sources: AEE INTEC, Global Wind Energy Council (GWEC), European PV Industry Association (EPIA), REN21 - Global Status Reports 2011-2017)*

Photo: AEE INTEC

4 Solar thermal market development and trends in 2016

4.1 General trends

Small-scale solar water heating systems

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 5% in the period 2015/2016. In particular, the large markets in China and Europe, which are the traditional mass markets of small-scale solar water heating systems for detached single family houses and apartment buildings, are under market pressure from heat pumps and photovoltaic systems.

Small-scale solar water heating systems for detached single family houses and apartment buildings represent approximately 90% of the annual installations. A declining interest in these systems is thus seen as critical.

The most dramatic development is in China where for the third year in a row the market has declined. After a –17% decline in 2014 and 2015, the year 2016 continued this trend with a 9% decline.

For detailed country trends please see **Chapter 6**.

Megawatt-scale systems

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 represents only about 3% of the overall global installed capacity.

4.2 Large-scale solar district heating and cooling

In the Scandinavian countries of Denmark and Sweden, but also in Austria, Germany, Spain and Greece large-scale solar thermal plants connected to local or district heating grids have been in use since the early 1980s. In recent years China has installed a number of large-scale systems for district heating.

By the end of 2016, 300 large-scale solar thermal systems >350 kW_{th} (500 m²) connected to heating networks and 18 systems connected to cooling networks were in operation (**Figure 5**). The total installed capacity of these systems equaled 1,154 MW_{th} (1,648,383 m²).

In 2016, 37 large-scale solar thermal systems were added compared to 21 new installations in 2015. Of these installations, 31 were installed in Denmark, 1 in Sweden, 1 in France and 4 in Germany. Moreover the collector area of 5 existing Danish plants was extended.

In 2016, close to 500,000 m² (350 MW_{th}) of solar collectors were added in large systems in Europe, primarily for district heating in Denmark. About 30% of this new collector area is from the world's largest plant in Silkeborg, Denmark which 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. The system in Vojens has 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 Europe, Germany and Austria also several MW-scale solar assisted district heating systems are installed. The largest German plants are 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) and has a capacity of 5.2 MW_{th}.

In Riyadh, Saudi Arabia another 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[8].

And Canada has a successful solar supported 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[9; 10].
Currently, the largest solar district heating system in China was installed 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.

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 http://www.solarthermalworld.org/content/saudi-arabia-womens-university-solar-district-heating
9 http://www.solarthermalworld.org/content/canada-district-heating-90-solar-fraction
10 http://www.dlsc.ca

The second largest system has a similar size of 7.9 MW_{th} (11,310m²) and was installed in 2008 in the new city in the resettlement district in Shenzhen.

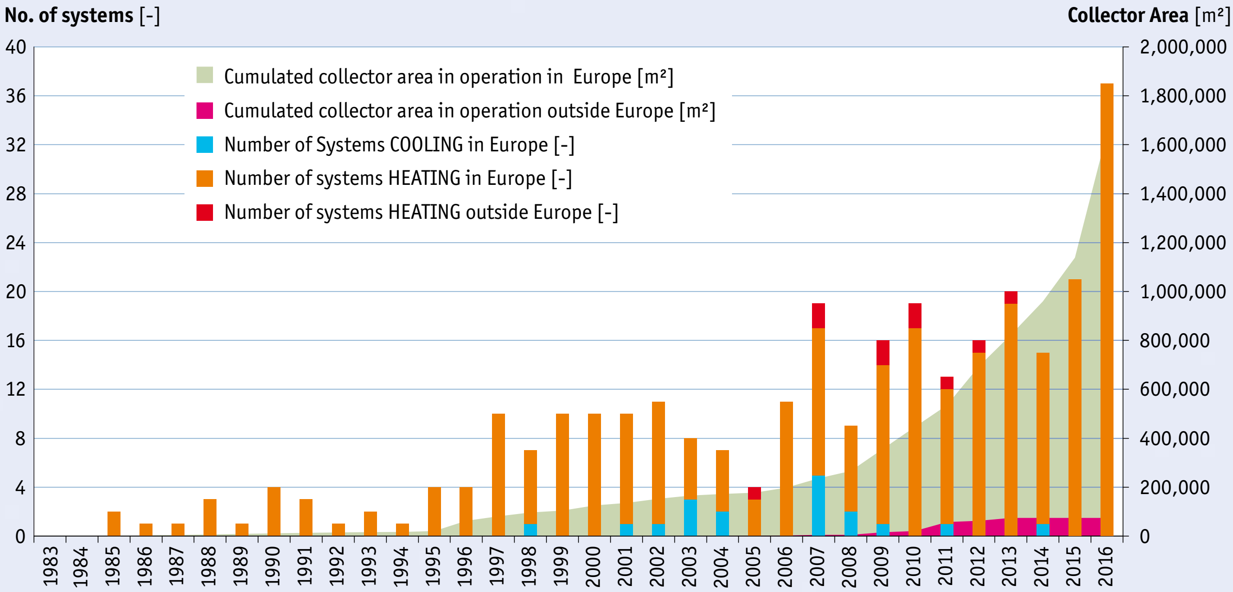


Figure 5: *Solar district heating and cooling worldwide – annual achievements and cumulated area in operation in 2016 (Data source: Jan-Olof Dalenbäck - Chalmers University of Technology, SE and Sabine Putz - IEA SHC Task 55)*

As mentioned already above, Denmark is the leader by far not only in Europe but also worldwide for both large-scale systems installed as well as capacity installed (**Figure 6**). In 2016, 31 solar district heating plants were installed and 5 existing plants were extended. The total installed capacity in operation in Denmark equaled 922 MW_{th} (1,317,635 m²). The average system size of these plants calculates to be 8.4 MW_{th} (11,979 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%.

Worldwide, Denmark is the only example of a mature and commercial solar district heating market. 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. Other countries to note are Germany with 29 demonstration plants (some of these with seasonal storage). Sweden (24 plants), France (17 plants), Greece, Poland (14 plants each) and Switzerland (9 plants).

Large-scale solar cooling applications were built in southern European countries with high cooling loads. Italy (5 plants) and Spain (5 plants) have several best practice examples.

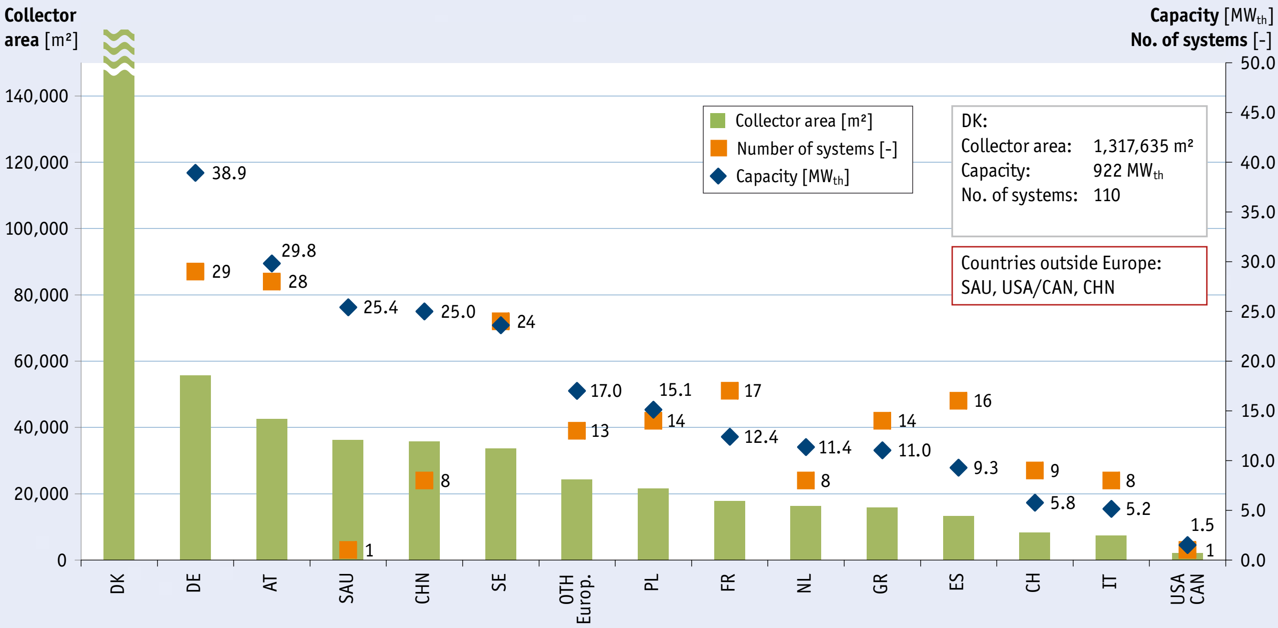


Figure 6: *Solar district heating and cooling – capacities and collector area installed and number of systems in 2016 (Data source: Jan-Olof Dalenbäck - Chalmers University of Technology, SE and Sabine Putz - IEA SHC Task 55)*

Photo: S.O.L.I.D Gesellschaft für Solarinstallation und Design mbH / René Prohaska

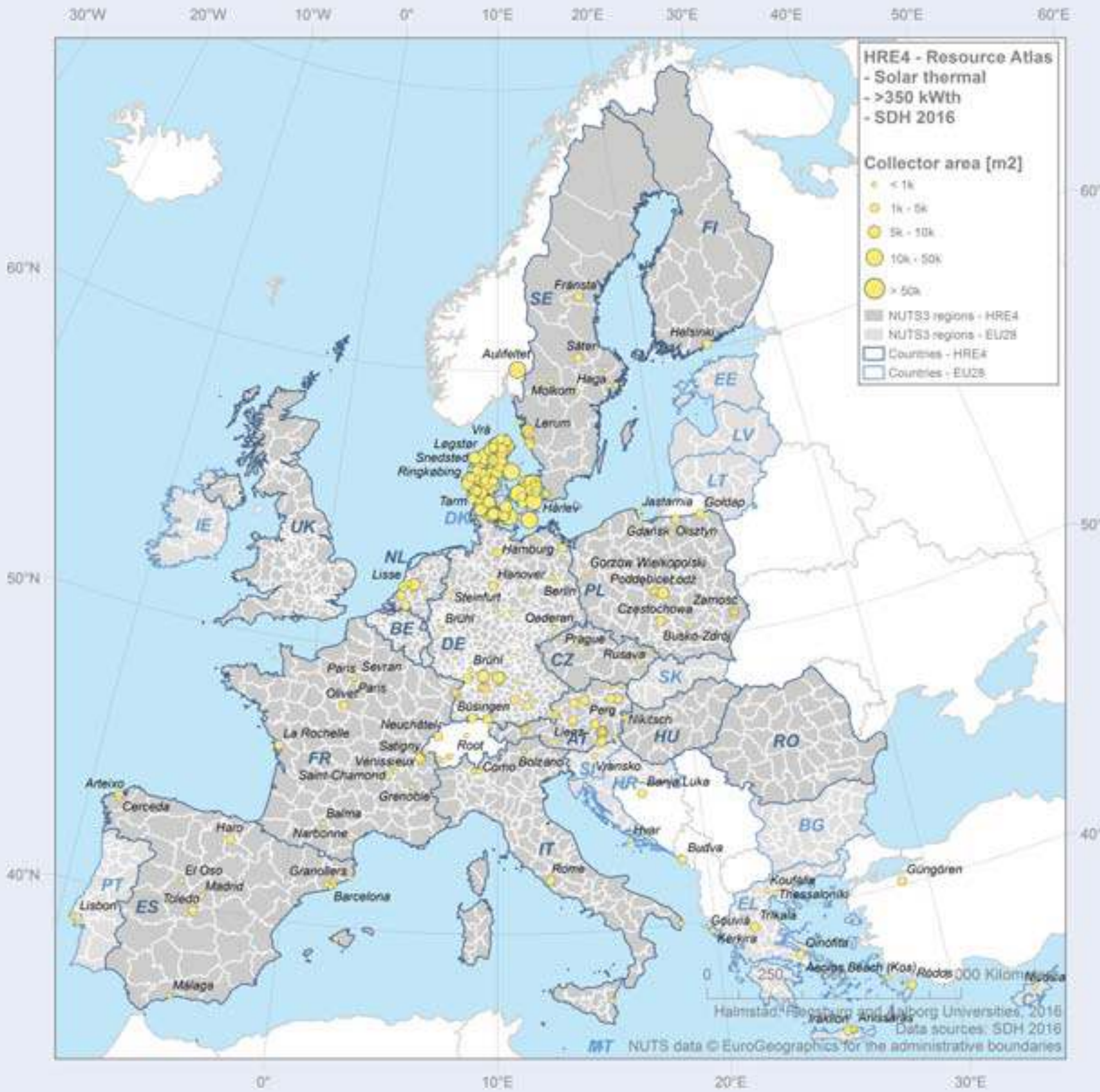


Figure 7: *Solar district heating systems > 500 m² (> 350 kW_{th}) in Europe. (Source: EU-project Heat Roadmap Europe)*

4.3 Solar process heat

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

Solar Heat for Industrial Processes (SHIP) is a growing market. A number of promising projects have been implemented in the last couple of years ranging from small-scale demonstration plants to very large systems in the several MW sector.

The world's largest solar process heat application was commissioned in Chile in June 2013. The installation has a thermal peak capacity of 27.5 MW_{th} and a total area of 39,300 m² of flat plate collectors connected to a 4,000 m³ thermal energy storage. The solar thermal system is designed to cover 85% of the process heat demand needed to refine copper at the state-owned Codelco[11] mining company's Gaby copper mine.

There are two other large SHIP plants, one system in the USA and the other in China. Probably the largest solar process heat application in the USA is at the Prestage Foods Processing Facility in North Carolina. The 5.5 MW_{th} (7,804 m²) solar thermal system, installed in April 2012, is equipped with flat plate collectors that supply hot water to a turkey processing plant, lessening the use of propane gas[12]. In China, the largest solar process heat application is connected to a dying and weaving mill factory. The system, with a thermal peak capacity of 9.1 MW_{th} (13,000 m²), was constructed in 2008 in the city of Hangzhou, Zhejiang province.

According to a study published by SOLRICO in early 2017, system designers and collector manufacturers reported more than 500 plants with an overall installed collector area of 416,414 m² for solar process heat worldwide[13].

For 238 of these systems more detailed information on the collector area, installed capacity, type of application and type of collector can be found in the SHIP database, which is an online portal operated by AEE INTEC in Austria[14]. The following figures show the analysis for the systems where detailed information is available, thus the overall number of systems analyzed is smaller than 500.

Figure 8 shows the distribution of 238 systems in terms of size. Twenty-two systems exceed 1,000 m² collector area, 26 systems have installed collector areas between 500 – 1,000 m², and 190 systems are smaller than 500 m².

11 http://www.solarthermalworld.org/content/chile-president-inaugurates-solar-field-275-mwth
12 http://solarthermalworld.org/content/usa-contractor-runs-7804-m2-collector-system-prestage-foods-factory
13 http://www.sunwindenergy.com/content/solar-process-heat-surprisingly-popular
14 http://ship-plants.info

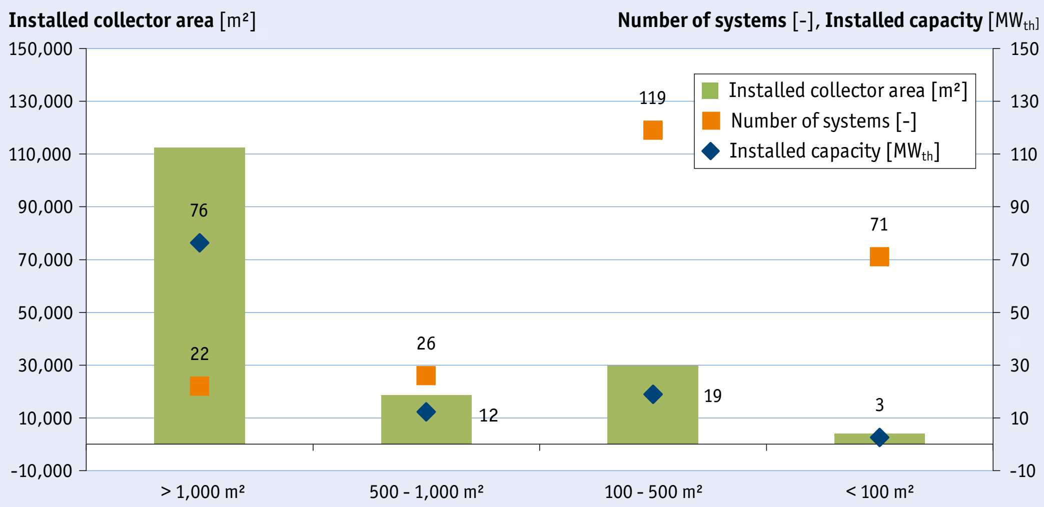


Figure 8: *Global solar process heat applications in operation by capacity and collector area at the end of 2016 (Source: IEA SHC Task49/IV SHIP database)*

Figure 9 shows the analyzed process heat systems in respect to the type of collector technology. The majority of the systems use flat plate collectors followed by evacuated tube collectors and parabolic trough collectors.

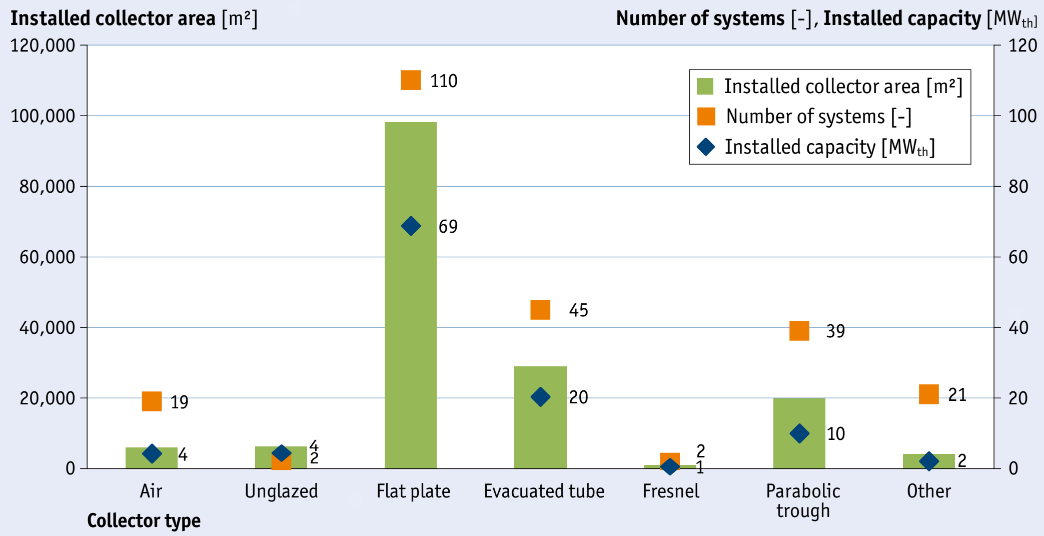


Figure 9: *Global solar process heat applications in operation by collector type at the end of 2016 (Source: IEA SHC Task49/IV SHIP database)*

With respect to the share of collector technologies, **Figure 10** shows that more than 88% of the installed systems are non-concentrating, about 12% or 13 MW_{th} are concentrating with parabolic trough collectors taking a share of 79%.

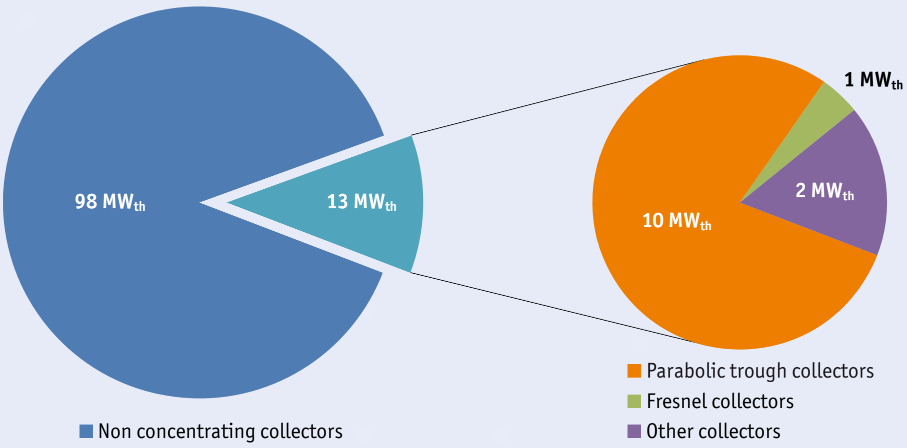


Figure 10: *Share of collector technologies (Source: IEA SHC Task49/IV SHIP database)*

Figure 11 shows the industry sectors of the 238 analyzed systems. The main sectors are mining, food and textile. Beverage, chemical and metal processing are also important sectors with 27, 14 and 15 installed solar process heat plants respectively.

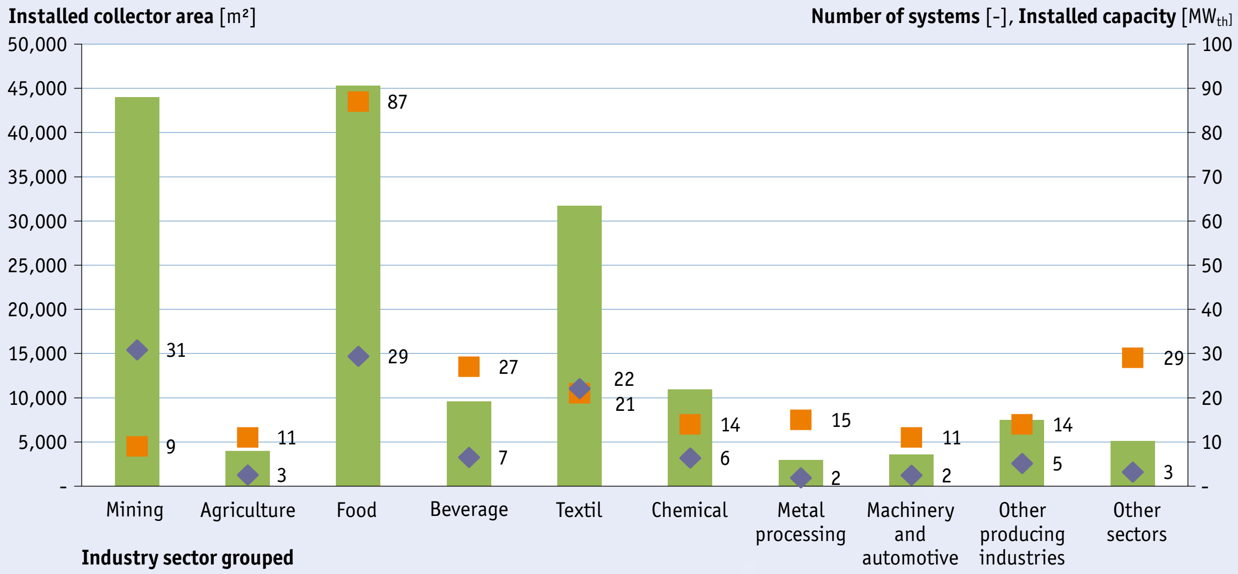


Figure 11: *Global solar process heat applications in operation in the industry sector at the end of 2016 (Source: IEA SHC Task49/IV SHIP database)*

In terms of distribution of solar process heat plants by country, the result is quite different if looking at the number of systems or the size of the installed plants. **Figure 12** shows the leading 15 countries worldwide.

In terms of the number of recorded systems, Mexico leads with 44 systems ahead of India with 36 plants and Austria with 25 plants.

In terms of size of recorded systems, Chile with only two systems leads with a total installed capacity of 25.3 MW_{th} and an average size per system of 12.7 MW_{th} ahead of China with an overall installed capacity of 24.4 MW_{th} (average size of 2 MW_{th}) and the United States with 14.6 MW_{th} and an average size per system of 0.8 MW_{th}.

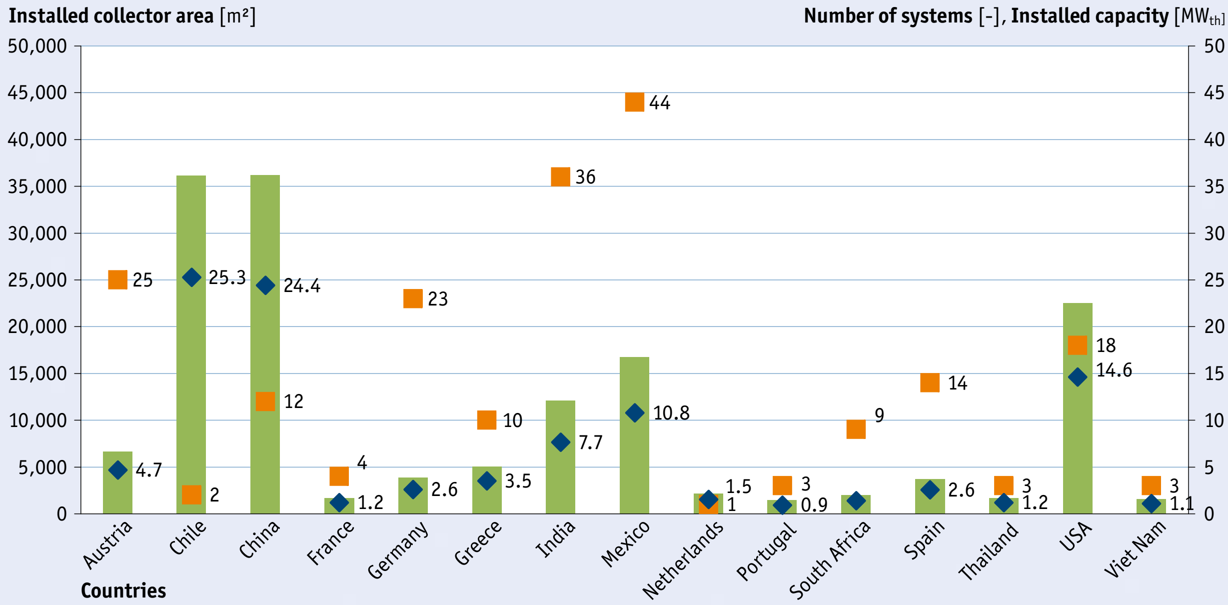


Figure 12: *Global solar process heat applications in operation by country at the end of 2016 (Source: IEA SHC Task49/IV SHIP database)*

The bubble diagram in **Figure 13** shows the specific useful heat delivery and the year operation started. The size of the bubbles symbolizes the size of the systems. Over the last ten years a number of systems have been installed, especially in Europe and in Asia. However, the biggest systems are installed in Latin America (Chile).

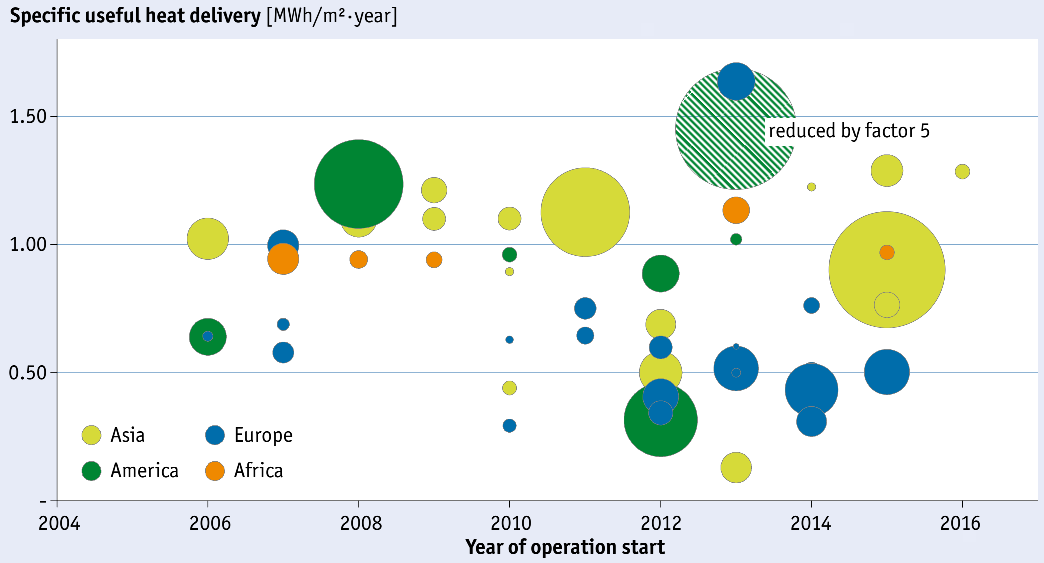


Figure 13: *Specific useful heat delivery of solar process heat plants (Source: IEA SHC Task49/IV SHIP database)*

Looking at the specific useful heat delivery, **Figure 14** shows the performance of these systems in respect to the latitude. Once again, the size of the bubbles symbolizes the size of the systems. This figure does not take into account that the specific heat delivery also depends on the process and the temperature level used for the process.

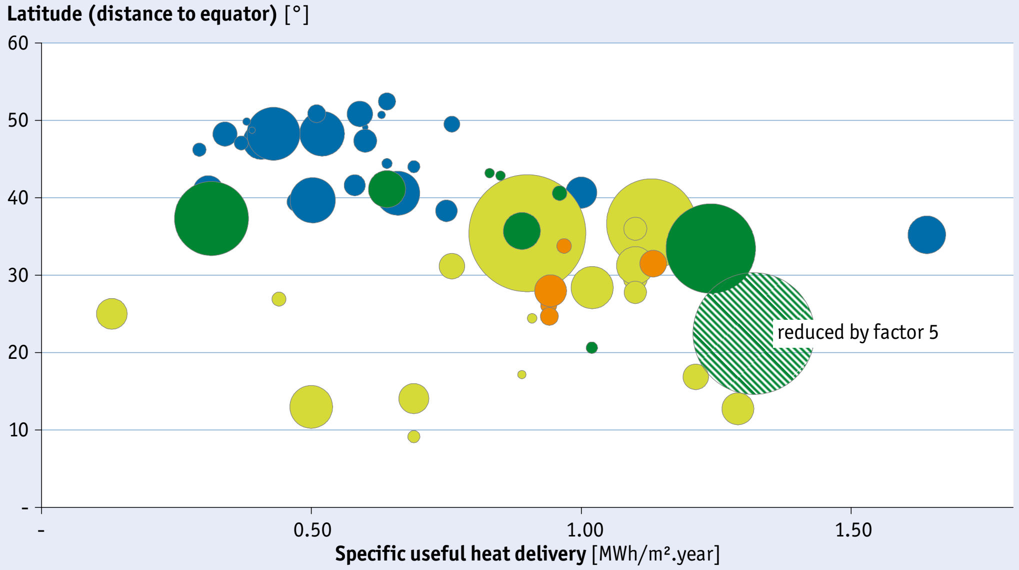


Figure 14: *Specific useful heat delivery and latitude of installed systems (Source: IEA SHC Task49/IV SHIP database)*

4.4 Solar air conditioning and cooling

In the growing global market for cooling and refrigeration, there is a huge potential for cooling systems that use solar thermal energy. A major argument for this application is that they consume less than conventional energy sources 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.

Although there is a niche market for solar thermal driven medium-sized capacity installations (e.g., in hotels and hospitals, especially on islands where fuel must be imported), widespread deployment has stagnated due to relatively high system costs, space requirements and the complexity of solar thermal-based cooling, especially for small-capacity systems.

Absorption and adsorption chillers have long dominated the solar cooling market and account for approximately 71% of capacity in operation. In 2015 and 2016, their market share increased, whereas desiccant cooling systems saw their market share decline.

Figure 15: *Market development 2004 – 2015 of small to large-scale solar air conditioning and cooling systems (Source: Solem Consulting, Tecsol)*

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 installed solar cooling installations worldwide are installed in Europe, most notably in Spain, Germany and Italy. In 2015 the share of the world's installed systems increased from 20% to 30% with the largest growth outside of Europe. Moreover, several larger solar cooling systems were installed in 2015 and 2016. These include systems for the European companies Wipotec (Germany) and AVL (Austria), and for the Sheikh Zayed Desert Learning Center in Abu Dhabi[15]. The majority of these systems are equipped with flat plate or evacuated tube collectors. By contrast, some thermal cooling machines driven by concentrated solar thermal energy (with concentrating solar thermal collectors, such as parabolic troughs and Fresnel collectors) were reported from India, Australia and Turkey[16].

The two largest solar cooling applications are in Singapore and the USA. The world's largest solar cooling application is located in Arizona, USA and was commissioned in May 2014. The installation covers a roof-mounted solar thermal collector field with a capacity of 3.4 MW_{th} (4,865 m^2) that supplies heat to a single-effect lithium bromide absorption chiller with a cooling capacity of 1.75 MW [17; 18]. In Singapore a solar cooling system installed in August 2011 with a total capacity of 2.73 MW_{th} (3,900 m^2) started operation at the United World College in Singapore. The roof mounted solar thermal collector field is hydraulically connected to a 1.76 MW_{th} absorption chiller and supplies hot water and cooling to approximately 2,900 students who live and study at the 76,000 m^2 campus [19].

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 1,229 MW_{th} (1,755,700 m^2) of glazed and unglazed air collectors were installed worldwide. The annual worldwide market is quite stable at a range of 70 MW_{th} (100,000 m^2).

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

15 Dr. Jakob energy research, 2016
16 Jakob U. (2013): Status and Perspective of Solar Cooling outside of Australia; Australian Solar Cooling 2013 Conference, Sydney 2013
17 http://www.solarthermalworld.org/content/usa-largest-solar-cooling-system-worldwide
18 http://www.solid.at/en/references/solar-cooling
19 http://www.solarthermalworld.org/content/singapore-second-largest-solar-cooling-installation-worldwide

5 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 5.1** to **5.4** 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 [€/m^2_{gross}] and refer to end-user (customer) prices excluding value added tax and subsidies. The LCOH is expressed as €-cents[20] 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 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.

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

Photo: S.O.L.I.D Gesellschaft für Solarinstallation und Design mbH

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. (cf. **Chapter 4.2** for further information).

In **Figure 16**, 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).

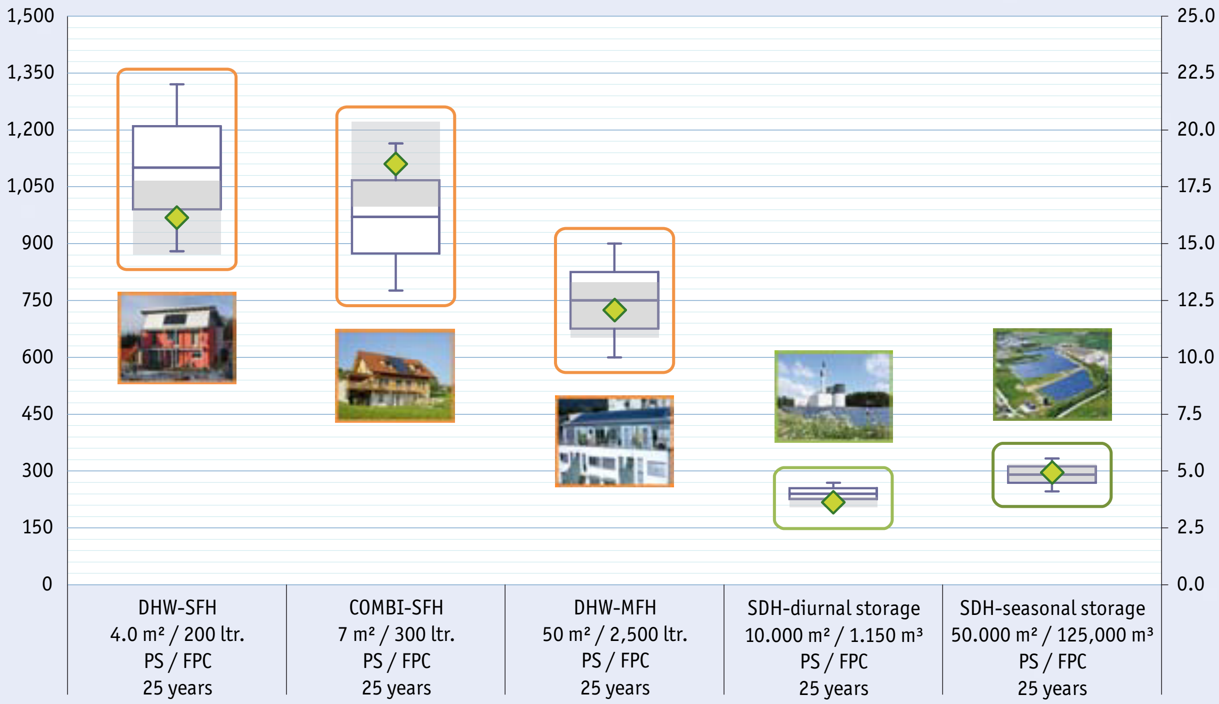


Figure 16: *Specific investment costs and levelized costs of heat for different solar thermal applications in Denmark (orange: small-scale domestic systems, green: large-scale commercial applications)*

5.1 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 17**, 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).

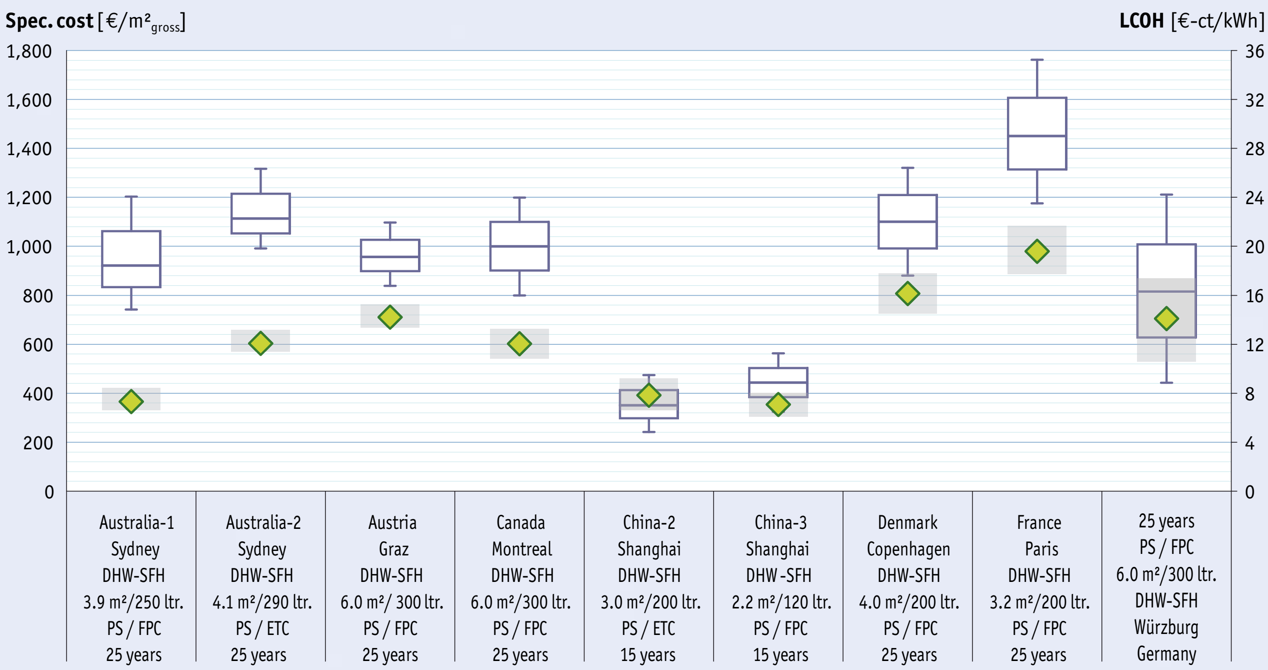


Figure 17: *Specific investment costs and levelized costs of solar thermal generated heat for small pumped domestic hot water systems*

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 18**, 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).

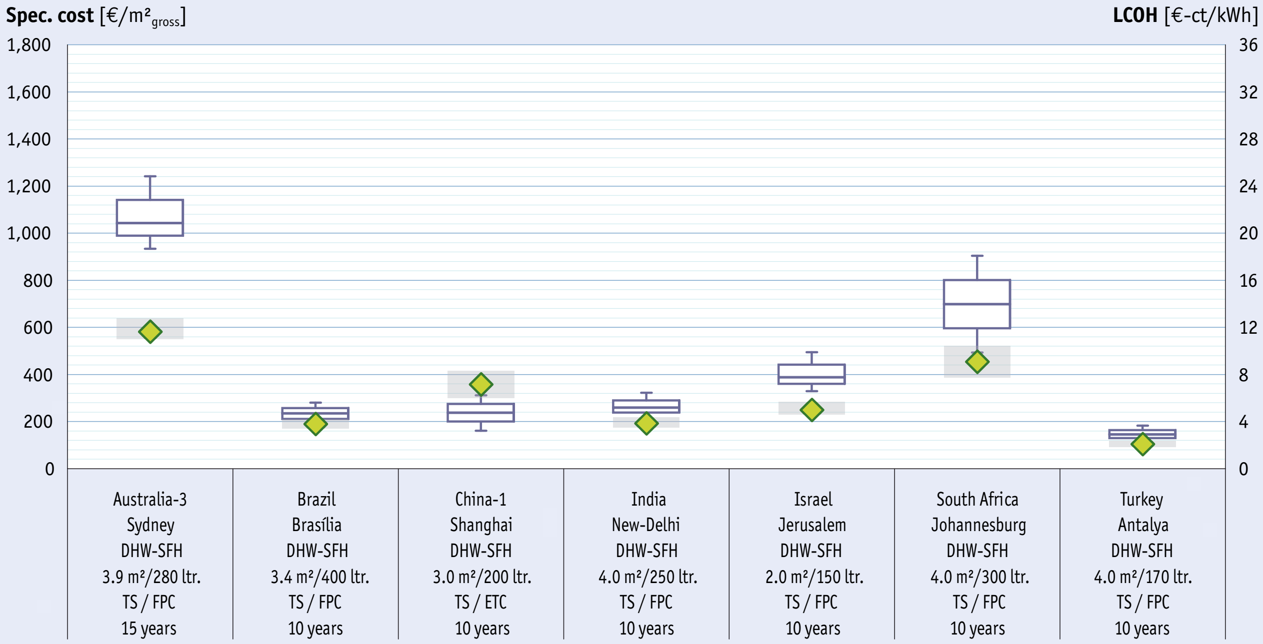


Figure 18: *Specific investment costs and levelized costs of solar thermal generated heat for small thermosiphon domestic hot water systems*

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).

5.2 Large domestic hot water systems

In **Figure 19**, 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).

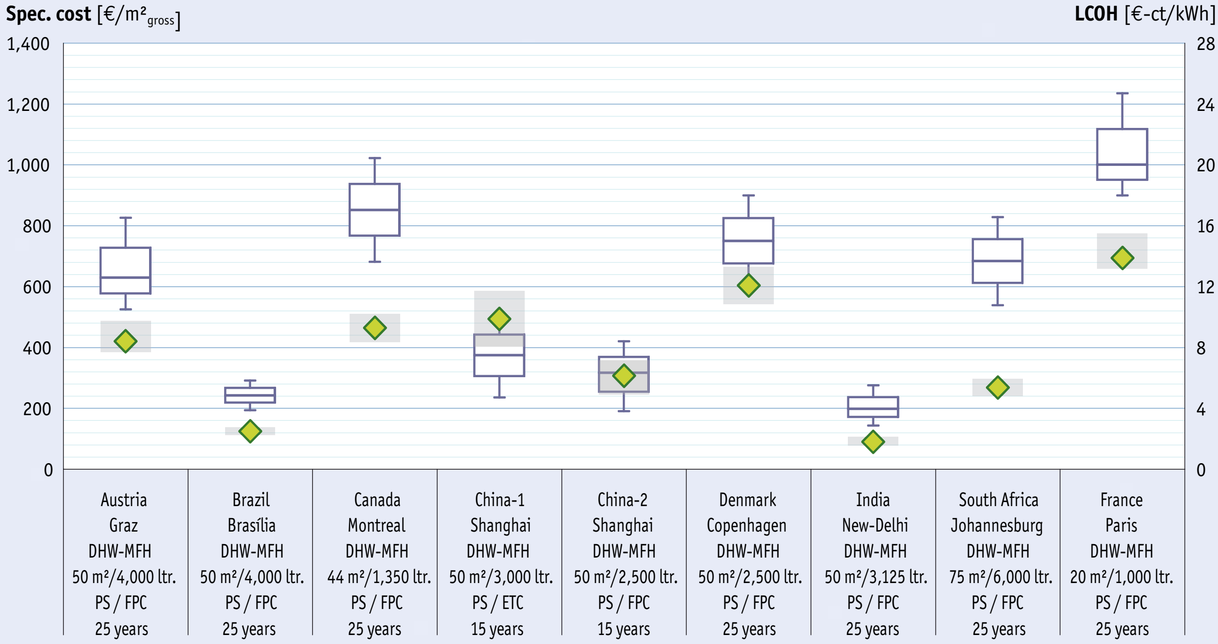


Figure 19: *Specific investment costs and levelized costs of solar thermal generated heat for large pumped domestic hot water systems*

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.

5.3 Combined hot water and space heating systems

In **Figure 20**, 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).

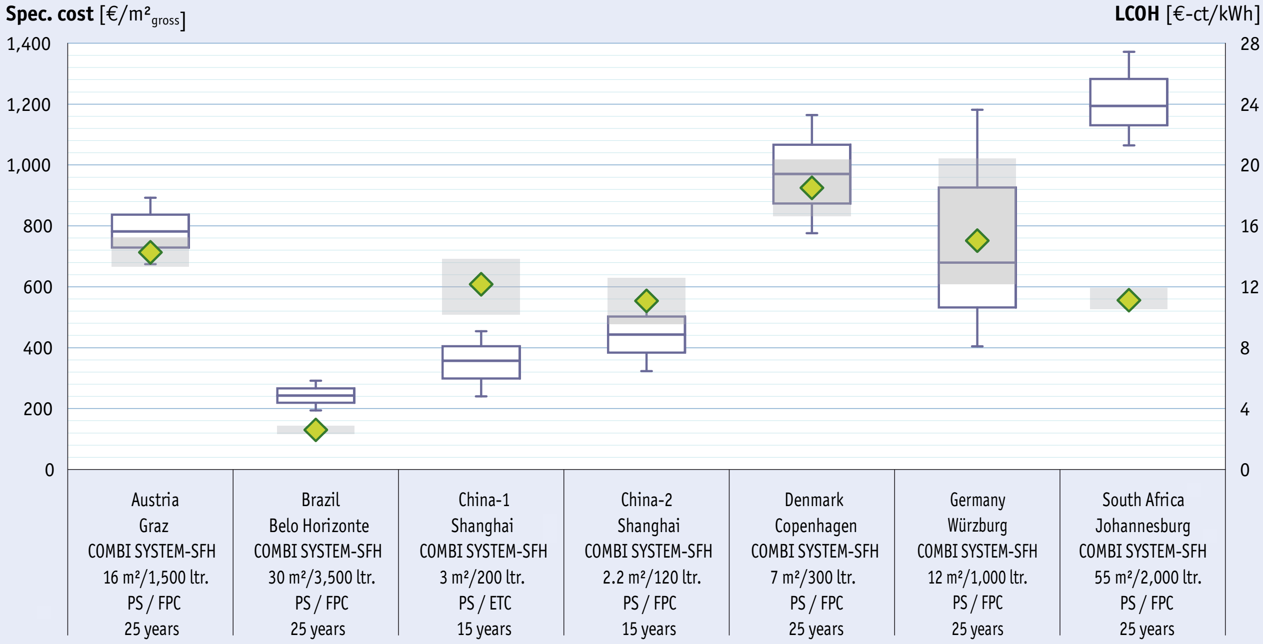


Figure 20: *Specific investment costs and levelized costs of solar thermal generated heat for small combined hot water and space heating systems*

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[21]).

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.

21 System investigated in South Africa is imported from Europe

5.4 Swimming pool heating systems

In **Figure 21**, 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).

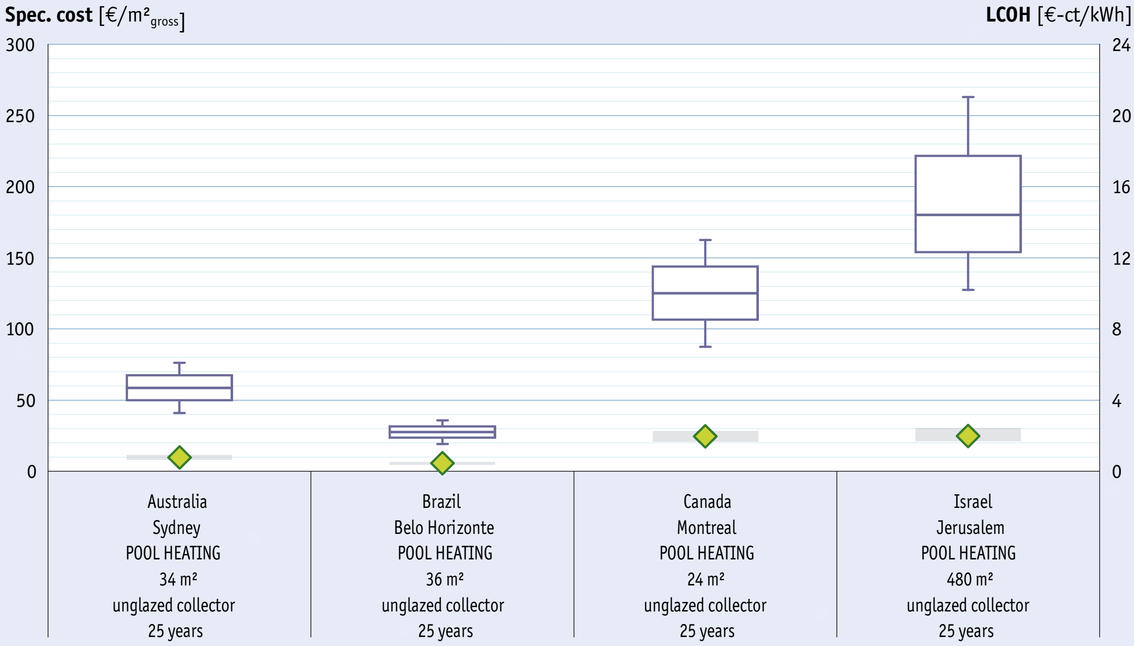


Figure 21: *Specific investment costs and levelized costs of solar thermal generated heat for swimming pool heating systems*

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

Photo: S.O.L.I.D Gesellschaft für Solarinstallation und Design mbH

6 Detailed global market data 2015 and country figures

The following chapters of the report show detailed solar thermal market figures for the year 2015 and country figures for 66 countries.

Background of the presented data

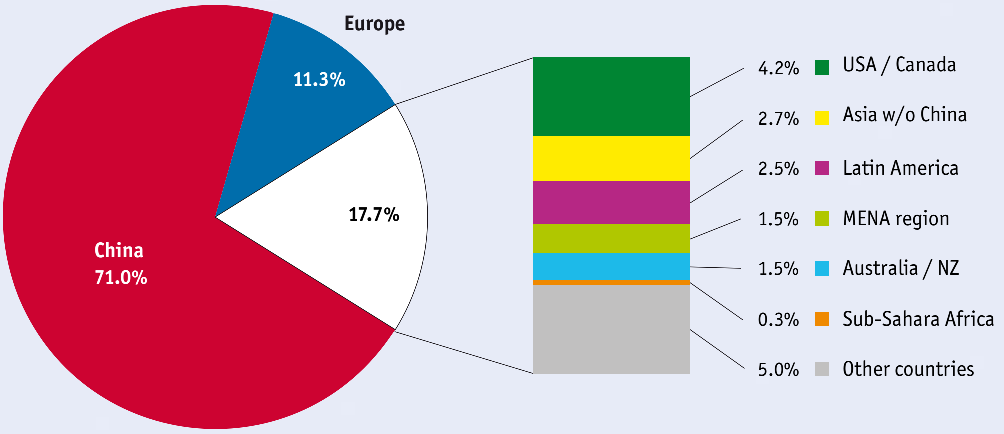
The following chapters of the report show figures of the actual collector area in operation in 2015 and not the cumulated collector area installed in a country. To determine the collector area (and respective capacity) in operation, either official country reports on the lifetime were used or, if such 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.

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.

6.1 General market overview of the total installed capacity in operation

By the end of 2015, an installed capacity of 435.9 GW_{th} corresponding to a total of 622.7 million square meters of collector area was in operation worldwide.

The vast majority of the total capacity in operation was installed in China (309.5 GW_{th}) and Europe (49.2 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 (18.4 GW_{th}), Asia excluding China (11.6 GW_{th}), Latin America (11.0 GW_{th}), the MENA countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (6.7 GW_{th}), Australia and New Zealand (6.4 GW_{th}), and Sub-Sahara African countries Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa and Zimbabwe (1.4 GW_{th}). The market volume of "all other countries" is estimated to amount for 5% of the total installations (21.8 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 region:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 22: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2015

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		127.3	1.4			129
Australia	3,605.0	2,309.3	109.9	210.0	6.3	6,241
Austria	323.3	3,269.0	60.1		2.5	3,655
Barbados		142.0	0.0			142
Belgium	31.5	319.4	57.2			408
Botswana		4.9	0.0			5
Brazil	2,933.2	5,699.8	35.6			8,669
Bulgaria		91.3	2.5			94
Burkina Faso#		0.7	0.1			1
Canada	559.8	48.7	32.3	280.7	34.2	956
Chile	41.2	106.6	33.6	0.0	0.1	181
China		24,885.0	284,585.0			309,470
Croatia		126.7	5.3			132
Cyprus	1.5	456.4	17.4			475
Czech Republic	397.6	292.0	84.2			774
Denmark	14.4	816.7	6.4	3.0	12.6	853
Estonia***		4.9	3.9			9
Finland	8.3	26.2	7.1			42
France (mainland)+	84.0	1,334.2	132.0	4.1	0.8	1,555
Germany	409.3	11,406.5	1,410.5		19.8	13,246
Ghana#		0.6	0.2			1
Greece		3,072.9	14.7			3,088
Hungary	11.4	141.2	47.0	1.6	1.4	203
India++		2,524.1	3,723.2		7.1	6,254
Ireland		146.3	77.6			224
Israel	25.2	3,169.2	0.0			3,194
Italy	30.7	2,526.6	395.3			2,953
Japan		2,355.9	45.8		367.6	2,769
Jordan*	4.2	687.7	190.5			882
Korea, South		1,173.1	102.7			1,276
Latvia		5.7	1.7			7
Lebanon		200.7	277.5			478
Lesotho		0.9	0.2			1
Lithuania		4.0	4.8			9
Luxembourg		33.8	5.3			39
Macedonia		29.2	7.6			37
Malta		28.5	7.1			36
Mauritius***		93.0	0.0			93
Mexico	680.4	730.9	560.7	0.5	6.1	1,979
Morocco*		315.7	0.0			316
Mozambique	0.1	0.0	0.8			1
Namibia	0.5	20.7	0.9			22
Netherlands	73.3	360.0	19.9			453
New Zealand**	4.9	100.1	6.8			112
Nigeria#			0.1			0.1
Norway***	1.3	28.1	3.1	0.1	2.9	33
Palestinian Territories		1,278.6	5.8			1,284
Poland		1,078.0	337.8			1,416
Portugal	1.5	667.3	18.7			687
Romania	0.2	64.5	46.3	0.6		112
Russia		12.3	1.2		0.0	13
Senegal#		0.1	1.1		0.8	1.9
Slovakia	0.7	93.2	14.8			109
Slovenia		119.0	15.4			134
South Africa	729.2	378.4	139.6			1,247
Spain	101.6	2,342.1	140.4			2,584
Sweden	119.3	179.3	50.2			349
Switzerland	142.0	874.2	79.9			1,096
Taiwan	1.4	1,072.0	89.5			1,163
Thailand***		118.4	0.0			118
Tunisia		538.3	49.1			587
Turkey		10,478.4	3,158.7	3.9		13,641
United Kingdom		435.7	118.8	15.5		570
United States	15,283.2	1,921.3	102.3	72.6	36.8	17,416
Uruguay		36.6	0.0			37
Zimbabwe		15.2	4.4			20
All other countries (5%)	1,348.4	4,785.1	15,602.7	31.2	26.3	21,794
TOTAL	26,968	95,705	312,055	624	525	435,874

Note: If no data is given: no reliable database for this collector type is available
* Total capacity in operation refers to the year 2014
** Total capacity in operation refers to the year 2009
*** Total capacity in operation is based on estimations for new installations in 2015
\# New included countries compared to the 2016 edition of this report
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
\++ The figures for India refer to fiscal year end (April 2015 – March 2016)

Table 1: *Total capacity in operation in 2015 [MW_{th}]*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL (excl. concentrators) [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		181,839	1,976			183,815
Australia	5,150,000	3,299,000	157,000	300,000	9,000	8,915,000
Austria	461,921	4,669,995	85,847		3,578	5,221,341
Barbados		202,860				202,860
Belgium	45,000	456,283	81,750			583,033
Botswana		7,000				7,000
Brazil	4,190,305	8,142,632	50,828			12,383,765
Bulgaria		130,380	3,520			133,900
Burkina Faso#		932	139			1,070
Canada	799,656	69,548	46,089	400,999	48,927	1,365,220
Chile	58,807	152,279	48,062	0	100	259,248
China		35,550,000	406,550,000			442,100,000
Croatia		181,017	7,575			188,592
Cyprus	2,213	652,034	24,800			679,047
Czech Republic	568,000	417,214	120,298			1,105,512
Denmark	20,500	1,166,719	9,197	4,300	18,000	1,218,716
Estonia***		6,930	5,590			12,520
Finland	11,800	37,451	10,072			59,323
France (mainland)+	120,000	1,906,000	188,500	5,800	1,100	2,221,400
Germany	584,700	16,295,000	2,015,000		28,300	18,923,000
Ghana#		831	306			1,137
Greece		4,389,900	21,000			4,410,900
Hungary	16,300	201,700	67,100	2,350	2,000	289,450
India++		3,605,862	5,318,855		10,200	8,934,917
Ireland		209,059	110,887			319,946
Israel	36,000	4,527,434				4,563,434
Italy	43,800	3,609,364	564,760			4,217,924
Japan		3,365,626	65,443		525,149	3,956,218
Jordan*	5,940	982,482	272,084			1,260,506
Korea, South		1,675,871	146,775			1,822,646
Latvia		8,092	2,440			10,532
Lebanon		286,719	396,414			683,133
Lesotho		1,357	296			1,653
Lithuania		5,700	6,900			12,600
Luxembourg		48,236	7,500			55,736
Macedonia		41,767	10,836			52,603
Malta		40,781	10,195			50,976
Mauritius***		132,793				132,793
Mexico	972,053	1,044,082	800,942	752	8,773	2,826,602
Morocco*		451,000				451,000
Mozambique	136	48	1,175			1,359
Namibia	780	29,625	1,313			31,718
Netherlands	104,693	514,233	28,471			647,397
New Zealand**	7,025	142,975	9,644			159,645
Nigeria#	0	58	90	0	35	184
Norway***	1,849	40,209	4,447	200	4,106	50,812
Palestinian Territ.		1,826,625	8,225			1,834,850
Poland		1,539,990	482,600			2,022,590
Portugal	2,130	953,272	26,680			982,082
Romania	340	92,200	66,150	800		159,490
Russia		17,547	1,665		50	19,262
Senegal#	0	83	1,568	0	1,090	2,740
Slovakia	1,000	133,100	21,150			155,250
Slovenia		170,000	22,000			192,000
South Africa	1,041,665	540,629	199,430	0	0	1,781,724
Spain	145,199	3,345,836	200,563			3,691,598
Sweden	170,410	256,121	71,734			498,265
Switzerland	202,820	1,248,810	114,180			1,565,810
Taiwan	1,937	1,531,413	127,834			1,661,184
Thailand***		169,113				169,113
Tunisia		769,054	70,104			839,158
Turkey		14,969,182	4,512,454	5,570		19,487,206
United Kingdom		622,468	169,783	22,100		814,351
United States	21,833,075	2,744,708	146,183	103,662	52,500	24,880,128
Uruguay		52,244				52,244
Zimbabwe		21,779	6,295			28,074
All other countries (5%)	1,926,319	6,836,057	22,289,616	44,554	37,522	31,134,068
TOTAL	38,526,374	136,721,149	445,792,329	891,087	750,430	622,681,370

Note: If no data is given: no reliable database for this collector type is available
* Total capacity in operation refers to the year 2014
** Total capacity in operation refers to the year 2009
*** Total capacity in operation is based on estimations for new installations in 2015
\# New included countries compared to the 2016 edition of this report
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
\+\+ The figures for India refer to fiscal year end (April 2015 – March 2016)

Table 2: *Total installed collector area in operation in 2015 [m²]*

The total installed capacity in operation in 2015 was divided into flat plate collectors (FPC): 95.7 GW_{th} (136.7 million square meters), evacuated tube collectors (ETC): 312.1 GW_{th} (445.8 million square meters), unglazed water collectors 27.0 GW_{th} (38.5 million square meters), and glazed and unglazed air collectors: 1.1 GW_{th} (1.6 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 22.0% and unglazed water collectors with 6.2%. Air collectors play only a minor role in the total numbers (**Figure 23**).

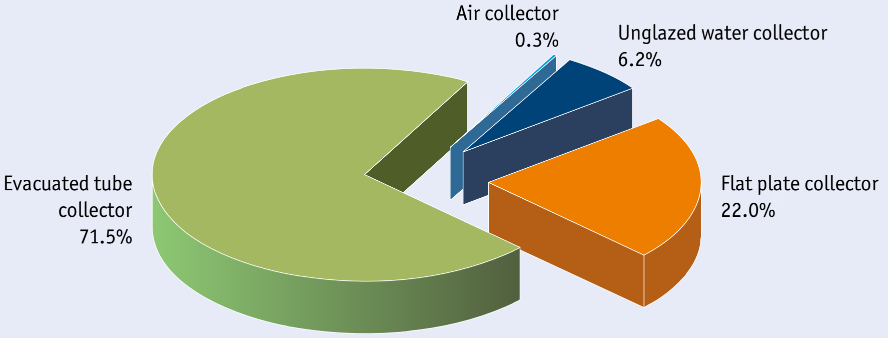


Figure 23: *Distribution of the total installed capacity in operation by collector type in 2015 - WORLD*

By contrast in Europe, the second largest marketplace for solar thermal collectors to China, flat plate collectors were much more widespread (**Figure 24**). Compared to 2014 the share of evacuated tube collectors increased in Europe by 1.5%.

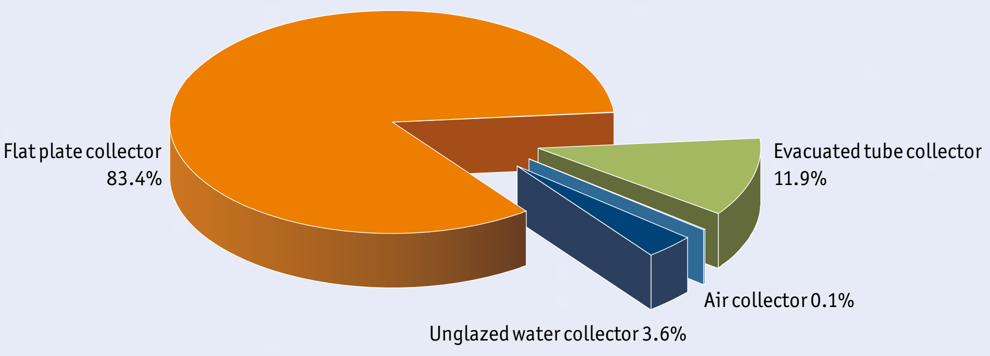


Figure 24: *Distribution of the total installed capacity in operation by collector type in 2015 - EUROPE*

22 The reduction of the total air collector capacity compared to the figures of 2014 is based on the fact that the glazed air collectors in Switzerland have reached the end of the service life time. The majority of these systems were used for agricultural hay drying.

Figure 25 shows the cumulated installed capacity of glazed and unglazed water collectors in operation for the 10 leading markets in 2015 in total numbers.

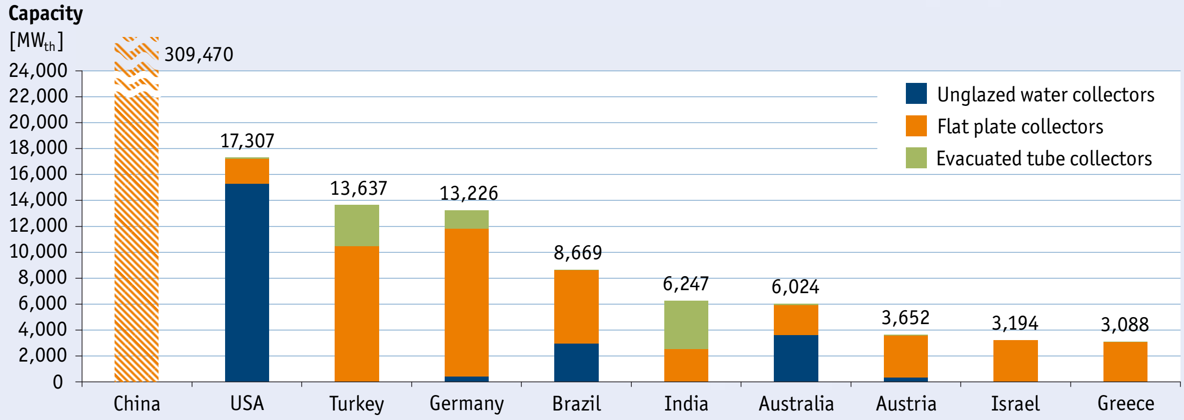


Figure 25: *Top 10 countries of cumulated water collector installations (absolute figures in MW_{th})*

Compared to the year 2014, the top 10 countries remained unchanged just the ranking the changed. Turkey overtook Germany and took the number three position and India overtook Australia and improved its position from seven to position six. This continued 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 in Australia, and to some extent in Brazil, unglazed water collectors play an important role. In the large European markets of 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 also remained unchanged compared to 2014. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2015 per 1,000 inhabitants were Barbados (489 kW_{th}/1,000 inhabitants), Austria (421 kW_{th}/1,000 inhabitants), Cyprus (400 kW_{th}/1,000 inhabitants), Israel (397 kW_{th}/1,000 inhabitants), Greece (287 kW_{th}/1,000 inhabitants), the Palestinian territories (276 kW_{th}/1,000 inhabitants), Australia (265 kW_{th}/1,000 inhabitants), China (226 kW_{th}/1,000 inhabitants), Turkey (172 kW_{th}/1,000 inhabitants) and Germany (164 kW_{th}/1,000 inhabitants).

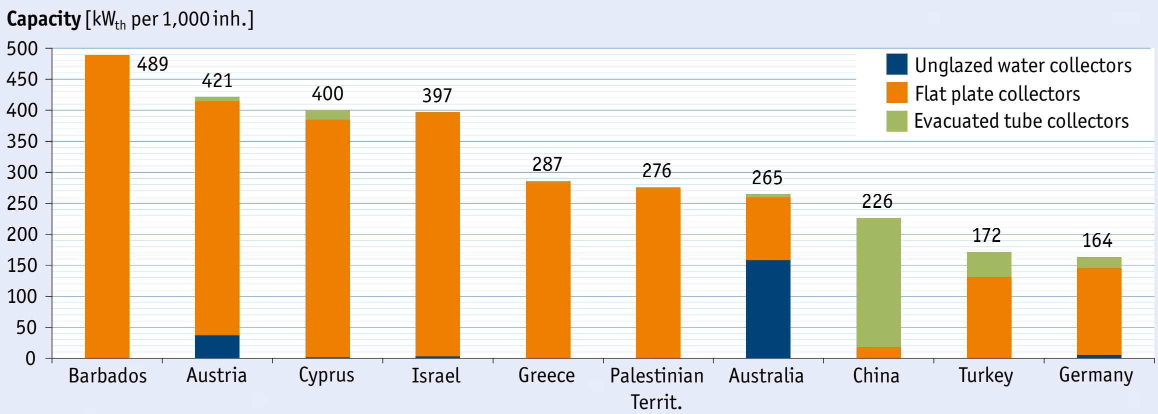


Figure 26: *Top 10 countries of cumulated water collector installations (relative figures in kW_{th} per 1,000 inhabitants)*

6.2 Total capacity of glazed water collectors in operation

With 309 GW_{th}, China was still by far the leader in terms of total installed capacity of glazed water collectors in 2015. 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, France, Poland, Mexico, the Palestinian Territories, South Korea and Taiwan had more than 1 GW_{th} of water collectors installed by the end of 2015 (**Figure** 27).

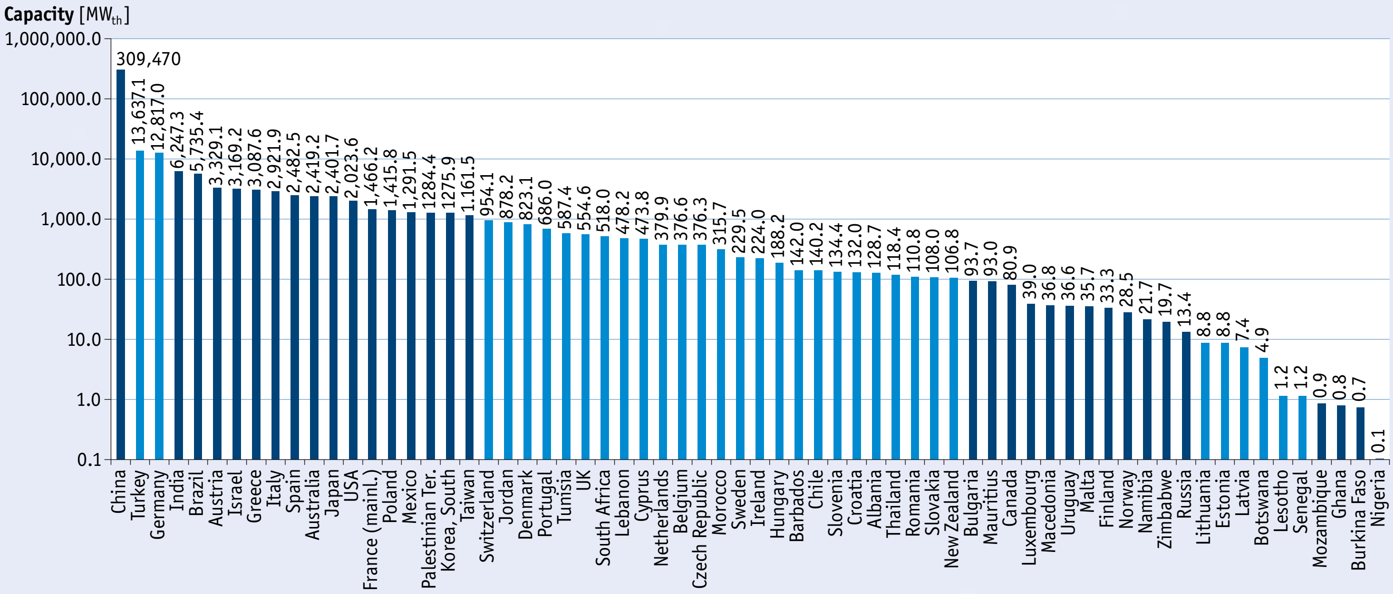


Figure 27: *Total capacity of glazed water collectors in operation by the end of 2015*

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, Denmark and Spain (**Figure 28**).

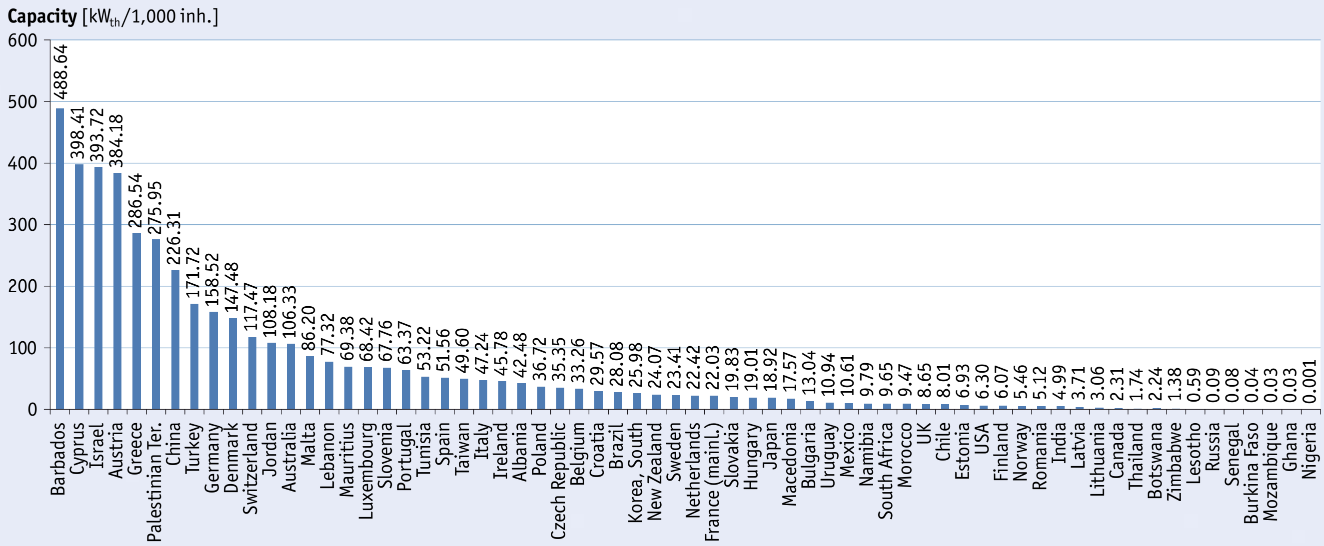


Figure 28: *Total capacity of glazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2015*

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

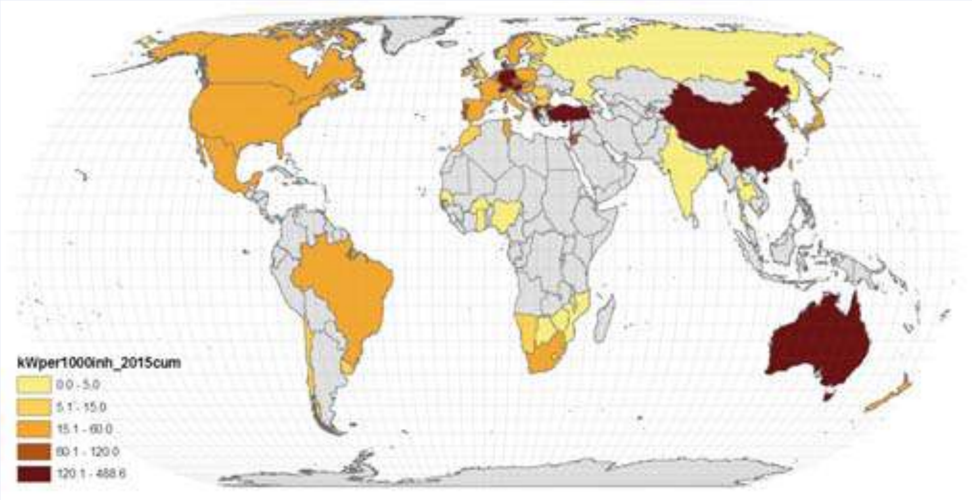


Figure 29: *Solar thermal market penetration per capita worldwide in kW_{th} per 1,000 inhabitants*

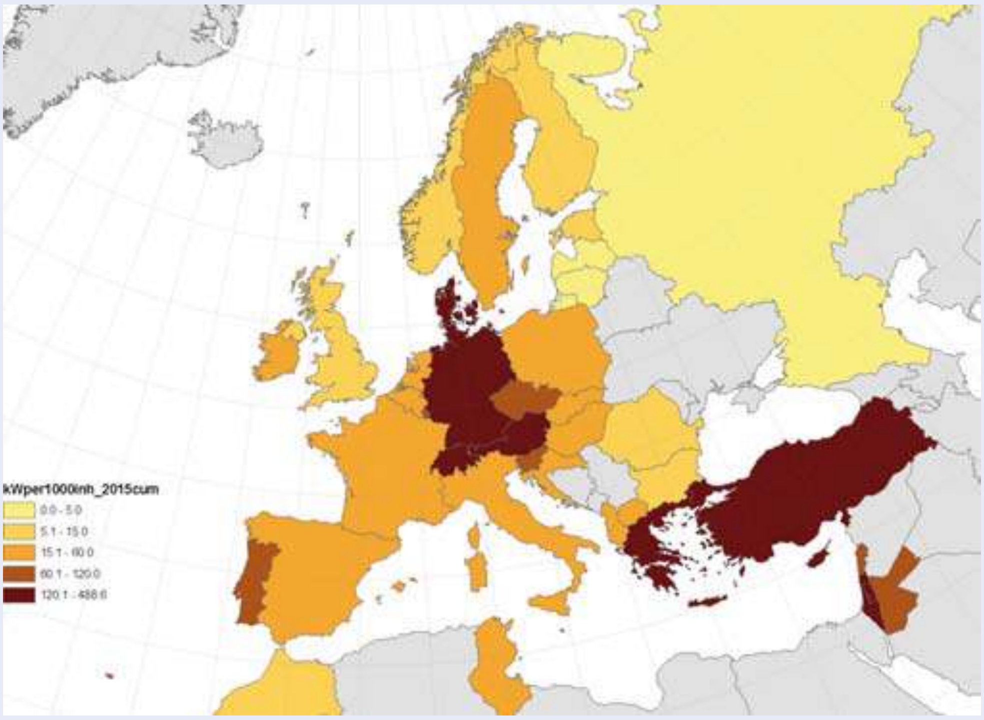


Figure 30: *Solar thermal market penetration per capita in Europe in kW_{th} per 1,000 inhabitants*

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

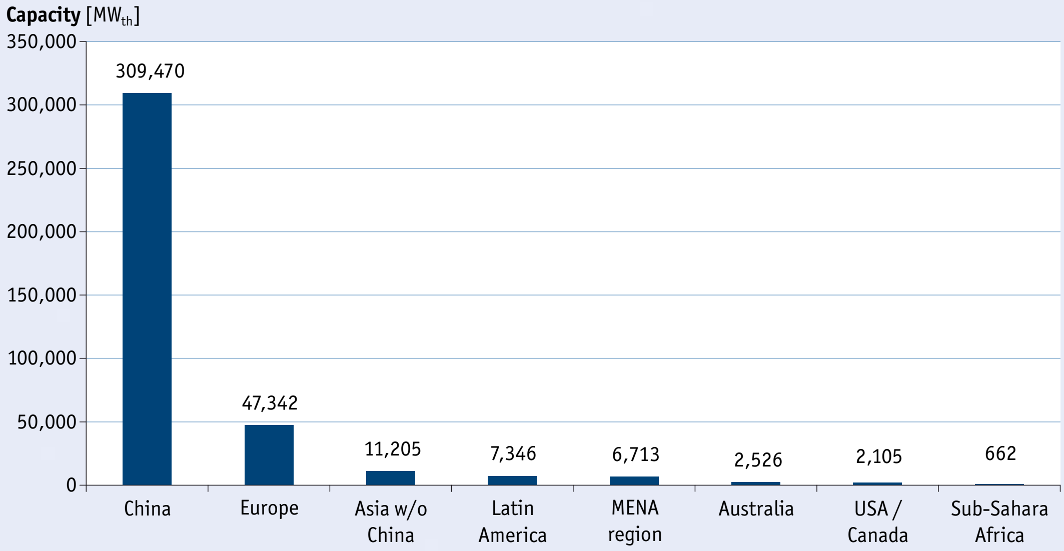
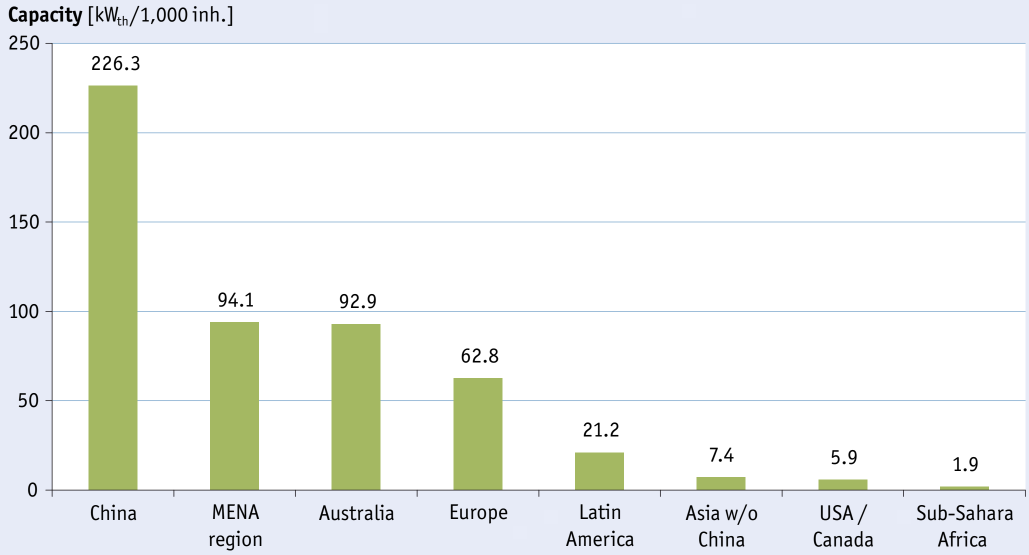


Figure 31: *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2015*

In terms of market penetration per capita by economic region, China again takes the lead. It is remarkable that in this point of view the MENA region and also Australia are ahead of Europe (**Figure 32**). This 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 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 region:	Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Figure 32: *Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in kW_{th} per 1,000 inhabitants in 2015*

6.4 Total capacity of unglazed water collectors in operation

Unglazed water collectors are mainly used for swimming pool heating. This type of collector 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 2015. **Figure 33** and **Figure 34** 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 2015.

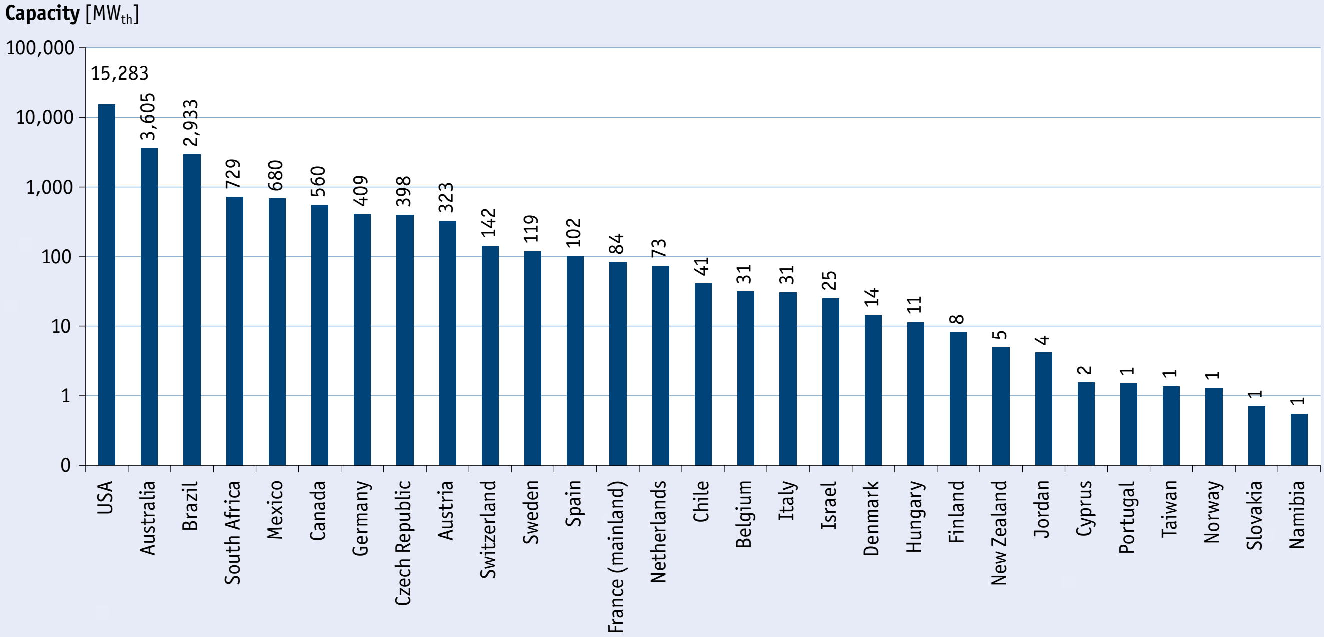


Figure 33: *Total capacity of unglazed water collectors in operation in 2015*

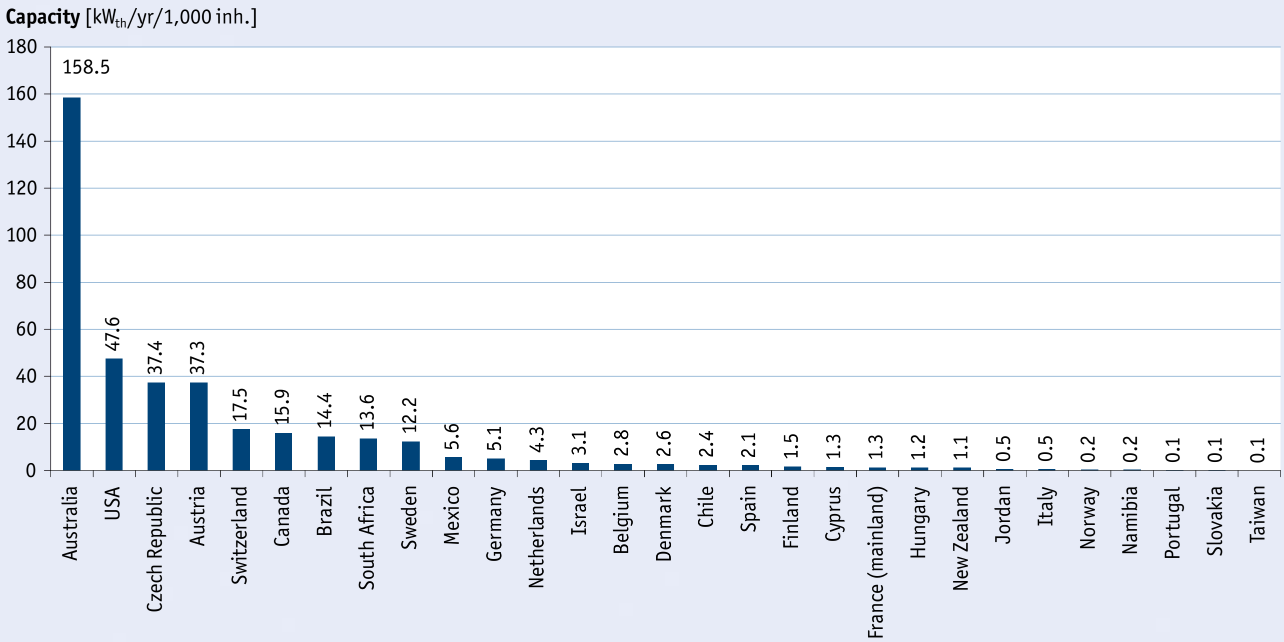


Figure 34: *Total capacity of unglazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2015*

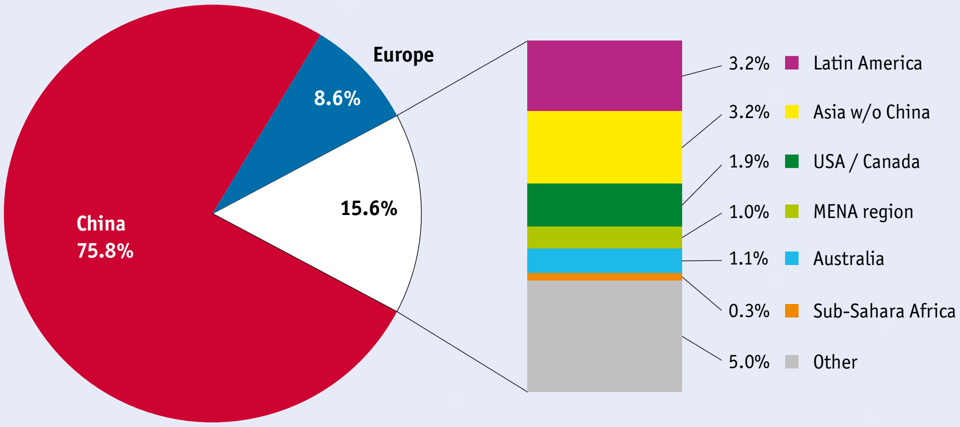
23 Solar Heat Worldwide (Ed.2008), Figure 3

6.5 New installed capacity in 2015 and market development

In the year 2015, a total capacity of 40.2 GW_{th}, corresponding to 57.4 million square meters of solar collectors, was installed world-wide. This means a decrease in new collector installations by 14% compared to the year 2014 (Figure 36).

The development of market growth from 2010 – 2015 is shown in Table 3. The year 2014 indicates the trend change. This was the first time a shrinking world market was observed, and has continued in 2015. Based on data already available for 2016, this trend seems likely to continue.

The main markets were in China (30.5 GW_{th}) and Europe (3.4 GW_{th}), which together accounted for 84% of the overall new collector installations in 2015. The rest of the market was shared between Latin America (1.3 GW_{th}), Asia excluding China (1.3 GW_{th}), the United States and Canada (0.8 GW_{th}), the MENA region (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 (2.0 GW_{th}).

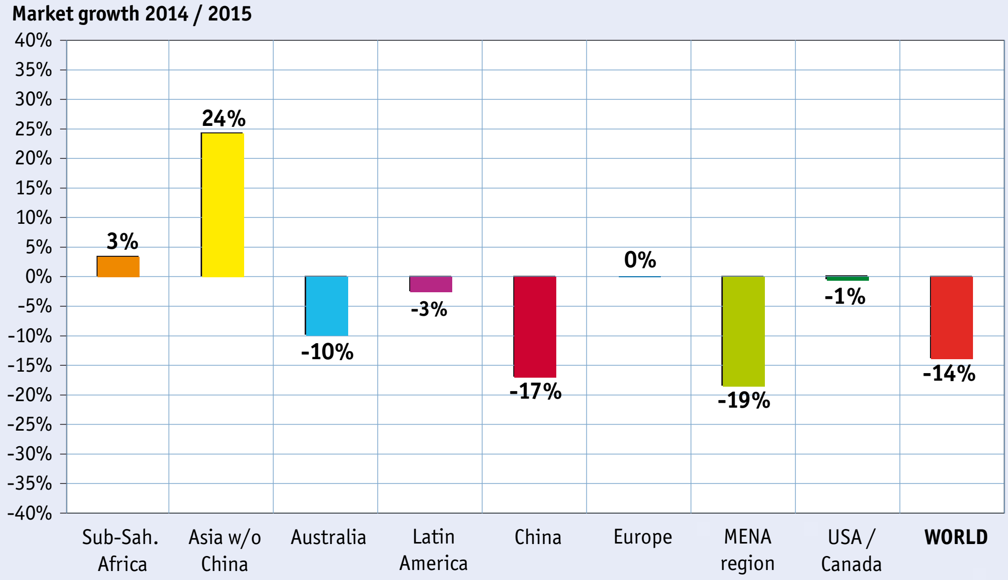


Sub-Sahara Africa:	Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia w/o China:	India, Japan, Korea South, Taiwan, Thailand
Latin America:	Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Macedonia, Norway, Russia, Switzerland,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

Figure 35: *Share of new installed capacity (glazed and unglazed water and air collectors) by economic regions in 2015*

From the top 10 markets in 2015 positive market development was reported from India (+31.8%), Turkey (+10.0%), Israel (+9.5%), Mexico (+7.8%) and Poland (+6.5%).The other major solar thermal markets within the top 10 countries namely China (–17.0%), Australia (–10.1%), Germany (–9.7%), Brazil (–2.7%) and the United States (–0.7%) suffered market declines.

In terms of economic regions, there was positive market growth in the period 2014/2015 in Asia (excluding China) and Sub-Sahara Africa. In Europe the market stagnated and in all other economic regions solar thermal system installations dropped (Figure 36).



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

Figure 36: *Market growth of new installed capacity (glazed and unglazed water collectors) 2014/2015 by economic region and worldwide*

The medium term market development in the different economic regions from 2010 – 2015 is shown in **Table 3** below. On the worldwide scale again the dominance of the Chinese market becomes obvious. The Chinese as well as the global market turned from significant growth rates in 2010/2011 to stagnation in 2012/2013 to negative growth rates starting in 2013/2014. The overall European markets showed slight declines, but stabilized again in the period 2014/2015. Besides Australia, which shows a clear downward trend, the markets in all other economic regions show ups and downs often driven by the introduction or abolishing of support measures.

	2010 / 2011	2011 / 2012	2012 / 2013	2013 / 2014	2014/15
Sub-Sahara Africa	↑ 30.2%	↘ –6.0%	↑ 19.2%	→ –1.0%	↗ 3.4%
Asia w/o China	↗ 8.0%	↑ 38.6%	↓ –20.3%	→ 2.9%	↑ 24.3%
Australia	↘ –8.9%	↘ –4.8%	↘ –9.1%	↓ –22.0%	↘ –9.9%
Latin America	↗ 6.0%	↑ 11.6%	↑ 16.2%	↗ 8.1%	→ –2.6%
China	↑ 17.6%	↗ 7.6%	→ 2.5%	↓ –17.6%	↓ –17.0%
Europe	→ 1.0%	↘ –7.4%	→ –2.5%	→ –2.9%	→ 0.1%
MENA Region	↗ 4.3%	↘ –4.1%	↑ 39.7%	↘ –4.9%	↓ –18.6%
United States / Canada	↓ –15.7%	→ 1.3%	↘ –4.6%	→ 0.5%	→ –0.6%
Other	14.3%	6.7%	1.9%	–15.2%	–13.9%
WORLD	↑ 14.3%	↗ 6.7%	→ 1.9%	↓ –15.2%	↓ –13.9%

Table 3: *Long term growths rates by economic region*

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		14.4	0.4			15
Australia	280.0	118.3	13.1	21.0	0.7	433
Austria	0.6	94.0	1.6		0.2	96
Barbados#		8.0				8
Belgium		26.8	4.7			32
Botswana		1.8				2
Brazil	427.0	537.1	17.5			982
Bulgaria		3.6	0.4			4
Burkina Faso#		0.7	0.1			1
Canada	15.8	1.9	2.4	10.2	9.8	40
Chile	7.0	17.6	7.4		0.1	32
China		3,850.0	26,600.0	0.1		30,450
Croatia		13.3	1.8			15
Cyprus		13.2	0.4			14
Czech Republic	21.0	15.4	6.3			43
Denmark		175.0	0.0	0.7		176
Estonia		0.7	0.7			1
Finland		2.3	1.2			4
France (mainland)+	1.4	64.1	3.4	0.5		69
Germany	17.5	511.7	52.5			582
Ghana#		0.1	0.0			0.1
Greece		189.7	0.4			190
Hungary	0.7	7.7	2.8	0.1	0.1	11
India++		123.4	965.7		0.7	1,090
Ireland		8.9	7.0			16
Israel	0.7	299.8	0.0			301
Italy		141.3	19.3			161
Japan		69.0	1.5		4.5	75
Korea, South		6.9	13.4			20
Latvia		1.1	0.2			1
Lebanon		14.9	22.8			38
Lesotho		0.05	0.10			0.1
Lithuania		0.6	1.0			2
Luxembourg		3.3	0.5			4
Macedonia		4.2	3.5			8
Malta		0.6	0.1			1
Mauritius*		6.2				6
Mexico	72.8	91.0	77.7			242
Mozambique	0.1	0.03	0.02			0.2
Namibia	0.5	3.4	0.00			4
Netherlands	1.8	12.3	2.8			17
Nigeria#		0.04	0.06			0.1
Norway		2.4	0.4			3
Palestinian Territories		34.3	0.2			34
Poland		157.5	36.4			194
Portugal		31.7	0.6			32
Romania		4.8	7.7			13
Russia		0.5	0.02			1
Senegal#			0.1			0.1
Slovakia		3.2	0.6			4
Slovenia		1.5	0.4			2
South Africa	55.3	20.3	16.8			92
Spain	2.4	158.7	7.8			169
Sweden	0.1	3.5	1.1			5
Switzerland	4.7	53.4	10.8			69
Taiwan		83.3	6.3			90
Thailand*		11.4				11
Tunisia		44.3				44
Turkey		749.7	717.3	0.7		1,468
United Kingdom		14.2	2.8			17
United States	585.0	113.5	5.9	7.4	7.7	719
Uruguay		4.2				4
Zimbabwe		0.2	2.0			2
All other countries (5%)	78.7	418.3	1,507.9	2	1	2,008
TOTAL	1,574	8,365	30,158	43	25	40,164

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)
# New included countries compared to the 2016 edition of this report
+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
++ The figures for India refer to fiscal year end (April 2015 – March 2016)

Table 4: *New installed capacity in 2015 [MW_{th}/a]*

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		20,574	544			21,118
Australia	400,000	169,000	18,700	30,000	1,000	618,700
Austria	890	134,260	2,320		270	137,740
Barbados#		11,430				11,430
Belgium		38,250	6,750			45,000
Botswana		2,500				2,500
Brazil	610,066	767,311	25,055			1,402,432
Bulgaria		5,100	500			5,600
Burkina Faso#		932	139			1,070
Canada	22,593	2,684	3,384	14,583	13,981	57,225
Chile	10,045	25,114	10,502		80	45,741
China		5,500,000	38,000,000	200		43,500,200
Croatia		19,000	2,500			21,500
Cyprus		18,800	600			19,400
Czech Republic	30,000	22,000	9,000			61,000
Denmark		250,000		1,000		251,000
Estonia		1,000	1,000			2,000
Finland		3,300	1,700			5,000
France (mainland)+	2,000	91,600	4,850	700		99,150
Germany	25,000	731,000	75,000			831,000
Ghana#		76	24			100
Greece		271,000	600			271,600
Hungary	1,000	11,000	4,000	150	150	16,300
India++		176,267	1,379,550		1,000	1,556,817
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
Mauritius*		8,880				8,880
Mexico	104,000	130,000	111,000			345,000
Mozambique	136	48	32			216
Namibia	780	4,802	3			5,585
Netherlands	2,621	17,548	3,971			24,140
Nigeria#	0	58	90	0	35	184
Norway		3,415	585			4,000
Palestinian Territories		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#	0	4	80	0	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*		16,251				16,251
Tunisia		63,223				63,223
Turkey		1,071,070	1,024,665	1,000		2,096,735
United Kingdom		20,322	3,967	500		24,789
United States	835,744	162,189	8,361	10,500	11,000	1,027,794
Uruguay		6,003				6,003
Zimbabwe		353	2,898			3,251
All other countries (5%)	112,401	597,501	2,154,112	3,086	1,790	2,868,890
TOTAL	2,248,019	11,950,020	43,082,243	61,719	35,795	57,377,797

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)
\# New included countries compared to the 2016 edition of this report
\+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered
++ The figures for India refer to fiscal year end (April 2015 – March 2016)

Table 5: *New installed collector area in 2015 [m²/a]*

New installations in 2015 are divided into flat plate collectors: 8.4 GW_{th} (12 million square meters), evacuated tube collectors: 30.2 GW_{th} (43.1 million square meters), unglazed water collectors: 1.6 GW_{th} (2.2 million square meters), and glazed and unglazed air collectors: 0.07 GW_{th} (0.1 million square meters).

With a share of 75.1%, evacuated tube collectors remain by far the most important solar thermal collector technology worldwide (**Figure 37**). In a global context, this breakdown is mainly driven by the dominance of the Chinese market where around 87% of all new installed collectors in 2015 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82% in 2011 to 75.1% in 2015 and in the same time frame flat plate collectors increased their share from 14.7% to 20.8%.

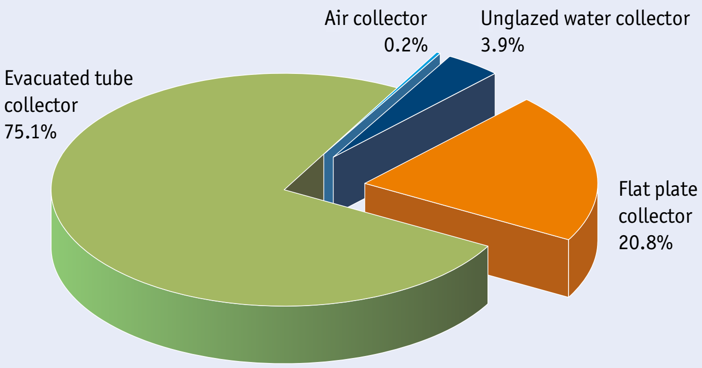
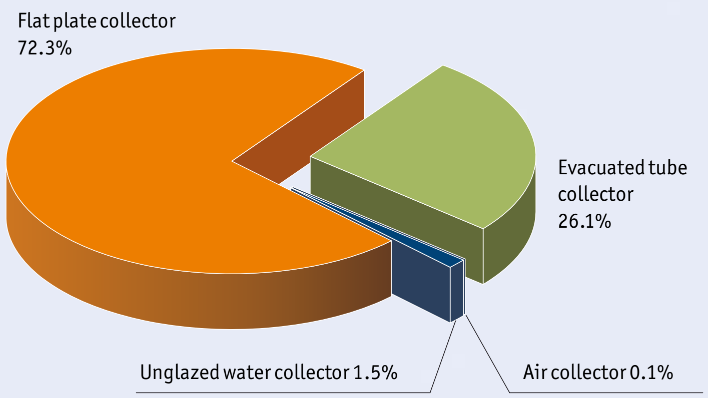


Figure 37: *Distribution of the new installed capacity by collector type in 2015 - WORLD*

In Europe the situation is almost the opposite compared to China with 72.3% of all solar thermal collectors installed in 2015 being flat plate collectors (**Figure 38**). In the medium term perspective, the share of flat plate collectors decreased in Europe from 81.5% in 2011 to 72.3% in 2015. While driven mainly by the markets in Turkey, Poland, Switzerland and Germany, evacuated tube collectors increased their share in Europe between 2011 and 2015 from 15.6% to 26.1%.



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

Figure 38: *Distribution of the new installed capacity by collector type in 2015 – EUROPE*

Figure 39 shows the new installed capacity of glazed and unglazed water collectors for the 10 leading markets in 2015 in total numbers. No big changes are observed in the top 10 countries compared to 2014. China remained the market leader in absolute terms followed by Turkey. Poland after 2013 entered again the top 10 countries and pushed Greece out of the leading countries. Germany faced a significant market decline the fourth year in a row, but held on to its sixth position rank.

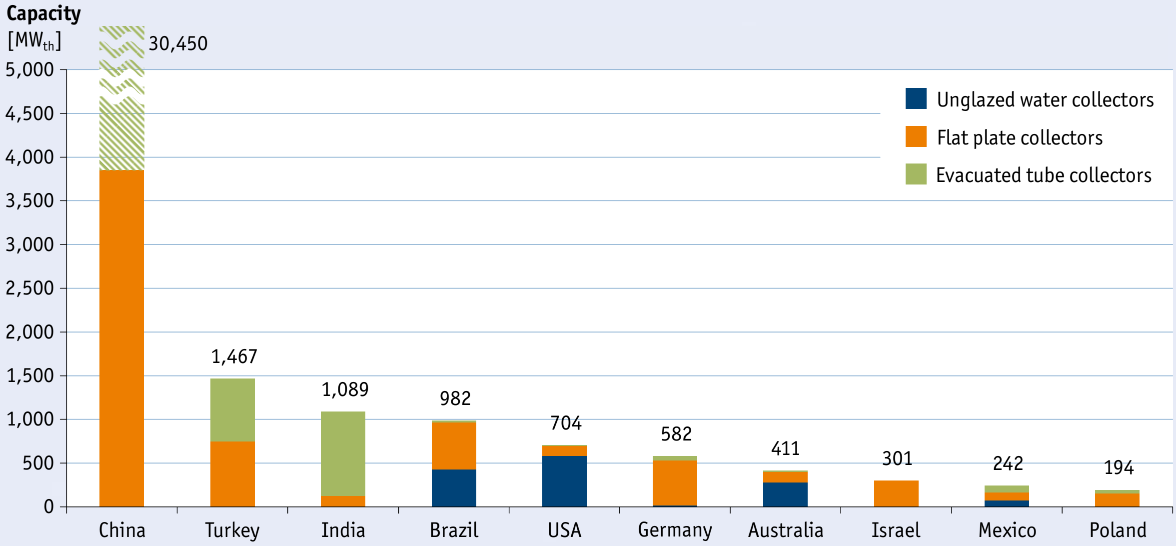


Figure 39: *Top 10 markets for glazed and unglazed water collectors in 2015 (absolute figures in MW_{th})*

In terms of new installed solar thermal capacity per 1,000 inhabitants in 2015, the top 10 countries remained the same as in 2014; and Israel kept the lead position. Fast climbers in 2015 were Denmark, which overtook China and the Palestinian Territories (West Bank and Gaza Strip) and now ranks second behind Israel. Turkey jumped from ranking seventh in 2014 to ranking fifth; and China slipped from second place in 2014 to fourth.

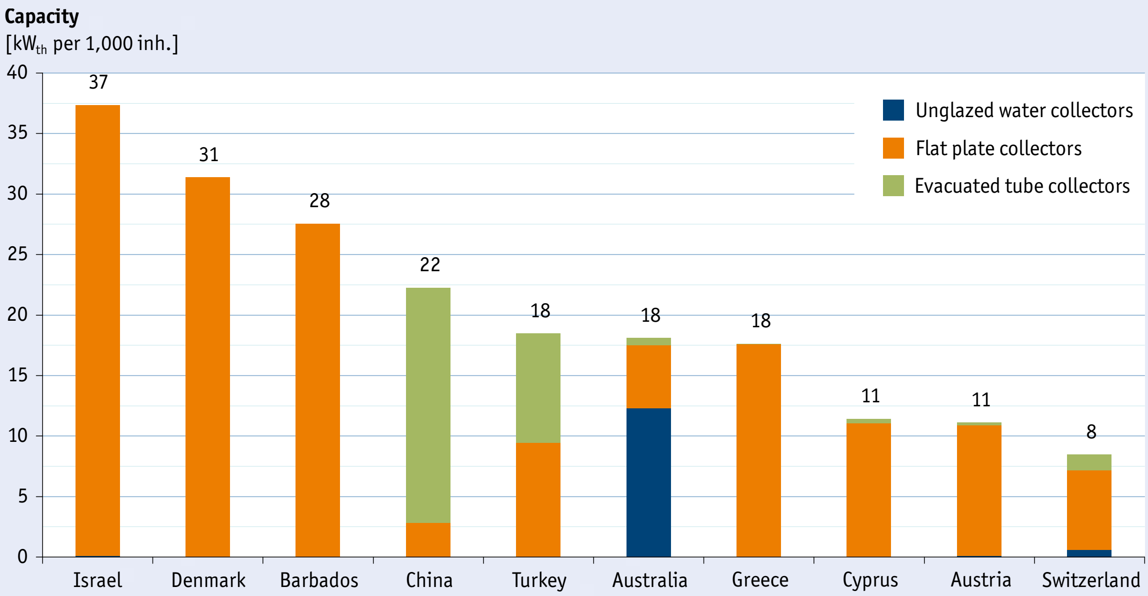


Figure 40: *Top 10 markets for glazed and unglazed water collectors in 2015 (relative figures in kW_{th} per 1,000 inhabitants)*

6.6 New installed capacity of glazed water collectors

In 2015 glazed water collectors accounted for 95.9% of the total new installed capacity with a market share of 79%. China was the most influential market in the global context (**Figure 41**).

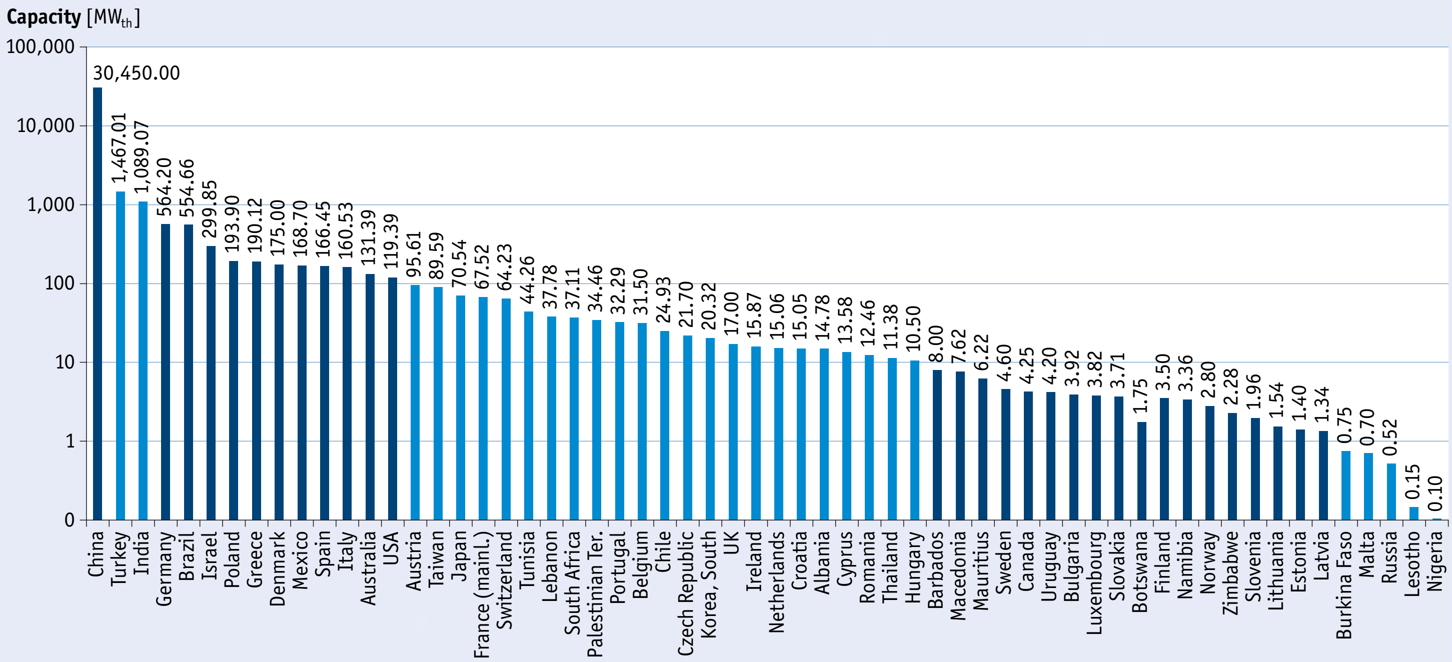


Figure 41: *New installed capacity of glazed water collectors in 2015*

In terms of new installed glazed water collector capacity per 1,000 inhabitants, Israel is the leader ahead of Denmark and Barbados. In this respect China ranks in the fourth place (**Figure 42**).

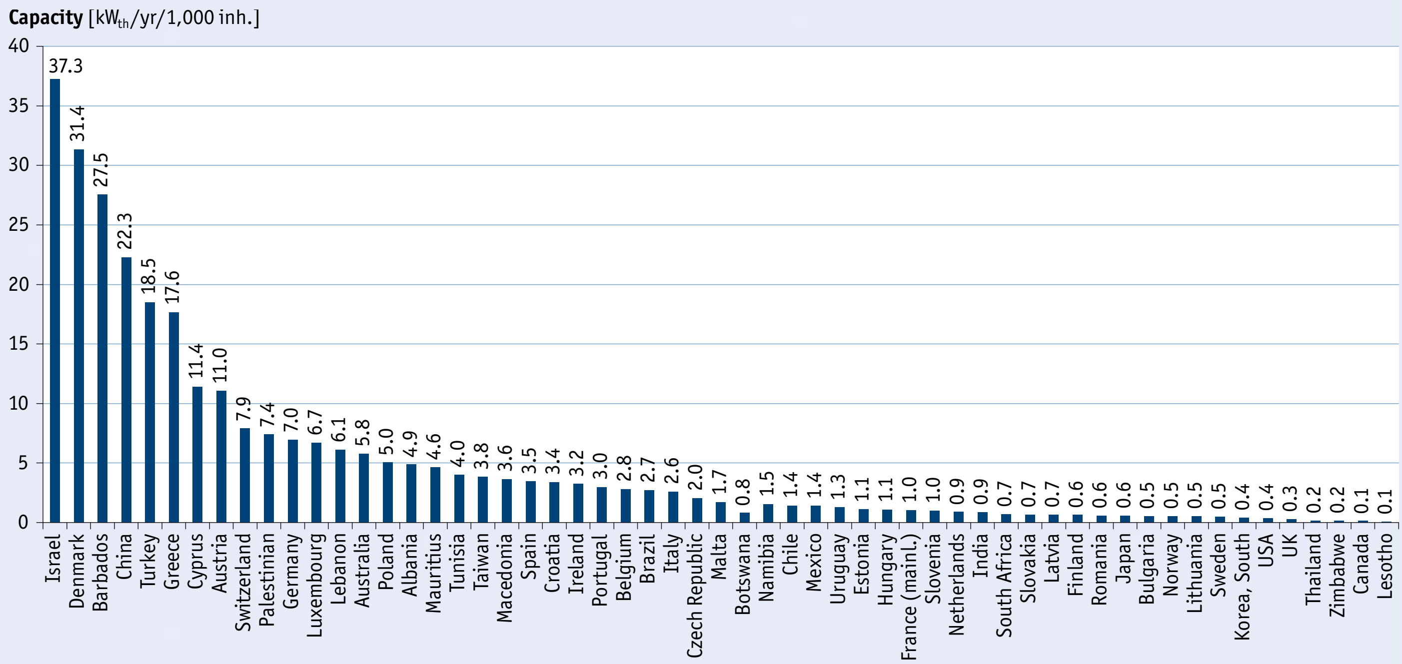


Figure 42: *New installed capacity of glazed water collectors in 2015 in kW_{th} per 1,000 inhabitants*

6.7 Market development of glazed water collectors between 2000 and 2015

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, which showed again a market decline of –14%.

The new installed glazed water collector capacity in 2015 amounted to 38.5 GW_{th} (**Figure 43**).

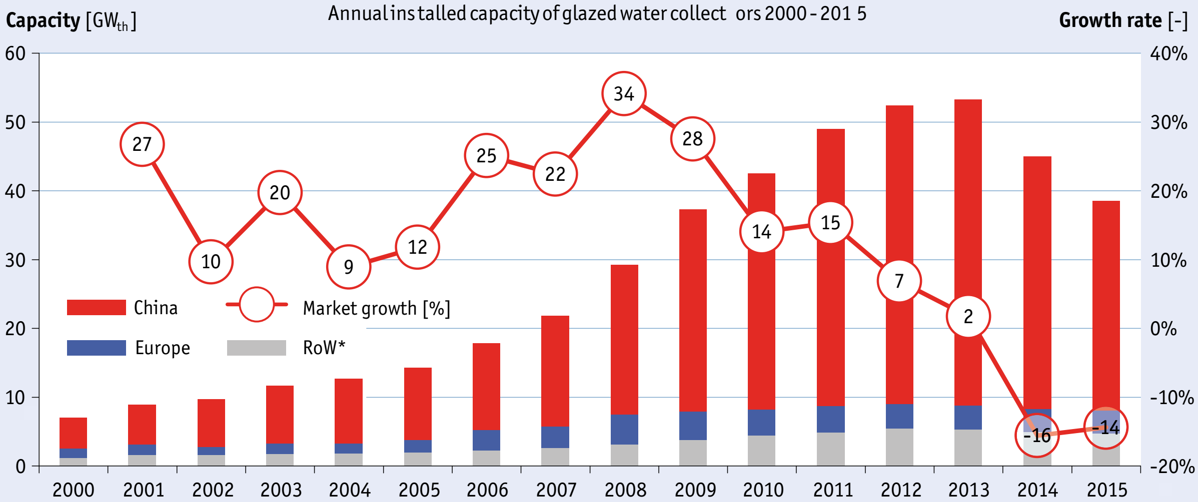


Figure 43: *Global market development of glazed water collectors from 2000 to 2015*

In 2000 the Chinese market was about three times as large as the European market while in 2015 the Chinese market exceeded the European market nine-fold (**Figure 44**).

It can be also seen in **Figure 44** 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 already had a low growth rate in 2012 and 2013 and shrank significantly in 2014 and 2015.

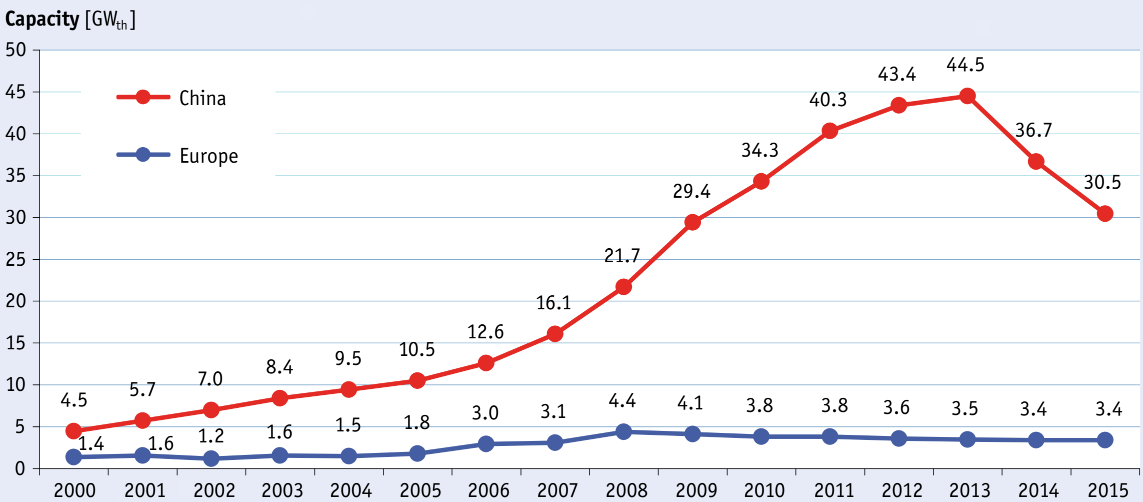
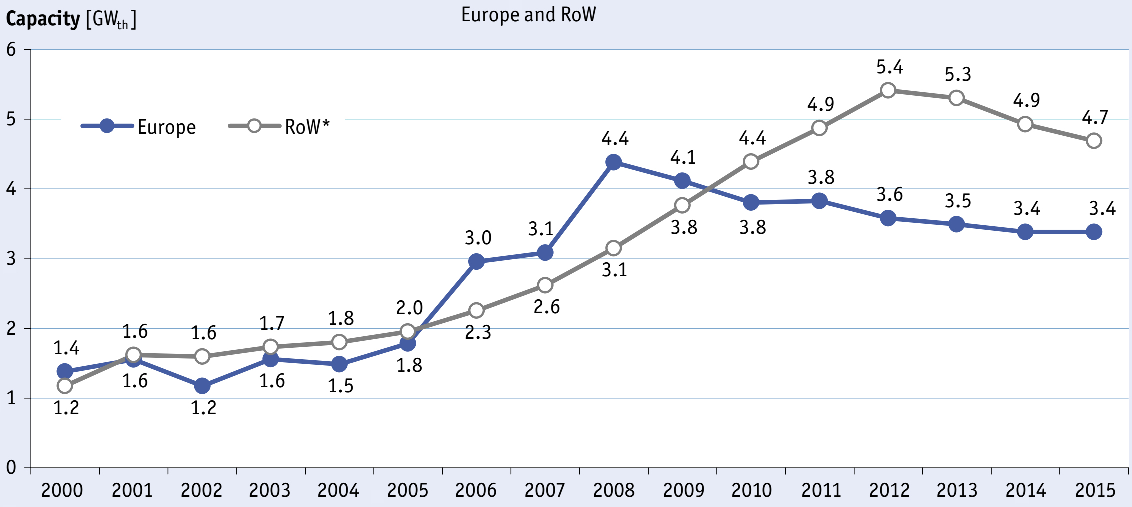


Figure 44: *Market development of glazed water collectors in China and Europe*

The European market peaked at 4.4 GW_{th} installed capacity in 2008 and has decreased steadily down to 3.4 GW_{th} where it remains for the second year. In the remaining markets worldwide (RoW) an upward trend could be observed between 2002 and 2012 and a falling tendency since 2013 (**Figure 45**).



Europe:	EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey
Rest of World (RoW):	Asia (India, Japan, Korea South, Taiwan, Thailand), Australia, Canada, USA
Latin America:	Brazil, Chile, Mexico, Uruguay
MENA region:	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 45: *Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2015*

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 region hold the largest market shares (see **Figure 46**).

"Asia w/o 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 2015. In sum this led to a market increase of 24% in the period 2014/2015.

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 (2009 – 2014). In 2015 a slight market decrease of –0.5% was recorded.

Glazed water collector markets in the MENA region were characterized by steady growth from 2000 to 2013. The market decline since 2014, which is shown in **Figure 46**, is explained by the fact that no 2015 data were received from two major markets namely Morocco and Jordan. The sales numbers in the most important market, Israel, increased in 2015.

The market volume for glazed water collectors in Australia was similar to the volume in Latin America and the MENA region in 2009 and continued to shrink more or less through 2015. In 2015, a slight decrease of 2.3% was reported.

Sub-Sahara African markets showed a decrease of 35% in 2015. Also in the United States and Canada the decreasing trend continued for the third year in a row (–7.2% in 2015).

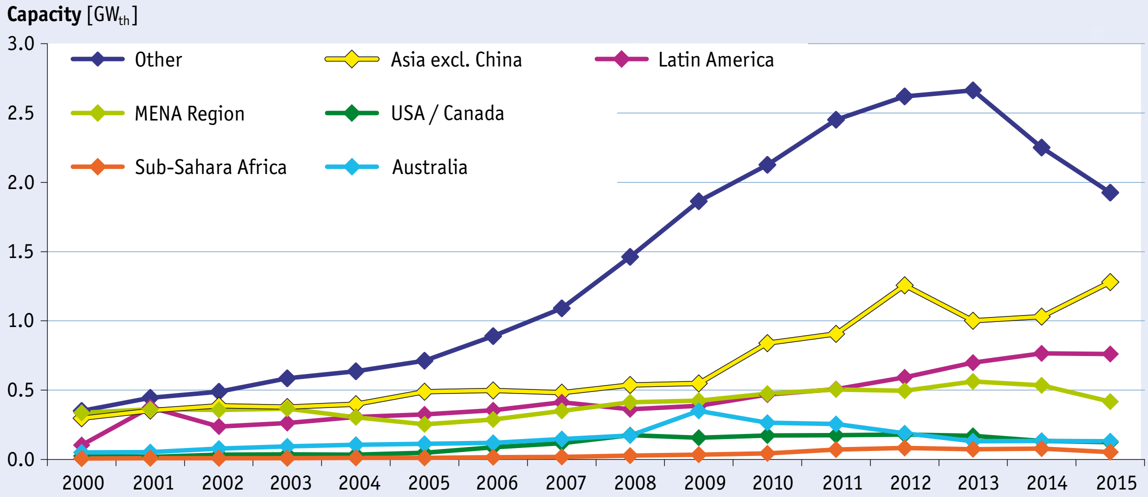


Figure 46: *Market development of glazed water collectors in Rest of World (excluding China and Europe) from 2000 to 2015*

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 5.3 kW_{th} per 1,000 inhabitants in 2015 (**Figure 47**).

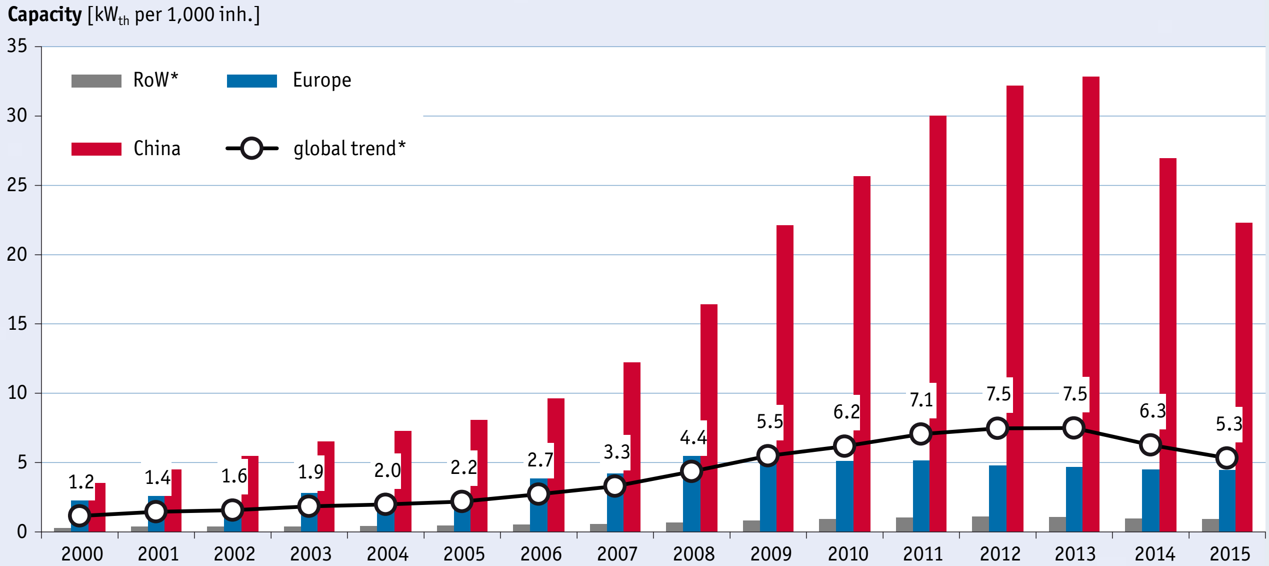


Figure 47: *Annual installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2015*

The fact that China suffered from major market declines in 2014 and 2015 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 22.3 kW_{th} per 1,000 inhabitants in 2015. Compared to 2014 when China ranked second, in 2015 it fell to fourth position behind Israel Denmark and Barbados as can be seen in **Figure 42**.

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 at 4.5 kW_{th} per 1,000 inhabitants in 2014 and 2015.

6.8 Market development of unglazed water collectors between 2000 and 2015

With a new installed capacity of 1.57 GW_{th} in 2015, unglazed water collectors accounted for 3.9% of the total installed solar thermal capacity (Figure 37). Compared to the year 2014 the market decreased by –3.1%.

The most important markets for unglazed water collectors in 2015 were the United States (585 MW_{th}), Brazil (427 MW_{th}), Australia (280 MW_{th}), Mexico (73 MW_{th}) and South Africa (55 MW_{th}) which accounted for 90% of the recorded unglazed water collector installations worldwide. Another 4% were installed in the Czech Republic (21 MW_{th}), Canada (16 MW_{th}), Germany (18 MW_{th}) and Chile (7 MW_{th}).

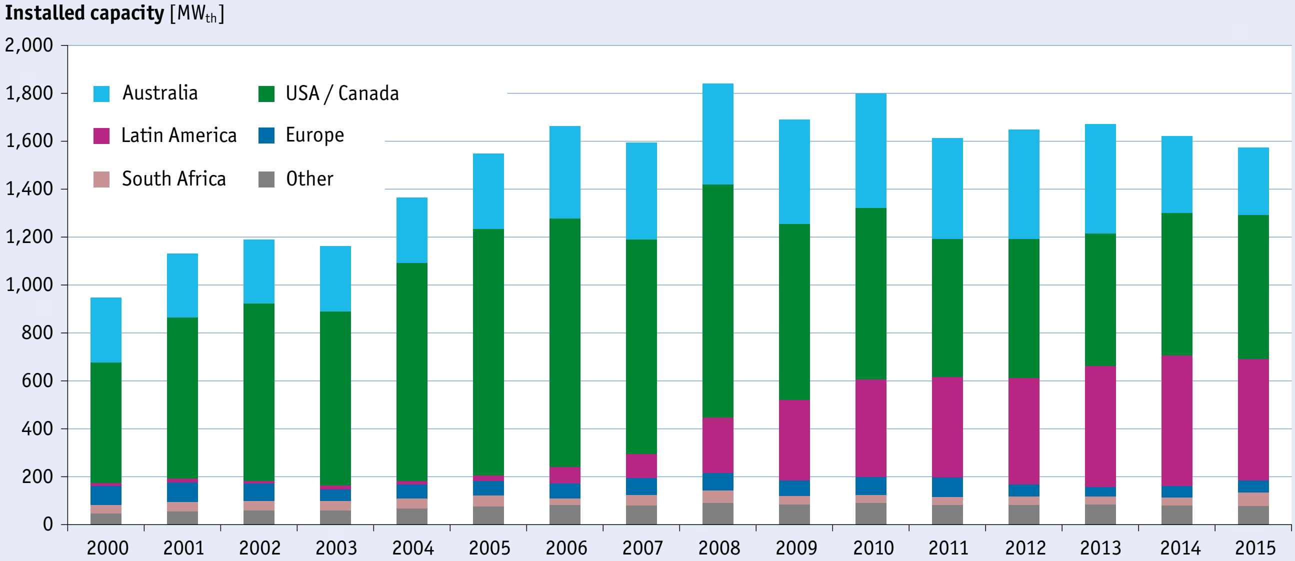


Figure 48: *Global market development of unglazed water collectors from 2000 to 2015*

The unglazed water collector market in the United States peaked in 2006 (1.01 GW_{th}) and has almost halved since then (0.58 GW_{th} in 2015). 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 has grown steeply since then. Australia 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.

7 Contribution to the energy supply and CO_2 reduction in 2015

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 1. The contribution of the total installed air collector capacity in operation in 2015 of 1.1 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 2015 in the 66 recorded countries was 357 TWh (= 1,286 PJ). This corresponds to a final energy savings equivalent of 38.4 million tons of oil and 124 million tons of CO_2. The calculated number of different types of solar thermal systems in operation was around 108 million (Table 6).

The most important field of application for solar thermal systems is domestic hot water heating (see section 8.3), and therefore, this type of application also accounted for the highest savings in terms of oil equivalent and CO_2. In 2015, 94 % of the energy provided by solar thermal systems worldwide was used for heating domestic hot water, mainly by small-scale systems in single-family houses (68 %) and larger applications attached to multi-family houses, hotels, schools, etc. (26 %). Swimming pool heating held a share of 4 % in the contribution to the energy supply and CO_2 reduction and the remaining 2 % were met by solar combi-systems.

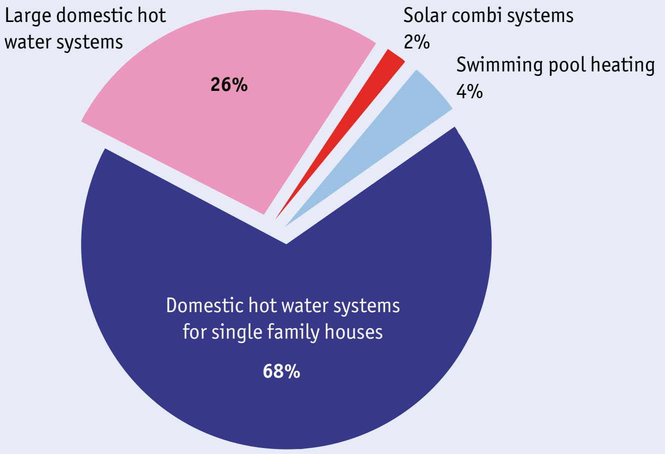


Figure 49: *Share of energy savings and CO_2 reduction by type of application of glazed and unglazed water collectors in operation in 2015*

Table 6 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 2015.

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	183,815	129	34,195	130	13,931	44,971
Australia	8,606,000	6,024	1,092,864	5,345	574,515	1,854,536
Austria	5,217,763	3,652	519,442	2,110	226,741	731,920
Barbados	202,860	142	50,715	179	19,241	62,111
Belgium	583,033	408	101,463	232	24,911	80,413
Botswana	7,000	5	1,050	4	434	1,400
Brazil	12,383,765	8,669	3,708,037	8,080	868,494	2,803,499
Bulgaria	133,900	94	23,302	66	7,091	22,889
Burkina Faso#	1,070	1	37	0	16	50
Canada	915,293	641	15,604	373	40,105	129,459
Chile	259,148	181	34,959	184	19,789	63,878
China	442,100,000	309,470	74,935,950	247,814	26,635,189	85,978,389
Croatia	188,592	132	32,820	95	10,188	32,887
Cyprus	679,047	475	296,804	604	64,872	209,407
Czech Republic	1,105,512	774	77,183	368	39,596	127,816
Denmark	1,196,416	837	109,607	506	54,373	175,518
Estonia***	12,520	9	2,179	5	540	1,743
Finland	59,323	42	10,324	24	2,584	8,340
France (mainland)+	2,214,500	1,550	462,479	1,044	112,167	362,076
Germany	18,894,700	13,226	2,218,962	7,693	826,900	2,669,234
Ghana#	1,137	1	25	0	10	33
Greece	4,410,900	3,088	1,177,577	3,072	330,228	1,065,977
Hungary	285,100	200	40,995	129	13,838	44,670
India++	8,924,717	6,247	3,930,668	7,706	828,296	2,673,741
Ireland	319,946	224	74,046	134	14,398	46,476
Israel	4,563,434	3,194	1,461,212	4,215	453,004	1,462,298
Italy	4,217,924	2,953	734,033	2,574	276,606	892,885
Japan	3,431,069	2,402	833,894	1,988	213,719	689,884
Jordan*	1,260,506	882	223,109	1,194	128,286	414,108
Korea, South	1,822,646	1,276	417,568	942	101,270	326,900
Latvia	10,532	7	1,833	4	480	1,550
Lebanon	683,133	478	75,486	566	60,805	196,277
Lesotho	1,653	1	179	0	35	113
Lithuania	12,600	9	2,193	5	567	1,829
Luxembourg	55,736	39	9,700	24	2,534	8,181
Macedonia	52,603	37	11,999	33	3,498	11,290
Malta	50,976	36	13,609	41	4,397	14,195
Mauritius***	132,793	93	88,529	113	12,183	39,325
Mexico	2,817,077	1,972	332,818	1,612	173,212	559,127
Morocco*	451,000	316	60,900	383	41,146	132,821
Mozambique	1,359	1	340	1	124	400
Namibia	31,718	22	3,917	29	3,110	10,038
Netherlands	647,397	453	154,088	258	27,771	89,646
New Zealand**	159,645	112	32,703	99	10,592	34,191
Nigeria#	149	0	27	0	10	33
Norway	46,506	33	2,118	16	1,682	5,428
Palestine	1,834,850	1,284	630,026	1,712	183,973	593,865
Poland	2,022,590	1,416	254,509	826	88,772	286,557
Portugal	982,082	687	178,027	758	81,494	263,061
Romania	158,690	111	27,616	88	9,419	30,405
Russia	19,212	13	898	8	860	2,777
Senegal#	1,650	1	400	2	168	542
Slovakia	155,250	109	19,001	72	7,790	25,146
Slovenia	192,000	134	29,037	80	8,586	27,715
South Africa	1,781,724	1,247	747,798	1,271	136,614	440,989
Spain	3,691,598	2,584	434,317	2,574	276,693	893,164
Sweden	498,265	349	37,831	182	19,573	63,182
Switzerland	1,565,810	1,096	189,448	618	66,464	214,544
Taiwan	1,661,184	1,163	327,934	1,010	108,603	350,571
Thailand***	169,113	118	38,647	142	15,256	49,247
Tunisia	839,158	587	254,053	757	81,343	262,574
Turkey	19,481,636	13,637	4,500,258	17,478	1,878,598	6,064,113
United Kingdom	792,251	555	137,873	308	33,085	106,800
United States	24,723,966	17,307	455,333	11,062	1,188,914	3,837,815
Uruguay	52,244	37	13,061	36	3,827	12,354
Zimbabwe	28,074	20	7,019	24	2,577	8,320
All other countries (5%)	31,051,993	21,736	6,395,877	18,353	1,972,617	6,367,608
TOTAL	621,039,853	434,728	108,090,504	357,355	38,408,705	123,983,301

Note: If no data is given: no reliable database for this collector type is available
** Total capacity in operation refers to the year 2009
# New included countries compared to the 2016 edition of this report
++ The figures for India refer to fiscal year end (April 2015 – March 2016)
* Total capacity in operation refers to the year 2014
*** Total capacity in operation is based on estimations for new installations in 2015
+ The figures for France relate to mainland France only, overseas territories of France (DOM) are not considered

Table 6: *Calculated annual collector yield and corresponding oil equivalent and CO_2 reduction of glazed and unglazed water collectors in operation by the end of 2015*

In Chapters 7.1 to 7.3, the annual collector yield, energy savings and CO_2 savings by economic regions and worldwide are graphed.

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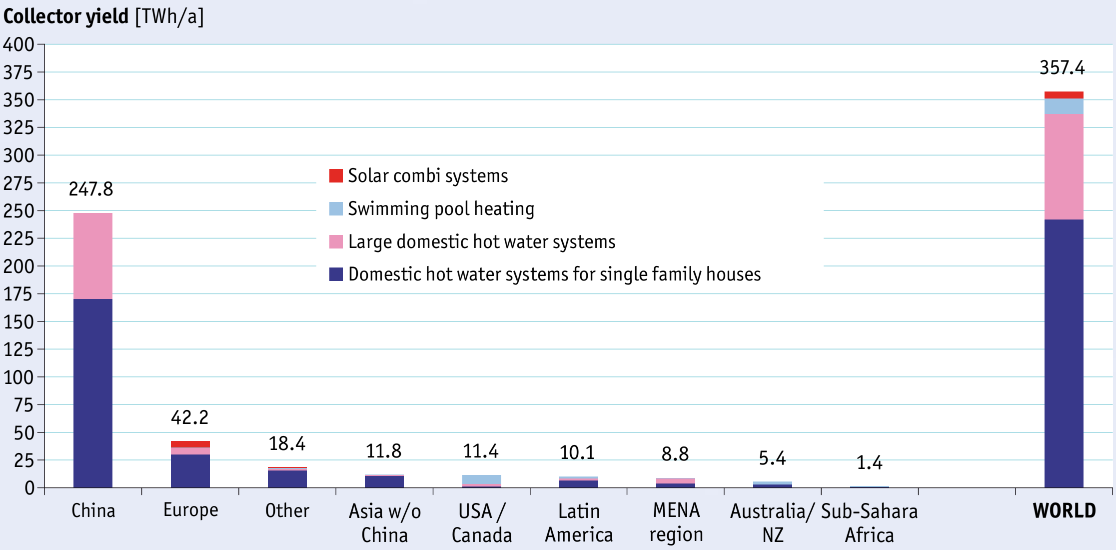
7.1 Annual collector yield by economic region

In 2015, gross solar thermal collector yields amounted to 357 TWh worldwide (Table 6) and the major share, 68%, was contributed by domestic hot water applications for single-family houses (Figure 49).

China accounted for 69% of the thermal energy gains (248 TWh), Europe for 12% (42 TWh) and the Rest of the World for 19% (67 TWh) (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 region:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

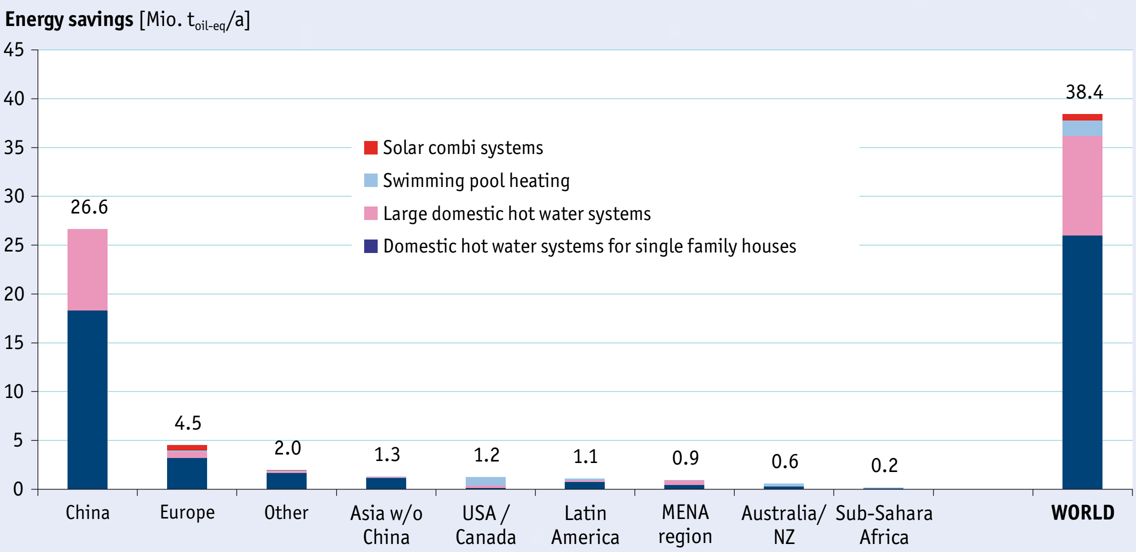
Figure 50: *Annual collector yield of unglazed and glazed water collectors in operation in 2015*

Photo: AEE INTEC

7.2 Annual energy savings by economic region

Considering an 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 446.7 TWh or 38.4 million tons of oil equivalent in 2015[24].

The breakdown shows that China accounted for 26.6 million tons oil equivalent, Europe for 4.5 million tons oil equivalent, and the rest of the world for 7.3 million tons oil equivalent (**Figure 51**).



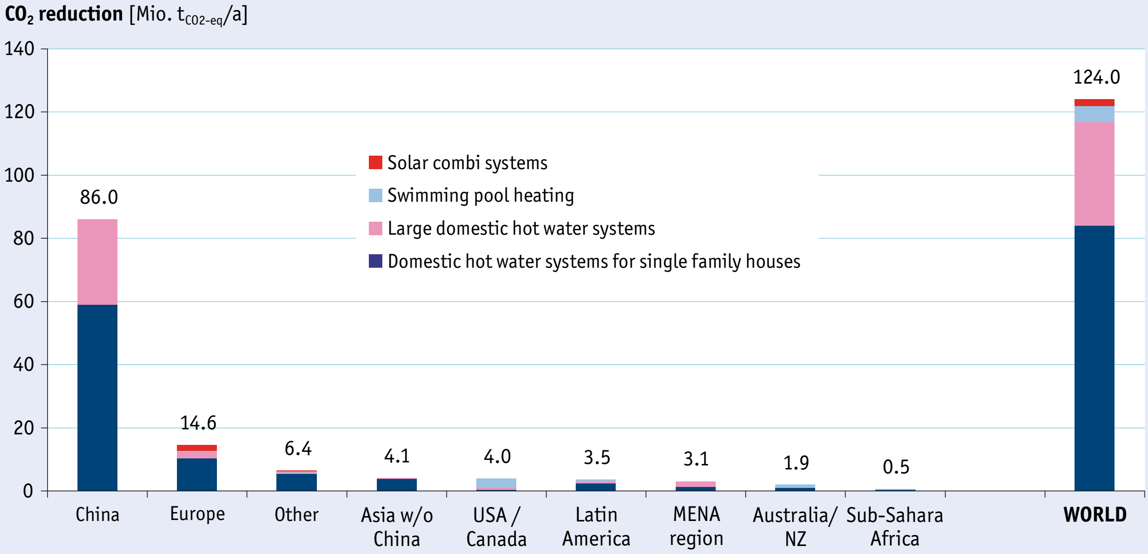
Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China: India, Japan, South Korea, Taiwan Thailand
Latin America: Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 28, Albania, Macedonia, Norway, Russia, Switzerland,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

Figure 51: *Annual energy savings in oil equivalent by unglazed and glazed water collectors in operation in 2015*

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

7.3 Annual contribution to CO_2 reduction by economic region

38.4 million tons of oil equivalents correspond to an annual CO_2 emission reduction of 124 million tons[25]. Here, the breakdown was China 86.0 million tons of CO_2e, Europe 14.6 million tons of CO_2e, and the rest of the world 23.4 million tons of CO_2e (see Figure 52).



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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 region:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 52: *Contribution to CO_2 reduction by unglazed and glazed water collectors in operation in 2015*

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

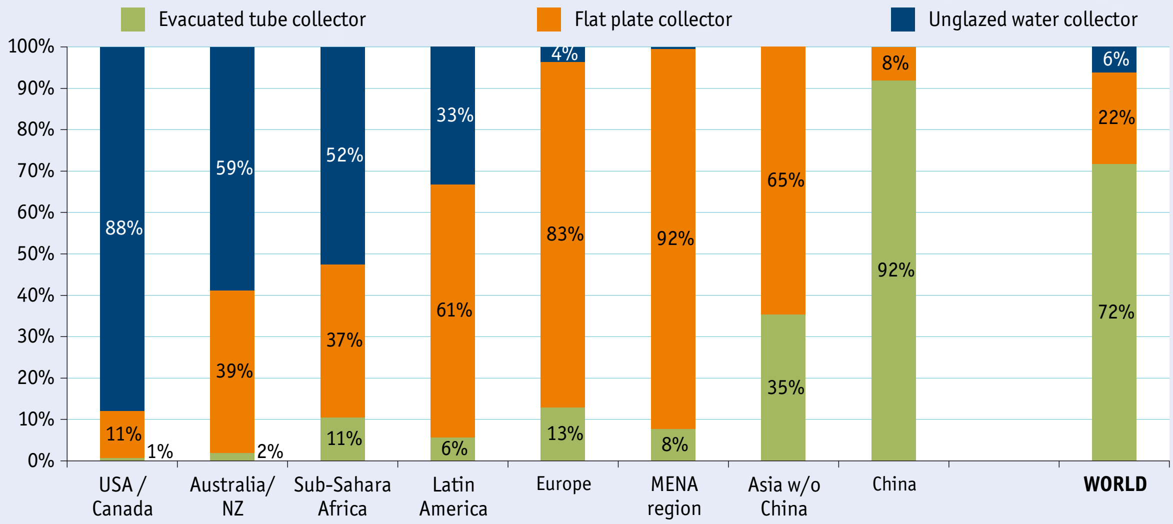
8 Distribution of systems by type and application in 2015

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 8.1 to 8.3, the share of these system types and applications are shown by different economic regions for both the cumulated capacity in operation in 2015 and the new installed capacity in 2015[26].

8.1 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 53) and a share of 75% of the new installed capacity (Figure 54). On the worldwide scale flat plate collectors accounted for 22 % of the cumulated capacity in operation (Figure 53) and a share of 21% of the new installed capacity (Figure 54). Unglazed water collectors accounted for 6% of the cumulated water collectors installed worldwide and for 4% of the new installed capacity.
In all economic regions besides China (evacuated tube collector) 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
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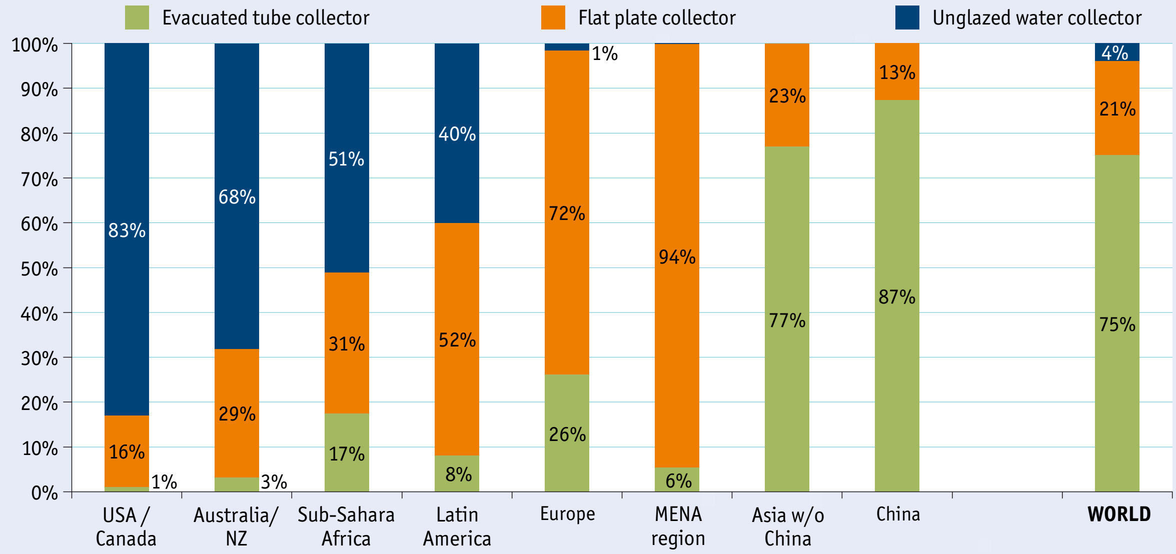
Europe: EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey
MENA region: Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 53: Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2015

26 It has to be considered that statistical information summarized in Chapters 6.1 to 6.4 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.



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

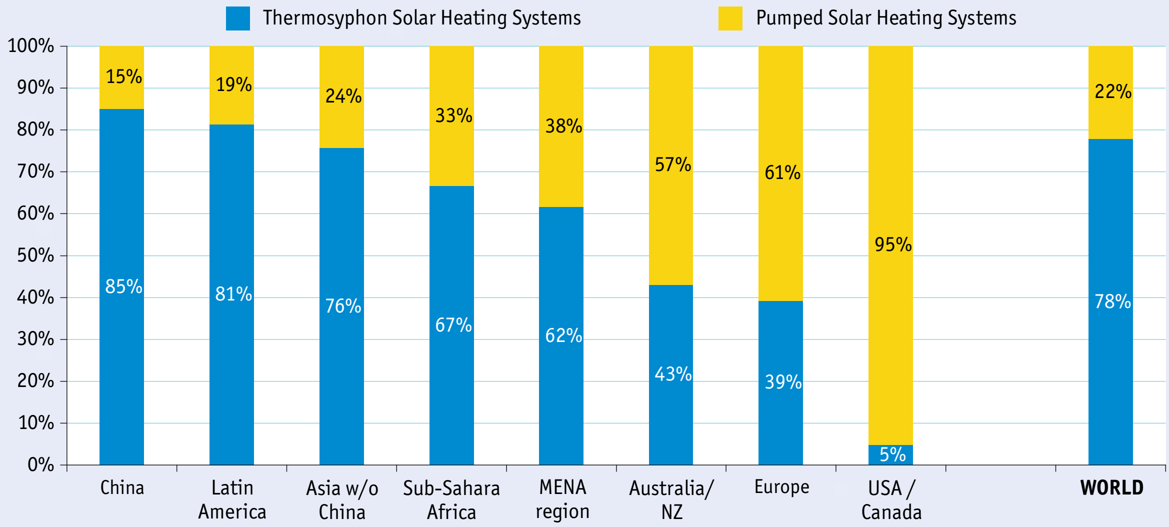
Figure 54: *Distribution by type of solar thermal collector for the new installed water collector capacity in 2015*

Photo: AEE INTEC

8.2 Distribution by type of system

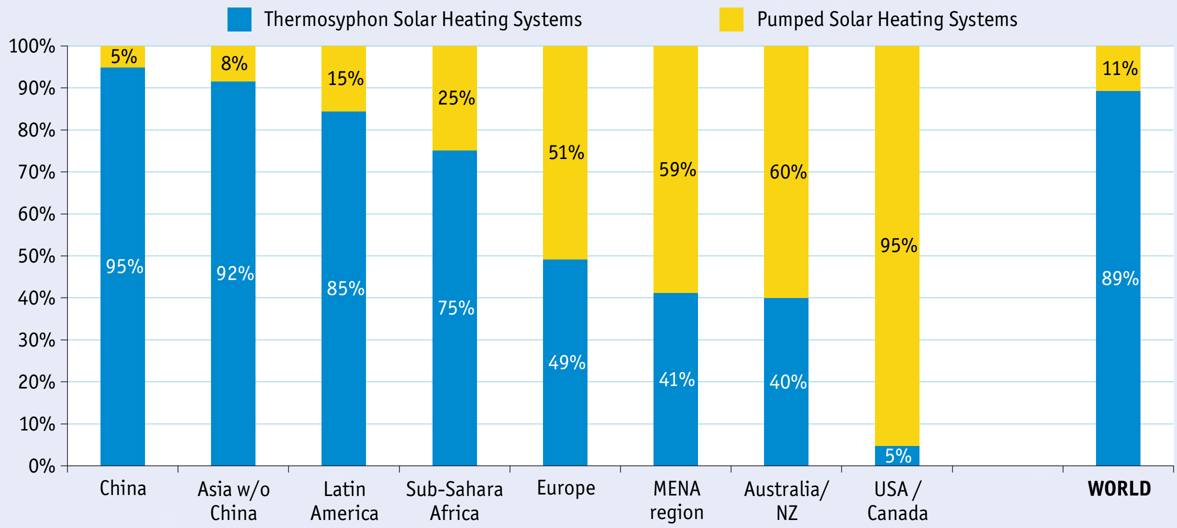
Worldwide, more than three quarters of all solar thermal systems installed are thermosiphon systems and the rest are pumped solar heating systems (**Figure 55**). Similar to the distribution by type of solar thermal collector in total numbers, the Chinese market influenced the overall figures the most. In 2015, 89% of the new installed systems were estimated to be thermosiphon systems while pumped systems only accounted for 11% (**Figure 56**).

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



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

Figure 55: *Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2015*

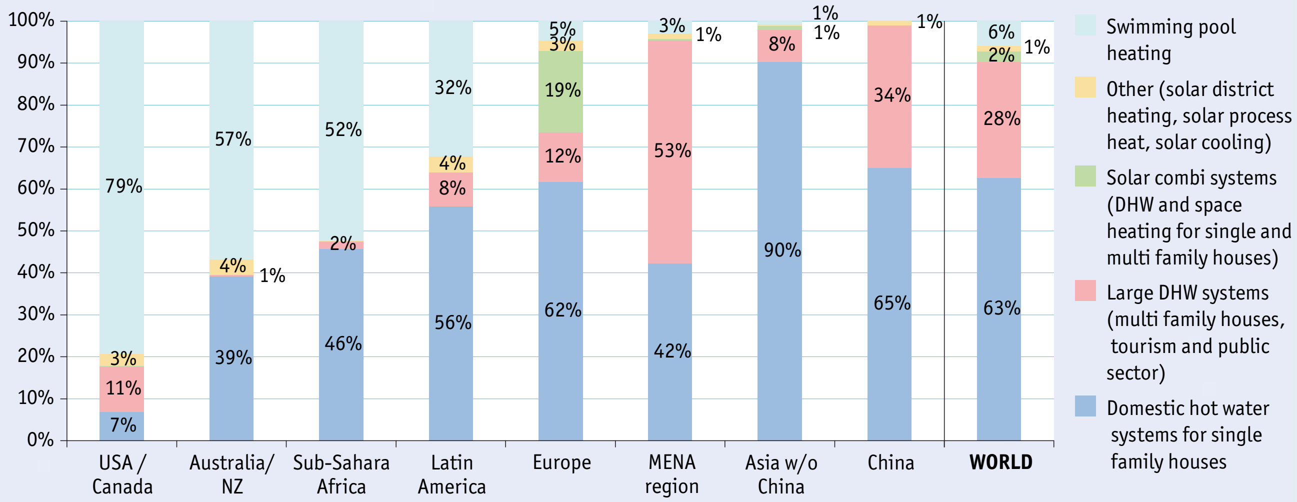


Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China: India, Japan, South Korea, Taiwan Thailand
Europe: EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey
Latin America: Barbados, Brazil, Chile, Mexico,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

Figure 56: *Distribution by type of system for the new installed glazed water collector capacity in 2015*

8.3 Distribution by kind of application

By the end of 2015, 621 million square meters of water-based solar thermal collectors corresponding to a thermal peak capacity of 434.7 GW_{th} were in operation worldwide (Table 6). Out of these, 6% were used for swimming pool heating, 63% were used for domestic hot water preparation in single-family houses and 28% were attached to larger domestic hot water systems for multifamily houses, hotels, hospitals, schools, etc. Around 2% of the worldwide installed capacity supplied heat for both domestic hot water and space heating (solar combi-systems). The remaining systems accounted for around 1% and delivered heat to other applications such as district heating networks, industrial processes or thermally driven solar cooling applications (Figure 57). 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 108 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 region:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 57: *Distribution of solar thermal systems by application for the total installed water collector capacity by economic region in operation by the end of 2015*

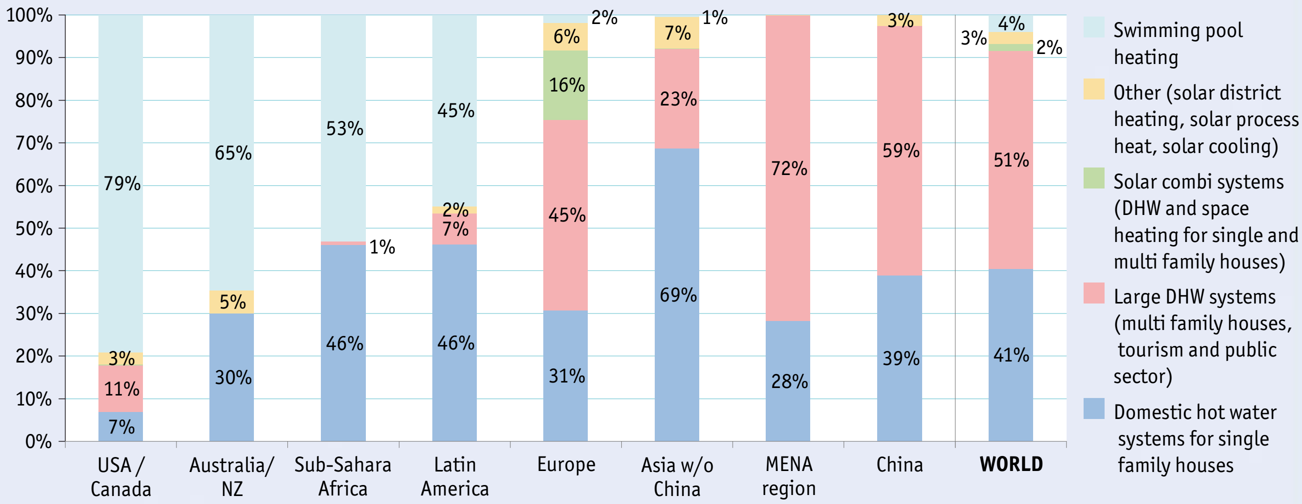
The new installed water-based solar thermal collector area amounted to 57.3 million square meters, which corresponds to 40.1 GW of thermal peak capacity (Table 4).

Compared to the cumulated installed capacity, the share of swimming pool heating was less for new installations (6% of total capacity and 4% of new 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 41% of new installations in 2015 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 51% of new installed capacity). It can be assumed that this market segment took over some of the market shares from both swimming pool heating and domestic hot water systems in single-family homes.

The share of applications, such as solar district heating and solar process heat are increasing the share steadily even if it is still on a low level of 3 % in a global context (Figure 58).

Photo: AEE INTEC



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 region:	Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

Figure 58: *Distribution of solar thermal systems by application for the new installed water collector capacity by economic region in 2015*

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[27].

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[28]. 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.

27 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.

28 Source: Defra / DECC 2013

9.1.1 Reference systems for swimming pool heating

The information in **Table 7** refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2015.

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	4,974,268	35	142,122	466
Austria	Graz	1,126	591,477	200	2,957	283
Belgium	Brussels	971	27,190	200	136	262
Brazil	Brasília	1,793	4,024,281	32	125,759	375
Bulgaria	Sofia	1,188	6,245	200	31	320
Canada	Montreal	1,351	798,824	200	3,994	386
Chile	Santiago de Chile	1,753	41,463	200	207	473
Croatia	Zagreb	1,212	8,795	200	44	327
Cyprus	Nicosia	1,886	1,637	200	8	508
Czech Republic	Praha	998	638,986	200	3,195	303
Denmark	Copenhagen	989	25,548	200	128	295
Estonia	Tallin	960	584	200	3	259
Finland	Helsinki	948	2,767	200	14	256
France	Paris	1,112	117,499	200	587	328
Germany	Würzburg	1,091	579,259	30	19,309	314
Greece	Athens	1,585	205,707	200	1,029	427
Hungary	Budapest	1,199	33,351	10	3,335	344
India	Neu-Delhi	1,961	89,247	16	5,578	529
Israel	Jerusalem	2,198	182,537	200	913	568
Italy	Bologna	1,419	196,707	200	984	442
Jordan	Amman	2,145	6,661	200	33	578
Korea, South	Seoul	1,161	14,685	200	73	313
Latvia	Riga	991	491	200	2	267
Lithuania	Vilnius	1,001	588	200	3	270
Luxembourg	Luxembourg	1,037	2,599	200	13	280
Macedonia	Skopje	1,381	526	20	26	372
Malta	Luqa	1,902	2,377	200	12	513
Mexico	Mexico City	1,706	1,006,099	200	5,030	311
Morocco	Rabat	2,000	18,040	200	90	539
Netherlands	Amsterdam	999	110,058	40	2,751	272
New Zealand	Wellington	1,401	11,175	200	56	378
Norway	Oslo	971	1,777	200	9	316
Palestinian Territories	Jerusalem	2,198	73,394	200	367	593
Portugal	Lisbon	1,686	4,910	200	25	421
Romania	Bucharest	1,324	7,401	200	37	357
Russia	Moscow	996	46	200	0	269
Slovakia	Bratislava	1,214	7,240	200	36	327
South Africa	Johannesburg	2,075	1,041,382	4	260,346	505
Spain	Madrid	1,644	184,580	200	923	472
Sweden	Gothenburg	934	142,675	200	713	295
Switzerland	Zürich	1,094	261,742	200	1,309	277
Taiwan	Taipei	1,372	14,951	175	85	319
Thailand	Bangkok	1,765	1,363	300	5	476
United Kingdom	London	943	36,947	200	185	254
United States	LA, Indianapolis	1,646	19,531,933	200	97,660	387
All other countries (5%)		1,463	1,883,727	200	9,419	394
	TOTAL		36,913,738		689,541	
	AVERAGE	1,401		54		394

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

Table 7: *Solar thermal systems for swimming pool heating in 2015*

Figure 59 shows the hydraulic scheme of the swimming pool reference system as used for the simulations of the solar energy yields.

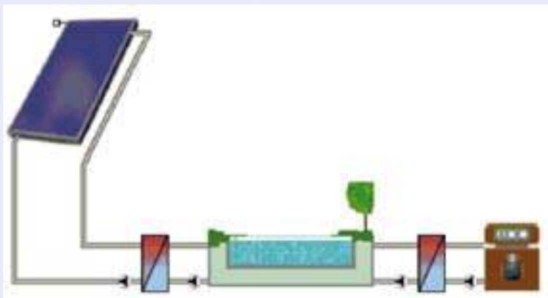


Figure 59: *Hydraulic scheme of the swimming pool reference system*

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

The information in **Table 8** refers to the total capacity of water collectors in operation used for domestic hot water heating in single-family houses at the end of 2015 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	107,827	3.3	32,675	713	TS
Australia	Sydney	1,674	3,304,704	3.5	944,201	844	PS
Austria	Graz	1,126	2,172,145	6.0	362,024	451	PS
Barbados	Grantley Adams	2,016	202,860	4.0	50,715	882	TS
Belgium	Brussels	971	361,258	4.0	90,315	423	PDS / PS
Botswana	Gaborone	2,161	4,200	4.0	1,050	961	TS
Brazil	Brasília	1,793	7,123,353	2.0	3,561,677	809	TS
Bulgaria	Sofia	1,188	82,967	4.0	20,742	524	PS
Burkina Faso	Ouagadougou	2,212	148	4.0	37	983	TS
Canada	Montreal	1,351	49,692	6.0	8,282	556	PS
Chile	Santiago de Chile	1,753	132,166	4.0	33,041	771	PS
China	Shanghai	1,282	287,365,000	4.0	71,841,250	592	TS
Croatia	Zagreb	1,212	116,855	4.0	29,214	539	PS
Cyprus	Nicosia	1,886	588,669	2.0	294,335	912	TS
Czech Republic	Praha	998	236,580	4.7	50,336	385	PS
Denmark	Copenhagen	989	370,889	4.0	92,722	454	PS
Estonia	Tallin	960	7,758	4.0	1,939	432	PS
Finland	Helsinki	948	36,758	4.0	9,189	441	PS
France	Paris	1,112	1,322,253	3.2	413,204	496	PS
Germany	Würzburg	1,091	8,256,364	5.6	1,474,351	424	PS
Ghana	Accra	2,146	100	4.0	25	954	PS
Greece	Athens	1,585	2,733,078	2.5	1,093,231	772	TS
Hungary	Budapest	1,199	165,529	5.0	33,106	473	PS
India	Neu-Delhi	1,961	7,809,127	2.0	3,904,564	882	TS
Ireland	Dublin	949	287,951	4.0	71,988	423	PS
Israel	Jerusalem	2,198	821,418	3.0	273,806	1,024	TS
Italy	Bologna	1,419	2,613,506	4.0	653,377	661	PS
Japan	Tokyo	1,175	3,290,395	4.0	822,599	586	TS
Jordan	Amman	2,145	1,003,076	4.6	218,060	986	TS
Korea, South	Seoul	1,161	1,652,538	4.0	413,134	525	PS
Latvia	Riga	991	6,526	4.0	1,631	462	PS
Lebanon	Beirut	1,935	259,591	4.0	64,898	860	TS
Lesotho	Maseru	2,050	359	2.0	179	911	0
Lithuania	Vilnius	1,001	7,807	4.0	1,952	450	PS
Luxembourg	Luxembourg	1,037	34,535	4.0	8,634	450	PS
Macedonia	Skopje	1,381	47,343	4.0	11,836	627	PS
Malta	Luqa	1,902	31,586	2.5	12,634	868	PS
Mauritius	Port Louis	1,920	132,793	1.5	88,529	854	TS
Mexico	Mexico City	1,706	1,267,685	4.0	316,921	718	PS
Morocco	Rabat	2,000	225,500	4.0	56,375	889	TS
Mozambique	Maputo	1,910	1,359	4.0	340	849	TS
Namibia	Windhoek	2,363	14,273	4.0	3,568	1,032	TS
Netherlands	Amsterdam	999	401,386	2.8	143,352	433	PDS / PS
New Zealand	Wellington	1,401	127,716	4.0	31,929	647	PS
Nigeria	Abuja	2,007	106	1.4	76	892	TS
Norway	Oslo	971	1,476	6.0	246	430	PS
Palestinian Territ.	Jerusalem	2,198	917,425	1.5	611,617	977	TS
Poland	Warsaw	1,024	1,415,813	6.0	235,969	397	PS
Portugal	Lisbon	1,686	682,547	4.0	170,637	804	PS
Romania	Bucharest	1,324	98,327	4.0	24,582	594	PS
Russia	Moscow	996	2,094	4.0	524	443	PS
Senegal	Dakar	2,197	1,601	2.0	800	977	TS
Slovakia	Bratislava	1,214	96,196	6.0	16,033	481	PS
Slovenia	Ljubjana	1,115	159,360	6.0	26,560	424	PS
South Africa	Johannesburg	2,075	725,696	1.5	483,797	1,009	TS
Spain	Madrid	1,644	1,476,639	4.0	369,160	766	PS
Sweden	Gothenburg	934	37,315	4.0	9,329	383	PS
Switzerland	Zürich	1,094	873,726	5.7	153,285	426	PS
Taiwan	Taipei	1,372	1,559,852	4.8	324,969	616	TS
Thailand	Bangkok	1,765	153,330	4.0	38,332	854	TS
Tunisia	Tunis	1,808	838,319	3.3	254,036	902	TS
Turkey	Antalya	1,795	17,923,105	4.0	4,480,776	910	TS
United Kingdom	London	943	490,894	4.0	122,723	415	PS
United States	LA, Indianapolis	1,646	1,730,678	6.0	288,446	646	PS
Uruguay	Montevideo	1,534	52,244	4.0	13,061	682	TS
Zimbabwe	Harare	2,017	28,074	4.0	7,019	854	TS
All other countries (5%)		1,399	24,928,467	4.0	6,232,117	622	TS / PS
	TOTAL		388,970,905		101,402,060		
	AVERAGE	1,517		3.8		622	

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

Table 8: *Solar thermal systems for domestic hot water heating in single-family houses by the end of 2015*

Figure 60 shows the hydraulic scheme used for the energy calculation for all pumped solar thermal systems and **Figure 61** refers to the thermosiphon systems.

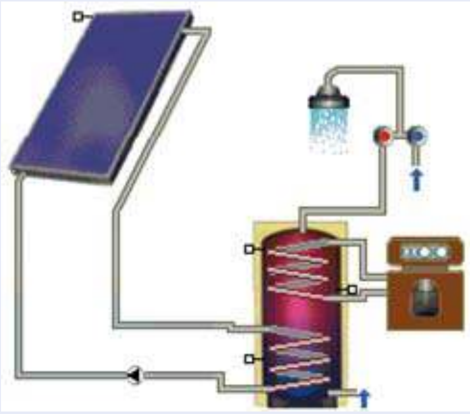


Figure 60: *Hydraulic scheme of the domestic hot water pumped reference system for single-family houses*

Figure 61: *Hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses*

For the Chinese thermosiphon systems the reference system above was used, but instead of a flat plate collector as shown in **Figure 61** a representative Chinese vacuum tube collector was used for the simulation.

Figure 62 shows the hydraulic scheme of domestic hot water reference system for multifamily houses as used for the simulations of the solar energy yields. As opposed to small-scale domestic hot water systems, all large-scale systems are assumed to be pumped solar thermal systems.

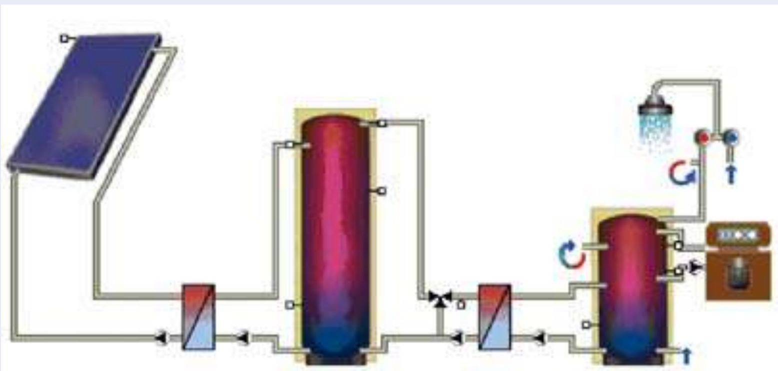


Figure 62: *Hydraulic scheme of the domestic hot water pumped reference system for multifamily houses*

9.1.3 Reference systems for domestic hot water preparation in multifamily houses

The information in **Table 9** refers to the total capacity of water collectors in operation used for domestic hot water heating in multi-family houses at the end of 2015 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	75,988	50.0	1,520	694
Australia	Sydney	1,674	327,028	50.0	6,541	725
Austria	Graz	1,126	405,132	50.0	8,103	505
Belgium	Brussels	971	82,144	50.0	1,643	405
Botswana	Gaborone	2,161	2,800	30.0	93	961
Brazil	Brasília	1,793	1,236,131	60.0	20,602	658
Bulgaria	Sofia	1,188	18,865	50.0	377	515
Burkina Faso	Ouagadougou	2,212	922	30.0	31	983
Canada	Montreal	1,351	35,312	50.0	706	621
Chile	Santiago de Chile	1,753	85,519	50.0	1,710	733
China	Shanghai	1,282	154,735,000	50.0	3,094,700	502
Croatia	Zagreb	1,212	26,571	50.0	531	506
Cyprus	Nicosia	1,886	77,902	50.0	1,558	750
Czech Republic	Praha	998	36,625	42.4	864	436
Denmark	Copenhagen	989	788,014	50.0	15,760	414
Estonia	Tallin	960	1,764	50.0	35	401
Finland	Helsinki	948	8,358	50.0	167	396
France	Paris	1,112	531,525	20.0	26,576	489
Germany	Würzburg	1,091	2,231,286	50.0	44,626	472
Ghana	Accra	2,146	1,037	30.0	35	954
Greece	Athens	1,585	621,452	50.0	12,429	642
Hungary	Budapest	1,199	25,630	50.0	513	522
India	Neu-Delhi	1,961	1,026,342	50.0	20,527	749
Ireland	Dublin	949	9,598	50.0	192	425
Israel	Jerusalem	2,198	3,559,479	3.0	1,186,493	919
Italy	Bologna	1,419	594,264	50.0	11,885	593
Japan	Tokyo	1,175	7,205	50.0	144	516
Jordan	Amman	2,145	250,769	50.0	5,015	801
Korea, South	Seoul	1,161	135,661	50.0	2,713	458
Latvia	Riga	991	1,484	50.0	30	414
Lebanon	Beirut	1,935	423,542	40.0	10,589	809
Lesotho	Maseru	2,050	1,288	30.0	43	911
Lithuania	Vilnius	1,001	1,775	50.0	36	418
Luxembourg	Luxembourg	1,037	7,853	50.0	157	433
Macedonia	Skopje	1,381	4,208	50.0	84	577
Malta	Luqa	1,902	7,182	50.0	144	794
Mexico	Mexico City	1,706	543,293	50.0	10,866	713
Morocco	Rabat	2,000	202,950	50.0	4,059	835
Namibia	Windhoek	2,363	17,445	50.0	349	814
Netherlands	Amsterdam	999	103,584	40.0	2,590	418
New Zealand	Wellington	1,401	15,965	50.0	319	585
Nigeria	Abuja	2,007	42	1.4	30	892
Norway	Oslo	971	16,148	50.0	323	406
Palestinian Territ.	Jerusalem	2,198	825,683	50.0	16,514	917
Poland	Warsaw	1,024	505,648	50.0	10,113	447
Portugal	Lisbon	1,686	294,625	40.0	7,366	705
Romania	Bucharest	1,324	22,358	50.0	447	553
Russia	Moscow	996	16,388	50.0	328	416
Senegal	Dakar	2,197	50	4.5	11	977
Slovakia	Bratislava	1,214	21,873	50.0	437	507
Slovenia	Ljubjana	1,115	3,840	50.0	77	477
South Africa	Johannesburg	2,075	14,619	4.0	3,655	867
Spain	Madrid	1,644	1,735,051	50.0	34,701	676
Sweden	Gothenburg	934	50,485	50.0	1,010	430
Switzerland	Zürich	1,094	104,325	20.0	5,216	457
Taiwan	Taipei	1,372	86,382	30.0	2,879	518
Thailand	Bangkok	1,765	12,587	80.0	157	737
Tunisia	Tunis	1,808	839	50.0	17	756
Turkey	Antalya	1,795	1,558,531	80.0	19,482	750
United Kingdom	London	943	111,620	50.0	2,232	393
United States	LA, Indianapolis	1,646	3,461,355	50.0	69,227	688
All other countries (5%)		1,259	3,141,453	50.0	62,829	526
	TOTAL		180,252,793		4,732,405	
	AVERAGE	1,485		38.1		526

Table 9: *Solar thermal systems for domestic hot water heating in multifamily houses by the end of 2015*

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 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 2015 as reported by each country.

Country	Reference climate	Horizontal irradiation [kWh/m²·a]	Total collector area (Combi system) [m²]	Collector area per system [m²]	Total number of systems	Spec. solar yield (Combi system) [kWh/m²·a]
Austria	Graz	1,126	2,049,009	14.0	146,358	369
Belgium	Brussels	971	112,441	12.0	9,370	342
Bulgaria	Sofia	1,188	25,823	12.0	2,152	418
Canada	Montreal	1,351	31,465	12.0	2,622	476
Croatia	Zagreb	1,212	36,371	12.0	3,031	426
Cyprus	Nicosia	1,886	10,839	12.0	903	663
Czech Republic	Praha	998	193,697	8.5	22,788	351
Denmark	Copenhagen	989	11,964	12.0	997	348
Estonia	Tallin	960	2,415	12.0	201	338
Finland	Helsinki	948	11,441	12.0	953	334
France	Paris	1,112	243,223	11.0	22,111	370
Germany	Würzburg	1,091	7,827,791	11.5	680,677	378
Greece	Athens	1,585	850,663	12.0	70,889	558
Hungary	Budapest	1,199	60,618	15.0	4,041	422
Ireland	Dublin	949	22,396	12.0	1,866	364
Italy	Bologna	1,419	813,447	12.0	67,787	499
Japan	Tokyo	1,175	133,812	12.0	11,151	414
Korea, South	Seoul	1,161	19,762	12.0	1,647	409
Latvia	Riga	991	2,031	12.0	169	349
Lithuania	Vilnius	1,001	2,430	12.0	202	352
Luxembourg	Luxembourg	1,037	10,749	12.0	896	365
Macedonia	Skopje	1,381	526	10.0	53	486
Malta	Luqa	1,902	9,831	12.0	819	669
Morocco	Rabat	2,000	4,510	12.0	376	704
Netherlands	Amsterdam	999	32,370	6.0	5,395	352
New Zealand	Wellington	1,401	4,789	12.0	399	493
Norway	Oslo	971	23,105	15.0	1,540	342
Palestinian Territories	Jerusalem	2,198	18,349	12.0	1,529	773
Poland	Warsaw	1,024	101,130	12.0	8,427	365
Romania	Bucharest	1,324	30,604	12.0	2,550	466
Russia	Moscow	996	692	15.0	46	350
Slovakia	Bratislava	1,214	29,941	12.0	2,495	427
Slovenia	Ljubjana	1,115	28,800	12.0	2,400	362
Spain	Madrid	1,644	295,328	10.0	29,533	619
Sweden	Gothenburg	934	267,790	10.0	26,779	389
Switzerland	Zürich	1,094	326,017	11.0	29,638	385
Thailand	Bangkok	1,765	1,834	12.0	153	621
United Kingdom	London	943	152,789	12.0	12,732	332
All other countries (5%)		1,139	1,098,152	12.0	91,513	401
	TOTAL		14,898,947		1,267,191	
	AVERAGE	1,241		11.8		401

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

Table 10: *Solar combi system reference for single and multifamily houses and the total collector area in operation in 2015*

Figure 63 shows the hydraulic scheme of domestic hot water reference system for multifamily houses as used for the simulations of the solar energy yields.

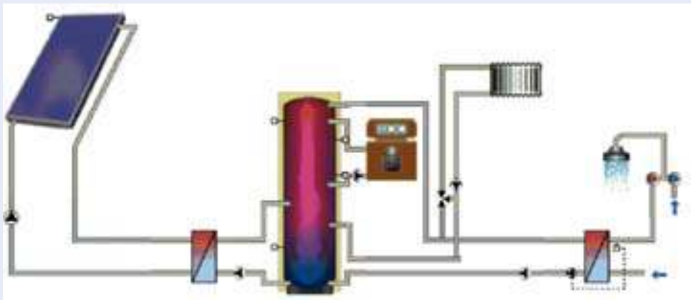


Figure 63: *Hydraulic scheme of the solar-combi reference system for single and multifamily houses*

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]

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 5 is quantified using the levelized cost of energy (LCOE) approach (e.g., acc. to /[29]/). 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

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

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:

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

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

All technical and economical parameters of the investigated solar thermal systems are elaborated for both the solar loop and solar energy storage. Conventional heat supply is not considered.
All specific benchmark figures are referred to gross collector area installed (e.g., €/m²$_{gross}$, kWh/m²$_{gross}$).
Cost data refer to end-user (customer) prices excluding value added taxes or subsidies. Solar energy yield SE is referred to as specific annual thermal energy delivered by the solar thermal collector in kWh per m² gross collector area installed (thermal losses in solar loop piping and thermal energy storage not considered).

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

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

29 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

In **Table 11**, 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 €/(m²gross)	MAX	MIN €-ct/kWh	MAX
Economies of Scale - Example Denmark (Figure 16)									
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 €/(m²gross)	MAX	MIN €-ct/kWh	MAX
Small domestic hot water systems (e.g. in single family homes) - A) Pumped systems (Figure 17)									
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 18)									
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 19)									
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 20)									
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 21)									
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 11** 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 11: *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
43	Netherlands	Amsterdam	999	1,131	10.0

No.	Country	Reference climate	Horizontal irradiation [kWh/m²·a]	Inclined irradiation [kWh/m²·a]	Avg. Outside air temp. [°C]
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

Table 12: *Reference climates for the 66 countries surveyed (Source: T-Sol expert version 4.5 and Meteonorm version 6.1)*

9.6 Population data

No	Country	2015	Reg. code
1	Albania	3,029,278	6
2	Australia	22,751,014	3
3	Austria	8,665,550	6
4	Barbados	290,604	4
5	Belgium	11,323,973	6
6	Botswana	2,182,719	1
7	Brazil	204,259,812	4
8	Bulgaria	7,186,893	6
9	Burkina Faso	18,931,686	1
10	Canada	35,099,836	8
11	Chile	17,508,260	4
12	China	1,367,485,388	5
13	Croatia	4,464,844	6
14	Cyprus	1,189,197	6
15	Czech Republic	10,644,842	6
16	Denmark	5,581,503	6
17	Estonia	1,265,420	6
18	Finland	5,476,922	6
19	France	66,553,766	6
20	Germany	80,854,408	6
21	Ghana	26,327,649	1
22	Greece	10,775,643	6
23	Hungary	9,897,541	6
24	India	1,251,695,584	2
25	Ireland	4,892,305	6
26	Israel	8,049,314	7
27	Italy	61,855,120	6
28	Japan	126,919,659	2
29	Jordan	8,117,564	7
30	Korea, South	49,115,196	2
31	Latvia	1,986,705	6
32	Lebanon	6,184,701	7
33	Lesotho	1,947,701	1
34	Lithuania	2,884,433	6
35	Luxembourg	570,252	6
36	Macedonia	2,096,015	6

No	Country	2015	Reg. code
37	Malta	413,965	6
38	Mauritius	1,339,827	1
39	Mexico	121,736,809	4
40	Morocco	33,322,699	7
41	Mozambique	25,303,113	1
42	Namibia	2,212,307	1
43	Netherlands	16,947,904	6
44	New Zealand	4,438,393	3
45	Nigeria	181,562,056	1
46	Norway	5,207,689	6
47	Palestinian Territories	4,654,421	7
48	Poland	38,562,189	6
49	Portugal	10,825,309	6
50	Romania	21,666,350	6
51	Russia	142,423,773	6
52	Senegal	13,975,834	1
53	Slovakia	5,445,027	6
54	Slovenia	1,983,412	6
55	South Africa	53,675,563	1
56	Spain	48,146,134	6
57	Sweden	9,801,616	6
58	Switzerland	8,121,830	6
59	Taiwan	23,415,126	2
60	Thailand	67,976,405	2
61	Tunisia	11,037,225	7
62	Turkey	79,414,269	6
63	United Kingdom	64,088,222	6
64	United States	321,368,864	8
65	Uruguay	3,341,893	4
66	Zimbabwe	14,229,541	1
	All other countries	2,460,600,783	9
	Σ Solar Thermal World Statistics	4,784,699,062	66%
	Σ Inhabitants world	7,245,299,845	100%

Table 13: *Inhabitants by the end of 2015 of the 66 surveyed countries in alphabetical order*

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

Region Code / Region		Σ Inhabitants	Share
1	Sub-Sahara Africa	341,687,996	4.7%
2	Asia w/o China	1,519,121,970	21.0%
3	Australia / New Zealand	27,189,407	0.4%
4	Latin America	347,137,378	4.8%
5	China	1,367,485,388	18.9%
6	Europe	754,242,299	10.4%
7	MENA Region	71,365,924	1.0%
8	United States / Canada	356,468,700	4.9%
9	Other countries	2,460,600,783	34.0%
TOTAL		7,245,299,845	100.0%

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 Region: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Table 14: *Inhabitants per economic region by the end of 2015*

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

9.7 Market data of the previous years

The data presented in **Chapters 6** 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}/m^2 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 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 15**, **Table 16** and **Table 17** these countries are highlighted 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		29,680	284			29,964
Australia	650,000	165,200	21,000	35,000	1,000	872,200
Austria	1,460	175,140	4,040		1,010	181,650
Barbados***		10,000				10,000
Belgium		48,500	10,500			59,000
Brazil	621,616	747,282	9,909			1,378,807
Bulgaria		5,100	500			5,600
Canada	21,804	3,125	3,650	23,904	5,584	58,067
Chile		59,300				59,300
China		6,500,000	57,060,000			63,560,000
Croatia		18,400	2,500			20,900
Cyprus	33	17,807	472			18,312
Czech Republic	35,000	32,306	12,225			79,531
Denmark		103,600	400			104,000
Estonia		1,000	1,000			2,000
Finland		3,000	1,000			4,000
France (mainland)		171,273	19,667	500		191,440
Germany		908,000	112,000			1,020,000
Greece		226,700	450			227,150
Hungary	800	10,500	7,500	200	200	19,200
India		330,000	770,000		4,000	1,104,000
Ireland		16,330	10,382			26,712
Israel*	2,800	450,000				452,800
Italy		261,360	35,640			297,000
Japan		142,568	2,847		9,270	154,685
Jordan		54,531	13,705			68,236
Korea, South		48,473				48,473
Latvia		1,500	500			2,000
Lebanon		22,000	35,000			57,000
Lithuania		800	1,400			2,200
Luxembourg		5,000	1,000			6,000
Macedonia		5,120	453			5,573
Malta		1,083	278			1,361
Mauritius		8,880				8,880
Mexico	98,550	85,725	85,725	400	400	270,800
Morocco		36,000				36,000
Mozambique			143			143
Namibia**						
Netherlands*	2,621	25,878	4,000			32,499
New Zealand**						
Norway		3,536	846		1,224	5,606
Palestinian Territorries		115,000	7,000			122,000
Poland		199,100	75,000			274,100
Portugal		54,374	2,860			57,234
Romania		9,000	14,850	800		24,650
Russia		1,555	135			1,690
Slovakia		5,200	1,000			6,200
Slovenia		8,000	2,000			10,000
South Africa	50,010	51,902	41,187			143,099
Spain	3,794	222,552	6,169			232,515
Sweden	351	6,124	2,487			8,962
Switzerland	10,952	107,962	14,012			132,926
Taiwan		110,221	10,616			120,838
Thailand		16,251				16,251
Tunisia		69,070				69,070
Turkey		1,082,308	837,539	500		1,920,347
United Kingdom		32,234	8,566	1,000		41,800
United States	771,400	223,800	11,600	11,300	7,800	1,025,900
Uruguay*		11,657				11,657
Zimbabwe		1,995	1,415			3,410
All other countries (5%)	119,536	687,526	3,119,234	3,874	1,605	3,931,776
TOTAL	2,390,727	13,750,529	62,384,687	77,478	32,093	78,635,513

* Revised due to new / adapted database in 2016.
** No data for new installations in the respective year available.
*** Based on Solar Water Heating Techscope Market Readiness Assessment - Reports UNEP 2015.

Table 15: *New installed collector area in 2013 (revised 2016) [m²]*

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
Botswana						
Brazil	643,888	781,118	15,864			1,440,870
Bulgaria		5,100	500			5,600
Burkina Faso						
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	0	800		151,300
Germany	20,000	814,800	85,200			920,000
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	13,705			68,236
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
Mauritius		8,880				8,880
Mexico	116,800	101,600	101,600			320,000
Morocco		36,000	0			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
Palestinian Territorries		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
Senegal						
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		16,251				16,251
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
All other countries (5%)	116,045	617,375	2,596,482	3,992	1,590	3,335,485
TOTAL	2,320,908	12,346,741	51,929,365	79,845	31,800	66,708,659

* Revised due to new / adapted database in 2017.
** No data for new installations in the respective year available.
*** Based on Solar Water Heating Techscope Market Readiness Assessment - Reports UNEP 2015.

Table 16: *New installed collector area in 2014 (revised 2017) [m²]*

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL (excl. concentrators) [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		161,265	1,432			162,697
Australia	5,000,000	3,227,000	138,000	300,000	8,800	8,673,800
Austria	502,651	4,574,575	84,572		3,308	5,165,106
Barbados**		191,430				191,430
Belgium	45,000	419,033	75,000			539,033
Brazil	3,580,239	7,411,321	25,773			11,017,333
Bulgaria		127,280	3,020			130,300
Canada	794,065	67,336	42,755	393,907	34,947	1,333,010
Chile	55,490	134,101	41,618			231,209
China		31,550,000	382,050,000			413,600,000
Croatia		162,017	5,075			167,092
Cyprus	2,213	664,034	24,200			690,447
Czech Republic	538,000	395,214	111,298			1,044,512
Denmark	20,500	927,644	9,197	3,300	18,000	978,641
Estonia		5,930	4,590			10,520
Finland	11,800	35,651	8,372			55,823
France (mainland)+	105,700	2,353,400	61,800	5,100	1,100	2,527,100
Germany	559,700	15,734,000	1,963,000		28,300	18,285,000
Greece		4,267,450	18,850			4,286,300
Hungary	15,300	190,700	63,100	2,200	1,850	273,150
India++		3,511,470	3,940,430		9,200	7,461,100
Ireland		198,578	101,605			300,183
Israel	35,200	4,492,434				4,527,634
Italy	43,800	3,425,404	537,240			4,006,444
Japan		3,659,155	71,828		518,714	4,249,697
Jordan	5,940	982,482	272,084			1,260,506
Korea, South*		1,665,983	127,630			1,793,613
Latvia		6,512	2,110			8,622
Lebanon*		265,371	363,786			629,157
Lesotho		250	150			400
Lithuania		4,900	5,500			10,400
Luxembourg		44,450	6,750			51,200
Macedonia		35,820	5,900			41,720
Malta		39,981	9,995			49,976
Mauritius		123,993				123,993
Mexico*	1,076,053	1,174,082	911,942	752	8,773	3,171,602
Morocco		451,000				451,000
Mozambique			1,143			1,143
Namibia*		24,823	1,310			26,133
Netherlands	109,822	509,511	24,500			643,833
New Zealand	7,025	142,975	9,644			159,645
Norway	1,849	36,794	3,862	200	4,106	46,812
Palestine		1,777,625	8,000			1,785,625
Poland		1,313,400	430,600			1,744,000
Portugal	2,130	917,201	25,850			945,181
Romania		87,900	55,150	800		143,850
Russia		16,830	1,634		50	18,514
Slovakia	500	131,300	21,150			152,950
Slovenia		170,000	21,500			191,500
South Africa	962,725	511,613	175,430			1,649,768
Spain	141,824	3,119,167	189,442			3,450,433
Sweden	170,328	256,651	70,199			497,178
Switzerland	208,310	1,175,880	100,450	720,000		2,204,640
Taiwan	1,984	1,481,756	122,249			1,605,989
Thailand		152,862				152,862
Tunisia		705,831	70,104			775,935
Turkey		14,698,112	3,487,789	4,570		18,190,471
United Kingdom		623,784	165,816	21,600		811,200
United States	21,335,963	2,805,546	137,822	104,900	41,500	24,425,731
Uruguay		46,241				46,241
Zimbabwe		21,426	3,397			24,823
All other countries (5%)	1,859,690	6,495,227	20,853,471	81,965	35,718	29,326,071
TOTAL	37,193,800	129,903,703	417,069,113	1,639,294	714,367	586,520,277

* Revised due to new / adapted database in 2017.
** Based on Solar Water Heating Techscope Market Readiness Assessment - Reports UNEP 2015.
\+ The figures for France refer to mainland France only, overseas territories are not considered.
++ The figures for India refer to the fiscal year April 2014 to March 2015.

Table 17: *Total collector area in operation by the end of 2014 (revised 2017) [m²]*

9.8 References to reports and persons that have supplied the data

The production of the report, *Solar Heat Worldwide 2015 – Edition 2017* 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 INTEC - Institute for Sustainable Technologies	Biermayr et al., 2016: Innovative Energietechnologien in Österreich – Marktentwicklung 2016 (Report in German) Out of operation systems calculated by AEE INTEC
Barbados	**Emily Chessin** UNEP's Global Solar Water Heating Market Transformation and Strengthening Initiative	Based on Solar Water Heating Techscope Market Readiness Assessment – Reports, UNEP 2015 New collectors calculated by AEE INTEC from cumulative data
Belgium	**ESTIF – European Solar Thermal Industry Federation** **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2016 Unglazed water collectors: AEE INTEC recordings
Botswana	**Dr. Edwin Matlotse** Botswana University	Cumulated area estimation AEE INTEC based on data provided by Edwin Matlotse
Brazil	**Marcelo Mesquita** Depto. Nac. de Aquecimento Solar da ABRAVA	DASOL ABRAVA Out of operation systems calculated based on DASOL ABRAVA long time recordings
Bulgaria	**ESTIF – European Solar Thermal Industry Federation** **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2016 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
Canada	**Reda Djebbar, Ph.D., P.Eng.** Natural Resources Canada	Clear Sky Advisors, April 2016 Report „Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2015)" 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	Franquicia Tributaria y Subsidios para Sistemas Solares Térmicos. Ministerio de Energía, Junio 2015; Estudio de Mercado de la Industria Solar Térmica en Chile y propuesta metodológica para su actualización permanente Dandilion Energía y Medio Ambiente Ltda. Octubre, 2012
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 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2016
Cyprus	**Soteris Kalogirou, PhD, DSc** Cyprus University of Technology **ESTIF – European Solar Thermal Industry Federation**	Cyprus Institute of Energy Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 New installations: Cyprus Institute of Energy cumulated installations: ESTIF 2016 / share FPC-ETC + unglazed: Cyprus Institute of Energy
Czech Republic	**Ales Bufka** Ministry of Industry and Trade	Ministry of Industry and Trade
Denmark	**Jan-Erik Nielsen** Planenergi **ESTIF – European Solar Thermal Industry Federation** **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Unglazed water collectors: AEE INTEC recordings
Estonia	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2016 (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 - Observatoire des énergies renouvelables, 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
Greece	**Vassiliki Drosou, M.Sc. PhD** CRES - Centre for Renewable Energy Sources **Costas Travasoras** (EBHE) **AEE INTEC**	Vassiliki Drosou (CRES), Costas Travasoras (EBHE) Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 New installations: ETC/FPC by ESTIF; Vassiliki DROSOU (CRES), Costas TRAVASAROS (EBHE) Cumulated installations: cumulated area: ESTIF 2016 / 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

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	**Dr. Asher Vaturi** ICTAF - Israel Bureau of Statistics **Eli Shilton** ELSOL	Israel Bureau of Statistics, Israel Ministry of water and energy & The Max Stern Yezreel Valley College (Dr. Asher Vaturi) ELSOL (Eli Shilton) Cumulated collector area calculated by AEE INTEC based on new installation and replacement figures from Israel Bureau of Statistics, ICTAF, Tel Aviv University, The Max Stern Yezreel Valley College (Dr. Asher Vaturi) and Eli Shilton (ELSOL)
Italy	**ESTIF – European Solar Thermal Industry Federation** **AEE INTEC**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Cumulated area: ESTIF 2016 / share FPC-ETC: AEE INTEC / unglazed water collectors: AEE INTEC
Japan	**Yamashita Noriaki** ISEP - Institute for Sustainable Energy Policies	ISEP; Solar System Development Association (SSDA) Out of operation systems calculated by ISEP
Jordan	**AEE INTEC**	AEE INTEC New installations: No new collectors for 2015, Cumulated installations: 2014
Korea, South	**Eunhee Jeong** Korea Energy Management Corporation (KEMCO)	2015 New & Renewable Energy Statistics by the Korea New & Renewable Energy Center, 2016
Latvia	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2016 (estimation)
Lebanon	**Haykal Khalil** 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 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2015 (estimation)
Luxembourg	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2015 (estimation)
Macedonia	**Prof. Dr. Ilja Nasov** National University St. Kiril and Metodij, Faculty for Natural Science, Institute of Physics, Solar Energy Department, Ul.Veljko Vlahovic 18/mezanin 1000 Skopje, Macedonia	2015 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 New and cumulated installations 2015 - projected by AEE INTEC (0% growth rate 2014 / 2015)

Mexico	**David Garcia** FAMERAC **Bärbel Epp** Solrico – Solar market research http://www.solrico.com	Glazed and unglazed water collectors: FAMERAC - Renewable Energy Industry Association Air collectors: SAHWIA - Solar Air Heating World Industry Association Data provided by Bärbel Epp Cumulated installations: calculated by AEE INTEC
Morocco	**Ashraf Kraidy** RECREEE - Regional Center for Renewable Energy and Energy Efficiency	2015 data projected by AEE INTEC (0% growth rate 2014 / 2015)
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 2015
Namibia	**Zivayi Chiguvare** Namibian Energy Institute Namibia University of Science and Technology	2014 – 2015 survey provided by Zivayi Chiguvare
Netherlands	**André Meurink** **Reinoud Segers** Statistics Netherlands (CBS)	Statistics Netherlands (CBS) New installed areas: Statistics Netherlands based on survey of sales. Market Shares: Expert estimates Netherlands Enterprise Agency and Holland Solar.
New Zealand		No data available since 2010 Cumulated area in 2009
Nigeria	**Okala Nwoke** National Centre for Energy Research and Development, University of Nigeria, Nsukka	National Centre for Energy Research and Development, University of Nigeria, provided by Okala Nwoke
Norway	**Peter Bernhard** Asplan Viak AS – KanEnergi **Ragnhild Bjelland-Hanley** Norwegian Solar Energy Society	2015 data projected by AEE INTEC (0% growth rate 2014 / 2015)
Palestinian Territ.	**Mohammed Mobayyed** EEU Director / Palestinian Energy Authority	Palestinian Energy Authority Cumulated area calculated by AEE INTEC (replacements not considered)
Poland	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016
Portugal	**APISOLAR - Associação Portuguesa da Indústria Solar** **ESTIF – European Solar Thermal Industry Federation**	APISOLAR (www.apisolar.pt) „Observatório Solar Térmico 2015" Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 New installations: APISOLAR Cumulated area: ESTIF 2016 / share FPC-ETC + unglazed: APISOLAR
Romania	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2016
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 Scienses (JIHT RAS) Dr. Semen Frid, Sophia Kiseleva - Moscow State University, Vitaly Butuzov - Energytechnologies Ltd. (Krasnodar); the source of information - JIHT RAS.

Senegal	**T. Ababacar** Université Cheikh Anta DIOP	Rapport de Marché du Solaire Thermique: Production d'Eau Chaude et Séchage de Produits Agricoles: provided by T. Ababacar
Slovakia	**ESTIF – European Solar Thermal Industry Federation**	Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016 Glazed water collectors: ESTIF, 2015
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 Solar Thermal Markets in Europe - Trends and Market Statistics 2015, ESTIF 2016
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 2015, Bundesamt für Energie 2016 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	**AEE INTEC**	Projected by AEE INTEC (0% growth rate 2014 / 2015)
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 12 years lifetime
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 2015 survey, with efficiency and lifetime Provided by Yehuda Lethbridge, 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	**Martín Scarone** Ministry of Industry, Energy and Mining	Ministry of Industry, Energy and Mining, Data provided by Martín Scarone
Zimbabwe	**Dr. Anton Schwarzlmüller** Domestic Solar Heating	SOLTRAIN survey (unpublished sources) Cumulated 2015: calculated by AEE INTEC

9.8.1 Additional literature and web sources used

The following reports and statistics were used in this report:

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- Bundesministerium für Verkehr, Innovation und Technologie (BMVIT): Innovative Energy Technologies in Austria - Market Development 2015; prepared by Peter Biermayr et al, Vienna, Austria june 2016
- Bundesverband Solarwirtschaft e.V. (BSW-Solar): Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) 2015; accessed October 2016
- ClearSky Advisors Inc.: Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2015); Prepared by ClearSky Advisors Inc., Dr. Reda Djebbar, Natural Resources Canada, March 2016
- European Solar Thermal Industry Federation (ESTIF): Solar Thermal Markets in Europe, Trends and Market Statistics 2015; Belgium - Brussels; November 2016
- 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:

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

9.9 List of Figures

9.10 List of Tables