Werner Weiss, Monika Spörk-Dür

Global Market Development
and Trends 2021
Detailed Market Figures 2020

SOLAR HEAT WORLD WIDE

Edition 2022

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

SHC
SOLAR HEATING & COOLING PROGRAMME
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Detailed Market Figures 2020

2022 Edition

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Table of Contents

1 Background

The Solar Heat Worldwide report has been published annually since 2005 within the framework of the Solar Heating and Cooling Technology Collaboration Programme (SHC TCP) of the International Energy Agency (IEA).

The goal of the report is to: 1) give an overview of the general trends. 2) highlight special applications and outstanding projects, 3) document the solar thermal capacity installed in the important markets worldwide, and 4) 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 collector types detailed in the report 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.

Photovoltaic Thermal (PVT) collectors are included, as the market for these types of collectors has grown in market relevance in recent years. PVT collectors convert solar radiation into both electricity and heat and thus will play an important role in the energy supply of the future.

The report's data was collected through a survey of the national delegates of the SHC TCP Executive Committee, Solar Heat Europe and national experts active in the field of solar thermal energy. As some of the 70 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.

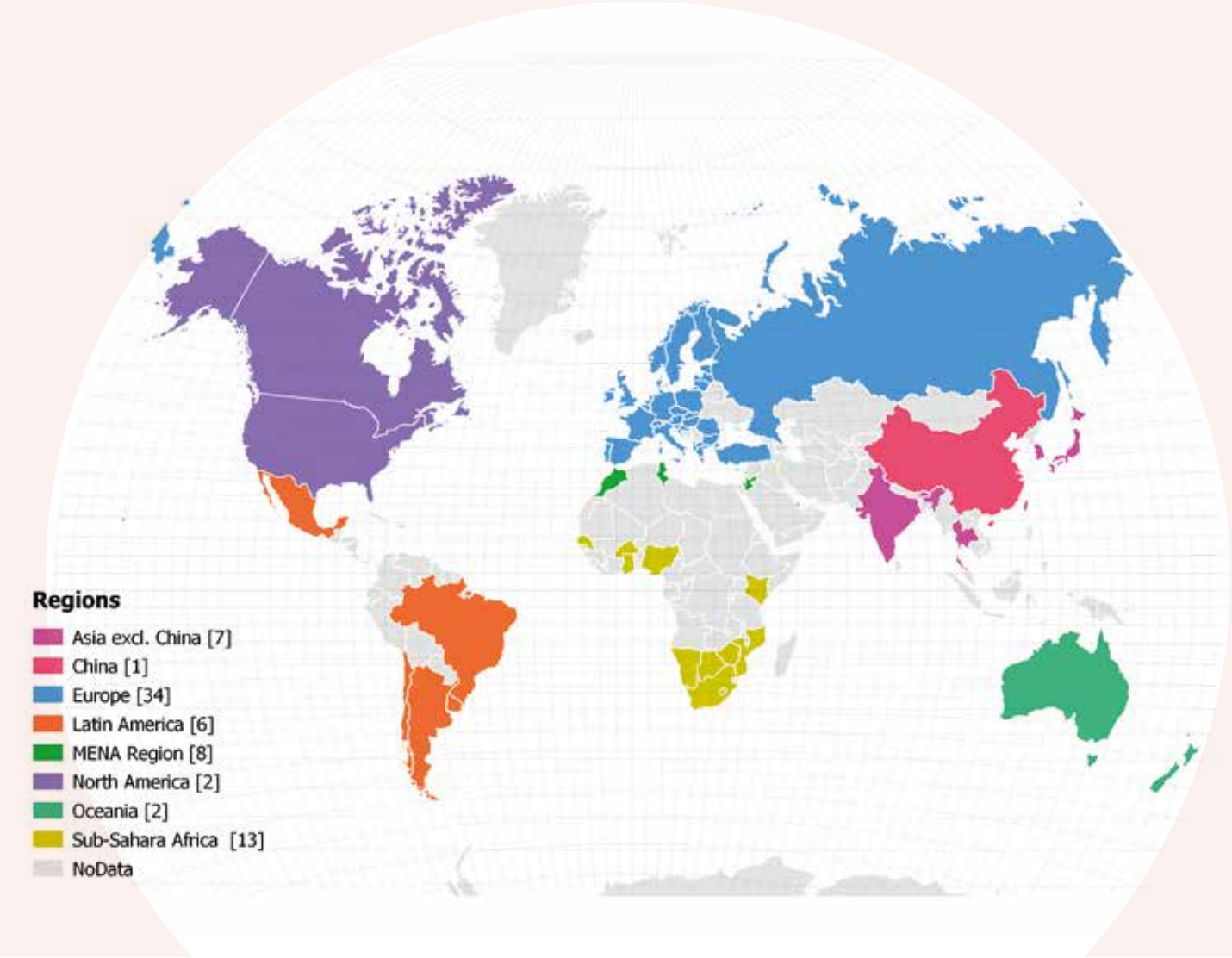


Figure 1: Countries shown in color have detailed market data. Countries shown in grey have estimated market data.
(Source: Natural Earth v.4.1.0, 2020/ AEE INTEC)

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

The report's 2022 edition and all past issues can be downloaded from the following website:
http://www.iea-shc.org/solar-heat-worldwide

2 Summary

Photo: GREENoneTEC Solar Industry

This report is split into three parts. The first part (Chapters 3 - 4) gives an overview of the global solar thermal market development in 2021. In addition, general trends are described and detailed 2021 data on successful applications, such as solar assisted district heating, solar heat for industrial processes and hybrid photovoltaic thermal systems, are documented.

The second part (Chapters 5 - 7) presents detailed market figures for 2020 from the 70 surveyed countries. In addition to the data from 68 countries documented in previous years, data from Bhutan and Kenya are new additions to this year's report. These chapters include the installed collector area, the distribution of the collectors across various systems and applications and the solar yields and avoided emissions.

The third part (chapter 8) documents the methodological approach, reference systems, climate and population data, literature references and data sources.

Global solar thermal market developments in 2021

The cumulated solar thermal capacity in operation at the end of 2021 was 522 GW_{th}, corresponding to 746 million square meters of collector area. This represents a net increase of 21 GW_{th} or 31 million square meters of collector area in 2021.

The worldwide solar thermal **market increased by 3% in 2021** compared to 2020.

The annual solar thermal energy yield amounted to 425 TWh, which correlates to savings of 45.7 million tons of oil and 147.5 million tons of CO_2.

Large-scale solar heating systems for district heating or residential, commercial and public buildings

In 2021, 44 new large-scale solar heating systems (>350 kW_{th}, 500 m^2) with a capacity of 142 MW_{th} were built. Twenty of these systems were installed in China and 14 in Europe, including one extension, seven in Turkey and three in Mexico.

The three largest of these systems were the solar district heating system in Præstø, Denmark, with a capacity of 5.6 MW_{th}, as well as the Nahwärme Friesach in Austria and the system in Mühlhausen, Germany, both with a capacity of 4.0 MW_{th}.

By the end of 2021, 530 large-scale documented solar thermal systems were in operation. The total installed capacity of these systems equaled 1,970 MW_{th}, corresponding to 2.8 million m^2 collector area.

Solar heat for industrial processes (SHIP)
Seventy-eight new SHIP plants with a collector area of 51,539 m^2 (36 MW^{th}) were documented in 2021 worldwide. With this, the number of SHIP projects in operation adds up to at least 975 systems with an overall installed collector area of 1.23 million m^2.

Photovoltaic-Thermal (PVT) collectors
The market for PVT collectors and systems saw significant global growth of 13% in 2021. At least 6,036 new PVT systems were commissioned in 2021. The cumulated number of PVT systems in operation at the end of 2021 was 34,000 representing a total collector area of 1.4 million m^2 (751 MW_{th}, 254 MWpeak).

Market status worldwide in 2020

While only the data of the leading 20 countries is available for 2021, the report includes very detailed 2020 data on 70 countries.

109 million solar thermal systems were in operation by the end of 2020.

The top 3 countries in terms of total installed capacity by the end of 2020 were China, Turkey and the United States.

However, the picture is clearly different when comparing the data on a per capita basis.
The top 10 countries in terms of installed capacity per 1,000 inhabitants are Barbados, Cyprus and Israel.

In 2020 **evacuated tube collectors represented 60%** of the newly installed capacity, followed by flat plate collectors with 34%.

In a global context, this breakdown is mainly driven by the dominance of the Chinese market, where around 72% of all newly installed collectors in 2020 were evacuated tube collectors, but also by the Indian market, with 88% of newly installed collector area being evacuated tubes.

Nevertheless, it is notable that the share of evacuated tube collectors worldwide decreased from about 82% in 2011 to 60% in 2020, and in the same time, flat plate collectors increased their share from about 15% to 34%.

In Europe, the situation is almost the opposite of that in China, with 71% of all solar thermal collectors installed in 2020 being flat plate collectors. In the medium-term perspective, however, the share of flat plate collectors decreased in Europe from 81% in 2011 to 71% in 2020. Overall, the share of evacuated tube collectors in Europe increased between 2011 and 2020 from 16% to 28%.

Distribution by system type
Pumped systems accounted for 64% of all newly installed systems in 2020, while 36% were thermosiphon systems.

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 380,000 worldwide in 2020.[1]

The estimated worldwide turnover of the solar thermal industry in 2020 is € 17 billion (US$ 18.7 billion).

Solar house Oberduernbach, Austria
Photo: Martin Ruehrnschopf

[1] Background information on the methodology used can be found in the Appendix, Chapter 8.3.

3 Worldwide solar thermal capacity in 2021

As shown in the figure below, the global solar thermal capacity of unglazed and glazed water collectors in operation grew from 62 GW_{th} (89 million m^2) in 2000 to 522 GW_{th} (746 million m^2) in 2021. The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 425 TWh in 2021 (Figure 2).

In 2021 a total capacity of 21 GW_{th} or 31 million square meters of collector area was installed. The 3% increase in installed collector area was the first after seven years of annual declines.

The solar thermal market increased by 3% in 2021

Global solar thermal capacity in operation and annual energy yields 2000-2021

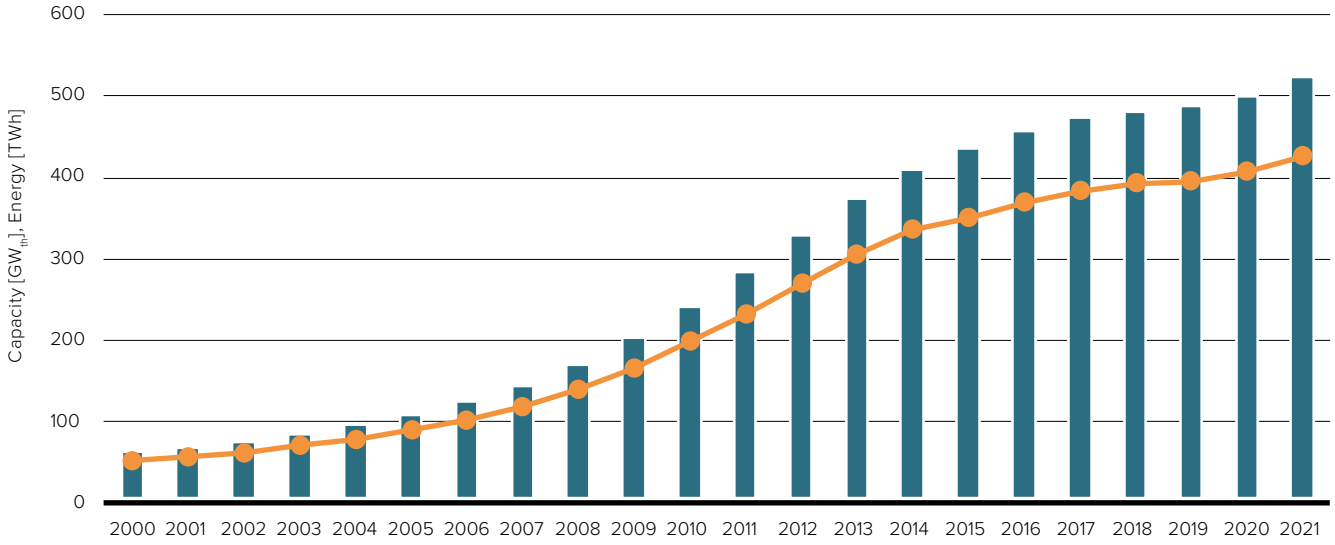


Figure 2: Global solar thermal capacity in operation and annual energy 2000-2021

Figure 3 shows the annual installed collector capacities and the net additions. The difference between the annually installed collector capacity and the net additions is subtracted from the global solar thermal capacity each year when the assumed statistical lifetime of the collectors of 25 years[2] is reached.

Environmental effects and contribution to climate goals

The global solar thermal energy yields of all installed solar thermal systems in 2021 correspond to a savings of 45.7 million tons of oil and 147.5 million tons of CO_2. This shows the significant contribution of solar thermal in reducing global greenhouse gas emissions.

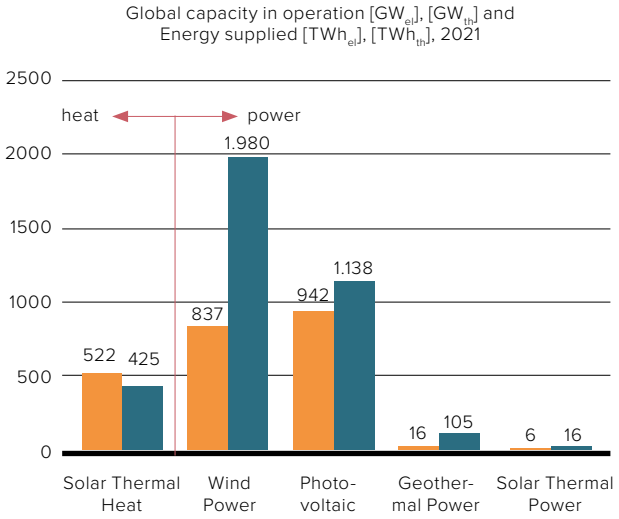
3.1 Solar thermal capacity in relation to the capacity of other renewable energy technologies

The cumulated solar thermal capacity in operation by the end of 2021 was 522 GW_{th}[3], following behind wind power's installed capacity of 837 GW_{el} and photovoltaics 942 GW_{el} of installed capacity (Figure 4). Geothermal energy and concentrated solar power (CSP) lag behind these three technologies in installed capacity. The total capacity of geothermal power was 16 GW_{el}.

In terms of energy, solar thermal systems supplied 425 TWh of heat, whereas wind turbines supplied 1,980 TWh and photovoltaic systems 1,138 TWh of electricity.

Figure 3: Global capacity in operation [GW_{el}], [GW_{th}] 2021 and annual energy yields [TWh_{el}], [TWh_{th}]

(Sources: AEE INTEC, Global Wind Energy Council (GWEC), Irena Renewable Energy Capacity Statistics 2022, IEA PVPS Snapshot Report, Solar Power Europe GMO report 2021-2025, REN21 (Duncan Gibb).



Total capacity in operation [GW_{th}, GW_{el}]
Energy supplied [TWh]

[2] For details on the lifetime see chapter 5
[3] The figures for 2021 are based on the latest market data from Australia, Austria, Brazil, China, Cyprus, Denmark, Germany, Greece, India, Italy, Mexico, Morocco, the Palestinian Territories, Poland, South Africa, Spain, Turkey and the United States, which represent about 95% of the cumulated installed capacity in operation in 2020.

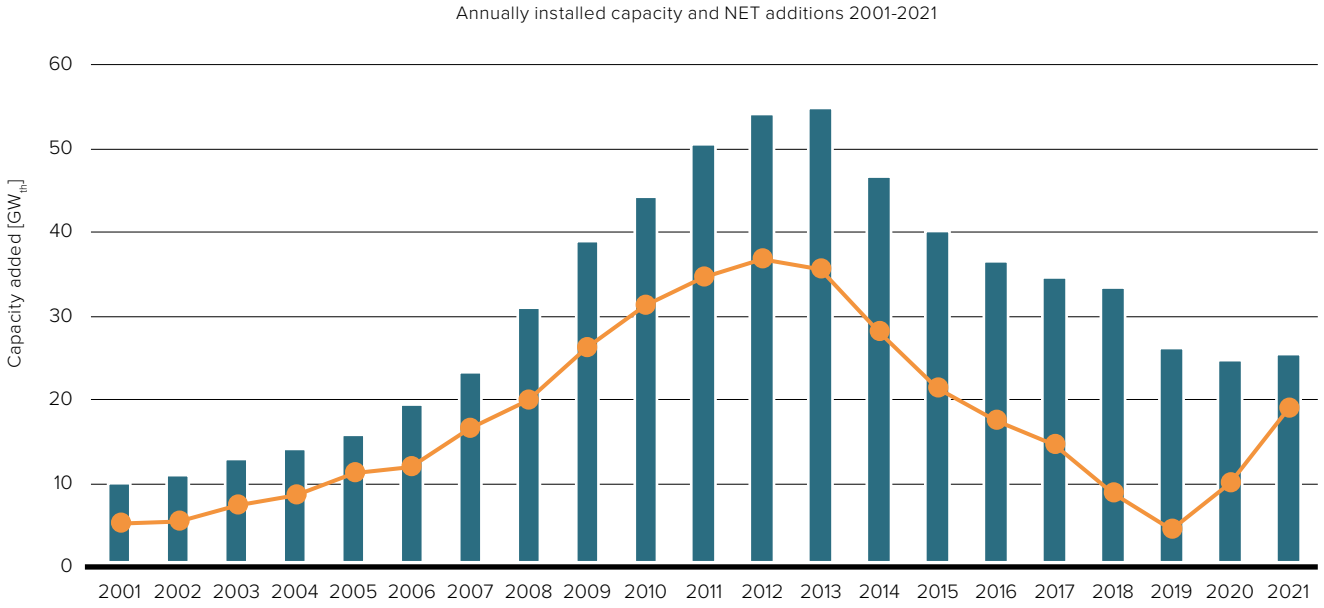


Figure 4: Annual installed collector capacities and the net additions

Annually installed capacity of water collectors [GW_{th}]
Water collectors NET additions [GW_{th}]

Solar District heating system with 18,732 m² evacuated tube collectors in Greifswald, Germany
Photo: Ritter XL Solar

3.2 China - Developments in the world's largest market

To get an idea of the scale and dominance of the Chinese solar thermal market, it is important to mention that of the 21 GW_{th} global installed capacity in 2021, China accounted for 83% or 18 GW_{th}. This is not a new development. In 2006 China already accounted for 69% of the world's installed collectors (Solar Heat Worldwide (2008)). Seventy-five percent of these installations were small thermosiphon systems installed in the thousands on urban apartment buildings as well as single-family houses.

Since 2006, the Chinese market has fundamentally changed. For example, in 2021, only 26% of all newly installed systems in China were thermosiphon systems, while pumped systems accounted for 74%.

As shown in Figure 5, the number of pumped systems is continuously increasing. This is due to financial incentives that have encouraged northern cities to use renewable energy for space heating and replace traditional fossil fuels to reduce carbon emissions. In addition, several reliable and effective solar district heating demonstration projects have been built in recent years.

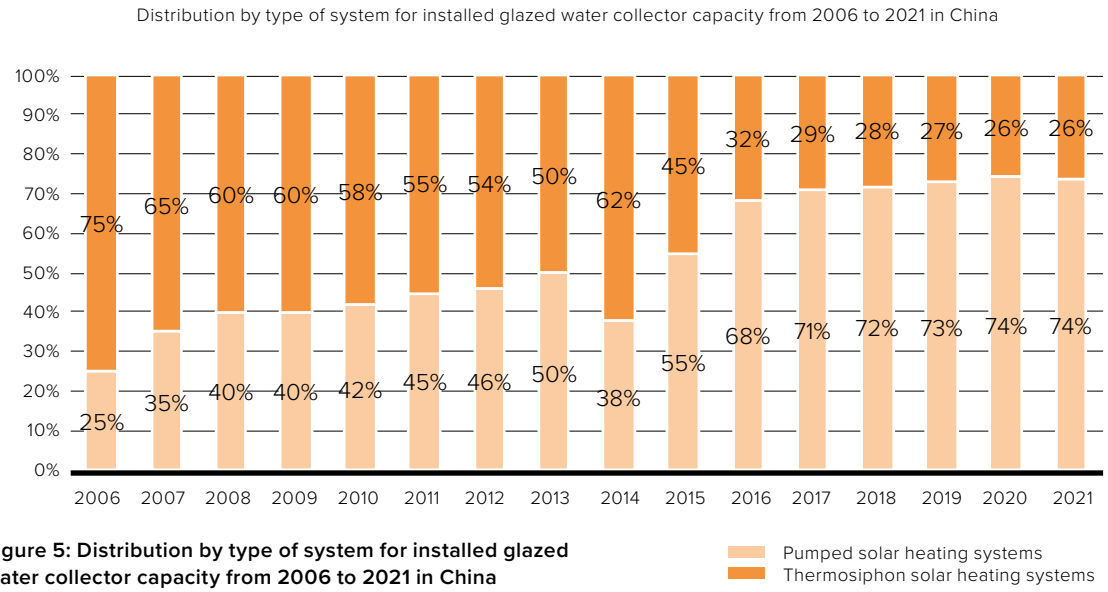


Figure 5: Distribution by type of system for installed glazed water collector capacity from 2006 to 2021 in China

The application of solar thermal systems has gradually changed from domestic water heating to solar combi-systems, solar district heating and industrial process heating. At the same time, the size of systems has increased significantly. A number of measures taken by China's central and local governments to reduce CO_2 emissions have contributed significantly to this development.

Figure 6 shows that the largest share of collector area installed in 2021 was for domestic hot water systems in multi-family dwellings, which accounted for about 63.6% of the installations. These are almost exclusively pumped systems with collector areas up to and over 1,000 square meters.

In single-family homes, domestic hot water systems accounted for 28.1% and solar combi-systems used for hot water and space heating accounted for about 6.1%. The share of other applications (solar process heat, solar air conditioning and solar district heating) was 2.2%.

The following picture shows one of the many Chinese solar combi-systems. An example of solar district heating can be found in chapter 4.2.

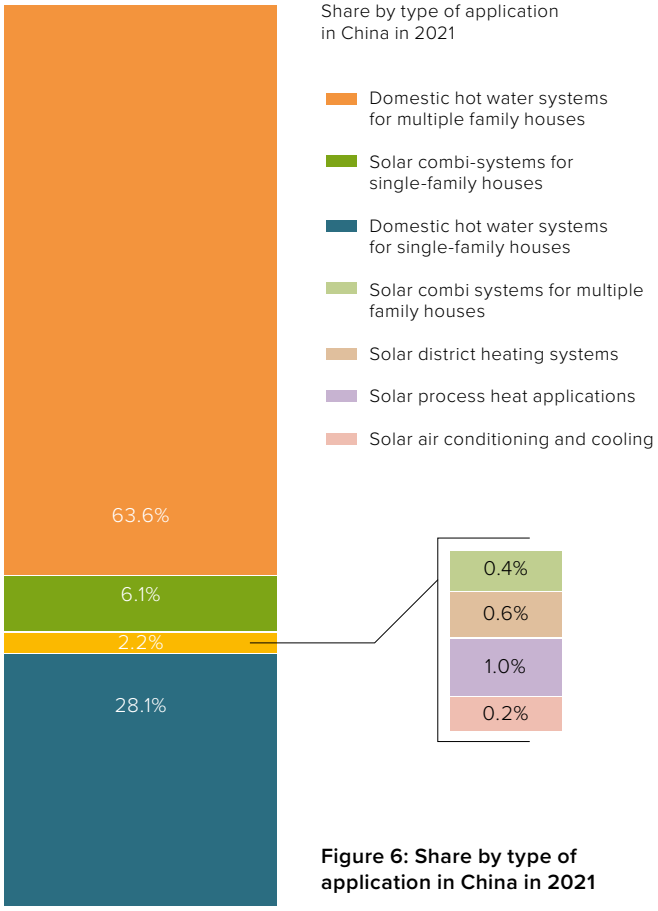


Figure 6: Share by type of application in China in 2021

Solar combi-system consisting of flat plate collectors and a heat pump for space heating at a nursing home in Guyuan County, Ningxia
Photo: Jiangsu Micòe Solar Energy Co. Ltd. China

4 Solar thermal market development and trends in 2021

Hallwang Event Center, Salzburg
Photo: Arch. Schindlmeier

As mentioned above, the global solar thermal market grew by 3% in 2021. This was due to the fact that China, by far the largest global market, stabilized and recorded a slight growth of 1%. There were also very positive market developments led by Italy's solid growth of 83%, followed by Brazil (28%), the United States (19%), Greece (18%), Poland (17%) and India (16%).

There was an opposite trend in Denmark due to the collapse of its solar district heating market sector. Here, the market decreased by 45% in 2021. Other traditionally strong markets also reported market declines, Spain (-19%), Austria (-7%) and Cyprus (-5%), as well as South Africa (-12%) and Australia (-3%).

83%
market growth in Italy 2021

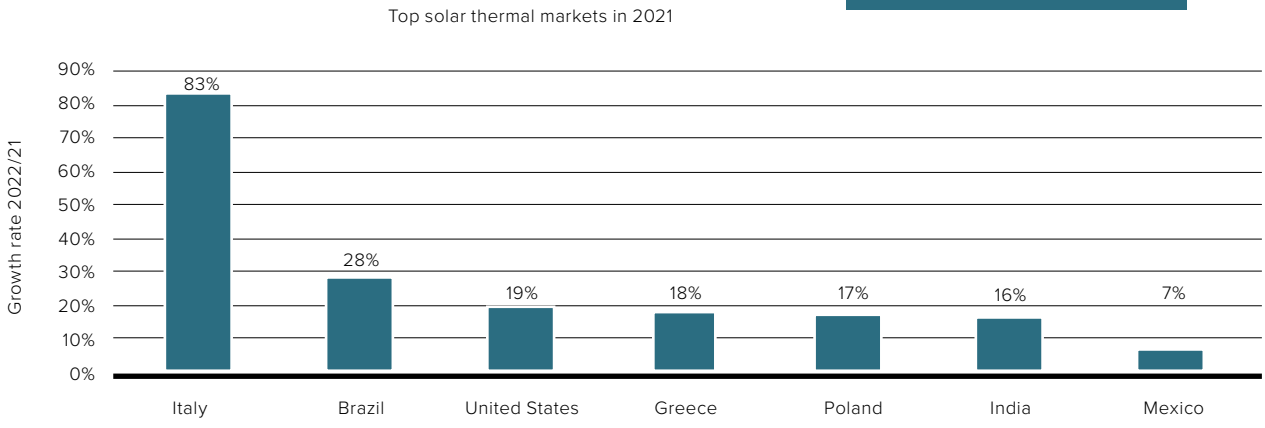


Figure 7: Countries with the highest growth rates in 2021

Simple thermosiphon systems are very common in the Sunbelt (between the 20th and 40th degrees of latitude in the northern and southern hemispheres)
Photo: AEE INTEC

4.1 Small-scale solar thermal heating systems

Small-scale solar water heating systems and, to a certain extent, solar combi-systems for combined hot water preparation and space heating in single-family houses, apartment buildings, multi-family houses, hotels and public buildings represent about 60% of the world's annual solar thermal installations.

In large parts of Europe and China, solar water heating applications are under increasing competition from photovoltaic systems and heat pumps and have lost market share in recent years. The predominant systems are pumped systems, which often use complex system technology.

The picture is different for thermosiphon systems. In Asia (excluding China), Latin America, Sub-Saharan Africa, and the Mediterranean region, thermosiphon systems are by far the dominant system type. Of the countries in Figure 7 above, thermosiphon systems dominate five out of the seven markets.

Solar district heating system installed in 2019 in the Saga District of Tibet has a capacity of 12.6 MW_{th}, corresponding to 18,000 m^2 flat plate collectors in combination with a 4,500 m^3 pit storage
Photo: Shandong Soletks Solar Energy Technology Co. Ltd., China

4.2 Large-scale solar thermal heating systems

In the Scandinavian countries Denmark and Sweden, as well as in Austria, Germany, Spain and Greece, large-scale solar thermal plants connected to local or district heating grids, or installed on large residential, commercial and public buildings have been in use since the early 1980s. It should be noted here that from the early 1980s up to 2016, the large-scale solar plant market was almost exclusively concentrated in Europe.

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Denmark dominated the large-scale system market - especially for solar district heating - for about a decade. However, due to a drastic change in energy technology policy and funding conditions, the Danish solar district heating market collapsed in 2020. As a result, in 2020 only one new solar district plant and three extensions were built, and in 2021 only one new system with an 8,013 m^2 collector area was commissioned in Denmark. The shift in policy and funding led Denmark to slip from first to third place among newly installed large-scale plants in 2021.

China reported twenty system installations in 2021, totaling a collector area of about 151,000 m^2 for district heating and large-scale building applications and accounting for 75% of the global market segment.

France ranked second behind China with 10,600 m^2 installed in the cities of Narbonne, Pons and Creutzwald.

The fourth place ranking goes to Austria, with one new large-scale system for district heating and one extension added to an existing district heating system in Graz, adding up to 7,950 m^2. Germany, with one system installed in 2021, ranks fifth (5,691 m^2) and Turkey sixth (5,621 m^2) with seven large-scale installations installed at hotels, mainly in Antalya.

By the end of 2021, 530 large-scale documented solar thermal systems (>350 kW_{th}, 500 m^2) were in operation. The total installed capacity of these systems equaled 1,970 MW_{th}, corresponding to 2.8 million m^2 collector area.

4.2.1 Solar district heating (SDH) systems

The largest sub-sector of large-scale solar thermal heating systems is solar district heating. By the end of 2021, 299 large-scale solar district heating systems (>350 kW_{th}, 500 m^2) with an installed capacity of 1,645 MW_{th} (2.35 million m^2) were in operation.

299 Solar district heating systems with 1.6 GW_{th} in operation

As shown in Figure 9, Denmark leads this market segment in terms of both the number of systems and the installed area. In addition to Denmark (125 systems) and China (41 systems), a number of other countries are showing an increasing interest in this type of plant, as they offer an excellent opportunity for decarbonizing the heat sector in neighborhoods and cities.

Countries to note are Germany (45 systems, some of these with seasonal storage), Sweden (24 systems), Austria (22 systems), Poland and France (with 8 systems each). Outside China and Europe, solar district heating systems are installed in Saudi Arabia, Japan, Kyrgyzstan, Russia (Asia excluding China), the USA, Canada, and South Africa (Figure 9).

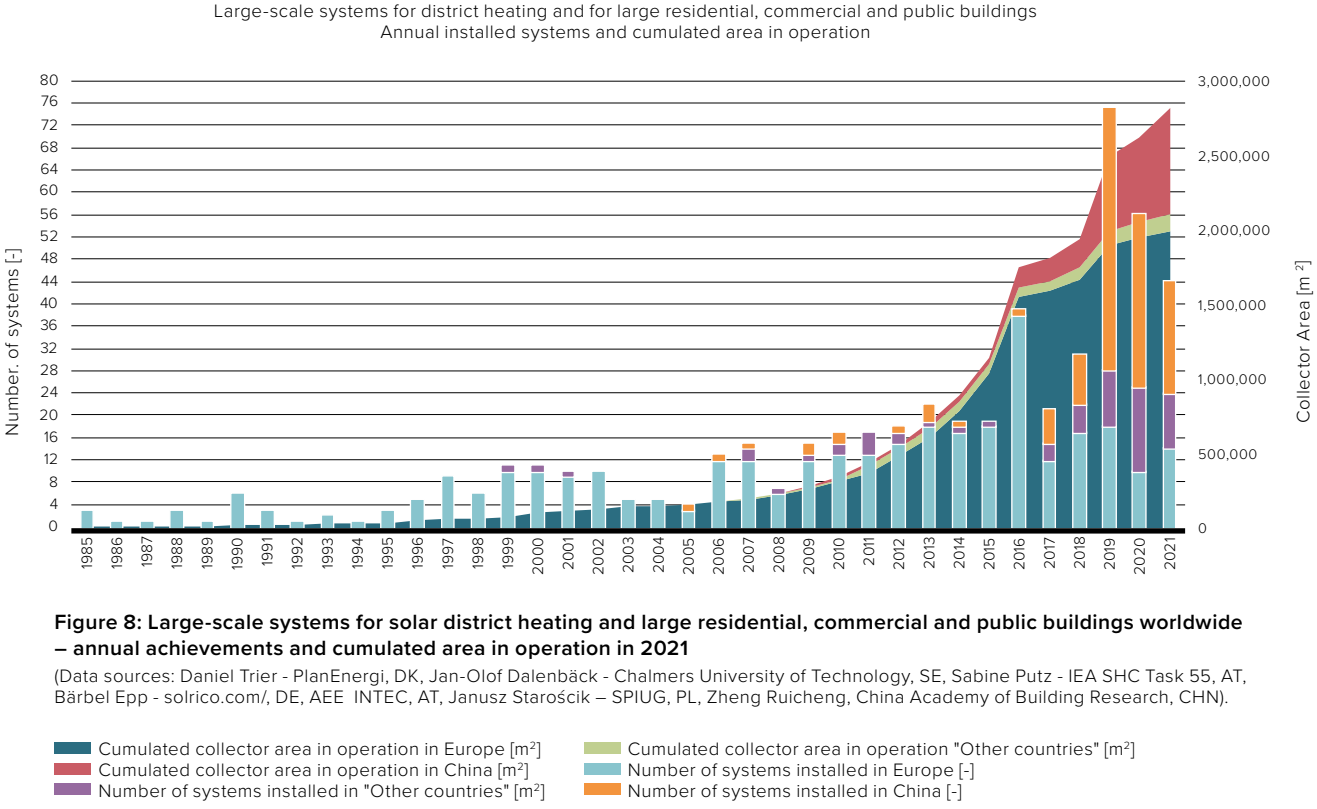

Figure 8: Large-scale systems for solar district heating and large residential, commercial and public buildings worldwide – annual achievements and cumulated area in operation in 2021

(Data sources: Daniel Trier - PlanEnergi, DK, Jan-Olof Dalenbäck - Chalmers University of Technology, SE, Sabine Putz - IEA SHC Task 55, AT, Bärbel Epp - solrico.com/, DE, AEE INTEC, AT, Janusz Starościk – SPIUG, PL, Zheng Ruicheng, China Academy of Building Research, CHN).

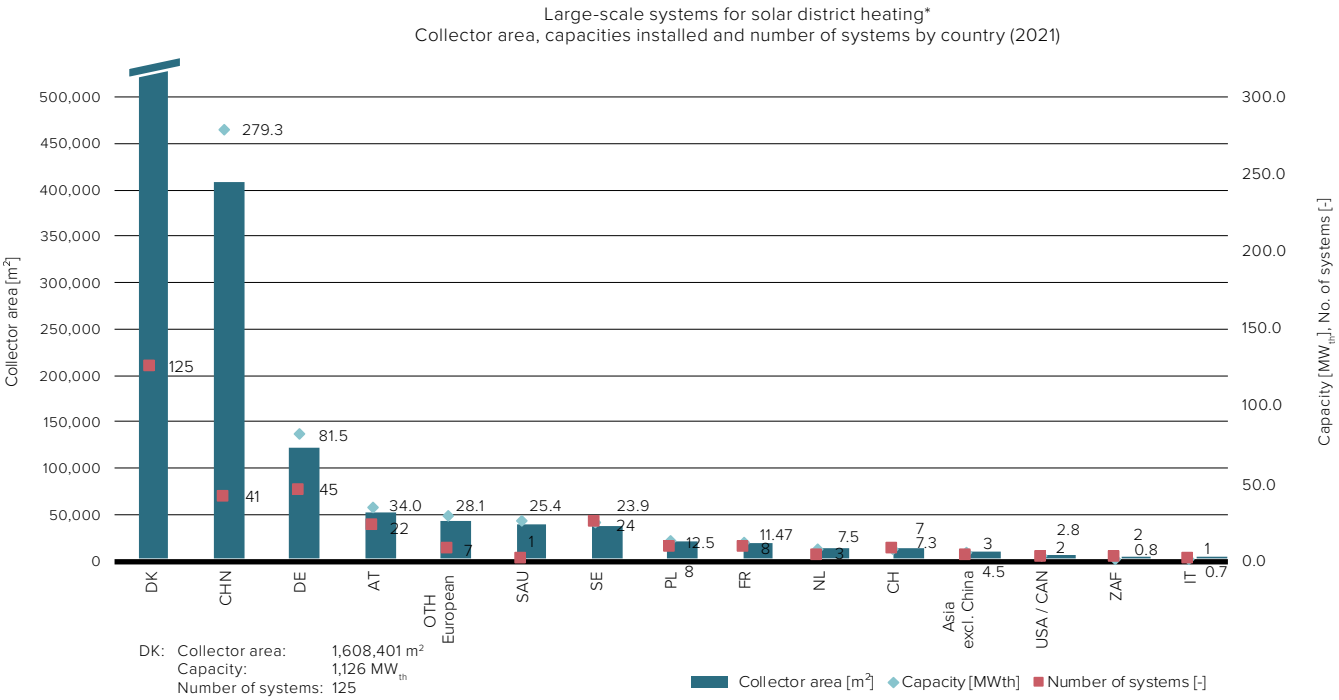

Table 1 lists the 20 largest solar district heating systems. By far, the largest system was built in the Danish city of Silkeborg in 2016. It has a collector area of almost 157,000 square meters, corresponding to a capacity of 110 MW_{th}. The table also shows the dominance of Denmark in this market segment, as 15 of the 20 largest systems are in Denmark.

Figure 9: Large-scale systems for solar district heating – capacity, installed collector area and number of systems in 2021

(Data sources: Daniel Trier - PlanEnergi, DK, Jan-Olof Dalenbäck - Chalmers University of Technology, SE, Sabine Putz - IEA SHC Task 55, AT, Bärbel Epp - solrico.com, DE)

* PVT and concentrating solar thermal systems add up to 158,421 m^2

Table 1: The twenty largest solar district heating systems

Installation	SDH Project	Country	Installed Collector Area m^2	Installed Capacity MW_{th}
2016	Silkeborg	Denmark	156,694	110
2016	Inner Mongolia	China	93,000	65
2015	Vojens stage 2	Denmark	52,492	37
2014	Dronninglund	Denmark	37,573	26
2011	Rhiad	Saudi Arabia	36,305	25
2015	Gram stage 2	Denmark	34,851	24
2019	Zhongba, Tibet	China	34,650	24
2019	Ringe	Denmark	31,224	22
2016	Brønderslev	Denmark	26,929	19
2018	Aabybro	Denmark	26,195	18
2019	Sæby, stage 2	Denmark	25,313	18
2019	Hadsten	Denmark	24,517	17
2016	Aalestrup	Denmark	24,129	17
2018	Langkasi, Tibet	China	22,275	16
2019	Salaspils	Latvia	21,672	15
2015	Hjallerup	Denmark	21,546	15
2014	Vildbjerg	Denmark	21,244	15
2019	Grenaa, stage 2	Denmark	20,673	14
2015	Hadsund	Denmark	20,513	14
2019	Høng	Denmark	20,160	14

(Sources: Planenergi, Solarthermalworld.org, Bärbel Epp)

The Austrian solar district heating system in Friesach, with a capacity of 4.1 MW_{th}, corresponding to 5,950 m^2 flat plate collectors, was installed in 2021
Photo: Greenonetec Solar Industry GmbH, Austria

4.2.2
Large-scale systems for buildings in the residential, public and commercial sector

Partial view of the solar installation on Lady Pohamba Hospital in Windhoek, Namibia
Photo: AEE INTEC

The second market of interest in the large-scale sector, besides solar district heating, is solar applications for residential, commercial and public buildings. At the end of 2021, around 230 large-scale solar thermal systems (>350 kW_{th}; 500 m^2) were supplying heat to residential, commercial and public buildings worldwide. The total installed capacity of these systems is 324 MW_{th} (463,100 m^2).

China leads this market segment with 84 installed systems and a capacity of 223 MW_{th}, followed by Turkey with 18 systems and an installed capacity of 14.2 MW_{th}. Latin America is in third place with 16 systems and an installed capacity of around 12 MW_{th}.

In addition to the European countries of Greece, France, Austria, Switzerland, Poland and Spain, a growing number of large-scale systems are being built in Latin America (Brazil, Mexico), the MENA region (Dubai, Jordan, Kuwait, United Arab Emirates) and Asia, excluding China (Cambodia, India, Thailand). These systems are often installed on hospitals, hotels and sports centers.

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Learn more about current research results and international cooperation on the topic of solar district heating: https://task68.iea-shc.org/

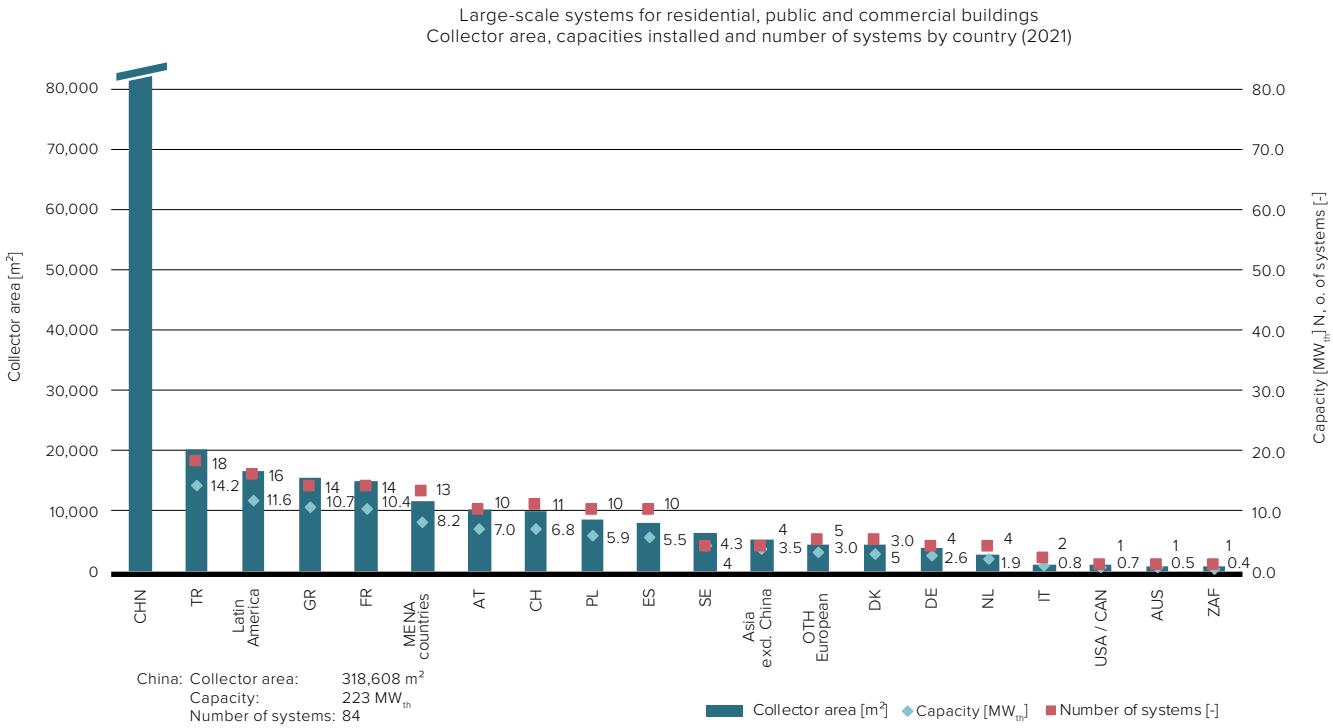

Figure 10: Large-scale systems for residential, public and commercial buildings – capacity, installed collector area and number of systems in 2021

4.3 Solar heat for industrial processes

Solar process heat system for Martini & Rossi with a capacity of 0.42 MW_{th} and equipped with high-vacuum flat plate collectors in Turin, Italy
Photo: TVP Solar, Switzerland

Across the globe, interest in solar thermal systems for industrial processes (SHIP) has grown steadily. A number of promising projects undertaken in the last couple of years range from small-scale demonstration plants to large 100 MW_{th} systems.

Many industrial processes demand vast amounts of heat, making this 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 – air collectors, flat plate and evacuated tube collectors for temperatures up to 100°C and concentrating solar thermal collectors, such as Scheffler dishes, Fresnel collectors and parabolic troughs for temperatures up to 400°C.

According to a study published by Solrico in early 2022 and a survey by AEE INTEC, at least 78 SHIP plants with a collector area of 51,539 m^2 (36 MW_{th}) were added in 2021 worldwide, so the number of SHIP projects in operation totals at least 975 systems with an overall installed collector area of 1.23 million m^2.

Industrial Process Heat: 975 systems with a 1.23 million m² collector area

For 394 of these systems, more detailed information on the collector area, installed capacity, and type of application and collector can be found in the SHIP database, an online portal operated by AEE INTEC in Austria[4].

Please note that only systems with a collector area larger than 50 m^2 are included in this report. The report's definition of SHIP can be found in the Appendix, chapter 8.6.

Figure 11 to Figure 15 show the analysis of the 394 systems, which have a total collector area of 1,012,613 m^2 gross and a thermal capacity of 507 MW_{th}. It is important to note that the data in these four graphs is dominated by the world's largest SHIP plant, the Miraah in Oman, which has a thermal capacity of 300 MW_{th}. and accounts for 59% of the total installed thermal capacity of all 394 documented SHIP applications.

The second largest SHIP application is for a greenhouse in Australia (36.6 MW_{th}copper mine in Chile (27.5 MW_{th}) for their copper winning process. Together, these three plants represent 71% of the total installed thermal capacity.

Figure 11 shows the distribution of the 394 systems in terms of size. The three systems mentioned above exceed 21 MW_{th} of thermal capacity (30,000 m^2), 54 systems have installed capacities between 0.7 MW_{th} and 21 MW_{th} (1,000 m^2 - 29,999 m^2), 64 systems have installed capacities between 0.35 and 0.7 MW_{th} (500 – 9,999 m^2) and 273 systems are below 0.35 MW_{th} (<500 m^2).

[4] http://ship-plants.info/

Parabolic trough collectors installed at Comercial Forrajera de Lagos (COMFOSA) in Mexico

Copyright: COMFOSA

As shown in Figure 12, the majority of the solar process heat systems use flat-plate collectors followed by parabolic trough collectors and evacuated tube collectors. Parabolic trough collectors have the highest installed gross area, however, without the Miraah plant, it would rank third.

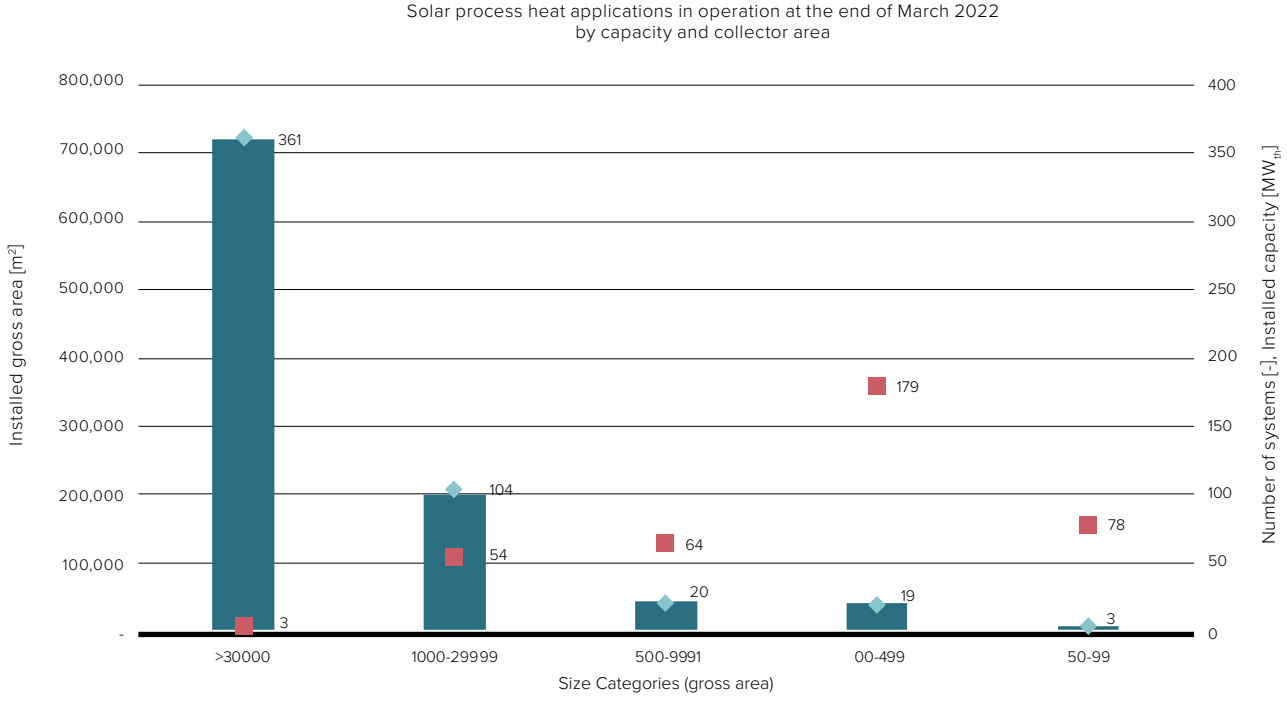

Figure 11: Solar process heat applications in operation at the end of March 2022 by capacity and collector area

(Source: IEA SHC Task64/IV SHIP database)

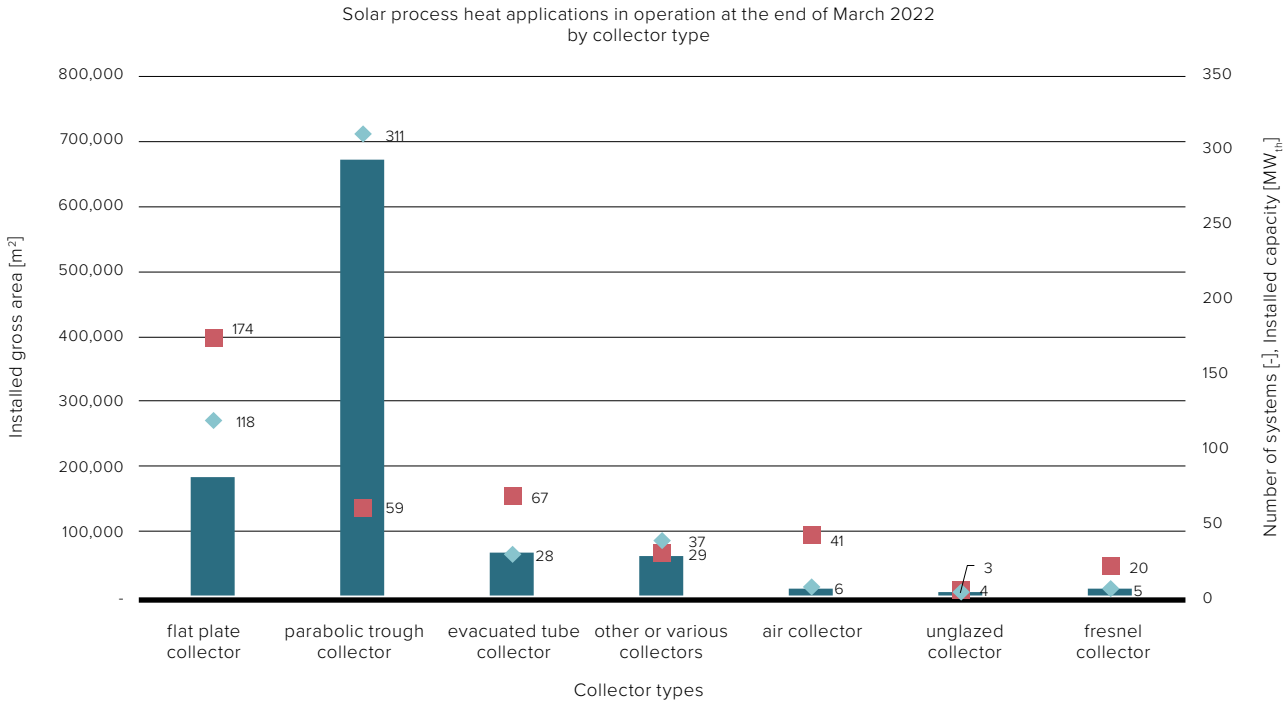

Figure 12: Solar process heat applications in operation at the end of March 2022 by collector type
(Source: IEA SHC Task49/IV SHIP database)

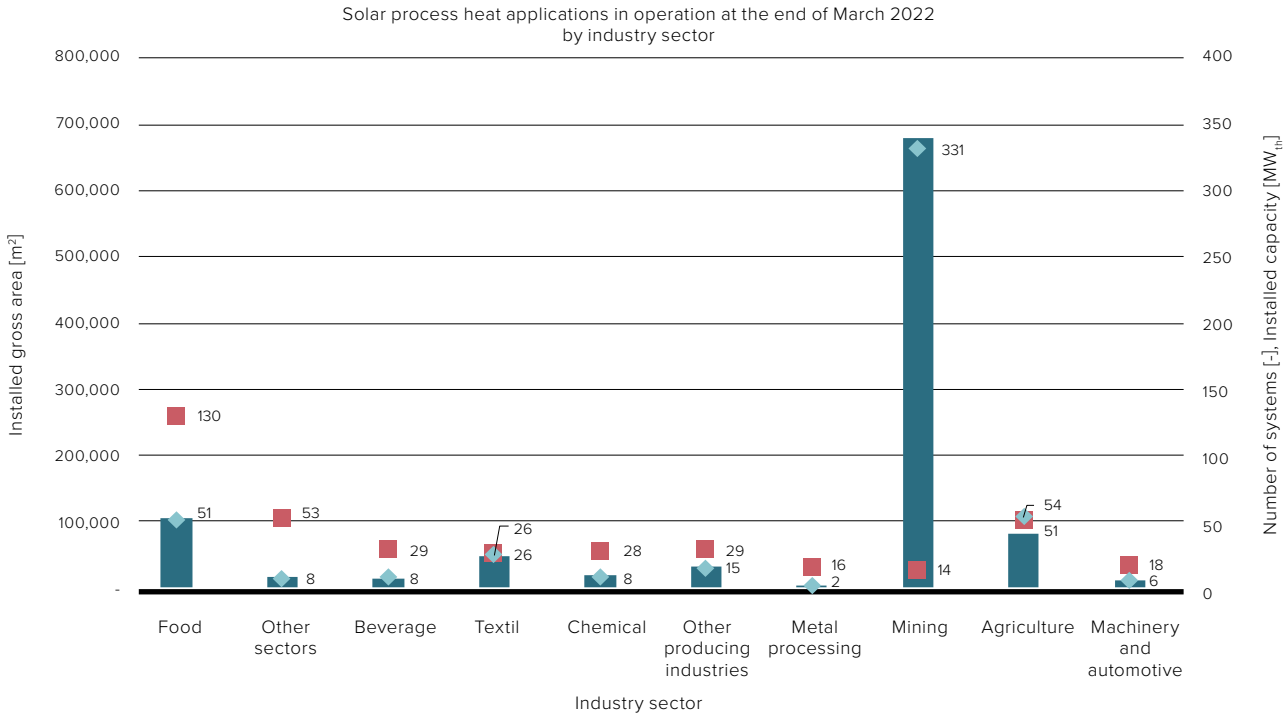

Figure 13: Solar process heat applications in operation worldwide at the end of March 2022 by industry sector
(Source: IEA SHC Task64/IV SHIP database)

Figure 13 shows the industry sectors of the 394 systems. The main sectors are mining, food and textile. The food and beverage sector grew again in 2021 and is the dominant sector in terms of number of installed systems. It accounts for 159 systems with an average size of 751 m^2gross and 59 MW_{th} of installed thermal capacity.

The mining industry, which includes two of the three largest systems, is the dominant sector in terms of installed thermal capacity. The 14 systems account for 65% of the total installed thermal capacity.
In the agricultural sector, 31 new plants were documented in 2021. A total of 51 systems with 54 GW_{th} are now confirmed.

Solar wood chip drying with air collectors, Austria
Photo: Austria Solar / CONA

Figure 14 documents the global installed solar process heat systems by country. Mexico, Germany and India have the highest number of installed systems, followed by Austria, the USA and Spain. Oman leads in terms of installed thermal capacity with its single installed system.

Table 2 documents all SHIP systems with a collector area greater than 5,000 m^2, corresponding to 3.5 MW$_{th}$.

Mexico leads
in the number of SHIP systems installed

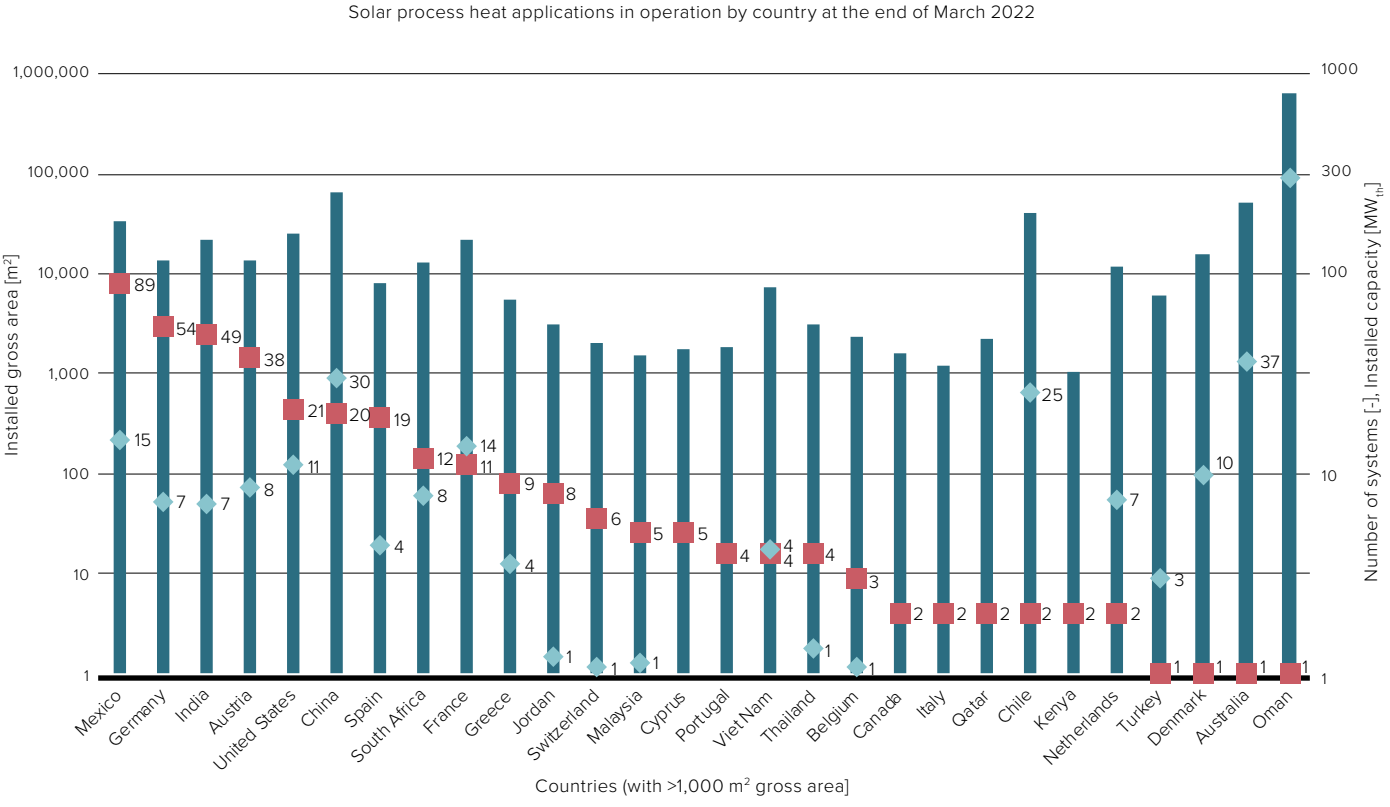

Figure 14: Solar process heat applications in operation worldwide by country at the end of March 2022.
Only countries with at least 0.7 MW$_{th}$ (1,000 m^2 gross area) are shown (377 of 394 systems accounting for >99% of installed thermal capacity)
(Source: IEA SHC Task64/IV SHIP database)

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Learn more about current research results and international cooperation on Solar Process Heat: https://task64.iea-shc.org/
and on Solar Energy in Industrial Water & Wastwater https://task62.iea-shc.org/

Table 2: Solar Heat for Industrial Processes (SHIP) plants > 5000 m^2

Commissioned	Site	Country	Collector size [m^2]	Installed Capacity [MW_{th}]
2017	Miraah Oman, Amal	Oman	630,000	300
2014	Sundrop Farms, Port Augusta	Australia	51,505	37
2013	Codelco Gabriela Mistral Mine	Chile	39,300	28
2015	Østervang Greenhouse, Varpelev	Denmark	15,680	10
2021	Brewery, Isodoun	France	14,252	10
2007	Daly Textile, Hangzhou	China	13,000	9
2015	Ruyi Textile, Shandong	China	9,903	7
2019	Tesselaar Freesias Greenhouse	Netherlands	9,300	6
2015	LVG Plants Krugerstorp	South Africa	9,135	6
2011	Jiangsu Printing and Dyeing	China	9,000	7
2012	Prestage Foods, St. Pauls, North Carolina	USA	7,804	5
2016	La Parerena Copper Mine	Mexico	6,270	4
2020	Packaging Business Turkey	Turkey	6,000	4
2010	Jinan, Shandong, pre-heating of industrial boiler	China	5,892	4
2011	Jingshi East Road Jinan	China	5,750	4
2008	Frito Lay, Arizona	USA	5,068	3.5
2018	Prime Asia Leather, Ba Ria-Vung Tau	Vietnam	5,018	3.5

(Source: ship-plants.info)

Solar heated greenhouses

In addition to the more traditional industrial sectors that use thermal solar systems highlighted above, a new sector is horticulture. Solar thermal plants are being used to heat greenhouses for flower and vegetable cultivation.
The following table provides an overview of the systems with collector areas larger than 50 m^2 between 2013 and 2020.

Table 3: Solar thermal systems for flower and vegetable cultivation

Country	Site	Commissioned	Installed capacity [MW_{th}]	Collector size [m^2]	Storage tank [m^3]
Netherlands	Nibbixwoud	2020	10.5	15,000	1,450
Ethiopia	Arerti	2020	2.91	4,170	1,400
China	Tibet	2020	3.5	5,000	n.a.
Guatemala	Chimaltenango	2020	1.52	2,175	300
Netherlands	Heerhugowaard	2019	6.51	9,300	1,300
USA	Oregon	2019	0.72	1,030	n/a
Austria	Vienna	2018	0.09	126	20
Uganda	Kampala	2017	3.23	4,614	900
South Africa	Krugersdorp	2015	6.40	9,135	2,100
Denmark	Østervang Varpelev	2015	9.89	14,112	4,800
Germany	Bohlingen	2015	0.67	960	n.a.
Australia	Port Augusta	2014	36.05	51,505	no
Ethiopia	Addis Ababa	2014	1.95	2,784	400
Namibia	Okahandja	2014	2,60	3,712	1,900
Kenya	Naivasha	2013	0.34	480	150
Morocco	Aït Melloul	2013	0.71	1,007	150
Mexico	Buenavista, Jalisco	2013	0.05	66	2.5

(Source: Bosman Van Zaal, G2 Energy, Solar Payback SHIP Supplier Survey 2020, AEE INTEC)

200 m² PVT-collector field for a new office/council building in Offenbach an der Quaich, Germany
Photo: Consolar, Germany

1.4 million m² PVT collector area installed worldwide

4.4 PVT – Photovoltaic Thermal Systems

Photovoltaic-Thermal (PVT) collectors combine the production of both types of solar energy – solar heat and solar electricity – simultaneously in one collector, thus reaching higher yields per area. This is particularly important if the available roof area is limited, but integrated solar energy concepts are needed to achieve a climate-neutral energy supply for consumers, such as in residential and commercial buildings.

The technology is somewhat more complex than just a PV or a solar thermal collector but provides significant advantages. The PV output can be slightly higher if the collectors are operated at temperatures below those of a PV-only module. Depending on the type of PVT collector, the produced temperature ranges from about -20°C up to +150°C and serves a wide range of applications. The solar thermal energy generated by a PVT system offers a lot of flexibility in the system design. The energy can be stored in many ways, including onsite tanks, aquifers, ground strata and pit storage systems. It can be used directly for hot water or space heating or for a secondary system such as a heat source (heat pumps). Cooling (radiative and convective) can also be provided directly during the night using the PVT collector's thermal absorber or indirectly through a machine driven by the PV electricity.

Global interest in PVT systems has grown steadily over the past years, leading to many specialized PVT technology suppliers entering the European market.

General market overview

The PVT data is based on a survey of 38 PVT collector manufacturers and PVT system suppliers in 14 different countries.

In 2021, the total installed PVT collector area was 1,442,596 m^2 (751 MW_{th}, 254 MW_{peak}). The vast majority of this collector area was installed in Europe (884,329 m^2), followed by Asia excluding China (307,540 m^2) and China (142,926 m^2), which together accounted for 668 MW_{th}, 226 MW_{peak} of the total installed capacity. The remaining installed collector area was shared between the MENA countries (Egypt, Israel and Iraq (68,626 m^2)), the Sub-Sahara African countries (Ghana, Lesotho and South Africa (22,926 m^2)), the United States and Canada (8,125 m^2), Australia (3,576 m^2), Latin America (637 m^2) and others (3,910 m^2).

In the European market, France is the market leader with an installed collector area of 598,157 m^2, followed by Germany with 127,640 m^2 and the Netherlands with 91,754 m^2. In Spain, Italy and Switzerland, collector areas range between 15,000 m^2 and 20,500 m^2. In the remaining European countries, collector areas of at least 15,146 m^2 were reported.

Table 4 shows the cumulated installed collector area by PVT collector type at the end of 2021.

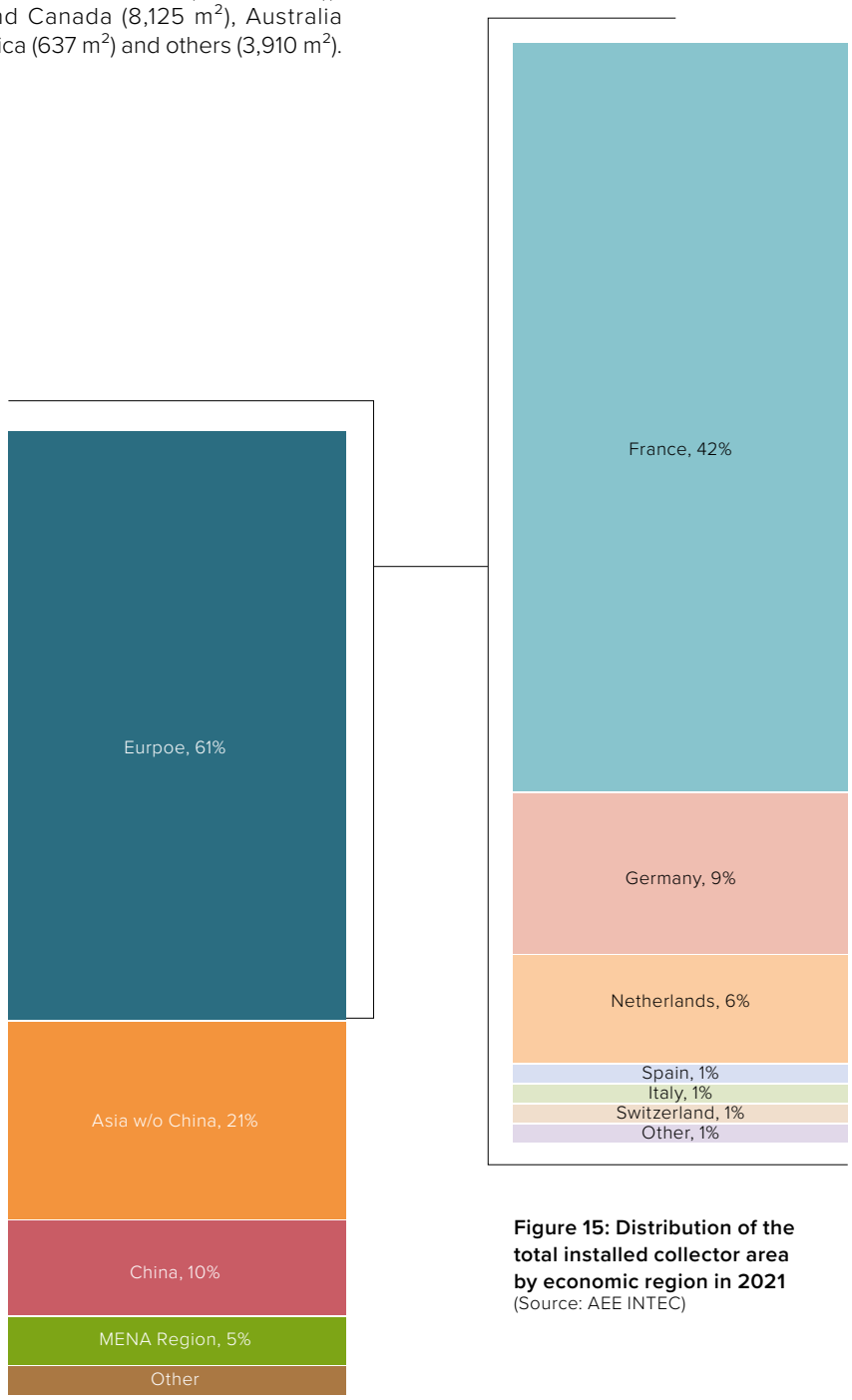

Figure 15: Distribution of the total installed collector area by economic region in 2021
(Source: AEE INTEC)

Table 4: Cumulated collector area by PVT collector type at the end of 2021

Country	Water Collectors [m²]			Air Collectors [m²]	Concentrators [m²]	TOTAL [m²]
	uncovered	covered	evacuated tube			
Albania	148	12	0	0	0	160
Australia	3,477	0	0	99	0	3,576
Austria	1,234	1,731	0	0	0	2,965
Belgium	2,314	0	32	290	15	2,651
Brazil	26	0	0	0	0	26
Bulgaria	517	43	0	0	0	560
Canada	0	32	0	0	0	32
Chile	213	113	0	0	10	337
China	141,721	1,034	0	0	171	142,926
Croatia	907	125	0	0	0	1,032
Denmark	109	0	0	0	0	109
Dubai	43	9	0	0	0	52
Ecuador	0	138	0	0	0	139
Egypt	0	0	0	0	21	21
France	49,633	949	0	547,575	0	598,157
Germany	122,738	4,196	0	512	195	127,640
Ghana	22,000	0	0	0	0	22,000
Iraq	0	16	0	0	0	16
Guadeloupe	0	4	0	0	0	4
Hungary	525	53	0	0	0	578
India	0	801	0	0	255	1,056
Iraq	0	30	0	0	0	30
Israel	68,575	0	0	0	0	68,575
Italy	13,793	2,334	0	0	0	16,127
Korea, South	280,814	0	0	0	0	280,814
Lesotho	0	48	0	0	0	48
Luxembourg	635	0	0	145	0	780
Macedonia	629	147	0	0	0	776
Maldives	0	0	0	0	21	21
Martinique	0	63	0	0	0	63
Netherlands	80,898	9,034	0	0	1,822	91,754
Norway	646	0	0	0	0	646
Pakistan	0	7	0	0	0	7
Paraguey	0	0	0	0	51	51
Peru	0	16	0	0	0	16
Poland	413	61	0	0	0	474
Portugal	335	338	0	0	0	672
Peru	0	50	0	0	0	50
Singapur	875	0	0	0	0	875
Slovakia	0	250	0	0	0	250
Slovenia	60	12	0	0	0	72
South Africa	0	79	32	0	767	878
Spain	1,552	18,946	0	0	0	20,498
Sweden	1,200	20	0	0	31	1,251
Sri Lanka	692	24	0	0	0	716
Switzerland	11,365	112	0	3,530	0	15,007
Tibet	24,000	0	0	0	0	24,000
Turkey	0	25	0	0	30	55
United Kingdom	891	426	252	348	135	2,051
United States	8,093	0	0	0	0	8,093
Uruguay	0	2	0	0	0	2
Other	629	3,250	16	0	15	3,910
Total	841,699	4,4527	332	552,499	3,538	1,442,596

(Source: AEE INTEC)

Market development of PVT collectors between 2017 und 2021

Based on data from the 38 PVT manufacturers, the market for PVT collectors saw a constant growth of 9% on average between 2017 and 2020. In 2021, the global market grew by around 13%.

This positive trend also was observed in the European market with an even higher growth rate of 21%, which corresponds to an increase of the yearly new installed capacity of 79,8 MW_{th} and 27,6 MW_{peak}.

The European PVT market grew by 21%

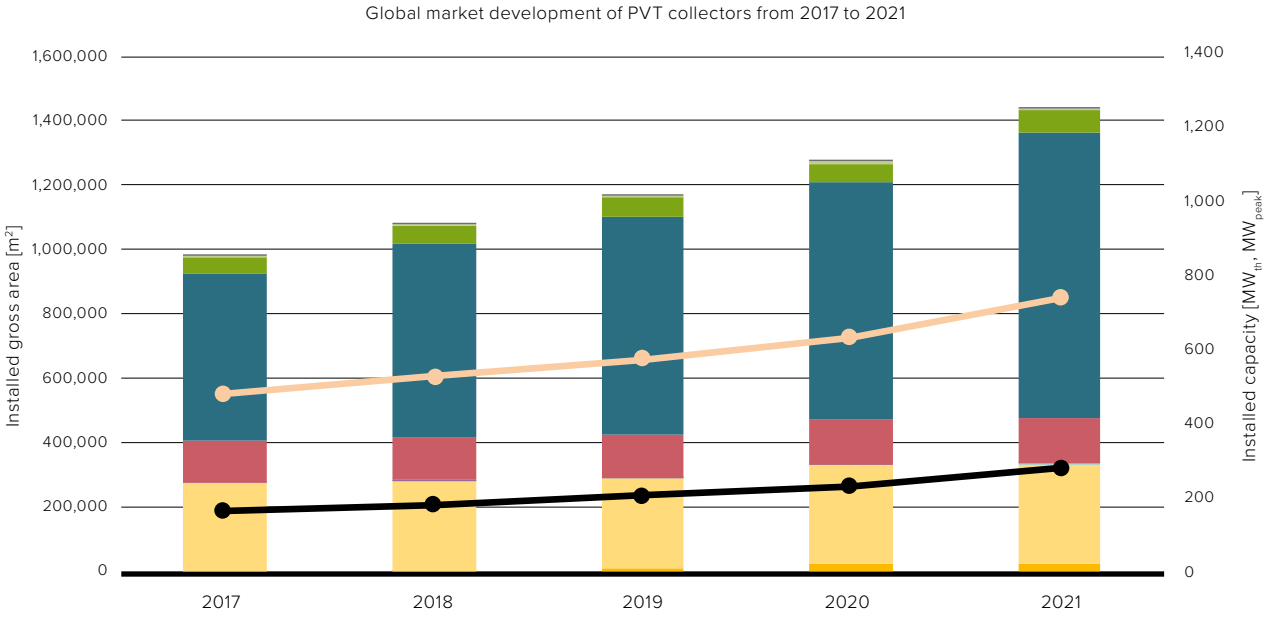

Figure 16: Global market development of PVT collectors from 2017 to 2021
(Source: AEE INTEC)

By the end of 2021, PVT collectors' total cumulative thermal capacity was 751 MW_{th}, and the PV power was 254 MW_{peak}. With a global share of 60% of installed thermal capacity, uncovered PVT water collectors were the dominating PVT technology, followed by air collectors with 37% and covered PVT water collectors with 3%. Evacuated tube collectors and concentrators play only a minor role in the total numbers.

High-temperature PVT system at Windtown Hotel in Langebaan, South Africa. 27.5 kW thermal and 7.6 kW electrical combined with a 19 kW heat pump
Photo: Solarus Smart Energy Solutions, NL

Table 5: Total installed PVT capacity in 2021 divided into thermal and electrical power

Country	Water Collectors						Air Collectors		Concentrators		TOTAL	
	uncovered		covered		evacuated tube							
	[kW_{th}]	[kW_{peak}]	[kW_{th}]	kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]	[kW_{th}]	[kW_{peak}]
Albania	76	29	7	2	0	0	0	0	0	0	82	31
Australia	1,804	672	0	0	0	0	54	17	0	0	1.857	689
Austria	618	227	881	298	0	0	0	0	0	0	1.498	525
Belgium	1,179	440	0	0	16	4	141	46	9	2	1.345	493
Brazil	13	5	0	0	0	0	0	0	0	0	13	5
Bulgaria	264	103	23	7	0	0	0	0	0	0	288	110
Canada	0	0	17	5	0	0	0	0	0	0	17	5
Chile	105	37	53	21	0	0	0	0	6	1	164	59
China	70,067	24,297	557	170	0	0	0	0	98	20	70,722	24,487
Croatia	508	174	68	20	0	0	0	0	0	0	576	194
Dubai	56	19	0	0	0	0	0	0	0	0	56	19
Denmark	23	8	5	1	0	0	0	0	0	0	28	10
Ecuador	0	0	75	23	0	0	0	0	0	0	75	23
Egypt	0	0	0	0	0	0	0	0	12	2	12	2
France	26,048	9,413	512	156	0	0	272,663	88,389	0	0	299,223	97,958
Germany	60,678	21,216	2,148	715	0	0	270	88	109	22	63,205	22,042
Ghana	11,958	4,140	0	0	0	0	0	0	0	0	11,958	4,140
Greece	0	0	9	3	0	0	0	0	0	0	9	3
Guadeloupe	0	0	2	1	0	0	0	0	0	0	2	1
Hungary	257	90	24	10	0	0	0	0	0	0	282	100
India	0	0	432	133	0	0	0	0	146	30	579	162
Iraq	28,212	9,110	16	5	0	0	0	0	0	0	28,229	9,115
Israel	33,928	12,043	0	0	0	0	0	0	0	0	33,928	12,043
Italy	6,816	2,424	1,088	439	0	0	0	0	0	0	7,904	2,863
Korea, South	137,599	47,828	0	0	0	0	0	0	0	0	137,599	47,828
Lesotho	0	0	26	8	0	0	0	0	0	0	26	8
Luxembourg	311	108	0	0	0	0	71	23	0	0	382	131
Macedonia	329	120	73	26	0	0	0	0	0	0	403	146
Maldives	0	0	0	0	0	0	0	0	12	2	12	2
Martinique	0	0	34	10	0	0	0	0	0	0	34	10
Netherlands	42,337	15,240	4,907	1,477	0	0	0	0	1,047	213	48,291	16,931
Norway	349	121	0	0	0	0	0	0	0	0	349	121
Pakistan	0	0	3	1	0	0	0	0	0	0	3	1
Paraguey	0	0	0	0	0	0	0	0	30	6	30	6
Peru	0	0	9	3	0	0	0	0	0	0	9	3
Poland	218	81	33	10	0	0	0	0	0	0	251	91
Portugal	168	62	183	55	0	0	0	0	0	0	350	117
Russia	0	0	27	8	0	0	0	0	0	0	27	8
Singapur	468	171	0	0	0	0	0	0	0	0	468	171
Slovakia	0	0	136	41	0	0	0	0	0	0	136	41
Slovenia	32	12	7	2	0	0	0	0	0	0	39	14
South Africa	0	0	43	13	16	4	0	0	441	90	500	107
Spain	775	284	9,587	3,270	0	0	0	0	0	0	10,362	3,554
Sweden	682	228	11	3	0	0	0	0	18	4	710	235
Sri Lanka	354	137	13	4	0	0	0	0	0	0	367	141
Switzerland	5,719	2,036	60	18	0	0	1,806	576	0	0	7,585	2,631
Tibet	13,632	4,564	0	0	0	0	0	0	0	0	13,632	4,564
Turkey	0	0	14	4	0	0	0	0	15	3	29	7
United Kingdom	440	154	205	78	109	29	170	55	69	15	994	331
United States	4,134	1,448	0	0	0	0	0	0	0	0	4,134	1,448
Uruguay	0	0	1	0	0	0	0	0	0	0	1	0
Other	320	114	1,496	617	7	2	0	0	8	2	1,830	735
Total	450,478	157,156	22,781	7,658	147	40	275,175	89,194	2.020	413	750,601	254,461

(Source: AEE INTEC)

Distribution by type of application

In 2021, suppliers of PVT technology commissioned at least 6,036 new PVT systems worldwide. As a result, the cumulated number of PVT systems in operation at the end of 2021 was 33,956. The breakdown is 77.2% used for solar air(pre)heating/ cooling buildings, followed by 9.5% for solar combi-systems that supply heat for both domestic hot water and space heating and 8.9% for domestic hot water preparation for single-family houses. Around 1.6% of the worldwide installed capacity provided heat and electricity to large domestic hot water systems for multifamily buildings, hotels, hospitals, schools, etc. The remaining systems account for around 5.4% and deliver heat and electricity to other applications, including swimming pool heating, district heating applications and solar heat for industrial applications.

Table 6 shows PVT systems by application.

Table 6: PVT systems by application

PVT-Applications	Number of installations [#]	Total collector area [m²] - 2021
Swimming pool heating	313	25,406
Domestic hot water systems SFH	3,030	95,032
Large domestic hot water systems	551	222,755
Solar combi systems for SFH	3,222	56,535
Large solar combi systems	439	79,726
Solar air systems	26,231	588,383
Solar district heating systems	88	29,963
Solar heat for industrial applications	82	24,364
Not classifiable		320,431
TOTAL		1,442,595

(Source: AEE INTEC)

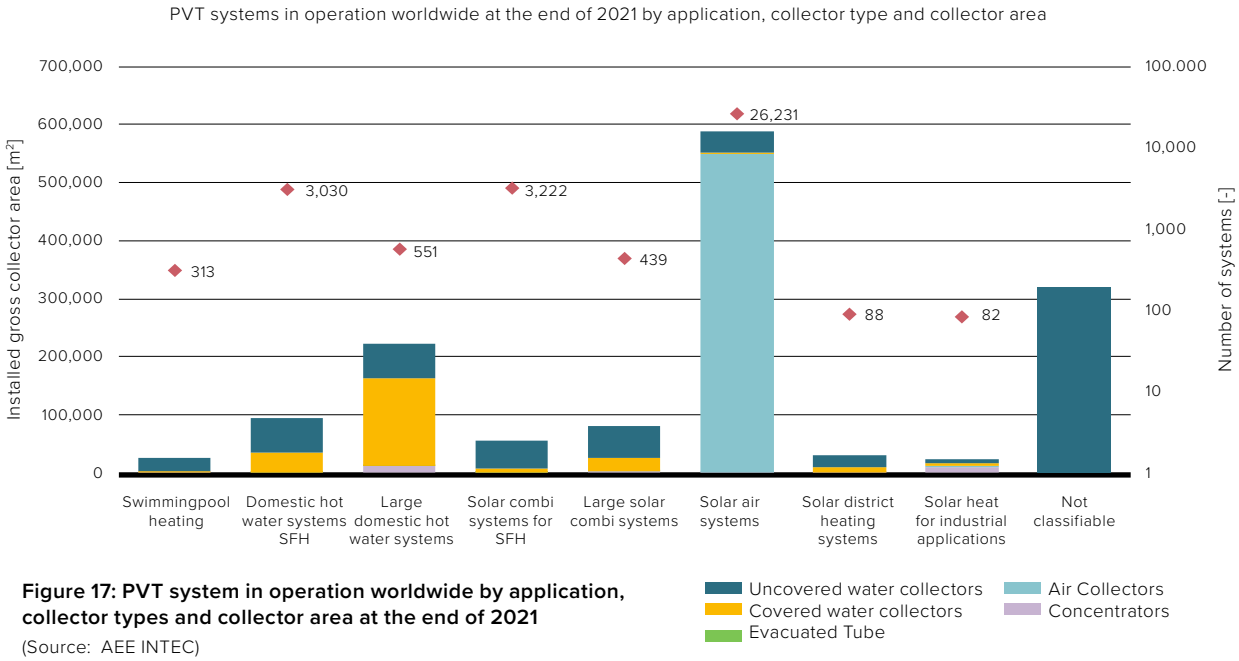

Figure 17: PVT system in operation worldwide by application, collector types and collector area at the end of 2021

(Source: AEE INTEC)

As shown in Figure 17 below, solar air systems dominate the PVT market. In a global context, this distribution is mainly driven by the dominance of the French market, where almost all of the manufactured PVT collectors are air collectors. Nevertheless, uncovered water-based PVT collectors are the most common technology.

By the end of 2021, 9,039 systems with uncovered PVT collectors were in operation, corresponding to a gross area of 844,544 m². Of these systems, 36% were used for domestic hot water preparation in single and multifamily houses, hotels, and hospitals. Around 35% of the systems supplied heat and electricity to households and electric heating elements for domestic hot water and space heating (combi-systems).

LEARN MORE

Learn more about Application of PVT collectors at: https://task60.iea-shc.org/

4.5
Solar air conditioning and cooling

3,500 m² flat plate solar collectors supply heat to drive a 660 kW absorption chiller at the company AVL in Graz, Austria
Photo: Christian Holter, SOLID Energy Systems

4.5.1
Small and medium-size applications

The global market for cooling and refrigeration will continue to grow, particularly in emerging countries, and by 2050 37% of the total electricity demand growth will be due to the electricity demand for air conditioning[5]. Thus, there is enormous potential for cooling systems that use solar energy, both solar thermal and PV driven solar cooling and air conditioning systems, as presented, for example, in the GIZ 2017 feasibility study for social housing buildings in Mexico[6] and the RCREEE/UNDP 2015 study on commercial buildings/applications in the Arab region[7]. A major argument for using solar thermally driven systems is that they consume less conventional energy (up to factor five[8]) 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 for solar cooling technology is its potential to reduce peak electricity demand, particularly in countries with significant cooling needs with grid constraints. Today, for example, 30% of India's total energy consumption in buildings is used for space cooling and reaches up to 60% of the summer peak load, and is already stretching the capacity of the Indian national electricity supply[9]. In other countries, like the USA, the peak load through air conditioning reaches >70% on hot days.

These mature cooling technologies are grabbing the attention of the OECD and emerging countries because cooling demand will continue to grow over the next decades and national electric grids need protection against overloads.

[5] https://www.iea.org/futureofcooling/
[6] http://task53.iea-shc.org/Data/Sites/53/media/events/meeting-09/workshop/09-jakob_results-from-feasibility-studies-of-solar-cooling-systems-in-mexico-and-the-arab-region.pdf
[7] https://www.solarthermalworld.org/sites/default/files/story/2016-04-05/solar_cooling_in_arab_region_0.pdf
[8] http://task53.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task53-C3-Final-Report.pdf
[9] Low energy cooling and ventilation in indian residences, https://doi.org/10.1080/23744731.2018.1522144

Solar sorption cooling applications are particularly adapted for medium to large size units (100 kW to several MWs). For several years now, China has been promoting a voluntary policy to develop such green sorption devices. And in 2019, Germany changed its incentives scheme for both vapor compression and sorption-based technologies to only support chillers and air conditioners that use natural refrigerants (sorption chillers 5 kW - 600 kW) in combination with a minimum required performance[10].

Solar thermal cooling is still a niche market, with more than 2,000 systems deployed globally as of 2021. And due to changing distribution channels and B2B sales of the sorption chillers, the tracking of newly installed solar-driven systems is difficult and can only be estimated. Small units with a capacity lower than 20 kW are getting more compact (and thus cheaper upfront costs) and targeting the mass markets. Medium to large-scale projects, 350 kW - 2,000 kW, are dominated by engineered systems. Of the small and medium capacity (<350 kW) solar cooling systems worldwide, 70% are installed in Europe. According to a survey carried out in early 2019 by SOLRICO for REN21[11],only a small number of new solar cooling systems in the small and medium range were installed in 2018, mainly in Italy and Germany. However, awareness of small to medium-scale solar thermal driven systems is rising, and there are several international initiatives (e.g., MI IC7, K-CEP, IEA SHC Programme, etc.), research projects (e.g., SunbeltChiller, HyCool[12], sol.e.h.[2][13] , Zeosol[14], etc.) and commercial solar thermal cooling projects (e.g., China, Spain, the USA, Egypt, Mali, Greece, Austria, Africa and Thailand).

The world's largest solar cooling system with a cooling capacity of 1.75 MW is located in Arizona, USA

4.5.2 Solar Cooling with a cooling capacity larger than 350 kW

Solar cooling using thermal absorption chillers with a cooling capacity larger than 350 kW/100 RT[15] has improved significantly in performance and, at the same time, decreased in cost. In addition, there have been significant improvements in the performance of large flat plate collectors at temperatures up to 120°C. This increase in performance combined with an economy of scale makes solar cooling applications cost-competitive for large office buildings, hotels, hospitals, and commercial/industrial applications.

The advantage of solar energy for cooling is that the supply, solar radiation, is available when the demand, cooling, is at its peak. In other words, cooling is needed when the sun is shining, which means during peak demand. Solar cooling saves money by avoiding the need to purchase electricity at its highest cost. Plus, solar thermal energy is an easy way to store the solar heat and shift it for cooling demands in the evenings and nights while keeping the remaining energy for morning cooling.

The electricity needed by a solar cooling system to run pumps and the cooling tower is relatively low. Depending on the climate, it may give Energy Efficiency Ratios (kW_{th}/kW_{el}) of 20 to 40 in systems with optimized variable speed-driven auxiliaries. Thus, the electric demand for air conditioning in a building is cut by more than 80% compared to conventional HVAC equipment.

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

The world's largest solar cooling application is located in Arizona, USA, and was commissioned in May 2014. The installation covers a roof-mounted solar thermal collector field with a capacity of 3.4 MW_{th} (4,865 m^2) that supplies heat to a single-effect lithium bromide absorption chiller with a cooling capacity of 1.75 MW.

Four other large solar cooling systems were installed in 2018; two systems in Italy and one in Singapore, all of which use evacuated tube collectors, and one system in Jordan that uses Fresnel collectors to provide the heat for the chiller.

In 2020, two larger solar cooling plants were commissioned. One is a plant with 660 kW cooling capacity in Graz, Austria, and the second plant is in the UAE.

Unfortunately, not a single large-scale new solar cooling system was commissioned in 2021.

[10] https://www.bafa.de/DE/Energie/Energieeffizienz/Klima_Kaeltetechnik/klima_kaeltetechnik_node.html
[11] Not published internal communication
[12] Jakob, Uli; Kiedaisch, Falko (2019) Analysis of a solar hybrid cooling system for industrial applications, SWC 2019-SHC 2019, paper ID 12143.
[13] Neyer, Daniel; et al. (2019) Solar Heating and Cooling in hot and humid climates – sol.e.h.^{2} Project Introduction, SWC 2019-SHC 2019, paper ID 10400.
[14] Roumpedakis, Tryfon; et al. (2019) Performance results of a solar adsorption cooling and heating unit, SWC 2019-SHC 2019, paper ID 11465
[15] Ton of refrigeration is a unit of power used in North America to describe the capacity of heat extraction in industrial air conditioning and refrigeration equipment.

Table 7: Large-scale solar cooling systems installed between 2008 and 2020

Country	Site	Commissioned	Installed capacity [kW_{th}]	Collector size [m^2]	Collector type	Cooling capacity [kW_{cold}]
Austria	Graz	2020	2,450	3,500	Flat plate	660
UAE	Dubai	2020	496	708	Flat plate	n.a.
Switzerland	Zurich	2019	800	1,143	Evacuated tube	600
Singapore	Mandai Depot	2018	2,308	3,297	Evacuated tube	850
Italy	Borgoricco	2018	1,046	1,494	Evacuated tube	700
Italy	Laives	2018	n.a.	n.a.	Evacuated tube	176
Jordan	Japan Tobacco International factory	2018	700	1,254	Fresnel	n.a.
Singapore	IKEA Alexandra	2017	1,730	2,472	Flat plate	880
Nicaragua	Hospital Militar Escuela, Dr. Alejandro Dávila Bolaños	2017	3,115	4,450	Flat plate	1,023
India	Office, Gujarat State Electricity Corporation	2017	1,102	1,575	Evacuated tube	528
India	Swiss Embassy, New Delhi	2017	630	441	Parabolic trough	210
China	Tianjin Zhongbei	2015	n.a.	n.a.	Evacuated tubes	698
Arizona, USA	Desert Mountain High School Scottsdale	2014	3,407	4,865	Flat plate	1,750
Johannesburg, South Africa	MTN Headquarter	2014	272	484	Fresnel	330
China	Dezhou Institute	2014	n.a.	720	Parabolic trough	n.a.
United Arab Emirates	Sheikh Zayed Desert Learning Center	2012	794	1,134	Flat plate	352
Jamaica	Digicel, Kingston		687	982	Flat plate	600
Singapore	United World College	2011	2,710	3,872	Flat plate	1,500
Qatar, Doha	Showcase football stadium	2010	700	1,408	Fresnel	n.a
Istanbul, Turkey	Metro shopping center	2009	840	1,200	Evacuated tube	n.a.
Spain, Sevilla	Sevilla University, Escuela Superior de Ingenieros	2009		352	Fresnel	n.a.
Lisbon, Portugal	CGD Lisbon	2008	1,105	1,579	Flat plate	585
Rome, Italy	Metro Cash & Carry	2008	2,100	3,000	Flat plate	700

4.5.3 Trends and outlook

The demand for cooling and refrigeration will continue its rapid growth, particularly in emerging countries (several hundred million AC units are estimated to be sold per year by 2050[16]). This means there is a huge potential for cooling systems that use solar energy – thermal systems and photovoltaic (PV) systems.

The trend regarding solar cooling can be seen in Table 7. In the past 13 years, very few large installations were realized each year. A change in this trend is not foreseeable at present.

Despite the potential presented in many studies, it will not be possible to exploit it until system prices and complexity are significantly reduced. Furthermore, it must, unfortunately, be noted that only a very few specialized companies are currently dealing with this topic. It is, therefore, the hope that IEA SHC Task 65 will provide the needed impetus through its joint research and development efforts.

[16] https://www.iea.org/futureofcooling/

LEARN MORE

Learn more about Solar Cooling for the Sunbelt Regions at: https://task65.iea-shc.org/

4.6
Solar air heating systems

Solar air heating systems are designed to heat air directly for applications requiring warm air. The primary uses for solar air heaters are heating of buildings, including ventilation air, and process or crop drying systems. Solar air heating is currently an under-utilized solar technology. The recent COVID requirements to increase fresh air in buildings will increase energy demand and CO_2 emissions, and solar heating of this fresh air is an excellent solution to minimize this increased energy demand.

Space heating consumes more energy than hot water in most buildings. In colder climates, space heating is usually the largest energy consumer in a building. As it is the air in a building that is heated, air collectors are ideally suited to heat this air directly without heat exchangers. To take advantage of the lower winter sun angles and eliminate any snow accumulation typical of roof-mounted systems, most solar air collectors used for heating buildings are wall-mounted. When heat is not needed during the summer, the panels are generally left dormant as stagnation temperature is not usually an issue.

Solar air heating systems can be building integrated and typically reduce between 20–30% of the conventional energy used to heat a building. The air is generally taken off the top of the wall, and the heated or pre-heated fresh air is then connected to existing or new fans and ducted into the building via the ventilation system.

Process applications are different as they operate either all year or during the harvest season, allowing the panels to be roof-mounted to capture the higher sun angles.
Solar air heaters in agriculture are primarily for drying applications requiring low temperature.

For the past 30 years, solar air heating systems have been used worldwide by schools, municipalities, military, agricultural, commercial and industrial entities, as well as in residential buildings.

Storage of the heat is possible, but most solar air systems do not include storage to minimize costs.

Canada leads the solar air collector market with 334 MWth

Toronto Transit Commission (TTC) McNicoll Bus Garage; Toronto, Canada
2,200 m² of black SolarWall air heating systems were integrated into the south and west elevations.
The system is used for ventilation heating
Photo: SolarWall Conserval Engineering Inc.

The following table lists those countries where more than 10,000 m² of solar air collectors are documented.

Table 8: Countries with larger solar air collector markets - Total installed air collector areas in 2020

Country	Air Collectors [m²]		Total [m²]	Installed capacity [MW_{th}]
	unglazed	glazed		
Canada	424,478	52,451	476,929	334
Australia	250,000	10,000	260,000	182
Japan		252,787	252,787	177
United States	127,431	71,000	198,431	139
United Kingdom	23,600		23,600	17
Denmark	4,300	18,000	22,300	16
Germany		18,240	18,240	13
Turkey	12,570		12,570	9
India		12,400	12,400	9
France (mainland)	10,558	1,100	11,658	8
China	7,700	3,000	10,700	7

By the end of 2020, 985 MW_{th} (1,405,962 m²) of glazed and unglazed air collectors were installed worldwide. The annual worldwide market in 2020 was in the range of 12 MW_{th} (17,000 m²).

Solar space heating with air collectors is not as common in Europe, while in North America, building-integrated solar air collectors are the most popular form of solar thermal systems in the commercial, industrial and institutional markets due to their low cost and architectural integration into buildings. Architects are creative as they integrate solar air heaters into the facades.

5 Detailed global market data and country statistics in 2020

Energiebunker Wilhelmsburg, Hamburg, Germany
Source: Ritter XL Solar, Photographer Oliver Killig

The following chapters of the report provide detailed solar thermal market figures for 2020 and country figures for 70 countries.

Background of the presented data

The figures in the following chapters are the collector area in operation in 2020 and not the cumulated collector area installed in a country, meaning that system lifetimes are considered. 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 until 2018. According to the CSTIF approach, the operation lifetime was 10 years. From 2019 on, an increased lifetime is used to calculate the cumulated collector area accounting for the fact that the share of large systems in China has increased over the past few years. According to this approach, a lifetime of

12 years is used for 2020, increasing to 13 years in 2021. For Germany, a lifetime of 25 years was used in accordance with accumulated market statistic figures for Germany published by BSW[17].

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

5.1 General market overview of the total installed capacity in operation

By the end of 2020, an installed capacity of 500 GW_{th}, corresponding to a total of 714 million m^2 of collector area, was in operation worldwide.

The vast majority of the total capacity in operation was installed in China (364.0 GW_{th}) and Europe (59.5 GW_{th}), which accounted for 84.7% of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (19.1 GW_{th}), Latin America (17.4. GW_{th}), Asia excluding China (16.6 GW_{th}), the MENA[18] countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (7.6 GW_{th}), Australia and New Zealand (6.9 GW_{th}), and the Sub-Sahara African countries Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa and Zimbabwe (2.3 GW_{th}). The market volume of "all other countries" is estimated to amount to 5% of the total installations, excluding China (6.8 GW_{th}).

[17] Bundesverband Solarwirtschaft e.V.
[18] Middle East and North Africa

Municipal district heating network in Mühlhausen, Germany with 5.691 m^2 collector area
Photo: Ritter XL Solar

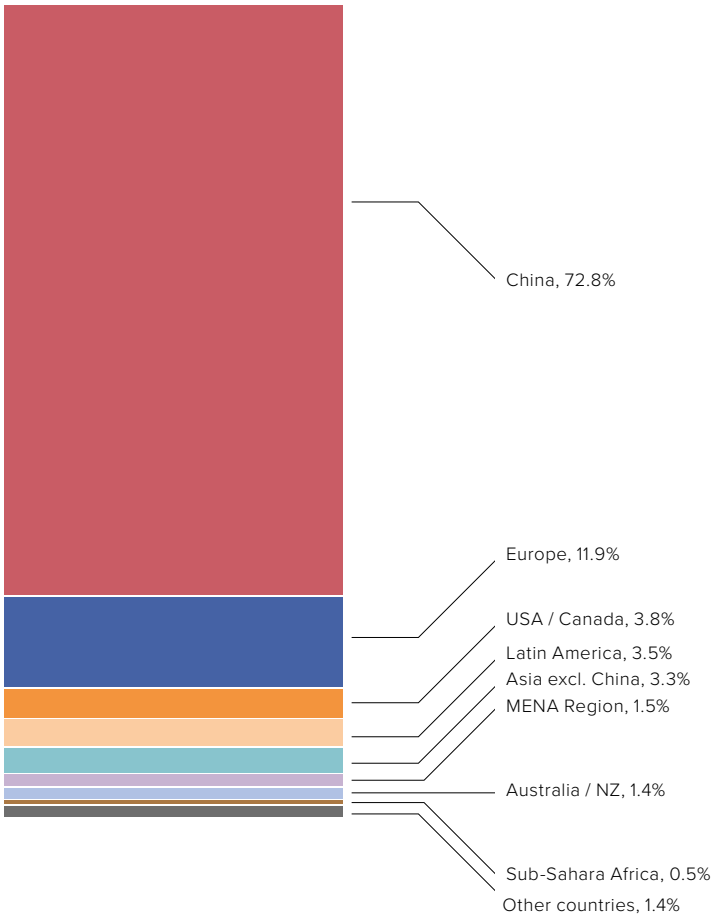

Figure 18: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan, Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Table 9: Total capacity in operation in 2020 [MW_{th}]

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		197.9	7.9			206
Argentina	61.3	47.4	90.3		0.2	199
Australia	4,028.5	2,398.2	167.3	175.0	7.0	6,776
Austria	168.7	3,215.5	57.5		4.3	3,446
Barbados		180.7				181
Belgium	31.5	407.6	75.6			515
Bhutan		0.3	0.0			
Botswana		10.4	1.7			12
Brazil	5,160.1	7,812.5	135.2			13,108
Bulgaria		120.5	4.1			125
Burkina Faso		2.3	1.0			3
Canada	518.5	49.4	36.1	297.1	36.7	938
Cape Verde		1.7				2
Chile	45.9	199.4	38.0		0.2	284
China+		42,546.7	321,445.7	5.4	2.1	364,000
Croatia		179.3	9.3			189
Cyprus	1.5	566.0	16.5			584
Czech Republic	350.0	332.6	109.8			792
Denmark	14.4	1,295.6	6.4	3.0	12.6	1,332
Estonia		8.4	5.9			14
Finland	8.3	34.0	15.2			57
France (mainland)	61.6	1,432.8	131.7	7.4	0.8	1,634
France (overseas)++		721.3	31.0			
Germany	328.4	12,118.1	1,474.5		12.8	13,934
Ghana		2.6	1.1			4
Greece		3,477.7	16.0			3,494
Hungary	12.8	190.4	58.7	2.4	1.6	266
India		3,049.9	8,417.3		8.7	11,476
Ireland		153.3	89.7			243
Israel	27.3	3,421.9	0.0			3,449
Italy	30.7	2,962.7	468.3			3,462
Japan		2,190.8	36.5		177.0	2,404
Jordan*	4.2	687.7	190.5			882
Kenya		211.1	105.6			
Latvia		25.4	2.6			28
Lebanon		180.2	334.6			515
Lesotho		1.5	1.5			3
Lithuania		6.4	9.2			16
Luxembourg		42.1	6.2			48
Malta		41.5	10.4			52
Mauritius**		93.0	0.0			93
Mexico	1,150.3	1,323.3	1,103.3	0.5	6.1	3,584
Morocco+++		627.2				627
Mozambique	0.1		1.7			2
Namibia	1.1	36.0	1.0			38
Netherlands	54.0	363.7	50.8			469
New Zealand***	4.9	100.1	6.8			112
Nigeria		1.3	7.5		1.2	10.0
North Macedonia		48.7	38.0			87
Norway	1.3	26.4	3.0	0.1	2.9	34
Palestinian Territories		1,312.5	5.8			1,318
Poland		1,756.4	348.2			2,105
Portugal	1.5	848.2	22.3			872
Romania	0.2	83.4	80.2			164
Russia	0.1	16.2	2.7			19
Senegal	0.0	3.3	3.6		0.8	7.7
Slovakia	0.7	105.8	20.9			127
Slovenia	0.0	87.5	16.5			104
South Africa	945.8	492.1	307.3			1,745
South Korea	0.0	1,040.4	312.0	0.3	0.1	1,353
Spain	113.2	3,010.7	167.8	3.2	1.6	3,296
Sweden	119.7	194.5	50.8			365
Switzerland	122.9	981.0	100.2			1,204
Taiwan	1.4	1,175.9	93.3			1,271
Thailand****		110.3	0.0			110
Tunisia		754.5	49.1			804
Turkey		12,007.9	6,408.8	8.8		18,426
United Kingdom		803.9	221.6	16.5		1,042
United States	15,808.2	2,113.5	124.0	89.2	49.7	18,185
Uruguay		60.5				60
Zimbabwe		15.3	39.0			54
All other countries (5% of world market excluding China)	1,535.7	4,082.7	1,144.7	31.8	17.1	6,812
TOTAL	30,715	124,200	344,340	641	343	500,239

Note: If no data is given: no reliable database for this collector type is available
* cumulated collector area by end of 2014
** cumulated collector area by end of 2015
*** cumulated collector area by end of 2009
**** cumulated collector area by end of 2016
\+ Exports excluded
++ France overseas calculated based on Eurobserver Reports 2015-2019
+++ 2021 revised timeseries according to MDPI Switzerland 2021

Table 10: Total installed collector area in operation in 2020 [m²]

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		282,703	11,262			293,965
Argentina	87,628	67,688	129,068	40	316	284,740
Australia	5,755,000	3,426,000	239,000	250,000	10,000	9,680,000
Austria	240,935	4,593,638	82,203		6,168	4,922,944
Barbados		258,192				258,192
Belgium	45,000	582,355	107,950			735,305
Bhutan		460				460
Botswana		14,871	2,404			17,275
Brazil	7,371,543	11,160,785	193,083			18,725,411
Bulgaria		172,107	5,870			177,977
Burkina Faso		3,282	1,399			4,681
Canada	740,764	70,627	51,582	424,478	52,451	1,339,902
Cape Verde		2,466				2,466
Chile	65,550	284,894	54,305		300	405,049
China+		60,781,000	459,208,101	7,700	3,000	519,999,801
Croatia		256,181	13,308			269,489
Cyprus	2,213	808,559	23,567			834,339
Czech Republic	500,000	475,092	156,923			1,132,015
Denmark	20,500	1,850,789	9,197	4,300	18,000	1,902,786
Estonia		11,940	8,360			20,300
Finland	11,800	48,580	21,643			82,023
France (mainland)	87,989	2,046,818	188,208	10,558	1,100	2,334,673
France (overseas)++		1,030,446	44,270			
Germany	469,110	17,311,564	2,106,388		18,240	19,905,302
Ghana		3,770	1,608			5,378
Greece		4,968,100	22,900			4,991,000
Hungary	18,300	271,934	83,888	3,418	2,300	379,840
India		4,356,997	12,024,753		12,400	16,394,150
Ireland		218,935	128,127			347,062
Israel	39,000	4,888,434				4,927,434
Italy	43,800	4,232,461	669,003			4,945,264
Japan		3,129,653	52,095		252,787	3,434,535
Jordan*	5,940	982,482	272,084			1,260,506
Kenya		301,620	150,810			452,430
Latvia		36,272	3,740			40,012
Lebanon		257,390	478,010			735,400
Lesotho		2,155	2,102			4,257
Lithuania		9,117	13,113			22,230
Luxembourg		60,163	8,900			69,063
Malta		59,333	14,833			74,166
Mauritius**		132,793				132,793
Mexico	1,643,353	1,890,402	1,576,142	752	8,773	5,119,422
Morocco+++		896,000				896,000
Mozambique	136	48	2,358			2,542
Namibia	1,560	51,419	1,393			54,372
Netherlands	77,200	519,620	72,530			669,350
New Zealand***	7,025	142,975	9,644			159,645
Nigeria		1,866	10,782		1,670	14,318
North Macedonia		69,517	54,216		12	123,745
Norway	1,849	37,705	4,349	200	4,106	48,210
Palestinian Territories		1,874,993	8,225			1,883,218
Poland		2,509,130	497,460			3,006,590
Portugal	2,130	1,211,769	31,820			1,245,719
Romania	340	119,080	114,590	800		234,810
Russia	137	23,190	3,872	2	64	27,265
Senegal		4,741	5,083		1,203	11,027
Slovakia	1,000	151,150	29,790			181,940
Slovenia		125,000	23,600		10	148,610
South Africa	1,351,102	702,972	439,008			2,493,082
South Korea		1,486,336	445,760	400	200	1,932,696
Spain	161,736	4,301,014	239,663	4,550	2,250	4,709,213
Sweden	171,007	277,821	72,578			521,406
Switzerland	175,600	1,401,400	143,200			1,720,200
Taiwan	1,937	1,679,874	133,244			1,815,055
Thailand****		157,536				157,536
Tunisia		1,077,817	70,104			1,147,921
Turkey		17,154,182	9,155,454	12,570		26,322,206
United Kingdom		1,148,437	316,598	23,600		1,488,634
United States	22,583,130	3,019,355	177,193	127,431	71,000	25,978,109
Uruguay		86,419				86,419
Zimbabwe		21,848	55,720			77,568
All other countries (5% of world market excluding China)	2,193,911	5,832,382	1,635,281	45,426	24,387	9,731,387
TOTAL	43,878,226	177,428,644	491,913,714	916,225	490,737	714,627,546

Note: If no data is given: no reliable database for this collector type is available
* cumulated collector area by end of 2014
** cumulated collector area by end of 2015
*** cumulated collector area by end of 2009
**** cumulated collector area by end of 2016
\+ Exports excluded
++ France overseas calculated based on Eurobserver Reports 2015-2019
+++ 2021 revised timeseries according to MDPI Switzerland 2021

The total installed capacity in operation in 2020 was divided into flat plate collectors (FPC): 124.2 GW_{th} (177.4 million m^2), evacuated tube collectors (ETC): 344.3 GW_{th} (491.9 million m^2), unglazed water collectors: 30.7 GW_{th} (43.9 million m^2), and glazed and unglazed air collectors: 1 GW_{th} (1.4 million m^2).

With a global share of 68.9%, evacuated tube collectors were the predominant solar thermal collector technology, followed by flat plate collectors with 24.8% and unglazed water collectors with 6.1% (Figure 19). Air collectors play only a minor role in the total numbers.

In Europe, the second largest market to China, flat plate collectors were the dominant collector type (Figure 20). Compared to 2019, the share of evacuated tube collectors increased in Europe by 1%, and the share of unglazed water collectors decreased to 2.4% in 2020.

Figure 21 shows the cumulated installed capacity of glazed and unglazed water collectors in operation for the 10 leading markets in 2020 in total numbers.

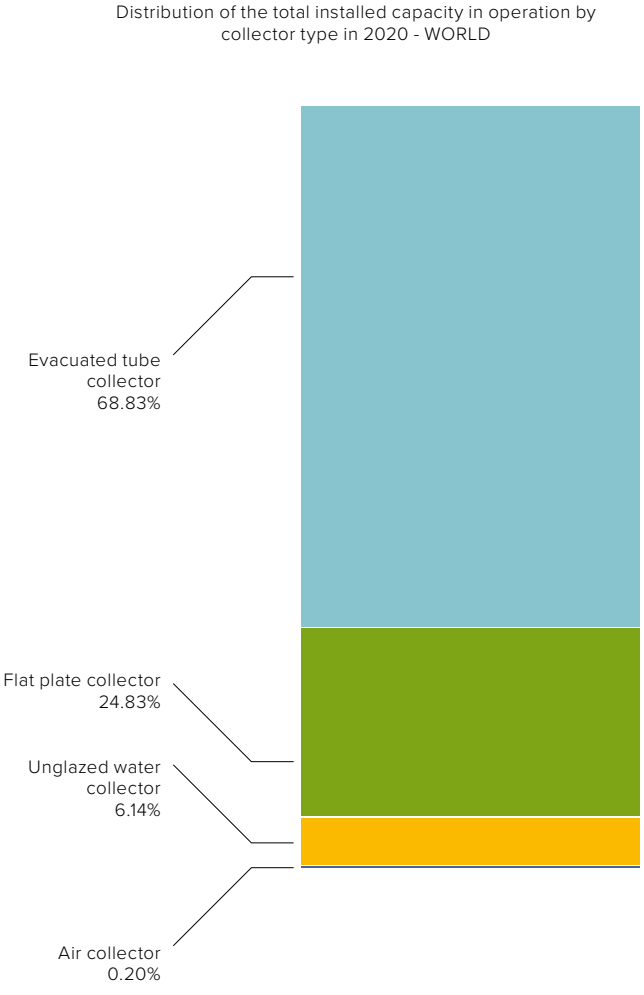

Figure 19: Distribution of the total installed capacity in operation by collector type in 2020 – WORLD

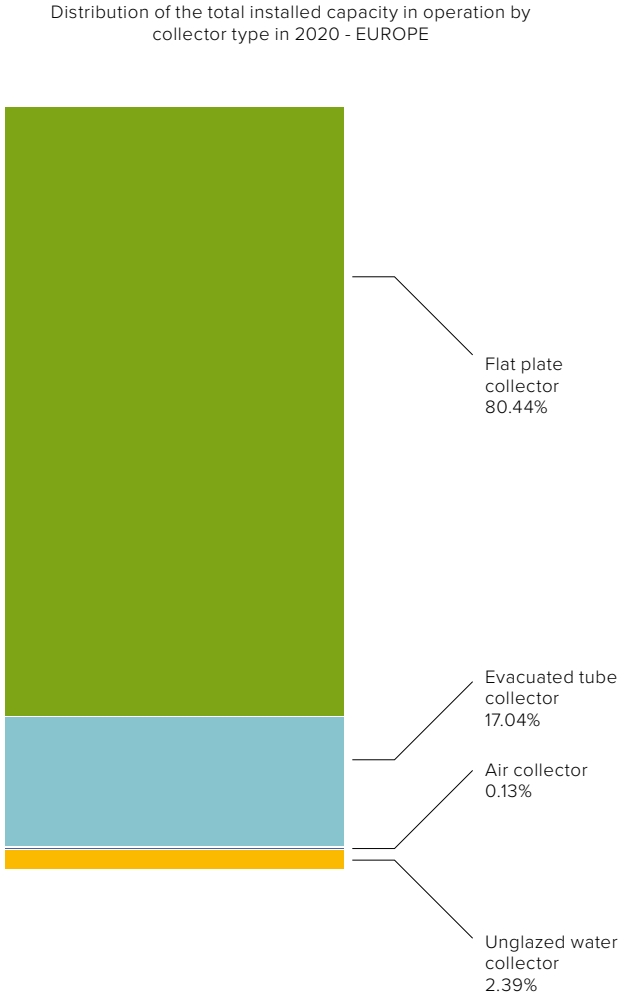

Figure 20: Distribution of the total installed capacity in operation by collector type in 2020 – EUROPE

Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom

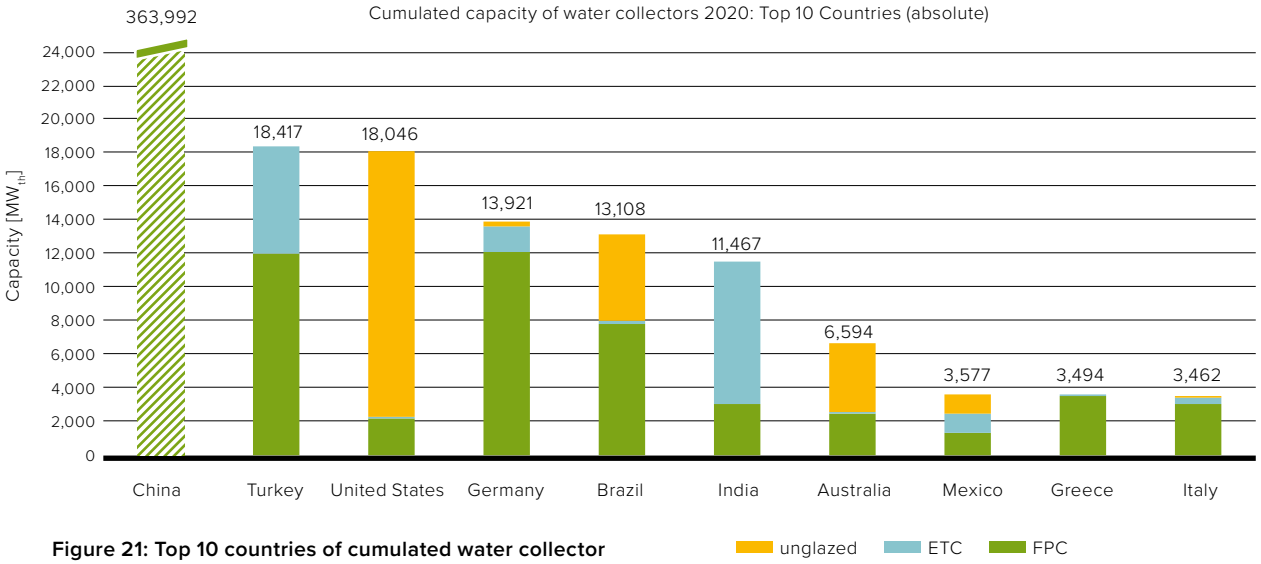

Figure 21: Top 10 countries of cumulated water collector installations in 2020 (absolute figures in MW_{th})

Compared to 2019, the first seven positions remained the same, as did Greece in the ninth position. Mexico moved to the eighth position ousting Austria from this position and the top 10 list. Italy took the tenth position from Israel.

China remained the world leader in total capacity and a market dominated by evacuated tube collectors. The United States held its third position due to its high number of installed unglazed water collectors. Besides the United States, only Australia and, to some extent Brazil, have large numbers of unglazed water collectors installed. In the large European markets, Germany, Austria and Greece, flat plate collectors were the most dominant collector technology. In Turkey, over the past several years, there has been a strong trend toward evacuated tube collector technology.

The top 10 countries with the highest market penetration per capita are shown in Figure 22. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2020 per 1,000 inhabitants were Barbados (600 kW_{th}/1,000 inhabitants), Cyprus (461 kW_{th}/1,000 inhabitants), Israel (398 kW_{th}/1,000 inhabitants), Austria (389 kW_{th}/1,000 inhabitants), Greece (329 kW_{th}/1,000 inhabitants), the Palestinian Territories (274 kW_{th}/1,000 inhabitants), China (259 kW_{th}/1,000 inhabitants), Australia (259 kW_{th}/1,000 inhabitants), France (overseas) (227 kW_{th}/1000 inhabitants) and Turkey (231 kW_{th}/1,000 inhabitants). Denmark was ousted from the top 10 countries with the highest market penetration (m^2/1,000 inhabitants) in 2020.

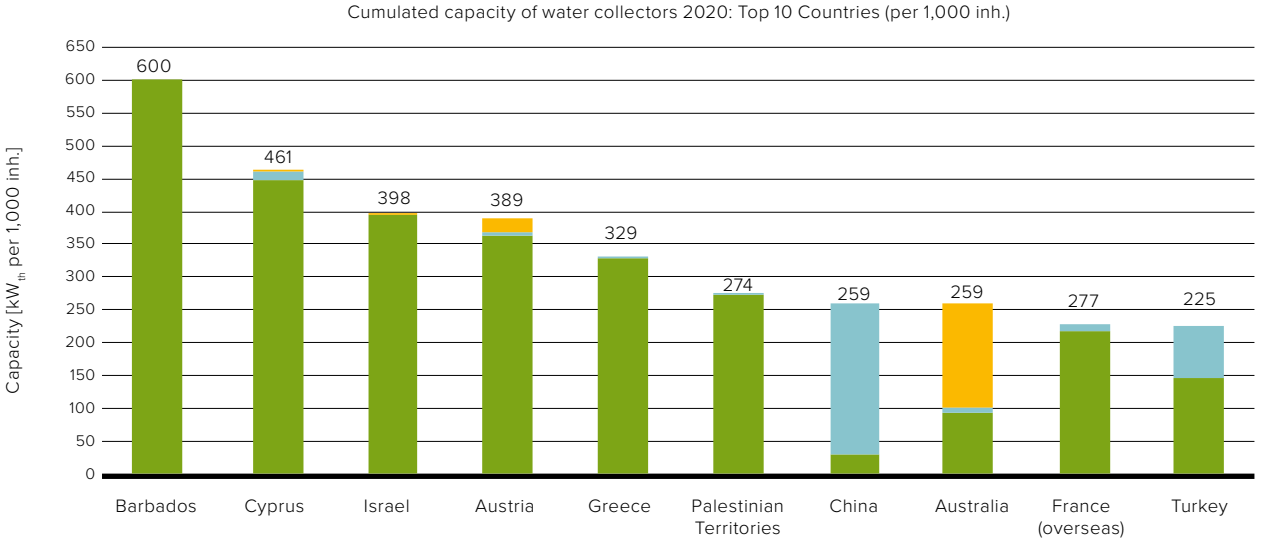

Figure 22: Top 10 countries of cumulated water collector installations per 1,000 inhabitants in 2020 (relative figures in kW_{th})

5.2
Total capacity of glazed water collectors in operation

With 363.9 GW_{th}, China was again the overriding leader in terms of total installed capacity of glazed water collectors in 2020. Turkey, Germany, and India have installed capacities between 20 GW_{th} and 10 GW_{th}. (Figure 23).

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 the solar thermal per capacity levels of the large European markets in Germany, Turkey, Denmark and Spain (Figure 24).

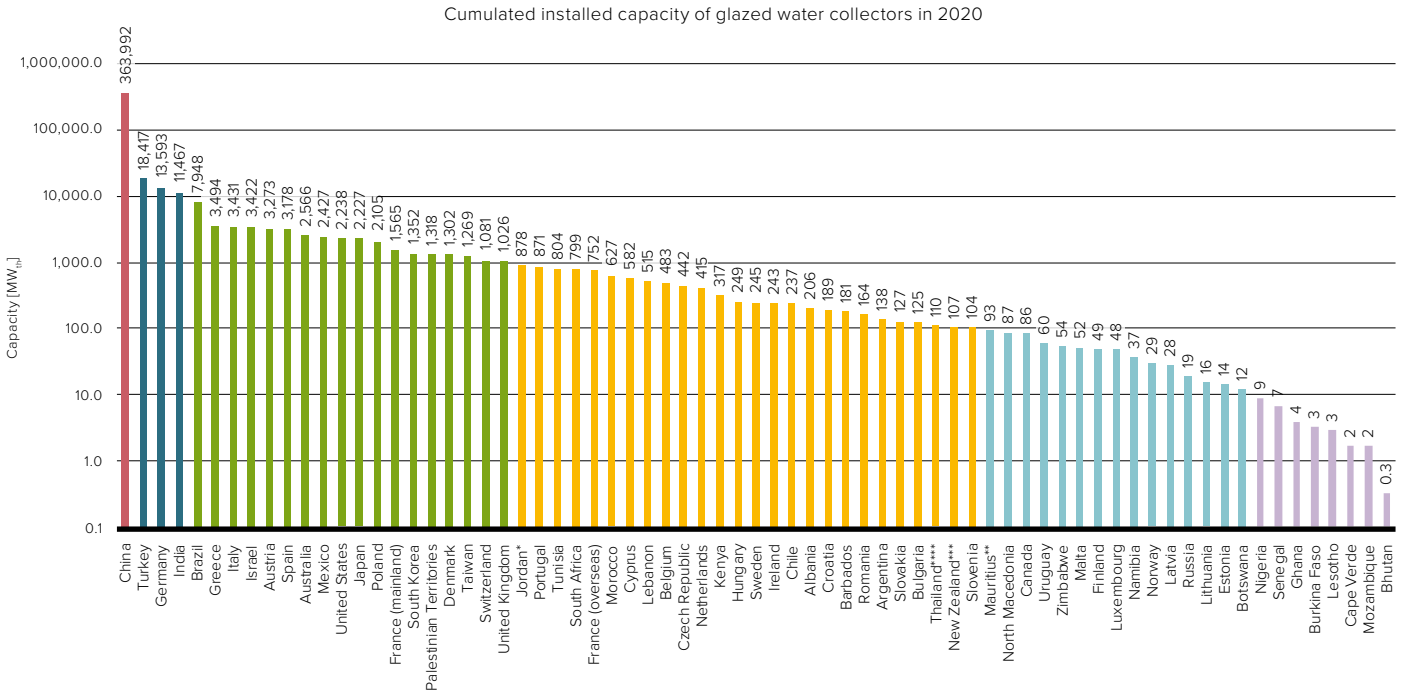

Figure 23: Total capacity of glazed water collectors in operation by the end of 2020

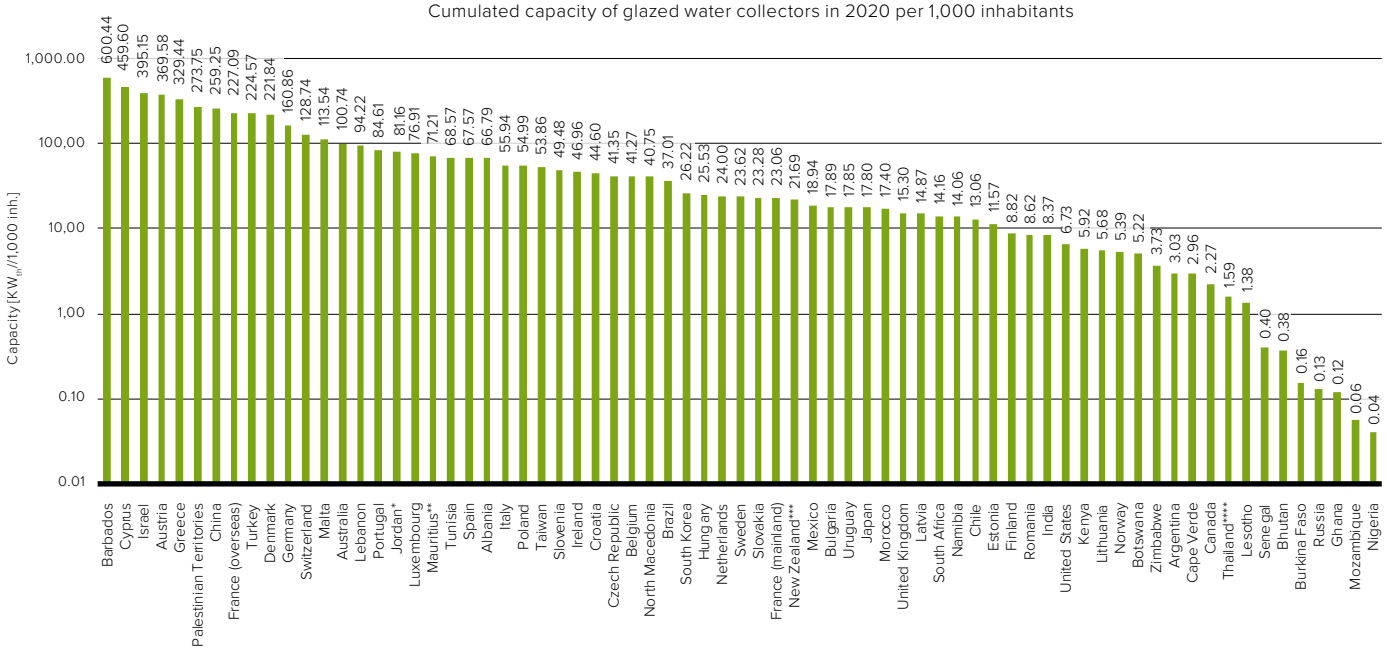

Figure 24: Total Capacity of glazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2020

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

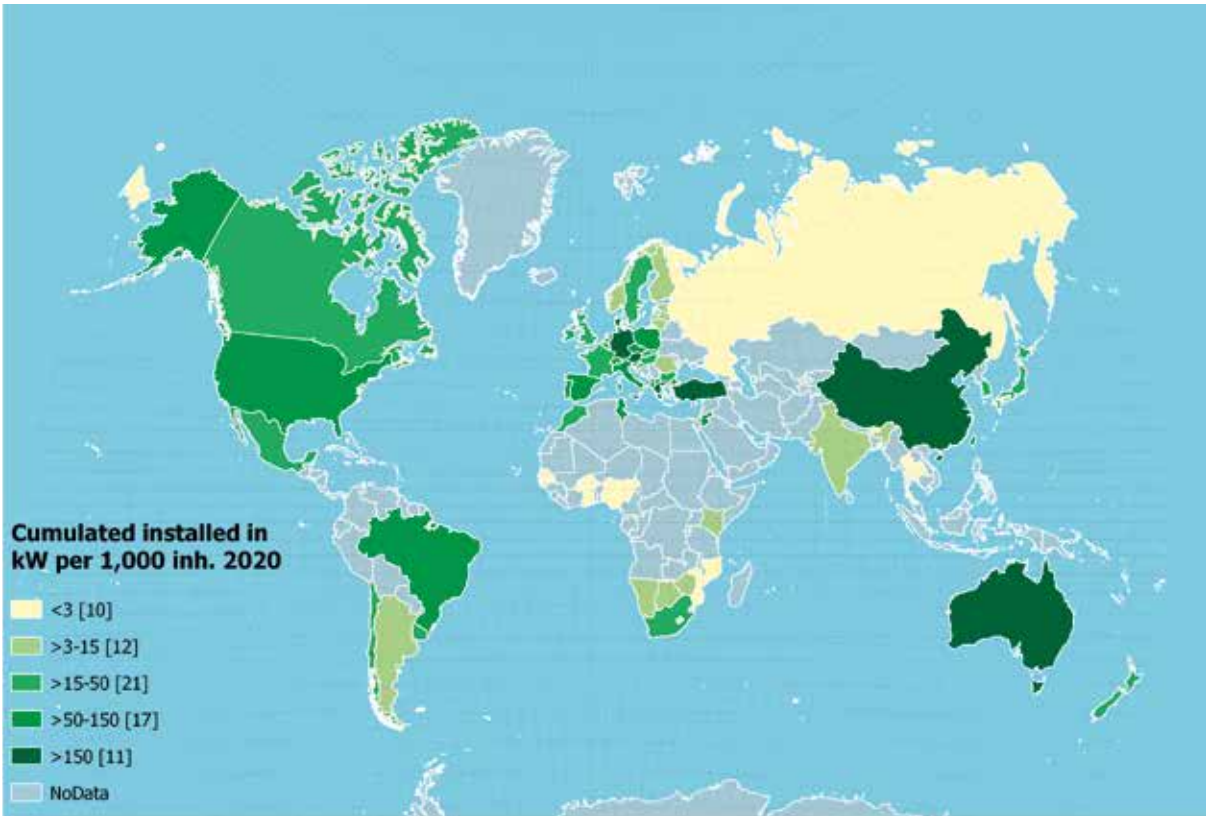

Figure 25: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants – WORLD

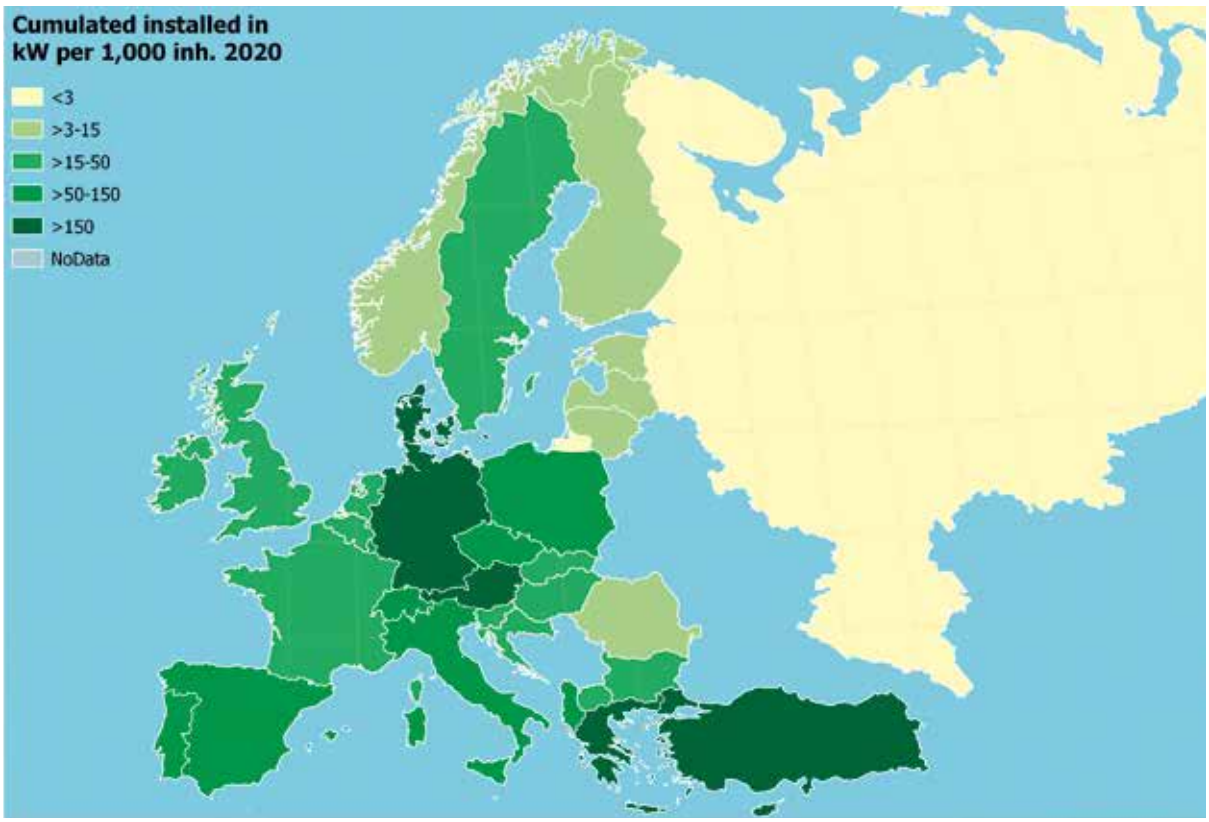

Figure 26: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants – EUROPE

Photo: Greenonetec Solar Industry / Austria Solar

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

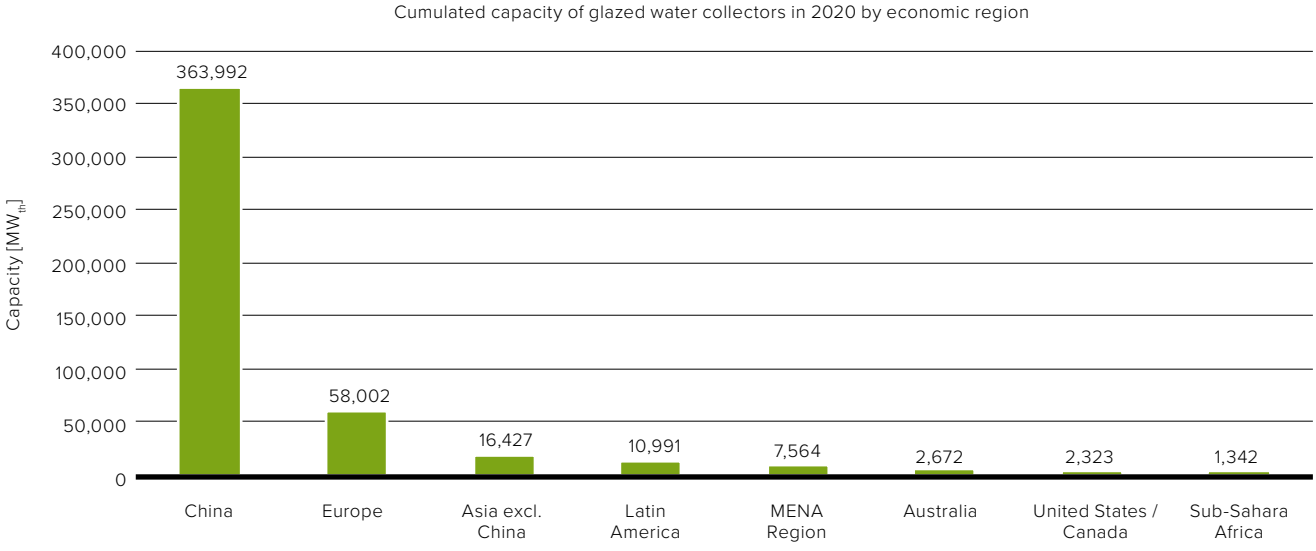

Figure 27: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2020

In terms of market penetration per capita by economic region, China again takes the lead. Remarkably, the MENA countries and Australia are ahead of Europe, which only confirms the very unbalanced market distribution in Europe (Figure 28). 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 penetration.

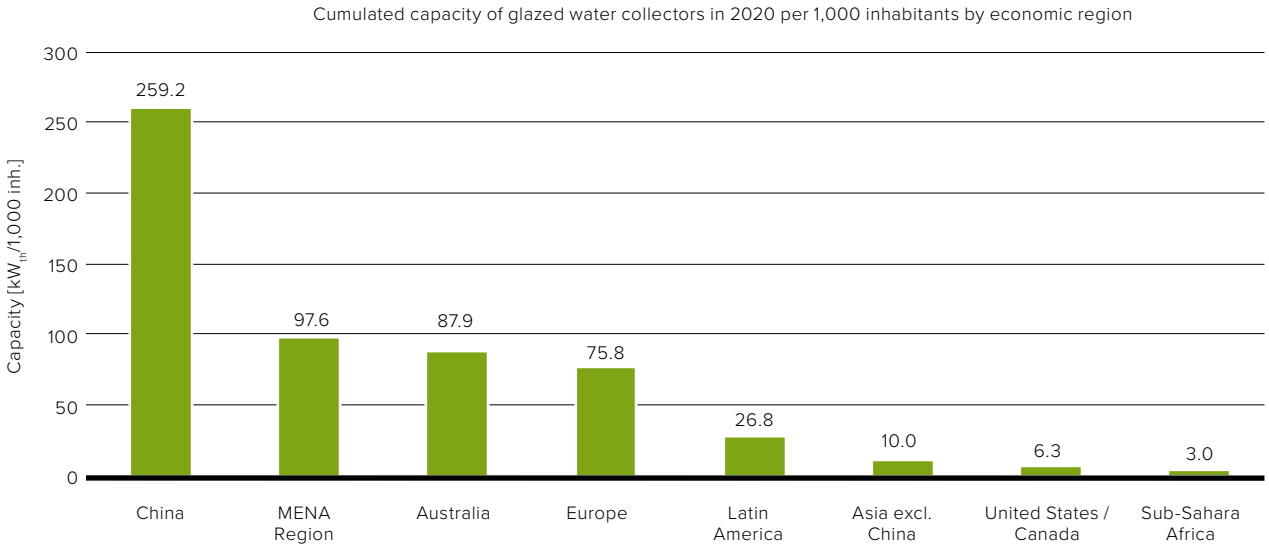

Figure 28: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in kWth per 1,000 inhabitants in 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia excluding China: Bhutan, India, Japan, South Korea, Taiwan, Thailand
Latin America:Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Aussenkehr, low-cost social housing project, Namibia
Photo: AEE INTEC

5.4 Total capacity of unglazed water collectors in operation

Unglazed water collectors are mainly used for swimming pool heating. This type of collector has lost a significant market share over the past decade. The percentage of unglazed water collectors in the total installed collector capacity was reduced from 21%[19] in 2005 to just 6% in 2020. Figure 30 and Figure 31 show the total installed capacity of unglazed water collectors and total installed capacity of unglazed water collectors per 1,000 inhabitants at the end of 2020.

[19] Solar Heat Worldwide (Ed.2008), Figure 3

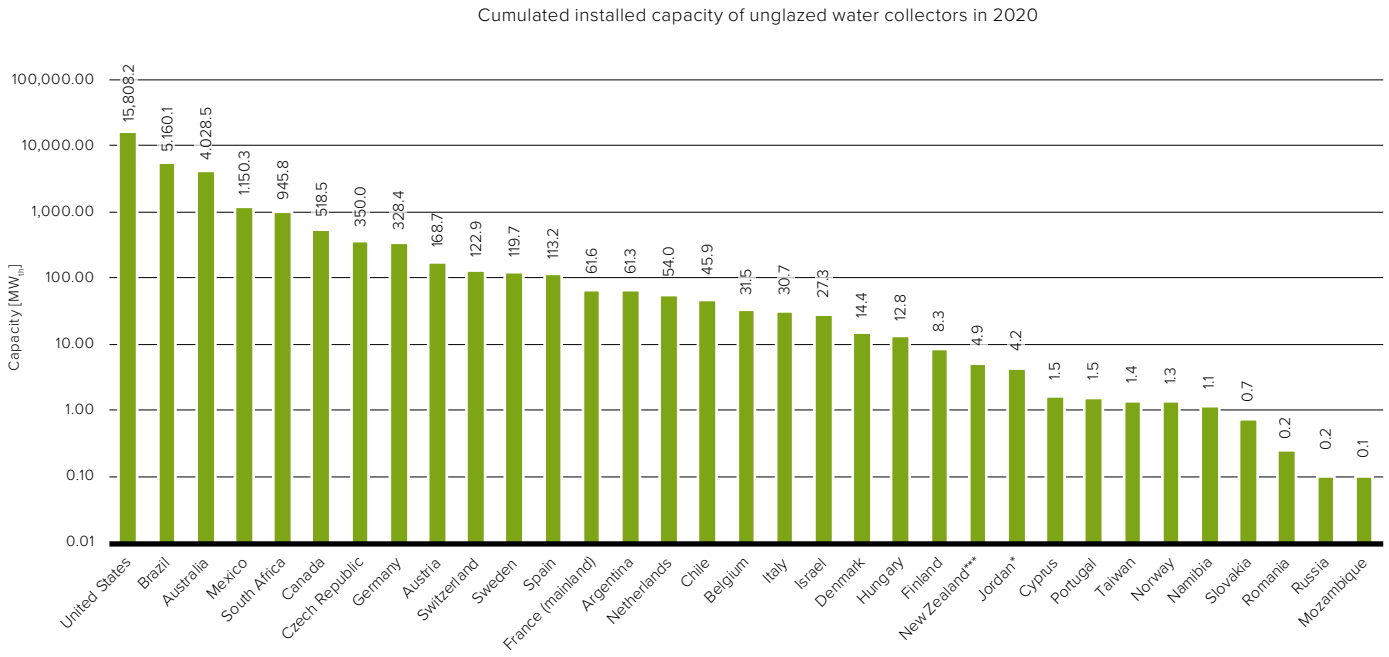

Figure 29: Total capacity of unglazed water collectors in operation in 2020

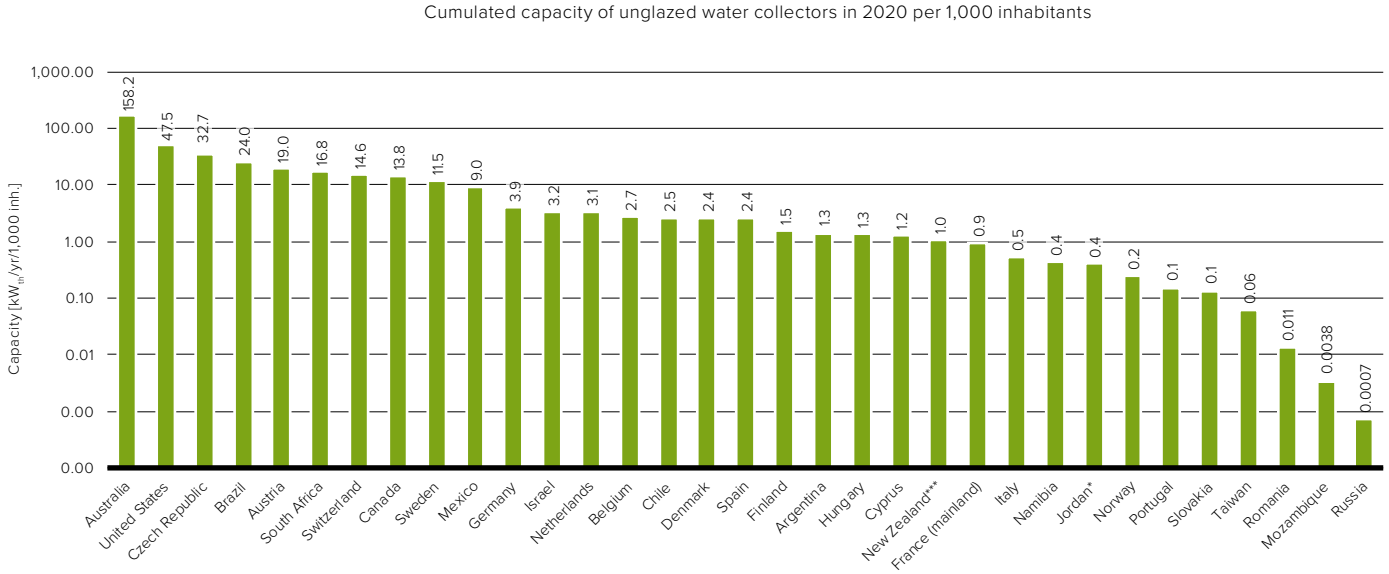

Figure 30: Total capacity of unglazed water collectors in operation in kW$_{th}$ per 1,000 inhabitants in 2020

Multi-story residential building in Lahti, Finland
Photo: Solar Heat Europe

5.5 Newly installed capacity in 2020 and market development

In 2020, a total capacity of 24.7 GW_{th}, corresponding to 35.3 million m^2 of new solar collectors, was installed worldwide.

The main markets were in China (17.5 GW_{th}) and Europe (2.8 GW_{th}), which accounted for 82.3% of all new collector installations in 2020. The rest of the market was shared between Latin America (1.4 GW_{th}), Asia excluding China (1.2 GW_{th}), the United States and Canada (0.5 GW_{th}), MENA countries (0.4 GW_{th}), Australia (0.4 GW_{th}), and Sub-Sahara African countries (0.1 GW_{th}). The market volume of "all other countries" is estimated to amount to 0.4 GW_{th} (511,000 m^2).

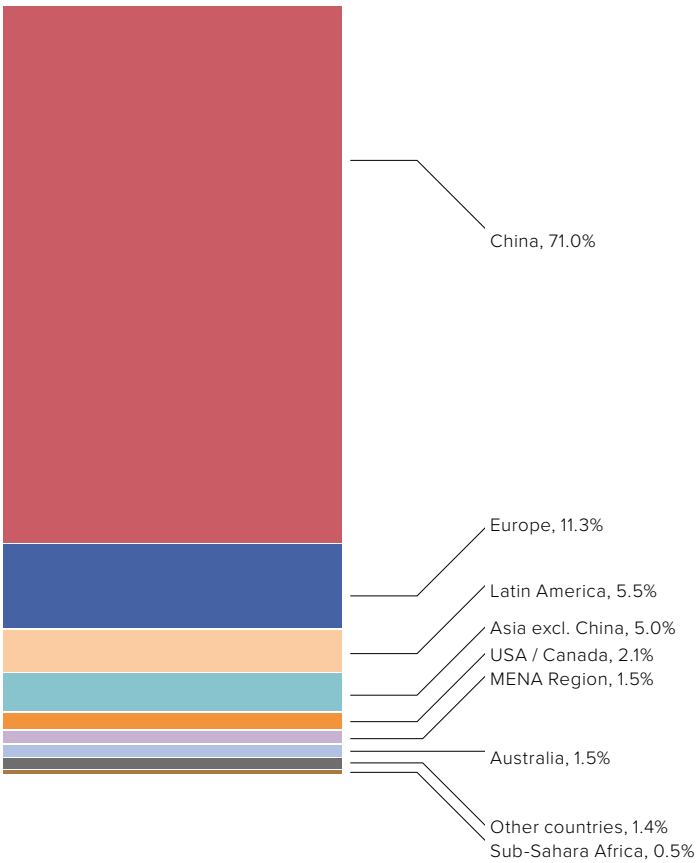

Figure 31: Share of newly installed capacity (glazed and unglazed water and air collectors) by economic regions in 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan, Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Table 11: Newly installed capacity in 2020 [MW_{th}/a]

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		7.5	1			8
Argentina	24	16.4	28			68
Australia	266	102.2	11			380
Austria	1	50.5	1		1	53
Barbados*		8.6	0			9
Belgium		12.7	3			16
Bhutan		0.3				0.3
Botswana		0.7				1
Brazil	498	471.5	23			992
Bulgaria	0	16.5	0.4			17
Burkina Faso*	0	0.1	0.2			0.3
Canada	1	0.2	0.2	5	1	7
Cape Verde**		0.1				0.1
Chile		17.6				18
China		4,867.8	12,667			17,535
Croatia		11.2	0.7			12
Cyprus		51.9				52
Czech Republic		10.5	4.9			15
Denmark		10.2				10
Estonia		0.6	0.4			1
Finland		4.9	0.6			5
France (mainland)	0.4	32.1	0.2			33
France (overseas)		64.0	0.0			64
Germany		381.2	69.2			450
Ghana**		0.5	0.4			1
Greece		212.9	0.3			213
Hungary		14.7	2.8			18
India		145.0	1,016.1		0.1	1,161
Ireland		1.0	1.7			3
Israel		245.0				245
Italy		75.8	10.3			86
Japan		34.9	0.6		0.6	36
Jordan		0.0				0
Kenya		5.9	2.9			9
Latvia		0.9	0.2			1
Lebanon		6.6	9.9			17
Lesotho		0.3	0.6			1
Lithuania		0.4	0.7			1
Luxembourg		2.0				2
Malta		0.4	0.1			0
Mexico	74.5	91.1	98.7			264
Morocco		50.2				50
Mozambique**		0.0	0.2			0
Namibia		2.7				3
Netherlands	1.8	15.0	5.8			23
Nigeria		0.3	2.5			3
North Macedonia		3.0	4.9			8
Norway		0.9	0.1			1
Palestinian Territories		32.4	0.0			32
Poland		111.5	1.3			113
Portugal		47.9	0.9			49
Qatar						0
Romania		4.8	6.4			11
Russia		0.5	0.1			1
Senegal**		1.1	0.7			2
Slovakia		5.3	1.1			6
Slovenia		0.9	0.1			1
South Africa	39.6	20.3	51.9			112
South Korea		2.5	11.8			14
Spain	2.0	124.0	5.3			131
Sweden		1.3	2.1			3
Switzerland	2.6	20.3	2.2			25
Taiwan		25.2				25
Thailand		0.0				0
Tunisia		35.8				36
Turkey		691.6	657.3	1.8		1,351
United Kingdom		9.2	2.8	0.0		12
United States	472.5	31.1		2.1	0.7	506
Uruguay		7.3				7
Zimbabwe		0.0	2.8			3
All other countries (5% of world market excluding China)	72.8	176.5	107.8	0.5	0.1	358
TOTAL	1,456.2	8,398.3	14,823.9	9.2	2.9	24,691

Note: If no data is given: no reliable database for this collector type is available.
* 0% growth assumed
** estimation

Table 12: Newly installed collector area in 2020 [m²/a]

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		10,680	968			11,648
Argentina	34,496	23,451	39,786	20	158	97,911
Australia	380,000	146,000	16,200			542,200
Austria	1,730	72,210	1,400		720	76,060
Barbados*		12,300				12,300
Belgium		18,200	4,300			22,500
Bhutan		460				460
Botswana		1,032	115			1,147
Brazil	710,810	673,600	32,360			1,416,770
Bulgaria		23,500	500			24,000
Burkina Faso*		100	310			410
Canada	1,475	261	321	7,000	1,000	10,057
Cape Verde**		150				150
Chile		25,183				25,183
China		6,954,000	18,096,033			25,050,033
Croatia		15,968	1,055			17,023
Cyprus		74,193				74,193
Czech Republic		15,000	7,000			22,000
Denmark		14,613				14,613
Estonia		855	570			1,425
Finland		7,000	855			7,855
France (mainland)	600	45,807	330			46,737
France (overseas)		91,425				91,425
Germany		544,564	98,888			643,452
Ghana**		776	520			1,296
Greece		304,100	400			304,500
Hungary		21,000	4,038			25,038
India		207,209	1,451,524		150	1,658,883
Ireland		1,472	2,367			3,839
Israel		350,000				350,000
Italy		108,250	14,700			122,950
Japan		49,907	861		887	51,655
Jordan						0
Kenya		8,364	4,182			12,546
Latvia		1,350	250			1,600
Lebanon		9,448	14,173			23,621
Lesotho		406	863			1,269
Lithuania		638	1,063			1,701
Luxembourg		2,800				2,800
Malta		545	136			681
Mexico	106,400	130,080	141,000			377,480
Morocco		71,700				71,700
Mozambique**			237			237
Namibia		3,807	8			3,815
Netherlands	2,620	21,430	8,330			32,380
Nigeria*		393	3,515			3,908
North Macedonia		4,274	6,948		12	11,234
Norway		1,350	73			1,423
Palestinian Territories		46,236				46,236
Poland		159,270	1,830			161,100
Portugal		68,450	1,250			69,700
Romania		6,840	9,120			15,960
Russia		784	85			869
Senegal**		1,500	1,000			2,500
Slovakia		7,600	1,520			9,120
Slovenia		1,300	100		10	1,410
South Africa	56,629	28,967	74,180			159,776
South Korea		3,552	16,918			20,470
Spain	2,798	177,103	7,539			187,440
Sweden		1,898	3,000			4,898
Switzerland	3,715	28,940	3,180			35,835
Taiwan		36,000				36,000
Tunisia		51,094				51,094
Turkey		988,000	939,000	2,500		1,929,500
United Kingdom		13,155	4,048			17,203
United States	675,058	44,448		3,000	1,000	723,506
Uruguay		10,418				10,418
Zimbabwe			4,050			4,050
All other countries (5% of world market excluding China)	104,017	252,179	154,051	659	207	511,114
TOTAL	2,080,348	11,997,585	21,177,051	13,179	4,144	35,272,307

Note: If no data is given: no reliable database for this collector type is available.
* 0% growth assumed
** estimation

New installations in 2020 are divided into flat plate collectors: 8.4 GW_{th} (11.9 million m^2), evacuated tube collectors: 14.8 GW_{th} (23 million square meters), unglazed water collectors: 1.5 GW_{th} (2.1 million m^2), and glazed and unglazed air collectors: 0.01 GW_{th} (0.017 million m^2).

With a share of 60.0%, evacuated tube collectors remain the most important solar thermal collector technology worldwide (Figure 32).

In a global context, this breakdown is mainly driven by the dominance of the Chinese market, where around 72% of all newly installed collectors in 2020 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82% in 2011 to 60.0% in 2020 while in the same time frame flat plate collectors increased their share from 14.7% to 34.0%.

In Europe, the situation is almost the opposite of China, with 71.5% of all solar thermal collectors installed in 2020 being flat plate collectors (Figure 33). In the medium-term perspective, the share of flat plate collectors decreased in Europe from 81.5% in 2011 to 71.5% in 2020. While driven mainly by the markets in Turkey, Poland, Switzerland and Germany, evacuated tube collectors increased their share in Europe between 2011 and 2020 from 15.6% to 28.1%.

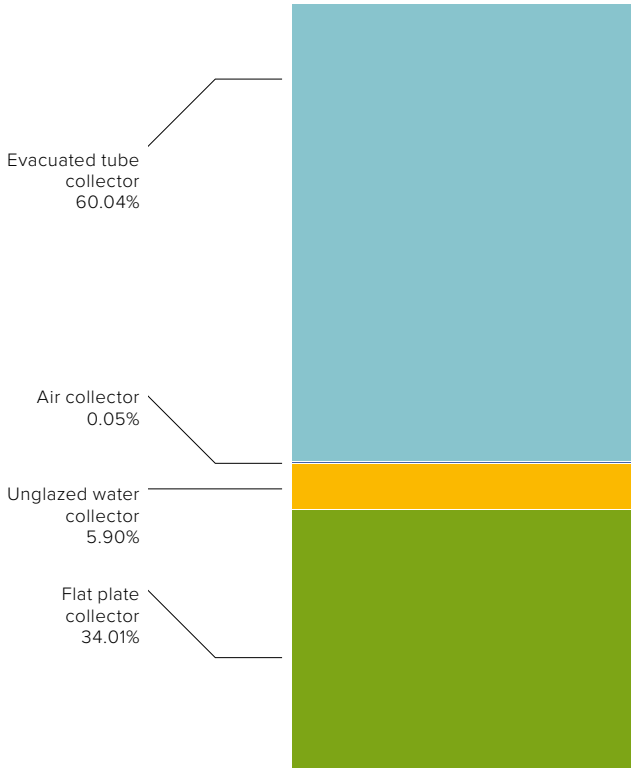

Figure 32: Distribution of newly installed capacity by collector type in 2020 – WORLD

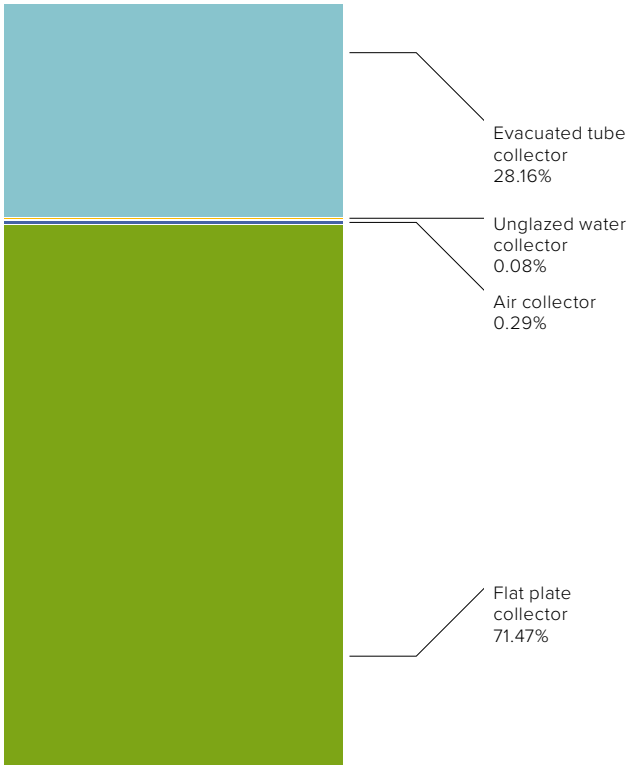

Figure 33: Distribution of newly installed capacity by collector type in 2020 – EUROPE

Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom

Figure 34 shows the newly installed capacity of glazed and unglazed water collectors for the 10 leading markets in 2020 in total numbers. China remained the market leader in absolute terms, followed by Turkey and India. Brazil and the United States rank four and five in absolute numbers and are ahead of Germany and Australia. Mexico, Israel and Greece are within the top 10 countries, ranking eighth to tenth.

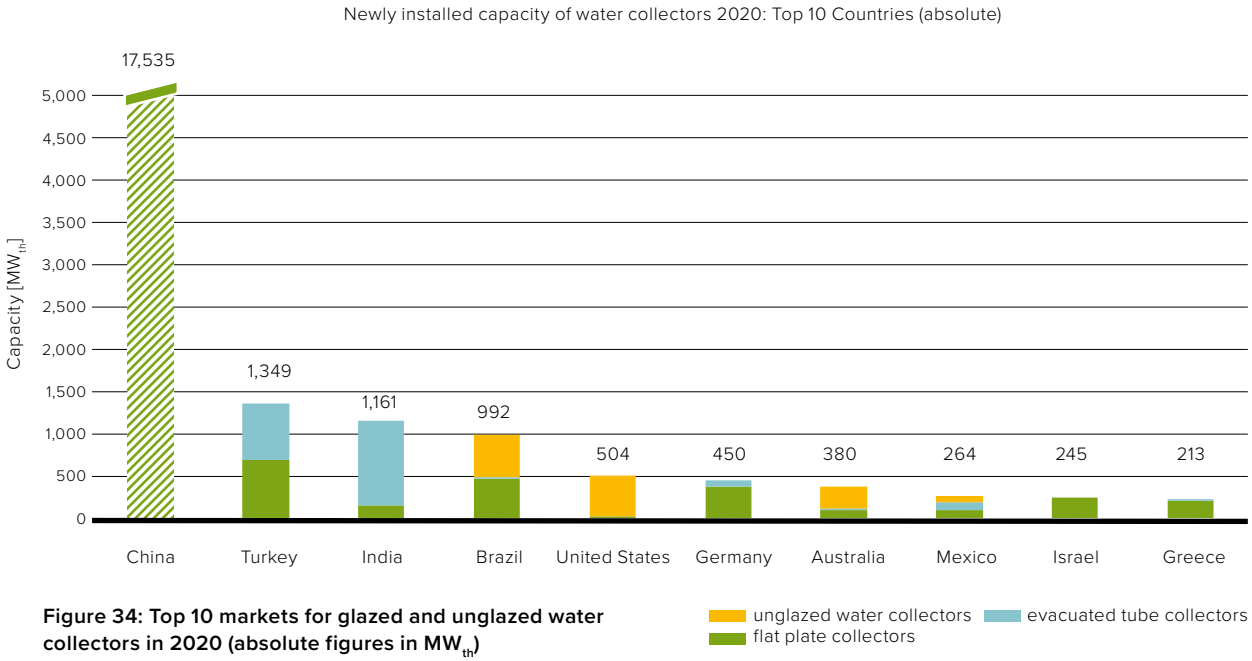

Figure 34: Top 10 markets for glazed and unglazed water collectors in 2020 (absolute figures in MW$_{th}$)

In terms of newly installed water collectors capacity per 1,000 inhabitants in 2020, the top 10 countries are shown in Figure 35.
Cyprus, Barbados, Israel and Greece rank first to fourth in 2020, like the year before. France (overseas) takes the fifth place from Denmark, which is no longer in the top 10. Turkey, Australia and China rank sixth to ninth, the Palestinian Territories take the ninth place and Austria ranks tenth.

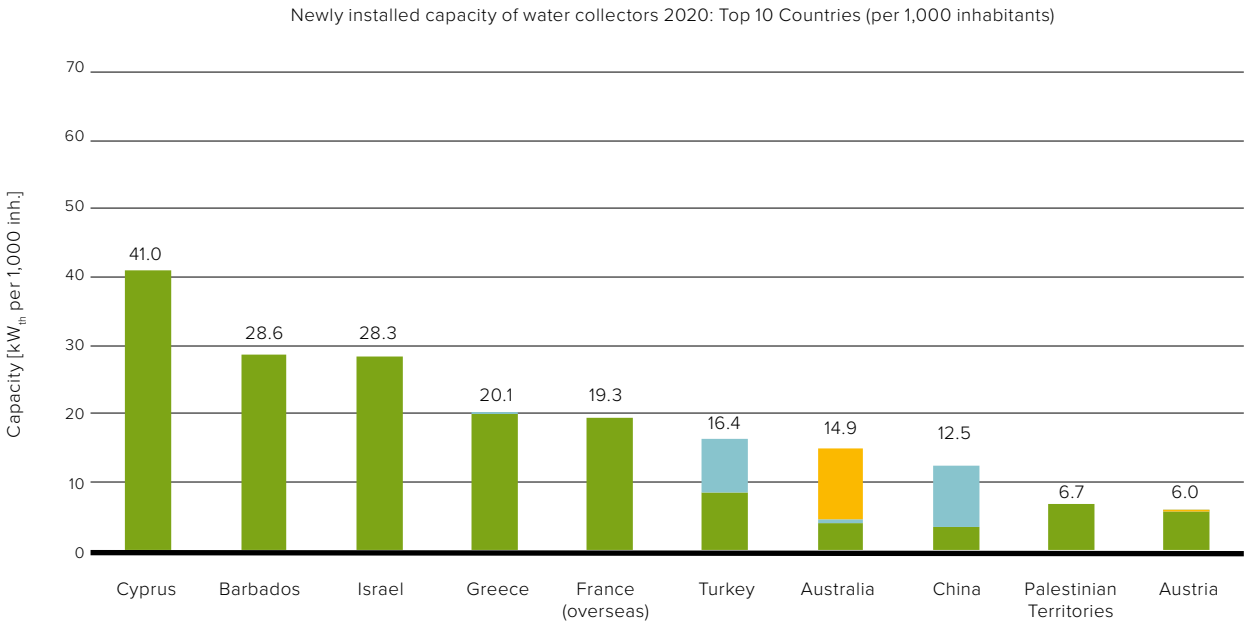

Figure 35: Top 10 markets for glazed and unglazed water collectors in 2020 (in kW$_{th}$ per 1,000 inhabitants)

5.6
Newly installed capacity of glazed water collectors

In 2020, glazed water collectors accounted for 94% of the total newly installed capacity. China was the most influential market in the global context (Figure 36).

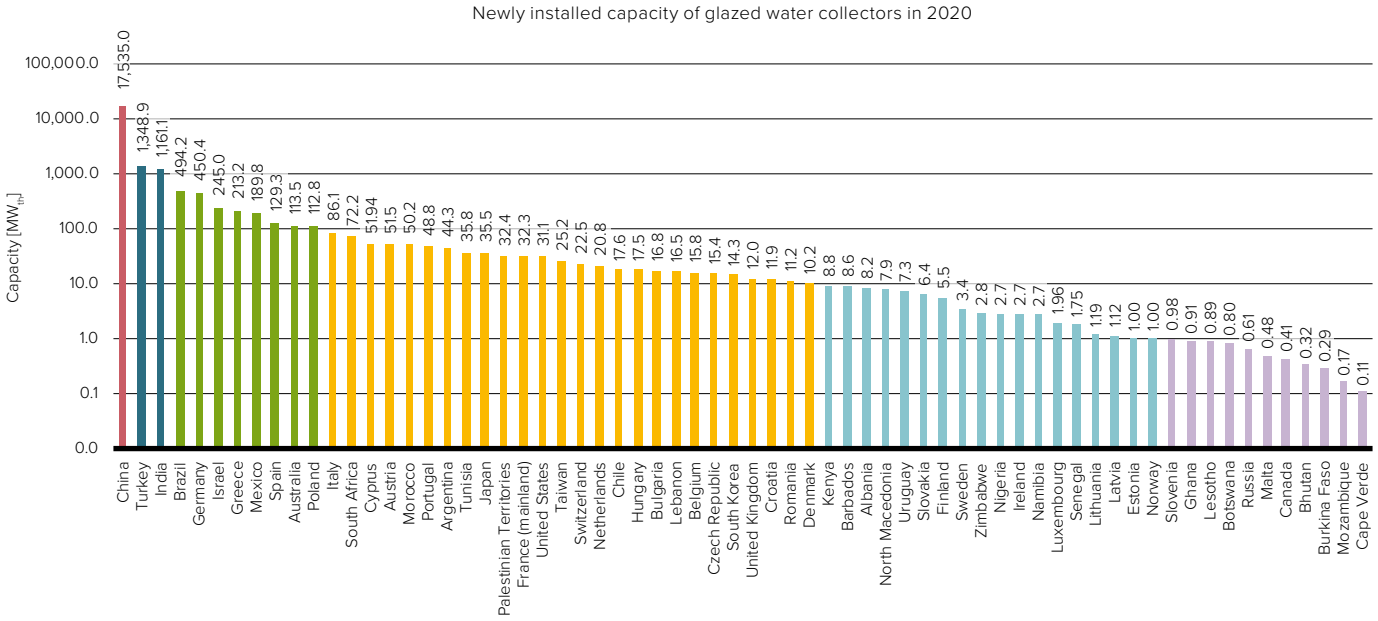

Figure 36: Newly installed capacity of glazed water collectors in 2020

In terms of newly installed glazed water collector capacity per 1,000 inhabitants, Cyprus is again the leader, ahead of Israel and Barbados. In this respect, China ranks in eighth place (Figure 37).

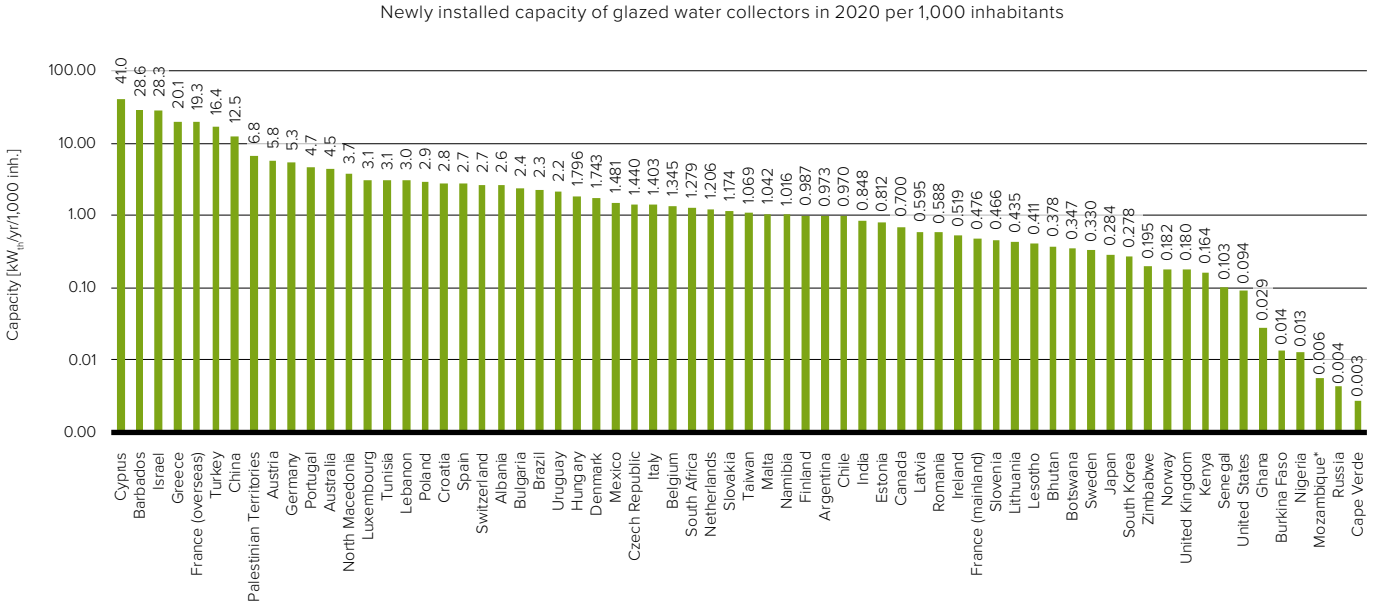

Figure 37: Newly installed capacity of glazed water collectors in 2020 in kW$_{th}$ per 1,000 inhabitants

The following figures show the solar thermal market penetration per capita of the newly installed capacity in 2020 worldwide and in Europe.

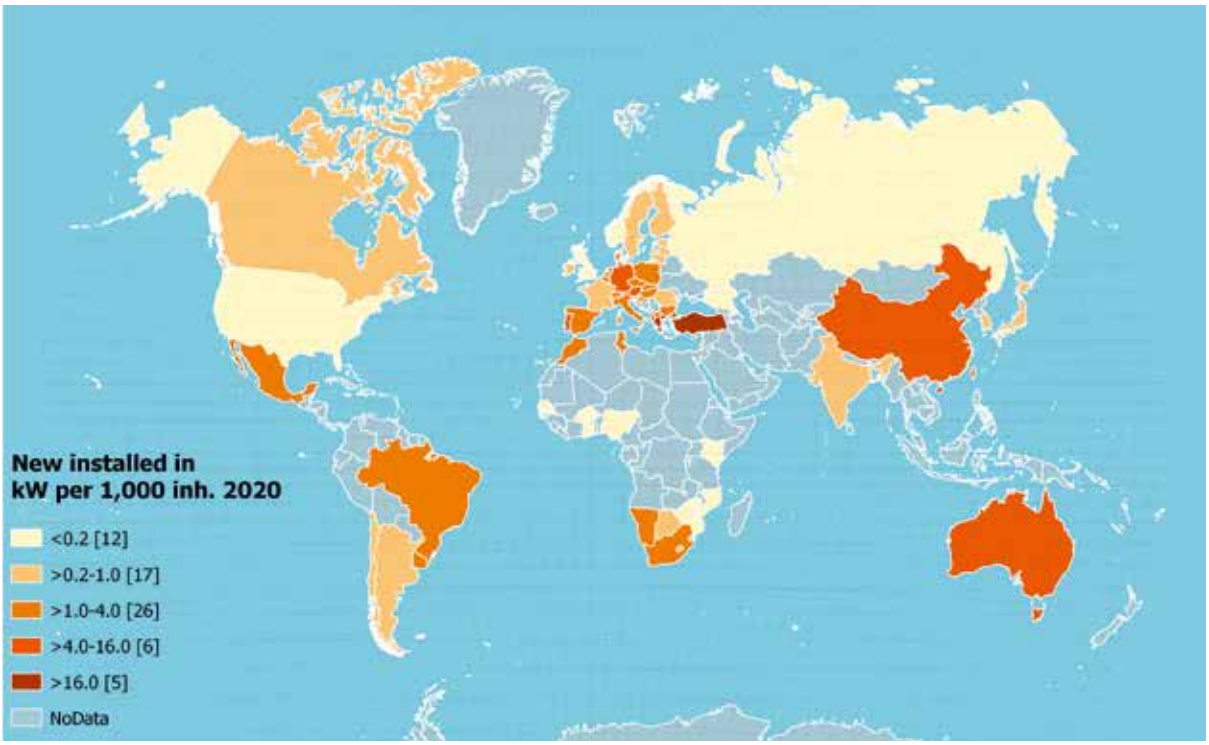

Figure 38: Newly installed capacity in 2020 in kW_{th} per 1,000 inhabitants – WORLD
(Source: Natural Earth v.4.1.0, 2020/ AEE INTEC).

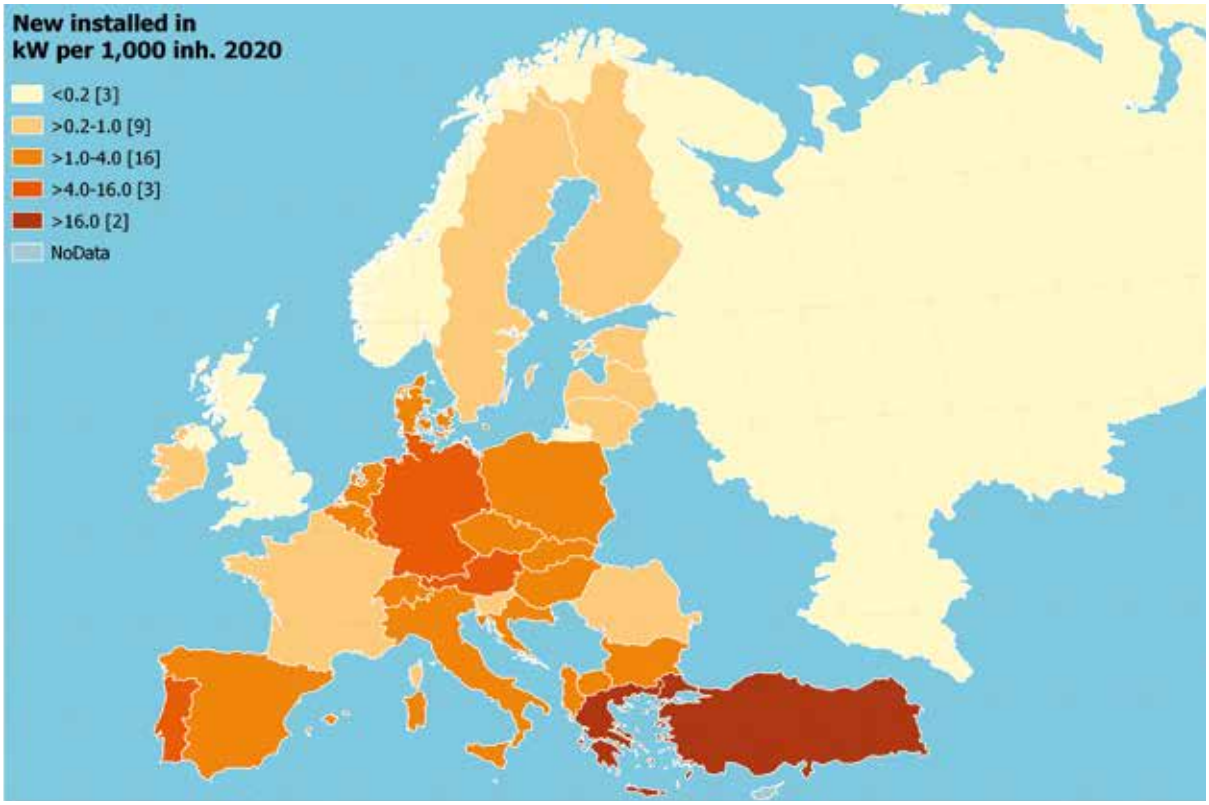

Figure 39: New Installed capacity in 2020 in kW_{th} per 1,000 inhabitants – EUROPE
(Source: Natural Earth v.4.1.0, 2020/ AEE INTEC)

5.7 Market development of glazed water collectors between 2000 and 2020

The worldwide market of glazed water collectors was characterized by a steady upward trend between 2000 and 2011 and then leveled off in 2012 and 2013 at around 50 GW_{th}. In 2014, a significant market decline of -15.6% was reported for the first time since 2000. This trend continued with slightly recovering markets in 2017 and 2018, but 2019 saw a 16% decline, recovering again in 2020 with minus 6%.
The newly installed glazed water collector capacity in 2020 amounted to 23.2 GW_{th} (Figure 40).

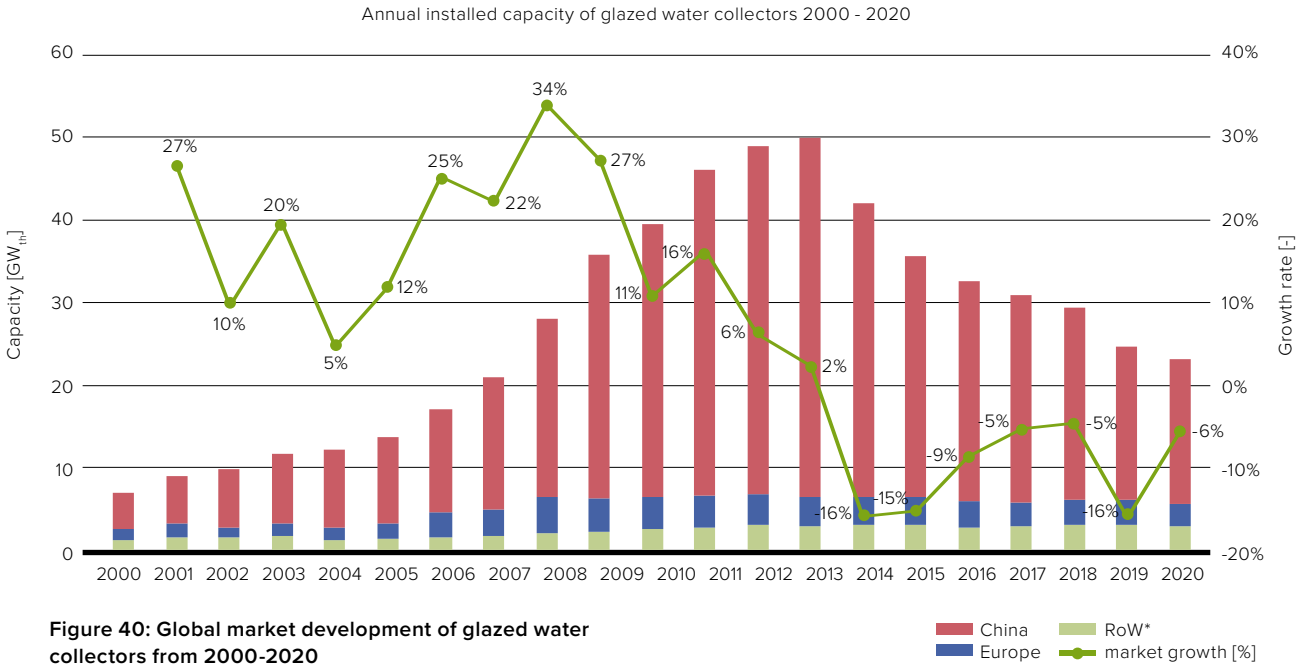

Figure 40: Global market development of glazed water collectors from 2000-2020

In 2000, the Chinese market was about three times as large as the European market, and by 2020, the Chinese market exceeded the European market by about six-fold (Figure 41).
Figure 41 also shows that after years of very high growth rates in China, this trend has changed in the past years. Compared to the years before, the Chinese market began to experience low growth rates in 2012 and 2013 and then shrank significantly in 2014 and 2015. However, this downward trend became less dramatic from 2015 to 2020.

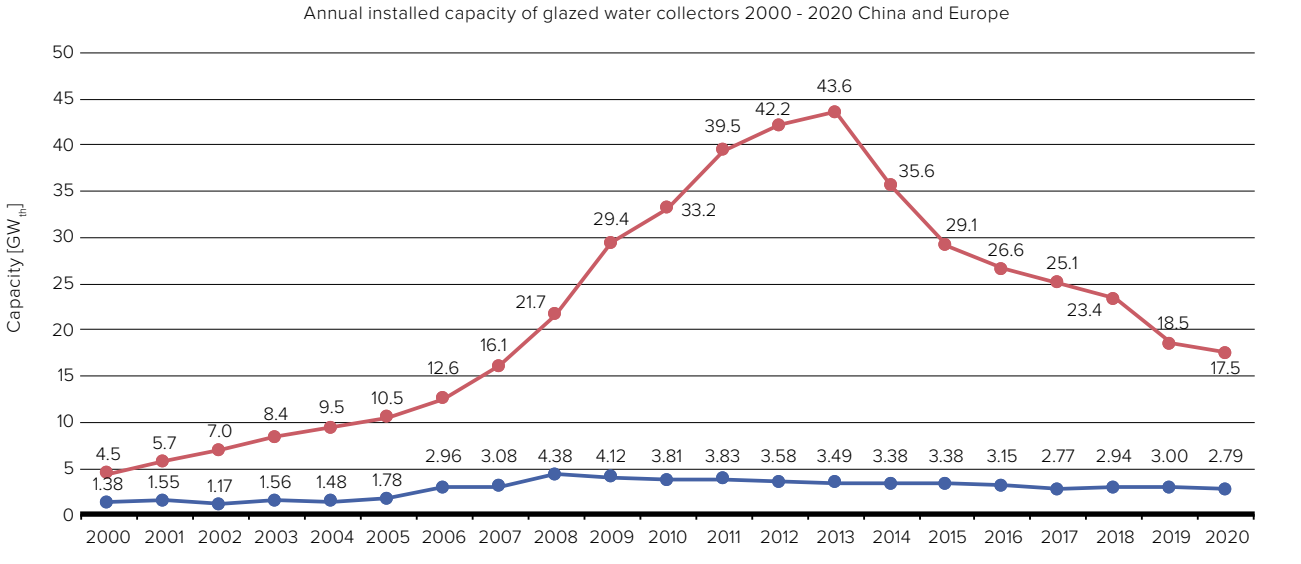

Figure 41: Market development of glazed water collectors in China and Europe 2000-2020

The European market peaked at 4.4 GW_{th} installed capacity in 2008 and has decreased steadily down to 2.8 GW_{th} in 2017, showed a slight recovery in 2019, and went again down to 2.8 GW_{th} in 2020. In the "remaining markets worldwide" (RoW), an upward trend could be observed between 2002 and 2012 and a falling trend from 2013 to 2016. In 2016 a slight upward trend was noticeable but declined again in 2020 (Figure 42).

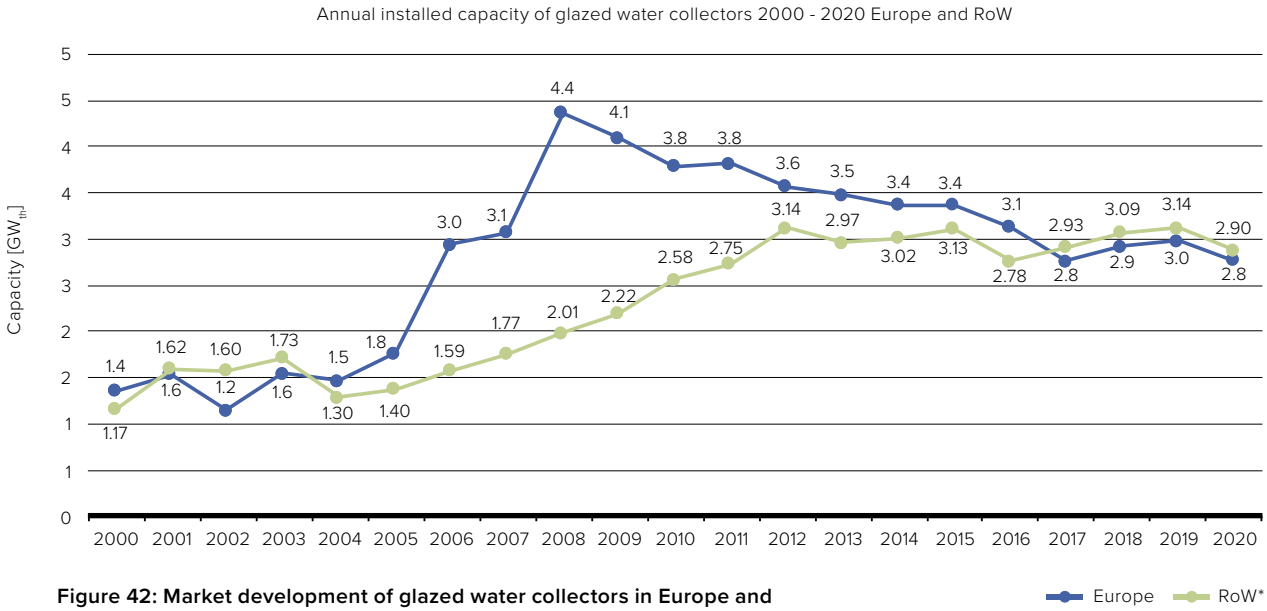

Figure 42: Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2020

Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
Rest of World (RoW): Asia (Bhutan, India, Japan, South Korea, Taiwan, Thailand), Australia, Canada, United States
Latin America (Argentina, Brazil, Chile, Mexico, Uruguay)
MENA countries (Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia)
Sub-Sahara Africa (Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe),
"All other countries" see figures for 2020 in Tables 4 and 5

Rest of the World (RoW) includes all economic regions other than China and Europe. Of these regions, Asia (excluding China), Latin America and the MENA countries hold the largest market shares (see Figure 43).

"Asia excl. China" is mainly influenced by the large Indian market, which dropped in 2013 but recovered significantly in 2014 and 2015. After a drop again in 2016, it shows an upward trend. Other markets covered within this economic region are Japan and South Korea.

Latin America showed the most steady and dynamic upward trend of all the economic regions until 2014. The dominant Brazilian market and the large Mexican market plus the evolving markets, for example, in Chile, are responsible for the positive growth rates over the past six years. Since 2015, the market in this region has been stable, with slight decreases in 2017 and 2018 but recovering again in 2019 and 2020.

Glazed water collector markets in the MENA countries saw steady growth from 2000 to 2013. The market decline since 2014, shown in Figure 43, is explained by the fact that from 2015 on, there was no data for one of the major markets - Jordan. The sales numbers in the most important market, Israel, slightly decreased in 2020.

The market volume for glazed water collectors in Australia was similar to that in Latin America and the MENA countries in 2009 but began to shrink more or less through 2015. In 2020, the market showed a 2% decrease.

Sub-Sahara African markets were stable in 2020. In the United States and Canada, the decreasing trend continued with a significant decline in 2020.

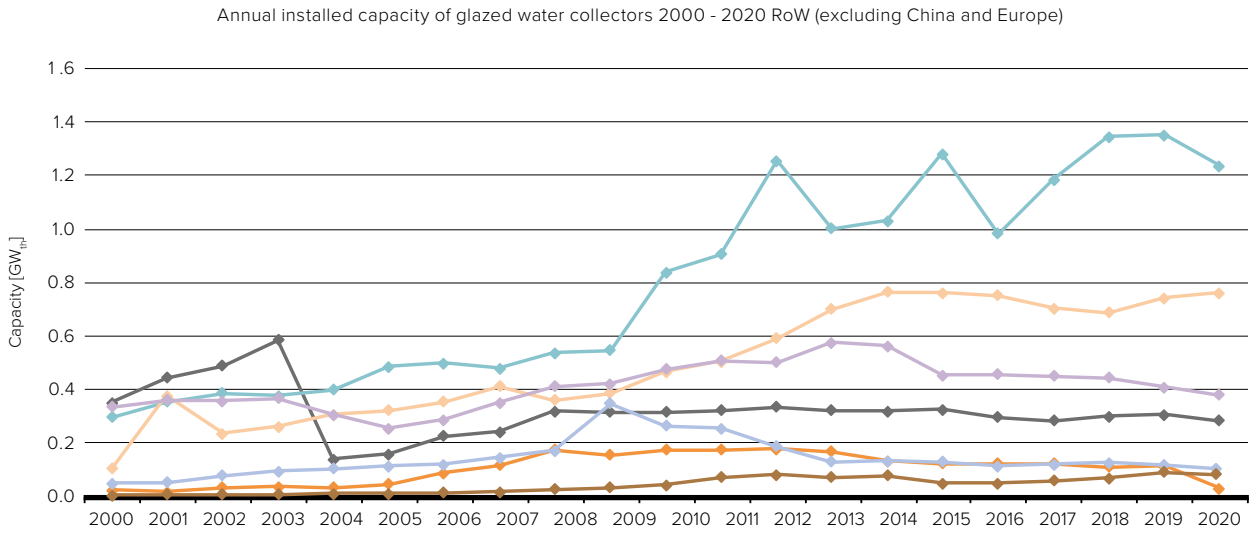

Figure 43: Market development of glazed water collectors in Latin America, United States / Canada, Sub-Sahara Africa, Asia, the MENA region and Australia (excluding China and Europe) from 2000 to 2020

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

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 7.0 kW_{th} per 1,000 inhabitants in 2013 and dropped down to 3.0 kW_{th} per 1,000 inhabitants in 2020 (Figure 44).

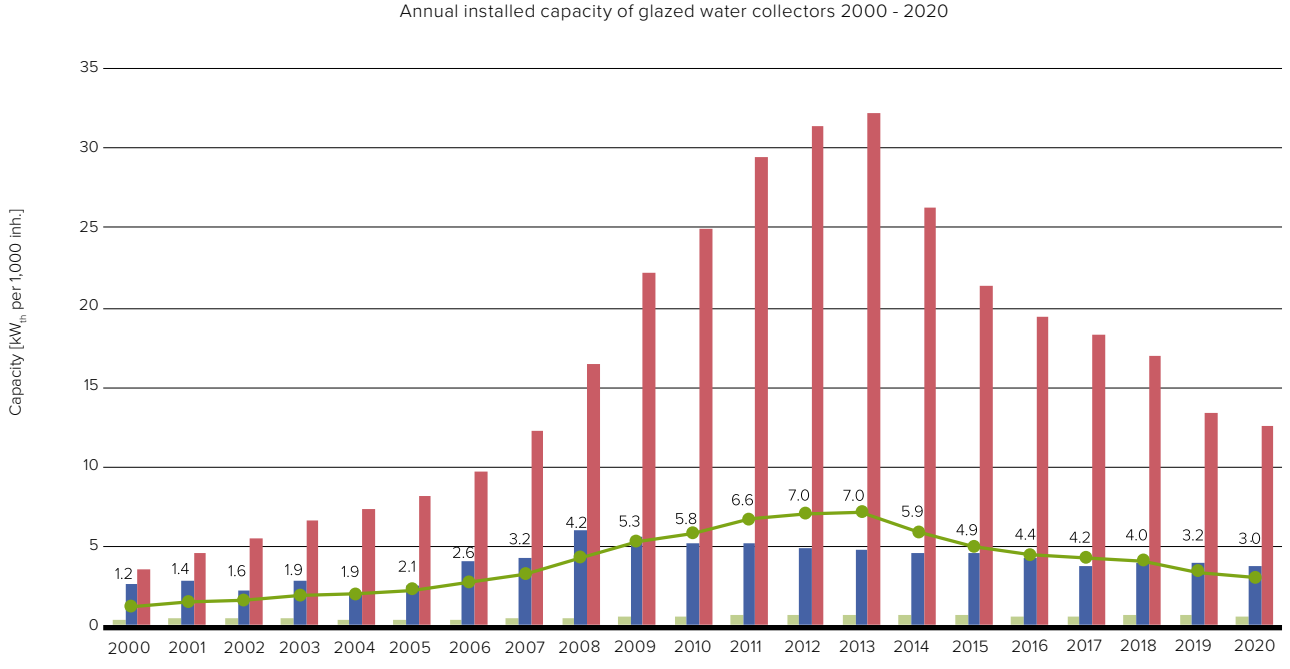

Figure 44: Annual installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2020

The fact that China suffered major market declines from 2014 to 2016 is also reflected in the market penetration of glazed water collector installations per capita. The annually installed capacity rose from 3.5 kW_{th} per 1,000 inhabitants in 2000, peaked at 32.2 kW_{th} per 1,000 inhabitants in 2013 and fell to 12.5 kW_{th} per 1,000 inhabitants in 2020.

In Europe, market penetration peaked in 2008 at 5.9 kW_{th} per 1,000 inhabitants. The downward trend between 2009 and 2013 seems to have stabilized from 2014 on and lies at 3.6 kW_{th} per 1,000 inhabitants in 2020.

5.8 Market development of unglazed water collectors between 2000 and 2020

With a newly installed capacity of 1.5 GW_{th} in 2020, unglazed water collectors accounted for 5.9% of the total installed solar thermal capacity (Figure 32). Compared to 2019, the market was stable.

The most important markets for unglazed water collectors in 2020 were the United States (473 MW_{th}), Brazil (498 MW_{th}) and Australia (266 MW_{th}). Mexico reported 75 MW_{th} installed unglazed water collector area and South Africa 40 MW_{th}. The capacity in these countries accounted for 93% of the recorded unglazed water collector installations worldwide. Switzerland (2.6 MW_{th}), Spain (2 MW_{th}) and the Netherlands (1.8 MW_{th}) also reported unglazed water collector installations in 2020.

Solar system for outdoor pool Obersulm, Germany
Photo: AST Eis- und Solartechnik GmbH, Austria

The unglazed water collector market in the United States peaked in 2006 (1.01 GW_{th}) and has about halved since then (0.47 GW_{th} in 2020). Nevertheless, the annual global market volume for unglazed water collectors has remained nearly constant because of the Brazilian market, which entered in 2007 and peaked in 2014 at 0.45 GW_{th}. Australia has faced a market decline since 2010 and is now the third largest market for unglazed water collectors behind that of the United States and Brazil.

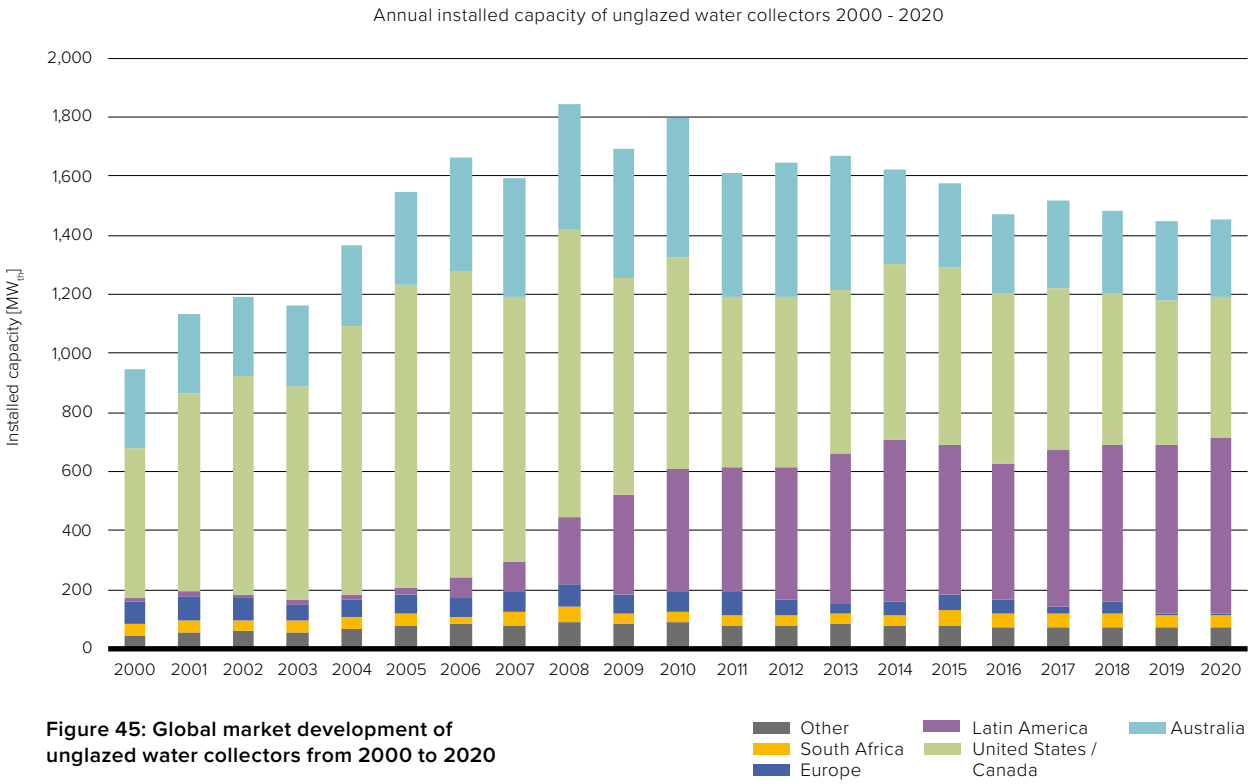

Figure 45: Global market development of unglazed water collectors from 2000 to 2020

6 Contribution to the energy supply and CO_2 reduction in 2020

In this section, the total installed glazed and unglazed water collectors' contribution to the thermal energy supply and CO_2 reduction is detailed.

The annual collector yield of all water-based solar thermal systems for the simulated applications (swimming pool, DHW for single-family houses, DHW for multi-family houses and solar combi-systems) in operation at the end of 2020 in the 70 recorded countries was 406 TW_h (= 1,460 PJ). This corresponds to a final energy savings equivalent of 43.6 million tons of oil and 137.9 million tons of CO_2. The calculated number of solar thermal systems in operation was around 108 million (Table 13). The CO_2 emissions saved by the thermal solar systems in operation in 2020 were about 138 million t/a or 3.2 times the CO_2 emissions of Switzerland[20].

[20] https://de.statista.com/statistik/daten/studie/961158/umfrage/treibhausgas-emissionen-in-der-schweiz/

The basis for these calculations is the total glazed and unglazed water collector area in operation in each country, as shown in Table 10. The 1.0 GW_{th} contribution of the total installed air collector capacity in operation in 2020 was not taken into consideration – with only a share of around 0.2% 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 and characteristic climatic conditions were considered for each country. A more detailed description of the methodology can be found in the Appendix (see Chapter 8).

* Total capacity in operation refers to the year 2014
** Total capacity in operation refers to the year 2015
*** Total capacity in operation refers to the year 2009

**** Total capacity in operation refers to the year 2016
\+ The figures for France relate to mainland France only, overseas departments and regions are not considered.
++ For France overseas no collector yield was calculated because of different reference climates

Table 13 summarizes the calculated annual collector yields and the corresponding oil equivalents and CO^2 reductions of all water-based solar thermal systems in 2020.

Country	YIELD - Total						
	Total collector area [m^2]	Total capacity [MWth]	Calculated number of systems	Collector yield [GWh/a]	Collector yield [TJ/a]	Energy savings [t_{oe}/a]	CO_2 reduction [t_{CO2e}/a]
Albania	293,965	206	63,632	208	747	22,305	70,594
Argentina	284,384	199	40,711	189	680	20,316	64,300
Australia	9,420,000	6,594	1,131,307	5,743	20,673	617,216	1,953,487
Austria	4,914,887	3,440	523,012	2,030	7,309	218,212	690,640
Barbados	258,192	181	59,797	227	817	24,400	77,226
Belgium	735,569	515	126,138	291	1,047	31,267	98,960
Bhutan	460	0.3	46	0.3	1	34	106
Botswana	17,275	12	2,822	6	22	670	2,122
Brazil	18,726,013	13,108	5,093,586	11,687	42,072	1,256,079	3,975,491
Bulgaria	178,045	125	32,457	89	321	9,590	30,352
Burkina Faso	4,681	3	296	4	16	469	1,484
Canada	863,059	604	33,984	361	1,300	38,798	122,797
Chile	404,749	283	128,016	289	1,039	31,023	98,188
China	519,989,101	363,992	71,514,101	284,938	1,025,775	30,625,282	96,929,017
Croatia	269,592	189	49,145	138	496	14,814	46,888
Cyprus	834,330	584	364,572	741	2,669	79,697	252,240
Czech Republic	1,132,378	793	103,087	388	1,398	41,748	132,133
Denmark	1,880,486	1,316	112,425	785	2,825	84,347	266,958
Estonia	20,308	14	3,702	8	30	891	2,821
Finland	81,986	57	12,834	32	115	3,434	10,869
France (mainland)+	2,323,015	1,626	422,001	1,093	3,936	117,510	371,920
France (overseas)++	1,074,716	752	0	0	0	0	0
Germany	19,893,931	13,926	2,348,506	8,114	29,210	872,089	2,760,161
Ghana	5,378	4	282	5	17	521	1,649
Greece	4,992,906	3,495	1,396,939	3,544	12,757	380,871	1,205,457
Hungary	373,962	262	51,945	174	628	18,742	59,317
India	16,381,750	11,467	8,050,164	14,416	51,898	1,549,466	4,904,059
Ireland	347,062	243	80,322	145	523	15,618	49,431
Israel	4,927,434	3,449	1,629,535	4,607	16,584	495,142	1,567,126
Italy	4,947,136	3,463	893,949	3,051	10,984	327,926	1,037,887
Japan	3,163,326	2,214	765,881	1,830	6,589	196,710	622,586
Jordan*	1,260,506	882	223,109	1,194	4,297	128,286	406,026
Kenya	452,430	317	7,013	57	204	6,080	19,243
Latvia	40,027	28	7,297	17	62	1,858	5,879
Lebanon	735,400	515	122,824	618	2,224	66,393	210,134
Lesotho	4,257	3	1,215	4	14	403	1,276
Lithuania	22,238	16	4,054	9	34	1,018	3,221
Luxembourg	69,089	48	12,595	30	107	3,194	10,108
Malta	74,166	52	29,666	64	232	6,918	21,897
Mauritius**	132,793	93	88,529	113	408	12,183	38,558
Mexico	5,109,897	3,577	635,303	2,996	10,786	322,016	1,019,180
Morocco	896,000	627	125,844	772	2,780	83,012	262,732
Mozambique	2,542	2	370	2	7	221	701
Namibia	54,372	38	6,560	49	177	5,284	16,724
Netherlands	669,350	469	155,126	272	978	29,196	92,406
New Zealand***	159,645	112	33,595	100	359	10,708	33,889
Nigeria	12,648	9	4,836	11	40	1,192	3,773
North Macedonia	123,733	87	28,421	77	277	8,259	26,141
Norway	43,903	31	2,188	16	58	1,737	5,497
Palestine	1,883,218	1,318	673,185	1,784	6,422	191,747	606,881
Poland	3,006,590	2,105	378,329	1,228	4,420	131,960	417,654
Portugal	1,245,719	872	226,480	963	3,467	103,512	327,615
Romania	234,099	164	42,634	131	473	14,131	44,725
Russia	27,213	19	1,577	9	34	1,016	3,216
Senegal	9,824	7	2,448	10	34	1,029	3,258
Slovakia	182,009	127	23,210	86	310	9,253	29,285
Slovenia	148,600	104	23,246	63	226	6,734	21,312
South Africa	2,493,082	1,745	614,644	1,829	6,585	196,611	622,275
South Korea	1,931,985	1,352	446,134	1,006	3,621	108,104	342,151
Spain	4,702,413	3,292	562,161	3,297	11,870	354,377	1,121,602
Sweden	521,305	365	37,413	188	678	20,247	64,081
Switzerland	1,719,902	1,204	223,696	695	2,502	74,711	236,461
Taiwan	1,814,323	1,270	360,690	1,108	3,988	119,050	376,793
Thailand****	157,527	110	36,288	133	478	14,262	45,138
Tunisia	1,147,577	803	337,354	1,030	3,707	110,677	350,294
Turkey	26,309,636	18,417	6,077,526	23,603	84,971	2,536,882	8,029,232
United Kingdom	1,465,034	1,026	366,259	608	2,190	65,386	206,948
United States	25,779,678	18,046	370,854	10,887	39,192	1,170,108	3,703,393
Uruguay	86,419	60	18,107	58	210	6,264	19,826
Zimbabwe	77,568	54	31,512	66	238	7,102	22,477
All other countries (5% of world market excluding China)	9,699,965	6,790	1,448,758	5,290	19,045	568,612	1,799,656
TOTAL	713,246,758	499,273	108,826,241	405,607	1,460,186	43,594,920	137,977,923

7 Distribution of systems by type and application in 2020

The use of solar thermal energy varies significantly 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).

7.1 Distribution by type of solar thermal collector

In terms of the total water collector capacity worldwide in 2020, evacuated tube collectors dominated with 69% of the cumulated capacity in operation (Figure 46) and a share of 60% of the newly installed capacity (Figure 47). Worldwide flat plate collectors accounted for about 25% of the cumulated capacity in operation (Figure 46) and a 34% share of the newly installed capacity (Figure 47). Unglazed water collectors accounted for 6% of both the cumulated water collectors installed worldwide and the newly installed capacity.

In China, evacuated tube collectors are the dominant collector type. In North America, Australia and Sub-Sahara Africa (mainly driven by South Africa) unglazed water collectors represent the largest share. In the other regions, flat plate collectors are dominant.

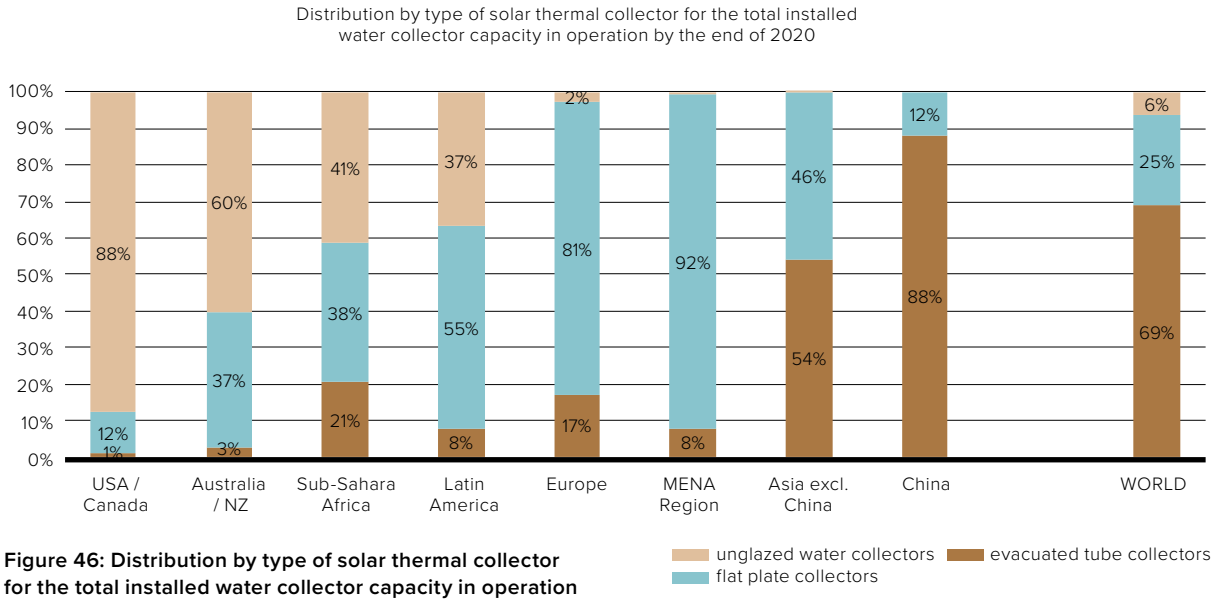

Figure 46: Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestine, Tunisia

The distribution of the newly installed collector area is shown below. Evacuated tube collectors are dominant in China and Asia (excluding China), driven by development in India and the increasing share in Sub-Sahara Africa. Unglazed collectors are dominant in North America and Australia. Flat plate collectors dominate in Latin America, Europe and the MENA region.

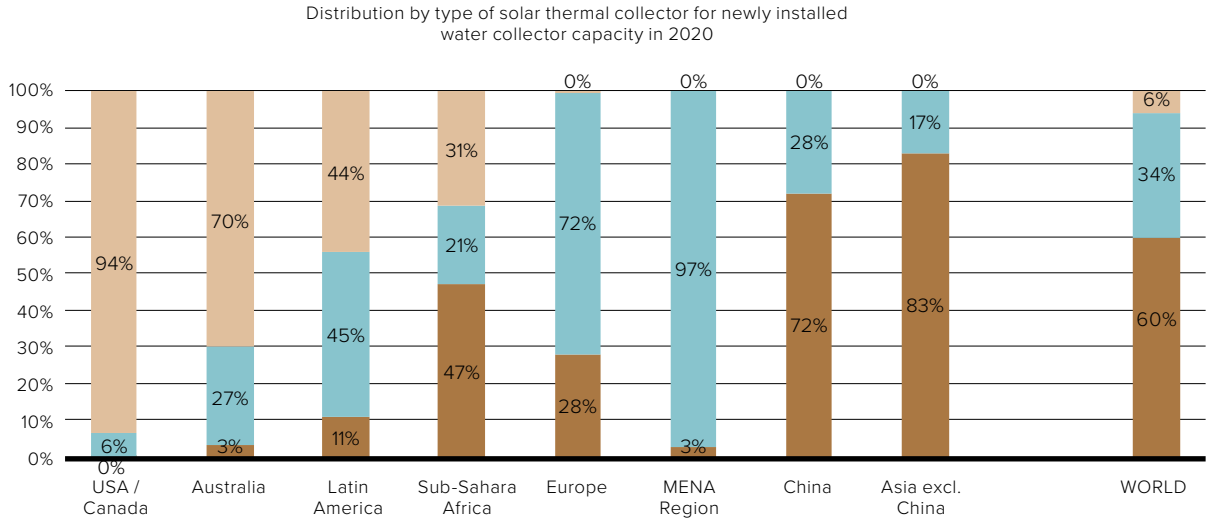

Figure 47: Distribution by type of solar thermal collector for newly installed water collector capacity in 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan Thailand
Latin America: Argentina, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

Thermosiphon systems in Mozambique
Photo: AEE INTEC

7.2 Distribution by type of system

Worldwide, about 58% of all solar thermal systems installed are thermosiphon systems and the rest are pumped solar heating systems (Figure 48).

Similar to the distribution by type of solar thermal collector in total numbers, the Chinese market influenced the overall figures the most. 26% of all newly installed systems in China were thermosiphon systems, while pumped systems accounted for 74%. The share of thermosiphon systems has been decreasing for several years in China (Figure 49).

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

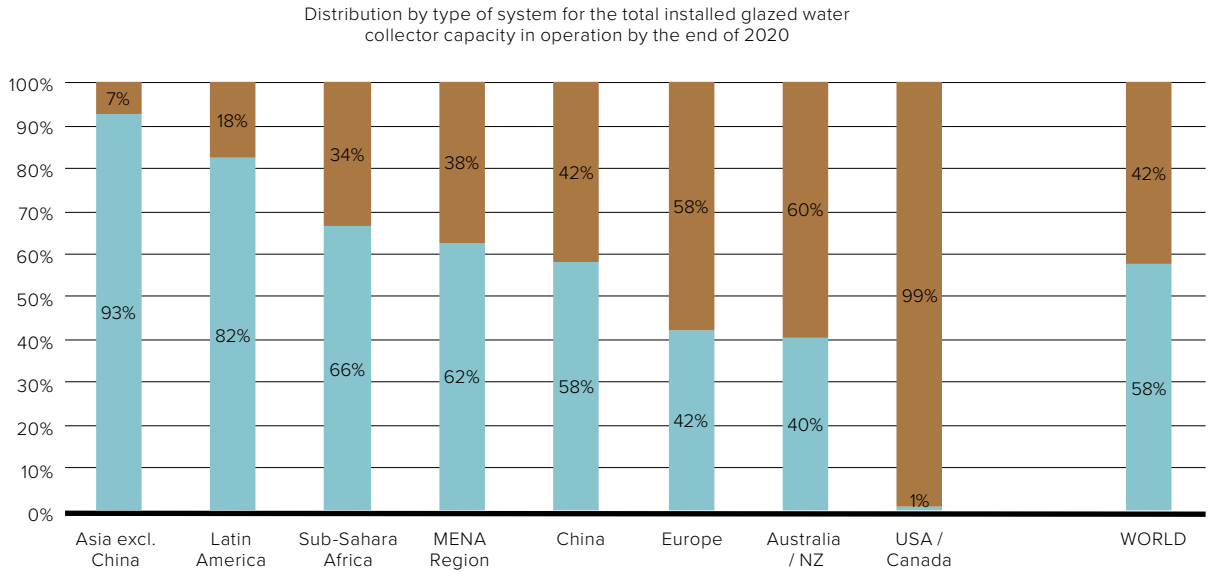

Figure 48: Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

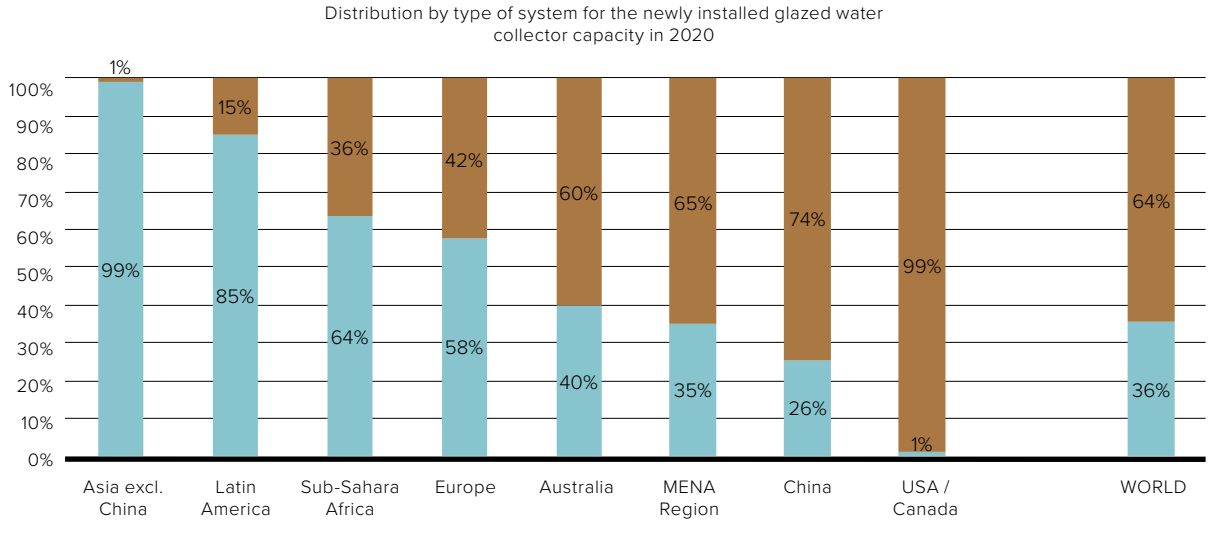

Figure 49: Distribution by type of system for the newly installed glazed water collector capacity in 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

7.3
Distribution by type of application

The newly installed water-based solar thermal collector area amounted to 35.3 million m², corresponding to 24.7 GW_{th} of thermal peak capacity (Table 11).
The largest share of the collector area installed in 2020 is large domestic hot water systems for multi-family houses, tourism and the public sector. Domestic hot water systems in single-family houses accounted for about 35% of installations in 2020. The share of swimming pool heating was 6%. The share for other applications, such as solar district heating and solar process heat, is about 2% globally (Figure 50).

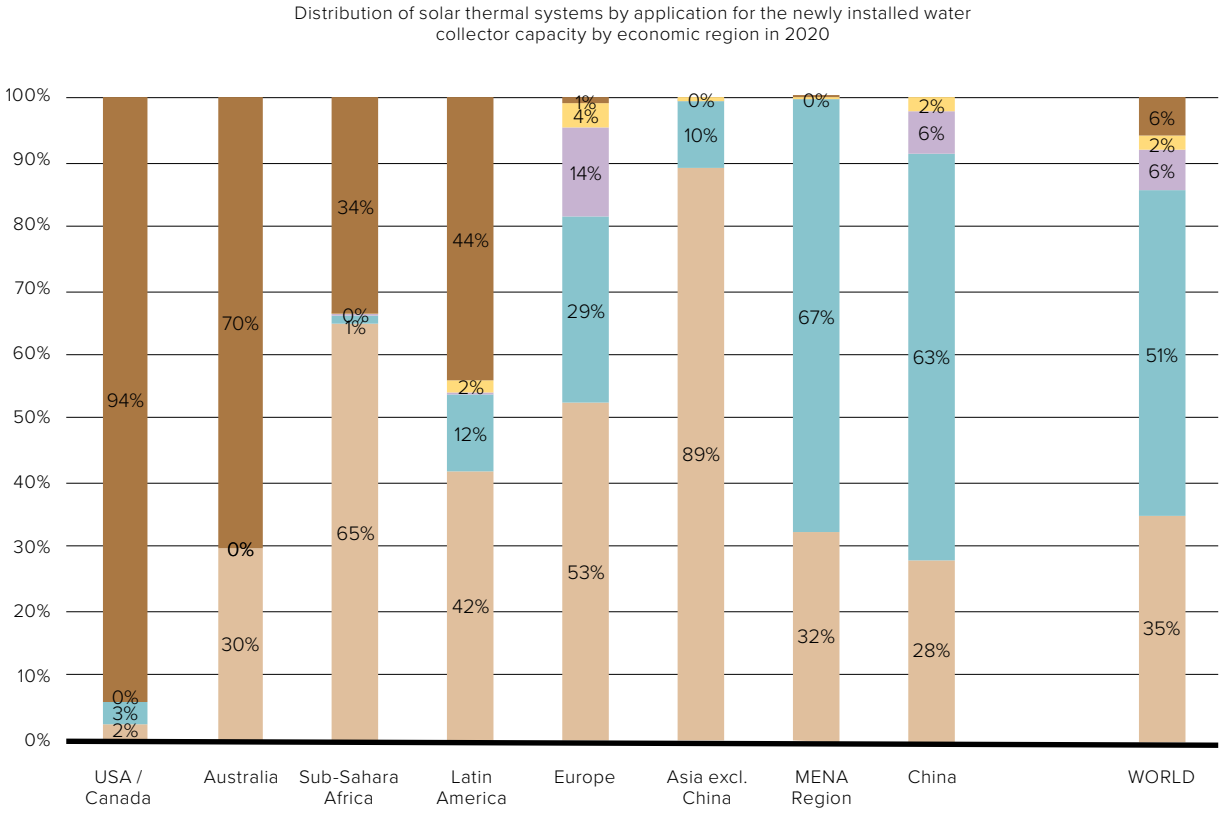

Figure 50: Distribution of solar thermal systems by application for the newly installed water collector capacity by economic region in 2020

Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Asia w/o China: Bhutan, India, Japan, South Korea, Taiwan Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

8 Appendix

8.1 Methodological approach for the energy calculation

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 multi-family houses, tourism sector and 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 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. Based on these boundary conditions, simulations were performed using T-Sol [T-Sol, Version 4.5 Expert, Valentin Energiesoftware, www.valentin-software.com] and gross solar yields for each country and 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[21].

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 kW_h.

Finally, the CO_2 emissions avoided by the different solar thermal applications are quoted as kilograms carbon dioxide equivalent (kg_{CO2e}) per tons of oil equivalent: 1 toe = 3.228 t CO2e[22]. The emission factor only accounts 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 relate only 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[23]. Furthermore, a hydraulic scheme is shown for each reference system.

[21] 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.

[22] Source: Carbon trust, Conversion factors Energy and carbon conversion, updated 2016

[23] For some countries no specific estimations are available concerning shares by type of application. In these cases shares given in previous reports were used for the calculation.

8.1.1 Reference systems for swimming pool heating

Table 14 refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2020.

Table 14: Solar thermal systems for swimming pool heating in 2020

Swimming Pool - Total						
Country	Reference climate	Horizontal irradiation [kWh/m²*a]	Total collector area (swimming pool) [m²]	Collector area per system [m²]	Total number of systems [-]	Specific solar yield (swimming pool) [kWh/m²*a]
Argentina	Buenos Aires	1,748	88,159	200	441	470
Australia	Sydney	1,674	5,746,200	35	164,177	466
Austria	Graz	1,126	240,922	200	1,205	283
Belgium	Brussels	971	44,854	200	224	261
Brazil	Brasília	1,793	7,377,812	32	230,557	375
Canada	Montreal	1,351	742,157	25	29,686	386
Chile	Santiago de Chile	1,753	65,569	15	4,371	471
Cyprus	Nicosia	1,886	2,253	200	11	507
Czech Republic	Praha	998	500,351	200	2,502	303
Finland	Helsinki	948	11,811	200	59	256
France (mainland)	Paris	1,112	87,989	200	440	328
Germany	Würzburg	1,091	469,335	30	15,644	314
Hungary	Budapest	1,199	18,332	10	1,833	344
Israel	Jerusalem	2,198	39,419	200	197	568
Italy	Bologna	1,419	44,507	200	223	442
Jordan	Amman	2,145	6,661	200	33	578
Mexico	Mexico City	1,706	1,645,387	200	8,227	311
Mozambique	Maputo	1,910	137	40	3	514
Namibia	Windhoek	2,363	1,577	40	39	636
Netherlands	Amsterdam	999	77,645	40	1,941	272
New Zealand	Wellington	1,401	7,024	200	35	378
Norway	Oslo	971	1,835	200	9	316
Portugal	Lisbon	1,686	2,491	200	12	421
Romania	Bucharest	1,324	234	200	1	356
Russia	Moscow	996	136	200	1	268
Slovakia	Bratislava	1,214	910	200	5	327
South Africa	Johannesburg	2,075	1,351,250	40	33,781	505
Spain	Madrid	1,644	159,882	200	799	472
Sweden	Gothenburg	934	171,021	200	855	295
Switzerland	Zürich	1,094	175,460	200	877	277
Taiwan	Taipei	1,372	1,997	175	11	319
United States	LA, Indianapolis	1,646	22,582,998	200	112,915	387
Other (5%)		1,464	2,222,645	200	11,113	394
TOTAL			43,888,961		622,230	
AVG		1,461		148		388

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

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

The information in Table 15 refers to the total capacity of water collectors in operation used for domestic hot water heating in single-family houses at the end of 2020, as reported by each country.

Figure 51 shows the hydraulic scheme of the swimming pool reference system used to simulate solar energy yields.

Figure 51: Hydraulic scheme of the swimming pool reference system

Table 15: Solar thermal systems for domestic hot water heating in single-family houses by the end of 2020

DHW-SFH - Total							
Country	Reference climate	Horizontal irradiation [kWh/m²*a]	Total collector area (DHW-SFH) [m²]	Collector area per system [m²]	Total number of systems [-]	Specific solar yield (DHW-SFH) [kWh/m²*a]	Type of system
Albania	Tirana	1,604	184,316	3	61,439	713	TS
Argentina	Buenos Aires	1,748	151,308	4	37,827	777	PS
Australia	Sydney	1,674	3,363,213	3.5	960,918	844	PS
Austria	Graz	1,126	2,194,531	6	365,755	451	PS
Barbados	Grantley Adams	2,016	237,537	4	59,384	882	TS
Belgium	Brussels	971	448,916	4	112,229	423	PDS / PS
Botswana	Gaborone	2,161	10,365	4	2,591	961	TS
Brazil	Brasília	1,793	9,670,122	2	4,835,061	809	TS
Bulgaria	Sofia	1,188	115,717	4	28,929	524	PS
Burkina Faso	Ouagadougou	2,212	647	4	162	983	TS
Canada	Montreal	1,351	12,779	6	2,130	556	PS
Chile	Santiago de Chile	1,753	243,460	2	121,730	771	PS
China	Shanghai	1,282	265,714,431	4	66,428,608	592	TS
Croatia	Zagreb	1,212	175,216	4	43,804	539	PS
Cyprus	Nicosia	1,886	723,075	2	361,538	912	TS
Czech Republic	Praha	998	324,219	4.7	68,983	385	PS
Denmark	Copenhagen	989	295,236	4	73,809	454	PS
Estonia	Tallin	960	13,199	4	3,300	432	PS
Finland	Helsinki	948	45,472	4	11,368	441	PS
France (mainland)	Paris	1,112	1,133,475	3.2	354,211	496	PS
Germany	Würzburg	1,091	8,756,356	5.6	1,563,635	424	PS
Ghana	Accra	2,146	473	4	118	954	TS
Greece	Athens	1,585	3,245,036	2.5	1,298,014	772	TS
Hungary	Budapest	1,199	205,361	5	41,072	473	PS
India	Neu-Delhi	1,961	16,088,603	2	8,044,301	882	TS
Ireland	Dublin	949	312,356	4	78,089	423	PS
Israel	Jerusalem	2,198	916,503	3	305,501	1,024	TS
Italy	Bologna	1,419	3,186,362	4	796,590	661	PS
Japan	Tokyo	1,175	3,016,297	4	754,074	586	TS
Jordan	Amman	2,145	1,003,076	4.6	218,060	986	TS
Kenya	Nairobi	1,931	382,303	4		859	
Latvia	Riga	991	26,015	4	6,504	462	PS
Lebanon	Beirut	1,935	463,030	4	115,757	860	TS
Lesotho	Maseru	2,050	1,974	2	987	911	TS
Lithuania	Vilnius	1,001	14,453	4	3,613	450	PS
Luxembourg	Luxembourg	1,037	44,903	4	11,226	450	PS
Malta	Luqa	1,902	74,166	2.5	29,666	868	PS
Mauritius	Port Louis	1,920	132,793	1.5	88,529	854	TS
Mexico	Mexico City	1,706	2,425,157	4	606,289	718	PS
Morocco	Rabat	2,000	466,667	4	116,667	889	TS
Mozambique	Maputo	1,910	1,385	4	346	849	TS
Namibia	Windhoek	2,363	23,758	4	5,939	1,032	TS
Netherlands	Amsterdam	999	399,057	2.8	142,520	433	PDS / PS
New Zealand	Wellington	1,401	131,287	4	32,822	647	PS
Nigeria	Abuja	2,007	9,043	4	2,261	892	TS
North Macedonia	Skopje	1,381	112,370	4	28,092	627	PS
Norway	Oslo	971	1,525	6	254	430	PS
Palestinian Territories	Jerusalem	2,198	980,843	1.5	653,895	977	TS
Poland	Warsaw	1,024	2,104,613	6	350,769	397	PS
Portugal	Lisbon	1,686	868,385	4	217,096	804	PS
Romania	Bucharest	1,324	151,996	4	37,999	594	PS
Russia	Moscow	996	4,220	4	1,055	443	PS
Senegal	Dakar	2,197	9,529	4	2,382	977	TS
Slovakia	Bratislava	1,214	117,702	6	19,617	481	PS
Slovenia	Ljubjana	1,115	133,740	6	22,290	424	PS
South Africa	Johannesburg	2,075	1,102,786	1.9	580,413	1,009	TS
South Korea	Seoul	1,161	1,765,900	4	441,475	525	PS
Spain	Madrid	1,644	1,912,645	4	478,161	766	PS
Sweden	Gothenburg	934	36,751	4	9,188	383	PS
Switzerland	Zürich	1,094	1,034,776	5.7	181,540	426	PS
Taiwan	Taipei	1,372	1,715,815	4.8	357,461	616	TS
Thailand	Bangkok	1,765	143,985	4	35,996	854	TS
Tunisia	Tunis	1,808	1,110,843	3.3	336,619	902	TS
Turkey	Antalya	1,795	24,204,865	4	6,051,216	910	TS
United Kingdom	London	943	1,465,034	4	366,259	415	PS
United States	LA, Indianapolis	1,646	1,322,764	6	220,461	646	PS
Uruguay	Montevideo	1,534	71,209	4	17,802	682	TS
Zimbabwe	Harare	2,017	62,054	2	31,027	854	TS
All other countries (5% of world market excluding China)		1,430	5,383,969	4	1,345,992	636	
TOTAL			372,201,968		99,983,419		
AVG		1,528		4		682	

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

Figure 52 shows the hydraulic scheme used for the energy calculation for all pumped solar thermal systems and Figure 55 refers to the thermosiphon systems.

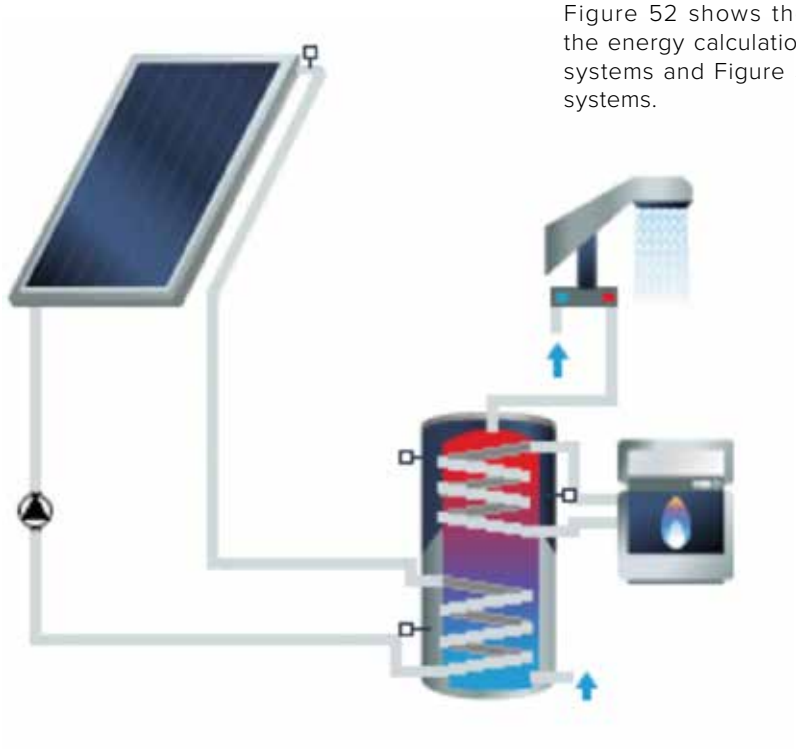

Figure 52: Hydraulic scheme of the domestic hot water pumped reference system for single-family houses

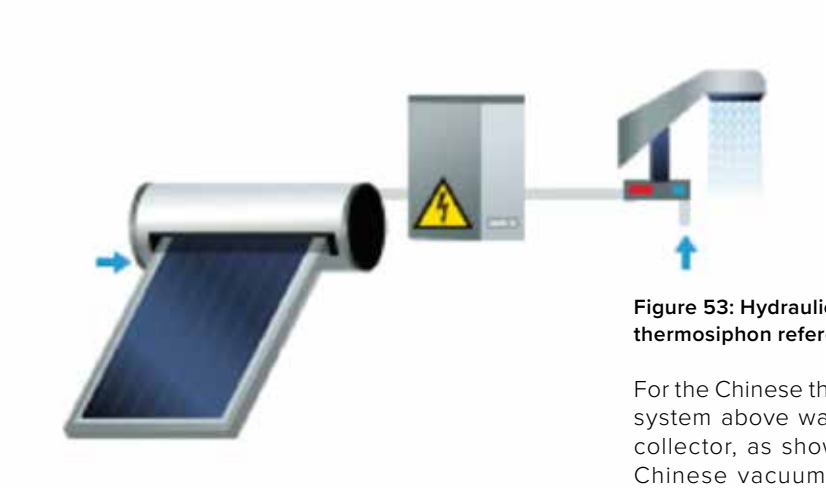

Figure 53: Hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses

For the Chinese thermosiphon systems, the reference system above was used, but instead of a flat plate collector, as shown in Figure 53, a representative Chinese vacuum tube collector was used for the simulation.

8.1.3
Reference systems for domestic hot water preparation in multi-family houses

The information in Table 16 refers to the total capacity of water collectors in operation used for domestic hot water heating in multi-family houses at the end of 2020 as reported by each country.

Table 16: Solar thermal systems for domestic hot water heating in multi-family houses by the end of 2020

DHW-MFH - Total						
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	109,649	50	2,193	694
Argentina	Buenos Aires	1,748	20,523	50	410	730
Australia	Sydney	1,674	310,587	50	6,212	725
Austria	Graz	1,126	409,308	50	8,186	505
Barbados	Grantley Adams	2,016	20,655	50	413	842
Belgium	Brussels	971	102,075	50	2,042	406
Bhutan	Thimphu	1,623	460	10	46	678
Botswana	Gaborone	2,161	6,910	30	230	903
Brazil	Brasília	1,793	1,678,078	60	27,968	658
Bulgaria	Sofia	1,188	26,312	50	526	515
Burkina Faso	Ouagadougou	2,212	4,033	30	134	924
Canada	Montreal	1,351	108,038	50	2,161	621
Chile	Santiago de Chile	1,753	95,719	50	1,914	732
China	Shanghai	1,282	254,274,670	50	5,085,493	502
Croatia	Zagreb	1,212	39,841	50	797	506
Cyprus	Nicosia	1,886	95,689	50	1,914	750
Czech Republic	Praha	998	49,013	42.4	1,156	436
Denmark	Copenhagen	989	1,519,432	50	30,389	413
Estonia	Tallin	960	3,001	50	60	401
Finland	Helsinki	948	10,293	50	206	396
France (mainland)	Paris	1,112	801,551	20	40,078	489
Germany	Würzburg	1,091	2,366,409	50	47,328	472
Ghana	Accra	2,146	4,904	30	163	896
Greece	Athens	1,585	737,862	50	14,757	642
Hungary	Budapest	1,199	74,838	50	1,497	522
India	Neu-Delhi	1,961	293,147	50	5,863	749
Ireland	Dublin	949	10,412	50	208	425
Israel	Jerusalem	2,198	3,971,512	3	1,323,837	918
Italy	Bologna	1,419	724,520	50	14,490	593
Japan	Tokyo	1,175	7,032	50	141	516
Jordan	Amman	2,145	250,769	50	5,015	801
Kenya	Nairobi	1,931	70,127	10	7,013	807
Latvia	Riga	991	5,915	50	118	414
Lebanon	Beirut	1,935	267,954	40	6,699	808
Lesotho	Maseru	2,050	2,269	10	227	856
Lithuania	Vilnius	1,001	3,286	50	66	418
Luxembourg	Luxembourg	1,037	10,210	50	204	433
Mexico	Mexico City	1,706	1,039,353	50	20,787	713
Morocco	Rabat	2,000	420,000	50	8,400	835
Mozambique	Maputo	1,910	1,020	50	20	798
Namibia	Windhoek	2,363	29,037	50	581	814
Netherlands	Amsterdam	999	151,366	40	3,784	418
New Zealand	Wellington	1,401	16,411	50	328	585
Nigeria	Abuja	2,007	3,605	1.4	2,575	838
North Macedonia	Skopje	1,381	10,101	50	202	577
Norway	Oslo	971	16,679	50	334	406
Palestinian Territories	Jerusalem	2,198	882,758	50	17,655	918
Poland	Warsaw	1,024	751,648	50	15,033	447
Portugal	Lisbon	1,686	374,842	40	9,371	705
Romania	Bucharest	1,324	34,561	50	691	553
Russia	Moscow	996	21,475	50	430	416
Senegal	Dakar	2,197	295	4.5	65	918
Slovakia	Bratislava	1,214	26,763	50	535	507
Slovenia	Ljubjana	1,115	4,458	50	89	477
South Africa	Johannesburg	2,075	39,046	87	449	867
South Korea	Seoul	1,161	144,967	50	2,899	485
Spain	Madrid	1,644	2,247,357	50	44,947	676
Sweden	Gothenburg	934	49,790	50	996	430
Switzerland	Zürich	1,094	123,555	20	6,178	457
Taiwan	Taipei	1,372	96,511	30	3,217	518
Thailand	Bangkok	1,765	11,820	80	148	737
Tunisia	Tunis	1,808	36,733	50	735	755
Turkey	Antalya	1,795	2,104,771	80	26,310	750
United States	LA, Indianapolis	1,646	1,873,916	50	37,478	688
Uruguay	Montevideo	1,534	15,210	50	304	641
Zimbabwe	Harare	2,017	15,514	32	485	842
All other countries (5% of world market excluding China)		1,238	1,307,260	50	26,145	517
TOTAL			280,337,826		6,871,326	
AVG		1,527		45		625

Figure 54 shows the hydraulic scheme of the domestic hot water reference system for multifamily houses used for the simulations of the solar energy yields. Unlike small-scale domestic hot water systems, all large-scale systems are assumed to be pumped solar thermal systems.

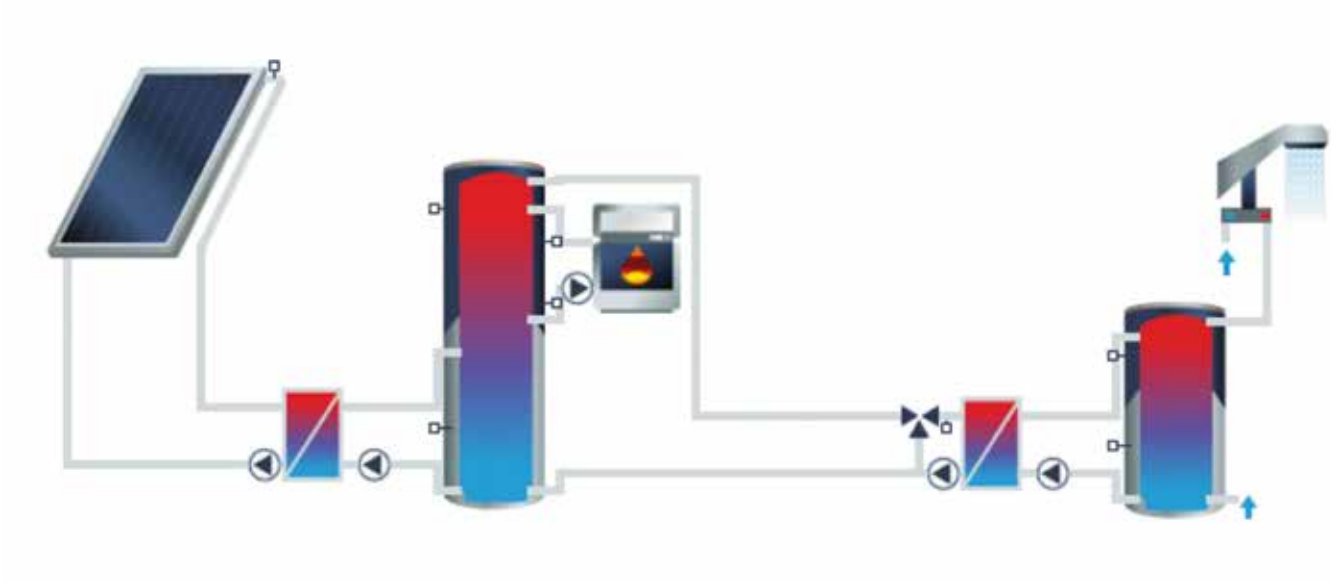

Figure 54: Hydraulic scheme of the domestic hot water pumped reference system for multi-family houses

8.1.4
Reference systems for domestic hot water preparation and space heating in single-family and multi-family houses (solar combi-systems)

The information in Table 17 refers to the total capacity of water collectors in operation used for domestic hot water and space heating in single-family and multi-family houses at the end of 2020, as reported by each country.

Table 17: Solar combi-system reference for single-family and multi-family houses and the total collector area in operation in 2020

DHW-MFH - Total						
Country	Reference climate	Horizontal irradiation [kWh/m²*a]	Total collector area (DHW-combi-systems) [m²]	Collector area per system [m²]	Total number of systems [-]	Specific solar yield (DHW-combi-systems) [kWh/m²*a]
Argentina	Buenos Aires	1,748	24,394	12	2,033	615
Austria	Graz	1,126	2,070,126	14	147,866	369
Belgium	Brussels	971	139,724	12	11,644	342
Bulgaria	Sofia	1,188	36,016	12	3,001	418
Canada	Montreal	1,351	86	12	7	476
Croatia	Zagreb	1,212	54,535	12	4,545	426
Cyprus	Nicosia	1,886	13,313	12	1,109	663
Czech Republic	Praha	998	258,795	8.5	30,446	351
Denmark	Copenhagen	989	65,817	8	8,227	348
Estonia	Tallin	960	4,108	12	342	338
Finland	Helsinki	948	14,410	12	1,201	334
France (mainland)	Paris	1,112	300,000	11	27,273	370
Germany	Würzburg	1,091	8,301,830	11.5	721,898	378
Greece	Athens	1,585	1,010,009	12	84,167	558
Hungary	Budapest	1,199	75,431	10	7,543	422
Ireland	Dublin	949	24,294	12	2,025	364
Italy	Bologna	1,419	991,746	12	82,646	499
Japan	Tokyo	1,175	139,997	12	11,666	414
Latvia	Riga	991	8,097	12	675	349
Lebanon	Beirut	1,935	4,417	12	368	681
Lesotho	Maseru	2,050	14	12	1	721
Lithuania	Vilnius	1,001	4,499	12	375	352
Luxembourg	Luxembourg	1,037	13,976	12	1,165	365
Morocco	Rabat	2,000	9,333	12	778	704
Netherlands	Amsterdam	999	41,282	6	6,880	352
New Zealand	Wellington	1,401	4,923	12	410	493
North Macedonia	Skopje	1,381	1,263	10	126	486
Norway	Oslo	971	23,865	15	1,591	342
Palestine	Jerusalem	2,198	19,617	12	1,635	773
Poland	Warsaw	1,024	150,330	12	12,527	365
Romania	Bucharest	1,324	47,308	12	3,942	466
Russia	Moscow	996	1,382	15	92	350
Slovakia	Bratislava	1,214	36,634	12	3,053	427
Slovenia	Ljubjana	1,115	10,402	12	867	362
South Korea	Seoul	1,161	21,118	12	1,760	409
Spain	Madrid	1,644	382,529	10	38,253	619
Sweden	Gothenburg	934	263,743	10	26,374	389
Switzerland	Zürich	1,094	386,110	11	35,101	385
Thailand	Bangkok	1,765	1,722	12	143	621
All other countries (5% of world market excluding China)		1,150	786,091	12	65,508	405
TOTAL			15,743,287		1,349,265	
AVG		1,286		12		452

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

Figure 55 shows the hydraulic scheme of the domestic hot water reference system for multifamily houses used for the simulations of the solar energy yields

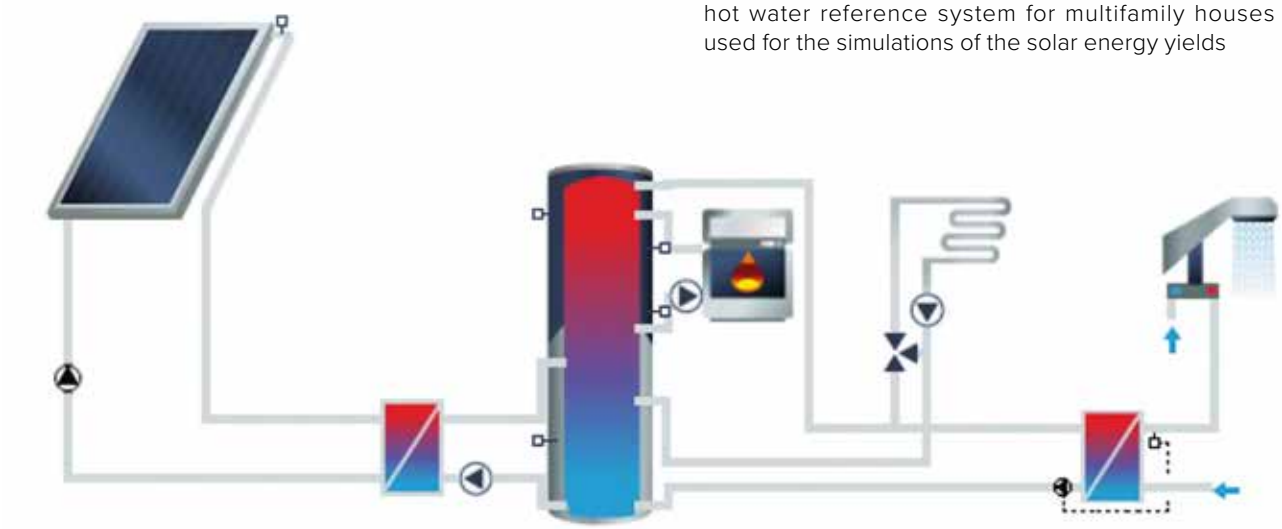

Figure 55: Hydraulic scheme of the solar-combi reference system for single and multi-family houses

8.2 Reference collectors

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

η = 0.85
a_1 = 20 [W/m^{2}K]
a_2 = 0.1 [W/m^2 K^2]

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

η = 0.8
a_1 = 3.69 [W/m^{2}K]
a_2 = 0.007 [W/m^2 K^2]

8.2.3 Data of the Chinese reference vacuum tube collector

η = 0.74
a_1 = 2.5 [W/m^{2}K]
a_2 = 0.013 [W/m^2 K^2]

8.3 Methodological approach for the job calculation

The job calculation is based on a comprehensive literature study, information provided by the China National Renewable Energy Centre and IRENA and 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 costs, advanced automated production of flat plate or evacuated tube collectors and heat storages – pumped systems with a total of 133 m^2 solar collector area have to be installed on average per full-time job. Countries with low labor costs and advanced automated production of evacuated tube collectors and heat storages - thermosiphon systems with a total of 87 m^2 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 a 200 m^2 solar collector area must be installed per full-time job.

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

8.4
Reference climates

Table 18: Reference climates for the 70 countries surveyed

No.	Country	Reference climate	Horizontal irradiation [kWh/m²*a]	Inclined irradiation [kWh/m²*a]	Avg. outside air temp. [°C]
1	Albania	Tirana	1,604	1,835	13.5
2	Argentina	Buenos Aires	1,748	1,971	17.5
3	Australia	Sydney	1,674	1,841	18.1
4	Austria	Graz	1,126	1,280	9.2
5	Barbados	Grantley Adams	2,016	2,048	27.4
6	Belgium	Brussels	971	1,095	10.0
7	Bhutan	Thimphu	1,623	1,790	11.0
8	Botswana	Gaborone	2,161	2,365	18.0
9	Brazil	Brasília	1,793	1,838	22.0
10	Bulgaria	Sofia	1,188	1,304	10.1
11	Burkina Faso	Ouagadougou	2,212	2,270	25.0
12	Canada	Montreal	1,351	1,568	6.9
13	Cape Verde	Praia	2,096	2,168	23.6
14	Chile	Santiago de Chile	1,753	1,850	14.5
15	China	Shanghai	1,282	1,343	17.1
16	Croatia	Zagreb	1,212	1,352	11.3
17	Cyprus	Nicosia	1,886	2,098	19.9
18	Czech Republic	Praha	998	1,111	7.9
19	Denmark	Copenhagen	989	1,164	8.1
20	Estonia	Tallin	960	1,126	5.3
21	Finland	Helsinki	948	1,134	4.6
22	France (mainland)	Paris	1,112	1,246	11.0
23	Germany	Würzburg	1,091	1,225	9.5
24	Ghana	Accra	2,146	2,161	23.7
25	Greece	Athens	1,585	1,744	18.5
26	Hungary	Budapest	1,199	1,346	11.0
27	India	Neu-Delhi	1,961	2,275	24.7
28	Ireland	Dublin	949	1,091	9.5
29	Israel	Jerusalem	2,198	2,400	17.3
30	Italy	Bologna	1,419	1,592	14.3
31	Japan	Tokyo	1,175	1,287	16.7
32	Jordan	Amman	2,145	2,341	17.9
33	Kenya	Nairobi	1,931	1,932	19.4
34	Latvia	Riga	991	1,187	6.3
35	Lebanon	Beirut	1,935	2,132	19.9
36	Lesotho	Maseru	2,050	2,290	15.2
37	Lithuania	Vilnius	1,001	1,161	6.2
38	Luxembourg	Luxembourg	1,037	1,158	8.4
39	Malta	Luqa	1,902	2,115	18.7
40	Mauritius	Port Louis	1,920	2,010	23.3
41	Mexico	Mexico City	1,706	1,759	16.6
42	Morocco	Rabat	2,000	2,250	17.2
43	Mozambique	Maputo	1,910	2,100	22.8
44	Namibia	Windhoek	2,363	2,499	21.0
45	Netherlands	Amsterdam	999	1,131	10.0
46	New Zealand	Wellington	1,401	1,542	13.6
47	Nigeria	Abuja	2,007	2,051	25.7
48	North Macedonia	Skopje	1,381	1,521	12.5
49	Norway	Oslo	971	1,208	5.8
50	Palestinian Territories	Jerusalem	2,198	2,400	17.3
51	Poland	Warsaw	1,024	1,156	8.1
52	Portugal	Lisbon	1,686	1,875	17.4
53	Romania	Bucharest	1,324	1,473	10.6
54	Russia	Moscow	996	1,181	5.9
55	Senegal	Dakar	2,197	2,259	24.9
56	Slovakia	Bratislava	1,214	1,374	10.3
57	Slovenia	Ljubjana	1,115	1,231	9.8
58	South Africa	Johannesburg	2,075	2,232	15.6
59	South Korea	Seoul	1,161	1,280	12.7
60	Spain	Madrid	1,644	1,844	15.5
61	Sweden	Gothenburg	934	1,105	7.2
62	Switzerland	Zürich	1,094	1,218	9.6
63	Taiwan	Taipei	1,372	1,398	20.8
64	Thailand	Bangkok	1,765	1,898	29.1
65	Tunisia	Tunis	1,808	2,038	19.3
66	Turkey	Antalya	1,795	1,958	18.4
67	United Kingdom	London	943	1,062	12.0
68	United States	LA, Indianapolis	1,646	1,816	14.3
69	Uruguay	Montevideo	1,534	1,647	15.9
70	Zimbabwe	Harare	2,017	2,087	18.9

8.5 Population data

Table 19: Inhabitants by the end of 2020 of the 70 surveyed countries in alphabetical order

No	Country	2020	Region Code
1	Albania	3,080,930	6
2	Argentina	45,479,650	4
3	Australia	25,467,706	3
4	Austria	8,856,348	6
5	Barbados	301,001	4
6	Belgium	11,708,235	6
7	Bhutan	850,853	2
8	Botswana	2,316,910	1
9	Brazil	214,752,313	4
10	Bulgaria	6,965,462	6
11	Burkina Faso	20,833,136	1
12	Canada	37,649,603	8
13	Cape Verde	582,153	1
14	Chile	18,182,486	4
15	China	1,404,031,889	5
16	Croatia	4,229,585	6
17	Cyprus	1,267,376	6
18	Czech Republic	10,698,037	6
19	Denmark	5,868,927	6
20	Estonia	1,228,296	6
21	Finland	5,572,355	6
22	France (mainland)	67,858,873	6
22	France (overseas)	3,312,790	6
23	Germany	84,498,245	6
24	Ghana	31,643,281	1
25	Greece	10,604,841	6
26	Hungary	9,756,400	6
27	India	1,369,541,070	2
28	Ireland	5,173,463	6
29	Israel	8,659,792	7
30	Italy	61,337,765	6
31	Japan	125,135,727	2
32	Jordan	10,819,966	7
33	Republic of Kenya	53,513,653	1
34	Latvia	1,883,186	6
35	Lebanon	5,463,514	7
36	Lesotho	2,162,195	1
37	Lithuania	2,739,816	6
38	Luxembourg	628,615	6
39	Malta	457,270	6
40	Mauritius	1,305,308	1
41	Mexico	128,092,570	4
42	Morocco	36,055,311	7
43	Mozambique	30,097,734	1
44	Namibia	2,629,632	1
45	Netherlands	17,274,001	6
46	New Zealand	4,925,334	3
47	Nigeria	213,986,428	1
48	North Macedonia	2,125,463	6
49	Norway	5,465,387	6
50	Palestinian Territories	4,815,587	7
51	Poland	38,270,292	6
52	Portugal	10,288,283	6
53	Romania	18,986,068	6
54	Russia	142,588,206	6
55	Senegal	17,005,241	1
56	Slovakia	5,439,808	6
57	Slovenia	2,102,452	6
58	South Africa	56,434,963	1
59	South Korea	51,577,174	2
60	Spain	47,041,387	6
61	Sweden	10,382,678	6
62	Switzerland	8,398,489	6
63	Taiwan	23,563,036	2
64	Thailand	69,291,926	2
65	Tunisia	11,719,458	7
66	Turkey	82,009,212	6
67	United Kingdom	67,022,855	6
68	United States	332,639,102	8
69	Uruguay	3,389,361	4
70	Zimbabwe	14,546,146	1
	All other countries	2,612,290,814	9
	∑ Solar Thermal World Statistics	5,144,582,605	66%
	∑Inhabitants world	7,756,873,419	

(France mainland and France overseas counted as one country)
Data source: International Data Base of the U.S. Census Bureau http://www.census.gov/population/international/data/idb/informationGateway.php

Table 20: Inhabitants per economic region by the end of 2020

Region Code	Region	∑Inhabitants	Share
1	Sub-Sahara Africa	447,056,780	6%
2	Asia excl. China	1,639,959,786	21%
3	Australia	30,393,040	0.4%
4	Latin America	410,197,381	5%
5	China	1,404,031,889	18%
6	Europe	765,121,396	10%
7	MENA Region	77,533,628	1%
8	United States / Canada	370,288,705	5%
9	Other countries	2,612,290,814	34%
TOTAL		7,756,873,419	100%

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

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Namibia, Nigeria, Mozambique, Senegal, South Africa, Zimbabwe
Asia excl. China: Bhutan, India, Japan, South Korea, Taiwan, Thailand
Latin America: Argentina, Barbados, Brazil, Chile, Mexico, Uruguay
Europe: Albania, EU 27, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA Region: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

8.6 Definition of SHIP systems

In November 2019, the IEA Solar Heating and Cooling Programme defined solar heat for industrial processes (SHIP systems). This definition only refers to the collection and documentation of SHIP systems as part of the Solar Heat Worldwide report.

Applications considered as SHIP Systems

Industrial Process Applications
All solar thermal systems, direct or indirect (via heat storage), connected to an industrial process. Systems that, in addition to the industrial process, also supply the space heating for the production halls, offices or showers are taken into account.

Agricultural Applications
Solar thermal systems used for drying wood chips, crops, fruits, etc. and heat for animal breeding.

Greenhouses
Solar thermal systems supplying heat for commercial food and flower production, nurseries and vegetable farming.

Service Sector
Solar thermal systems supplying commercial laundries, car/truck washing, and sewage sludge drying facilities with heat.

Solar cooling of industrial processes
This refers to all cooling processes in industrial plants.

Not considered in this definition:

- Solar air conditioning of office buildings or industry halls
- Tourism sector like hotels (including laundries of hotels)
- Health sector: hospitals, clinics
- Boarding schools
- Military barracks
- Showers or canteens for workers

Minimum size of systems

For the worldwide survey, only installations larger than 50 m^2 are considered. The minimum size of the plants surveyed was determined since small plants in many countries are not recorded separately. This does not mean that there are no SHIP systems with smaller collector areas. In some countries (e.g., Germany), the number of SHIP plants with collector areas below 50 m^2 is significantly higher than the realized plants above that limit.

8.7 Methodological adjustments and market data of the previous years

Change in the method for estimating global installed capacity

Global solar thermal capacity is based on the latest market data from about 20 of the largest solar thermal markets in terms of added capacity. These were the following countries for the year 2021 listed in order of their added capacity: China, India, Turkey, Brazil, Germany, Greece, Mexico, Italy, Poland, Spain, Australia, South Africa, Cyprus, Austria, United States, Palestinian Territories, Denmark which represented 94.4% of the cumulative installed capacity in operation in 2020. The added capacities in the other countries, for which new additions are available until 2020, were projected according to the trend over the past two years. The rest of the world, which means countries without detailed solar thermal market information in 2020 and previous years, were estimated to be 5% of the global market volume without China in 2020.

Until 2019, the “rest of the world” was considered 5% of the global market, including China, which overestimated its market share. This methodological change should be noted when comparing data from this year's edition of Solar Heat Worldwide with earlier editions.

Conversion from square meters to capacity

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

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.

Data from the previous years

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

In Table 21, Table 22 and Table 23, these countries are marked accordingly and in Chapter 8.8 (References), the respective data source is cited.

Table 21: Newly installed collector area in 2018 [m²]

Newly installed collector area in 2018 [m²]						
Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		23,068.0	2,764.0			25,832
Argentina *	9,318.0	10,393.0	24,748.0			44,459
Australia	400,000.0	165,000.0	18,200.0	5,000.0	1,000.0	589,200
Austria	510.0	97,100.0	1,130.0		650.0	99,390
Barbados		12,300.0				12,300
Belgium		25,000.0	4,900.0			29,900
Botswana		807.8	421.2			1,229
Brazil	627,321.0	594,482.0	28,397.0			1,250,200
Bulgaria		4,600.0	450.0			5,050
Burkina Faso		100.0	310.0			410
Canada	980.0	230.0	340.0	13,630.0	1,120.0	16,300
Cape Verde		380.0				380
Chile		21,228.0	427.0			21,655
China +		5,980,000.0	27,388,821.0	3,000.0	1,000.0	33,372,821
Croatia		18,850.0	592.0			19,442
Cyprus		56,552.0	0.0			56,552
Czech Republic	30,000.0	16,500.0	7,500.0			54,000
Denmark		71,879.0		0.0		71,879
Estonia		900.0	600.0			1,500
Finland		2,700.0	900.0			3,600
France (mainland)	1,200.0	49,500.0	1,840.0	1,005.0		53,545
France (overseas territories)		97,139.0				97,139
Germany		505,000.0	68,500.0			573,500
Ghana		750.0	250.0			1,000
Greece		328,500.0	500.0			329,000
Hungary	500.0	11,000.0	2,000.0	668.0	100.0	14,268
India		213,053.0	1,575,323.0		250.0	1,788,626
Ireland		7,540.7	4,698.3			12,239
Israel	1,000.0	415,000.0				416,000
Japan		74,582.0	1,147.0		2,996.0	78,725
Latvia		1,350.0	250.0			1,600
Lebanon		15,360.0	29,303.0			44,663
Lesotho		65.0	140.0			205
Lithuania		750.0	1,250.0			2,000
Luxembourg		3,418.0	0.0			
Mexico	119,400.0	151,640.0	134,500.0			
Morocco		65,000.0				65,000
Mozambique **			237.0			237
Namibia		3,937.0	21.3			3,958
Netherlands	2,620.0	31,400.0	6,800.0			
Nigeria		392.6	3,515.2		800.0	4,708
North Macedonia		5,200.0	11,364.0			16,564
Norway		1,350.0	73.0			1,423
Palestine		44,820.0	0.0			44,820
Portugal		46,000.0	1,000.0			47,000
Romania	0.0	7,200.0	9,600.0			16,800
Russia		624.8	370.4			995
Senegal		1,650.0	1,350.0	0.0	0.0	3,000
Slovakia	0.0	8,000.0	1,600.0			9,600
Slovenia		1,450.0	200.0			1,650
South Africa	65,231.0	41,056.0	27,590.0			133,877
South Korea		3,552.0	16,918.0			20,470
Spain	3,866.0	191,966.0	9,698.0			205,530
Switzerland	5,640.0	53,429.0	5,078.0			64,147
Taiwan		36,000.0				36,000
Tunisia		63,873.0				63,873
Turkey		948,000.0	932,000.0	400.0		1,880,400
United Kingdom		6,557.0	1,879.0	500.0		8,936
United States	730,200.0	152,530.0	7,950.0	5,000.0	4,000.0	899,680
Uruguay		6,600.0				6,600
Zimbabwe		26.9	17,887.4			17,914
Other (5% of the world market excluding China)	105,146.6	272,498.6	157,805.6	1,379.1	574.5	537,404
TOTAL	2,102,932.6	11,429,485.4	30,544,805.4	30,582.1	12,490.5	44,120,296

* 0% growth assumed ** revised 2022 according to new database + exports excluded

Table 22: Newly installed collector area in 2019 [m²]

Newly installed collector area in 2019 [m²]						
Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		21,986	2,284.0			24,270
Argentina	34,496.0	23,451	39,786.0	20.0	158.0	97,911
Australia	380,000.0	157,000	17,400.0			554,400
Austria	460.0	90,040	310.0		770.0	91,580
Barbados **		12,300				12,300
Belgium		23,500	4,300.0			27,800
Botswana		2,531	67.8			2,599
Brazil	662,451.0	627,773	30,761.0			1,320,985
Bulgaria		23,500	450.0			23,950
Burkina Faso **		100	310.0			410
Canada	1,165.0	609	1,629.0	10,000.0	4,100.0	17,503
Cape Verde		150				150
Chile		25,183				25,183
China *		6,557,000	19,903,000.0	700.0		26,460,700
Croatia		18,786	1,241.0			20,027
Cyprus		69,945	0.0			69,945
Czech Republic		15,675	7,125.0			22,800
Denmark		194,000		0.0		194,000
Estonia		855	570.0			1,425
Finland		7,000	855.0			7,855
France (mainland)	1,000.0	42,500	2,265.0	900.0		46,665
France (overseas)		75,364				75,364
Germany		441,000	70,000.0			511,000
Ghana		500	200.0			700
Greece		361,000	500.0			361,500
Hungary		11,400	4,750.0			16,150
India		272,156	1,542,460.0		100.0	1,814,716
Ireland		12,389				12,389
Israel		360,000				360,000
Japan		58,257	635.0		1,492.0	60,384
Latvia		22,900	250.0			23,150
Lebanon		21,608	19,239.0			40,847
Lesotho ***		235	501.0			736
Lithuania		750	1,250.0			2,000
Luxembourg		2,900	0.0			2,900
Malta		521	130.2			651
Mexico	118,300.0	146,400	143,500.0			408,200
Morocco		76,600				76,600
Mozambique ***			237.0			237
Namibia		4,155	8.1			4,163
Netherlands	2,620.0	31,280	17,590.0			51,490
Nigeria **		393	3,515.2		800.0	4,708
North Macedonia		4,924	10,850.0			15,774
Norway		1,350	73.0			1,423
Poland		282,160	5,030.0			287,190
Portugal		67,739	1,240.0			68,979
Romania	0.0	6,840	9,120.0			15,960
Russia		1,186	100.0			1,286
Senegal		1,500	1,000.0	0.0	0.0	2,500
Slovakia	0.0	7,600	1,520.0			9,120
Slovenia		1,200	200.0			1,400
South Africa	60,324.0	28,160	71,763.0			160,247
South Korea		3,552	16,918.0	400.0	200.0	21,070
Spain	2,900.0	193,650	7,600.0	1,300.0	1,000.0	206,450
Sweden	522.0	1,126				1,648
Switzerland	3,996.0	34,294	4,484.0			42,774
Taiwan **		36,000				36,000
Tunisia		62,812				62,812
Turkey		950,000	935,000.0	100.0		1,885,100
United Kingdom	0.0	5,149	1,428.0	1,000.0		7,577
United States	696,420.0	154,050	6,400.0	4,500.0	500.0	861,870
Uruguay		10,418				10,418
Zimbabwe		10	13,869.0			13,879
All other countries (5% of world market excluding China)	103,402.8	278,315	158,963.9	958.9	480.0	542,120
TOTAL	2,068,056.8	12,123,293.8	23,082,278.2	19,878.9	9,600.0	37,303,108

* exports excluded ** 0% growth assumed in 2019 *** revised 2022 due to new database + figures for France overseas according to ObservEr2020

Table 23: Total collector area in operation by the end of 2019 [m²]

Total installed collector area in operation 2019 [m²]						
Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		272,023	10,294			282,317
Argentina	53,132	44,237	89,282			186,651
Australia	5,658,000	3,454,000	226,000	300,000	12,800	9,650,800
Austria	282,065	4,677,407	85,482		5,448	5,050,402
Barbados ++++		247,368				247,368
Belgium	45,000	567,385	103,650			716,035
Bhutan						0
Botswana		13,839	2,289			16,128
Brazil	6,660,733	10,537,530	160,723			17,358,986
Bulgaria		152,977	5,370			158,347
Burkino Faso ++++		3,182	1,089			4,271
Canada	766,287	70,991	51,423	425,344	51,613	1,365,658
Cape Verde		2,313				2,313
Chile	65,550	259,711	54,305		300	379,866
China		53,827,000	441,092,000	7,700	3,000	494,929,700
Croatia		240,838	13,308			254,146
Cyprus	2,213	786,086	23,567			811,866
Czech Republic	500,000	466,776	149,923			1,116,699
Denmark	20,500	1,836,176	9,197	4,300	18,000	1,888,173
Estonia		10,565	8,360			18,925
Finland	11,800	42,590	20,788			75,178
France (mainland)	93,450	2,975,600	233,100	10,558	1,100	3,313,808
France (overseas)		300,000				300,000
Germany	494,600	17,287,000	2,107,500		19,760	19,908,860
Ghana		2,994	1,087			4,081
Greece		4,844,500	23,000			4,867,500
Hungary	18,300	256,334	79,850	3,418	2,300	360,202
India	0	4,149,788	10,573,229	0	12,250	14,735,267
Ireland		280,445	121,586			402,031
Israel	39,000	4,808,434				4,847,434
Italy	43,800	4,138,911	654,303			4,837,014
Japan		3,374,466	64,025		283,161	3,721,652
Jordan	5,940	982,482	272,084			1,260,506
Kenya						0
Latvia		35,042	3,490			38,532
Lebanon		337,650	356,389			694,039
Lesotho*****		1,749	1,239			2,988
Lithuania		8,600	12,050			20,650
Luxembourg		58,563	8,900			67,463
Malta		58,807	14,702			73,509
Mauritius		132,793				132,793
Mexico	1,536,953	1,760,322	1,435,142	752	8,773	4,741,942
Morocco		825,000				825,000
Mozambique	136	48	2,121			2,305
Namibia	1,560	47,612	1,385			50,557
Netherlands	82,380	525,950	64,200			672,530
New Zealand	7,025	142,975	9,644			159,645
Nigeria ++++		1,473	7,267	0	1,670	10,410
North Macedonia		65,243	47,268			112,511
Norway	1,849	37,869	4,276	200	4,106	48,301
Palestine		1,828,757	8,225			1,836,982
Poland		2,349,860	495,630			2,845,490
Qatar						0
Romania	340	113,440	105,470	800		220,050
Russia	137	22,406	3,787	2	64	26,396
Senegal		3,241	4,083	0	1,203	8,527
Slovakia	1,000	147,850	28,270			177,120
Slovenia		125,000	23,500			148,500
South Africa	1,294,473	674,005	364,828	0	0	2,333,306
South Korea		1,482,784	428,842			1,911,626
Spain	158,938	4,123,911	232,124	1,300	1,000	4,517,273
Sweden	171,007	309,000	72,578			552,585
Switzerland	181,770	1,391,890	140,360			1,714,020
Taiwan	1,937	1,643,874	133,244			1,779,055
Thailand		157,536				157,536
Tunisia		1,026,723	70,104			1,096,827
Turkey		17,606,182	8,216,454	10,070		25,832,706
United Kingdom	523,111	622,495	314,554	23,600		1,483,760
United States	22,541,021	3,051,087	177,285	126,103	70,000	25,965,496
Uruguay		86,419				86,419
Zimbabwe		21,848	51,670			73,518
All other countries (5% of world market excluding China)	2,171,902	5,740,198	1,474,446	47,708	25,976	9,460,230
TOTAL	43,438,040	168,630,969	470,580,910	961,855	522,525	684,134,299

8.8
References to reports and persons who have supplied the data

The production of the report, Solar Heat Worldwide – Edition 2022, 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 - Albania-EU Energy Efficiency Centre	
Argentina	**Federico Pescio,** **Martín Sabre** ENERGÍA SOLAR TÉRMICA Instituto Nacional de Tecnología Industrial (INTI) Energías Renovables Centro de Investigación y Desarrollo en Energías Renovables	Censo Nacional de Energía Solar Térmica (baja temperatura) Instituto Nacional de Tecnología Industrial (INTI)	Cumulated calculated by AEE INTEC based on newly installed, 0% growth assumed
Australia	**Dr. David Ferrari** Economic Affairs Officer, United Nations Environment and Social Committee for Asia and the Pacific, Bangkok	UN ESCAP, with data from the Clean Energy Regulator and industry surveys/interviews	Out of operation systems calculated by UN ESCAP
Austria	**Werner Weiss** AEE - Institute for Sustainable Technologies	Biermayr et al, 2021: Innovative Energietechnologien in Österreich – Marktentwicklung 2020 (Report in German)	Out of operation systems calculated by AEE INTEC
Barbados	**James Husbands** Solardynamics Ltd.	Timeline based on Solar Water Heating Techscope Market Readiness Assessment – Reports, UNEP 2015	0% growth assumed
Belgium	**Pedro Dias,** Secretary General Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation AEE INTEC **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe, 2021 Unglazed water collectors: AEE INTEC recordings
Bhutan	Ministry of Economic Affairs Department of Renewable Energy Alternate Energy Division **Ms. Dawa Zam**		New in edition 2022
Botswana	**Karen Gibson** SIAB Solar Industries Association Botswana	Industry survey 2020	
Brazil	**Dr. Danielle Johann,** Diretora Executiva ABRASOL Associção Brasileira de Energia Solar Térmica	ABRASOL	Out of operation systems calculated based on ABRASOL long time recordings
Bulgaria	**Pedro Dias,** Secretary General Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe, 2021
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	Cumulated calculated by AEE INTEC; 0% growth assumed in 2020
Canada	**Reda Djebbar, Ph.D., P.Eng.** Natural Resources Canada (NRC)	J.L Richards Report "Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2019-2020)"	Out of operation systems considered by NRC air collectors provided by John Hollick
Cape Verde	**Antúnio Barbosa**	Country Market Report on solar thermal heating systems, solar drying and solar cooling, September 2015	Cumulated calculated by AEE INTEC; 0% growth assumed in 2020

* cumulated collector area by end of 2014
** cumulated collector area by end of 2015
*** cumulated collector area by end of 2009
**** cumulated collector area by end of 2016
***** revised 2022

\+ exports excluded
++ France overseas calculated based on Eurobserver Reports 2015-2020
+++ 2021 revised time series according to MDPI Switzerland 2021
++++ calculated based on 0% growth

Country	Contact	Source	Remarks
Chile	**Andrés Véliz Araya** División Energías Renovables Ministerio de Energía / Gobierno de Chile	Minvu Program, Law 20365 (Tax Benefit) www.minenergia.cl/sst/	Cumulated calculated by AEE INTEC; 0% growth assumed in 2020
China	**Ruicheng Zheng** China Academy of Building Research CSTIF - Chinese Solar Thermal Industry Federation	CSTIF - Chinese Solar Thermal Industry Federation	Exports excluded, out of operation systems calculated by AEE INTEC (12 years lifetime in 2020 considered)
Croatia	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors:_ Solar Heat Europe, 2021
Cyprus	**Panayiotis Kastanias** Cyprus Employers and Industrialists Federation	FPC Cyprus Union of Solar Thermal Industrialists (EBHEK) and the Cyprus Employers & Industrialists Federation (OEB)	Cumulated calculated by AEE INTEC based on replacement figures provided by Panayiotis Kastanias
Czech Republic	**Ales Bufka** Ministry of Industry and Trade Pedro Dias, Secretary General Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe AEE INTEC	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Unglazed water collectors: AEE INTEC recordings
Denmark	**Jan-Erik Nielsen, Daniel Trier** Planenergi		Unglazed water collectors: AEE INTEC recordings
Estonia	**Pedro Dias,** Secretary General Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021 (estimation)
Finland	**Pedro Dias,** Secretary General Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021 (estimation)
France	**Paul Kaaijik,** ADEME - Agence de l'Environnement et de la Maîtrise de l'Énergie **John Hollick** SAHWIA - Solar Air Heating World Industry Association	EurobservER' 2021 Air collectors: John Hollick France overseas: Eurobser'Er 2021	Cumulated France overseas based on EurobservEr reports 2015-2021
Germany	**Dr. Andrea Liesen** BSW - Bundesverband Solarwirtschaft e.V., **John Hollick** SAHWIA - Solar Air Heating World Industry Association	BSW - Bundesverband Solarwirtschaft e.V. Air collectors: John Hollick	FPC/ETC: BSW solar long time recordings; unglazed water collectors & glazed air collectors: AEE INTEC recordings
Ghana	**Divine Atsu** Koforidua Polytechnic Department of Energy Systems Engineering		
Greece	**Costas Travasoras** EBHE – Greek Solar Industry Association Vassiliki Drosou CRES – Center for Renewable Energy Sources		
Hungary	**Pál Varga** MÉGNAP- Hungarian Solar Thermal Industry Federation **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021 Air collectors: John Hollick	Glazed water collectors: Solar Heat Europe 2021 cumulated calculated based on newly installed

Country	Contact	Source	Remarks
India	**Jaideep N. Malaviya** Malaviya Solar Energy Consultancy	Malaviya Solar Energy Consultancy (based on market survey)	New and cumulated installations based on survey from Malaviya Solar Energy Consultancy; out of operation systems considered, in 2016 recorded data changed from fiscal to calendar year
Ireland	**Mary Holland** Sustainable Energy Authority of Ireland	Grant Scheme Data, BER database; Energy policy statistical support unit of Sustainable Energy Authority of Ireland	Cumulated calculated by AEE INTEC based on newly installed collector areas
Israel	**Eli Shilton** ELSOL **Bärbel Epp** Solrico – Solar market research	ELSOL (Eli Shilton), data provided by Bärbel Epp	Cumulated collector area calculated by AEE INTEC based on new installation and replacement figures from Eli Shilton (ELSOL)
Italy	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe AEE INTEC	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Cumulated area: Solar Heat Europe 2021/ share FPC-ETC: AEE INTEC / unglazed water collectors: AEE INTEC
Japan	**Manami Mizutani** Japan Solar System Development Association	Japan Solar System Development Association Long time series	
Jordan	AEE INTEC	AEE INTEC	New installations: no new collectors for 2020 reported Cumulated installations by end of 2014
Kenya	**Fred Ishugah** East African Centre of Excellence for Renewable Energy and Efficiency (EACREEE)	Study of the Solar Water Heating Industry in Kenya, Energy Regulatory Commission of Kenya, Nairobi, 2017	New in edition 2022
Latvia	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021
Lebanon	**Hussein El Samra, Rani Al Achkar** Lebanese Center for Energy Conservation (LCEC)	Lebanese Center for Energy Conservation (LCEC)	
Lesotho	**Ivan Yaholnitsky** **Puleng Mosothoane** Bethel Business and Community Development Center (BBCDC)	SOLTRAIN Study, data provided by Puleng Mosothoane	Revised in 2022 according to new database
Lithuania	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021 (estimation)
Luxembourg	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021 (estimation)
Malta	**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	**Devika Balgobin** Statistician Environment Statistics Unit Ministry of Environment and Sustainable Development	Statistics Mauritius	No new collector area 2020; cumulated collector area by end of 2015
Mexico	**David Garcia** FAMERAC **Bärbel Epp** Solrico – Solar market research	Glazed and unglazed water collectors: FAMERAC - Renewable Energy Industry Associationdata provided by Bärbel Epp Air collectors: SAHWIA - Solar Air Heating World Industry Association	Cumulated installations: calculated by AEE INTEC

Country	Contact	Source	Remarks
Morocco	**Ashraf Kraidy** RECREEE - Regional Center for Renewable Energy and Energy Efficiency	"A New Project for a Much More Diverse Moroccan Strategic Version: The Generalization of Solar Water Heater" by Fatima Zohra Gargab, Amine Allouhi, Tarik Kousksou, Haytham El-Houari, Abdelmajid Jamil; MDPI Switzerland 2021	Newly installed and cumulated collector areas according to timeline
Mozambique	**Alberto Pondeca** Sunpower Engineering https://www.sunpowermz.com/	Market sales	Cumulated installations calculated by AEE INTEC
Namibia	**Fenni Shidhika** Namibia Energy Institute Namibia University of Science and Technology	Namibia Energy Institute-Solar Water Heaters-Survey 2020	
Netherlands	**Reinoud Segers** **Maria José Linders** Statistics Netherlands (CBS)	Statistics Netherlands (CBS)	Newly installed areas: Statistics Netherlands based on survey of sales. Market Shares: Expert estimates Netherlands Enterprise Agency and Holland Solar.
New Zealand			No data available since 2010 Cumulated area in 2009
Nigeria	**Okala Nwoke** National Centre for Energy Research and Development, University of Nigeria, Nsukka		Cumulated calculated by AEE INTEC; 0% growth assumed in 2020
North Macedonia	**Prof. Dr. Ilja Nasov** National University St. Kiril and Metodij, Faculty for Natural Science, Institute of Physics, Solar Energy Department **Stefan Trajkov** Macedonian Solar Energy Association	Public custom administration and Macedonian Solar Energy Association	Cumulated installations calculated by AEE INTEC based on new installation figures
Norway	**Dr. Michaela Meir** Aventasolar	Solvarmeanlegg i Norge 2019 commissioned by The Norwegian Solar Energy Cluster (Solenergiklyngen), provided by Michaela Meir	0% growth assumed in 2020, cumulated calculated by AEE INTEC (flat plate collectors: 4 % out of operation considered)
Palestinian Territories	**Mohammed Mobayyed** EEU Director Palestinian Energy Authority **Abdallah Azzam** Palestinian Central Bureau of Statics Natural Resource Statistics	Palestinian Energy Authority	
Poland	**Janusz Starościk** - President Association of Heating Appliances manufacturers and Importers in Poland (SPIUG)	SPIUG (Association of heating Appliances Producers and Importers in Poland) – market research	
Portugal	**Pedro Dias,** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021
Romania	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021
Russia	**Prof. Vitaly Butuzov** Energotechnologies Service Ltd. Krasnodar **Dr. Semen Frid** JIHT RAS - Joint Institute for High Temperatures of Russian Academy of Sciences **Dr. Sophia Kiseleva** - Lomonosow Moscow State University	The source of information - Energotechnologies Service Ltd. (ETS)	
Senegal	**T. Ababacar** Université Cheikh Anta DIOP	Rapport de Marché du Solaire Thermique: Production d' Eau Chaude et Séchage de Produits Agricoles	0% growth assumed
Slovakia	**Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021

Country	Contact	Source	Remarks
Slovenia	**Ciril Arkar** University of Ljubljana, Faculty of Mechanical Engineering	Eco Fund, Slovenian Environmental Public Fund	
South Africa	**Dr. Richmore Kaseke** Centre of Renewable and Sustainable Energy Studies Stellenbosch University	SWH manufacturer, SHW installers survey	
South Korea	**Ki-Young Choi** Korea Energy Management Corporation (KEMCO) **Kyoung-ho Lee** Solar Thermal and Geothermal Research Center New and Renewable Energy Research Division Korea Institute of Energy Research (KIER)	2018 New & Renewable Energy Statistics by the Korea New & Renewable Energy Center, KEA 2019;	Time series revised 2020 0% growth assumed for 2020 for newly installed collector area
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	**Viktor Döhlen** Swedish ExCo for IEA SHC **Pedro Dias** Secretary General Solar Heat Europe (ESTIF) - European Solar Thermal Industry Federation **Leopoldo Micò** Solar Heat Europe	Solar Thermal Markets in Europe - Trends and Market Statistics 2020, Solar Heat Europe 2021	Glazed water collectors: Solar Heat Europe 2021
Switzerland	**http://www.swissolar.ch/**	SWISSOLAR - Markterhebung Sonnenenergie 2020, Bundesamt für Energie 2021	Out of operation systems calculated by SWISSOLAR
Taiwan	**K.M. Chung** Energy Research Center - National Cheng Kung University	Installers association	Cumulated calculated by AEE INTEC; 0% growth assumed in 2020
Thailand	**Charuwan Phipatana**-phuttapanta Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy	GIZ study, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy (Subsidized systems)	No new collector area in 2020; cumulated area by end of 2016
Tunisia	**Abdelkader Baccouche** Agence Nationale pour la Maîtrise de l'Energie (ANME)	ANME (National Agency of Energy Conservation)	Provided by Bärbel Epp
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, Bural Heating Corporation Ltd.; cumulated installations calculated by AEE INTEC considering 15 years lifetime
United Kingdom	**Elizabeth Waters** Renewables, Heat and Consumption BEIS - Department for Business, Energy & Industrial Strategy **John Hollick** SAHWIA - Solar Air Heating World Industry Association	UK Solar Trade Association and ESTIF Reports collated in BEIS annual survey Active Solar 2019 survey with efficiency and lifetime, Air collectors provided by John Hollick	
United States	**Brad Heavner** California Solar and Storage Association (CALSSA) **Pam Murphey** IEA SHC Technology Program **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Water Collectors and air collectors: IAPMO Solar Heating & Cooling Programs; Air collectors: SAHWIA	New installations: CALSSA 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	Cumulated calculated by AEE INTEC; 0% growth assumed in 2020
Zimbabwe	**Samson Mhlanga** National University of Science and Technology, Bulawayo	Dr. Anton Schwarzlmüller Domestic Solar Heating unpublished statistics; SOLTRAIN survey 2020 (unpublished sources)	Cumulated calculated by AEE INTEC

8.9 Additional literature and web sources used

The following reports and statistics were used in this report.

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- Bundesamt für Energie (BFE): Statistik Sonnenenergie, Referenzjahr 2020; prepared by SWISSOLAR, Thomas Hostettler, Bern, Switzerland July 2021
- Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Austria – Innovative Energy Technologies - Market Development 2020; Ed. Peter Biermayr et al, Vienna, Austria June 2021
- Bundesverband Solarwirtschaft e.V. (BSW-Solar): Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) 2022; accessed April 2022
- ClearSky Advisors Inc.: Survey of Active Solar Thermal Collectors, Industry and Markets in Canada (2019-2020); Prepared by ClearSky Advisors Inc., Dr. Reda Djebbar, Natural Resources Canada, April 2021
- Eurobserv'ER 2021, The State of Renewable Energies in Europe, Edition 2021
- Global Market Outlook for Solar Power / 2019-2023, Solar Power Europe, 2019
- GWEC / Global Wind Report 2021, Global Wind Energy Council, March 2022
- IEA Global Energy Review 2022
- IEA PVPS Snapshot 2021
- IRENA Renewable capacity highlights, April 2022
- IRENA Renewable Energy and Jobs: Annual Review 2020
- IRENA Renewable Energy Statistics 2021
- Lehr, U. et.al (2015), Beschäftigung durch erneuerbare Energien in Deutschland: Ausbau und Betrieb, heute und morgen
- Solar Heat Europe (ESTIF): Solar Heat Markets in Europe, Trends and Market Statistics 2020, December 2021
- Solar Power Europe (2021): Global Market Outlook for Solar Power 2021-2025
- Study of the Solar Water Heating Industry in Kenya, Energy Regulatory Commission of Kenya (ERC), Nairobi, 2017
- Weiss, W. (2003) Wirtschaftsfaktor Solarenergie, Wien
- Weiss, W., Biermayr, P. (2006) Potential of Solar Thermal in Europe, published by ESTIF
- Wimmer, L. et al. (2019), Monitoring of renewable process heat plants within the gas sector.

The following online sources were used in this report:

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

http://www.asit-solar.com/

http://helioscsp.com/concentrated-solar-power-had-a-global-total-installed-capacity-of-6451-mw-in-2019

https://www.solarpowereurope.org/

http://www.giz.de/

http://www.iea-shc.org/

http://www.irena.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/

https://www.statista.com/statistics/476281/global-capacity-of-geothermal-energy

http://www.swissolar.ch/

8.10 List of Figures

8.11 List of Tables

Sion, Switzerland. 41 PVT collectors on a building in the city center (sustainable building with Minergie label)
Photo: DualSun, Switzerland