Werner Weiss, Monika Spörk-Dür

Global Market Development
and Trends 2022
Detailed Market Figures 2021

SOLAR HEAT WORLD WIDE

Edition 2023

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

SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

SOLAR HEAT WORLDWIDE

Global Market Development and Trends 2022
Detailed Market Figures 2021

2023 Edition

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8200 Gleisdorf, Austria

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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 key 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 collectors has grown in market relevance in recent years. PVT collectors convert solar radiation into electricity and heat and thus could 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 71 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.

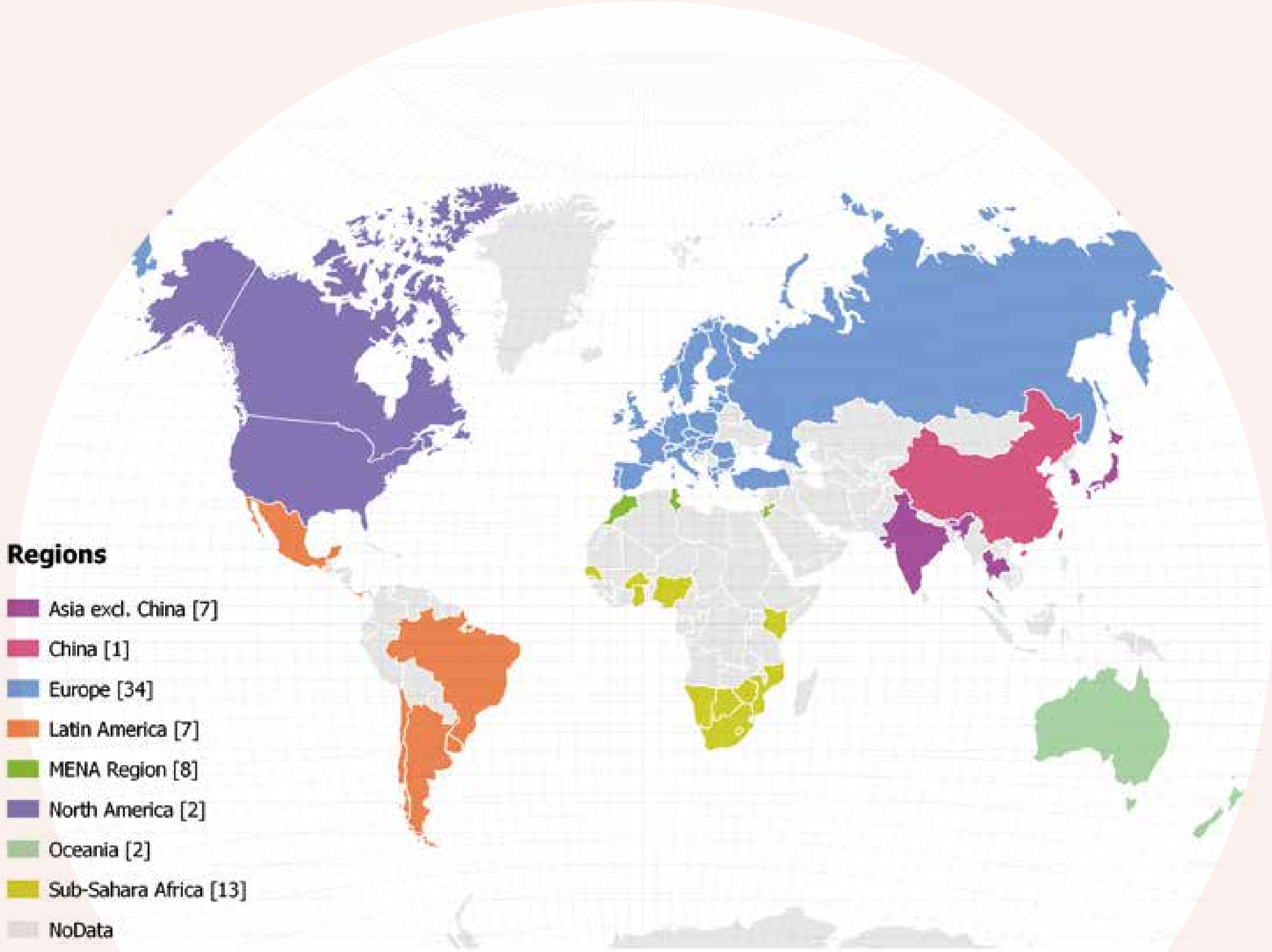

Figure 1: Countries shown in color have detailed market data. Countries shown in grey have estimated market data.
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

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 2023 edition and past editions can be downloaded from the website, **http://www.iea-shc.org/solar-heat-worldwide.**

2 Summary

This report is split into three parts. The first part (Chapters 3 - 5) gives an overview of the 2022 global solar thermal market and general trends and highlights thriving applications, such as solar-assisted district heating, solar heat for industrial processes, and hybrid photovoltaic thermal systems. And Chapter 5 includes an outlook for 2023 developments.

The second part (Chapters 6 - 8) presents detailed market figures for 2021 from the 71 surveyed countries. A new country included in this year's edition is Panama. Besides the installed collector area and the related installed capacity, the second part of the report includes the distribution of the collectors across various systems and applications and the solar yields and avoided emissions.

The third part (Chapter 9) documents the methodological approach, reference systems, climate and population data, literature references, and data sources.

Photo: Steinbeis Forschungsinstitut Solites, Germany

Global solar thermal market developments in 2022

The cumulated solar thermal capacity in operation at the end of 2022 was 542 GW_{th}, corresponding to 774 million square meters of collector area. This represents a net increase of 19 GW_{th} or 27.1 million square meters of collector area in 2022.

Despite the generally positive development, especially in some strong European markets, the global solar thermal market shrank by 9.3% in 2022 compared to 2021. This was mainly due to the massive market slumps in China (-12.4%) and India (-21%).
The annual solar thermal energy yield amounted to 442 TWh, which correlates to savings of 47.48 million tons of oil and 153.3 million tons of CO_2.

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

In 2022, 41 new large-scale solar heating systems (>350 kW_{th}, 500 m^2) with a capacity of 178 MW_{th} were built. Thus, by the end of 2022, 571 large-scale solar thermal systems were operating worldwide. The total installed capacity of these systems equaled 2,148 MW_{th}, corresponding to 3.1 million m^2 collector area.

The largest sub-sector of large-scale solar thermal heating systems is solar district heating. By the end of 2022, 325 large-scale solar district heating systems with an installed capacity of 1,795 MW_{th} (2.56 million m^2) were documented in operation.

Solar heat for industrial processes (SHIP)

In 2022, at least 114 new SHIP plants with a capacity of 30 MW_{th} were installed worldwide. This is a significant increase in the number of installations compared to 2021, with 78 new installations. The total number of SHIP plants is now up to at least 1,089 systems with a 1.22 million m^2 collector area and a capacity of 856 MW_{th}.

Photovoltaic-Thermal (PVT) collectors

After years of steady growth, the global PVT market shrank by 51% in 2022. The newly installed capacity in 2022 amounted to 42.4 MW_{th} and 21.7 MW_{peak}. Thus, the cumulative installed PVT collector area is 1.5 million m^2, which relates to a thermal capacity of 789 MW_{th} and an electrical capacity of 276 MW_{peak}.

Market status worldwide in 2021

While 2022 data is only available for the leading 20 countries, the report includes detailed 2021 data on 71 countries.

115 million solar thermal systems were in operation at the end of 2021.

The top 5 countries by total installed capacity at the end of 2021 were China, Turkey, the United States, Germany and Brazil.

However, the picture is clearly different when comparing the data on a per capita basis.
The top 5 countries by installed capacity per 1,000 inhabitants are Barbados, Cyprus, Israel, Austria and Greece.

In 2021 **evacuated tube collectors represented 59%** of the newly installed capacity, followed by flat plate collectors with a share of 34%.

In the global context, this breakdown is mainly driven by the dominance of the Chinese market, where around 74% of all newly installed collectors in 2021 were evacuated tube collectors, but also by the Indian market, with 92% of newly installed collectors being evacuated tubes.

Nevertheless, it is notable that the share of evacuated tube collectors worldwide decreased from about 82% in 2011 to 59% in 2021, and at the same time, flat plate collectors increased their share from close to 15% to 34%.

In Europe, the situation is almost the opposite of that in China, with 72% of all solar thermal collectors installed in 2021 being flat plate collectors. In the medium term, however, the share of flat plate collectors decreased in Europe from 81% in 2011 to 72% in 2021. In contrast, Europe's share of evacuated tube collectors increased between 2011 and 2021 from 16% to 28%.

Distribution by system type

Pumped systems accounted for 62% of all newly installed systems in 2021, while 38% 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 production, installation and maintenance of solar thermal systems is estimated to be 389,000 worldwide in 2021.[1]

The estimated worldwide turnover of the solar thermal industry in 2021 is € 17.4 billion (US$ 19.1 billion).

[1] Background information on the methodology used can be found in the Appendix, Chapter 9.3.

Solar district heating system, Graz, Austria.
Photo: SOLID Solar Energy Systems, Austria

3 Worldwide solar thermal capacity in 2022

As shown in the figure below, the global solar thermal capacity of unglazed and glazed water collectors grew from 62 GW_{th} (89 million m^2) in 2000 to 542 GW_{th} (774 million m^2) in 2022. The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 442 TWh in 2022 (Figure 2).

In 2022 a total capacity of 19 GW_{th} or 27.1 million square meters of collector area was installed. After seven years of annual declines in installed collector area between 2014 and 2019 and a slight increase in 2021, 2022 showed a decrease of 9.3%. Despite an upward trend with rising sales figures in most economic regions since 2021, this positive trend is overshadowed by two of the largest markets, China and India. The declines in these two markets are justified in China by the harsh lockdown measures caused by the Covid-19 pandemic and in India by changes in subsidies and strong competition from photovoltaics.

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 collector lifetime of 25 years[2] is reached.

[2] For details on the lifetime see chapter 5

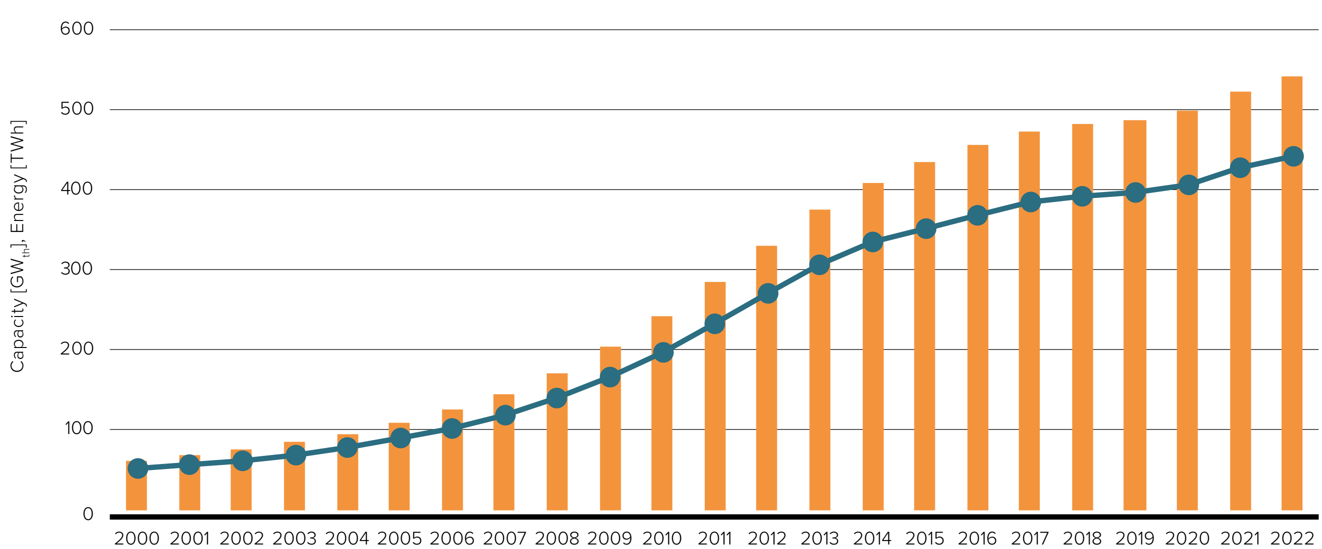

Figure 2: Global solar thermal capacity in operation and annual energy 2000-2022

Global solar thermal capacity in operation [GW_{th}]
Global solar thermal energy yield [TWh]

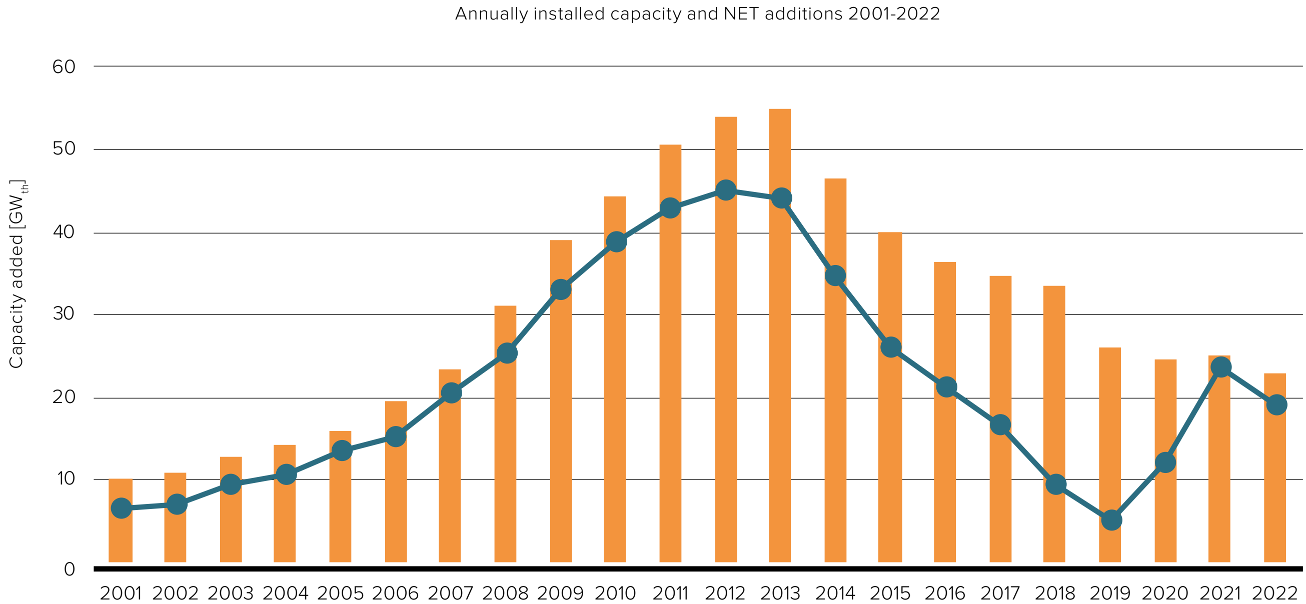

Figure 3: Annual installed collector capacity and net additions

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

Figure 4 shows the annual installed collector capacity by collector type and the total installed collector capacity. This clearly shows how different the various collector types have developed globally. While the market for flat plate (FPC) and unglazed collectors remained almost constant, the market for evacuated tube collectors (ETC) slumped massively between 2013 and 2020. This is primarily due to market developments in China and, to some extent, India, as evacuated tube collectors dominate these two countries.

Environmental effects and contribution to climate goals

The global solar thermal energy yield of all installed solar thermal systems in 2022 corresponds to a savings of 47.48 million tons of oil and 153.3 million tons of CO_2. This shows the significant contribution of this technology in reducing global greenhouse gas emissions.

153.3
million tons of CO_2 avoided

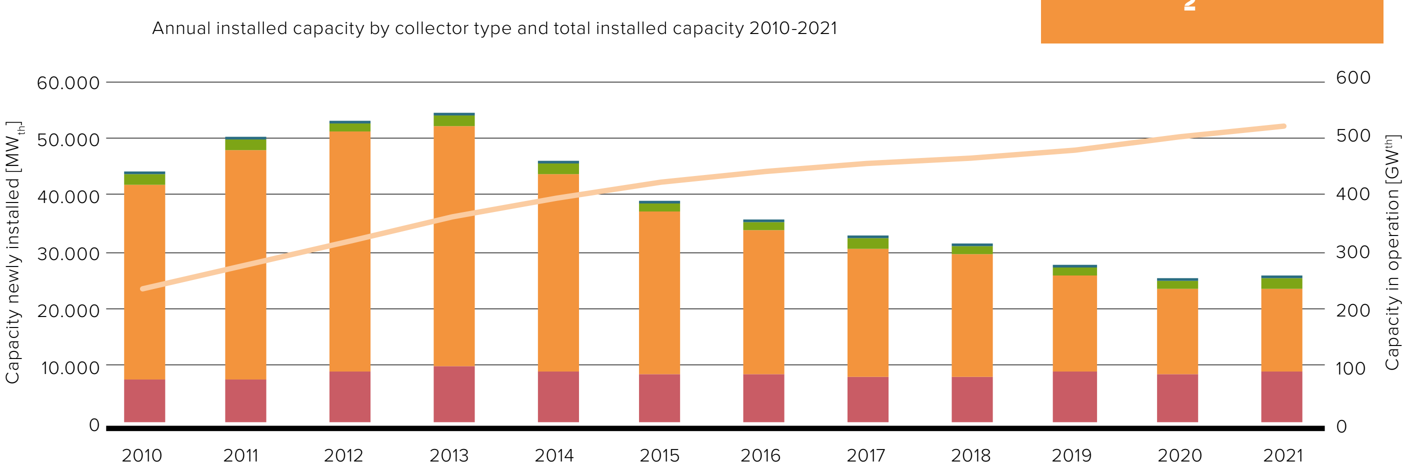

Figure 4: Annual installed capacity by collector type and total installed capacity 2010-2021

EPC
ETC
unglazed
air collectors
in operation

Högslätten solar district heating park with 3,000 m^2 parabolic trough collectors, Sweden
Photo: Absolicon Solar Collector AB, Sweden

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 2022 was 540 GW_{th}[3], which trailed behind wind power's installed capacity of 906 GW_{el} and photovoltaics 1,153 GW_{el} of installed capacity (Figure 5). 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}, and solar thermal power, also referred to as CSP, was 6.4 GW_{el}.

In terms of energy, solar thermal systems supplied 440 TWh of heat, whereas wind turbines supplied 2,215 TWh and photovoltaic systems 1,312 TWh of electricity.

[3] The figures for 2022 are based on the latest market data from Australia, Austria, Brazil, China, Cyprus, Denmark, France (mainland), Germany, Greece, India, Italy, the Palestinian Territories, Poland, South Africa and Spain, which represent about 87% of the cumulated installed capacity in operation in 2022.

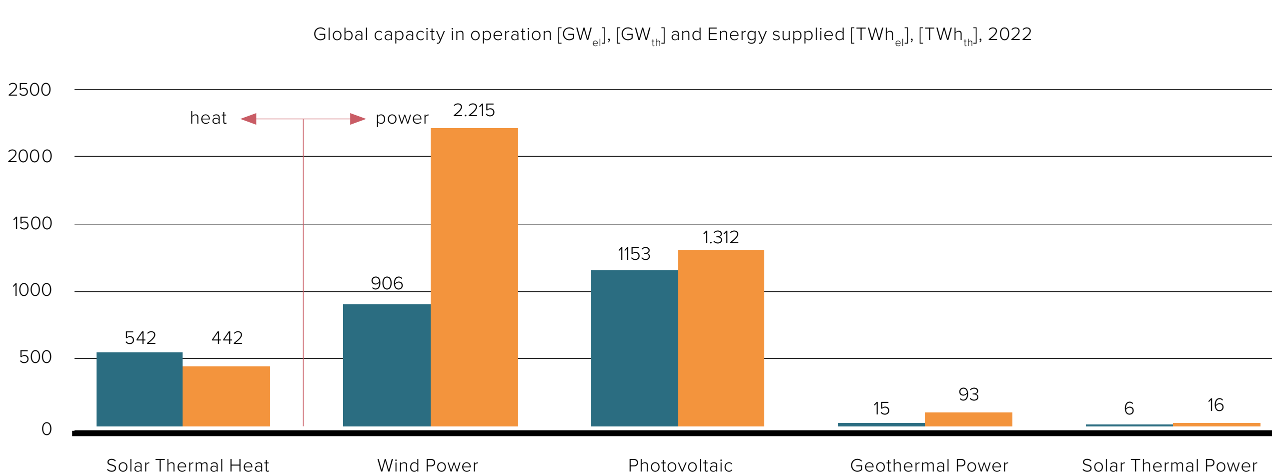

Figure 5: Global capacity in operation [GW_{el}], [GW_{th}] 2022 and annual energy yields [TWh_{el}], [TWh_{th}]
Sources: Solar Thermal: AEE INTEC, Wind Power: Global Wind Energy Council (GWEC), Photovoltaic: IEA Solar PV (https://www.iea.org/reports/solar-pv), Geothermal Power (https://statista.com), Solar Thermal Power: IRENA Renewable Energy Capacity Statistics 2022

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

4 Outlook 2023 and beyond

Global final energy consumption for heating and cooling has remained virtually unchanged at around 50% for many years. According to the IEA Renewables 2022 report[4], industrial processes are responsible for 53% of the final energy consumed for heat, while another 44% is used in buildings for space and water heating. The remainder is used in agriculture, primarily for greenhouse heating.

The heating sector is dominated by fossil fuels. Apart from the use of traditional biomass, only 11% of the global heating needs were met by modern renewables in 2021. According to Eurostat, the share of renewables for heating and cooling in the European Union was 22.9% in 2021. This is twice the global share but still did not cover even a quarter of heat consumption.

Due to the increasing impact of global warming and current concerns about energy security triggered by the war in Ukraine, the heating sector is receiving increasing political attention. Recent heat-related policy updates include the US Inflation Reduction Act passed in August 2022, the European REPowerEU plan published in May 2022, and China's 14th five-year energy plan to 2025 released in March 2022.

The IEA Renewables 2022 report projects the global heat consumption – excluding ambient heat harnessed by heat pumps – to grow almost 14 EJ (+6%) during 2022-2027.

This demand will only be met to a smaller extent by the direct electrification of the heating sector. The majority will have to be covered by geothermal energy, modern use of biomass and solar thermal energy.

With the building and industrial sectors consuming about 97% of the final energy consumed for heat, there is enormous potential for solar thermal to not only provide hot water and space heating but also be used for district heating in urban areas and industrial process heat.

Based on the data available to date, demand for large-scale solar thermal systems appears to increase significantly in 2023. If one also considers that the development of large-scale systems for solar district heating and industrial process heat has a long lead time and that most of the policies related to renewable heat were only implemented in 2022, then it can be assumed there will be significant growth in the number of solar thermal systems in the coming years.

As mentioned above, increased demand is particularly expected in the district heating sector. Solar thermal energy offers a cost-effective way to make urban district heating systems CO_2 neutral. As shown by plants already installed, solar heat can be provided at costs between 20 and 50 €/MWh under favorable conditions. This is significantly lower than the prices end customers currently pay for district heating.

The following paragraphs highlight recent developments and trends in solar district heating and solar heating for industrial processes (SHIP).

Solar district heating projects in the pipeline range from 400 - 500 MW_{th}

[4] Renewables 2022: Renewable analysis and forecasts to 2027, IEA, January 2023

Photo: SavoSolar / Solar Heat Europe

Clear upward trend in solar district heating in Europe

According to the German Steinbeis research institute Solites, in 2022, the total collector area for district heating in Germany grew by 30% compared to the previous year. This positive trend appears set to continue in 2023 and beyond. Nine systems representing a collector area of 28,000 m^2 (19.6 MW_{th}) are under construction or in an advanced planning stage. Another 66 systems with a collector area of 454,550 m^2 (318 MW_{th}) are in under concrete discussion, according to Solites. One of these is a plant in the city of Leipzig, Germany. The construction of the largest solar district heating plant in Germany with a collector area of 65,000 m^2 (45.5 MW_{th} capacity) was announced by Stadtwerke Leipzig in April 2023. The commissioning is planned for 2025.

Things are also on the move in the **Netherlands**. A large-scale solar district heating system will be completed in the first quarter of 2023 in the city of Groningen. This plant has a collector area of 48,000 m^2 (33.6 MW_{th} capacity).

A new dynamic is also emerging in the **Western Balkan** countries of Serbia and Kosovo. A solar plant with a 58,000 m^2 collector area (40.6 MW_{th} capacity) and a 408,000 m^3 seasonal storage are planned for the renewable supply of the district heating of Pristina, the capital city of Kosovo. Planning for this plant is at a very advanced stage and is expected to come online in 2024. Two district heating plants are planned for Serbia. The feasibility study for a 35,000 m^2 (24.5 MW_{th} capacity) plant in the city of Pancevo is completed. And a solar district heating plant in the range of 45 to 136 MW_{th} is planned for the city of Novi Sad in combination with a seasonal storage[5].

A new dimension is opening up in China

A 79.8 MW_{th} solar plant for the Handan Bay Water World resort opens up a new dimension. The 114,000 m^2 parabolic trough collector system supplies the hotel's HVAC and hot water systems, indoor swimming pool, and ice and snowmaking system for an indoor ski slope. Completion and commissioning are scheduled for the end of the second quarter of 2023[6].

Positive outlook for SHIP plants

The second sector expected to see some upturn in 2023 is solar heat for industrial processes (SHIP). According to solarthermalworld[7], a new picture will emerge in 2023 with a significant increase in plants using solar process heat above 100 °C. The multi-MW plants currently under construction in Europe and whose commissioning is planned for 2023 promise a sevenfold increase. These include the chemical site in Turnhout, **Belgium**, with 2.5 MW_{th} capacity, and two systems at breweries in **Spain** with 28.5 MW_{th} and 4 MW_{th}, respectively.

In addition to the solar systems mentioned above, a solar thermal heating plant, heat pumps, and a storage facility for a malting plant in **Croatia** are being implemented with the support of the European Innovation Fund. The solar plant consists of 23,400 m^2 of flat plate collectors in combination with a 5,000 m^3 hot water storage tank. Commissioning is planned for the first quarter of 2024.

The first GW-scale SHIP plant

By far, the largest solar process heat plant is in the planning stage in **Saudi Arabia**[8]. Saudi Arabia's leading mining company signed an MOU in 2022 to facilitate a study to develop the first solar steam project in the kingdom to decarbonize an alumina refinery. When complete, the 1,500 MW_{th} solar steam plant will reduce carbon emissions by over 600,000 tons annually. This represents more than 50% reduction of the carbon footprint in this alumina refinery.

1.5 GW_{th} solar steam project for an alumina refinery

[5] www.ehp-magazine.com
[6] Source: He Tao, China Academy of Building Research
[7] https://solarthermalworld.org/news/high-level-of-dynamism-on-the-ship-world-market-in-2022/
[8] https://www.glasspoint.com/maaden-press-release

5 Solar thermal market development and trends in 2022

Golan Winery, Israel
Photo: Tigi Ltd., Israel

The worldwide market development in 2022 is very mixed. As mentioned above, the global solar thermal market declined by 9.3% in 2022. This was mainly influenced by two countries, China and India. Developments in these two dominant countries overshadow otherwise relatively positive developments in other economic regions, such as Europe. China, by far the world's largest market, recorded a market slump of 12.4%, heavily impacted by the Covid-19 pandemic lockdowns. India, another significant and large market, saw a drop in their solar thermal market from 16% growth in 2021 to -21% in 2022, primarily driven by strong competition with photovoltaics. On the other hand, the country with the largest market increase in 2022 was Lebanon which reported an increase of 145% compared to 2021. This was mainly driven by the removal of electricity subsidies, the rise in fuel prices, and depreciation of the local currency which occurred that year. These factors have encouraged individuals to install solar water heaters as an alternative to relying on electricity for heating purposes. Even if the Lebanon is not one of the worldwide leading solar thermal markets the market increase is remarkable.

In Europe, Italy, Greece and Poland recorded positive market developments for two years in a row. After a staggering market growth of 83% in 2021, Italy's solar thermal market maintained its strong market growing by 43% in 2022. Greece experienced similarly positive development, with 18% growth in 2021 and 17% in 2022. Poland also had two consecutive years of strong market growth. The growth in 2021 was 17% and 11% in 2022.

Positive European market developments in 2022 were seen in France (29%) and Cyprus (5%). In Africa, South Africa, the most robust solar thermal market in Sub-Sahara Africa, reported an increase of 9%. The market in the USA increased by 3%, mainly due to the increase of unglazed collector areas.

Despite the global energy crisis caused by the war in Ukraine and the clear requirements in many countries for a radical changeover to renewable energies, former market frontrunners like Denmark, which recorded a solar thermal market decline of 67% in 2022, have not grown. Other traditionally strong countries like Australia (-7%), Austria (-16%), Brazil (-2%), the Palestinian Territories (-4%), Spain (-5%) and Turkey (-4%), also reported market slumps.

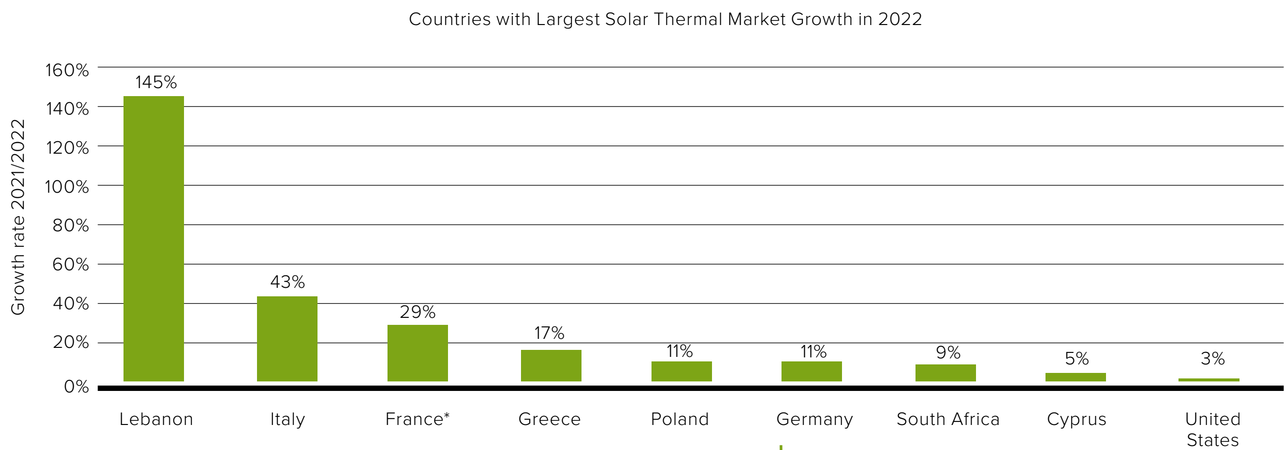

Figure 6: Reporting countries with the highest growth rates in 2022

* preliminary data based on Uniclima Report

145%
market growth in Lebanon 2022

Solar house by architect Achatz, Austria. Hot water, space heating, and cooling with the sun
Photo: Installateur und Baddesign Grünseis e.U.

5.1 Small-scale solar thermal heating systems

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

In large parts of Europe and China, these applications are under increasing competition from photovoltaic systems and heat pumps and have lost market share in recent years. The systems are predominantly pumped systems that are characterized by complex system technology.

The picture is different for thermosiphon systems. In Asia (excluding China), Latin America, Sub-Sahara Africa, and the Mediterranean region, thermosiphon systems are by far the dominant system type.

LEARN MORE

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https://task66.iea-shc.org/

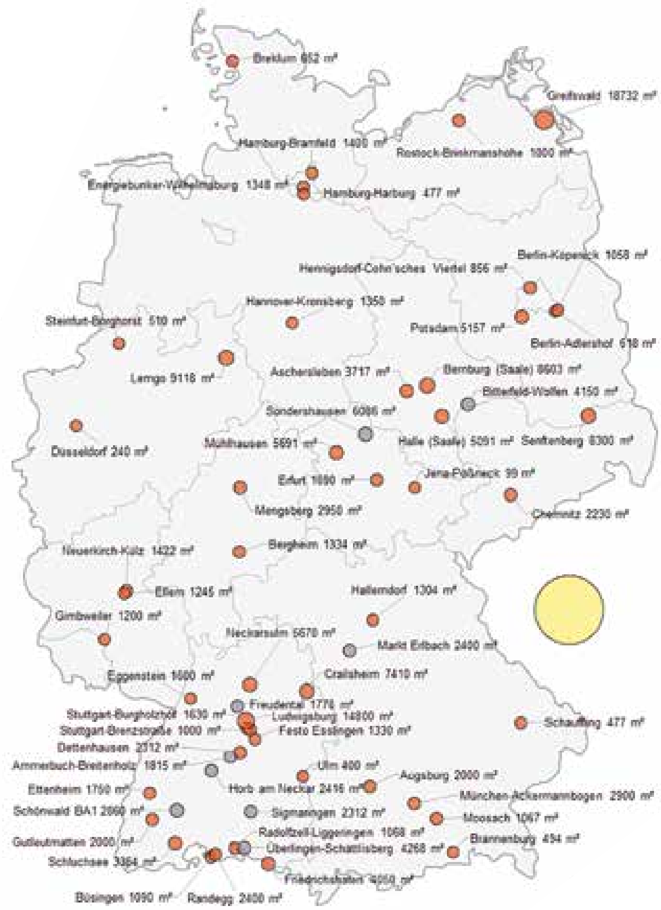
The 4,286 m^2 ground-mounted vacuum tube solar thermal system supports the renewable heat supply for 24,700 residents in Ueberlingen, Germany
Photo: Stadtwerke am See GmbH & Co. KG

5.2 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 that from the early 1980s to 2016, the large-scale plant market was almost exclusively concentrated in Europe.

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, since 2020 only one new plant has been built per year in Denmark, and three extensions added to existing plants – in 2021, a solar district heating system with 8,013 m^2 and in 2022, a system with 2,664 m^2 collector area. As a result, Denmark slipped from first to third place among newly installed large-scale plants.

China reported the installation of 171,068 m^2 collectors for district heating and 25 other large-scale systems, with an average of 6,945 m^2 per plant, corresponding to about 25 installed systems in 2022. In addition to China and Denmark, new plants were commissioned in Germany and Austria in 2022.In Germany, eight systems were installed with a total collector area of 44,923 m^2, primarily for solar district heating systems in smaller towns and municipalities. With this, 2022 was a record year for solar heating networks in Germany.



- In operation, 49 systems with a collector area of about 146,204 m^2
- Planned, 9 systems with a collector area of about 28,085 m^2
- In preparation, 66 systems with a collector area of about 454,550 m^2

Figure 7: In Germany, 49 solar district heating networks with 146,204 m^2 in operation in March 2023
Source: Steinbeis Research Institute Solites

Austria ranked fourth in 2022 with the addition of an extension added to a large-scale system for district heating in the city of Graz. The collector area installed was 2,134 m^2; the total collector area of this district heating system now adds up to about 6,134 m^2.

By the end of 2022, 571 large-scale solar thermal systems (>350 kW_{th}, 500 m^2) were operating worldwide. The total installed capacity of these systems equaled 2,148 MW_{th}, corresponding to 3.1 million m^2 collector area.

2022 was a record year for solar district heating networks in Germany

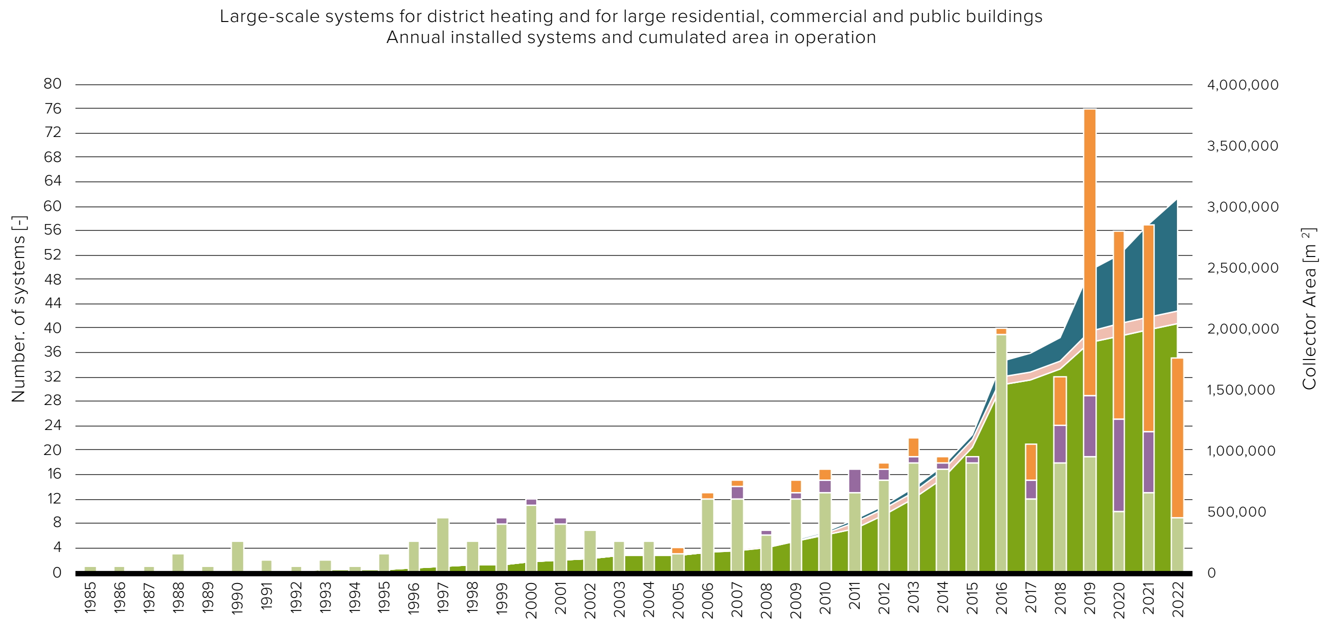


Figure 8: Large-scale systems for solar district heating and large residential, commercial and public buildings worldwide – annual installations and cumulated area in operation in 2022

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.

- Cumulated collector area in operation in Europe [m²]
- Cumulated collector area in operation in China [m²]
- Number of systems installed in "Other countries" [m²]
- Cumulated collector area in operation "Other countries" [m²]
- Number of systems installed in Europe [-]
- Number of systems installed in China [-]

* Other countries:
MENA countries: Dubai, Jordan, Kuwait, Morocco, Saudi Arabia, Tunisia, UAE
Latin America: Brazil, Colombia, Mexico
Asia excl, China: Cambodia, Japan, Kyrgyzstan, India, Russia, South Korea, Thailand, Turkey
Plus: Australia, Canada, South Africa, USA

5.2.1
Solar district heating (SDH) systems

325 Solar district heating systems with 1.8 GW_{th} in operation

The largest sub-sector of large-scale solar thermal heating systems is solar district heating. By the end of 2022, 325 large-scale solar district heating systems (>350 kW_{th}, 500 m^2) with an installed capacity of 1,795 MW_{th} (2.56 million m^2) were documented in operation. As shown in Figure 9, Denmark leads this market segment in both the number of systems and the installed area. In addition to Denmark (123 systems) and China (67 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 entire cities.

Countries to note are Germany (51 systems, some of these with seasonal storage), Sweden (23 systems), Austria (20 systems), Poland and France (with 8 systems each). Outside China and Europe, there are solar district heating systems installed in Saudi Arabia, Japan, Kyrgyzstan, Russia (Asia excluding China), the USA, Canada, and South Africa (Figure 9).

Table 1 lists the 20 largest solar district heating systems. By far, the largest system is in the Danish city of Silkeborg, built 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 Denmark's market dominance, with 16 of the 20 largest systems built in Denmark to date.

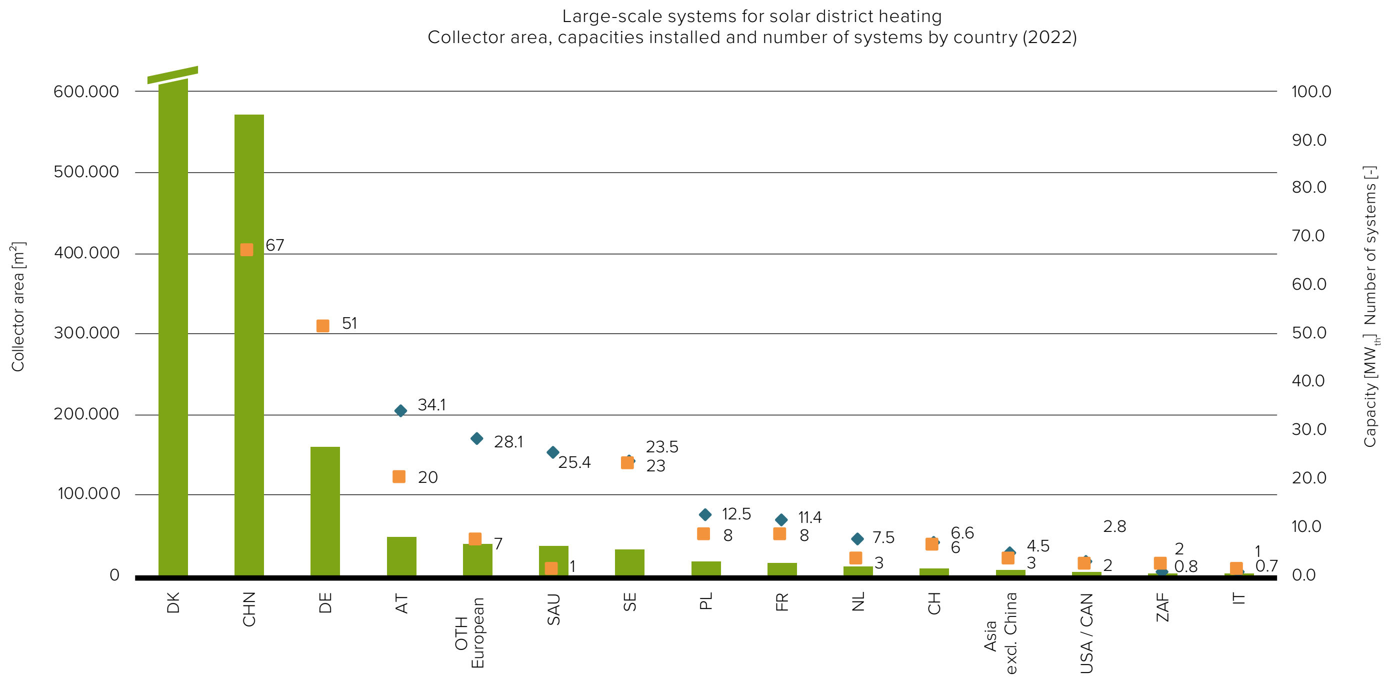


Figure 9: Large-scale systems for solar district heating – capacities and collector area installed and number of systems by the end of 2022

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[9].

[9] Usually, countries report single systems that are documented regarding project name, country and installed collector size. In 2021 and 2022 China reported total collector area and average system size for solar district heating systems.

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
2015	Hadsund	Denmark	20,513	14
2019	Høng	Denmark	20,160	14

Sources: Planenergi, Solarthermalworld.org, Bärbel Epp

Solar district heating plant in Lemgo, Germany, consists of 9,181 m^2 vacuum tube collectors
Photo: Stadtwerke Lemgo GmbH / Viessmann

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

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 2022, 246 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 353 MW_{th} (504,422 m^2).

China leads this market segment with 98 installed systems and a capacity of 251 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, an increasing number of large-scale systems are being built in Latin America (Brazil and 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.

Hotel Alixares in Granada, Spain
Photo: TiSUN / Solar-Heat-Europe

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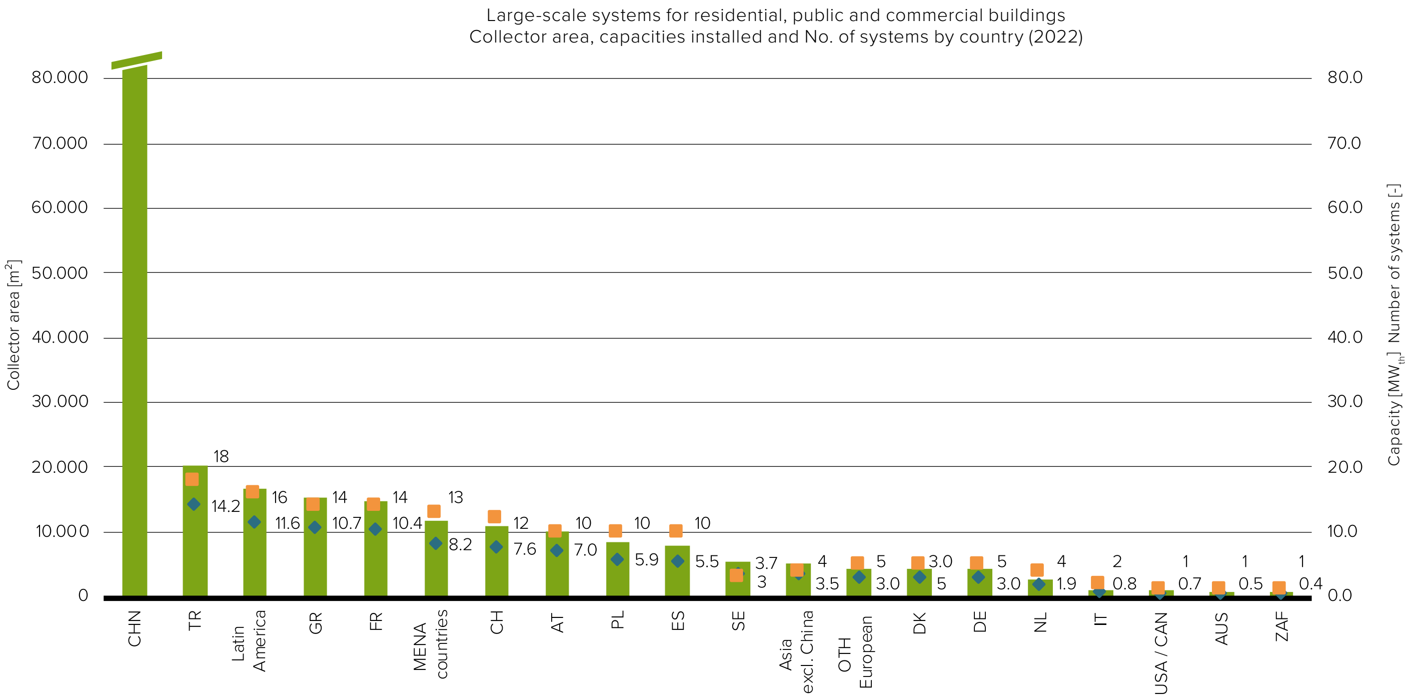

Figure 10: Large-scale systems for residential, public and commercial buildings – capacities and collector area installed and number of systems in 2022

Collector area [m²] ◆ Capacity [MW_{th}] ■ Number of systems [-]

China: Collector area: 359,103 m²
Capacity: 251 MW_{th}
Number of systems: 98

A leading Swiss milk processing company uses 147 kWth (210 m²) of high vacuum flat plate collectors for cheese production
Photo: TVP Solar, Switzerland

5.3 Solar heat for industrial processes

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

The market for solar thermal systems for industrial processes (SHIP) has been dynamic in recent years. According to a study published by the German agency solrico[10] in early 2023 and the SHIP database, the number of SHIP systems in operation totals at least 1,089 systems with 1.22 million m² collector area related to a capacity of 856 MW_{th}. It should be noted in addition to the number of SHIP plants reported, a larger number of SHIP plants have been built in China, but there is no detailed data available.

[10] https://solarthermalworld.org/news/high-level-of-dynamism-on-the-ship-world-market-in-2022/

Of the 1,089 documented systems with a size of at least 50 m^2 collector area or 35 kW_{th}, 494 systems are detailed (collector area, installed capacity, and the type of application and collector) in a SHIP database. This database is an online portal operated by AEE INTEC in Austria[11]. These 494 SHIP systems account for a total collector area of 1,071,706 m^2 and a thermal capacity of 645 MW_{th}[12]. Only the data of these 494 SHIP systems are presented in the following figures.

In 2022, at least 114 new SHIP systems with a capacity of 30 MW_{th} were installed worldwide, according to the solrico study mentioned above. Eighty-four of these newly installed systems (total collector area 39,600 m^2, 27.8 MW_{th}) are documented in detail in the SHIP database.

The following graph shows the development of the 494 documented SHIP systems from 2000 to 2022 in terms of the number of systems installed every year and the total capacity installed annually. In terms of the number of SHIP systems installed annually, a clear upward trend is visible. However, if one looks at the annual installed capacity, there is no significant increase in this market. It should be noted that the installed capacity of 334 MW_{th} in 2017 is mainly due to the Miraah plant in Oman. Excluding this plant, the average annual capacity installed is just under 30 MW_{th} based on the documented systems in the SHIP database and at about 50 MW_{th} based on data published by solrico.

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

[12] According to an agreement within the IEA SHC Task 64/IV, the conversion of m^2 collector area into kWth is also done for concentrating solar thermal systems with a factor of 0.7. Only the Mirrah system in Oman was converted with a lower factor due to the special glass house construction.

Development over time of 494 installed SHIP systems

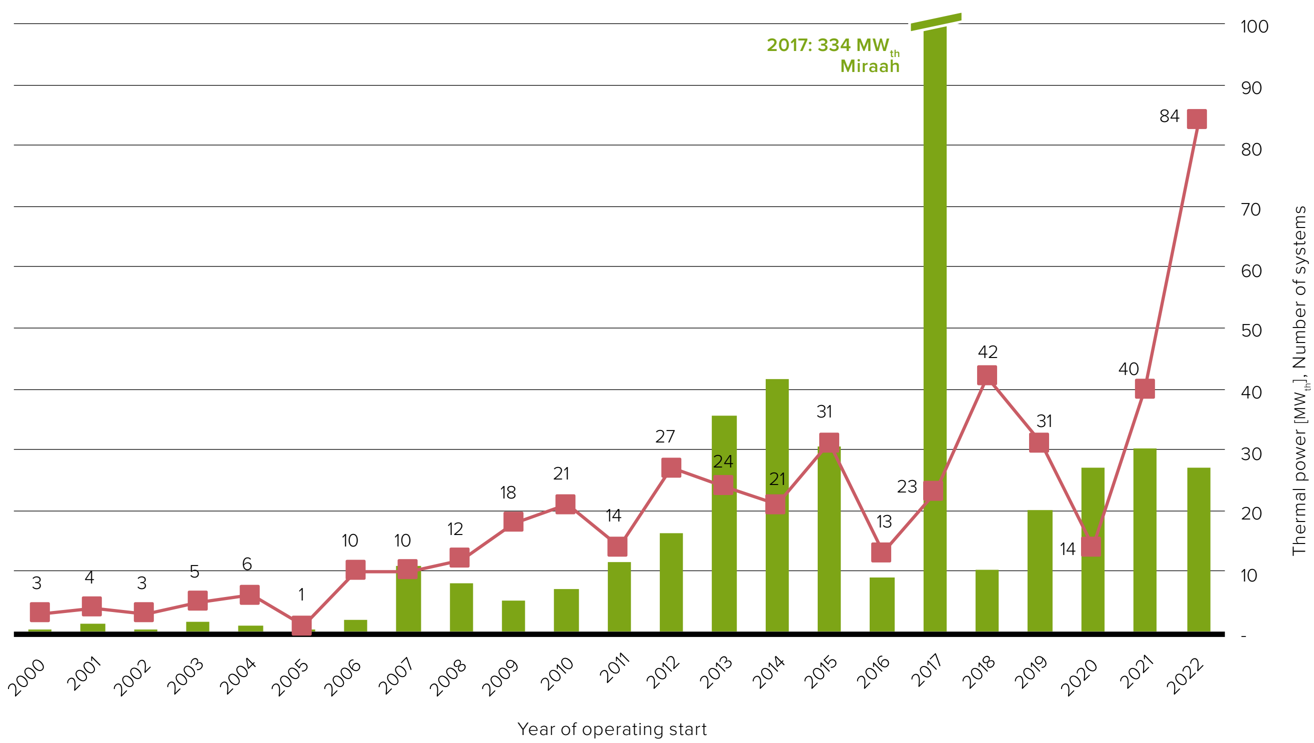

Figure 11: Development over time of the 494 installed SHIP systems from which detailed data are available Source: SHIP database

The following figures are dominated by the world's largest solar process heat application in Oman, commissioned in 2017 and continuously expanded. Currently, the plant's thermal capacity is 330 MW_{th}, accounting for 51% of the total installed thermal capacity of the 494 documented solar process heat applications worldwide. The second largest system is a greenhouse project in Australia with 36 MWth and the third largest system is installed at a copper mine in Chile with a thermal capacity of 27.5 MW_{th}. Together, those three plants make up 65% of the total installed thermal capacity.

Figure 12 shows the distribution of the 494 systems in terms of size. The three systems mentioned above exceed 21 MW_{th} of thermal capacity (30,000 m^2), 67 systems have installed capacities between 0.7 MW_{th} and 21 MW_{th} (1,000 m^2 - 29,999 m^2) of thermal capacity, 65 systems have installed capacities between 0.35 and 0.7 MW_{th} (500 – 999 m^2) and 116 systems are below 0.35 MW_{th} (<500 m^2).

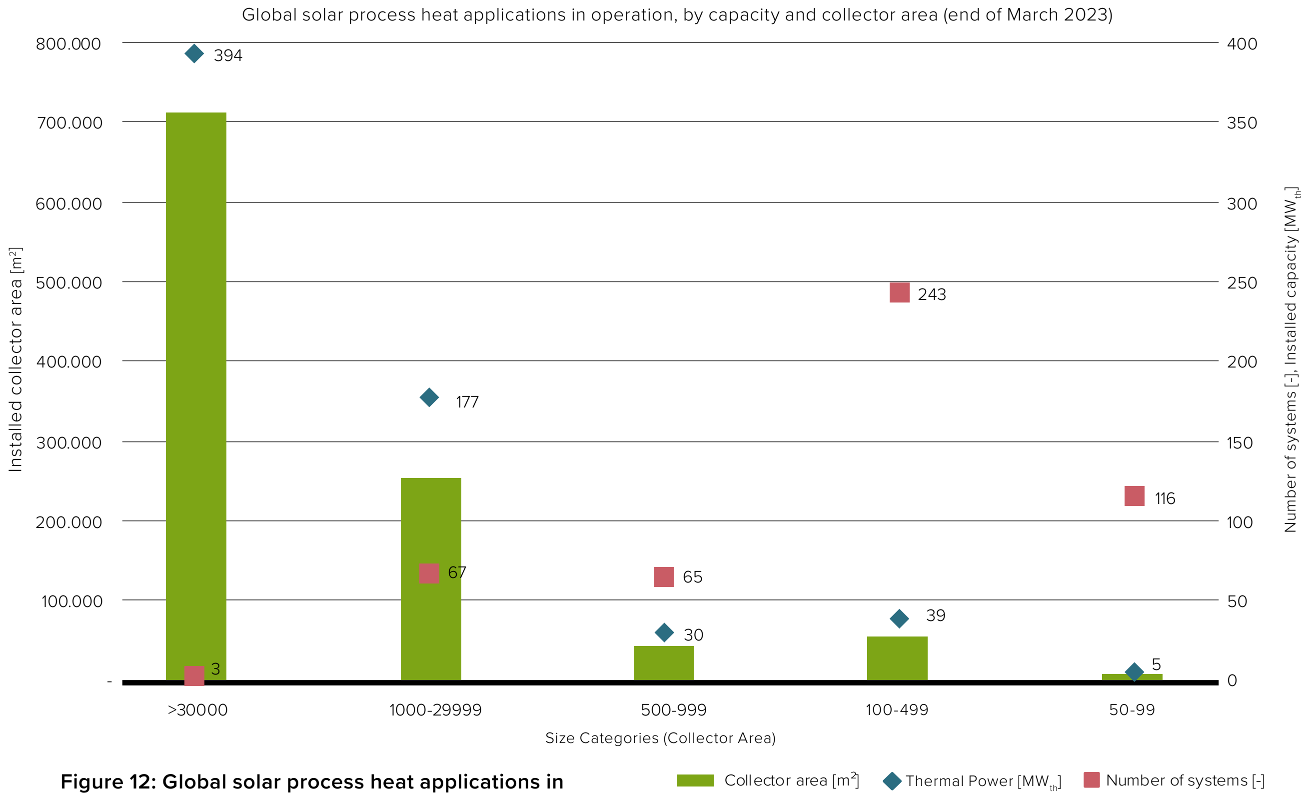

Figure 12: Global solar process heat applications in operation the end of March 2023 by number, capacity and collector area Source: IV SHIP database

The process heat systems by collector technology are presented in Figure 13. The majority of the systems use flat plate collectors to produce solar process heat, followed by parabolic trough collectors and evacuated tube collectors. Parabolic trough collectors have the highest installed area; however, without the Miraah plant, it would only rank third.

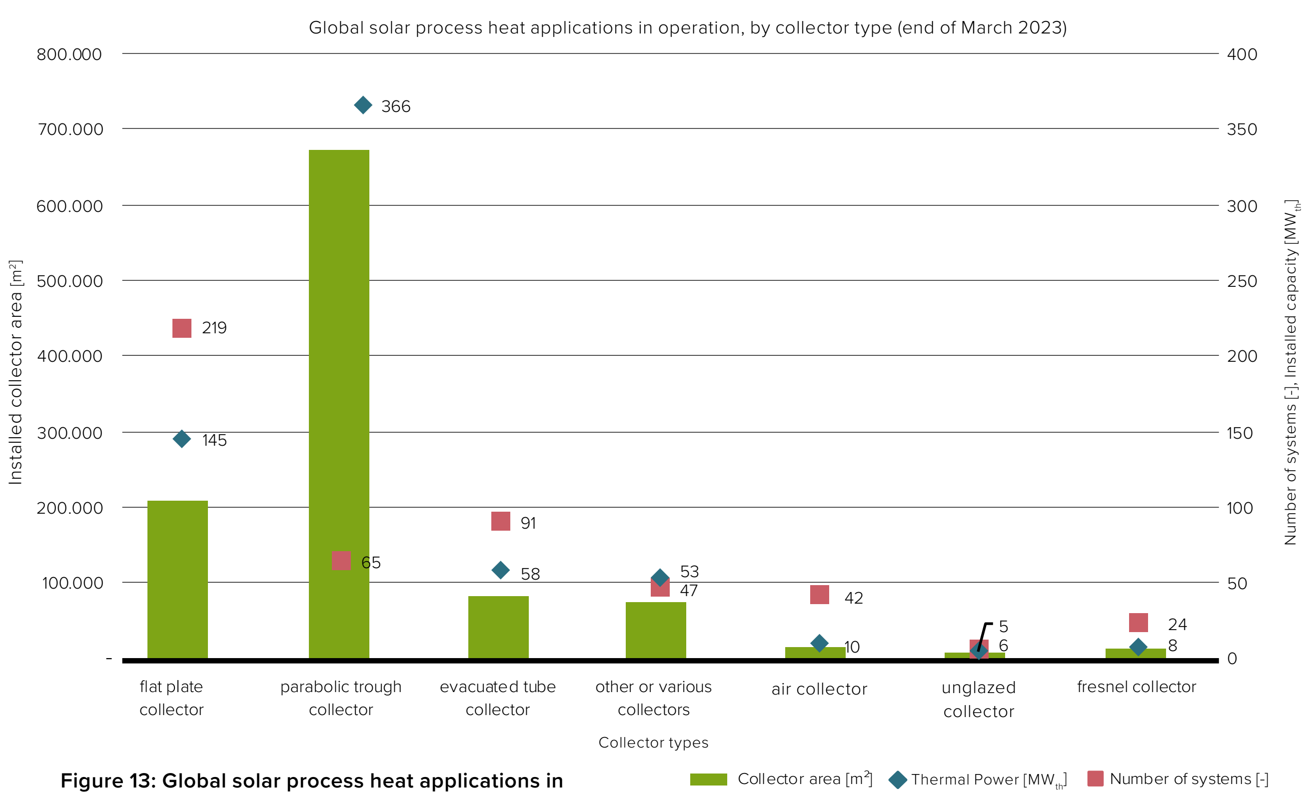

Figure 13: Global solar process heat applications in operation at the end of March 2023 by collector type
Source: SHIP database

Solar process heat system at the Ball Corporation, headquartered in Fairfield, California, USA. Flat plate collectors with a capacity of 2.8 MW_{th} (3,956 m^2) provide the heat for washing beverage aluminum cans
Photo: SOLID Solar Energy Systems, Austria

Figure 14 shows the industry sectors of the 494 documented systems. The **food and beverage sector** has grown again and is the dominant sector in terms of number of installed systems. This sector accounts for 180 systems with an average size of 638 m^2 and an installed thermal capacity of 80 MW_{th}. In contrast, the mining sector includes two of the three largest systems and thus is the dominant sector in terms of installed thermal capacity (59%).

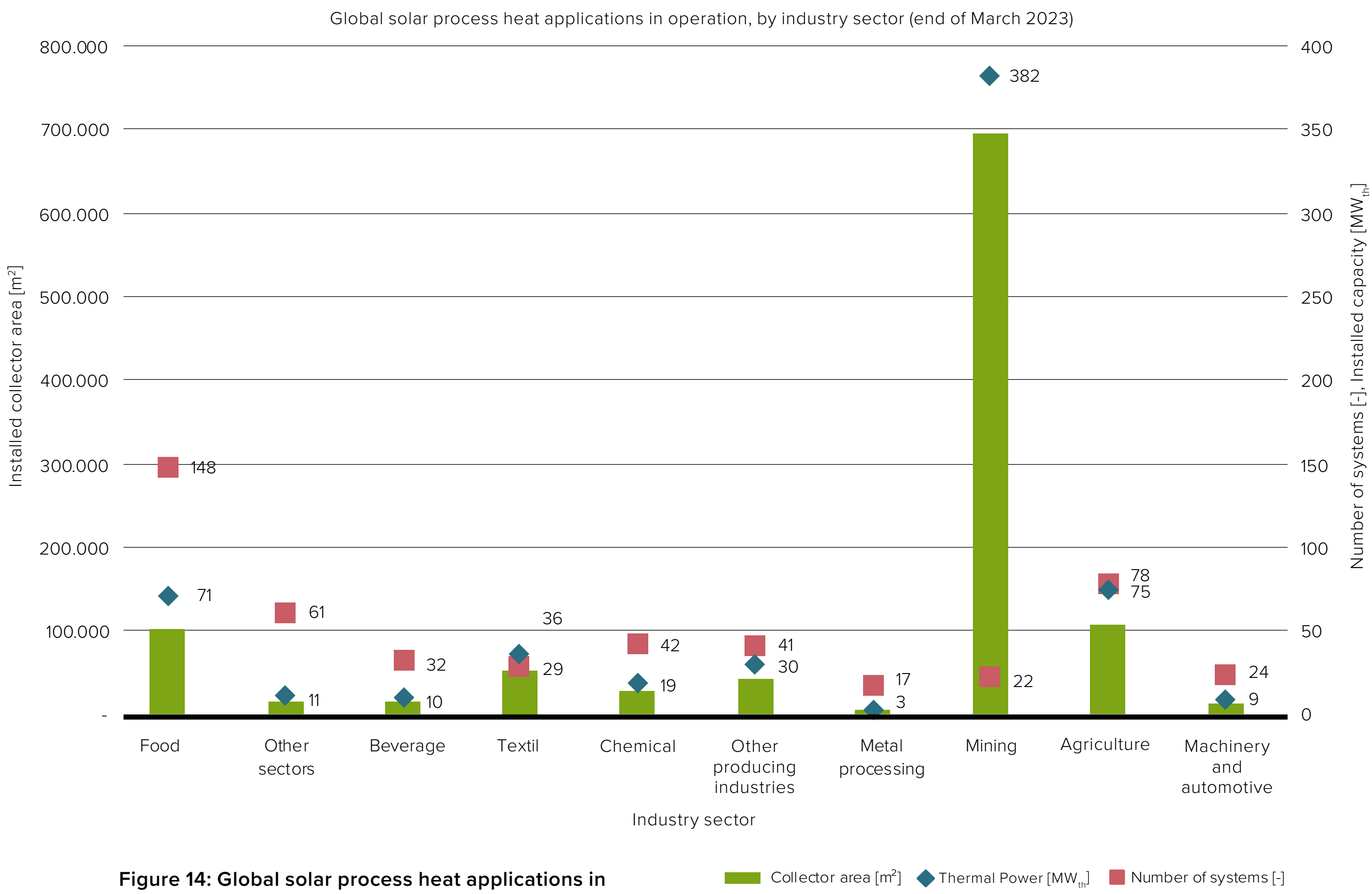

Figure 14: Global solar process heat applications in operation at the end of March 2023 by industry sector
Source: SHIP database

Figure 15 presents the globally installed solar process heat systems by country. Mexico has achieved more than 100 installed SHIP systems with a thermal capacity of 18 MWth. A growing market is also in Europe, with 39 new systems installed in 2022 (+25%) and an increase in area by 12,249 m^2 and in thermal capacity of 8.57 MW_{th} (+11%). Oman leads in terms of installed thermal capacity with the two systems at the Amal Oilfield (Miraah and Amal II). China ranks fourth in this category with 49 systems and an installed collector area of 90,000 m^2 (63 MW_{th}). However, it should be noted that according to information from the China Academy of Building Research, a total of 359 SHIP systems with a total collector area of 256,000 m^2 were installed in 2021 alone. Unfortunately, the China Academy of Building Research could not provide detailed data on the individual systems, so they could not be included in these figures.

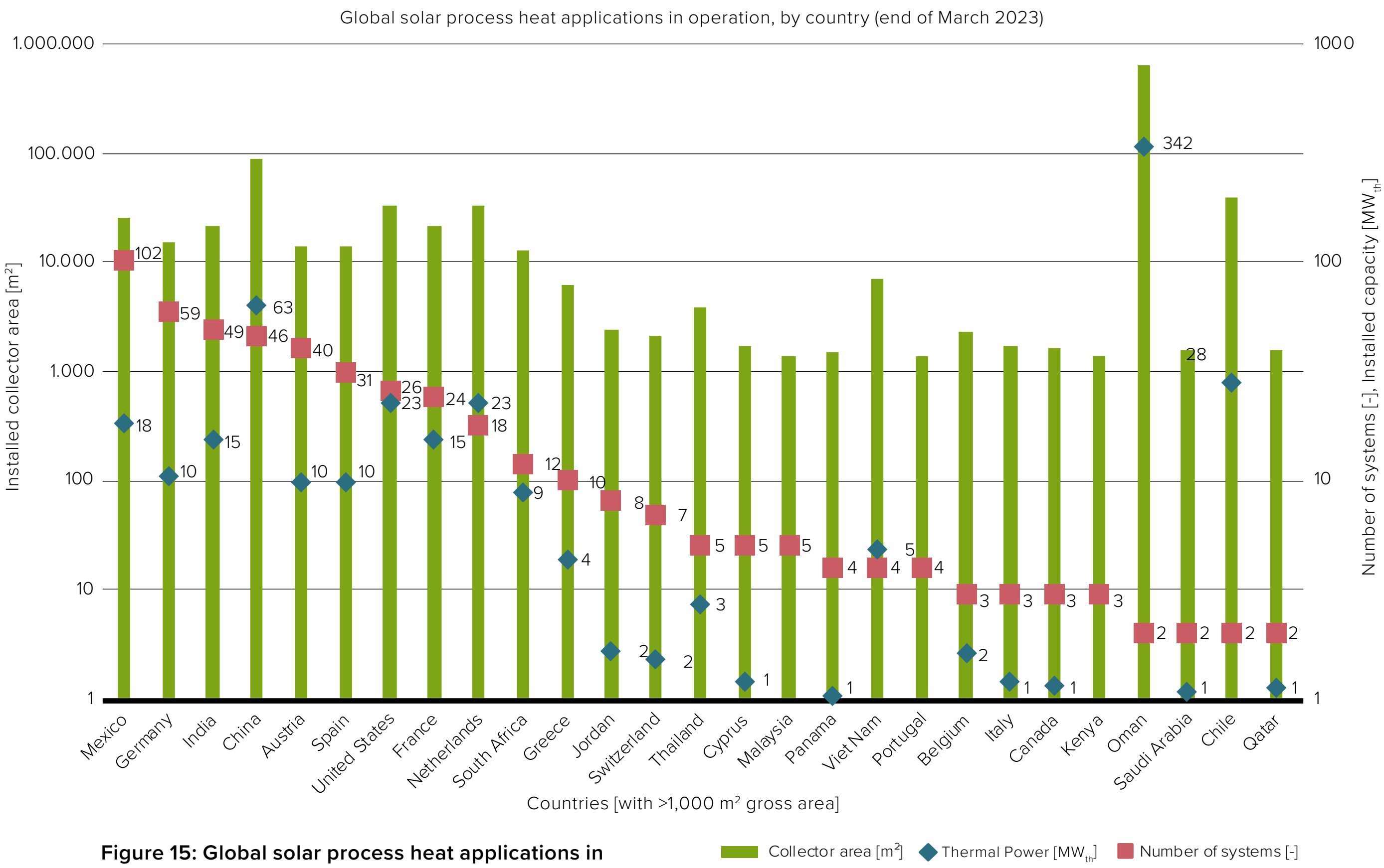

Figure 15: Global solar process heat applications in operation by country at the end of March 2023
Source: IEA SHC Task64/IV SHIP database

Only countries with at least 0.7 MW_{th} (1,000 m^2 collector area) are shown in Figure 15 (474 of 494 systems accounting for >99% of installed thermal capacity).

Table 2 documents all SHIP systems with a collector area larger than 5,000 m^2 corresponding to 3.5 MW_{th}.

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EU Projects: https://friendship-project.eu http://www.inship.eu/ http://ship2fair-h2020.eu/

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

Commissioned	Site	Country	Collector size	Installed Capacity MW_{th}
2017	Miraah Oman, Amal	Oman	622,080	330
2014	Sundrop Farms, Port Augusta	Australia	51,505	36
2013	Codelco Gabriela Mistral Mine	Chile	39,300	28
2020	Amal II	Oman	17,280	12
2020	Mol Freesia Greenhouse	Netherlands	15,000	11
2015	Østervang Greenhouse, Varpelev	Denmark	14,112	10
2021	Maltery, Issoudun	France	13,243	9
2007	Daly Textile, Hanghzhou	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
2012	Prestage Foods St. Pauls, North Carolina	USA	7,804	5
2011	Jiangsu Printing and Dyeing	China	7460	5
2016	La Parerena Copper Mine	Mexico	6,270	4
2021	Packaging Business, Izmir	Turkey	6,000	4
2011	Jingshi East Road Jinan	China	5,750	4
2010	Jinan, Shanddong, pre-heating of industrial boiler	China	5,184	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	-
Ethiopia	Addis Ababa	2014	1.95	2,784	400
Namibia	Okahandja	2014	2.74	3,915	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

PVT system with a thermal capacity of 19,1kW$_{th}$ and 6kW$_{peak}$ on a pool house in Grasse, France
Photo: DualSun, France

5.4 PVT – Photovoltaic Thermal Systems

Photovoltaic Thermal (PVT) collectors combine the production of both types of solar energy – solar heat and solar electricity – 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 also needed to achieve a climate-neutral energy supply for consumers in residential and commercial buildings.

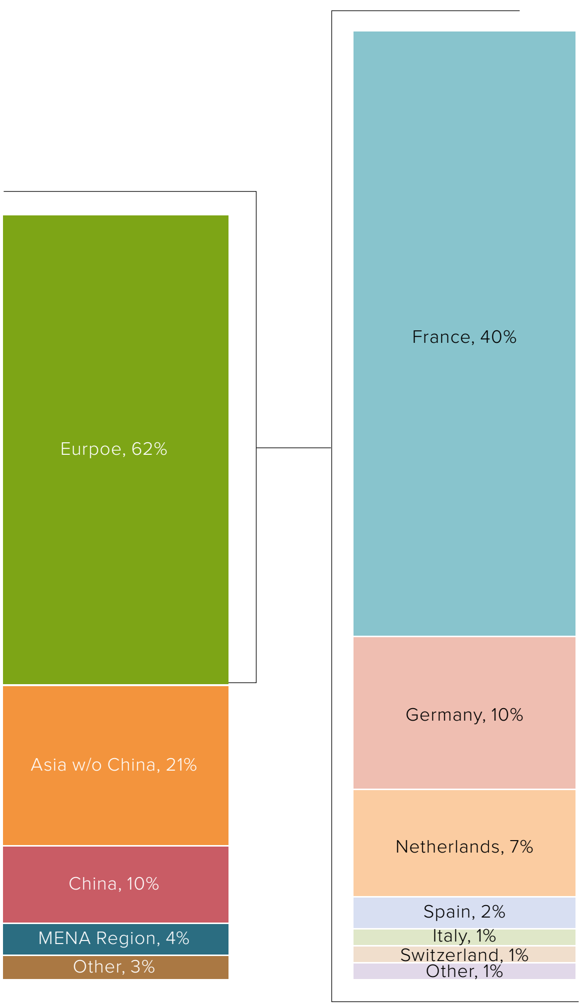

Figure 16: Distribution of the total installed collector area by economic region in 2022
Source: AEE INTEC

PVT technology is somewhat more complex than just a PV or a solar thermal collector but provides significant advantages. The PV production can be slightly higher if the collectors are operated at temperatures below those of a PV-only module. Depending on the type of PTV 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 PVT systems 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, space heating, or 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.

1.5 million m² PVT collector area installed worldwide

General market overview

In 2022, the total installed PVT collector area was 1,524,945 m^2 (789 MW$_{th}$, 276 MW$_{peak}$). The vast majority of this collector area is installed in Europe (950,155 m^2) followed by Asia excluding China (316,653 m^2) and China (146,926 m^2), which together account for 789 MW$_{th}$, 276 MW$_{peak}$ of the total installed capacity. The remaining installed collector area is shared between the MENA countries (Egypt, Israel, and Iraq (69,372 m^2) and the Sub-Sahara African countries (Ghana, Lesotho and South Africa (22,926 m^2), United States and Canada (10,145 m^2), Australia (3,576 m^2), Latin America (637 m^2) and others (4,555 m^2).

In the European Market, France is the market leader with an installed collector area of 608,172 m^2, followed by Germany with 146,729 m^2 and the Netherlands with 111,342 m^2. In Spain, Italy, and Switzerland, collector areas range between 18,695 m^2 and 26,360 m^2. In the remaining European countries, collector areas of at least 19,011 m^2 were reported.

With a global share of 60% of installed thermal capacity, uncovered PVT water collectors were the dominating PVT technology, followed by air PVT collectors with 37% and covered PVT water collectors with 3%. Evacuated tube collectors and concentrators play only a minor role in the total numbers. Table 4 shows the cumulated installed collector area by PVT collector type at the end of 2022.

Table 4: Cumulated collector area by PVT collector type at the end of 2022

Country	Water Collectors [m²]			Air Collectors [m²]	Concentrators [m²]	TOTAL [m²]
	uncovered	covered	evacuated tube			
Albania	364	30	0	0	0	394
Australia	3,477	0	0	99	0	3,576
Austria	1,861	2,107	0	0	0	3,968
Belgium	3,160	0	32	290	15	3,497
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	145,721	1,034	0	0	171	146,926
Croatia	907	125	0	0	0	1,032
Cyprus	0	0	3	0	0	3
Czech Republic	0	4	0	0	0	4
Denmark	109	32	0	0	0	141
Dubai	43	9	0	0	0	52
Ecuador	0	138	0	0	0	139
Egypt	0	0	0	0	21	21
France	59,465	1,132	0	547,575	0	608,172
Germany	140,605	5,414	3	512	195	146,729
Ghana	22,000	0	0	0	0	22,000
Greece	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	69,322	0	0	0	0	69,322
Italy	16,149	2,546	0	0	0	18,695
Korea, South	280,814	0	0	0	0	280,814
Kosovo	176	14	0	0	0	190
Lesotho	0	48	0	0	0	48
Luxembourg	635	0	0	145	0	780
Macedonia	1,278	199	0	0	0	1,477
Maldives	0	0	0	0	21	21
Martinique	0	63	0	0	0	63
Netherlands	98,456	11,030	33	0	1,822	111,342
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
Romania	46	4	0	0	0	50
Russia	0	50	0	0	0	50
Singapur	875	0	0	0	0	875
Slovakia	0	250	0	0	0	250
Slovenia	90	15	0	0	0	104
South Africa	0	79	32	0	767	878
Spain	1,552	24,808	0	0	0	26,360
Sweden	1,200	20	0	0	31	1,251
Sri Lanka	1,805	24	0	0	0	1,829
Switzerland	16,189	128	0	3,530	0	19,846
Tibet	32,000	0	0	0	0	32,000
Turkey	0	25	0	0	30	55
United Kingdom	1,241	639	458	348	135	2,820
United States	10,093	20	0	0	0	10,113
Uruguay	0	2	0	0	0	2
Other	1,274	3,250	16	0	15	4,555
Total	913,581	54,749	578	552,499	3,538	1,524,945

(Source: AEE INTEC)

Table 5: Total installed PVT capacity in 2022 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	185	88	15	5	0	0	0	0	0	0	199	93
Australia	1,781	656	0	0	0	0	54	17	0	0	1,835	673
Austria	932	397	1,039	364	0	0	0	0	0	0	1,970	761
Belgium	1,596	664	0	0	16	4	141	46	9	2	1,762	716
Brazil	13	5	0	0	0	0	0	0	0	0	13	5
Bulgaria	258	98	19	7	0	0	0	0	0	0	277	106
Canada	0	0	14	6	0	0	0	0	0	0	14	6
Chile	105	37	52	21	0	0	0	0	6	1	162	59
China	72,115	25,412	452	180	0	0	0	0	98	20	72,665	25,612
Croatia	506	172	54	22	0	0	0	0	0	0	560	194
Cyprus	0	0	0	0	1	0	0	0	0	0	1	0
Czech Republic	0	0	2	1	0	0	0	0	0	0	2	1
Dubai	56	19	18	5	0	0	0	0	0	0	73	24
Denmark	23	8	5	1	0	0	0	0	0	0	28	10
Ecuador	0	0	67	24	0	0	0	0	0	0	67	24
Egypt	0	0	0	0	0	0	0	0	12	2	12	2
France	30,838	11,976	575	189	0	0	271,352	88,288	0	0	302,766	100,453
Germany	69,743	26,139	2,717	923	1	0	263	87	109	22	72,834	27,172
Ghana	11,958	4,140	0	0	0	0	0	0	0	0	11,958	4,140
Greece	0	0	7	3	0	0	0	0	0	0	7	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	410	135	0	0	0	0	146	30	557	164
Iraq	28,212	9,110	13	5	0	0	0	0	0	0	28,225	9,115
Israel	34,192	12,164	0	0	0	0	0	0	0	0	34,192	12,164
Italy	8,017	3,077	1,197	474	0	0	0	0	0	0	9,214	3,551
Korea, South	137,599	47,828	0	0	0	0	0	0	0	0	137,599	47,828
Kosovo	0	49	0	2	0	0	0	0	0	0	0	51
Lesotho	0	0	21	8	0	0	0	0	0	0	21	8
Luxembourg	311	108	0	0	0	0	71	23	0	0	382	131
Macedonia	659	299	100	35	0	0	0	0	0	0	760	334
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	51,035	19,923	5,015	1,892	14	4	0	0	1,046	213	57,110	22,032
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	7	3	0	0	0	0	0	0	7	3
Poland	214	79	30	10	0	0	0	0	0	0	245	89
Portugal	168	62	159	58	0	0	0	0	0	0	326	119
Romania	24	13	2	1	0	0	0	0	0	0	26	14
Russia	0	0	22	9	0	0	0	0	0	0	22	9
Singapur	462	166	0	0	0	0	0	0	0	0	462	166
Slovakia	0	0	108	43	0	0	0	0	0	0	108	43
Slovenia	47	20	8	2	0	0	0	0	0	0	55	22
South Africa	0	0	34	14	16	4	0	0	441	90	491	108
Spain	775	284	12,375	4,267	0	0	0	0	0	0	13,151	4,550
Sweden	682	228	11	3	0	0	0	0	18	4	710	235
Sri Lanka	916	442	10	4	0	0	0	0	0	0	926	446
Switzerland	8,161	3,362	63	21	0	0	1,806	576	0	0	10,030	3,959
Tibet	17,727	6,795	0	0	0	0	0	0	0	0	17,727	6,795
Turkey	0	0	11	4	0	0	0	0	15	3	26	8
United Kingdom	620	251	322	113	196	52	170	55	66	15	1,373	486
United States	5,148	1,998	11	3	0	0	0	0	0	0	5,159	2,001
Uruguay	0	0	1	0	0	0	0	0	0	0	1	0
Other	650	294	1,496	617	7	2	0	0	7	2	2,160	914
Total	486,336	176,576	26,523	9,496	251	67	273,856	89,092	2,014	412	788,980	275,643

(Source: AEE INTEC)

As shown in Table 5, PVT collectors' total cumulative thermal capacity by the end of 2022 was 789 MW$_{th}$, and the PV power was 276 MW$_{peak}$.

The global PVT market shrank by 52% in 2022

Market development of PVT collectors between 2017 and 2022

Based on the market data from the 43 PVT manufacturers, the market for PVT collectors saw a constant growth of +9% on average between 2017 and 2020. It reached its highest level in 2021 at +13%. But in 2022, there was a dramatic market slump of -52% compared to the previous year. The newly installed capacity in 2022 amounted to 42.4 MW_{th} and 21.7 MW_{peak}.

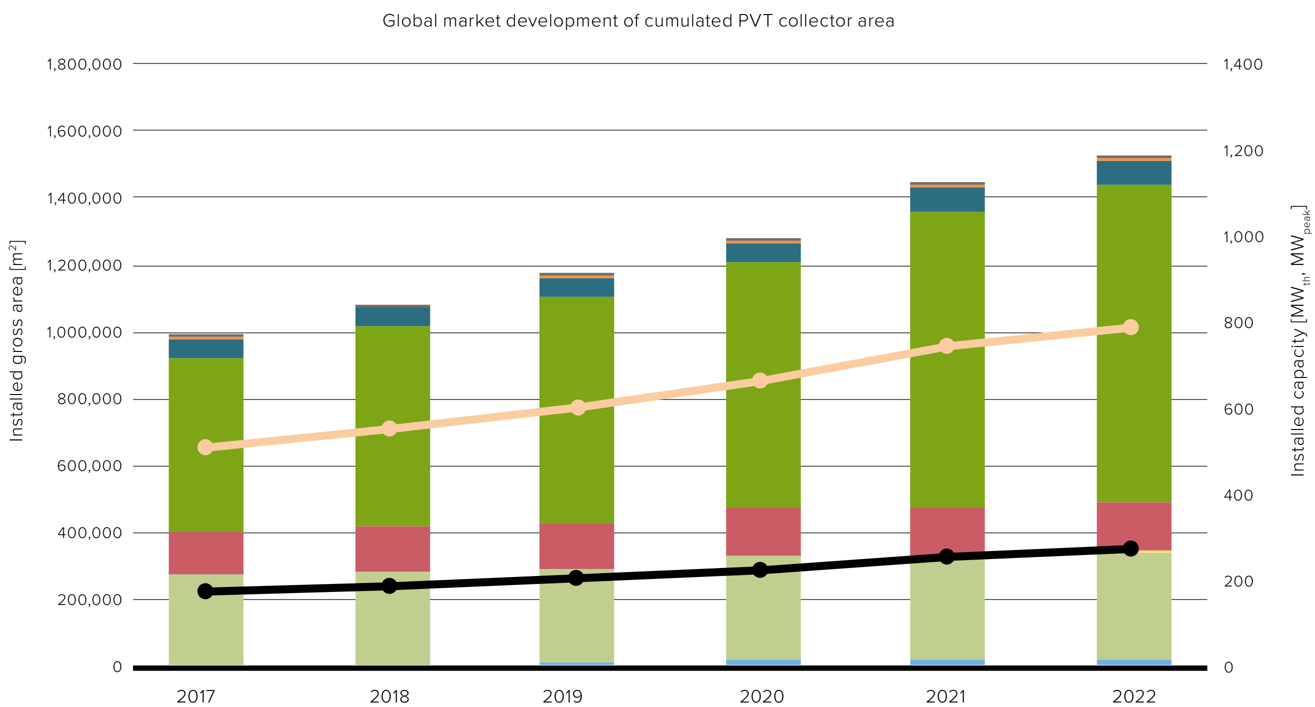

Figure 17: Global market development of PVT-collectors from 2017 to 2022
Source: AEE INTEC

PVT system integrated into a flat roof of a detached house in Germany
Photo: EVO Deutschland GmbH

Market development in 2022

As shown in Figure 17, the global interest in PVT systems grew steadily between 2017 and 2021. However, in 2022, the market was negatively affected by restrictive and discontinued PVT subsidies in some countries. In addition, the war in Ukraine has caused uncertainties in energy supply security, energy price instability, and inflation. As a result, there was a huge increase in the demand for PV systems in 2022.
Some PVT manufacturers responded to the increased demand for PV technologies by focusing mainly on the PV market. And PVT was not able to capitalize on the PV momentum in all countries. As a result, strong, previously dominating markets like France came to a near halt while others continued to grow[13] (Figure 19).

The significant global marked decline in 2022 is mainly due to the downturn in the French market. Changes in their funding scheme led to a collapse of the air-PVT collector market in 2022 (-90%). The Netherlands, another traditionally strong European PVT market, also reported a market decline of -43%.

However, there were European countries with solid PVT market growth. Italy reported a massive increase of +414% (2,568 m^2), followed by Germany with +126% (19,089 m^2), Switzerland with +103% (4,840 m^2), and Spain with +52% (5,862 m^2). The growth in these countries, however, could not compensate for the massive market slumps in France and the Netherlands.

The fact that France suffered a major market decline in air-PVT collectors in 2022 is also reflected in the breakdown of the different PVT collector types in 2021 and 2022, shown in Figure 18. Air-PVT collectors were the dominant collector type in 2021 at 45.5%, ahead of uncovered PVT collectors at 44.2%. In 2022, the market share of uncovered PVT collectors increased to 87%, and air-PVT collectors almost completely disappeared from the market.

[13] The 2022 PVT data are based on feedback of 29 PVT collector manufactures and PVT system suppliers from 12 different countries.

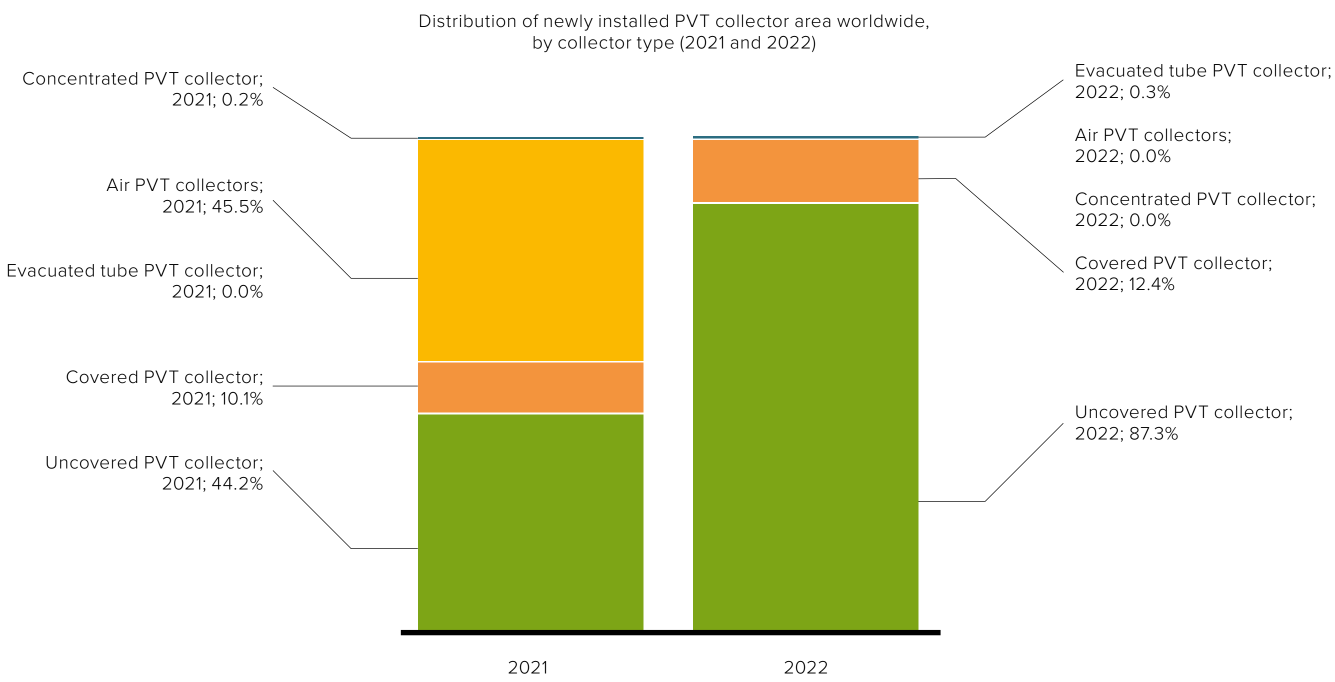

Figure 18: Distribution of newly installed PVT collector area worldwide by collector type in 2021 (left) 2022 (right)
Source: AEE INTEC

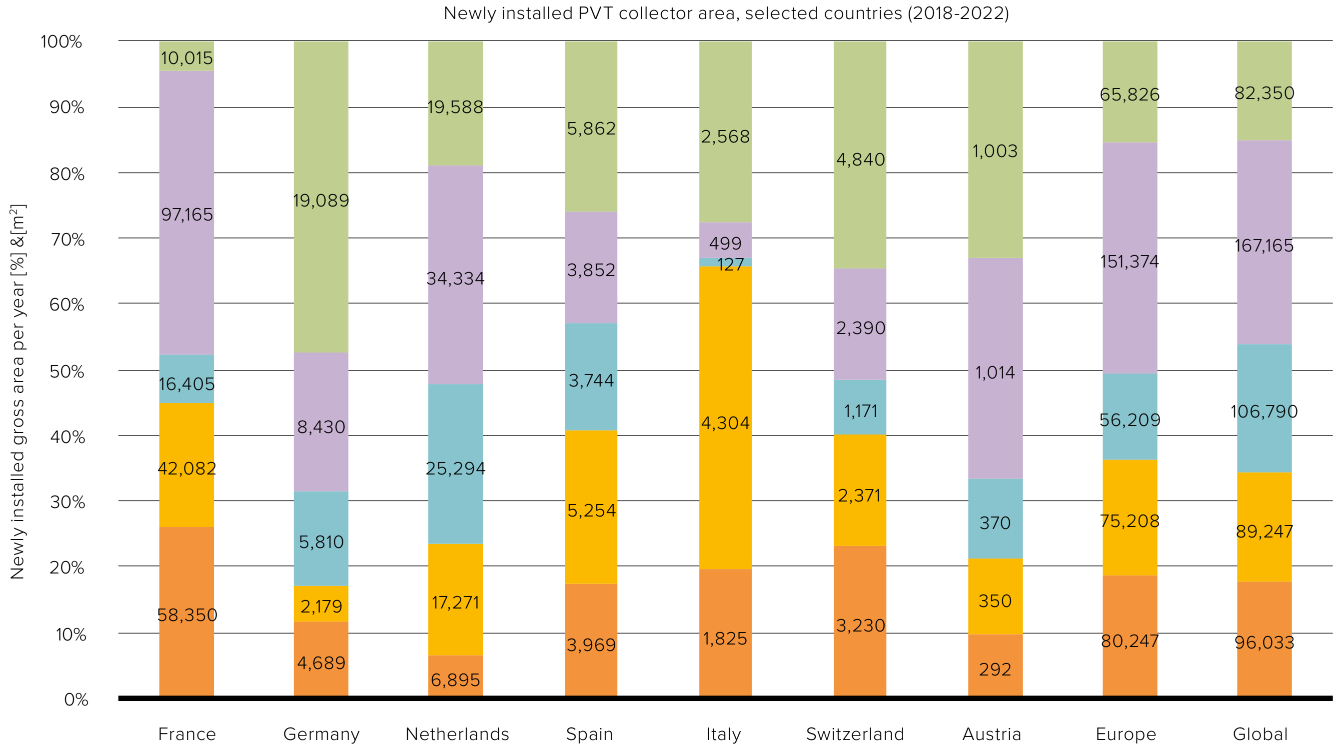

Figure 19: Newly installed PVT collector area in selected countries, Europe and Global from 2018 to 2022 Source: AEE INTEC

5.5 Solar air conditioning and cooling

700 m² vacuum tube solar collectors supply heat to drive a 348 kW water/LiBr absorption chiller for air-conditioning a new cafeteria and kitchen at Camp Castor in Mali
Photo: Frank Molter, SolarNext.

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 for air conditioning[14]. 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 2022 technical economic analysis for PV-powered air-conditioning in buildings of 13 emerging countries[15], GIZ 2017 feasibility study for social housing buildings in Mexico[16], and RCREEE/UNDP 2015 study on commercial buildings/applications in the Arab region[17].

A major argument for solar thermal-driven systems is that they consume less conventional energy (up to a factor of five[18]) 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

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for space cooling and reaches 60% of the summer peak load and is already stretching the capacity of the Indian national electricity supply[19]. In other countries, like the USA, the peak load through air conditioning reaches >70% on hot days.

There are mature cooling technologies 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. 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 to 600 kW) in combination with a minimum required performance[20].

Solar thermal cooling is still a niche market, with over 2,000 systems deployed globally as of 2022. And due to changing distribution channels and B2B sales of the sorption chillers, tracking 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 (thus cheaper upfront costs) and targeting the mass markets. Medium to large-scale projects, 30 kW to 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[21], only a few 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), research projects (e.g., SunBeltChiller[22], FRIENDSHIP[23], SHIP2FAIR[24], HyCool[25], sol.e.h.^{2}[26], Zeosol[27]) and commercial solar thermal cooling projects (e.g., China, the USA, Mexico, Mali, Uganda, Nigeria, Morocco, Egypt, Jordan, Dubai, Greece, Spain, Austria, Netherlands, Ukraine, India and Thailand).

Solar thermally driven 348 kW cooling capacity water/LiBr absorption chiller for air-conditioning at 16/10 °C chilled water temperature in Mali
Photo: Frank Molter, SolarNext

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[28] 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 a solar cooling system needs to run pumps and a cooling tower is relatively low. Depending on the climate, it may give Energy Efficiency Ratios (kWth/kWel) of 20 to 40 in systems with optimized variable speed-driven auxiliaries.

14 https://www.iea.org/futureofcooling/
15 https://www.green-cooling-initiative.org/fileadmin/user_upload/220607_Proklima_Solar_AC_med.pdf
16 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
17 https://www.solarthermalworld.org/sites/default/files/story/2016-04-05/solar_cooling_in_arab_region_0.pdf
18 http://task53.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task53-C3-Final-Report.pdf
19 Low energy cooling and ventilation in indian residences, https://doi.org/10.1080/23744731.2018.1522144
20 https://www.bafa.de/DE/Energie/Energieeffizienz/Klima_Kaeltetechnik/klima_kaeltetechnik_node.html
21 Not published internal communication
22 https://industrial-solar.de/en/industrial-solar-company/research-development-projects/sunbeltchiller-project/
23 https://friendship-project.eu/ship-200-300/
24 http://ship2fair-h2020.eu/demo-2-bodegas-roda
25 Jakob, Uli; Kiedaisch, Falko (2019) Analysis of a solar hybrid cooling system for industrial applications, ISES SWC 2019-SHC 2019, doi:10.18086/swc.2019.55.07.
26 Neyer, Daniel; et al. (2019) Solar Heating and Cooling in hot and humid climates – sol.e.h.^{2} Project Introduction, ISES SWC 2019-SHC 2019, paper ID 10400.
27 Roumpedakis, Tryfon; et al. (2019) Performance results of a solar adsorption cooling and heating unit, ISES SWC 2019-SHC 2019, paper ID 11465
28 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.

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 system with a cooling capacity of 3.5 MW for a packaging factory is in Izmir, Turkey[29]. The plant was commissioned at the end of 2021 and formally inaugurated in June 2022. The installation covers two solar thermal collector fields with a total capacity of 2.5 MW_{th} (5,000 m^2). The solar system supplies heat to two double-effect lithium bromide absorption chillers with a cooling capacity of 1.4 MW and 2.1 MW, respectively, to match the size of the associated solar collector fields. The installed double-effect absorption chillers can achieve a COP up to 1.40.

In 2022 three larger solar cooling systems with 972 kW cooling capacity were commissioned. The total collector capacity of these systems is 1.86 MW_{th}, corresponding to a 2,660 m^2 collector area.

Table 6: Large-scale solar cooling systems installed between 2008 and 2022

Country	Site	Commissioned	Installed capacity [kW_{th}]	Collector size [m^2]	Collector type	Cooling capacity [kW_{cold}]
Spain	Barcelona	2022	560	800	Fresnel	260
Spain	Barcelona	2022	252	360	Fresnel	12
Italy	Padova	2022	1,050	1,500	Evacuated tube	700
Turkey	Izmir	2021	2,500	6,000	Parabolic trough	3,500
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	2009	840	1,200	Evacuated tube	n.a.
Learning Center	2012	794	1,134	Flat plate	352	n.a.
Kingston, Jamaica	Digicel		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

Sources: Blackdot Energy, Industrial Solar, Ritter XL Solar, SOLID Solar Energy Systems, SOLRICO, Vicot Solar Energy, Cosmosolar, SOLITERM Group, Marco Calderoni, R2M Solution Srl

[29] Lokurlu, Ahmet; Ramesh, Akshay (2022) Parabolic Trough Collector (PTC) system for combined cooling and heating supply for a factory building in Turkey. EuroSun 2022, paper ID 1558.

Solar Refrigeration for the process industry

Solar thermal collectors and sorption chillers can also provide cold energy for process refrigeration at industrial sites. From the technical perspective, the main challenge is the lower temperatures often required by refrigeration processes, which can be close to 0 °C or even negative. In turn, this reflects a higher temperature needed for the chiller to drive the sorption process. Medium temperature collectors such as Fresnel, parabolic troughs and vacuum collectors can be employed to meet such high activation temperatures. Alternatively, hybrid chillers have been tested in combination with solar thermal[30], connecting an electric chiller and a sorption chiller in series. In this way, the sorption device cools down the condenser of the electric chiller, thus increasing its efficiency without the need for the sorption chiller to reach very low temperatures.

According to the EU HYCOOL project, energy demand for process refrigeration is some 4% of industry's final energy demand end-use in 2015 in EU28 (100 TWh/y). Cold energy is required at temperatures 0 to 15 °C (2%), 1% is required at -30 to 0 °C and 1% at below -30 °C. Space cooling at industrial sites uses another 1% of industry's final energy demand.

Trends and outlook

The demand for cooling and refrigeration will continue its rapid growth, particularly in emerging countries (several hundred million AC units estimated to be sold annually by 2050[31]). 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 14 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, exploiting it will not be possible until system prices and complexity are significantly reduced.

[30] https://hycool-project.eu
[31] https://www.iea.org/futureofcooling/

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5.6
Solar air heating systems

SolarWall air heating system at Montana State University provides ventilation heating
Photo: SolarWall Conserval Engineering Inc.

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

Space heating consumes more energy than hot water in most buildings. In colder climates, space heating is usually the largest consumer of energy in a building. As it is the air in the buildings that is heated, air collectors are ideally suited to heat this air directly without heat exchangers. Most solar air collectors for heating buildings are wall-mounted to take advantage of the lower winter sun angles and eliminate snow accumulation on roof-mounted systems. 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 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 rise.

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

Heat storage is possible, but most solar air systems do not include storage to minimize costs.

The following table lists the countries with more than 10,000 m^2 of solar air collectors.

Table 7: Largest solar air collector markets - total installed air collector areas in 2021

Country	Air Collectors [m^2]		Total [m^2]	Installed capacity [MW_{th}]
	unglazed	glazed		
Canada	436,767	56,214	492,981	345
Australia	250,000	10,000	260,000	182
Japan		230,888	230,888	161
United States	129,595	71,000	201,595	141
China	20,817	23,000	43,819	31
United Kingdom	24,600		24,600	17
Denmark	4,300	18,000	22,300	16
Germany		16,720	16,720	12
Turkey	13,570		13,570	10
India		12,400	12,400	9
France (mainland)	10,758	1,100	11,858	8

By the end of 2021, 1 GW_{th} (1.44 million m^2) of glazed and unglazed air collectors was installed worldwide. The annual worldwide market in 2021 was in the range of 38 MW_{th} (54,193 m^2).

Using solar air collectors for space heating is not common in Europe. In North America, however, 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 can be creative in integrating solar air heaters into building facades.

Canada leads the solar air collector market with 345 MW_{th}

6 Detailed global market data and country statistics in 2021

Solar district heating Sigmaringen in Germany with 2,312 m² collector area in connection with a 400 m³ heat storage
Photo: Ritter Energie- und Umwelttechnik GmbH & Co. KG

The following chapters of the report provide detailed solar thermal market figures for the year 2021 and country figures for 71 countries.

Background of the 2021 data

The figures in the following chapters represent the collector area in operation in 2021, not the cumulated collector area installed in a country, meaning that system lifetimes are considered. To determine the collector area and operation capacity, 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 13 years is used for 2021, increasing to 14 years in 2022. For Germany, a lifetime of 25 years was used in accordance with accumulated market statistic figures for Germany published by BSW[32].

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.

6.1 General market overview of the total installed capacity in operation

Installation of thermosiphon systems in Mozambique
Photo: Rudi Moschik, AEE INTEC

By the end of 2021, an installed capacity of 524 GW_{th}, corresponding to a total of 748 million m^2 of collector area, was in operation worldwide.

The vast majority of the total capacity in operation was installed in China (381.6 GW_{th}) and Europe (62.2 GW_{th}), which accounted for 84.7% of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (19.2 GW_{th}), Latin America and Caribbean (19.0 GW_{th}), Asia excluding China (17.8 GW_{th}), the MENA[33] countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (7.8 GW_{th}), Australia and New Zealand (7.0 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 (2.4 GW_{th}). The market volume of "all other countries" is estimated to be 5% of the total installations, excluding China (7.1 GW_{th}).

[32] Bundesverband Solarwirtschaft e.V.
[33] Middle East and North Africa

Figure 20: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2021

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 and the Caribbean: Argentina, Barbados, Brazil, Chile, Mexico, Panama, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

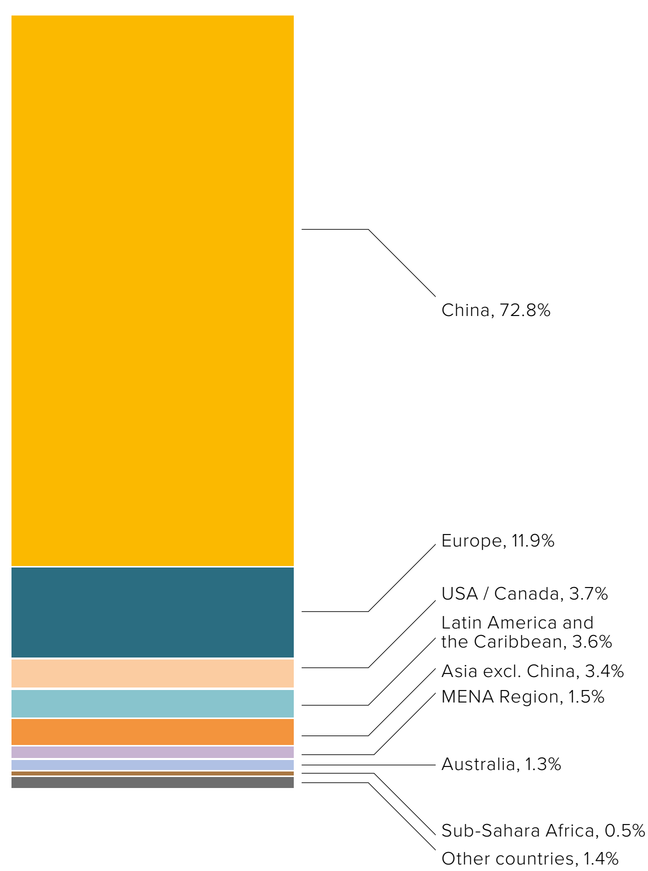

Table 8: Total capacity in operation in 2021 [MW_{th}]

Country	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		205.4	8.6			214
Argentina	85.5	63.8	118.2	0.0	0.3	268
Australia	4,124.2	2,380.7	176.0	175.0	7.0	6,863
Austria	146.9	3,131.8	58.4		5.1	3,342
Barbados+		180.7				181
Belgium	31.5	414.2	77.5			523
Bhutan		0.3				0.3
Botswana		11.2	1.8			13
Brazil	5,824.3	8,352.2	162.1			14,339
Bulgaria		120.5	4.1			125
Burkina Faso+		2.3	1.0			3
Canada	503.5	48.9	36.2	305.7	39.3	934
Cape Verde		1.8				2
Chile	45.9	217.1	38.0		0.2	301
China		47,136.6	334,188.7	14.6	16.1	381,356
Croatia		186.1	9.3			195
Cyprus	1.5	601.6	16.5			620
Czech Republic	350.0	335.8	111.2			797
Denmark	14.4	1,278.0	6.4	3.0	12.6	1,314
Estonia		9.4	5.9			15
Finland	8.3	35.0	14.6			58
France (mainland)	58.4	1,460.5	132.6	7.5	0.8	1,660
France (overseas)		770.4	30.8			801
Germany	310.5	13,515.6	1,730.0		11.7	15,568
Ghana		3.1	1.4			5
Greece		3,606.5	16.0			3,623
Hungary	12.8	200.4	55.9	2.4	1.6	273
India	0.0	3,153.1	9,663.2	0.0	8.7	12,825
Ireland		202.4	89.7			292
Israel	27.3	3,477.9				3,505
Italy	30.7	3,073.7	480.5	0.1		3,585
Japan		2,010.6	29.8		161.6	2,202
Jordan*	4.2	687.7	190.5			882
Kenya		217.0	108.5			325
Latvia		26.6	2.4			29
Lebanon		259.3	273.3			533
Lesotho		1.7	2.8			4
Lithuania		6.9	9.8			17
Luxembourg		44.6	6.2			51
Malta		42.2	10.6			53
Mauritius**		93.0				93
Mexico	1,230.8	1,413.5	1,214.7	0.5	6.1	3,866
Morocco		676.9				677
Mozambique	0.1	0.0	2.1			2
Namibia	1.1	38.9	1.0			41
Netherlands	50.6	356.0	56.7			463
New Zealand***	4.9	100.1	6.8			111.8
Nigeria+		1.3	7.5	0.0	1.2	10
North Macedonia		53.2	40.8		0.0	94
Norway+	1.3	26.4	3.0	0.1	2.9	34
Palestinian Territories		1,350.7				1,351
Poland		1,886.7	350.3			
Panama		0.5				0.5
Portugal	1.5	898.8	21.4			922
Romania	0.2	94.2	80.2	0.6		175.2
Russia	0.1	16.7	2.7	0.0	0.0	20
Senegal+		3.3	3.6	0.0	0.8	8
Slovakia	0.7	115.9	19.8			136
Slovenia		89.4	16.5		0.0	106
South Africa	986.0	503.4	353.8			1,843
South Korea		1,040.4	312.0	0.4	0.2	1,353
Spain	114.6	3,109.8	173.9	6.8	1.6	3,407
Sweden	119.7	179.2	50.8			350
Switzerland	118.9	982.0	102.1			1,203
Taiwan+	1.4	1,175.9	93.3			1,271
Thailand****		110.3				110
Tunisia		791.1	49.1			840
Turkey		11,858.8	7,070.3	9.5		18,939
United Kingdom		653.0	246.7	17.2		917
United States	15,930.5	2,098.4	124.0	90.7	50.4	18,294
Uruguay		75.1				75
Zimbabwe		15.3	45.7			61
All other countries (5% solar thermal world market excluding China)	1,586.4	4,218.2	1,269.9	32.6	16.4	7,124
TOTAL	**31,729**	**131,500**	**359,587**	**667**	**345**	**523,827**

Note: If no data is given: no reliable database for this collector type is available
* Total capacity in operation refers to the year 2014
** Total capacity in operation refers to the year 2015
*** Total capacity in operation refers to the year 2009
**** Total capacity in operation refers to the year 2016
\+ Total capacity in operation refers to the year 2020

Table 9: Total installed collector area in operation in 2021 [m^2]

Country	Water Collectors [m^2]			Air Collectors [m^2]		TOTAL [m^2]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		293,383	12,230			305,613
Argentina	122,124	91,139	168,854	60	474	382,651
Australia	5,891,734	3,400,996	251,429	250,000	10,000	9,804,159
Austria	209,865	4,474,008	83,413		7,268	4,774,554
Barbados+		258,192				258,192
Belgium	45,000	591,724	110,700			747,424
Bhutan		460				460
Botswana		16,061	2,614			18,675
Brazil	8,320,474	11,931,663	231,592			20,483,729
Bulgaria		172,107	5,870			177,977
Burkina Faso+		3,282	1,399			4,681
Canada	719,239	69,891	51,737	436,767	56,214	1,333,848
Cape Verde		2,613				2,613
Chile	65,550	310,077	54,305		300	430,232
China		67,338,000	477,412,430	20,819	23,000	544,794,250
Croatia		265,893	13,308			279,201
Cyprus	2,213	859,430	23,567			885,210
Czech Republic	500,000	479,677	158,826			1,138,503
Denmark	20,500	1,825,742	9,197	4,300	18,000	1,877,739
Estonia		13,358	8,360			21,718
Finland	11,800	49,998	20,788			82,586
France (mainland)	83,400	2,086,420	189,440	10,758	1,100	2,371,118
France (overseas)		1,100,620	43,980			1,144,600
Germany	443,620	19,308,064	2,471,388		16,720	22,239,792
Ghana		4,470	2,058			6,528
Greece		5,152,200	22,800			5,175,000
Hungary	18,300	286,294	79,850	3,418	2,300	390,162
India	0	4,504,364	13,804,626	0	12,400	18,321,390
Ireland		289,166	128,127			417,293
Israel	39,000	4,968,434				5,007,434
Italy	43,800	4,391,058	686,455	120		5,121,433
Japan		2,872,248	42,587		230,888	3,145,723
Jordan*	5,940	982,482	272,084			1,260,506
Kenya		309,984	154,992			464,975
Latvia		38,050	3,490			41,540
Lebanon		370,437	390,422			760,859
Lesotho		2,371	4,046			6,417
Lithuania		9,811	14,050			23,861
Luxembourg		63,706	8,900			72,606
Malta		60,318	15,079			75,397
Mauritius**		132,793				132,793
Mexico	1,758,293	2,019,282	1,735,322	752	8,773	5,522,422
Morocco		967,000				967,000
Mozambique	136	48	2,949			3,133
Namibia	1,560	55,619	1,393			58,573
Netherlands	72,320	508,520	80,930			661,770
New Zealand***	7,025	142,975	9,644			159,645
Nigeria+		1,866	10,782	0	1,670	14,318
North Macedonia		76,039	58,329		32	134,400
Norway+	1,849	37,705	4,349	200	4,106	48,210
Palestinian Territories		1,929,522				1,929,522
Panama		665				665
Poland		2,695,230	500,460			
Portugal	2,130	1,284,064	30,570			1,316,764
Romania	340	134,519	114,590	800		250,249
Russia	137	23,919	3,876	2	64	27,998
Senegal+		4,741	5,083	0	1,203	11,027
Slovakia	1,000	165,540	28,270			194,810
Slovenia		127,739	23,600		10	151,349
South Africa	1,408,585	719,089	505,359			2,633,033
South Korea		1,486,336	445,760	600	300	1,932,996
Spain	163,736	4,442,514	248,463	9,750	2,250	4,866,713
Sweden	171,000	255,937	72,578			499,515
Switzerland	169,800	1,402,900	145,800			1,718,500
Taiwan+	1,937	1,679,874	133,244			1,815,055
Thailand****		157,536				157,536
Tunisia		1,130,157	70,104			1,200,261
Turkey		16,941,182	10,100,454	13,570		27,055,206
United Kingdom		932,866	352,402	24,600		1,309,868
United States	22,757,856	2,997,722	177,100	129,595	72,000	26,134,273
Uruguay		107,255				107,255
Zimbabwe		21,848	65,290			87,138
All other countries (5% of world market excluding China)	2,266,330	6,025,958	1,814,172	46,594	23,477	10,176,531
TOTAL	45,326,593	187,857,154	513,695,866	952,706	492,550	748,324,868

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

* Total collector area in operation refers to the year 2014

** Total collector area in operation refers to the year 2015

*** Total collector area in operation refers to the year 2009

**** Total collector area in operation refers to the year 2017

\+ Total collector area in operation refers to the year 2020

The total installed capacity in operation in 2021 was divided into flat plate collectors (FPC): 131.9 GW_{th} (188.4 million m^2), evacuated tube collectors (ETC): 359.4 GW_{th} (513.5 million m^2), unglazed water collectors: 31.7 GW_{th} (45.3 million m^2), and glazed and unglazed air collectors: 1.0 GW_{th} (1.4 million m^2).

With a global share of 68.6%, evacuated tube collectors were the predominant solar thermal collector technology, followed by flat plate collectors at 25.2% and unglazed water collectors at 6.2% (Figure 21). 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 in 2021 (Figure 22). Europe's share of evacuated tube collectors stands at 17.9% and the share of unglazed water collectors at 2.2% in 2021.

Roof integrated flat plate collectors
Photo: Wagner & Co./ Solar Heat Europe

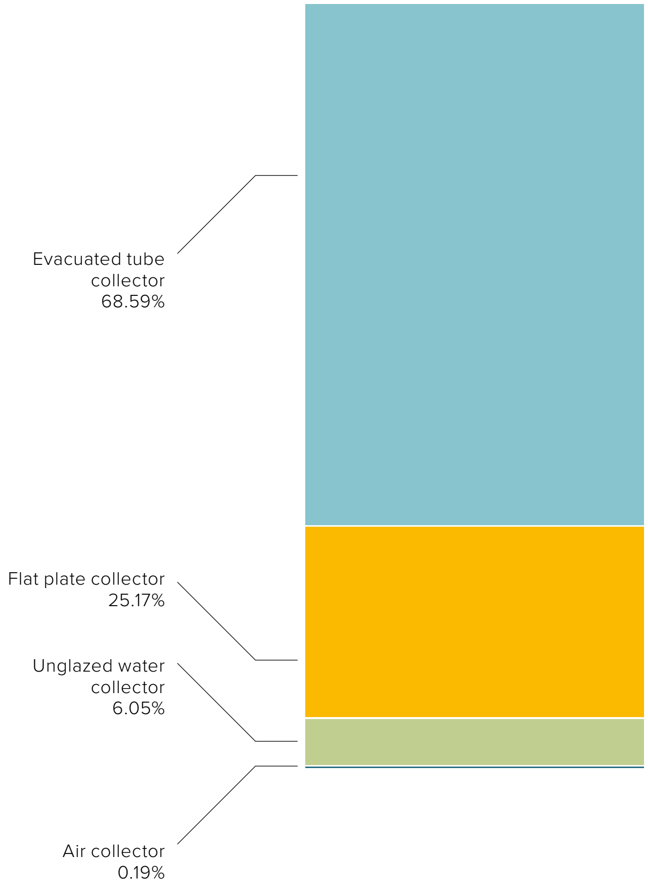

Figure 21: Distribution of the total installed capacity in operation by collector type in 2021 – WORLD

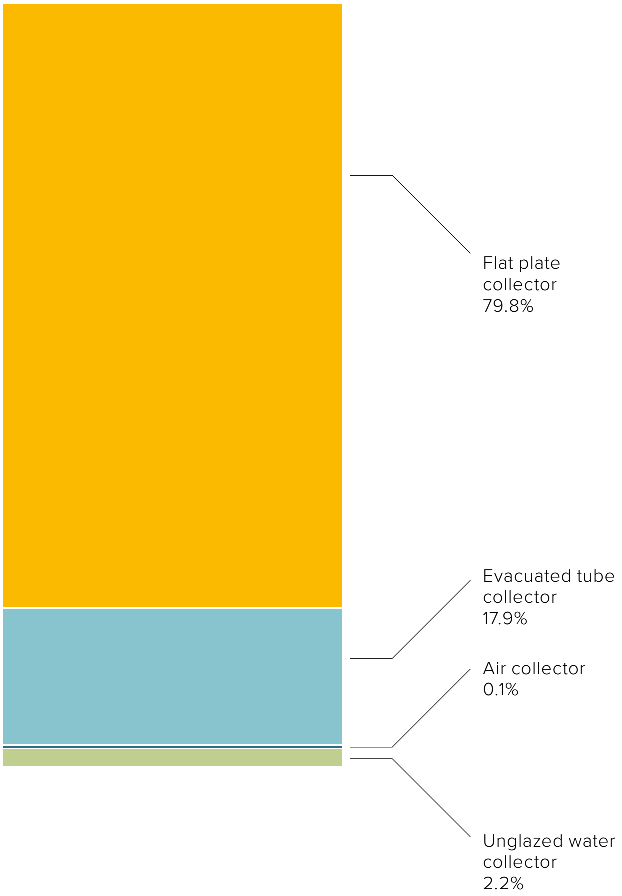

Figure 22: Distribution of the total installed capacity in operation by collector type in 2021 – EUROPE
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom

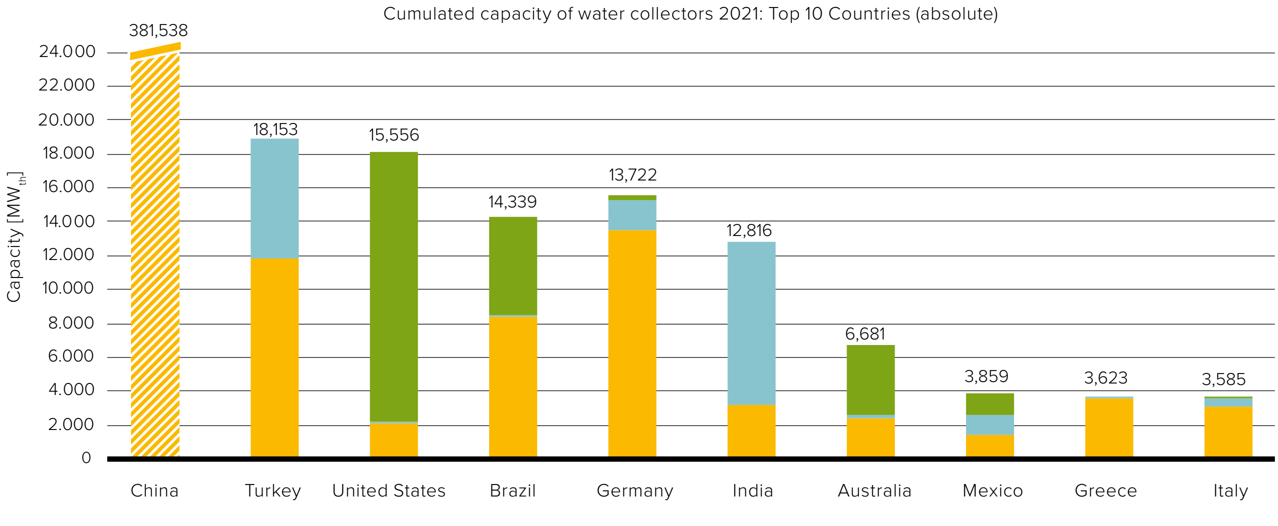

Figure 23: Top 10 countries of cumulated water collector installations in 2021 (absolute figures in MW_{th})

Compared to the year 2020, the rankings remain the same. 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, there has been a strong trend toward evacuated tube collector technology over the past several years.

The top 10 countries with the highest market penetration per capita are shown in Figure 24. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2021 per 1,000 inhabitants were Barbados (599 kW_{th}/1,000 inhabitants), Cyprus (484 kW_{th}/1,000 inhabitants), Israel (399 kW_{th}/1,000 inhabitants), Austria (376 kW_{th}/1,000 inhabitants), Greece (343 kW_{th}/1,000 inhabitants), the Palestinian Territories (275 kW_{th}/1,000 inhabitants), China (271 kW_{th}/1,000 inhabitants), Australia (259 kW_{th}/1,000 inhabitants), France (overseas) (241 kW_{th}/1000 inhabitants) and Turkey (229 kW_{th}/1,000 inhabitants).

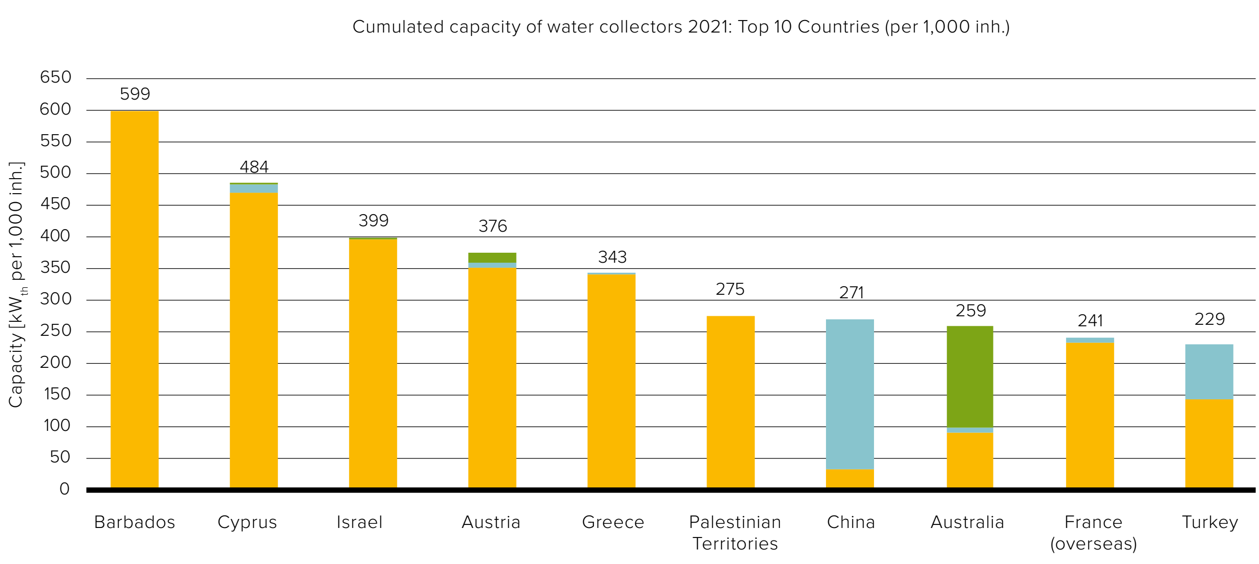

Figure 24: Top 10 countries by cumulated water collector installations per 1,000 inhabitants in 2021 (relative figures in kW_{th})

6.2
Total capacity of glazed water collectors in operation

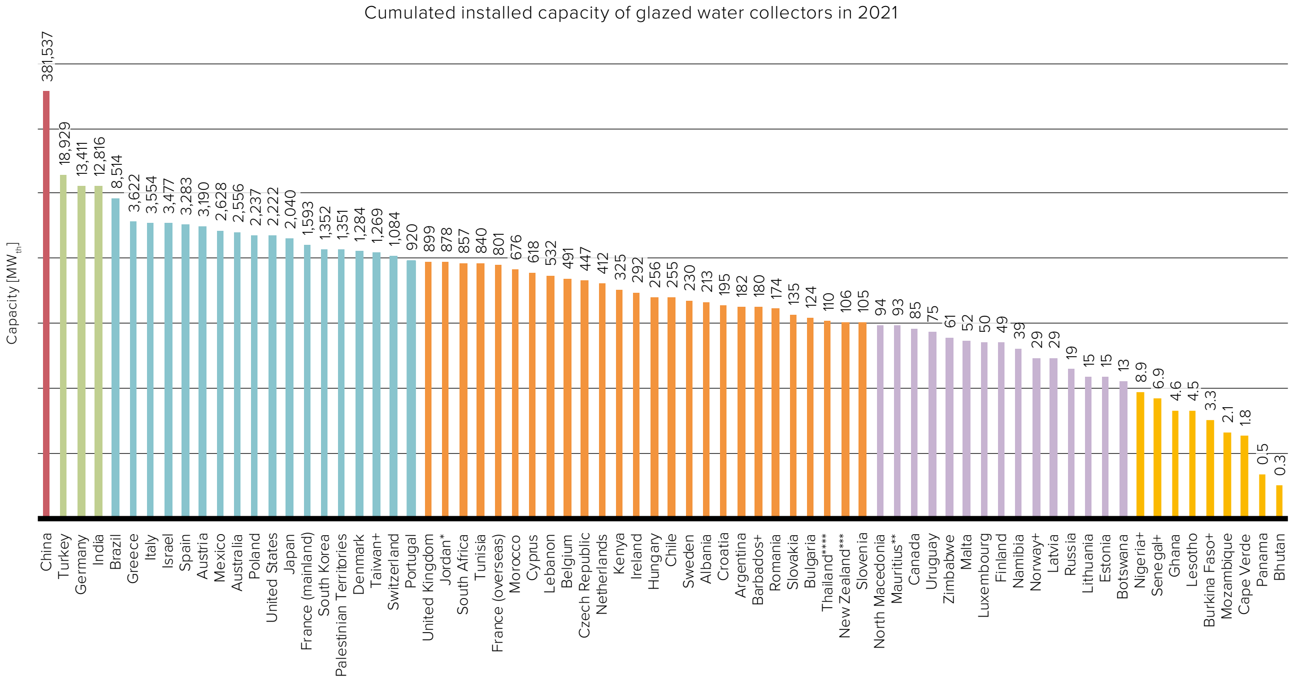

Figure 25: Total capacity of glazed water collectors in operation by the end of 2021

With 381.5 GW_{th}, China was once again the overriding leader in total installed capacity of glazed water collectors in 2021. Turkey, Germany and India follow with installed capacities between 20 GW_{th} and 10 GW_{th}. (Figure 25).

In terms of the total installed capacity of glazed water collectors in operation per 1,000 inhabitants, five countries continued their dominance: 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).

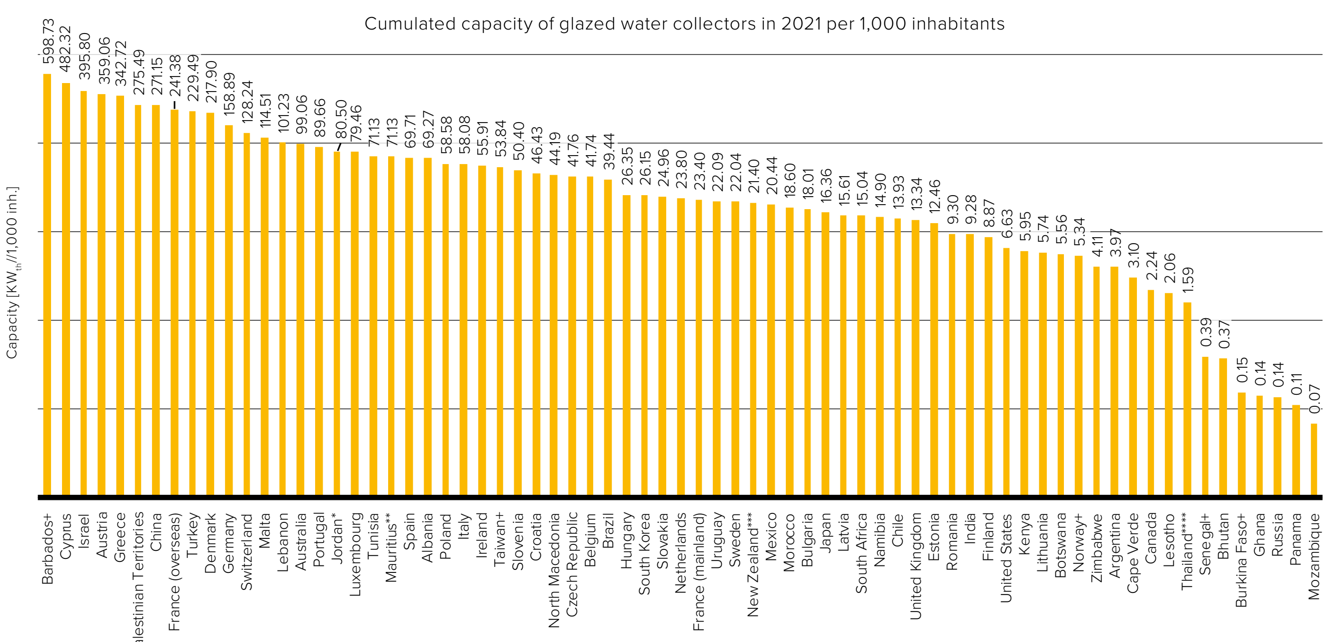

Figure 26: Total Capacity of glazed water collectors in operation in kWth per 1,000 inhabitants in 2021

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

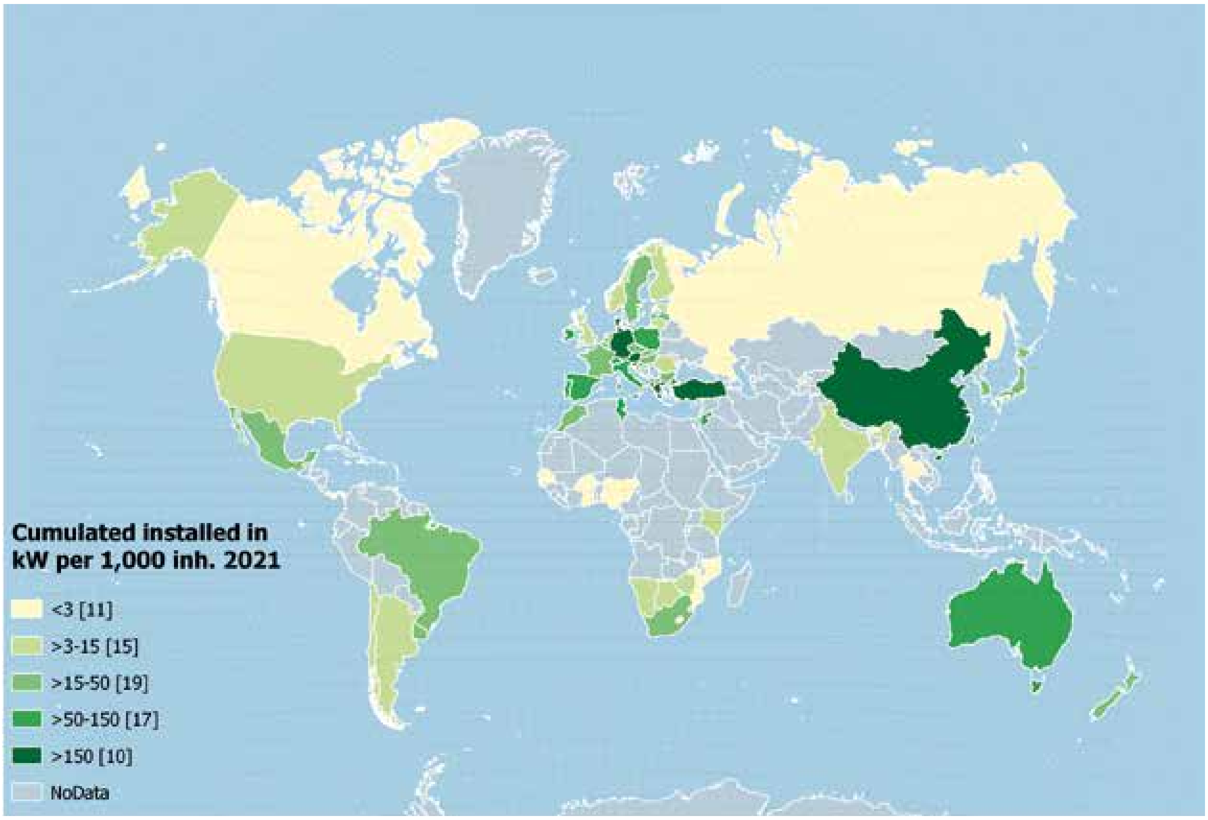

Figure 27: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants – WORLD

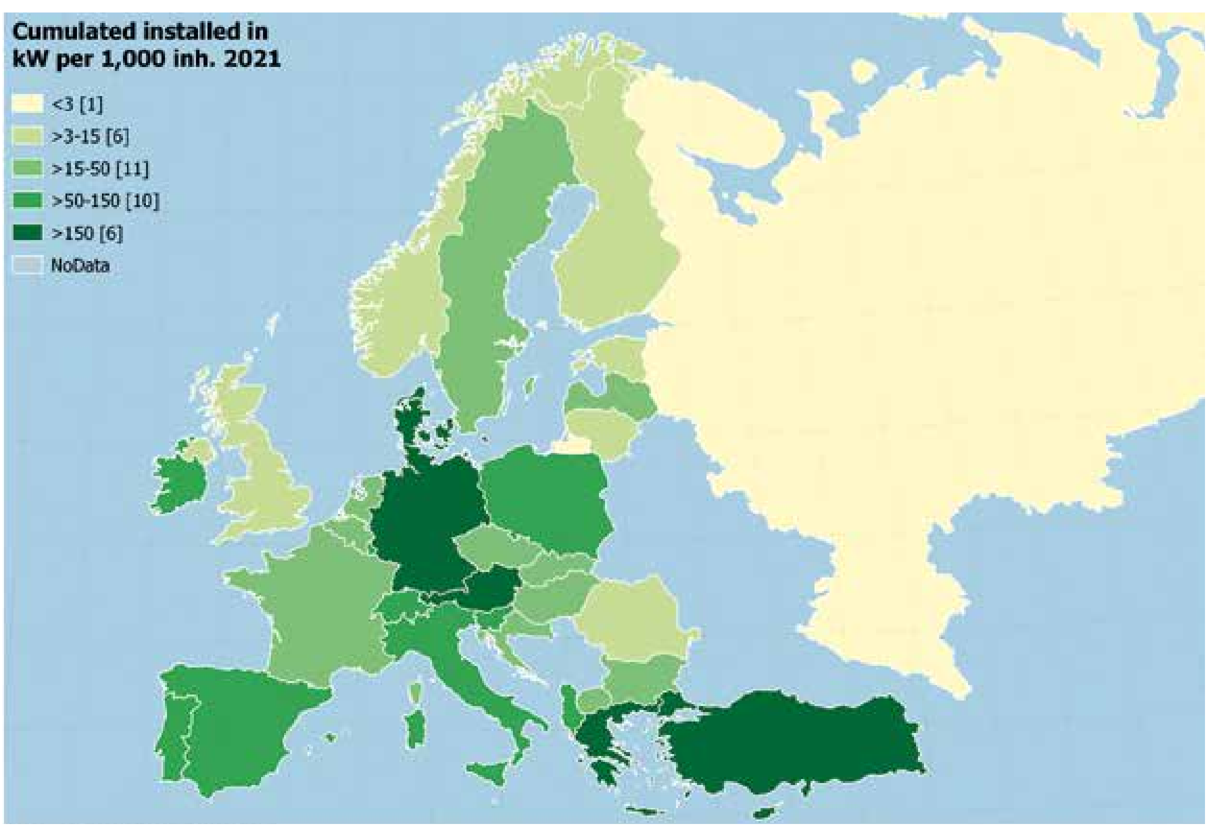

Figure 28: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants – EUROPE

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

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 29). 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.

Photo: Helioclim France / Solar-Payback

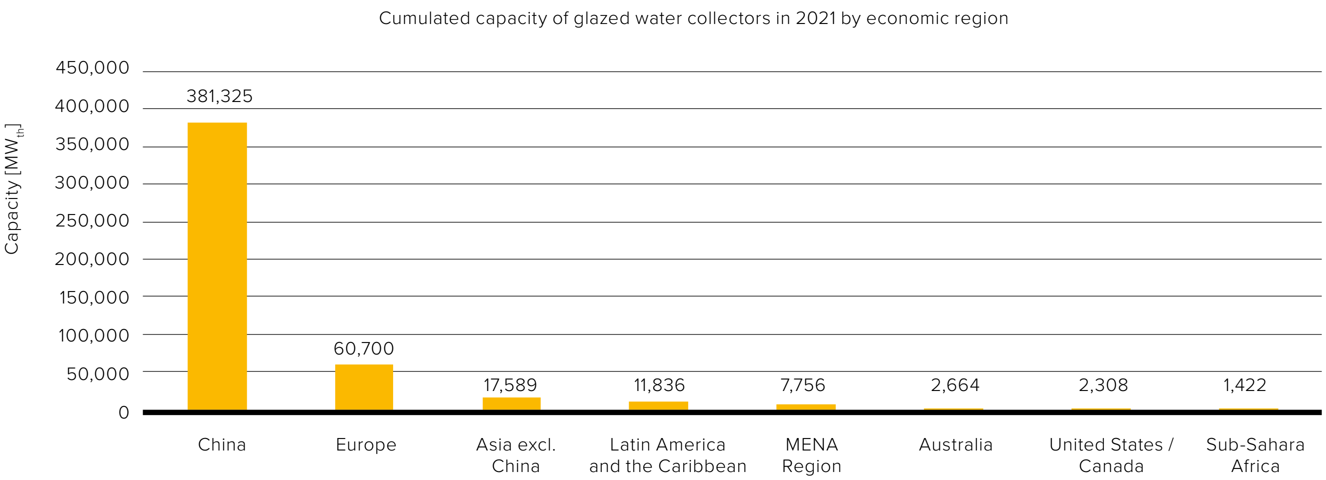

Figure 29: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2021

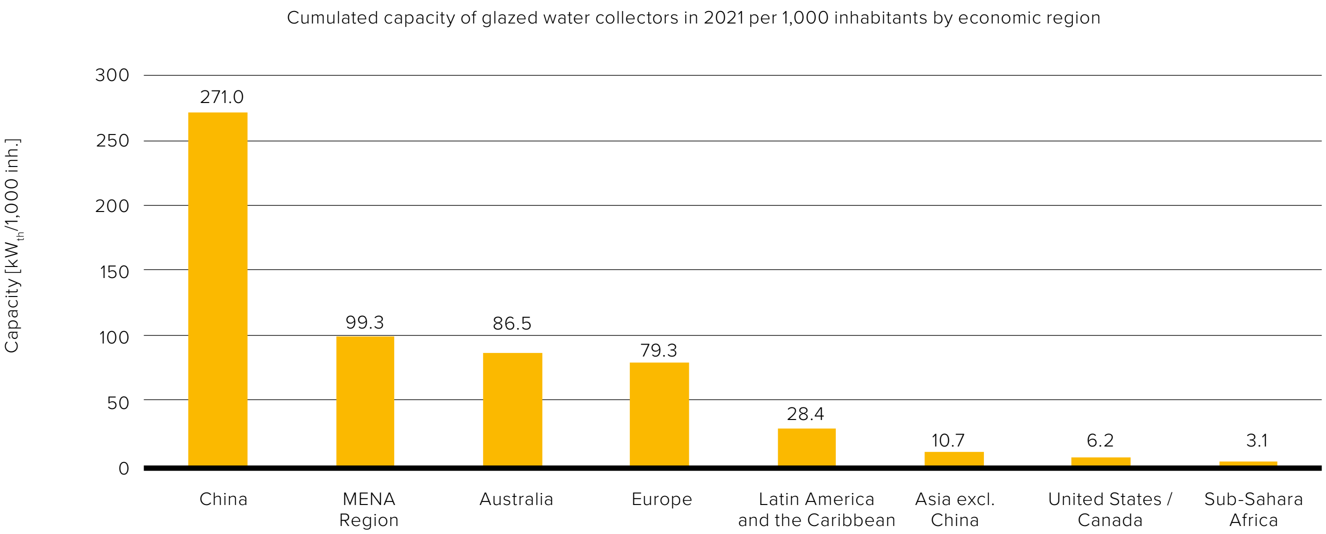

Figure 30: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in kW$_{th}$ per 1,000 inhabitants in 2021

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 and the Caribbean: Argentina, Barbados, Brazil, Chile, Mexico, Panama, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

6.4 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%[34] in 2005 to just 6% in 2021. Figure 31 and Figure 32 show the total installed capacity of unglazed water collectors and total installed capacity of unglazed water collectors per 1,000 inhabitants at the end of 2021.

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

Solar water heating system in a monastery in Bhutan
Photo: Werner Weiss, AEE INTEC

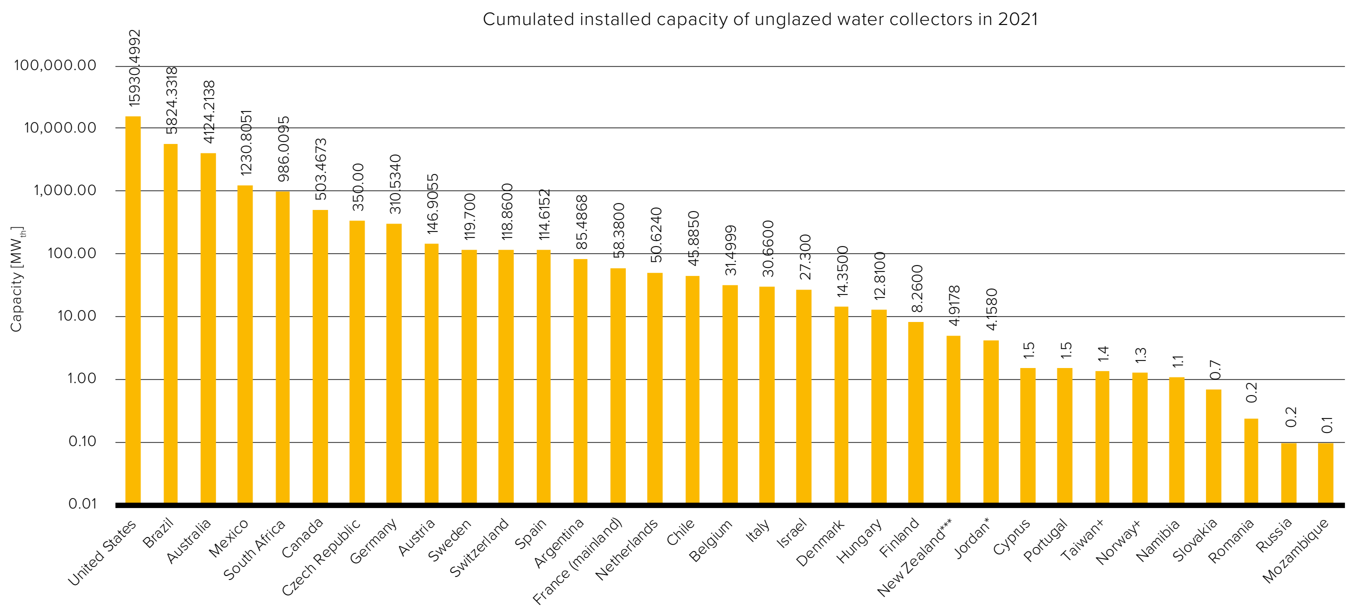

Figure 31: Total capacity of unglazed water collectors in operation in 2021

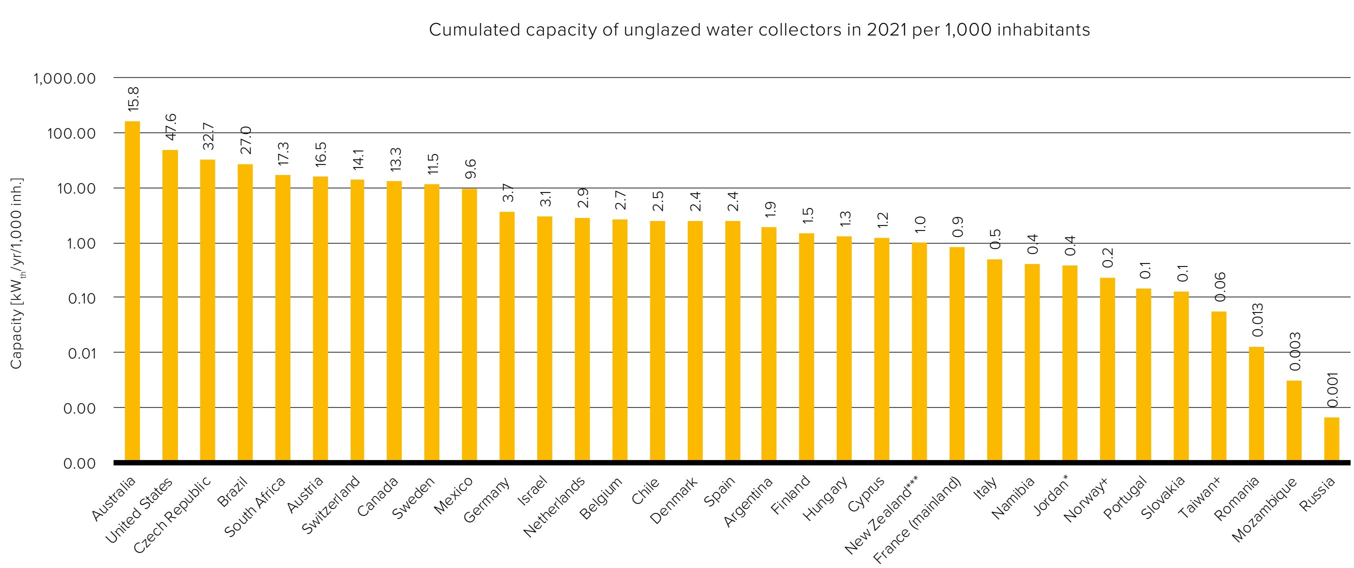

Figure 32: Total capacity of unglazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2021

6.5
Newly installed capacity in 2021 and market development

In 2021, a total capacity of 25.4 GW_{th}, corresponding to 36.3 million m^2 of new solar collectors, was installed worldwide.

The main markets were China (17.6 GW_{th}) and Europe (2.9 GW_{th}), accounting for 80.7% of all 2021 collector installations. The rest of the market was shared between Latin America and the Carribean (1.6 GW_{th}), Asia excluding China (1.4 GW_{th}), the United States and Canada (0.6 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 be 0.4 GW_{th} (559,000 m^2).

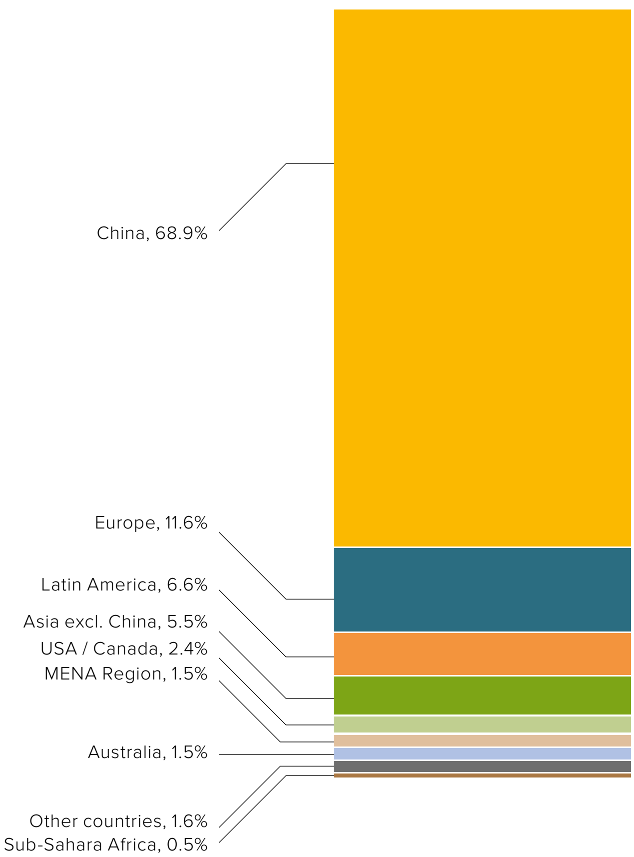

Figure 33: Share of newly installed capacity (glazed and unglazed water and air collectors) by economic regions in 2021

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, Brazil, Chile, Mexico, Panama, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

14th Avenue housing project in Johannesburg, South Africa. The project consists of 15 solar thermal systems with a total collector area of 531 m^2
Photo: ALT ENER PRO PTY LTD, South Africa

Table 10: Newly installed capacity in 2021 [MW_{th}/a]

Country	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania*		7.5	1			8
Argentina	24.1	16.4	28	0	0	69
Australia	266.0	92.1	10			368
Austria	0.7	45.2	3		1	49
Belgium		9.5	2			12
Bhutan		0.3				0.3
Botswana		0.8	0			1
Brazil	664.3	581.9	27			1,273
Bulgaria		16.5	0.4			17
Canada*	1.0	0.2	0.2	4	1	6
Cape Verde		0.1				0.1
Chile*		17.6				18
China		4,974.9	12,337	9	14	17,335
Croatia		9.0				9
Cyprus		49.3	0.0			49
Czech Republic		12.0	1.3			13
Denmark		5.6	0.0	0		6
Estonia		1.0				1
Finland		2.3				2
France (mainland)	0.4	44.7	1.2	0		47
France (overseas territories)		63.3				63
Germany		367.2	81.9			449
Ghana		0.5	0.3			1
Greece		251.0	0.3			251
Hungary		15.4				15
India		105.9	1,245.9		0	1,352
Ireland		2.7				3
Israel		245.0	0.0			245
Italy		145.3	12.2	0		158
Japan		34.8	0.4		1	36
Kenya*		5.9	2.9			9
Latvia		1.2				1
Lebanon		6.2	11.6			18
Lesotho		0.3	1.1			1
Lithuania		0.5	0.7			1
Luxembourg		2.5	0.0			3
Malta		0.7	0.2			1
Mexico	80.5	90.2	111.4			282
Morocco		50.2	0.0			50
Mozambique			0.4			0
Namibia		2.9				3
Netherlands	1.8	13.7	5.9			21
Nigeria*		0.3	2.5			3
North Macedonia		4.1	3.4		0	7
Palestinian Territories		37.4	0.0			37
Panama		0.5				0
Poland		130.3	2.1			132
Portugal		53.9				54
Romania	0.0	11.5				12
Russia	0.0	0.5	0.0			1
Slovakia	0.0	9.1				9
Slovenia		1.0				1
South Africa	40.2	11.3	46.4			98
Spain	1.4	99.1	6.2	4		110
Sweden		1.4				1
Switzerland	2.9	15.8	3.1			22
Tunisia		36.6	0.0			37
Turkey		688.8	661.5	1		1,351
United Kingdom		24.8	5.4			30
United States	565.9	35.2		2	1	604
Uruguay*		7.3	0.0			7
Zimbabwe			6.7			7
Other (5% of the world market excluding China)	86.8	183.5	120.3	0.6	0.2	391
TOTAL	1,736.0	8,645	14,743	21	17	25,162

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

Table 11: Newly installed collector area in 2021 [m^2/a]

Country	Water Collectors [m^2]			Air Collectors [m^2]		TOTAL [m^2]
	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	131,600	14,600			526,200
Austria	930	64,570	3,810		1,100	70,410
Belgium		13,600	3,000			16,600
Bhutan		460				460
Botswana		1,190	210			1,400
Brazil	948,931	831,223	38,509			1,818,663
Bulgaria		23,500	500			24,000
Canada*	1,475	261	321	6,000	1,000	9,057
Cape Verde		150				150
Chile*		25,183				25,183
China		7,107,000	17,623,914	13,119	20,000	24,764,033
Croatia		12,912				12,912
Cyprus		70,360	0			70,360
Czech Republic		17,097	1,903			19,000
Denmark		8,013				8,013
Estonia		1,468				1,468
Finland		3,223				3,223
France (mainland)	600	63,910	1,760	200		66,470
France (overseas territories)		90,440				90,440
Germany		524,500	117,000			641,500
Ghana		700	450			1,150
Greece		358,600	400			359,000
Hungary		22,050				22,050
India		151,267	1,779,873		15	1,931,155
Ireland		3,898				3,898
Israel		350,000				350,000
Italy		207,548	17,452	120		225,120
Japan		49,736	610		887	51,233
Kenya*		8,364	4,182			12,546
Latvia		1,648				1,648
Lebanon		8,910	16,547			25,457
Lesotho		396	1,584			1,980
Lithuania		700	1,000			1,700
Luxembourg		3,574				3,574
Malta		1,051	263			1,314
Mexico	114,940	128,880	159,180			403,000
Morocco		71,700				71,700
Mozambique			592			592
Namibia		4,201				4,201
Netherlands	2,620	19,590	8,400			30,610
Nigeria*		393	3,515			3,908
North Macedonia		5,868	4,800		20	10,688
Palestinian Territories		53,453				53,453
Panama		665				665
Poland		186,100	3,000			189,100
Portugal		77,045				77,045
Romania	0	16,439				16,439
Russia	0	729	4			733
Slovakia	0	13,000				13,000
Slovenia		1,439				1,439
South Africa	57,483	16,117	66,351			139,951
South Korea+				200	100	300
Spain	2,000	141,500	8,800	5,200		157,500
Sweden		1,955				1,955
Switzerland	4,090	22,630	4,470			31,190
Tunisia		52,340				52,340
Turkey		984,000	945,000	1,000		1,930,000
United Kingdom		35,387	7,675			43,062
United States	808,417	50,274		3,000	1,000	862,691
Uruguay*		10,418				10,418
Zimbabwe			9,570			9,570
Other (5% of the world market excluding China)	123,999	262,124	171,899	828	225	559,076
TOTAL	2,479,981	12,349,479	21,061,899	29,688	24,505	35,945,552

Note: If no data is given, no reliable database is available for this collector type.
* 0% growth assumed
\+ only air collectors reported (provided by John Hollick)

New installations in 2021 by collector type: flat plate collectors: 8.6 GW_{th} (12.4 million m^2), evacuated tube collectors: 15.0 GW_{th} (21.4 m^2), unglazed water collectors: 1.7 GW_{th} (2.5 million m^2), and glazed and unglazed air collectors: 0.04 GW_{th} (0.054 million m^2).

With a 59% share, evacuated tube collectors remain the most important solar thermal collector technology worldwide (Figure 34).

In a global context, this breakdown is mainly driven by the dominance of the Chinese market, where around 72% of all newly installed collectors in 2021 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82% in 2011 to 60% in 2020 while in the same time frame, flat plate collectors increased their share from 14.7% to 34%.

In Europe, the situation is almost the opposite of China, with 72.4% of all solar thermal collectors installed in 2021 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 72.4% in 2021. 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 27.2%.

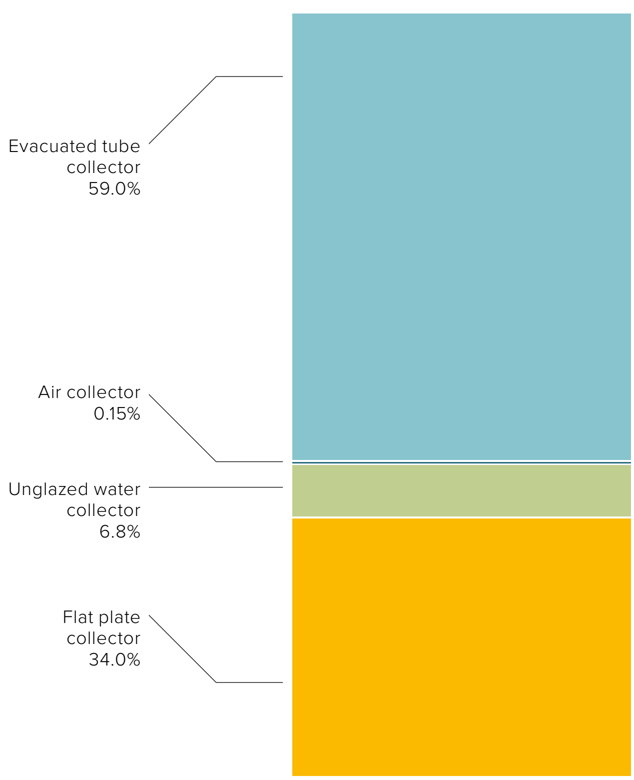

Figure 34: Distribution of the newly installed capacity by collector type in 2021 – WORLD

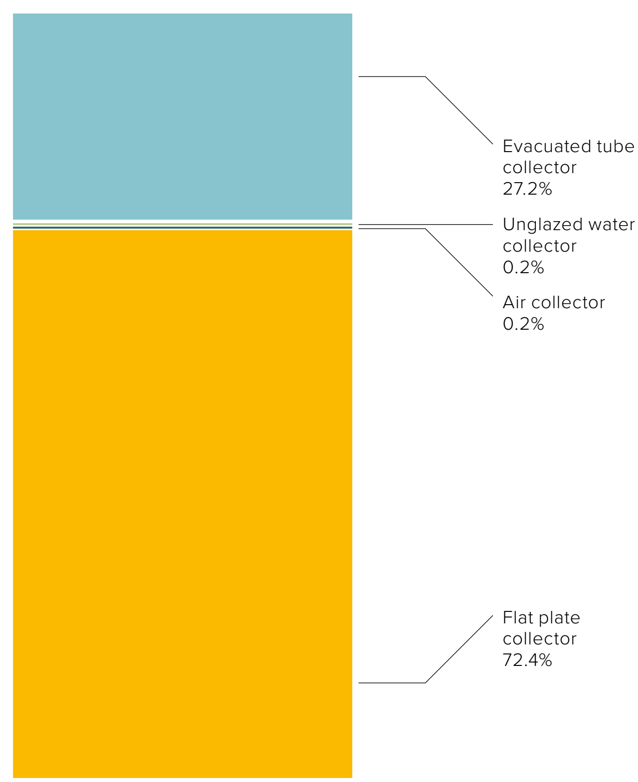

Figure 35: Distribution of the newly installed capacity by collector type in 2021 – EUROPE

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

Thermosiphon systems in Neom Tabuk, Saudi Arabia
Photo: Greenonetec Solarindustrie GmbH

Figure 34 shows the newly installed capacity of glazed and unglazed water collectors for the 10 leading markets in 2021 in total numbers. China remained the market leader in absolute terms, followed by India and Turkey. Brazil and the United States rank four and five and are ahead of Germany and Australia. Mexico, Greece and Israel are within the top 10 countries, ranking eighth to tenth.

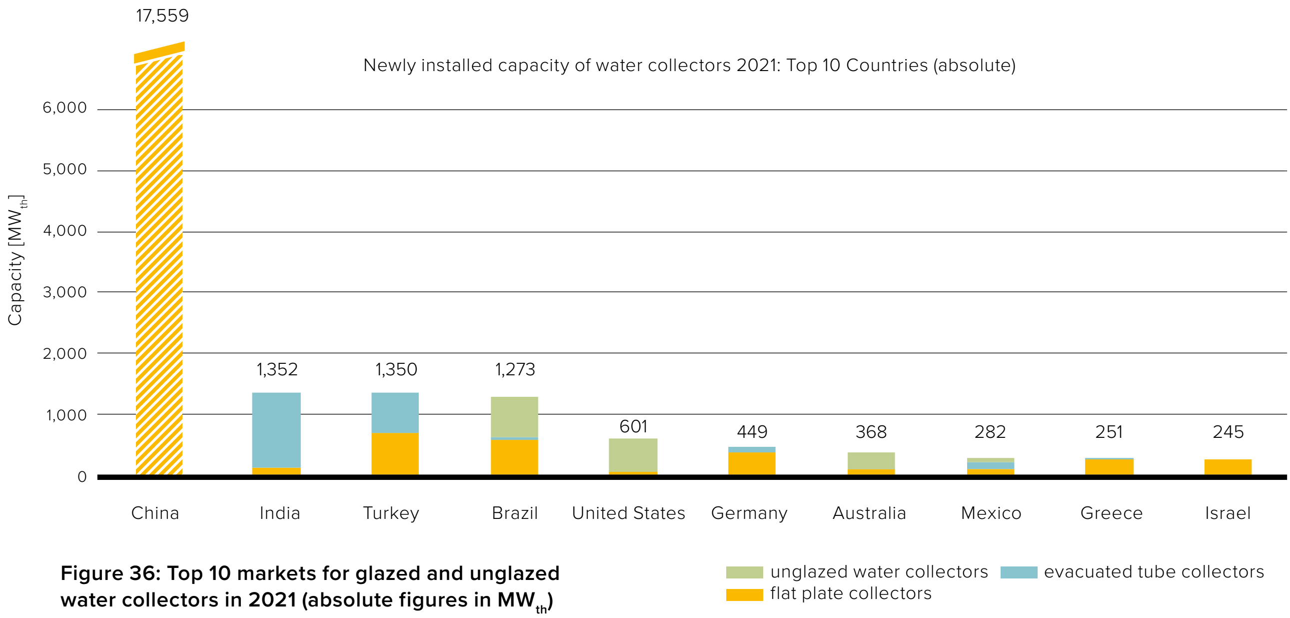

Figure 36: Top 10 markets for glazed and unglazed water collectors in 2021 (absolute figures in MW$_{th}$)

In terms of newly installed solar thermal capacity per 1,000 inhabitants in 2021, the top 10 countries are shown in Figure 37. Cyprus, Israel, Greece and France (overseas) rank first to fourth, followed by Turkey, Australia and China ranking fifth to seventh, the Palestinian Territories taking eighth place, Brazil ranking ninth and Austria tenth.

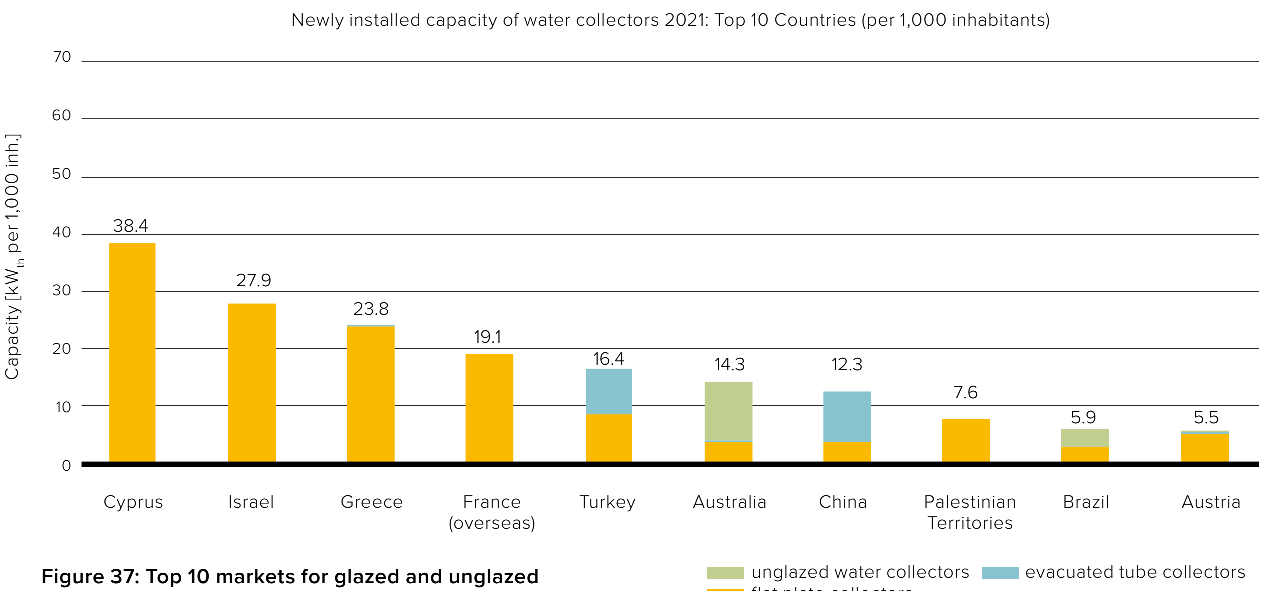

Figure 37: Top 10 markets for glazed and unglazed water collectors in 2021 (in kW$_{th}$ per 1,000 inhabitants)

6.6 Newly installed capacity of glazed water collectors

In 2021, glazed water collectors accounted for 94% of the total newly installed capacity. China was the most influential market in the global context (Figure 38).

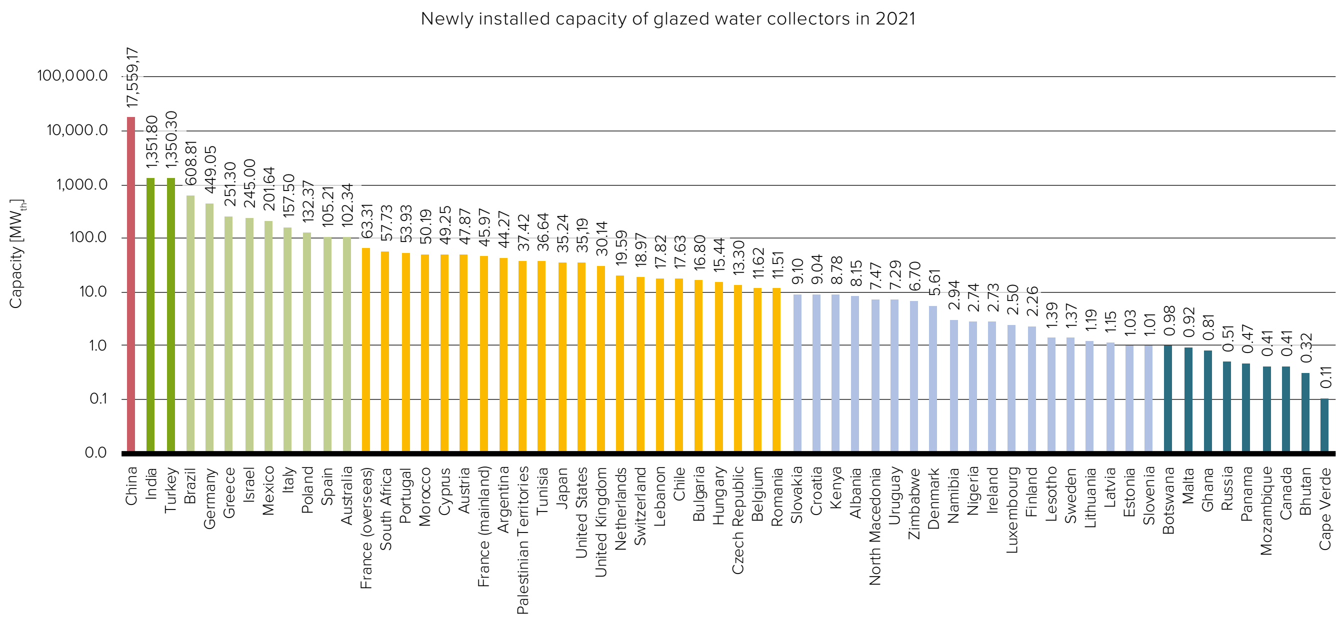

Figure 38: Newly installed capacity of glazed water collectors in 2021

In terms of newly installed glazed water collector capacity per 1,000 inhabitants, Cyprus is again the leader ahead of Israel Greece and France (overseas). In this respect, China ranks in 6th place (Figure 39).

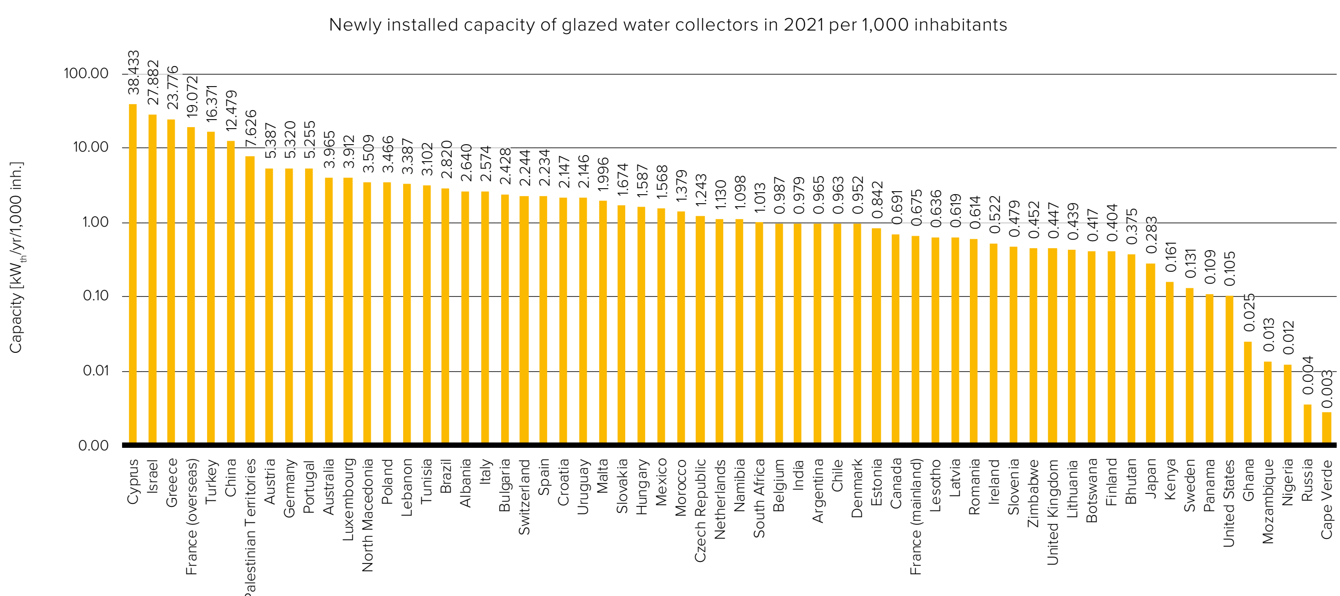

Figure 39: Newly installed capacity of glazed water collectors in 2021 in kW_{th} per 1,000 inhabitants

The following figures show the solar thermal market penetration per capita of the newly installed capacity in 2021 worldwide and in Europe.

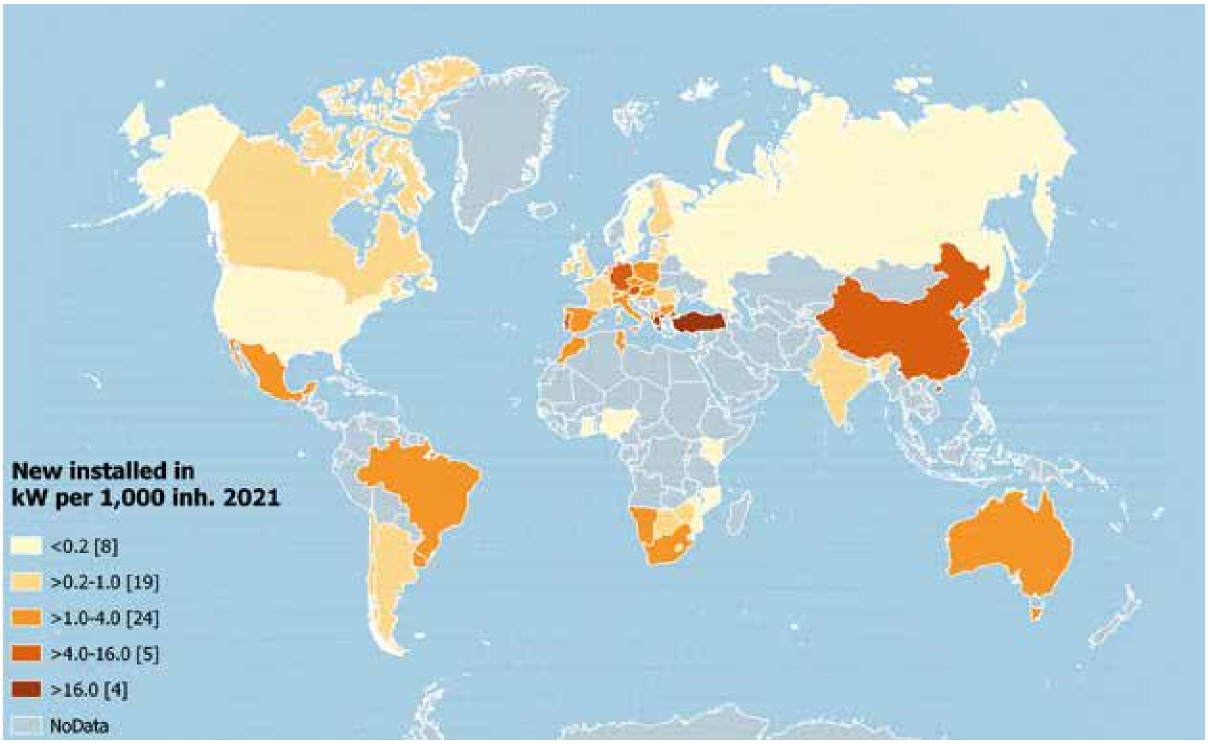

Figure 40: Newly installed capacity in 2021 in kW_{th} per 1,000 inhabitants – WORLD
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC)

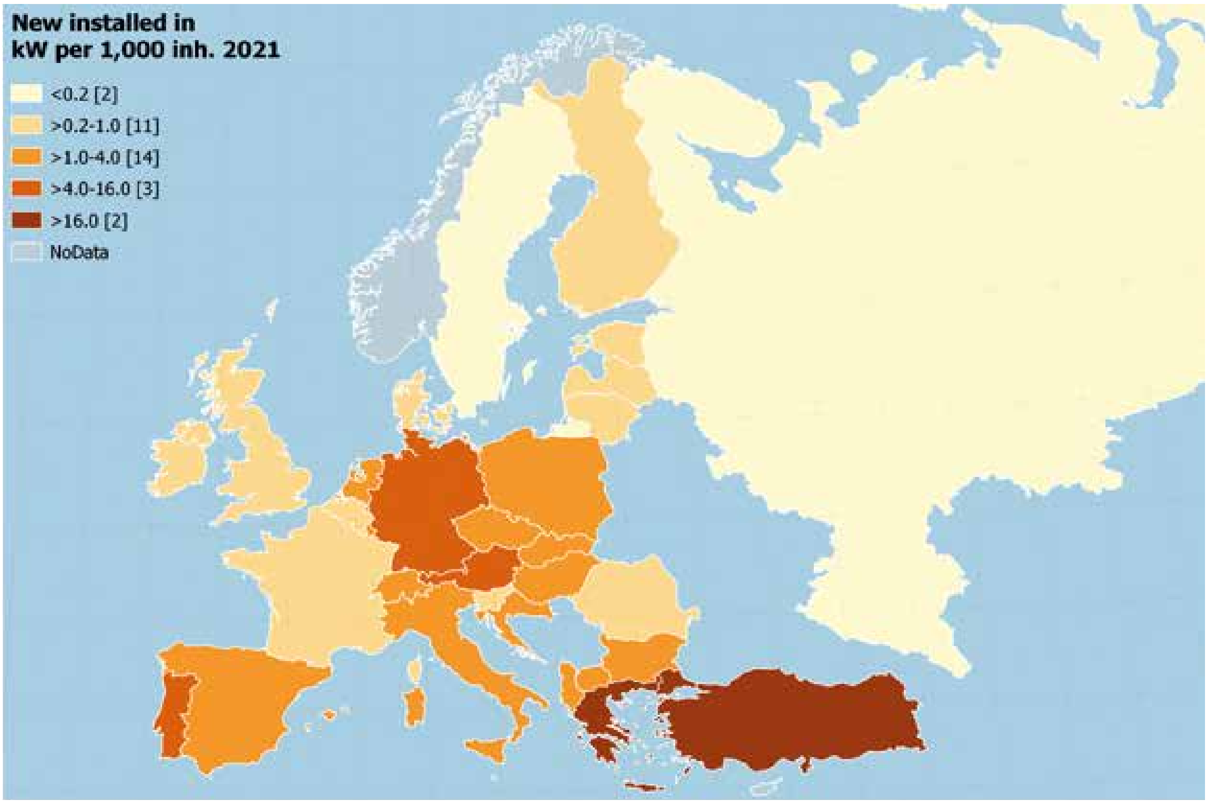

Figure 41: New Installed capacity in 2021 in kW_{th} per 1,000 inhabitants – EUROPE
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

6.7 Market development of glazed water collectors between 2000 and 2021

The worldwide market of glazed water collectors saw a steady upward trend between 2000 and 2011, which leveled off in 2012 and 2013 at around 50 GW_{th}. More or less sharp market declines characterized the years between 2014 and 2020. In 2021, the trend reversed with a growth of 1%. The newly installed glazed water collector capacity in 2021 equaled 23.4 GW_{th} (Figure 42).

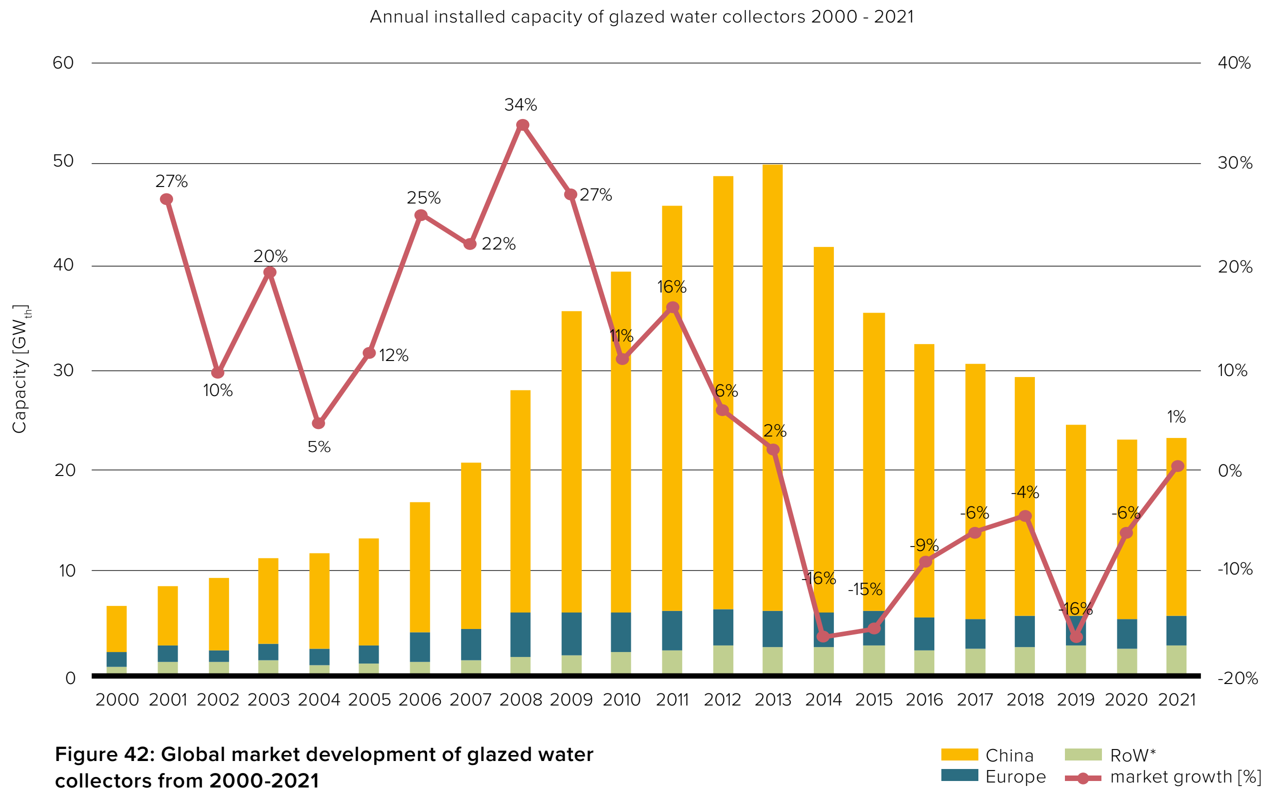

Figure 42: Global market development of glazed water collectors from 2000-2021

In 2000, the Chinese market was about three times as large as the European market, and by 2021, the Chinese market exceeded the European market by about six-fold (Figure 43).
Figure 43 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 shrank continuously since then, with a decrease of 1% from 2020 to 2021.

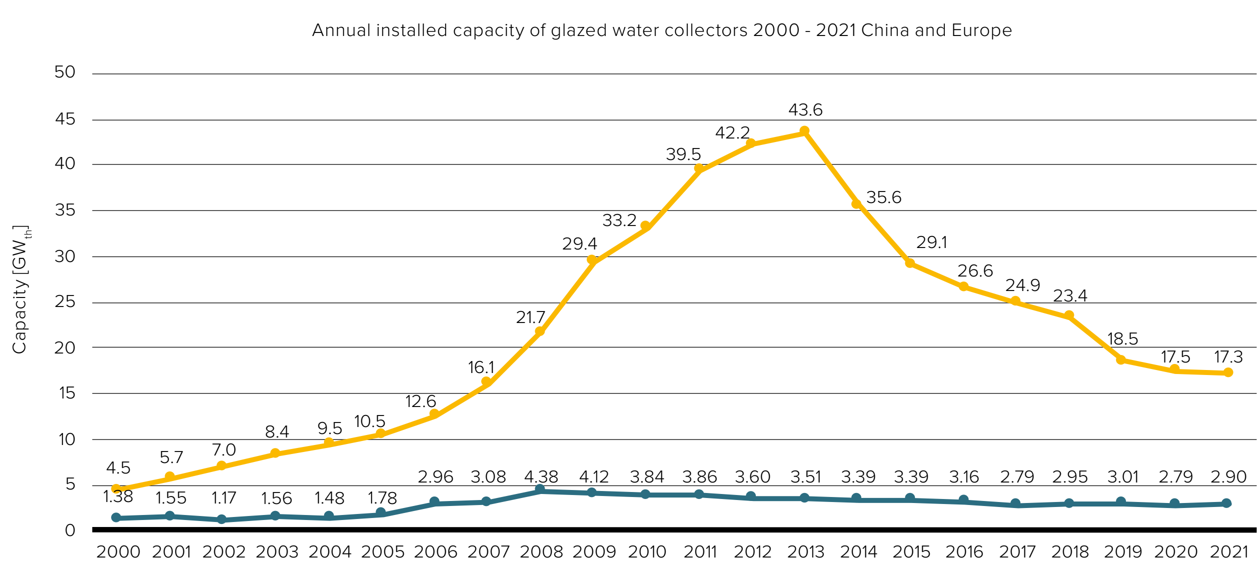

Figure 43: Market development of glazed water collectors in China and Europe 2000-2021

The European market peaked at 4.4 GW_{th} installed capacity in 2008 and has decreased steadily to 2.8 GW_{th} in 2017, with a slight recovery in 2019 and then down to 2.8 GW_{th} in 2020. In Europe, a slight increase can also be seen again in 2021. In the "remaining markets worldwide" (RoW), an upward trend is observed between 2002 and 2012. With the exception of 2016 and 2020, there has been continuous market growth in these countries since 2013 (Figure 44).

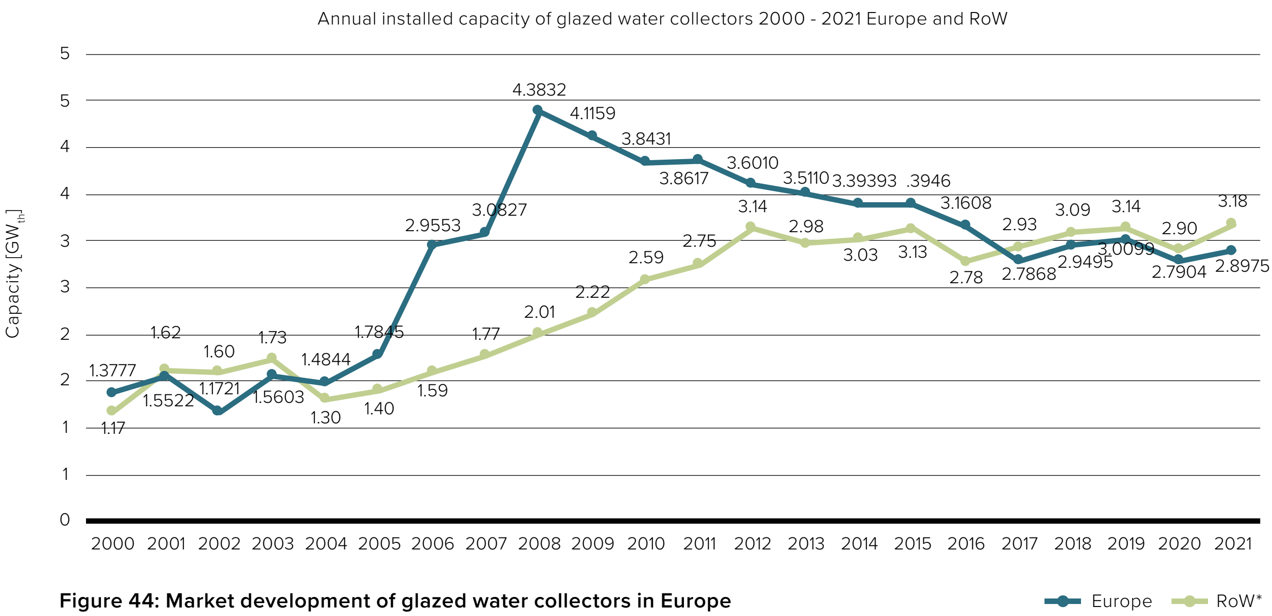

Figure 44: Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2021

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, Panama, 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 2021 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 44).

"Asia excl. China" is mainly influenced by the large Indian market. Other countries in this economic region with a significant solar thermal market are Japan and South Korea. Since 2000, this solar thermal market has almost quadrupled. Between 2000 and 2009, annual installations grew only slowly, but between 2010 and 2021, there was a clear upward trend. During this period, annual installations grew by a factor of 2.5.

Latin America showed the most steady and dynamic upward trend of all the economic regions.
The annual installed collector area increased ninefold between 2000 and 2021. The dominant Brazilian market, the large Mexican market and the evolving markets, for example, in Chile, are responsible for the positive growth rates.

Glazed water collector markets in the MENA countries grew steadily from 2000 to 2013. The market decline starting in 2014, shown in Figure 45, is explained by the fact that from 2015 on, there was no data for the two major markets – Morocco and Jordan – and the sales in the most important market, Israel, slightly decreased in 2020. In 2021, the MENA region did see a slight upward trend again.

The market volume for glazed water collectors in Australia was similar to that in Latin America and the MENA countries in 2009 and continued to shrink more or less continuously until 2021.

Sub-Sahara African markets have grown continuously since 2000, albeit at a very low level compared with other regions. In the United States and Canada, the decreasing trend continued with a significant decline in 2020.

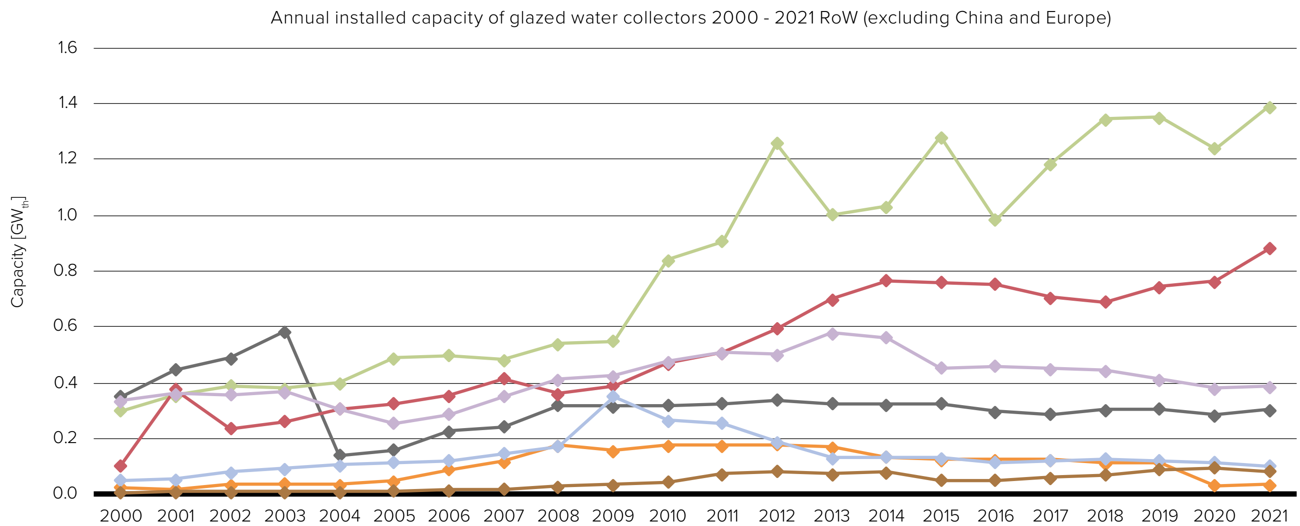

Figure 45: Market development of glazed water collectors in Latin America, United States / Canada, Sub-Sahara Africa, Asia, the MENA region and Australia (excluding China and Europe) from 2000 to 2021

Asia excl. China: Bhutan, India, Japan, South Korea, Taiwan, Thailand
Latin America: Argentina, Brazil, Chile, Mexico, Panama, 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 2021 (Figure 46).

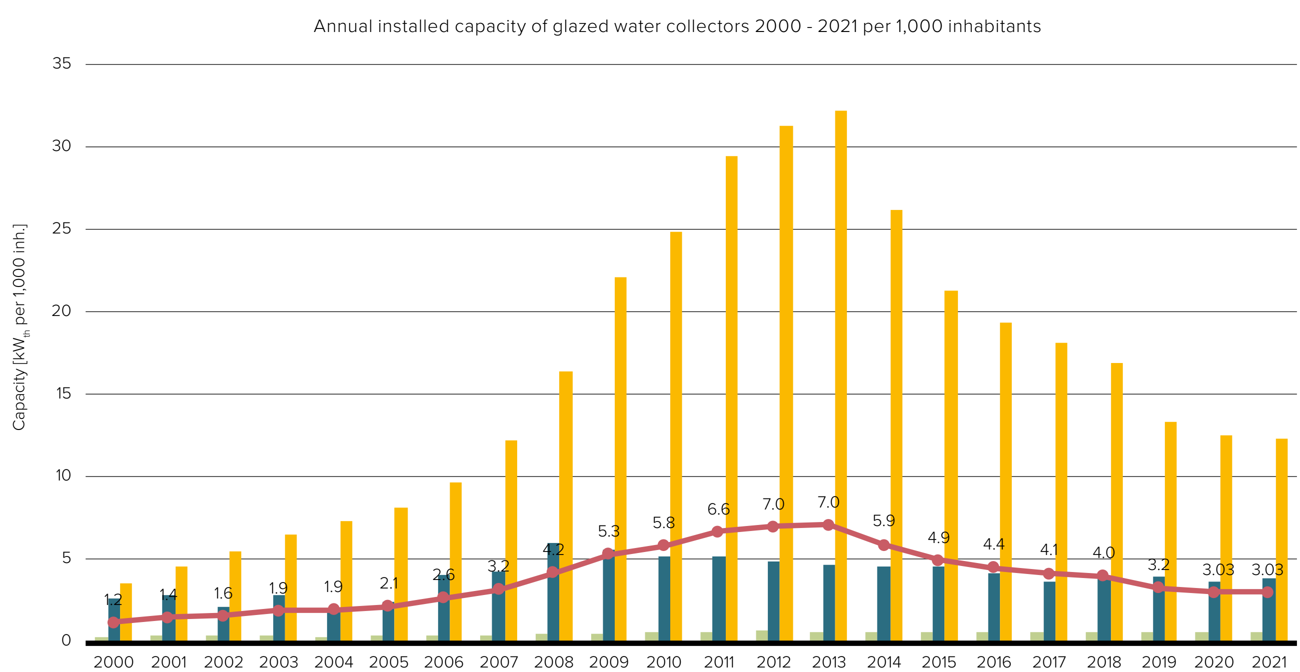

Figure 46: Annual installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2021

The fact that China suffered major market declines from 2014 to 2016 is reflected in the market penetration of glazed water collector installations per capita. The annual installed capacity rose from 3.5 kW_{th} per 1,000 inhabitants in 2000 and peaked at 32.2 kW_{th} per 1,000 inhabitants in 2013 and fell to 12.5 kW_{th} per 1,000 inhabitants in 2021.

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 3.8 kW_{th} per 1,000 inhabitants in 2021.

6.8 Market development of unglazed water collectors between 2000 and 2021

With a newly installed capacity of 1.7 GW_{th} in 2021, unglazed water collectors accounted for 6.8% of the total installed solar thermal capacity (Figure 32). Compared to 2020, the market increased mainly because of market increases in Brazil (20%) and the United States (33%).

The most important markets for unglazed water collectors in 2021 were the United States (566 MW_{th}), Brazil (664 MW_{th}) and Australia (266 MW_{th}). Mexico reported 80 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 (2.9 MW_{th}), Spain (1.4 MW_{th}) and the Netherlands (1.8 MW_{th}) also reported unglazed water collector installations in 2021.

Solar system for a public outdoor pool
Photo: SOLKAV, 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 2019). 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 the United States and Brazil.

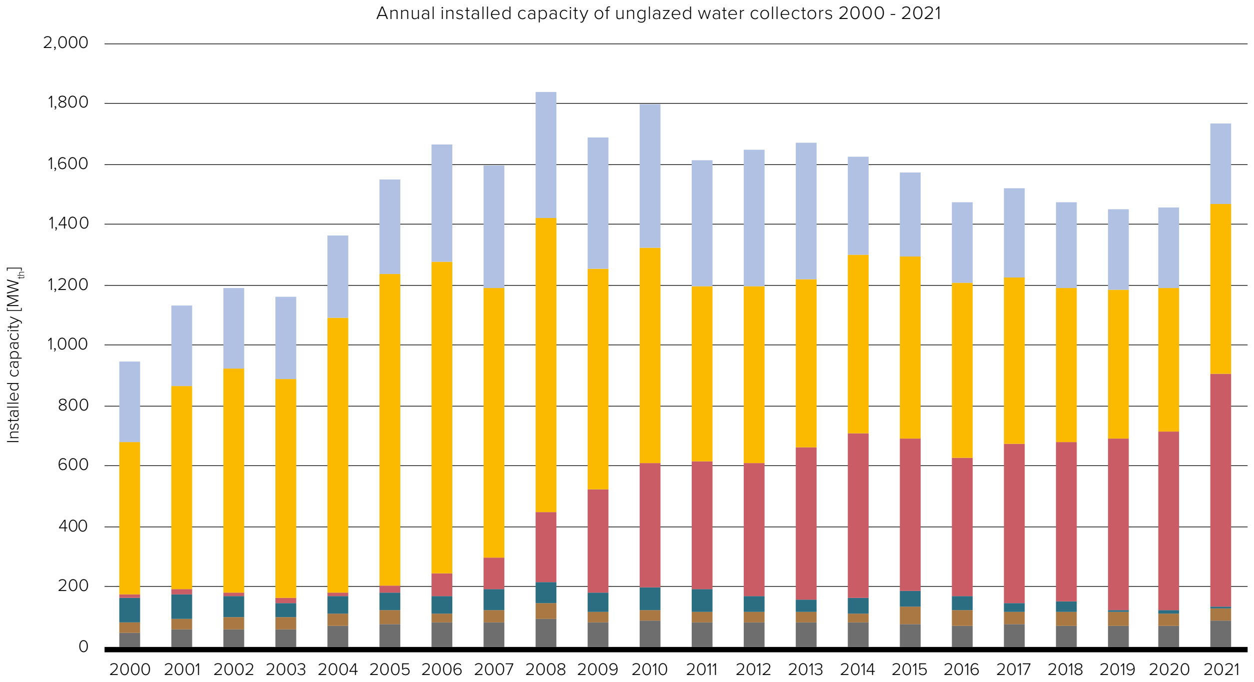

Figure 47: Global market development of unglazed water collectors from 2000 to 2021

7 Contribution to the energy supply and CO_2 reduction in 2021

This section reports on the total installed glazed and unglazed water collectors' contribution to the thermal energy supply and CO_2 reduction.

At the end of 2021 in the 71 recorded countries, 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) is 426 TWh (= 1,538 PJ). This corresponds to a final energy savings equivalent of 45.9 million tons of oil and 145.4 million tons of CO_2. The calculated number of solar thermal systems in operation is around 115 million (Table 12). Therefore, the CO_2 emissions saved by the thermal solar systems in operation is about 145.4 million t/a or 3.4 times the CO_2 emissions of Switzerland (2020)[35].

The basis for these calculations is the total glazed and unglazed water collector area in operation in each country, as shown in Table 8. The 1.0 GW_{th} contribution of the total installed air collector capacity in operation in 2021 is omitted from the calculation due to its small 0.2% share of the total installed collector capacity.

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 are considered for each country. A more detailed description of the methodology can be found in the appendix (see Chapter 9).

Table 12 summarizes the calculated annual collector yields and the corresponding oil equivalents and CO_2 reductions of all water-based solar thermal systems in 2021.

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

* 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 2017
\+ Total capacity in operation refers to the year 2020

Table 12: Calculated annual collector yield and corresponding oil equivalent and CO_2 reduction of glazed and unglazed water collectors in operation by the end of 2021

Country	Energy calculation ALL Water based systems						
	YIELD - Total						
	Total collector area [m^2]	Total capacity [MW_{th}]	Calculated number of systems	Collector yield [GWh/a]	Collector yield [TJ/a]	Energy savings [t_{oe}/a]	CO_2 reduction [t_{CO2e}/a]
Albania	305,613	214	66,153	216	777	23,188	73,391
Argentina	382,117	267	54,702	254	914	27,298	86,398
Australia	9,544,159	6,681	1,146,218	5,818	20,946	625,351	1,979,235
Austria	4,765,455	3,336	507,110	1,969	7,087	211,577	669,642
Barbados+	258,192	181	59,797	227	817	24,400	77,226
Belgium	747,692	523	128,217	296	1,065	31,782	100,591
Bhutan	460	0.3	46	0.3	1	34	106
Botswana	18,675	13	3,050	18	63	1,882	5,955
Brazil	20,484,387	14,339	5,571,874	12,784	46,022	1,374,025	4,348,791
Bulgaria	178,045	125	32,457	89	321	9,590	30,352
Burkina Faso+	4,681	3	296	4	16	469	1,484
Canada	840,951	589	33,113	352	1,266	37,804	119,651
Cape Verde	0		0	0			
Chile	429,932	301	135,981	307	1,104	32,953	104,297
China	544,750,430	381,325	74,919,527	298,506	1,074,622	32,083,625	101,544,674
Croatia	279,308	196	50,916	143	514	15,348	48,578
Cyprus	885,200	620	386,801	787	2,832	84,556	267,619
Czech Republic	1,138,868	797	103,678	391	1,406	41,988	132,891
Denmark	1,855,439	1,299	110,927	774	2,788	83,223	263,402
Estonia	21,726	15	3,961	9	32	953	3,018
Finland	82,549	58	12,922	32	116	3,458	10,943
France (mainland)	2,359,260	1,651	469,085	1,142	4,110	122,701	388,349
France (overseas departments)	1,144,600	801	430,599	929	3,346	99,891	316,156
Germany	22,230,747	15,562	2,624,370	9,067	32,641	974,528	3,084,380
Ghana	6,528	5	342	6	21	632	2,002
Greece	5,176,976	3,624	1,448,439	3,674	13,227	394,912	1,249,897
Hungary	384,280	269	53,378	179	645	19,259	60,954
India	18,316,395	12,821	9,103,993	16,147	58,131	1,735,541	5,492,987
Ireland	417,293	292	96,576	175	629	18,779	59,434
Israel	5,007,434	3,505	1,655,992	4,682	16,854	503,181	1,592,569
Italy	5,123,251	3,586	925,773	3,160	11,375	339,600	1,074,835
Japan	2,903,788	2,033	702,419	1,680	6,048	180,553	571,451
Jordan**	1,260,506	882	223,109	1,194	4,297	128,286	406,026
Kenya	464,975	325	105,433	395	1,424	42,506	134,532
Latvia	41,556	29	7,575	18	65	1,928	6,104
Lebanon	760,859	533	127,076	639	2,301	68,691	217,408
Lesotho	6,417	4	1,832	6	20	608	1,924
Lithuania	22,238	16	4,054	9	34	1,018	3,221
Luxembourg	72,634	51	13,241	31	112	3,358	10,627
Malta	75,397	53	30,159	65	236	7,033	22,260
Mauritius***	132,793	93	88,529	113	408	12,183	38,558
Mexico	5,512,897	3,859	685,407	3,232	11,636	347,412	1,099,559
Morocco	967,000	677	135,816	834	3,001	89,590	283,551
Mozambique	3,133	2	456	3	9	273	864
Namibia	58,573	41	7,066	53	191	5,692	18,016
Netherlands	661,770	463	153,369	269	967	28,866	91,360
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	134,368	94	30,864	83	300	8,969	28,387
Norway+	43,903	31	2,188	16	58	1,737	5,497
Palestinian Territories	1,929,522	1,351	689,737	1,828	6,580	196,462	621,802
Poland	3,195,690	2,237	430,672	1,278	4,601	137,370	434,775
Portugal	1,316,764	922	239,396	1,018	3,665	109,415	346,300
Romania	249,544	175	45,447	140	505	15,064	47,676
Russia	27,935	20	1,626	12	42	1,247	3,947
Senegal+	9,824	7	2,448	10	34	1,029	3,258
Slovakia	194,884	136	24,851	92	332	9,907	31,357
Slovenia	151,339	106	23,674	64	230	6,858	21,705
South Africa	2,632,072	1,842	663,339	1,942	6,990	208,705	660,550
South Korea+	1,931,985	1,352	446,134	1,006	3,621	108,104	342,151
Spain	4,854,713	3,398	580,368	3,404	12,254	365,854	1,157,928
Sweden	499,418	350	35,842	180	650	19,397	61,391
Switzerland	1,718,203	1,203	223,475	694	2,500	74,637	236,227
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	1,199,901	840	352,736	1,077	3,876	115,724	366,266
Turkey	27,041,636	18,929	6,246,618	24,260	87,335	2,607,464	8,252,625
United Kingdom	1,285,268	900	201,659	455	1,637	48,875	154,690
United States	25,932,678	18,153	373,055	10,951	39,425	1,177,053	3,725,372
Uruguay	107,255	75	22,472	72	260	7,774	24,606
Zimbabwe	87,138	61	35,400	74	267	7,978	25,251
Other (5% of world market excluding China)	10,106,163	7,074	1,521,913	5,534	19,922	594,787	1,882,500
TOTAL	750,075,214	525,053	115,481,831	427,496	1,538,985	45,947,518	145,423,894

8 Distribution of systems by type and application in 2021

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).

8.1 Distribution by type of solar thermal collector

In terms of the total water collector capacity worldwide in 2021, evacuated tube collectors dominated with 68.6% of the cumulated capacity in operation (Figure 48) and a share of 59% of the newly installed capacity (Figure 49). Worldwide flat plate collectors accounted for about 25.2% of the cumulated capacity in operation (Figure 48) and a 34% share of the newly installed capacity (Figure 49). Unglazed water collectors accounted for 6% of the cumulated water collectors installed worldwide and 6.8% of the newly installed capacity.

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

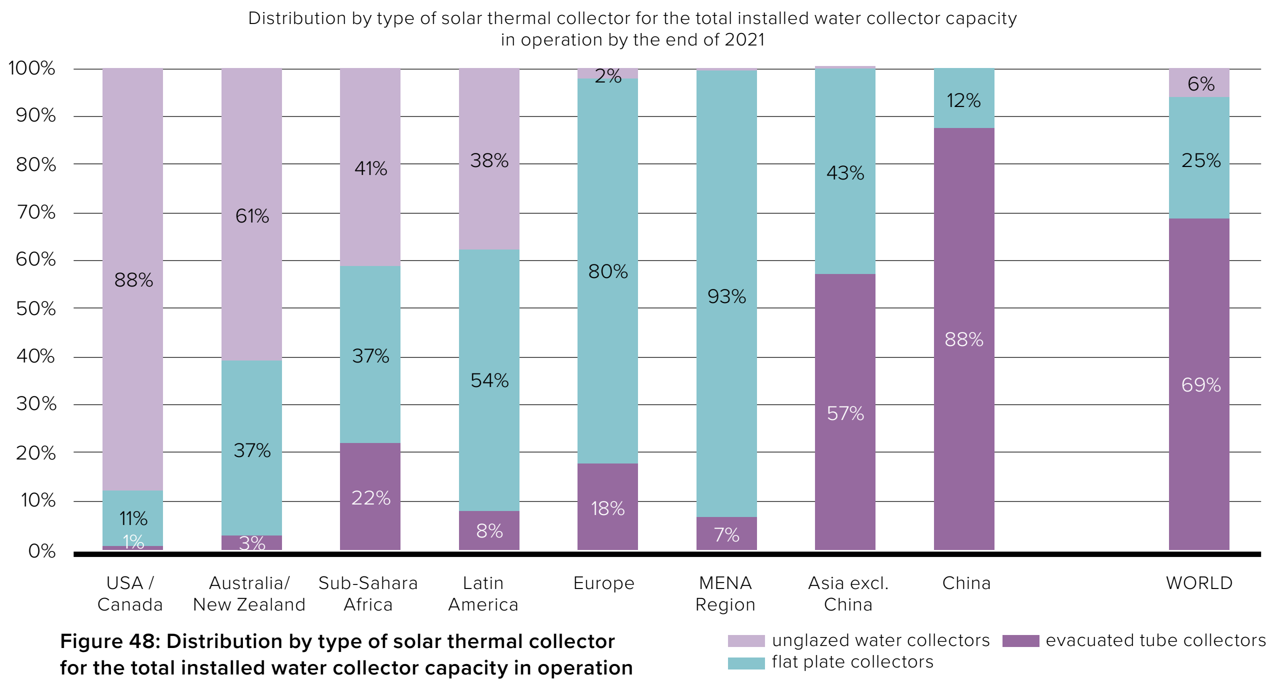

Figure 48: Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2021

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, Asia (excluding China), driven by development in India, and with an increasing share in Sub-Sahara Africa. Unglazed collectors are dominant in North America and Australia. Flat plate collectors are dominant in Latin America, Europe and the MENA region.

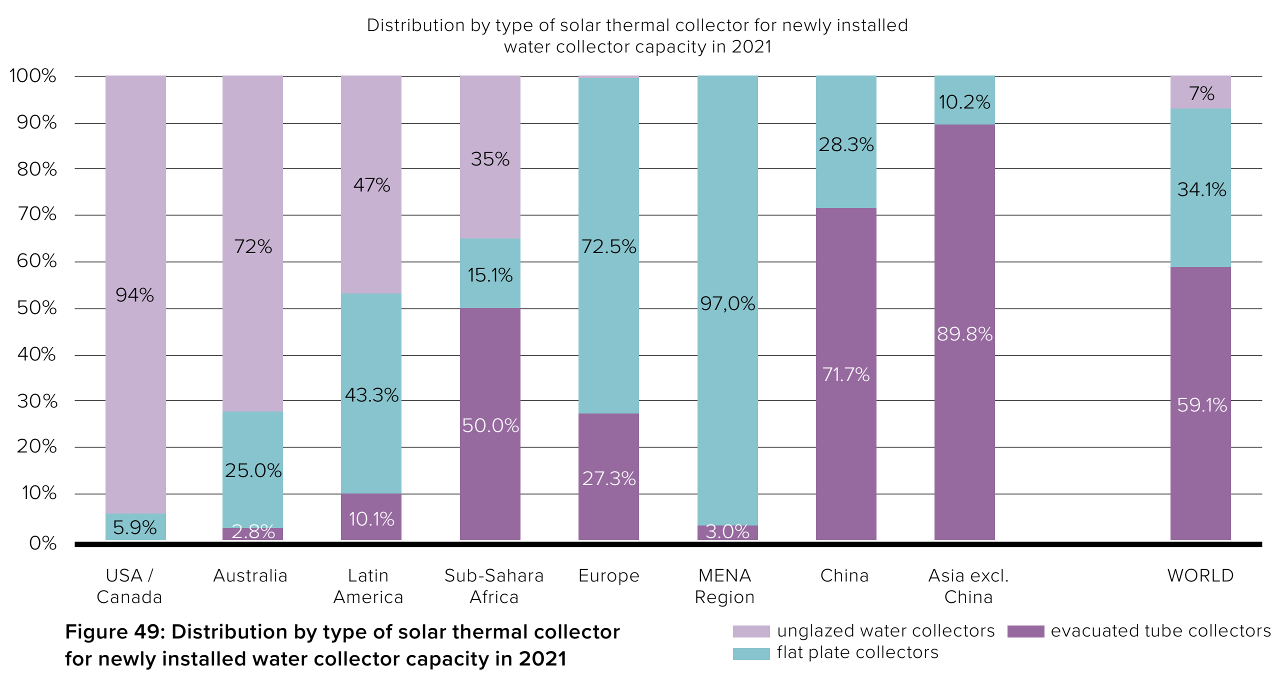

Figure 49: Distribution by type of solar thermal collector for newly installed water collector capacity in 2021

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

Photo: Werner Weiss, AEE INTEC

8.2
Distribution by type of system

Worldwide, about 55% of all solar thermal systems installed are thermosiphon systems and the rest are pumped solar heating systems (Figure 50).

Similar to the distribution by type of solar thermal collector in total numbers, the Chinese market influenced the overall figures the most. 28% of all newly installed systems in China were thermosiphon systems, while pumped systems accounted for 72%. The share of thermosiphon systems has decreased in China for several years (Figure 51).

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.

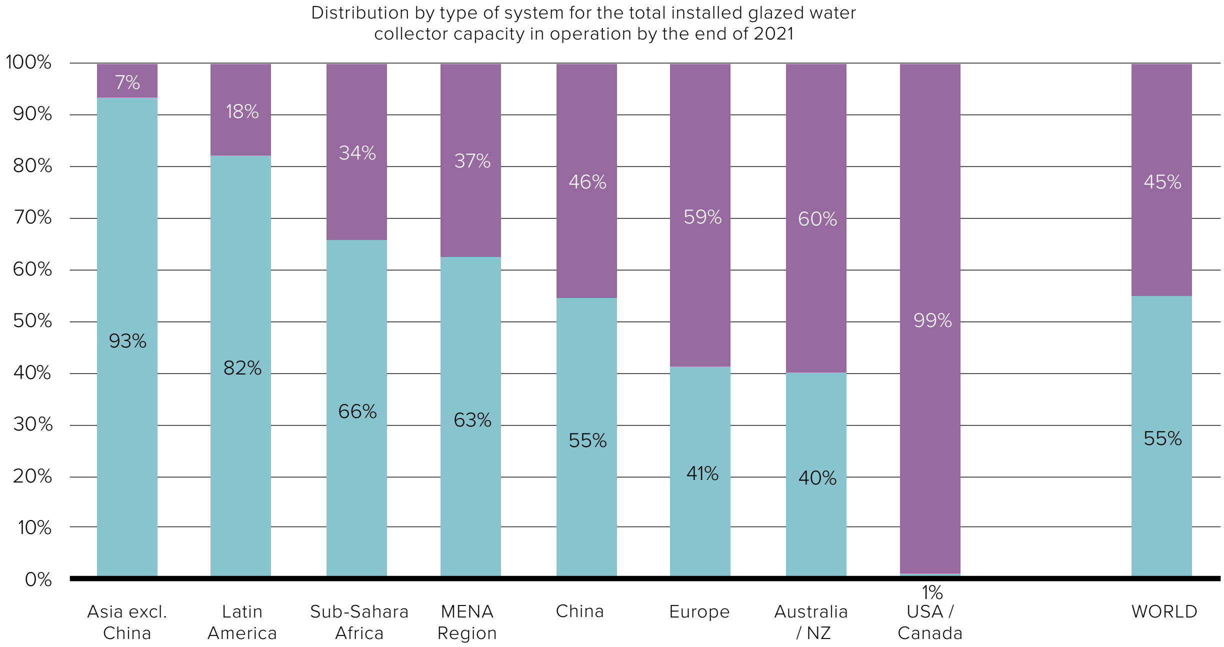

Figure 50: Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2021

Pumped solar heating systems
Thermosiphon solar heating systems

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 and the Caribbean: Argentina, Barbados, Brazil, Chile, Mexico, Panama, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

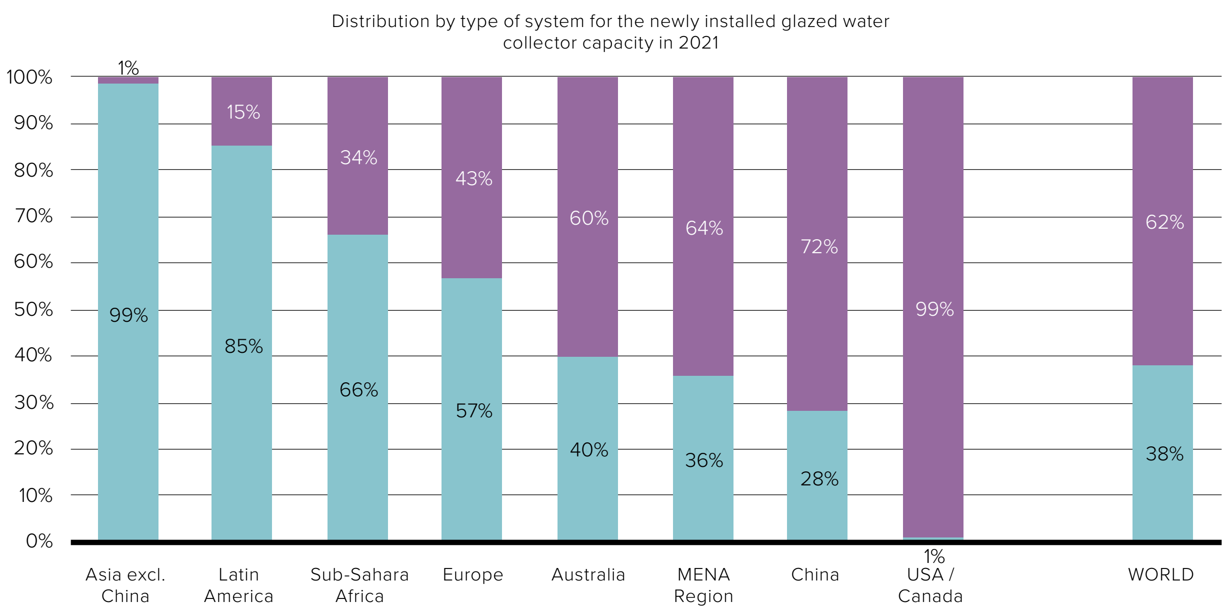

Figure 51: Distribution by type of system for the newly installed glazed water collector capacity in 2021

Pumped solar heating systems
Thermosiphon solar heating systems

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 and the Caribbean: Argentina, Barbados, Brazil, Chile, Mexico, Panama, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

8.3 Distribution by type of application

The newly installed water-based solar thermal collector area in 2021 is 35.9 million, corresponding to 25.1 GW_{th} of thermal peak capacity (Table 11).

The largest share of the collector area installed in 2021 is large domestic hot water systems for multi-family houses, tourism and the public sector. Domestic hot water systems in single-family homes accounted for about 36% of installations in 2021. The share of swimming pool heating was 7%. The share for other applications, such as solar district heating and solar process heat, is about 2% globally (Figure 52).

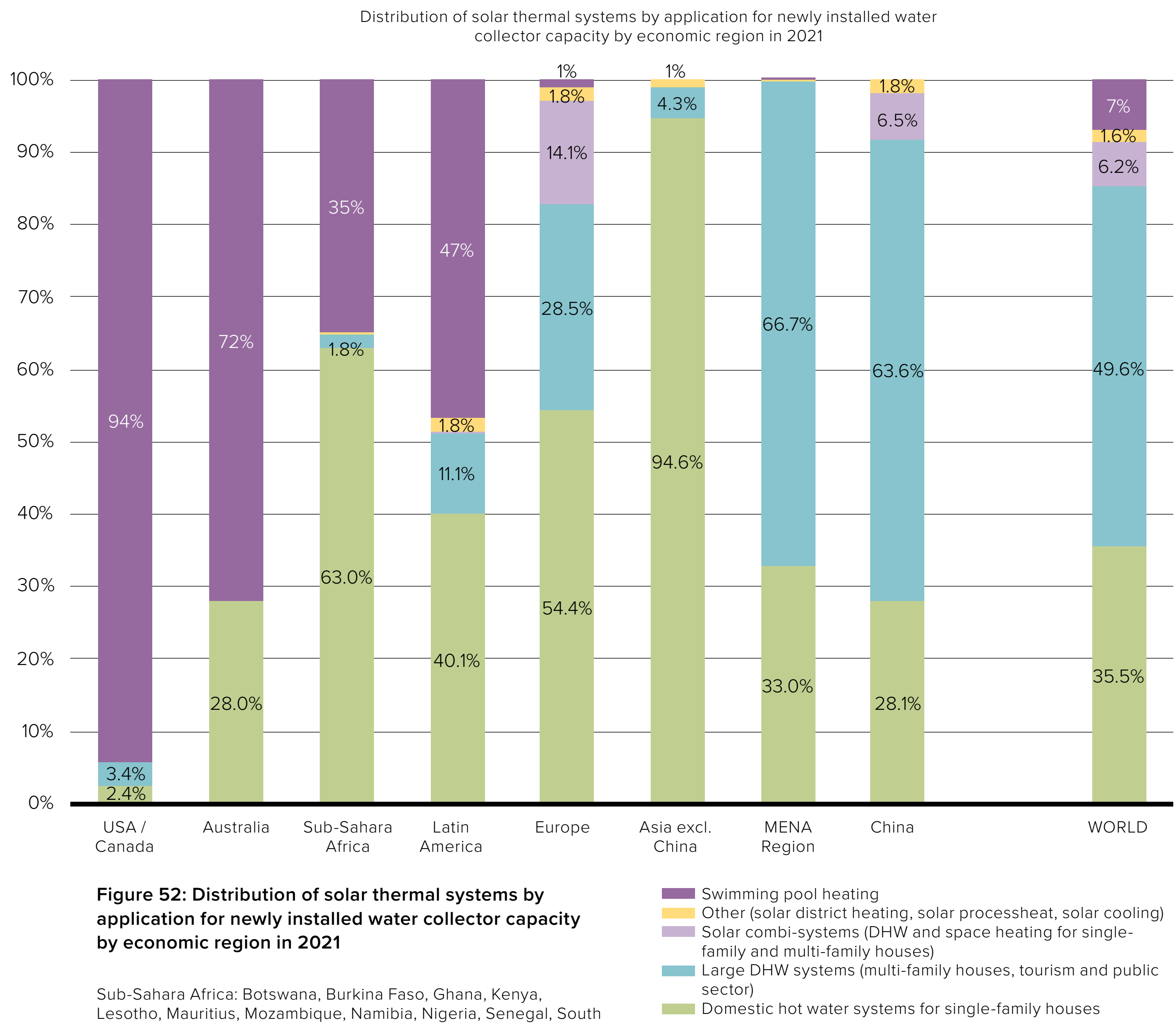

Figure 52: Distribution of solar thermal systems by application for newly installed water collector capacity by economic region in 2021

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 and the Caribbean: Barbados, Brazil, Chile, Mexico, Panama, Uruguay
Europe: EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom
MENA countries: Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

9 Appendix

9.1 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 included), 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 each system were obtained. The gross solar yields refer to the solar collector heat output and do not include heat losses through transmission piping or storage heat losses[36].

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

Finally, the CO_2 emissions avoided by the different solar thermal applications are quoted as kilograms of carbon dioxide equivalent ($kgCO_2e$) per ton of oil equivalent: 1 toe = 3.228 t CO_2e[37]. 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 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[38]. Furthermore, a hydraulic scheme is shown for each reference system.

[36] 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.
[37] Source: Carbon trust, Conversion factors Energy and carbon conversion, updated 2016
[38] 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.

9.1.1
Reference systems for swimming pool heating

Table 13 refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2021.

Table 13: Solar thermal systems for swimming pool heating in 2021

Energy calculation Swimming Pool						
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	118,456	200	592	470
Australia	Sydney	1,674	5,821,937	35	166,341	466
Austria	Graz	1,126	233,597	200	1,168	283
Belgium	Brussels	971	45,593	200	228	261
Brazil	Brasília	1,793	8,070,589	32	252,206	375
Canada	Montreal	1,351	723,146	25	28,926	386
Chile	Santiago de Chile	1,753	69,649	15	4,643	471
Cyprus	Nicosia	1,886	2,390	200	12	507
Czech Republic	Praha	998	503,218	200	2,516	303
Finland	Helsinki	948	11,892	200	59	256
France (mainland)	Paris	1,112	83,400	200	417	328
Germany	Würzburg	1,091	524,464	30	17,482	314
Hungary	Budapest	1,199	18,838	10	1,884	344
Israel	Jerusalem	2,198	40,059	200	200	568
Italy	Bologna	1,419	46,092	200	230	442
Jordan	Amman	2,145	6,661	200	33	578
Mexico	Mexico City	1,706	1,775,153	200	8,876	311
Mozambique	Maputo	1,910	169	40	4	514
Namibia	Windhoek	2,363	1,699	40	42	636
Netherlands	Amsterdam	999	76,765	40	1,919	272
New Zealand	Wellington	1,401	7,024	200	35	378
Norway	Oslo	971	1,835	200	9	316
Poland	Warsaw	1,024	63,914	200	320	276
Portugal	Lisbon	1,686	2,634	200	13	421
Romania	Bucharest	1,324	249	200	1	356
Russia	Moscow	996	293	200	1	268
Slovakia	Bratislava	1,214	974	200	5	327
South Africa	Johannesburg	2,075	1,408,673	40	35,217	505
Spain	Madrid	1,644	165,060	200	825	472
Sweden	Gothenburg	934	163,841	200	819	295
Switzerland	Zürich	1,094	175,287	200	876	277
Taiwan	Taipei	1,372	1,997	175	11	319
United Kingdom	London	943	488,402	200	2,442	254
United States	LA, Indianapolis	1,646	22,717,026	200	113,585	387
Other (5%)		1,463	2,282,683	200	11,413	392
TOTAL			45,653,660		653,355	
AVG		1,434		151		381

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

Figure 53 shows the hydraulic scheme of the swimming pool reference system used for the simulations of the solar energy yields.

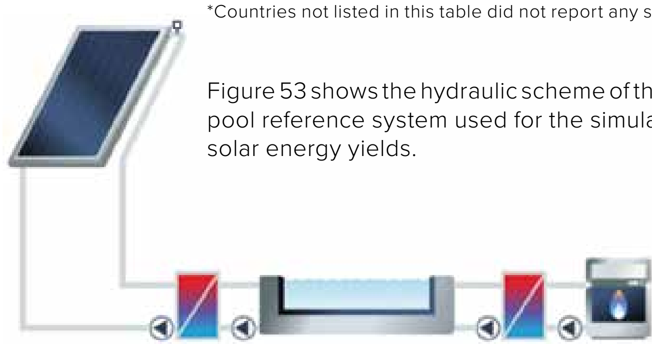

Figure 53: Hydraulic scheme of the swimming pool reference system

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

The information in Table 14 refers to the total capacity of water collectors used for domestic hot water heating in single-family houses at the end of 2021, as reported by each country.

Table 14: Solar thermal systems for domestic hot water heating in single-family houses by the end of 2021

Energy calculation DHW-SFH							
DHW-MFH - Total							
Country	Reference climate	Horizontal irradiation [kWh/m²*a]	Total collector area (DHW-SFH) [m²]	Collector area per system [m²]	Total number of systems [-]	SSpecific solar yield (DHW-SFH) [kWh/m²*a]	Type of system
Albania	Tirana	1,604	191,619	3	63,873	713	TS
Argentina	Buenos Aires	1,748	203,308	4	50,827	777	PS
Australia	Sydney	1,674	3,407,541	3.5	973,583	844	PS
Austria	Graz	1,126	2,127,809	6	354,635	451	PS
Barbados	Grantley Adams	2,016	237,537	4	59,384	882	TS
Belgium	Brussels	971	456,315	4	114,079	423	PDS / PS
Botswana	Gaborone	2,161	11,205	4	2,801	961	TS
Brazil	Brasília	1,793	10,578,148	2	5,289,074	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	12,451	6	2,075	556	PS
Chile	Santiago de Chile	1,753	258,608	2	129,304	771	PS
China	Shanghai	1,282	278,367,470	4	69,591,867	592	TS
Croatia	Zagreb	1,212	181,530	4	45,383	539	PS
Cyprus	Nicosia	1,886	767,162	2	383,581	912	TS
Czech Republic	Praha	998	326,078	4.7	69,378	385	PS
Denmark	Copenhagen	989	291,304	4	72,826	454	PS
Estonia	Tallin	960	14,121	4	3,530	432	PS
Finland	Helsinki	948	45,784	4	11,446	441	PS
France (mainland)	Paris	1,112	1,342,400	2.5	419,500	496	PS
France (overseas departments)	"Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea"	1,834	1,066,767	4	426,707	815	TS
Germany	Würzburg	1,091	9,784,911	5.6	1,747,306	424	PS
Ghana	Accra	2,146	574	4	144	954	TS
Greece	Athens	1,585	3,364,669	2.5	1,345,867	772	TS
Hungary	Budapest	1,199	211,027	5	42,205	473	PS
India	Neu-Delhi	1,961	18,203,468	2	9,101,734	882	TS
Ireland	Dublin	949	375,564	4	93,891	423	PS
Israel	Jerusalem	2,198	931,383	3	310,461	1,024	TS
Italy	Bologna	1,419	3,299,795	4	824,949	661	PS
Japan	Tokyo	1,175	2,766,178	4	691,545	586	TS
Jordan	Amman	2,145	1,003,076	4.6	218,060	986	TS
Kenya	Nairobi	1,931	392,904	4	98,226	859	TS
Latvia	Riga	991	27,008	4	6,752	462	PS
Lebanon	Beirut	1,935	479,059	4	119,765	860	TS
Lesotho	Maseru	2,050	2,976	2	1,488	911	TS
Lithuania	Vilnius	1,001	14,453	4	3,613	450	PS
Luxembourg	Luxembourg	1,037	47,207	4	11,802	450	PS
Malta	Luqa	1,902	75,397	2.5	30,159	868	PS
Mauritius	Port Louis	1,920	132,793	1.5	88,529	854	TS
Mexico	Mexico City	1,706	2,616,421	4	654,105	718	PS
Morocco	Rabat	2,000	503,646	4	125,911	889	TS
Mozambique	Maputo	1,910	1,707	4	427	849	TS
Namibia	Windhoek	2,363	25,593	4	6,398	1,032	TS
Netherlands	Amsterdam	999	394,538	2.8	140,906	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	122,028	4	30,507	627	PS
Norway	Oslo	971	1,525	6	254	430	PS
Palestinian Territories	Jerusalem	2,198	1,004,959	1.5	669,973	977	TS
Poland	Warsaw	1,024	2,396,768	6	399,461	397	PS
Portugal	Lisbon	1,686	917,910	4	229,478	804	PS
Romania	Bucharest	1,324	162,024	4	40,506	594	PS
Russia	Moscow	996	4,374	4	1,094	443	PS
Senegal	Dakar	2,197	9,529	4	2,382	977	TS
Slovakia	Bratislava	1,214	126,028	6	21,005	481	PS
Slovenia	Ljubjana	1,115	136,205	6	22,701	424	PS
South Africa	Johannesburg	2,075	1,192,764	1.9	627,770	1,009	TS
South Korea	Seoul	1,161	1,765,900	4	441,475	525	PS
Spain	Madrid	1,644	1,974,591	4	493,648	766	PS
Sweden	Gothenburg	934	35,208	4	8,802	383	PS
Switzerland	Zürich	1,094	1,033,753	5.7	181,360	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	1,161,493	3.3	351,967	902	TS
Turkey	Antalya	1,795	24,878,305	4	6,219,576	910	TS
United Kingdom	London	943	796,866	4	199,217	415	PS
United States	LA, Indianapolis	1,646	1,330,615	6	221,769	646	PS
Uruguay	Montevideo	1,534	88,378	4	22,095	682	TS
Zimbabwe	Harare	2,017	69,710	2	34,855	854	TS
Other (5% of world market excluding China)		1,437	5,657,713	4	1,414,428	639	
TOTAL			391,524,645		105,820,051		
AVG		1,532		4		684	

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

Figure 54 shows the hydraulic scheme used for the energy calculation for all pumped solar thermal systems and Figure 55 refers to the thermosiphon systems.

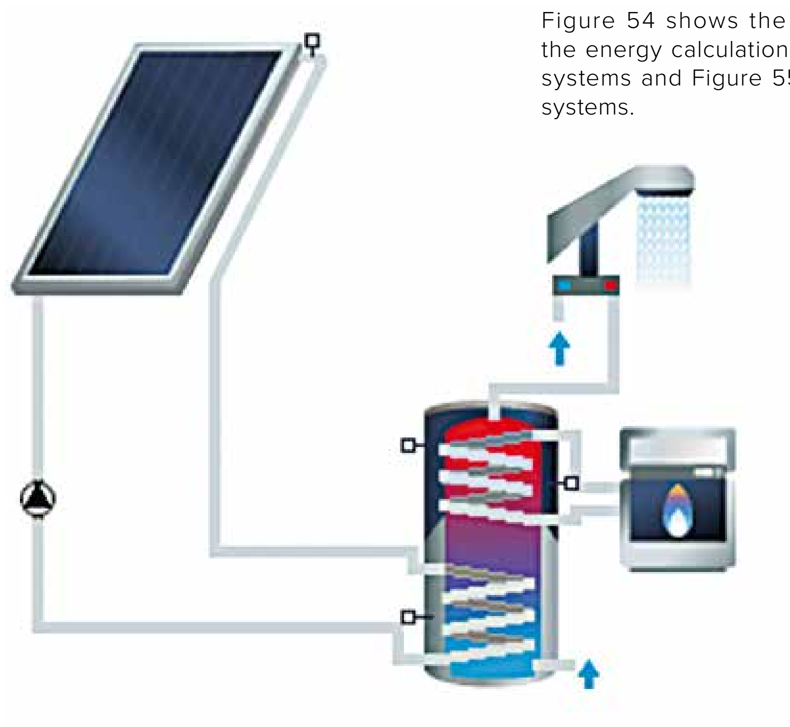

Figure 54: Hydraulic scheme of the domestic hot water pumped reference system for single-family houses

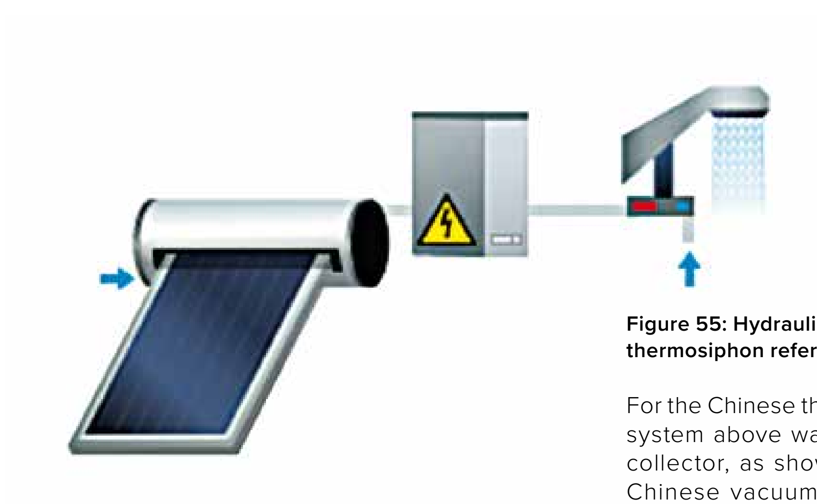

Figure 55: Hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses

For the Chinese thermosiphon systems, the reference system above was used, but instead of a flat plate collector, as shown in Figure 55, a representative Chinese vacuum tube collector was used for the simulation.

9.1.3
Reference systems for domestic hot water preparation in multi-family houses

The information in Table 15 refers to the total capacity of water collectors used for domestic hot water heating in multi-family houses at the end of 2021, as reported by each country.

Table 15: Solar thermal systems for domestic hot water heating in multi-family houses by the end of 2021

Energy calculation DHW-MFH						
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	113,994	50	2,280	694
Argentina	Buenos Aires	1,748	27,576	50	552	730
Australia	Sydney	1,674	314,681	50	6,294	725
Austria	Graz	1,126	396,863	50	7,937	505
Barbados	Grantley Adams	2,016	20,655	50	413	842
Belgium	Brussels	971	103,758	50	2,075	406
Bhutan	Thimphu	1,623	460	10	46	678
Botswana	Gaborone	2,161	7,470	30	249	903
Brazil	Brasília	1,793	1,835,650	60	30,594	658
Bulgaria	Sofia	1,188	26,312	50	526	515
Burkina Faso	Ouagadougou	2,212	4,033	30	134	924
Canada	Montreal	1,351	105,270	50	2,105	621
Chile	Santiago de Chile	1,753	101,675	50	2,033	732
China	Shanghai	1,282	266,382,960	50	5,327,659	502
Croatia	Zagreb	1,212	41,277	50	826	506
Cyprus	Nicosia	1,886	101,523	50	2,030	750
Czech Republic	Praha	998	49,294	42.4	1,163	436
Denmark	Copenhagen	989	1,499,194	50	29,984	413
Estonia	Tallin	960	3,211	50	64	401
Finland	Helsinki	948	10,363	50	207	396
France (mainland)	Paris	1,112	872,460	20	43,623	489
France (overseas departments)	Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea	1,834	77,833	50	3,892	766
Germany	Würzburg	1,091	2,644,377	50	52,888	472
Ghana	Accra	2,146	5,953	30	198	896
Greece	Athens	1,585	765,064	50	15,301	642
Hungary	Budapest	1,199	76,903	50	1,538	522
India	Neu-Delhi	1,961	112,927	50	2,259	749
Ireland	Dublin	949	12,519	50	250	425
Israel	Jerusalem	2,198	4,035,992	3	1,345,331	918
Italy	Bologna	1,419	750,313	50	15,006	593
Japan	Tokyo	1,175	9,357	50	187	516
Jordan	Amman	2,145	250,769	50	5,015	801
Kenya	Nairobi	1,931	72,071	10	7,207	807
Latvia	Riga	991	6,141	50	123	414
Lebanon	Beirut	1,935	277,230	40	6,931	808
Lesotho	Maseru	2,050	3,420	10	342	856
Lithuania	Vilnius	1,001	3,286	50	66	418
Luxembourg	Luxembourg	1,037	10,734	50	215	433
Mexico	Mexico City	1,706	1,121,323	50	22,426	713
Morocco	Rabat	2,000	453,281	50	9,066	835
Mozambique	Maputo	1,910	1,257	50	25	798
Namibia	Windhoek	2,363	31,281	50	626	814
Netherlands	Amsterdam	999	149,652	40	3,741	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	10,969	50	219	577
Norway	Oslo	971	16,679	50	334	406
Palestine	Jerusalem	2,198	904,463	50	18,089	918
Poland	Warsaw	1,024	479,354	50	9,587	447
Portugal	Lisbon	1,686	396,220	40	9,906	705
Romania	Bucharest	1,324	36,841	50	737	553
Russia	Moscow	996	21,871	50	437	416
Senegal	Dakar	2,197	295	4.5	65	918
Slovakia	Bratislava	1,214	28,656	50	573	507
Slovenia	Ljubjana	1,115	4,540	50	91	477
South Africa	Johannesburg	2,075	30,635	87	352	867
South Korea	Seoul	1,161	144,967	50	2,899	485
Spain	Madrid	1,644	2,320,144	50	46,403	676
Sweden	Gothenburg	934	47,699	50	954	430
Switzerland	Zürich	1,094	123,433	20	6,172	457
Taiwan	Taipei	1,372	96,511	30	3,217	518
Thailand	Bangkok	1,765	11,820	80	148	737
Tunisia	Tunis	1,808	38,408	50	768	755
Turkey	Antalya	1,795	2,163,331	80	27,042	750
United States	LA, Indianapolis	1,646	1,885,037	50	37,701	688
Uruguay	Montevideo	1,534	18,877	50	378	641
Zimbabwe	Harare	2,017	17,428	32	545	842
Other (5% of world market excluding China)		1,238	1,332,773	50	26,655	517
TOTAL			293,041,328		7,149,602	
AVG		1,531		45		636

Figure 56 shows the hydraulic scheme of the domestic hot water reference system for multi-family 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

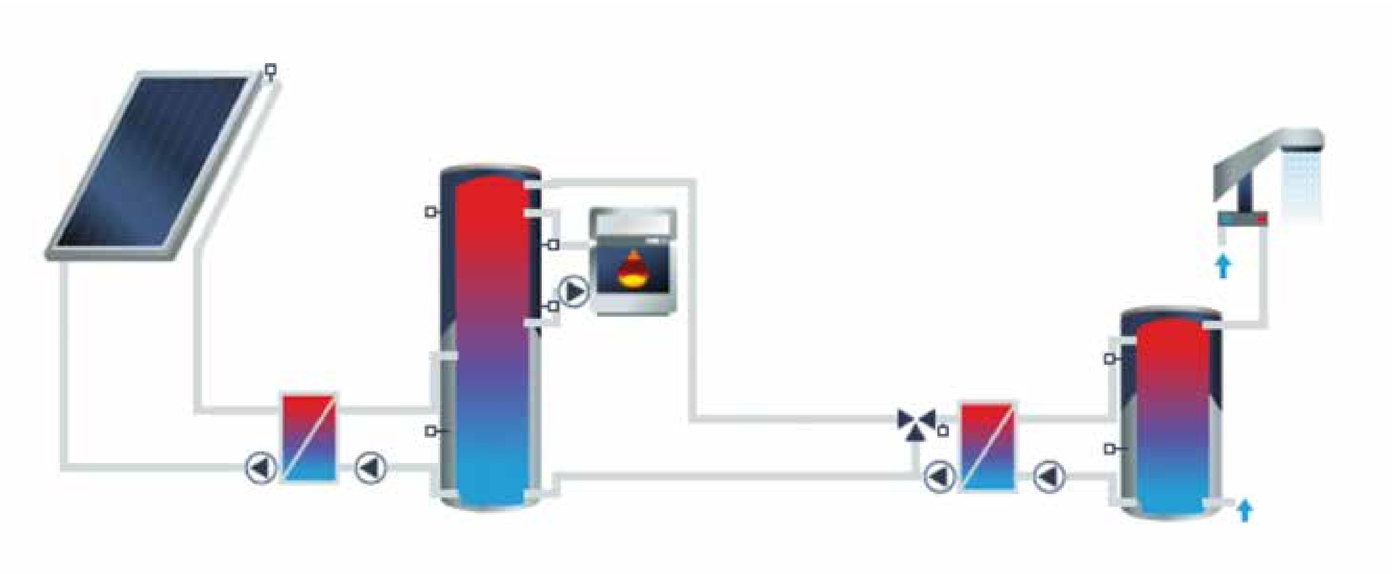

Figure 56: Hydraulic scheme of the domestic hot water pumped reference system for multi-family houses

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

The information in Table 16 refers to the total capacity of water collectors used for domestic hot water and space heating in single-family and multi-family houses at the end of 2021, as reported by each country.

Table 16: Solar combi-system reference for single-family and multi-family houses and the total collector area in operation in 2021

Energy calculation DHW-combi-systems						
Solar combi-systems - 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	32,777	12	2,731	615
Austria	Graz	1,126	2,007,186	14	143,370	369
Belgium	Brussels	971	142,027	12	11,836	342
Bulgaria	Sofia	1,188	36,016	12	3,001	418
Canada	Montreal	1,351	84	12	7	476
Croatia	Zagreb	1,212	56,501	12	4,708	426
Cyprus	Nicosia	1,886	14,125	12	1,177	663
Czech Republic	Praha	998	260,278	8.5	30,621	351
Denmark	Copenhagen	989	64,940	8	8,118	348
Estonia	Tallin	960	4,395	12	366	338
Finland	Helsinki	948	14,509	12	1,209	334
France (mainland)	Paris	1,112	61,000	11	5,545	370
Germany	Würzburg	1,091	9,276,995	11.5	806,695	378
Greece	Athens	1,585	1,047,244	12	87,270	558
Hungary	Budapest	1,199	77,512	10	7,751	422
Ireland	Dublin	949	29,211	12	2,434	364
Italy	Bologna	1,419	1,027,052	12	85,588	499
Japan	Tokyo	1,175	128,253	12	10,688	414
Latvia	Riga	991	8,406	12	701	349
Lebanon	Beirut	1,935	4,570	12	381	681
Lesotho	Maseru	2,050	21	12	2	721
Lithuania	Vilnius	1,001	4,499	12	375	352
Luxembourg	Luxembourg	1,037	14,693	12	1,224	365
Morocco	Rabat	2,000	10,073	12	839	704
Netherlands	Amsterdam	999	40,814	6	6,802	352
New Zealand	Wellington	1,401	4,923	12	410	493
North Macedonia	Skopje	1,381	1,371	10	137	486
Norway	Oslo	971	23,865	15	1,591	342
Palestine	Jerusalem	2,198	20,099	12	1,675	773
Poland	Warsaw	1,024	255,655	12	21,305	365
Romania	Bucharest	1,324	50,430	12	4,202	466
Russia	Moscow	996	1,397	15	93	350
Slovakia	Bratislava	1,214	39,226	12	3,269	427
Slovenia	Ljubjana	1,115	10,594	12	883	362
South Korea	Seoul	1,161	21,118	12	1,760	409
Spain	Madrid	1,644	394,918	10	39,492	619
Sweden	Gothenburg	934	252,670	10	25,267	389
Switzerland	Zürich	1,094	385,729	11	35,066	385
Thailand	Bangkok	1,765	1,722	12	143	621
Other (5% of world market excluding China)		1,149	832,995	12	69,416	404
TOTAL			16,659,891		1,428,151	
AVG		1,286		12		452

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

Figure 57 shows the hydraulic scheme of the domestic hot water reference system for multi-family houses used for the simulations of the solar energy yields.

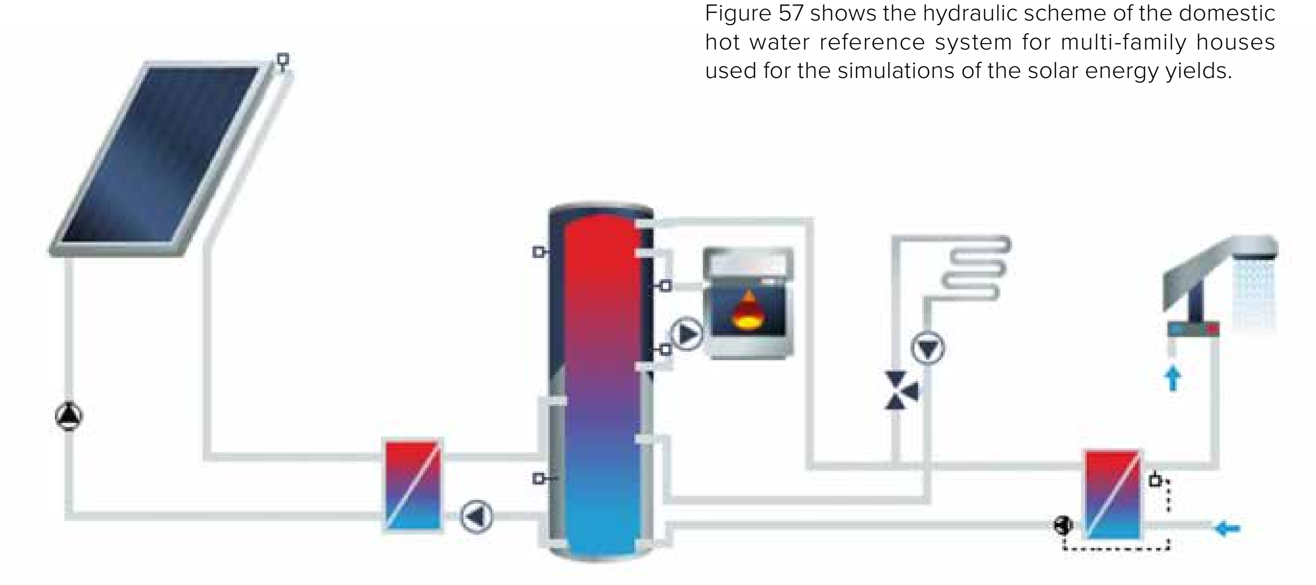

Figure 57: Hydraulic scheme of the solar-combi reference system for single and multi-family houses

9.2
Reference collectors

9.2.1
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]

9.2.2
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]

9.2.3
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]

9.3
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:

- Countries with high labor costs. Advanced automated production of flat plate or evacuated tube collectors and heat storages – pumped systems with an average 133 m^2 solar collector area installed per full-time job.
- Countries with low labor costs. Advanced automated production of evacuated tube collectors and heat storages – thermosiphon systems with an average 87 m^2 solar collector area installed per full-time job.
- Countries with low labor costs. Mainly manual flat plate collector production – thermosiphon systems with an average 87 m^2 solar collector area installed per full-time job.
- Swimming pool systems with unglazed polymeric collectors or air collectors – around 200 m^2 solar collector area installed per full-time job.

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

9.4
Reference climates

Table 17: Reference climates for the 71 countries surveyed
(France mainland and overseas departments counted as one country)

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	France (overseas departments)	Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea	1,834	1,925	21.7
24	Germany	Würzburg	1,091	1,225	9.5
25	Ghana	Accra	2,146	2,161	23.7
26	Greece	Athens	1,585	1,744	18.5
27	Hungary	Budapest	1,199	1,346	11.0
28	India	Neu-Delhi	1,961	2,275	24.7
29	Ireland	Dublin	949	1,091	9.5
30	Israel	Jerusalem	2,198	2,400	17.3
31	Italy	Bologna	1,419	1,592	14.3
32	Japan	Tokyo	1,175	1,287	16.7
33	Jordan	Amman	2,145	2,341	17.9
34	Kenya	Nairobi	1,931	1,932	19.4
35	Latvia	Riga	991	1,187	6.3
36	Lebanon	Beirut	1,935	2,132	19.9
37	Lesotho	Maseru	2,050	2,290	15.2
38	Lithuania	Vilnius	1,001	1,161	6.2
39	Luxembourg	Luxembourg	1,037	1,158	8.4
40	Malta	Luqa	1,902	2,115	18.7
41	Mauritius	Port Louis	1,920	2,010	23.3
42	Mexico	Mexico City	1,706	1,759	16.6
43	Morocco	Rabat	2,000	2,250	17.2
44	Mozambique	Maputo	1,910	2,100	22.8
45	Namibia	Windhoek	2,363	2,499	21.0
46	Netherlands	Amsterdam	999	1,131	10.0
47	New Zealand	Wellington	1,401	1,542	13.6
48	Nigeria	Abuja	2,007	2,051	25.7
49	North Macedonia	Skopje	1,381	1,521	12.5
50	Norway	Oslo	971	1,208	5.8
51	Palestinian Territories	Jerusalem	2,198	2,400	17.3
52	Panama	Panama City	1,787	1,813	26.8
53	Poland	Warsaw	1,024	1,156	8.1
54	Portugal	Lisbon	1,686	1,875	17.4
55	Romania	Bucharest	1,324	1,473	10.6
56	Russia	Moscow	996	1,181	5.9
57	Senegal	Dakar	2,197	2,259	24.9
58	Slovakia	Bratislava	1,214	1,374	10.3
59	Slovenia	Ljubjana	1,115	1,231	9.8
60	South Africa	Johannesburg	2,075	2,232	15.6
61	South Korea	Seoul	1,161	1,280	12.7
62	Spain	Madrid	1,644	1,844	15.5
63	Sweden	Gothenburg	934	1,105	7.2
64	Switzerland	Zürich	1,094	1,218	9.6
65	Taiwan	Taipei	1,372	1,398	20.8
66	Thailand	Bangkok	1,765	1,898	29.1
67	Tunisia	Tunis	1,808	2,038	19.3
68	Turkey	Antalya	1,795	1,958	18.4
69	United Kingdom	London	943	1,062	12.0
70	United States	LA, Indianapolis	1,646	1,816	14.3
71	Uruguay	Montevideo	1,534	1,647	15.9
72	Zimbabwe	Harare	2,017	2,087	18.9

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

9.5
Population data

Table 18: Inhabitants by the end of 2021 of the 71 surveyed countries in alphabetical order (France mainland and overseas departments counted as one country)

No	Country	2021	Region Code
1	Albania	3,088,385	6
2	Argentina	45,864,941	4
3	Australia	25,809,973	3
4	Austria	8,884,864	6
5	Barbados	301,865	4
6	Belgium	11,778,842	6
7	Bhutan	859,364	2
8	Botswana	2,350,667	1
9	Brazil	215,903,281	4
10	Bulgaria	6,919,180	6
11	Burkina Faso	21,382,659	1
12	Canada	37,943,231	8
13	Cape Verde	589,451	1
14	Chile	18,307,925	4
15	China	1,407,098,834	5
16	Croatia	4,208,973	6
17	Cyprus	1,281,506	6
18	Czech Republic	10,702,596	6
19	Denmark	5,894,687	6
20	Estonia	1,220,042	6
21	Finland	5,587,442	6
22	France (mainland)	68,084,217	6
23	France (overseas departments and regions)	3,319,391	6
24	Germany	84,409,193	6
25	Ghana	32,372,889	1
26	Greece	10,569,703	6
27	Hungary	9,728,337	6
28	India	1,380,721,926	2
29	Ireland	5,224,884	6
30	Israel	8,787,045	7
31	Italy	61,196,793	6
32	Japan	124,687,293	2
33	Jordan	10,909,567	7
34	Republic of Kenya	54,685,051	1
35	Latvia	1,862,687	6
36	Lebanon	5,261,372	7
37	Lesotho	2,177,740	1
38	Lithuania	2,711,566	6
39	Luxembourg	639,589	6
40	Malta	460,891	6
41	Mauritius	1,306,837	1
42	Mexico	128,569,498	4
43	Morocco	36,400,581	7
44	Mozambique	30,888,034	1
45	Namibia	2,678,191	1
46	Netherlands	17,337,403	6
47	New Zealand	4,991,442	3
48	Nigeria	219,463,862	1
49	North Macedonia	2,128,262	6
50	Norway	5,509,591	6
51	Palestinian Territories	4,906,308	7
52	Panama	4,271,368	4
53	Poland	38,185,913	6
54	Portugal	10,263,850	6
55	Romania	18,748,356	6
56	Russia	142,320,790	6
57	Senegal	17,462,980	1
58	Slovakia	5,436,066	6
59	Slovenia	2,102,106	6
60	South Africa	56,978,635	1
61	South Korea	51,715,162	2
62	Spain	47,103,121	6
63	Sweden	10,432,235	6
64	Switzerland	8,453,550	6
65	Taiwan	23,572,052	2
66	Thailand	69,480,520	2
67	Tunisia	11,811,335	7
68	Turkey	82,482,383	6
69	United Kingdom	67,419,123	6
70	United States	334,998,398	8
71	Uruguay	3,398,239	4
72	Zimbabwe	14,829,988	1
73	Other (5%)	2,652,283,584	9
∑ Solar Thermal World Statistics		5,179,435,021	66%
∑Inhabitants world		7,831,718,605	

Data source: International Data Base of the U.S. Census Bureau
http://www.census.gov/population/international/data/idb/informationGateway.php

Table 19: Inhabitants per economic region by the end of 2021

Region Code	Region	∑Inhabitants	Share
1	Sub-Sahara Africa	457,166,984	6%
2	Asia excl. China	1,651,036,317	21%
3	Australia	30,801,415	0.4%
4	Latin America and the Caribbean	416,617,117	5%
5	China	1,407,098,834	18%
6	Europe	765,696,517	10%
7	MENA Region	78,076,208	1%
8	United States / Canada	372,941,629	5%
9	Other countries	2,652,283,584	34%
TOTAL		7,831,718,605	100%

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Namibia, Nigeria, Mauritius, Mozambique, Senegal, South Africa, Zimbabwe
Asia excl. China: Bhutan, India, Japan, South Korea, Taiwan, Thailand
Latin America and the Caribbean: 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

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

9.6 Definition of SHIP systems

In November 2019, the IEA Solar Heating and Cooling Programme defined solar heat for industrial processes (SHIP systems). This definition refers only to the collection and documentation of SHIP systems in this 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 also 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.

9.7 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, was 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 kWth/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 23, Table 24 and Table 25, these countries are marked accordingly and the respective data source is cited in Chapter 9.8 (References).

Table 20: 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		21,986.0	2,284.0			24,270
Argentina	34,496.0	23,451.0	39,786.0	20.0	158.0	97,911
Australia	380,000.0	157,000.0	17,400.0			554,400
Austria	460.0	90,040.0	310.0		770.0	91,580
Barbados*		12,300.0				12,300
Belgium		23,500.0	4,300.0			27,800
Botswana		2,530.9	67.8			2,599
Brazil	662,451.0	627,773.0	30,761.0			1,320,985
Bulgaria		23,500.0	450.0			23,950
Burkina Faso*		100.0	310.0			410
Canada	1,165.0	609.0	1,629.0	10,000.0	4,100.0	17,503
Cape Verde		150.0				150
Chile		25,183.0				25,183
China+		6,557,000.0	19,903,000.0	700.0		26,460,700
Croatia		18,786.0	1,241.0			20,027
Cyprus		69,945.0	0.0			69,945
Czech Republic		15,675.0	7,125.0			22,800
Denmark		194,000.0		0.0		194,000
Estonia		855.0	570.0			1,425
Finland		7,000.0	855.0			7,855
France (mainland)	1,000.0	42,500.0	2,265.0	900.0		46,665
France (overseas territories)		75,364.0				75,364
Germany		441,000.0	70,000.0			511,000
Ghana		500.0	200.0			700
Greece		361,000.0	500.0			361,500
Hungary		11,400.0	4,750.0			16,150
India		272,156.0	1,542,460.0		100.0	1,814,716
Ireland		12,389.0				12,389
Israel		360,000.0				360,000
Italy		132,000.0	19,600.0			151,600
Japan		58,257.0	635.0		1,492.0	60,384
Kenya		8,120.0	4,060.0			12,180
Latvia		22,900.0	250.0			23,150
Lebanon		21,608.0	19,239.0			40,847
Lesotho		175.0	621.0			796
Lithuania		750.0	1,250.0			2,000
Luxembourg		2,900.0	0.0			2,900
Maldives						0
Malta		520.6	130.2			651
Mexico	118,300.0	146,400.0	143,500.0			408,200
Morocco		76,600.0				76,600
Mozambique**			237.0			237
Namibia		4,155.0	8.1			4,163
Netherlands	2,620.0	31,280.0	17,590.0			51,490
Nigeria*		392.6	3,515.2		800.0	4,708
North Macedonia		4,924.0	10,850.0			15,774
Norway*		1,350.0	73.0			1,423
Palestine		46,479.0	0.0			46,479
Poland		282,160.0	5,030.0			287,190
Portugal		67,739.0	1,240.0			68,979
Romania	0.0	6,840.0	9,120.0			15,960
Russia		1,186.0	100.0			1,286
Senegal		1,500.0	1,000.0	0.0	0.0	2,500
Slovakia	0.0	7,600.0	1,520.0			9,120
Slovenia		1,200.0	200.0			1,400
South Africa	60,324.0	28,160.0	71,763.0			160,247
South Korea*		3,552.0	16,918.0	400.0	200.0	21,070
Spain	2,900.0	193,650.0	7,600.0	1,300.0	1,000.0	206,450
Sweden	522.0	1,126.0				1,648
Switzerland	3,996.0	34,294.0	4,484.0			42,774
Taiwan*		36,000.0				36,000
Tunisia		62,812.0				62,812
Turkey		950,000.0	935,000.0	100.0		1,885,100
United Kingdom		18,593.0	6,334.3	1,000.0		25,927
United States	696,420.0	154,050.0	6,400.0	4,500.0	500.0	861,870
Uruguay		10,418.0				10,418
Zimbabwe		10.0	13,869.0			13,879
Other (5% of the world market excluding China)	103,402.8	624,599.7	1,206,968.5	995.8	480.0	1,936,447
	2,068,056.8	12,491,993.8	24,139,369.1	19,915.8	9,600.0	38,728,935

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

Table 21: Newly installed collector area in 2020 [m²]

Country	Newly installed collector area in 2020 [m²]					
	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		10,680	968.0			11,648
Argentina	34,496.0	23,451	39,786.0	20.0	158.0	97,911
Australia	380,000.0	146,000	16,200.0			542,200
Austria	1,730.0	72,210	1,400.0		720.0	76,060
Barbados*		12,300				12,300
Belgium		18,200	4,300.0			22,500
Bhutan		460				460
Botswana		1,032	115.0			1,147
Brazil	710,810.0	673,600	32,360.0			1,416,770
Bulgaria		23,500	500.0			24,000
Burkina Faso*		100	310.0			410
Canada	1,475.0	261	321.0	7,000.0	1,000.0	10,057
Cape Verde		150				150
Chile		25,183				25,183
China+		6,954,000	18,096,033.0			25,050,033
Croatia		15,968	1,055.0			17,023
Cyprus		74,193	0.0			74,193
Czech Republic		15,000	7,000.0			22,000
Denmark		14,613				14,613
Estonia		1,425				1,425
Finland		7,000				7,000
France (mainland)	600.0	45,807	330.0			46,737
France (overseas territories)++		91,425				91,425
Germany		544,564	98,888.0			643,452
Ghana		776	520.0			1,296
Greece		304,100	400.0			304,500
Hungary		21,000				21,000
India		207,209	1,451,524.0		150.0	1,658,883
Ireland		1,472	2,367.0			3,839
Israel		350,000				350,000
Italy		108,250	14,700.0			122,950
Japan		49,907	861.0		887.0	51,655
Kenya		8,364	4,182.0			12,546
Latvia		1,600				1,600
Lebanon		9,448	14,173.0			23,621
Lesotho**		286	1,103.0			1,389
Lithuania		700	1,000.0			1,700
Luxembourg		3,913	0.0			3,913
Malta		545	136.0			681
Mexico	106,400.0	130,080	141,000.0			377,480
Morocco		71,700				71,700
Mozambique**			237.0			237
Namibia		3,807	8.1			3,815
Netherlands	2,620.0	21,430	8,330.0			32,380
Nigeria*		393	3,515.2			3,908
North Macedonia		4,274	6,948.0		12.0	11,234
Norway*		1,350	73.0			1,423
Palestine		46,401	0.0			46,401
Poland		159,270	1,830.0			161,100
Portugal		69,700				69,700
Romania		6,840	9,120.0			15,960
Russia		784	85.5			869
Senegal*		1,500	1,000.0			2,500
Slovakia		13,000				13,000
Slovenia		1,300	100.0		10.0	1,410
South Africa	56,629.0	28,967	74,180.0			159,776
South Korea*		3,552	16,918.0			20,470
Spain	2,798.0	177,103	7,539.0			187,440
Sweden		1,898	3,000.0			4,898
Switzerland	3,900.0	31,830	4,390.0			40,120
Taiwan*		36,000				36,000
Tunisia		51,094				51,094
Turkey		988,000	939,000.0	2,500.0		1,929,500
United Kingdom		17,597	6,472.1			24,069
United States	675,058.0	44,448		3,000.0	1,000.0	723,506
Uruguay*		10,418				10,418
Zimbabwe			4,050.0			4,050
Other (5% excluding China)	104,027.2	253,023	153,805.0	658.9	207.2	511,721
TOTAL	2,080,543.2	12,014,450.0	21,172,132.8	13,178.9	4,144.2	35,284,449

* 0% growth assumed ** revised 2022 due to new data base + exports excluded ++ figures for France overseas according to ObservEr2021

Table 22: Total collector area in operation by the end of 2020 [m²]

Total installed collector area in operation 2019 [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
Burkino 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+		60,231,000	459,788,516	7,700	3,000	520,030,216
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	20,788			81,168
France (mainland)	87,989	2,046,818	188,208	10,558	1,100	2,334,673
France (overseas territories)		1,030,446	44,270			1,074,716
Germany	469,110	19,021,564	2,385,388		18,240	21,894,302
Ghana		3,770	1,608			5,378
Greece		4,968,100	22,900			4,991,000
Hungary	18,300	267,184	79,850	3,418	2,300	371,052
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		36,522	3,490			40,012
Lebanon		361,209	374,192			735,401
Lesotho		1,975	2,462			4,437
Lithuania		9,180	13,050			22,230
Luxembourg		61,132	8,900			70,032
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	513,330	72,530			663,060
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
Palestine		1,876,069				1,876,069
Poland		2,509,130	497,460			
Portugal	2,130	1,213,019	30,570			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	156,550	28,270			185,820
Slovenia		126,300	23,600		10	149,910
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	171,000	266,582	72,578			510,160
Switzerland	175,600	1,401,400	143,200			
Taiwan++	1,937	1,679,874	133,244			
Thailand****		157,536				
Tunisia		1,077,817	70,104			
Turkey		17,154,182	9,155,454	12,570		
United Kingdom		914,239	350,842	24,600		1,289,681
United States	22,583,130	3,019,355	177,193	127,431	71,000	25,978,109
Uruguay++		96,837				96,837
Zimbabwe		21,848	55,720			77,568
Other (5% excluding China)	2,193,911	5,915,429	1,645,469	45,479	24,387	9,824,675
TOTAL	43,878,219	178,539,579	492,697,902	917,278	490,737	716,523,715

* cumulated collector area by end of 2009 ** cumulated collector area by end of 2014 *** cumulated collector area by end of 2015
**** cumulated collector area by end of 2017 + exports excluded ++ calculated based on 0% growth

9.8 References to reports and persons who have supplied the data

The production of the report, Solar Heat Worldwide – Edition 2023 was kindly supported by national representatives of the recorded countries or other official sources of information as cited below.

A special thanks to Janet L. Sawin, Ph.D. (Co-Author and Special Advisor, REN21 Renewables Global Status Report) for the good data exchange and data reconciliation.

Country	Contact	Source	Remarks
Albania	**Dr. Eng. Edmond M. HIDO** EEC - Albania-EU Energy Efficiency Centre	EEC - Albania-EU Energy Efficiency Centre	0% growth assumed
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** Exemplary Energy, Melbourne Victoria Australia	data from the Clean Energy Regulator and industry surveys / interviews	
Austria	**Werner Weiss** AEE - Institute for Sustainable Technologies	Biermayr et al, 2022: Innovative Energietechnologien in Österreich – Marktentwicklung 2021 (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	2021 no new data reported; cumulated collector area end of 2020
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe, 2022 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 2021	
Brazil	**Dr. Danielle Johann,** Diretora Executiva ABRASOL Associção Brasileira de Energia Solar Térmica	ABRASOL Pesquisa Produção e Vendas de Sistemas de Aquecimento Solar 2023 Base 2022	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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe, 2022
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; no new data 2021; cumulated collector area by end of 2020
Canada	**Reda Djebbar, Ph.D., P.Eng.** Natural Resources Canada (NRC) **John Hollick** SAHWIA - Solar Air Heating World Industry Association	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 2021

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 2021
China	**Ruicheng Zheng** China Academy of Building Research **Dr. Janet Sawin** REN21	China Academy of Building Research Technical Committee of Thermal Conversion, China Renewabel energy Society 2022 China Solar Thermal Industry Operation Status Report, https://mp.weixin.qq.com/s/1jXYS-8iMpstP2-3ddSerw	Exports excluded, out of operation systems calculated by AEE INTEC (13 years lifetime considered) 2022 data provided by Dr. Janet Sawin, REN21
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe, 2022
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	**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 2021, Solar Heat Europe 2022	Unglazed water collectors: AEE INTEC recordings
Denmark	**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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022 (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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022 (estimation)
France mainland **France overseas**	**Paul Kaaijik,** ADEME - Agence de l'Environnement et de la Maîtrise de l'Énergie **John Hollick** SAHWIA - Solar Air Heating World Industry Association	EurobservER' 2022 France overseas: Eurobser'Er 2022 Air collectors: John Hollick	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 Cumulated: 25 years liefetime considered
Ghana	**Divine Atsu** Koforidua Polytechnic Department of Energy Systems Engineering		New installed systems provided by Dr. Divine Atsu; cumulated calculated by AEE INTEC
Greece	**Costas Travasoras** EBHE – Greek Solar Industry Association **Dr. 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 2021, Solar Heat Europe 2022 Air collectors: John Hollick	Glazed water collectors: Solar Heat Europe 2022 Cumulated collector area 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 Consultanc
Ireland	**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 2021, Solar Heat Europe 2022	Cumulated calculated by AEE INTEC based on newly installed collector areas
Israel	**Eli Shilton** ELSOL **Bärbel Epp** Solrico – Solar market research	ELSOL (Eli Shilton)	0% growth assumed; 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 **Federico Musazzi** Associazioni Assoclima e Assotermica ANIMA Confindustria Meccanica Varia	Solar Thermal Markets in Europe - Trends and Market Statistics 2021, Solar Heat Europe 2022	Growth rates 2021/2022 provided by Federico Musazzi Cumulated area: Solar Heat Europe 2022/ 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 2021 reported Cumulated installations by end of 2014
Kenya	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 0% growth assumed for 2021
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022
Lebanon	**Sorina Mortada Phd Eng.** Lebanese Center for Energy Conservation (LCEC)	Lebanese Center for Energy Conservation (LCEC)	2022 data provided by Ammar Fadlallah, Energy Engineer (LCEC) 2023 revised timeseries
Lesotho	**Ivan Yaholnitsky** **Puleng Mosothoane** Bethel Business and Community Development Center (BBCDC)	SOLTRAIN Study, data provided by Ivan Yaholnitsky	Revised in 2022 according to new data base
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022 (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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022 (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)	2021 data provided by Mark Anthony Callus, The Energy and Water Agency, Malta
Mauritius	**Devika Balgobin** Statistician Environment Statistics Unit Ministry of Environment and Sustainable Development	Statistics Mauritius	Cumulated collector area by end of 2015
Mexico	**David Garcia** FAMERAC **Bärbel Epp** Solrico – Solar market research	2021 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	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 2021; 0% growth assumed
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 2021	
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 new data available since 2010 Cumulated area by end of 2009
Nigeria	**Okala Nwoke** National Centre for Energy Research and Development, University of Nigeria, Nsukka		No new data reported 2021 Cumulated collector area by end of 2020
North Macedonia	**Prof. Dr. Ilja Nasov** National University St. Kiril and Metodij, Faculty for Natural Science, Institute of Physics, Solar Energy Department	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	No new data reported for 2021 Cumulated collector area by end of 2020
Palestinian Territories	**Mohammed Mobayyed** EEU Director Palestinian Energy Authority **Abdallah Azzam** Palestinian Central Bureau of Statics Natural Resource Statistics	Palestinian Energy Authority	
Panama	https://solarthermalworld.org/news	Commercial solar heat market in Panama starts moving, https://solarthermalworld.org/news	New 2023
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022
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	No new data reported 2021 Cumulated collector area by end of 2020

Country	Contact	Source	Remarks
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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022
Slovenia	**Ciril Arkar** University of Ljubljana, Faculty of Mechanical Engineering	Eco Fund, Slovenian Environmental Public Fund	Glazed water collectors: Solar Heat Europe 2022
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;	No new data reported for 2021 Cumulated collector area by end of 2020
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	**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 2021, Solar Heat Europe 2022	Glazed water collectors: Solar Heat Europe 2022
Switzerland	**http://www.swissolar.ch/**	SWISSOLAR - Markterhebung Sonnenenergie 2021, Bundesamt für Energie 2022 (in German)	Out of operation systems calculated by SWISSOLAR
Taiwan	**K.M. Chung** Energy Research Center - National Cheng Kung University	Installers association	No new data in 2021 Cumulated collector area by end of 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)	Cumulated collector area by end of 2016
Tunisia	**Abdelkader Baccouche** Agence Nationale pour la Maîtrise de l'Energie (ANME)	ANME (National Agency of Energy Conservation)	2021 data provided by Bärbel Epp, solrico.com
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	MCS data (microgeneration certification scheme) data Air collectors provided by John Hollick	Data revised according to new timeline provided by Elizabeth Waters 2023
United States	**Brad Heavner** California Solar and Storage Association (CALSSA) **Pam Murphey** IEA SHC Technology Program	Water Collectors and air collectors: IAPMO Solar Heating & Cooling Programs Air collectors: John Hollick 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	No new data reported for 2021 Cumulated collector area by end of 2020
Zimbabwe	**Samson Mhlanga** National University of Science and Technology, Bulawayo	Dr. Anton Schwarzlmüller Domestic Solar Heating unpublished statistics SOLTRAIN survey 2021 (unpublished sources)	Cumulated calculated by AEE INTEC

9.9 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 2021; prepared by SWISSOLAR, Thomas Hostettler, Bern, Switzerland July 2022
- Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Austria – Innovative Energy Technologies - Market Development 2021; Ed. Peter Biermayr et al, Vienna, Austria June 2022
- Bundesverband Solarwirtschaft e.V. (BSW-Solar): Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) 2023; accessed May 2023
- 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 2022, The State of Renewable Energies in Europe, Edition 2022
- Global Market Outlook for Solar Power / 2022-2026, Solar Power Europe, 2022
- GWEC / Global Wind Report 2022, Global Wind Energy Council, March 2023
- IEA Global Energy Review 2023
- IEA PVPS Snapshot 2021
- IRENA Global Geothermal Market and Technology Assessment, 2023
- IRENA Renewable capacity highligths, April 2022
- IRENA Renewable Energy and Jobs: Annual Review 2022
- IRENA Renewable Energy Statistics 2022
- 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 2021, December 2022
- 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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https://www.amee.ma/

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

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

http://www.giz.de/

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

https://www.iea.org/reports/solar-pv

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

http://www.irena.org/

https://mp.weixin.qq.com/s/1jXYS-8iMpstP2-3ddSerw

http://www.olade.org/

http://www.ren21.net/

http://sahwia.org/

http://www.solar-district-heating.eu/

https://www.solarpowereurope.org/

http://www.solarthermalworld.org/

http://www.solarwirtschaft.de/

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

http://www.swissolar.ch/

9.10 List of Figures

9.11 List of Tables