Werner Weiss, Monika Spörk-Dür

Global Market Development
and Trends 2023
Detailed Market Figures 2022

SOLAR HEAT WORLDWIDE

Edition 2024

SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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

SOLAR HEAT WORLDWIDE

Global Market Development and Trends 2023
Detailed Market Figures 2022

2024 Edition

Werner Weiss, Monika Spörk-Dür

AEE - Institute for Sustainable Technologies
8200 Gleisdorf, Austria

IEA Solar Heating & Cooling Programme, June 2024

Supported by

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

Notice:
The Solar Heating and Cooling Programme functions within a framework created by the International Energy Agency (IEA). Views, findings and publications of the Solar Heating and Cooling Programme do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

Design/Layout: HAI.CC
Printed by DORRONG Graz

DOI: 10.18777/ieashc-shww-2024-0001

Acknowledgments

The authors would like to give special thanks to the following contributors to this edition of the Solar Heat Worldwide Report:

Chapter Contributors

Chapter 5.3:
Solar Heat for Industrial Processes
Wolfgang Gruber-Glatzl and René Baumann
AEE INTEC, Austria
Bärbel Epp, Solrico, Germany

Chapter 5.4:
Photovoltaic-Thermal Systems (PVT)
Carina Seidnitzer-Gallien and Thomas Ramschak, AEE INTEC, Austria

Chapter 5.5:
Photovoltaic generated heat
Prof Robert Taylor, School of Mechanical and Manufacturing Engineering, Sydney, Australia
Lavhe Maluleke, Stellenbosch University, South Africa

Chapter 5.6:
Solar Air Conditioning and Cooling
Dr Uli Jakob, Dr Jakob energy research GmbH & Co. KG, Germany
Daniel Neyer, Neyer Brainworks GmbH, Austria
Marco Calderoni, R2M Solution Srl, Italy

Chapter 5.7:
Solar Air Heating Systems
John Hollick, SolarWall Conserval Engineering Inc., Canada

Country Data Contributors

We very much appreciate the long-term cooperation with all national delegates of the IEA SHC Executive Committee, Solar Heat Europe, and national experts, who provide updated solar thermal market data from 72 countries around the globe every year. All these contributors are listed in the Appendix of this report.

Advice and copy editing

The authors would like to thank Pamela Murphy, Secretariat of the IEA SHC Technology Collaboration Programme, for her valuable feedback, ideas for improvement, and copy editing of the report.

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). This unique series of reports documents solar thermal energy development over the last twenty years.

The 2024 edition and past editions can be downloaded from the website, http://www.iea-shc.org/solar-heat-worldwide.

The report aims to achieve the following objectives:

1. Provide an overview of the general trends in the solar thermal industry.
2. Highlight unique applications and noteworthy projects within the sector.
3. Document the installed solar thermal capacity across key global markets.
4. Assess the contribution of solar thermal systems to energy supply and quantify the reduction in CO_2 emissions resulting from their operation.

The collector types detailed in the report are unglazed collectors, glazed flat plate collectors (FPC), evacuated tube collectors (ETC) with water as the energy carrier, and glazed and unglazed air collectors.

Photovoltaic Thermal (PVT) systems are included, as this market has grown in relevance in recent years.

Photovoltaic-generated heat systems are a pioneering technology, and this edition documents them in more detail for the first time.

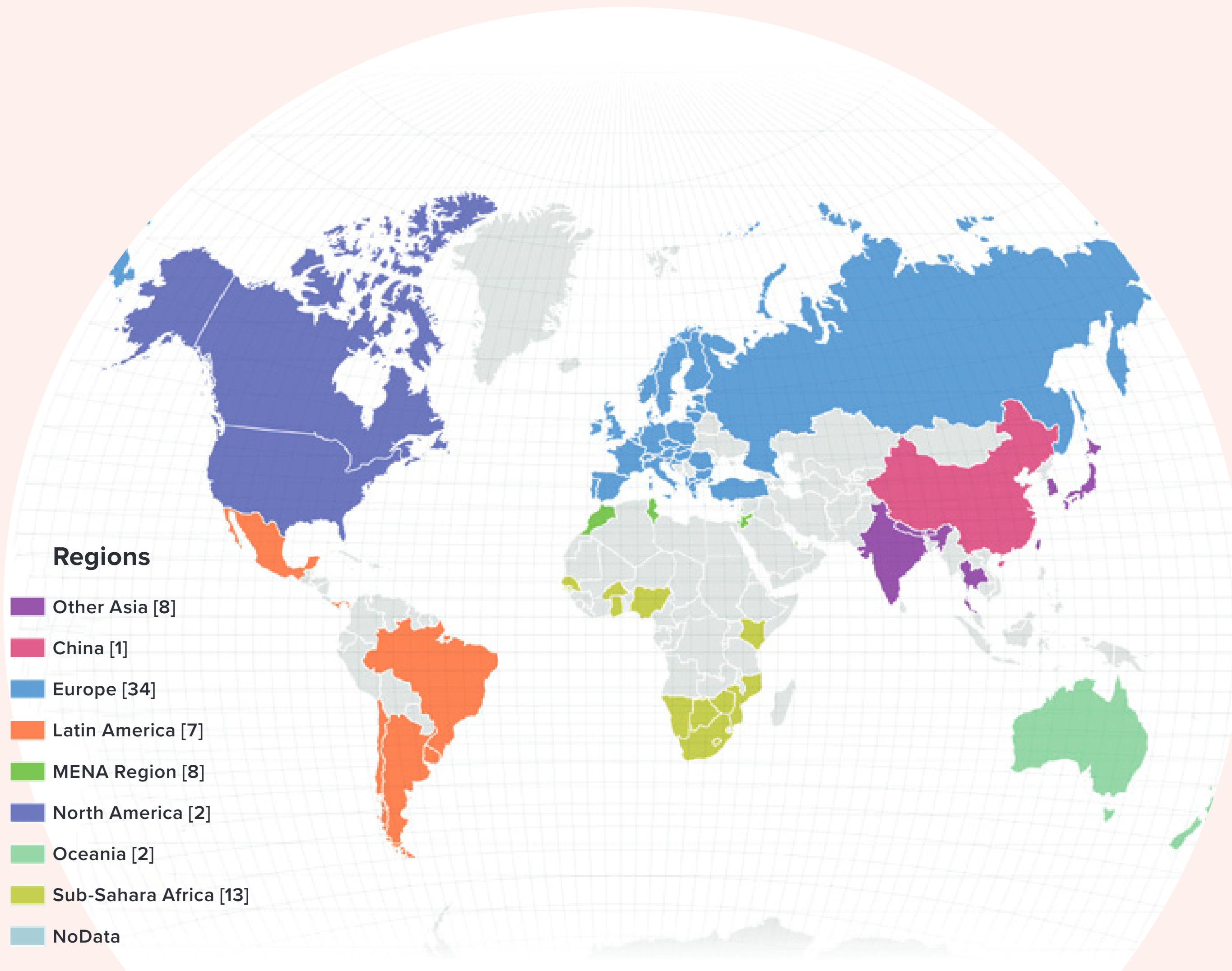

Figure 1: Countries shown in color have detailed market data. Countries shown in grey have estimated market data.
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

The 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 72 countries included in this report have very detailed statistics and others have only estimates from experts, the data was checked for plausibility based on various publications.

The collector area, also known 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 2024 edition and past editions can be downloaded from the website, **http://www.iea-shc.org/solar-heat-worldwide.**

2 Summary

This report is divided into three sections: The first part (Chapters 3 - 5) provides an overview of the global solar thermal market in 2023, highlighting key trends and showcasing successful applications such as solar-assisted district heating, solar heat for industrial processes, hybrid photovoltaic thermal systems, and photovoltaic generated heat systems. Additionally, Chapter 5 offers insights and projections for developments expected in 2024.

The second part (Chapters 6 - 8) offers detailed market data for 2022 from 72 surveyed countries. Notably, this year's edition includes data from Nepal, a new country, in the survey. Alongside figures for installed collector area and related capacity, this section delves into the distribution of collectors across various systems and applications, as well as solar yields and emissions reduction.

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

Photo: Abora Solar, Spain

Global solar thermal market developments in 2023

As of the end of 2023, the total operational solar thermal capacity reached 560 GW_{th}, equivalent to 800 million square meters of collector area. This means a net increase of 18 GW_{th} or 26 million square meters of collector area in 2023, or in other words, an increase in cumulative global installed capacity of 3% in 2023 compared to 2022.

The annual solar thermal energy yield of this installed capacity amounted to 456 TWh, which correlates to savings of 49.1 million tons of oil and 158.4 million tons of CO_2.

Despite the overall increase in total installed capacity, it's noteworthy that the installed capacity of 21 GW_{th} or 30 million square meters of collector area in 2023 marked a decrease from the previous year's figure of 22.7 GW_{th}. This indicates a 7% decline in the global solar thermal market compared to 2022.

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

In 2023, 28 new large-scale solar heating systems (>350 kW_{th}, 500 m^2) were constructed, totaling 139 MW_{th} capacity. This brought the global count to 598 systems, with a combined capacity of 2,285 MW_{th}, corresponding to 3.3 million square meters of collector area.

The largest sub-sector of large-scale solar thermal heating systems is solar district heating, comprising 336 systems with 1,908 MW_{th} capacity (2.73 million square meters).

Solar heat for industrial processes (SHIP)
In 2023, at least 116 new SHIP plants with a capacity of 94 MW_{th} were installed worldwide.
This means a tripling of installed capacity compared to 2022. Even though this is a very good development, it should be noted that this corresponds to the average installed capacity in the solar process heat sector over the last seven years.

The total number of SHIP plants is approximately 1,200 systems, with a 1.4 million square meters collector area and a capacity of 951 MW_{th}.

Photovoltaic-Thermal (PVT) collectors
After experiencing steady growth averaging 9% annually between 2017 and 2020, followed by an all-time high of 13% in 2021, the trend took a sharp turn in 2022. The decline, driven by the end of subsidies for PVT in certain countries, led to market slumps of 51% in 2022 and 30% in 2023.

The newly installed capacity in 2023 was 29.5 MW_{th} and 14.5 MW_{peak}. Thus, the cumulative installed PVT collector area is 1.6 million square meters, which relates to a thermal capacity of 822 MW_{th} and an electrical capacity of 292 MW_{peak}.

Photovoltaic-generated heat systems
An emerging trend is the utilization of photovoltaic-generated heat. This can be seen in the small system sector with directly coupled "PV2Heat" systems in South Africa, where 34,000 systems of this type have been installed. In addition, with a growing number of solar combisystems providing hot water and space heating supply in residential buildings, and the two PV district heating systems built in 2023.

Market status worldwide in 2022

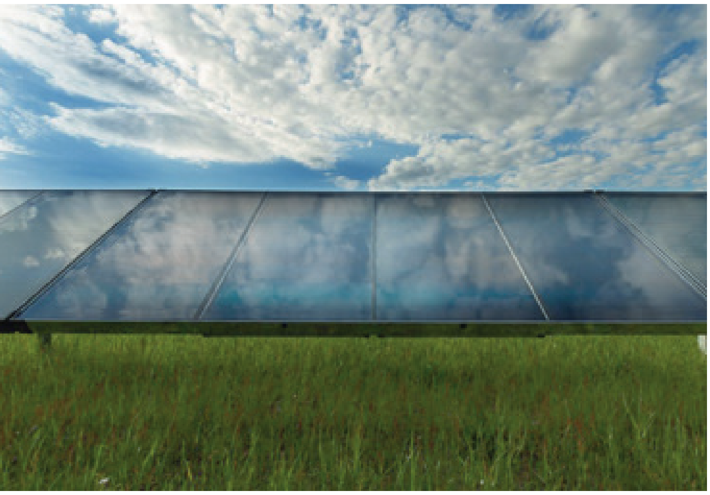

Photo: Savo Solar / Solar Heat Europe

While 2023 data is only available for 20 leading countries, the report includes detailed 2022 data on 72 countries.

122 million solar thermal systems were in operation at the end of 2022.

The top 5 countries by total installed capacity at the end of 2022 were again The People's Republic of China (hereinafter China), Turkey, the United States, Germany and Brazil.

However, the picture is 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 2022 **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 73% of all newly installed collectors in 2022 were evacuated tube collectors, but also by the Indian market, with 95% 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 2022, while 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 2022 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 2022. 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 61% of all newly installed systems in 2022, while 39% 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 345,000 worldwide in 2022.[1]

The estimated worldwide turnover of the solar thermal industry in 2022 is € 15.3 billion (US$ 16.4 billion).

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

3 Worldwide solar thermal capacity in 2023

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 560 GW_{th} (800 million m^2) in 2023. The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 456 TWh in 2023. The cumulated worldwide installed capacity increased by 3% in 2023 compared to 2022. (Figure 2).

Figure 3 shows the annual installed collector capacities and the net additions.[2] In 2023, a total capacity of 21 GW_{th}, or 30 million square meters of collector area, was installed. This means the global solar thermal market declined 7% compared to 2022.

Over the past decade, it's evident that the yearly rate of new installations has decreased by over fifty percent. Most of this development is due to the ongoing challenges in the real estate sector in China, which have persisted for several years. This became clear again in 2023, as the globally dominant Chinese market experienced a significant slump of 7.7%.

[2] The net addition is the difference between the annually installed collector capacity minus the collector capacity of those collectors that have reached their statistical lifespan of 25 years. For details in the lifespan see chapter 6.

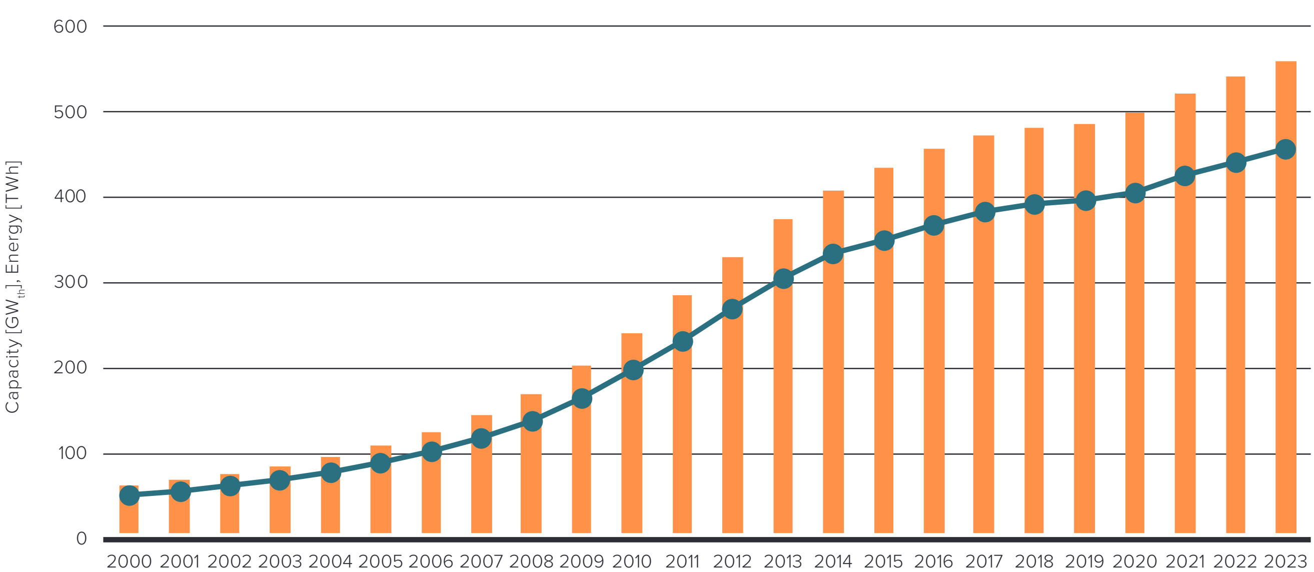

Figure 2: Global solar thermal capacity in operation and annual energy 2000-2023

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

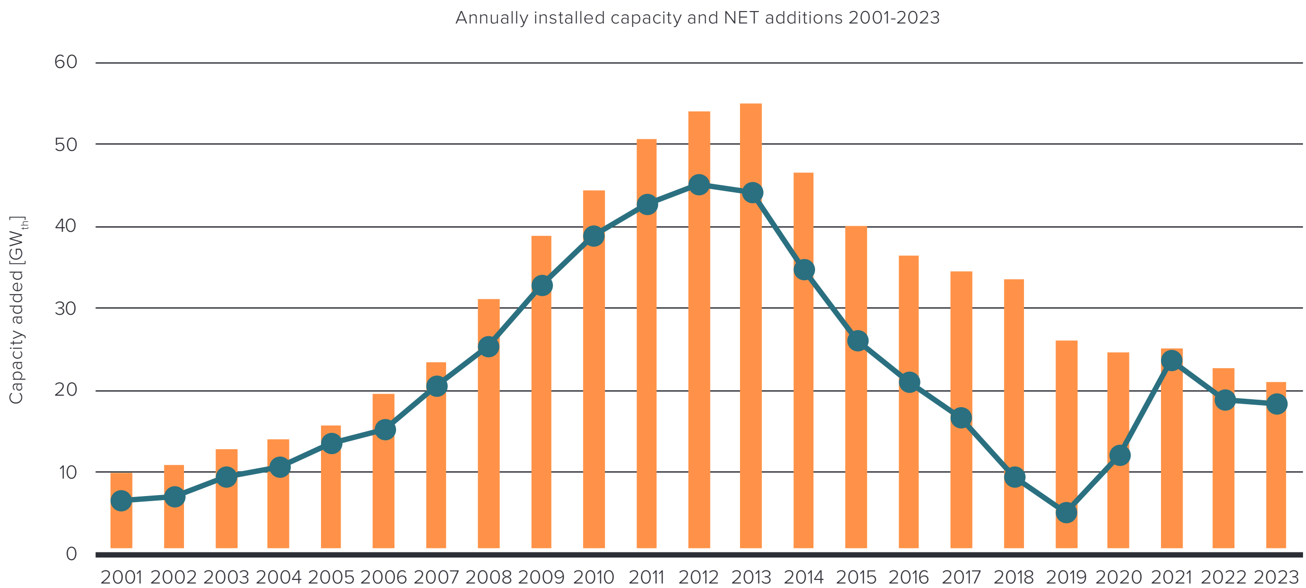

Figure 3: Annual installed collector capacity and net additions

Figure 4 illustrates the annual installed collector capacity categorized by collector type and 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) contracted. This is again 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

In 2023, the global solar thermal energy yield from all installed systems corresponds to savings of 49.1 million tons of oil and 158.4 million tons of CO_2. This underscores the substantial contribution of this technology toward mitigating global greenhouse gas emissions.

158.4
million tons of CO_2 avoided

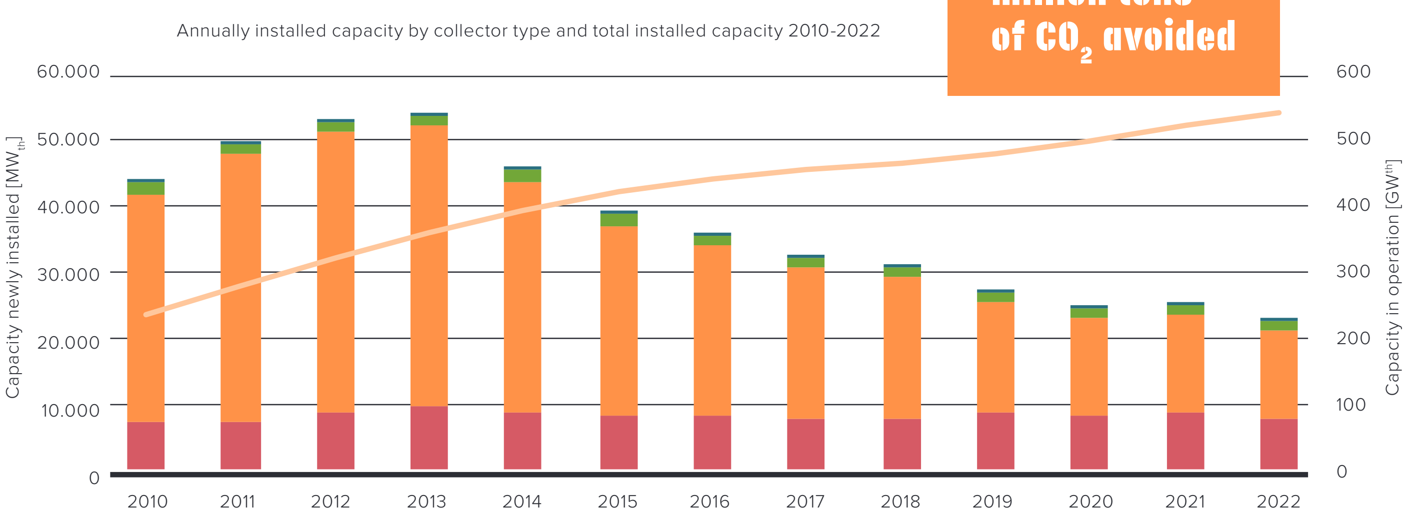

Figure 4: Annually installed capacity by collector type and total installed capacity 2010-2022

Parabolic trough collectors at Iberafrica in Kenya
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 2023 was 560 GW_{th}[3], which trailed behind wind power's installed capacity of 1,021 GW_{el} and photovoltaics 1,581 GW_{el} of installed capacity (Figure 5). Geothermal energy and concentrated solar (thermal) power (CSP) lag behind these three technologies in installed capacity. The total capacity of geothermal power was 15 GW_{el}. and CSP was 7 GW_{el}.

In terms of energy, solar thermal systems supplied 456 TWh of heat, whereas wind turbines supplied 2,496 TWh and photovoltaic systems 1,805 TWh of electricity.

[3] The figures for 2023 are based on the latest market data from Australia, Austria, Belgium, Bhutan, Brazil, China, Cyprus, Denmark, Germany, Greece, India, Italy, Mozambique, Poland, Portugal, South Africa, Spain, Switzerland, Turkey, United Kingdom and USA which represent about 95% of the cumulated installed capacity in operation in 2023.

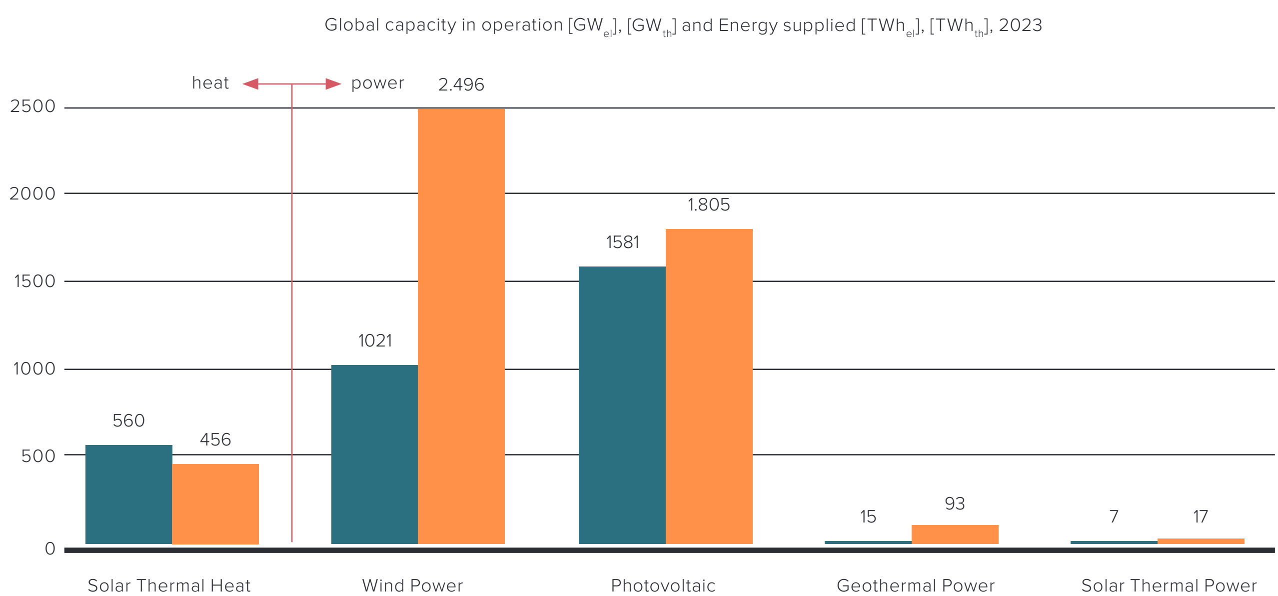

Figure 5: Global capacity in operation [GW_{el}], [GW_{th}] 2023 and annual energy yields [TWh_{el}], [TWh_{th}]
(Solar Thermal: AEE INTEC, Wind Power: Global Wind Energy Council (GWEC), Photovoltaic: IEA Solar PVPS (https://iea-pvps.org/snapshot-reports/snapshot-2024/), Geothermal Power and Solar Thermal Power: Irena Renewable Energy Capacity Statistics 2023

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

4 Outlook 2024 and beyond

Even if the annual heat consumption expanded by 6% over 2017-2022 [4], the global final energy consumption for heating and cooling has remained virtually unchanged at around 50% of the total final energy consumption for many years. According to the IEA Renewables 2022 report, 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.[5] The remainder is used in agriculture, primarily for greenhouse heating.

The heating sector is dominated by fossil fuels. Apart from traditional biomass, only 13% of the global heating needs were met by modern renewables in 2022.[4] 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.

The IEA Renewables Report 2023 assumes that the share of heat from renewable energy will increase by more than 40% (+12 EJ) worldwide in 2023-2028. However, this growth corresponds to only 70% of the projected global increase in total heat demand, leading to a rise in fossil fuel consumption for heat and the associated CO_2 emissions (+5%/+0.6 Gt CO_2 in annual emissions).

This means that we must significantly accelerate the implementation of renewables if we want to achieve the international targets for reducing greenhouse gas emissions on time.

This demand for renewables can only be met through the intensive utilization of solar thermal energy, modern biomass applications, geothermal energy, and carbon-free electricity.

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, demand for large-scale solar thermal systems appears to increase in 2024. 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 expected in the building and industry sectors. 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 heat costs range from
€20 to €50/MWh

[4] Renewables 2023 – Analyses IEA, January 2024
[5] Renewables 2022: Renewable analysis and forecasts to 2027, IEA, January 2023

Increasing demand for solar district heating in Europe

According to the German Steinbeis research institute Solites, in March 2024, six new solar thermal systems for district heating networks with a total collector area of 13,955 square meters (9.4 GW_{th}) went into operation in 2023. Although this is less than expected, it is because the announced federal funding program for efficient district heating networks was released with a delay. Nevertheless, the positive trend of previous years appears set to continue in 2024 and beyond. Nine systems representing a collector area of 112,000 m^2 (78 MW_{th}) are under construction or in an advanced planning stage. Another 70 systems with a collector area of 400,000 m^2 (280 MW_{th}) are under concrete discussion or construction, according to Solites.

78 MW_{th} solar district heating in the pipeline in Germany

One of these German systems is in Sonderhausen with 4.3 MW_{th} of high-vacuum flat plate collectors (6,086 m^2). This system should start operating at the end of the first half 2024. In March 2024, in the city of Leipzig, construction began on the largest solar district heating plant in Germany. It has a capacity of 41 MW_{th} (58.500 m^2). During summer, the plant is expected to supply up to 20% of Leipzig's heat demand, contributing an average of around 2% annually. The plant is scheduled to be completed by the end of 2025 and will feed heat into the city's district heating network starting in 2026.

Another large-scale solar district heating system with a collector area of 48,000 m^2 (33.6 MW_{th} capacity) is nearing completion in Groningen in the Netherlands. According to information from the installation company, this system is scheduled to be completed in June 2024.[6]

Large-scale SHIP plants in the pipeline

In 2023, 116 solar thermal systems were built and put into operation, supplying industrial processes in various sectors. A clear trend here was that the large industrial process heat systems were predominantly built with concentrating collectors that enable the provision of higher temperatures (see Chapter 5.3.1).

This trend will continue in the coming years, as shown by currently planned systems worldwide. Some of these SHIP systems are presented below.

1.5 GW_{th} for an Aluminum Refinery

By far, the largest solar thermal plant in the project planning phase is the first GW-scale plant for an aluminum refinery of the Saudi Arabian mining company Ma'aden Group. As reported in the 2023 edition of the Solar Heat Worldwide report, the system builder Glasspoint and Saudi Arabia's leading mining company signed a memorandum of understanding in 2022 to build the world's largest solar process heat plant. The plant is to be built in Ras al Khair with a capacity of 1.5 GW_{th}, corresponding to a collector area of 6 km^2. It will produce 3,000 GWh annually using parabolic trough collectors and reduce the refinery's carbon emissions by 600,000 tons annually. The average daily steam production is expected to be 14,000 tons. Construction is scheduled to start in 2024, and the first solar steam will be used to refine bauxite ore into aluminum oxide in 2026.[7]

154 MW_{th} for Chilean copper mines

Building on the good experiences that began in 2013 with the commissioning of the 38 MW_{th} system for the Gabriela Mistral copper mine in Chile's Atacama Desert, the Chilean energy supply company Gasco is planning to build three large industrial solar thermal systems for electrolysis baths in copper mines. A total of three flat-plate collector fields with a total capacity of 154 MW_{th} are planned. Two solar thermal systems with 90 MW_{th} and 23 MW_{th} for the Minera Escondida copper mine and another with 41 MW_{th} for the Spence copper mine. Commissioning is scheduled for 2025.[8]

154 MW_{th} for Chilean copper mines scheduled

First commercial Fresnel collector system in Latin America

The first commercial Fresnel collector system in Latin America is at an advanced stage of implementation. The planning for the solar process heat system for the Unilever plant in Cuernavaca, Mexico, has been completed. The steam produced is intended to be used in the factory's production of personal care products. The construction of the solar heat system with a capacity of 365 kW_{th} (521 m^2) is planned for the second half of 2024.[9]

16.4 MW_{th} malting plant in Croatia

Despite some delays in planning and constructing 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 (16.4 MW_{th}) of flat plate collectors in combination with a 5,000 m^3 hot water storage tank.

[6] TVP Solar, April 2024
[7] Source: https://www.glasspoint.com/projects/maaden-solar, March 2024
[8] https://solarthermalworld.org, 23 February 2024
[9] Source: Miguel Frasquet Herraiz, Solatom

5 Solar thermal market development and trends in 2023

Multi-family house solar system "Im Werk" in Uster, Switzerland
Photo: Soltop Energie AG, Switzerland

The global market development in 2023 presents a varied landscape. Despite an overall decline of 7% in the global solar thermal market, mainly due to a decline of 7.7% in China, there are notable areas of growth.
In India, also one of the world's most important markets, the market for solar thermal energy grew by 27 %.

Growing markets are emerging in Southern Africa and Latin America, with some small African markets showing significant increases. Mozambique reported a notable 40% market increase, while South Africa experienced a 12% growth. Similarly, Mexico and Brazil saw growth rates of 5% and 3% respectively.

In Europe, only a handful of countries, including the United Kingdom and Greece, saw positive market growth in 2023. The UK solar thermal market grew by an impressive 66%, and Greece experienced a 10% growth. With this, Greece is the sole European country to have sustained uninterrupted growth for many years. Meanwhile, former European market leaders like Denmark faced a 25% decline. Similarly, traditionally strong countries such as Spain saw declines of 26%, along with Germany, Poland, and Cyprus experienced decreases of 46%, 38%, and 10%, respectively. The situation is similar in Australia, where the market declined by 8% in 2023.

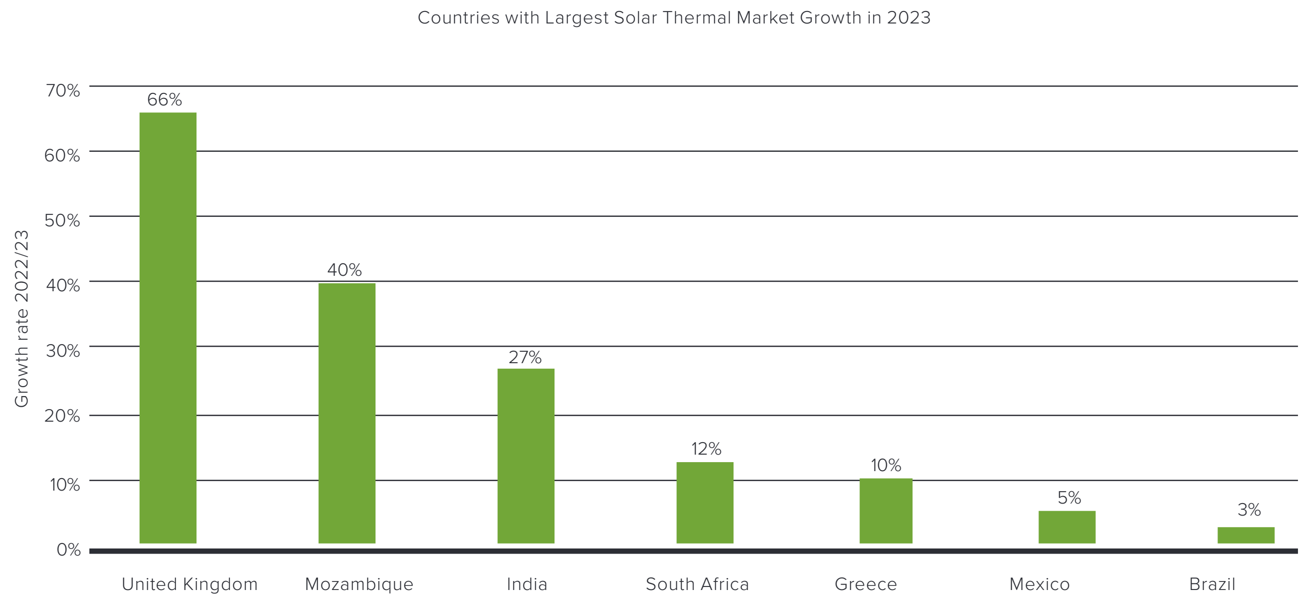

Figure 6: Reporting countries with the highest growth rates in 2023

66%
market growth in the UK in 2023

Roof-integrated solar system for hot water preparation
Photo: Velux / Solar Heat Europe

5.1 Small-scale solar thermal heating systems

Approximately 60% of the world's annual installations consist of small-scale solar water heating systems and solar combi-systems for combined hot water preparation and space heating for single-family and multi-family houses, apartment buildings, hotels, and public buildings.

However, in many parts of Europe and China, these systems face growing competition from photovoltaic systems and heat pumps, resulting in a decline in market share in recent years. The systems are predominantly pumped systems that are characterized by complex system technology.

In contrast, thermosiphon systems dominate in Asia (excluding China), Latin America, Sub-Saharan Africa, and the Mediterranean region. The market for this type of system is relatively stable and so far, has come under less price pressure from photovoltaic systems. Only in South Africa there is increasing competition from PV2Heat systems. For detailed information, see also section 5.5.

LEARN MORE

Learn more about Solar Energy in Buildings at:
https://task66.iea-shc.org/

Photo: GREENoneTEC Solarindustrie GmbH, Austria

5.2 Large-scale solar thermal heating systems

Since the early 1980s, several large-scale solar thermal systems have been operational in Scandinavian countries and Central Europe, serving local or district heating networks and installed on large residential, commercial, and public buildings.

Since 2010, Denmark has been the dominant player in the large-scale system market and for nearly a decade in solar district heating. However, a significant shift in energy technology policy and funding conditions led to the collapse of the Danish solar district heating market in 2020. Subsequently, since 2020, Denmark has only seen the construction of three new plants and the extension of three existing ones. Compared to the very large systems built in previous years, it is remarkable, that one of the new systems added in 2023 was relatively small, with a collector area of only 2,000 m^2 (1.4 MW_{th}). Consequently, Denmark has slipped from first to fourth place among newly installed large-scale plants.

In 2023, China reported installing five new district heating systems with a collector area of 147,206 m^2 (103 MW_{th}) and 16 other large-scale systems with a 33,734 m^2 (23.7 MW_{th}) collector area. In addition to China and Denmark, new plants were commissioned in Germany and Austria in 2023. In Germany, six solar district heating systems were installed with a collector area of 13,955 m^2, and there are nine systems with a collector area of 112,000 m^2 under construction or in the planning phase and 70 further systems in the pipeline.

In 2023, Austria reported two expansions of existing large-scale district heating systems. The newly installed collector area totaled 2,173 m^2 (1.5 MW_{th}); The total collector area of these district heating systems is now 1,954 m^2 (1.4 MW_{th}) and 6,807 m^2 (4.8 MW_{th}).

By the end of 2023, 598 large-scale solar thermal systems (>350 kW_{th}, 500 m^2) were operating worldwide. Their total installed capacity equaled 2.3 GW_{th}, corresponding to a 3.3 million square meters collector area.

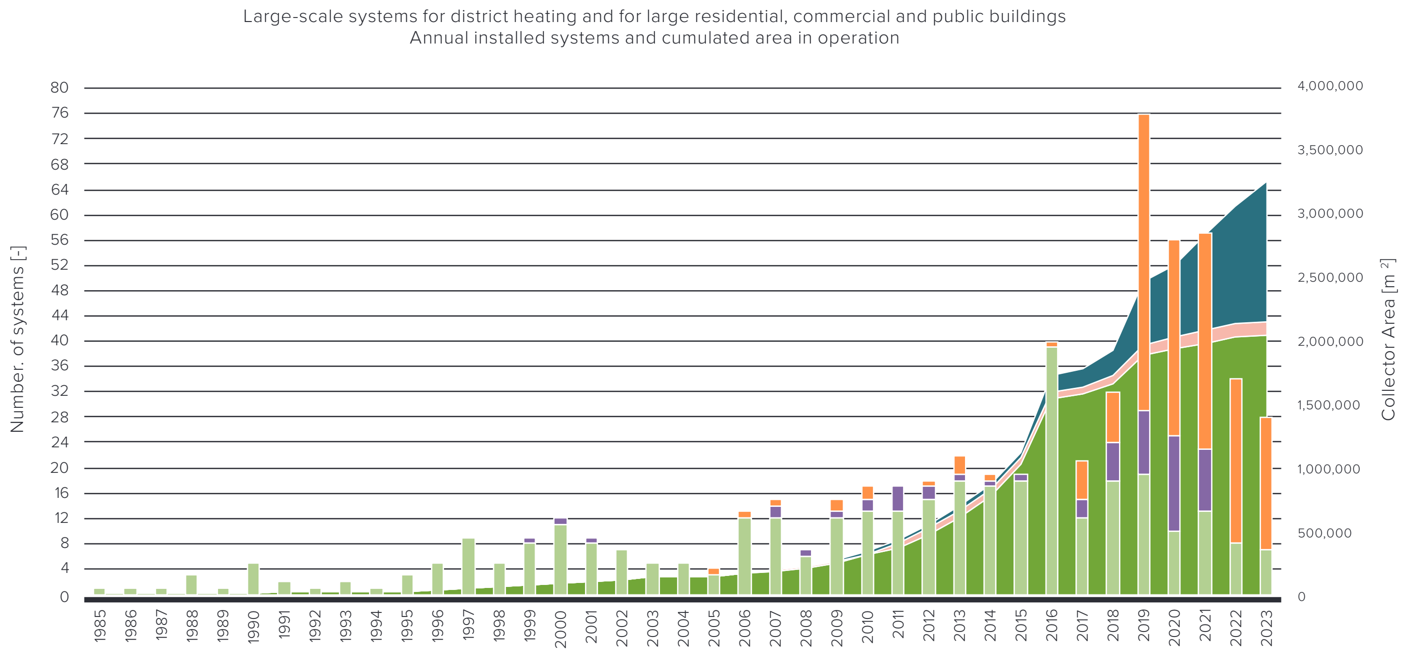

Figure 7: Large-scale systems for solar district heating and large residential, commercial, and public buildings worldwide – annual installations and cumulated area in operation in 2023

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 [m^2]
- Cumulated collector area in operation in China [m^2]
- Number of systems installed in "Other countries" [m^2]
- Cumulated collector area in operation "Other countries" [m^2]
- 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
Other Asia: Cambodia, Japan, Kyrgyzstan, India, Russia, South Korea, Thailand, Turkey
Plus: Australia, Canada, South Africa, USA

5.2.1
Solar district heating (SDH) systems

The largest sub-sector of large-scale solar thermal heating systems is solar district heating. By the end of 2023, 336 large-scale solar district heating systems (>350 kW_{th}, 500 m^2) with an installed capacity of 1,908 MW_{th} (2.73 million square meters) were reported in operation.

As shown in Figure 8, Denmark leads in this market segment, boasting the highest number of systems and installed area. Alongside Denmark (124 systems) and China (72 systems), several other countries have a growing interest in this plant type. Solar district heating systems present a compelling opportunity to decarbonize the heat sector in neighborhoods and entire cities.

Countries to note are Germany (56 systems, some with seasonal storage), Sweden (23 systems), Austria (20 systems), Poland and France (with 8 systems each). Outside China and Europe, solar district heating systems are installed in Saudi Arabia, Japan, Kyrgyzstan, Russia (Other Asia), the USA, Canada, and South Africa.

336 Solar district heating systems with 1.9 GW_{th} in operation

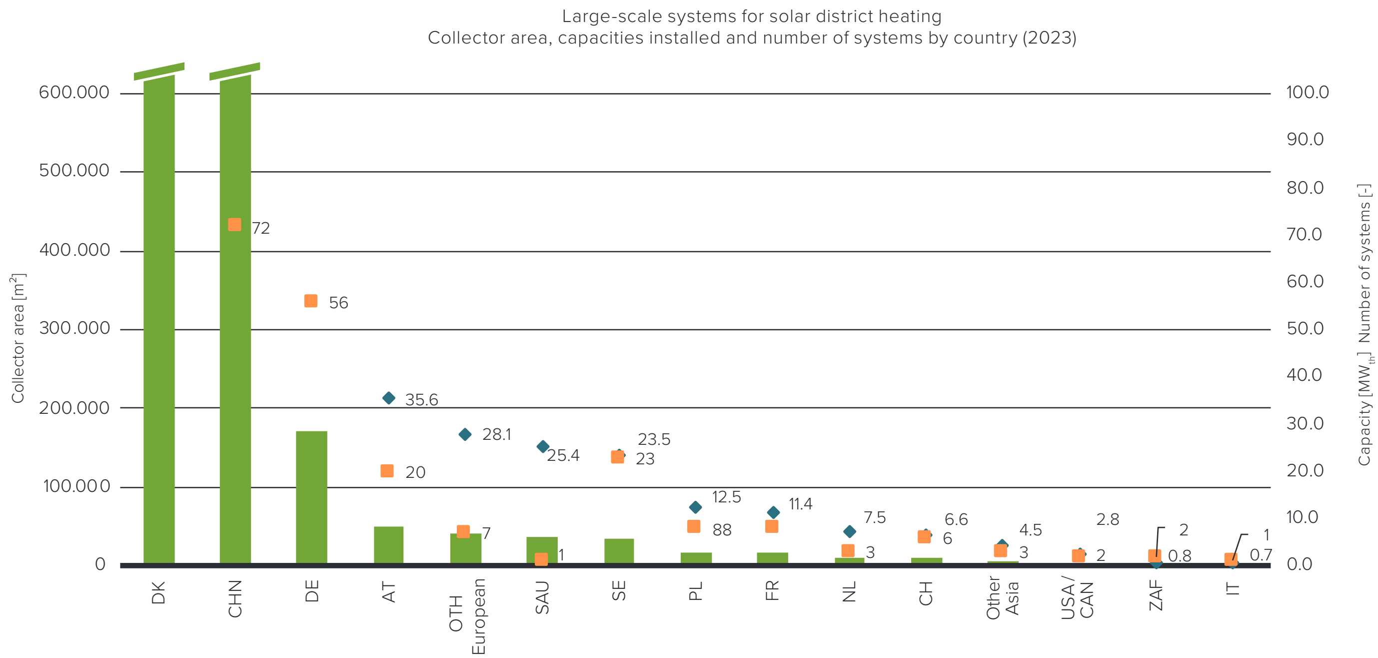

Figure 8: Large-scale systems for solar district heating – capacities and collector area installed and number of systems by the end of 2023

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

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 m², corresponding to a capacity of 110 MW_{th}. The second largest plant, with 65 MW_{th}, is in China.

The table also clearly shows the dominance of these two countries in terms of the number of largest solar district heating systems. Eleven of the 20 largest plants are in Denmark and seven are in China.

Table 1: The twenty largest solar district heating systems

Installation	SDH Project	Country	Installed Collector Area m²	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
2023	Longzi, Tibet	China	45036	32
2014	Dronninglund	Denmark	37,573	26
2023	Lazi, Tibet	China	36,700	26
2011	Rhiad	Saudi Arabia	36,305	25
2015	Gram stage 2	Denmark	34,851	24
2019	Zhongba, Tibet	China	34,650	24
2023	Dingri, Tibet	China	34250	24
2019	Ringe	Denmark	31,224	22
2023	Seni, Tibet	China	28356	20
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

Sources: PlanEnergi, Solarthermalworld.org, Bärbel Epp, China Academy of Building Research

Solar district heating plant in Søllested, Denmark, consists of 4,700 m^2 double glazed flat plate collectors
Photo: SavoSolar / Solar Heat Europe

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

Beyond solar district heating, another significant market segment in the large-scale sector involves solar applications for residential, commercial, and public buildings. By the end of 2023, 262 large-scale solar thermal systems (>350 kW_{th}, 500 m^2) were providing heat to these buildings globally. The total installed capacity of these systems is 377 MW_{th} (538,216 m^2).

China leads this market segment with 114 installed systems and a capacity of 275 MW_{th}, followed by Turkey with 18 systems and an installed capacity of 14.2 MW_{th}. Latin America ranks third with 16 systems and an installed capacity of approximately 12 MW_{th}.

Moreover, alongside European countries like Greece, France, Austria, Switzerland, Poland, and Spain, an increasing number of large-scale systems are being constructed in Latin America (Brazil and Mexico), the MENA region (Dubai, Jordan, Kuwait, United Arab Emirates), and Other Asia (Cambodia, India, Thailand). These systems are commonly installed in hospitals, hotels, and sports centers.

Solar thermal system for an apartment building in Zurich, Switzerland
Photo: Soltop Energie AG, Switzerland

LEARN MORE

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

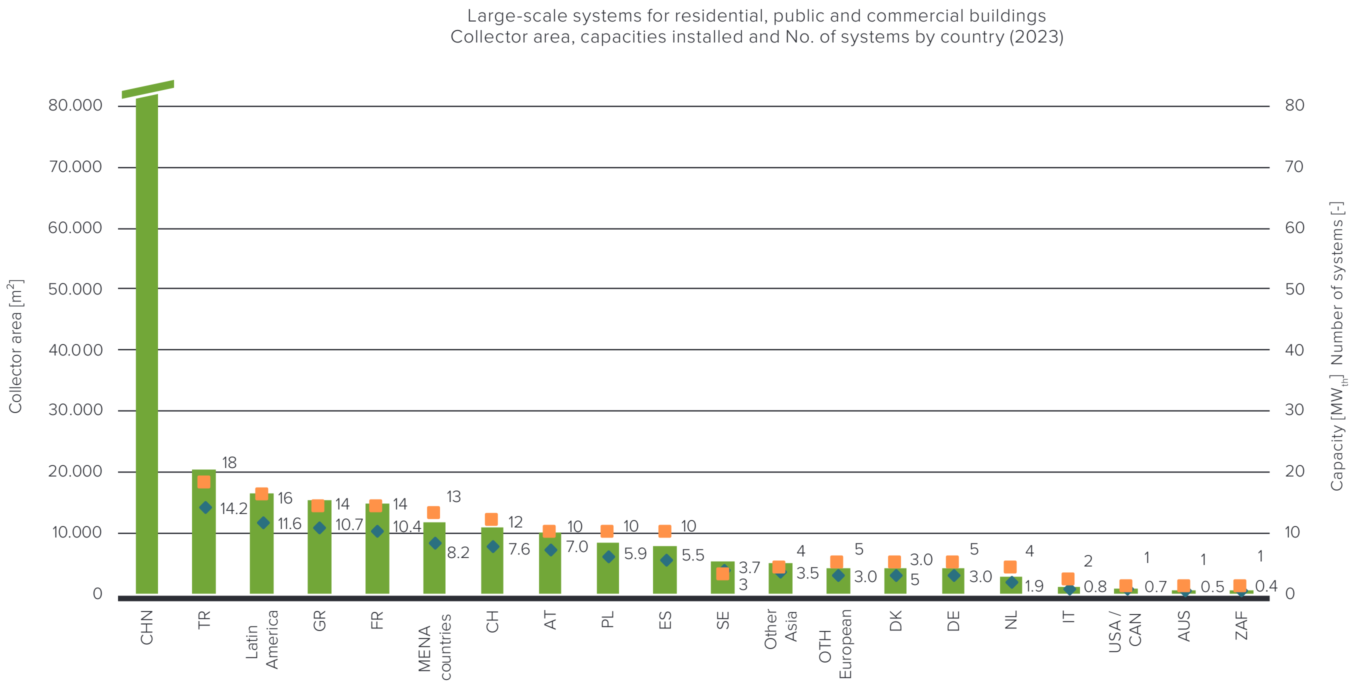

Figure 9: Large-scale systems for residential, public, and commercial buildings – capacities and collector area installed and number of systems in 2023

5.3 Solar heat for industrial processes

According to the IEA analysis, industrial accounts for two-thirds of industrial energy demand and almost one-fifth of global energy consumption.[10] It also constitutes most of the direct industrial CO_2 emitted yearly, as most industrial heat still originates from fossil-fuel combustion. At the same time, many companies have clear targets for reducing greenhouse gas emissions.

The challenge in decarbonizing industry is that industrial heat covers a wide range of temperature levels for different processes and end applications.

Electrification can be a solution for certain high-temperature industrial processes, such as steel production. For industrial low-temperature process heat up to 400°C, solar thermal systems are an excellent option. More than a thousand systems operating across various industry sectors worldwide impressively demonstrate this.
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.

According to a study published by the German agency solrico[11] in March 2024 and the SHIP database, the number of SHIP systems in operation totals at least 1,209 systems with 1.359 million square meters collector area related to a capacity of 951 MW_{th}.

Parabolic trough collectors for one of the breweries of the Carlsberg Group in Salonika, Greece
Photo: Absolicon

Although the market for solar thermal systems for industrial processes (SHIP) fluctuates in the number of systems installed per year and the annual installed capacity, it is a relatively stable market. Between 2017 and 2023, approximately 100 new SHIP systems with an average capacity of 1.1 MW_{th} each were commissioned each year.

[10] https://www.iea.org/commentaries/clean-and-efficient-heat-for-industry
[11] https://solarthermalworld.org/news/the-netherlands-and-spain-drive-ship-market-2023/

	2017	2018	2019	2020	2021	2022	2023	Annual average
No. of commissioned SHIP systems	107	99	86	85	73	116	116	97
Newly installed capacity [MW_{th}]	153	39	251	93	36	31	94	100
Average capacity/system [MW_{th}]	1,43	0,39	2,92	1,09	0,49	0,27	0,81	1,1

Table 2: Development of commissioned SHIP systems over the past seven years
Source: Solrico with additions from AEE INTEC

The analysis of the top 3 countries in terms of the number of installed systems and installed capacity also shows how diverse the SHIP market is. Mexico is ahead of Germany and the Netherlands in the total number of systems installed. In terms of the installed capacity of SHIP systems, the picture is entirely different, with Oman in first place, followed by China and Spain. For details, see Figure 13.

5.3.1.
New trends in solar process heat in 2023

In 2023, at least 116 new SHIP systems with a capacity of 94 MW_{th} were installed worldwide, according to the solrico study mentioned above. One hundred five of these newly installed systems (total collector area 133,000 m^2, 93 MW_{th}) are also documented in detail in the SHIP database.[12]

Two factors were particularly noteworthy in 2023. Even if the total number of documented solar process heat systems has not increased, it is remarkable that after two years with relatively small systems, the average system size has more than tripled compared to the systems installed in 2022. The second change in the market concerns the types of collectors used. In previous years, flat-plate collectors were primarily utilized for industrial applications. However, by 2023, **concentrating collectors** became the predominant choice, especially in larger systems. From the beginning of 2023 to March 2024, a total of 11 solar systems for industrial process heat with concentrating collectors with a total installed capacity of 120 MW_{th} were installed. It is worth noting that most of **the systems were installed in breweries**. In addition, an extraordinary plant was completed for the tourism industry in China in the first quarter of 2024.

Some of these systems are presented in more detail below.

Solar Snow for the Handan Bay Water World in China

A 80 MW_{th} solar plant for the Handan Bay Water World resort in the province of Hebei opens a new dimension. The 114,000 m^2 parabolic trough collector system provides heat to a thermal oil loop. Forty percent of the solar heat supplies an ice and snowmaking system for an indoor ski slope, as well as the hotel's HVAC and hot water systems and the indoor swimming pool.

An 80 MW_{th} parabolic trough collector system supplies snow for an indoor ski hall, as well as heating and cooling at the Handan Bay Water World in China
Photo: Inner Mongolia Xuchen Energy Co., Ltd

Breweries point the way

With four solar industrial process heat plants built in 2023, the brewing industry is pointing the way to a sustainable future for the food and beverage industry.

What Heineken, one of the world's largest brewery groups, began in 2013 at the Gösser Brewery in Austria has been impressively continued. At the Göss plant, the brewing process was converted from steam to hot water supply with the help of a 1 MW_{th} flat-plate collector system. The brewery group has now opted for concentrating collector systems to reach higher temperatures at their Spanish breweries in Sevilla and Valencia.

With a 30 MW_{th} parabolic trough collector system, now the largest solar industrial heating system in Europe, Heineken is setting new standards in the field of solar process heat in Sevilla. The parabolic troughs generate pressurized water at 210°C. To compensate for the fluctuations in production and demand, a thermal storage consisting of eight stratified, pressurized steel tanks with a total volume of 800 m^3 completes the system. The expected annual solar yield is 35,000 MWh, with heat being available for 15 to 20 Euro/MWh.

By switching to renewable heat, the brewery can reduce its gas consumption by more than 60% and reduce its carbon footprint by almost 7,000 tons of CO_2 equivalent per year.
What is also interesting about this project, built by the AZTEQ group, is that the heat supply is handled via a thermal power purchase agreement (TPA). The energy service provider Engie España operates the plant and supplies heat at a fixed price. At the end of the 20-year term of the agreement, ownership of the solar thermal plant is transferred to Heineken.

A section of Europe's largest solar industrial heat plant, with a capacity of 30 MW_{th}, was installed by Engie in cooperation with Azteq-Solarlite Spain at the Heineken brewery in Sevilla, Spain
Photo: Wolfgang Gruber-Glatzl, AEE INTEC

Another Heineken SHIP system, equipped with 6,000 m^2 of linear **Fresnel collectors**, began operation in March 2024 in Valencia, Spain. The solar field consists of 182 modules with a peak output of 4.2 MW_{th} and covers 10% of the brewery's steam needs. In addition, its 1.5 MWh storage allows it to operate in transition periods and store part of the energy generated on weekends.

This system also sets new standards, as it is the world's largest solar thermal system with Fresnel collectors.[13] The brewery also signed a steam purchase agreement with the turnkey supplier.

Two further solar process heat systems for breweries were built in 2023 in Bari, Italy, for Birra Peroni, and in Salonika, Greece, for the Carlsberg Group by the Swedish company Absolicon. Both systems, with a thermal capacity of 660 kW_{th}, supply the pasteurization process of the breweries.

660 m^2 parabolic trough collectors for the Brewery Birra Peroni in Bari, Italy
Photo: Absolicon, Sweden

Drying of spent grain from breweries

In connection with the solar thermal boom in breweries, two solar process heat systems with 7 MW_{th} air collectors should not go unmentioned. The Spanish animal feed specialist L. Pernía uses the Solar Wall air collector systems at its two locations in Sevilla and Madrid to dry spent grain from breweries, which is processed into animal feed.

3.9 MW_{th} parabolic trough collector system supplies drying ovens

A parabolic trough collector system with 5,540 m^2 of collector area (3.9 MW_{th}) and a heat storage supplies an Avery Dennison plant in Turnhout, Belgium, with solar-generated process heat. Avery Dennison is a global leader in self-adhesive materials and technologies. The products are used, among other things, in the automotive industry, construction, medical technology, and personal care. The solar field generates heat at temperatures of approximately 280°C. This is used for the partial solar operation of the drying ovens in the production lines for coating adhesive tapes. An annual yield of up to 2.7 GWh of thermal energy is expected, saving 2.3 GWh of gas annually.

3.9 MW_{th} Parabolic trough collector system at the company Avery Dennison in Turnhout, Belgium
Photo: Avery Dennison

[12] http://ship-plants.info/ data retrieved by 31st March 2024
[13] https://www.theheinekencompany.com/newsroom/heineken-and-csin-open-worlds-largest-solar-thermal-plant-with-innovative-fresnel-technology-for-industrial-use-in-spain/

5.3.2. Distribution of solar process heat systems across processes, countries, and sectors

As mentioned above, out of the 1,209 documented systems with a size of at least 50 m² collector area or 35 kW_{th}, 615 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.[14] These 615 SHIP systems account for a total collector area of 1,325,853 m² and a thermal capacity of 823 MW_{th}.[15] Only the data of these 615 SHIP systems are presented in the following figures. The data includes installed systems through March 2024.

The following figures are dominated by the world's largest solar process heat application in Oman, commissioned in 2017 and continuously expanded. The plant's current thermal capacity is 330 MW_{th}, accounting for 40% of the total installed thermal capacity of the 615 documented solar process heat applications worldwide. The figures include the new and second largest system at Handan Bay Water World, with 79.8 MW_{th}. Arguably, a unique application of SHIP. The third largest system is a greenhouse project in Australia with a capacity of 36 MW_{th}. In fourth place is the Heineken brewery in Sevilla, commissioned in 2023, with a capacity of 30.3 MW_{th}. A copper mine in Chile with a thermal capacity of 27.5 MW_{th}, once the largest system, is now fifth in the SHIP ranking.

Together, these five plants make up 61% of the total installed thermal capacity.

Figure 10 shows the distribution of the 615 systems in terms of size. The five systems mentioned above exceed 21 MW_{th} of thermal capacity (30,000 m²), 85 systems have installed capacities between 0.7 MW_{th} and 21 MW_{th} (1,000 m² - 29,999 m²) of thermal capacity, 79 systems have installed capacities between 0.35 and 0.7 MW_{th} (500 – 999 m²), and 446 systems are below 0.35 MW_{th} (<500 m²).

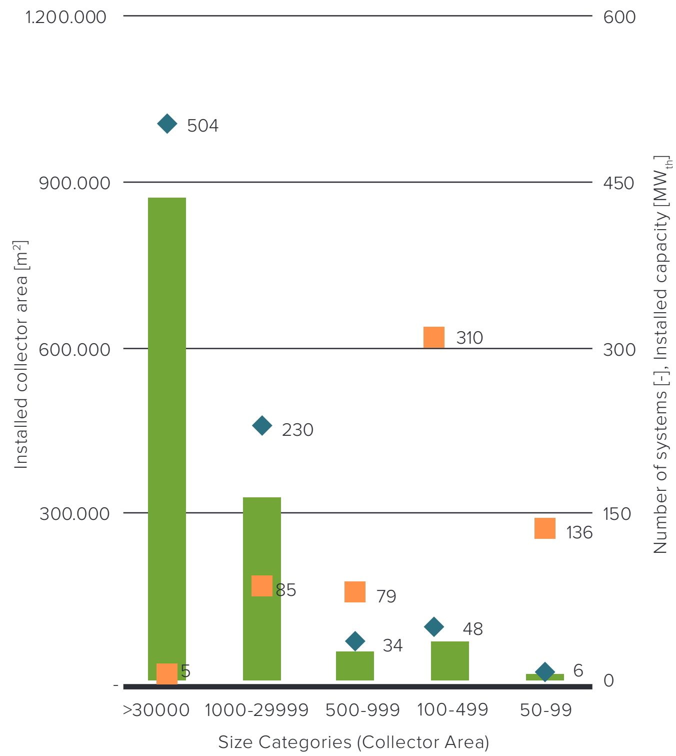

Figure 10: Global solar process heat applications in operation the end of March 2024 by number, capacity, and collector area
Source: SHIP database

Collector area [m²] · Thermal Power [MW_{th}] · Number of systems [-]

The process heat systems by collector technology are presented in Figure 11. 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 solidified their dominance in installed capacity and average system size. Three of the five largest SHIP systems use parabolic trough collectors. The average size of the 72 documented plants is 6.7 MW_{th}, showing the trend towards large systems that operate at higher temperatures.

[14] http://ship-plants.info/ data retrieved by 31st March 2024
[15] According to an agreement within the IEA SHC Task 64/IV, the conversion of m² collector area into kW_{th} 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.

Lactosol is the largest SHIP plant in France. It combines a 10.4 MW_{th} solar thermal flat-plate collector field with a 3,000 m³ water tank to supply hot air to the spray drying tower of a whey-powder facility of Lactoserum France. Project: Newheat
Photo: IMAGESinAIR Productions

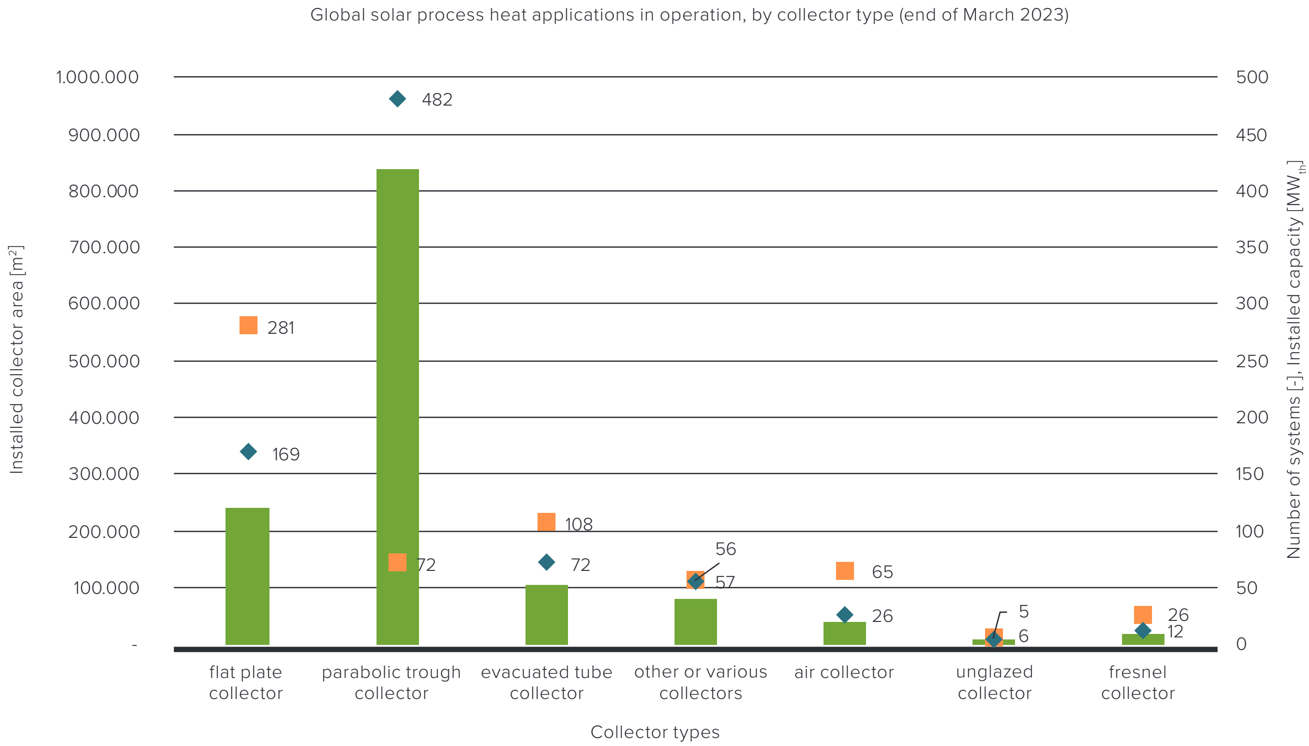

Figure 11: Global solar process heat applications in operation in March 2024 by collector type

Source: SHIP database

Figure 12 shows the industry sectors of the 615 documented systems. The food and beverage sectors continue to grow and is the dominant sector in terms of number of installed systems. This sector accounts for 199 systems with an average size of 1,083 m² and an installed thermal capacity of 151 MW_{th}.

In contrast, the mining sector includes two of the five largest SHIP systems and thus is the dominant sector in terms of installed thermal capacity. However, its share has decreased from 59% to 47%, while the share of food and beverage has increased from 13% to 18%.

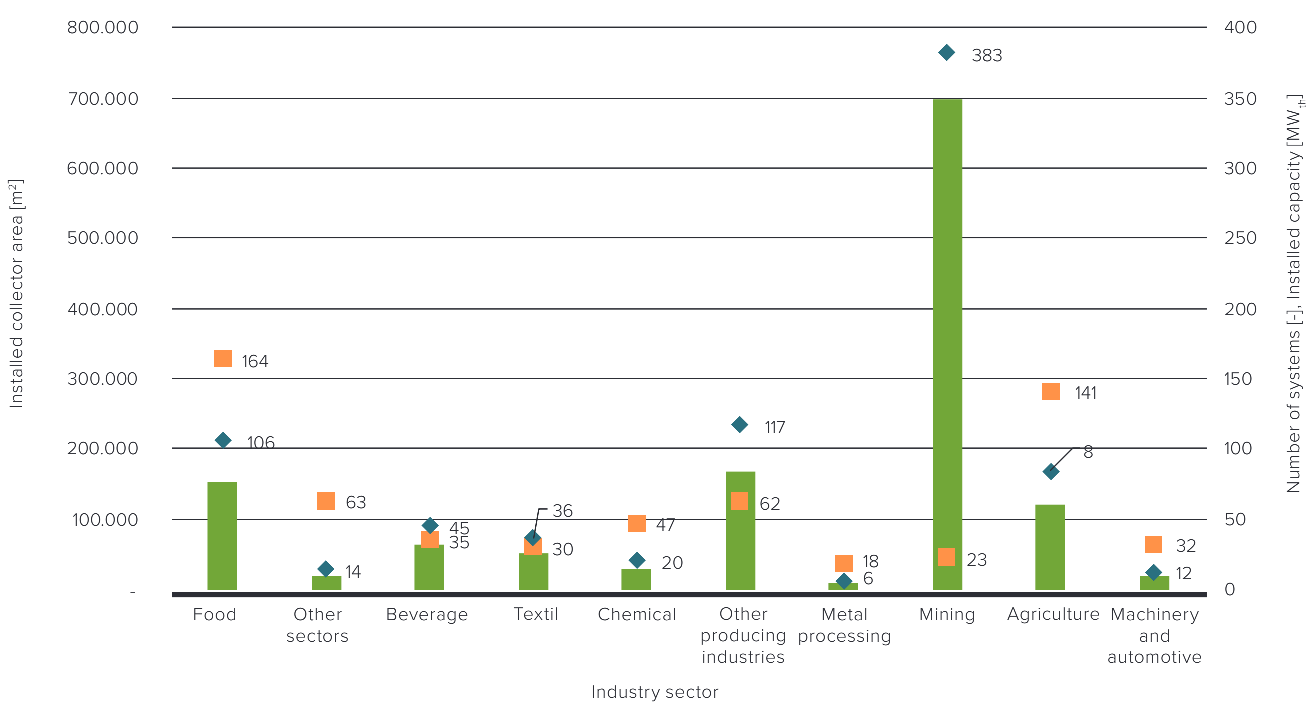

Figure 12: Global solar process heat applications in operation at the end of March 2024 by industry sector

Source: SHIP database

Figure 13 presents the globally installed solar process heat systems by country. Mexico has achieved 119 installed SHIP systems with a thermal capacity of 21 MW_{th} and leads when it comes to the number of installations.

The order looks different if it is related to the installed capacity. Oman leads in terms of installed thermal capacity (342 MW_{th}) with the two systems at the Amal Oilfield (Miraah and Amal II). China ranks second in this category with 55 systems and an installed capacity of 153 MW_{th}. However, it should be noted that according to information from the China Academy of Building Research, significantly more solar process heat systems have been built since 2021. 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.

The leading countries in Europe in terms of installed capacity in the SHIP segment are Spain (59 MW_{th}), the Netherlands (29 MW_{th}) and France (28 MW_{th}). The USA and Chile are also among the top 10 countries with 28 MW_{th} of installed capacity each.

Industrial process heating systems developed enormous momentum in Europe in 2023. In this year alone, 77 new systems were installed (+90%). This corresponds to an increase in area by 110,183 m^2 and in thermal capacity of 77.1 MW_{th} (+792%) compared to 2022.

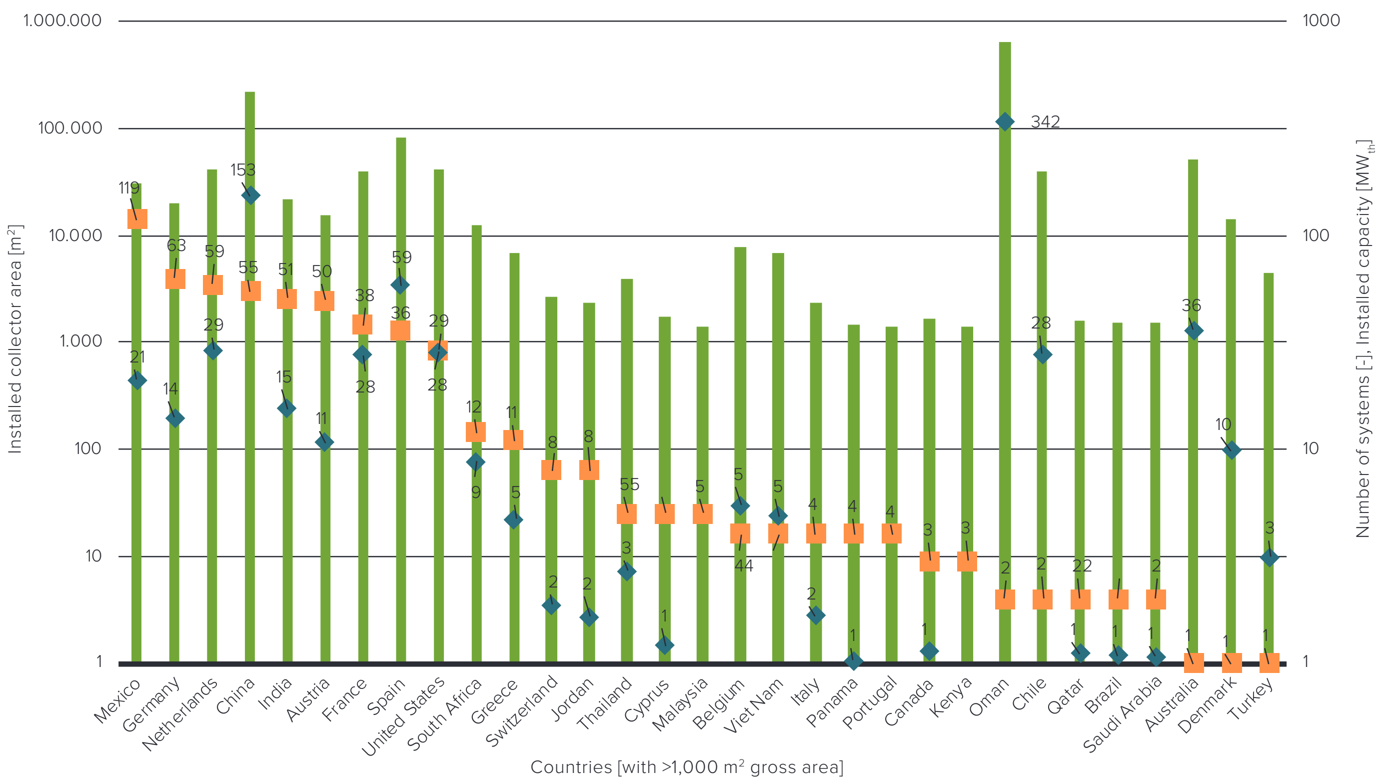

Figure 13: Global solar process heat applications in operation by country in March 2024
Source: SHIP database

Only countries with at least 0.7 MW_{th} (1,000 m^2 collector area) are shown in Figure 13 (593 of 615 systems accounting for >99% of installed thermal capacity).

Table 3 documents all SHIP systems with a collector area larger than 5,000 m^2 corresponding to 3.5 MW_{th}.

LEARN MORE

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

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

Table 3: Solar Heat for Industrial Processes (SHIP) plants > 5000 m²

Country	Site	Commissioned	Installed capacity [MW_{th}]	Collector size [m^2]
Oman	Miraah Oman, Amal	2017	330	622,080
China	Handan Bay	2024	80	114,000
Australia	Sundrop Farms, Port Augusta	2014	36	51,505
Spain	Heineken Brewery Seville	2023	30	43,414
Chile	Codelco Gabriela Mistral Mine	2013	28	39,300
Oman	Amal II	2020	12	17,280
France	Lactoserum Milk powder, Verdun	2023	11	15,317
France	Maltery, Issoudun	2021	9	13,243
China	Daly Textile, Hanghzhou	2007	9	13,000
Spain	Solarwall Madrid	2023	7	10,000
Spain	Solarwall Seville	2023	7	10,000
China	Ruyi Textile, Shandong	2015	7	9,903
USA	Prestage Foods St. Pauls, North Carolina	2012	5	7,804
China	Jiangsu Printing and Dyeing	2011	5	7460
Mexico	La Parerena Copper Mine	2016	4	6,270
Turkey	Packaging Business, Izmir	2021	4	6,000
Spain	Heineken, Quart de Poblet, Solatom, Valencia	2024	4	6,000
China	Jiangsu Jiashengyuan Agricultural Development, Sunrain	2023	4	6,000
China	Jingshi East Road Jinan	2011	4	5,750
Belgium	Avery Dennison, Turnhout	2023	4	5,540
China	Jinan, Shanddong, pre-heating of industrial boiler	2010	4	5,184
USA	Frito Lay, Arizona	2008	3.5	5,068
Vietnam	Prime Asia Leather, Ba Ria-Vung Tau	2018	3.5	5,018

Source: ship-plants.info

In addition to the more traditional industrial sectors that use thermal solar systems highlighted above, is horticulture. Solar thermal plants are being used to heat greenhouses for flower and vegetable cultivation. The following table provides an overview of the top 10 systems with collector areas larger than 50 m² between 2013 and 2020.

Table 4: Overview of the 10 largest solar thermal systems for flower and vegetable cultivation

Country	Site	Commissioned	Installed capacity [MW_{th}]	Collector size [m^2]	Storage tank [m^3]
Australia	Port Augusta	2014	36.05	51,505	-
Netherlands	Nibbixwoud	2020	10.5	15,000	1,450
Netherlands	Mol Freesia	2020	11	15,000	-
Denmark	Østervang Varpelev	2015	9.89	14,112	4,800
Netherlands	Heerhugowaard	2019	6.51	9,300	1,300
Netherlands	Tesselaar Freesias	2019	6	9,300	-
South Africa	Krugersdorp	2015	6.40	9,135	2,100
China	Tibet	2020	3.5	5,000	n.a.
Uganda	Kampala	2017	3.23	4,614	900
Ethiopia	Arerti	2020	2.91	4,170	1,400

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

Domestic hot water and swimming pool system with 2,082 m² PVT in Barcelona, Spain
Photo: Abora Solar, Spain

5.4
PVT – Photovoltaic Thermal Systems

Photovoltaic-Thermal collectors (PVT) are hybrid solar panels that generate both electricity (photovoltaic) and heat (thermal) from sunlight. These collectors integrate photovoltaic cells, which convert sunlight into electricity, with a thermal absorber to capture heat energy, thus reaching higher yields per area. This is particularly important if the available roof area is limited and integrated solar energy concepts are needed to achieve a climate-neutral energy supply for consumers, such as in residential and commercial buildings.

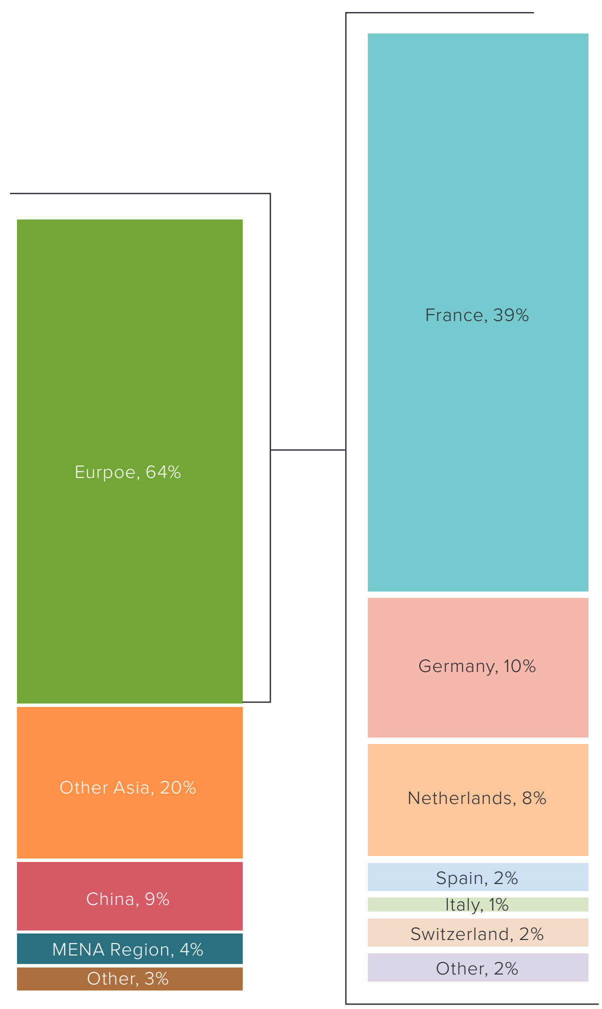

Figure 14: Distribution of the total installed collector area by economic region in 2023
Source: AEE INTEC

The technology is more complex than just a PV or a solar thermal collector but provides additional significant advantages. The PV production can be slightly higher if the collectors operate at temperatures below that of PV-only modules. Depending on the type of PVT collectors, 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 significant 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.

General market overview

In 2023, the total installed PVT collector area was 1,589,553 m² (822 MW_{th}, 292 MW_{peak}). The vast majority of this collector area was installed in Europe (1,011,212 m²) followed by Other Asia (318,329 m²) and China (146,926 m²), which together accounted for 822 MW_{th}, 292 MW_{peak} of the total installed capacity. The remaining installed collector area was shared between the MENA countries (Egypt, Israel, and Iraq (70,130 m²), Sub-Sahara African countries (Ghana, Lesotho, and South Africa (22,926 m²), United States and Canada (11,133 m²), Australia (3,576 m²), Latin America (766 m²), and others (4,555 m²).

In the European Market, France is the market leader with an installed collector area of 616,551 m² followed by Germany with 162,549 m² and the Netherlands with 127,303 m². In Spain, Italy, and Switzerland, collector areas range between 25,915 m² and 34,192 m². In the remaining European countries, collector areas of at least 23,664 m² were reported.

With a global share of 63% of installed thermal capacity, uncovered PVT water collectors were the dominating PVT technology, followed by air PVT collectors with 33% and covered PVT water collectors with 4%. Evacuated tube collectors and concentrators play only a minor role in the total numbers. Table 5 shows the cumulated installed collector area by PVT collector type at the end of 2023.

1.6 million m² PVT collector area installed worldwide

PVT system (240 collectors, 617 m², 390 kW_{th}, 17 kW_{el}) installed at the British Library in Central London, UK. Annual CO_2 savings of 58 tons
Photo: Naked Energy Ltd, UK

Table 5: Cumulated collector area by PVT collector type at the end of 2023

Country	Water Collectors [m²]			Air Collectors [m²]	Concentrators [m²]	TOTAL [m²]
	uncovered	covered	evacuated tube			
Albania	364	30	0	0	0	394
Argentine	129	0	0	0	0	129
Australia	3,477	0	0	99	0	3,576
Austria	1,929	2,710	0	0	0	4,639
Belgium	4,177	0	32	290	15	4,515
Brazil	26	0	0	0	0	26
Bulgaria	1,017	43	0	0	0	1,060
Canada	393	32	7	0	0	432
Chile	213	113	0	0	10	337
China	177,721	1,034	0	0	171	178,926
Croatia	907	125	0	0	0	1,032
Cyprus	0	0	3	0	0	3
Czech Republic	0	4	0	0	0	4
Denmark	117	54	0	0	0	171
Dubai	43	9	0	0	0	52
Ecuador	0	138	0	0	0	139
Egypt	0	0	0	0	21	21
Finland	312	0	0	0	0	312
France	67,024	1,952	0	547,575	0	616,551
Germany	154,900	6,939	3	512	195	162,549
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	70,054	0	0	0	0	70,054
Italy	18,091	2,696	0	0	0	20,787
Korea, South	280,814	0	0	0	0	280,814
Kosovo	176	14	0	0	0	190
Lebanon	25	0	0	0	0	25
Lesotho	0	48	0	0	0	48
Luxembourg	709	0	0	145	0	854
Macedonia	1,358	199	0	0	0	1,557
Maldives	0	0	0	0	21	21
Martinique	0	63	0	0	0	63
Netherlands	113,654	11,794	33	0	1,822	127,303
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	1,313	61	0	0	0	1,374
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	130	15	0	0	0	144
South Africa	0	79	32	0	767	878
Spain	1,552	32,640	0	0	0	34,192
Sweden	1,200	20	0	0	31	1,251
Sri Lanka	3,461	44	0	0	0	3,505
Switzerland	22,257	128	0	3,530	0	25,915
Turkey	0	25	0	0	30	55
United Kingdom	1,440	1,539	640	348	135	4,102
United States	10,676	20	7	0	0	10,702
Uruguay	0	2	0	0	0	2
Other	1,274	3,250	16	0	15	4,555
Total	965,358	67,385	773	552,499	3,538	1,589,553

Source: AEE INTEC

Table 6: Total installed PVT capacity in 2023 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	200	93
Argentine	0	0	0	0	0	0	0	0	0	0	0	0
Australia	1,781	656	0	0	0	0	54	17	0	0	1,835	673
Austria	968	416	1,372	469	0	0	0	0	0	0	2,340	885
Belgium	2,115	948	0	0	16	4	141	46	9	2	2,281	1,000
Brazil	13	5	0	0	0	0	0	0	0	0	13	5
Bulgaria	513	238	19	7	0	0	0	0	0	0	531	245
Canada	200	110	14	6	3	1	0	0	0	0	216	116
Chile	105	37	52	21	0	0	0	0	6	1	162	59
China	89,866	32,207	452	180	0	0	0	0	98	20	90,416	32,407
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	59	21	30	9	0	0	0	0	0	0	89	30
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
Finland	0	0	0	0	0	0	0	0	0	0	0	0
France	34,701	14,083	1,029	330	0	0	271,352	88,288	0	0	307,081	102,701
Germany	77,048	30,124	3,562	1,189	1	0	263	87	109	22	80,983	31,423
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	34,566	12,368	0	0	0	0	0	0	0	0	34,566	12,368
Italy	9,009	3,618	1,280	501	0	0	0	0	0	0	10,289	4,119
Korea, South	137,599	47,828	0	0	0	0	0	0	0	0	137,599	47,828
Kosovo	90	49	8	2	0	0	0	0	0	0	98	51
Lebanon	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	21	8	0	0	0	0	0	0	21	8
Luxembourg	349	129	0	0	0	0	71	23	0	0	419	152
Macedonia	701	321	100	35	0	0	0	0	0	0	802	356
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	58,827	24,160	5,441	2,031	14	4	0	0	1,046	213	65,328	26,407
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	672	329	30	10	0	0	0	0	0	0	702	340
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	68	31	8	2	0	0	0	0	0	0	75	33
South Africa	0	0	34	14	16	4	0	0	441	90	491	108
Spain	775	284	16,714	5,630	0	0	0	0	0	0	17,489	5,914
Sweden	682	228	11	3	0	0	0	0	18	4	710	235
Sri Lanka	1,760	903	21	8	0	0	0	0	0	0	1,781	911
Switzerland	11,264	5,054	63	21	0	0	1,806	576	0	0	13,134	5,651
Turkey	0	0	11	4	0	0	0	0	15	3	26	8
United Kingdom	722	307	819	268	273	72	170	55	66	15	2,050	717
United States	5,449	2,160	11	3	3	1	0	0	0	0	5,462	2,164
Uruguay	0	0	1	0	0	0	0	0	0	0	1	0
Other	651	294	1,496	617	7	2	0	0	7	2	2,161	914
Total	512,696	190,880	33,531	11,699	333	88	273,856	89,092	2,014	412	822,430	292,172

Source: AEE INTEC

As shown in the table, PVT collectors' total cumulative thermal capacity by the end of 2023 was 822 MW$_{th}$, and the PV power was 292 MW$_{peak}$.

Market development of PVT collectors between 2017 and 2023

Based on the market data provided by 46 PVT manufacturers, the market experienced robust growth of 9% on average between 2017 and 2020. In 2021, it reached its highest value at +13%, but in 2022, it faced challenges leading to a significant decline of 37%. Unfortunately, this trend continued in 2023. The newly installed capacity in 2023 amounted to 29.5 MWt_h and 14,5 MW_{peak}. This is a decrease of 30.4% compared to the installed thermal capacity in 2022.

In 2023, the global PVT market shrank by 30%

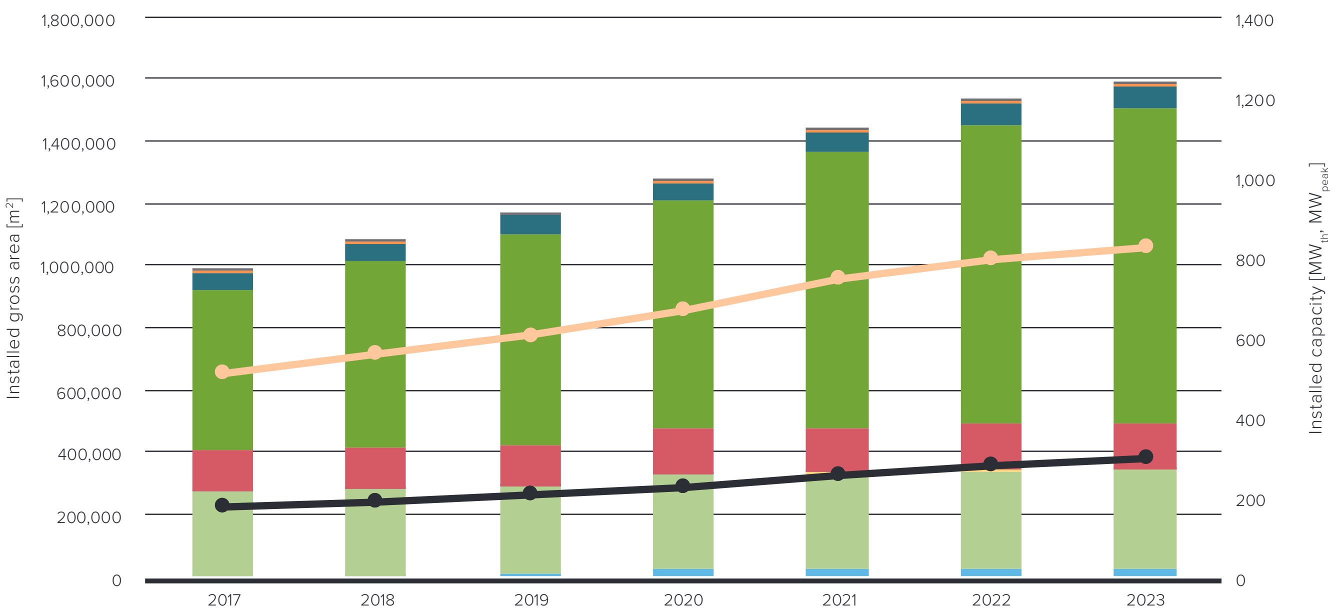

Figure 15: Global market development of PVT collectors from 2017 to 2023
Source: AEE INTEC

100 PVT solar panels at the town hall Offenbach an der Queich, Germany, operate in combination with a 50 kW heat pump
Photo: Consolar Solare Energiesysteme GmbH, Germany

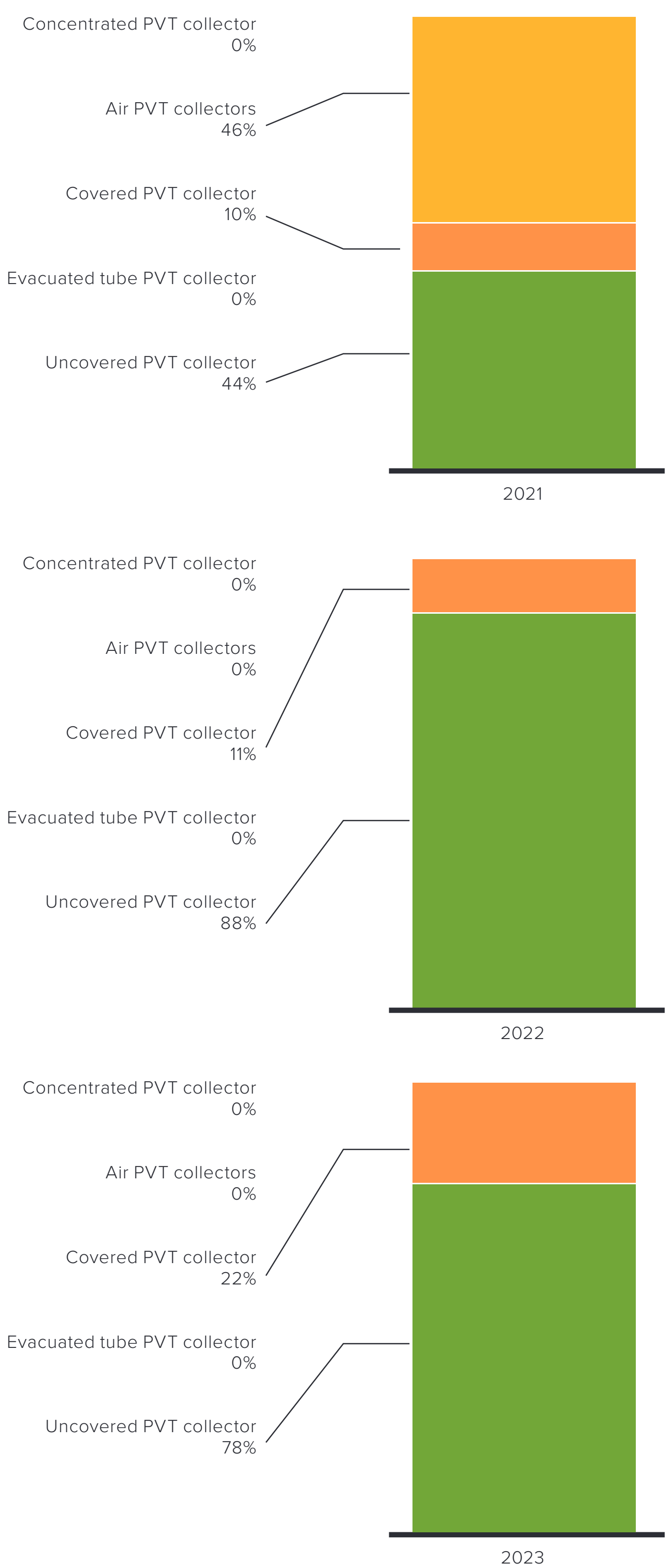

Figure 16: Distribution of newly installed PVT collector area worldwide by collector type from 2021 to 2023
Source: AEE INTEC

Market development in 2023

As mentioned above and shown in Figure 15, global interest in PVT systems grew steadily between 2017 and 2021. However, in 2022, the PVT market was negatively affected by declining or discontinued subsidies in some countries. At the same time, the demand for photovoltaic systems increased significantly worldwide due to large-scale subsidies and support measures.

Some PVT manufacturers responded to the increased demand for PV technologies by focusing mainly on the PV market. However, PVT was not able to capitalize on the PV momentum in every country. As a result, strong, previously dominant markets like France came to a near halt while smaller markets continued to grow.[16]

The significant global marked decline started in 2022, mainly due to the downturn in the French market. Changes in the French funding scheme led to the Air PVT collector market collapse in 2022 (-90%) and continued in 2023 (-16%). Other traditionally strong PVT markets in Europe, Germany (-22%), and the Netherlands (-59%) also reported market declines in 2023.

On the positive side, there were European countries with growing PVT markets. Spain reported a growth of +34% (7,832 m^2), and Belgium 20% (1,018 m^2). However, the increase in these countries could not compensate for the overall market slumps.

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, as shown in Figure 16. Air PVT collectors were the dominant collector type in 2021 at 45.5%, ahead of uncovered PVT collectors at 44.2%. In 2023, the market share of uncovered PVT collectors decreased slightly from 87% to 78 %, while covered PVT collectors increased by 10%. Air PVT collectors, evacuated tube PVT, and concentrated PVT have almost disappeared from the market.

[16] The 2023 PVT data are based on feedback from 28 PVT collector manufactures and PVT system suppliers from 12 different countries.

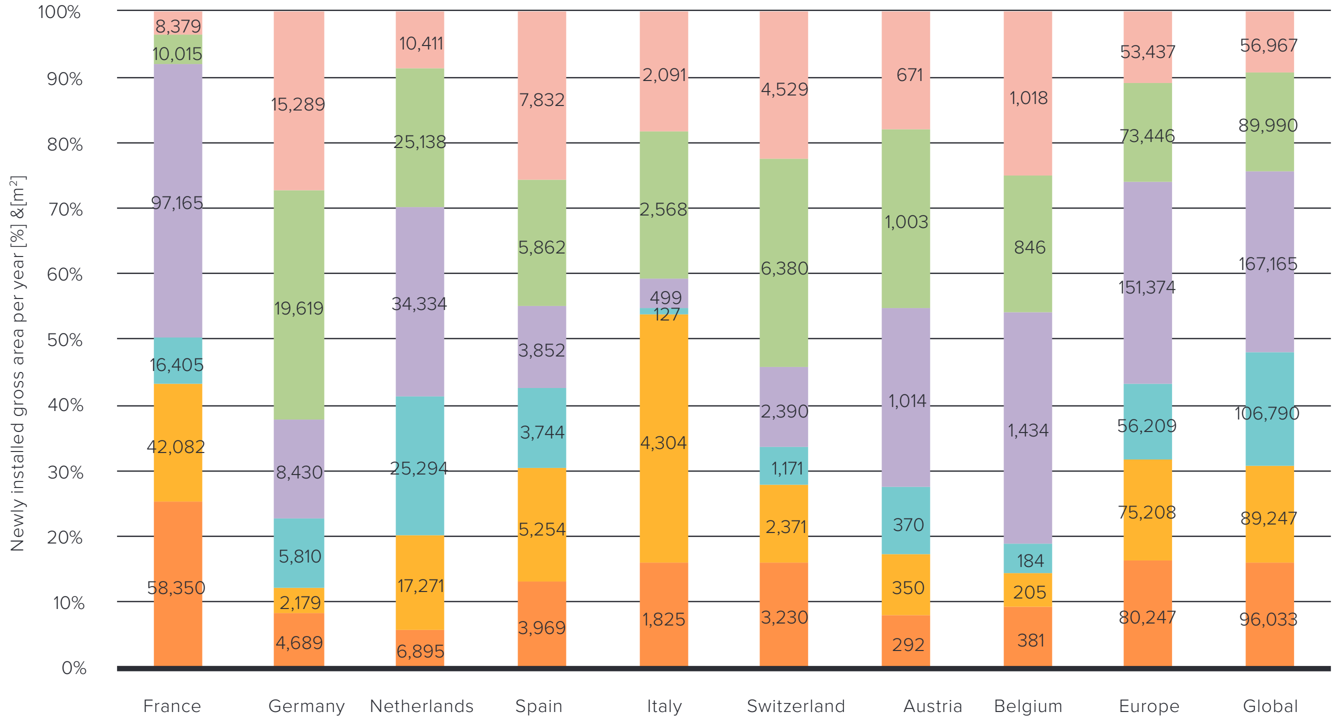

Figure 17: Newly installed PVT collector area in selected countries from 2018 to 2023 Source: AEE INTEC

5.5 Photovoltaic generated heat - PGH

In its Renewables 2023 report, the International Energy Agency expects global heat consumption in the building sector to stagnate over the period 2023-2028.[17]

Modern uses of renewable energy sources for space and water heating, as well as for cooking, are projected to expand nearly 40% in the meantime, raising the share of renewables in the building sector's heat consumption from 15% in 2023 to 21% in 2028, and displacing 5.7 EJ of fossil fuel consumption by 2028.

According to the IEA report mentioned above, renewable electricity will be the fastest-growing renewable heat source in buildings between 2023 and 2028. Its use will expand by two-thirds globally (+2.2 EJ) and contribute almost 40% of the sectoral increase in renewable heat consumption. This means that in the building sector, too, the electrification of the heating sector will take the largest share in the transition from traditional fossil fuel-based heating systems to renewable heating technologies.

PV2Heat systems installed in South Africa
Photo: Bongani Xakaza, SANEDI, South Africa

This shift is driven by various factors, including efforts to reduce greenhouse gas emissions, improve energy efficiency, and increase the integration of renewable energy sources into the heating sector.
However, challenges to widespread electrification of the heat sector remain, including the need for sufficient renewable energy generation capacity and grid infrastructure upgrades to support increased electricity demand.

LEARN MORE

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

In addition to these factors, the discussion about the electrification of the heating sector is also about questioning renewable heating technologies such as biomass, geothermal energy, and solar thermal energy and replacing them with photovoltaics (PV). While PV panels are primarily associated with generating electricity for various applications, including powering homes and businesses, they can also be utilized for heating purposes through electrification. Electric heating technologies, such as heat pumps or electric resistance heaters, can efficiently convert the electricity generated by PV panels into heat for space heating, water heating, or industrial processes. This Photovoltaic Generated Heat (PGH) discussion is being driven above all by the significant and ongoing price reductions in photovoltaics, which put traditional renewable heating technologies under economic pressure.

When photovoltaic solar collectors were >100 USD/Watt, solar thermal hot water was the vanguard technology for households to utilize their own solar resources. This has led to a large installed base of solar thermal systems. In 2024, a residential photovoltaic system can be installed for <1 USD/Watt in most markets. This dramatic cost reduction has made PV-driven electric hot water options viable. In fact, a directly connected "PV2Heat" system may now represent the most affordable and reliable option in some markets. In high PV penetration markets, several emerging solutions are being brought to market to increase the solar electricity consumed in water heating, space heating, and even district heating.

Examples of PGH system concepts and installations are presented below.

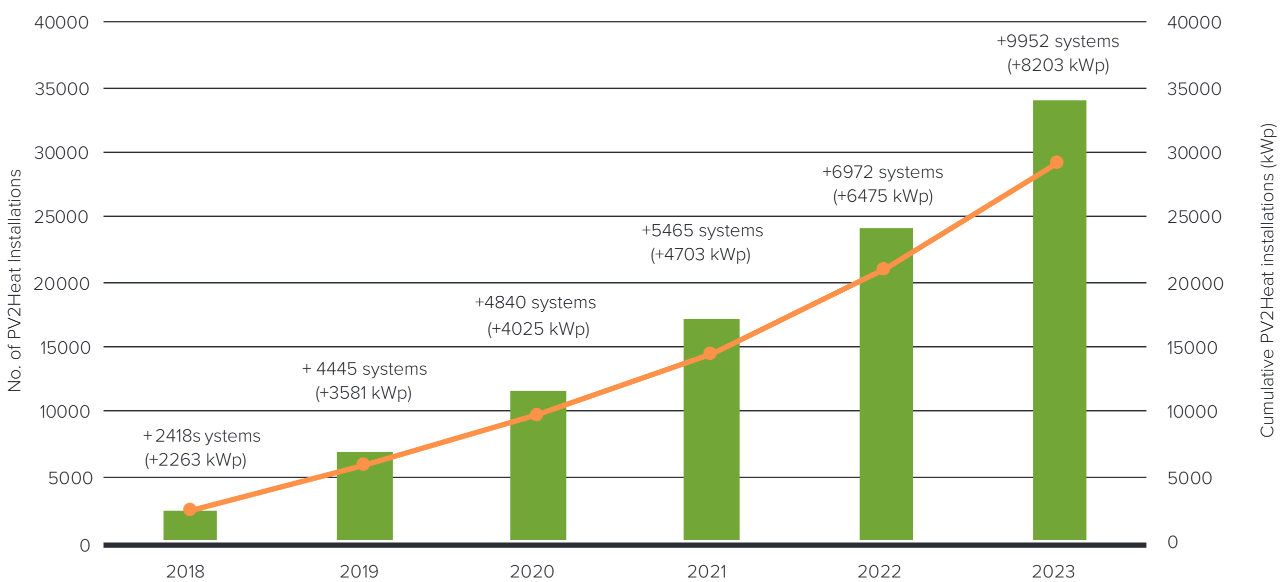

Figure 18: PV2Heat Market development in South Africa between 2018 and 2023
Source: Lavhe Maluleke, Stellenbosch University, South Africa

5.5.1. Direct Coupled "PV2Heat" Technologies

So-called "PV2Heat" systems couple the direct current (DC) from rooftop PV panels directly to a DC resistance heating element in the hot water tank (i.e., no inverter and minimal intermediary electronics). In areas with unreliable grid service, high connection costs, or low up-front capital, "PV2Heat" systems represent an ideal hot water technology.

PV2Heat systems are increasingly offered at a lower cost than solar thermal thermosyphon systems. In addition to cost benefits, this type of system also has the advantage that hot water storage tanks no longer need to be installed on the roof and do not have any stagnation or frost issues.

As presented for the first time in the 2021 edition of the Solar Heat Worldwide report, a considerable and growing market has developed in recent years, particularly in some countries in southern Africa. As shown in Figure 18, by the end of 2023, 34,000 "PV2Heat" systems had been installed in South Africa.

[17] Renewables 2023 – Analyses IEA, January 2024

A 144 kWpeak photovoltaic system supplies the multi-family house with electricity, hot water, and space heating[18]
Photo: Markus Ursprung, Switzerland

5.5.2.
Partially Coupled PV Hot Water Technologies

Partially coupled systems are particularly interesting in markets with high levels of installed PV on the electrical grid (e.g., a pronounced 'duck' curve). This has led to a dramatic reduction in the export value of generated PV electricity. Australia is a leader in PV penetration, with >1kWe installed capacity per person in 2024. Pure electric water heaters represent one-third of the Australian hot water market. The humble hot water storage tank in these systems can easily store ~10kWh of energy, and emerging products can unlock the value of this energy storage through PV self-consumption schemes that optimize usage patterns and real-time pricing and work together with other grid-connected systems.

Another option is PV diverters, which ensure excess PV electricity is routed to thermal loads when PV generation exceeds the house's other energy requirements. These devices have been developed predominantly by manufacturers in the United Kingdom.

5.5.3.
Solar Combisystem powered by PV

A solar combisystem, is a type of solar thermal system that integrates solar energy for both space heating and domestic hot water (DHW) production in residential or commercial buildings. This type of system still has a significant market share, particularly in some central and northern European countries. It combines solar thermal collectors with other components, such as a hot water storage tank, backup heating source (e.g., a boiler or electric heater), and control systems to provide space heating and DHW throughout the year.

A solar combisystem powered by PV instead of thermal collectors has a few examples in Germany and Switzerland where it provides 100% of the building's heat supply.

The following picture shows a multi-family house in Switzerland with a building-integrated 144 kW_{peak} photovoltaic system. The PV electricity is used to heat a 100 m^3 hot water tank with a diameter of four meters and a height of 12 meters. The water in the well-insulated tank is heated to 95°C in summer using electric heating elements. This hot water supplies the multi-party and communal house with hot water all year and space heating in winter.

5.5.4.
PV district heating in Germany

A new solar heating concept for municipalities in Germany is to use photovoltaic systems with heat pumps to supply municipalities with district heating from the sun instead of the traditional solar thermal systems used for district heating.

In September 2023, a ground-mounted photovoltaic system with a capacity of 125 MW was commissioned in the German municipality of Bundorf.
1.5 MW of the PV plant is directly connected to the neighboring heating center of the district heating network. There, a 400 kW electric boiler and a 200 kW air heat pump process the solar power into heat. Solar power will generate approximately 54% of the heat demand for an initial 30 connected buildings throughout the year. A few more buildings will be connected in the coming years.

A 75 m^3 buffer storage tank ensures the balance between daytime and nighttime heating demands and reserves for rainy days. In cases where this capacity falls short of meeting the district heating grid's winter requirements, a 200 kW wood-chip boiler can step in.

According to the Bundorf plant's general contractor, further projects using the PV-heat pump-biomass concept are in progress.[19]

125 MW_{peak} PV system in Bundorf, Germany, uses part of the solar power to supply the district heating network
Photo: MaxSolar, Germany

A second German example of the solar electrification of district heating systems was built in Altensteig Wart. Heat for the hybrid district heating system is provided by an 800 kW biomass boiler, a 375 kW heat pump, and a 100 kW combined heat and power (CHP) unit. In summer, the heat pump is supplied with power by a 70 kW_{peak} photovoltaic system. As the PV system cannot provide all of the electricity during the heating period, the electricity is generated by the CHP plant.[20]

While these two PV-powered district heating systems may still be relatively small in capacity, they represent innovative approaches to how sector coupling could revolutionize the electrification of the heating sector.

5.6 Solar air conditioning and cooling

Small and medium-sized applications

The global market for cooling and refrigeration will continue to grow, particularly in the Global South, and by 2050, 37% of the total electricity demand growth will be for air conditioning.[21] 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 developing countries[22], GIZ 2017 feasibility study for social housing buildings in Mexico[23], and RCREEE/UNDP 2015 study on commercial buildings/ applications in the Arab region[24].

A central argument for solar thermal-driven systems is that they consume less conventional energy (up to a factor of five[25]) and use natural refrigerants, such as water and ammonia. In Europe, their application is also pushed by the European F-gas Regulation No. 573/2024[26] to establish the total elimination of hydrofluorocarbons by 2050. Another driver for solar cooling technology is its potential to reduce peak electricity demand, particularly in countries with significant cooling needs and grid constraints. Today, for example, 30% of India's total energy consumption in buildings is used for space cooling, and it reaches 60% of the summer peak load, which is already stretching the capacity of the Indian national electricity supply.[27] 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 developing 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.[28]

Heat from 294 m^2 of flat plate CPC (Compound Parabolic Collector) solar collectors drive a 70 kW water/LiBr absorption chiller for air-conditioning at the CERMI center in Praia, Cape Verde, since 2013
Photo: JER

Solar thermal cooling is still a niche market, with over 2,000 systems deployed globally as of 2023. 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

[18] www.synergieplus.ch
[19] Source: Personal communication with AGFW and Maxsolar
[20] Sources: AGFW and Stadtwerke Altensteig, Germany
[21] https://www.iea.org/futureofcooling/
[22] https://www.green-cooling-initiative.org/fileadmin/user_upload/220607_Proklima_Solar_AC_med.pdf
[23] 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
[24] https://www.solarthermalworld.org/sites/default/files/story/2016-04-05/solar_cooling_in_arab_region_0.pdf
[25] http://task53.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task53-C3-Final-Report.pdf
[26] https://eur-lex.europa.eu/eli/reg/2024/573/oj
[27] Low energy cooling and ventilation in indian residences, https://doi.org/10.1080/23744731.2018.1522144
[28] https://www.bafa.de/DE/Energie/Energieeffizienz/Klima_Kaeltetechnik/klima_kaeltetechnik_node.html

LEARN MORE

Learn more about Solar Water Heating for 2030 at:
https://task69.iea-shc.org/

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[29], 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. There are several international initiatives (e.g., Global Cooling Pledge, MI IC7, K-CEP, IEA SHC Programme), research projects (e.g., SunBeltChiller[30], FRIENDSHIP[31], SHIP2FAIR[32], HyCool[33], sol.e.h.^{2}[34], Zeosol[35]) 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). This is also reflected in the development and activities of small-capacity components and system manufacturers/suppliers targeting the high-volume market segment of cooling and air conditioning devices, i.e., 2.5 kW to 25 kW. A market and sales uptake can be observed at the manufacturing level, with an increase in sales of almost 15% last year.[36] Most of the cooling systems sold are powered by solar thermal systems. Some systems are configured for use with a backup heat supply (e.g., district heating); others are configured with a thermal energy storage system. The global market for low-capacity cooling and air conditioning systems is focused on exporting to Asia, the Middle East, African countries, North and South America, and the EU.

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[37] has improved significantly in performance and 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 purchasing 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 (kW_{th}/kW_{el}) of 20 to 40 in systems with optimized variable speed-driven auxiliaries. Thus, the electric demand for air conditioning in a building is cut by more than 80% compared to conventional HVAC equipment. Even though the technical and economic conditions for solar cooling and air conditioning have improved significantly, this remains a challenging market, as reflected in the comparatively low number of solar cooling systems built in recent years.

The world's largest solar cooling system with a cooling capacity of 3.5 MW for a packaging factory is in Izmir, Turkey.[38] 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 of up to 1.40.

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

[29] Not published internal communication
[30] https://forum.iea-shc.org/Data/Sites/1/publications/2023-12-Task65-Sunbelt-Chiller.pdf
[31] https://friendship-project.eu/ship-200-300/
[32] http://ship2fair-h2020.eu/demo-2-bodegas-roda
[33] 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.
[34] 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.
[35] Roumpedakis, Tryfon; et al. (2019) Performance results of a solar adsorption cooling and heating unit, ISES SWC 2019-SHC 2019, paper ID 11465
[36] Internal IEA SHC Task 65 communication
[37] 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.
[38] 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.

Table 7: 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
Cape Verde	CERMI Praia	2013	164	294	Flat plate Compound Parabolic Collector	70
Johannesburg, South Africa	MTN Headquarter	2014	272	484	Fresnel	330
China	Dezhou Institute	2014	n.a.	720	Parabolic trough	n.a.
India	Honeywell Technology Solutions Lab Pvt. Hyderabad	2013	n.a.	820	Parabolic trough	350
United Arab Emirates	Sheikh Zayed Desert Learning Center	2012	794	1,134	Flat plate	352
Kingston, Jamaica	Digicel	2012	687	982	Flat plate	600
India	National Institute of Solar Energy Gurugram	2011	n.a.	288	Parabolic trough	100
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.
India	Mahindra Vehicle Manufacturers Ltd. Pune	2008	n.a.	1,152	Dish	315
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, R2M Solution Srl., IEA SHC Task 65

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[39], 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.

A newly launched EU-HEU-funded project called RE-WITCH[40] will demonstrate advanced thermally-driven industrial cooling technologies in four industrial applications (brewery, food, biodiesel, and machinery industry). This includes hybrid systems based on adsorption and absorption processes (different sizes from 40 to 400 kW cooling capacity) driven by an optimized mix of low-grade waste heat and renewable sources (innovative high vacuum flat plate solar collector fields). Another approach for hospitals, such as containerized solutions using natural refrigerant chillers and photovoltaics, is being pursued in the EU-funded project SophiA.[41] A three-stage refrigeration cascade with natural refrigerants (propane, CO_2, and ethane) reliably ensures the three required temperature levels. The most spacious room inside the container is cooled down to +5°C. Lockable shelves on the wall allow the storage of medicines and food products. The freezer chamber at –30°C is accessible only through the refrigerated room. Besides the storage possibility, there are two deep freezer boxes that can cool down to -70°C. Everything is powered by the PV panels installed on the roof of the containers.

The potential for solar thermal cooling and industrial applications was investigated in the SunBeltChiller project[42], using a newly developed GIS tool to amalgamate geographical data in a manner conducive to ascertaining localized reference conditions for solar cooling systems within Sunbelt regions. Moreover, this methodology can be adapted to generate insights into potential deployment sites and the feasibility of specific solar cooling systems. Supplementing this approach with data such as population density, industrial areas, and purchasing power (GDP) lays the groundwork for prospective market studies focusing on particular products or technologies. Consequently, prospective sites can be pinpointed, and economic variables can be factored into identifying current and future markets, as shown on the following map.

1 MW Solar cooling system at the Hospital Militar Escuela in Managua, Nicaragua
Photo: SOLID Solar Energy Systems

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

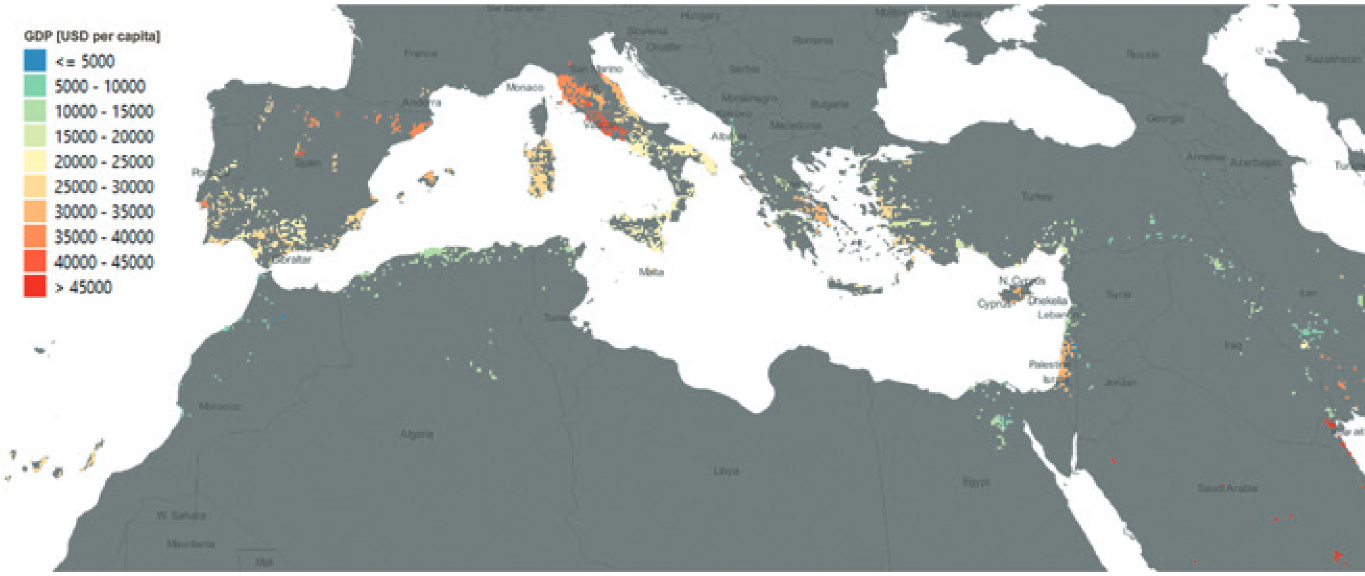

Figure 19: World map cut-out identifying the potential for the SunBeltChiller for industrial purposes (e.g., process cold) in the Mediterranean region (conducted on a 10 km raster grid, considering the Gross Domestic Product (GDP) levels)
Source: ZAE Bayern, 2023

Trends and outlook

The demand for cooling and refrigeration will continue its rapid growth, particularly in the Global South (several hundred million AC units are estimated to be sold annually by 2050[43]). This means there is a huge potential for cooling systems that use solar energy, such as thermal and photovoltaic (PV) systems.

Therefore, current and future product development focuses on compact, small-scale solar air conditioning units with air-cooled absorption and adsorption chillers and small-scale and large multi-stage desiccant systems with solar thermal collectors or desiccant-coated components. In addition, the development and market launch of x.N stage chillers (half, single, 1.N, double, triple) with new, medium temperature collectors and thermally driven heat pump systems for heating and cooling, also in hybrid operation with vapor compression chillers. Not to forget the future market penetration of small PV-driven components with new heat pumps/chillers using natural refrigerants like propane.[44]

Table 7 shows the trend regarding medium to large-scale solar cooling. In the past 15 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.

On the other hand, the most recently signed Global Cooling Pledge at the COP28 conference[45] shows that cooling is a very serious and important global issue. According to the Global Cooling Watch 2023 report[46], cooling-related emissions could be reduced by over 60% compared to normal operations by 2050 while expanding access to cooling to 3.5 billion people. Combined with a decarbonized power grid, emissions reductions could be up to 96%.

5.7. Solar air heating systems

Solar air heating systems are designed to heat air directly for applications requiring warm air. They are primarily used to heat buildings, including ventilation air, and to process and dry crops. Solar air heating is currently an under-utilized solar technology. Triggered by the COVID-19 requirements to increase fresh air in buildings, energy demand and CO_2 emissions have increased. 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 buildings that is heated, air collectors are ideally suited to heat this air directly without heat exchangers. Most solar air collectors for heating

[39] https://hycool-project.eu
[40] https://ieecp.org/projects/re-witch/
[41] https://sophia4africa.eu/de/
[42] https://task65.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task65-DA1--Climatic-Conditions-and-Applications.pdf
[43] https://www.iea.org/futureofcooling/
[44] Jakob, U. (2023) Solar Cooling for emerging markets. Keynote ISES Solar World Congress 2023, New Delhi, India
[45] https://www.cop28.com/en/global-cooling-pledge-for-cop28
[46] https://www.unep.org/resources/global-cooling-watch-2023

Solar air heating systems on the mechanical room penthouses at the Canary Commons, a condo community in Toronto, Canada
Photo: SolarWall Conserval Engineering Inc.

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 to 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 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 temperatures.

For the past 30 years, solar air heating systems have been used worldwide by schools, municipalities, military, agricultural, commercial, and industrial entities, and 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 8: Largest solar air collector markets - total installed air collector areas in 2022

Country	Air Collectors [m^2]		Total [m^2]	Installed capacity [MW_{th}]
	unglazed	glazed		
Canada	440,069	60,539	500,608	350
Australia	250,000	10,000	261,000	182
Japan		208,378	208,378	146
United States	129,595	72,000	202,595	142
China	41,639	46,000	87,639	61
United Kingdom	24,800		24,800	17
Denmark	4,300	18,000	22,300	16
Germany		17,920	17,920	13
Turkey	13,570		13,570	10
India		12,400	12,400	9
France (mainland)	10,858	1,100	11,958	8

By the end of 2022, 954 MW_{th} (1.36 million square meters) of glazed and unglazed air collectors were installed worldwide. The annual worldwide market in 2022 was in the range of 60 MW_{th} (85,735 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
solar air collector market with 350 MW_{th}

6 Detailed global market data and country statistics in 2022

At the Rothaus brewery in Germany, almost 1,000 m² of vacuum tube collectors supply the bottle washing machines with heat
Photo: Rothaus brewery, Germany

The following chapters of the report provide detailed solar thermal market figures for the year 2022 and country figures for 72 countries.

Background of the 2022 data

The figures in the following chapters represent the collector area in operation in 2022, 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 ten 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.[47]

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 Sunpad systems in Cairo, Egypt
Photo: GREENoneTEC Solarindustrie GmbH, Austria

By the end of 2022, an installed capacity of 542.7 GW_{th}, corresponding to a total of 775 million m^2 of collector area, was in operation worldwide.

The vast majority of the total capacity in operation was installed in China (396.4 GW_{th}) and Europe (63.2 GW_{th}), which accounted for 84.7% of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (19.3 GW_{th}), Latin America and Caribbean (20.6 GW_{th}), Other Asia (18.5 GW_{th}), the MENA countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (8.1 GW_{th}), Australia and New Zealand (6.8 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 (2.6 GW_{th}). The market volume of "all other countries" is estimated to be 5% of the total installations, excluding China (7.3 GW_{th}).

[47] Bundesverband Solarwirtschaft e.V.
[48] 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 2022

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, Nepal, South Korea, Chinese Taipei, Thailand
Latin America and 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

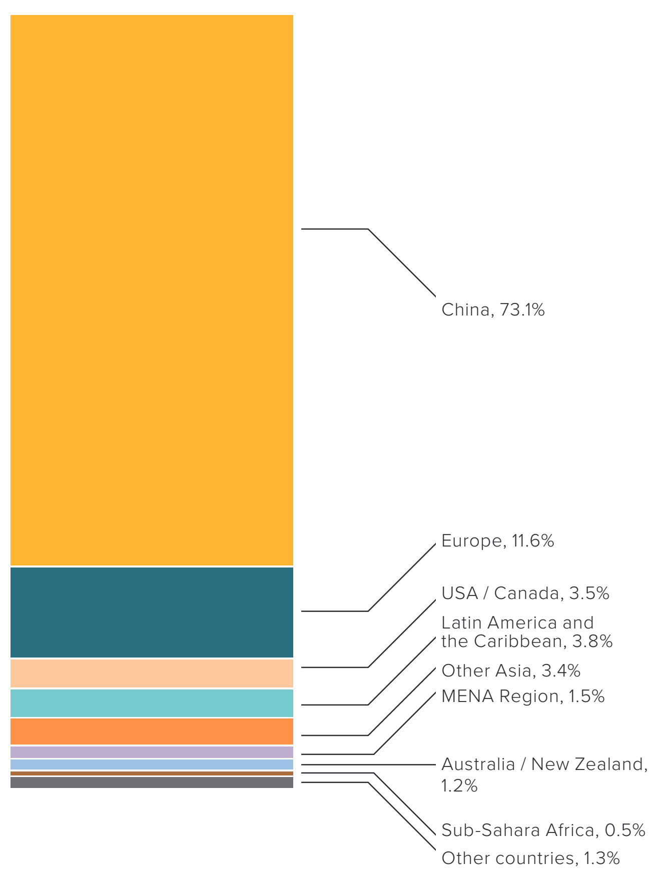

Table 9: Total capacity in operation in 2022 [MW_{th}]

Country/Region/Economy	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		220.7	10.0			231
Argentina	70.7	95.9	186.5	0.0	0.3	353
Australia	4,133.5	2,328.2	184,1		7.0	6,653
Austria	120.0	3,048.1	56.8		5.2	3,230
Barbados+		180.7				181
Belgium		434.0	105.0			539
Bhutan		0.6				0.6
Botswana++		12.1	2.0			14
Brazil	6,468.7	8,876.7	188.8			15,534
Bulgaria		150.5	4.1			155
Burkina Faso+		2.3	1.0			3
Canada	488.3	48.3	36.7	308.0	42.4	924
Cape Verde+++		1.8				2
Chile	45.9	226.2	38.0		0.2	310
China		51,166.5	345.165.0	29.1	32.2	396,393
Croatia		192.8	9.3			202
Cyprus	1.5	601.6	16.5			620
Czech Republic	297.5	345.0	112.8			755
Denmark	14.4	1,249.3	6.4	3.0	12.6	1,286
Estonia		10.3	5.9			16
Finland	8.3	39.4	14.6			62
France (mainland)	47.4	1,475.7	133.7	7.6	0.8	1,665
France (overseas)		828.5	30.5			859
Germany	292.8	13,678.0	1.832.9		12.5	15,816
Ghana++		3.6	1.8			5
Greece		3,779.4	16.0			3,795
Hungary	12.8	205.6	55.9	2.4	1.6	278
India	0.0	2,918.6	10,562.8	0.0	8.7	13,490
Ireland		202.1	89.7			292
Israel++	27.3	3,533.9				3,561
Italy	30.7	3,237.2	498.3	0.1		3,766
Japan		1,854.1	23.9		145.9	2,024
Jordan*	4.2	687.7	190.5			882
Kenya++		222.8	111.4			334
Latvia		27.7	2.4			30
Lebanon		284.3	352.1			636
Lesotho		1.7	2.9			5
Lithuania		7.3	10.5			18
Luxembourg		46.3	6.2			52
Malta		43.1	10.6			54
Mauritius**		93.0				93
Mexico	1,309.7	1,504.4	1,338.8	0.5	6.3	4,160
Morocco++		726.6				727
Mozambique	0.1	0.0	2.9			3
Namibia	1.1	41.8	1.0			44
Nepal++++		21.0	189.0			210
Netherlands	47.2	350.4	66.0			464
New Zealand***	4.9	100.1	6.8			112
Nigeria+		1.3	7.5	0.0	1.2	10
North Macedonia		57.3	44.2		0.0	102
Norway	1.3	25.4	3.2	0.1	2.9	33
Palestinian Territories		1,386.6				1,387
Panama		0.5				0.5
Poland		2,032.6	351.4			2,384
Portugal	1.5	1,058.8	22.8			1,083
Romania	0.2	105.3	80.2	0.6		186
Russia	0.1	58.8	2.9	0.0	0.1	62
Senegal+		3.3	3.6	0.0	0.8	8
Slovakia	0.7	125.3	19.8			146
Slovenia		89.6	16.6		0.0	106
South Africa	1,014.8	525.4	409.9			1,950
South Korea		1,040.4	312.0	0.9	0.2	1,354
Spain	116.0	3,203.9	178.8	10.2	1.6	3,511
Sweden	119.7	182.7	50.8			353
Switzerland	114.8	977.7	103.3			1,196
Chinese Taipei+	1.4	1,175.9	93.3			1,271
Thailand****		110.3				110
Tunisia		827.7	49.1			877
Turkey		11,476.9	7,665.7	11.1		19,154
United Kingdom	76.2	397.5	181.3	17.4		672
United States	16,028.6	2,092.0	123.8	90.0	50.4	18,385
Uruguay	0.4	77.2	4.6			82
Zimbabwe		15.3	68.7			84
All other countries (5% solar thermal world market excluding China)	1,626.4	4,262.5	1,384.6	23.8	15.8	7,313
TOTAL	**32,529**	**136,416**	**372,858**	**505**	**349**	**542,657**

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
++ Calculated based on 0% growth 2022
+++ Total capacity in operation refers to the year 2021
++++ New in ed. 2024

Table 10: Total installed collector area in operation in 2022 [m^2]

Country/Region/Economy	Water Collectors [m^2]			Air Collectors [m^2]		TOTAL [m^2]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		315,223	14,262			329,485
Argentina	101,031	136,988	266,427	60	474	504,979
Australia	5,905,000	3,326,000	263,000		10,000	9,504,000
Austria	171,445	4,354,358	81,213		7,458	4,614,474
Barbados+		258,192				258,192
Belgium		620,000	150,000			770,000
Bhutan		824				824
Botswana++		17,251	2,824			20,075
Brazil	9,240,937	12,681,068	269,716			22,191,721
Bulgaria		214,938	5,850			220,788
Burkina Faso+		3,282	1,399			4,681
Canada	697,545	68,996	52,459	440,069	60,539	1,319,608
Cape Verde+++		2,613				2,613
Chile	65,550	323,148	54,305		300	443,303
China		73,095,000	493,092,921	41,639	46,000	566,275,560
Croatia		275,393	13,308			288,701
Cyprus	2,213	859,430	23,567			885,210
Czech Republic	425,000	492,844	161,162			1,079,006
Denmark	20,500	1,784,756	9,197	4,300	18,000	1,836,753
Estonia		14,743	8,360			23,103
Finland	11,800	56,298	20,788			88,886
France (mainland)	67,756	2,108,161	190,939	10,858	1,100	2,378,814
France (overseas)		1,183,629	43,588			1,227,217
Germany	418,245	19,540,064	2,618,388		17,920	22,594,617
Ghana++		5,170	2,508			7,678
Greece		5,399,200	22,800			5,422,000
Hungary	18,300	293,749	79,850	3,418	2,300	397,617
India	0	4,169,361	15,089,718	0	12,400	19,271,479
Ireland		288,748	128,127			416,875
Israel++	39,000	5,048,434				5,087,434
Italy	43,800	4,624,511	711,855	120		5,380,286
Japan		2,648,684	34,074		208,378	2,891,136
Jordan*	5,940	982,482	272,084			1,260,506
Kenya++		318,348	159,174			477,521
Latvia		39,572	3,490			43,062
Lebanon		406,122	502,949			909,071
Lesotho		2,371	4,101			6,472
Lithuania		10,441	15,050			25,491
Luxembourg		66,080	8,900			74,980
Malta		61,624	15,087			76,711
Mauritius**		132,793				132,793
Mexico	1,870,933	2,149,187	1,912,587	752	9,061	5,942,520
Morocco++		1,038,000				1,038,000
Mozambique	136	48	4,129			4,313
Namibia	1,560	59,713	1,395			62,669
Nepal++++		30,000	270,000			300,000
Netherlands	67,440	500,570	94,350			662,360
New Zealand***	7,025	142,975	9,644			159,645
Nigeria+		1,866	10,782	0	1,670	14,318
North Macedonia		81,907	63,129		32	145,068
Norway	1,849	36,349	4,577	200	4,106	47,082
Palestinian Territories		1,980,900				1,980,900
Panama		665				665
Poland		2,903,730	501,960			
Portugal	2,130	1,512,502	32,553			1,547,185
Romania	340	150,479	114,590	800		266,209
Russia	137	83,950	4,184	2	144	88,417
Senegal+		4,741	5,083	0	1,203	11,027
Slovakia	1,000	178,940	28,270			208,210
Slovenia		128,000	23,670		10	151,680
South Africa	1,449,753	750,504	585,628			2,785,885
South Korea		1,486,336	445,760	1,300	300	1,933,696
Spain	165,736	4,577,051	255,463	14,550	2,250	5,015,050
Sweden	171,000	260,937	72,578			504,515
Switzerland	164,000	1,396,700	147,500			1,708,200
Chinese Taipei+	1,937	1,679,874	133,244			1,815,055
Thailand****		157,536				157,536
Tunisia		1,182,497	70,104			1,252,601
Turkey		16,395,608	10,950,989	15,815		27,362,412
United Kingdom	108,850	567,846	258,931	24,800		960,427
United States	22,897,975	2,988,552	176,914	128,578	72,000	26,264,019
Uruguay	509	110,308	6,614			117,431
Zimbabwe		21,848	98,188			120,036
All other countries (5% of world market excluding China)	2,323,493	6,089,264	1,978,070	33,980	22,613	10,447,420
TOTAL	**46,469,866**	**194,880,272**	**532,654,326**	**721,241**	**498,258**	**775,223,963**

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
++ Calculated based on 0% growth 2022
+++ Total capacity in operation refers to the year 2021
++++ New in ed. 2024

The total installed capacity in operation in 2022 was divided into flat plate collectors (FPC): 136.4 GW_{th} (194.8 million m^2), evacuated tube collectors (ETC): 372.8 GW_{th} (532.7 million m^2), unglazed water collectors: 32.5 GW_{th} (46.5 million m^2), and glazed and unglazed air collectors: 0.9 GW_{th} (1.2 million m^2).

With a global share of 68.7%, evacuated tube collectors were the predominant solar thermal collector technology, followed by flat plate collectors at 25.1% and unglazed water collectors at 6.0% (Figure 21). Air collectors play only a minor role in the total numbers.

In Europe, the second largest market after China, flat plate collectors were the dominant collector type in 2022 (Figure 22). Europe's share of evacuated tube collectors was 18.7%.

Installation of a ground-mounted solar thermal hot water system in Bhutan
Photo: Rudi Moschik, AEE INTEC

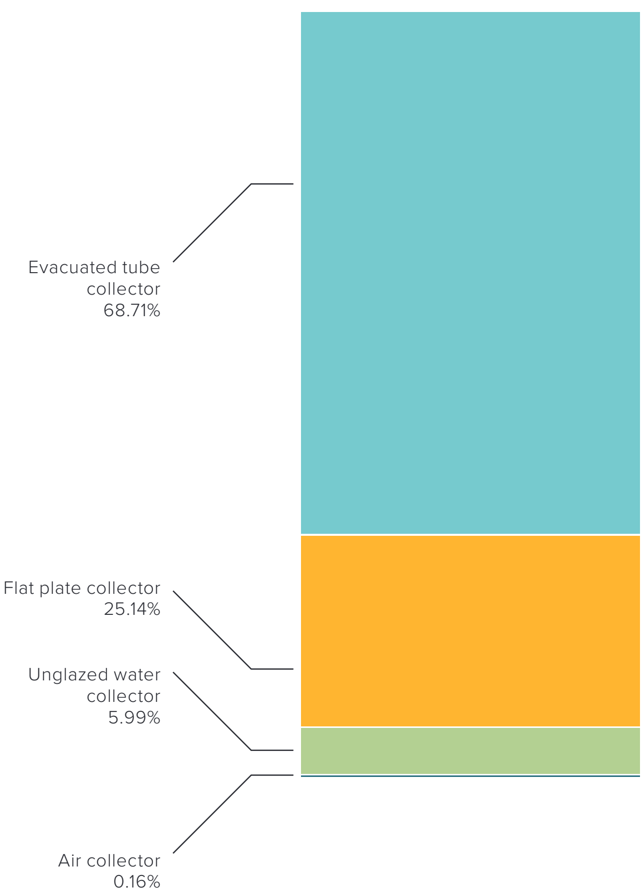

Figure 21: Distribution of the total installed capacity in operation by collector type in 2022 – WORLD

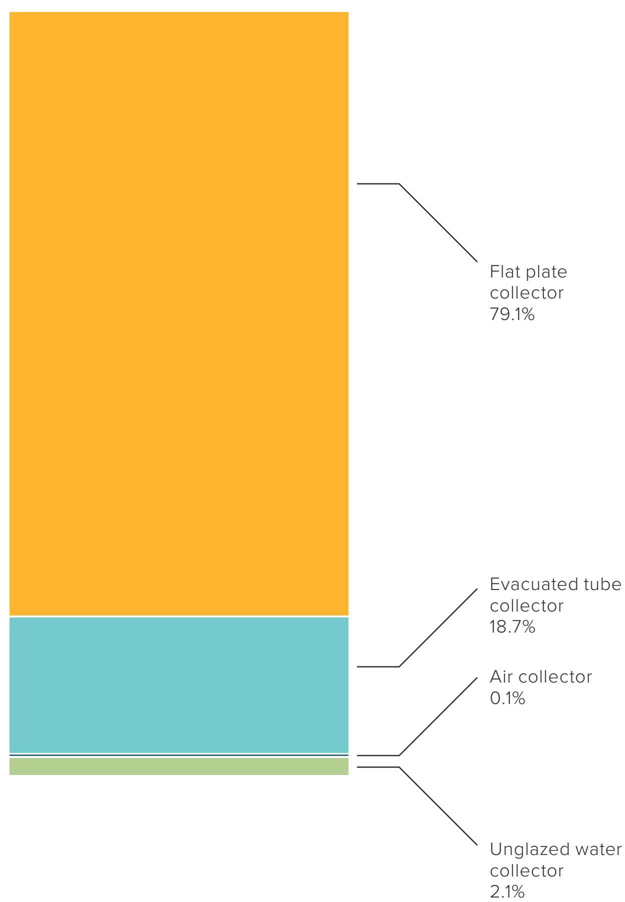

Figure 22: Distribution of the total installed capacity in operation by collector type in 2022 – EUROPE
EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom

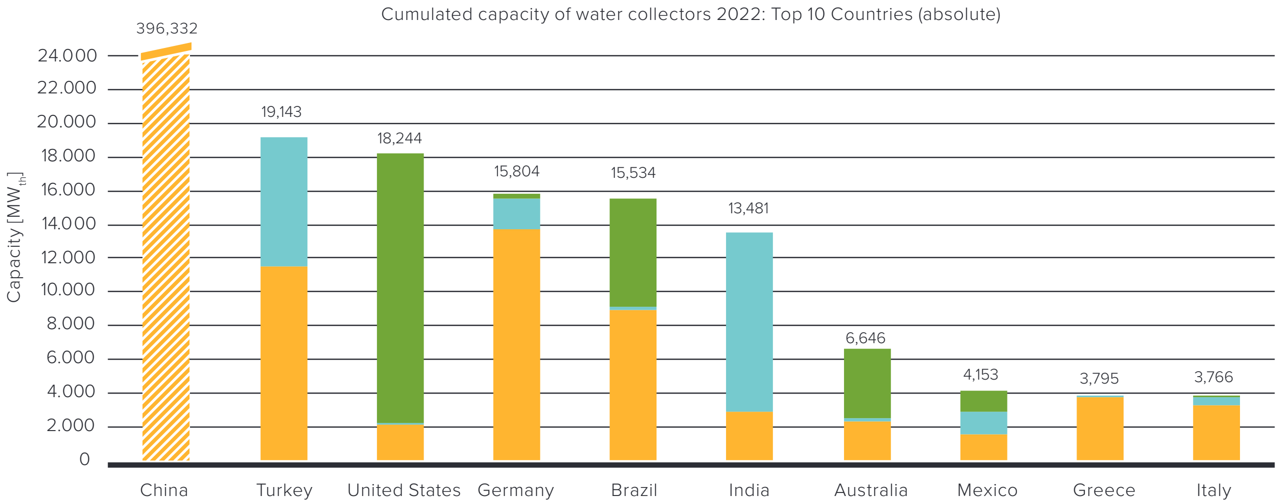

Figure 23: Top 10 countries of cumulated water collector installations in 2022 (absolute figures in MW_{th})

Compared to the year 2021, 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 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 2022 per 1,000 inhabitants were Barbados (597 kW_{th}/1,000 inhabitants), Cyprus (478 kW_{th}/1,000 inhabitants), Israel (391 kW_{th}/1,000 inhabitants), Austria (362 kW_{th}/1,000 inhabitants), Greece (360 kW_{th}/1,000 inhabitants), China (281 kW_{th}/1,000 inhabitants), the Palestinian Territories (268 kW_{th}/1,000 inhabitants), France (overseas) (254 kW_{th}/1000 inhabitants) Australia (254 kW_{th}/1,000 inhabitants), and Turkey (231 kW_{th}/1,000 inhabitants).

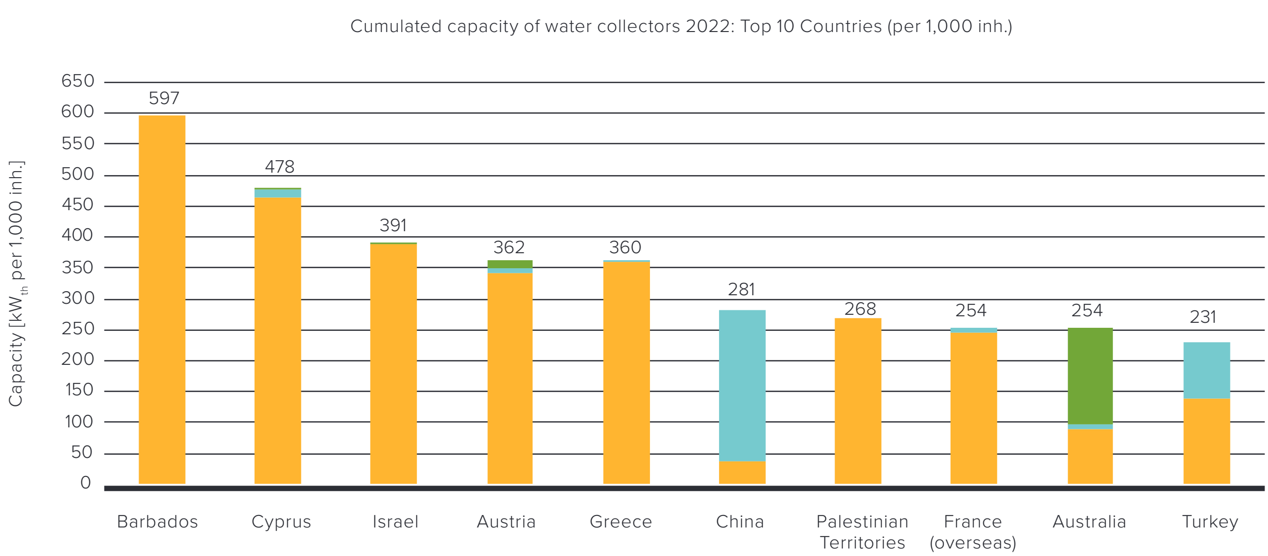

Figure 24: Top 10 countries by cumulated water collector installations per 1,000 inhabitants in 2022 (relative figures in kW_{th})

6.2 Total capacity of glazed water collectors in operation

In 2022, China maintained its dominant position as the leading country in total installed capacity of glazed water collectors, with 396.3 GW_{th}. Turkey, Germany, and India followed closely, with installed capacities ranging from 19 GW_{th} to 9 GW_{th}. (Figure 25).

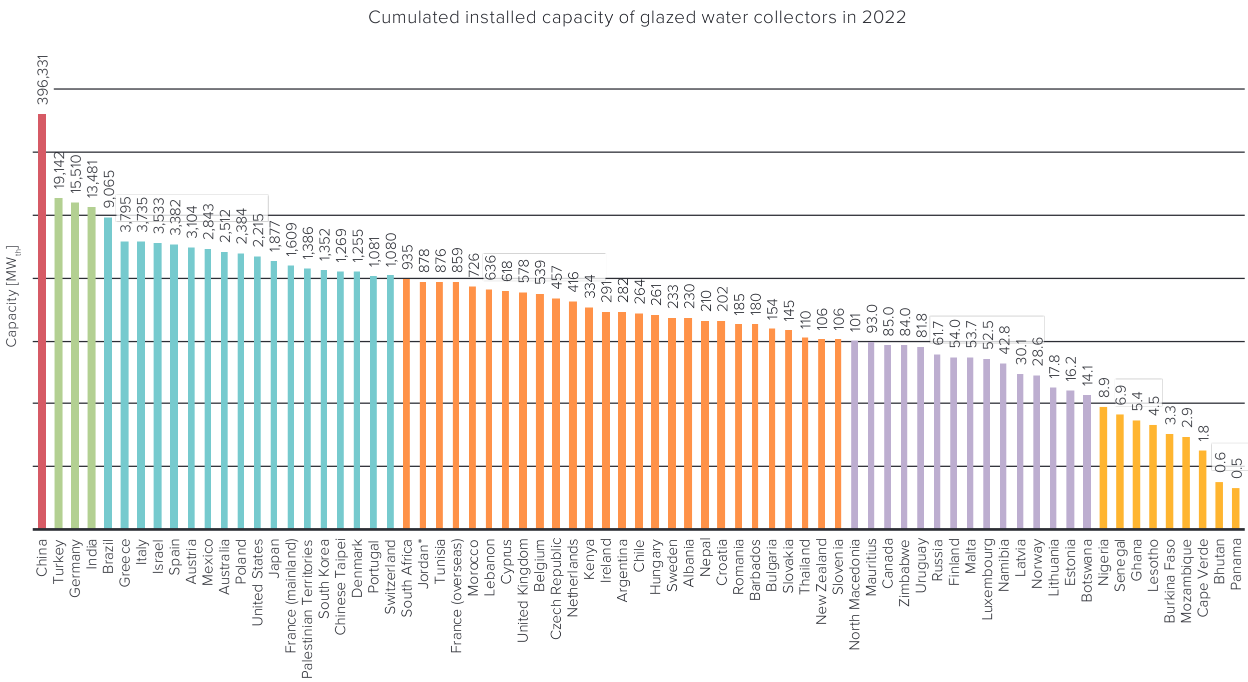

Figure 25: Total capacity of glazed water collectors in operation by the end of 2022

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 sixth in terms of market penetration. Nevertheless, it is remarkable that China, with its 1.41 billion inhabitants, exceeds the solar thermal per capita levels of the large European markets in Germany, Turkey, Denmark, and Spain (Figure 26)

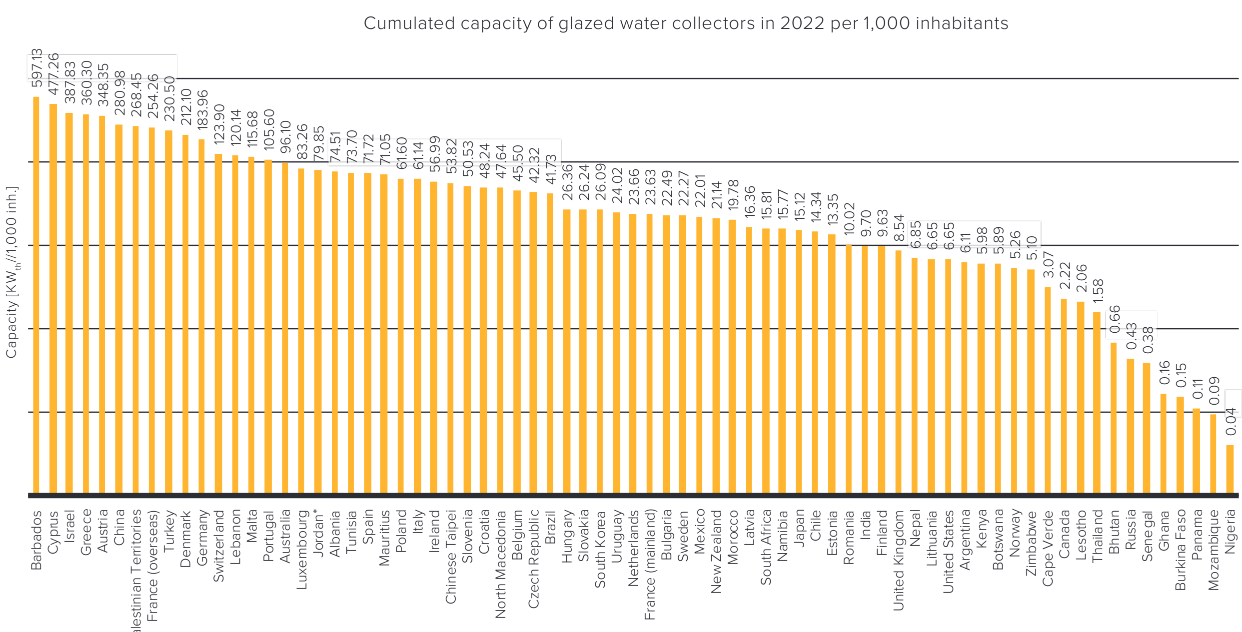

Figure 26: Total Capacity of glazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2022

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

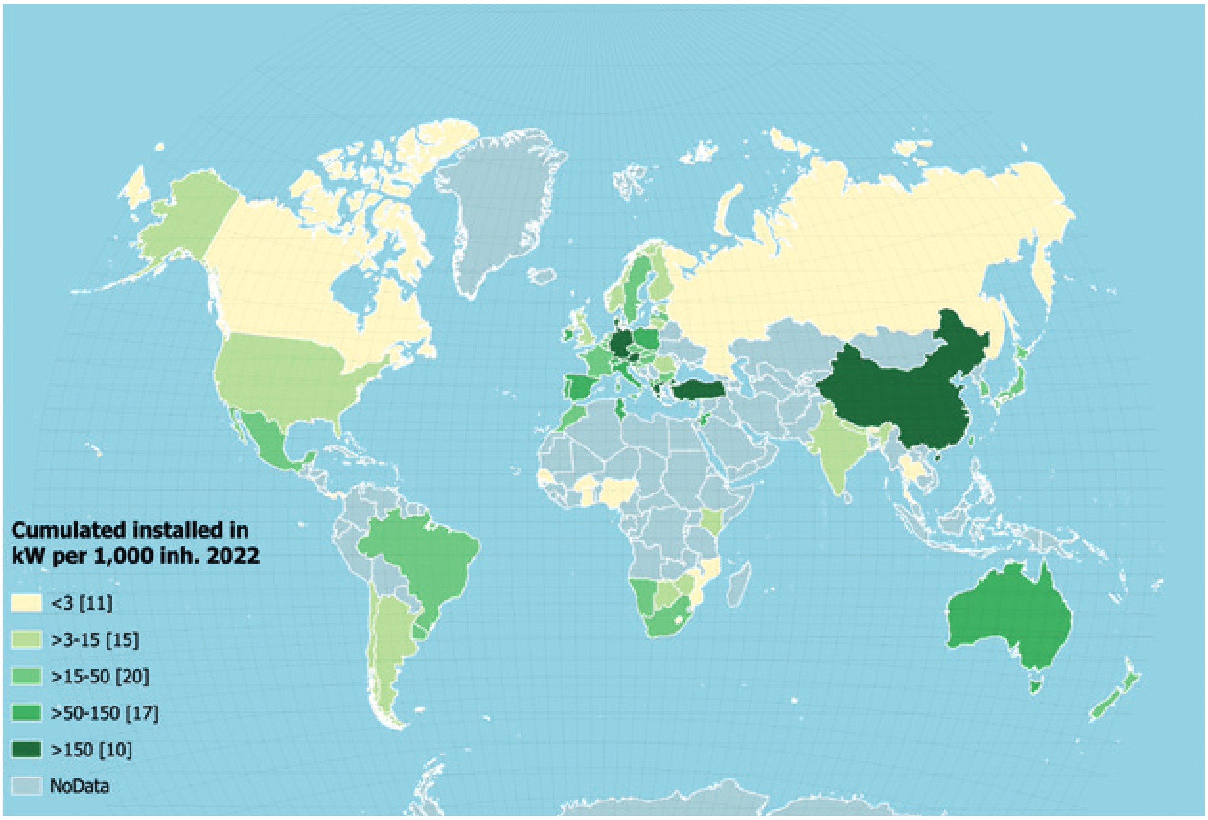

Figure 27: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants – WORLD

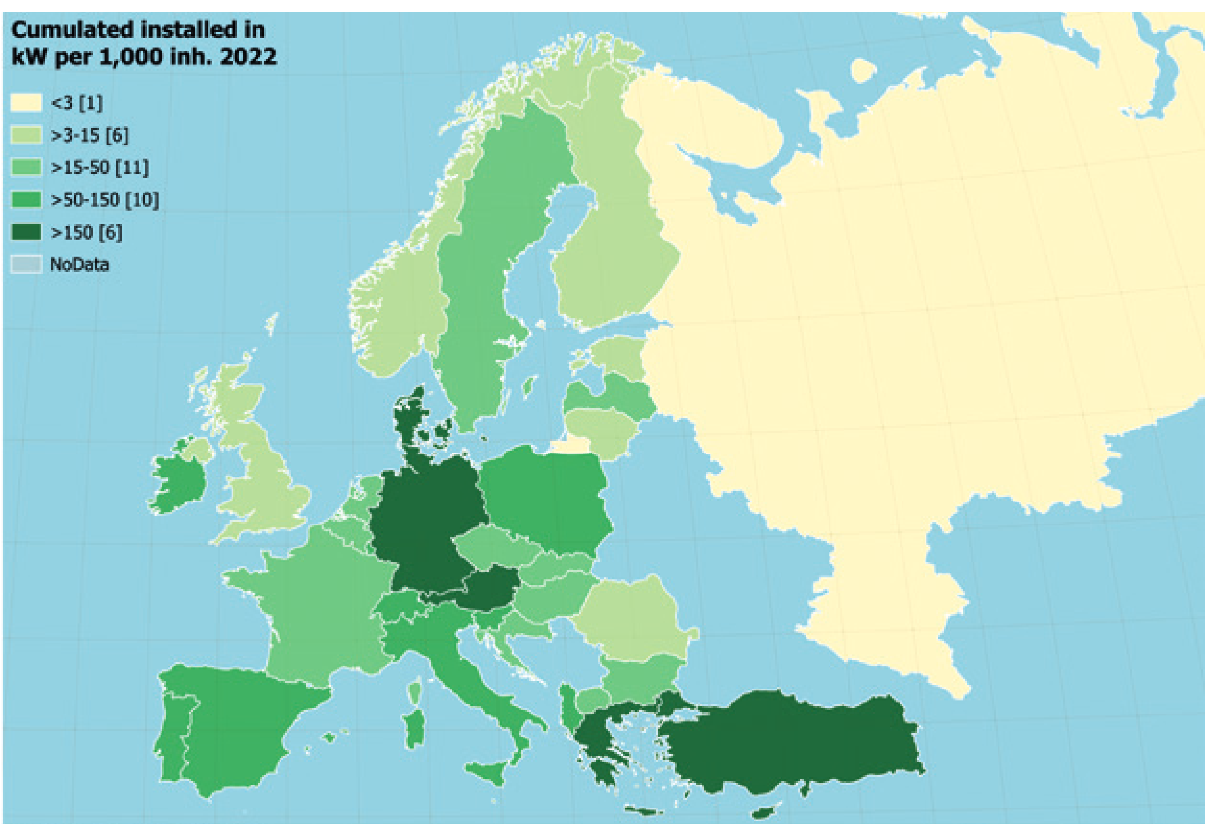

Figure 28: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants – EUROPE

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

When considering market penetration per capita by economic region, China remains at the forefront. Notably, the MENA countries and Australia surpass Europe in this regard, highlighting the significant imbalance in market distribution across 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.

Heat storages for the Heineken brewery in Seville, Spain
Photo: Engie, Spain

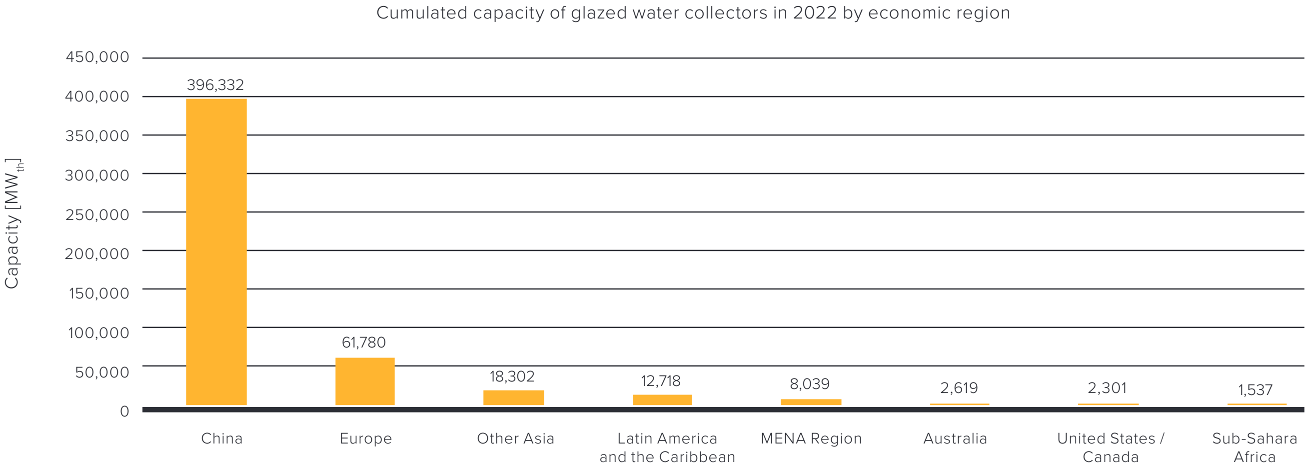

Figure 29: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2022

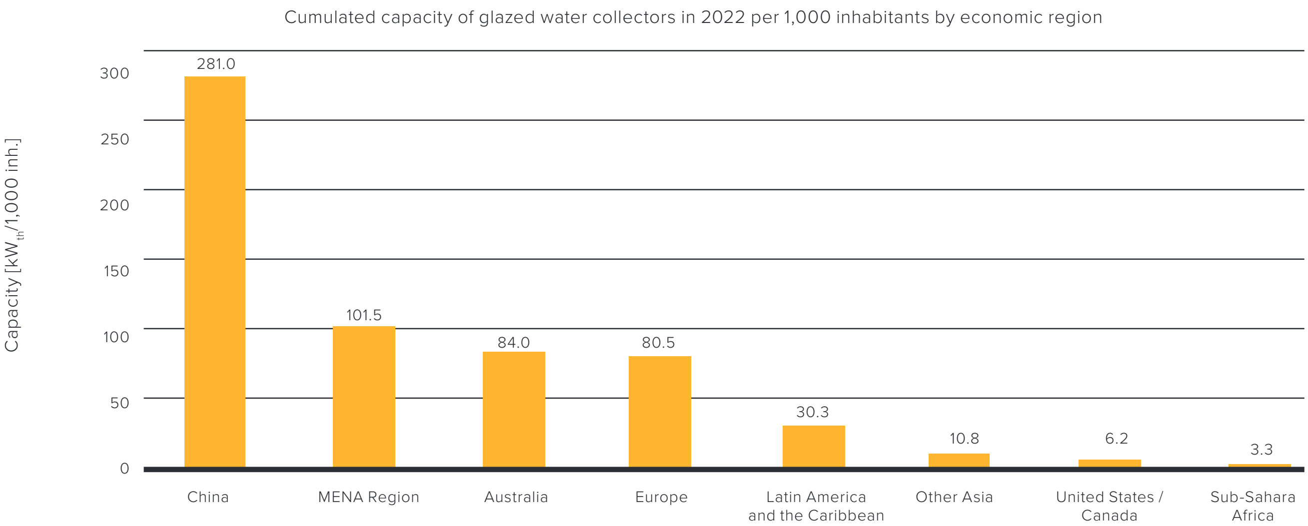

Figure 30: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in kW_{th} per 1,000 inhabitants in 2022

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, Nepal, South Korea, Chinese Taipei, 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% in 2005[49] to just 6% in 2022. Figure 31 and Figure 32 show the total installed capacity of unglazed water collectors and the total installed capacity per 1,000 inhabitants at the end of 2022.

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

Flat plate collector system in Mexico
Photo: Mexichem / Solar Payback

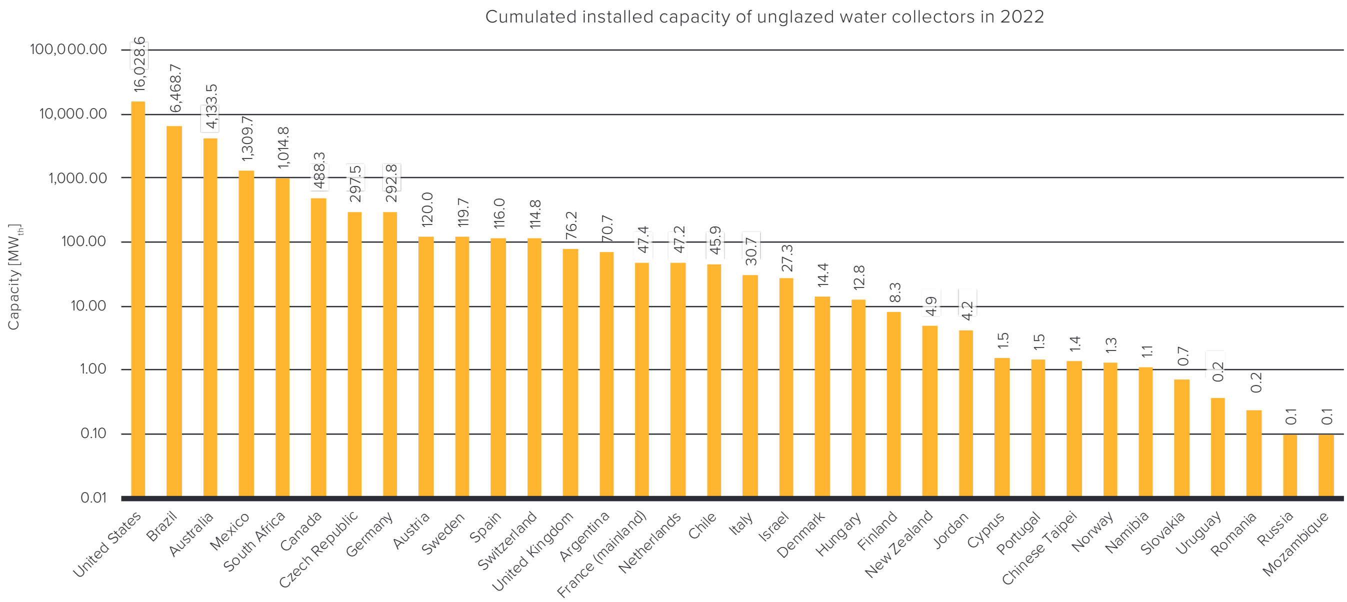

Figure 31: Total capacity of unglazed water collectors in operation in 2022

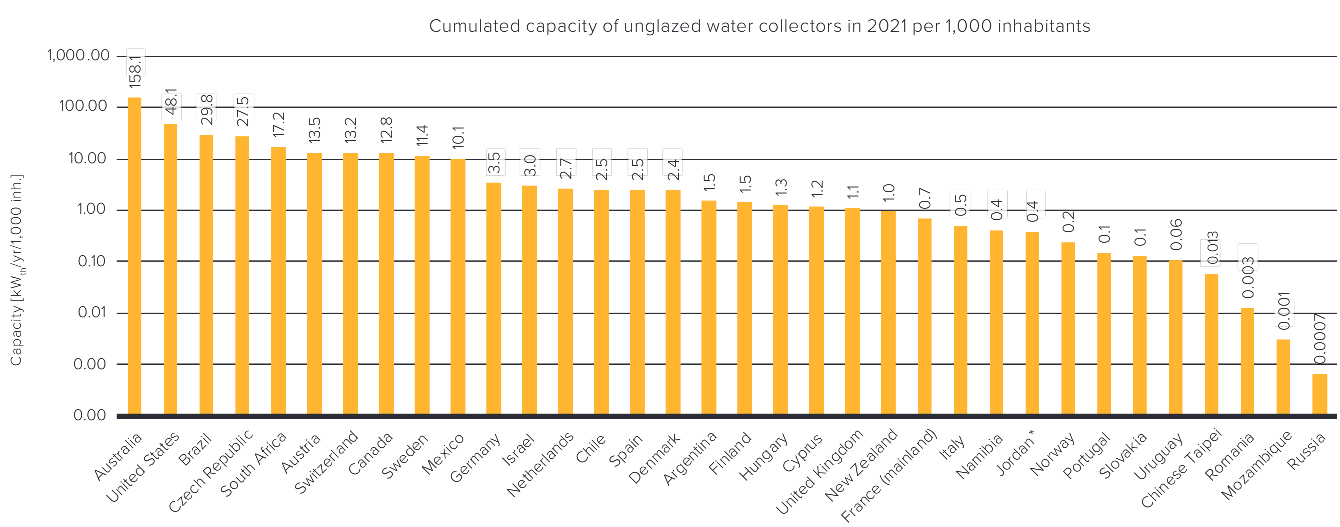

Figure 32: Total capacity of unglazed water collectors in operation in kW$_{th}$ per 1,000 inhabitants in 2021

6.5 Newly installed capacity in 2022 and market development

In 2022, a total capacity of 22.7 GW_{th}, corresponding to 32.5 million m^2 of new solar collectors, was installed worldwide.

The main markets were China (15.0 GW_{th}) and Europe (3.0 GW_{th}), accounting for 79% of all 2022 collector installations. The rest of the market was shared between Latin America and the Caribbean (1.6 GW_{th}), Other Asia (1.2 GW_{th}), the United States and Canada (0.6 GW_{th}), MENA countries (0.5 GW_{th}), Australia (0.3 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} (550,867 m^2).

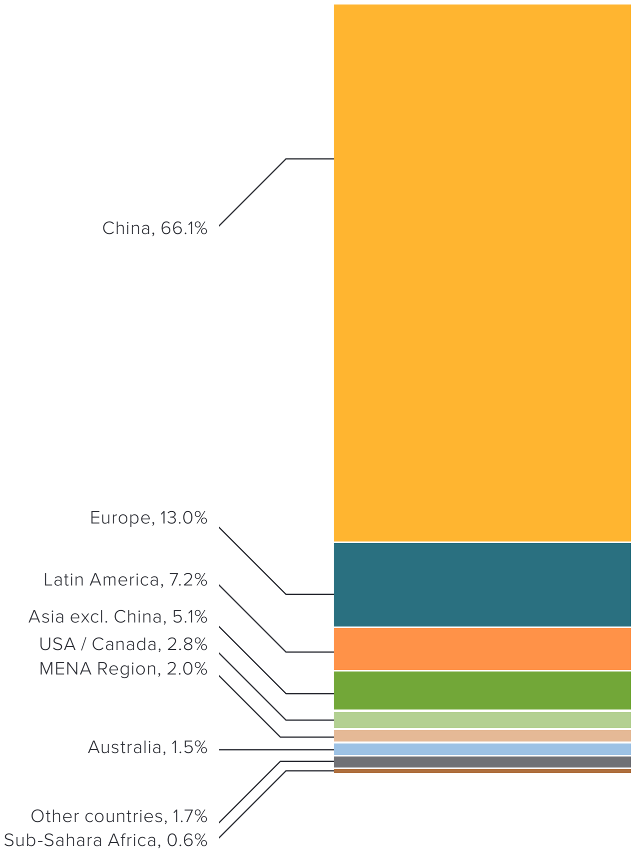

Figure 33: Share of newly installed capacity (glazed and unglazed water and air collectors) by economic regions in 2022

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, South Korea, Chinese Taipei, Thailand
Latin America: 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

Thermosiphon systems at the CPS Sisters youth hostel in Harare, Zimbabwe
Photo: Werner Weiss, AEE INTEC

Table 11: Newly installed capacity in 2022 [MW_{th}/a]

Country/Region/Economy	Water Collectors [m^2]			Air Collectors [m^2]		TOTAL [m^2]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		12.4	1			14
Argentina	4.7	24.5	49	0.01	0.1	78
Australia	245.0	86.5	10		1	342
Austria	1.0	39.8	0.5		0.1	41
Belgium		11.2	2			14
Bhutan		0.6				0.6
Botswana*		0.8	0.1			1
Brazil	644.3	574.9	27			1,246
Bulgaria		17.0				17
Canada	1.5	0.003	0.6	14	3	19
Chile		9.1				9
China		4,029.9	10,976	15	16	15,037
Croatia		8.4				8
Cyprus		51.7				52
Czech Republic		16.2	1.6			18
Denmark		1.9				2
Estonia		1.0				1
Finland		5.6				6
France (mainland)		45.0	2.0	0.1		47
France (overseas territories)		75.2				75
Germany		366.8	129.5			496
Ghana*		0.5	0.3			1
Greece		293.0	0.3			293
Hungary		9.8				10
India		52.9	1,009.0		0.01	1,062
Ireland		0.8				1
Israel*		245.0				245
Italy		157.3	13.9			171
Japan		41.9	0.2		1	43
Kenya*		5.9	2.9			9
Latvia		1.1				1
Lebanon		16.8	69.6			86
Lesotho			0.0			0
Lithuania		0.5	0.7			1
Luxembourg		2.5	0.0			3
Malta		1.2	0.0			1
Mexico	78.8	90.9	124.1		0.2	294
Morocco		50.2				50
Mozambique			0.8			1
Namibia		2.9	0.001			3
Nepal		4.9	43.7			49
Netherlands	1.8	18.2	9.4			29
North Macedonia		4.1	3.4		0.01	7
Norway		1.1	0.1			1
Palestinian Territories		36.0	0.0			36
Panama*		0.5				0
Poland		146.0	1.1			147
Portugal		44.9	1.4			46
Romania	0.0	11.2				11
Russia	0.0	0.5	0.2			1
Slovakia	0.0	11.9				12
Slovenia		0.6	0.05	0.004		1
South Africa	28.8	22.0	56.2			107
South Korea				0.5		0
Spain	1.4	95.6	4.9	3		105
Sweden		3.5				4
Switzerland	2.2	15.2	2.1			20
Tunisia		36.6	0.0			37
Turkey		653.8	638.4	2		1,294
United Kingdom	3.4	1.2	1.7	0.1		7
United States	587.4	29.3		3		619
Uruguay	0.4	2.1	4.6			7
Zimbabwe			23.0			23
Other (5% of the world market excluding China)	84.3	182.2	117.8	1.2	0.2	386
TOTAL	1,685.1	7,673	13,329	38	21	22,746

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)

Table 12: Newly installed collector area in 2022 [m²/a]

Country/Region/Economy	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		17,680	1,640			19,320
Argentina	6,769	35,000	69,373	20	158	111,320
Australia	350,000	123,533	13,728		1,000	488,261
Austria	1,480	56,830	660		190	59,160
Belgium		16,000	3,500			19,500
Bhutan		824				824
Botswana*		1,190	210			1,400
Brazil	920,463	821,248	38,124			1,779,835
Bulgaria		24,296				24,296
Canada	2,100	4	902	19,991	4,325	27,322
Chile		13,071				13,071
China		5,757,000	15,680,491	20,819	23,000	21,481,310
Croatia		12,000				12,000
Cyprus		73,924				73,924
Czech Republic		23,167	2,336			25,503
Denmark		2,664				2,664
Estonia		1,425				1,425
Finland		8,000				8,000
France (mainland)		64,355	2,795	200		67,350
France (overseas territories)		107,410				107,410
Germany		524,000	185,000			709,000
Ghana*		700	450			1,150
Greece		418,600	400			419,000
Hungary		14,000				14,000
India		75,572	1,441,467		15	1,517,054
Ireland		1,116				1,116
Israel*		350,000				350,000
Italy		224,695	19,923			244,618
Japan		59,898	354		753	61,005
Kenya*		8,364	4,182			12,546
Latvia		1,600				1,600
Lebanon		23,952	99,378			123,330
Lesotho			55			55
Lithuania		700	1,000			1,700
Luxembourg		3,574	0			3,574
Malta		1,772	8			1,780
Mexico	112,640	129,905	177,265		288	420,098
Morocco		71,700				71,700
Mozambique			1,180			1,180
Namibia		4,094	2			4,096
Nepal		6,940	62,462			69,402
Netherlands	2,620	26,050	13,420			
North Macedonia		5,868	4,800		20	10,688
Norway		1,512	82			1,594
Palestinian Territories		51,378	0			51,378
Panama*		665				665
Poland		208,500	1,500			210,000
Portugal		64,117	1,983			66,100
Romania	0	15,960				15,960
Russia	0	682	239			921
Slovakia	0	17,000				17,000
Slovenia		800	70	5		875
South Africa	41,168	31,415	80,269			152,852
South Korea				700		700
Spain	2,000	136,500	7,000	4,800		150,300
Sweden		5,000				5,000
Switzerland	3,210	21,770	2,970			27,950
Tunisia		52,340	0			52,340
Turkey		934,000	912,000	2,245		1,848,245
United Kingdom	4,891	1,773	2,432	200		9,295
United States	839,122	41,834		4,000		884,956
Uruguay	509	3,053	6,614			10,176
Zimbabwe			32,898			32,898
Other (5% of the world market excluding China)	120,367	260,232	168,220	1,693	355	550,867
TOTAL	2,407,339	10,961,252	19,041,382	54,673	30,104	32,494,750

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 2022 by collector type: flat plate collectors: 7.7 GW_{th} (11 million m^2), evacuated tube collectors: 13.3 GW_{th} (19.1 m^2), unglazed water collectors: 1.7 GW_{th} (2.4 million m^2), and glazed and unglazed air collectors: 0.06 GW_{th} (0.085 million m^2).

Evacuated tube collectors, with a 59% share, 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 73% of all newly installed collectors in 2022 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82% in 2011 to 59% in 2022, while flat plate collectors increased their share from 14.7% to 34% in the same time frame.

In Europe, the situation is almost the opposite of China, with 71.9% of all solar thermal collectors installed in 2022 being flat plate collectors (Figure 35). In the medium term, the share of flat plate collectors decreased in Europe from 81.5% in 2011 to 71.9% in 2022. 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 27.6%.

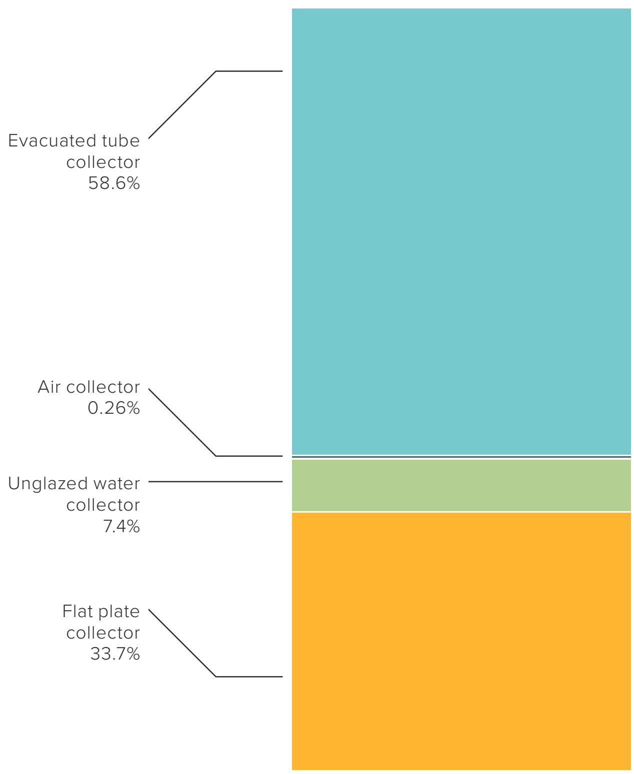

Figure 34: Distribution of the newly installed capacity by collector type in 2022 – WORLD

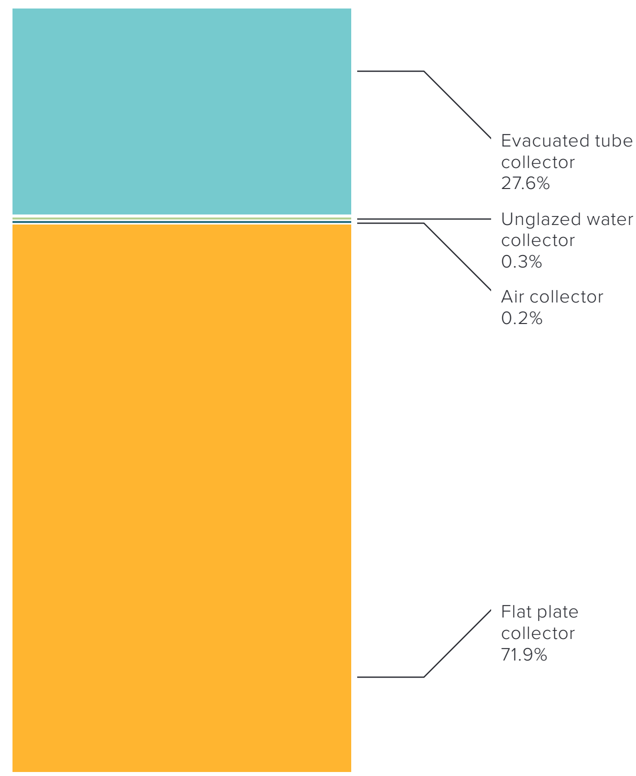

Figure 35: Distribution of the newly installed capacity by collector type in 2022 – EUROPE

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

Pumped 210 m^2 flat-plate collector system at the Lady Pohamba hospital in Windhoek, Namibia
Photo: Werner Weiss, AEE INTEC

Figure 36 shows the total capacity of newly installed glazed and unglazed water collectors for the 10 leading markets in 2022. China remained the market leader in absolute terms, followed by Turkey and Brazil. India and the United States rank fourth and fifth, ahead of Germany and Australia. Mexico, Greece, and Israel are among the top 10 countries, ranking ninth and tenth.

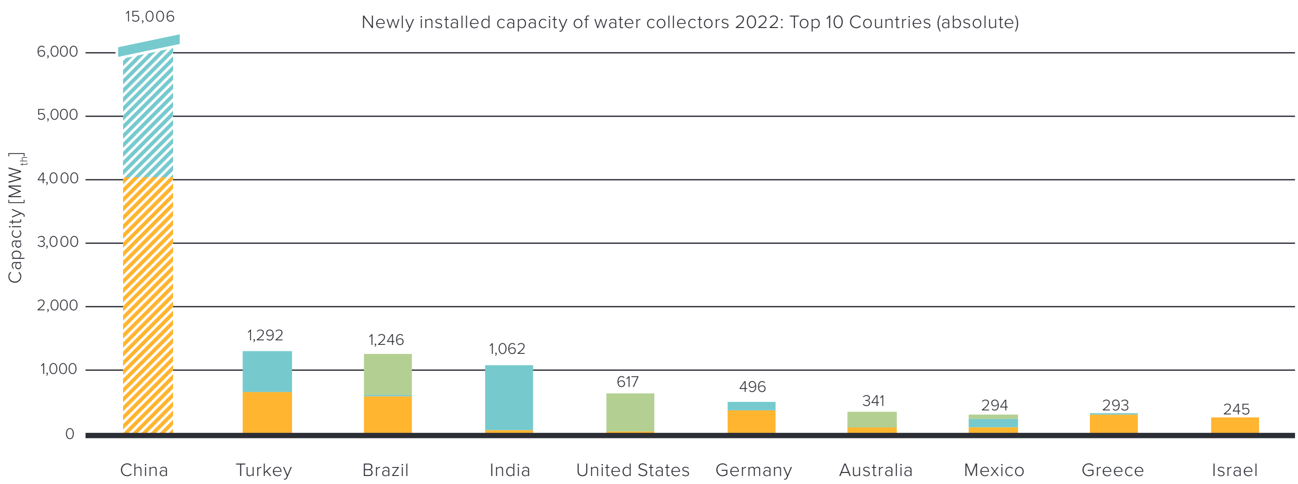

Figure 36: Top 10 markets for glazed and unglazed water collectors in 2022 (absolute figures in MW$_{th}$)

In terms of newly installed solar thermal capacity per 1,000 inhabitants in 2022, the top 10 countries are shown in Figure 37.

Cyprus, Greece, Israel, and France (overseas) rank first to fourth, followed by Lebanon, Turkey, Australia, and China, ranking fifth to eighth, the Palestinian Territories ninth place, and Germany tenth.

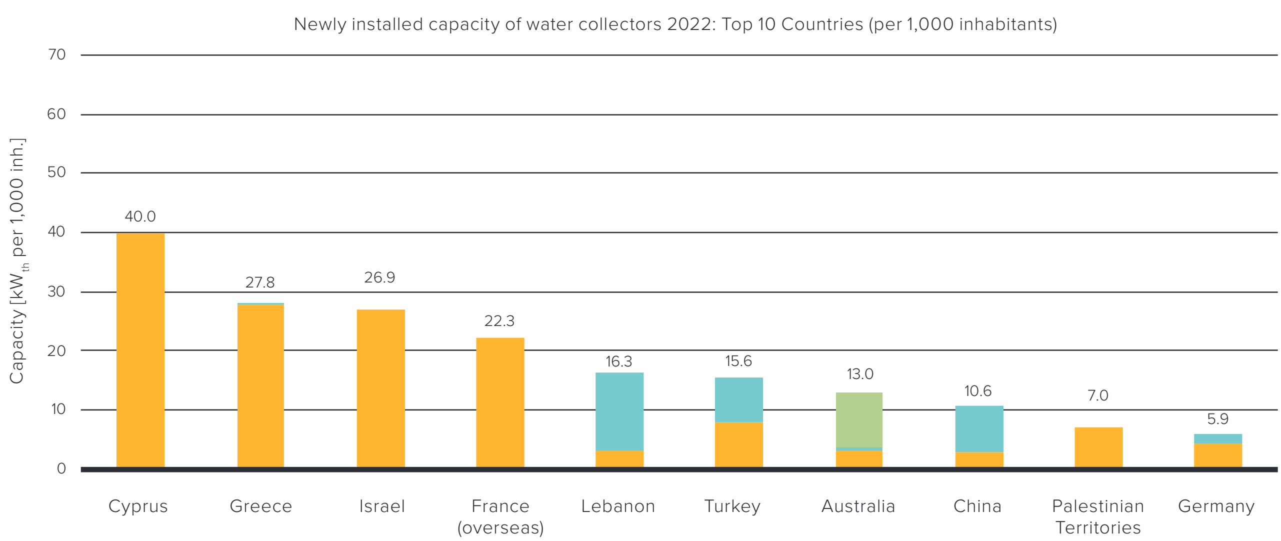

Figure 37: Top 10 markets for glazed and unglazed water collectors in 2022 (in kW$_{th}$ per 1,000 inhabitants)

6.6 Newly installed capacity of glazed water collectors

In 2022, glazed water collectors accounted for 92% of the total newly installed capacity. China was the most influential market in the global context (Figure 38).

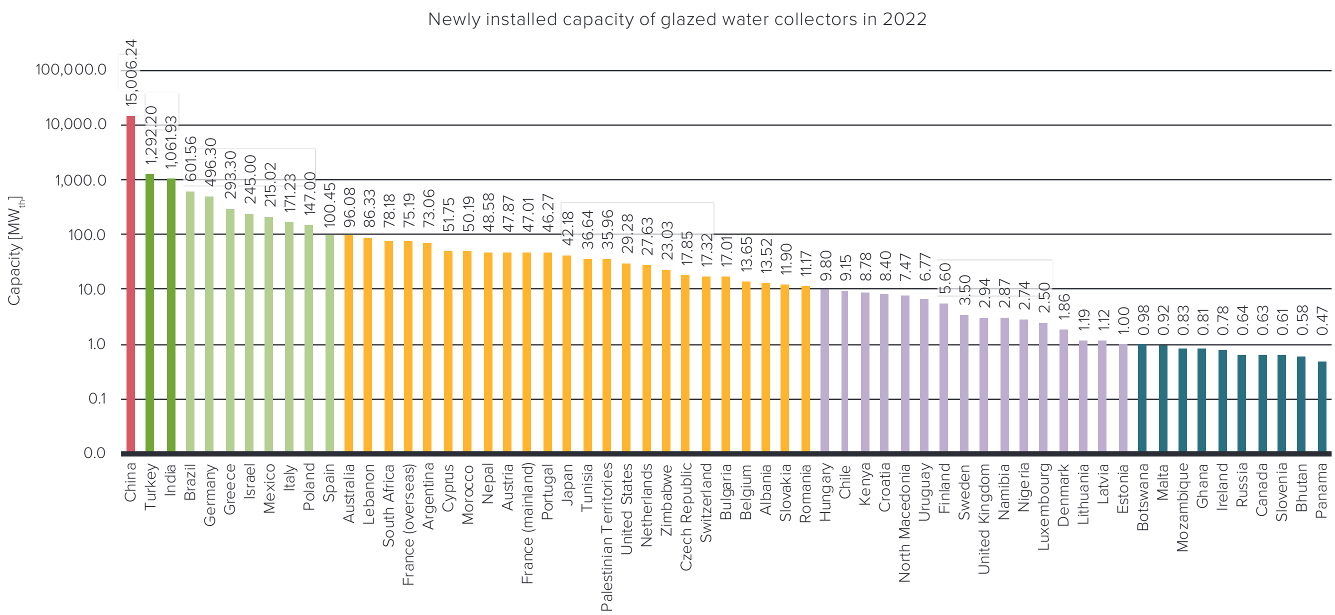

Figure 38: Newly installed capacity of glazed water collectors in 2022

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 7th place (Figure 39).

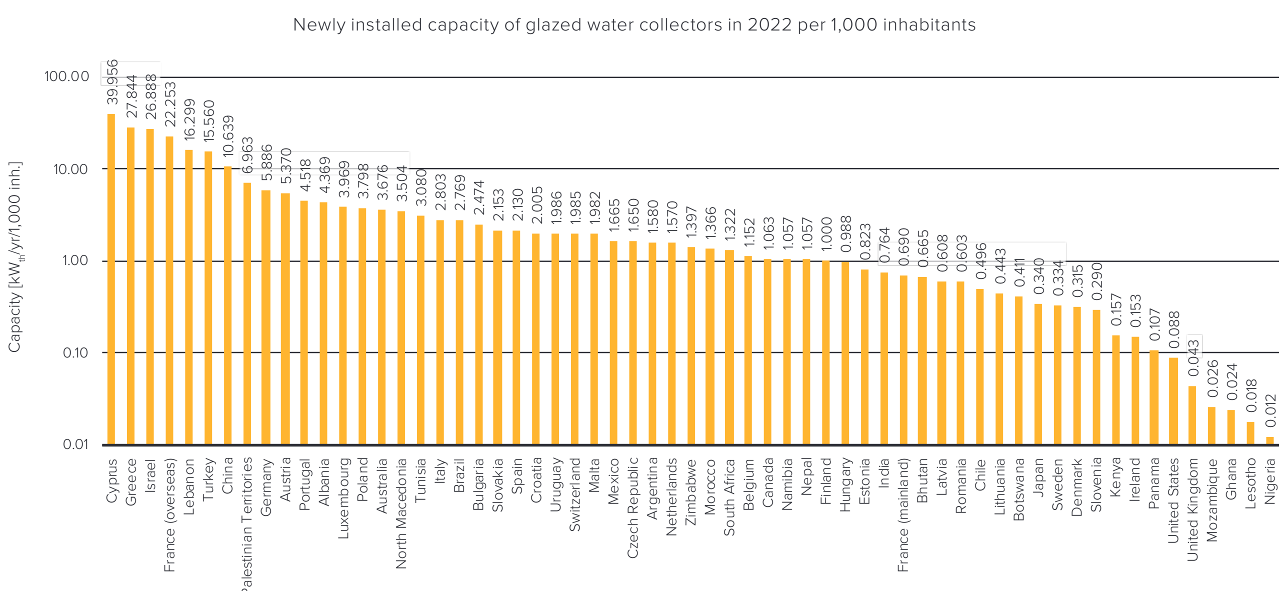

Figure 39: Newly installed capacity of glazed water collectors in 2022 in kW_{th} per 1,000 inhabitants

The following figures show the solar thermal market penetration per capita of the newly installed capacity in 2022 worldwide and in Europe.

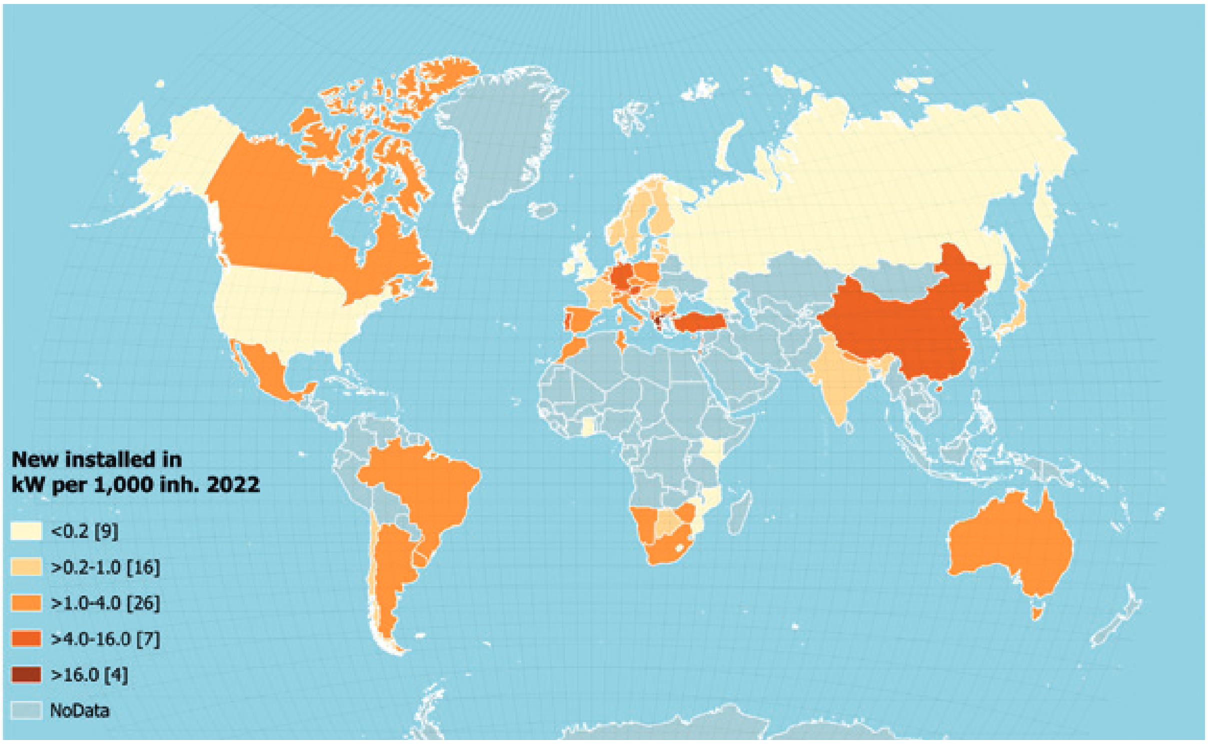

Figure 40: Newly installed capacity in 2022 in kW_{th} per 1,000 inhabitants – WORLD
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC)

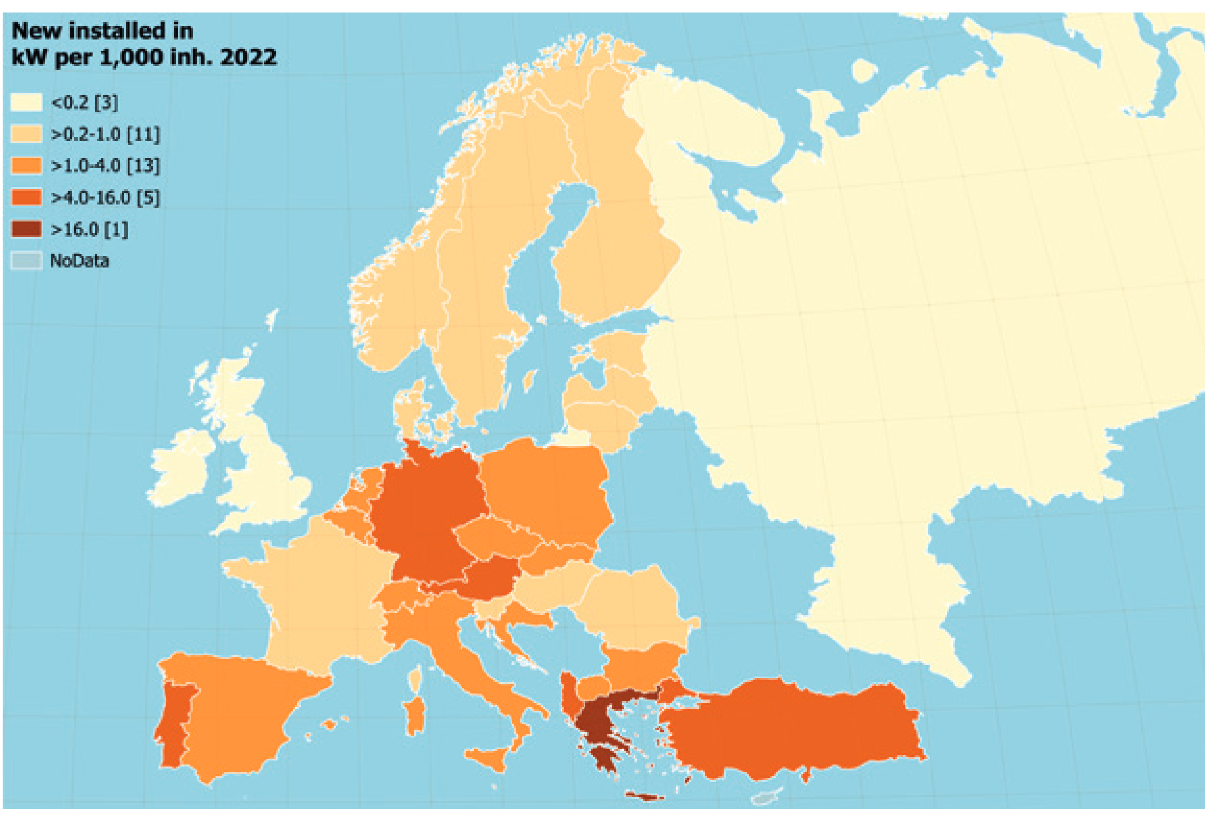

Figure 41: New Installed capacity in 2022 in kW_{th} per 1,000 inhabitants – EUROPE
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

6.7 Market development of glazed water collectors between 2000 and 2022

The worldwide market of glazed water collectors saw a steady upward trend between 2000 and 2013, with a high of around 50 GW_{th} in 2013. However, from 2014 onwards, the market for glazed collectors experienced a continuous decline, reaching a low of 21 GW_{th} in 2022. (Figure 42).

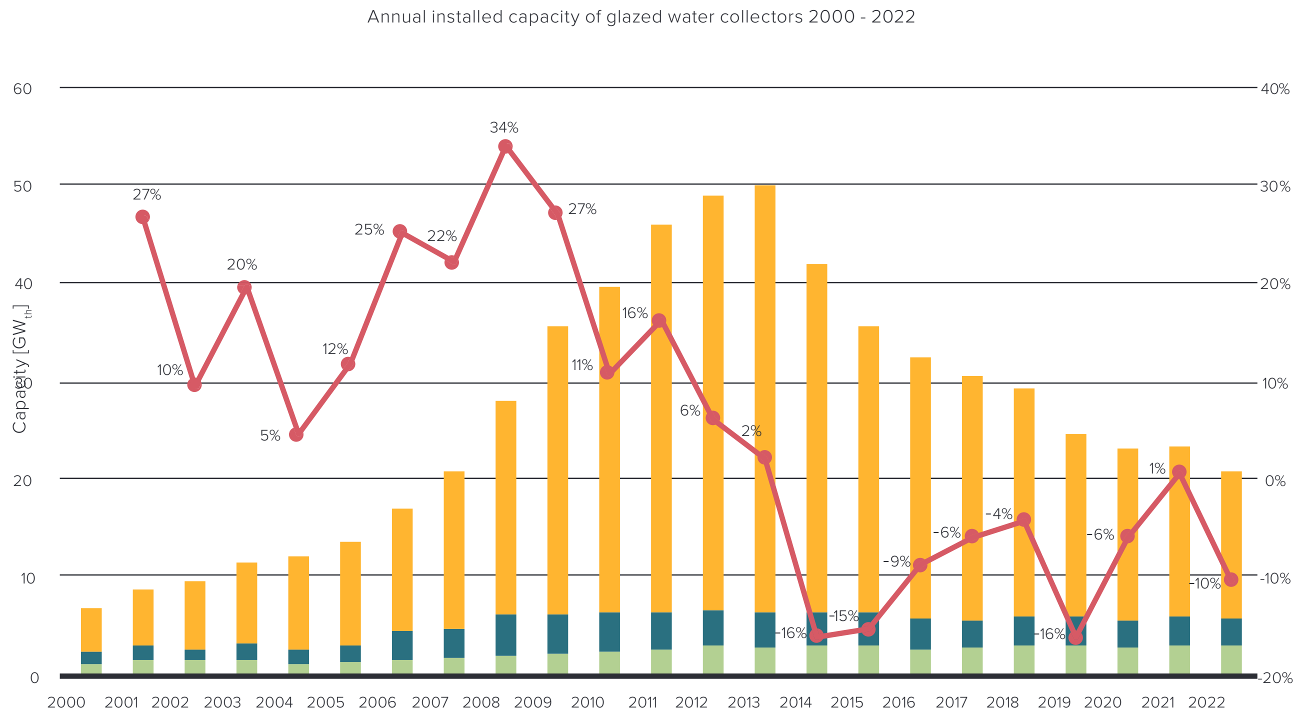

Figure 42: Global market development of glazed water collectors from 2000-2022

Figure 43 illustrates the market development in two key regions, Europe and China, from 2000 to 2022. In Europe, the installed capacity tripled from 2000 to 2008, followed by a continuous decline from 2009 onwards. China experienced rapid annual growth in installed capacity since the early 2000s, with a tenfold increase in annual installed capacity by 2013 compared to the year 2000. However, from 2014 onwards, China has seen a continuous decline.

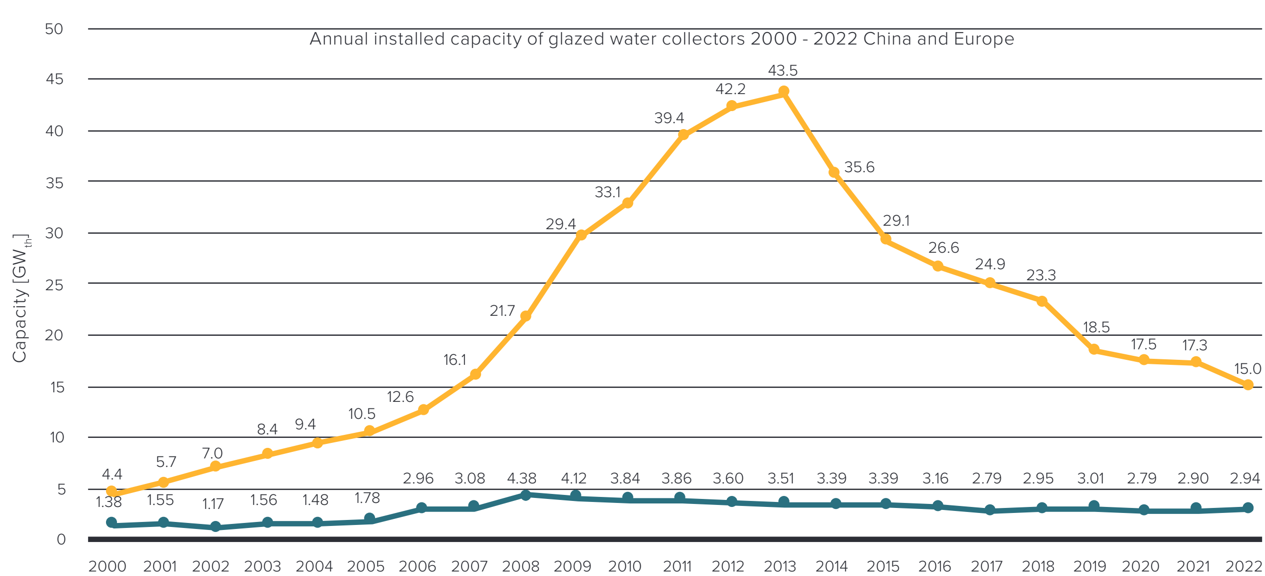

Figure 43: Market development of glazed water collectors in China and Europe 2000-2022

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).

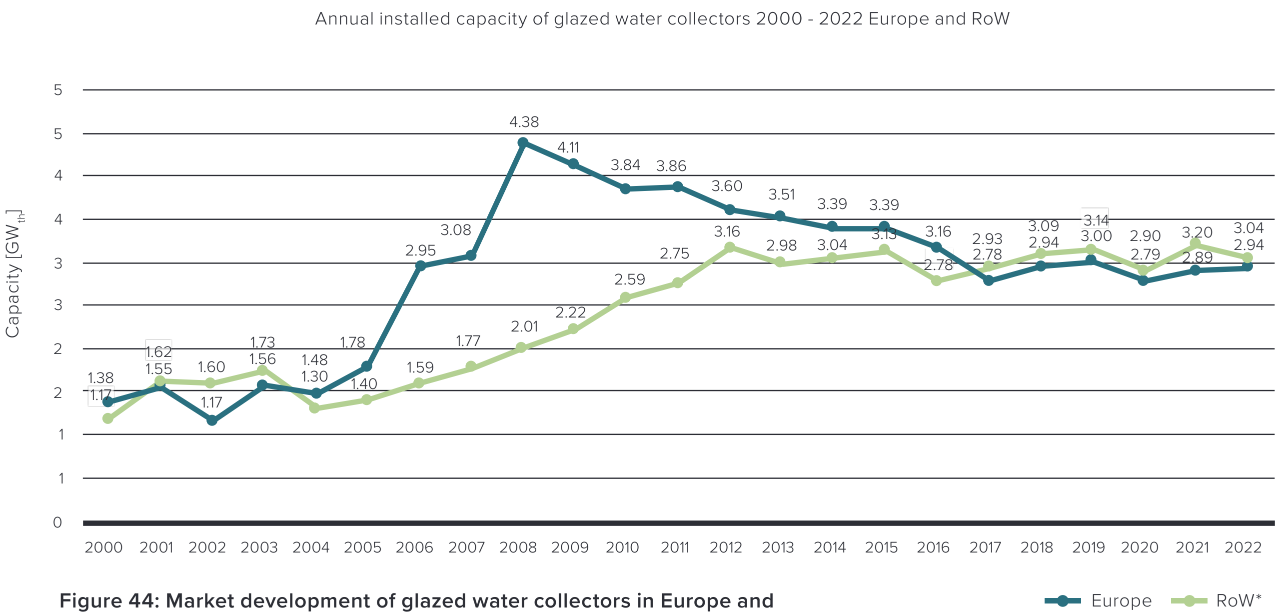

Figure 44: Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2022

Rest of World (RoW, excluding China): Asia (Bhutan, India, Japan, Nepal, South Korea, Chinese Taipei, 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 2022 in Tables 4 and 5

The Rest of the World (RoW) includes all economic regions other than China and Europe. Of these regions, Other Asia, Latin America, and the MENA countries hold the largest market shares (see Figure 45).

"Other Asia" 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. The growth phase in this region reached its first peak in 2012. In the following decade, up to 2022, the market stabilized with some ups and downs at an annual installed capacity of around 1.2 GW_{th}.

Latin America demonstrated the most consistent and dynamic upward trend among all economic regions. The annual installed capacity surged ninefold between 2000 and 2022. This growth can be attributed to the dominant Brazilian market, the substantial Mexican market, and the emerging markets in countries like Chile and Argentina.

The glazed water collector markets in the MENA countries experienced steady growth from 2000 to 2013. However, the decline in the market starting in 2014, as depicted in Figure 45, can be attributed to the absence of data for the two major markets – Morocco and Jordan – from 2015 onwards. Additionally, sales in the key market, Israel, saw a slight decrease in 2020. Since 2021, the MENA region has witnessed a slight upward trend again, primarily driven by the solar thermal markets in Lebanon and the Palestinian Territories.

The Australian market saw continuous growth from 2000 to 2009. However, from 2010 to 2022, a clear and sustained decline in annual sales is evident.

Sub-Saharan African markets have grown continuously since 2000, overtaking previously strong players like Australia, the USA, and Canada.

After a period of growth in the United States and Canada until 2013, there were severe slumps, and in 2020, the installed capacity fell well below the level of the sub-Saharan countries.

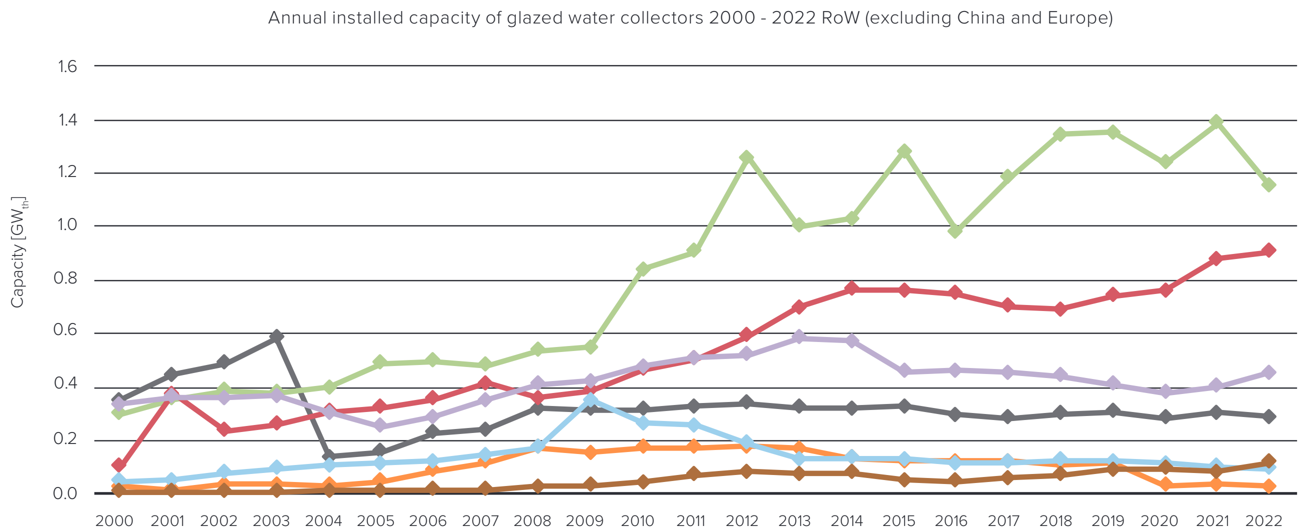

Figure 45: Market development of glazed water collectors in Latin America, United States / Canada, Sub-Sahara Africa, Other Asia, the MENA region, and Australia (excluding China and Europe) from 2000 to 2022

Other Asia: Bhutan, India, Japan, Nepal, South Korea, Chinese Taipei, 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 7.1 kW_{th} per 1,000 inhabitants in 2013 and dropped to 2.7 kW_{th} per 1,000 inhabitants in 2022 (Figure 46).

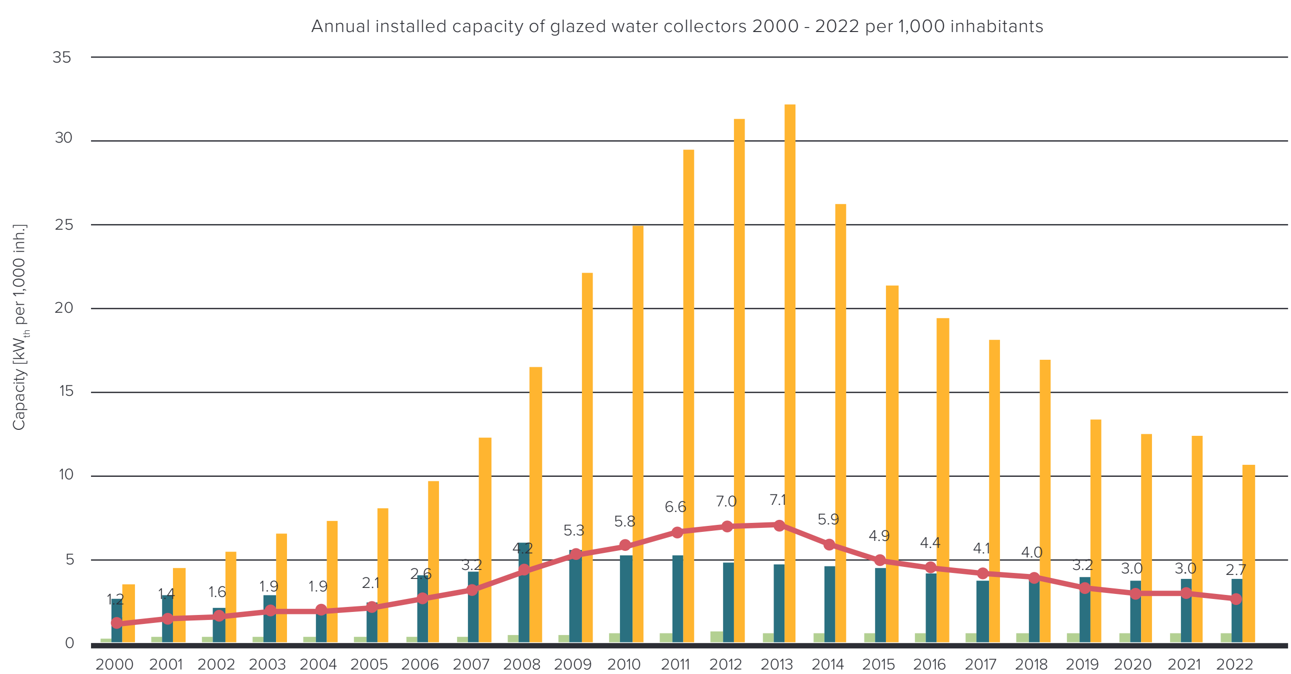

Figure 46: Annually installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2022

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, peaked at 32.2 kW_{th} per 1,000 inhabitants in 2013, and then fell to 10.6 kW_{th} per 1,000 inhabitants in 2022.

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 onwards and was 2.7 kW_{th} per 1,000 inhabitants in 2022.

6.8
Market development of unglazed water collectors between 2000 and 2022

With a newly installed capacity of 1.7 GW_{th} in 2022, unglazed water collectors accounted for 7.4% of the total installed solar thermal capacity (Figure 34). Compared to 2021, the market slightly decreased by -3.0% because of decreases in Brazil (-3%) and Australia (-7.9%). The second largest market, the United States, saw a market increase (+3.8%).

The most important markets for unglazed water collectors in 2022 were the United States (587 MW_{th}), Brazil (644 MW_{th}), and Australia (245 MWth). Mexico reported 79 MW_{th} installed unglazed water collector area and South Africa 29 MWt_{th}. The capacity in these countries accounted for 94% of the recorded unglazed water collector installations worldwide. Switzerland (2.2 MW_{th}), Spain (1.4 MW_{th}), and the Netherlands (1.8 MW_{th}) also reported unglazed water collector installations in 2022.

Solar district heating Jelling, Denmark
Photo: SavoSolar / Solar Heat Europe

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 2021 at 0.66 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.

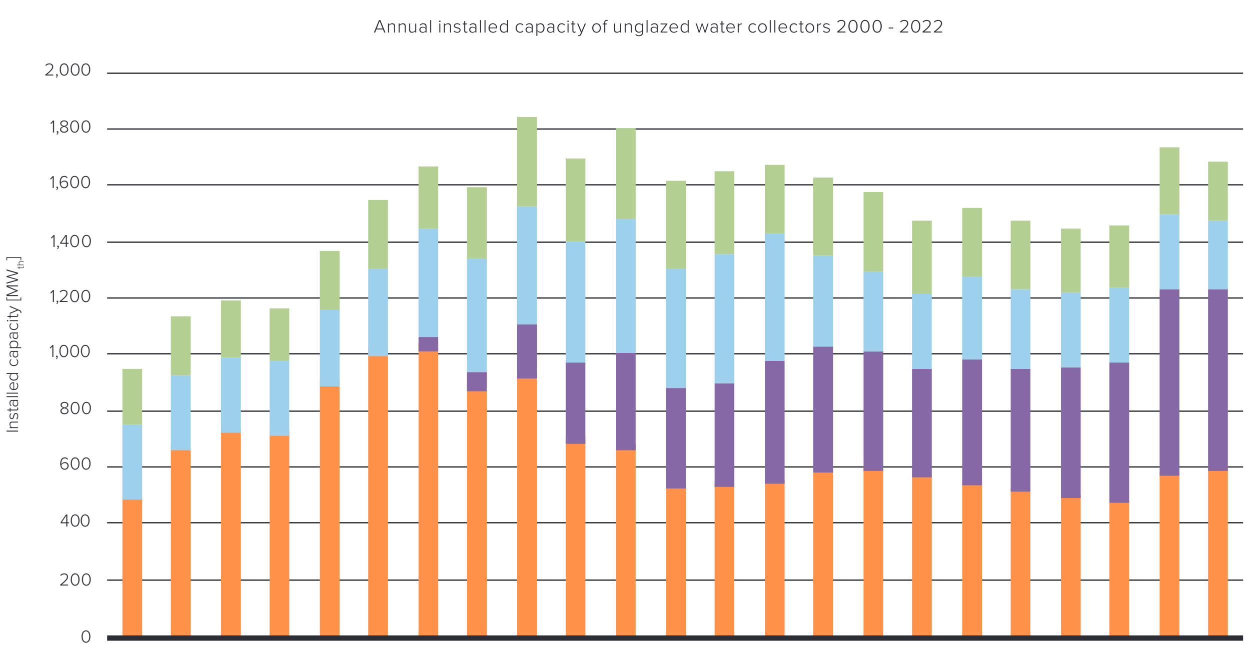

Figure 47: Global market development of unglazed water collectors from 2000 to 2022

7 Contribution to the energy supply and CO_2 reduction in 2022

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 2022 in the 72 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 443 TWh (= 1,594 PJ). This corresponds to a final energy savings equivalent to 47.6 million tons of oil and 150.7 million tons of CO_2. The calculated number of solar thermal systems in operation is around 122 million (Table 13). Therefore, the CO_2 emissions saved by the thermal solar systems in operation is about 150.7 million t/a or 3.6 times the CO_2 emissions of Switzerland (2022).[50]

The basis for these calculations is the total glazed and unglazed water collector area in operation in each country, as shown in Table 10. The 0.9 GW_{th} contribution of the total installed air collector capacity in operation in 2022 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, www.valentin-software.comfor 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 13 summarizes the calculated annual collector yields and the corresponding oil equivalents and CO_2 reductions of all water-based solar thermal systems in 2022.

[50] https://www.bafu.admin.ch/bafu/de/home/themen/klima/inkuerze.html

* 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
\++ Calculated based on 0% growth 2022
\+++ New in ed. 2024

Table 13: Calculated annual collector yield and corresponding oil equivalent and CO_2 reduction of glazed and unglazed water collectors in operation by the end of 2022

Country/Region/ Economy	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	329,485	231	30,702	230	828	24,728	78,265
Argentina	504,445	353	72,214	335	1,207	36,037	114,057
Australia	9,494,000	6,646	1,188,757	5,775	20,791	620,734	1,964,624
Austria	4,607,016	3,225	495,850	1,910	6,875	205,259	649,644
Barbados+	258,192	181	59,797	227	817	24,400	77,226
Belgium	770,000	539	132,090	305	1,097	32,742	103,629
Bhutan	824	0.6	138	0.6	2	62	195
Botswana++	20,075	14	3,279	19	68	2,023	6,402
Brazil	22,191,721	15,534	6,036,473	13,850	49,860	1,488,596	4,711,405
Bulgaria	220,788	155	40,264	111	398	11,897	37,653
Burkina Faso+	4,681	3	296	4	16	469	1,484
Canada	819,000	573	32,252	343	1,233	36,821	116,540
Chile	443,003	310	141,910	311	1,121	33,467	105,923
China	566,187,921	396,332	81,059,237	309,937	1,115,774	33,312,259	105,433,299
Croatia	288,701	202	52,649	148	532	15,871	50,231
Cyprus	885,210	620	386,801	787	2,832	84,556	267,619
Czech Republic	1,079,006	755	98,260	370	1,333	39,793	125,946
Denmark	1,814,453	1,270	108,477	757	2,726	81,385	257,584
Estonia	23,103	16	4,213	9	34	1,014	3,210
Finland	88,886	62	13,908	35	125	3,721	11,778
France (mainland)	2,366,856	1,657	494,232	1,156	4,160	124,208	393,120
France (overseas)	1,227,217	859	287,611	996	3,587	107,101	338,976
Germany	22,576,697	15,804	2,666,131	9,211	33,161	990,035	3,133,460
Ghana++	7,678	5	402	7	25	744	2,354
Greece	5,422,000	3,795	1,517,572	3,850	13,859	413,761	1,309,554
Hungary	391,899	274	54,413	183	658	19,632	62,136
India	19,259,079	13,481	8,717,275	16,746	60,286	1,799,876	5,696,607
Ireland	416,875	292	96,479	175	628	18,760	59,374
Israel++	5,087,434	3,561	1,682,448	4,756	17,123	511,220	1,618,012
Italy	5,380,166	3,766	972,566	3,319	11,950	356,765	1,129,162
Japan	2,682,758	1,878	645,916	1,549	5,575	166,458	526,839
Jordan*	1,260,506	882	223,109	1,194	4,297	128,286	406,026
Kenya++	477,521	334	108,278	406	1,462	43,653	138,162
Latvia	43,062	30	7,853	19	67	1,999	6,327
Lebanon	909,071	636	151,914	764	2,750	82,103	259,856
Lesotho	6,472	5	1,848	6	21	613	1,940
Lithuania	25,491	18	4,649	11	39	1,167	3,693
Luxembourg	74,980	52	13,674	32	116	3,467	10,974
Malta	76,711	54	30,684	67	240	7,156	22,648
Mauritius**	132,793	93	88,529	113	408	12,183	38,558
Mexico	5,932,707	4,153	740,135	3,495	12,583	375,666	1,188,982
Morocco++	1,038,000	727	145,789	895	3,221	96,168	304,370
Mozambique	4,313	3	628	3	13	376	1,189
Namibia	62,669	44	7,561	57	204	6,090	19,276
Nepal+++	300,000	210	144,095	243	873	26,065	82,495
Netherlands	662,360	464	146,308	267	960	28,654	90,690
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	145,036	102	33,314	90	324	9,681	30,641
Norway	42,775	30	2,132	16	57	1,692	5,356
Palestinian Territories	1,980,900	1,387	708,103	1,877	6,756	201,693	638,359
Poland	3,405,690	2,384	440,810	1,364	4,911	146,616	464,038
Portugal	1,547,185	1,083	281,288	1,196	4,306	128,562	406,899
Romania	265,409	186	48,354	149	537	16,027	50,727
Russia	88,271	62	16,407	38	138	4,107	13,000
Senegal+	9,824	7	2,448	10	34	1,029	3,258
Slovakia	208,210	146	26,561	99	355	10,589	33,514
Slovenia	151,670	106	23,703	64	229	6,844	21,661
South Africa	2,785,885	1,950	722,797	2,076	7,472	223,084	706,060
South Korea	1,932,096	1,352	446,134	1,006	3,621	108,104	342,151
Spain	4,998,250	3,499	597,527	3,505	12,616	376,671	1,192,164
Sweden	504,515	353	36,201	182	656	19,591	62,005
Switzerland	1,708,200	1,196	222,135	690	2,485	74,190	234,811
Chinese Taipei+	1,815,055	1,271	360,690	1,108	3,988	119,050	376,793
Thailand****	157,536	110	36,288	133	478	14,262	45,138
Tunisia	1,252,601	877	368,117	1,124	4,045	120,770	382,238
Turkey	27,346,597	19,143	6,317,064	24,533	88,320	2,636,870	8,345,694
United Kingdom	935,627	655	146,800	331	1,192	35,579	112,608
United States	26,063,441	18,244	403,637	10,978	39,520	1,179,903	3,734,393
Uruguay	117,431	82	24,489	79	285	8,498	26,898
Zimbabwe	120,036	84	48,765	102	368	10,990	34,784
Other (5% of world market excluding China)	10,390,827	7,274	1,544,680	5,650	20,339	607,234	1,921,897
TOTAL	774,004,464	541,803	122,245,349	442,854	1,594,273	47,598,193	150,648,281

8 Distribution of systems by type and application in 2022

The use of solar thermal energy varies significantly from region to region. It 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 2022, evacuated tube collectors dominated with 68.7% of the cumulated capacity in operation (Figure 48) and a share of 58.7% of the newly installed capacity (Figure 49). Worldwide, flat plate collectors accounted for about 25.3% of the cumulated capacity in operation (Figure 48) and a 33.8% share of the newly installed capacity (Figure 49). Unglazed water collectors accounted for 6% of the cumulated water collectors installed worldwide and 7.4% 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.

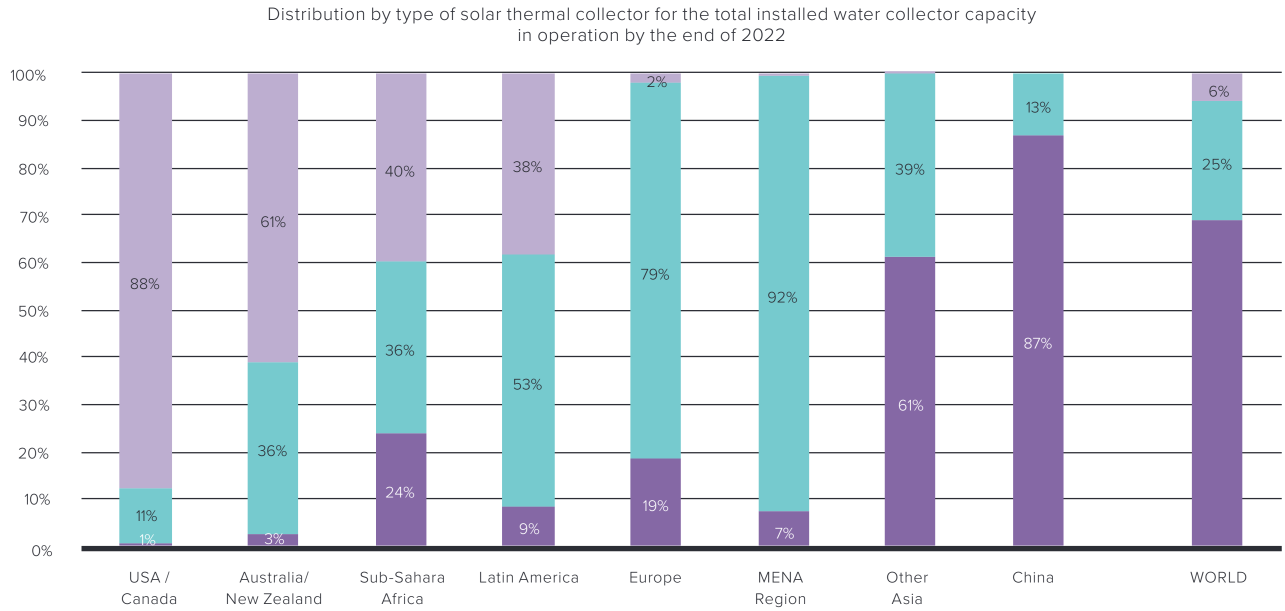

Figure 48: Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2022

unglazed water collectors
evacuated tube collectors
flat plate collectors

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, South Korea, Chinese Taipei, 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

The distribution of the newly installed collector area is shown below. Evacuated tube collectors are dominant in China, Other Asia, 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.

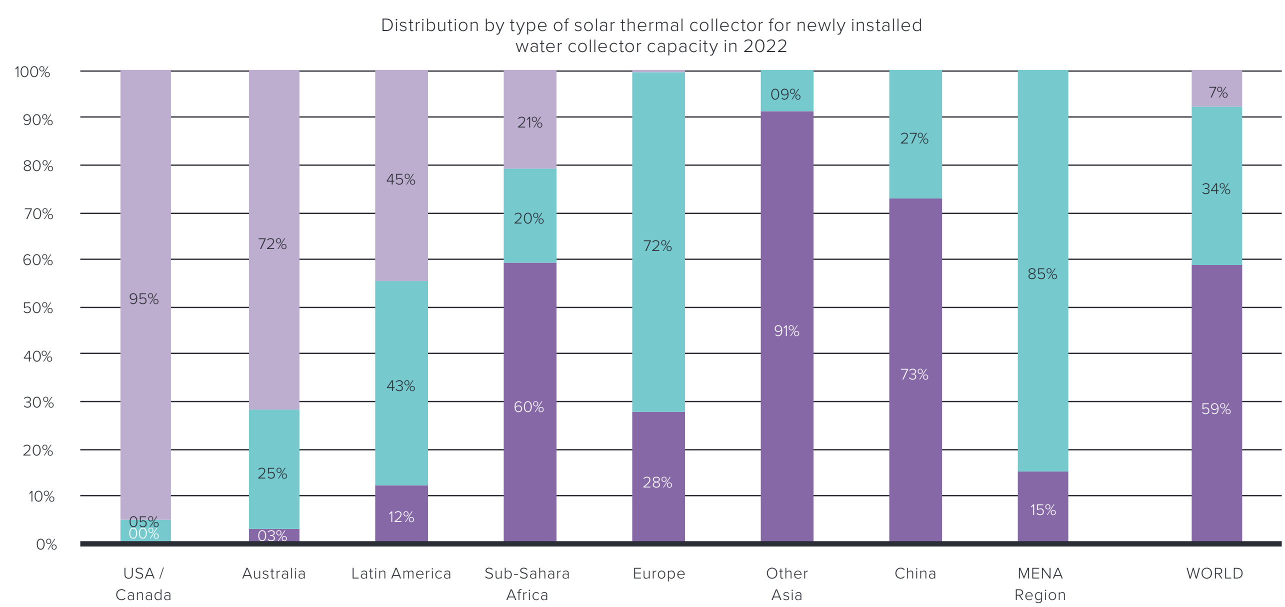

Figure 49: Distribution by type of solar thermal collector for newly installed water collector capacity in 2022

unglazed water collectors
evacuated tube collectors
flat plate collectors

Sub-Sahara Africa: Botswana, Burkina Faso, Cape Verde, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, South Korea, Chinese Taipei, 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; 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.

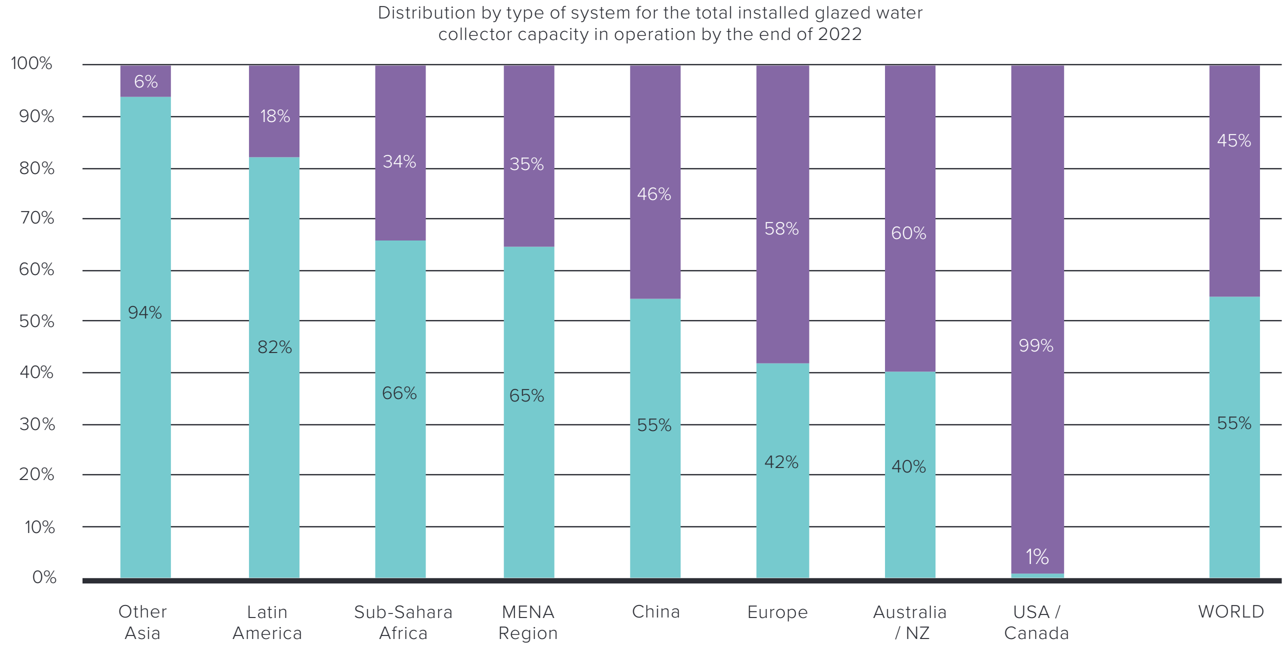

Figure 50: Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2022

Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, South Korea, Chinese Taipei 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

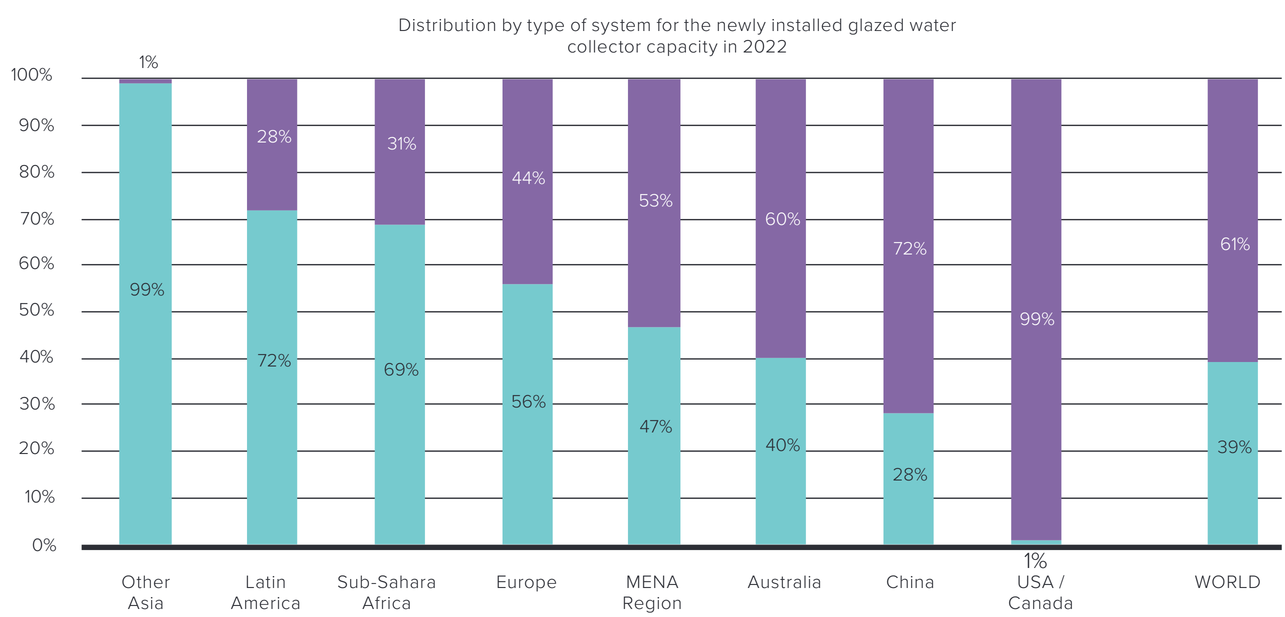

Figure 51: Distribution by type of system for the newly installed glazed water collector capacity in 2022

Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, South Korea, Chinese Taipei, 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 2022 is 32.4 million, corresponding to 22.7 GW_{th} of thermal peak capacity (Table 11).

The largest share of the collector area installed in 2022 was for 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 2022. The share of swimming pool heating was 7.5%. The share for other applications, such as solar district heating and solar process heat, is about 2% globally (Figure 52).

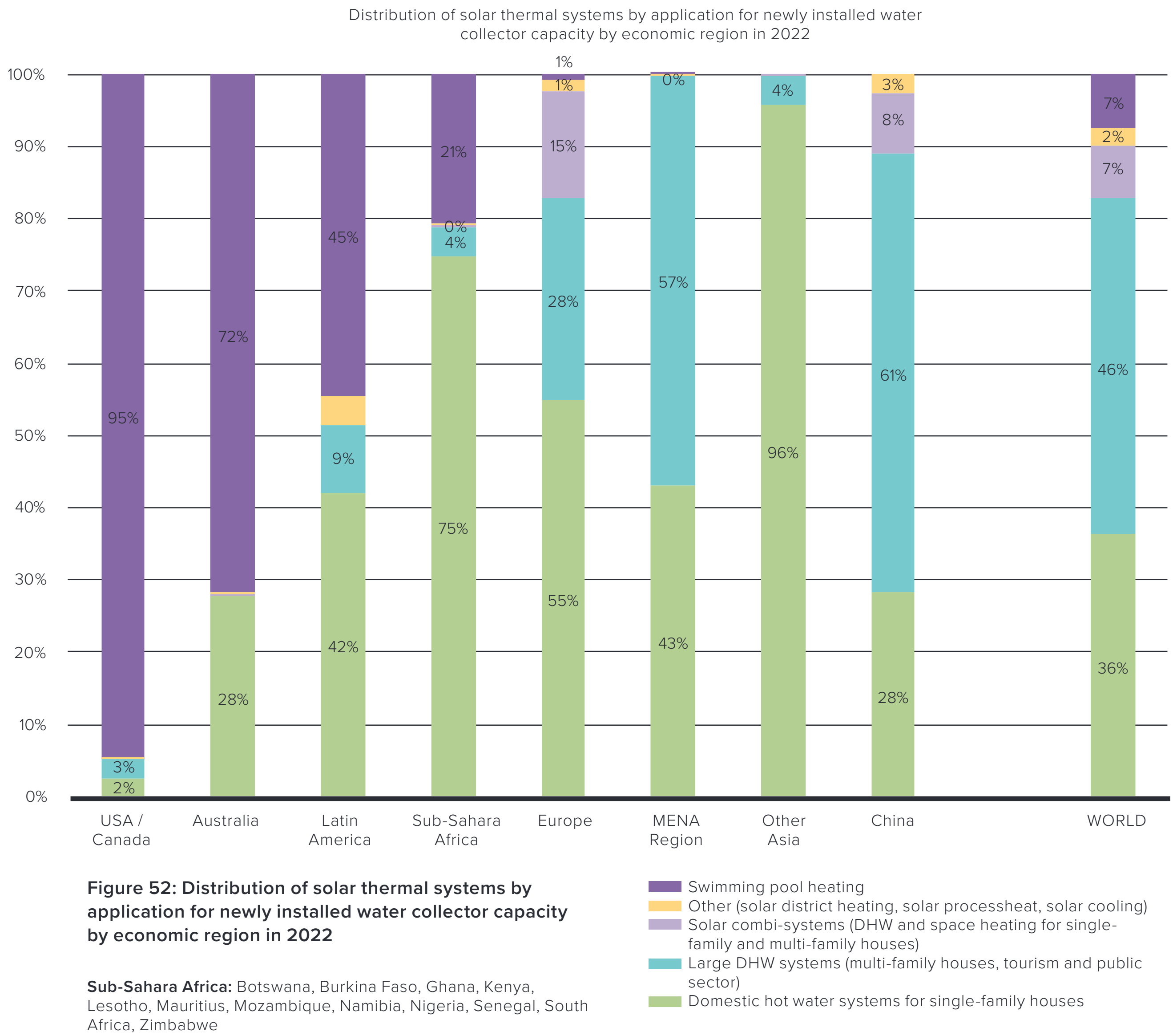

Figure 52: Distribution of solar thermal systems by application for newly installed water collector capacity by economic region in 2022

Sub-Sahara Africa: Botswana, Burkina Faso, Ghana, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Zimbabwe
Other Asia: Bhutan, India, Japan, South Korea, Chinese Taipei, 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 combisystems 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.[51]

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 = 3.165 t CO_2e[52]. 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.[53] Furthermore, a hydraulic scheme is shown for each reference system.

[51] 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.
[52] Source: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020 (07/05/2024)
[53] 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 14 refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2022.

Table 14: Solar thermal systems for swimming pool heating in 2022

Energy calculation Swimming Pool						
Swimming Pool - Total						
Country/Region/ Economy	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	156,378	200	782	470
Australia	Sydney	1,674	5,895,774	35	168,451	466
Austria	Graz	1,126	171,445	200	857	283
Belgium	Brussels	971	46,970	200	235	261
Brazil	Brasília	1,793	8,743,538	32	273,236	375
Canada	Montreal	1,351	704,340	25	28,174	386
Chile	Santiago de Chile	1,753	89,496	15	5,966	471
Cyprus	Nicosia	1,886	2,390	200	12	507
Czech Republic	Praha	998	476,921	200	2,385	303
Finland	Helsinki	948	12,800	200	64	256
France (mainland)	Paris	1,112	71,006	200	355	328
Germany	Würzburg	1,091	532,810	30	17,760	314
Hungary	Budapest	1,199	19,203	10	1,920	344
Israel	Jerusalem	2,198	40,699	200	203	568
Italy	Bologna	1,419	48,421	200	242	442
Jordan	Amman	2,145	6,661	200	33	578
Mexico	Mexico City	1,706	1,868,803	200	9,344	311
Mozambique	Maputo	1,910	233	40	6	514
Namibia	Windhoek	2,363	1,817	40	45	636
Netherlands	Amsterdam	999	88,520	40	2,213	272
New Zealand	Wellington	1,401	7,024	200	35	378
Norway	Oslo	971	1,788	200	9	316
Poland	Warsaw	1,024	68,114	200	341	276
Portugal	Lisbon	1,686	3,094	200	15	421
Romania	Bucharest	1,324	265	200	1	356
Russia	Moscow	996	335	200	2	268
Slovakia	Bratislava	1,214	1,041	200	5	327
Slovenia	Ljubjana	1,115	1,517	200	8	
South Africa	Johannesburg	2,075	1,448,660	40	36,217	505
Spain	Madrid	1,644	169,941	200	850	472
Sweden	Gothenburg	934	165,481	200	827	295
Switzerland	Zürich	1,094	174,236	200	871	277
Chinese Taipei	Taipei	1,372	1,997	175	11	319
United Kingdom	London	943	355,538	200	1,778	254
United States	LA, Indianapolis	1,646	22,883,701	200	114,419	387
Uruguay	Montevideo	1,534	470		2	413
Other (5%)		1,449	2,329,616	200	11,648	392
TOTAL			46,591,044		679,322	
AVG		1,427		152		382

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

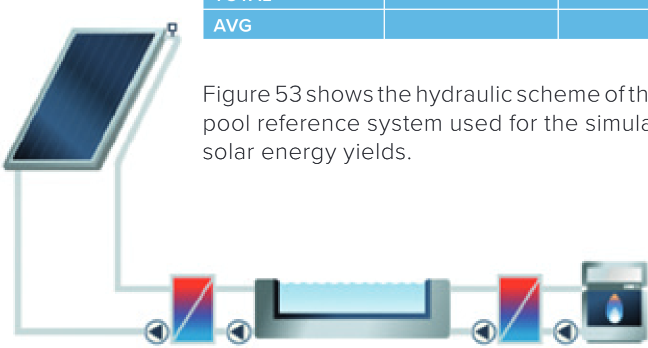

Figure 53: Hydraulic scheme of the swimming pool reference system

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

The information in Table 15 refers to the total capacity of water collectors used for domestic hot water heating in single-family houses at the end of 2022, as reported by each country.

Table 15: Solar thermal systems for domestic hot water heating in single-family houses by the end of 2022

Energy calculation DHW-SFH							
DHW-MFH - Total							
Country/Region/ Economy	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	76,955	3	25,652	713	TS
Argentina	Buenos Aires	1,748	268,393	4	67,098	777	PS
Australia	Sydney	1,674	3,569,744	3.5	1,019,927	844	PS
Austria	Graz	1,126	2,081,759	6	346,960	451	PS
Barbados	Grantley Adams	2,016	237,537	4	59,384	882	TS
Belgium	Brussels	971	470,098	4	117,524	423	PDS / PS
Bhuthan	Thimphu	1,623	371	4	93	721	TS
Botswana	Gaborone	2,161	12,045	4	3,011	961	TS
Brazil	Brasília	1,793	11,460,184	2	5,730,092	809	TS
Bulgaria	Sofia	1,188	143,551	4	35,888	524	PS
Burkina Faso	Ouagadougou	2,212	647	4	162	983	TS
Canada	Montreal	1,351	12,128	6	2,021	556	PS
Chile	Santiago de Chile	1,753	268,487	2	134,243	771	PS
China	Shanghai	1,282	300,079,598	4	75,019,900	592	TS
Croatia	Zagreb	1,212	187,707	4	46,927	539	PS
Cyprus	Nicosia	1,886	767,162	2	383,581	912	TS
Czech Republic	Praha	998	309,037	4.7	65,753	385	PS
Denmark	Copenhagen	989	284,869	4	71,217	454	PS
Estonia	Tallin	960	15,021	4	3,755	432	PS
Finland	Helsinki	948	49,277	4	12,319	441	PS
France (mainland)	Paris	1,112	1,443,782	3.2	451,182	496	PS
France (overseas departments)	"Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea"	1,834	1,143,766	4	285,942	815	TS
Germany	Würzburg	1,091	9,940,614	5.6	1,775,110	424	PS
Ghana	Accra	2,146	676	4	169	954	TS
Greece	Athens	1,585	3,525,262	2.5	1,410,105	772	TS
Hungary	Budapest	1,199	215,119	5	43,024	473	PS
India	Neu-Delhi	1,961	17,358,208	2	8,679,104	882	TS
Ireland	Dublin	949	375,188	4	93,797	423	PS
Israel	Jerusalem	2,198	946,263	3	315,421	1,024	TS
Italy	Bologna	1,419	3,466,580	4	866,645	661	PS
Japan	Tokyo	1,175	2,538,187	4	634,547	586	TS
Jordan	Amman	2,145	1,003,076	4.6	218,060	986	TS
Kenya	Nairobi	1,931	403,506	4	100,876	859	TS
Latvia	Riga	991	27,998	4	6,999	462	PS
Lebanon	Beirut	1,935	572,715	4	143,179	860	TS
Lesotho	Maseru	2,050	3,002	2	1,501	911	TS
Lithuania	Vilnius	1,001	16,574	4	4,143	450	PS
Luxembourg	Luxembourg	1,037	48,750	4	12,188	450	PS
Malta	Luqa	1,902	76,711	2.5	30,684	868	PS
Mauritius	Port Louis	1,920	132,793	1.5	88,529	854	TS
Mexico	Mexico City	1,706	2,823,969	4	705,992	718	PS
Morocco	Rabat	2,000	540,625	4	135,156	889	TS
Mozambique	Maputo	1,910	2,350	4	588	849	TS
Namibia	Windhoek	2,363	27,383	4	6,846	1,032	TS
Nepal	Kathmandu	1,771	135,000	4	33,750	787	TS
Netherlands	Amsterdam	999	372,370	2.8	132,989	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	131,716	4	32,929	627	PS
Norway	Oslo	971	1,486	6	248	430	PS
Palestinian Territories	Jerusalem	2,198	1,031,719	1.5	687,813	977	TS
Poland	Warsaw	1,024	2,401,011	6	400,169	397	PS
Portugal	Lisbon	1,686	1,078,536	4	269,634	804	PS
Romania	Bucharest	1,324	172,390	4	43,098	594	PS
Russia	Moscow	996	63,220	4	15,805	443	PS
Senegal	Dakar	2,197	9,529	4	2,382	977	TS
Slovakia	Bratislava	1,214	134,697	6	22,449	481	PS
Slovenia	Ljubjana	1,115	136,503	6	22,751	424	PS
South Africa	Johannesburg	2,075	1,303,794	1.9	686,207	1,009	TS
South Korea	Seoul	1,161	1,765,900	4	441,475	525	PS
Spain	Madrid	1,644	2,032,972	4	508,243	766	PS
Sweden	Gothenburg	934	35,561	4	8,890	383	PS
Switzerland	Zürich	1,094	1,027,558	5.7	180,273	426	PS
Chinese Teipei	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	1,212,142	3.3	367,316	902	TS
Turkey	Antalya	1,795	25,158,869	4	6,289,717	910	TS
United Kingdom	London	943	580,089	4	145,022	415	PS
United States	LA, Indianapolis	1,646	1,539,249	6	256,542	646	PS
Uruguay	Montevideo	1,534	96,293	4	24,073	682	TS
Zimbabwe	Harare	2,017	96,029	2	48,014	854	TS
Other (5% of world market excluding China)		1,433	5,734,217	4	1,433,554	637	
TOTAL			415,178,645		111,637,176		
AVG		1,537		4		686	

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 56 refers to the thermosiphon systems.

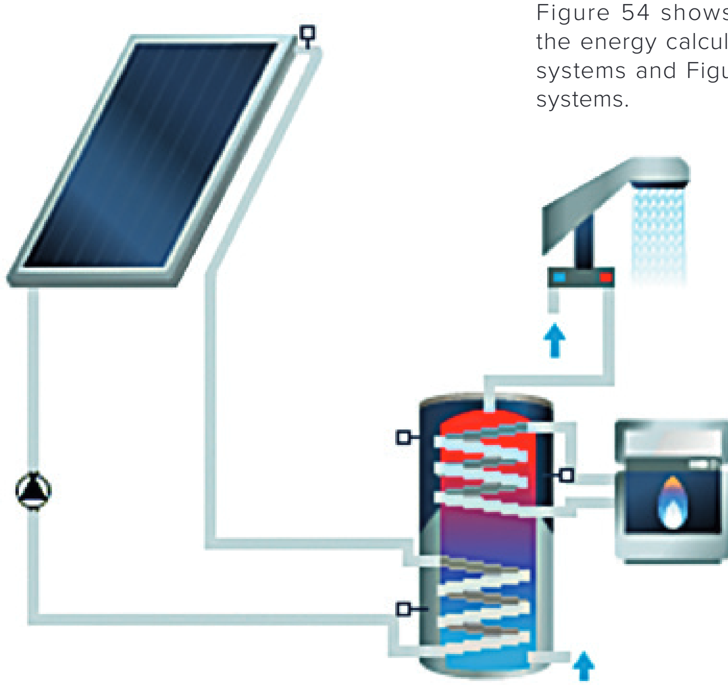

Figure 54: Hydraulic scheme of the domestic hot water pumped reference system for single-family houses

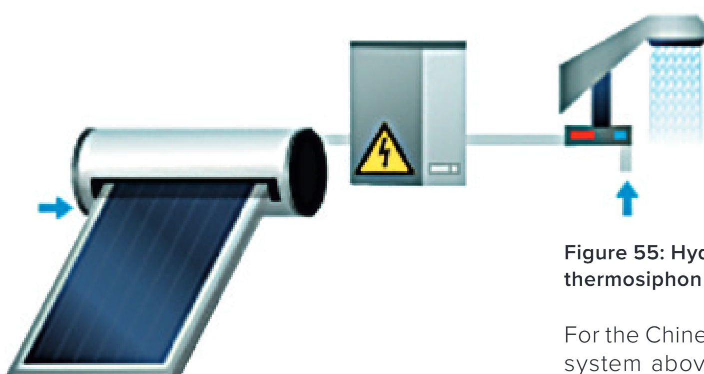

Figure 55: Hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses

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 16 refers to the total capacity of water collectors used for domestic hot water heating in multi-family houses at the end of 2022, as reported by each country.

Table 16: Solar thermal systems for domestic hot water heating in multi-family houses by the end of 2022

Energy calculation DHW-MFH						
DHW-MFH - Total						
Country/Region/ Economy	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	252,530	50	5,051	694
Argentina	Buenos Aires	1,748	36,404	50	728	730
Australia	Sydney	1,674	18,988	50	380	725
Austria	Graz	1,126	388,274	50	7,765	505
Barbados	Grantley Adams	2,016	20,655	50	413	842
Belgium	Brussels	971	106,892	50	2,138	406
Bhutan	Thimphu	1,623	453	10	45	678
Botswana	Gaborone	2,161	8,030	30	268	903
Brazil	Brasília	1,793	1,988,712	60	33,145	658
Bulgaria	Sofia	1,188	32,641	50	653	515
Burkina Faso	Ouagadougou	2,212	4,033	30	134	924
Canada	Montreal	1,351	102,533	50	2,051	621
Chile	Santiago de Chile	1,753	85,021	50	1,700	732
China	Shanghai	1,282	254,784,564	50	5,095,691	502
Croatia	Zagreb	1,212	42,681	50	854	506
Cyprus	Nicosia	1,886	101,523	50	2,030	750
Czech Republic	Praha	998	46,718	42.4	1,102	436
Denmark	Copenhagen	989	1,466,078	50	29,322	413
Estonia	Tallin	960	3,416	50	68	401
Finland	Helsinki	948	11,154	50	223	396
France (mainland)	Paris	1,112	852,068	20	42,603	489
France (overseas departments)	Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea	1,834	83,451	50	1,669	766
Germany	Würzburg	1,091	2,686,456	50	53,729	472
Ghana	Accra	2,146	7,002	30	233	896
Greece	Athens	1,585	801,580	50	16,032	642
Hungary	Budapest	1,199	78,394	50	1,568	522
India	Neu-Delhi	1,961	1,908,575	50	38,171	749
Ireland	Dublin	949	12,506	50	250	425
Israel	Jerusalem	2,198	4,100,472	3	1,366,824	918
Italy	Bologna	1,419	788,237	50	15,765	593
Japan	Tokyo	1,175	9,569	50	191	516
Jordan	Amman	2,145	250,769	50	5,015	801
Kenya	Nairobi	1,931	74,016	10	7,402	807
Latvia	Riga	991	6,366	50	127	414
Lebanon	Beirut	1,935	331,233	40	8,281	808
Lesotho	Maseru	2,050	3,449	10	345	856
Lithuania	Vilnius	1,001	3,769	50	75	418
Luxembourg	Luxembourg	1,037	11,085	50	222	433
Mexico	Mexico City	1,706	1,239,936	50	24,799	713
Morocco	Rabat	2,000	486,563	50	9,731	835
Mozambique	Maputo	1,910	1,730	50	35	798
Namibia	Windhoek	2,363	33,468	50	669	814
Nepal	Kathmandu	1,771	165,000	50	3,300	740
Netherlands	Amsterdam	999	158,550	40	3,964	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	11,840	50	237	577
Norway	Oslo	971	16,250	50	325	406
Palestinian Territories	Jerusalem	2,198	928,547	50	18,571	918
Poland	Warsaw	1,024	595,996	50	11,920	447
Portugal	Lisbon	1,686	465,555	40	11,639	705
Romania	Bucharest	1,324	39,198	50	784	553
Russia	Moscow	996	22,438	50	449	416
Senegal	Dakar	2,197	295	4.5	65	918
Slovakia	Bratislava	1,214	30,628	50	613	507
Slovenia	Ljubjana	1,115	3,033	50	61	477
South Africa	Johannesburg	2,075	32,414	87	373	867
South Korea	Seoul	1,161	144,967	50	2,899	485
Spain	Madrid	1,644	2,388,743	50	47,775	676
Sweden	Gothenburg	934	48,177	50	964	430
Switzerland	Zürich	1,094	122,693	20	6,135	457
Chinese Teipei	Taipei	1,372	96,511	30	3,217	518
Thailand	Bangkok	1,765	11,820	80	148	737
Tunisia	Tunis	1,808	40,083	50	802	755
Turkey	Antalya	1,795	2,187,728	80	27,347	750
United States	LA, Indianapolis	1,646	1,633,846	50	32,677	688
Uruguay	Montevideo	1,534	20,668	50	413	641
Zimbabwe	Harare	2,017	24,007	32	750	842
Other (5% of world market excluding China)		1,244	1,449,131	50	28,983	519
TOTAL			283,930,124		6,984,809	
AVG		1,535		45		638

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

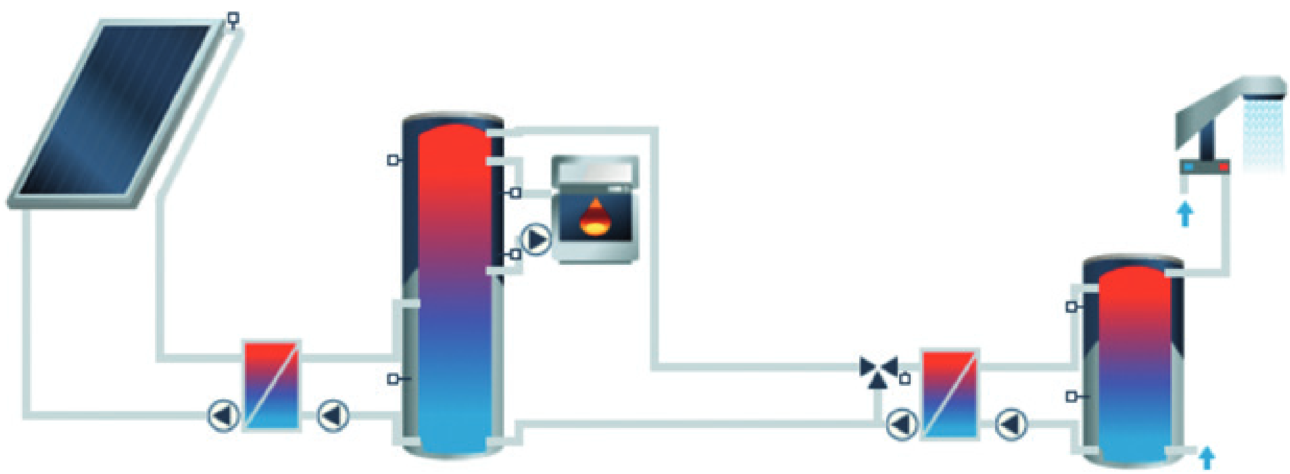

Figure 56: Hydraulic scheme of the domestic hot water pumped reference system for multi-family houses

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 17 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 2022, as reported by each country.

Table 17: Solar combisystem reference for single-family and multi-family houses and the total collector area in operation in 2022

Energy calculation DHW-combi-systems						
Solar combi-systems - Total						
Country/Region/ Economy	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	43,271	12	3,606	615
Australia	Sydney	1,674	9,494	12	791	589
Austria	Graz	1,126	1,963,747	14	140,268	369
Belgium	Brussels	971	146,317	12	12,193	342
Bulgaria	Sofia	1,188	44,680	12	3,723	418
Canada	Montreal	1,351	82	12	7	476
China	Shanghai	1,282	11,323,758	12	943,647	388
Croatia	Zagreb	1,212	58,423	12	4,869	426
Cyprus	Nicosia	1,886	14,125	12	1,177	663
Czech Republic	Praha	998	246,677	8.5	29,021	351
Denmark	Copenhagen	989	63,506	8	7,938	348
Estonia	Tallin	960	4,675	12	390	338
Finland	Helsinki	948	15,616	12	1,301	334
France (mainland)	Paris	1,112	1,003	11	91	370
Germany	Würzburg	1,091	9,424,615	11.5	819,532	378
Greece	Athens	1,585	1,097,228	12	91,436	558
Hungary	Budapest	1,199	79,015	10	7,901	422
Ireland	Dublin	949	29,181	12	2,432	364
Italy	Bologna	1,419	1,078,964	12	89,914	499
Japan	Tokyo	1,175	134,138	12	11,178	414
Latvia	Riga	991	8,714	12	726	349
Lebanon	Beirut	1,935	5,454	12	455	681
Lesotho	Maseru	2,050	21	12	2	721
Lithuania	Vilnius	1,001	5,159	12	430	352
Luxembourg	Luxembourg	1,037	15,173	12	1,264	365
Morocco	Rabat	2,000	10,813	12	901	704
Netherlands	Amsterdam	999	42,850	6	7,142	352
New Zealand	Wellington	1,401	4,923	12	410	493
North Macedonia	Skopje	1,381	1,480	10	148	486
Norway	Oslo	971	23,252	15	1,550	342
Palestinian Territories	Jerusalem	2,198	20,634	12	1,720	773
Poland	Warsaw	1,024	340,569	12	28,381	365
Romania	Bucharest	1,324	53,656	12	4,471	466
Russia	Moscow	996	2,277	15	152	350
Slovakia	Bratislava	1,214	41,924	12	3,494	427
Slovenia	Ljubjana	1,115	10,617	12	885	362
South Korea	Seoul	1,161	21,118	12	1,760	409
Spain	Madrid	1,644	406,594	10	40,659	619
Sweden	Gothenburg	934	255,199	10	25,520	389
Switzerland	Zürich	1,094	383,417	11	34,856	385
Thailand	Bangkok	1,765	1,722	12	143	621
Other (5% of world market excluding China)		1,131	845,940	12	70,495	398
TOTAL			28,280,022		2,396,977	
AVG		1,295		12		454

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 multifamily houses used for the simulations of the solar energy yields.

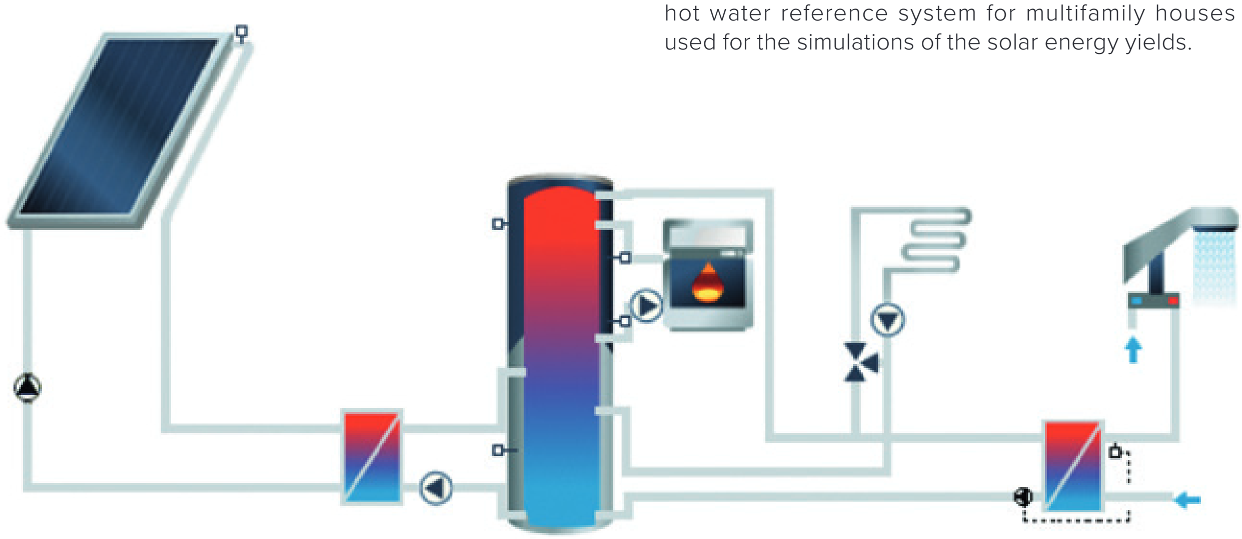

Figure 57: Hydraulic scheme of the solar-combi reference system for single and multi-family houses

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/m²K]
a_2 = 0.1 [W/m² K²]

9.2.2
Data of the reference collector for all other applications except for China

η = 0.8
a_1 = 3.69 [W/m²K]
a_2 = 0.007 [W/m² K²]

9.2.3
Data of the Chinese reference vacuum tube collector

η = 0.74
a_1 = 2.5 [W/m²K]
a_2 = 0.013 [W/m² K²]

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 m² 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 m² 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 m² solar collector area installed per full-time job.
- Swimming pool systems with unglazed polymeric collectors or air collectors – around 200 m² 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 18: Reference climates for the 72 countries surveyed

No.	Country/Region/ Economy	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	Nepal	Kathmandu	1,771	1,960	18.6
47	Netherlands	Amsterdam	999	1,131	10.0
48	New Zealand	Wellington	1,401	1,542	13.6
49	Nigeria	Abuja	2,007	2,051	25.7
50	North Macedonia	Skopje	1,381	1,521	12.5
51	Norway	Oslo	971	1,208	5.8
52	Palestinian Territories	Jerusalem	2,198	2,400	17.3
53	Panama	Panama City	1,787	1,813	26.8
54	Poland	Warsaw	1,024	1,156	8.1
55	Portugal	Lisbon	1,686	1,875	17.4
56	Romania	Bucharest	1,324	1,473	10.6
57	Russia	Moscow	996	1,181	5.9
58	Senegal	Dakar	2,197	2,259	24.9
59	Slovakia	Bratislava	1,214	1,374	10.3
60	Slovenia	Ljubjana	1,115	1,231	9.8
61	South Africa	Johannesburg	2,075	2,232	15.6
62	South Korea	Seoul	1,161	1,280	12.7
63	Spain	Madrid	1,644	1,844	15.5
64	Sweden	Gothenburg	934	1,105	7.2
65	Switzerland	Zürich	1,094	1,218	9.6
66	Chinese Teipei	Taipei	1,372	1,398	20.8
67	Thailand	Bangkok	1,765	1,898	29.1
68	Tunisia	Tunis	1,808	2,038	19.3
69	Turkey	Antalya	1,795	1,958	18.4
70	United Kingdom	London	943	1,062	12.0
71	United States	LA, Indianapolis	1,646	1,816	14.3
72	Uruguay	Montevideo	1,534	1,647	15.9
73	Zimbabwe	Harare	2,017	2,087	18.9

Source: T-Sol expert version 4.5, Meteonorm version 6.1 and Global Solar Atlas (https://globalsolaratlas.info/map).

9.5
Population data

Table 19: Inhabitants by the end of 2022 of the 72 surveyed countries in alphabetical order

No	Country/Region/ Economy	2022	Region Code
1	Albania	3,095,344	6
2	Argentina	46,245,668	4
3	Australia	26,141,369	3
4	Austria	8,913,088	6
5	Barbados	302,674	4
6	Belgium	11,847,338	6
7	Bhutan	867,775	2
8	Botswana	2,384,246	1
9	Brazil	217,240,060	4
10	Bulgaria	6,873,253	6
11	Burkina Faso	21,935,389	1
12	Canada	38,232,593	8
13	Cape Verde	596,707	1
14	Chile	18,430,408	4
15	China	1,410,539,758	5
16	Croatia	4,188,853	6
17	Cyprus	1,295,102	6
18	Czech Republic	10,816,746	6
19	Denmark	5,920,767	6
20	Estonia	1,211,524	6
21	Finland	5,601,547	6
22	France (mainland)	68,092,884	6
	France (overseas departments and regions)	3,378,669	6
23	Germany	84,316,622	6
24	Ghana	33,107,275	1
25	Greece	10,533,871	6
26	Hungary	9,920,415	6
27	India	1,389,637,446	2
28	Ireland	5,120,464	6
29	Israel	9,111,963	7
30	Italy	61,095,551	6
31	Japan	124,214,766	2
32	Jordan	10,998,531	7
33	Republic of Kenya	55,864,655	1
34	Latvia	1,842,226	6
35	Lebanon	5,296,814	7
36	Lesotho	2,193,970	1
37	Lithuania	2,683,546	6
38	Luxembourg	630,364	6
39	Malta	464,186	6
40	Mauritius	1,308,222	1
41	Mexico	129,150,971	4
42	Morocco	36,738,229	7
43	Mozambique	31,693,239	1
44	Namibia	2,712,364	1
45	Nepal	30,666,598	2
46	Netherlands	17,601,564	6
47	New Zealand	5,053,004	3
48	Nigeria	225,082,083	1
49	North Macedonia	2,130,936	6
50	Norway	5,443,828	6
51	Palestinian Territories	5,165,249	7
52	Panama	4,337,768	4
53	Poland	38,699,570	6
54	Portugal	10,242,081	6
55	Romania	18,519,899	6
56	Russia	142,183,583	6
57	Senegal	17,923,036	1
58	Slovakia	5,527,637	6
59	Slovenia	2,101,208	6
60	South Africa	59,150,970	1
61	South Korea	51,844,834	2
62	Spain	47,163,418	6
63	Sweden	10,483,647	6
64	Switzerland	8,724,310	6
65	Chinese Taipei	23,580,712	2
66	Thailand	69,648,117	2
67	Tunisia	11,896,972	7
68	Turkey	83,047,706	6
69	United Kingdom	67,791,400	6
70	United States	333,287,557	8
71	Uruguay	3,407,213	4
72	Zimbabwe	16,481,694	1
73	Other (5%)	2,666,728,749	9
∑ Solar Thermal World Statistics ∑Inhabitants world		5,239,974,046 7,906,702,795	66%

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

Table 20: Inhabitants per economic region by the end of 2022

Region Code	Country/Region/ Economy	∑Inhabitants	Share
1	Sub-Sahara Africa	470,433,850	6%
2	Other Asia	1,690,460,248	21%
3	Australia	31,194,373	0.4%
4	Latin America and the Caribbean	419,114,762	5%
5	China	1,410,539,758	18%
6	Europe	767,503,147	10%
7	MENA Region	79,207,758	1%
8	United States / Canada	371,520,150	5%
9	Other countries	2,666,728,749	34%
Total		7,906,702,795	100%

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

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

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 more than 20 of the largest solar thermal markets in terms of added capacity. These were the following countries for the year 2023 listed in order of their added capacity: China, Turkey, United States, Brazil, Germany, India, Australia, Mexico, Greece, Italy, Spain, Austria, Poland, South Africa, Denmark, Portugal, Switzerland, Lebanon, United Kingdom, Cyprus, Belgium, Mozambique and Bhutan which represented 94.9% of the cumulative installed capacity in operation in 2022. The added capacities in the other countries, for which new additions are available until 2022, 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 2022 and previous years, was estimated to be 5% of the global market volume without China in 2022.

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

Conversion from square meters to capacity

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

Making the installed capacity of solar thermal collectors comparable with that of other energy sources, solar thermal experts from seven countries agreed upon a methodology to convert installed collector area into solar thermal capacity.

The methodology was developed during a meeting with IEA SHC Programme officials and major solar thermal trade associations in Gleisdorf, Austria, in September 2004. The represented associations from Austria, Canada, Germany, the Netherlands, Sweden, and the United States, as well as the European Solar Thermal Industry Federation (ESTIF) and the IEA SHC Programme, agreed to use a factor of 0.7 kW_{th}/m^2 to derive the nominal capacity from the area of installed collectors.

Data from the previous years

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

In Table 21, Table 22, and Table 23, these countries are marked accordingly and the respective data source is cited in Chapter 9.8 (References).

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

Country/Region/Economy	Newly installed collector area in 2020 [m²]					
	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		10,680.0	968.0			11,648
Argentina	34,496.0	23,451.0	39,786.0	20.0	158.0	97,911
Australia	380,000.0	146,000.0	16,200.0			542,200
Austria	1,730.0	72,210.0	1,400.0		720.0	76,060
Barbados*		12,300.0				12,300
Belgium		18,200.0	4,300.0			22,500
Bhutan		460.0				460
Botswana		1,032.0	115.0			1,147
Brazil	710,810.0	673,600.0	32,360.0			1,416,770
Bulgaria		23,520.0	480.0			24,000
Burkina Faso*		100.0	310.0			410
Canada	1,475.0	261.0	321.0	7,000.0	1,000.0	10,057
Cape Verde		150.0				150
Chile*		25,183.0				25,183
China+		6,954,000.0	18,096,033.0			25,050,033
Croatia		15,968.0	1,055.0			17,023
Cyprus		74,193.0	0.0			74,193
Czech Republic		15,000.0	7,000.0			22,000
Denmark		14,613.0				14,613
Estonia		1,425.0				1,425
Finland		7,000.0				7,000
France (mainland)	600.0	45,807.0	330.0			46,737
France (overseas territories)++		91,425.0				91,425
Germany		544,564.0	98,888.0			643,452
Ghana		776.0	520.0			1,296
Greece		304,100.0	400.0			304,500
Hungary		21,000.0				21,000
India		207,209.0	1,451,524.0		150.0	1,658,883
Ireland		1,472.4	2,367.0			3,839
Israel		350,000.0				350,000
Italy		108,250.0	14,700.0			122,950
Japan		49,907.0	861.0		887.0	51,655
Kenya		8,364.0	4,182.0			12,546
Latvia		1,600.0				1,600
Lebanon		9,448.0	14,181.0			23,629
Lesotho**		286.0	1,103.0			1,389
Lithuania		700.0	1,000.0			1,700
Luxembourg		3,913.0	0.0			3,913
Malta		545.0	136.0			681
Mexico	106,400.0	130,080.0	141,000.0			377,480
Morocco*		71,700.0				71,700
Mozambique**			237.0			237
Namibia		3,807.0	8.1			3,815
Netherlands	2,620.0	21,430.0	8,330.0			32,380
Nigeria*		392.6	3,515.2			3,908
North Macedonia		4,274.0	6,948.0		12.0	11,234
Norway*		1,350.0	73.0			1,423
Palestinian Territories		46,401.0	0.0			46,401
Poland		159,270.0	1,830.0			161,100
Portugal		69,700.0				69,700
Romania		6,840.0	9,120.0			15,960
Russia		783.5	85.5			869
Senegal*		1,500.0	1,000.0			2,500
Slovakia		13,000.0				13,000
Slovenia		1,300.0	100.0		10.0	1,410
South Africa	56,629.0	28,967.0	74,180.0			159,776
South Korea*		3,552.0	16,918.0			20,470
Spain	2,798.0	177,103.0	7,539.0			187,440
Sweden		1,898.0	3,000.0			4,898
Switzerland	3,900.0	31,830.0	4,390.0			40,120
Chinese Taipei*		36,000.0				36,000
Tunisia		51,094.0				51,094
Turkey		988,000.0	939,000.0	2,500.0		1,929,500
United Kingdom++	4,261.0	4,153.0	3,121.0			11,535
United States	675,058.0	44,448.0		3,000.0	1,000.0	723,506
Uruguay*		10,418.0				10,418
Zimbabwe			4,050.0			4,050
Other (5% of the world market excluding China)	104,251.4	252,316.0	153,628.0	658.9	207.2	511,062
Total	2,085,028.4	12,000,319.5	21,168,592.8	13,178.9	4,144.2	35,271,264

* 0% growth assumed, ** revised 2022 according to new database
+ exports excluded, ++ revised 2024 according to new data base

Table 22: Newly installed collector area in 2021 [m²]

Newly installed collector area in 2020 [m²]						
Country/Region/Economy	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		14,840	1,360.0			16,200
Argentina	6,634.0	34,300	67,986.0	20.0	158.0	109,098
Australia	380,000.0	131,600	14,600.0			526,200
Austria	930.0	64,570	3,810.0		1,100.0	70,410
Belgium		13,600	3,000.0			16,600
Bhutan		460				460
Botswana		1,190	210.0			1,400
Brazil	948,931.0	831,223	38,509.0			1,818,663
Bulgaria		25,184				25,184
Canada*	1,475.0	261	321.0	6,000.0	1,000.0	9,057
Cape Verde		150				150
Chile*		25,183				25,183
China+		7,107,000	17,623,914.0	13,119.4	20,000.0	24,764,033
Croatia		12,912				12,912
Cyprus		70,360				70,360
Czech Republic		17,097	1,903.0			19,000
Denmark		8,013				8,013
Estonia		1,468				1,468
Finland		3,223				3,223
France (mainland)	600.0	63,910	1,760.0	200.0		66,470
France (overseas territories)		90,440				90,440
Germany		524,500	117,000.0			641,500
Ghana		700	450.0			1,150
Greece		358,600	400.0			359,000
Hungary		22,050				22,050
India		151,267	1,779,873.0		15.0	1,931,155
Ireland		3,898				3,898
Israel		350,000				350,000
Italy		207,548	17,452.0	120.0		225,120
Japan		49,736	610.0		887.0	51,233
Kenya*		8,364	4,182.0			12,546
Latvia		1,648				1,648
Lebanon		11,399	38,940.0			50,339
Lesotho		396	1,584.0			1,980
Lithuania		700	1,000.0			1,700
Luxembourg		3,574				3,574
Malta		1,051	263.0			1,314
Mexico	114,940.0	128,880	159,180.0			403,000
Morocco*		71,700				71,700
Mozambique			592.0			592
Namibia		4,201				4,201
Nepal		6,690	60,208.0			66,898
Netherlands	2,620.0	19,590	8,400.0			30,610
Nigeria		393	3,515.2			3,908
North Macedonia*		5,868	4,800.0		20.0	10,688
Palestinian Territories		53,453	0.0			53,453
Panama		665				665
Poland		186,100	3,000.0			189,100
Portugal		77,045				77,045
Romania	0.0	16,439				16,439
Russia	0.0	729	4.0			733
Slovakia	0.0	13,000				13,000
Slovenia		1,439				1,439
South Africa	57,483.0	16,117	66,351.0			139,951
South Korea+++				200.0	100.0	300
Spain	2,000.0	141,500	8,800.0	5,200.0		157,500
Sweden		1,955				1,955
Switzerland	4,090.0	22,630	4,470.0			31,190
Tunisia		52,340				52,340
Turkey		984,000	945,000.0	1,000.0		1,930,000
United Kingdom++	4,638.0	21,943	4,462.0			31,043
United States	808,417.0	50,274		3,000.0	1,000.0	862,691
Uruguay*		10,418				10,418
Zimbabwe			9,570.0			9,570
Other (5% excluding China)	122,776.7	262,778	177,556.1	828.4	225.3	564,165
TOTAL	2,455,534.7	12,362,561.2	21,175,035.3	29,687.8	24,505.3	36,047,324

* 0% growth assumed, ** revised 2022 due to new data base
\+ exports excluded, ++ revised 2024 according to new data base, +++ only air collectors reported (provided by John Hollick)

Table 23: Total collector area in operation by the end of 2021 [m²]

Total installed collector area in operation 2021 [m²]						
Country/Region/Economy	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		297,543	12,622			310,165
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		193,811	5,850			199,661
Burkino 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	834,684	23,567			860,464
Czech Republic	450,000	479,677	158,826			1,088,503
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 territories)		1,100,620	43,980			1,144,600
Germany	443,726	19,308,064	2,471,388		19,200	22,242,378
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	4,093,789	13,648,251	0.00	12,400	17,754,440
Ireland		289,166	128,127			417,293
Israel++	39,000	4,968,434				5,007,434
Italy	43,800	4,354,211	686,455	120		5,084,586
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		382,170	403,571			785,741
Lesotho		2,371	4,046			6,417
Lithuania		9,117	13,113			22,230
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	36,394	4,422	200	4,106	46,972
Palestinian Territories		1,929,522				1,929,522
Panama		665				665
Poland		2,695,230	500,460			3,195,690
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
Chinese Taipei+++	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	108,850	687,745	262,963	24,600		1,084,158
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
Other (5% excluding China)	2,263,704	6,002,980	1,806,608	46,594	23,608	10,143,494
TOTAL	45,382,923	187,152,477	513,455,144	952,706	495,160	747,438,411

*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, ***** new 2023 + exports excluded ++ calculated based on 0% growth
+++ cumulated collector area by end of 2020, ++++ revised 2024 according to new data base+ exports excluded

9.8 References to reports and persons who have supplied the data

The production of the report, Solar Heat Worldwide – Edition 2024, was kindly supported by national representatives of the recorded countries or other official sources of information as cited below.

Country	Contact	Source	Remarks
Albania	**Dr. Eng. Edmond M. HIDO** Interlogistic SHPK	Interlogistic SHPK	
Argentina	**Dr. Christian Navntoft** Solarmate SA https://www.solarmate.com.ar	Censo Nacional de Energía Solar Térmica (baja temperatura) Instituto Nacional de Tecnología Industrial (INTI)	Cumulated calculated by AEE INTEC based on newly installed,
Australia	**Dr. David Ferrari** Exemplary Energy, Melbourne, Victoria	UN ESCAP, with data from the Clean Energy Regulator and industry surveys / interviews	Out of operation systems calculated by UN ESCAP
Austria	**Werner Weiss** AEE - Institute for Sustainable Technologies	Biermayr et al, 2024: Innovative Energietechnologien in Österreich – Marktentwicklung 2023 (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	No new data reported; cumulated data by end of 2020
Belgium	**Leopoldo Mico** Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation AEE INTEC	Belsolar 2024	
Bhutan	**Ms. Dawa Zam** Ministry of Economic Affairs Department of Renewable Energy Alternate Energy Division	Ministry of Economic Affairs Department of Renewable Energy Installations by companies 2022 and 2023	New in edition 2022
Botswana	**Karen Gibson** SIAB Solar Industries Association Botswana		0% growth assumed
Brazil	**Dr. Danielle Johann** Diretora Executiva ABRASOL Associção Brasileira de Energia Solar Térmica	ABRASOL	Out of operation systems calculated based on ABRASOL long time recordings
Bulgaria	**Leopoldo Mico** Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Euroserv'ER July 2023	Newly installed: Euroserv'ER July 2023; cumulated calculated by AEE INTEC based on average out of operation (2013 to 2021)
Burkina Faso	**Kokouvi Edem N'Tsoukpoe** International Institute for Water and Environmental Engineering Ouagadougou, Burkina Faso	Rapport de l'étude de marché du solaire thermique: production d'eau chaude et de séchage de produits agricoles, 2015	No new data 2022; cumulated by end of 2020
Canada	**Lucio Mesquita, PhD** Natural Resources Canada	2022 Solar Thermal Market Survey	Out of operation systems considered by NRC air collectors provided by Bärbel Epp, Solrico
Cape Verde	**Antúnio Barbosa**	Country Market Report on solar thermal heating systems, solar drying and solar cooling, September 2015	No new data 2022; cumulated by end of 2021
Chile	**Andrés Véliz Araya** Sustainable Energy Division, Ministry of Energy, Chile Government;	Minvu Program, Law 20365 (Tax Benefit) www.minenergia.cl/sst/	no information about pumped systems as law 20,365 ended its validity

Country	Contact	Source	Remarks
China	**Ruicheng Zheng** China Academy of Building Research **He Tao** China Academy of Building Research CSTIF - Chinese Solar Thermal Industry Federation	China Renewable Energy Society, CSTIF - Chinese Solar Thermal Industry Federation	Exports excluded, out of operation systems calculated by AEE INTEC (2022 14 years lifetime considered)
Croatia	**DiasLeopoldo Mico** Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Euroserv'ER July 2023Solar	Cumulated calculated by AEE INTEC, out of operation considered (average 2020/2021)
Cyprus	**Panayiotis Kastanias** Cyprus Employers and Industrialists Federation	FPC Cyprus Union of Solar Thermal Industrialists (EBHEK) and the Cyprus Employers & Industrialists Federation (OEB)	Cumulated calculated by AEE INTEC based on replacement figures provided by Panayiotis Kastanias
Czech Republic	**Leopoldo Mico** Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation AEE INTEC	Euroserv'ER July 2023	Unglazed water collectors: AEE INTEC recordings
Denmark	**Daniel Trier** Planenergi		DH plants only; unglazed water collectors: AEE INTEC recordings
Estonia	**Leopoldo Mico** Secretary General Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Euroserv'ER July 2023	estimation according to the trend
Finland	**Leopoldo Mico** Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry FederationPedro	Euroserv'ER July 2023	estimation according to the trend
France	**Paul Kaaijik** ADEME - Agence de l'Environnement et de la Maîtrise de l'Énergie **Frédéric Tuillé** Research Manager Observ'ER **John Hollick** SAHWIA - Solar Air Heating World Industry Association	EurObserv'ER 2023 Air collectors: John Hollick France overseas: Eurobser'Er 2023	Data provided by Frédéric Tuillé
Germany	**Dr. Andrea Liesen** BSW - Bundesverband Solarwirtschaft e.V., **John Hollick** SAHWIA - Solar Air Heating World Industry Association **Dirk Mangold**, Executive Director, Solites Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems **Magdalena Berberich**, Solites Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems	BSW - Bundesverband Solarwirtschaft e.V. Air collectors: John Hollick Solar district heating: Solites Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems	Data provided by Charlotte Brauns, BSW; FPC/ETC: BSW solar long time recordings; unglazed water collectors & glazed air collectors: AEE INTEC recordings SDH data provided by Dirk Mangold and Magdalena Berberich
Ghana	**Divine Atsu** Koforidua Polytechnic Department of Energy Systems Engineering		0% growth assumed; cumulated calculated based on 0% growth
Greece	**Costas Travasaros** EBHE – Greek Solar Industry Association **Vassiliki Drosou** CRES – Center for Renewable Energy Sources		Data provided by Costas Travasaros (EBHE)
Hungary	**Leopoldo Mico** Head of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry FederationPedro **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Eurobserv'ER2023Air collectors: John Hollick	Cumulated calculated by AEE INTEC based on new installed 2022 from Eurobserv'ER 2023; shares FPC/ETC AEE INTEC

Country	Contact	Source	Remarks
India	**Jaideep N. Malaviya** Malaviya Solar Energy Consultancy	Malaviya Solar Energy Consultancy (based on market survey)	New and cumulated installations based on survey from Malaviya Solar Energy Consultancy
Ireland	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Eurobserv'ER July 2023	Cumulated calculated by AEE INTEC based on newly installed collector areas; shares FPC/ETC AEE INTEC
Israel	**Eli Shilton** ELSOL **Bärbel Epp** Solrico – Solar market research		0% growth assumed; cumulated calculated by AEE INTEC based on 0% growth (replacement rate as of 2020 used for the calculation)
Italy	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation AEE INTEC	Solar Thermal Market Survey	Cumulated area: Solar Heat Europe 2021/ share FPC-ETC: AEE INTEC unglazed water collectors: AEE INTEC
Japan	**Manami Mizutani** Japan Solar System Development Association	Japan Solar System Development Association Long time series	
Jordan	AEE INTEC	AEE INTEC	No data for 2022; 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	0% growth assumed
Latvia	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Eurobserv'ER 2023	Eurobserv'ER 2023 (estimation)
Lebanon	**Dr. Sorina Mortada** **Ammar Fadlallah** Lebanese Center for Energy Conservation (LCEC)	Lebanese Center for Energy Conservation (LCEC)	Data provided by Ammar Fadlallah
Lesotho	**Ivan Yaholnitsky** **Puleng Mosothoane** Bethel Business and Community Development Center (BBCDC)	SOLTRAIN Study, data provided by Puleng Mosothoane	
Lithuania	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Eurobserv'ER 2023	Newly installed Eurobserv'ER 2023 (estimation); cumulated calculated by AEE INTEC based on newly installed
Luxembourg	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Eurobserv'ER 2023	Eurobserv'ER 2023 (estimation)
Malta	**Mark Anthony Callus** Sustainable Energy and Water Conservation Unit (SEWCU) Ministry for Energy and Health	Sustainable Energy and Water Conservation Unit (SEWCU) based on data provided by the Regulator for Energy and Water Services (REWS)	
Mauritius	**Devika Balgobin** Statistician Environment Statistics Unit Ministry of Environment and Sustainable Development	Statistics Mauritius	No new collector area 2022; cumulated collector area by end of 2015
Mexico	**David Garcia** FAMERAC **Bärbel Epp** Solrico – Solar market research	Glazed and unglazed water collectors: FAMERAC - Renewable Energy Industry Association Air collectors: SAHWIA - Solar Air Heating World Industry Association	Cumulated installations: calculated by AEE INTEC
Morocco	**Bärbel Epp** Solrico - Solar market research AEE INTEC	"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	0% growth assumed 2022

Country	Contact	Source	Remarks
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 2022	
Nepal	**Avishek Malla** International Centre for Integrated Mountain Development	Solar Water Heating System Database https://www.researchgate.net/publication/299487583_Solar_Water_Heating_System_Database_in_Nepal/figures (07/05/2024)	New 2024
Netherlands	**Reinoud Segers** **Maria José Linders** **Laura Geurts** Statistics Netherlands (CBS) The Hague	Statistics Netherlands (CBS)	Newly installed areas: Statistics Netherlands based on survey of sales. Market Shares: Expert estimates Netherlands Enterprise Agency and Holland Solar. Data provided by Laura Geurts
New Zealand			No 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 2022; cumulated 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	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	Cumulated calculated by AEE INTEC based on 12% growth for new installed collector area; 4 % out of operation considered
Palestinian Territories	**Mohammed Mobayyed** EEU Director Palestinian Energy Authority **Abdallah Azzam** Palestinian Central Bureau of Statics Natural Resource Statistics	Palestinian Energy Authority	
Poland	**Janusz Starościk** President Association of Heating Appliances Manufacturers and Importers in Poland (SPIUG)	SPIUG (Association of Heating Appliances Producers and Importers in Poland) – market research	
Portugal	**Jorge Facão** Laboratório de Energia Solar Laboratório Nacional de Energia e Geologia (LNEG) Lisboa	Data provided by Jorge Facão (2024)	
Romania	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry	Eurobserv'ER 2023	2021Eurobserv'ER 2023 (estimation)
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 2022
Slovakia	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal Industry	Eurobserv'ER 2023	
Slovenia	**Ciril Arkar** University of Ljubljana, Faculty of Mechanical Engineering	Eco Fund, Slovenian Environmental Public Fund	

Country	Contact	Source	Remarks
South Africa	**Karin Kritzinger** and **Lavhelesani Maluleke** 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 2022; 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	**Leopoldo Mico** Secretary GeneralHead of Operations & EU Projects Solar Heat Europe (ESTIF) – European Solar Thermal IndustryPedro	Eurobserv'ER 2023	Glazed water collectors: Solar Heat Europe 2021
Switzerland	http://www.swissolar.ch/	SWISSOLAR - Markterhebung Sonnenenergie 2022, Bundesamt für Energie 2023	Out of operation systems calculated by SWISSOLAR
Chinese Taipei	**K.M. Chung** Energy Research Center - National Cheng Kung University	Installers association	No new data 2022; 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)	No new collector area in 2022; 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)	0% growth assumed; cumulated calculated by AEE INTEC based on 0% growth
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	MSC (microgeneration certification scheme) data used Air collectors provided by John Hollick	Revised timeline (2024)
United States	**Brad Heavner** California Solar and Storage Association (CALSSA) **Pam Murphey** IEA SHC Technology Program **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Unglazed and FPC provided by Brad Heavner Air collectors: SAHWIA provided by John Hollick	New installations: CALSSA No new ETC data available 2022 Totals: calculated by AEE INTEC considering 25 years lifetime
Uruguay	**Dr. Luis Christian Navntoft** Solarmate SA https://www.solarmate.com.ar	Analysis of imported equipment under category 8419.12.00 NCM (assuming a total area of 2,2m2 per imported unit) Proportions of each type of collector and system obtained from the latest pool of solar thermal and PV equipment performed by the government in 2018: https://www.gub.uy/ministerio-industria-energia-mineria/sites/ministerio-industria-energia-mineria/files/2020-07/Equipamiento%20Solar%202017-2018.pdf	Cumulated calculated by AEE INTEC based on newly installed
Zimbabwe	**Samson Mhlanga** National University of Science and Technology, Bulawayo	Dr. Anton Schwarzlmüller Domestic Solar Heating unpublished statistics; SOLTRAIN survey 2022 (unpublished sources)	Cumulated calculated by AEE INTEC based on newly installed

9.9 Additional literature and web sources used

The following reports and statistics were used in this report.

- ABRASOL, Producao e Vendas de Sistemas de Aquecimento Solar 2023, April 2024
- Bundesamt für Energie BFE, Sektion Analysen und Perspektiven, Statistik Sonnenenergie, Referenzjahr 2022; Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, Juli 2023
- Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Austria – Innovative Energy Technologies - Market Development 2022; Ed. Peter Biermayr et al, Vienna, Austria June 2023
- Bundesverband Solarwirtschaft e.V. (BSW), Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) - BSW Faktenblatt Solarwärme, Februar 2024
- Eurobserv'ER 2023, The State of Renewable Energies in Europe, Edition July 2023
- Global Market Outlook for Solar Power / 2019-2023, Solar Power Europe, 2019
- GWEC / Global Wind Report 2023, Global Wind Energy Council, March 2023
- GWEC / Global Wind Report 2024, Global Wind Energy Council, April 2024
- IEA PVPS Snapshot 2021
- IRENA (2024) Renewable Capacities Statistics 2024, International Renewable Energy Agency, Abu Dhabi
- IRENA Renewable Energy and Jobs: Annual Review 2020
- IRENA Photovoltaic Systems Programme, Snapshot of Global PV Markets 2024, Report IEA-PVSP T1-42: 2024
- Lehr, U. et.al (2015), Beschäftigung durch erneuerbare Energien in Deutschland: Ausbau und Betrieb, heute und morgen
- Navntovt, L.C. et al., Análisis del potencial solar térmico en Argentina, Ministerio Economía Argentina, November 2022
- Photovoltaics Report, Fraunhofer Institute for Solar Energy Systems - ISE, with support from PSE Projects GmbH, February 2023
- Solar Heat Europe (ESTIF), Decarbonising Heat with Solar Thermal - Market Outlook 2022/2023
- Solar Power Europe (2021): Global Market Outlook for Solar Power 2021-2025
- Study of the Solar Water Heating Industry in Kenya, Energy Regulatory Commission of Kenya (ERC), Nairobi 2017
- Weiss, W. (2003) Wirtschaftsfaktor Solarenergie, Wien
- Weiss, W., Biermayr, P. (2006) Potential of Solar Thermal in Europe, published by ESTIF
- Wimmer, L. et al. (2019), Monitoring renewable process heat plants within the gas sector.

The following online sources were used in this report:

https://abrasol.org.br/wp-content/uploads/2024/05/Solar-Heating-Systems-Production-and-Sales-2024.pdf

https://www.amee.ma/

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

https://helioscsp.com

https://www.solarpowereurope.org/

http://www.giz.de/

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

http://www.irena.org/

http://www.olade.org/

http://www.ren21.net/

http://sahwia.org/

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

http://www.solarwirtschaft.de/

http://www.solrico.com/

http://www.solarthermalworld.org/

http://www.swissolar.ch/

9.10 List of Figures

9.11 List of Tables

Photo: DualSun, France