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Global Market Development and Trends 2024
Detailed Market Figures 2023

SOLAR HEAT WORLDWIDE

Edition 2025

SHC
SOLAR HEATING & COOLING PROGRAMME
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Republic of Austria

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2025 Edition

AEE - Institute for Sustainable Technologies
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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 2025 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 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. These are proven technologies for many applications and have been, and still are dominant solar thermal technologies in this sector.

Besides the dominant solar thermal technologies mentioned above, Photovoltaic Thermal (PVT) systems are included, as this market has grown in relevance in recent years.

A pioneering technology is Photovoltaic hot water systems, that are also described in this edition of the report.

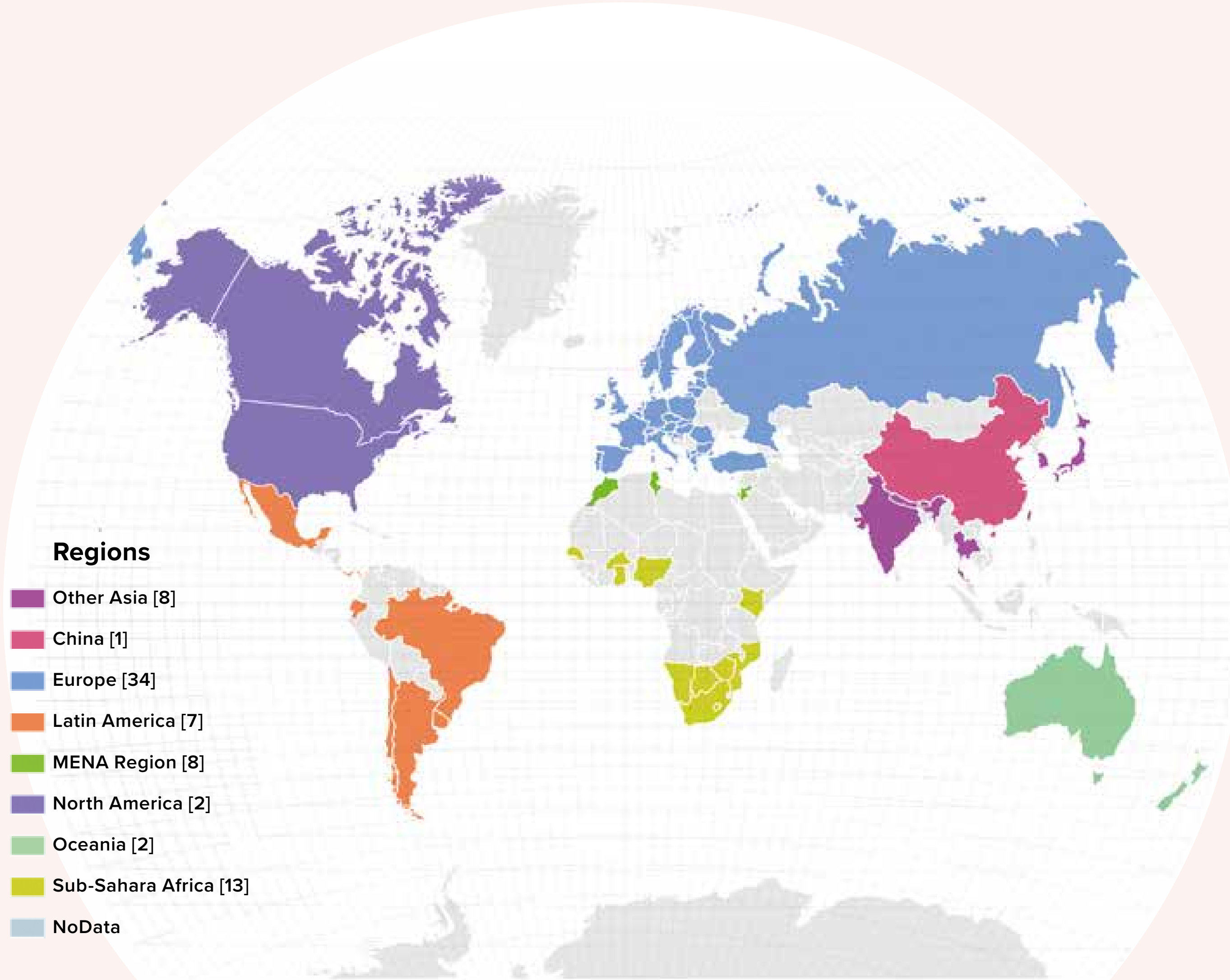


Figure 1: Countries shown in color have detailed market data. Countries shown in grey have estimated market data.
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

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 73 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. If there are any country experts who would like to contribute to future reports, please reach out to IEA SHC Secretariat or to AEE INTEC directly. The report relies on the active participation of the country experts in the field.

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

Details with regard to this calculation method are presented in the Annex to this report.

2 Summary

Photo: Modulo Solar

There are three sections of the report: The first part (Chapters 3 - 5) provides an overview of the global solar thermal market in 2024, 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 from experts with regards to developments expected in 2025.

The second part (Chapters 6 - 8) offers detailed market data for 2023 from 73 surveyed countries. This year's edition includes data from Ecuador, 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 system types 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.

Global solar thermal market developments in 2024

As of the end of 2024, the total operational solar thermal capacity reached 544 GW_{th}, equivalent to 777 million square meters of collector area.

The annual solar thermal energy yield of the total installed capacity amounted to 443 TWh, which correlates to savings of 47.6 million tons of oil equivalent and 153.5 million tons of CO_2.[1]

The newly installed capacity of 17.8 GW_{th} or 25.4 million square meters of collector area in 2024 marked a decrease from the previous year's figure. This indicates a 14% decline in the global solar thermal market compared to 2023.

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

In 2024, the commissioning of 24 new large-scale solar heating systems (>350 kW_{th}, 500 m^2) were reported, totaling 93 MW_{th} capacity. This brought the global count to 622 systems, with a combined capacity of 2,378 MW_{th}, corresponding to 3.4 million square meters of collector area.

The largest sub-sector of large-scale solar thermal heating systems is solar district heating, comprising 346 systems with 1,982 MW_{th} capacity (2.8 million square meters).

Solar heat for industrial processes (SHIP)
In 2024, at least 106 new SHIP plants with a capacity of 120 MW_{th} were installed worldwide.

This means that the positive trend of 2023 is continuing, and an increase of around 30% with regards to installed capacity could be reached compared to 2023. This corresponds to a five-year high with regards to installed capacity in the solar process heat sector.

The total number of SHIP plants is approximately 1,315 systems, with a 1.531 million square meters collector area and a capacity of 1,071 MW_{th}.

Photovoltaic-Thermal (PVT) collectors
Based on the market data of 46 PVT manufacturers, the market for PVT collectors was characterized by a constant growth of +8% on average between 2017 and 2024. After declines with regard to newly installed collector areas in 2022 and 2023, mainly driven by the end of subsidies for PVT in some of the countries, current figures for 2024 reflect a market recovery. The newly installed capacity in 2024 amounted to 37.5 MWth and 18.6 MWpeak. This is an increase of 13% compared to the installed thermal capacity in 2023.

The cumulative installed PVT collector area by the end of 2024 was 1.7 million square meter, which relates to a thermal capacity of 866 MW_{th} and an electrical capacity of 316 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 "PV hot water" systems in South Africa, where at least 34,000 systems of this type have been installed in the last years. In addition, PV hot water systems are used with a growing number of solar combisystems providing hot water and space heating supply in residential buildings. In Germany, PV starts to play a role with regards to district heating systems.

Photo: GREENoneTEC Solarindustrie GmbH

Market status worldwide in 2023

While 2024 data is available for 14 leading countries, the report includes detailed 2023 data on 73 countries.

126 million solar thermal systems were in operation at the end of 2023.

The top 5 countries by total installed capacity of water collectors at the end of 2023 were The People’s Republic of China (hereinafter China), Turkey, the United States, Brazil and Germany.

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, Greece, Israel and Austria.

In 2023 **evacuated tube collectors represented 61%** of the newly installed capacity, followed by flat plate collectors with a share of 32%.

In the global context this breakdown is mainly driven by the dominance of the Chinese market where around 74% of all newly installed collectors in 2023 were evacuated tube collectors. Also included is the Indian market with 93% 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 61% in 2023, while flat plate collectors increased their share from close to 15% to 32%.

In Europe, the situation is almost the opposite of that in China, with 71% of all solar thermal collectors installed in 2023 being flat plate collectors. In the medium term, however, the share of flat plate collectors decreased in Europe from 81% in 2011 to 71% in 2023. In contrast, Europe's share of evacuated tube collectors increased between 2011 and 2023 from 16% to 28%.

Distribution by system type
Pumped systems accounted for 62% of all newly installed systems in 2022, while 38% were thermosiphon systems.

Employment and turnover
Based on a comprehensive literature survey and data collected from detailed country reports, the number of jobs in the production, installation, and maintenance of solar thermal systems is estimated to be 318,000 worldwide in 2023.[2]

The estimated worldwide turnover of the solar thermal industry in 2023 is € 13.9 billion (US$ 15.7 billion).

[1] For Details please see Chapter 9.1.
[2] Background information on the methodology used can be found in the Appendix, Chapter 9.3.

3 Worldwide solar thermal capacity in 2024

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 544 GW_{th} (777 million m^2) in 2024. The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 443 TWh in 2024. (Figure 2). This means a net decrease of 3% collector area and capacity compared to 2023 with regards to total installed collector area in operation. The decrease is due to the fact that the calculation methodology used considers a theoretical lifetime of 15 to 25 years, depending on collector type and country. In most cases the collector's lifetime is higher than the theoretical lifetime, that is not reflected in the figures. A second factor of influence is the competition of technologies with regards to hot water preparation; proven solar thermal technologies compete with emerging technologies like PV hot water as well as hybrid PV thermal collector technologies but also with heat pumps. Therefore, the market for solar thermal technologies is under pressure on a global scale.

Figure 3 shows the annual installed collector capacities. In 2024, a total capacity of 17.8 GW_{th}, or 25.6 million square meters of collector area, was installed. This means the global solar thermal market declined 14% compared to 2023.

Over the past decade, it's evident that the yearly rate of new installations has decreased by over fifty percent. This is mainly driven by the Chinese market due to ongoing challenges in the real estate sector in China, which have persisted for several years. This became clear again in 2024, as the globally dominant Chinese market experienced a significant slump of 17%. Further, the Chinese market is saturated with solar domestic hot water for households in rural areas. Driven by the goal of carbon neutrality, all of the potential of renewables should be unlocked and the potential for solar thermal applications remains high with regard to all types of applications in the heating and cooling sector.

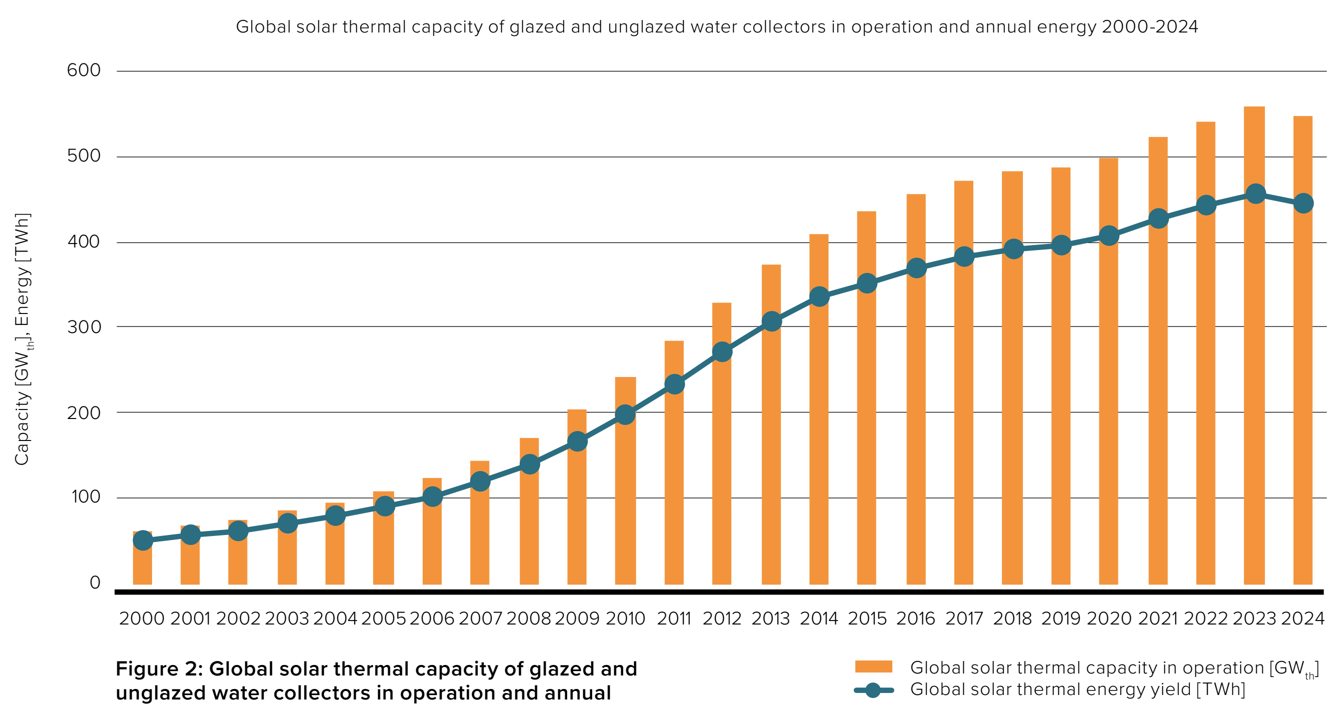


Figure 2: Global solar thermal capacity of glazed and unglazed water collectors in operation and annual energy yield 2000-2024

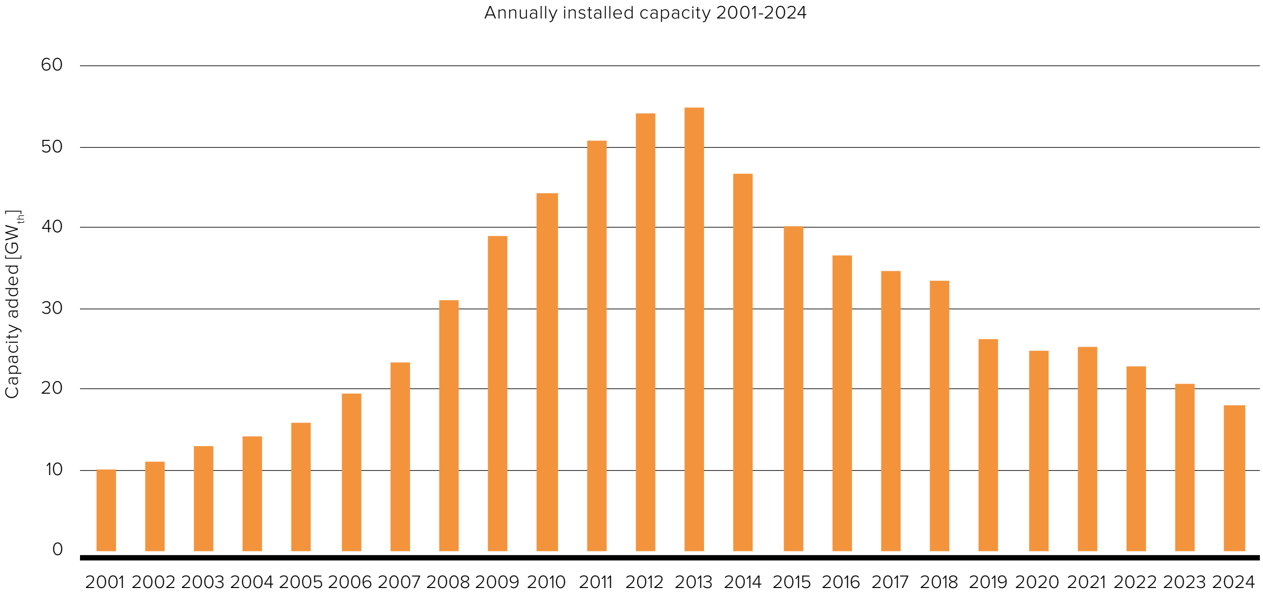


Figure 3: Annually installed capacity of glazed and unglazed water collectors 2001-2024

Regarding the long-term rate of new installations, the evaluation shows that the growth rate was 3.5% on average between 2001 and 2024.

Figure 4 illustrates the annually installed collector capacity categorized by collector type and total installed collector capacity. 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 are dominant in these two countries.

Environmental effects and contribution to climate goals

In 2024, the global solar thermal energy yield from all installed systems corresponds to savings of 47.6 million tons of oil and 153.5 million tons of CO_2. This underscores the substantial contribution of this technology toward mitigating global greenhouse gas emissions.

153.5
million tons of CO_2 avoided

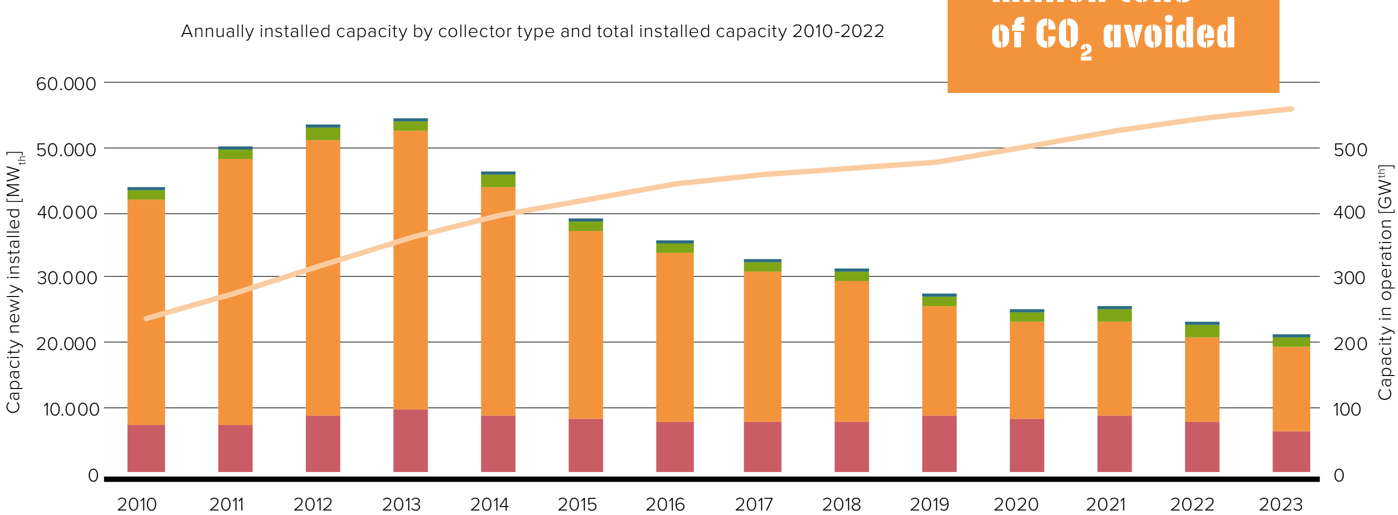


Figure 4: Annually installed capacity by collector type and total installed capacity 2010-2023

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 2024 was 544 GW_{th}[3], which trailed behind wind power's installed capacity of 1,136 GW_{el} and photovoltaics 2,247 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 17 GW_{el}. and CSP was 7 GW_{el}.

In terms of energy, solar thermal systems supplied 443 TWh of heat, whereas wind turbines supplied 2,777 TWh and photovoltaic systems 2,437 TWh of electricity.

As of the end of 2024, global green hydrogen production capacity and energy yield remain in the early stages of development, though significant growth is anticipated. The installed water electrolyser capacity is estimated to increase to 5 GW by the end of 2024. China leads in terms of committed projects, potentially accounting for nearly 70% of the 2024 capacity.[4]

Bird's view of the solar thermal plant at Renquishausen, Germany with 620 kW (890 m^2)
Photo: Ritter Solartechnik GmbH & Co. KG

Estimating the annual energy yield of green hydrogen production involves considering the efficiency of electrolysis and a capacity factor. Assuming an electrolyser efficiency of 65% and a capacity factor of 50%, a 1 GW electrolyser could produce approximately 2.85 terawatt-hours (TWh) of hydrogen energy annually. Based on this estimation, the projected 5 GW capacity by the end of 2024 could yield around 14.25 TWh per year.

[3] The figures for 2024 are based on the latest market data from Argentina, Australia, Austria, Brazil, China, Cyprus, Canada, Germany, Greece, Lebanon, India, Italy, Poland, Spain, Turkey, USA and Uruguay which represent about 94% of the cumulated installed capacity in operation in 2023.
[4] Source: IEA (2024), Global Hydrogen Review 2024, online https://www.iea.org/reports/global-hydrogen-review-2024

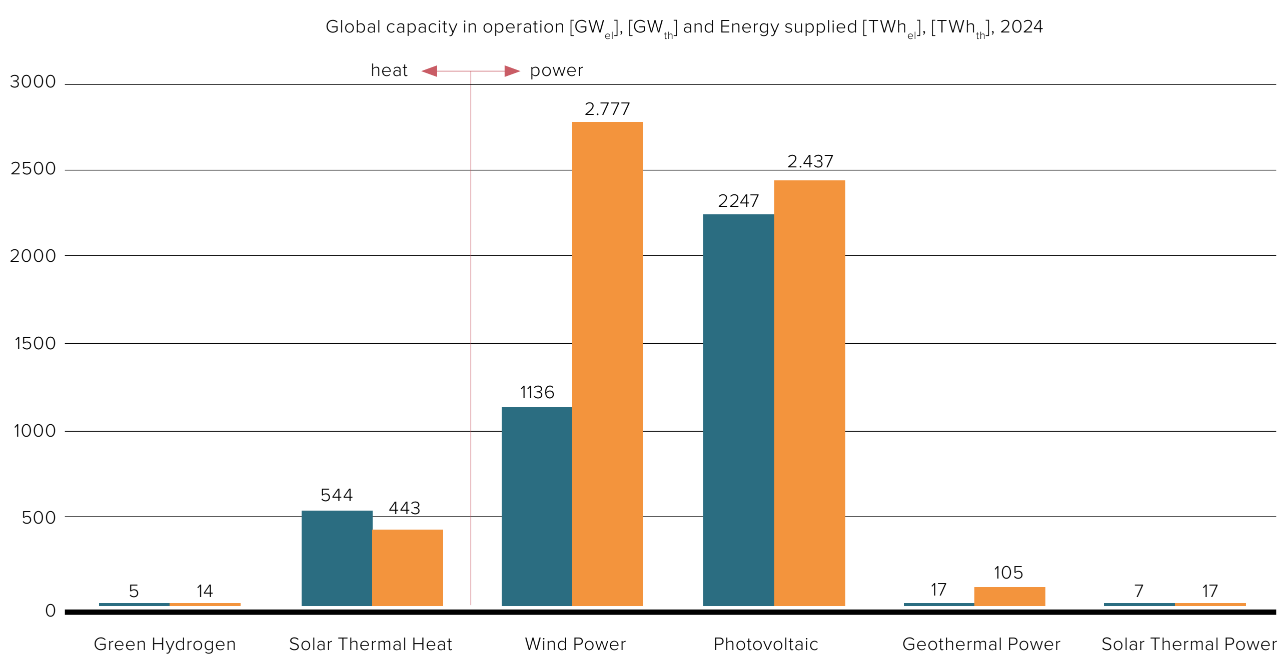


Figure 5: Global capacity in operation [GW_{el}], [GW_{th}] 2024 and annual energy yields [TWh_{el}], [TWh_{th}]
(Solar Thermal: AEE INTEC, Wind Power: Global Wind Energy Council (GWEC), Photovoltaic: IEA Solar PVPS (https://iea-pvps.org/snapshot-reports/snapshot-2024/), Geothermal Power and Solar Thermal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

4 Outlook 2025 and beyond

Heating and cooling represent around 50% of global final energy use, offering a major opportunity for impactful climate action. Although fossil fuels still dominate, significant progress is underway—renewables supplied 10% of global heating demand in 2023, and momentum continues to grow. In the European Union, the renewable share in heating and cooling rose to a record 26.2% in 2023, up from 25.0% in 2022, marking steady progress toward a cleaner, more sustainable energy system.

Solar thermal energy offers a key solution for decarbonizing hot water preparation and heating, especially in buildings and industry, which together use 97% of heat energy. While applications for solar hot water preparation in buildings is still the predominant application in most of the regions worldwide, there is growing interest in large-scale solutions such as district heating and solar process heat that signals a promising development. Solar thermal energy for example 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 favourable conditions. This is significantly lower than the prices end customers currently pay for district heating.

The EU's 2021 Climate Law mandates climate neutrality by 2050 and a 55% emissions cut by 2030. Key legislation like the Energy Performance of Buildings Directive, Renewable Energy Directive, and Energy Efficiency Directive supports the growth of renewables and solar heat. Solar mandates, building decarbonization, and renewable-powered district heating (with ~19,000 networks in Europe) are central to this transition.

Large scale applications for solar heat in industrial processes (SHIP)

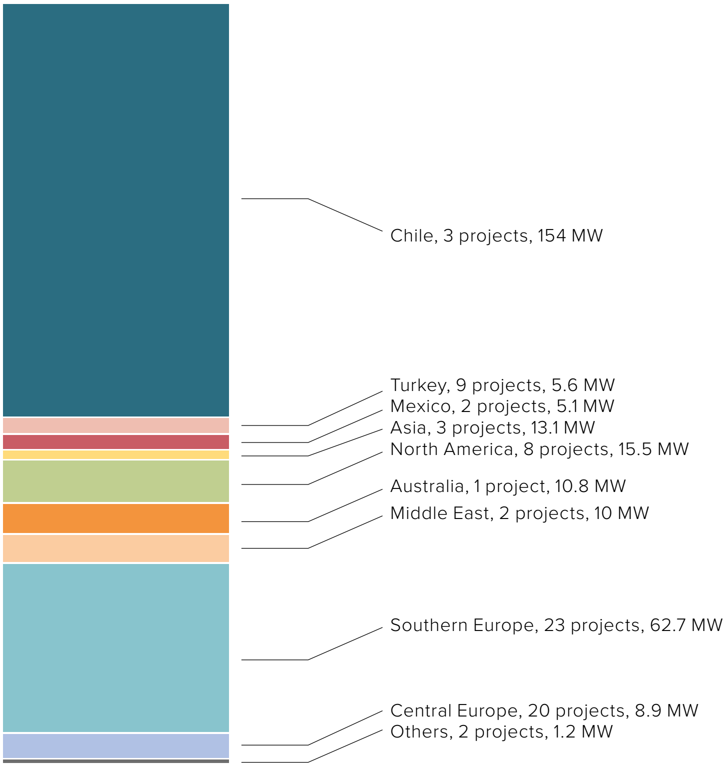


Figure 6: SHIP projects planned [MW_{th}][5]
Source: solrico; Status: March 2025

Global expansion of solar industrial heat

Solar process heat is spreading worldwide. Projects are currently under construction or in planning on all five continents. Project developers have reported 73 plants totaling 277 MW that are to be realized by 2027 the majority of them in Europe. The regional distribution of the future SHIP market is part of the Solar Industrial Heat Outlook 2025-2027.[6] The SHIP world market 2024 counted 106 new systems with a total capacity of 120 MW (see chapter 5.3).

[5] The capacity of the announced SHIP projects is weighted according to the probability of realization. This means that projects are included in the Outlook with 30%, 60% or 100% of their capacity, depending on the planning phase they are in.
[6] https://solarthermalworld.org/news/global-expansion-of-solar-industrial-heat-key-insights-from-the-latest-outlook/

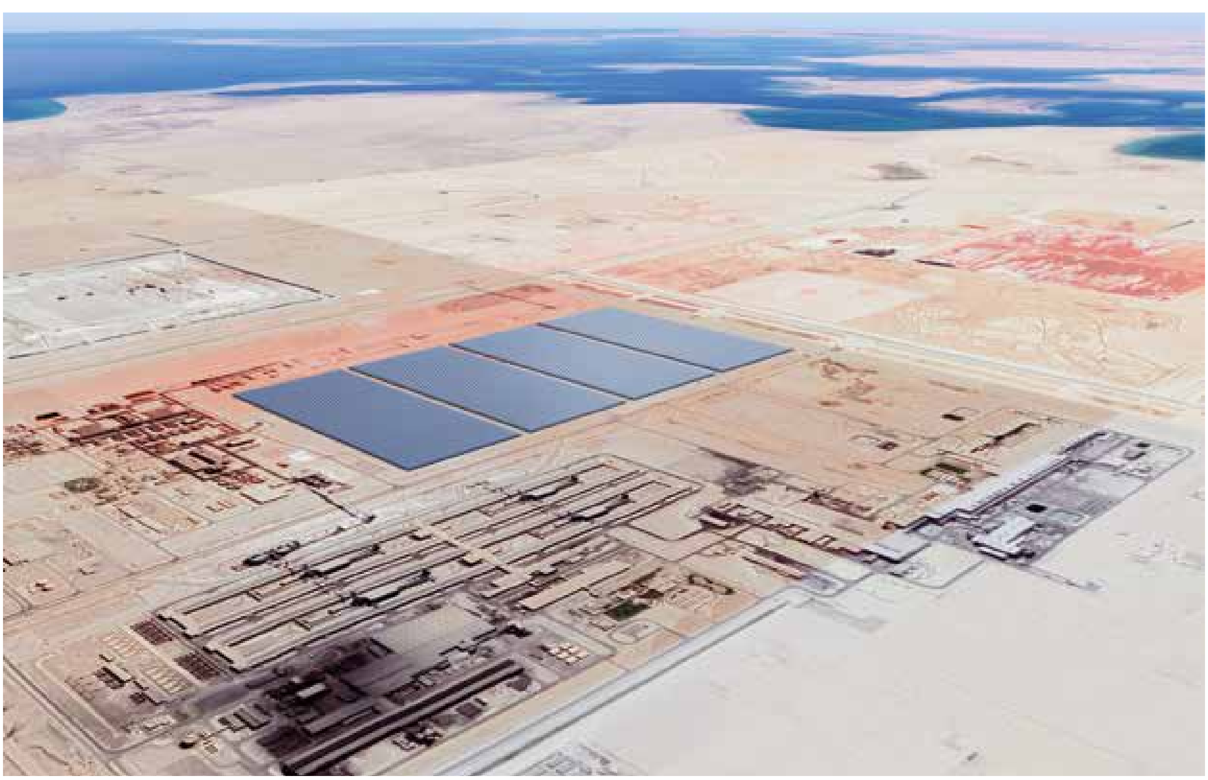
Chile dominates the future SHIP market in terms of new capacity additions (154 MW) due to the three multi-MW mining facilities that Chilean power utility Gasco is currently constructing. These are 90 MW and 23 MW respectively for the copper mine Minera Escondida and a further 41 MW for the Spence copper mine. The first two plants with flat plate collectors are under construction starting at the beginning of the year 2025. The Spence plant is being held up by the Environmental Impact Study for the mine's lifetime extension. The complete capacity is planned to be commissioned before the end of 2027.

154 MW_{th} for Chilean copper mines scheduled

Substantial capacity will also be added in **Southern Europe**: 23 projects with 62.7 MW. The focus countries here are France, Spain and Greece. A broad base of project developers has already acquired funding for their projects here, including New Heat (France), Azteq Energy (Belgium) and Protarget (Germany).

In **Australia** Mars Petcare secured funding of AUD 17 million from the Australian Renewable Energy Agency (ARENA) to install a concentrating solar heat plant with a capacity of 18 MW.[7] The solar thermal installation should help to replace 50 % of the natural gas consumption of the factory in Wodonga in the state of Victoria. An EPC contract was signed last year with the Belgian company Azteq which filed for bankruptcy in December 2024 but started fresh in mid-January 2025 with a new leadership team. As a result Mars Petcare has repeated the invitation to tender.

The **Middle East** has two projects totaling 10 MW to the Solar Industrial Heat Outlook 2025-2027, a small share compared to a forecast two years ago. This shift in trend is due to the delayed implementation of the Glasspoint plant in Saudi Arabia. In 2023 the Glasspoint team was confident that the first sections of the plant at the aluminum manufacturer Ma'aden would go into operation as early as 2026. Instead, Glasspoint has now reached an agreement with the client for the construction of a 9 MW technology showcase project. Glasspoint is working on the FEED study for the first phase of the GMTS (GlassPoint Ma'aden Technology Show Case) of 28,000 m^2 on Ma'aden's land that will be finished in 2026. Consequently, the start of construction for the entire plant with more than 1 GW will be delayed.



Rendering of Full scale Ma'aden Project (distant)
Source: Glasspoint

The dominance of heat delivery contracts in large SHIP projects

Heat delivery contracts are the dominant business model of the SHIP industry, 90% of the planned capacity of 277 MW will be based on contracts with the clients. This is of course also due to the dominance of the three mining projects in Chile, where Gasco is assuming the role of solar heat supplier. From the Solar Industrial Heat Outlook 2025-2027 it can be concluded that large SHIP projects are more likely to be built by energy service companies, while EPC contracts are generally concluded with customers for smaller projects.

Large-scale district heating on the Balkan

The realization of two huge SDH projects in the Balkans is progressing. A 44 MW collector field is to be built in Priština, Kosovo, together with a 380,000 m^3 seasonal storage facility.[8] Land is available North-west of Priština, with several kilometers of pipeline connecting the solar plant to the existing heating grid. EUR 80 million is planned to be co-financed by three partners, with KfW bank providing a EUR 31.5 million interest-free loan. The Western Balkans Investment Framework (WBIF) grants an investment of EUR 21.5 million. Additionally, the European Bank for Reconstruction and Development (EBRD) will provide a EUR 23.5 million loan to the Kosovo government. The implementation partner, a consortium of iC group and Clean Energy Solutions both from Austria was chosen in January 2024 and prepared the two-stage tender. Offers within the pre-qualification tender were accepted until Mid-April 2025.

In the Serbian town of Novi Sad a 27 MW collector field is planned together with an 850,000 m^3 seasonal storage, a heat pump of 17 MW plus an electric boiler of 60 MW. Land for the solar field and seasonal storage are available within the city's sanitary water supply protected area. The investment costs are expected to be around EUR 105 million. The sum is provided by a loan from EBRD and co-financed with an investment grant of up to EUR 21 million to be provided by the EU through WBIF. Additionally, an EU grant of EUR 3.1 million is available for implementation and supervision. The tendering for the implantation partner is under preparation as of April 2025.[9]

India

The availability and deployment of solar thermal technology are crucial for industrial decarbonization, with systems capable of meeting temperature needs up to and beyond 400°C. India implemented a substantial programme of solar thermal industrial process heat systems which resulted in the installation of 65,436 m^2 of solar collector area as of September 2019 (MNRE). In terms of number of projects, it represented 244 projects, of which 61 projects of 24,207 m^2 for process heat have been realized.

Some of these installations later received support through a financial assistance scheme initiated by the Government of India, implemented by the Ministry of Micro, Small and Medium Enterprises (MSME), and coordinated by the United Nations Industrial Development Organization (UNIDO) with funding from the Global Environment Facility.

To scale adoption, it is recommended to focus on large-scale industrial applications, which would attract investment and skilled professionals. Pilot projects, driven by competitive bidding based on benchmark energy costs from fossil fuels, could be launched by the Solar Energy Corporation of India with support through viability gap funding. A national solar thermal program offering up to 30% capital subsidies and tax incentives could further boost deployment.

Industries may be encouraged to adopt solar thermal through mandatory renewable heat obligations and ambitious energy benchmarks, supported by financing mechanisms offering long-term loans. MSMEs should be allowed to access financial support under schemes like the Pradhan Mantri Mudra Yojana and CGTMSE, and benefit from low-interest financing.

71 MW_{th} for SDH on the Balkan is scheduled

Solar cooling and air conditioning

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).[10] This means there is a huge potential for cooling systems that use solar energy, such as thermal and photovoltaic (PV) systems. Current and future product development focuses on

[7] https://solarthermalworld.org/news/parabolic-trough-collector-field-as-part-of-100-carbon-free-heat-supply-for-food-factory-in-australia/
[8] https://solarthermalworld.org/news/eur-65-million-provided-for-solar-district-heating-in-kosovo/
[9] Information provided by Bojan Bogdanovic from EBRD
[10] https://www.iea.org/futureofcooling/

Solar thermal plant at Häusern, Germany with 1.21 MW_{th} (1,733 m^2)
Photo: Ritter Solartechnik GmbH & Co. KG

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 is ongoing. Not to forget the future market penetration of small PV-driven components with new heat pumps/chillers using natural refrigerants like propane.[11]

In the past 16 years, very few large installations were realized each year. Despite the potential presented in many studies, exploiting it will not be possible until system prices and complexity are significantly reduced.

The signed Global Cooling Pledge at the COP28 conference[12] also shows that cooling is a very serious and important global issue. According to the Global Cooling Watch 2023 report[13], 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%.

New Research and Development

Research and development have always played a central role in the evolution of solar thermal technology. For some decades, continuous improvements have been made to solar collectors and the core components used in solar thermal systems. However, since the early 2010s, groundbreaking innovations—particularly in residential applications—have become less frequent, even as significant research continues to advance in the industrial sector.

In 2024, the European Solar Thermal Technology Panel undertook a revision of the sector's research and innovation priorities, building upon the foundation laid by the Strategic Research and Innovation Agenda published in 2022.

Advanced solar thermal systems are increasingly integrated with heat pumps and PVT (Photovoltaic-Thermal) technologies, though further R&D is needed to boost PVT performance. Thermal Energy Storage (TES) plays a growing role in grid flexibility, supported by AI-driven controls and cloud-based monitoring. Research is also expanding into low- and medium-temperature applications, especially within the water-energy nexus.

Building-integrated systems aim to achieve high solar fractions in Zero-Emission Buildings through prefabricated, multifunctional solar façades. Scalable design tools are needed to adapt systems across diverse building types and climates.

Large-scale integration focuses on Solar Heat for Industrial Processes (SHIP) and Solar District Heating (SDH), with growing interest in systems operating up to 250°C. Advances in thermal storage, urban energy planning tools, and certification frameworks are also essential.

Next-generation collectors—including PVT, flat plate vacuum, and polymer-based systems target improved efficiency, lower costs, and environmental sustainability. Emerging research includes solar fuel production and photocatalytic processes while automation and modular manufacturing are also being explored to enhance scalability.

[11] Jakob, U. (2023) Solar Cooling for emerging markets. Keynote ISES Solar World Congress 2023, New Delhi, India
[12] https://www.cop28.com/en/global-cooling-pledge-for-cop28
[13] https://www.unep.org/resources/global-cooling-watch-2023

5 Solar thermal market development and trends in 2024

65,000 m² solar district heating plant under construction in Leipzig, Germany
Photo: Ritter Solartechnik GmbH & Co. KG

The global market development in 2024 presents a varied landscape. Despite an overall decline of 14% in the global solar thermal market, mainly due to a decline of 17% in China and 24% decline in India, there are notable areas of growth, especially in Latin American countries like Brazil and Mexico. In Brazil market growth was 11% and Mexico reported 14% growth in 2024.

In Europe, Cyprus and Turkey saw positive market growth in 2024, with 10% market growth in Turkey and a 2% growth in Cyprus. Traditionally strong European countries such as Spain, Italy and Greece experienced decreases of 30%, 36% and 26% respectively, along with Germany and Poland, with a decrease of 42% and 43% respectively. In Australia, the market declined by 16% in 2024. In the United States of America the market declined by 31%.

14%
market growth in Mexico in 2024

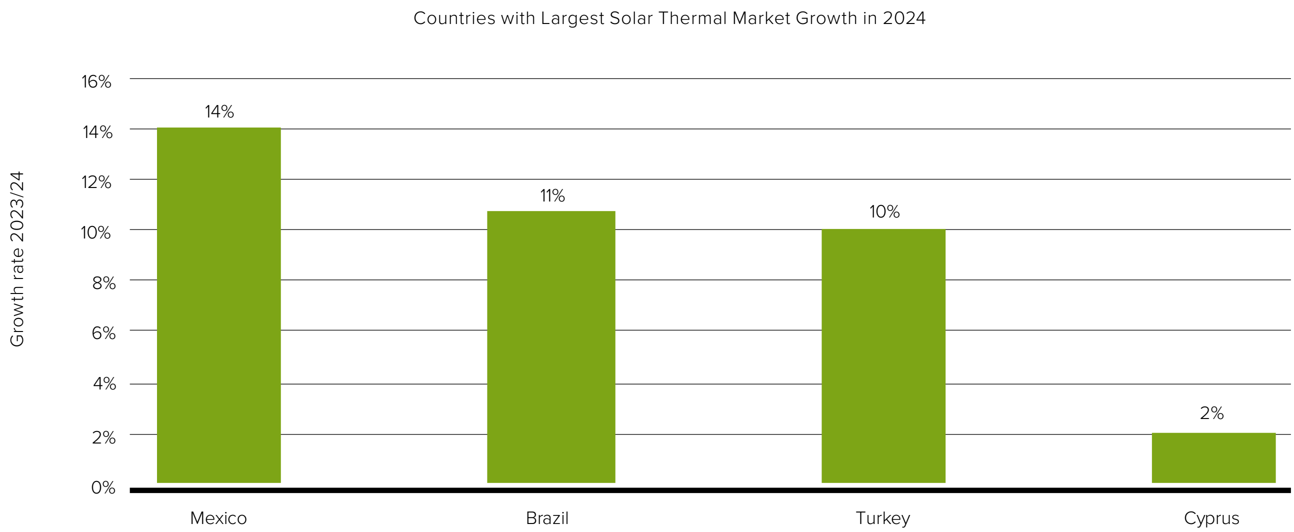


Figure 7: Reporting countries with positive growth rates in 2024

5.1 Small-scale solar thermal heating systems

Approximately 87% 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 PV hot water systems. For detailed information about PV hot water systems, see section 5.5.

Thermosiphon systems at tourism lodge in Mozambique
Photo: SOLTRAIN, AEE INTEC

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Bracht – 100% renewable district heating, 11,637 m² collectora area (7.5 MW) and 26,600 m³ seasonal pit thermal storage providing 75 to 80% solar fraction under construction in Germany
Photo: Viessmann

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. No new district heating plant has been reported for Denmark in 2024.

In 2024, China reported the installation of four new district heating systems with a collector area of 45,079 m² (32 MW_{th}) and 14 other large-scale systems for buildings or hospitals with a 28,107 m² (19.7 MW_{th}) collector area. In addition to China, new plants were commissioned in the Netherlands, Germany and Austria. In the Netherlands, the largest solar district heating plant that was installed in Europe in 2024 has been commissioned in Groningen. The collector area of this system is 48,800 m² (34 MWt_{th}). In Germany, three solar district heating systems were installed with a collector area of 9,804 m² and there are further sixteen systems representing a collector area of 204,136 m² (143 MW_{th}) under construction or in an advanced planning stage.

In 2024, Italy reported one solar district heating system with a collector area of 917 m² (0.6 MW_{th}) and Austria also reported one district heating system with an installed collector area of 555 m² (0.4 MW_{th}).

By the end of 2024, 622 large-scale solar thermal systems (>350 kW_{th}, 500 m²) were operating worldwide. Their total installed capacity equaled 2.4 GW_{th}, corresponding to a 3.4 million square meter collector area.

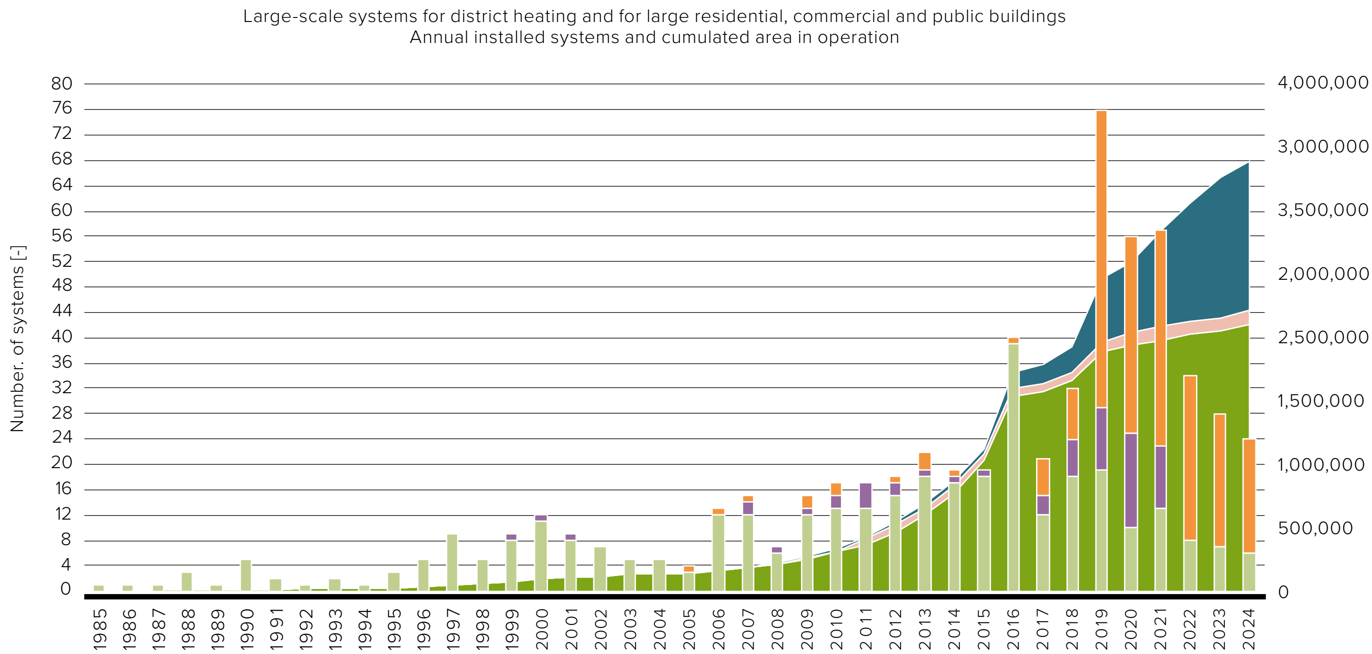


Figure 8: Large-scale systems for solar district heating and large residential, commercial, and public buildings worldwide – annual installations and cumulated area in operation in 2024

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, Bian Mengmeng, China Academy of Building Reasearch, CHN

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

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

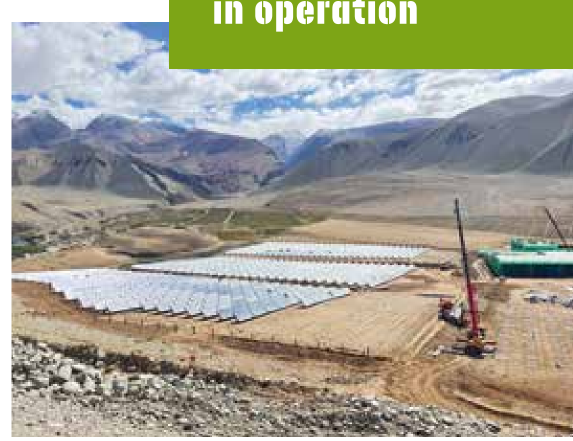
5.2.1
Solar district heating (SDH) systems

The largest sub-sector of large-scale solar thermal heating systems is solar district heating. By the end of 2024, 346 large-scale solar district heating systems (>350 kW_{th}, 500 m²) with an installed capacity of 1,982 MW_{th} (2.8 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 (76 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 (59 systems, some with seasonal storage), Sweden (23 systems), Austria (21 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.

346 Solar district heating systems with 2.0 GW_{th} in operation



Solar district heating system for Burang County, China. 45,230.6 m² completed at the beginning of 2025
Beijing Huaye Sunshine New Energy Co., Ltd.

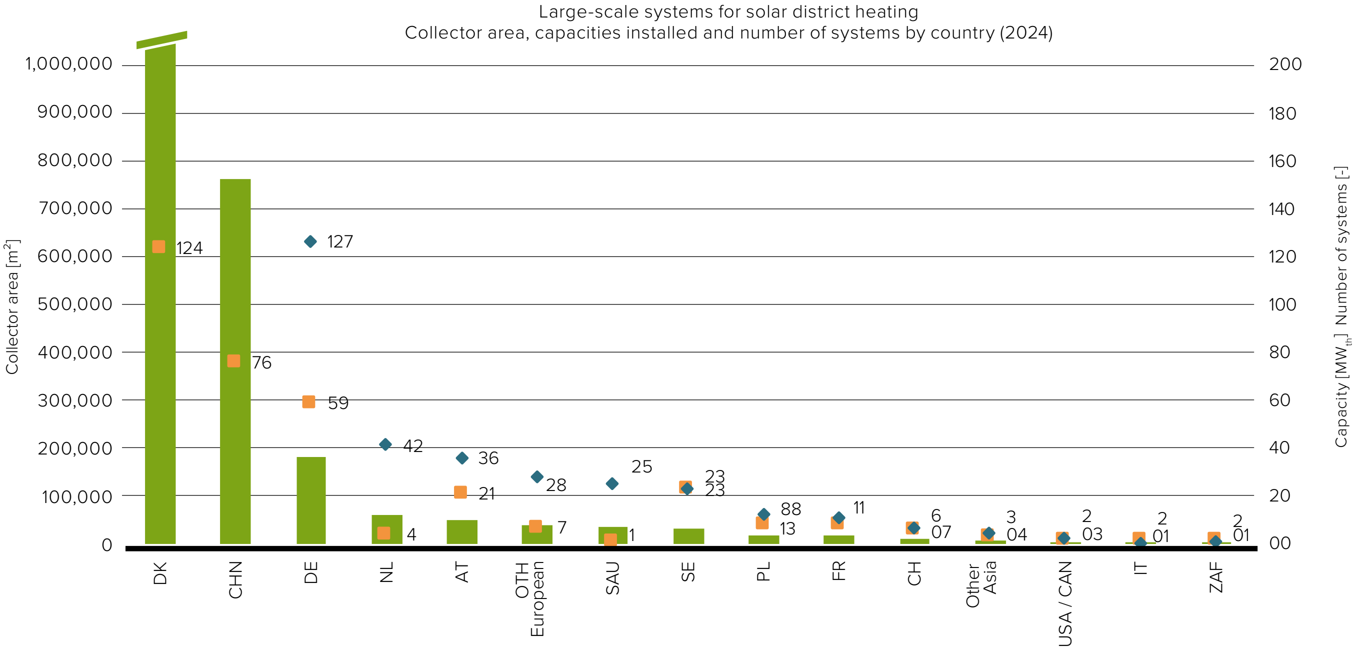


Figure 9: Large-scale systems for solar district heating – capacities and collector area installed and number of systems by the end of 2024

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, Bian Mengmeng, China Academy of Building Reasearch, CHN)

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 m^2, corresponding to a capacity of 110 MW$_{th}$. The second largest plant, with 65 MW$_{th}$, is located in China.
In 2024, one large system with 36,000 m^2 collector was added in China (Qusum county, Tibet) that ranks ninth in the list of the twenty largest systems.

The table below clearly shows the dominance of these two countries in terms of the number of large solar district heating systems. Ten of the twenty largest plants are in Denmark and eight are in China.
In 2024, the fourth largest system was commissioned in Groningen, Netherlands, with a collector area of 48,800 m^2.

Table 1: The twenty largest solar district heating systems

Installation	SDH Project	Country	Installed Collector Area m^2	Installed Capacity MW$_{th}$
2016	Silkeborg	Denmark	156,694	110
2016	Inner Mongolia	China	93,000	65
2015	Vojens stage 2	Denmark	52,492	37
2024	Groningen	Netherlands	48,800	34
2023	Longzi, Tibet	China	45,036	32
2014	Dronninglund	Denmark	37,573	26
2023	Lazi, Tibet	China	36,700	26
2011	Rhiad	Saudi Arabia	36,305	25
2024	Qusum County, Tibet	China	36,000	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

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

The 48,800 m² collector area (34 MW) commissioned in 2024, supplies heat to a district heating network in Groningen, Netherlands. It ranks fourth with regards to collector area for district heating systems worldwide
Photo: TVP Solar

Increasing demand for solar district heating in Europe and China

According to the German Steinbeis research institute Solites, three new solar thermal systems for district heating networks with a total collector area of 9,804 square meters (6.9 MW_{th}) went into operation in 2024. Although this is less than expected, there are several projects in the pipeline. The positive trend of previous years appears to continue in 2025 and beyond. Sixteen systems representing a collector area of 204,136 m² (143 MW_{th}) are under construction or in an advanced planning stage. However, policy regulations and subsidies play an important role with regards to the project development of large-scale solar district heating systems. As the project development phase for large-scale district heating projects in most cases is more than 5 years, political commitment and stable regulations are essential for large projects aiming at decarbonizing district heating.

In March 2024, in the city of Leipzig, construction began on the largest solar district heating plant in Germany. It has a capacity of 46 MW_{th} (65,000 m²). 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 48,800 m² (33.6 MW_{th} capacity) has been completed in Groningen in the Netherlands. It is a combined waste heat and solar thermal system plant with seasonal storage. In summertime the 12 hectares solar thermal field will provide heat for the district heating system, whereas the waste heat of a data center will be seasonally stored to supply heat in winter.

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 2024, 276 large-scale solar thermal systems (>350 kW_{th}, 500 m²) were providing heat to these buildings globally. The total installed capacity of these systems is 396 MW_{th} (566,322 m²).

China leads this market segment with 128 installed systems and a capacity of 295 M_{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.

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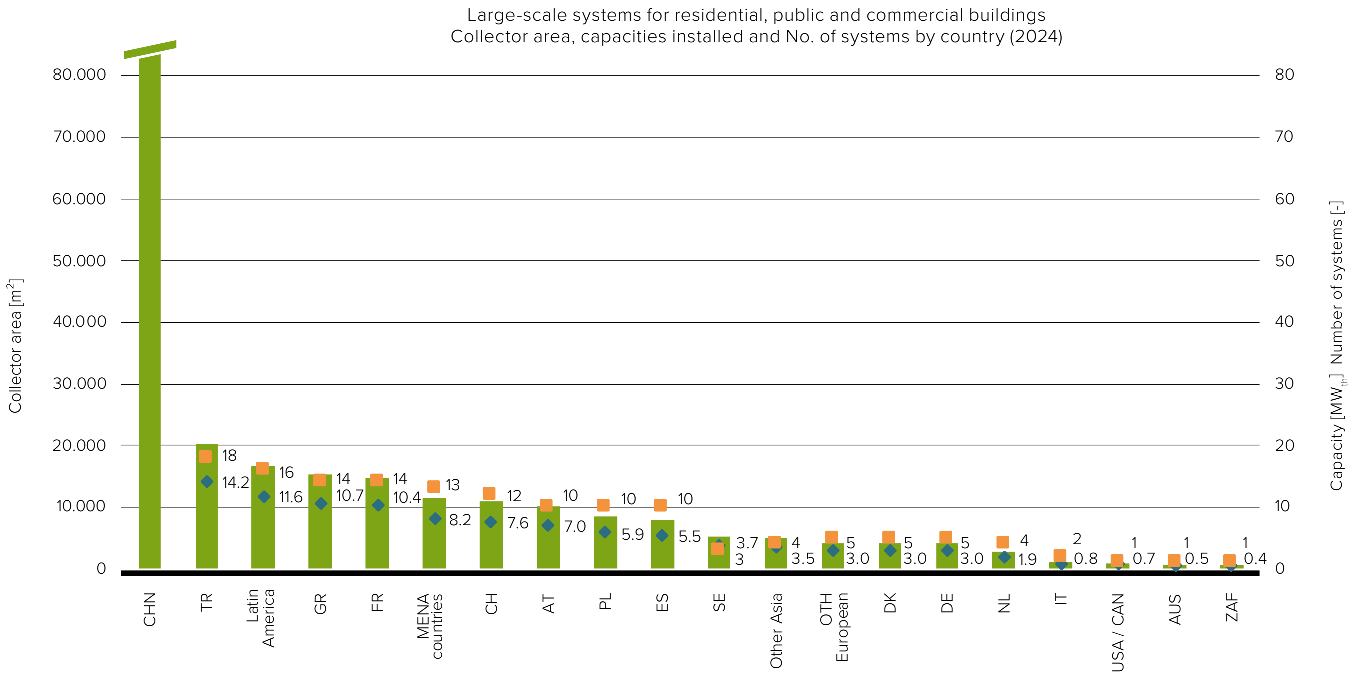

Figure 10: Large-scale systems for residential, public, and commercial buildings – capacities and collector area installed and number of systems in 2024

5.3 Solar heat for industrial processes

According to the IEA, industrial heat accounts for two-thirds of industrial energy demand and almost one-fifth of global energy consumption.[14] It also constitutes most of the direct industrial CO_2 emitted yearly, as industrial heat still originates mostly from fossil-fuel combustion. At the same time, many companies have clear targets for reducing greenhouse gas emissions.

The challenge of decarbonizing industry is that temperature levels for different processes and end applications vary in a wide range. Electrification and changes with regard to the process itself 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 thousand systems operating across various industry sectors worldwide impressively demonstrate this.

Depending on the temperature level of the heat needed, different types of solar thermal collectors are used, e.g. air collectors, flat plate, and evacuated tube collectors for temperatures up to 100 °C and concentrating solar thermal collectors, such as Scheffler dishes, Fresnel collectors and parabolic troughs for temperatures between 100 °C up to 400 °C.

1,315 SHIP systems in operation worldwide

According to a study done by the German company solrico[15] in February 2025, the number of SHIP systems in operation totals at least 1,315 systems with 1.531 million square meters collector area related to a capacity of 1,071 MW_{th}.

The market for solar thermal systems for industrial processes (SHIP) fluctuates in the number of systems installed per year and the annual installed capacity, but on average approximately 100 new SHIP systems with an average capacity of 1.1 M_{Wth} have been commissioned each year between 2017 and 2024. The table below shows the development of commissioned systems over the past seven years.

[14] https://www.iea.org/commentaries/clean-and-efficient-heat-for-industry
[15] https://solarthermalworld.org/news/global-ship-market-reaches-five-year-high-despite-national-fluctuations/

Table 2: Development of commissioned SHIP systems over the past eight years

	2017	2018	2019	2020	2021	2022	2023	2024	Annual average
No. of commissioned SHIP systems	107	99	86	85	73	116	116	106	99
Newly installed capacity [MW_{th}]	153	39	251	93	36	31	94	120	102
Average capacity/system [MW_{th}]	1,43	0,39	2,92	1,09	0,49	0,27	0,81	1,13	1,1

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 shows the diversity of the SHIP market. Mexico is ahead of the Netherlands and China, in the total number of systems installed. In terms of installed capacity, the picture is quite different, with Oman in first place, followed by China and Spain. For details, please see Figure 14 in section 5.3.2.

5.3.1. Trends in solar process heat in 2024

In 2024, at least 106 SHIP systems with a capacity of 120 MW_{th} were installed worldwide, according to the solrico study mentioned above. Most of the plant information added to the SHIP database[16] in 2024 was provided by solrico. Ninety-nine of these newly installed systems (total collector area 61,000 m^2, 41 MW_{th}) are also documented in detail in the SHIP database.

Two factors were particularly noteworthy in 2024. Even though the total number of documented solar process heat systems has not seen a significant increase, the trend toward larger installations has continued. The average system size more than tripled 2023 compared to 2022 and increased by more than 30% in 2024 compared to 2023.
The second trend that was observed in 2023 relates to the types of collectors used. In previous years flat-plate collectors were primary utilized for industrial applications. By 2023, **concentrating collectors** became the predominant choice, especially in larger systems, and this trend continued in 2024 with 2/3s of the installed systems for industrial heat using concentrating technologies. One extraordinary large plant (114,000 m^2 parabolic trough collector system) was completed for the tourism industry in China in the first quarter of 2024 at Handan leisure park that is used to produce solar snow. It also supplies the hotel's HVAC and hot water systems and the indoor swimming pool. The plant has already been described in more detail in last year's report.

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

Decarbonisation of Breweries

In 2024, the world's largest solar thermal system with Fresnel collectors was installed at Heineken brewery in Valencia, Spain. The system is equipped with 6,000 m^2 of linear Fresnel collectors and 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.

The starting point for Heineken probably was in 2013 at the Gösser Brewery in Austria, when Heineken installed the first solar thermal plant to deliver solar thermal heat to the brewing process with a 1 MW_{th} flat-plate collector system. Before this could be done, it was necessary to change the process from steam to hot water supply. The brewery group has now opted for concentrating collector systems to reach higher temperatures at their Spanish breweries in Sevilla (30 MW_{th} parabolic trough installed in 2023), and Valencia installed in 2024.

The world's largest solar thermal system with Fresnel collectors was inaugurated at Heineken brewery in Valencia, Spain in 2024
Photo: Kyotherm / Solatom

What is also interesting about the projects in Sevilla and Valencia is that the heat supply is handled via a thermal power purchase agreement (TPA). Energy service providers operate the plants and supply heat at a fixed price (Energy-as-a-Service model). The client's benefit from energy savings happens without bearing the investment costs.

First industrial Fresnel collector system in Latin America

The first industrial 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.[17]

Solar thermal plant used for tea drying in Kenya

In 2024, Absolicon installed a 180 kW concentrating solar thermal field and a thermal storage unit of more than 1 MWh, storing excess heat from day to night in Kenya's largest tea district. Tea drying poses great environmental challenges, as it requires burning large amounts of firewood, leading to deforestation and stress on water sources used for Eucalyptus plantations to meet the demand of firewood. The installation could transform global tea production, and it is the world's first plant to use concentrating solar collectors and thermal storage to dry tea. The solar field demonstrates how solar energy could protect forests and reduce the environmental impact of tea production. The project has been funded by the Nordic Climate Facility (NCF) and implemented at Chelal Tea Factory together with WWF Kenya and Tealand Engineering & Construction Ltd.

World's first concentrating solar thermal collector field used for tea drying installed at Chelal Tea Factory in Kenya's largest tea district
Photo: Absolicon

[16] http://ship-plants.info/ data retrieved on 31 March 2025
[17] Source: Miguel Frasquet Herraiz, Solatom

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

As mentioned above, out of the 1,315 documented systems with a size of at least 50 m^2 collector area or 35 kW_{th}, 714 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.[18] These 714 SHIP systems account for a total collector area of 1,386,874 m^2 and a thermal capacity of 863 MW_{th}.[19] Only the data of these 714 SHIP systems are presented in the following figures. The data includes installed systems through March 2025.

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 38% of the total installed thermal capacity of the 714 documented solar process heat applications worldwide. The figures further include the second largest system at Handan Bay Water World, with 79.8 MW_{th}. Arguably, it is 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 58% of the total installed thermal capacity.

Figure 11 shows the distribution of the 714 systems in terms of size. The five systems mentioned above exceed 21 MW_{th} of thermal capacity (30,000 m^2), 93 systems have installed capacities between 0.7 MW^{th} and 21 MW_{th} (1,000 m^2 - 29,999 m^2) of thermal capacity, 138 systems have installed capacities between 0.35 and 0.7 MW_{th} (500 – 999 m^2), and 478 systems are below 0.35 MW_{th} (<500 m^2).

At Pepsico in Feira de Santana, Brazil, 1,150 m^2 of high-vacuum flat plate collectors provide heat for boiler feedwater preheating
Photo: TVP Solar

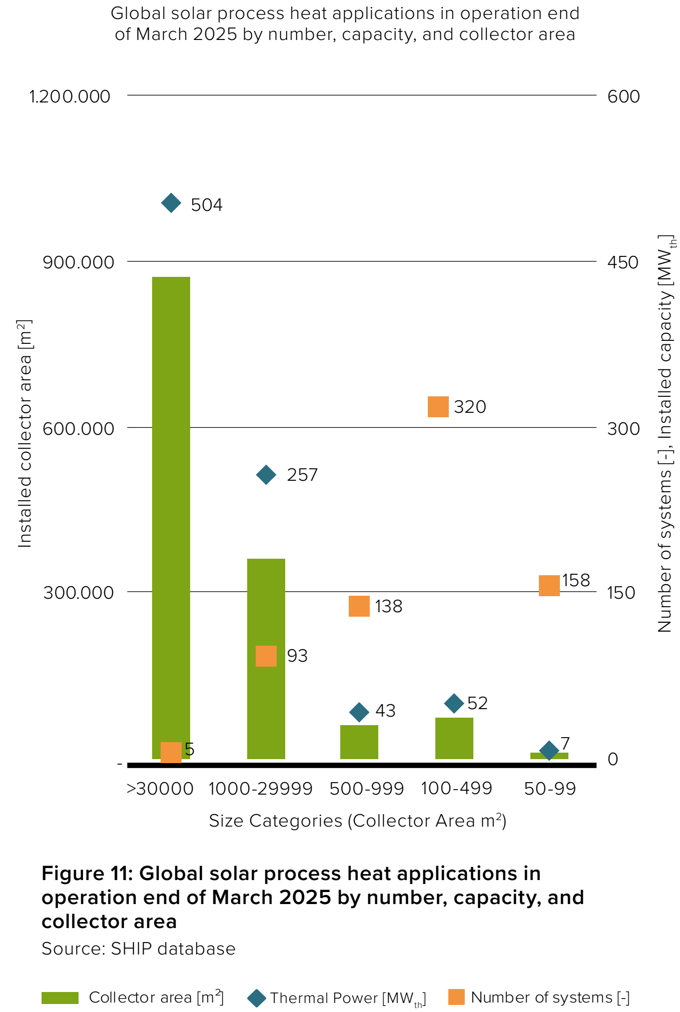

Figure 11: Global solar process heat applications in operation end of March 2025 by number, capacity, and collector area
Source: SHIP database

The process heat systems by collector technology are presented in Figure 12. Most 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 75 documented plants is 6.9 MW_{th}, showing the trend towards large systems that operate at higher temperatures.

[18] http://ship-plants.info/ data retrieved by 31. March 2024
[19] According to an agreement within the IEA SHC Task 64/IV, the conversion of m^2 collector area into kWth is also done for concentrating solar thermal systems with a factor of 0.7. Only the Mirrah system in Oman was converted with a lower factor due to the special glass house construction.

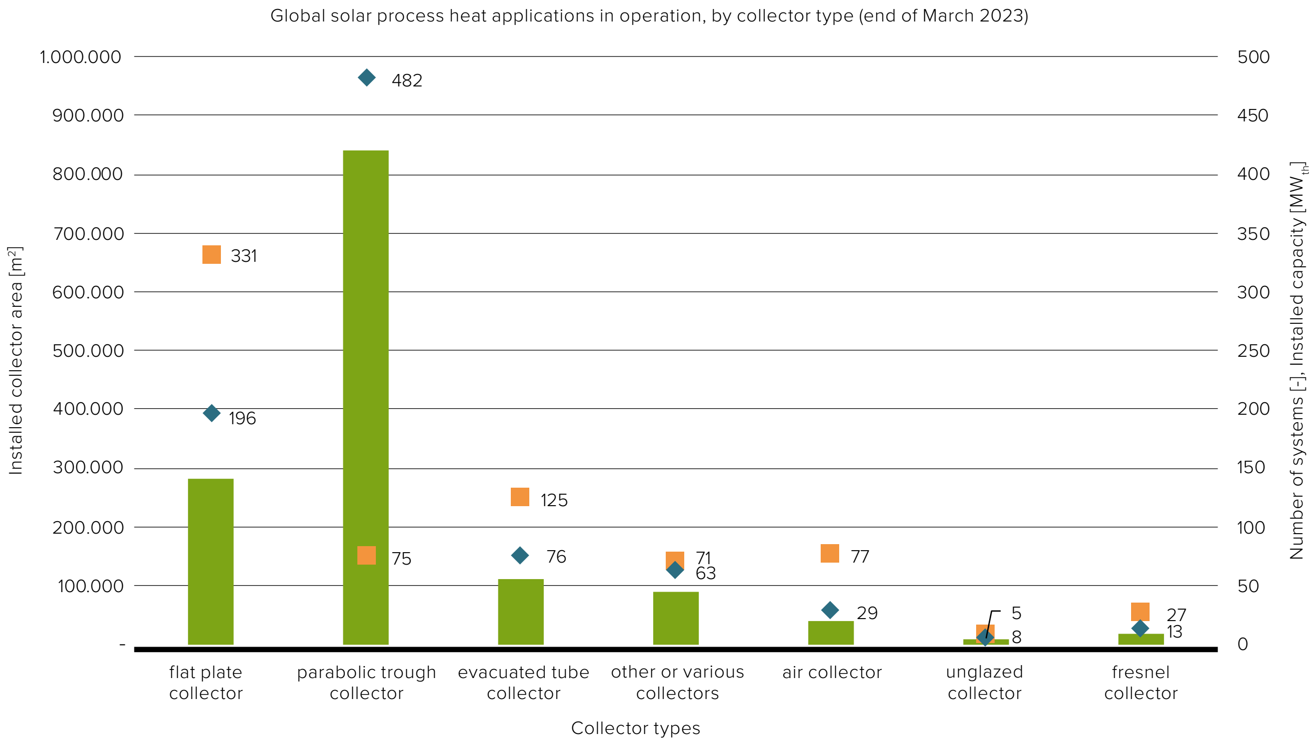

Figure 12: Global solar process heat applications in operation end of March 2025, by collector type
Source: SHIP database

Figure 13 shows the industry sectors of the 714 documented systems. The **food and beverage sectors** continue to grow and are the dominant sector in terms of number of installed systems. This sector accounts for 215 systems with an average size of 1,083 m^2 and an installed thermal capacity of 156 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 47% to 44%, while the share of food and beverage stayed at 18%.

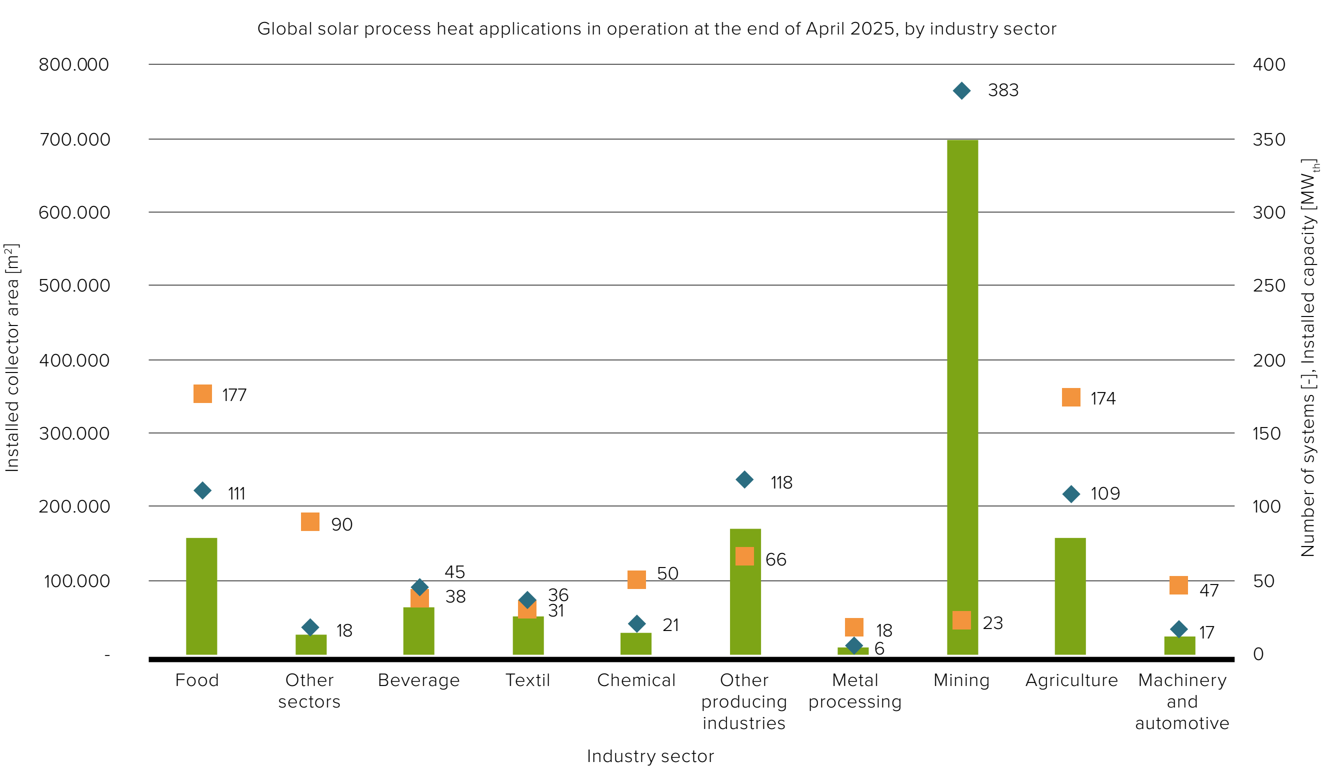

Figure 13: Global solar process heat applications in operation at the end of March 2025, by industry sector
Source: SHIP database

Figure 14 presents the globally installed solar process heat systems by country. Mexico has achieved 139 installed SHIP systems with a thermal capacity of 24 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 an installed capacity of 157 MW_{th} and a number of 70 systems installed. 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 but could not be documented in the SHIP database because of lack of detailed information. The leading countries in Europe in terms of installed capacity in the SHIP segment are Spain (59 MW_{th}), the Netherlands (32 MW_{th}) and France (28 MW_{th}). The USA and Chile are also among the top 10 countries with 29 MW_{th} and 28 MW_{th} respectively, of installed capacity each.

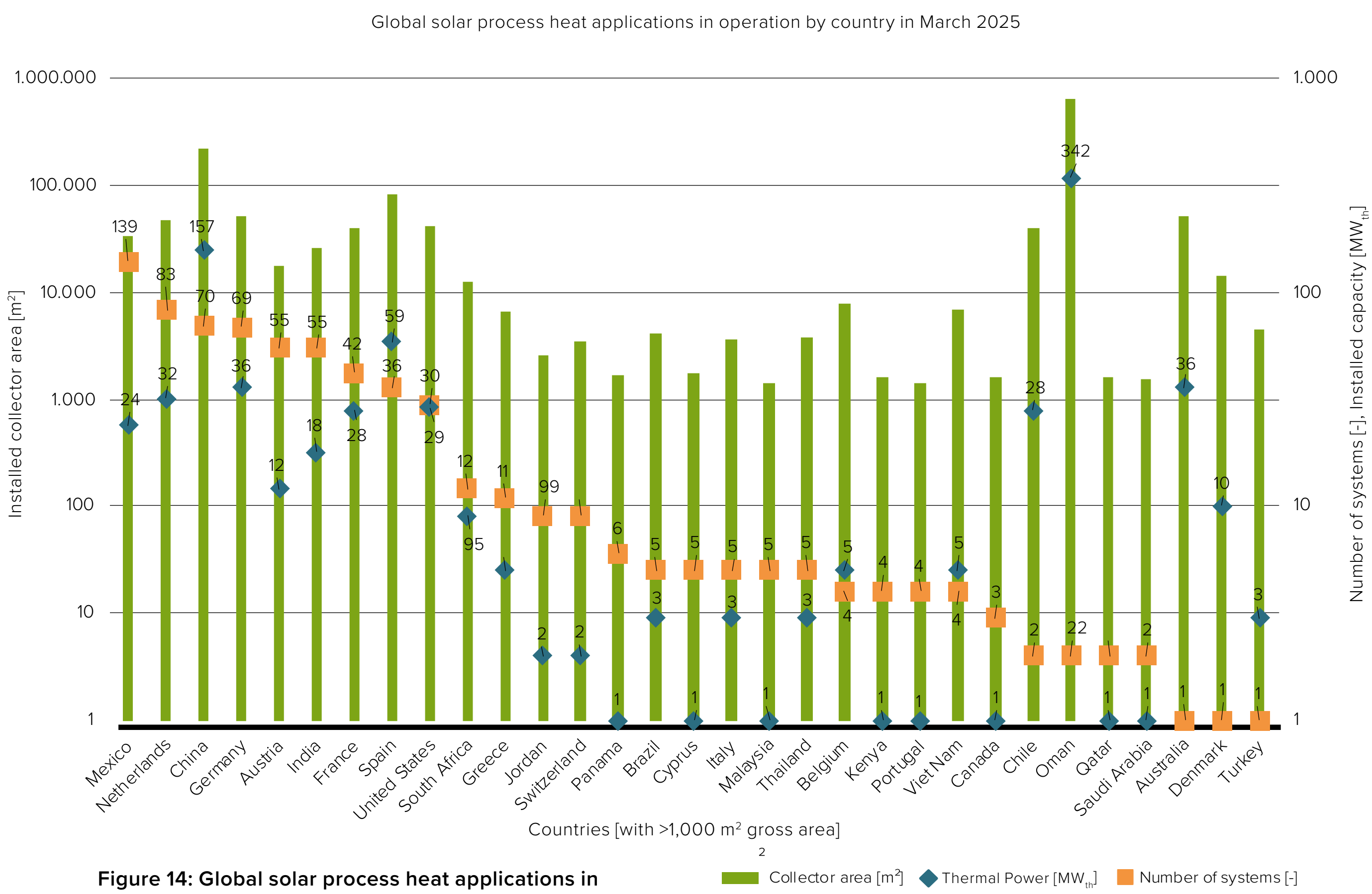

Figure 14: Global solar process heat applications in operation by country in March 2025
Source: SHIP database

Only countries with at least 0.7 MW_{th} (1,000 m^2 collector area) are shown in Figure 14 (681 of 714 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}.

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

Absolicon installation with the brewery Birra Peroni in Bari, Italy, is producing both steam and pressurized hot water for the pasteurizers
Photo: Absolicon

Table 3: Solar Heat for Industrial Processes (SHIP) plants > 5000 m^2

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
Germany	Bauer Holzenergie GmbH	2024	20	28,872
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	7,460
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

Industrial plant at Carrosserie Pfister in Herisau, Switzerland, 106 kWp of electrical power and 324 kW_{th} of thermal power are generated by uncovered photovoltaic-thermal (PVT) collectors
Photo: Aldrian Althaus, soblue AG

5.4 PVT – Photovoltaic Thermal Systems

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

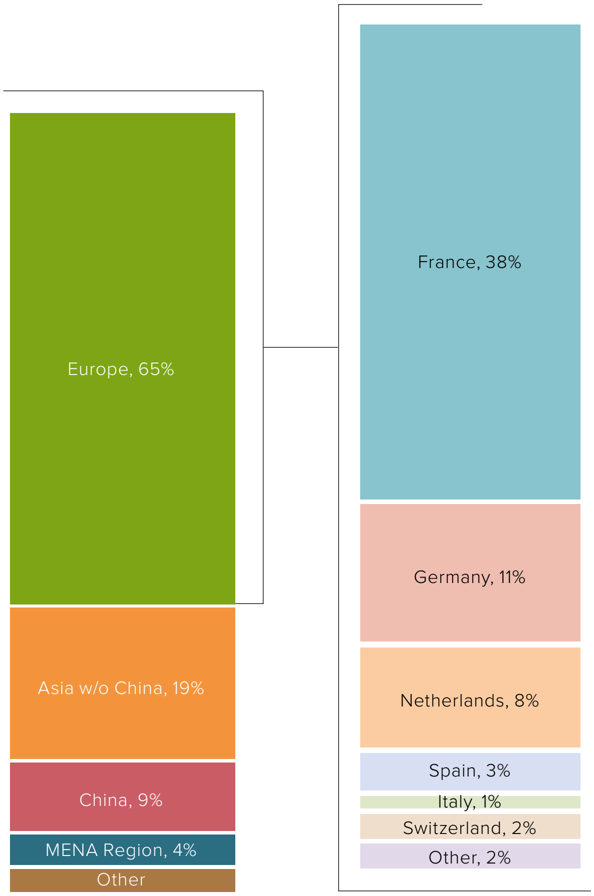


Figure 15: Distribution of the total installed collector area by economic region in 2024
Source: AEE INTEC

The technology is somewhat more complex than just a PV or a solar thermal collector and provides additional significant advantages. The PV production can be slightly higher if the collectors are operated at temperatures below those of PV-only module. 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 flexibility in the system design. The energy can be stored in many ways, including onsite tanks, aquifers, ground strata and pit storage systems. It can be used directly for hot water or space heating or for a secondary system such as a heat source (heat pumps). Cooling (radiative and convective) can also be provided directly during the night using the PVT collector's thermal absorber or indirectly through a machine driven by the PV electricity.

General market overview

In 2024, the total installed PVT collector area was 1,670,447 m^2 (864 MW$_{th}$, 315 MW$_{peak}$). The vast majority was installed in Europe (1,082,790 m^2) followed by Asia, excluding China (318,851 m^2) and in China (154,926 m^2), which together accounted for 864 MW$_{th}$, 315 MW$_{peak}$ of the total installed capacity. The remaining installed collector area was shared between the MENA countries (Egypt, Israel, Iraq and Lebanon (70,130 m^2)), the Sub-Sahara African countries (Ghana, Lesotho, La Réunion and South Africa (23,053 m^2)), United States and Canada (11,738 m^2), Australia (3,639 m^2), Latin America (766 m^2) and others (4,555 m^2).

In the European Market, France is the market leader with an installed collector area of 629,136 m^2 followed by Germany with 184,869 m^2 and the Netherlands with 141,769 m^2. In Spain, Italy, and Switzerland collector areas range between 22,820 m^2 and 42,332 m^2. In the remaining European countries, collector areas of at least 31,745 m^2 were reported.

With a global share of 61% 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 5%. Evacuated tube collectors and concentrators play only a minor role in the total numbers.

Table 4 shows the cumulated installed collector area by PVT collector type at the end of 2024.

As shown in the following Table 5, PVT collectors' total cumulative thermal capacity by the end of 2024 was 866 MW$_{th}$, and the PV power was 316 MW$_{peak}$.

1.67 million m²
PVT collector area installed worldwide

Newly built Austrian sports arena with a thermal demand of 1.4 GWh/a enabling a complete decarbonisation by using 1.130 m^2 Sunmaxx PVT modules combined with 80 ground probes and 540 kW brine heat pump
Photo: Sunmaxx PVT GmbH

Table 4: Cumulated collector area by PVT collector type at the end of 2024

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	3,540	0	0	99	0	3,639
Austria	5,371	3,454	0	0	0	8,825
Belgium	4,240	0	32	290	15	4,577
Brazil	26	0	0	0	0	26
Bulgaria	1,407	43	0	0	0	1,450
Canada	686	32	7	0	0	724
Chile	213	113	0	0	10	337
China	153,721	1,034	0	0	171	154,926
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	70,578	10,983	0	547,575	0	629,136
Germany	175,765	8,334	3	512	255	184,869
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	20,124	2,696	0	0	0	22,820
Korea, South	280,814	0	0	0	0	280,814
Kosovo	176	14	0	0	0	190
La Réunion	62	65	0	0	0	127
Lebanon	25	0	0	0	0	25
Lesotho	0	48	0	0	0	48
Luxembourg	795	0	0	145	0	940
Macedonia	1,450	199	0	0	0	1,649
Maldives	0	0	0	0	21	21
Martinique	0	63	0	0	0	63
Netherlands	125,720	11,994	33	2,200	1,822	141,769
Norway	734	0	0	0	0	734
Pakistan	0	7	0	0	0	7
Paraguey	0	0	0	0	51	51
Peru	0	16	0	0	0	16
Poland	1,947	61	0	0	0	2,008
Portugal	335	338	0	0	0	672
Romania	95	4	0	0	0	99
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	40,780	0	0	0	42,332
Sweden	1,200	20	0	0	31	1,251
Sri Lanka	3,983	44	0	0	0	4,027
Switzerland	26,462	128	0	3,530	0	30,120
Tibet	32,000	0	0	0	0	32,000
Turkey	0	140	0	0	30	170
United Kingdom	2,005	3,099	640	348	135	6,227
United States	10,988	20	7	0	0	11,014
Uruguay	0	2	0	0	0	2
Other	1,274	3,250	16	0	15	4,555
Total	1,022,741	88,636	773	554,699	3,598	1,670,447

Source: AEE INTEC

Table 5: Total installed PVT capacity in 2024 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	66	36	0	0	0	0	0	0	0	0	66	36
Australia	1,813	673	0	0	0	0	54	17	0	0	1,867	690
Austria	2,718	1,376	1,757	661	0	0	0	0	0	0	4,475	2,037
Belgium	2,147	965	0	0	16	4	141	46	9	2	2,312	1,017
Brazil	13	5	0	0	0	0	0	0	0	0	13	5
Bulgaria	711	346	19	7	0	0	0	0	0	0	730	354
Canada	349	191	14	6	3	2	0	0	0	0	366	199
Chile	105	37	52	21	0	0	0	0	6	1	162	59
China	76,189	27,643	452	180	0	0	0	0	98	20	76,739	27,842
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	29	12	0	0	0	0	0	0	88	33
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	159	87	0	0	0	0	0	0	0	0	159	87
France	36,507	15,074	5,613	2,863	0	0	271,352	88,288	0	0	313,472	106,225
Germany	87,655	35,941	4,269	1,583	1	0	263	87	139	29	92,328	37,641
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	10,043	4,185	1,273	517	0	0	0	0	0	0	11,316	4,702
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
La Réunion	32	17	36	11	0	0	0	0	0	0	68	29
Lebanon	13	7	0	0	0	0	0	0	0	0	13	7
Lesotho	0	0	21	8	0	0	0	0	0	0	21	8
Luxembourg	393	153	0	0	0	0	71	23	0	0	463	176
Macedonia	748	347	100	35	0	0	0	0	0	0	848	382
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	64,960	27,524	5,518	2,148	14	4	1,179	384	1,046	213	72,718	30,272
Norway	394	146	0	0	0	0	0	0	0	0	394	146
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	994	506	30	10	0	0	0	0	0	0	1,024	516
Portugal	168	62	159	58	0	0	0	0	0	0	326	119
Romania	49	26	2	1	0	0	0	0	0	0	51	27
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	20,865	7,866	0	0	0	0	0	0	21,640	8,150
Sweden	682	228	11	3	0	0	0	0	18	4	710	235
Sri Lanka	2,025	1,049	21	8	0	0	0	0	0	0	2,047	1,057
Switzerland	13,402	6,226	63	21	0	0	1,806	576	0	0	15,271	6,823
Tibet	17,743	6,795	0	0	0	0	0	0	0	0	17,743	6,795
Turkey	0	0	74	24	0	0	0	0	15	3	89	27
United Kingdom	1,009	465	1,641	632	289	102	170	55	66	15	3,175	1,269
United States	5,607	2,247	11	3	3	2	0	0	0	0	5,621	2,253
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	542,103	207,009	44,349	17,585	350	121	275,035	89,477	2,045	419	863,883	314,611

Source: AEE INTEC

Market development of PVT collectors between 2017 und 2024

Based on the market data of the 46 PVT manufacturers, the market for PVT collectors was characterized by a constant growth of +8% on average between 2017 and 2024. It reached its highest value in 2021 at +13%. After 2023, the PVT market increased by 11% year over year. The newly installed capacity in 2024 amounted to 37.5 MW_{th} and 18.6 MW_{peak}. This is an increase of 13% compared to the installed thermal capacity in 2023. Despite this positive trend, the current figures reflect a slight market recovery. Key indicators remain below the levels recorded in 2022.

In 2024, the global PVT market increased by 4.3%

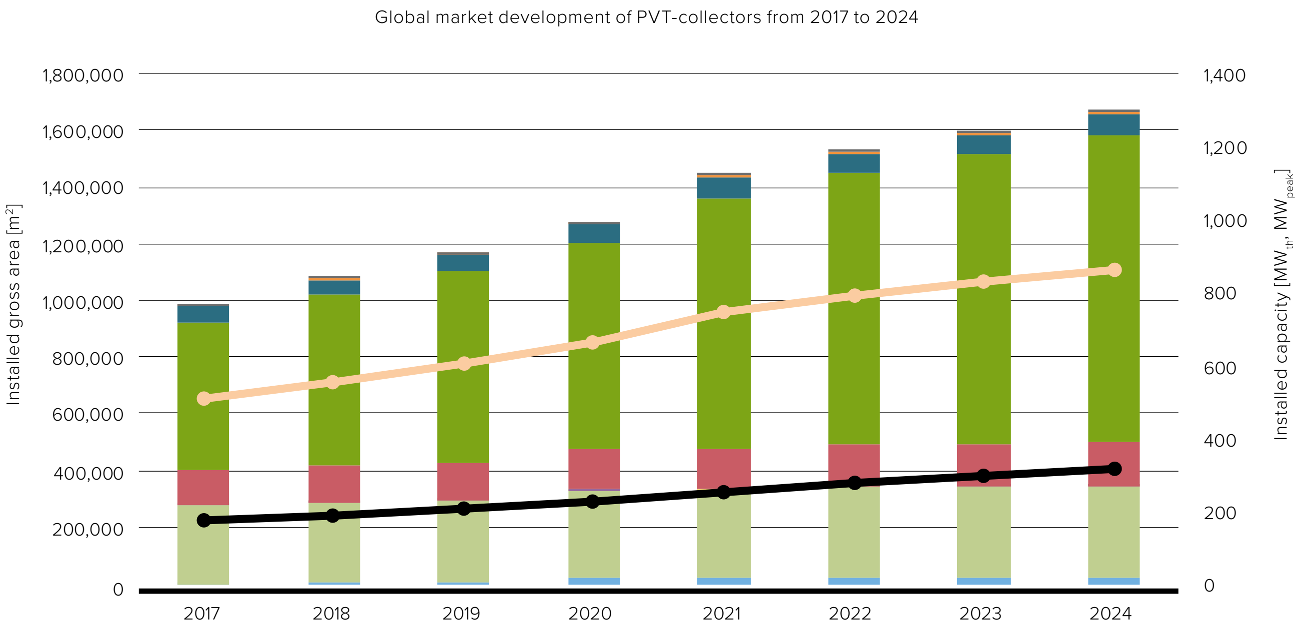


Figure 16: Global market development of PVT collectors from 2017 to 2024
Source: AEE INTEC

Uncovered PVT collectors for combined power and heat generation: 144 modules with 46.8 kW_p electrical output and 142.28 kW_{th} thermal output feed the local heating network and regenerate geothermal probes
Photo: PA-ID Process GmbH

Residential use of Triple Solar PVT panels as a unique energy source for the PVT heat pump in a neighbourhood in Germany
Photo: Cees Mager, Triple Solar

Market development in 2024

As mentioned above and shown in Figure 17, global interest in photovoltaic-thermal (PVT) systems grew steadily between 2017 and 2021. After peaking in 2021, the market experienced significant declines in 2022 and 2023. In 2024, a slight increase in newly installed PVT area is observed, although it remains below the 2022 level.

The global PVT market[14] is currently in a phase of consolidation and strategic realignment. Following a sharp drop in new installations of over 46% in 2022 and an additional 27% in 2023 primarily due to the expiration of support schemes in key markets such as France initial signs of stabilization and potential future growth are now emerging. Although the discontinuation of incentives, particularly in France, had a negative effect on the PVT market, several new manufacturers have since entered the field. In addition, some developments are becoming apparent in China, even though the market there remains far from comparable to the dominant photovoltaic sector. After reaching a low point in newly installed area in 2023, that was impacted by geopolitical effects, a modest recovery is now visible in 2024.

This slight growth is primarily driven by traditionally strong PVT markets in Europe (Figure 18). In Germany, newly installed area reached approximately 22,320 m^2 (+46%), and the Netherlands recorded 14,466 m^2 (+39%). In contrast, the French market remains stagnant. Following the collapse of the air collector segment and significant changes to the incentive framework, the largest air collector manufacturer in France ceased operations in 2024. In addition to these traditional growth markets, smaller European countries reported impressive increases. Austria experienced growth of approximately 4,186 m^2 (+524%), and the United Kingdom reported a rise of 2,125 m^2 (+66%). However, these national gains were not sufficient to offset the overall global market contraction.

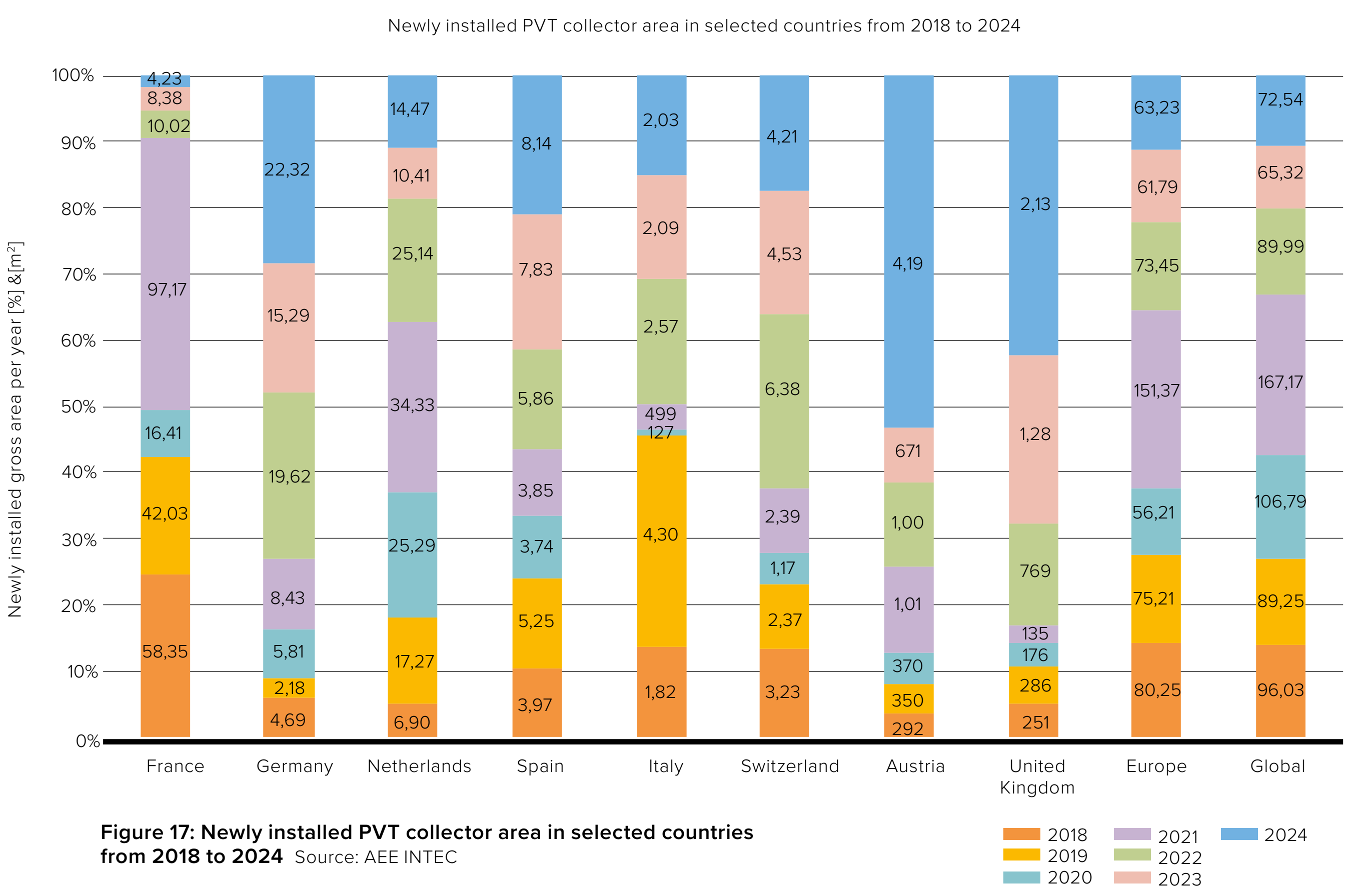
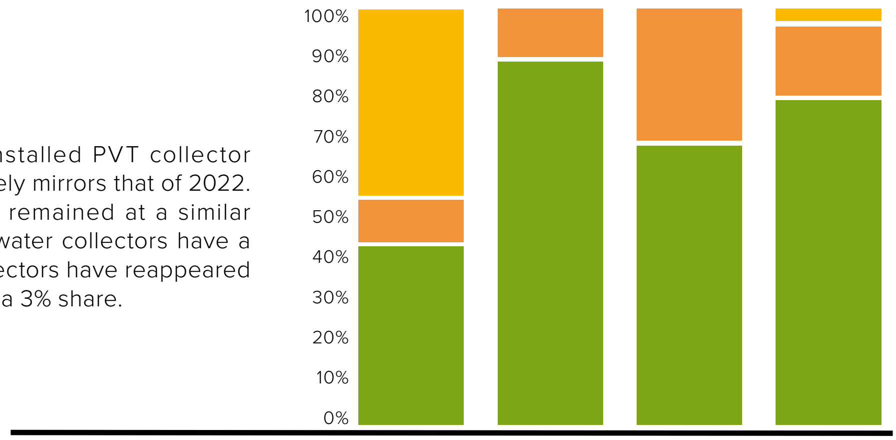


Figure 17: Newly installed PVT collector area in selected countries from 2018 to 2024 Source: AEE INTEC

The distribution of newly installed PVT collector types in 2024 (Figure 18) closely mirrors that of 2022. Uncovered water collectors remained at a similar level of 79%, while covered water collectors have a share of 18%. Notably, air collectors have reappeared on the market, accounting for a 3% share.



	2021	2022	2023	2024
Concentrated PVT collector	0%	0%	0%	0%
Air PVT collectors	46%	0%	0%	3%
Evacuated tube PVT collector	0%	0%	0%	0%
Covered PVT collector	10%	11%	32%	17%
Uncovered PVT collector	44%	88%	68%	80%

Figure 18: Distribution of newly installed PVT collector area worldwide by collector type, 2021 to 2024
Source: AEE INTEC

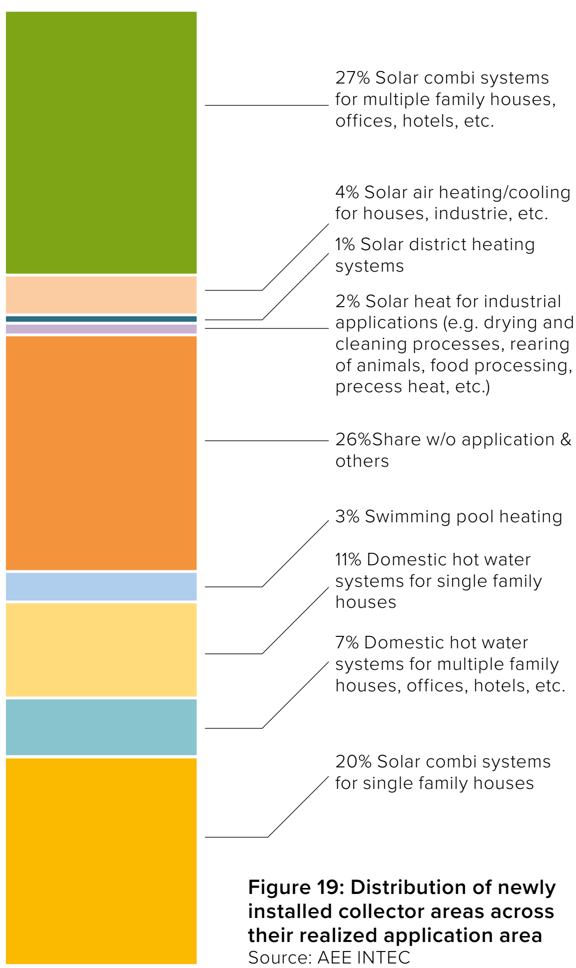


Figure 19: Distribution of newly installed collector areas across their realized application area
Source: AEE INTEC

In 2024, a total of 72,544 m^2 of newly installed PVT collector area was recorded across various application segments (Figure 19). The largest shares were attributed to solar combi systems for multiple family houses, offices, and hotels (27%), followed by systems for single family houses (20%). Domestic hot water systems contributed 11% in single family homes and 7% in multi-residential or commercial buildings. Additional applications included solar air heating and cooling (4%), swimming pool heating (3%), solar heat for industrial processes (2%) and solar district heating systems (1%). Notably, 26% of the installed area was reported without a specific application classification. Overall, residential and building-integrated applications continue to dominate, while industrial and district-scale systems remain niche.

In summary, after two challenging years, the PVT market is showing early signs of recovery. Technological developments, the emergence of new market players, and differentiated trends across European countries are laying the groundwork for renewed growth in the coming years.

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

5.5
Photovoltaic generated heat - PGH

According to the IEA Renewables 2024 report, heat remains the primary end-use sector, accounting for almost half of global final energy consumption and 40% of energy-related CO_2 emissions in 2023. During 2017-2023, annual heat demand expanded 7% (+14 EJ) globally. For 2024-2030 global renewable heat consumption is expected to grow by more than 50% (15 EJ), representing 2.4 times the increase of the previous six-year period. During this same time, renewable energy use for heating and cooking in buildings is expected to grow 45% (+7 EJ), increasing the share of renewables in building heat from 17% in 2023 to 24% in 2030. The report further states that renewable electricity in buildings will increase even faster, almost doubling (+3 EJ) globally during the outlook period.[20]

These trends show that although renewable energy supply is rapidly increasing, it is not keeping up with the growth in demand. If we hope to get a net reduction in greenhouse gas emissions, it will take continued effort to improve energy efficiency and—importantly—a full integration of renewable energy sources (including photovoltaics) into the heating sector. However, several 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.

In recent years, new PV heating technologies have emerged as a viable alternative to solar thermal technologies. These include devices where the PV electricity is devoted to the heating applications and those which share with other electrical loads (for powering electronics and appliances in homes and businesses). These options enable conventional electric heating technologies, such as heat pumps or electric resistance heaters to run on solar electricity for space heating, water heating, or industrial processes. The implementation of Photovoltaic Generation Heat (PGH) is driven by the significant and ongoing price reductions in photovoltaics, which put traditional renewable heating technologies under economic pressure.

Surplus electricity (10 kWp PV system) delivers heat to refurbished single-family house, optimizing electricity self-consumption
Photo: My-PV, Austria

When the cost of photovoltaic solar collectors was >100 USD/Watt, solar thermal hot water was the first-choice 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 "PV hot water" system may now represent the most affordable and reliable option in some markets. Solutions that are being brought to the market include the consumption hot water preparation, space heating, and even district heating.

5.5.1.
Direct Coupled "PV hot water" Technologies

"PV hot water" systems refer to setups where the direct current (DC) produced by rooftop photovoltaic panels is sent straight to a DC resistance heater inside a hot water tank—bypassing the need for an inverter and using minimal additional electronics. These systems are particularly well-suited for areas with unreliable electricity supply, high grid connection costs, or limited upfront investment capacity.

Compared to traditional solar thermal thermosyphon systems, PV hot water systems are now being offered at more competitive prices. Beyond cost savings, they offer additional advantages: hot water tanks no longer need rooftop installation, and the systems avoid issues like stagnation and freezing.

As presented for the first time in the 2021 edition of Solar Heat Worldwide, interest in PV hot water systems has grown significantly, especially in southern African countries. By the end of 2023, South Africa had installed over 34,000 of these systems, as illustrated in Figure 20.[21]

[20] IEA 2024, Renewables 2024 - Analysis and forecast to 2030, International Energy Agency, October 2024
[21] Study done by Lavhe Maluleke, CRSES Stellenbosch University, South Africa.

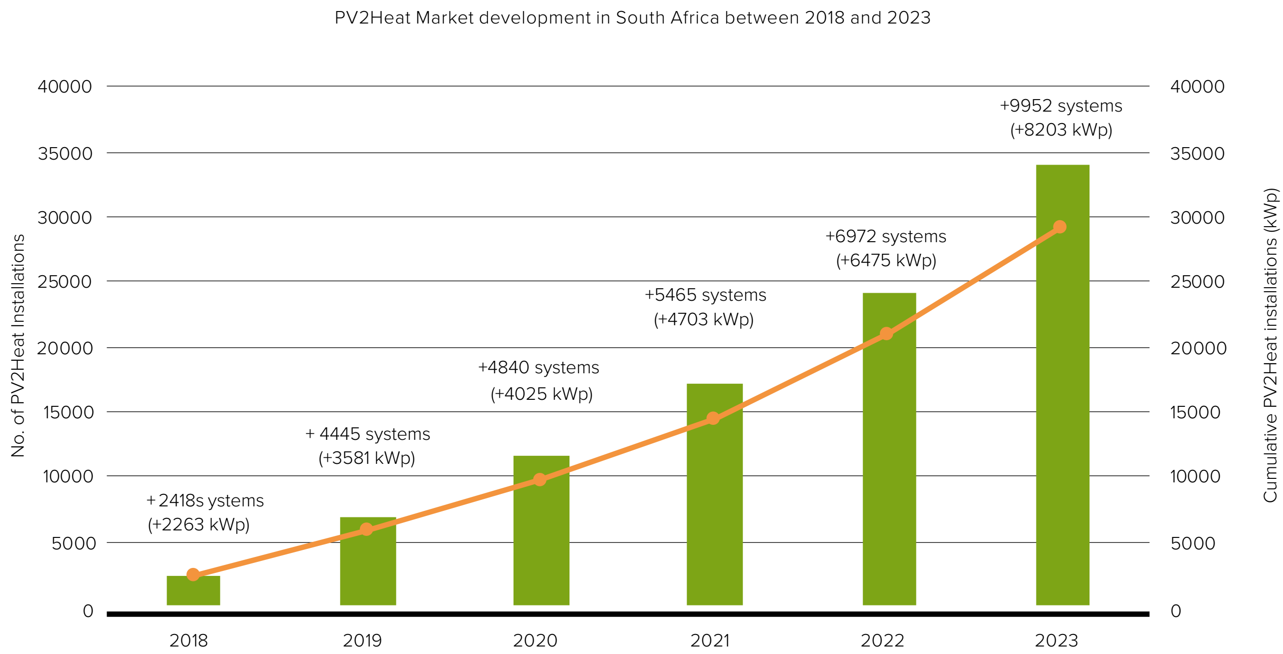


Figure 20: PV2Heat Market development in South Africa between 2018 and 2023

Source: Lavhe Maluleke, Stellenbosch University, South Africa

5.5.2. Partially Coupled PV Hot Water Technologies

Partially coupled systems are particularly interesting in markets with elevated levels of installed PV on the electrical grid often characterized by phenomena like the 'duck curve', where midday solar generation exceeds demand. This oversupply has significantly reduced the export value of surplus PV electricity. Australia stands out as a global leader in solar adoption, with more than 1 kW of installed PV capacity per person as of 2024. In this context, electric water heaters account for around one-third of the country's hot water systems. These systems' storage tanks, capable of holding approximately 10 kWh of thermal energy, can serve as effective energy buffers. New technologies are emerging that maximize self-consumption of PV electricity by synchronizing energy use with generation and leveraging dynamic pricing, often integrating with broader smart grid systems. Another approach involves PV diverters, which automatically redirect excess solar power to heat water or other thermal loads when household electricity demand is low. These solutions have been primarily developed in the United Kingdom and are gaining popularity in high-solar-generation markets.

5.5.3. Solar Combisystem powered by PV

A solar combisystem is a type of integrated solar thermal solution designed to supply both space heating and domestic hot water (DHW) in residential or commercial buildings. These systems remain widely used, especially in parts of central and northern Europe, where they continue to hold a notable market share. Traditional solar combisystems rely on solar thermal collectors combined with key components such as hot water storage tanks, backup heat sources (like boilers or electric heaters), and control units (for a more detailed description please see Figure 58 in the appendix). Together, these elements ensure a reliable supply of heat and hot water throughout the year.

The photovoltaic system (25 kWp) supports DHW preparation and heating. The main heating system (heat pump) can be completely switched off during summer months

Photo: My-PV, Austria

More recently, there have been emerging examples of combisystems powered by photovoltaics (PV) rather than thermal collectors. In countries like Austria, Germany, and Switzerland, some of these PV-based systems have been shown to cover 100% of a building's heating needs, marking an innovative shift in solar heating technology.

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 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. A 400 kW electric boiler and a 200 kW air heat pump transform power to heat. As to the design of the system, solar power will generate approximately 54% of the heat demand for thirty buildings connected to the district heating network throughout the year. 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 stores heat 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.[22]

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 the electricity during the heating period, the electricity is generated by the CHP plant.[23]

These two PV-powered district heating systems may still be small in capacity, but they represent an innovative approach and demonstrate how sector coupling of electricity grid and district heating network could contribute to the decarbonization of the heating sector.

5.5.5.
Conclusion

While renewable heat consumption is projected to rise significantly by 2030, it still lags behind overall energy demand growth, highlighting the need for improved energy efficiency and deeper integration of all renewables into heating systems. New PV-based technologies, including direct and partially coupled "PV hot water" systems, combi systems, and PV-powered district heating, are emerging as economically viable and scalable solutions across a range of settings—from individual homes to entire municipalities. These systems offer practical advantages, such as low installation costs, simple designs, and great flexibility. Innovative projects in countries like Germany, South Africa, and Australia illustrate the potential of solar electrification to decarbonize heat and reduce dependence on fossil fuels.

5.6.
Solar air conditioning and cooling

Since 2020, 3,463 m^2 flat-plate collector area and a 70 m^3 heat storage tank operate, among other things, a 650 kW water/LiBr absorption chiller to provide heat and cooling for AVL List GmbH in Graz, Austria, achieving CO_2 savings of 320 t/year.
Photo: SOLID Solar Energy Systems

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.[24] 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[25], GIZ 2017 feasibility study for social housing buildings in Mexico[26], and RCREEE/UNDP 2015 study on commercial buildings/applications in the Arab region.[27]

[22] Source: Personal communication of Werner Weiss with AGFW and Maxsolar
[23] Sources: AGFW and Stadtwerke Altensteig, Germany
[24] https://www.iea.org/futureofcooling/
[25] https://www.green-cooling-initiative.org/fileadmin/user_upload/220607_Proklima_Solar_AC_med.pdf
[26] 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
[27] https://www.solarthermalworld.org/sites/default/files/story/2016-04-05/solar_cooling_in_arab_region_0.pdf

A central argument for solar thermal-driven systems is that they consume less conventional energy (up to a factor of five[28]) 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[29] 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.[30] 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 Global South 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 chiller units. 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.[31]

Solar thermal cooling is still a niche market, with over 2,000 systems deployed globally as of 2024. Due to changing distribution channels and B2B sales of the sorption chillers, tracking newly installed solar-driven systems is difficult and can only be estimated. Small units with a capacity lower than 20 kW are getting more compact (thus cheaper upfront costs) and targeting the mass markets. Medium to large-scale projects, 30 kW to 2,000 kW, are dominated by engineered systems. Of the small and medium capacity (<350 kW) solar cooling systems worldwide, 70% are installed in Europe. According to a survey carried out in early 2019 by solrico for REN21[32], 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., RE-WITCH[33], SunBeltChiller[34], FRIENDSHIP[35], SHIP2FAIR[36], HyCool[37], sol.e.h.^{2}[38], Zeosol[39]) 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% in the last years.[40] 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[41] 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.

[28] http://task53.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task53-C3-Final-Report.pdf
[29] https://eur-lex.europa.eu/eli/reg/2024/573/oj
[30] Low energy cooling and ventilation in indian residences, https://doi.org/10.1080/23744731.2018.1522144
[31] https://www.bafa.de/DE/Energie/Energieeffizienz/Klima_Kaeltetechnik/klima_kaeltetechnik_node.html
[32] Not published internal communication
[33] https://ieecp.org/projects/re-witch
[34] https://forum.iea-shc.org/Data/Sites/1/publications/2023-12-Task65-Sunbelt-Chiller.pdf
[35] https://friendship-project.eu/ship-200-300/
[36] http://ship2fair-h2020.eu/demo-2-bodegas-roda
[37] 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.
[38] 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.
[39] Roumpedakis, Tryfon; et al. (2019) Performance results of a solar adsorption cooling and heating unit, ISES SWC 2019-SHC 2019, paper ID 11465
[40] Internal IEA SHC Task 65 communication
[41] Ton of refrigeration is a unit of power used in North America to describe the capacity of heat extraction in industrial air conditioning and refrigeration equipment.

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

Country	Site	Commissioned	Installed capacity [kW_{th}]	Collector size [m^2]	Collector type	Cooling capacity [kW_{cold}]
Mali	Camop Castor	2022	450	700	Evacuated tube	348
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., SolarNext, IEA SHC Task 65

The electricity a solar cooling system needs to run pumps and a cooling tower is relatively low. Depending on the climate, it may give Energy Efficiency Ratios (kWth/kWel) of 20 to 40 in systems with optimized variable speed-driven auxiliaries. 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.[42] 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, four larger solar cooling systems with a 1.3 MW cooling capacity were commissioned. Their total collector capacity is 2.31 MW_{th}, corresponding to a 3,360 m^2 collector area.

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

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[43], 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[44] 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.[45] 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.

LEARN MORE

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

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[46]). 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.[47]

In the past 16 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 signed Global Cooling Pledge at the COP28 conference[48] shows that cooling is a very serious and important global issue. According to the Global Cooling Watch 2023 report[49], 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%. Moreover, the cooling market in developing economies is projected to grow from approximately 300 billion to 600 billion USD, or more, by 2050. With billions of people worldwide affected by extreme heatwaves intensified by the climate crisis, improving access to sustainable cooling has become essential.

This highlights the timeliness and importance of the solar cooling technology as key driver and its potential to reduce greenhouse gas emissions and peak electricity demand, especially in countries with high cooling needs and grid limitations. To tackle this challenge, IEA SHC Task 65 adopted an innovative approach – adapting existing concepts and technologies to the Sunbelt regions, utilizing solar energy (either thermal or photovoltaic).

Solar air heating systems as part of a multi-residential community near Lake Ontario, Canada
Photo: SolarWall Conserval Engineering Inc.

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 air directly without heat exchangers. Most solar air collectors for heating buildings are wall-mounted to take advantage of the lower winter sun angles and eliminate snow accumulation on roof-mounted systems. When heat is not needed during the summer, the panels are generally left dormant, as stagnation temperatures are not usually an issue.

[42] 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.
[43] https://hycool-project.eu
[44] https://ieecp.org/projects/re-witch/
[45] https://sophia4africa.eu/de/
[46] https://www.iea.org/futureofcooling/
[47] Jakob, U. (2023) Solar Cooling for emerging markets. Keynote ISES Solar World Congress 2023, New Delhi, India
[48] https://www.cop28.com/en/global-cooling-pledge-for-cop28
[49] https://www.unep.org/resources/global-cooling-watch-2023

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

Process applications are different as they operate 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 7: Largest solar air collector markets - total installed air collector areas in 2023

Country	Air Collectors [m^2]		Total [m^2]	Installed capacity [MW_{th}]
	unglazed	glazed		
Canada	462,653	58152	520,805	365
United States	114,926	72,000	186,926	131
Japan		185,496	185,496	130
China	44,739	46,500	91,239	64
United Kingdom	24,800		24,800	17
Denmark	4,300	18,000	22,300	16
Spain	18,150	2,250	20,400	14
Germany		16,640	16,640	12
Turkey	15,815		15,815	11
India		12,430	12,430	9
France (mainland)	10,958	1,100	12,058	8
Mexico	752	9275	10,027	7

By the end of 2023, 842 MW_{th} (1.20 million square meters) of glazed and unglazed air collectors were installed worldwide. The annual worldwide market in 2023 was in the range of 26 MW_{th} (37,515 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 commercial, industrial, and institutional markets due to their low cost and architectural building integration. Architects can be creative integrating solar air heaters into building facades.

Canada leads
solar air collector market with 365 MW_{th}

6 Detailed global market data and country statistics in 2023

SOLTRAIN partner Green Line Africa installed 196 m² glazed PVT collectors (137.2 kW thermal, 44.0 kW electrical) for DHW at a private hospital in Cape Town
Photo: SOLTRAIN / Solarus Smart Energy Solutions

The following chapters of the report provide detailed solar thermal market figures for the year 2023 and country figures for 73 countries.

Background of the 2023 data

The figures in the following chapters represent the collector area in operation in 2023, not the cumulated collector area installed in a country, meaning system lifetimes are considered. To determine collector area and operation capacity, official country reports on the lifetime were used, or, if reports were not available, a 25-year lifetime for a system was calculated. The collector area in operation was 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. Using this approach, the lifetime has been increased between 2018 and 2023 from 10 years to a lifetime of 15 years which was used for 2023. For Germany, a lifetime of 25 years was used in accordance with accumulated market statistic figures for Germany published by BSW.[50]

Analysis further distinguishes between distinct types of solar thermal collectors: unglazed water collectors, glazed water collectors including flat plate collectors (FPC), 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

Solar thermal Installation in Bhutan
Photo: AEE INTEC, Werner Weiss

By the end of 2023, an installed capacity of 559 GW_{th}, corresponding to a total of 799 million m^2 of collector area, was in operation worldwide.

In China a total capacity of 410.1 GW_{th} was in operation, in Europe the total capacity in operation was 63.9 GW_{th}. China and Europe accounted for 85% of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (19.2 GW_{th}), Latin America and Caribbean (22.2 GW_{th}), Other Asia (19.2 GW_{th}), the MENA[51] countries Israel, Jordan, Lebanon, Morocco, Palestinian Territories and Tunisia (8.2 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 (2.7 GW_{th}). The market volume of "all other countries" is estimated to be 5% of the total installations, excluding China (7.5 GW_{th}).

[50] Bundesverband Solarwirtschaft e.V.
[51] Middle East and North Africa

Figure 21: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2023

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

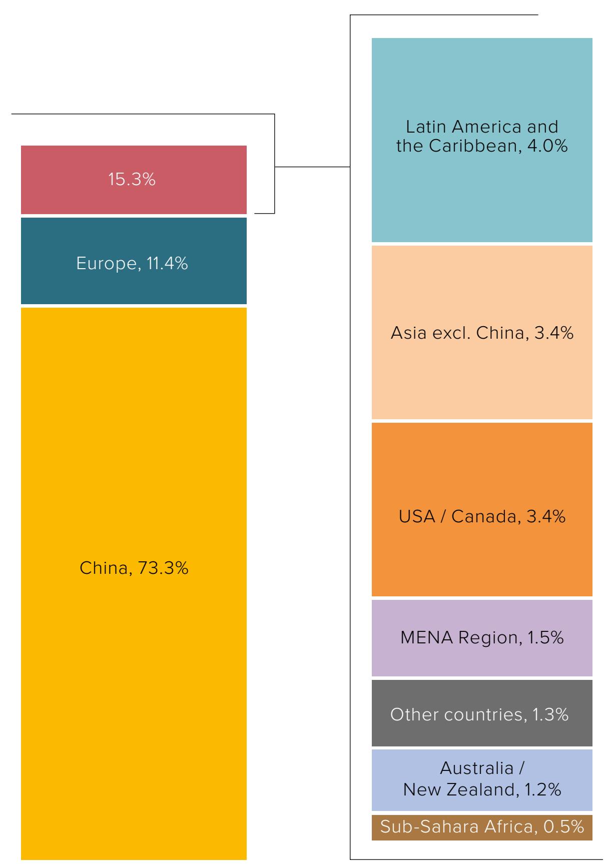


Table 8: Total capacity in operation in 2023 [MW_{th}]

Country/Region/Economy	Water Collectors [MW_{th}]			Air Collectors [MW_{th}]		TOTAL [MW_{th}]
	unglazed	FPC	ETC	unglazed	glazed	
Albania++		233.0	11.1			244
Argentina	77.3	109.3	207.5	0.0	0.3	395
Australia	4,157.9	2,328.5	190.4		3.5	6,680
Austria	98.1	2,964.7	55.9		6.1	3,125
Barbados+		180.7				181
Belgium		441.0	107.1			548
Bhutan	0.0	1.5	0.0			1.5
Botswana++		12.9	2.1			15
Brazil	7,072.3	9,466.1	219.0			16,757
Bulgaria		151.9	4.1			156
Burkina Faso+		2.3	1.0			3
Canada	471.9	49.0	36.7	323.9	40.7	922
Cape Verde+++		1.8				2
Chile	45.9	235.0	38.0		0.2	319
China		54,721.1	355,337.8	31.3	32.6	410,123
Croatia		198.7	9.3			208
Cyprus	1.5	617.7	16.5			636
Czech Republic	280.0	348.7	115.2			744
Denmark	14.4	1,228.2	6.4	3.0	12.6	1,265
Ecuador++++		0.1			0.0	
Estonia		11.1	5.9			17
Finland	8.3	44.6	14.6			67
France (mainland)	44.3	1,548.3	134.3	7.7	0.8	1,735
France (overseas)		873.5	30.1			904
Germany	274.9	13,664.6	1,867.3		11.6	15,818
Ghana++		4.1	2.1			6
Greece		4,093.6	15.8			4,109
Hungary	12.8	207.1	55.9	2.4	1.6	280
India		2,745.1	11,658.3		8.7	14,412
Ireland		201.8	89.7			291
Israel+++++	27.3	3,533.9				3,561
Italy	30.7	3,350.4	512.2	0.1		3,893
Japan		1,735.8	21.1		129.8	1,887
Jordan*	4.2	687.7	190.5			882
Kenya+++++		222.8	111.4			334
Latvia		28.6	2.4			31
Lebanon		307.1	400.7			708
Lesotho++		1.7	3.0			5
Lithuania		7.7	11.2			19
Luxembourg		47.8	6.2			54
Malta		24.4	10.6			35
Mauritius**		93.0				93
Mexico	1,392.4	1,592.3	1,477.3	0.5	6.5	4,469
Morocco+++++		726.6				727
Mozambique	0.1	0.0	4.0			4
Namibia++	1.1	44.7	1.0			47
Nepal++++		21.0	189.0			210
Netherlands	47.6	344.8	74.6			467
New Zealand***	4.9	100.1	6.8			112
Nigeria+		1.3	7.5	0.0	1.2	10
North Macedonia		57.7	44.2			102
Norway	1.3	25.6	3.2	0.1	2.9	33
Palestinian Territories		1,386.6				1,387
Panama		0.6				1
Poland		2,123.8	351.7			2,476
Portugal	1.5	961.1	23.9			986
Romania	0.2	115.8	80.2	0.6		197
Russia	0.1	59.6	3.0	0.0	0.1	63
Senegal+		3.3	3.6	0.0	0.8	8
Slovakia	0.7	133.2	19.8			154
Slovenia		87.5	16.7		0.0	104
South Africa	1,050.6	549.1	470.3			2,070
South Korea		1,040.4	312.0			1,352
Spain	118.3	3,273.1	183.4	12.7	1.6	3,589
Sweden	119.7	181.0	50.8			351
Switzerland	110.6	971.3	103.7			1,186
Chinese Taipei+	1.4	1,175.9	93.3			1,271
Thailand****		110.3				110
Tunisia++		864.4	49.1			913
Turkey		11,227.3	8,149.0	11.1		19,387
United Kingdom	76.2	390.3	178.6	17.4		663
United States	15,950.5	2,096.5	123.7	80.4	50.4	18,302
Uruguay	0.7	79.4	9.3			89
Zimbabwe++		15.3	91.8			107
All other countries (5% solar thermal world market excluding China)	1,657.9	4,303.5	1,488.7	24.2	14.7	7,489
TOTAL	**33,158**	**140,790**	**385,112**	**515**	**327**	**559,902**

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 2017
\+ Total capacity in operation refers to the year 2020
++ Calculated based on 0% growth 2022
+++ Total capacity in operation refers to the year 2021
++++ Total capacity in operation refers to the year 2022
+++++ New in ed. 2025

Table 9: Total installed collector area in operation in 2023 [m²]

Country/Region/Economy	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania++		332,903	15,902			348,805
Argentina	110,462	156,167	296,427	60	474	563,590
Australia	5,939,832	3,326,368	272,000		5,000	9,543,200
Austria	140,181	4,235,225	79,892		8,746	4,464,044
Barbados+		258,192	0			258,192
Belgium		630,000	153,000			783,000
Bhutan		2,136	55			2,191
Botswana++		18,441	3,034			21,475
Brazil	10,103,248	13,522,955	312,796			23,938,999
Bulgaria		217,007	5,850			222,857
Burkina Faso+		3,282	1,399			4,681
Canada	674,139	69,989	52,392	462,653	58,152	1,317,325
Cape Verde+++		2,613				2,613
Chile	65,551	335,735	54,305		300	455,891
China		78,173,000	507,625,412	44,739	46,500	585,889,651
Croatia		283,835	13,308			297,143
Cyprus	2,213	882,374	23,567			908,154
Czech Republic	400,000	498,177	164,635			1,062,812
Denmark	20,500	1,754,586	9,200	4,300	18,000	1,806,586
Ecuador++++		205			22	227
Estonia		15,926	8,360			24,286
Finland	11,800	63,658	20,788			96,246
France (mainland)	63,240	2,211,880	191,920	10,958	1,100	2,479,098
France (overseas)		1,247,800	43,070			1,290,870
Germany	392,765	19,520,910	2,667,542		16,640	22,597,857
Ghana++		5,870	2,958			8,828
Greece		5,848,000	22,500			5,870,500
Hungary	18,300	295,864	79,850	3,418	2,300	399,732
India		3,921,526	16,654,684		12,430	20,588,640
Ireland		288,241	128,127			416,368
Israel+++++	39,000	5,048,434				5,087,434
Italy	43,800	4,786,330	731,778	120		5,562,028
Japan		2,479,727	30,107		185,496	2,695,330
Jordan*	5,940	982,482	272,084			1,260,506
Kenya+++++		318,348	159,174			477,521
Latvia		40,796	3,490			44,286
Lebanon		438,725	572,455			1,011,180
Lesotho++		2,371	4,262			6,633
Lithuania		11,069	16,050			27,119
Luxembourg		68,267	8,900			77,167
Malta		34,905	15,095			50,000
Mauritius**		132,793				132,793
Mexico	1,989,203	2,274,729	2,110,365	752	9,275	6,384,324
Morocco+++++		1,038,000				1,038,000
Mozambique	136	48	5,779			5,963
Namibia++	1,560	63,807	1,397			66,765
Nepal++++	0	30,000	270,000			300,000
Netherlands	68,060	492,620	106,600			667,280
New Zealand***	7,025	142,975	9,644			159,645
Nigeria+		1,866	10,782		1,670	14,318
North Macedonia		82,438	63,155			145,593
Norway	1,849	36,505	4,586	200	4,106	47,246
Palestinian Territories		1,980,900				1,980,900
Panama		815				815
Poland		3,034,030	502,460			3,536,490
Portugal	2,130	1,373,000	34,143			1,409,273
Romania	340	165,410	114,590	800		281,140
Russia	137	85,190	4,340		200	89,867
Senegal+	0	4,741	5,083		1,203	11,027
Slovakia	1,000	190,301	28,270			219,571
Slovenia	0	125,000	23,870		15	148,885
South Africa	1,500,791	784,387	671,794			2,956,971
South Korea	0	1,486,336	445,760			1,932,096
Spain	169,052	4,675,887	261,999	18,150	2,250	5,127,338
Sweden	171,000	258,533	72,578			502,111
Switzerland	158,000	1,387,500	148,100			1,693,600
Chinese Taipei+	1,937	1,679,874	133,244			1,815,055
Thailand****		157,536				157,536
Tunisia++		1,234,837	70,104			1,304,941
Turkey		16,038,999	11,641,459	15,815		27,696,273
United Kingdom	108,850	557,614	255,197	24,800		946,461
United States	22,786,415	2,994,975	176,728	114,926	72,000	26,145,045
Uruguay	1,018	113,361	13,228			127,607
Zimbabwe++		21,848	131,086			152,934
All other countries (5% solar thermal world market excluding China)	2,368,393	6,147,799	2,126,700	34,576	21,020	10,698,488
TOTAL	**47,367,868**	**201,128,972**	**550,159,409**	**736,268**	**466,899**	**799,859,416**

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 2017
- \+ Total capacity in operation refers to the year 2020
- ++ Calculated based on 0% growth 2022
- +++ Total capacity in operation refers to the year 2021
- ++++ Total capacity in operation refers to the year 2022
- +++++ New in ed. 2025

The share of collector types in total installed capacity operational in 2023 was the following:
140.8 GW_{th} (201.1 million m^2) flat plate collectors (FPC) 385.1 GW_{th} (550.2 million m^2) evacuated tube collectors (ETC),$_{h}$, 33.2 GW_{th} unglazed water collectors (47.4 million m^2), glazed and unglazed air collectors: 0.8 GW_{th} (1.2 million m^2).

Evacuated tube collectors are the predominant collector type with a global share of 68.8%, flat plate collectors had a share of 25.1% and unglazed water collectors had a share of about 6.0% (Figure 22). 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 2023 (Figure 23). Europe's share of evacuated tube collectors was 1.9%.

Ground-mounted solar thermal hot water system in Bhutan
Photo: AEE INTEC, Werner Weiss

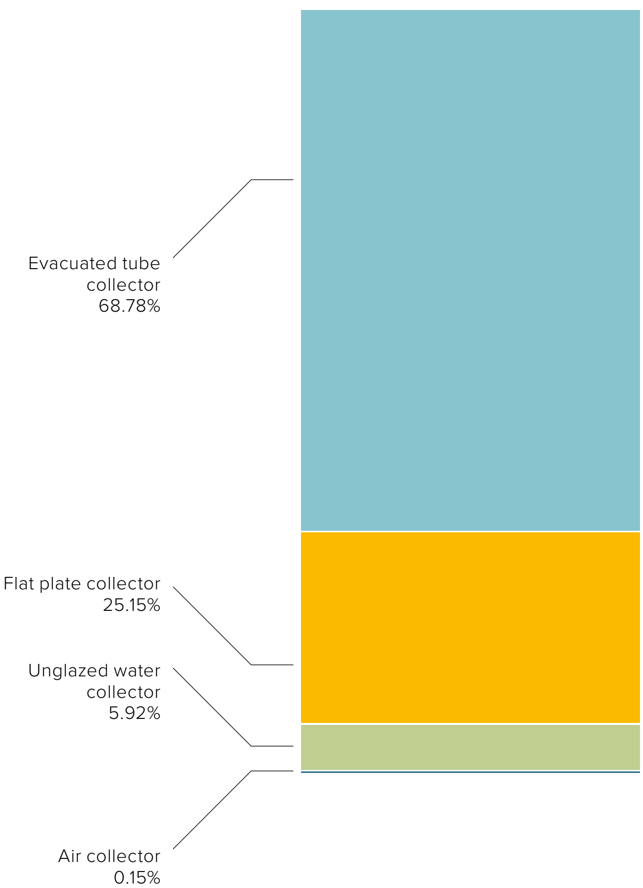


Figure 22: Distribution of the total installed capacity in operation by collector type in 2023 – WORLD

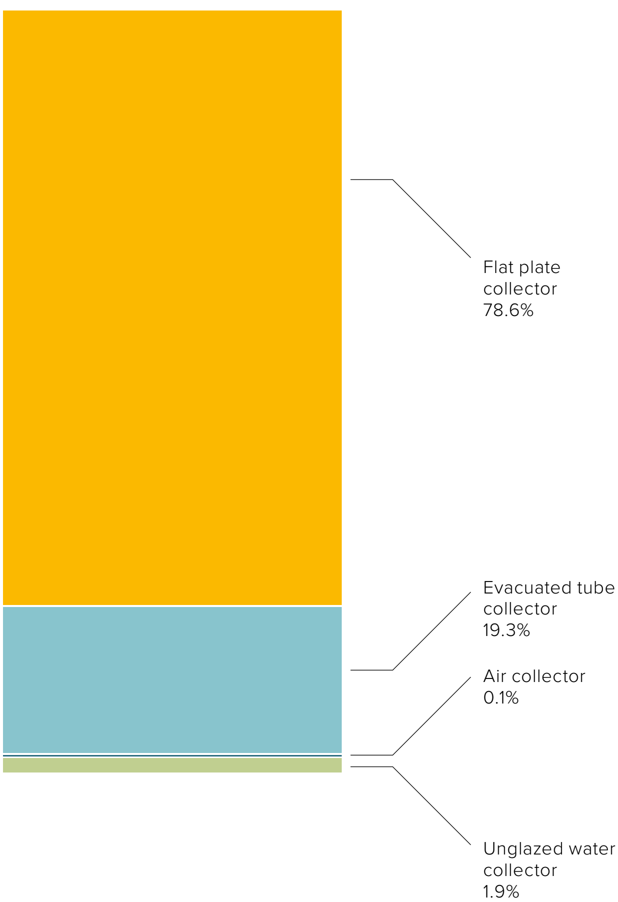


Figure 23: Distribution of the total installed capacity in operation by collector type in 2023 – EUROPE
EU 27, Albania, North Macedonia, Norway, Russia, Switzerland, Turkey, United Kingdom

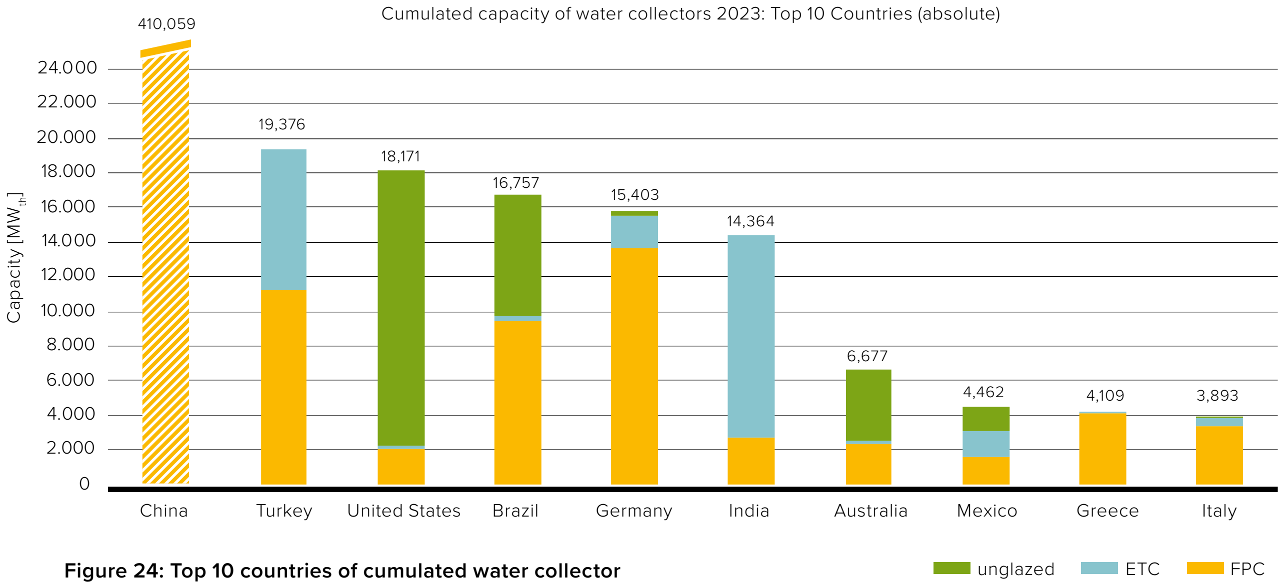


Figure 24: Top 10 countries of cumulated water collector installations in 2023 (absolute figures in MW$_{th}$)

Comparing to the year 2022, Brazil is now ahead of Germany and ranks fourth behind China, Turkey and the United States. China remained the world leader in total capacity and a market dominated by evacuated tube collectors. The United States held its third position based on its high number of installed unglazed water collectors. Besides the United States, Australia and Brazil have installed large numbers of unglazed water collectors. In the large European markets, Germany, Greece and Italy, flat plate collectors are the dominant collector technology. In Turkey, there has been a strong trend toward evacuated tube collector technology over the past several years largely due to a few local producers.

The top 10 countries with the highest market penetration per capita are shown in Figure 25. The leading countries in cumulated glazed and unglazed water collector capacity in operation in 2023 per 1,000 inhabitants were Barbados (596 kW$_{th}$/1,000 inhabitants), Cyprus (486 kW$_{th}$/1,000 inhabitants), Greece (391 kW$_{th}$/1,000 inhabitants), Israel (385 kW$_{th}$/1,000 inhabitants), Austria (342 kW$_{th}$/1,000 inhabitants), China (291 kW$_{th}$/1,000 inhabitants), France (overseas) (267 kW$_{th}$/1000 inhabitants), the Palestinian Territories (263 kW$_{th}$/1,000 inhabitants), Australia (252 kW$_{th}$/1,000 inhabitants), and Turkey (232 kW$_{th}$/1,000 inhabitants).

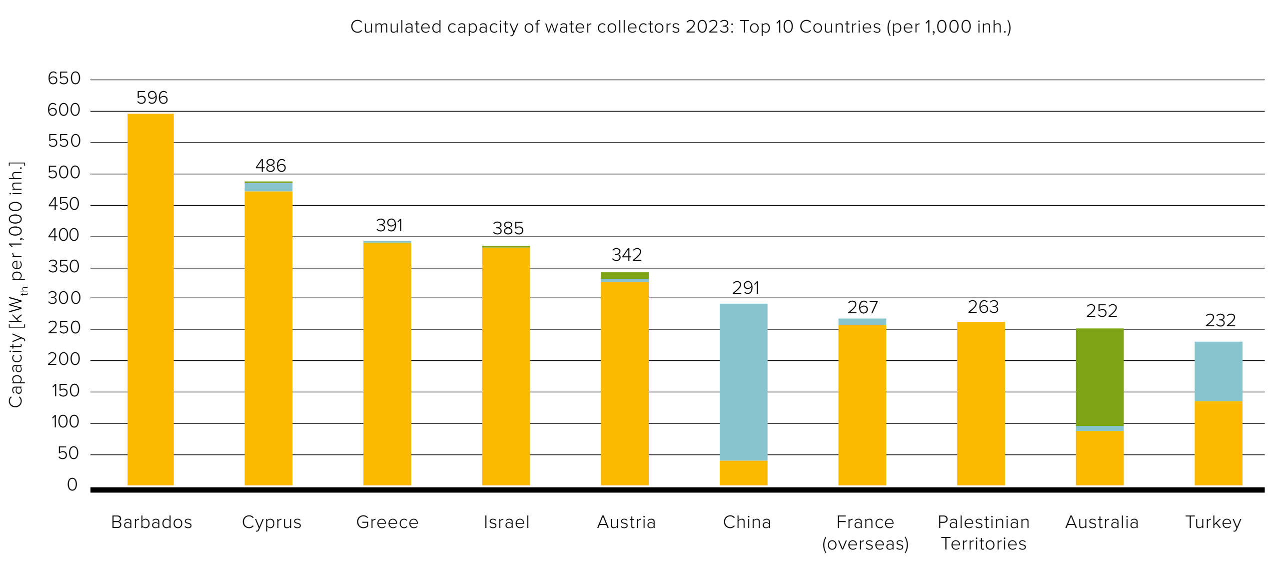


Figure 25: Top 10 countries by cumulated water collector installations per 1,000 inhabitants in 2023 (relative figures in kW$_{th}$)

6.2 Total capacity of glazed water collectors in operation

In glazed water collectors in operation, China was the leading country with an installed collector capacity of 410.1 GW_{th}. Turkey, Germany, India and Brazil followed on position two to five, with installed capacities ranging from 19.4 GW_{th} to 9.7 GW_{th}. (Figure 26).

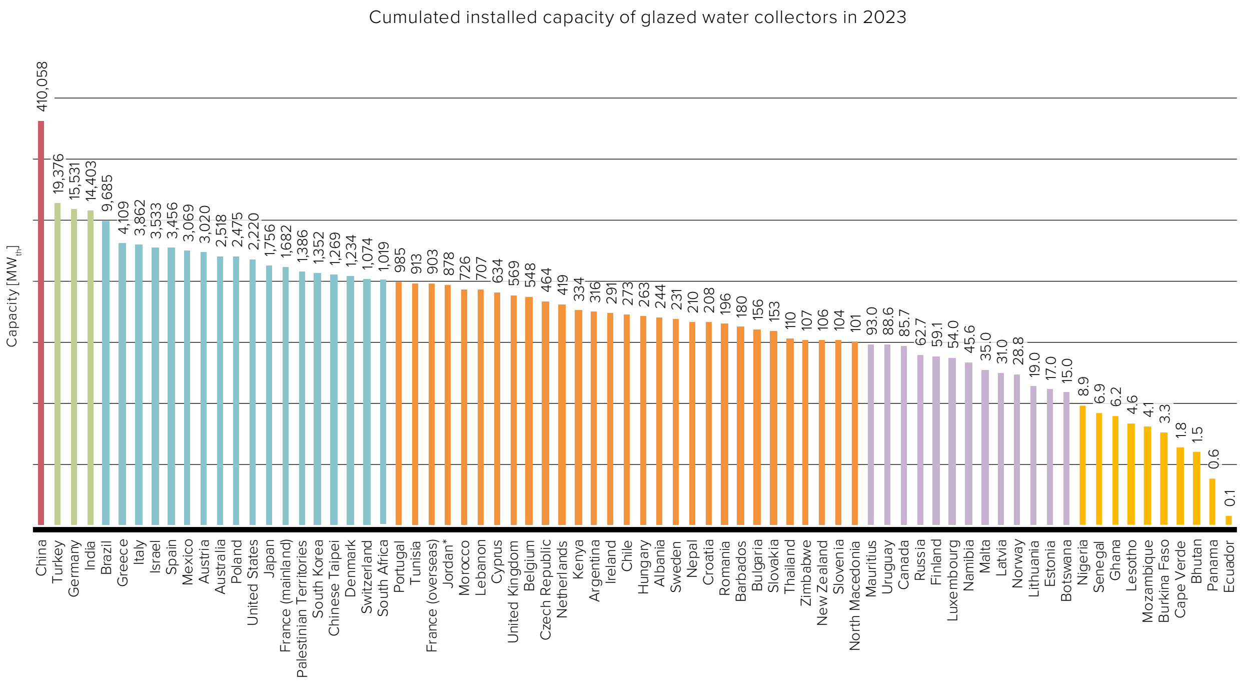


Figure 26: Total capacity of glazed water collectors in operation by the end of 2023

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 large European markets in Germany, Turkey, Denmark, and Spain (Figure 26)

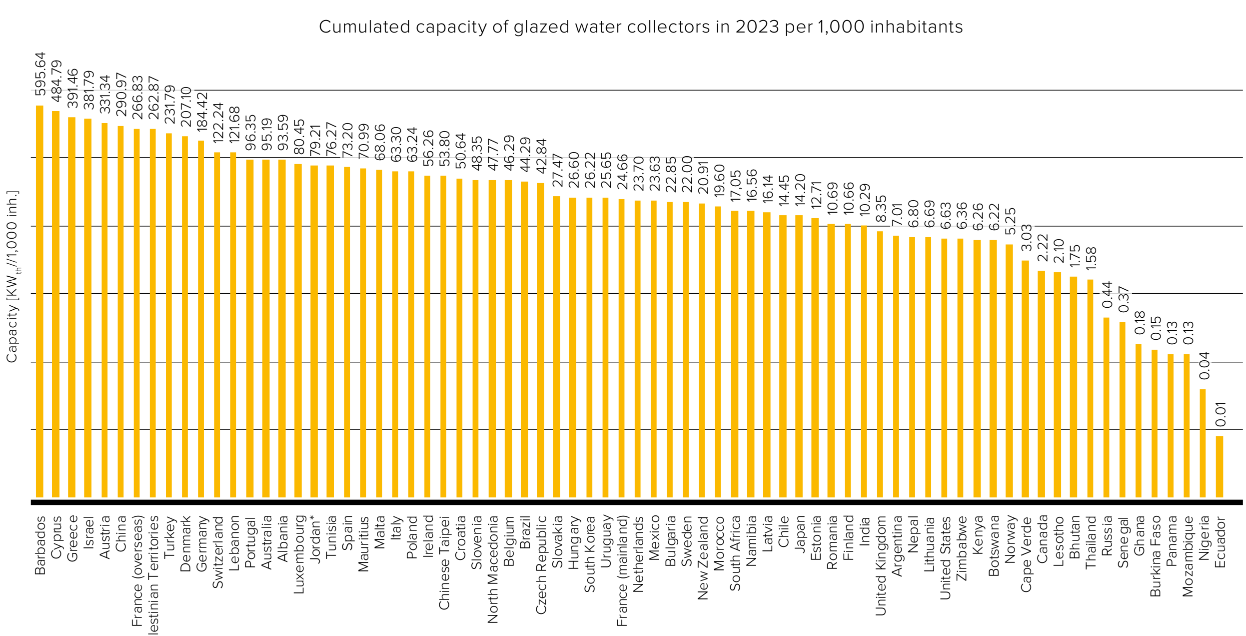


Figure 27: Total Capacity of glazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2023

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

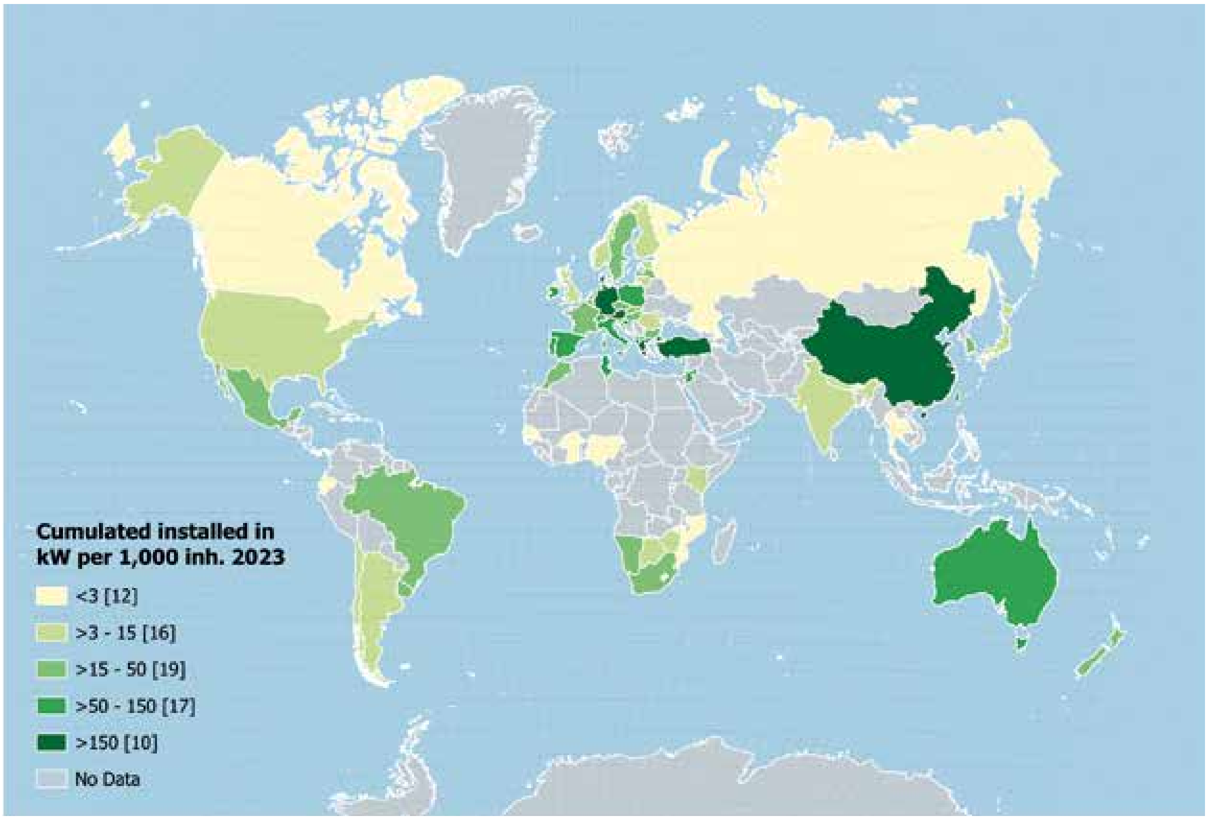


Figure 28: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants, glazed water collectors – WORLD

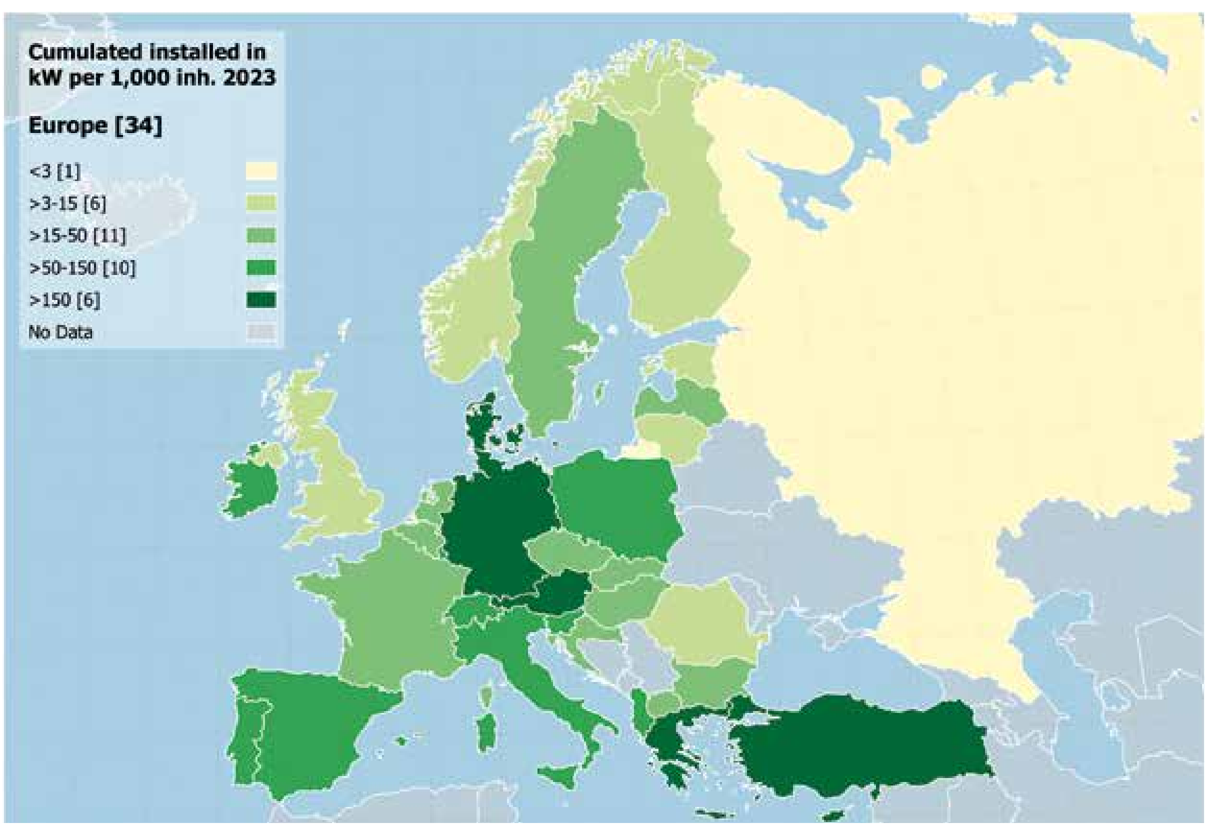


Figure 29: Solar thermal market penetration per capita in kW_{th} per 1,000 inhabitants, glazed water collectors – EUROPE

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. The MENA countries and Australia surpass Europe in this regard. This is due to the market imbalance across European countries (Figure 29). Whereas some European countries like Cyprus, Austria and Greece belong to the world market leaders' group in terms of high market penetration, others like the Baltic countries have negligible solar thermal penetration.

2,230 m² solar thermal installation with heat storage for district heating in Chemnitz, Germany
Photo: GREENoneTEC Solarindustrie GmbH

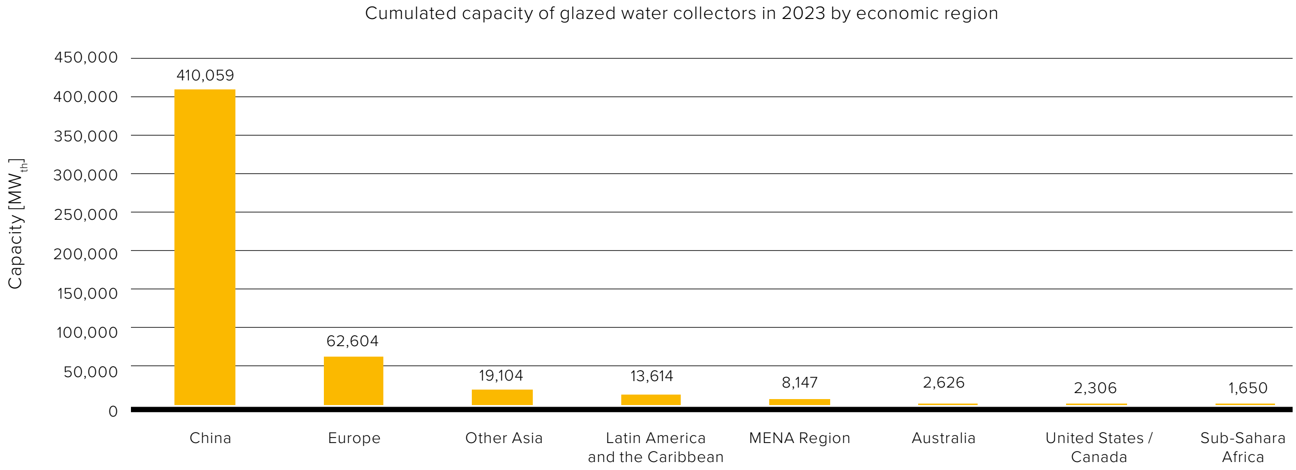


Figure 30: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region in 2023

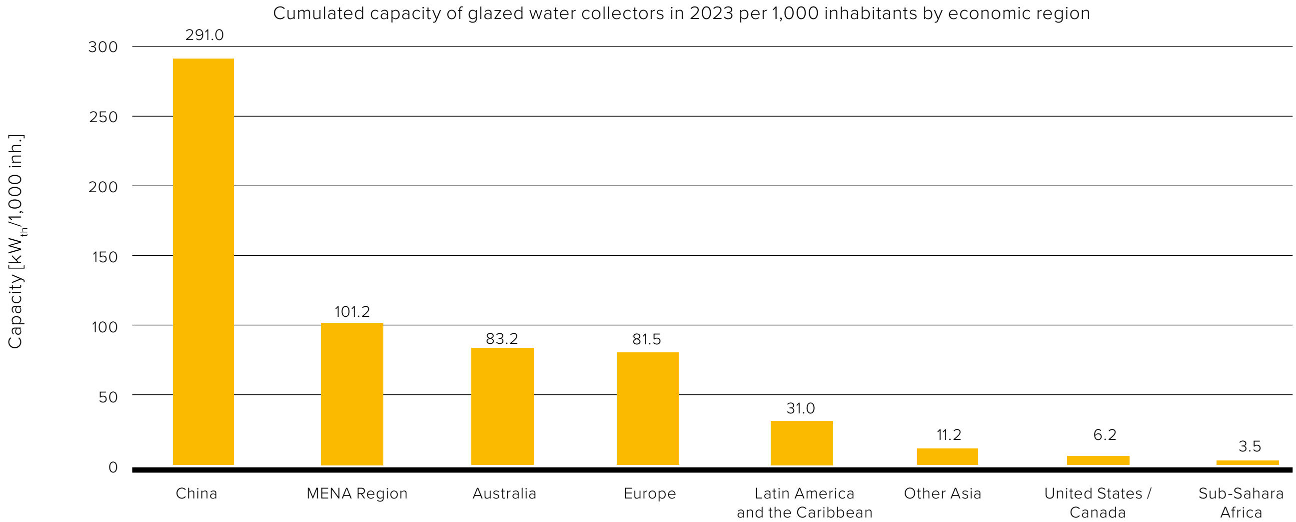


Figure 31: Total capacity of glazed flat plate and evacuated tube collectors in operation by economic region and in kW$_{th}$ per 1,000 inhabitants in 2023

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, Ecuador, 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 primary used for swimming pool heating, however this type of collector has lost a significant market share over the past decade. The percentage of unglazed water collectors in total installed collector capacity was reduced from 21% in 2005[52] to less than 6% in 2023. Figure 32 and Figure 33 show the total installed capacity of unglazed water collectors and the total installed capacity per 1,000 inhabitants at the end of 2023. The United States and Brazil are ahead with regards to total figures, whereas Australia takes the lead in total installed capacity per 1,000 inhabitants.

Thermosiphon system installed in Botswana
Photo: SOLTRAIN, AEE INTEC

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

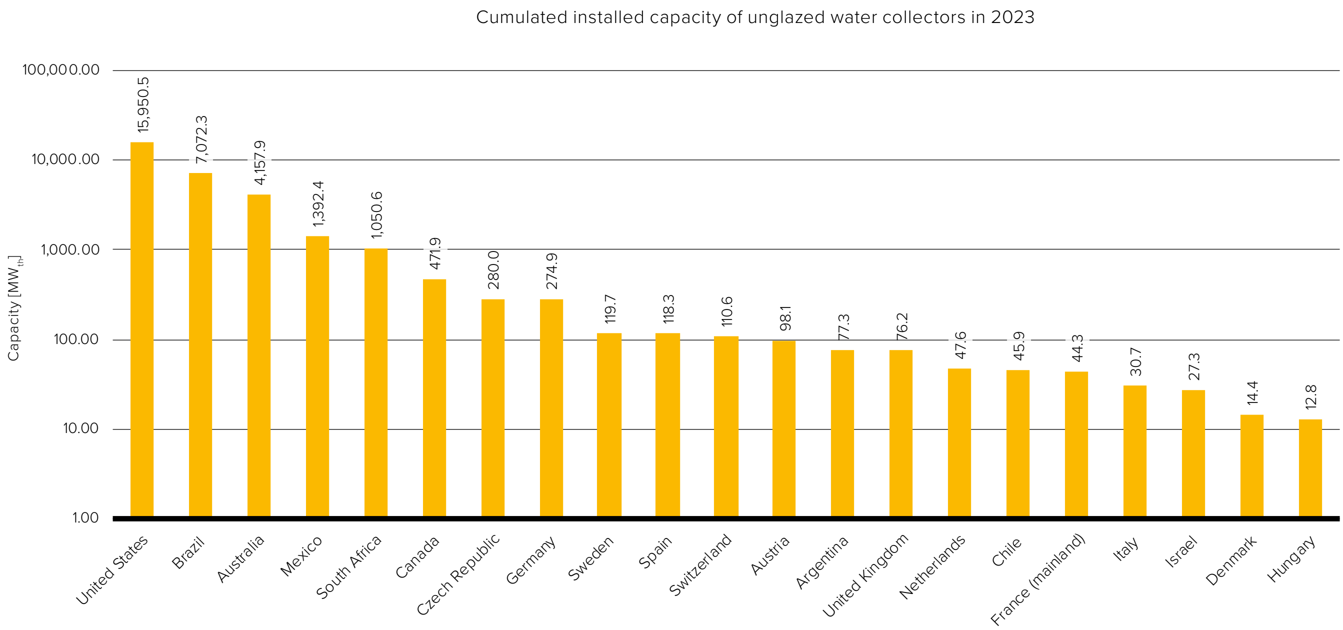


Figure 32: Total capacity of unglazed water collectors in operation in 2023

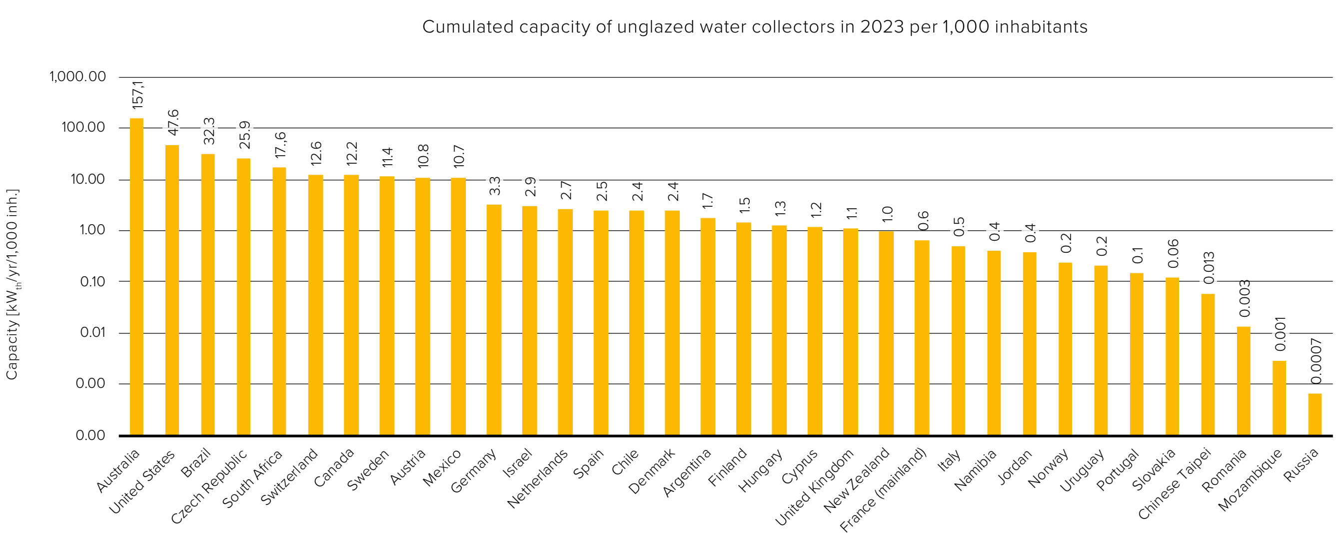


Figure 33: Total capacity of unglazed water collectors in operation in kW_{th} per 1,000 inhabitants in 2023

6.5
Newly installed capacity in 2023 and market development

In 2023, the total capacity of newly installed collectors according to figures from reporting countries was 20.8 GW_{th} corresponding to 29.7 million m^2 collector area installed.

China (13.7 GW_{th}) and Europe (2.6 GW_{th}), accounted for 78.6% of all installations in 2023. The rest of the market was shared between Latin America and the Caribbean (1.7 GW_{th}), "Other Asia" (1.4 GW_{th}), the United States and Canada (0.4 GW_{th} Australia (0.3 GW_{th}), Sub-Sahara African countries (0.2 GW_{th})) and MENA countries (0.2 GW_{th}). The market volume of "all other countries" is estimated to be 0.4 GW_{th} (502,104 m^2).

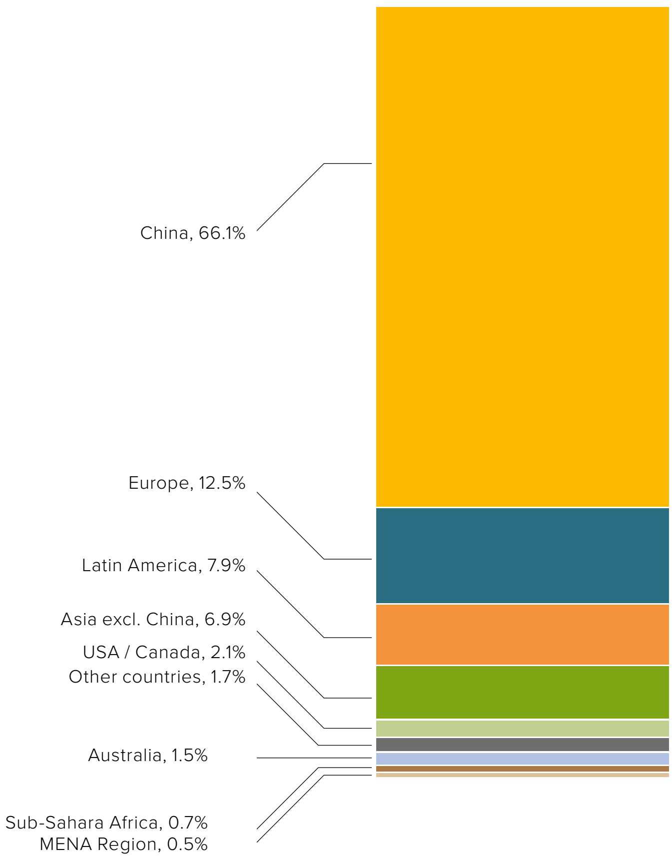


Figure 34: Share of newly installed capacity (glazed and unglazed water and air collectors) by economic regions in 2023

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, Ecuador, 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 installed in Nepal
Photo: Hans Schnitzer

Table 10: Newly installed capacity in 2023 [MW_{th}/a]

Country/Region/Economy	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania*		12.4	1.1			14
Argentina	6.6	13.4	21.0			41
Australia	231.0	69.3	12.2			312
Austria	0.7	30.7	0.9		0.9	33
Belgium		7.0	2.1			9
Bhutan		0.6	0.0			0.6
Botswana*		0.8	0.1			1
Brazil	603.6	647.5	30.2			1,281
Bulgaria		9.7				10
Canada	1.7	0.5	0.3	18.2	1.1	22
Chile		8.8				9
China		3,554.6	10,172.7	1.5		13,729
Croatia		8.7				9
Cyprus		46.7				47
Czech Republic		15.7				16
Denmark		1.4				1
Ecuador		0.1		0.0		
Estonia		0.9				1
Finland		5.2				5
France (mainland)		79.0	1.4			80
France (overseas territories)		62.4				62
Germany		187.0	76.4			263
Ghana*		0.5	0.3			1
Greece		322.5	0.2			323
Hungary		9.0				9
India		94.5	1,251.3		0.0	1,346
Ireland		0.7				1
Italy		136.0	15.4			151
Japan		46.9	0.3		0.5	48
Latvia		1.1				1
Lebanon		22.8	48.7			71
Lesotho*			0.0			0
Lithuania		1.2				1
Luxembourg		2.4				2
Malta		1.2	0.0			1
Mexico	82.8	87.9	138.4		0.2	309
Morocco			0.0			0
Mozambique			1.2			1
Namibia*		2.9	0.0			3
Nepal		3.6	32.0			36
Netherlands	1.8	14.0	8.8			25
North Macedonia		0.4	0.0			0
Norway		1.1	0.1			1
Palestinian Territories						0
Panama		0.1				0
Poland		91.2	0.4			92
Portugal		36.0	1.1			37
Romania		10.9				11
Russia		0.9	0.1		0.0	1
Slovakia		10.8				11
Slovenia		1.0	0.1			1
South Africa	35.7	24.2	60.3			120
South Korea+				0.7		1
Spain	1.3	69.6	4.6	2.5		78
Sweden		3.2				3
Switzerland	2.0	15.3	1.9			19
Tunisia*			36.6			37
Turkey		641.2	617.4			1,259
United Kingdom	3.8	4.1	2.9			11
United States	396.1	20.8		2.8		420
Uruguay*	0.4	2.1	4.6			7
Zimbabwe*			23.0			23
Other (5% of the world market excluding China)	72.0	152.0	126.1	1.3	0.1	351
TOTAL	1,440	6,595	12,694	27	3	20,758

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, Solarwall, Canada)

Table 11: Newly installed collector area in 2023 [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	9,432	19,179	30,000			58,611
Australia	330,000	98,958	17,463			446,421
Austria	1,038	43,891	1,319		1,288	47,536
Belgium		10,000	3,000			13,000
Bhutan		852	55			907
Botswana*		1,190	210			1,400
Brazil	862,311	925,065	43,080			1,830,456
Bulgaria		13,800				13,800
Canada	2,480	735	371	25,939	1,593	31,118
Chile		12,587				12,587
China		5,078,000	14,532,491	2,200		19,612,691
Croatia		12,473				12,473
Cyprus		66,740				66,740
Czech Republic		22,472				22,472
Denmark		2,000				2,000
Ecuador		205		22		227
Estonia		1,354				1,354
Finland		7,360				7,360
France (mainland)		112,885	2,000			114,885
France (overseas territories)		89,085				89,085
Germany		267,075	109,087			376,162
Ghana*		700	450			1,150
Greece		460,700	300			461,000
Hungary		12,880				12,880
India		135,065	1,787,566		10	1,922,641
Ireland		1,027				1,027
Italy		194,238	22,050			216,288
Japan		66,952	362		753	68,067
Latvia		1,564				1,564
Lebanon		32,602	69,508			102,110
Lesotho*			55			55
Lithuania		1,698				1,698
Luxembourg		3,387				3,387
Malta		1,772	8			1,780
Mexico	118,270	125,542	197,778		288	441,878
Morocco			0			0
Mozambique			1,650			1,650
Namibia*		4,094	2			4,096
Nepal		5,084	45,754			50,838
Netherlands	2,620	19,980	12,550			35,150
North Macedonia		531	26			557
Norway		1,512	82			1,594
Palestinian Territories						0
Panama		150				150
Poland		130,300	500			130,800
Portugal		51,410	1,590			53,000
Romania		15,577				15,577
Russia		1,240	156		56	1,452
Slovakia		15,456				15,456
Slovenia		1,400	200			1,600
South Africa	51,038	34,572	86,166			171,776
South Korea+				1,000		1,000
Spain	1,840	99,487	6,536	3,600		111,463
Sweden		4,600				4,600
Switzerland	2,810	21,920	2,700			27,430
Tunisia*			52,340			52,340
Turkey		916,000	882,000			1,798,000
United Kingdom	5,393	5,886	4,116			15,395
United States	565,889	29,649		4,000		599,538
Uruguay*	509	3,053	6,614			10,176
Zimbabwe*			32,898			32,898
Other (5% of the world market excluding China)	102822.6	217137.6	180114.8	1819.0	209.9	502,104
TOTAL	**2,056,452**	**9,420,752**	**18,134,787**	**38,580**	**4,198**	**29,654,769**

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, Solarwall, Canada)

The breakdown for new installations in 2023 by collector type is 6.6 GW_{th} (9.4 million m^2) flat plate collectors, 12.7 GW_{th} (18.1 million m^2) evacuated tube collectors, 1.4 GW_{th} (2.1 million m^2) unglazed water collectors and 0.03 GW_{th} (0.043 million m^2) glazed and unglazed air collectors:

Evacuated tube collectors, with a 61% share, remain the most dominant solar thermal collector technology worldwide (Figure 35).

Globally, this breakdown is driven by the dominance of the Chinese and Indian market, where approximately 74% and 93%, respectively of newly installed collectors in 2023 were evacuated tube collectors. Nevertheless, it is notable that the share of evacuated tube collectors decreased from about 82% in 2011 to 61% in 2023, while flat plate collectors increased their share from 14.7% to 32% in the same period.

In Europe, the dominant collector technology is flat plate collectors, 71.1% of all solar thermal collectors installed in 2023 were flat plate collectors (Figure 36). In Europe, the share of flat plate collectors decreased from 81.5% in 2011 to 71.1% in 2023. Driven by markets in Turkey, Poland, Switzerland, and Germany, evacuated tube collectors increased their share in Europe between 2011 and 2020 from 15.6% to 28.4%.

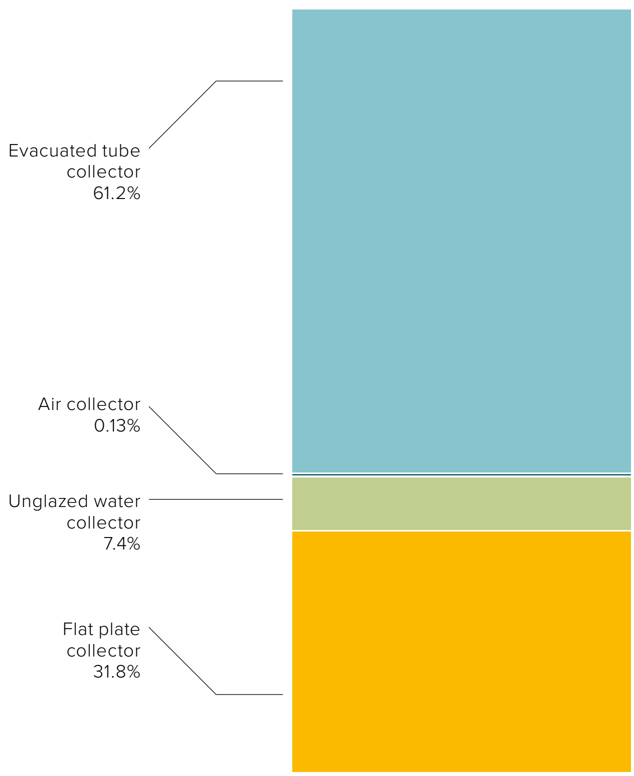


Figure 35: Distribution of newly installed capacity by collector type in 2023 – WORLD

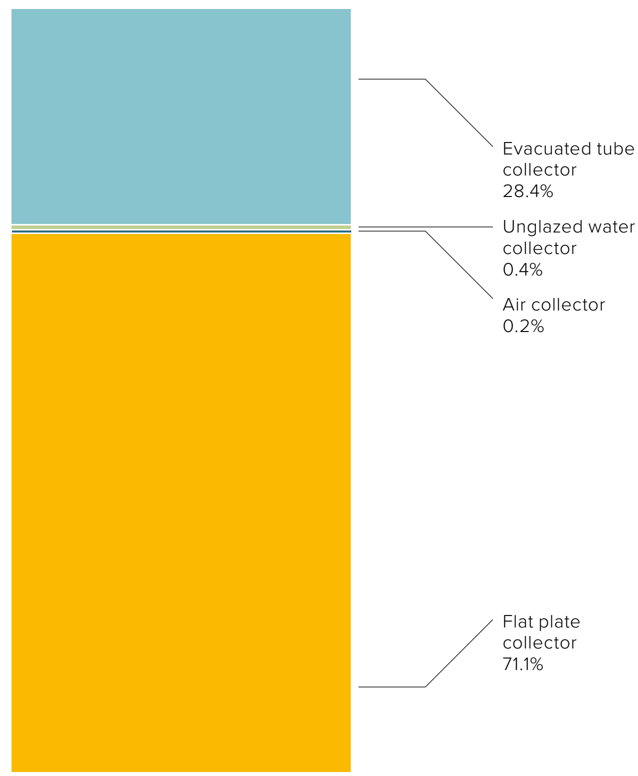


Figure 36: Distribution of newly installed capacity by collector type in 2023 – EUROPE

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

Thermosiphon systems installed at Hospital Militar de Maputo, Mozambique
Photo: SOLTRAIN, AEE INTEC

Figure 37 shows the total capacity of newly installed glazed and unglazed water collectors for the 10 leading markets in 2023. China was market leader in absolute terms, followed by India and Brazil. Turkey, and the United States rank fourth and fifth, ahead of Greece and Australia. Mexico, Germany, and Italy are among the top 10 countries, ranking eighth to tenth.

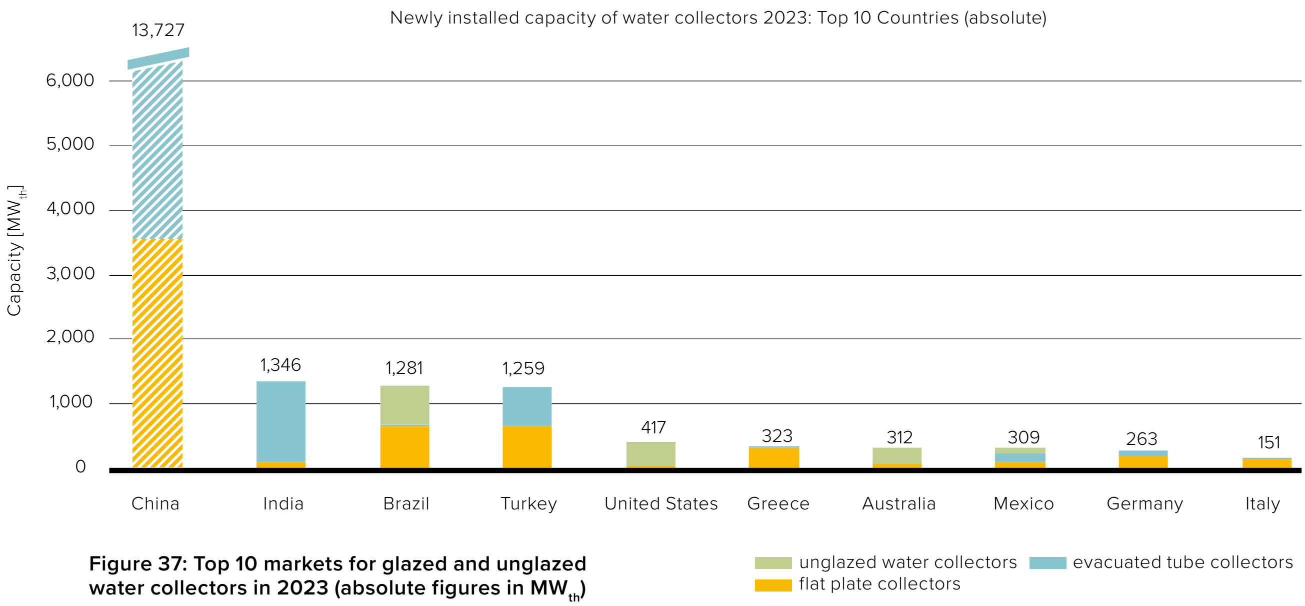


Figure 37: Top 10 markets for glazed and unglazed water collectors in 2023 (absolute figures in MW_{th})

In terms of newly installed solar thermal capacity per 1,000 inhabitants, the top 10 countries reporting new installation figures in 2023, are shown in Figure 38. Cyprus, Greece, France (overseas) and Turkey rank first to fourth, followed by Lebanon, Australia, and China, ranking fifth to seventh. Brazil, Canada and Portugal ranking eighth to tenth.

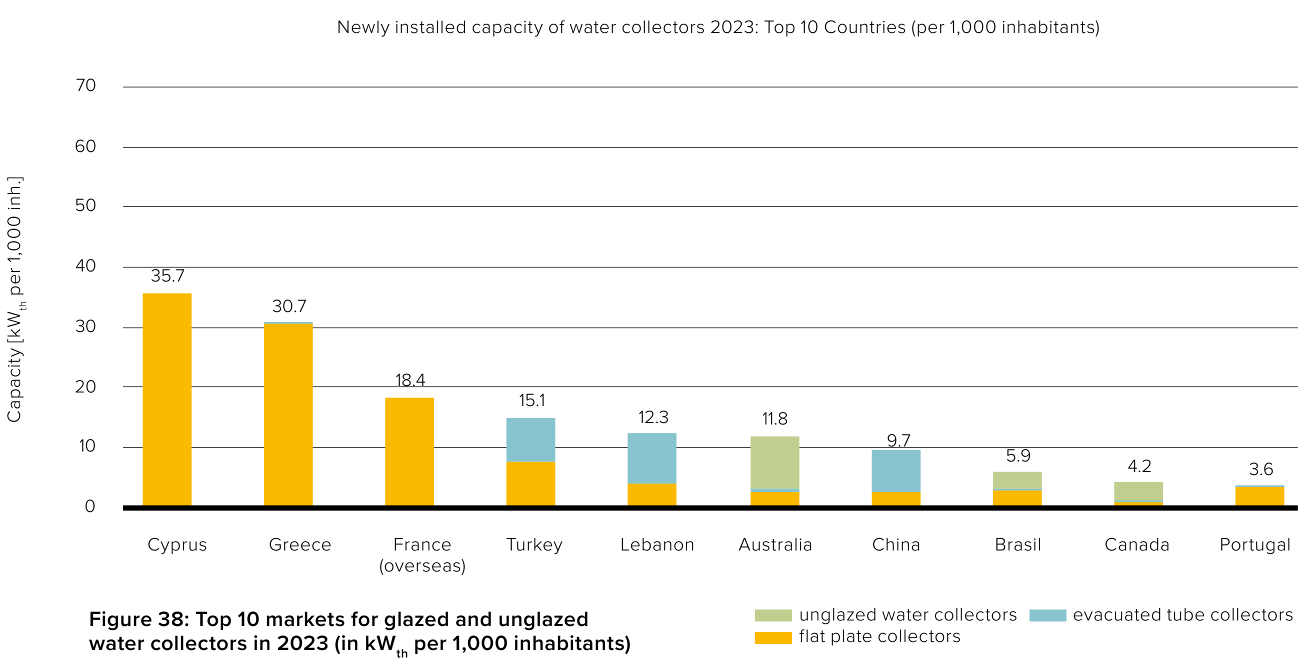


Figure 38: Top 10 markets for glazed and unglazed water collectors in 2023 (in kW_{th} per 1,000 inhabitants)

6.6
Newly installed capacity of glazed water collectors

Regarding installed collectors by system type, in 2023, 93% of the newly installed collectors were glazed water collectors, with China adding 13.7 GW_{th} in 2023. Exports are not included. (Figure 39).

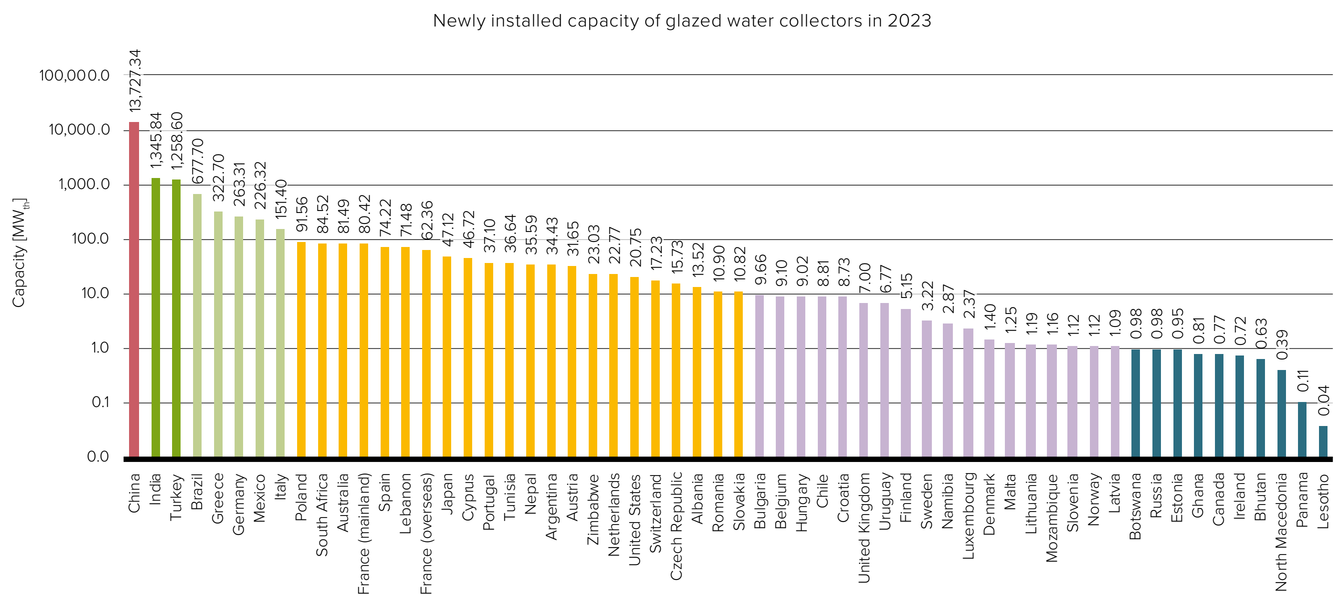


Figure 39: Newly installed capacity of glazed water collectors in 2023

The market penetration (installed glazed water collector capacity per 1,000 inhabitants) is shown in Figure 40. Cyprus ranks in front of Greece and France (overseas territories). In this respect, China ranks in 6th place.

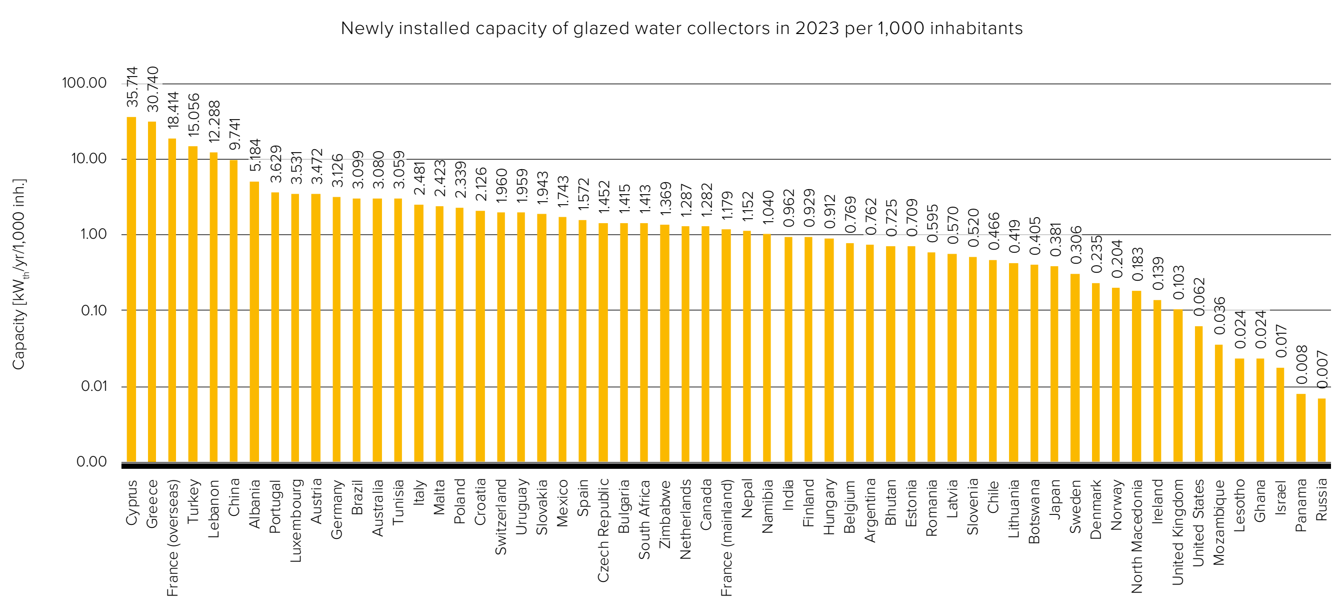


Figure 40: Newly installed capacity of glazed water collectors in 2023 in kW_{th} per 1,000 inhabitants

The following figures show the solar thermal market penetration per capita of the newly installed capacity in 2023 worldwide and in Europe.

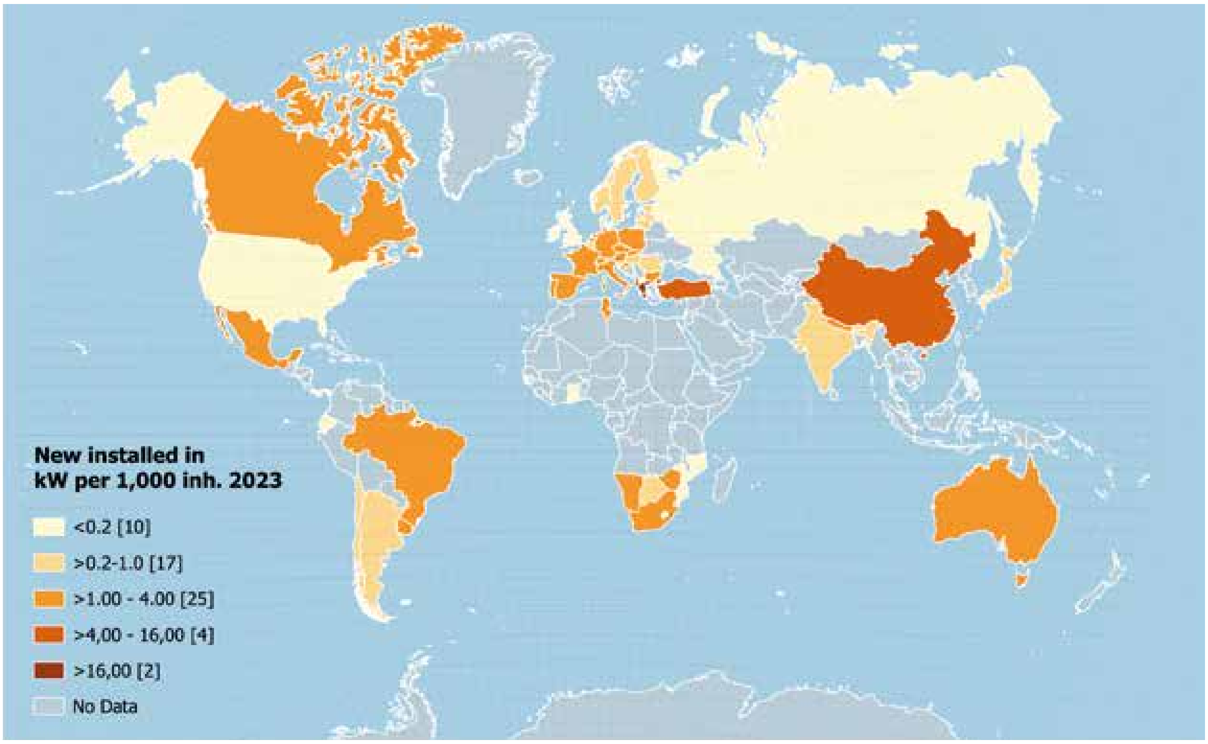


Figure 41: Newly installed capacity in 2023 in kW_{th} per 1,000 inhabitants, glazed water collectors – WORLD
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

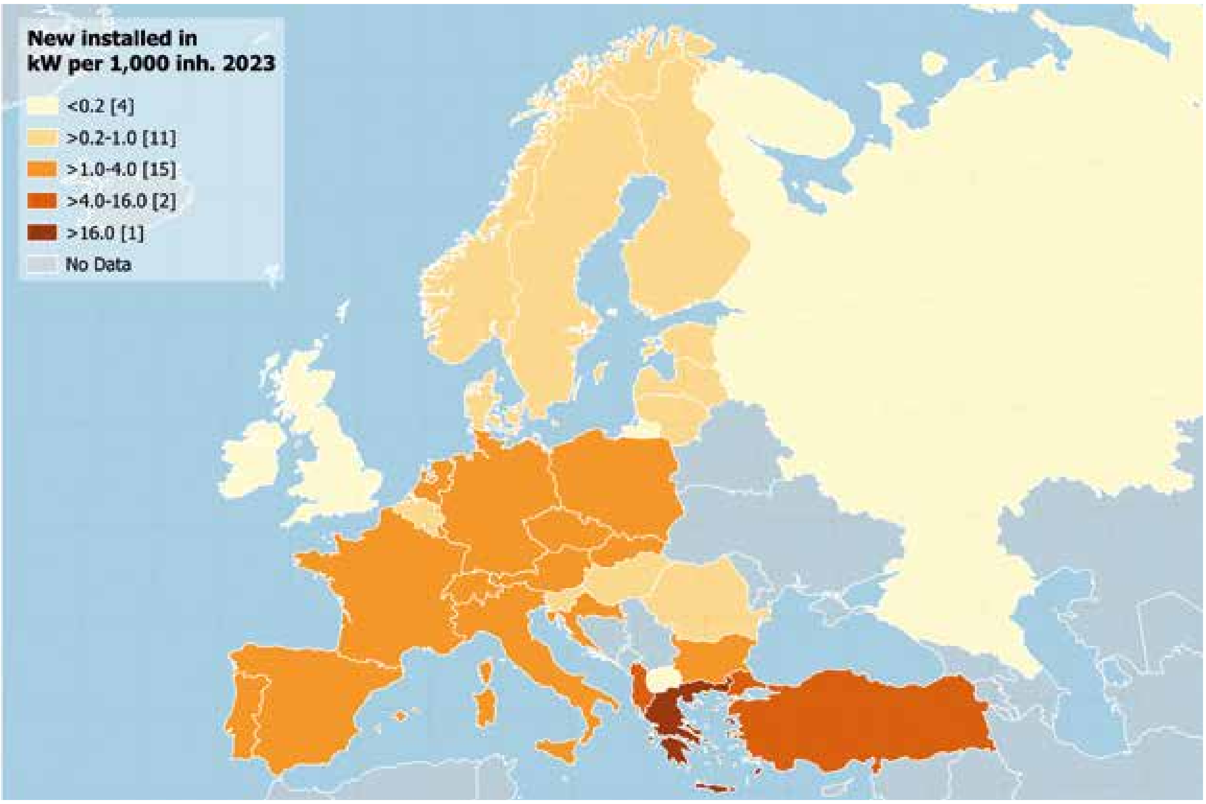


Figure 42: Newly installed capacity in 2023 in kW_{th} per 1,000 inhabitants, glazed water collectors – EUROPE
Source: Natural Earth v.4.1.0, 2020/ AEE INTEC

6.7 Market development of glazed water collectors between 2000 and 2023

The worldwide market of yearly installed glazed water collectors saw double-digit growth between 2000 and 2011 and reached a high of approximately 50 GW_{th} in 2013. From 2014 onwards, the market for glazed water collectors experienced a continuous decline, reaching 19 GW_{th} in 2023. However, the glazed collector area of newly installed in 2023 was 2.8 times the collector area installed in 2000. This illustrates a steady yearly growth rate of about 5% on average (Figure 43).

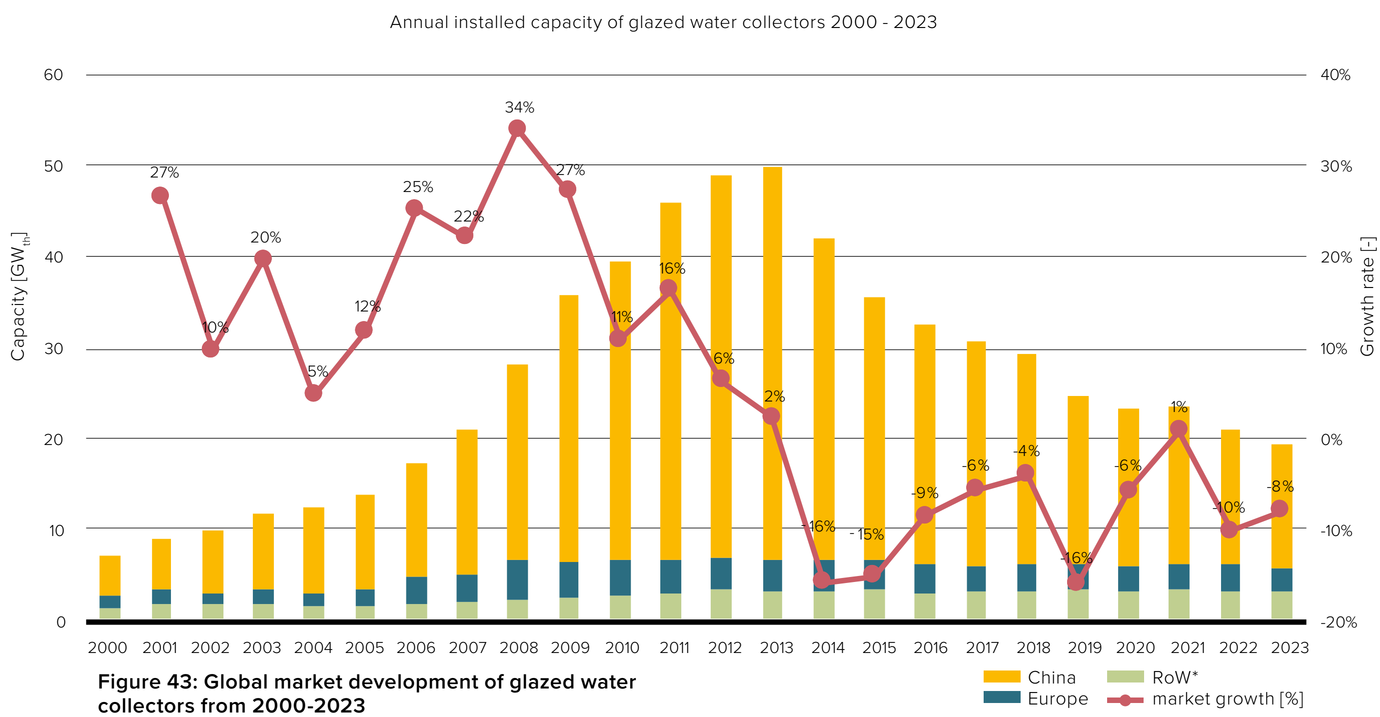


Figure 43: Global market development of glazed water collectors from 2000-2023

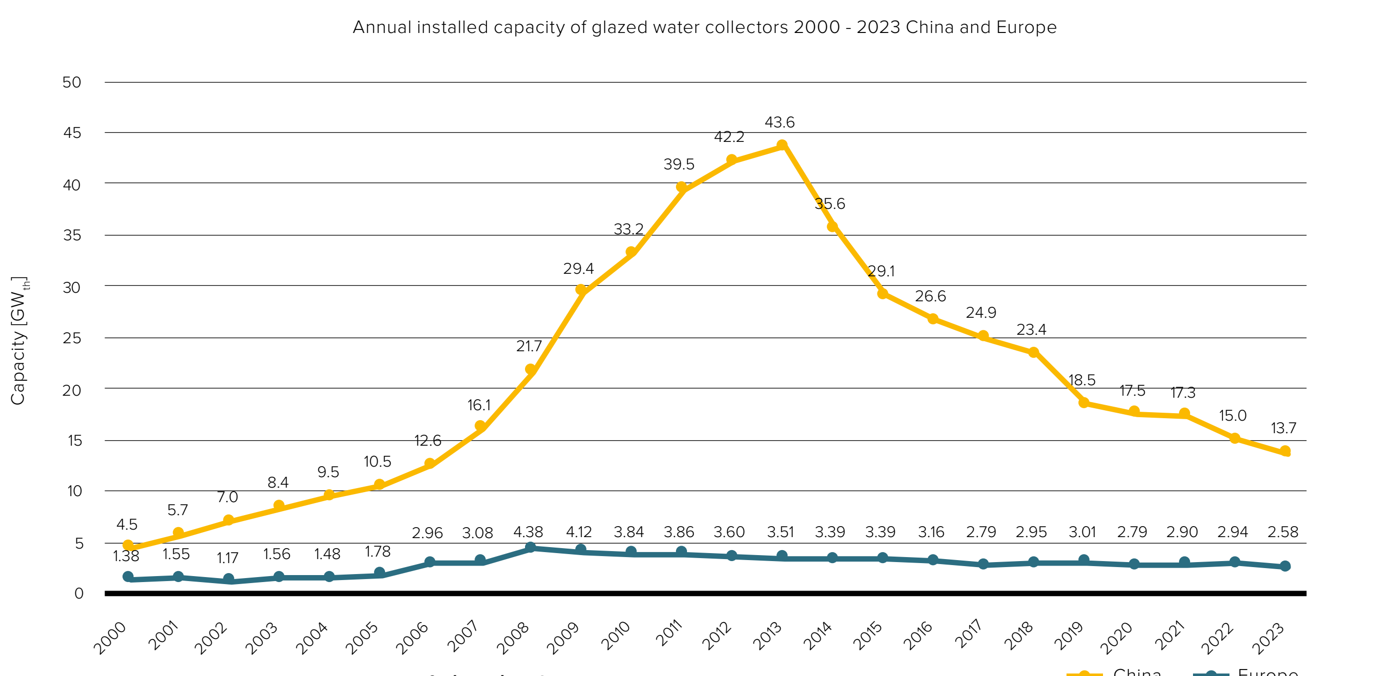


Figure 44: Market development of glazed water collectors in China and Europe from 2000-2023

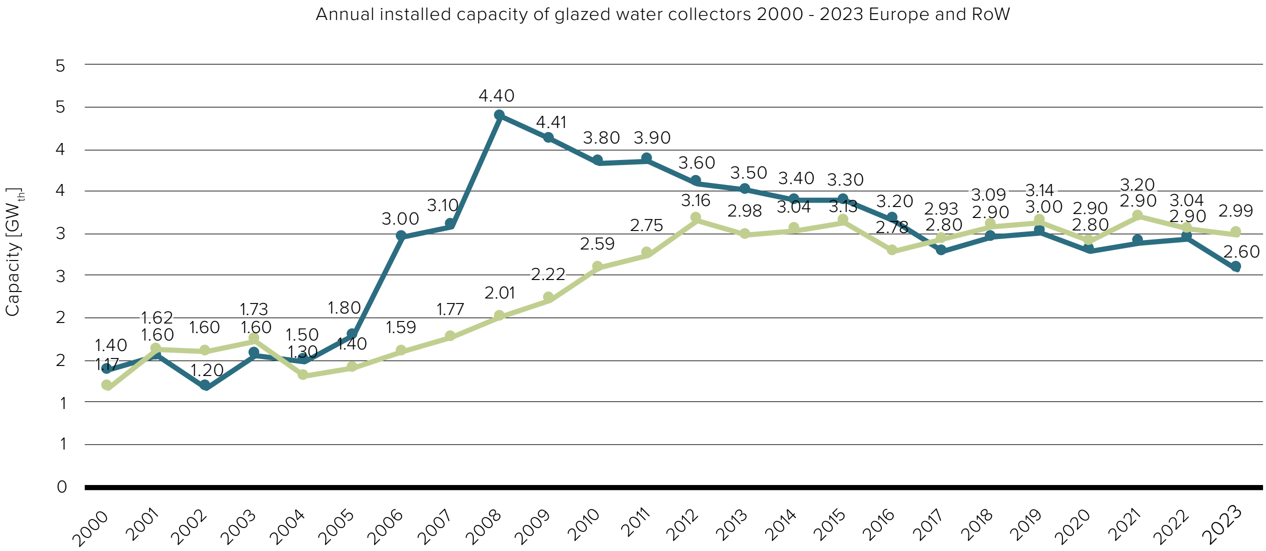


Figure 45: Market development of glazed water collectors in Europe and the rest of the world (RoW, excluding China) from 2000 to 2023

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

Figure 43 illustrates the market development in two important regions, Europe and China, from 2000 to 2023. In Europe a high was reached in 2008, followed by a continuous decline from 2009 onward. The newly installed collector area in 2023 was about 1.9 times higher than in 2000, corresponding to a yearly growth rate of about 3% on average. China experienced rapid annual growth in installed capacity since the early 2000s, with a tenfold increase in annual installed capacity by 2013 compared to 2000. However, from 2014 onwards, China has seen a continuous decline, but the newly glazed water collector area in 2023 was about three times the area of the year 2000. The yearly annual growth rate in China was about 5% on average between 2000 and 2023.

The European market peaked at 4.4 GW_{th} installed capacity in 2008 and decreased steadily to 2.8 GW_{th} in 2017. A slight increase was seen in Europe between 2017 and 2019 and again between 2021 and 2022. In the "Rest of the World" (RoW), a clear upward trend was observed between 2002 and 2012. From 2013 to 2022, this market was stable with only minor fluctuations and an annual installed capacity hovering around 3 GW_{th} (Figure 45).

The "Rest of the World" (RoW) includes all economic regions other than China and Europe. Of these regions, Asia (excluding China), Latin America, and the MENA countries hold the largest market shares (see Figure 46).

"Other Asia" is 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 difficulties 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 2023. This growth can be attributed to the dominant Brazilian market, the substantial Mexican market, and the emerging markets in countries like Chile and Argentina. In some Latin American countries, there is growing interest in the installation of solar thermal systems to produce heat for the industrial sector (mining sector, food industry) to decarbonize industries.

The glazed water collector markets in the MENA countries experienced steady growth from 2000 to 2013. However, the market decline starting in 2014, as depicted in Figure 46, can be attributed to the absence of data for two major markets, Morocco and Jordan from 2015 onwards. Additionally, sales in Israel, the key market, saw a slight decrease in 2020. Since 2021, the MENA region has witnessed a slight upward trend, primarily driven by the solar thermal markets in Lebanon and the Palestinian Territories. For 2023, few countries reported new installation figures, except Lebanon. For Tunisia 0% growth was assumed.

The Australian market saw continuous growth from 2000 to 2009. However, from 2010 to 2023, a clear and sustained decline in annual sales is evident. Australia faces intense competition with solar PV installations. Australia is one of the countries with the highest PV penetration worldwide.[53]

[53] https://task69.iea-shc.org/

Sub-Saharan African markets have grown continuously since 2000, overtaking previously strong players like Australia, the USA, Canada and there is still immense potential as penetration rates remain low. However, the upfront cost for solar thermal installations poses some challenges in these countries. A commitment by governments to support the integration of solar thermal for hot water preparation would be helpful in developing financial schemes to help overcome this barrier.

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. It is noteworthy that the database changed in 2020 for the United States, meaning that figures for evacuated tube collectors are not reported since then.

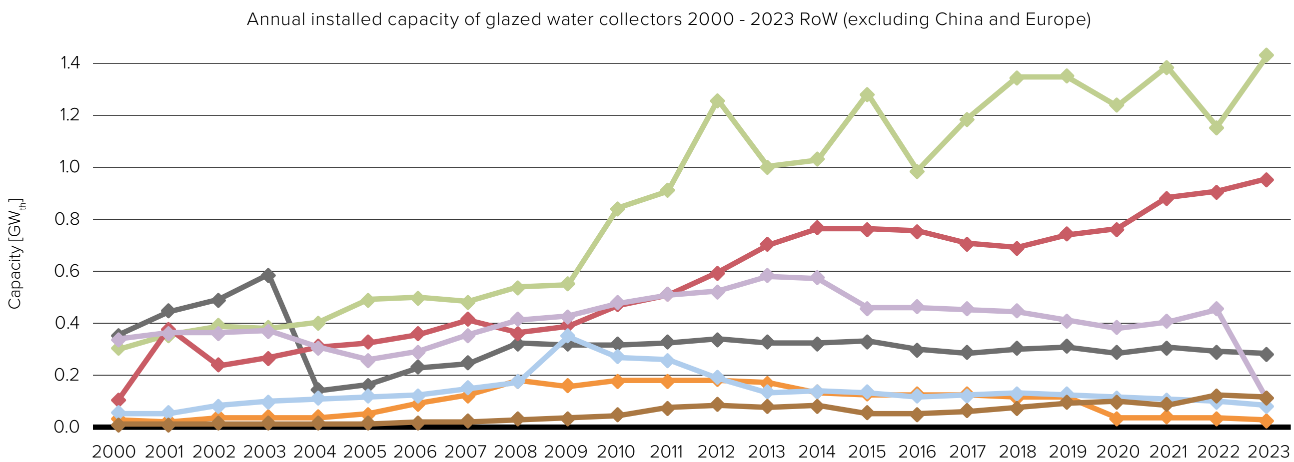


Figure 46: Market development of glazed water collectors in Latin America, United States / Canada, Sub-Sahara Africa, Other Asia, the MENA region, and Australia (excluding China and Europe) from 2000 to 2023

Other Asia: Bhutan, India, Japan, Nepal, South Korea, Chinese Taipei, Thailand
Latin America: Argentina, Brazil, Chile, Ecuador, 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

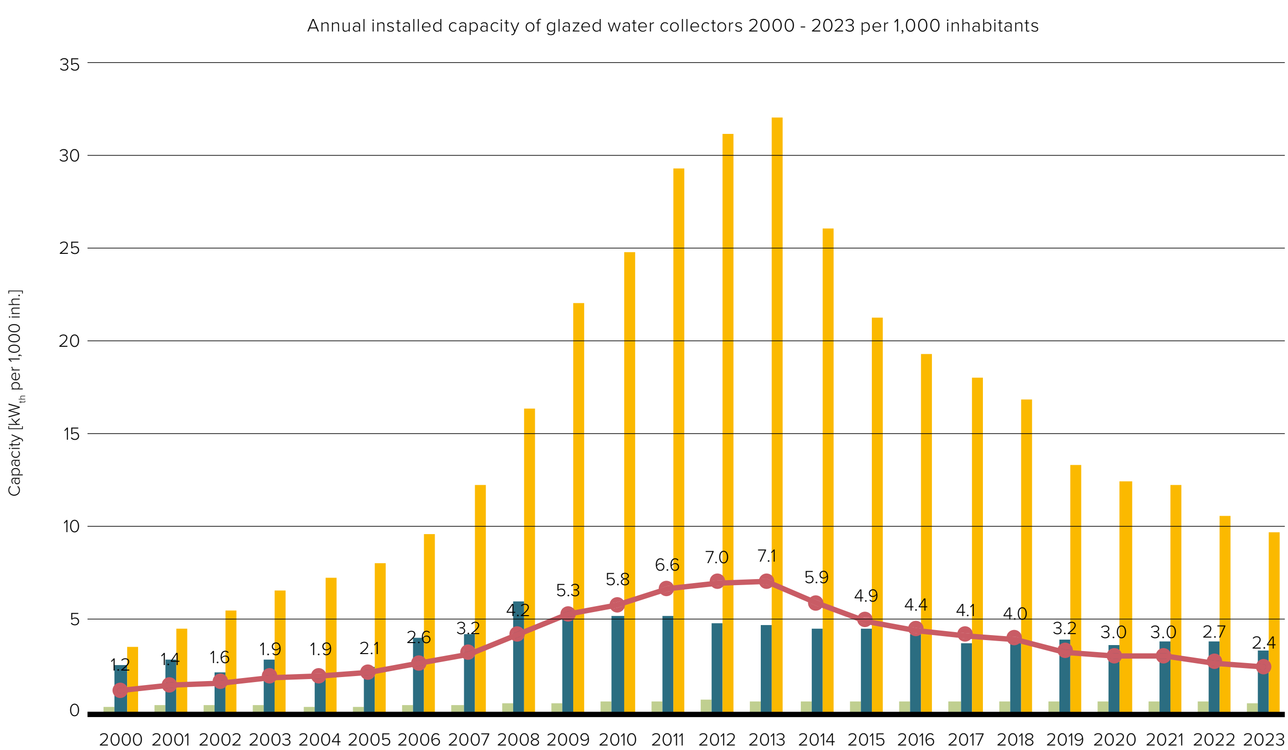


Figure 47: Annually installed capacity of glazed water collectors in kW_{th} per 1,000 inhabitants from 2000 to 2023

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 2.4 kW_{th} per 1,000 inhabitants in 2023 (Figure 47), meaning that it doubled from 2000 to 2023.

As outlined above, China and Europe have the most significant impact on markets. The fact that China suffered major market declines from 2014 to 2016 is also reflected in the market penetration of per capita glazed water collector installations. 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 9.6 kW_{th} per 1,000 inhabitants in 2023. The market apears to be saturated for systems producing DHW, however new applications in industry and district heating will support renewed growth.[54]

In Europe, market penetration peaked in 2008 at 5.9 kW_{th} per 1,000 inhabitants. The downward trend between 2009 and 2013 apears to have stabilized from 2014 onwards and was 3.4 kW_{th} per 1,000 inhabitants in 2023.

The overall global trend shows that the market doubled between 2000 and 2023.

[54] According to the information of CABR, personal communication with Bian Mengmeng.

6.8 Market development of unglazed water collectors between 2000 and 2023

The newly installed capacity of unglazed water collectors was 1.4 GW_{th} in 2023, accounting for 6% of the total installed solar thermal capacity (Figure 35). Compared to 2023, the market decreased by -14.6% because of decreases in the large markets Brazil (-6.3%), Australia (-5.7%) and the Unites States (-32.4%). Mexico and South Africa saw a market increase (5.0% and 24.0% respectively).

The most important markets for unglazed water collectors in 2023 were the United States (396 MW_{th}), Brazil (604 MW_{th}), and Australia (231 MW_{th}). Mexico reported 83 MW_{th} installed unglazed water collector area and South Africa 36 MW_{th}. The capacity installed in these countries accounted for 94% of the recorded unglazed water collector installations worldwide. Switzerland (2.0 MW_{th}), Spain (1.3 MW_{th}), and the Netherlands (1.8 MW_{th}) also reported unglazed water collector installations in 2023.

The unglazed water collector market in the United States peaked in 2006 (1.01 GW_{th}) and has almost halved since (0.47 GW_{th} in 2019). The annual global market for unglazed water collectors has remained almost 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.

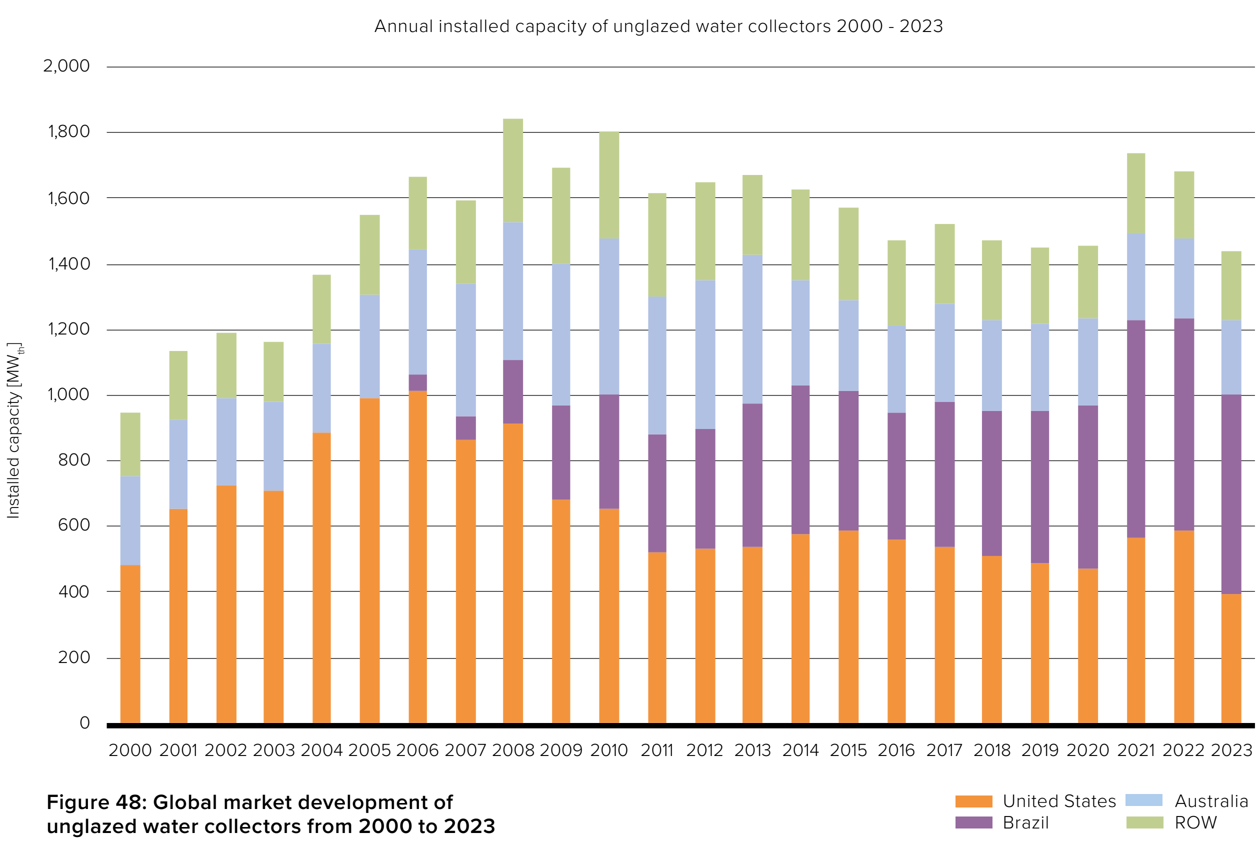


Figure 48: Global market development of unglazed water collectors from 2000 to 2023

7 Contribution to the energy supply and CO_2 reduction in 2023

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 2023, the annual collector yield of all water-based solar thermal systems for the simulated applications swimming pools, DHW for single-family houses, DHW for multi-family houses, and solar combi-systems is 455 TWh (= 1,640 PJ). This corresponds to a final energy savings equivalent to 49 million tons of oil and 155 million tons of CO_2. The calculated number of solar thermal systems in operation is around 126 million (Table 12). The CO_2 emissions saved by the thermal solar systems in operation is about 155 million t/a.

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 0.8 GW_{th} contribution of the total installed air collector capacity in operation in 2023 is omitted from the calculation due to its small 0.1% 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, distinct types of collectors, applications and characteristic climatic conditions are considered for each country. A more detailed description of the methodology can be found in the appendix (see Chapter 9).

Table 12 summarizes the calculated annual collector yields and the corresponding oil equivalents and CO_2reductions of all water-based solar thermal systems in 2023.

* 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 12: Calculated annual collector yield and corresponding oil equivalent and CO_2 reduction of glazed and unglazed water collectors in operation by the end of 2023

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++	348,805	244	32,502	244	877	26,178	82,854
Argentina	563,056	394	227,383	374	1,347	40,224	127,309
Australia	9,538,200	6,677	1,078,967	5,790	20,843	622,290	1,969,548
Austria	4,455,298	3,119	479,521	1,847	6,649	198,499	628,250
Barbados+	258,192	181	59,797	227	817	24,400	77,226
Belgium	783,000	548	134,320	310	1,115	33,295	105,379
Bhutan	2,191	2	367	2	6	164	520
Botswana++	21,475	15	3,508	20	72	2,164	6,848
Brazil	23,938,999	16,757	6,511,758	14,940	53,785	1,605,801	5,082,360
Bulgaria	222,857	156	40,641	112	402	12,008	38,006
Burkina Faso+	4,681	3	296	4	16	469	1,484
Canada	796,520	558	33,025	406	1,460	43,595	137,978
Chile	455,591	319	181,188	329	1,183	35,308	111,751
China	585,798,412	410,059	111,706,977	319,996	1,151,984	34,393,326	108,854,876
Croatia	297,143	208	54,188	152	547	16,335	51,699
Cyprus	908,154	636	396,826	807	2,906	86,747	274,555
Czech Republic	1,062,812	744	96,785	365	1,313	39,196	124,056
Denmark	1,784,286	1,249	106,674	745	2,681	80,032	253,301
Estonia	24,286	17	4,429	10	36	1,066	3,375
Finland	96,246	67	15,059	37	135	4,029	12,753
France (mainland)	2,467,040	1,727	534,991	1,207	4,344	129,703	410,512
France (overseas)	1,290,870	904	305,934	1,049	3,776	112,735	356,806
Germany	22,581,217	15,807	2,666,665	9,213	33,167	990,233	3,134,088
Ghana++	8,828	6	463	8	29	855	2,707
Greece	5,870,500	4,109	1,643,104	4,168	15,005	447,987	1,417,879
Hungary	394,014	276	54,707	184	661	19,738	62,471
India	20,576,210	14,403	9,578,046	17,947	64,608	1,928,928	6,105,058
Ireland	416,368	291	96,361	174	628	18,737	59,302
Israel+++++	5,087,434	3,561	1,682,448	4,756	17,123	511,220	1,618,012
Italy	5,561,908	3,893	1,005,419	3,431	12,353	368,817	1,167,305
Japan	2,509,834	1,757	607,332	1,452	5,228	156,101	494,059
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	44,286	31	8,076	19	69	2,056	6,507
Lebanon	1,011,180	708	214,297	867	3,122	93,218	295,036
Lesotho	6,633	5	1,894	6	21	628	1,989
Lithuania	27,119	19	4,946	12	42	1,241	3,929
Luxembourg	77,167	54	14,073	33	120	3,569	11,295
Malta	50,000	35	20,000	43	156	4,664	14,762
Mauritius**	132,793	93	88,529	113	408	12,183	38,558
Mexico	6,374,297	4,462	801,823	3,764	13,551	404,586	1,280,514
Morocco+++++	1,038,000	727	145,789	895	3,221	96,168	304,370
Mozambique	5,963	4	868	5	17	519	1,644
Namibia	66,765	47	8,055	60	217	6,488	20,535
Nepal++++	300,000	210	145,165	244	880	26,258	83,108
Netherlands	667,280	467	147,394	269	967	28,867	91,364
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	145,593	102	33,442	90	326	9,718	30,759
Palestinian Territories	1,980,900	1,387	708,103	1,877	6,756	201,693	638,359
Poland	3,536,490	2,476	533,955	1,417	5,099	152,246	481,860
Portugal	1,409,273	986	256,215	1,090	3,922	117,102	370,629
Romania	280,340	196	51,074	158	567	16,929	53,580
Russia	89,667	63	16,667	39	140	4,172	13,206
Senegal+	9,824	7	2,448	10	34	1,029	3,258
Slovakia	219,571	154	28,010	104	374	11,167	35,343
Slovenia	148,870	104	23,266	62	225	6,717	21,261
South Africa	2,956,971	2,070	741,442	2,221	7,995	238,685	755,437
South Korea	1,932,096	1,352	446,134	1,006	3,621	108,104	342,151
Spain	5,106,938	3,575	610,520	3,581	12,891	384,862	1,218,088
Sweden	502,111	351	36,028	181	653	19,498	61,710
Switzerland	1,693,600	1,186	220,237	684	2,464	73,556	232,804
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++	1,304,941	913	383,499	1,171	4,214	125,817	398,209
Turkey	27,680,458	19,376	6,394,186	24,833	89,399	2,669,062	8,447,582
United Kingdom	921,661	645	200,738	359	1,291	38,556	122,030
United States	25,958,118	18,171	402,006	10,933	39,360	1,175,135	3,719,303
Uruguay	127,607	89	26,611	86	309	9,235	29,228
Zimbabwe++	152,934	107	62,129	130	469	14,002	44,317
Other (5% of world market excluding China)	10,642,892	7,450	1,582,152	5,796	20,867	622,992	1,971,769
TOTAL	798,652,616	559,057	125,526,914	455,429	1,639,543	48,949,756	154,925,978

8 Distribution of systems by type and application in 2023

8.1 Distribution by type of solar thermal collector

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, and others such as heating of industrial processes, solar district heating or solar thermal cooling).

In terms of the total water collector capacity worldwide in 2023, evacuated tube collectors dominated with 69% of the cumulated capacity in operation (Figure 49) and a share of 61.2% of the newly installed capacity (Figure 50). Worldwide, flat plate collectors accounted for about 25% of the cumulated capacity in operation (Figure 49) and a 31.8% share of the newly installed capacity (Figure 50). Unglazed water collectors accounted for 6% of the cumulated water collectors installed worldwide and 6.9% of the newly installed capacity.

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

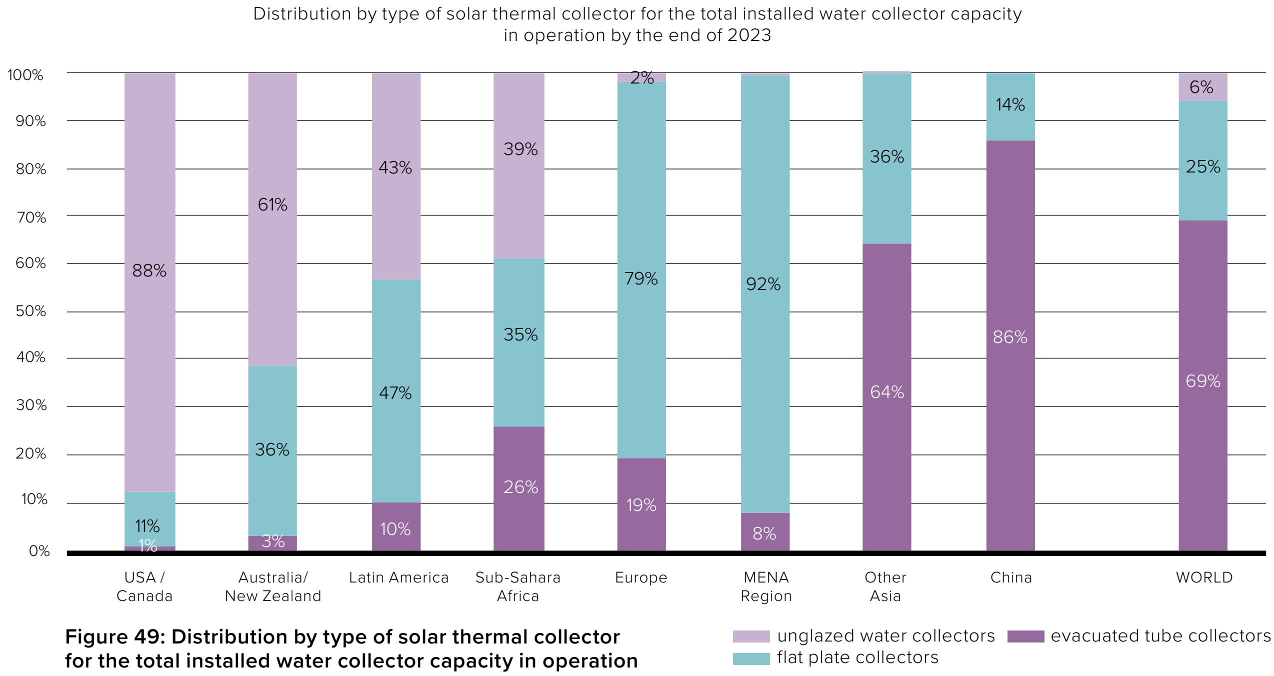


Figure 49: Distribution by type of solar thermal collector for the total installed water collector capacity in operation by the end of 2023

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

The distribution of the newly installed collector area is shown below. Evacuated tube collectors dominate in China, Other Asia, driven by development in India, and with an increasing share in Sub-Sahara Africa.

Unglazed collectors dominate in North America and Australia. Flat plate collectors dominate in Latin America, Europe, and the MENA region.

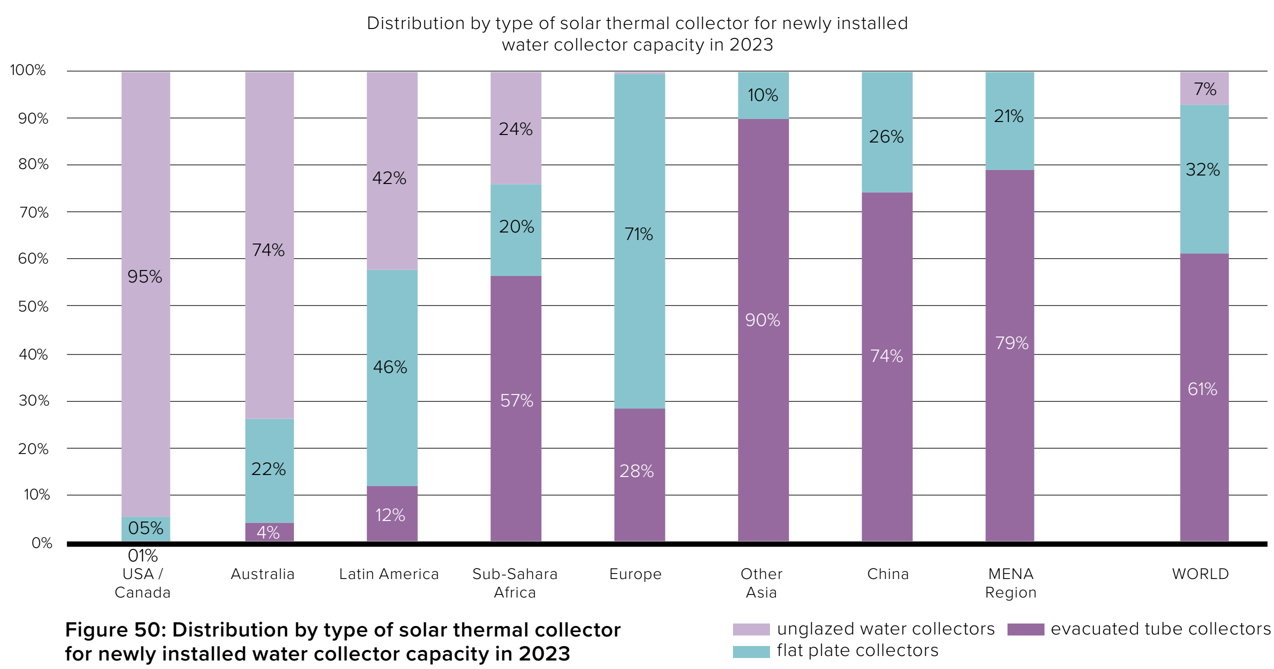


Figure 50: Distribution by type of solar thermal collector for newly installed water collector capacity in 2023

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

Photo: SOLTRAIN, AEE INTEC

8.2 Distribution by type of system

Worldwide, about 53% of all solar thermal systems installed are thermosiphon systems; the balance are pumped solar heating systems (Figure 51).

Like the distribution by type of solar thermal collector in total numbers, the Chinese market influences the overall figures the most. In China 24% of all newly installed systems were thermosiphon systems, while pumped systems accounted for 76%. The share of thermosiphon systems has decreased in China for several years (Figure 52).

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

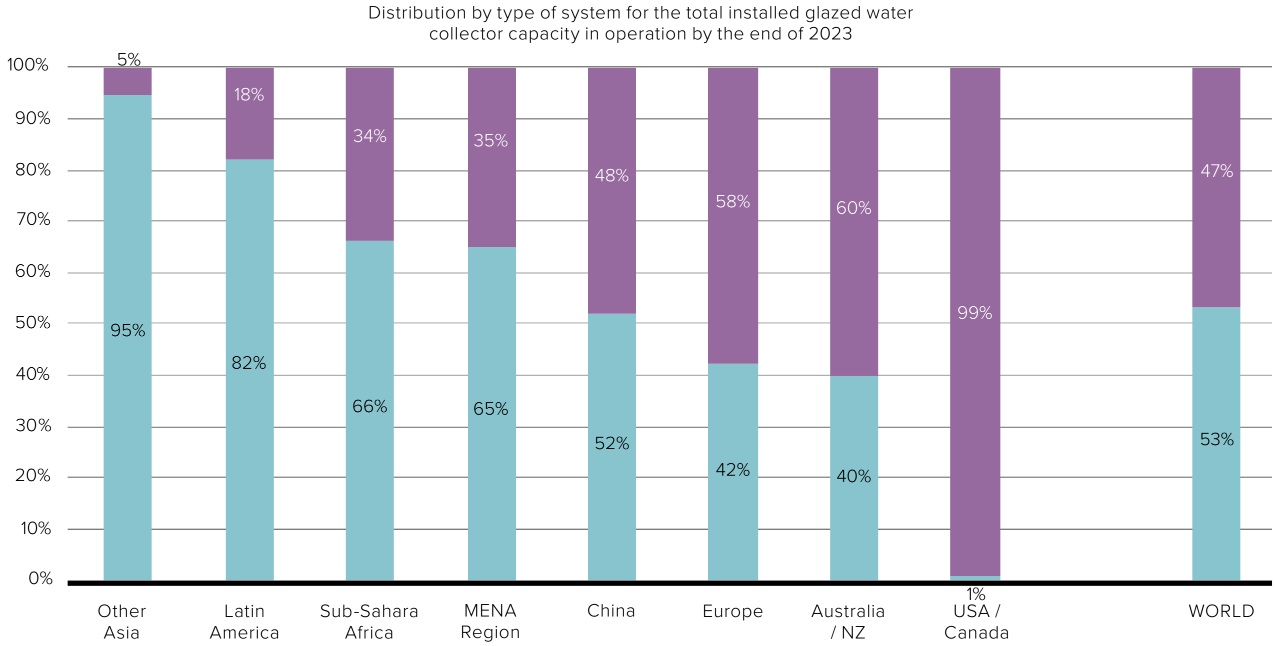


Figure 51: Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2023

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

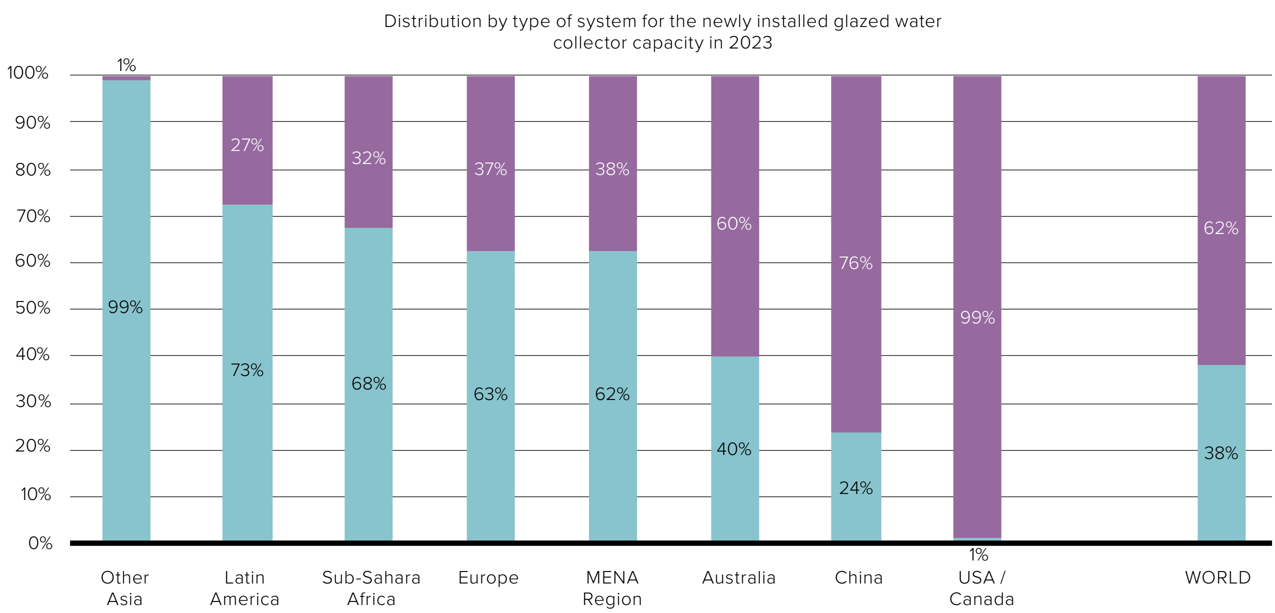


Figure 52: Distribution by type of system for the newly installed glazed water collector capacity in 2023

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, Ecuador, 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 2023 is 29.7 million, corresponding to 20.8 GW_{th} of thermal peak capacity (Table 10).

The largest share of collector area installed in 2023 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 35% of installations in 2023, while the share of swimming pool heating was 7%. The share for other applications, such as solar district heating and solar process heat, was about 6% globally (Figure 53).

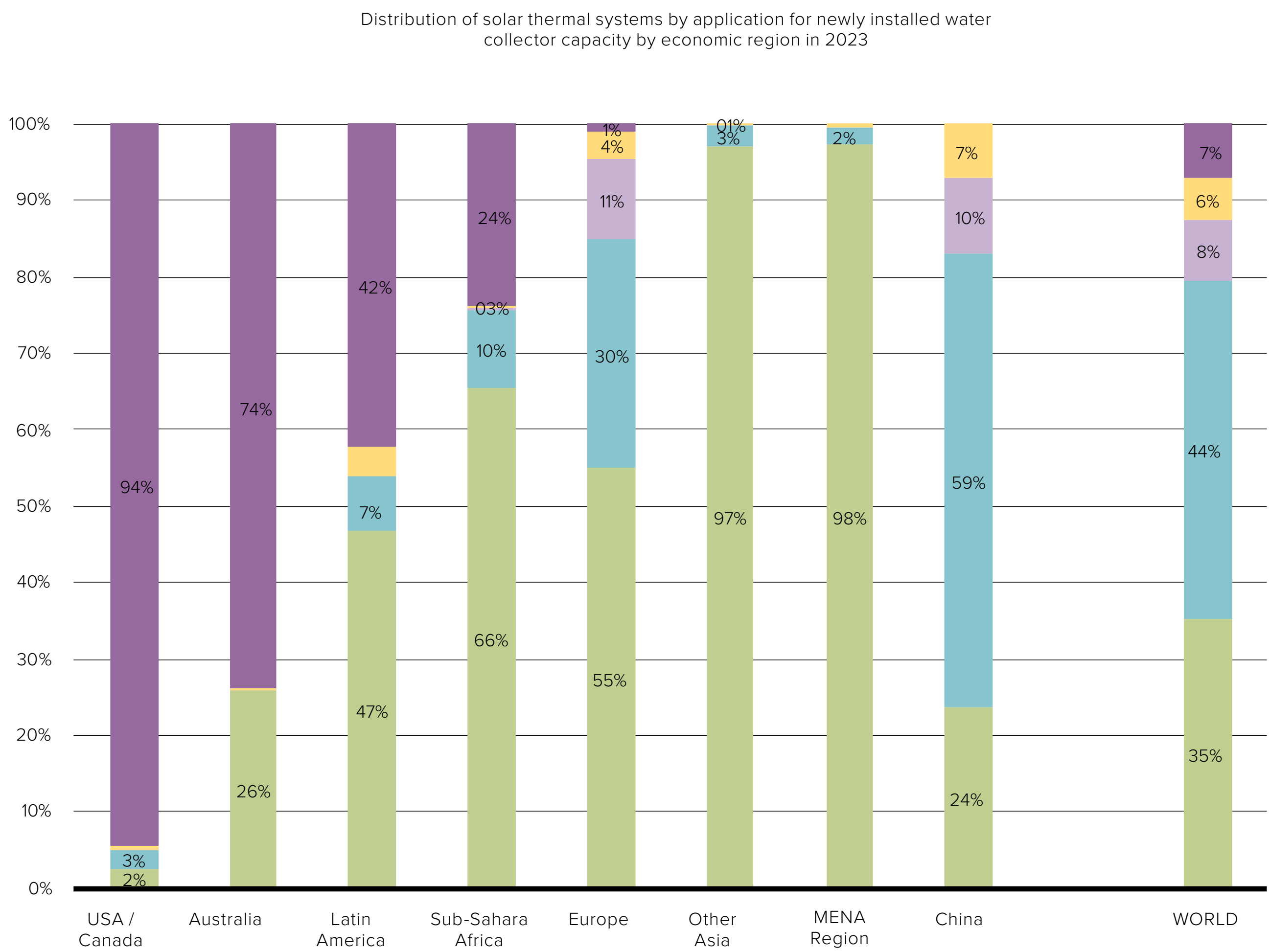


Figure 53: Distribution of solar thermal systems by application for newly installed water collector capacity by economic region in 2023

- Swimming pool heating
- Other (solar district heating, solar processheat, solar cooling)
- Solar combi-systems (DHW and space heating for single-family and multi-family houses)
- Large DHW systems (multi-family houses, tourism and public sector)
- Domestic hot water systems for single-family houses

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, Ecuador, 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 method 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 given 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 DHW 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 found 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 found. 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.[55]

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.[56] 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 decided for each country. Since this could only be done in a 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 replace systems running on oil. This is 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.[57] Furthermore, a hydraulic scheme is shown for each reference system.

[55] 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

[56] Source: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020 (07/05/2024)

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

9.1.1
Reference systems for swimming pool heating

Table 13 refers to the total capacity of water collectors in operation used for swimming pool heating as reported from each country by the end of 2023.

Table 13: Solar thermal systems for swimming pool heating in 2023

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	174,547	2	87,274	470
Australia	Sydney	1,674	5,970,913	35	170,598	466
Austria	Graz	1,126	165,799	200	829	283
Belgium	Brussels	971	47,763	200	239	261
Brazil	Brasília	1,793	9,431,966	32	294,749	375
Canada	Montreal	1,351	363,213	25	14,529	386
Chile	Santiago de Chile	1,753	65,507	15	4,367	471
Cyprus	Nicosia	1,886	2,452	200	12	507
Czech Republic	Praha	998	469,763	200	2,349	303
Finland	Helsinki	948	13,859	200	69	256
France (mainland)	Paris	1,112	63,156	200	316	328
Germany	Würzburg	1,091	532,917	30	17,764	314
Hungary	Budapest	1,199	19,307	10	1,931	344
India	New Delhi	1,961	2,058	16	129	527
Israel	Jerusalem	2,198	40,699	200	203	568
Italy	Bologna	1,419	50,057	200	250	442
Jordan	Amman	2,145	6,661	200	33	578
Lebanon	Beirut	1,935	2,022	40	51	520
Mexico	Mexico City	1,706	1,986,079	200	9,930	311
Mozambique	Maputo	1,910	322	40	8	514
Namibia	Windhoek	2,363	1,936	40	48	636
Netherlands	Amsterdam	999	89,178	40	2,229	272
New Zealand	Wellington	1,401	7,024	200	35	378
Norway	Oslo	971	1,795	200	9	316
Poland	Warsaw	1,024	70,730	20	3,536	276
Portugal	Lisbon	1,686	2,819	200	14	421
Romania	Bucharest	1,324	280	200	1	356
Russia	Moscow	996	341	200	2	268
Slovakia	Bratislava	1,214	1,098	200	5	327
Slovenia	Ljubjana	1,115	1,489	200	7	300
South Africa	Johannesburg	2,075	1,499,184	21.6	69,407	505
Spain	Madrid	1,644	173,636	200	868	472
Sweden	Gothenburg	934	164,692	200	823	295
Switzerland	Zürich	1,094	172,747	200	864	277
Chinese Taipei	Taipei	1,372	1,997	175	11	319
United Kingdom	London	943	148,387	20	7,419	254
United States	LA, Indianapolis	1,646	22,791,228	200	113,956	387
Uruguay	Montevideo	1,534	510	200	3	413
Other (5%)		1,449	2,386,129	200	11,931	392
TOTAL			46,924,261		816,800	
AVG		1,454		132		393

Figure 54 shows the hydraulic scheme of the swimming pool reference system used for the simulations of solar energy yields.

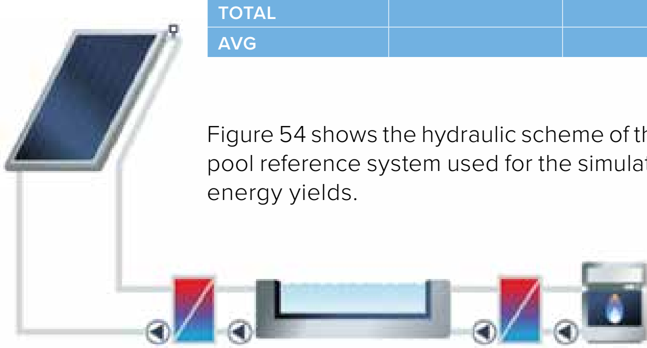


Figure 54: Hydraulic scheme of the swimming pool reference system

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

The information in Table 14 refers to the total capacity of water collectors used for domestic hot water heating in single-family houses at the end of 2023, as reported by each country.

Table 14: Solar thermal systems for domestic hot water heating in single-family houses by the end of 2023

Energy calculation DHW-SFH							
DHW-SFH - 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 [-]	Specific solar yield (DHW-SFH) [kWh/m²*a]	Type of system
Albania	Tirana	1,604	81,467	3	27,156	713	TS
Argentina	Buenos Aires	1,748	299,577	2.5	119,831	777	PS
Australia	Sydney	1,674	3,538,672	3.9	907,352	844	PS
Austria	Graz	1,126	2,013,202	6	335,534	451	PS
Barbados	Grantley Adams	2,016	237,537	4	59,384	882	TS
Belgium	Brussels	971	478,035	4	119,509	423	PDS / PS
Bhuthan	Thimphu	1,623	986	4	246	721	TS
Botswana	Gaborone	2,161	12,885	4	3,221	961	TS
Brazil	Brasília	1,793	12,362,508	2	6,181,254	809	TS
Bulgaria	Sofia	1,188	144,897	4	36,224	524	PS
Burkina Faso	Ouagadougou	2,212	647	4	162	983	TS
Canada	Montreal	1,351	66,908	6	11,151	556	PS
Chile	Santiago de Chile	1,753	315,604	1.8	175,336	771	PS
China	Shanghai	1,282	305,200,973	4	76,300,243	592	TS
Croatia	Zagreb	1,212	193,196	4	48,299	539	PS
Cyprus	Nicosia	1,886	787,046	2	393,523	912	TS
Czech Republic	Praha	998	304,399	4.7	64,766	385	PS
Denmark	Copenhagen	989	280,133	4	70,033	454	PS
Estonia	Tallin	960	15,790	4	3,948	432	PS
Finland	Helsinki	948	53,357	4	13,339	441	PS
France (mainland)	Paris	1,112	1,578,630	3.2	493,322	496	PS
France (overseas departments)	"Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea"	1,834	1,217,900	4	304,475	815	TS
Germany	Würzburg	1,091	9,942,604	5.6	1,775,465	424	PS
Ghana	Accra	2,146	777	4	194	954	TS
Greece	Athens	1,585	3,816,867	2.5	1,526,747	772	TS
Hungary	Budapest	1,199	216,280	5	43,256	473	PS
India	New-Delhi	1,961	18,998,015	2	9,499,007	882	TS
Ireland	Dublin	949	374,731	4	93,683	423	PS
Israel	Jerusalem	2,198	946,263	3	315,421	1,024	TS
Italy	Bologna	1,419	3,583,681	4	895,920	661	PS
Japan	Tokyo	1,175	2,391,872	4	597,968	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	28,794	4	7,198	462	PS
Lebanon	Beirut	1,935	1,000,057	4.7	212,778	860	TS
Lesotho	Maseru	2,050	3,077	2	1,538	911	TS
Lithuania	Vilnius	1,001	17,632	4	4,408	450	PS
Luxembourg	Luxembourg	1,037	50,172	4	12,543	450	PS
Malta	Luqa	1,902	50,000	2.5	20,000	868	PS
Mauritius	Port Louis	1,920	132,793	1.5	88,529	854	TS
Mexico	Mexico City	1,706	3,061,427	4	765,357	718	PS
Morocco	Rabat	2,000	540,625	4	135,156	889	TS
Mozambique	Maputo	1,910	3,249	4	812	849	TS
Namibia	Windhoek	2,363	29,173	4	7,293	1,032	TS
Nepal	Kathmandu	1,771	135,000	4	33,750	787	TS
Netherlands	Amsterdam	999	375,136	2.8	133,977	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	132,222	4	33,055	627	PS
Norway	Oslo	971	1,491	6	249	430	PS
Palestinian Territories	Jerusalem	2,198	1,031,719	1.5	687,813	977	TS
Poland	Warsaw	1,024	2,493,225	5.2	479,466	397	PS
Portugal	Lisbon	1,686	982,398	4	245,599	804	PS
Romania	Bucharest	1,324	182,088	4	45,522	594	PS
Russia	Moscow	996	64,220	4	16,055	443	PS
Senegal	Dakar	2,197	9,529	4	2,382	977	TS
Slovakia	Bratislava	1,214	142,047	6	23,674	481	PS
Slovenia	Ljubjana	1,115	133,983	6	22,331	424	PS
South Africa	Johannesburg	2,075	1,410,475	2.1	671,655	1,009	TS
South Korea	Seoul	1,161	1,765,900	4	441,475	525	PS
Spain	Madrid	1,644	2,077,180	4	519,295	766	PS
Sweden	Gothenburg	934	35,391	4	8,848	383	PS
Switzerland	Zürich	1,094	1,018,775	5.7	178,732	426	PS
Chinese Taipei	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	1,262,791	3.3	382,664	902	TS
Turkey	Antalya	1,795	25,466,021	4	6,366,505	910	TS
United Kingdom	London	943	773,274	4	193,318	415	PS
United States	LA, Indianapolis	1,646	1,533,029	6	255,505	646	PS
Uruguay	Montevideo	1,534	104,638	4	26,159	682	TS
Zimbabwe	Harare	2,017	122,347	2	61,174	854	TS
Other (5% of world market excluding China)		1,433	5,873,320	4	1,468,330	638	
TOTAL			424,905,349		114,716,594		
AVG		1,537		4		638	

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

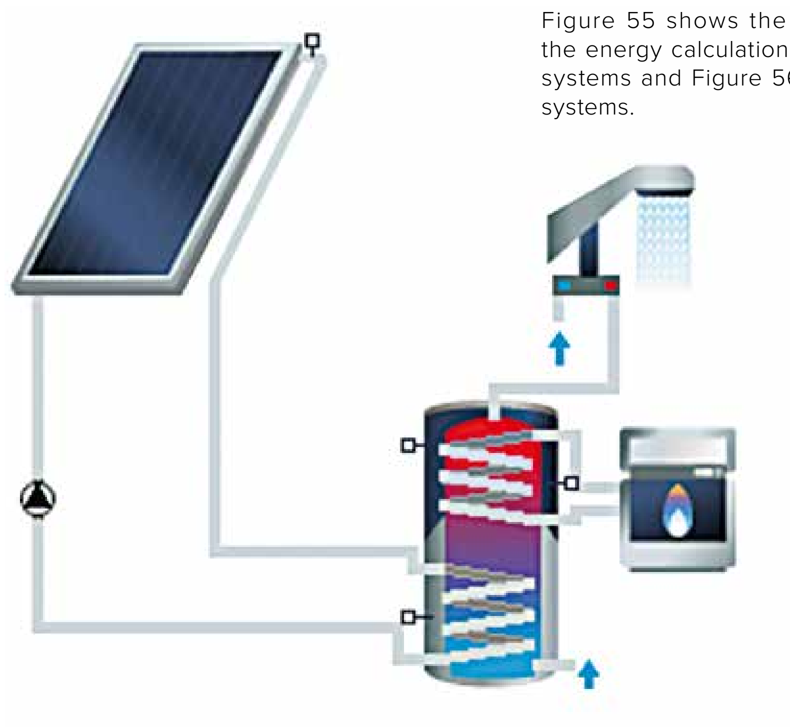


Figure 55 shows the hydraulic scheme used for the energy calculation for all pumped solar thermal systems and Figure 56 refers to the thermosiphon systems.

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

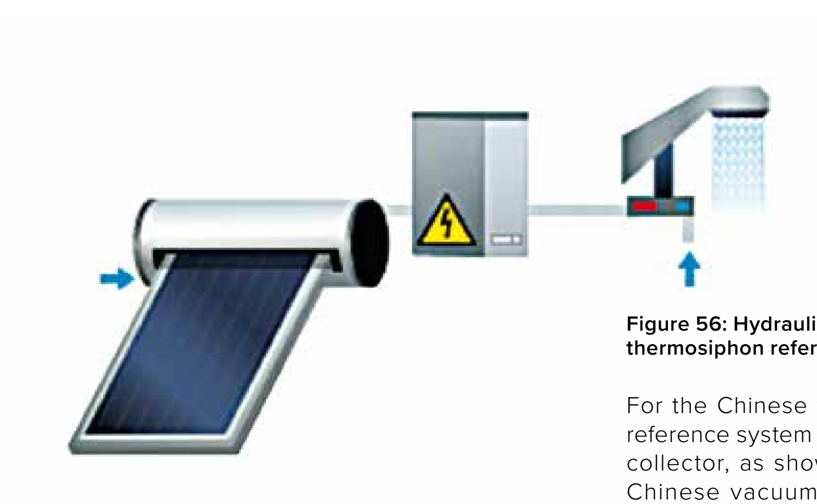


Figure 56: Hydraulic scheme of the domestic hot water thermosiphon reference system for single-family houses

For the Chinese thermosiphon systems, the above reference system was used, but instead of a flat plate collector, as shown in Figure 56, a representative Chinese vacuum tube collector was used for the simulation.

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

The information in Table 15 refers to the total capacity of water collectors used for domestic hot water heating in multi-family houses at the end of 2023, as reported by each country.

Table 15: Solar thermal systems for domestic hot water heating in multi-family houses by the end of 2023

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	267,338	50	5,347	694
Argentina	Buenos Aires	1,748	40,633	2.5	16,253	730
Australia	Sydney	1,674	19,076	50	382	725
Austria	Graz	1,126	375,487	50	7,510	505
Barbados	Grantley Adams	2,016	20,655	50	413	842
Belgium	Brussels	971	108,696	50	2,174	406
Bhutan	Thimphu	1,623	1,205	10	121	678
Botswana	Gaborone	2,161	8,590	30	286	903
Brazil	Brasília	1,793	2,145,294	60	35,755	658
Bulgaria	Sofia	1,188	32,947	50	659	515
Burkina Faso	Ouagadougou	2,212	4,033	30	134	924
Canada	Montreal	1,351	366,935	50	7,339	621
Chile	Santiago de Chile	1,753	74,263	50	1,485	732
China	Shanghai	1,282	267,124,076	50	5,342,482	502
Croatia	Zagreb	1,212	43,929	50	879	506
Cyprus	Nicosia	1,886	104,155	50	2,083	750
Czech Republic	Praha	998	46,017	42.4	1,085	436
Denmark	Copenhagen	989	1,441,703	50	28,834	413
Estonia	Tallin	960	3,590	50	72	401
Finland	Helsinki	948	12,078	50	242	396
France (mainland)	Paris	1,112	825,160	20	41,258	489
France (overseas departments)	"Basse-Terre, Papeete, Saint Pierre (Miquelon), Cayenne, Noumea"	1,834	72,970	50	1,459	766
Germany	Würzburg	1,091	2,686,993	50	53,740	472
Ghana	Accra	2,146	8,051	30	268	896
Greece	Athens	1,585	867,886	50	17,358	642
Hungary	Budapest	1,199	78,817	50	1,576	522
India	New-Delhi	1,961	1,578,195	20	78,910	749
Ireland	Dublin	949	12,491	50	250	425
Israel	Jerusalem	2,198	4,100,472	3	1,366,824	918
Italy	Bologna	1,419	814,863	50	16,297	593
Japan	Tokyo	1,175	8,087	50	162	516
Jordan	Amman	2,145	250,769	50	5,015	801
Kenya	Nairobi	1,931	74,016	10	7,402	807
Latvia	Riga	991	6,547	50	131	414
Lesotho	Maseru	2,050	3,535	10	353	856
Lithuania	Vilnius	1,001	4,009	50	80	418
Luxembourg	Luxembourg	1,037	11,408	50	228	433
Mexico	Mexico City	1,706	1,326,791	50	26,536	713
Morocco	Rabat	2,000	486,563	50	9,731	835
Mozambique	Maputo	1,910	2,392	50	48	798
Namibia	Windhoek	2,363	35,656	50	713	814
Nepal	Kathmandu	1,771	165,000	50	3,300	740
Netherlands	Amsterdam	999	159,728	40	3,993	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	11,885	50	238	577
Norway	Oslo	971	16,312	50	326	406
Palestinian Territories	Jerusalem	2,198	928,547	50	18,571	918
Poland	Warsaw	1,024	618,886	25	24,755	447
Portugal	Lisbon	1,686	424,057	40	10,601	705
Romania	Bucharest	1,324	41,404	50	828	553
Russia	Moscow	996	22,793	50	456	416
Senegal	Dakar	2,197	295	4.5	65	918
Slovakia	Bratislava	1,214	32,299	50	646	507
Slovenia	Ljubjana	1,115	2,977	50	60	477
South Africa	Johannesburg	2,075	46,232	121.4	381	867
South Korea	Seoul	1,161	144,967	50	2,899	485
Spain	Madrid	1,644	2,440,686	50	48,814	676
Sweden	Gothenburg	934	47,947	50	959	430
Switzerland	Zürich	1,094	121,645	20	6,082	457
Taiwan	Taipei	1,372	96,511	30	3,217	518
Thailand	Bangkok	1,765	11,820	80	148	737
Tunisia	Tunis	1,808	41,758	50	835	755
Turkey	Antalya	1,795	2,214,437	80	27,680	750
United States	LA, Indianapolis	1,646	1,627,243	50	32,545	688
Uruguay	Montevideo	1,534	22,459	50	449	688
Zimbabwe	Harare	2,017	30,587	32	956	641
Other (5% of world market excluding China)		1,244	1,484,284	50	29,686	842
TOTAL			296,271,148		7,303,267	
AVG		1,529		44		518

Figure 57 shows the hydraulic scheme of the domestic hot water reference system for multi-family houses used for the simulations of the solar energy yields. Unlike small-scale domestic hot water systems, all large-scale systems are assumed to be pumped solar thermal systems.

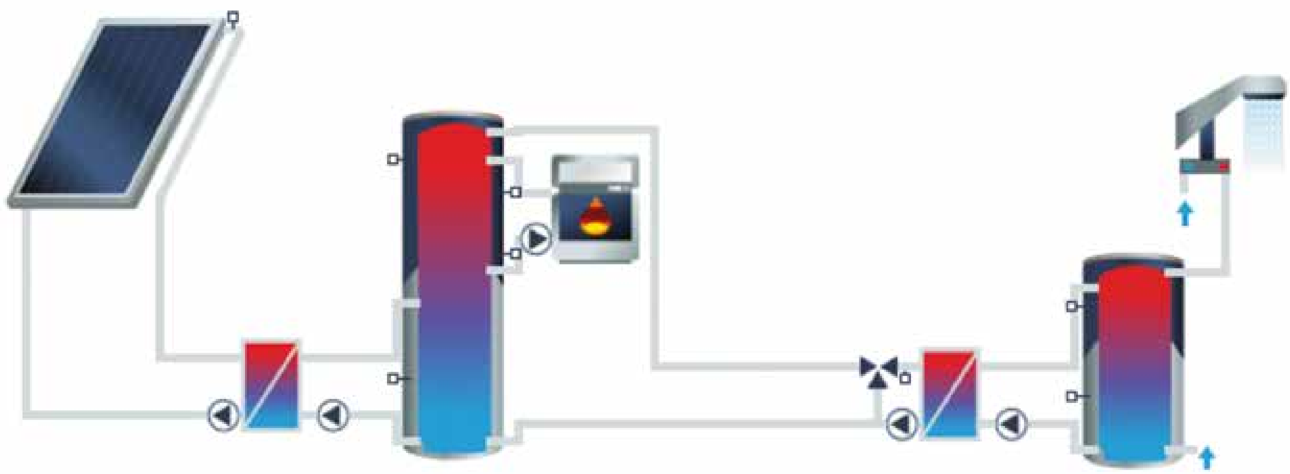


Figure 57: Hydraulic scheme of the domestic hot water pumped reference system for multi-family houses

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

The information in Table 16 refers to the total capacity of water collectors used for domestic hot water and space heating in single-family and multi-family houses at the end of 2023, as reported by each country.

Table 16: Solar combisystem reference for single-family and multi-family houses and the total collector area in operation in 2023

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	48,298	12	4,025	615
Australia	Sydney	1,674	9,538	15	636	589
Austria	Graz	1,126	1,899,077	14	135,648	369
Belgium	Brussels	971	148,787	12	12,399	342
Bulgaria	Sofia	1,188	45,099	12	3,758	418
Canada	Montreal	1,351	80	12	7	476
China	Shanghai	1,282	13,473,363	12	1,122,780	388
Croatia	Zagreb	1,212	60,132	12	5,011	426
Cyprus	Nicosia	1,886	14,491	12	1,208	663
Czech Republic	Praha	998	242,974	8.5	28,585	351
Denmark	Copenhagen	989	62,450	8	7,806	348
Estonia	Tallin	960	4,915	12	410	338
Finland	Helsinki	948	16,909	12	1,409	334
France (mainland)	Paris	1,112	1,046	11	95	370
Germany	Würzburg	1,091	9,426,502	11.5	819,696	378
Greece	Athens	1,585	1,187,989	12	98,999	558
Hungary	Budapest	1,199	79,441	10	7,944	422
Ireland	Dublin	949	29,146	12	2,429	364
Italy	Bologna	1,419	1,115,411	12	92,951	499
Japan	Tokyo	1,175	110,433	12	9,203	414
Latvia	Riga	991	8,962	12	747	349
Lebanon	Beirut	1,935	9,101	6.2	1,468	681
Lesotho	Maseru	2,050	22	12	2	721
Lithuania	Vilnius	1,001	5,488	12	457	352
Luxembourg	Luxembourg	1,037	15,616	12	1,301	365
Morocco	Rabat	2,000	10,813	12	901	704
Netherlands	Amsterdam	999	43,168	6	7,195	352
New Zealand	Wellington	1,401	4,923	12	410	493
North Macedonia	Skopje	1,381	1,486	10	149	486
Norway	Oslo	971	23,341	15	1,556	342
Palestinian Territories	Jerusalem	2,198	20,634	12	1,720	773
Poland	Warsaw	1,024	353,649	13.5	26,196	365
Romania	Bucharest	1,324	56,675	12	4,723	466
Russia	Moscow	996	2,313	15	154	350
Slovakia	Bratislava	1,214	44,212	12	3,684	427
Slovenia	Ljubjana	1,115	10,421	12	868	362
South Korea	Seoul	1,161	21,118	12	1,760	409
Spain	Madrid	1,644	415,436	10	41,544	619
Sweden	Gothenburg	934	253,983	10	25,398	389
Switzerland	Zürich	1,094	380,140	11	34,558	385
Thailand	Bangkok	1,765	1,722	12	143	621
Other (5% of world market excluding China)		1,131	866,462	12	72,205	399
TOTAL			30,525,763		2,582,138	
AVG		1,295		12		398

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

Figure 58 shows the hydraulic scheme of the domestic hot water reference system for multifamily houses used for the simulations of the solar energy yields.

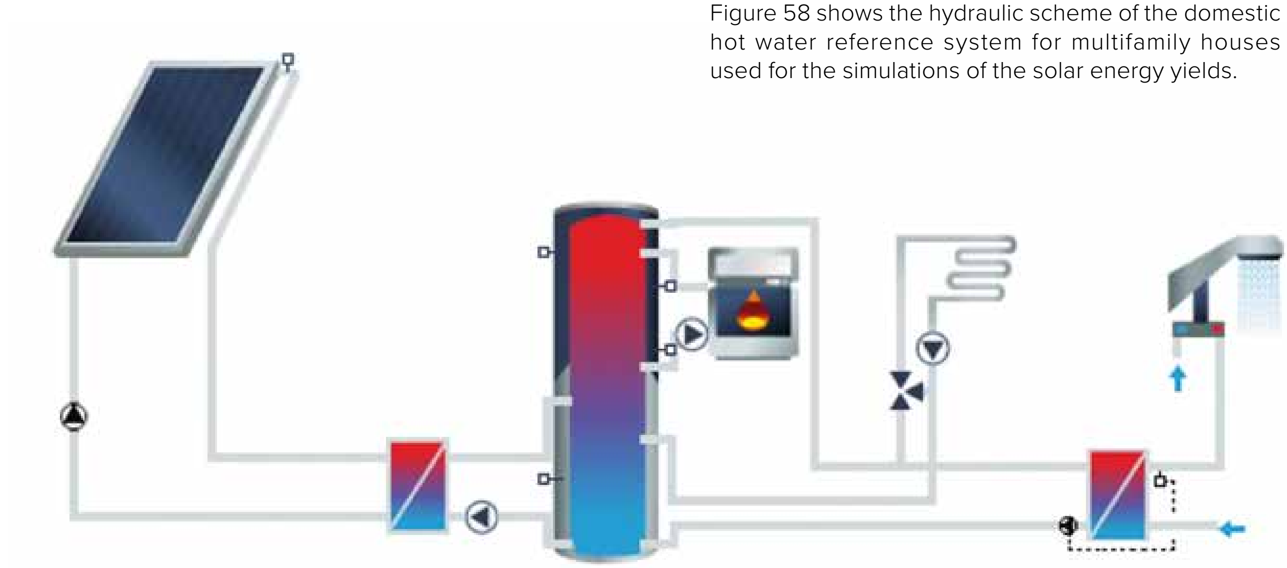


Figure 58: Hydraulic scheme of the solar-combi reference system for single and multi-family houses

9.2 Reference collectors

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

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

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

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

9.2.3 Data of the Chinese reference vacuum tube collector

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

9.3 Methodological approach for 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 made to calculate the number of full-time jobs:

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

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

9.4
Reference climates

Table 17: Reference climates for the 73 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	Ecuador	Quito	2,020	2,023	18.0
21	Estonia	Tallin	960	1,126	5.3
22	Finland	Helsinki	948	1,134	4.6
23	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 Taipei	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 18: Inhabitants by the end of 2023 of the 73 surveyed countries in alphabetical order

No	Country/Region/ Economy	2023	Region Code
1	Albania	2,608,869	6
2	Argentina	45,207,044	4
3	Australia	26,461,166	3
4	Austria	9,116,209	6
5	Barbados	303,431	4
6	Belgium	11,841,113	6
7	Bhutan	876,181	2
8	Botswana	2,417,596	1
9	Brazil	218,689,757	4
10	Bulgaria	6,827,736	6
11	Burkina Faso	22,375,576	1
12	Canada	38,628,008	8
13	Cape Verde	603,901	1
14	Chile	18,895,448	4
15	China	1,409,294,306	5
16	Croatia	4,107,115	6
17	Cyprus	1,308,120	6
18	Czech Republic	10,830,412	6
19	Denmark	5,961,534	6
	Ecuador	18,134,133	4
20	Estonia	1,337,696	6
21	Finland	5,546,864	6
22	France (mainland)	68,235,759	6
22	France (overseas departments and regions)	3,386,450	6
23	Germany	84,220,184	6
24	Ghana	33,846,114	1
25	Greece	10,497,595	6
26	Hungary	9,885,834	6
27	India	1,399,179,585	2
28	Ireland	5,180,761	6
29	Israel	9,256,230	7
30	Italy	61,021,855	6
31	Japan	123,719,238	2
32	Jordan	11,086,716	7
33	Republic of Kenya	53,428,379	1
34	Latvia	1,920,991	6
35	Lebanon	5,816,920	7
36	Lesotho	2,210,646	1
37	Lithuania	2,836,390	6
38	Luxembourg	671,419	6
39	Malta	514,254	6
40	Mauritius	1,309,448	1
41	Mexico	129,875,529	4
42	Morocco	37,067,420	7
43	Mozambique	32,513,805	1
44	Namibia	2,756,722	1
45	Nepal	30,899,443	2
46	Netherlands	17,694,798	6
47	New Zealand	5,109,702	3
48	Nigeria	230,842,743	1
49	North Macedonia	2,133,410	6
50	Norway	5,477,028	6
51	Palestinian Territories	5,274,938	7
52	Panama	4,404,108	4
53	Poland	39,142,267	6
54	Portugal	10,223,150	6
55	Romania	18,326,327	6
56	Russia	141,505,279	6
57	Senegal	18,384,660	1
58	Slovakia	5,569,395	6
59	Slovenia	2,155,242	6
60	South Africa	59,795,503	1
61	South Korea	51,589,095	2
62	Spain	47,222,613	6
63	Sweden	10,536,338	6
64	Switzerland	8,793,404	6
65	Chinese Taipei	23,588,613	2
66	Thailand	69,794,997	2
67	Tunisia	11,976,182	7
68	Turkey	83,593,483	6
69	United Kingdom	68,138,484	6
70	United States	334,914,895	8
71	Uruguay	3,454,376	4
72	Zimbabwe	16,819,805	1
73	Other (5%)	2,705,990,007	9
∑ Solar Thermal World Statistics ∑Inhabitants world		5,279,170,737 7,985,160,744	66%

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

Table 19: Inhabitants per economic region by the end of 2023

Region Code	Country/Region/ Economy	∑Inhabitants	Share
1	Sub-Sahara Africa	477,304,898	6%
2	Other Asia	1,699,647,152	21%
3	Australia	31,570,868	0.4%
4	Latin America and the Caribbean	438,963,826	5%
5	China	1,409,294,306	18%
6	Europe	768,368,378	10%
7	MENA Region	80,478,406	1%
8	United States / Canada	373,542,903	5%
9	Other countries	2,705,990,007	34%
Total		7,985,160,744	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, Ecuador, Mexico, Panama, 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) are 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 considered.

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 for the previous years

Change in the method for estimating global installed capacity

Global solar thermal capacity is based on the latest market data from 14 of the largest solar thermal markets in terms of added capacity. These were the following countries for the year 2024 listed in order of their added capacity: China, Turkey, India, Brazil, Mexico, Germany, Greece, Italy, Australia, Spain, Poland, Cyprus, Austria, Argentina, Uruguay and Canada which represented 92.7% of the cumulative installed capacity in operation in 2023. The added capacities in the other countries, for which new additions are available until 2023, 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 2023 and previous years, was estimated to be 5% of the global market volume without China in 2023.

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 previous years

The following tables provide data from 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 20, Table 21, and Table 22, these countries are marked accordingly, and the respective data source is cited in Chapter 9.8 (References).

Table 20: Newly installed collector area in 2021 [m²]

Country/Region/Economy	Newly installed collector area in 2021 [m²]					
	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		14,840.0	1,360.0			16,200
Argentina**	6,634.0	34,300.0	67,986.0	20.0	158.0	109,098
Australia	380,000.0	131,600.0	14,600.0			526,200
Austria	930.0	64,570.0	3,810.0		1,100.0	70,410
Belgium		13,600.0	3,000.0			16,600
Bhutan		460.0				460
Botswana		1,190.0	210.0			1,400
Brazil	948,931.0	831,223.0	38,509.0			1,818,663
Bulgaria		25,184.0				25,184
Canada**	1,475.0	261.0	321.0	6,000.0	1,000.0	9,057
Cape Verde		150.0				150
Chile*		25,183.0				25,183
China+		7,107,000.0	17,623,914.0	13,119.4	20,000.0	24,764,033
Croatia		12,912.0				12,912
Cyprus		70,360.0	0.0			70,360
Czech Republic		17,097.0	1,903.0			19,000
Denmark		8,013.0		0.0		8,013
Estonia		1,468.0				1,468
Finland		3,223.0				3,223
France (mainland)	600.0	63,910.0	1,760.0	200.0		66,470
France (overseas territories)		90,440.0				90,440
Germany		524,500.0	117,000.0			641,500
Ghana		700.0	450.0			1,150
Greece		358,600.0	400.0			359,000
Hungary		22,050.0				22,050
India		151,267.0	1,779,873.0		15.0	1,931,155
Ireland		3,898.0				3,898
Israel*		350,000.0				350,000
Italy		207,548.0	17,452.0	120.0		225,120
Japan		49,736.0	610.0		887.0	51,233
Kenya*		8,364.0	4,182.0			12,546
Latvia		1,648.0				1,648
Lebanon		11,399.0	38,940.0			50,339
Lesotho		396.0	1,584.0			1,980
Lithuania		700.0	1,000.0			1,700
Luxembourg		3,574.0	0.0			3,574
Malta		1,051.0	263.0			1,314
Mexico	114,940.0	128,880.0	159,180.0			403,000
Morocco*		71,700.0				71,700
Mozambique			592.0			592
Namibia		4,200.5				4,201
Nepal		6,690.0	60,208.0			66,898
Netherlands	2,620.0	19,590.0	8,400.0			30,610
Nigeria		392.6	3,515.2			3,908
North Macedonia*		5,868.0	4,800.0		20.0	10,688
Palestinian Territories		53,453.0	0.0			53,453
Panama***		665.0				665
Poland		186,100.0	3,000.0			189,100
Portugal		77,045.0				77,045
Romania	0.0	16,439.0				16,439
Russia	0.0	729.0	4.0			733
Slovakia	0.0	13,000.0				13,000
Slovenia		1,439.0				1,439
South Africa	57,483.0	16,117.0	66,351.0			139,951
South Korea++				200.0	100.0	300
Spain	2,000.0	141,500.0	8,800.0	5,200.0		157,500
Sweden		1,955.0				1,955
Switzerland	4,090.0	22,630.0	4,470.0			31,190
Tunisia		52,340.0				52,340
Turkey		984,000.0	945,000.0	1,000.0		1,930,000
United Kingdom**	4,638.0	21,943.0	4,462.0			31,043
United States	808,417.0	50,274.0		3,000.0	1,000.0	862,691
Uruguay*		10,418.0				10,418
Zimbabwe			9,570.0			9,570
Other (5% excluding China)	122,776.7	262,778.1	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 according to new database
+ exports excluded, ++ revised 2024 according to new data base

Table 21: Newly installed collector area in 2022 [m²]

Country/Region/Economy	Newly installed collector area in 2022 [m²]					
	Water Collectors [m²]			Air Collectors [m²]		TOTAL [m²]
	unglazed	FPC	ETC	unglazed	glazed	
Albania		17,680.0	1,640.0			19,320
Argentina	6,769.0	35,000.0	69,373.0	20.0	158.0	111,320
Australia	350,000.0	123,533.0	13,728.0		1,000.0	488,261
Austria	1,480.0	56,830.0	660.0		190.0	59,160
Belgium		16,000.0	3,500.0			19,500
Bhutan		824.0				824
Botswana		1,190.0	210.0			1,400
Brazil	920,463.0	821,248.0	38,124.0			1,779,835
Bulgaria		24,296.0				24,296
Canada	2,100.0	4.0	902.0	19,991.0	4,325.0	27,322
Chile		13,071.0				13,071
China+		5,757,000.0	15,680,491.0	20,819.4	23,000.0	21,481,310
Croatia		12,000.0				12,000
Cyprus		73,924.0	0.0			73,924
Czech Republic		23,167.0	2,336.0			25,503
Denmark		2,664.0		0.0		2,664
Estonia		1,425.0				1,425
Finland		8,000.0				8,000
France (mainland)		64,355.0	2,795.0	200.0		67,350
France (overseas territories)++		107,410.0				107,410
Germany		524,000.0	185,000.0			709,000
Ghana*		700.0	450.0			1,150
Greece		418,600.0	400.0			419,000
Hungary		14,000.0				14,000
India		75,572.0	1,441,467.0		15.0	1,517,054
Ireland		1,116.0				1,116
Israel*		350,000.0				350,000
Italy		224,695.0	19,923.0			244,618
Japan		59,898.0	354.0		753.0	61,005
Kenya*		8,364.0	4,182.0			12,546
Latvia		1,600.0				1,600
Lebanon		23,952.0	99,378.0			123,330
Lesotho			55.0			55
Lithuania		700.0	1,000.0			1,700
Luxembourg		3,574.0	0.0			3,574
Malta		1,772.1	8.2			1,780
Mexico	112,640.0	129,905.0	177,265.0		288.0	420,098
Morocco*		71,700.0				71,700
Mozambique			1,180.0			1,180
Namibia		4,094.0	2.0			4,096
Nepal		6,940.0	62,462.0			
Netherlands	2,620.0	26,050.0	13,420.0			42,090
North Macedonia		1,010.0	5.7		20.0	1,036
Norway*		1,512.0	82.0			1,594
Palestinian Territories		51,378.0	0.0			51,378
Panama		665.0				
Poland		208,500.0	1,500.0			210,000
Portugal		64,117.0	1,983.0			66,100
Romania	0.0	15,960.0				15,960
Russia	0.0	682.0	239.0			921
Slovakia	0.0	17,000.0				17,000
Slovenia		800.0	70.0	5.0		875
South Africa	41,168.0	31,414.8	80,269.2			152,852
South Korea*				700.0		700
Spain	2,000.0	136,500.0	7,000.0	4,800.0		150,300
Sweden		5,000.0				5,000
Switzerland	3,210.0	21,770.0	2,970.0			27,950
Thailand		0.0	0.0		0.0	
Tunisia*		52,340.0				52,340
Turkey		934,000.0	912,000.0	2,245.0		1,848,245
United Kingdom++	4,891.2	1,772.7	2,431.5	200.0		9,295
United States	839,122.0	41,834.0		4,000.0		884,956
Uruguay*	509.0	3,053.0	6,614.0			10,176
Zimbabwe			32,898.0			32,898
Other (5% of the world market excluding China)	120,367.0	259,955.9	167,783.0	1,692.7	355.2	550,154
Total	2,407,339.2	10,956,117.5	19,036,150.6	54,673.1	30,104.2	32,484,385

* 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 22: Total collector area in operation by the end of 2022 [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		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
Burkino Faso+++		3,282	1,399			4,681
Canada++	697,853	70,179	52,087	447,095	56,214	1,323,428
Cape Verde+++++		2,613				2,613
Chile++	65,550	323,148	54,305		300	443,303
China+		73,095,000	493,092,921	42,539	46,500	566,276,960
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	10,958	1,100	2,378,914
France (overseas territories)		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	3,786,461	14,867,118	0.00	12,415	18,665,994
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			3,405,690
Portugal	2,130	1,344,590	32,553			1,379,273
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
Other (5% excluding China)	2,323,509	6,060,336	1,966,335	34,355	22,386	10,406,921
TOTAL	46,470,190	194,301,715	532,419,618	729,642	494,221	774,415,387

*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 2025, 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	no new data reported; 0% growth assumed
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	**Christian Fink** 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	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023 /2024, Solar Heat Europe 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	
Botswana	**Karen Gibson** SIAB Solar Industries Association Botswana		No new data reported, 0% growth assumed
Brazil	**Dr. Danielle Johann** Diretora Executiva ABRASOL Associção Brasileira de Energia Solar Térmica	ABRASOL	Out of operation systems calculated by AEE INTEC based on ABRASOL long time recordings
Bulgaria	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	Newly installed: Solar Heat Europe 2024 (estimation); 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 2023; cumulated by end of 2020
Canada	**Lucio Mesquita, PhD** Natural Resources Canada	2023 Solar Thermal Market Survey (Solrico, Bärbel Epp)	Out of operation systems calculated by AEE INTEC based on newly installed
Cape Verde	**Antúnio Barbosa**	Country Market Report on solar thermal heating systems, solar drying and solar cooling, September 2015	No new data 2023; 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	**Bian Mengmeng** 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 (15 years lifetime)
Croatia	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	Cumulated calculated by AEE INTEC, out of operation considered
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	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation AEE INTEC	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe	Unglazed water collectors: AEE INTEC recordings
Denmark	**Daniel Trier** Planenergi		DH plants only; unglazed water collectors: AEE INTEC recordings
Estonia	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	estimation according to the trend
Finland	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	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 2024 Air collectors: John Hollick	Data provided by Frédéric Tuillé
Germany	**Dr. Andrea Liesen** BSW - Bundesverband Solarwirtschaft e.V., **John Hollick** SAHWIA - Solar Air Heating World Industry Association **Anna Laura Ulbrichs** 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 Anna Laura Ulbrichs
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 Vassiliki Drosou and Costas Travasaros (EBHE)
Hungary	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024 Euroserv'ER July 2024 Air collectors: John Hollick	Cumulated calculated by AEE INTEC based on new; 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; out of operation systems considered
Ireland	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	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		No new data reported; cumulated by end of 2022
Italy	**Zeno Benciolini** President, Solterm Italia **John Hollick** SAHWIA - Solar Air Heating World Industry Association	Solar Thermal Market Survey	Cumulated calculated by 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 2023; 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	No new data 2023; Cumulated data by end of 2022
Latvia	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	estimation according to the trend
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	No data 2023; 0% growth assumed
Lithuania	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	cumulated calculated by AEE INTEC based on newly installed (estimation)
Luxembourg	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal Industry Federation	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	estimation according to the trend
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 2023; cumulated collector area by end of 2015
Mexico	**David Garcia** FAMERAC	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		"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	No new data 2023; cumulated by end of 2022

Country	Contact	Source	Remarks
Mozambique	**Alberto Pondeca** Sunpower Engineering https://www.sunpowermz.com/	Market sales	Cumulated installations calculated by AEE INTEC
Namibia	**Helvi Ileka** Namibia Energy Institute Namibia University of Science and Technology	Namibia Energy Institute-Solar Water Heaters-Survey 2022	0% growth assumed; cumulated calculated by AEE INTEC
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)	
Netherlands	**Reinoud Segers** **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			Cumulated area by end of 2009
Nigeria	**Okala Nwoke** National Centre for Energy Research and Development, University of Nigeria, Nsukka		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	Data provided by Jordan Kabranov Cumulated installations calculated by AEE INTEC based on new installation figures
Norway	**Dr. Michaela Meir** Aventasolar	Solvarmeanlegg i Norge 2019 commissioned by The Norwegian Solar Energy Cluster (Solenergiklyngen), provided by Michaela Meir	0% growth assumed; cumulated calculated by AEE INTEC; 4 % out of operation considered
Palestinian Territories	**Mohammed Mobayyed** EEU Director Palestinian Energy Authority **Abdallah Azzam** Palestinian Central Bureau of Statistics Palestinian Energy & Enviroment Research Center	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		
Romania	**Valérie Séjourné** Solar Heat Europe (ESTIF) – European Solar Thermal Industry	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	Solar Heat Europe 2024 (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 2023; cumulated by end of 2020
Slovakia	**Valérie Séjourné** Solar Heat Europe (ESTIF) – European Solar Thermal Industry	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	Solar Heat Europe (estimation)
Slovenia	**Ciril Arkar** University of Ljubljana, Faculty of Mechanical Engineering	Eco Fund, Slovenian Environmental Public Fund	

Country	Contact	Source	Remarks
South Africa	**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 2023; 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	**Valérie Séjourné** Managing Director Solar Heat Europe (ESTIF) – European Solar Thermal IndustryPedro	Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, Solar Heat Europe 2024	
Switzerland	Swissolar http://www.swissolar.ch/	Statistik Sonnenenergie 2023, Bundesamt für Energie BFE, Juli 2024	gross collector area since 2020
Chinese Taipei	**K.M. Chung** Energy Research Center - National Cheng Kung University	Installers association	No new data 2023; 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 provided by John Hollick	New installations: A. Kutay Ulke; 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) **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 2023: CALSSA No new ETC data available 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 0% growth
Zimbabwe	**Samson Mhlanga** National University of Science and Technology, Bulawayo	Dr. Anton Schwarzlmüller Domestic Solar Heating unpublished statistics; SOLTRAIN survey (unpublished sources)	Cumulated calculated by AEE INTEC based on 0% growth

9.9
Additional literature and web sources used

The following reports and statistics were used in this report.

- Bundesamt für Energie (BFE): Statistik Sonnenenergie, Referenzjahr 2023; prepared by SWISSOLAR, Thomas Hostettler, Bern, Switzerland July 2024
- Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Austria – Innovative Energy Technologies - Market Development 2023; Ed. Peter Biermayr et al, Vienna, Austria June 2024
- Bundesverband Solarwirtschaft e.V. (BSW-Solar): Statistische Zahlen der deutschen Solarwärmebranche (Solarthermie) 2025; BSW Faktenblatt Solarwärme; März 2025; accessed May 2025
- Eurobserv'ER Edition 2024, The State of Renewable Energies in Europe
- Fraunhofer-Institut für Solare Energiesysteme ISE und Bundesverband Solarwirtschaft e. V. (2025): Solare Prozesswärme für die deutsche Industrie – Ertrag und Wirtschaftlichkeit im Vergleich zu konventioneller Wärmeversorgung, Freiburg und Berlin, Germany
- Global Wind Energy Council (GWEC), Global Wind Report 2025, April 2025
- IEA Global Energy Review 2025
- IEA Global Hydrogen Review 2024
- IEA PVPS Snapshot of Global PV Markets 2025
- IEA Renewables 2024
- IRENA (2024) Renewable Capacities Statistics 2024, International Renewable Energy Agency, Abu Dhabi
- IRENA Renewable Energy and Jobs: Annual Review 2020
- Lehr, U. et.al (2015), Beschäftigung durch erneuerbare Energien in Deutschland: Ausbau und Betrieb, heute und morgen
- Natural Resources Canada 2024: Report about the Canadian Solar Thermal Market Survey
- Solar Heat Europe (ESTIF): Decarbonising Heat with Solar Thermal - Market Outlook 2023/2024, December 2024
- 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://www.amee.ma/

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