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RENEWABLES 2022
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SOLAR THERMAL HEATING AND COOLING

The global solar thermal market grew 3% in 2021, to 25.6 GW_{th}, bringing the total global capacity to around 524 GW_{th}. China again led in new installations, followed by India, Turkey, Brazil and the United States.

Annual sales of solar thermal units grew at double-digit rates in several large markets, including Brazil, France, Greece, India, Italy, Morocco, Poland, Portugal and the United States. Demand was up due to increased activities in the construction sector in many countries, additional support schemes as part of national economic recovery policies, and rising fossil fuel and electricity prices globally. Large collector manufacturers benefited more than small manufacturers from the growing market and continued to consolidate their market positions. The 20 largest flat plate collector manufacturers increased production 15%. Chinese large collector manufacturers continued to expand their portfolios into renewable heating more broadly, with half of them offering stand-alone heat pumps and solar heat pump solutions.

Industrial companies around the world are turning increasingly to a zero carbon heat supply. At least 71 solar industrial heat (SHIP) solutions, totalling 36 MW_{th}, started operation globally in 2021, an increase of 8% to bring the total to around 975 SHIP plants. Another 44 MW_{th} of SHIP capacity was under construction by year's end, including the largest SHIP system in Europe (15 MW_{th}), which will provide process heat for a whey powder factory in France.

Due to growing interest in the electrification of heating, demand for PV-thermal (PV-T) or hybrid collectors increased again in 2021. Thirty manufacturers reported sales of PV-T capacity of at least 88 MW_{th} during the year, up 45% from 61 MW_{th} in 2020. The largest markets for new additions were France, the Netherlands, Israel, Germany and Spain.

WIND POWER

An estimated 102 GW of wind power capacity was installed in 2021, including a record 18.7 GW offshore. China led the market, followed distantly by the United States, Brazil, Vietnam and the United Kingdom. Annual additions increased total capacity by 13.5% to more than 845 GW.

While onshore additions dropped relative to 2020, as installations declined in China and the United States, offshore additions surged due largely to a dramatic policy-driven rise off the coast of China. Nearly every region of the world saw record market growth; not including China, global installations were up more than 14% in 2021. The economics of wind energy continued to be the primary driver for new capacity, combined with the need to increase energy security and to mitigate climate change.

However, the wind sector faces several challenges, including a lack of grid infrastructure and permitting issues. These were compounded in 2021 by rising costs due to pandemic-induced supply chain constraints, labour shortages, shipping backlogs and rising prices for major raw material inputs. While turbine prices continued to fall in China, average prices elsewhere rose to levels not seen since 2015, and major manufacturers reported losses. Outside of China, the industry is urging an increased focus on the system value of wind energy rather than solely on continually declining costs and prices.

Although the offshore segment accounts for a relatively small portion of global wind power capacity, it is attracting significant attention. An increasing number of governments and developers, as well as oil and gas majors and other energy providers, are turning to floating offshore turbines.

Turbine manufacturers continued to focus on technology innovation to achieve the lowest possible levelised cost of energy in response to the transition to renewable energy auctions as well as rising material costs and other pressures. The industry also is innovating to address challenges associated with scaling up production, transport and other logistical issues, and to enhance the value of wind energy while further improving its environmental and social sustainability.

KEY FACTS

- **China** remained the world's largest market for solar thermal capacity additions in 2021, followed distantly by India, Turkey, Brazil and the United States.
- **Annual sales** grew at double-digit rates in several large solar thermal markets, including Brazil, France, Greece, India, Italy, Morocco, Poland, Portugal and the United States.
- **Large collector manufacturers** benefited more than small manufacturers from the growing market and continued to consolidate their market positions.
- **Solar industrial heat capacity** under construction was dominated by higher-temperature systems that use concentrating collector technologies.

SOLAR THERMAL HEATING

The global solar heat market grew 3% in 2021 to 25.6 gigawatts-thermal (GW_{th})[i], up from 24.9 GW_{th} in 2020.[1] This reversal, after seven years of decline, was the result of several factors, including rebounded demand (particularly in China) in the wake of COVID-19 related trade and traffic restrictions; increased construction activity in many countries; additional support schemes under national economic recovery policies; and rising fossil fuel and electricity prices.[2] Sales grew at double-digit rates in several large solar thermal markets including Italy (83%), France (70%), Brazil (28%), Portugal (22%), the United States (19%), Greece and India (18% each), Poland (17%) and Morocco (10%).[3]

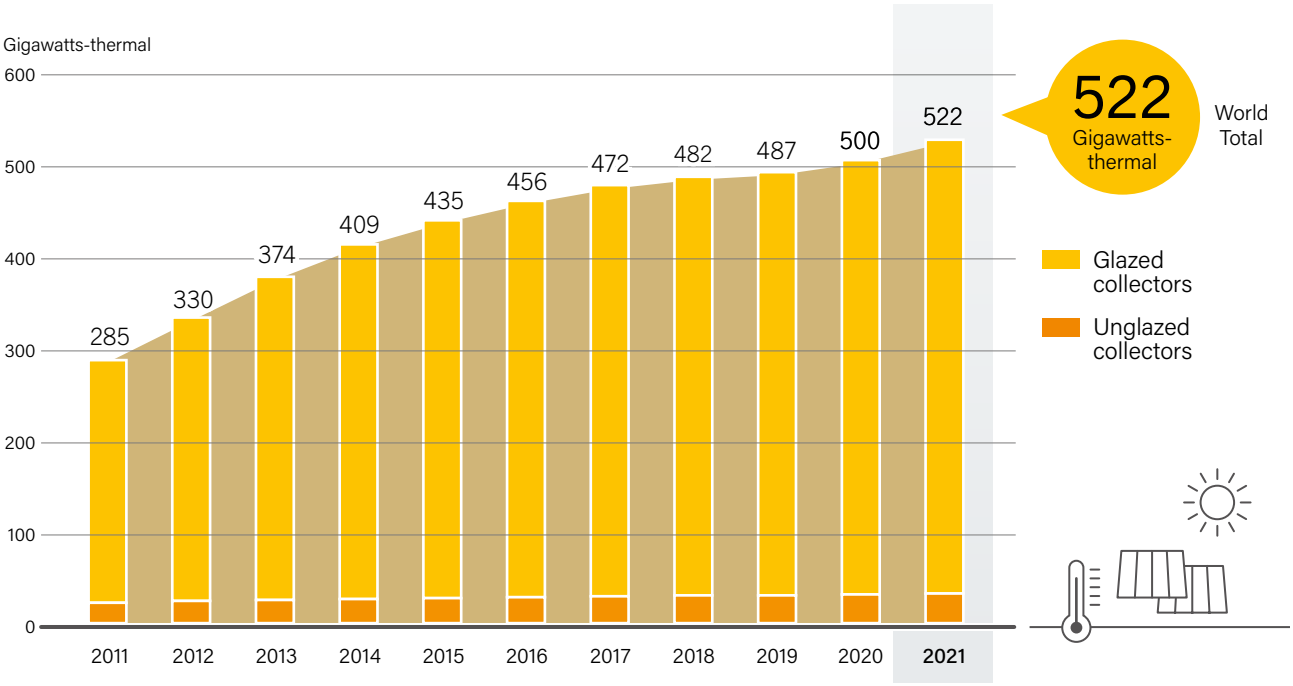
In some large residential markets (such as Australia, Austria, China, France, Germany and Spain), solar thermal solutions continued to face fierce competition from heat pumps and biomass boilers, both of which offer stand-alone solutions for hot water and/or space heating.[4] However, in some markets (such as China, France and Spain), utility and industry demand for large-scale solar heat projects helped offset the slowing household demand for solar water heaters.[5]

The transition continued from small residential solar thermal systems to large central procurement offers for big construction projects and commercial and industrial plants (such as in Austria, China and France). This resulted in consolidation among collector manufacturers globally, as only large producers were able to respond to the new demand structure.[6] Some of the world's largest collector manufacturers further consolidated their market position by receiving new orders from smaller producers that closed their own factories in Europe, in response to years of declining sales, and chose to purchase collectors from large producers.[7] Despite growing sales volumes, the large equipment manufacturers increased their prices for solar collectors and storage tanks and reduced their margins in 2021 to meet the challenge of rapidly rising material costs.[8]

By year's end, millions of residential, commercial and industrial clients in at least 134 countries were benefiting from solar thermal heating and cooling systems.[9] Cumulative global solar thermal capacity in operation reached an estimated 522 GW_{th} in 2021, up 4% from 502 GW_{th} in 2020.[10] (→ *See Figure 40.*) Total global capacity in operation at the end of 2021 was enough to provide around 427 terawatt-hours (1,537 petajoules) of heat annually, equivalent to the energy content of 251 million barrels of oil.[11]

i Global data for annual capacity additions and total capacity in operation in this section include all collector types: glazed (flat plate and vacuum tube collector technology), unglazed, concentrating, air and photovoltaic-thermal (PV-T). In previous editions of the GSR, global additions and totals included only glazed and unglazed collectors. The change is being made because formerly niche applications (concentrating, air and PV-T) are playing a growing role in some national markets and because data availability has increased.

FIGURE 40.
Solar Water Heating Collectors Global Capacity, 2011-2021



Source: Based on IEA SHC. See endnote 5 for this section.

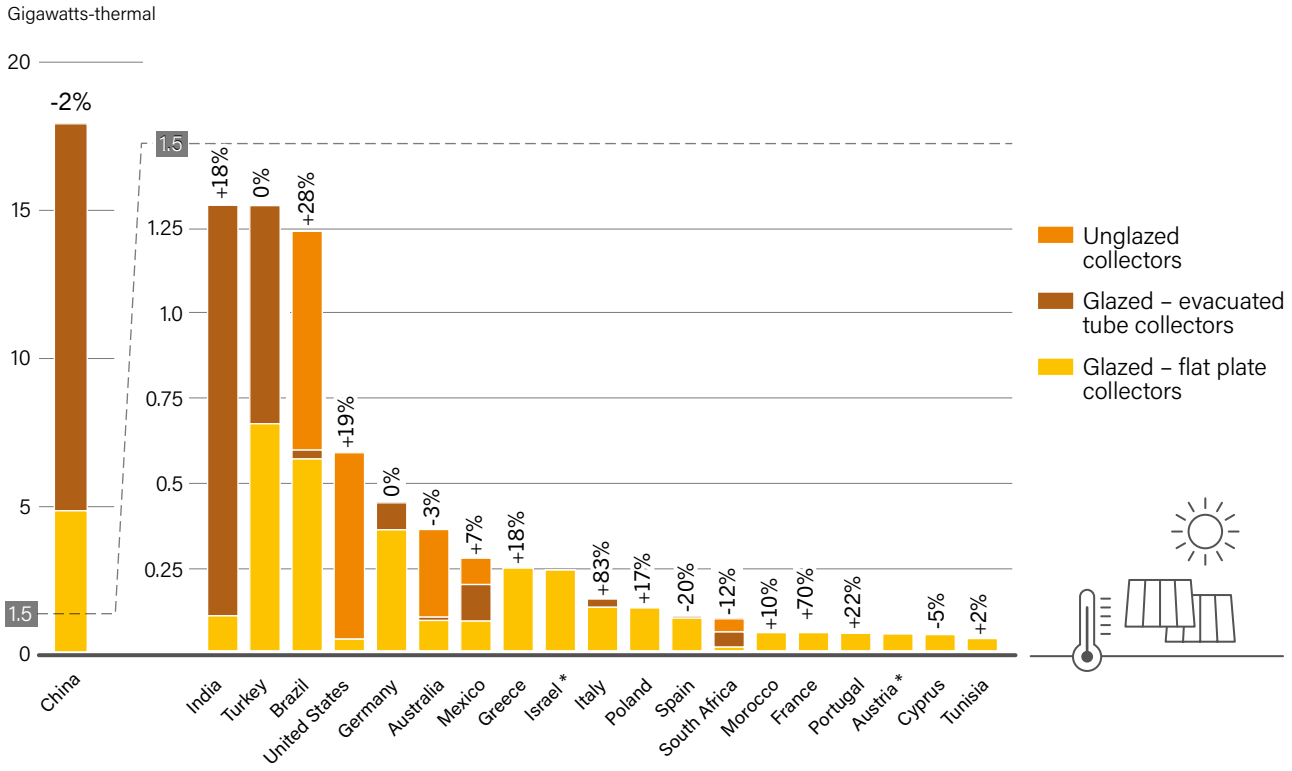
Note: Data are for glazed and unglazed solar water collectors and do not include concentrating, air or hybrid collectors.

As most residential and commercial solar heat projects include a storage tank unit, solar heat deployment plays an important role in creating a market for thermal energy storage (TES) capacity, which helps to integrate high shares of renewables in buildings and industry. Assuming a minimum storage volume of 50 litres per square metre of collector area in operation, the global solar thermal storage capacity reached an estimated 2,620 gigawatt-hours (GWh) at the end of 2021.[12]

China remained the world's largest national market for solar thermal systems of all types, accounting for 73% of the cumulative world capacity, followed distantly by the United States, Turkey, Germany and Brazil. The top 20 countries for new additions remained more or less the same in 2021, led by China, India, Turkey, Brazil and the United States.[13] (→ *See Figure 41.*)

Europe added
11% more solar thermal capacity
in 2021 than in 2020, due to increased policy support.

FIGURE 41.
Solar Water Heating Collector Additions, Top 20 Countries for Capacity Added, 2021



Source: See endnote 13 for this section.

Note: Additions represent gross capacity added. Numbers atop bars represent the rate of growth in annual sales relative to 2020.
*Additions for Austria and Israel refer to 2020 (latest data available). For Morocco, the share of collector types was not available.

TOP COUNTRY MARKETS

China's solar thermal market ended its downward slide after eight years of continuous decline.[14] Manufacturers installed 17.7 GW_{th} of solar thermal capacity in 2021, around the same as in 2020.[15] The market turnaround was driven by growth in central hot water and space heating projects for the housing industry, spurred by overall economic recovery following the pandemic-related lockdowns.[16]

Across China, newly installed solar thermal capacity for space heating (both district systems and individual buildings) increased 15%, adding a total of 2 GW_{th}.[17] The increase was due largely to "green" heating policies aimed at replacing coal boilers in the country's north to improve air quality.[18] The market also was aided by industry promotional activities: for example, in the leading solar provinces of Shandong and Jiangsu, manufacturers of solar thermal systems offered trade-in options tied to building renovations, which helped stimulate demand, particularly among rural households.[19]

Industry consolidation in China continued in 2021, with only large solar equipment manufacturers bidding on central procurement offers for solar thermal equipment and large solar collector fields.[20] In reaction to the declining market volumes in recent years, Chinese large collector manufacturers continued to expand their portfolios into renewable heating more broadly. By the end of 2021, half of China's producers were offering stand-alone heat pumps and solar heat pump solutions.[21]

Vacuum tube collectors continued to dominate the Chinese solar thermal market, although their share in new additions was down from 87% in 2015 to 72% in 2021.[22] The top three companies for vacuum tube collector production in 2021 were Solareast Group, Linuo Paradigma and Sangle.[23] The long-term transition from vacuum tube to flat plate collectors has been driven by building codes that mandate the use of solar thermal systems in new construction and in major renovations to reduce local air pollution. Such regulations have increased the demand for façade- and balcony-integrated applications, where flat plate collectors have been the preferred solution.[24]

China's flat-plate collector sales again rose slightly (2%) in 2021, to 5 GW_{th} (7.11 million square metres).[25] Since 2015, when the flat plate collector market was 3.9 GW_{th}, manufacturers have met all of the increases in annual demand through improved utilisation rates at existing facilities.[26] In 2021, the seven largest Chinese producers of flat plate collectors increased their combined sales volumes by 11%, growing faster than the total domestic market for this technology.[27] The seven companies were: Solareast Group (including the Sunrain and Micoe brands), followed by Jinheng Solar (with its export brand BTE Solar), Linuo Paradigma, Sangle, Fivestar, Haier and Sunte Solar.[28]

Due to the growing interest in electrification of heating, demand for PV-Thermal increased **45% globally** in 2021.

Across China, the implementation of two new national policies in 2021 spurred investments in solar thermal projects. The "Double Carbon" strategy calls for China to achieve peak carbon emissions by 2030 and carbon neutrality by 2060.[29] As a result, in 2021 preparation was under way for a 77 megawatt-thermal (MW_{th}) solar heat field to provide space heating and snow production at a "green" leisure park in Hebei.[30] In addition, a new national building code (to be enforced in April 2022) mandates that new buildings in China include solar thermal, solar PV or heat pump systems.[31]

Among the other top countries for new solar thermal additions, **India** caught up with Turkey in 2021 to rank second after China. India's market grew 18% relative to 2020, to 1.35 GW_{th}, whereas Turkey's sales remained stable for the third consecutive year, at 1.35 GW_{th}.[32] Neither country had financial support schemes for solar thermal in place, so the Indian industry relied mainly on solar building obligations, and the Turkish industry on the cost competitiveness of solar water heaters.[33]

India's market has been driven by a solar building obligation in place since 2007 in the state of Karnataka, where 70% of the country's new capacity was installed during 2021.[34] India appeared to be on track to meet its target of 14 GW_{th} by the end of 2022 (set by the National Solar Mission in late 2009), reaching a total of 12.7 GW_{th} in operation at the end of 2021.[35]

Vacuum tube collectors accounted for 92% of newly installed capacity in India in 2021, up from 87% in 2020.[36] This was mainly because rising material costs (and hence higher prices) led to a 25% decline in flat plate collector sales.[37]

In **Turkey**, residential solar water heaters remained the backbone of the solar thermal industry, whereas trends for large solar heat applications varied. Demand grew significantly in the Mediterranean coast tourist region, where several large systems were installed.[38] The payback periods for solar thermal in the region are relatively short due to high irradiation and a good match between hot water demand and the high solar-yield season.[39] In contrast, public demand for central solar hot water systems in Turkish hospitals, dormitories and prisons declined in 2021.[40] Altogether, Turkey had 18.9 GW_{th} of solar thermal capacity in operation at year's end, or 4% of the global total.[41]

Among the top five countries, **Brazil** experienced the largest growth in new additions (up 28%), adding 1.27 GW_{th} in 2021.[42] New solar heating systems for swimming pools (unglazed collectors) reached 664 MW_{th} (up 33%) as people spent more time at home during the pandemic and invested in home improvements.[43] Annual installations of solar hot water systems for residential and commercial consumers increased 23%, to 609 MW_{th}, due to growth in the construction sector as well as rising electricity prices caused by drought-induced power shortages and blackouts.[44] Brazil continued to rank fifth globally for total operating capacity, with 14.3 GW_{th} by year's end.[45]

The **United States** ranked fifth for solar thermal sales in 2021 (adding 601 MW_{th}), bringing its total capacity in operation to 18.2 GW_{th}.[46] The country remained the second largest market for unglazed collectors (566 MW_{th}) after Brazil, followed by Australia (266 MW_{th}).[47] As in Brazil, new solar pool heating systems drove the US solar thermal market, helping to increase US additions 19% in 2021.[48]

Whereas in India, Turkey, and Brazil, solar water heaters are cost-effective compared to electricity-driven hot water solutions, in the United States and most European countries financial incentives are still needed to reduce upfront investment costs for solar thermal technology. This is because these latter regions have higher equipment and labour costs, and in some cases lower solar resources.[49]

Europe added 11% more solar thermal capacity in 2021 than in 2020, due to new "green heat" support schemes for buildings and industry to support national targets for climate neutrality.[50] In several European countries, demand also was driven by the growth in new housing units.[51] Altogether, an estimated 1.49 GW_{th} of new solar thermal capacity was added across the region, up 2% from the pre-COVID year of 2019 (1.47 GW_{th}).[52] By the end of 2021,

more than 10 million solar thermal systems, totalling 36 GW_{th}, were in operation across Europe, mostly in households.[53] Most of these systems include storage tanks, with an estimated 180 GWh in combined thermal storage capacity.[54]

The top five European countries for new additions in 2021 were Germany, Greece, Italy, Poland and Spain.[55] Three of these countries – Germany, Italy and Poland – have depended heavily on subsidies in recent years.

In **Germany**, the world's sixth largest solar thermal market, annual sales were similar to 2020 (around 450 MW_{th}), when additions grew by 26%.[56] This was despite a new national support scheme, launched in 2020, to accelerate decarbonisation in buildings.[57] The scheme drove up sales of biomass boilers (41%) and heat pumps (28%) in 2021, but did not affect annual installations of solar thermal systems.[58] The country's solar associations pointed to this unequal growth in heating technologies under the policy and called for solar thermal energy to be included among the "privileged technologies" in German building regulations on outdoor construction[i].[59] By year's end, Germany reached 15 GW_{th} of solar thermal capacity in operation, around 3% of the global total and 42% of the European total.[60]

Greece was the second largest European market, adding more systems than ever before for a newly installed capacity of 251 MW_{th}.[61] The drivers were the same as in previous years: cost-competitive solar thermal systems; a national solar building regulation that mandates a minimum 60% solar hot water for new buildings; and the Energy Savings in Households programme, which provides lowincome families with grants covering 60% of the upfront investment in solar water heaters.[62]

Italy's annual additions rose a record 83% to 158 MW_{th}, enabling the country to pass both Poland and Spain.[63] This strong growth was driven by increased construction activity combined with a new green building policy, the "Superbonus" for energy-efficient buildings.[64] This policy, which entered into force in February 2021, provided homeowners and housing co-operatives with a 110% tax reduction when jumping at least two classes in the building efficiency standard through so-called driving measures, such as thermal insulation and boiler replacement, including with solar thermal systems.[65]

In **Poland**, Europe's fourth largest market, additions increased 17% to 132 MW_{th} newly installed.[66] Although this was more than in 2020, it was below the pre-COVID volume of 201 MW_{th} installed in 2019.[67] Sales of residential solar water heaters continued to dominate new additions, triggered by support from European Union (EU) funds[ii].[68] Increasing investor interest in hybrid systems for space heating, including solar thermal combined with heat pumps, provided hope for rising solar thermal demand in the years to come.[69]

Spain was the only top-five European market where capacity additions fell in 2021. Spain´s solar sales have been driven mainly by the national technical building code (CTE) in recent years, rather than by financial support schemes.[70] However, revision of the CTE in January 2021 resulted in a market decline of 20% for the year, to 107 MW_{th}.[71] Instead of requiring that a minimum share of hot water demand in new buildings be met with solar thermal systems, the revised code calls for a minimum 60-70% of hot water needs to be supplied by renewable energy more broadly.[72] As a result, the share of new solar thermal capacity added that was driven by the CTE declined from 87% in 2020 to 82% in 2021.[73]

By contrast, solar heat in Spain's industry and service sector received substantial support from EU funds, totalling EUR 108 million (USD 122 million) in 2021 for 51 projects (62 MW_{th} in total).[74] A huge increase in commercial and industrial solar heat capacity is expected in 2022-2023, as all projects that received grants must be in operation before June 2023.[75] Industry representatives expect total installed costs to fall due to economies of scale, standardisation of solutions and a general maturing of the technology suppliers.[76]

Across Europe, flat plate collectors have dominated markets for decades, whereas in Asia vacuum tube collectors have represented well over half of annual additions.[77] In 2021, the largest producers of flat plate collectors in Europe were Greenonetec (Austria), Dimas (Greece), Bosch Thermotechnik (Germany) and Papaemmanouel (Greece).[78] The region's 10 largest flat plate collector manufacturers increased their combined sales 21% during the year, faster than the European market overall (11%).[79]

As in China, Europe's large producers profited from market consolidation as smaller manufacturers closed factories and purchased collectors from larger producers instead.[80] Some European technology suppliers also took advantage of the inability of Chinese manufacturers to supply markets in Europe and the Americas due to high transport costs.[81] For example, Greek manufacturers, already successful global exporters, shipped a record 582 MW_{th} of solar thermal capacity in 2021, up 33% from 2020.[82] Greece's export volumes nearly tripled between 2014 and 2021, from 189 MW_{th} to 582 MW_{th}.[83]

i Outdoor construction includes, for example, utility poles and power plants.

ii Funding was allocated from the European Regional Development Fund, whose purpose is to transfer money from Europe's richer regions to invest in the infrastructure and services of underdeveloped regions.

DISTRICT HEATING

Although most of the solar thermal capacity installed globally continued to be for water heating in individual buildings, the use of **solar thermal technology in district heating** also expanded in 2021.[84] (→ *See Figure 42*) Data on completed solar district heating systems were reported only from Europe, however, and the number of plants brought online in the region fell slightly from 10 (totalling 33 MW_{th}) in 2020 to 9 (totalling 23 MW_{th}) in 2021.[85] Reasons for the decline included long planning periods, challenging permitting processes and installation delays due to the pandemic.[86]

The leading solar district heating market was France, with three systems (totalling 7.2 MW_{th}) brought online during the year, followed by two systems in Austria (5.4 MW_{th}).[87] Denmark, Germany, the Netherlands and Sweden each completed one new installation.[88] Solar district heating plants also were likely commissioned in China (as part of the newly added 2 GW_{th} of space heating capacity in 2021), but national statistics do not distinguish between collector fields heating individual buildings and those heating multiple buildings via district networks.[89]

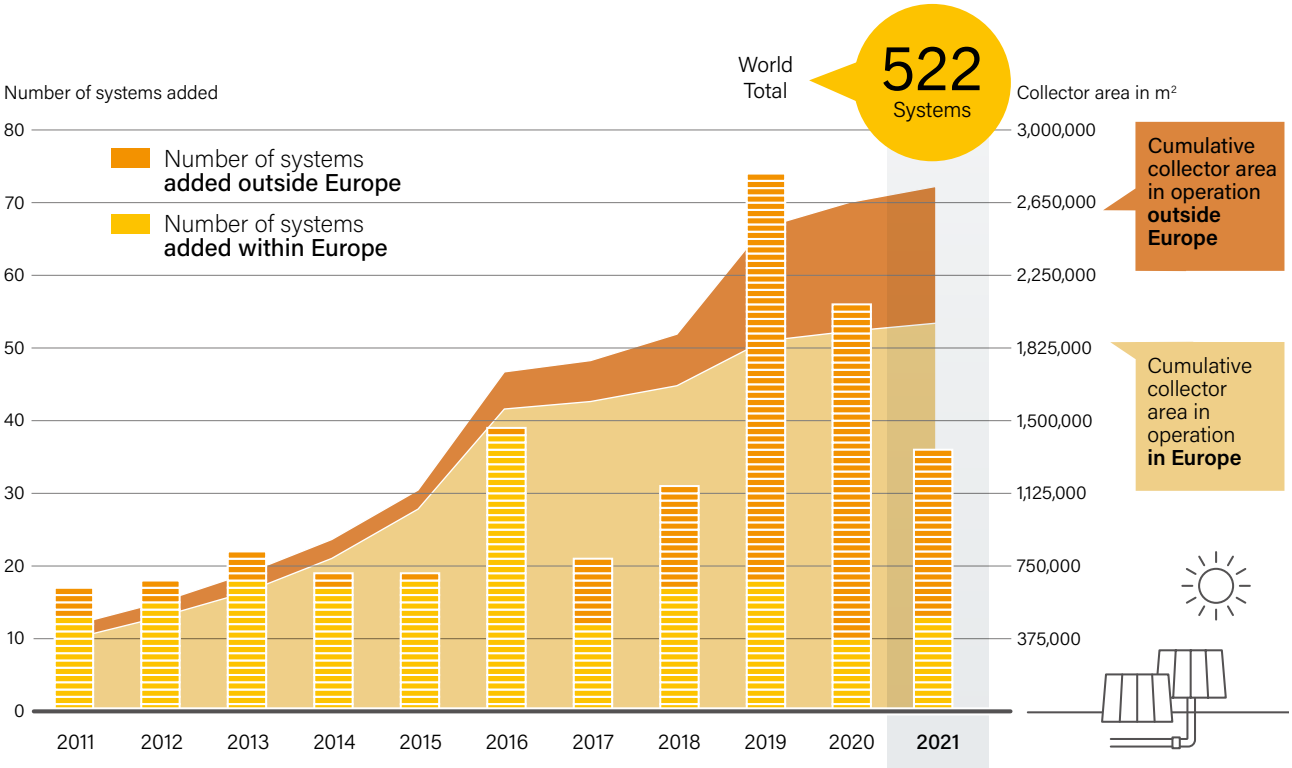
Elsewhere in Europe, air quality problems and rising energy security concerns increased interest in solar district heating, including in the Western Balkan countries, where studies were under way for future projects.[90] The European Bank for Reconstruction and Development, in co-operation with Germany's KfW bank, extended its solar district heating support to additional cities in the region in 2021.[91] By year's end, pre-feasibility studies were completed in Pristina (Kosovo), and in Bor, Pancevo and Novi Sad (all Serbia)[i]; these four cities aim to generate up to a combined 170 GW_{th} of solar heat annually.[92] Three additional pre-feasibility studies were under development to explore the potential for solar district heating plants in Korca (Albania), Nis (Serbia) and Zenica (Bosnia and Herzegovina).[93]

Despite minimal additions in 2021, Denmark remained the world leader in solar district heating capacity, with more than 1 GW_{th} in operation by year's end.[94] The levelised cost of heat for solar district heating plants in the country fell an estimated 32% between 2010 and 2019, from 6.6 US cents per kilowatt-hour (kWh) to 4.5 US cents per kWh.[95] Factors behind the cost reduction included greater developer experience, increased competition among a small number of project developers and economies of scale.[96]

The weighted-average installed cost of the six solar district heating plants newly commissioned in Denmark in 2019 (latest data available) was USD 409 per kilowatt-thermal (kW_{th}), down from USD 573 per kW_{th} in 2010.[97] In comparison, the weighted-average total cost of the 12 solar district heating plants commissioned in Germany between 2018 and 2020 was USD 769 per kW_{th}.[98]

i By year's end, both Pristina and Pancevo had advanced to the feasibility study level.

FIGURE 42.
Large Solar Heat Plants, Global Annual Additions and Total Area in Operation, 2011-2021



Source: Based on IEA SHC. See endnote 84 for this section.

Note: Figure includes plants with collector fields of at least 350 kilowatts-thermal (kWth) (500 m²), either for solar district heating or for solar hot water and/or solar space heating of residential, commercial and public buildings. Data are for solar water collectors and concentrating collectors.

The top markets for solar industrial heat in 2021 were **Mexico, Netherlands and Austria.**

INDUSTRIAL HEAT

In addition to generating heat for buildings, solar thermal technologies provide emission-free heat for a large number of production-related processes. Many industrial companies around the world, including multinational corporations, are turning to green heat solutions – including solar heat technologies – to meet their social and environmental goals.[99] This is important considering that industry is among the most difficult economic sectors to decarbonise, given the long investment cycles for new energy infrastructure.[100]

By the end of 2021, at least 975 **solar industrial heat plants (SHIP)**, totalling more than 826 MW_{th}, were supplying process heat to factories worldwide.[101] This heat is used for processes including boiling, cleaning, distilling, pasteurizing, pulping, malting, dyeing and bleaching.[102] Both the installation and commissioning of SHIP projects were delayed in 2021 due to pandemic-related restrictions and shortages of raw material supplies.[103] In all, 71 SHIP projects with a total capacity of 36 MW_{th} came online during the year, down from 87 projects and 93 MW_{th} in 2020.[104]

The ranking of countries with the highest numbers of newly commissioned projects changed significantly in 2021. China, which led the SHIP world market in 2020 with 30 new plants, reported only 7 new systems and was overtaken by Mexico, with 18 plants, followed by the Netherlands (15 plants) and Austria (11 plants).[105] The global decline in the SHIP market in 2021 is due to this Chinese contraction; outside of China, the market increased from 57 plants in 2020 to 64 plants in 2021.[106] In terms of capacity additions, France (10 MW_{th}) overtook China (8.2 MW_{th}), followed by third place Turkey (3.8 MW_{th}).[107]

Although commissioning was down during 2021, construction of new SHIP plants accelerated, and at least 44 MW_{th} of capacity for 16 projects was in the pipeline by year's end.[108] SHIP capacity under construction was dominated by higher-temperature systems that use concentrating collector technologies: 12 concentrating heat systems totalling 32 MW_{th} were planned to be commissioned in 2022, up sharply from the 9 MW_{th} of concentrating heat capacity commissioned globally in 2021 for both the industrial and service sectors.[109]

China, Mexico and India remained the key markets for SHIP turnkey system providers.[110] The leading companies involved in the engineering and construction of SHIP facilities (ranked by number of projects in operation by the end of 2021) were Modulo Solar (Mexico), Solareast Group (China), Linuo Paradigma (China), Inventive Power (Mexico) and G2Energy (Netherlands).[111]

For the first time, weighted-average data on the levelised cost of heat for a large number of SHIP plants were published in 2021[i]. Costs differ by country due to varying cost structures for materials and labour and differing irradiation levels, among other factors.[112] SHIP plants commissioned in China, Mexico and India between 2010 and 2020 produced heat for around 4 US cents per kWh[ii] on average.[113] This compared to an average of 6.4 US cents per kWh in Southern Europe and 9.2 US cents per kWh in Central Europe.[114] Central Europe shows the widest range in the levelised cost of heat over the period because, as the SHIP market matured, small projects with relatively high costs gave way to large projects with lower costs.[115] The average installed cost of SHIP plants in Europe dropped 68% between 2014 and 2020 (from USD 1,679 per kW_{th} to USD 531 per kW_{th}), due mainly to economies of scale.[116]

While SHIP plants in Mexico are cost competitive with fossil fuels, particularly liquefied petroleum gas, in many other countries achieving competitiveness against oil and natural gas is dependent on public funding.[117] In France, the largest new SHIP plant of 2021 (10 MW_{th}), which came online in September at a malting plant, received EUR 3 million (USD 3.4 million) from the French energy agency Ademe.[118] Based on this subsidy, the project developer Kyotherm (France) was able to offer the malting plant a solar heat price that was below what the client paid previously for gas-produced heat. Kyotherm played a pioneering role in operating as a solar heat energy service company (ESCO).[119]

i The number of projects with cost-performance indicators for SHIP plants within the database for the International Renewable Energy Agency is still small. To compare regional cost differences, values for the levelised cost of heat are averaged over a 10-year period. The values in this paragraph are based on 252 projects, or around 26% of the global SHIP market.

ii The weighted-average levelised cost of heat for SHIP plants in Asia (60 plants, mainly in India and China) was 3.9 US cents per kWh and in Mexico (81 plants) was 4.4 US cents per kWh.

Other SHIP technology suppliers have turned their attention to heat delivery contracts, since the ESCO model reduces the risk of the industrial heat user and speeds business decision making because the engagement is free from capital expenditure and does not burden the equity of the client.[120] During 2021, the Belgium company Atzeq was constructing its fourth ESCO project, a 3.8 MW_{th} parabolic trough collector field that will supply steam to a chemical producer in Belgium.[121] Inventive Power (Mexico) commissioned its first ESCO project, a parabolic trough collector facility with 332 kW_{th} of capacity for a food processor.[122] Modulo Solar (Mexico) financed and installed two plants (totalling 1.7 MW_{th}) with an ESCO model to provide heat for private swimming pools.[123]

The number of multi-MW SHIP plants under engineering or construction continued to grow in 2021, driven by rising fossil fuel prices and by financial support schemes in Europe and the US state of California.[124] The project developer NewHeat (France) took the lead in finding industrial clients.[125] It announced the start of the construction of a 15 MW_{th} SHIP plant for a whey powder factory in France, supported by Ademe, and secured a grant of EUR 4.5 million (USD 5.1 million) from the EU innovation fund for a 20 MW_{th} plant for a malting factory in Croatia.[126] Also in Europe, Simona Alexe – greenixcloud (Austria) carried out a feasibility study for a 25 MW_{th} SHIP plant for a textile company in Austria, and an EU-funded Spanish support scheme awarded a grant to Engie Servicios Energéticos (Spain) for a 30 MW_{th} plant at a brewery.[127] For comparison, the largest SHIP plant already in operation in Europe at year's end was a 10.5 MW_{th} facility for an agricultural business in the Netherlands.[128]

California's Food Production Investment Program, established in 2018 to encourage food producers in the state to reduce greenhouse gas emissions, awarded grants totalling USD 13 million to four SHIP plants with a combined capacity of at least 22.6 MW_{th}.[129] The largest US solar steam producing system (2.3 MW_{th}) was commissioned in early 2021 at an almond processor.[130] At year's end, two other solar steam producing systems for dairies (8.4 MW_{th} and 11.9 MW_{th}) were under construction, and the fourth SHIP plant (also for a dairy) was in the planning phase.[131] The four grants supported the business development of a new generation of US-based concentrating solar heat technology suppliers: Hyperlight Energy, Sunvapor and Skyven Energy.[132]

OTHER DEVELOPMENTS

Leading developers of all types of solar heat plants are using stock markets to gain additional capital to pre-finance project development costs.[133] In 2021, Tigi (Israel) started trading shares in the cleantech sector of the Tel Aviv Stock Exchange, raising around USD 10 million.[134] Heliogen (US) successfully raised USD 415 million in the run-up to its initial public offering in December 2021 by using a special purpose acquisition company.[135] Savosolar (Finland), listed on Nasdaq Nordic since 2015, gained up to EUR 5.4 million (USD 6.1 million) by rights issues in 2021.[136] Prior to 2021, only Savosolar and three other solar thermal manufacturers were listed on stock markets globally.[137]

Due to growing interest in the electrification of heating, demand for photovoltaic-thermal, or hybrid collectors, increased again in 2021. PV-T collectors consist of a thermal absorber below a solar PV module and deliver both electricity and thermal energy that can be used as a flexible energy source for heat pumps in buildings.[138] During the year, 30 manufacturers reported sales of PV-T capacity of at least 88 MW_{th} (connected to 31 MW electric), up 45% from 61 MW_{th} in 2020.[139]

The largest markets for new PV-T additions (by capacity added) were France, the Netherlands, Israel, Germany and Spain.[140] France achieved the highest annual growth with nearly six times more PV-T capacity added in 2021 (68 MW_{th}) than in 2020.[141] Within the country, the popularity increased of both PV-T air solutions for space heating and unglazed PV-T collectors as the heat source for heat pumps.[142] In all key markets, demand among residential and commercial clients has been driven by the ability to produce both heat and electricity from the same roof space, thus generating a higher yield per area.[143]

Innovative business models such as
heat delivery contracts
attracted new customers.

SOLAR THERMAL HEATING

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3 Additions on the country level were provided to REN21 during February-April 2022 from the following sources: D. Johann, Brazilian Solar Thermal Energy Association (ABRASOL), São Paulo, Brazil; E. Porcheyre, Enerplan, La Ciotat, France; C. Travasaros, Greek Solar Industry Association (EBHE), Piraeus, Greece; J. Malaviya, Solar Thermal Federation of India (STFI), Pune, India; F. Musazzi, ANIMA, the Federation of Italian Associations in the Mechanical and Engineering Industries, Milan, Italy; J. Staroscik, Association of Manufacturers and Importers of Heating Appliances (SPIUG), Warsaw, Poland; B. Heavner, California Solar & Storage Association (CALSSA), Sacramento, California, United States (US new additions of vacuum tube collectors were not available). For Morocco, a 10% increase in additions in 2021 was estimated based on the import value in million USD for the months January to September 2021, which increased 13% compared to the same period the previous year, from Trademap, https://www.trademap.org (for Morocco, the share of vacuum tube and flat plate collectors was not available).

4 Data on national market development were provided to REN21 during February-April 2022 from the following sources: D. Johann, ABRASOL, São Paulo, Brazil; R. Hackstock, Austria Solar, Graz, Austria; H. Cheng, Shandong SunVision Management Consulting, Dezhou, China; E. Porcheyre, Enerplan, La Ciotat, France; A. Liesen, BSW Solar, Berlin, Germany; P. Polo, Spanish Solar Thermal Association (ASIT), Madrid, Spain.

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6 Epp, op. cit. note 2.

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9 Solarthermalworld.org reported on solar thermal sales activities in at least 134 countries worldwide during 2008-2020, from Ibid.

10 Global data for annual capacity additions in operation in this chapter text include all collector types: glazed (flat plate and vacuum tube collector technology), unglazed, concentrating, air and PV-Thermal (PV-T) as per Weiss and Spörk-Dür, op. cit. note 1. **Figure 40** based on the following: Global solar thermal capacity for glazed and unglazed collectors is based on the latest market data from the following solar thermal markets Australia, Austria, Brazil, China, Cyprus, Denmark, Germany, Greece, India, Italy, Mexico, Palestinian Territories, Poland, South Africa, Spain, Turkey and United States, which presented 94% of the cumulative installed capacity in operation in 2020; Weiss and Spörk-Dür, op. cit. note 1.

11 Weiss and Spörk-Dür, op. cit. note 1. Equivalence of 425 TWh and 250 million barrels of oil equivalent from Kyle's Converter, http://www.kylesconverter.com.

12 Estimate of 2,505 GWh of solar thermal storage capacity in operation globally is based on the assumption that each square metre of collector area has a minimum of 50 litres of water storage capacity, which can potentially store 3.75 kWh per 100 litres when considering a temperature increase from 15°C to 80°C, from P. Dias, Solar Heat Europe, Brussels, Belgium, personal communication with REN21, April 2022.

13 The Netherlands was the only country to drop from the list of top 20 countries. France returned to the top 20 list in 2021 thanks to the commissioning of several large-scale solar heat plants for utilities and industry. **Figure 41** based on the latest market data available for gross additions of glazed and unglazed water collectors (not including concentrating, PV-T and air collectors), at the time of publication, for countries that together represent 97% of the world total. Data from original country sources include gross national additions and were provided to REN21 during February-April 2022 from the following sources: D. Ferrari, Sustainability Victoria, Melbourne, Australia (for Australia, additions of unglazed collectors refer to 2020 because updated data for 2021 were not available); additions for Austria refer to 2020 (latest data available) as provided by W. Weiss, AEE INTEC, Vienna, Austria; D. Johann, ABRASOL, São Paulo, Brazil; H. Cheng, Shandong SunVision Management Consulting, Dezhou, China (7% was subtracted from the Chinese additions reported by Cheng, because the figures included vacuum tube collectors that were manufactured in China and exported to other countries); P. Kastanias, Cyprus Union of Solar Thermal Industrialists (EBHEK), Nicosia, Cyprus; E. Porcheyre, Enerplan, La Ciotat, France (for France, additions only refer to Metropolitan France as data for the overseas departments were not available); A. Liesen, BSW Solar, Berlin, Germany; C. Travasaros, EBHE, Piraeus, Greece; J. Malaviya, STFI, Pune, India; additions in Israel refer to 2020 (latest data available) as provided by E. Shilton, Elsol, Kohar-yair, Israel; F. Musazzi, ANIMA, Milan, Italy; D. Garcia, Solar Thermal Manufacturers Organisation (FAMERAC), Mexico City, Mexico; P. Dias, Solar Heat Europe, Brussels, Belgium (for Portugal); J. Staroscik, Association of Manufacturers and Importers of Heating Appliances (SPIUG), Warsaw, Poland; K. Kritzinger, Centre for Renewable and Sustainable Energy Studies, University of Stellenbosch, Stellenbosch, South Africa; P. Polo, ASIT, Madrid, Spain; A. Baccouche, ANME, Tunis, Tunisia; K. Ülke, Bural Heating, Kayseri, Turkey; B. Heavner, CALSSA, Sacramento, California, United States (for the United States, new additions of vacuum tube collectors were not available). For Morocco, a 10% increase in additions in 2021 related to 2020 was estimated based on the import value in million USD for the months January to September 2021, which increased 13% compared to the same period in the previous year, from Trademap, https://www.trademap.org (for Morocco, share of vacuum tube and flat plate collectors was not available).

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