CENTRE FOR RENEWABLE & SUSTAINABLE ENERGY STUDIES

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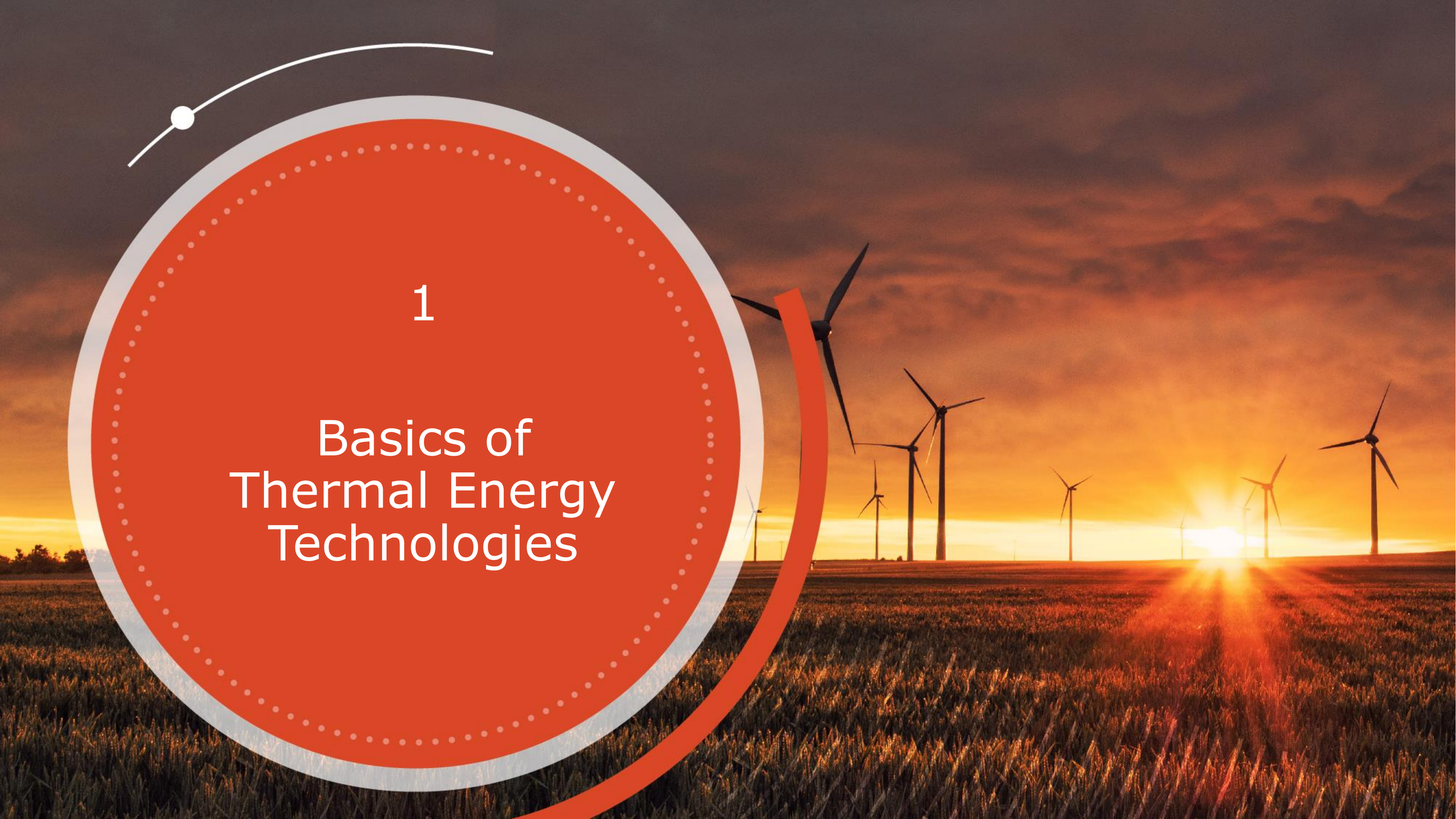
Visualisation of Thermal Energy Data

December 2025

Don Fitzgerald
Francois Rozon



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Basics of Thermal Energy Technologies

Basics of Thermal Energy Technologies

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Thermal energy is the portion of energy within an energy system that is associated with **heat generation**, **distribution**, **storage**, or **consumption**.

It includes both **low-** and **high-temperature** heat used for:

Residential & commercial heating /cooling

District heating /cooling

Industrial processes

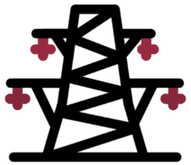
Power generation

Residential and commercial refers to space and water heating or cooling for one property.
District heating or cooling refers to large centralised systems that supply many properties.

It can be delivered from **energy sources** such as:

Fossil fuels

Biomass



Electricity

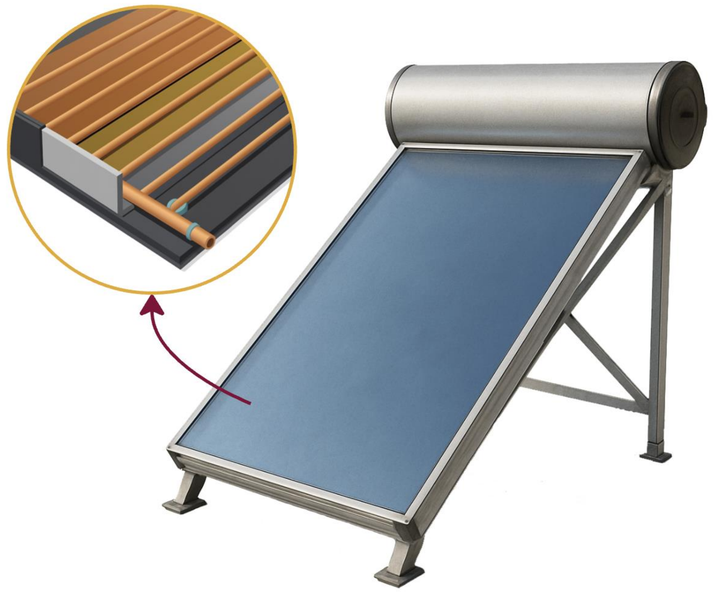
Solar thermal

Geothermal

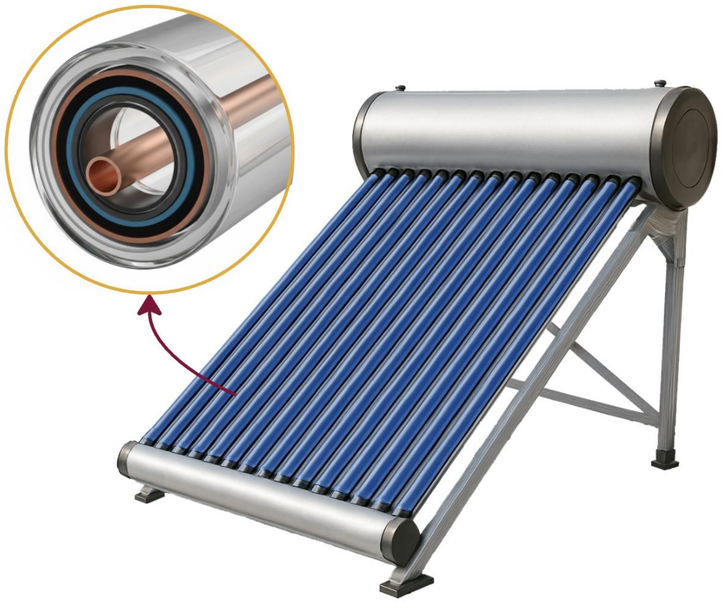
Basics of Thermal Energy Technologies

1.1. Domestic Solar Heater Technologies

The two most common **Solar Water Heater (SWH)** technologies consist of the **Flat Plate Collector (FPC)** and the **Evacuated Tube Collector (ETC)**. An FPC consists of winding copper pipes inside a frame, usually with a glass covering, that heat the water directly running through the pipes. An ETC uses parallel glass tubes with a vacuum for insulation and a secondary refrigerant-like liquid to absorb and transfer the heat to the water.



Flat Plate Collector
(FPC)



Evacuated Tube Collector
(ETC)

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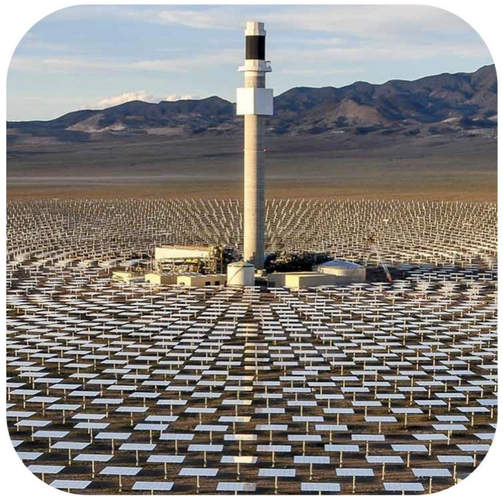
1.2. Solar Thermal Technologies



Concentrated Solar Power
(CSP)

CSP systems use **mirrors** or **lenses** to focus sunlight onto a **central receiver**, heating a fluid to **high temperatures**. This thermal energy is then used to produce **steam** that drives a turbine connected to a generator, producing **electricity**. CSP systems often include thermal energy storage, allowing **power generation** even when the sun isn't shining.

Photovoltaic Thermal
(PVT)

PVT systems combine **solar PV** panels with a **thermal collector** to generate both **electricity** and **heat** from the same surface area. The PV panel converts **sunlight** into **electricity**, while a fluid behind the panel captures waste heat, improving overall **energy efficiency**. PVT systems are ideal for applications needing both **power** and **thermal energy**.

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1.3. Sustainability Technologies

Heat Pump
(HP)

A **HP** is a highly **efficient** device that transfers **heat** from one place to another using a **refrigeration cycle**. It can extract heat from the **air**, **ground**, or **water** and move it indoors for **heating**, or reverse the cycle for **cooling**. HPs use **electricity** but deliver more thermal energy than they consume, making them an **energy-efficient solution** for space and water heating.

Thermal Energy Storage
(TES)

TES systems store excess **heat** for later use, improving **energy efficiency** and balancing **supply** and **demand**. They typically use materials like **water**, **molten salts**, or **phase change materials** to retain thermal energy. Heat can be collected from **solar systems**, **waste heat**, or electricity-driven **HPs**, and release it when needed for **space heating**, **cooling**, or **industrial processes**.

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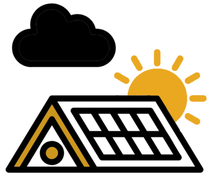
1.3. Traditional Technologies

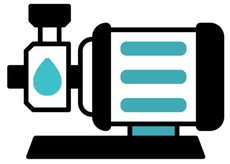
Coal and **oil burners** generate heat by combusting **fossil fuels**, commonly used in older industrial and residential systems. **Biomass burners** use organic materials like **wood pellets** or **agricultural waste** as a renewable alternative. **Electric boilers** and **geysers** heat water using **electrical resistance**, offering cleaner operation but often at higher **energy costs** if not paired with renewable electricity.

1.4. Important Definitions



Solar fraction (SF) is a measure of how much of a system's **total heating** or **energy demand** is covered by **solar energy** compared to **electrical energy**. It is usually expressed as a **percentage** and indicates the contribution of solar power compared to other energy sources.

Coefficient of Performance (COP) is a measure of a **heating** or **cooling** system's **efficiency**. It is the ratio of useful **thermal energy output** to the **electrical energy input**. Heat Pumps have a COP **greater than 1**, meaning they provide **more thermal energy** than the **electrical energy input**.



Thermosyphon systems rely on **natural convection**: hot water rises from the collector into a tank placed **above it**, requiring no pump. These are systems are easily identified as the tank sits **above** the collectors on the roof. Pumped systems, by contrast, use an **electric pump** to circulate water between the **collector** and a **tank**, allowing more flexible placement of components. The tank may now sit anywhere **below** the collectors.

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World Trends

Globally, solar-thermal collector capacity has grown steadily, with large contributions from domestic hot-water systems in Asia, Europe, and Latin America. Energy yield in TWh tracks this rising installed base. However, growth slowed after 2013 as earlier subsidy programmes ended in China and Denmark.

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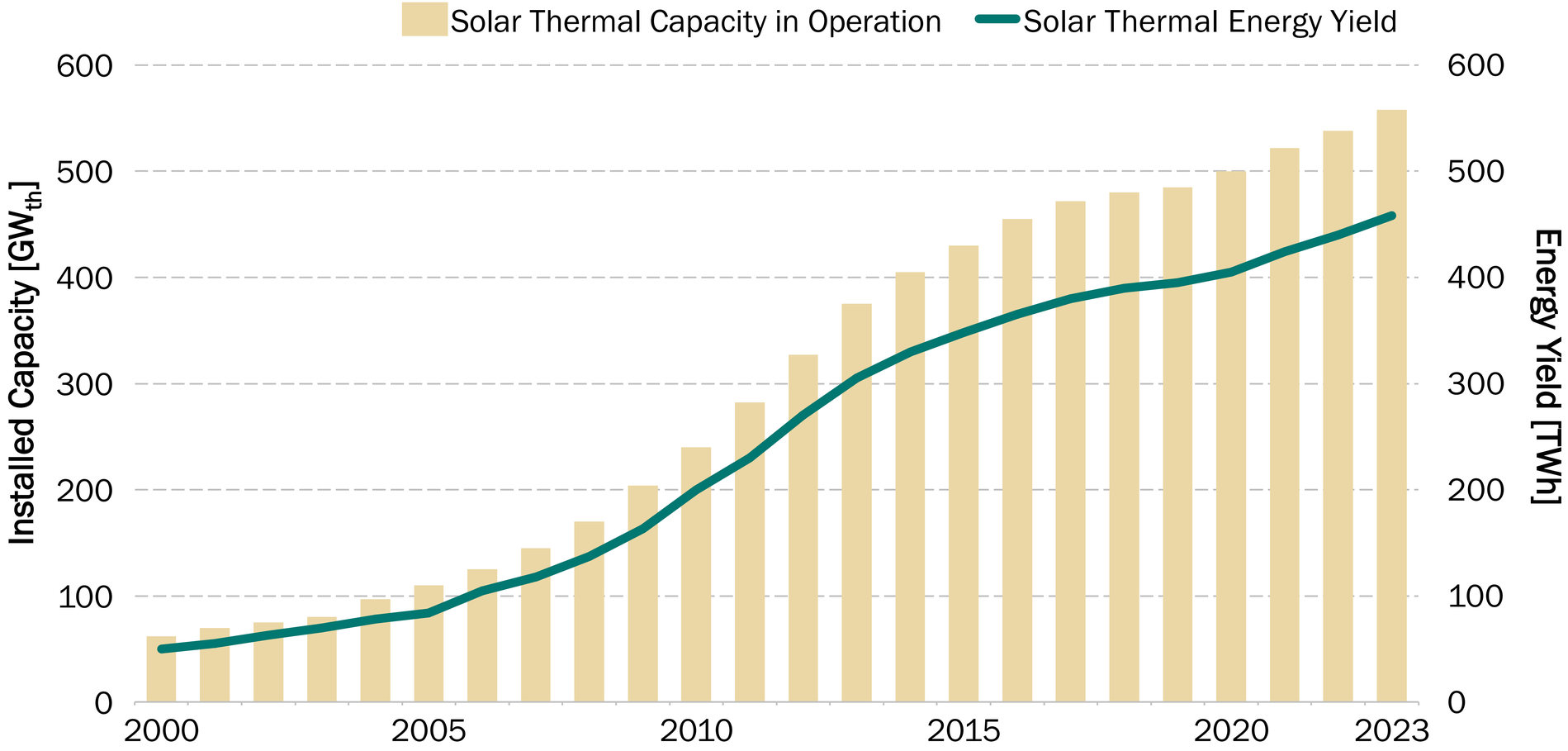
Global Solar Thermal Capacity and Annual Yield



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Source: AEE INTEC 2024.

This next diagram contrasts total operational solar-thermal capacity with newly installed capacity each year. Flat-plate collectors (FPCs) and evacuated tubes (ETCs) dominate. Although many mature markets slowed post-2013, new regions — MENA, Latin America — are now expanding.

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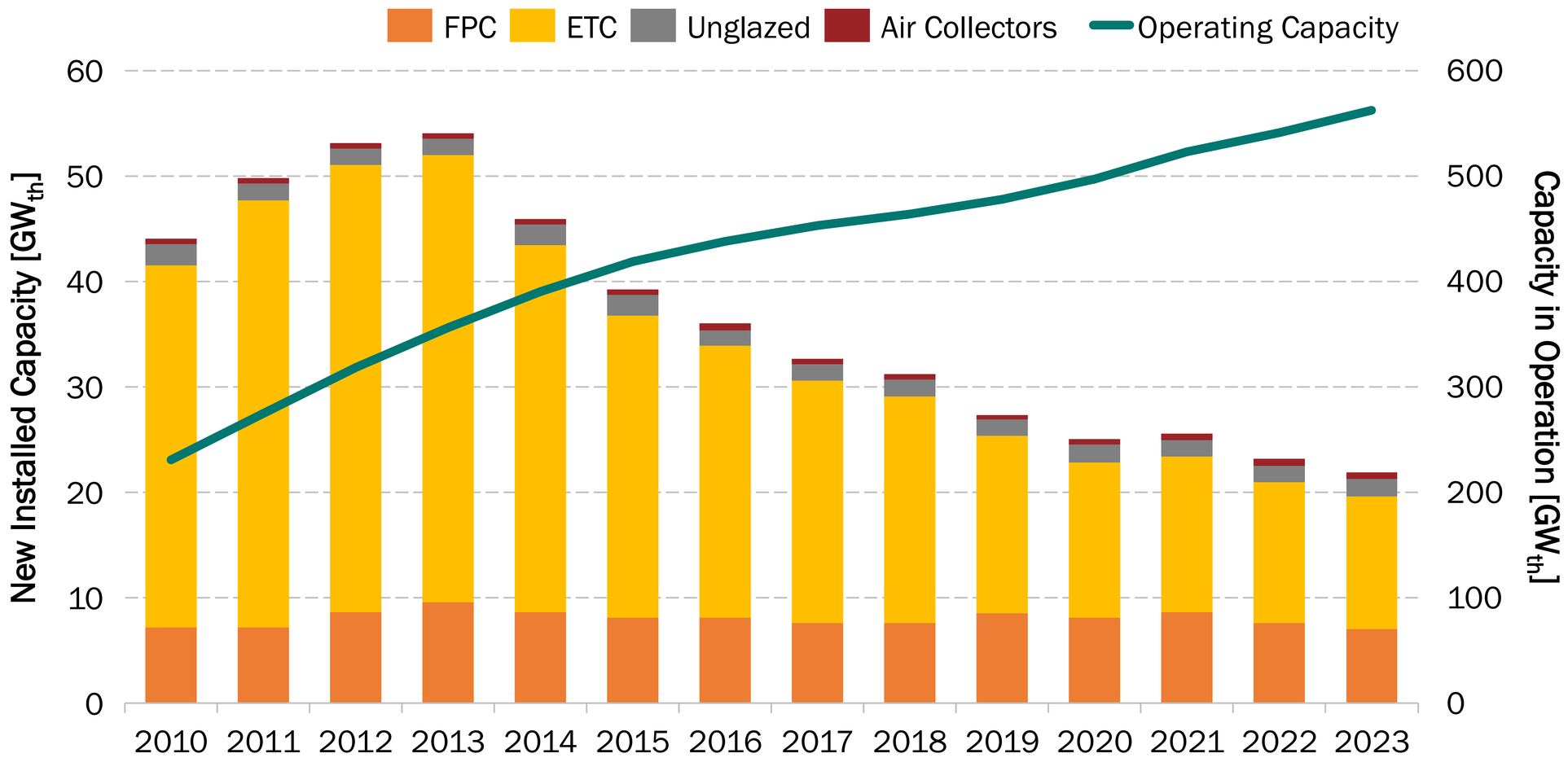
Global Solar Thermal Capacity by Technology



Source: AEE INTEC 2025. **Notes:** FPC = Flat Plate Collector; ETC = Evacuated Tube Collector.

Here, global thermal capacity and actual energy delivered is compared to other renewable energy sources globally. Solar thermal power generation is out shadowed by solar thermal heat, and power from wind and photovoltaics (PV). The distribution of solar thermal collector area, for heat or power, is shown by region.

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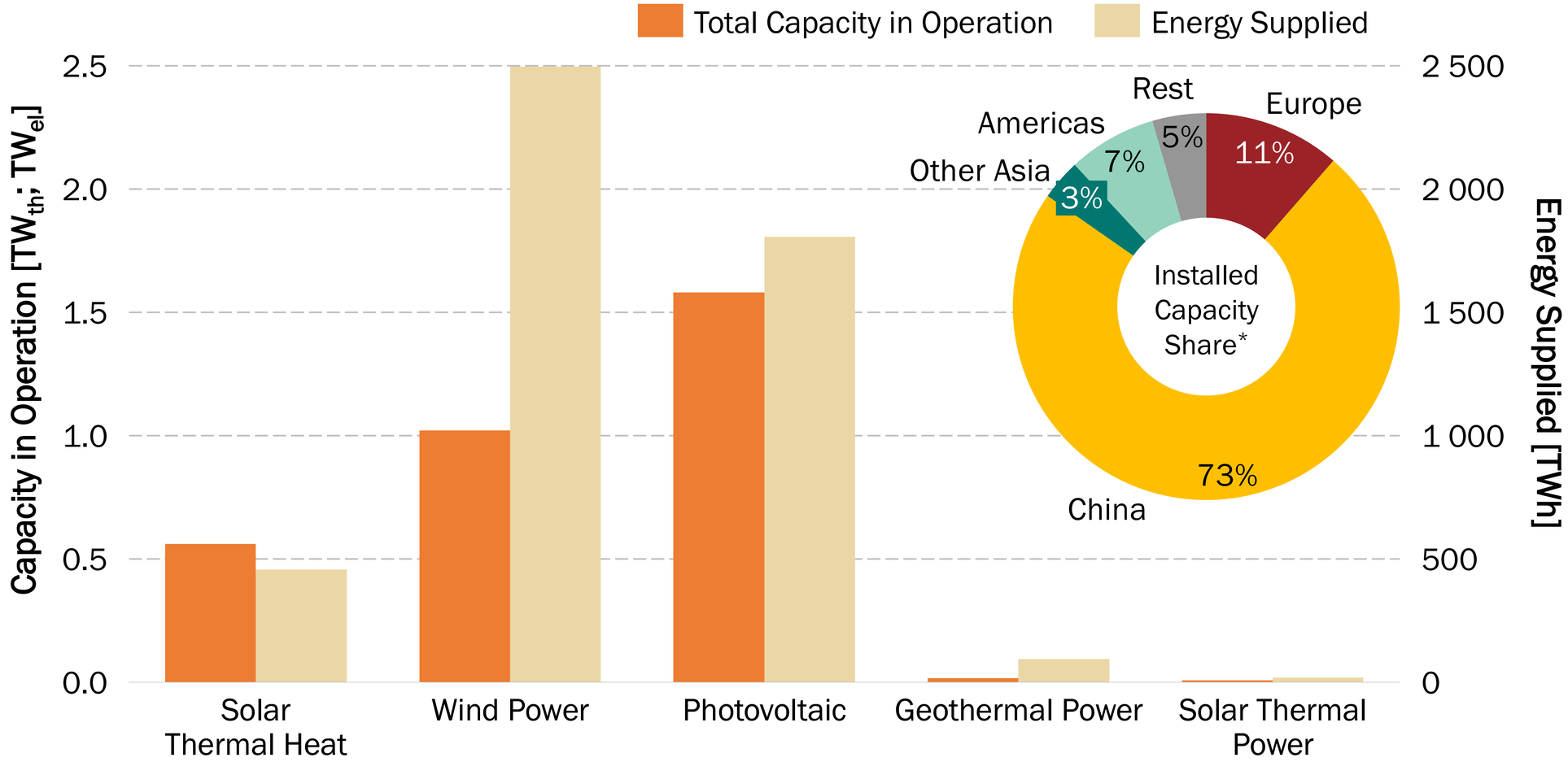
Global Operational Capacity and Annual Energy Yields 2023



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Source: AEE INTEC 2024. **Notes:** TW_{th} = Terawatt thermal; TW_{el} = Terawatt electrical; *installed capacity share includes glazed and unglazed water and air collectors in operation.

This data shows the global distribution of total collector area across different applications, including domestic hot water (DHW), large DHW systems, swimming pools, and solar combi-systems. Domestic water heating remains the dominant use in most regions, but the use of larger DHW systems is growing.

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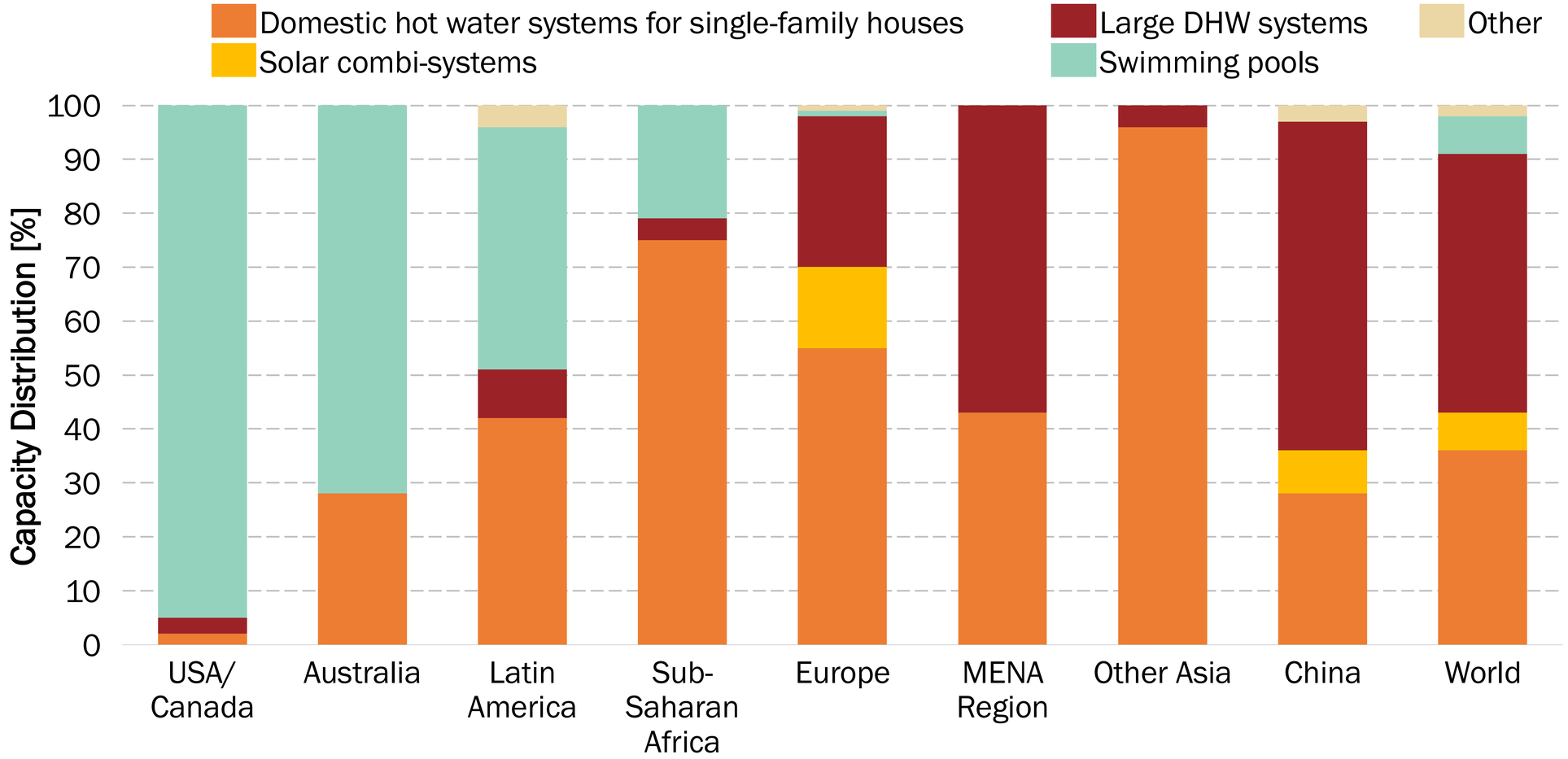
Distribution of Solar Thermal System Capacity 2022



Source: AEE INTEC 2024. **Notes:** DWH = Domestic Hot Water.

The map below shows the capacity density of installed solar thermal capacity per 1000 inhabitants. Highlighted countries with high market penetration density include China, Turkey, Denmark, Germany, Austria, and Greece.

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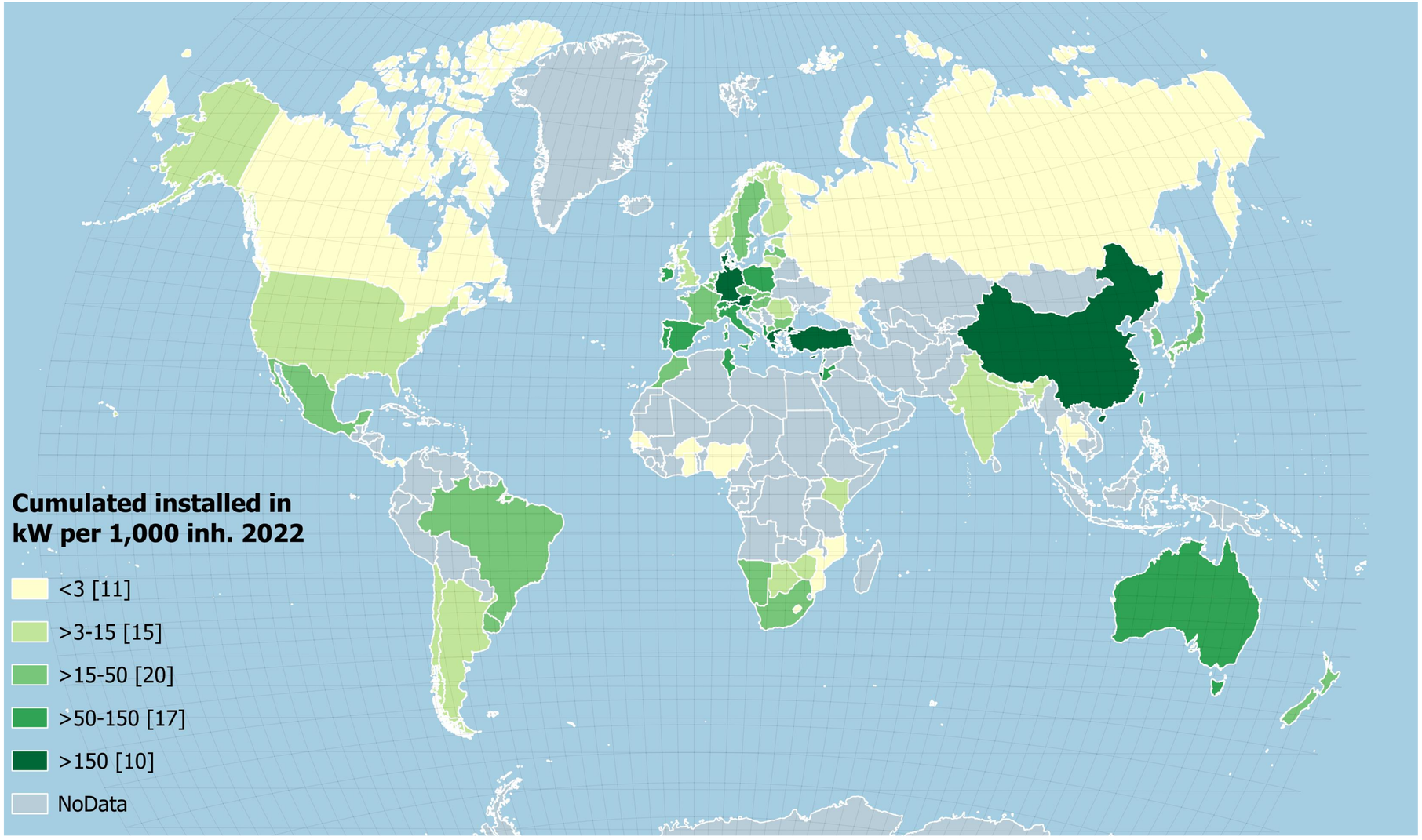

Source: SHIP 2025.

Photovoltaic Thermal Systems (PVT) combine solar thermal heat and PV electricity production within the same collector. This can boost total energy yield per installed collector area. This is especially promising when the available installation area is limited, such as the rooftop of high-rise buildings. Adoption remains modest compared to traditional PV and thermal systems, partly due to higher costs and varying market support. Europe has seen the biggest growth of PVT systems (65%), followed by Asia (28%), MENA (4%), and the rest of the world (3%).

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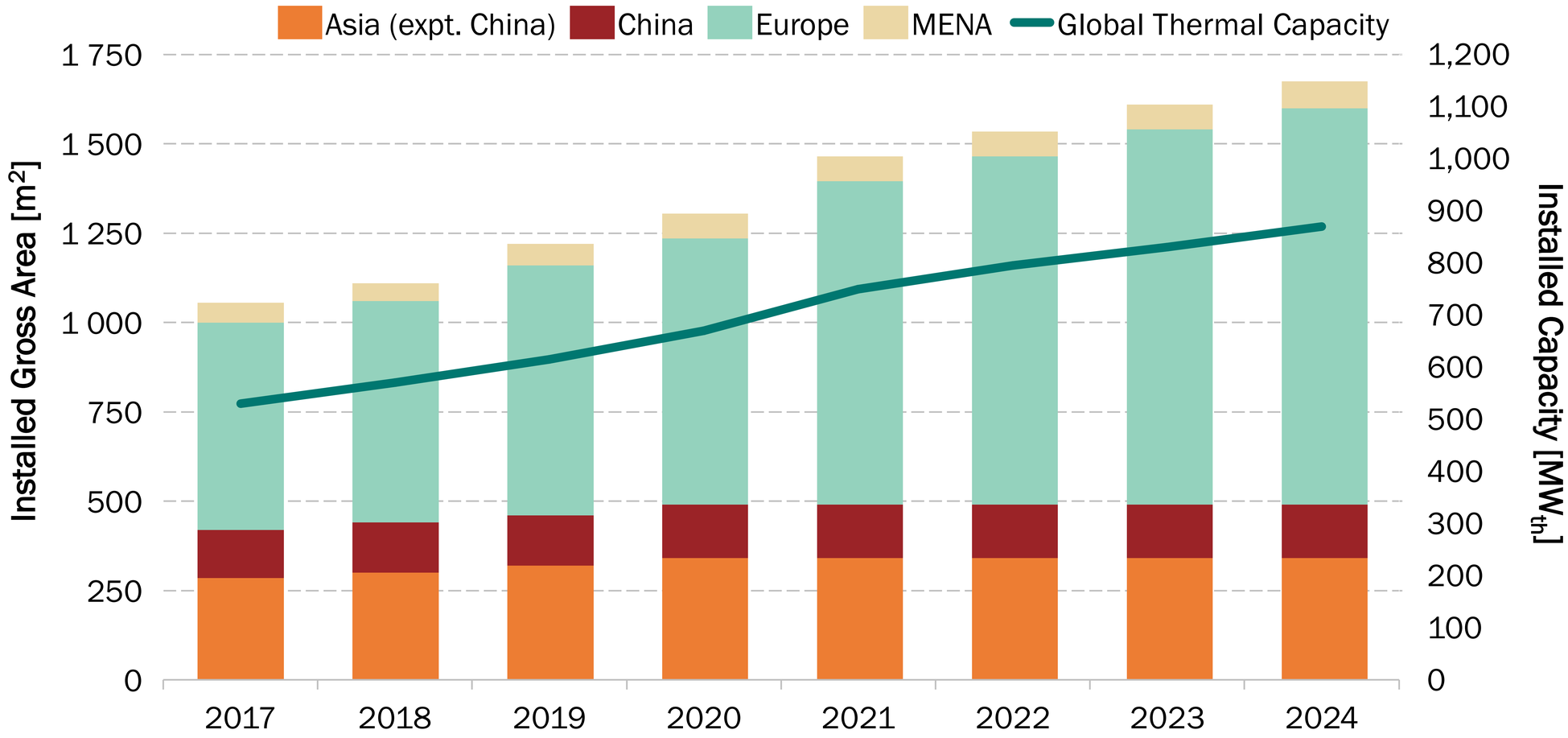
Global Market Development of PVT-Collectors



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Source: AEE INTEC 2025. **Notes:** MW_{th} = Megawatt thermal; MENA = Middle-East and North-Africa; PVT = photovoltaic thermal systems.

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Thermal Energy in South Africa

South Africa's solar-thermal market grew rapidly during the period when Eskom subsidies were available (until around 2015). After subsidies ended, installations slowed but remained supported by building regulations requiring solar or heat-pump water heating in new buildings.

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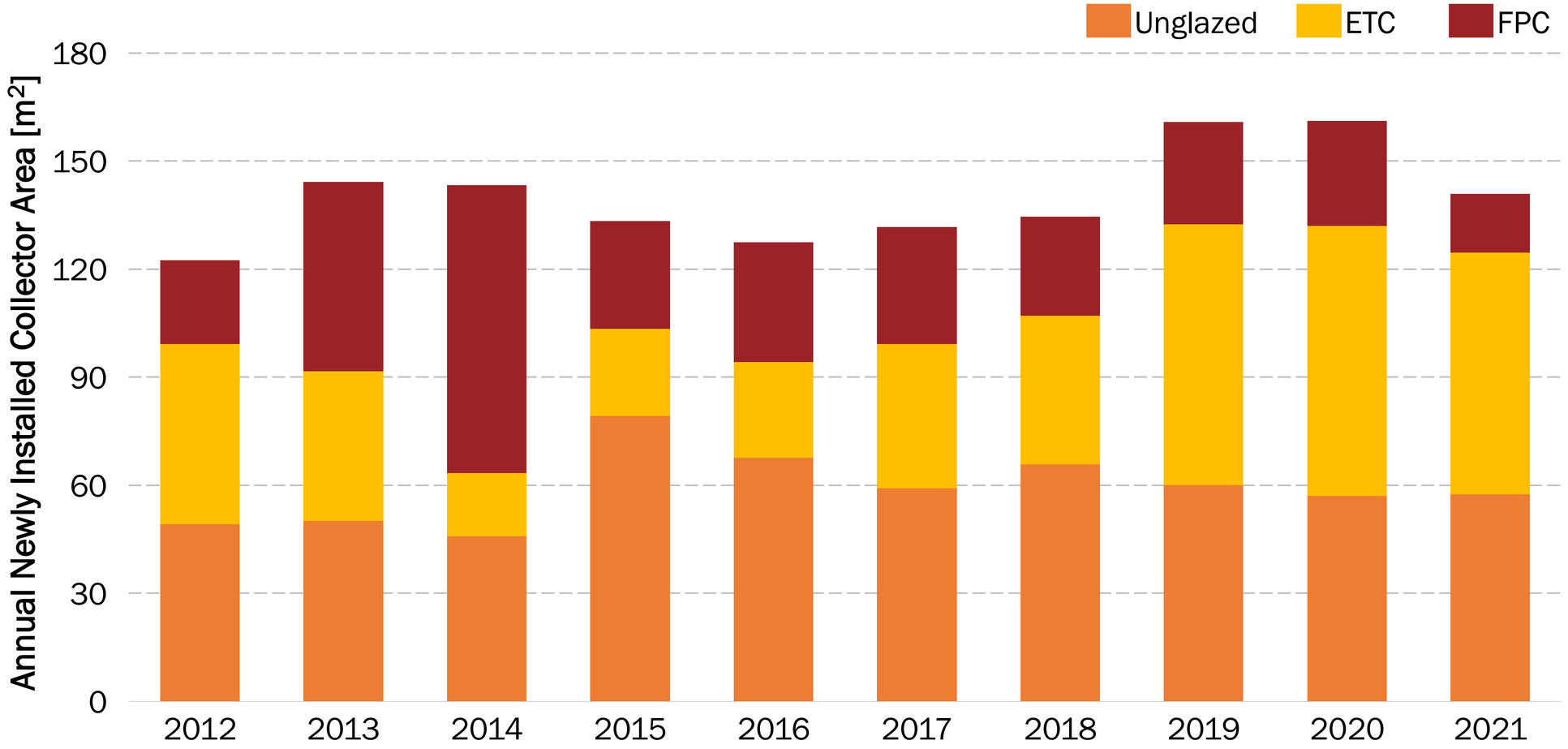
Annual Newly Installed Collectors in South Africa



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Source: Solar Thermal World 2023. **Notes:** FPC = Flat Plate Collector; ETC = Evacuated Tube Collector.

4

Industry

The SHIP database (Solar Heat for Industrial Processes) is a public online platform that maps and documents industrial solar-thermal installations worldwide. Managed by AEE INTEC under the IEA Solar Heating & Cooling Programme, it provides detailed information on each project, including its location, collector type, thermal capacity, industrial sector, and operating temperature range. The database helps researchers, engineers, and developers understand global market trends, compare technologies, and identify suitable reference cases for new industrial heat projects. Because industrial heat represents a major share of global energy demand, the SHIP database serves as an important resource for tracking how solar thermal is being adopted across different sectors and regions.

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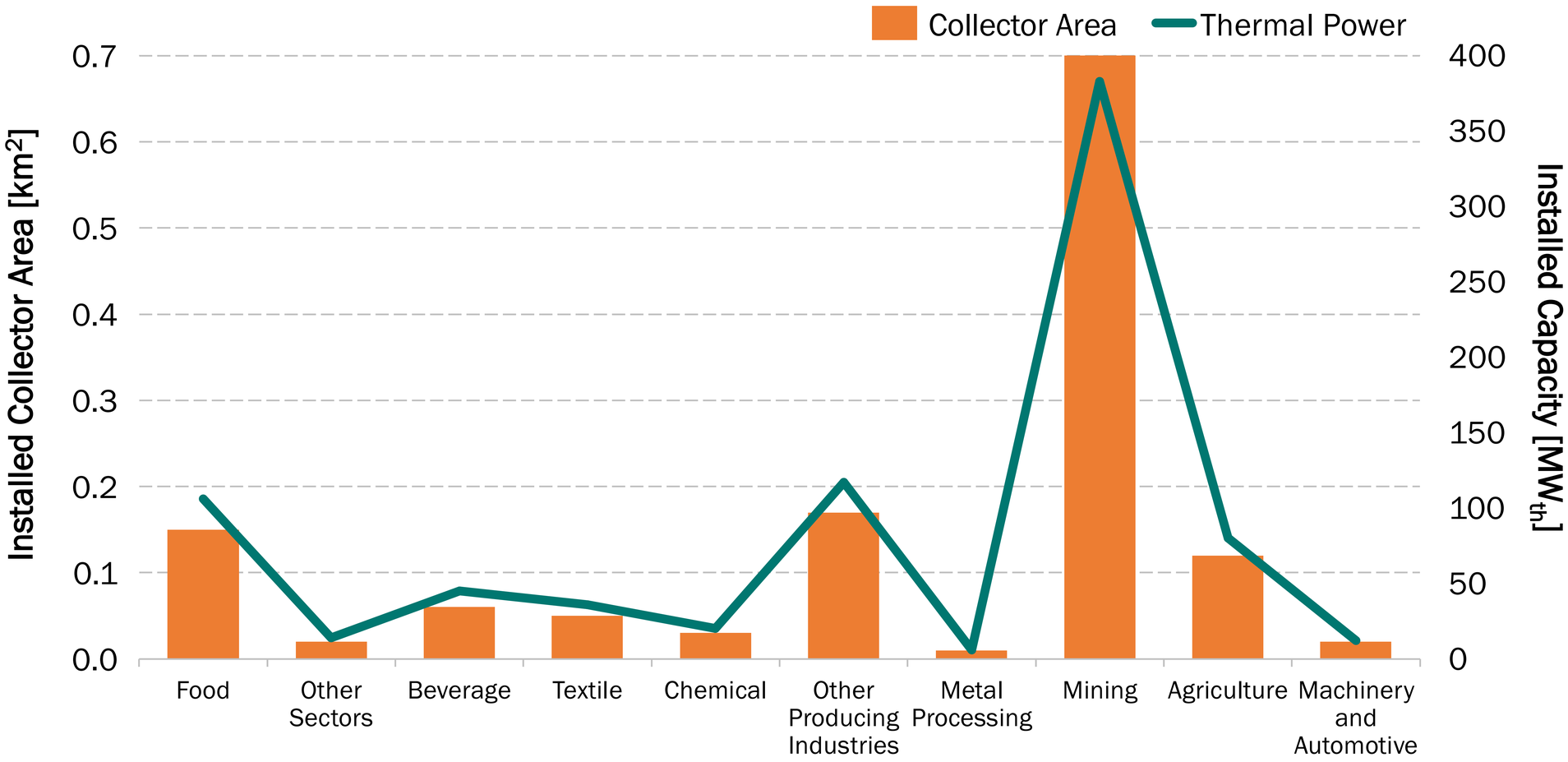
Global Solar Process Heat Applications 2024



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Source: AEE INTEC 2024; SHIP 2025.

The diagram below provides detail into which solar thermal technologies are being used in industry across all sectors. This is dominated by parabolic trough collectors for larger scale systems compared to domestic applications.

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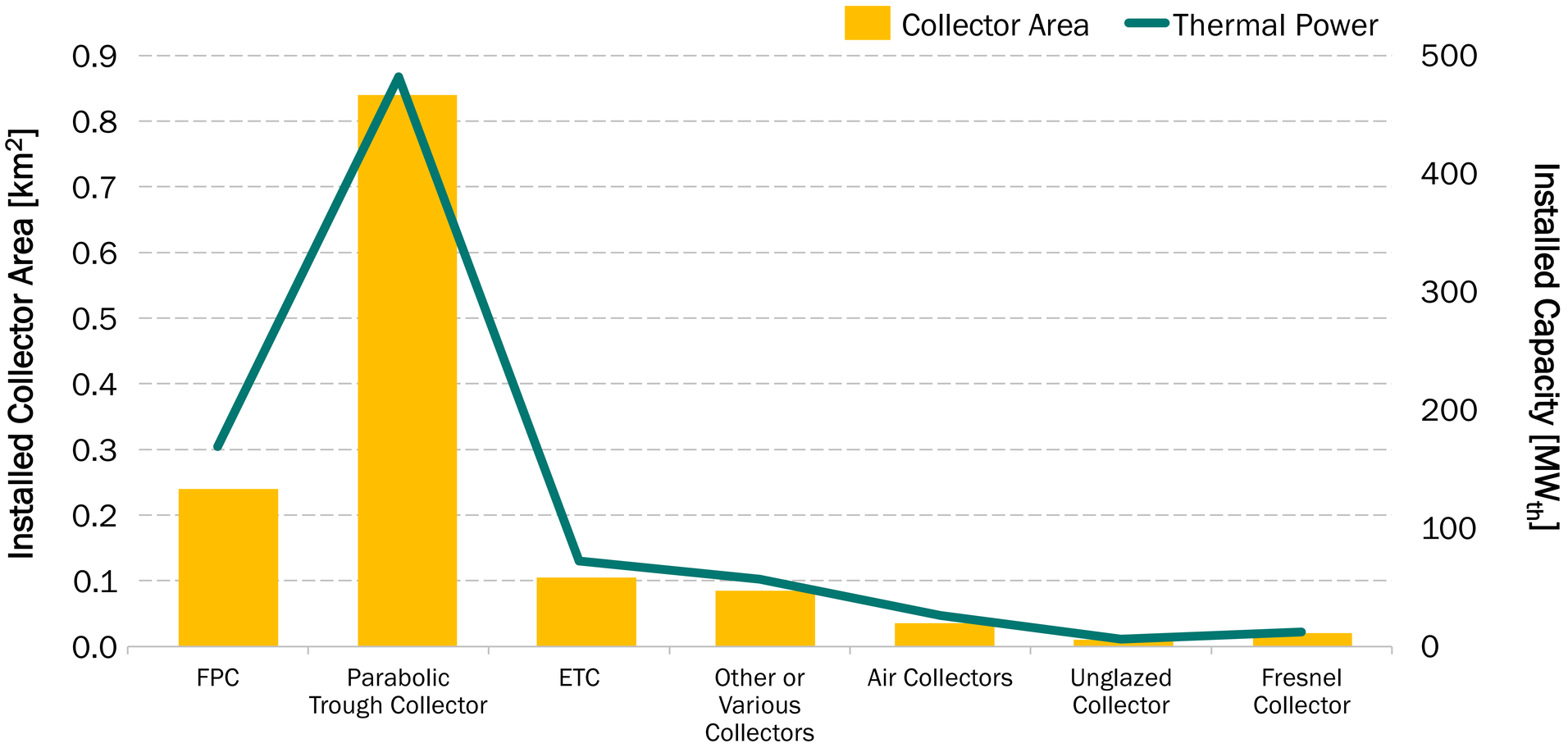
Global Solar Process Heat Applications 2024



Source: AEE INTEC 2024; SHIP 2025. **Notes:** FPC = Flat Plate Collector; ETC = Evacuated Tube Collector.

The industry data is then categorised by country in terms of installed collector area and total number of systems. Interestingly, Oman has the largest collector area by far, installed in only 2 systems.

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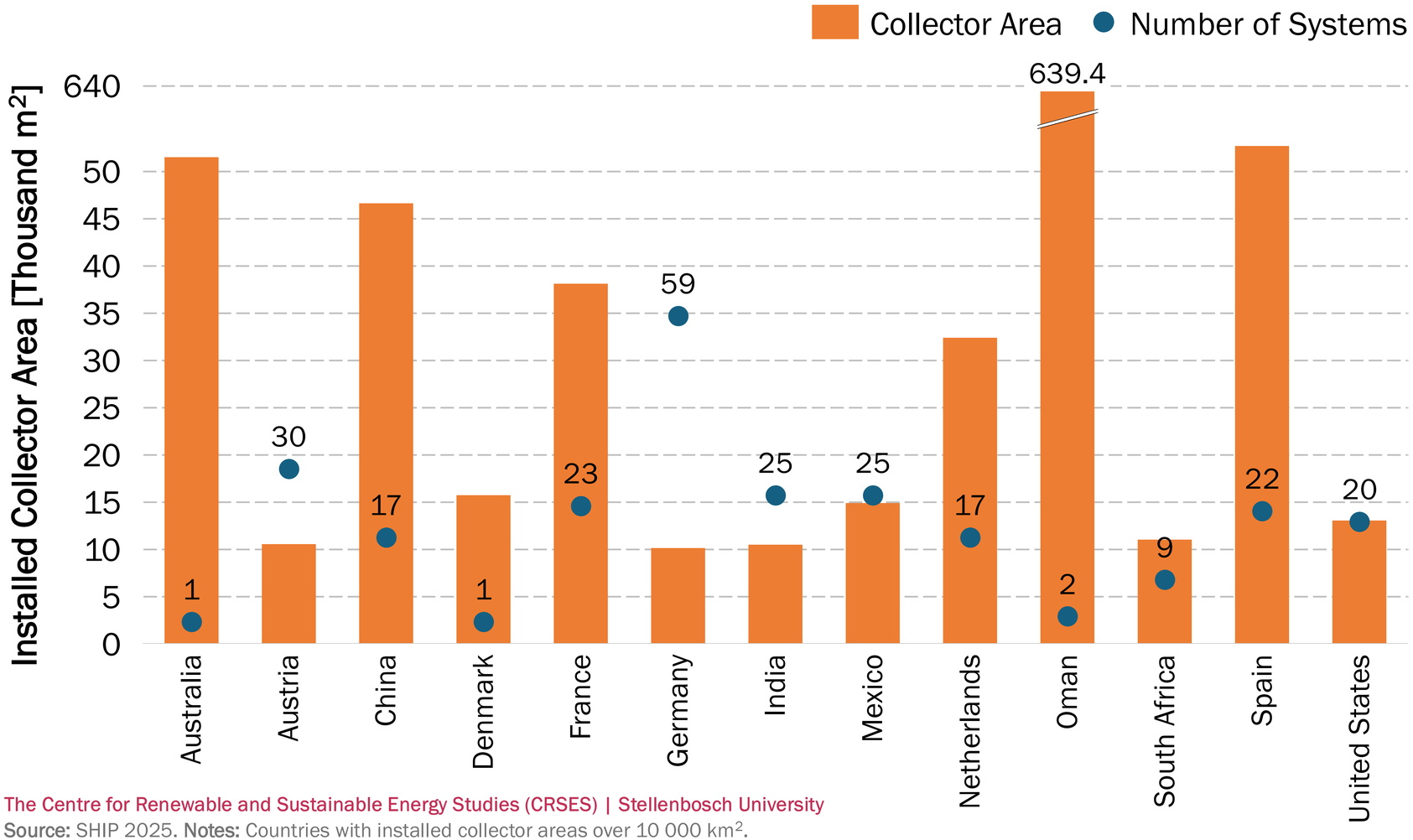
Global Solar Process Heat Applications 2024



Source: SHIP 2025. **Notes:** Countries with installed collector areas over 10 000 km^2.

Finally, we look at the thermal power each of these countries has installed in industry applications.

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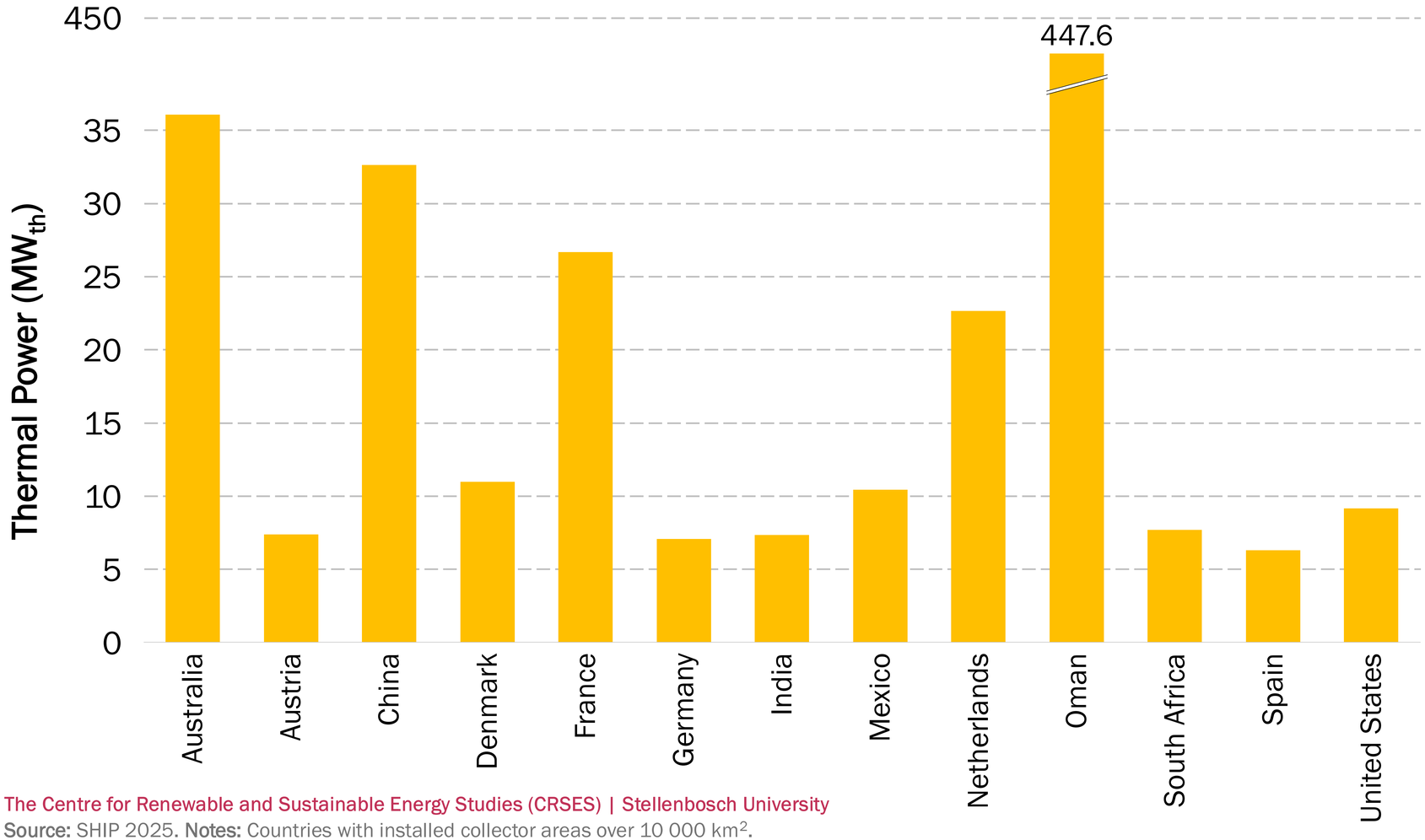
Global Solar Process Heat Applications 2024



Source: SHIP 2025. **Notes:** Countries with installed collector areas over 10 000 km^2.

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