Solar Hot Water Market Analysis

Status quo and Prospects of Thermosyphon and PV Hot Water Systems

IEA SHC TASK 69 | Solar Hot Water for 2030

Technology Collaboration Programme
by iea

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Status quo and Prospects of Thermo-syphon and PV Hot Water Systems

This is a report from SHC Task 69: Solar Hot Water for 2030 and work performed in Subtask A: State-of-the-art and operating environments in different regions and Subtask B: Thermosyphon hot water systems

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- *Solar District Heating (Tasks 7, 45, 55, 68)*
- *Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)*
- *Solar Thermal & PV (Tasks 16, 35, 60)*
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Contents

1 Executive Summary

Introduction: The residential sector accounts for around one-third of global energy demand, of which 25% is attributed to domestic hot water (DHW). In some regions, DHW preparation can amount to more than half of the total household energy use. Driven by rising living standards and increased awareness for hygiene, the hot water demand is anticipated to increase in the coming years. Improvements in building efficiency is likely to significantly reduce the space heating demand, making domestic hot water an even more important factor of the energy use in buildings. With a renewable share of ~12 % in the residential sector, there is huge potential for decarbonisation as gas and oil-fired boilers and grid-tied electric water heaters are still the predominant technologies for DHW preparation. Techno-economic innovations are necessary for “untapping sustainable and efficient DHW tapping”.

Solar hot water technologies: Two technologies that are likely to play a significant role in the solar hot water market in 2030 and beyond are covered in this report: Thermosyphon solar water heating and photovoltaic (PV) driven hot water production. These technologies represent opposite poles regarding market status, market dynamics and recent technological advancement. In 2023, solar thermal systems produced an estimated 450 TWh solar energy with the installed collector area of around ~ 800 million m2 (560 GWth), whereof more than 80% is attributed to DHW production (the rest is spread among other usages like space heating, swimming pool heating, solar cooling etc.) [1]. The estimated work force in the solar heating and cooling sector was estimated to be 681 thousand people in 2023 [2]. Thermosyphon systems use natural convection (thermosyphon effect) to circulate water without the need for pumps or electricity, which allows cost-effective, simple system designs without moving parts, and with low installation and maintenance costs. This makes them especially popular for single family houses in rural areas and the global south. Despite the global solar thermal market has declined with regards to the newly installed capacity since its peak in 2013, on the long run the yearly installed collector area nearly doubled during the last 20 years [1].

Contrary to the well-established technology of solar thermosiphon systems, Photovoltaic (PV) driven solar electric hot water production is an emerging technology with substantial growth rates in recent years. Supported by substantial price reductions regarding PV panels, increase in efficiency, simple system designs, and smart integration in existing electric energy infrastructure, PV hot water systems might become a main driver for solar hot water production in some countries, especially in countries with high solar PV market penetration, using surplus electricity for heating hot water. A broad range of technological possibilities is yet to be explored on a mass scale, including PV2Heat systems with coupling of a direct current (DC) PV panel to a resistance heating element in the hot water tank, using PV diverters or combinations with heat pumps and smart tanks. In some countries PV driven systems are used for space heating and domestic hot water in residential and commercial buildings. These systems are gaining interest in countries like Austria, Germany or Switzerland and have shown to cover 100% of a buildings heating need.

Methodology: This report provides a market analysis of the thermosyphon and PV hot water markets, addressing the status quo, as well as promising opportunities and challenges for the thermosyphon and PV hot water market. One of their key characteristics of the global solar hot water market is its regional diversification in terms of market penetration, deployed technologies, hot water demand, main competitors, etc. The market analysis for thermosyphon systems tries to address this issue by providing in-depth analyses for all relevant market regions, elaborating the regional economic, environmental, technical and political boundary conditions. As the PV hot water market is not yet as developed and data is scarce, the analysis is limited to a spotlight to selected regions with notable market activity.

Besides desk research and shared insights from task experts, two surveys to gain first-hand market insight have been conducted. Within Subtask A, a Questionnaire for Manufacturers of Thermosyphon Systems has been conducted, where a total of 54 answers from manufacturers were received from October 2023 – May 2024. Within Subtask C, a PV Hot Water Stakeholder Survey was done in the last quarter of 2023 with a total of 44 respondents. Furthermore, additional analysis of the market data collected for the Solar Heat Worldwide report have been conducted.

Findings: Thermosyphon systems are expected to remain a key player in the solar hot water market, with diverse regional applications and market dynamics. The systems are primarily used in residential buildings, especially in rural areas, with some applications for multiple-storey residential buildings, hotels, hospitals and public buildings. The design varies based on climate; direct systems are common in warmer climates where there is no risk of freezing, while indirect systems are used in colder areas. China is dominating global production and exports with evacuated tube collector systems. Price variations are significant, with lower prices in low-cost manufacturing hubs like China and India, and higher costs in highly industrialized countries. All regions have local industries, with some manufacturers like in Sub-Sahara Africa producing exclusively for local demand. Government policies and subsidy schemes play a crucial role with regard to adoption; in some regions it is required that new buildings are equipped with solar energy systems. Most of Chinese manufacturers expect no or low growth market, while the market players in other regions, especially in Sub-Sahara Africa, Latin America and Europe's Mediterranean area are more optimistic. Urbanization is likely to take a toll on the thermosyphon market, as roof areas become scarce and expectations regarding comfort grow. Global trends show increasing integration of smart components and digital technologies. Despite being well-established, thermosyphon systems still hold potential for cost reductions through innovations, mass production, and improved regulatory frameworks. Besides cost reductions, crucial success factors are to improve the reputation of thermosyphon systems through increased marketing activities and better durability and reliability.

2 Introduction

The global energy demand for domestic hot water (DHW) is significant, as water heating is one of the largest energy uses in households worldwide. The International Energy Agency (IEA) estimates that about 25% of residential energy consumption worldwide is used for water heating [3]. Buildings account for around one-third of global energy demand and carbon emissions, with direct energy consumption in buildings representing 30% of global final energy consumption in 2022. As the renewable energy share of heat consumed in buildings stood just at 11.5% in 2011, there is a substantial potential for decarbonisation [4].

The demand for domestic hot water (DHW) is anticipated to rise in the coming years, driven by several key factors. Global population growth, projected to reach 9.4 to 10.2 billion by 2050, will increase water demand across various sectors, including domestic use. Additionally, rapid urbanization and rising living standards, especially in developing countries, are leading to greater adoption of modern amenities that require hot water. Increased awareness of hygiene practices, particularly post-pandemic, has contributed to higher hot water usage in households. As an example, the Danish population has increased the number and duration of baths and showers, at the same time expecting least possible delays for hot water delivery at the tap. Consequently, the yearly DHW consumption per capita in Denmark has augmented from 10 m3/year to around 15 m3/year over the last 20 years [5].

Furthermore, improvements in building efficiency have been identified as a key solution to tackle current and pending environmental and energy issues [6]. In cold winter climates, a large share of this thermal energy is employed for space heating, which can be significantly reduced by improving the thermal performance of the buildings' envelope and heating/ventilation systems. Consequently, the space heating need of newly built and renovated buildings is drastically diminished in order to tend towards nearly Zero Energy Building standards [7]. While energy use for building space heating has been continuously decreasing over the last decades, the energy needed to produce domestic hot water (DHW) has remained relatively consistent.

Typical energy sources and systems used to produce domestic hot water vary greatly on a global scale as an overview of different countries by Hicham Johra from Aalborg University [8] shows. Predominant in many countries are gas or oil-fired boilers and grid-supplied electric resistance water heaters. To increase the renewable share, two technologies which will be likely to play the biggest role in the solar hot water market in 2030 and beyond are covered in this report: solar thermal thermosyphon systems and photovoltaic (PV) derived hot water.

Solar thermal water heating is by far the most established renewable technology to provide hot water, dating back to the 1970s, gaining momentum due to the oil crises that spurred interest in renewable energy alternatives. Large-scale adoption and significant contributions to domestic hot water (DHW) production started in the 1990s and 2000s. In 2023, solar thermal systems produced an estimated 450 TWh solar energy with the installed collector area amounting to ~ 800 m2 (560 GWth), whereof more than 80% is used for domestic hot water (DHW) [1].

Thermosyphon solar water heating systems are a type of passive solar water heater that uses natural convection (thermosyphon effect) to circulate water without the need for pumps or electricity. This makes them cost-effective, with lower installation and maintenance costs compared to active solar water heating systems. Their system design is simple and lacks moving parts. Thermosyphon systems are particularly attractive for rural areas with no or unreliable electricity supply. These systems are the dominant system type in Asia, Africa and Latin America [9].

While solar thermal hot water technologies will likely remain of great importance for the years to come, photovoltaic (PV) solar electric water heating is an emerging technology which might take up an important role on the market. Supported by substantial price reductions, increase in efficiency, simple system designs, and smart integration in existing electric energy infrastructure, the installed PV capacity surpasses solar thermal capacity by a factor of about four [9]. Although the PV water heater market is still small, countries like China, South Africa or Australia show promising growth [10].

3 Market Analysis for Thermosyphon Systems

3.1 Development of the thermosyphon market

According to the IEA SHC Solar Heat Worldwide Report, the global solar thermal market is analysed regarding eight different regions as shown in Figure 1. These regions are used in the subsequent market analysis of this report as well. The regions are Other Asia (India and Japan as the main markets), China, Europe, Latin America, MENA (Middle East and North Africa) Region, North America (USA and Canada), Oceania and Sub-Sahara Africa. Comparing these regions, the shares of thermosiphons vary widely, with large shares of thermosiphon systems (>80%) installed in the Mediterranean region in Europe like in Greece and Cyprus, Latin American countries like Chile and Argentina, Japan and India in Other Asian countries and Sub-Sahara Africa countries like Lesotho, Botswana and Zimbabwe (Figure 2).

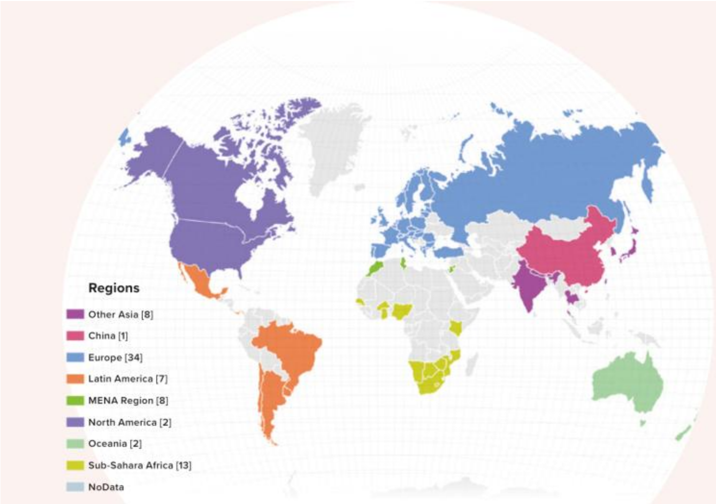


Figure 1. Countries in eight regions according to IEA SHC Solar Heat Worldwide Report. Source: IEA SHC Solar Heat Worldwide Report Ed. 2025

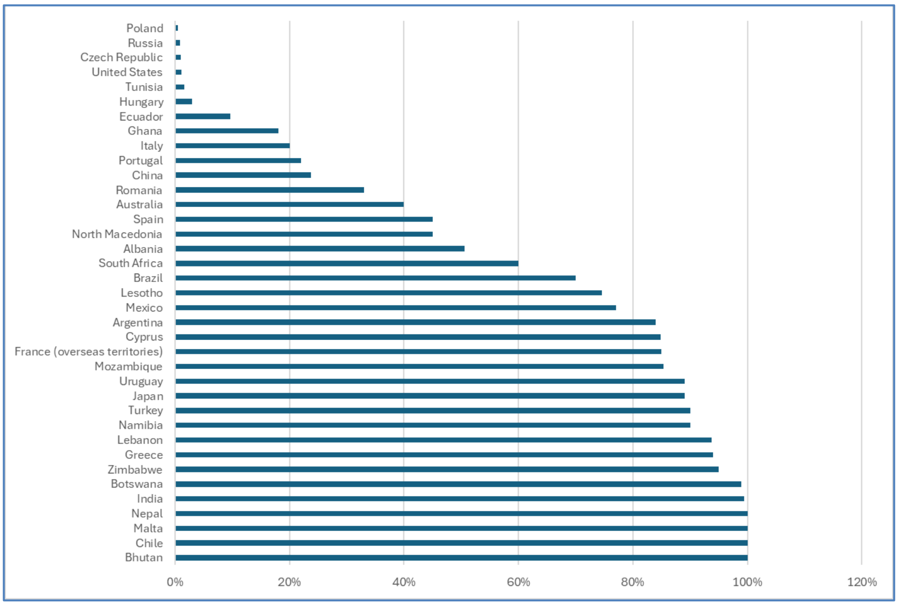


Figure 2. Share of thermosyphon systems (newly installed systems 2023). Source: IEA SHC Solar Heat Worldwide Report Ed. 2025

Figure 3 and **Error! Reference source not found.** show the shares of thermosiphon systems with regards to newly installed solar thermal water collector areas and total installed solar thermal water collector areas in operation for the year 2021 regarding the different regions. The figures show that Other Asia (excl. China), Latin America and Sub-Sahara Africa countries have remarkable shares of newly installed systems and total installed systems in operation, reaching 99% with regards to Other Asia in 2021, 85% in Latin America and 66% in Sub-Sahara African countries (newly installed) and 93% with regards to Other Asia, 82% in Latin America and 66% in Sub-Sahara Africa respectively with regards to total installed collector areas in operation.

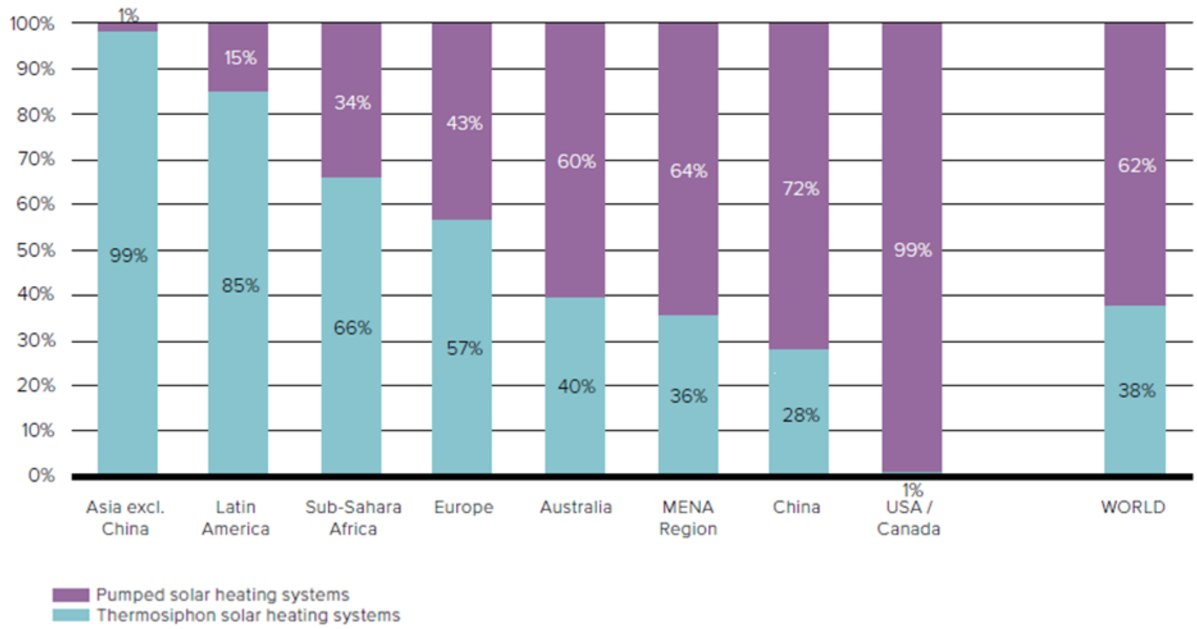


Figure 3 Distribution by type of system for the newly installed glazed water collector capacity in 2021. Source: IEA SHC Solar Heat Worldwide Report Ed. 2023

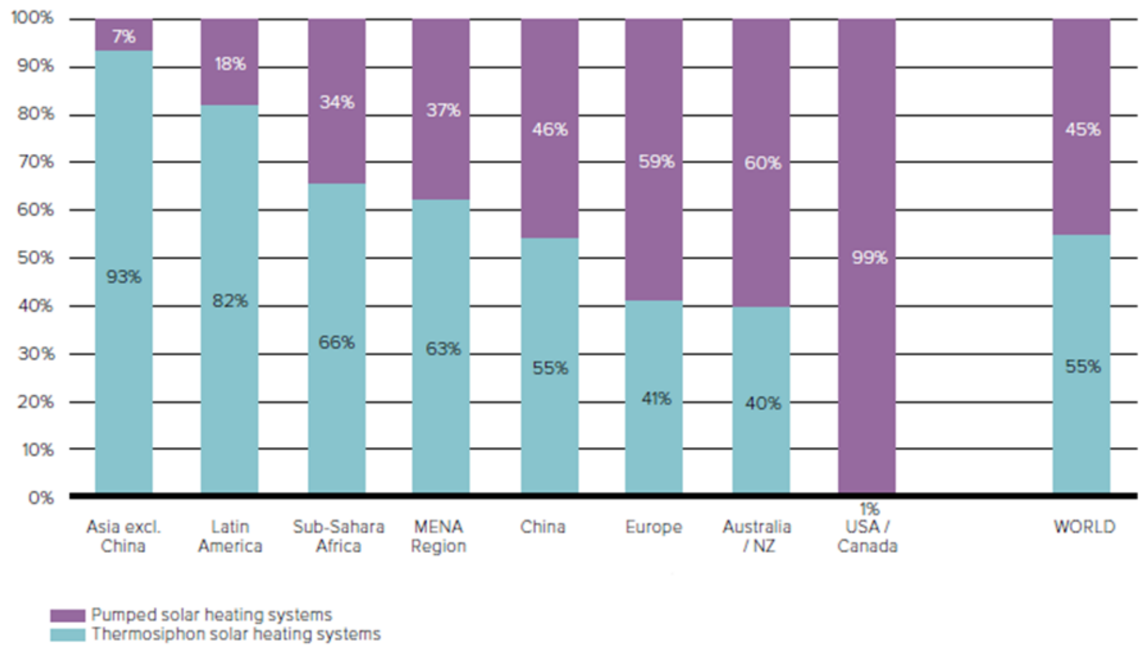


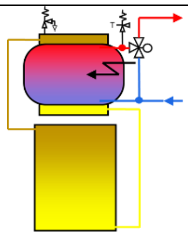
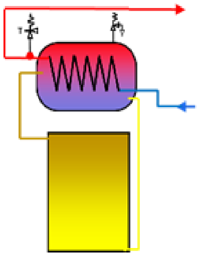
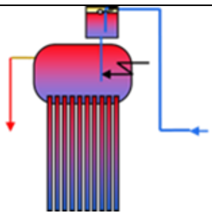
Figure 4. Distribution by type of system for total installed glazed water collector capacity in operation in 2021. Source: IEA SHC Solar Heat Worldwide Report Ed. 2023

3.2 Classification of thermosyphon systems

The thermosyphon systems considered in this study can be roughly distinguished by collector type used (flat plate collector – FLAT or evacuated tubes – ETC) and whether they are direct (DIR) or indirect systems (IND). Direct systems are directly connected to the tank whereas indirect systems use a heat exchanger placed in the hot water tank, double jacket tanks or heat pipes. OTHER as used in the survey of this study refers for example to PV/T collectors or pumped solar thermal systems.

The following exemplary schemes illustrate different solar thermosyphon system types. Indirect systems as well as direct systems can be equipped with flat plate collectors or evacuated tube collectors respectively. Heat exchangers in use regarding indirect systems are for example double jacket tanks or internal heat exchangers. Regarding the full spectrum of solar thermal collectors and systems including applications, an overview can be found in several publications, e. g. [11][12][13][14].

Table 1 Exemplary types of solar thermosyphon systems: Indirect solar thermosyphon system with electrical backup heating and double jacket tank, indirect solar thermosyphon system with hot water storage and internal heat exchanger, direct solar thermosyphon system with hot water storage tank and evacuated tubes. (Source schematics: AEE INTEC / Rudi Moschik, Photos: AEE INTEC / SOLTRAIN)

 	Indirect solar thermosyphon system with electrical backup heating. The collector can be flat plate or evacuated tubes respectively. The heat exchange in this case is done via double jacket tank.
 	Indirect solar thermosyphon system with hot water storage and internal heat exchanger. The collector can be flat plate or evacuated tubes respectively.
 	Direct solar thermosyphon system with hot water storage tank and evacuated tubes.

3.3 Overview of survey results

Within IEA SHC Task 69, a comprehensive first-hand analysis of the thermosyphon market was conducted based on a *Questionnaire for Manufacturers of Thermosyphon Systems*. The questionnaire consisted of 21 questions covering "Production Data", "Target Markets and Costs", "Product Placement / Business Models" and "Innovation / Market Outlook". The questionnaire was distributed in English, Chinese and Spanish through the networks of the experts. A total of 54 answers from manufacturers were received from October 2023 – May 2024. In this section, a short overview of the global survey outcomes is given, in Chapters 3.4 to 3.12 detailed analyses for each region are given.

Responses: Figure 5 shows the main production sites of the survey respondents. With regards to the eight global market regions as defined in the IEA SHC Solar Heat Worldwide Report, the MENA (Middle East and North Africa) region is missing. Despite all efforts there have not been any responses from local manufacturers of the MENA region.

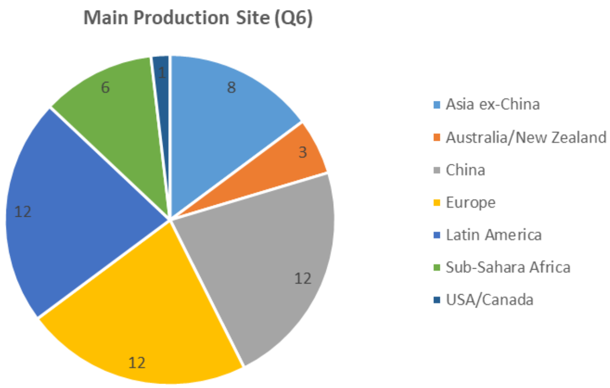
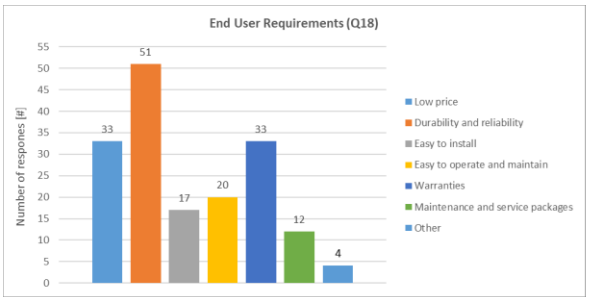


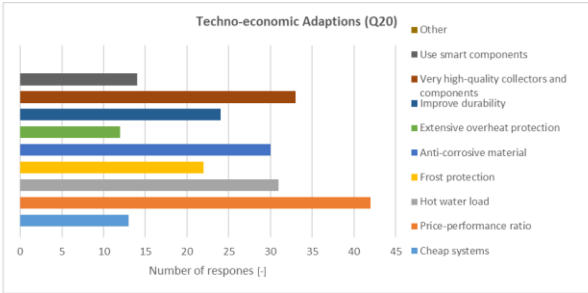
Figure 5 Distribution of Manufacturers who answered the questionnaire

Production data (Q7 – Q12): Figure 6 characterizes the systems the survey respondents produce. The survey covers both small companies with a yearly production < 1,000 m2 and large manufacturers with > 500,000 m2. The large manufacturers except one company are based in China. Typical systems have a gross collector area of ~2 m2 and a tank volume in the range 150-200L.

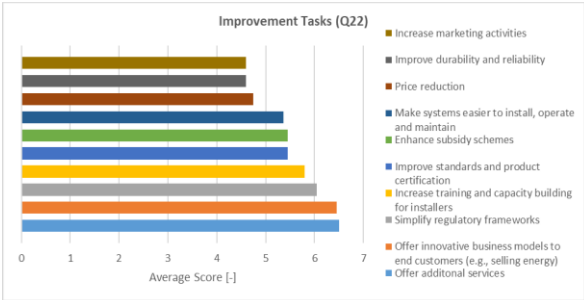
Figure 6. Number of product models (a), gross area (b), tank volume (c) and yearly production of different collector types (d).

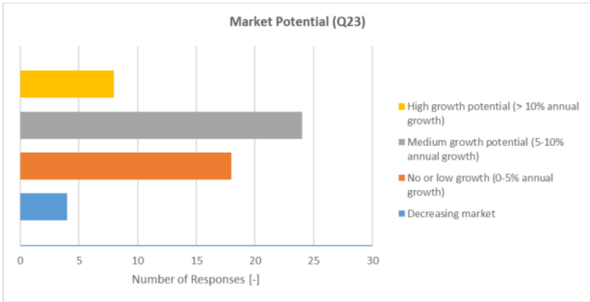
The figures below summarize the global market environment the manufacturers are subject to. Figure 7 (a) shows that the most important end user requirement is durability and reliability, followed by low price and warranties. As detailed analysis for the different regions show, durability and reliability are the top end user requirement in each market region. Regarding techno-economic adaptions shown in Figure 7 (b) by the manufacturers, optimization of the price-performance ratio – which comes as no surprise – is a measure taken by most manufacturers. Notably, about a quarter already uses smart components, which is one of the major global trends as discussed later. The two most important improvement task are centred around increasing marketing activities and improving durability and reliability, showing the necessity to establish a better reputation of the technology. The global market potential, as shown in Figure 7 (d) is seen as stable or cautiously optimistic. As will be discussed later, most of Chinese manufacturers expect no or low growth market, while the market players in other regions, especially in Sub-Sahara Africa, Latin America and Europe's Mediterranean area are more optimistic.





(a) *(b)*





(c) *(d)*

Figure 7. End user requirements (a), Techno-economic adaptations (b), Improvement tasks (c) and Market potential (d).

3.4 Asia excl. China (Region #1a) – India

Thermosyphon market and regional boundary conditions

Main applications: The main application scenarios for thermosyphon systems in India are single houses in rural areas and multiple storey residential buildings in urban areas. Direct systems with evacuated tube collectors (DIR-ETC) are predominantly used in urban and semi-urban areas, whereas indirect systems with flat plate collectors (IND-FLAT) and indirect systems with evacuated tube collectors (IND-ETC), are seldomly used. The dominant configuration per household is “2m^2 + 200L” in the price range of USD 250 – 500.

As of December 2023, the cumulative installed capacity of all solar thermal technologies in India has crossed 20 million m^2 (16.5 GW$_{th}$) and accounts for less than 1% of the energy consumption for thermal applications (250 Mtoe). Solar water heaters (SWHs) account for 97% of the installed capacity of solar thermal in India. Among the SWHs, 82% of the installed capacity is estimated to be in residential buildings, 14% in commercial and institutional buildings, and 4% in industries.

Market environment and challenges: Compared to electric water heaters, thermosyphon systems need to ensure they deliver hot water during monsoon and winter days when bright sunlight is seldomly available. Thermosyphon systems as supplementary can be used in hybrid mode with other renewable forms like PV and heat pumps. For users, simpler installation and use will bring great convenience. For some areas with special needs, corrosion resistance, frost resistance and other requirements are also important considerations when purchasing a water heater. Finally, all manufacturers want to ensure that they adhere to the quality standards mandated by the government as it will ensure confidence of investors.

Hot water load: The Electricity Act 2013 identifies average daily hot water requirements per person as 25 litres for bathing and other domestic use. Owing to the vast geographical area, India is divided into five zones with regard to the solar thermal potential, characterized by the hot water demand and climate conditions as shown in Figure 8. The division in zones is as follows:

- *Zone, I* comprises the western and southern states of Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, and Kerala. The solar resource is adequately available year-round, and the region has high urban population.
- *Zone II* comprises the states of western and central states Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, and Odisha, having 4-6 months of hot water requirement and adequate solar radiation during the hot water requirement season.
- *Zone III* consists of the northern and eastern states of Punjab, Haryana, Delhi NCR, Uttar Pradesh, Bihar, and West Bengal, has 4-6 months of hot water requirement, but suffers from poor solar radiation (due to fog) during the peak hot water demand season (December–January).
- *Zone IV* consists of the states of the northeastern region and is characterised by low hot water requirement and relatively poor solar radiation.
- *Zone V* is made up of the northern states of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. The region has a cold climate and therefore has a high hot water demand and most of the region does not suffer from fog during peak winter months.

Depending on the zones, the hot water demand varies anywhere between 15 litres to 50 litres per day per person.

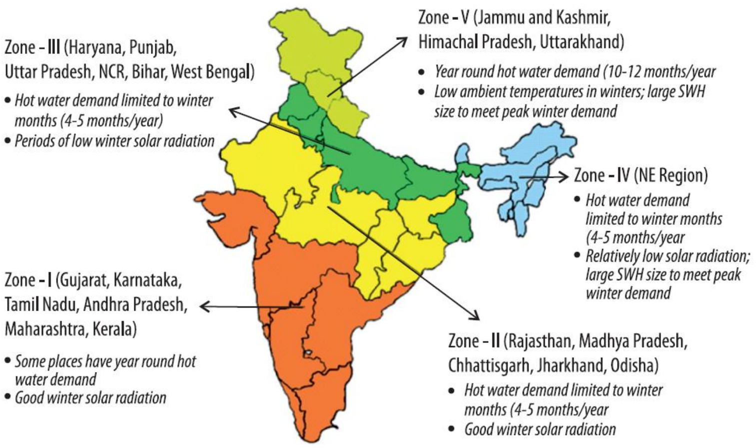


Figure 8. Climatic Zoning Map of India. Source: [IN1]

Environmental conditions: India's land area of 3,287,240 km² receives solar radiation worth 4,300 quadrillion kcal (5,000 trillion kWh) every year. The daily average solar energy incident over India varies from 3,500 to 6,000 kcal/m² (4.0 to 7.0 kWh/m²) with about 2,300-3,200 sunshine hours per year, depending on the location. Figure 9 shows the Direct Normal Irradiance (DNI) map of India as well as the Global Horizontal Irradiance according to SOLARGIS Solar Resource map.

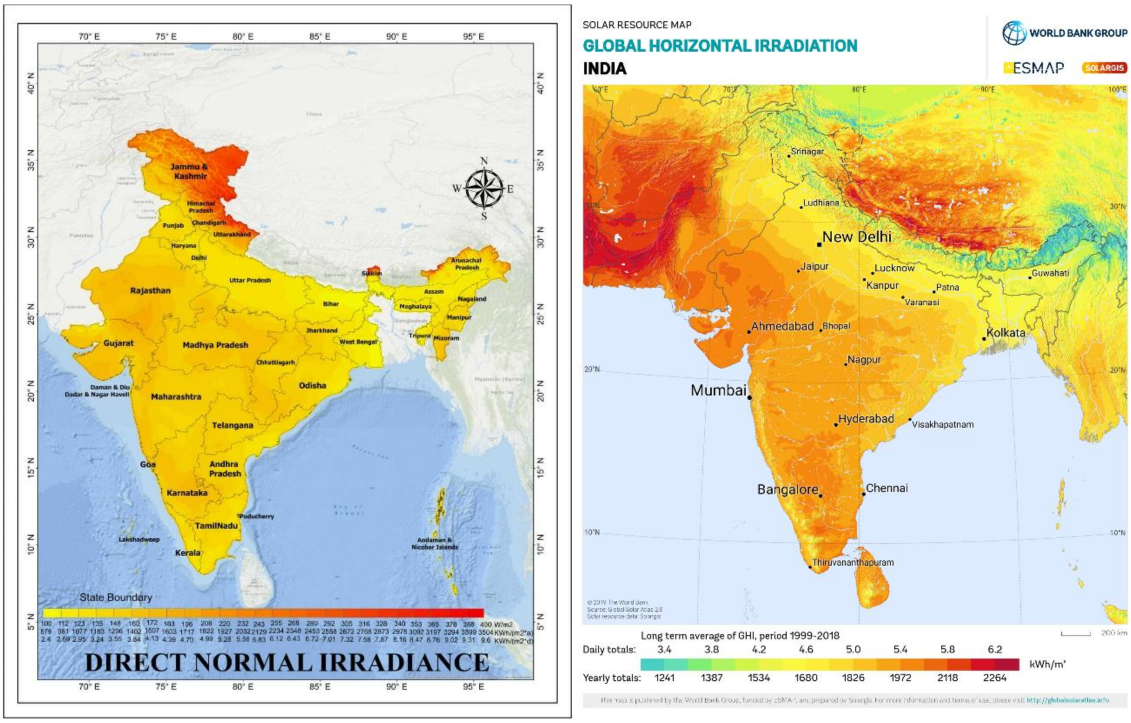


Figure 9. Direct Normal Irradiance (left) and global horizontal irradiation map of India. Source: National Institute of Wind Energy (left), SOLARGIS Solar Resource map (right) [IN2, IN3].

The northernmost region of Ladakh receives the world's highest DNI equivalent of 400 W/m² DNI on average. Western states of Rajasthan and Gujarat receive anywhere between 200-280 W/m² DNI.

Subsidy schemes, promotion schemes, government policies: Solar water heaters are one of the oldest technologies deployed in India since 1990. The market growth spurred by the turn of century owing to Federal subsidies and selected State government subsidies. In 2010, the National Solar Mission was announced with a target of 20 million m² collector area and generous subsidies of 40% of the system cost, which was a strong industry driver. However, this scheme was halted in 2015 as the volumes grew and the government assessed the technology's market fit as acceptable. Another policy measure is the Electricity Act 2013, which requires to meet 20% of building heating demands through solar thermal, but leaves the adoption to municipal corporations and municipalities. While some entities successfully adopted it and continue to do so, a couple of State governments also made it mandatory to install solar water heaters to get building completion certificates as Demand Side Management practice. Of lately, Bureau of Energy Efficiency has come out with Star labelling programme based on the heat efficiency each model delivers.

Product certification schemes, standards: **Error! Reference source not found.** gives on overview of the relevant standards for Solar Water Heaters.

Table 2. Standards for Solar Water Heaters in India, published by the Bureau of Indian Standards (BIS) [IN4].

Standard	Description
IS 16543 (2016)	All glass evacuated solar collector tubes – Specification
IS 16544 (2016	All glass evacuated tubes solar water heating systems
IS 16368 (2015)	Test procedure for thermosyphon type domestic solar hot water heating systems
IS 16542 (2016)	Direct insertion type storage water tank for all glass evacuated solar collector tubes – Specification

IS 12933: Part 1 (2003)	Solar flat plate collector – Specification: Part 1 requirements (Second Revision)
IS 12933: Part 2 (2003)	Solar flat plate collector – Specification: Part 2 components (Second Revision)

Market Survey

Overview: In the survey conducted, questionnaire results of 6 manufacturers of thermosyphon systems from 4 States, i.e. Karnataka, Maharashtra, Tamil Nadu and Punjab, were received as shown in Figure 10. These manufacturers are located where the demand for Solar water heaters is highest and feature in the top 10 leading manufacturers of India.

Figure 10. The distribution of Indian manufacturers who participated in the survey.

Production data (Q7 – Q12): According to the survey, 100% of the manufacturers produce solar collectors, storage tanks and mounting systems themselves, 33% of them produce electrical back-up heating, and 17% produce pipes, valves and associated fittings (see Figure 11).

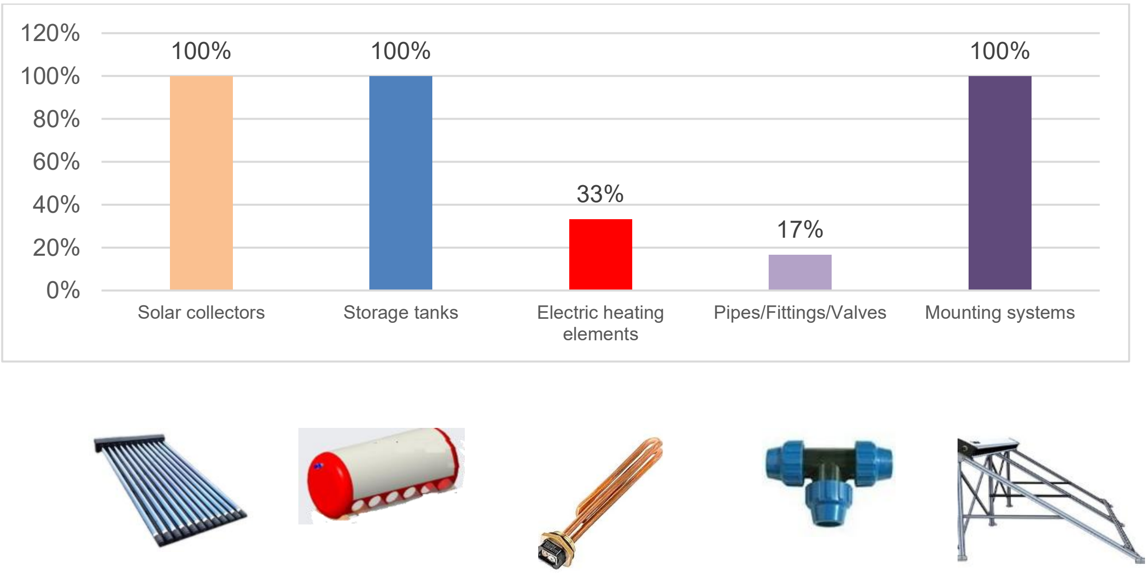


Figure 11. Produced components of thermosyphon systems (Q7).

Besides thermosyphon systems, forced circulation solar water heaters and heat pumps are the most systems produced by solar manufacturers in India with a share of 83%. 50% produce electric heaters and 33% produce gas fired heaters. No PV hot water systems or oil-fired water heaters are produced by solar manufacturer from the survey (see Figure 12).

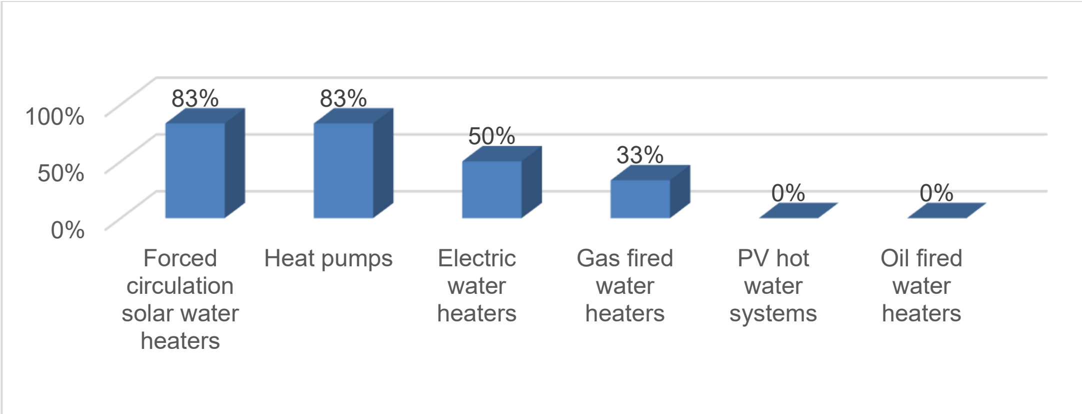


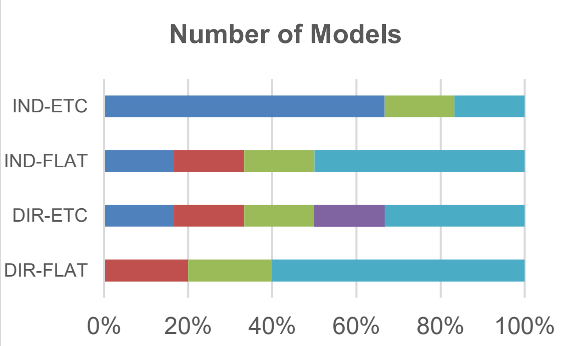
Figure 12. Solar hot water systems or components produced by manufacturers besides thermosyphon systems (Q8). Source: Malaviya Solar Energy Consultancy

There are four common thermosyphon system types on the market, including direct systems with flat plate collectors (DIR-FLAT), direct systems with evacuated tube collectors (DIR-ETC), indirect systems with flat plate collectors (IND-FLAT) and indirect systems with evacuated tube collectors (IND-ETC), see Figure 13.

DIR-FLAT DIR-ETC IND-FLAT IND-ETC

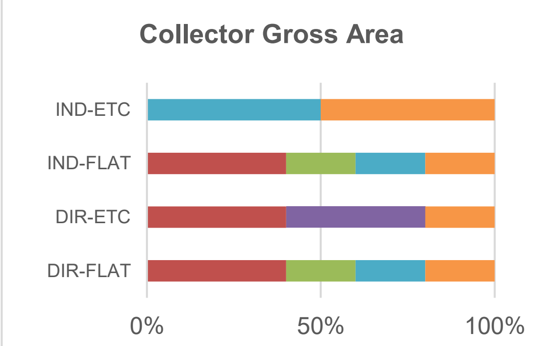
Figure 13. Appearance of four main types of common thermosyphon systems in the market

The results of the manufacturers' responses to the number of produced different models, approximate collector surface (gross area) of the most produced model, approximate tank volume of the most produced model and company's yearly production (in gross collector area) in the questionnaire are summarized in Figure 14.



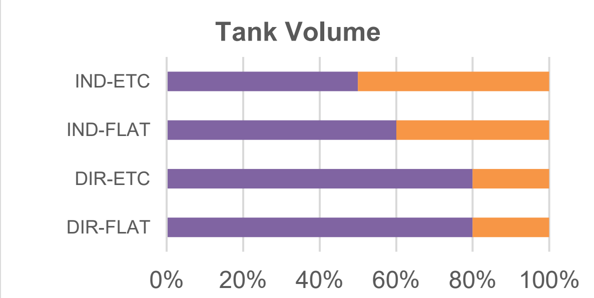
	DIR-FLAT	DIR-ETC	IND-FLAT	IND-ETC
None	0	1	1	4
1-5	1	1	1	0
6-10	1	1	1	1
11-20	0	1	0	0
>20	3	2	3	1

(a)



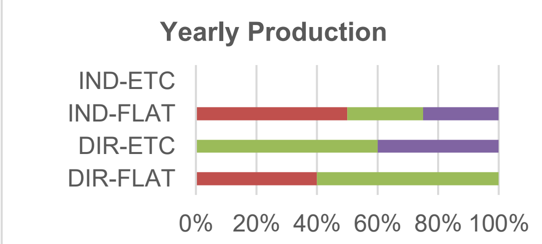
	DIR-FLAT	DIR-ETC	IND-FLAT	IND-ETC
< 2 m2	2	2	2	0
~2 m2	1	0	1	0
~3 m2	0	2	0	0
~5 m2	1	0	1	1
> 5 m2	1	1	1	1

(b)



	DIR-FLAT	DIR-ETC	IND-FLAT	IND-ETC
~100 L	0	0	0	0
~150 L	0	0	0	0
~200 L	4	4	3	1
~300 L	0	0	0	0
> 300 L	1	1	2	1

(c)



	DIR-FLAT	DIR-ETC	IND-FLAT	IND-ETC
< 1,000 m2	0	0	0	0
1,000 - 10,000 m2	2	0	2	0
10,000 - 50,000 m2	3	3	1	0
50,000 - 500,000 m2	0	2	1	0
> 500,000 m2	0	0	0	0

(d)

Figure 14. Production data with (a) number of produced models, (b) collector gross area, (c) tank volume and (d) yearly production (Q9-Q12).

The survey results showed that DIR-ETC and DIR- FLAT are the most popular systems in India, followed by IND-FLAT. Although two manufacturers list that they produce IND-ETC systems, yearly production data from these manufacturers are not available. The most common models are of following features listed in Table 3.

Table 3: Most common solar water heater models used in India

DIR-ETC systems: • Gross area: < 2 m^2 • Tank volume: 200L	DIR-FLAT systems: • Gross area: 2 m^2 • Tank volume: 200L
IND-FLAT systems: • Gross area: > 2 m^2 • Tank volume: > 300L	

Target markets and costs (Q13 – Q17): The main target market region for the thermosyphon systems is India for all six manufacturers. Three manufacturers have secondary markets in Africa, Nepal and South Africa respectively. Two manufacturers have Asian countries as the third biggest market (see Figure 15).

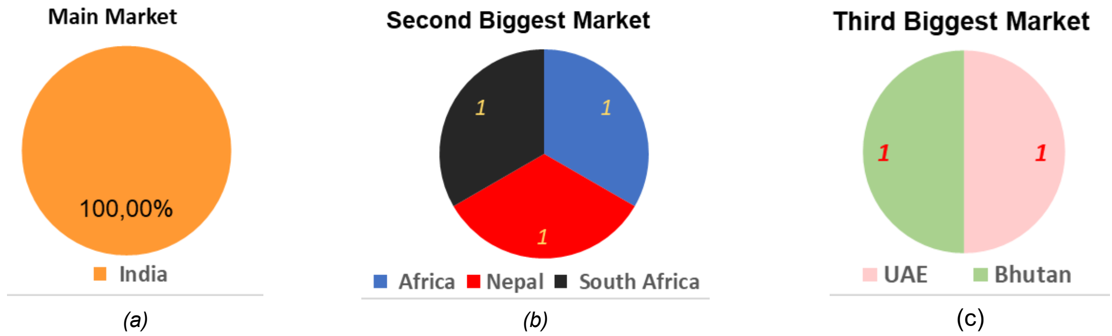


Figure 15. Market region(s) (Q13-Q16), showing (a) main target regions, (b) second biggest market and (c) third biggest market.

Typical final customer prices (including shipping, installation and taxes) for a standard sized thermosyphon system (with 150 L tank and 2 m² collector) in the main market, i.e. India, are $250-500 USD for 50% of the survey respondents followed by 33% with $500-1,000 USD, while little under 17% with < $250 USD (Figure 16).

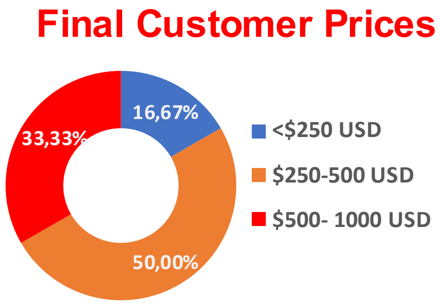


Figure 16. Typical final customer prices for a standard sized thermosyphon system in the main market (Q17).

Product placement/ business models (Q18 – Q21): The two most important end user requirements in target markets are “Low price” and “Durability and Reliability” (Figure 17).

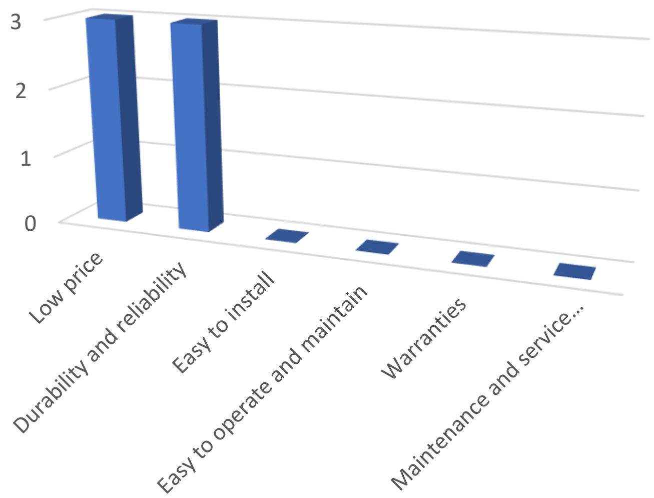


Figure 17. Most important end user requirements in target market(s) (Q18).

The distribution channels and business models used for the different target markets is solely selling to wholesalers (Figure 18).

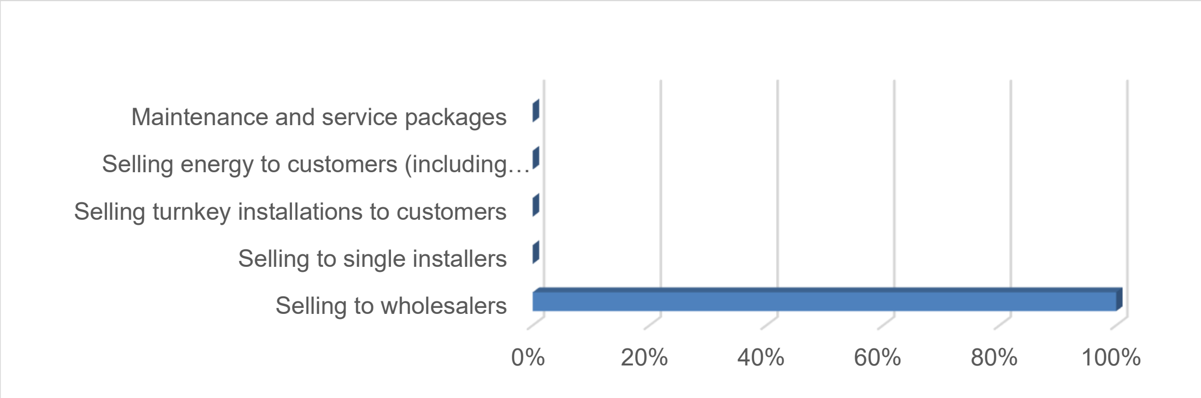


Figure 18. Distribution channels and business models uses in different target market(s) (Q19).

The main techno-economic adaption is “Adjust the system design in accordance with the regional hot water load conditions” with 67% of the survey respondents, followed by “Make systems as cheap as possible” and “Optimize the price-performance ratio”, which were priorities in 16% of the cases (see Figure 19).

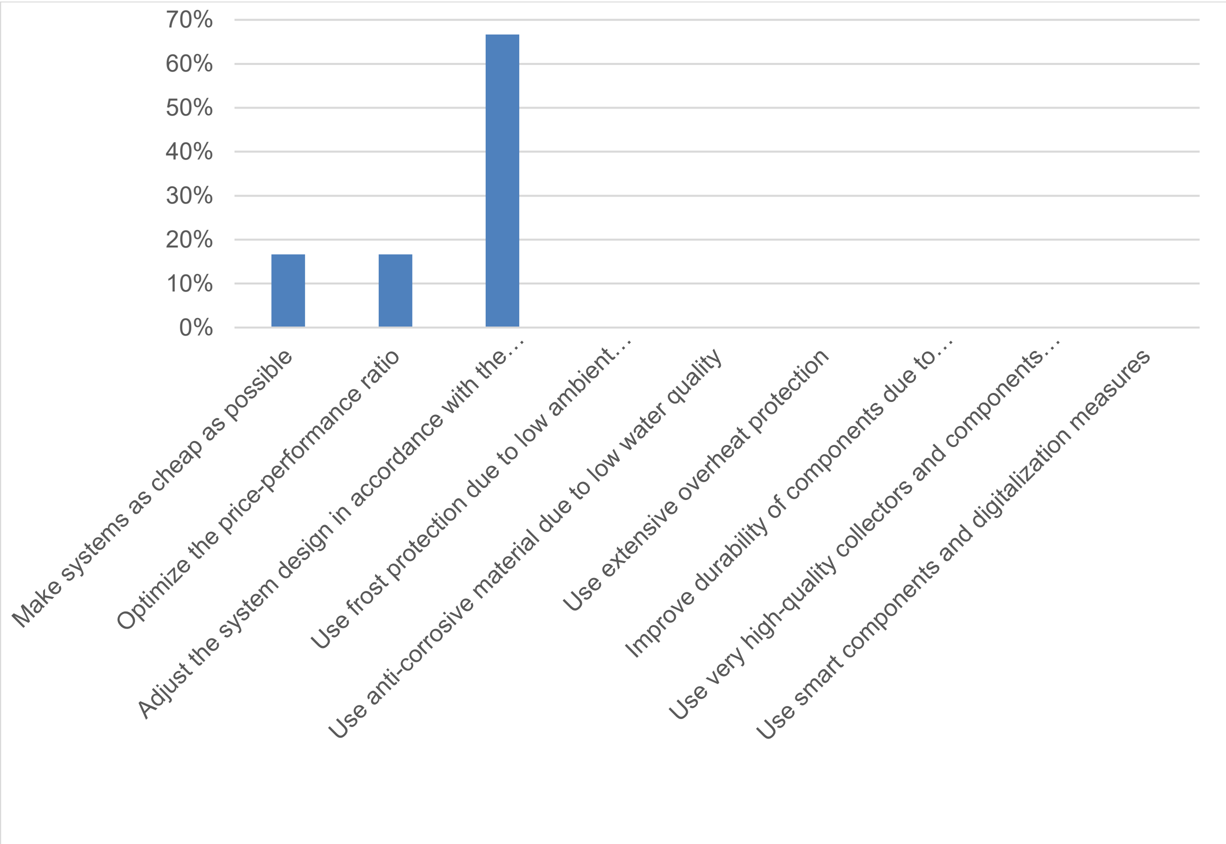


Figure 19. Techno-economic adaptions made to tailor products successfully to the target market(s) (Q20).

The main competitors and alternative technical solutions to provide hot water in target markets are electric heaters with 83% of the manufacturers, followed by 67% for oil fired water heaters, 50% for gas fired heaters and finally by heat pumps, PV hot water and forced circulation solar heated systems (Figure 20).

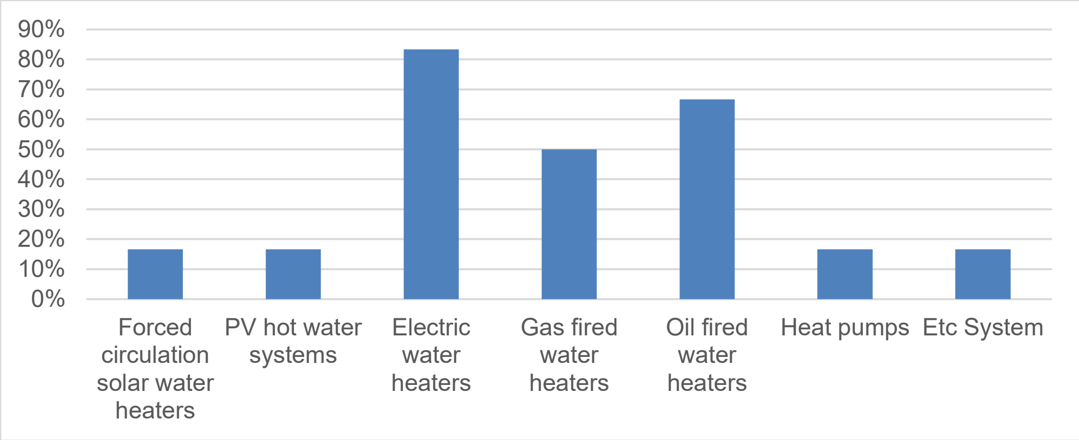


Figure 20. Competitors and alternative technical solutions to provide hot water in target market(s) (Q21).

Innovation and market outlook (Q22 – Q29): The most urgent tasks to make systems more competitive and reduce market barriers are "Offer additional services (warranties, maintenance, etc.) to end customers", "Improve standards and certification", "Improve durability and reliability" and "Simplify regulatory frameworks" (see **Error! Reference source not found.**).

Table 4 Tasks to make systems more competitive and reduce market barriers (Q22).

1st important	Offer additional services (warranties, maintenance, etc.) to end customers
2nd important	Improve standards and product certification
	Improve durability and reliability
	Simplify regulatory frameworks (e.g., building regulations)
3rd important	Enhance subsidy schemes
	Offer innovative business models to end customers (e.g., selling energy)
	Increase marketing activities (e.g., inform customers about energy savings and carbon reduction potential)
4th important	Price reduction (to achieve competitive energy prices)
	Make systems easier to install, operate and maintain
	Increase training and capacity building for installers

For thermosyphon systems, the description of the future market potential is mainly "Medium growth (5~10% annual growth)" (see Figure 21). No manufacturers give the market a high growth potential.

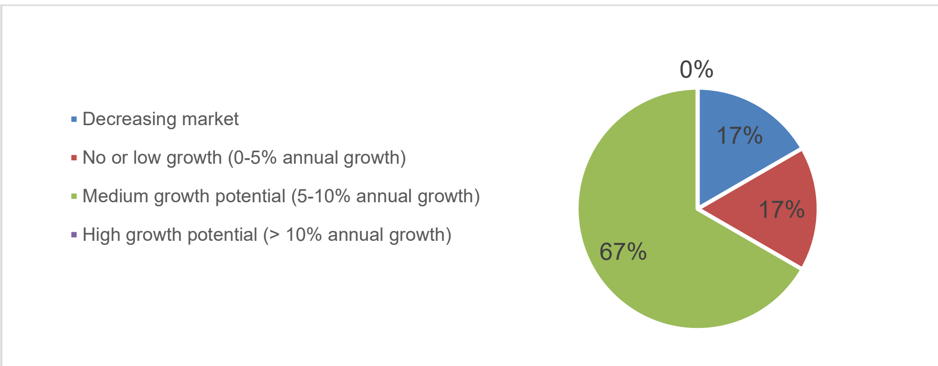


Figure 21. Market expectations (Q23).

The main region that manufacturers see more growth potential is Asia ex-China (see Figure 22). For all manufacturers, the country where they see the most growth potential is India (Q25).

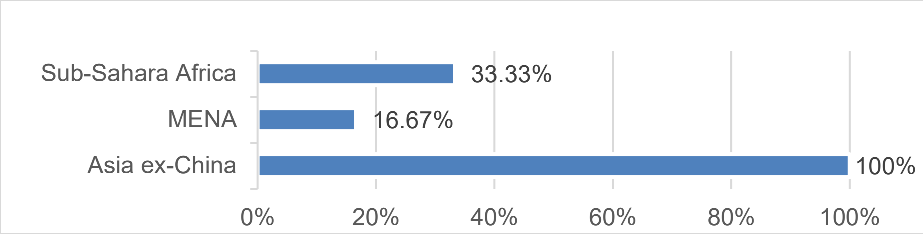
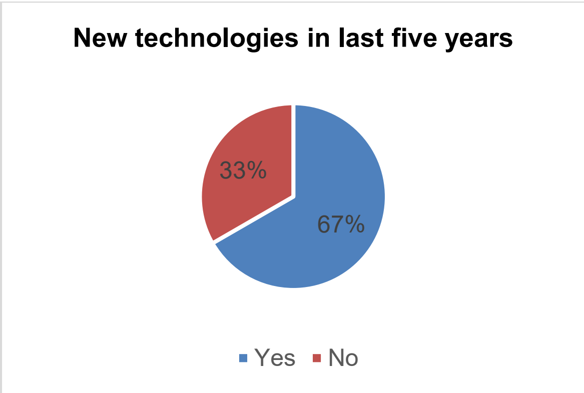
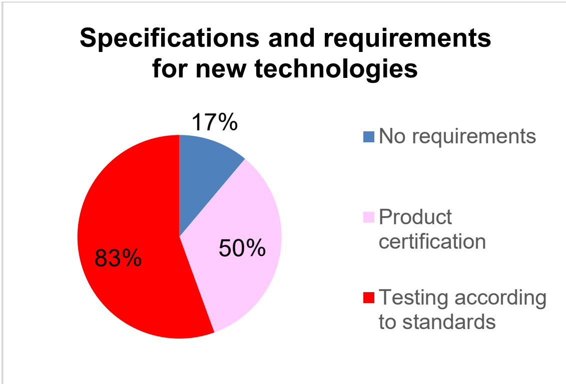


Figure 22. Market regions where manufacturers see most growth potential (Q24).

In response to the question of whether any new technologies have been introduced in the past five years, 67% answered "Yes" and 33% "No". For the requirement for newly introduced technologies, 83% listed “Testing According to Standards” followed by 50% for “Product Specification” and 17% opted for “No requirements”.





(a) *(b)*

Figure 23. Market regions where manufacturers see most growth potential (Q24).

Discussion, conclusion and outlook

India’s market is virtually stable to around 1 to 1.2 million m² annually and Indian manufacturers do not foresee a significantly growing business in the future for thermosyphon domestic hot water systems.

- **Future applications:** From the questionnaire and the current market situation in India, the application of thermosyphon water heaters is largely for domestic hot water requirements. It is a tradition in India to take a warm water bath hence thermosyphon systems are best suited for it. Thermosyphon systems for single family houses will continue to be the dominant market and very little scope for commercial (hotels, hospitals and hostels) and industrial hot water applications are expected.
- **Market development:** With regards to the future of thermosyphon systems, the manufacturers believe that it will be a “sustaining” market for the next few years and likely decline if no new policies and regulations, such as the Quality Control Order, are implemented.
- **Main competitors**: According to the survey, the manufacturers see electric water heaters as the main competitors and alternative technical solution. In the short run, PV traded under net-metering scheme in combination with heat pumps is likely to become a challenging alternative for thermosyphon domestic hot water systems. With more mature technologies coming for heat pump systems several manufacturers are likely to shift to this technology in the future. In the long-run, power production by hydrogen energy will have a more prominent role.

To address the market challenges of thermosyphon water heaters, the following points should be addressed:

1. **Use glass lined storage tanks due to water hardness:** Glass lined storage tanks are the hot focus of the technological development in India. Owing that most of the India’s geography is dependent on ground water that has high levels of pH and hardness, to ensure that solar water heaters are free from leakages during their life cycle, glass line tanks are a promising development to ensure faith of investors in the technology. Most of the manufacturers are now producing glass lined tanks that will prevent corrosion of storage tanks.
2. **Use and integration of smart technologies:** Manufacturers should make systems easier through intelligent technology to improve the smart control of hot water systems, such as cell phone control, water temperature visualization and monitoring. For users, simpler use will bring great convenience.
3. **Strict implementation of Quality Control Order for durability and reliability:** India has been plagued with sub-standard systems that seldomly last beyond five years. The need of the hour is to implement strict

quality control through an Order. Government of India is in the process of making this Order mandatory to protect the consumers. On that basis, warranties and maintenance services can be given to customers, which was rated the top priority to make systems more competitive by the manufacturers.

4. **Extending subsidy and incentives:** Government of India has come out with PV rooftop schemes with generous subsidies. As a result, masses are now opting for PV systems on their rooftop. In order to create a level playing field, solar water heaters need equal treatment. Besides other incentives like mandatory installation before obtaining building completion certificates, property tax rebates can also boost the markets.

Literature and resources

[IN1] Sameer Maithel et al. (2015), Capturing Sun for Heat – Potential, Vision, and Action Plan for Decentralised Solar Thermal Technologies and Applications in India, SHAKTI Sustainable Energy Foundation, New Delhi, 2015 https://shaktifoundation.in/wp-content/uploads/2017/06/Final_Report_High_Res_Single_2.pdf?utm_source=chatgpt.com

[IN2] National Institute of Wind Energy: Wind and Solar Resource Map. https://maps.niwe.res.in/resource_map/map/solar/ (accessed 2024-05-10)

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[IN6] Ministry of New and Renewable Energy. https://mnre.gov.in/en/solar-thermal/ (accessed 2024-05-10)

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[IN8] Exemplary Direct Flat Plate Solar Thermal System https://www.chinagomon.com/showroom/standard-solar-water-heater.html (accessed 28/03/2026)

[IN9] Exemplary Direct Evacuated Tube Solar Thermal System https://www.indiamart.com/proddetail/racold-solar-water-heater-18929521112.html (accessed 28/03/2026)

[IN10] Exemplary Indirect Flat Plate Solar Thermal System http://file.china-nengyuan.com/999/product/big/201409/p021010001410219858.jpg (accessed 28/03/2026)

[IN11] Exemplary Indirect Evacuated Tube Solar Thermal System https://imposol.en.made-in-china.com/product/zsTQYHCVCckX/China-Solar-Collector-58mm-1800mm.html?pv_id=1jkr5fnc0a52&faw_id=1jkr5fnlq1e5&bv_id=1jkr5gj9u3e&pbv_id=1jkr5fmra0e6n (accessed 28/03/2026)

3.5 Asia excl. China (Region #1b) – Japan

Thermosyphon market and regional boundary conditions

Main applications: The main applications for thermosyphon systems installed in Japan are for detached houses. There are some examples of installations in multi-family dwellings, but they are few and far between. The most common type of thermosyphon system used in Japan is the indirect system with flat-plate collectors (IND-PLAT), accounting for about 80%. About 2-3% are direct connections with flat plate collectors (DIR-PLAT) and the rest are vacuum tube collectors (IND-ETC). Indirect systems with flat plate collectors (IND-PLAT) have typical capacities of 4 m^2 collector area and 200 L tank volume per household and an average manufacturer's suggested retail price of 250,000 yen (USD 1,667). In contrast, the average selling price at a mass retailer is approximately 200,000 yen (USD 1,333). Furthermore, the installation cost is approximately 150,000 yen (USD 1,000), which translates to an initial cost of approximately 350,000 yen (USD 2,333) to be borne by the user.

Market environment and challenges: In 1980, Japan faced an "oil shock" (a situation in which no oil came in from overseas). During this period, sales of thermosyphon systems, which do not require fuel, reached their peak (800,000 units sold per year). However, sales of thermosyphon systems have since shrunk to 20,000 units per year (by 2023) as the stable supply of crude oil, heat pumps, and solar photovoltaic (PV) power generation have become more widespread. However, after the Japanese government implemented its "Carbon Neutral Declaration" in 2020 [J1], sales volume recovered slightly. Compared to pump-based solar thermal systems, thermosyphon systems require no electricity and are therefore attracting more attention than before.

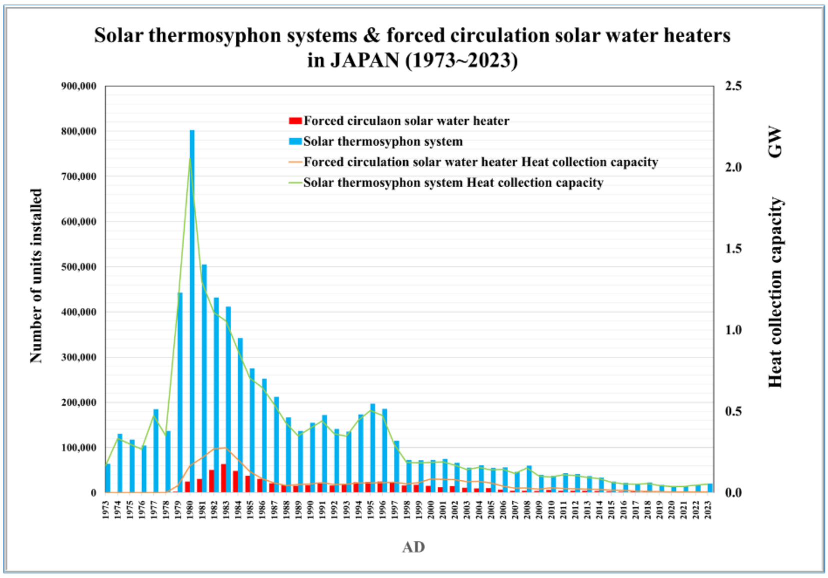


Figure 24. Market development of thermosyphon and forced circulation water heaters in Japan. Source: Japan Solar Systems Development Association [J2]

Gas water heaters are the mainstay of water heating in Japanese households, but thermosyphon systems are beginning to be recognized as a means of reducing water heating energy, energy-saving devices, and CO_2 emissions. In addition, the reduction of gas bills is a major advantage for users.

Hot water load: Japan has its own culture and use of hot water compared to other countries. One of them is to soak in a bathtub filled with hot water (40°C or higher). In addition, Japanese people soak in the bathtub almost every day, which results in higher demand and increased hot water temperatures being used compared to other countries. The annual heat consumption of hot water for a typical Japanese household (family of four) is about 16.6 GJ (4,600 kWh), or 45 MJ (12.5 kWh) per day. Per capita daily consumption is 11.25 MJ (3.13 kWh); if water at 15°C is heated to 40°C, the amount of hot water used per person per day is approximately 100 L.

Environmental conditions: Solar radiation in each region of Japan is based on historical weather data, with hourly information provided 365 days a year by the New Energy and Industrial Technology Development Organization (NEDO), a national organization, and other sources. As shown in Figure 25, in the northern part of Japan, solar irradiance is lower than in the southern part, and snowfall also affects weather conditions, so the number of solar thermal devices installed is currently low. The Pacific side of Honshu and Kyushu have high solar irradiance and are suitable for solar thermal equipment.

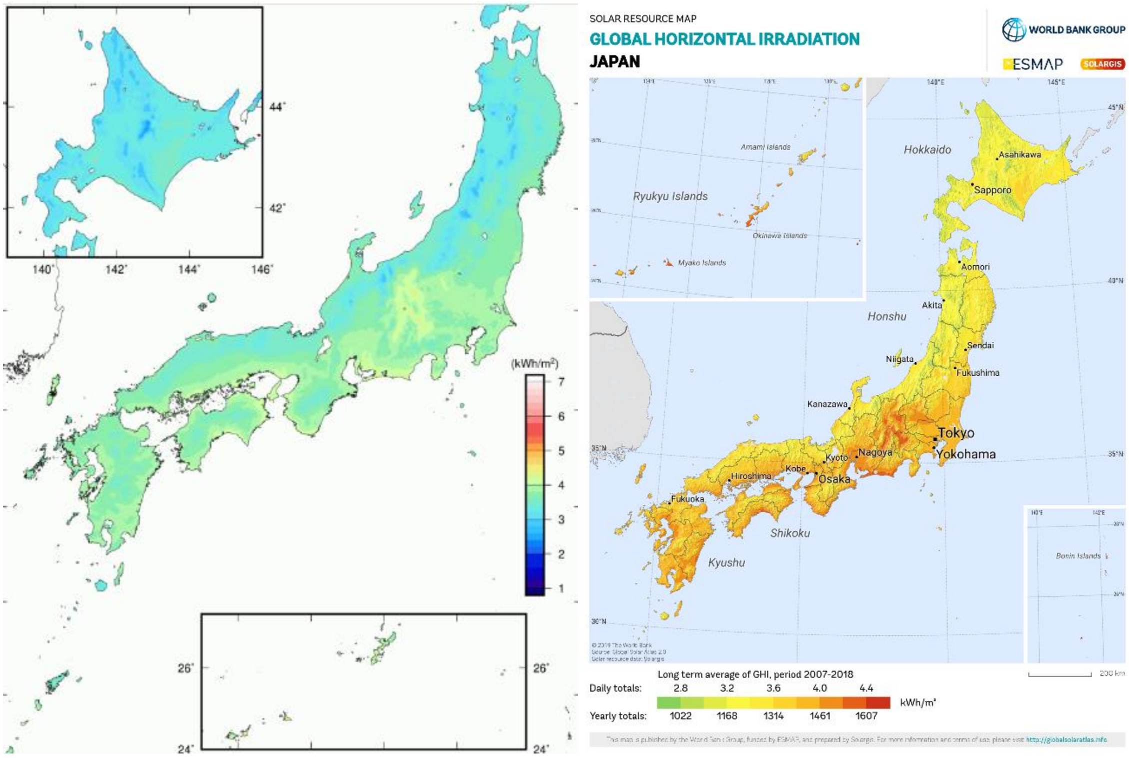


Figure 25. Average daily and yearly solar irradiance for Japan. Source: Nedo Solar radiation database (left), SOLARGIS Solar Resource map (right) [J3, J4]

Subsidy schemes, promotion schemes, government policies: There are two types of subsidy programs: national and local. Currently, the government offers various subsidy programs to promote carbon neutrality, including subsidies to promote ZEH (Zero Energy Houses). Under this subsidy program, solar thermal equipment is subsidized, and thermosyphon systems are also allowed.

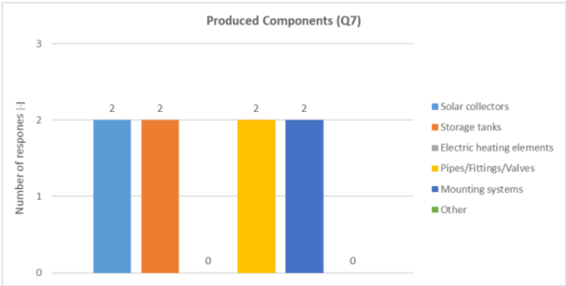
In addition, each prefectural government offers its own subsidies. The Tokyo Metropolitan Government's subsidy program is particularly substantial, subsidizing half of the total amount of installation and equipment costs.

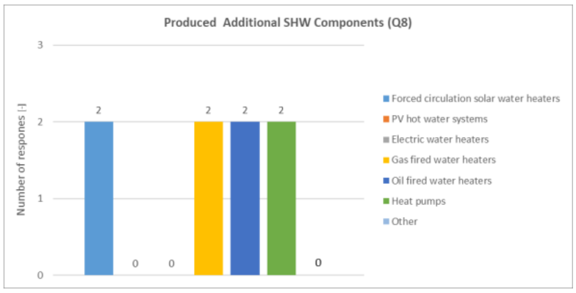
Product certification schemes, standards: The only certification system for solar thermal equipment in Japan is the “Solar System Certification System”. In order to obtain this certification, it is necessary to meet the JIS (Japan Industrial Standards) standards related to solar thermal equipment, specifically JIS A4111 (Solar water heater) and A4112 (Solar Collectors) [J5], which is based on ISO standards.

Market survey

Overview: Roughly 10 manufacturers are currently expected to produce and sell thermosyphon systems in Japan. Data was obtained from two of the major companies among them. These two companies manufacture approximately 70% of all thermosyphon systems. Besides these two companies, there are several assemblers of vacuum tube collectors (IND-ETC), which account for about 20% of thermosyphon systems, while most of these collectors are imported from China. In addition, some vacuum tube collectors used for commercial applications are made in Germany.

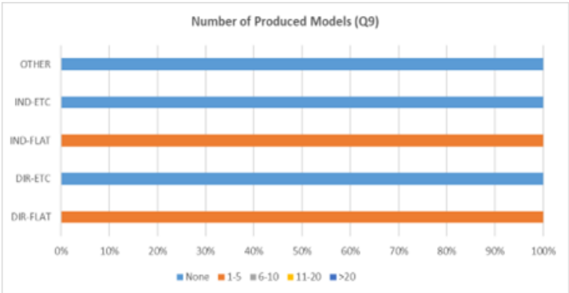
Production data (Q7 – Q12): The two companies who answered the survey produce and assemble the main components of thermosyphon systems such as flat-plate collectors, hot water storage tanks, pipes and mounting systems in-house as shown in Figure 26 (a). As shown in Figure 26 (b), they also manufacture and sell instantaneous gas and oil water heaters in addition to solar thermal equipment. These manufacturers are particularly adept at designing instantaneous water heaters that work well together as an auxiliary heat source in combination with solar thermal equipment. Figure 27 show that these companies mainly produce indirect flat-plate collectors thermosyphon systems.

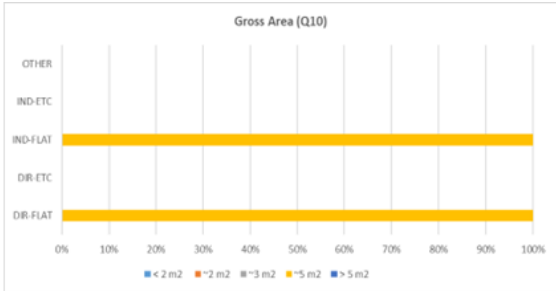




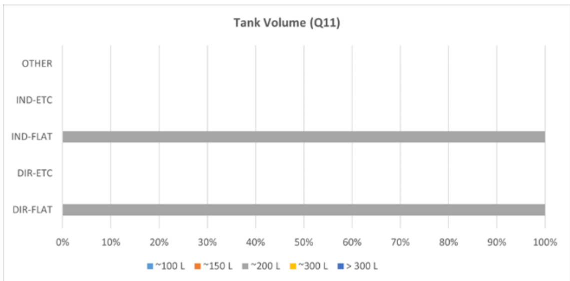
(a) *(b)*

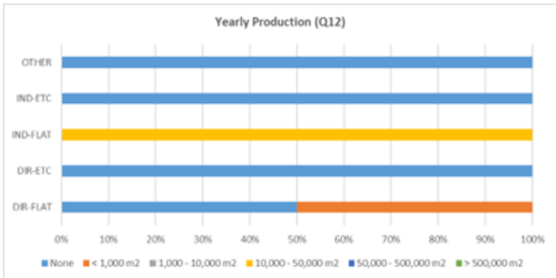
Figure 26. Produced components (a) and additional SHW Components (b).





(a) *(b)*





(c) *(d)*

Figure 27. Number of produced models (a), gross area (b), tank volume (c) and yearly production of different collector types (d).

Target markets and costs (Q13 – Q17): The primary target market for thermosyphon systems in Japan is domestic, with no exports as shown in Figure 28 and Table 5. In the domestic market, the main target market is from central to southern Japan, as the northern part of the country is affected by snowfall. Answers regarding final customer prices were given with USD 250-500 and USD 1,500-2,000 (see Figure 29), where the lower price range seems too low given the available market data.

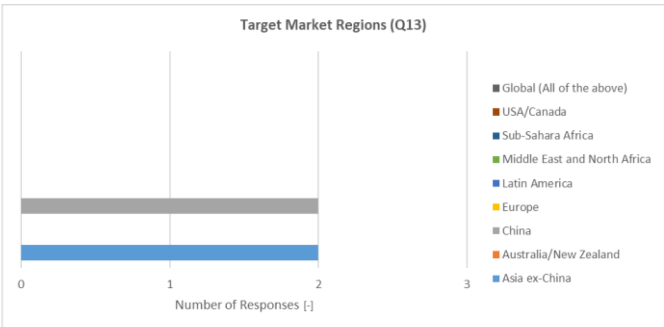


Figure 28. Target market regions.

Table 5. Biggest Markets.

The 1st biggest market (2)	Japan (2)
The 2nd biggest market (2)	N/A (2)
The 3rd biggest market (2)	N/A (2)

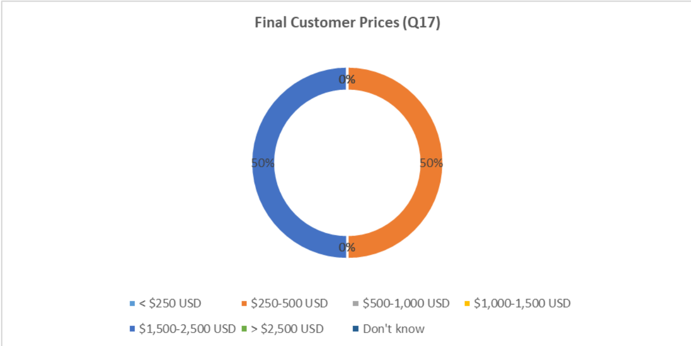
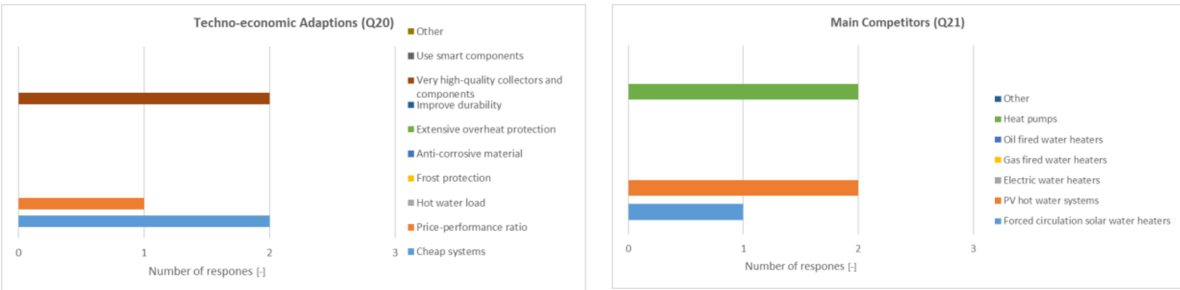


Figure 29. Final Customer Prices.

Product Placement/ Business Models (Q18 – Q21): Figure 31 and Figure 32 show the end user requirements, distribution channels, techno-economic adaptions and main competitors. Warranties and low prices are seen as important, as well as durability and reliability. Selling to single installers and wholesalers are the prevailing distribution channels. The most important techno-economic adaptations are high-quality collectors and components, cheap systems as well as good price-performance ratio. Heat pumps and PV hot water systems are seen as the main competitors, and, to a lesser extent, forced circulation solar water heaters.

(a) *(b)*

Figure 30. End user requirements (a) and Distribution channels (b).



(a) *(b)*

Figure 31. Techno economic adaptations (a) and Main competitors (b).

Innovation and Market Outlook (Q22 – Q29): The product maturity of thermosyphon systems in Japan is very high, and no major model changes have been made to the basic design elements between the first launch and now. The products have been simplified and there is little room for major cost reductions. However, a small number of examples of new technological elements have been developed in Japan in recent years. One example is a study of the application of transparent insulation to collector cover glass, in which a manufacturer experimented with the application of transparent insulation. Although the heat insulating effect was achieved in this experiment, it has not yet been applied to actual equipment because there are issues in mass production of transparent heat insulators on a large scale. Improvements to the selective absorption membrane applied to the surface of the collector are also being addressed as a research issue.

In order to expand the use of thermosyphon systems in the future, it is important to spread awareness of the high efficiency and excellence of these products, the increase of marketing activities is the main improvement task in eyes of the manufacturers as shown in Figure 32. It is also necessary to spread the word through the Internet and other means that thermosyphon systems with high conversion efficiency are one of the candidates for use on residential roofs, in addition to PV (photovoltaic) power generation.

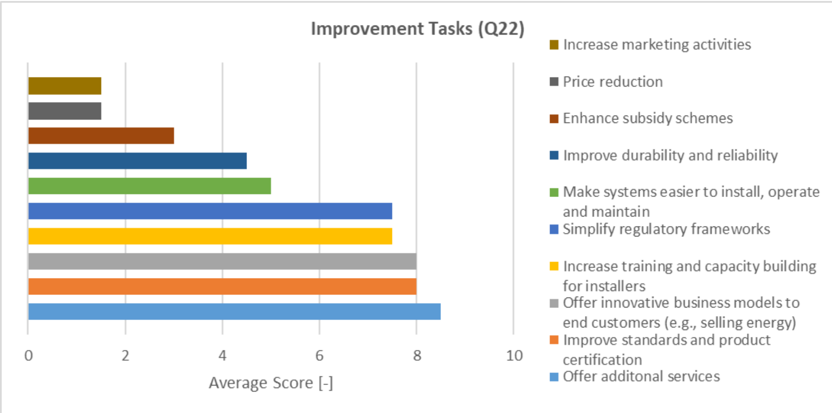
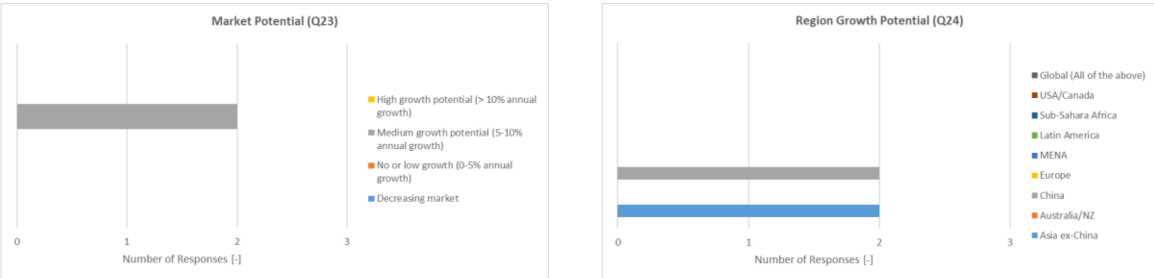


Figure 32. Improvement tasks as seen by the manufacturers.

Figure 33 (a) shows that the two companies expect a medium growth potential, focused on the domestic market and China (Figure 33 b).



(a) *(b)*

Figure 33. Market potential (a) and Region growth potential (b).

Discussion, conclusion and outlook

From the market analysis and the survey results, the following conclusions can be drawn:

1. The product maturity of thermosyphon systems in Japan is very high with little room for major cost reductions.
2. After reaching a sales peak of 800,000 units per year in 1980, sales volume has declined due to various factors and currently stands at approximately 20,000 units per year. However, since the Japanese government's declaration of “carbon neutrality” in 2020, the decline in sales has been halted and sales have begun to increase slightly.
3. 80% of thermosyphon systems installed in Japan are indirect systems with flat plate collectors (IND-PLAT), all of which are manufactured in Japan. Other vacuum tube collectors are mainly imported from China and assembled in Japan. Thermosyphon systems are mainly installed in the Pacific side of Honshu, Shikoku, and Kyushu, which are not affected by snowfall.
4. Compared to domestic energy-saving equipment and high-efficiency water heaters, solar thermal equipment has superior energy-saving and CO_2 reduction effects, as well as good cost performance. Therefore, sales expansion in Japan is desirable.
5. Currently, the main reason for the lack of sales expansion of solar thermal appliances in Japan is that their performance and the appliances themselves are not well known, i.e., there is a lack of publicity. It is important to make the awareness raising activities effective and to carry them out.
6. Roofs are a site of competition between PV and solar thermal devices. Due to the large population for a small land area, many families live in small lots and have limited roof area. For this reason, solar thermal

equipment should be installed on small roofs and PV on large roofs, i.e., the optimal installation of each leads to effective CO_2 emissions reduction.

Literature and resources

[J1] Green Growth Strategy Through Achieving Carbon Neutrality in 2050 (2020) https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html

[J2] Japan Solar System Development Association (2024): Market development of thermosyphon and forced circulation water heaters in Japan. Available online: https://ssda.or.jp/result/

[J3] NEDO (New Energy and Industrial Technology Development Organization) Solar Radiation database https://appww2.infoc.nedo.go.jp/appww/colormap.html

[J4] SOLARGIS Solar Resource Map (2021) Japan https://solargis.com/resources/free-maps-and-gis-data?locality=japan

[J5] Japan Quality Assurance Organisation https://www.jqa.jp/english/jis_a/e_list_a.html

3.6 China (Region #2)

Thermosyphon market and regional boundary conditions

Main applications: The main application scenarios for thermosyphon systems in China are household use for single houses in rural areas and multiple storey residential buildings in urban areas. Direct systems with evacuated tube collectors (DIR-ETC) are predominantly used in rural areas, while indirect systems, both with flat plate collectors (IND-PLAT) and evacuated tube collectors (IND-ETC), are predominantly used in multiple storey residential buildings in towns and cities. The dominant configuration per household is "2m^2 +150L" and the average price is around $500 USD.

Market environment and challenges: Compared to electric water heaters, thermosyphon systems need to improve durability and reliability to ensure a stable supply of hot water to users. In addition, with the development of smart electrical appliances, users have higher expectations for intelligent utilization of thermosyphon systems, such as cell phone control, water temperature visualization and monitoring. For users, simpler installation and use will bring great convenience. For some areas with special needs, corrosion resistance, frost resistance and other requirements are also important considerations when purchasing a water heater.

Hot water load: Chinese national standards GB 50364-2018 *Technical standard for solar water heating system of civil buildings* provides hot water load profiles of different applications. In GB 50364-2018, residential buildings are divided into Class II residential buildings and Class III residential buildings. Class II residential buildings (with their own hot water supply and shower facilities) have an average daily hot water load of 20 ~ 60 L per person per day, Class III residential buildings (with centralized hot water supply and shower facilities) have an average daily hot water load of 25 ~ 70 L per person per day.

Environmental conditions: The entire country has been categorized into four levels of solar resource zones based on total annual solar irradiation. Table 6 shows the basis for delineation of solar resource zones. China Solar Resource Zone Map is shown in Figure 34.

Table 6. Basis for delineation of solar resource zones (Source: GB/T 31155-2014, Classification of solar energy resources - Global radiation)

Solar Resource Zone	Threshold ($kWh \cdot m^{-2} \cdot a^{-1}$)	Threshold ($MJ \cdot m^{-2} \cdot a^{-1}$)	Symbol
Most rich area	$G \geq 1750$	$G \geq 6300$	A
Very rich area	$1400 \leq G < 1750$	$5040 \leq G < 6300$	B
Rich area	$1050 \leq G < 1400$	$3780 \leq G < 5040$	C
Normal area	$G < 1050$	$G < 3780$	D
G: yearly irradiation of global radiation			

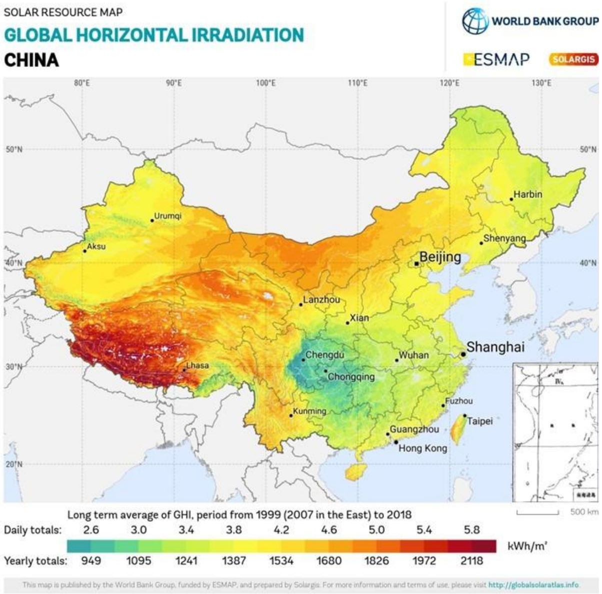


Figure 34. China Global Horizontal Irradiation Map. Source from © 2017 The World Bank, Solar resource data: Solargis.

The entire country has been categorized into five main building climate zones. Table 7 shows the description of the different building climate zones. China Building Climate Zoning Map is shown in Figure 35.

Table 7. Basis for delineation of building climate zones. Source: GB 50176-2016, Code for thermal design of civil building

Building Climate Zone	Zone description
I Severe cold zone	Areas where the average temperature of the coldest month is ≤-10℃ and the number of days with an average daily temperature ≤ 5℃ is ≥145 days.
II Cold zone	Areas where the average temperature of the coldest month meets -10℃-0℃ and the number of days with an average daily temperature ≤5℃ is 90~145 days.
III Hot-summer and cold-winter zone	Areas where the average temperature of the coldest month meets 0-10℃, the average temperature of the hottest month meets 25-30℃, the number of days with an average daily temperature ≤5℃ is 0-90 days and the number of days with an average daily temperature ≥25℃ is 40-110 days.
IV Hot-summer and warm-winter zone	Areas where the average temperature of the coldest month is > 10℃, the average temperature of the hottest month meets 25-29℃, and the number of days with an average daily temperature ≥25℃ is 100-200 days.
V Temperate zone	Areas where the average temperature of the coldest month meets 0-13℃, the average temperature of the hottest month meets 18-25℃, and the number of days with an average daily temperature ≤5℃ is 0-90 days.

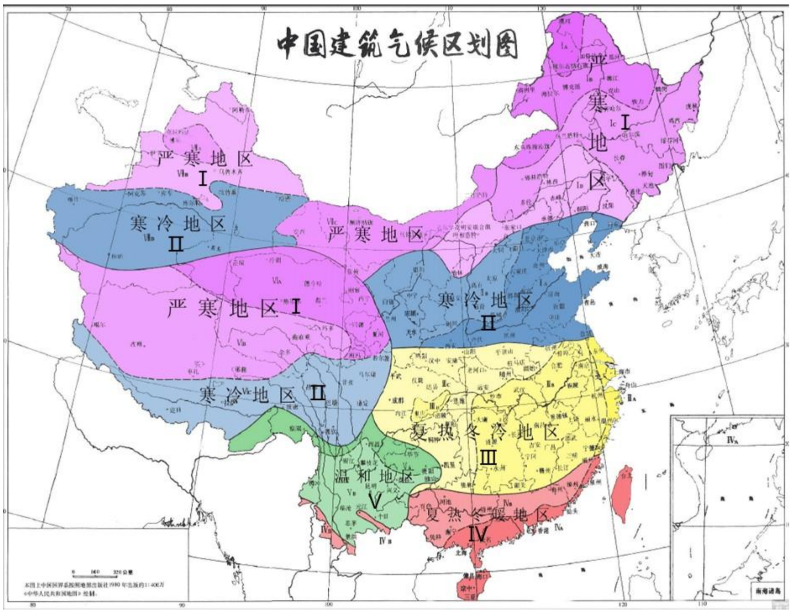


Figure 35. China Building Climate Zoning Map. Source: GB 50176-2016, Code for thermal design of civil building

Subsidy schemes, promotion schemes, government policies: Solar water heater have been used in China for nearly two decades, the development is relatively mature, so the subsidy mechanism has been withdrawn since the 2010s. However, in recent years an important policy has been introduced. According to the provisions of Chinese national standards GB 55015-2021 *General code for energy efficiency and renewable energy application in buildings*, all new buildings are required to install solar energy systems, including solar water heating systems, solar thermal systems, solar photovoltaic power generation systems, etc., without limitation to the form of technology. Besides, the Government promotes the application of renewable energy sources to achieve the goal of carbon peaking and carbon neutrality, which offers incentives to thermosyphon hot water applications.

Product certification schemes, standards: Chinese national standards GB 35606-2017 *Green product assessment—Solar water heating system* provides the technical requirements of solar water heating system, which includes thermosyphon systems. This standard is used for the green product certification.

Market survey

Overview: Survey results of 12 manufacturers of thermosyphon systems from four provinces (Beijing, Shandong, Jiangsu and Guangdong) were received. As shown in Figure 36, most of these manufacturers are located in the coastal region in places with the most active and concentrated manufacturing industry and top ranking regarding China's GDP.

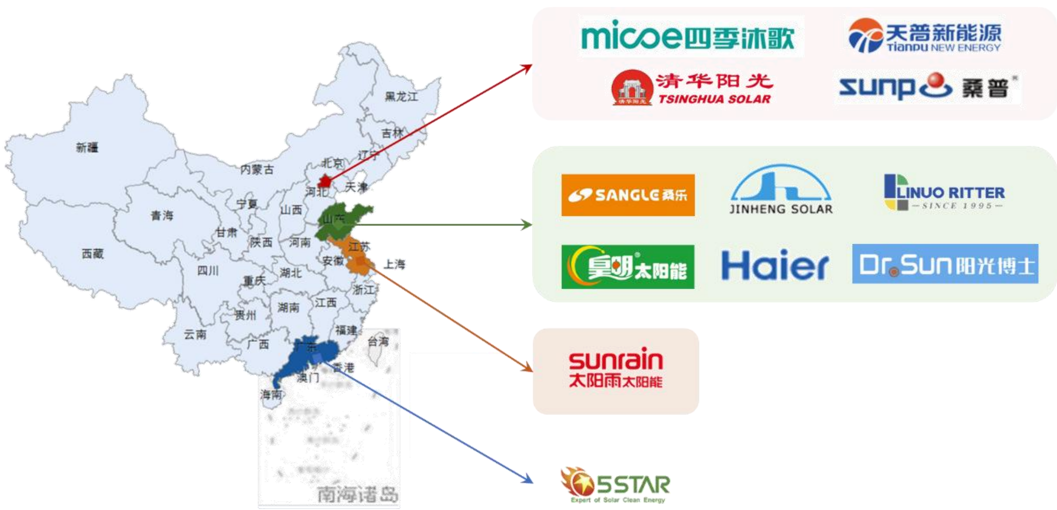
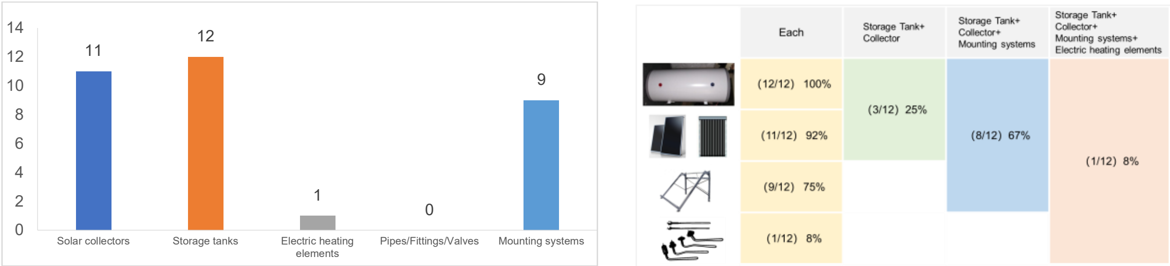


Figure 36. The distribution of manufacturers who participated in the survey.

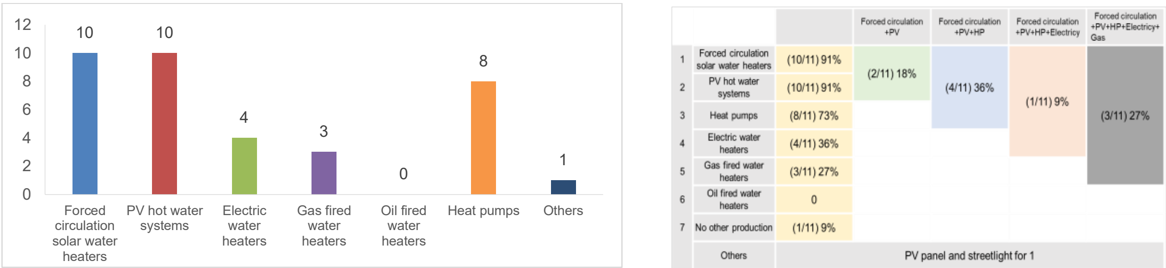
Production data (Q7 – Q12): Storage tanks, solar collectors and mounting systems, as the common components of thermosyphon systems, are mostly produced by the manufacturer themselves. As shown in Figure 37 (a), from 12 received answers, all manufacturers produce storage tanks themselves, 92% produce solar collectors, 75% produce mounting systems, and over two-thirds manufacturers produce these three components all by themselves. Only one manufacturer produces electric heating elements and no company in the survey produces pipes/fittings/valves.



(a) *(b)*

Figure 37. Produced components of thermosyphon systems (Q7), with (a) survey counts and (b) survey analysis.

Besides thermosyphon systems, forced circulation solar water heaters, PV hot water systems and heat pumps are the most common systems produced by solar manufacturers in China. Specifically, forced circulation solar water heaters and PV hot water systems are 91% manufacturers' second choice, heat pump is next to them taking a share of 73%. Meanwhile electric water heaters, gas fired water heaters and other systems are also produced by solar manufacturers but with 36% or less shares. No oil-fired water heaters are produced by solar manufacturer from the survey.



(a) *(b)*

Figure 38. Solar hot water systems or components produced by manufacturers besides thermosyphon systems (Q8), with (a) survey counts and (b) survey analysis.

There are four common thermosyphon system types on the market, namely direct systems with flat plate collectors (DIR-FLAT), direct systems with evacuated tube collectors (DIR-ETC), indirect systems with flat plate collectors (IND-FLAT) and indirect systems with evacuated tube collectors (IND-ETC).

DIR-FLAT DIR-ETC IND-FLAT IND-ETC

Figure 39. Appearances of four main types of common thermosyphon systems on the market.

The results of the manufacturers' responses to the number of produced models, approximate collector surface (gross area) of the most produced model, approximate tank volume of the most produced model and company's yearly production (in gross collector area) in the questionnaire are summarized in Figure 40.

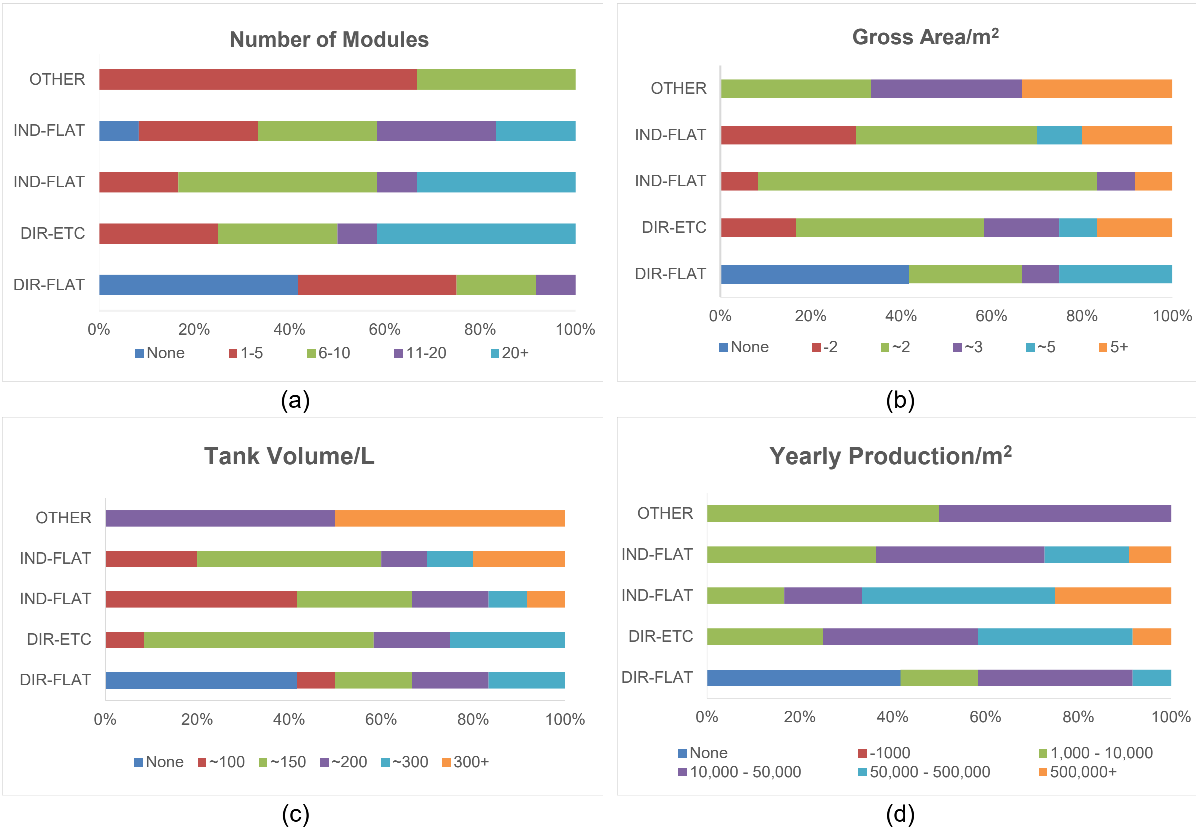
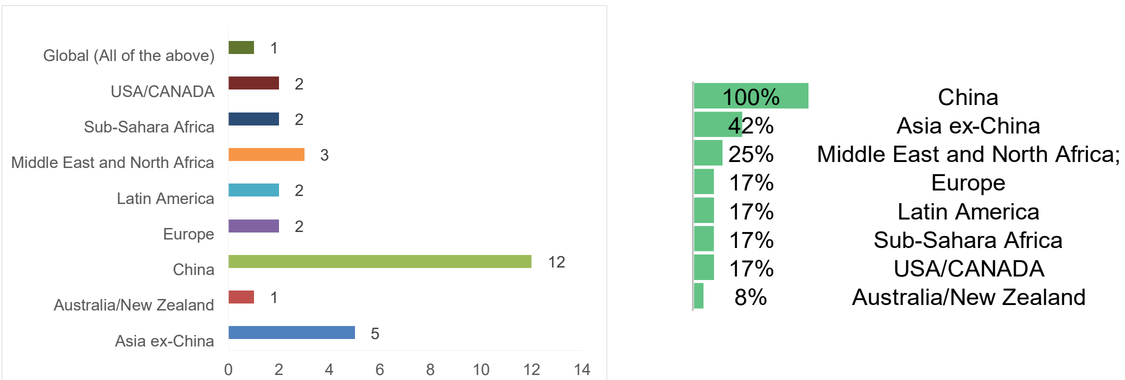


Figure 40. Production data with (a) number of produced models, (b) collector gross area, (c) tank volume and (d) yearly production (Q9-Q12).

The survey results show that DIR-ETC and IND-PLAT are the most popular systems in China both regarding number of models and yearly production. The most common models have the following features:

- Gross areas: 2 m^2
- Tank volume: 150L
- DIR-ETC system models: “2 m^2 +150L” and “>5 m^2 +300L”
- IND-PLAT system: “2 m^2 +100L” and “2m^2 +150L”

Target markets and costs (Q13 – Q17): The main target market region for thermosyphon systems is China (all 12 manufacturers). Five manufacturers also sell products to Asia excluding China. Besides, three manufacturers treat Middle East and North Africa as target markets. Similarly, USA/Canada, Sub-Sahara Africa, Latin America and Europe with two manufacturers in each and Australia/New Zealand and Global with one manufacturer in each, are considered to be target markets (Figure 41).



(a) *(b)*

Figure 41. Market region(s) (Q13-Q16), showing (a) main target regions, and (b) top-ranked countries.

As shown in Table 8 , from all 12 manufacturers who participated in the survey, five manufacturers only target the Chinese market. The remaining seven manufacturers have more than one target market (Q13).

Table 8 . Target market specifications (Q13).

Only China	5
China + Asia ex-China	2
China + MENA +SSA	1
China + Asia ex-China + Europe	1
China + Asia ex-China +Latin America + MENA	1
China + USA/CANADA	1
Global (All of the above)	1
Total	12

Table 9 shows, that the top three biggest target markets for Chinese manufacturers are distributed globally, covering the market regions China, Asia ex-China, Europe, Latin America and Australia/New Zealand. None of the Chinese manufacturers lists a country in the market regions Middle East, North Africa and Sub-Sahara Africa in the top three.

Table 9. The results of top 3 biggest markets (country) in sales measured in gross collector area (Q14-Q16).

The 1st biggest market (12)	CHINA (11) ISRAEL (1)
The 2nd biggest market (10)	CHINA (3) INDIA (2) JAPAN (1) PAKISTAN (1) PERU (1) AUSTRALIA (1) GERMANY (1)
The 3rd biggest market (10)	CHINA (3) INDONESIA (1) MALAYSIA (1) VIETNAM (1) PUERTO RICO (1) AUSTRALIA (1) GERMANY (1)

The typical final customer prices (including shipping, installation and taxes) for a standard sized thermosyphon system (with 150 L tank and 2 m^2 collector) in the main market (the 1st biggest market in Q14 is China) are listed in Table 10. The final price is approximately around $250-500 or $500-1,000 USD.

Table 10. Typical final customer prices for a standard sized thermosyphon system in the main market (Q17).

CHINA (11)	$250-500 USD	4
	$500-1,000 USD	5
	$1,000-1,500 USD	1
	Blank	1
ISRAEL (1)	Don't know	

Product placement/ business models (Q18 – Q21): The three most important end user requirements in the target markets are “Durability and Reliability”, “Warranties” and “Low price”, as shown in Figure 42.

12	100%	Durability and reliability
9	75%	Warranties
8	67%	Low Price
7	58%	Easy to install
7	58%	Easy to operate and maintain
6	50%	Maintenance and service packages

Figure 42. Most important end user requirements in target market(s) (Q18).

As shown in Figure 43, the main distribution channels and business models used for different target markets are “Selling to wholesalers” and “Selling to single installers”.

10	83%	Selling to wholesalers
10	83%	Selling to single installers
8	67%	Selling turnkey installations to customers
5	42%	Selling energy to customers
4	33%	Maintenance and service packages

Figure 43. Distribution channels and business models uses in different target market(s) (Q19).

The main techno-economic adaptions made to tailor products successfully to the target markets are “Adjustable system design”, “Price-performance ratio” and “Frost protection”, see Figure 44.

12	100%	Adjustable system design
11	92%	price-performance ratio
10	83%	Frost protection
9	75%	high thermal performance
9	75%	Smart and digital measure
8	67%	Durability of components
6	50%	Anti-corrosive material
4	33%	As cheap as possible
2	17%	Overheat protection

Figure 44. Techno-economic adaptions made to tailor products successfully to the target market(s) (Q20).

The main competitors and alternative technical solutions to provide hot water in target markets are heat pumps and PV hot water systems, see Figure 45.

7	58%	Heat pumps
6	50%	PV hot water systems
5	42%	Gas fired water heaters
4	33%	Froced circulation SWH
4	33%	Electric water heaters
0	0%	Oil fired water heaters
0	0%	Others

Figure 45. Competitors and alternative technical solutions to provide hot water in target market(s) (Q21).

Innovation and Market Outlook (Q22 – Q29): The most urgent tasks to make systems more competitive and reduce market barriers are “Improve standards and certification”, “Improve durability and reliability” and “Make systems easier to install, operate and maintain”, see Table 11.

Table 11. Tasks to make systems more competitive and reduce market barriers (Q22).

The 1st important	Improve standards and certification Improve durability and reliability Make systems easier
The 2nd important	Increase marketing activities Offer innovative business models
The 3rd important	Enhance subsidy schemes Simplify regulatory frameworks Increase training and capacity building
The 4th important	Offer additional services Price reduction

For thermosyphon systems, the expectation of the future market potential is mainly “No or low growth (0-5% annual growth)”.

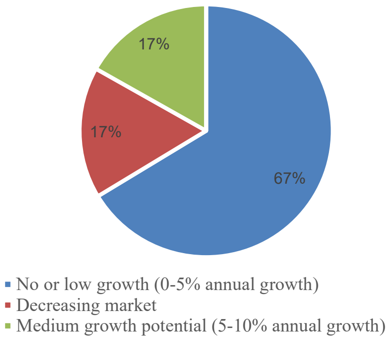


Figure 46. Market expectations (Q23).

The top market regions where manufacturers see the most growth potential are China, Asia ex-China and Europe, see Figure 47.

8	67%	China
7	58%	Asia ex-China
5	42%	Europe
2	17%	Middle East and North Africa;
2	17%	Sub-Sahara Africa
1	8%	Australia/New Zealand
1	8%	Latin America
1	8%	USA/CANADA
0	0%	Global (All of the above)

Figure 47. Market regions where manufacturers see most growth potential (Q24).

The countries that manufacturers see the highest growth potential in the next five years are India, Pakistan and Vietnam, see Figure 48.

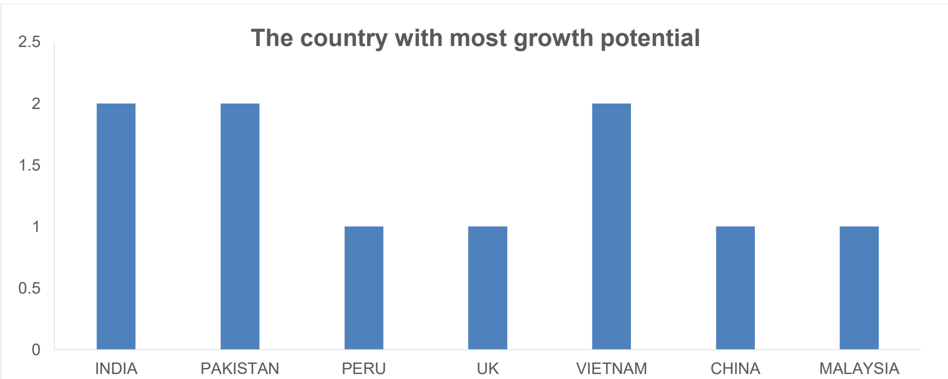


Figure 48. Country with the highest growth potential (Q25).

In response to the question of whether any new technologies have been introduced in the past five years, 34% answered "No" and 66% "Yes". Of these, 50% list “Smart control” as the new technology they have introduced, “Improved components” and “New equipment” occupies 8% respectively (Figure 49).

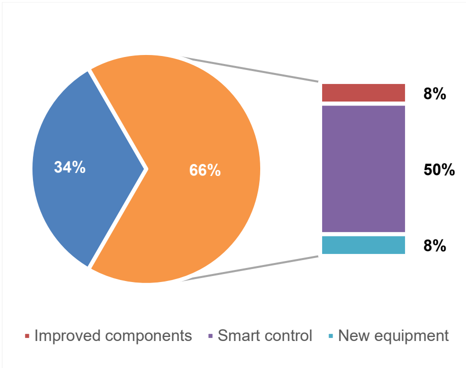


Figure 49. Introduction of new technologies (Q26, Q27).

Technical specifications and requirements of new technology products (Q28): For new technologies that manufacturers develop, the most important technical specifications and requirements to bring products to the market is the combination of “Product certification” and “Testing according to standards”.

Table 12. Technical specifications and requirements needed to bring products to the market (Q28).

	ONLY	BOTH
Product certification	1	7
Testing according to standards	3	

Discussion, conclusion and outlook

The most noticeable and outstanding points from the survey can be summarized as follows:

1. **Chinese manufacturers are not optimistic about the future development of thermosyphon systems.** With regard to the future of thermosyphon systems, five-sixths of the manufacturers believe that it will be a “Decreasing market” or market with “No or low growth (0-5% annual growth)”. Market regions with growth potential, in addition to China, are Asia ex-China and Europe.
2. **Heat pump and PV hot water heaters are the main competitors and alternative technical solutions.** The survey shows, that among the competitors and alternative technical solutions, heat pumps, PV hot water heater and gas fired water heaters take the top three ranking. Although forced circulation SHW are the most popular products produced by manufacturers in addition to thermosyphon systems, PV hot water systems and heat pumps will become the key products for the solar manufacturers in the future.
3. **Smart control is the hot focus of solar technical streams.** Facing the rapid market development, two-thirds of manufacturers have introduced new technologies in the past five years. The hot focus of most manufacturers are smart technologies, for example to improve smart control of hot water systems and introduce cloud platforms for data monitoring.
4. **Improve durability and reliability is an important task for the industry.** From the survey, “Durability and reliability” is the most important end user requirements in target markets. Meanwhile, “Improve durability and reliability” is also the most urgent task to make systems more competitive. So, “Durability and reliability” are the common concern both from users and manufacturers.

From the questionnaire and the current market situation in China, the applications of thermosyphon systems are mainly based on family household use. In this market segment, thermosyphon water heaters are facing challenges due to the rapid development of heat pumps and photovoltaic water heaters. In this context, the future development of thermosyphon systems can be addressed from the following points:

1. **Use and integration of smart technologies**. Manufacturers should make systems easier through intelligent technology to provide smart control for hot water systems, such as cell phone control, water temperature visualization and monitoring. For users, simpler use will bring great convenience.
2. **Improvement of standards for thermosyphon water heaters in terms of durability and reliability.** According to the findings of the survey, improving the durability and reliability are the most urgent tasks. Currently, there are ISO standards for durability and reliability testing of collectors and other components available, as well as thermal performance standards for solar hot water heaters. However, there is still a lack of standards for durability and reliability testing for whole solar water heating systems, especially in the case of direct systems with evacuated tube collectors (DIR-ETC), a product design where the components cannot be

separated. To improve the market perspectives of thermosyphon systems, it is therefore essential to revise the current standards and product certification schemes.

Literature and resources

[CN1] GB 50364-2018, Technical standard for solar water heating system of civil buildings

[CN2] GB 55015-2021, General code for energy efficiency and renewable energy application in buildings

[CN3] GB 35606-2017, Green product assessment—Solar water heating system

[CN4] GB 50176-2016, Code for thermal design of civil building

[CN5] Exemplary Direct Flat Plate Solar Thermal System https://www.chinagomon.com/showroom/standard-solar-water-heater.html (accessed 28/03/2026)

[CN6] Exemplary Direct Evacuated Tube Solar Thermal System https://www.indiamart.com/proddetail/racold-solar-water-heater-18929521112.html (accessed 28/03/2026)

[CN7] Exemplary Indirect Flat Plate Solar Thermal System http://file.china-nengyuan.com/999/product/big/201409/p021010001410219858.jpg (accessed 28/03/2026)

[CN8] Exemplary Indirect Evacuated Tube Solar Thermal System https://imposol.en.made-in-china.com/product/zsTQYHCVCckX/China-Solar-Collector-58mm-1800mm.html?pv_id=1jkr5fnc0a52&faw_id=1jkr5fnlq1e5&bv_id=1jkr5gj9u3e&pbv_id=1jkr5fmra0e6n (accessed 28/03/2026)

3.7 Europe (Region #3)

Thermosyphon market and regional boundary conditions

Main applications: In 2022, 56% of the newly installed systems in Europe were thermosyphon systems (compared to 44% pumped systems), driven by the large thermosyphon markets in Cyprus, Greece and Turkey [E1]. In Europe, thermosyphon systems for hot water preparation are only widely used in Mediterranean countries. Main applications are in residential buildings and in the tourism sector but there are also some installations in the public sector. Typical systems are equipped with flat plate collectors, in part with highly selective coatings. Typical system sizes are 2 m² and 4 m² collector area with tank volumes ranging between 150 and 300L.

Market environment and challenges: In case of frost conditions antifreeze mixtures are used as solar circuit working fluids. The inside of tanks is often double enamelled and magnesium anodes are used to prevent corrosion. Insulation of tanks prevents heat losses. Double jack tanks provide a good price-performance ratio.

In Europe, there are some local manufacturers of thermosyphon systems (e.g., GREENoneTEC, Calpak, Solimpeks etc.). Greece stands out with its market development that it has shown an increase despite of economic crises over the last decades. The country has a favourable climate such that a system typically covers 80 – 90% of the yearly hot water needs of a family. Major reasons for the country's long-term success are local manufacturing and stable regulatory framework conditions over many years. This enabled both a strong local and export market [E2].

Hot water load: In 2020, EU27 citizens and businesses used 72 litres of hot water (60 °C equivalent) for showers, baths and taps on average per capita and day, compared to 55 litres in 1990. For 2030 this is expected to remain fairly constant at 73 litres per day. Hot water consumption per capita varies greatly within the EU, with the Scandinavians using twice as much and Mediterranean countries using considerably less than the EU average [E3].

Environmental conditions: The global horizontal irradiation covered in the SOLARGIS map for Europe ranges from 800 kWh/m² in the northern parts of Great Britain to more than 2100 kWh/m² in the south of Spain, Cyprus and Turkey as shown in Figure 50.

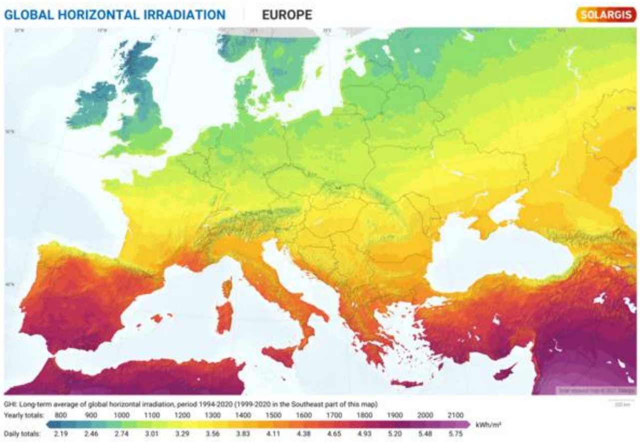


Figure 50. Global Horizontal Irradiance (GHI) map of Europe. Source: [E4].

The climatic conditions in Europe (European Union countries, Belarus, Great Britain, Iceland, Norway, Russian Federation, Switzerland, Turkey, Ukraine) are manly divided into four climates, namely subtropical climates, warm temperate climates, cold temperate climates and cold climates as shown in Figure 51. The countries in the subtropical climates are in the south of Europe (35° North to 45° North) and comprise Bulgaria, Croatia bordering the Mediterranean See (Adriatic See), Cyprus, Greece, Italy, Malta, Portugal, Romania, Spain and Turkey. Countries of the warm temperate climates (45° North to 60° North) are Austria, Belgium, Croatia (except Adriatic Coast), Czech Republic, Denmark, Estonia, France, Germany, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Moldova, Netherlands, Poland, Slovakia, Slovenia, Sweden and Switzerland. Finland (60° North to 70° North) is part of the cold temperate climate zone. The climate zones in the Russian Federation reach from warm temperate zone in the south to cold temperate zone, cold zone and subpolar zone in the far north. Iceland's climate zones are cold temperate in the south and subpolar in the north.

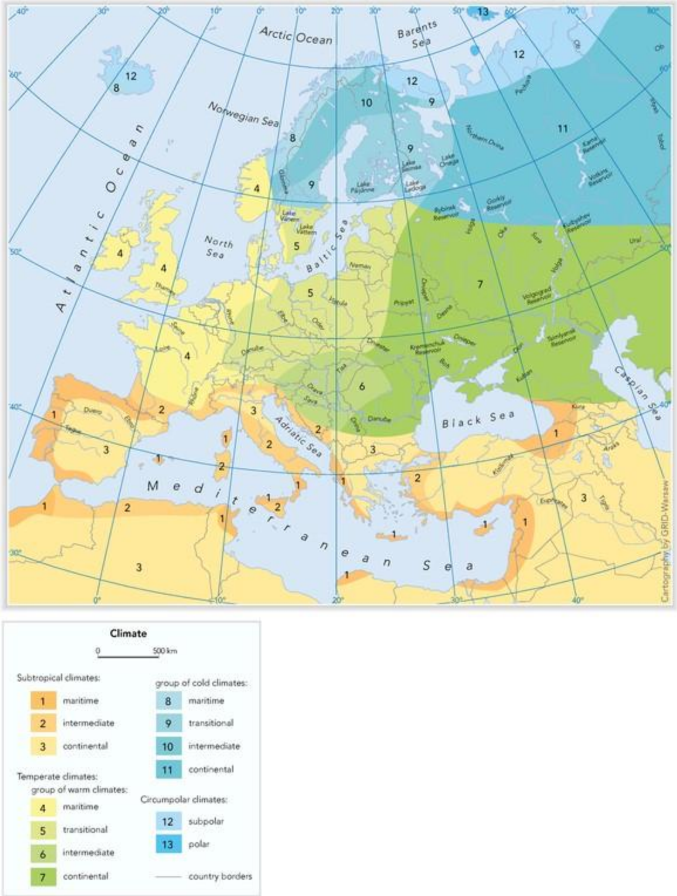


Figure 51. Climate Zones of Europe. Source: [E4].

Subsidy schemes, promotion schemes, government policies: The solar hot water market in Europe is very diverse because many countries have different policies and regulatory frameworks. The dominant technologies in the European countries are strongly influenced by these regulatory framework as well as available subsidies.

In Greece an income tax deduction is available for investments in renewable heating and cooling technologies like solar thermal. Depending on the project type 30-65% of the investment cost can be covered. [E10] Together with a strong solar thermal association focussing on high quality Solar Keymark certified products a strong solar thermal market was able to develop in Greece with several manufacturers of systems and components in place, like for example Andrianos, Calpak, Dimas, Papaemmanouel, Prime Laser Tech, Sole or Sammler. [E11, E12, E13]

In Turkey a couple of manufacturers for solar water heaters exist, amongst which Bural, Ezinc and Solimpeks are manufacturers with more than 20 years of experience.

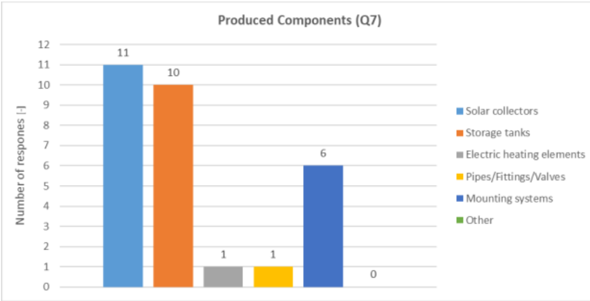
Certification Schemes: There are two voluntary product labels Solar Keymark [E6] and Solergy [E7]. The EU Energy Efficiency label is obligatory under the EU Energy Efficiency [E8] (EED) and the EU Ecodesign Directive [E9]. The products are tested according to the EN 12975:2022 standard.

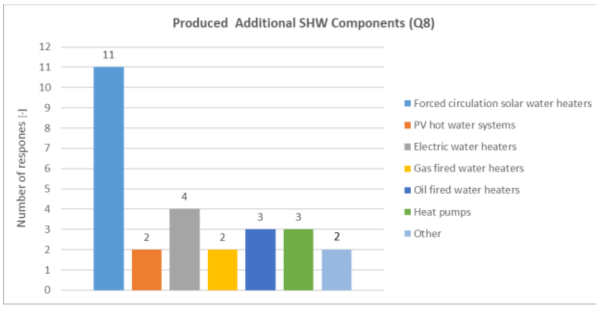
- EN 12975-1 Thermal solar systems and components – Solar collectors. Part 1: General Requirements
- EN 12975-2 Thermal solar systems and components – Solar collectors. Part 2: Test methods
- ISO 9060:2018, Solar energy – Specification and classification of instruments for measuring hemispherical solar and direct solar radiation. This publication was last reviewed and confirmed in 2024. It is a normative reference to EN 12975-2.

Market survey

Overview: Survey results from 12 manufacturers of thermosyphon systems were received from Greece (7 answers), Netherlands (2), Cyprus (1), Germany (1) and Austria (1).

Production data (Q7 – Q12): As shown in Figure 52 (a), most manufacturers of thermosyphon systems produce solar collectors and storage tanks by themselves. Most manufacturers also produce forced circulation solar water heaters and a broad range of other products (Figure 52 (b)).

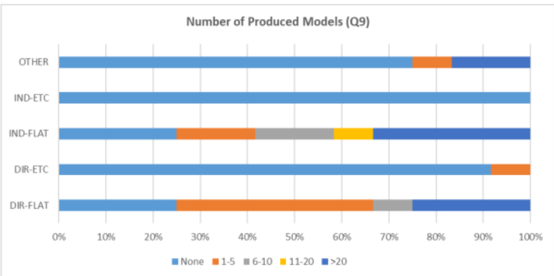


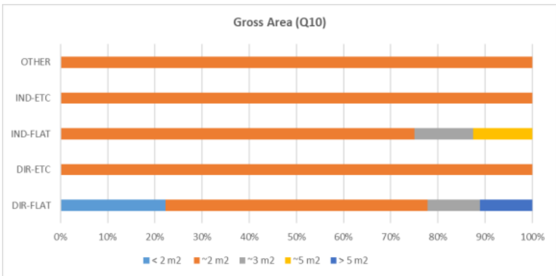


(a) *(b)*

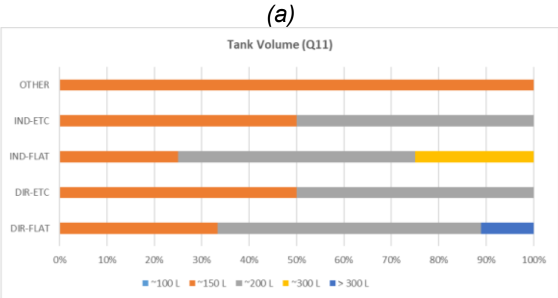
Figure 52. Produced Components (Q7-8).

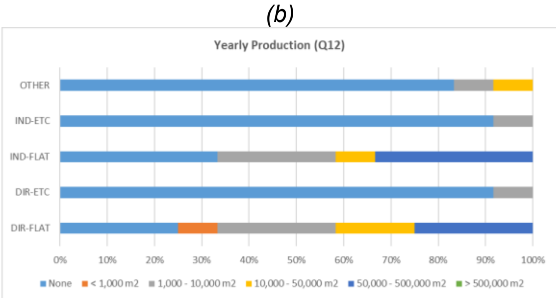
Produced number of models, gross area, tank volume and yearly production (Q9-12): Figure 53 (a) – (d) show production data. The most commonly produced models are direct and indirect systems with flat-plate collectors (DIR-FLAT, IND-FLAT), see Figure 53 (a), other collector technologies do not play a major role as it is the case for forced circulation systems in Europe. Most common system sizes are 2 m^2 gross collector area and 200L tank volume (Figure 53 (c)). Most manufacturers have a substantial yearly production, with 1-10,000 m² produced with regards to evacuated tube collectors. Regarding direct and indirect flat plate collector systems produced collector areas reach up to 500,000 m² per year (Figure 53 (d)), making use of economies of scale to decrease costs.





(a) *(b)*





(c) *(d)*

Figure 53. Produced number of models (a), gross area (b), tank volume (c) and yearly production (d) (Q9-12).

Target markets and costs (Q13 – Q17): As shown in Figure 54, most European manufacturers produce for the European market, followed by MENA and Latin America. Larger thermosyphon markets in China and Asia ex-China are not in the focus of European manufacturers, probably due to strong local competition. This is also confirmed by Table 13, showing that the biggest markets are mostly located within Europe.

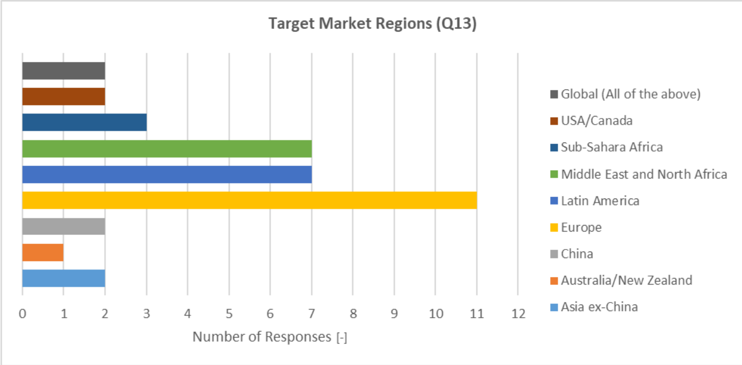


Figure 54. Target Market Regions (Q13).

Table 13. Biggest markets for European Manufacturers

The 1st biggest markets (10)	Greece (4) Portugal (2) Cyprus (1) France (1) Italy (1) Netherlands (1)
The 2nd biggest markets (9)	Italy (3) France (2) Egypt (1) Israel (1) Morocco (1) Puerto Rico (1)
The 3rd biggest markets (8)	Morocco (2) Cyprus (1) Jamaica (1) Portugal (1) Spain (1) Tanzania (1) UAE (1)

Final Customer Prices (Q17): Figure 55 shows typical final customer prices in Europe. System prices mainly range between $500-1,000 USD (34%) and $1,000-1,500 USD (42%).

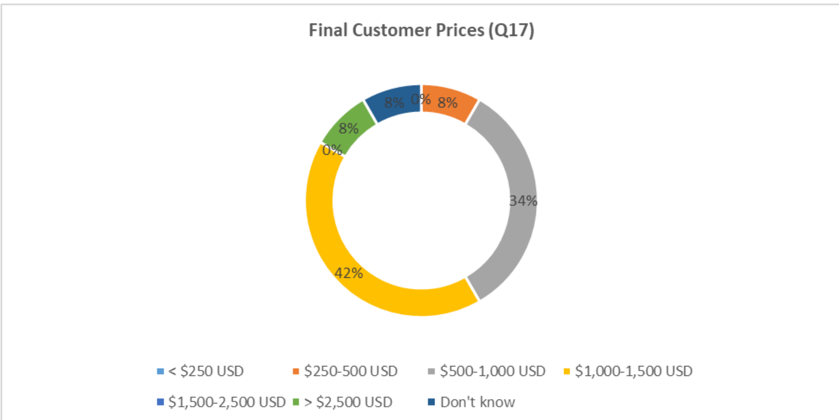
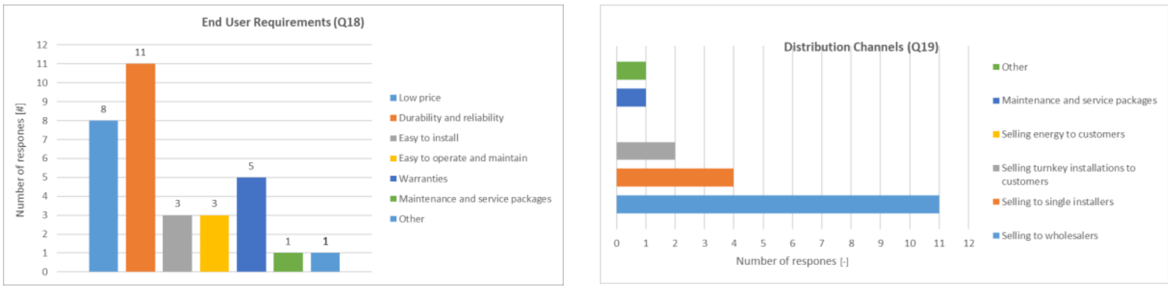


Figure 55. Final Customer Prices (Q17).

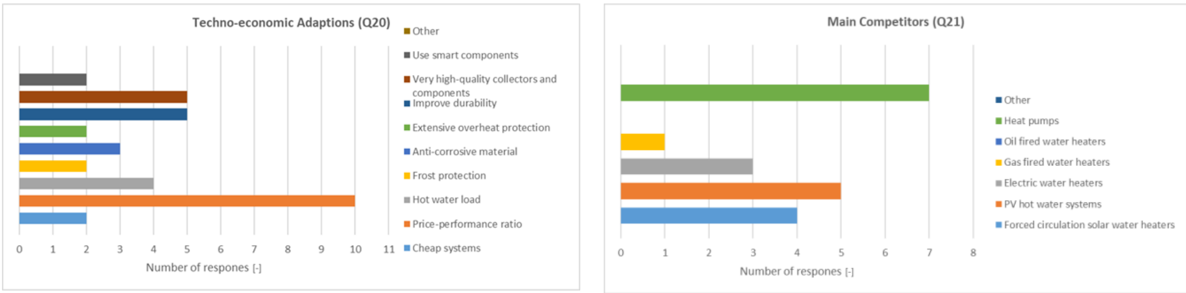
Product Placement/ Business Models (Q18 – Q21): The main end user requirements are durability and reliability combined with low prices (Figure 56 (a)). Most manufacturers sell to wholesalers, additional business models like selling turnkey installations only play a minor role (Figure 56 (b)).



(a) *(b)*

Figure 56. End user requirements and distribution channels (Q18-19).

Techno-economic adaptations and main competitors (Q20-21): As shown in Figure 57 (a), the major adaptions that European manufacturers make are optimizing the price-performance ratio of their products. Second important is to improve durability and use very high-quality collectors and components. Main competitors are heat pumps and PV hot water systems as well as forced circulation solar water heater and to some extent electrical water heaters. Oil and gas fired water heaters play a minor role (Figure 57 (b)).



(a) *(b)*

Figure 57. Techno-economic adaptations and main competitors (Q20-21).

Innovation and Market outlook (Q22 – Q29): As shown in Figure 58, the most important improvement task is price reduction (score 3.8), followed by enhancing subsidies (score 4), increase marketing activities (score 5), with innovative business models being the least important (score 7). This can be interpreted that the market is mature from a technical and economic perspective and that the main drivers are cost-related.

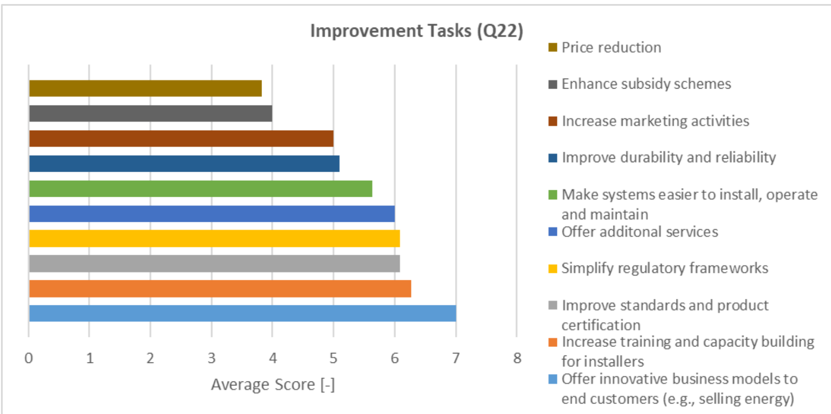
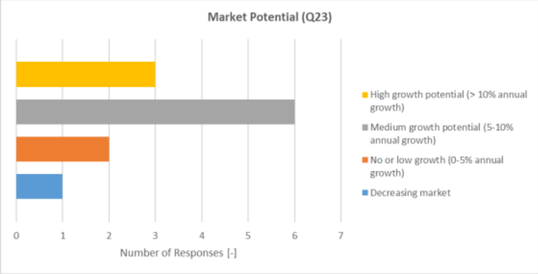
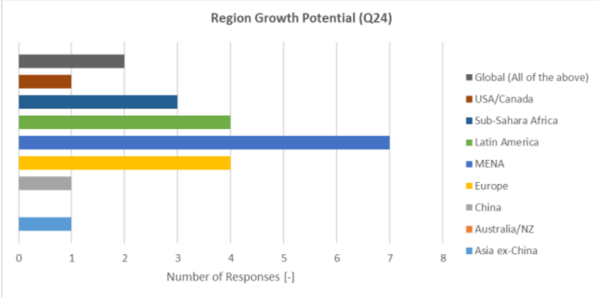


Figure 58. Improvement tasks (Q22).

Figure 59 (a) shows that most companies expect a medium growth potential (5-10% annual growth), focused on the existing market regions with an exceptionally high potential in the MENA region (Figure 59 (b)).



(a)



(b)

Figure 59. Market potential and region growth potential (Q23-24).

Discussion, conclusion and outlook

- Noticeable results from the survey are the growth potentials seen by the companies, with 75% of the company's estimating medium to high growth potentials with the highest growth potentials seen in the MENA region, in Europe and Latin America.
- Price reduction, enhanced subsidies and increased marketing activities are seen the most important measures to increase the market chances of thermosyphon systems.
- There is only little innovation seen in the thermosyphon markets in Europe. However, some innovation can be seen with regards to monitoring, visualisation and control of temperatures.
- Bigger companies are able to use economies of scale to achieve price reduction.

From the survey, the following conclusions can be drawn.

- **Markets:** A noticeable solar thermosyphon market exists mainly in the Mediterranean countries Greece, Cyprus, Spain, France and Turkey with a couple of manufacturers producing for the local European markets as well as export markets, but also in the Netherlands a thermosiphon market exists. Direct flat plate and indirect flat plate collector systems are the preferred systems produced. Besides thermosiphon systems the survey showed that the manufacturers mainly produce forced circulation solar thermal systems, fewer producing electrical heaters, heat pumps and oil heaters. PV hot water systems currently play a minor role.
- **Exports:** Export countries for European manufacturers are the MENA countries Israel, Morocco, Egypt and United Arab Emirates as well as Latin American countries like Jamaica and Puerto Rico, with a medium growth potential (5-10% growth) seen in the MENA region.
- **Necessary improvements:** For end users, durability and reliability of the product play a major role, followed by low price and warranties. With regards to techno-economic adaptations the price-performance-ratio is seen as essential from manufacturers perspective. Price reduction is seen as the most important improvement task, followed by enhanced subsidy schemes and increased marketing activities.

Future developments could include smart control to make the use of thermosiphon systems even more convenient for customers. At the same time increased marketing activities to raise awareness in countries without strong home markets and high price-performance ratio together with high durability and reliability are essential to use the full potential of thermosiphon systems in the Mediterranean regions.

Literature and resources

[E1] https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2024.pdf

[E2] https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2020.pdf

[E3] European Commission - Energy Efficient Products - Water Heaters (online accessed 27-10-2024 https://energy-efficient-products.ec.europa.eu/product-list/water-heaters_en)

[E4] SOLARGIS (accessed online 27/10/2024 https://solargis.com/resources/free-maps-and-gis-data?locality=europe)

[E5] European Energy Agency (accessed online 27-10-2024 https://www.eea.europa.eu/en/analysis/maps-and-charts/climate?activeTab=a7caf3b5-7254-4a24-8919-693d4115158b)

[E6] CEN Keymark (accessed online 27-10-2024 https://keymark.eu/en/products/solar-thermal-products)

[E7] Solar Heating Initiative For CO2 – free heat (accessed online 27-10-2024)

[E8] EU Energy Efficiency Directive (DIRECTIVE (EU) 2023/1791 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast), accessed online 27/10/2024 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

[E9] EU Ecodesign Directive (Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, accessed online 27/10/2024 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1781&qid=1730068028409

[E10] Renewable energy in Greece, https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/greece

[E11] The solar thermal market in Greece—review and perspectives, https://www.sciencedirect.com/science/article/abs/pii/S1364032103000649

[E12] EBHE Hellenic Federation of Solar Industries https://ebhe.gr/home-2-2/

[E13] Greek factories: a new collector every 72 seconds https://solarthermalworld.org/news/greek-factories-a-new-collector-every-72-seconds/

3.8 Latin America and the Caribbean (Region #4)

Thermosyphon market and regional boundary conditions

Introduction: Before describing the use of solar thermal energy in Latin America, it is important to underline some specific facts about the region.

Latin America and the Caribbean (hereafter "LAC") is composed of 48 separate administrative units including 33 countries and 15 dependent territories (U.K., Netherlands, U.S.A, and France) with various governance and political systems. The region spans approximately 20 million square kilometers (km^2), about 15% of the global land area. It covers two hemispheres, three oceans, and a multitude of ecosystems.

The region's total population is around 660 million people, out of which two countries, Mexico and Brazil, constitute 52% of the total population. If Colombia, Argentina, Peru, and Venezuela are added, then those 6 countries add up to 74% of the region's total population. The population distribution can be seen in Figure 60 [LAC1].

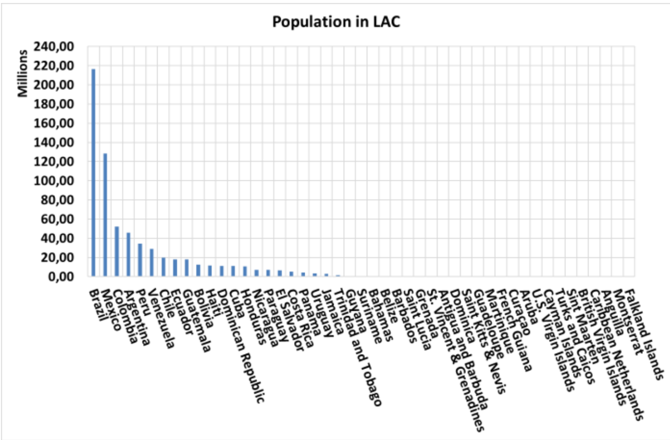


Figure 60. Population distribution in LAC. Source: [LAC1]

Main applications: The main application scenarios for thermosyphon systems are household use for single houses in urban areas. The preferred technology across LAC is direct. Direct flat plate collector thermosyphon systems (DIR-FLAT) are predominant. Direct systems with evacuated tube collectors (DIR-ETC) are predominantly used in colder and southern regions of LAC, where there are freezing problems. Indirect systems with flat plate collectors (IND-PLAT) are predominantly used in multiple-storey residential buildings in towns and cities and/or industries.

Market environment and challenges – overview: The asymmetric population distribution comes with a huge difference in the access to sanitary infrastructure such as water and sewage across the countries. This fact, associated with mild to high temperatures makes hot water a premium asset. Some countries do not use hot water because of the beneficial climate conditions or low income. In the Caribbean, the use of hot water is about 50%, meaning that only 50% of households have access to hot water heating infrastructure. In the southern part of LAC, the percentage rises to almost 100%. The colder the region, the more hot water is used. Only cold subregions use space heating systems of some kind. The rest of Latin America uses heat either for cooking or for hot water given that there is no need for space heating, but rather for space cooling. Figure 61 shows the use of hot water and the distribution of water heating technologies in some countries of LAC according to the report by Fundación Bariloche, 2018 [LAC2].

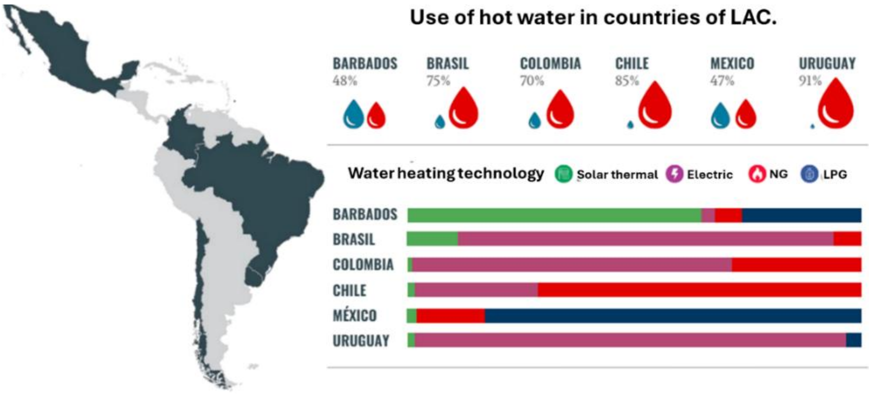


Figure 61. Use of hot water and water heating technologies in several LAC countries. Numbers show share of households with access to hot water. Source: [LAC2]

The main energy resources used to heat water are gas (natural or LPG), electricity, or solar thermal, depending on the availability of resources of that country. For example, the use of natural gas for water heating is popular in Argentina, but not so much in Uruguay. The options for the Caribbean are either LPG or electricity given their geographical situation consisting of islands. On the other hand, natural gas is the option for those countries that either have gas wells or can buy from these countries. Wood is seldomly deployed for water heating, mostly restricted to rural or indigenous communities. In Brazil, for example, electric water heaters are predominant, even though having gas wells. Overall, the energy resources used for obtaining hot water varies from one country of the region to another.

As stated, LAC is a very diverse region, with lots of asymmetries in population, economics, infrastructure, and environment. Nevertheless, all countries share one common feature: solar hot water use is still to be developed. Successful solar markets such as Brazil and Mexico have relied on economies of scale, incentives for social housing, financial mechanisms, and quality infrastructure to promote the technology. In contrast, the smaller but very successful market of Barbados has relied on word-of-mouth promotion, reaching the record of the most solar collector area installed per capita. Market developments, as well as other issues, are depending on the boundary conditions. The diversity of the region needs different promotion strategies adapted to attend to the local needs. What worked for Brazil, will not work for Uruguay, Colombia, or St. Lucia, given the huge differences among them.

In the LAC region, there are 40-50 manufacturers located in Brazil, 14-15 in Mexico, 4-5 in Argentina, and 2 manufacturers in Barbados. The other countries only import.

Market environment and challenges – country specifics: In the next paragraphs, specific market data will be presented for Brazil, Mexico, Argentina, Peru, Colombia, Uruguay, Bolivia, and Venezuela. Data referring to Brazil and Mexico was collected from manufacturers by IEA SHC Task 69 experts from LAC and has a greater level detail. Data of the other countries was collected using import statistics since only little or no manufacturers operate in these countries. According to the experience of manufacturers in Brazil, Mexico and Argentina alsom 80-90% are thermosiphon systems, 10-15% are forced systems, including swimming pool heating [LAC3].

Brazil is the third largest market in the world in terms of solar thermal collectors installed in 2023 with a newly installed capacity of 1,83 million m^2 collector area (1,281 MW$_{th}$) [ref L1]. In total, Brazil has an installed capacity of 24.5 million m^2 (17 GWth), but this figure could be significantly higher since the installed area represents only 5% of the potential area that could be installed in the country.

The biggest local problem in Brazil is electric showers, responsible for more than 90% of the market, which leads to the overloading of the electricity grid. Local governments have become aware of this problem, considering that solar heaters can perform this function more effectively. More recently, solar photovoltaic systems are being promoted as the sole solution to this issue, and what is being discussed is the inclusion of hybrid thermal solar systems and photovoltaic systems.

In Brazil, the general distribution of market segments are as follows: The residential sector accounts for 84%, followed by commercial and services at 12%, industrial at 3%, and social projects with only 1%. Except for Mexico, the distribution of market segments is very similar across LAC given the similarities in climate and hot water infrastructure [LAC3].

In Mexico, according to the "Iniciativa Calor Solar", the residential sector accounts for about 14% of the total energy consumption in Mexico. Almost 72% of the energy consumed in the residential sector is for low-temperature heat used in cooking (73%) and sanitary hot water (27%) being (756 petajoules per year, data from 2016).

According to data from FAMERAC (Mexican Solar Thermal Manufacturers Association), the solar thermal cumulated capacity in operation in Mexico by the end of 2023 was 4.5 GW_{th} (6.4 million m^2 collector area) [LAC4]. In 2023, a total of 442,930 m^2 were installed, from which 59.2% (270,330 m^2) were installed in the residential sector, 28% (118,270m^2) for swimming pool heating, 6.5% (27,300 m^2) in the industrial sector, 5.8% (24,350 m^2) in the commercial sector and 0.6% (2,680 m^2) in other sectors.

As stated above, data for the remaining countries for 2023 has been extracted from imports statistics, shown in Table 14. The total collector area was calculated assuming that each equipment/unit is equivalent to 2 m^2.

Table 14. Imports based on the MERCOSUR Common Nomenclature (MCN).

Country	Costs (USD)$^{(1)}$	Units	Collector area (m^2)$^{(3)}$
Argentina	2,067,204	12,830	25,660
Bolivia	75,642	739	1,478
Chile	4,043,458	11,632	23,264
Colombia	136,218	1,031	2,062
Paraguay	8,762	188	376
Peru	2,494,239	20,000	40,000
Venezuela	14,920$^{(2)}$	N/A	N/A
Uruguay	127,512	1,529	3,058
Total 2023	**4,909,577**	**36,317**	**72,634**

Notes: (1) Except for Venezuela, costs refer to FOB (Fee on Bord) price, i.e. price paid to the exporter for the product when the goods pass the ships rail at the named port of shipment; (2) CIF (Cost, Insurance and Freight) price, including transport to port of destination; (3) Assuming a collector area of 2 m^2/unit.

The following database requests were used to retrieve costs (USD) and units:

- *Argentina: Position 8419.19.10 and 8419.12.00 filtered by keyword "heater" and "solar". The rest were excluded.*
- *Bolivia: Position 8419.12.00. There was no information in the description.*
- *Colombia: Position 8419.12.00, 8419.90.10, and 8419.89.10 filtered by keywords "heater" and "solar". The rest were excluded.*
- *Paraguay: Position 8419.12.00, 8419.90.10, and 8419.19.00 filtered by keyword "heater" and "solar". The rest were excluded.*
- *Peru: Position 8419.19.00; 8419.90.00 and 8419.10.00 filtered by keyword "heater" and "solar". Output of data base request was costs (USD) FOB 2,494,239.45 and 60,320 units respectively. In the statistics, the units were all mixed between kits, spare parts, and equipment. More realistic is to assume a price of ~150 USD FOB per equipment, which gives ~20,000 units or equipment listed in the table.*
- *Venezuela: Position 8419.19.10. filtered by keywords "heater" and "solar". Only costs (USD) CIF 14,920 were available. The rest were excluded.*
- *Uruguay: Position 8419.12.00 filtered by keyword "heater" and "solar". The rest were excluded.*

Hot water load: Regarding technology needs, given the abundant solar resources of the region, a high-efficiency solar collector is not strictly needed, except for the southern part of the region in Argentina and Chile. Most basic solar collectors will suffice in terms of efficiency to obtain hot water. Furthermore, in countries with no water hardness, a direct system will suffice. This means a huge opportunity to bring down the costs of the technology.

A different case is that of solar heat for industrial processes, where depending on the case, a huge requirement of heat is needed.

Environmental conditions: LAC has a wide variety of climatic conditions, ranging from tropical to temperate, and arid. Abundant sunshine and solar resources in most of the region is a motivating fact to foster the development of the solar thermal market. Figure 62 shows the irradiation for LAC.

Figure 62. Latin America and Caribbean Horizontal Irradiation Map. Source from © 2017 The World Bank, Solar resource data: Solargis.

Subsidy schemes, promotion schemes and government policies: In Brazil, solar water heaters are a mature technology, having been used for more than 40 years. The following policies and incentives are currently in use:

- Exemption from federal taxes and reduction of state taxes for the commercialization of solar thermal systems
- IPTU verde: Reduction of property taxes in the urban territory at the municipal level. There are already more than 60 cities that implemented this program, in which the use of solar heaters is one of the main highlights for obtaining progressive discounts. Municipalities have the autonomy to determine their rules according to the needs of each city [LAC5].
- Lei solar São Paulo: Mandatory use of solar heaters in high-rise buildings with three or more bathrooms [LAC6].

Policy projects that are currently being approved by the Brazilian Congress:

- PL 3492/2023 - PRONASOL: A bill to reduce the use of fossil fuels in housing, it provides for various actions such as credit lines to facilitate access to technology for end consumers, funds from electricity concessionaires for innovation and technology programs.
- Minha casa, minha vida: The first version of this program, established in 2007, aimed at the low-income population, where the houses built by the government had to be delivered with solar heaters already installed. Since 2023, Minha Casa Minha Vida 2 is underway, and Congress is still discussing a project that includes solar heaters with photovoltaic panels for 2 million social houses expected to be delivered.

In Mexico at the federal level, the only program that includes incentives to acquire a solar water heater is “Hipoteca Verde” (green mortgage) from the INFONAVIT which grants an additional loan to acquire eco-technologies such as solar water heaters, among many others.

At the state level, there are multiple programs for instance Solar City in Mexico City, and other similar programs in the states of Guanajuato, Hidalgo, Puebla, etc. Such programs provide technical support and/or grants for the acquisition of solar water heaters in the residential, commercial, or industrial sectors.

In Argentina, the use of solar thermal systems in social housing is mandatory at a national level provided it is certified according to specific national procedures. Furthermore, in national government social houses it is mandatory to use local manufactured technology with the exception of the Patagonia region, where the use of solar collectors requires selective surface to be used all year round and that technology is not locally manufactured.

Nevertheless, each province may opt to use imported system and comply with provincial rather than national laws. So, there is a coexistence of imported with locally produced goods that are included in social housing,

In Barbados, the following incentives for consumption and manufacturing, created from pilot experiences, were added over the years and are still in force today:

- Tax Incentives: In 1974, a 30% tax was imposed on electric and gas heaters, increasing their prices, to make SWHs (CSA - Calentadores de agua solares) prices more competitive, and a tax exemption was also introduced for the import of inputs for the local production of SWHs that helped reduce product cost by 20%.
- Mandatory SWHs in public constructions: In 1977, the obligation to install SWHs in new public constructions was imposed.
- Tax benefits for homeowners (Homeowner Tax Benefit): From 1980 to 1992, another benefit was installed where the total cost of installing a SWHs was tax deductible up to a maximum of U$1,750. This incentive was stopped in 1992 as part of a process of government restructuring and economic recession.
- Homeowner Tax Benefit Improved: In 1996 the benefit was reinstated with some modifications. The homeowner can deduct up to $1,750 in annual taxes on any home improvements, repairs, renovations and energy efficiency measures and SWHs installation.

In Chile, from 2015 to 2020, Law No. 20.365 and later Law No. 20.897 established a tax benefit for those construction companies that implemented solar thermal energy in their new buildings. This benefit was not further implemented. Since 2011 until nowadays, social housing developed by the housing ministry (MINVU) includes a mandatory use of solar thermal systems and there is also a subsidy to integrate solar thermal in reconstruction of house after a natural catastrophe such as an earthquake.

Colombia has Law No. 1.715 which promotes the use of renewable energy and energy efficiency. Solar thermal is not included within the benefits for renewable energy. Instead, it is included in the energy efficiency benefits, replacing gas or electric water heaters.

The law defines three incentives to incorporate renewables and energy efficiency:

- Income tax deduction: The investment in solar thermal is tax deductible up to 50% of the cost.
- Imported SWHs are exempt of VAT and of import fees. (This needs clearance and certification from the energy agency).
- The cost of SWH can be used for accelerated depreciation.

To access to the benefits of Law 1715 it is only necessary to present adequate documents that demonstrate the quality of the solar thermal equipment, as well as project design and document that describes the goal for which it will be used.

In Uruguay, the following benefits were established

- In September 2009, Law No. 18,585 "Solar Thermal Energy" was approved, which requires the installation of solar thermal energy systems in new projects and comprehensive renovations in the sectors with the highest consumption of hot water, i.e., health centers, hotels, clubs, heated swimming pools and public organizations (at least 50% of the energy to heat the water in these facilities must come from the sun). This law was regulated through decree 451/011 and later modified by decree 325/12. Law No. 18,585 and its regulatory decrees establish an exemption from VAT, customs taxes and specific internal tax (IMESI) for the manufacturers of solar thermal collectors with a minimum national component of 35%, covering direct labour components, inputs, and utilities. To obtain the benefit, they must present the plans and have the national manufacturing certificate to the National Directorate of Industry of the Ministry of Energy and Mining (MIEM).
- In addition to this, the requirements for sanitary and construction pre-installations in social housing has been defined as mandatory. In the resolution of the Ministry of Housing, Territorial Planning and Environment (MVOTMA) that regulates the promotion of social housing, it establishes in article 8 "Pre-installation for water heating through solar energy" the following: "The projects must provide for the sanitary and construction facilities necessary so that homes can receive, in the future, equipment for heating water using solar energy". This last component is strongly supported in small pilot projects developed previously.
- The "Solar Plan" (Decree 50/2012) is a program to facilitate access to a solar thermal energy system at the residential level. The solar plan targets only the solar thermal system. It does not include the acquisition of an efficient support system, but rather the user continues using the pre-existing support system, which could be a water heater, a hot water tank or a boiler. In this way, the real savings of the solar thermal system will depend on the type of support system on which it is coupled.

The National Energy Directorate (DNE) coordinated the Solar Plan with all public and private institutions that were considered able to contribute to it. The "Solar Plan" had financing from the Mortgage Bank of Uruguay (BHU) in up to 60 instalments (5 years) for the purchase of solar thermal systems. This financing time allows the fee paid by the user to be of a value similar to the electricity/gas savings obtained by the use of the solar thermal equipment. For the first 2,000 users who acquire a solar thermal system within the framework of the solar plan, the Electrical Energy Company of Uruguay (UTE) provides an efficiency bonus to each family of 700 pesos per month (approximately U$25) for 24 months. The user can use this bonus as credit when paying their electricity bill. The equipment market in the solar plan requires certification and additionally, installations can only be carried out by registered professionals (RTI: technical installation managers, translated from Spanish as Responsible Técnico Instalación). As an additional requirement for the equipment purchased, each facility must have insurance issued by the State Insurance Bank (BSE) or any other insurer for 5 years against theft, weather (hail, winds, etc.), and vandalism. and against third parties for 50,000 U$.

Market survey

Overview: Survey results of 12 manufacturers and installers of thermosyphon systems (Brazil, Mexico, Argentina, Panama, and Paraguay and one installer from Aruba) were received and evaluated as shown in Figure 63.

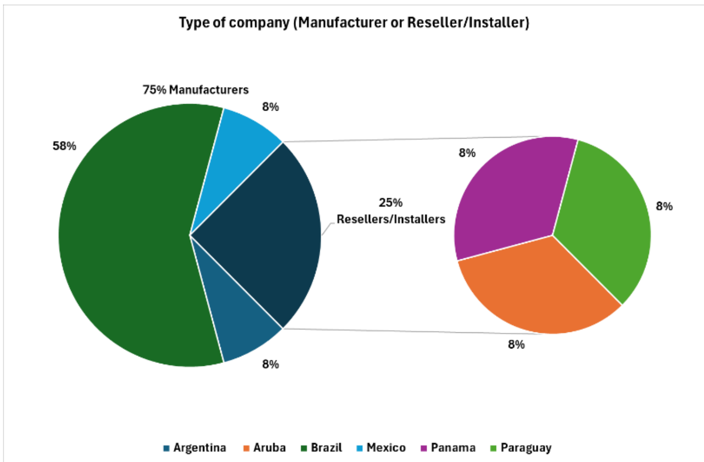


Figure 63. Distribution of manufacturers and resellers among the answers of the questionnaire.

Production data (Q7 – Q12): Solar collectors, storage tanks, mounting systems, and pipes/fittings/valves are the components of thermosyphon systems that are produced or sold by the companies who answered the survey as shown in Figure 64.

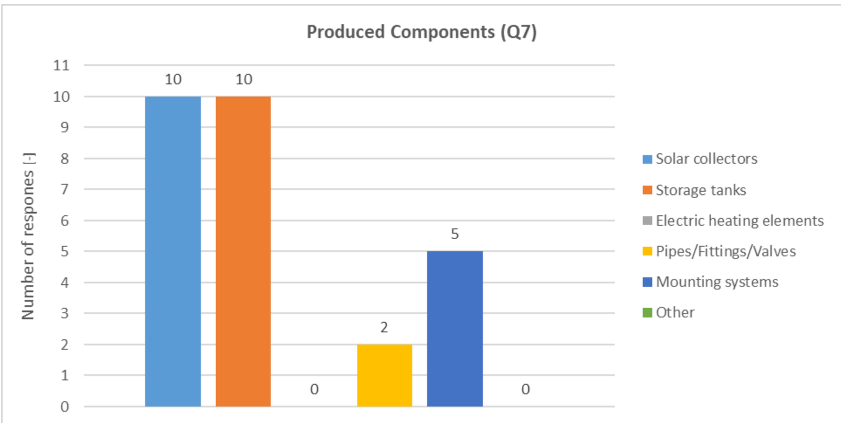


Figure 64. Produced components of thermosyphon systems (Q7).

Besides thermosyphon systems, forced circulation solar water heaters are produced by almost all companies that answered the questionnaire. Industries from LAC also produce or sell electric and gas-fired heaters and heat pumps, only one company produces air solar collectors, self-contained solar and flat plate collectors, as shown in Figure 65.

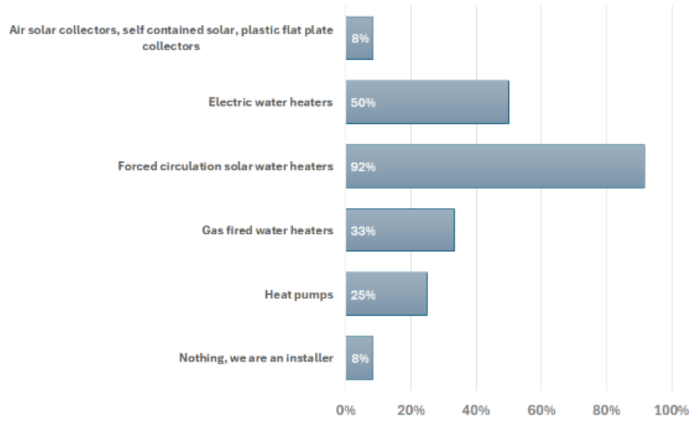


Figure 65. Solar hot water systems or components produced or sold besides thermosyphon systems (Q8).

As shown in Figure 66, the manufacturers' responses on the produced models make clear that the most commonly produced models are systems with flat plate collectors (DIR-FLAT) followed by other systems like unglazed or PVT and indirect systems equipped with evacuated tube collectors (IND-ETC). However, a more detailed view (Q9-10) shows that there are not only DIR-FLAT, but also IND-FLAT collectors produced in Latin American countries (Figure 67). As it was not possible to again address the companies within this research it would be essential for any follow up research to focus on a common understanding with regards to collector types and models to avoid misinterpretation.

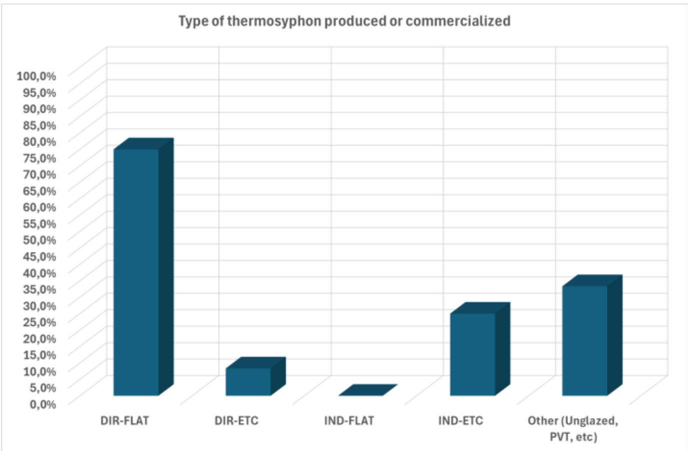


Figure 66. Production data with most commonly produced models (Q8).

According to Figure 67 common approximate areas are <2 m2 and ≈2 m2 and tank volumes are 200L and 300L. DIR-FLAT and IND-FLAT are the system types with the highest production numbers according to the questionnaire.

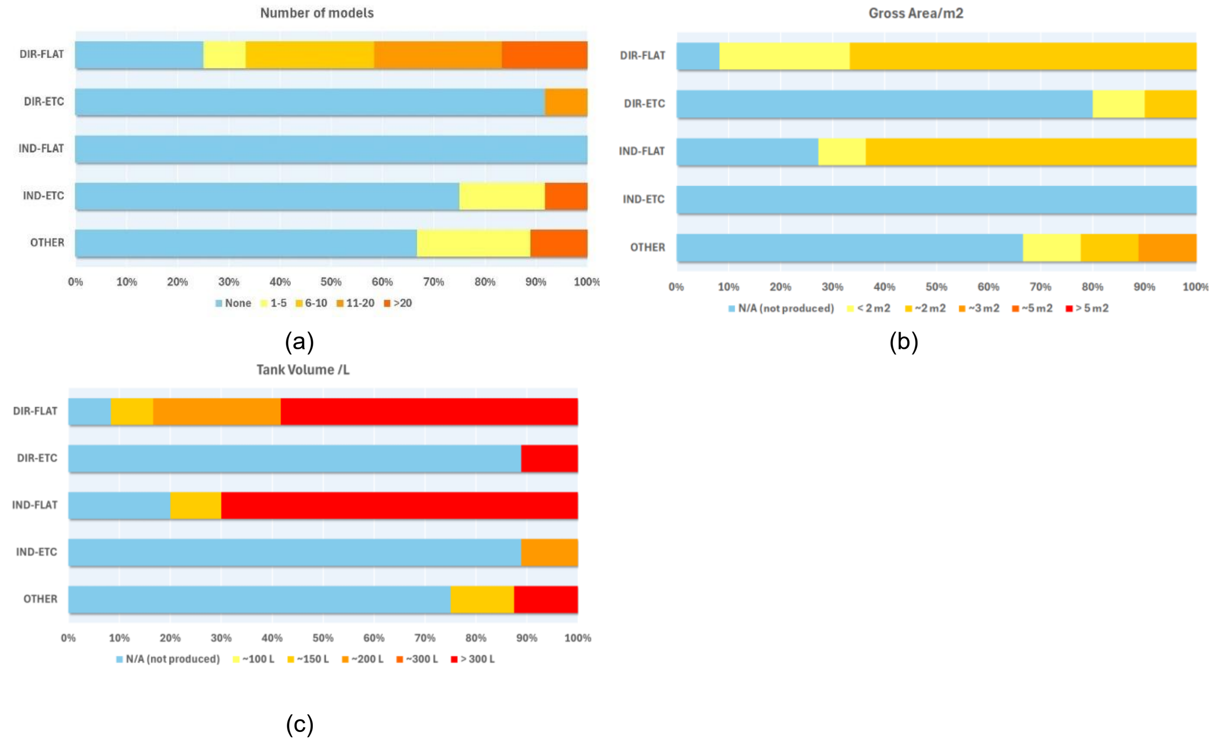


Figure 67. Production data with (a) number of produced models, (b) collector gross area and (c) tank volume (Q9-Q11).

Figure 68 shows the distribution of technology produced or sold within each range of yearly gross area: 55% produce or sell between 10,000 and 50,000 m² per year, being 50% of the DIR-FLAT type and 25% of the IND-FLAT type. On the other hand, 32% produce or sell between 1,000 and 10,000 m² per year, with 43% of DIR-FLAT and 43% of IND-FLAT.

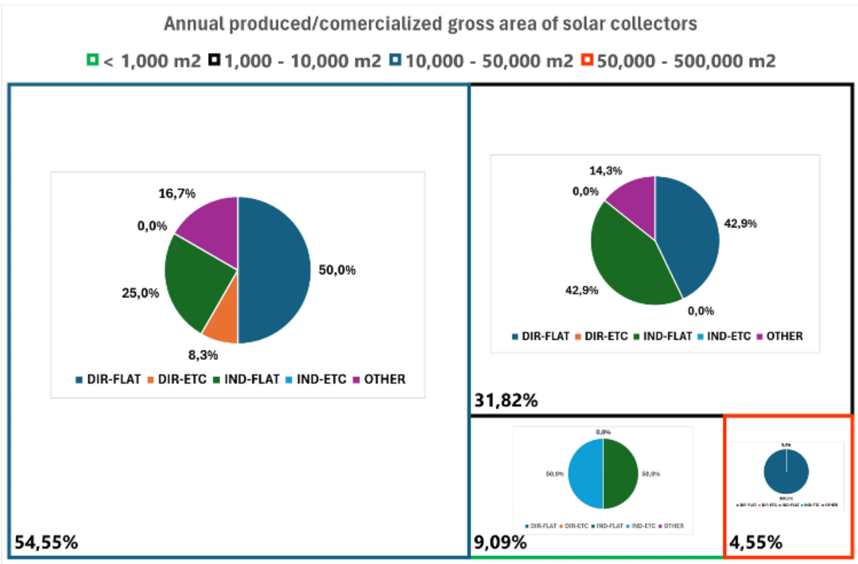


Figure 68. Annually produced or commercialized area of solar collectors by type (Q12).

Target markets and costs (Q13 – Q17): The target market region for all manufacturers is Latin America. All manufacturers are focused to their own country regarding sales, and only one Brazilian company exports to a second market (Mexico).

The typical final customer prices (including shipping, installation and taxes) for a standard-sized thermosyphon system (with a 150L tank and 2 m² collector) are distributed as shown in Figure 69.

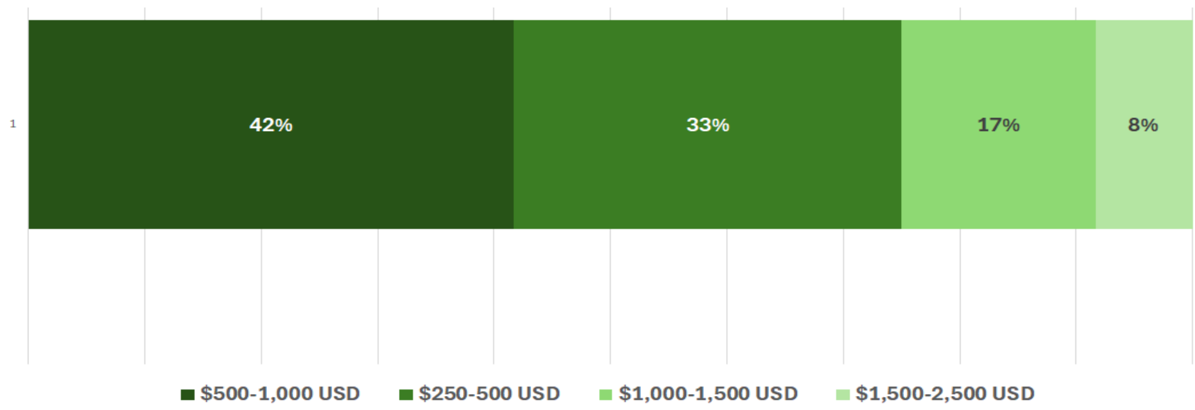


Figure 69. Typical final customer prices for a standard-sized thermosyphon system in the main market (Q17).

The most important end-user requirements are durability and reliability (100%), followed by low price (58%) and warranties (50%) as shown in Figure 70.

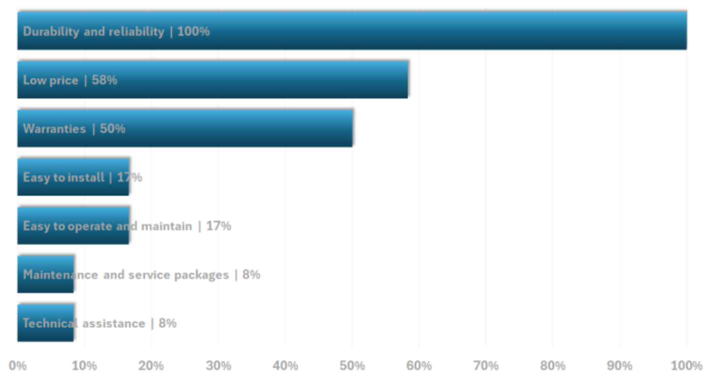


Figure 70. Most important end-user requirements in target market(s) (Q18).

Figure 71 shows the main distribution channels and business models used for different target markets. Most common are selling to wholesalers and selling turnkey installations with the same percentage of 58%, followed by selling to single installers (50%) and selling energy to customers (42%)

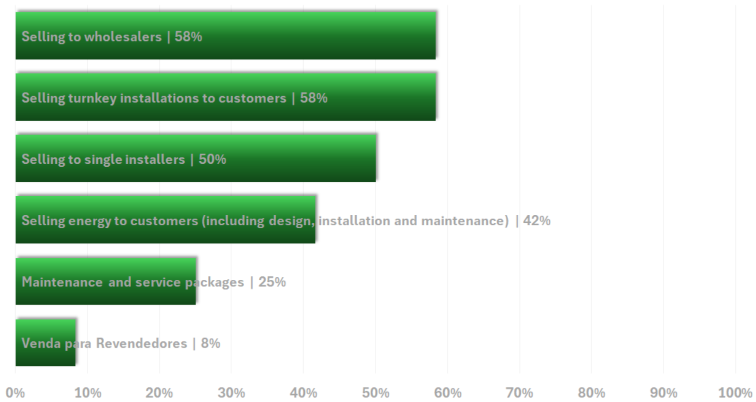


Figure 71. Distribution channels and business models used in different target market(s) (Q19).

Figure 72 shows the main techno-economic adaptions made to tailor products successfully to the target markets. The most important ones are optimizing the price-performance ratio and using anticorrosive material due to low water quality, both with 67% of the answers.

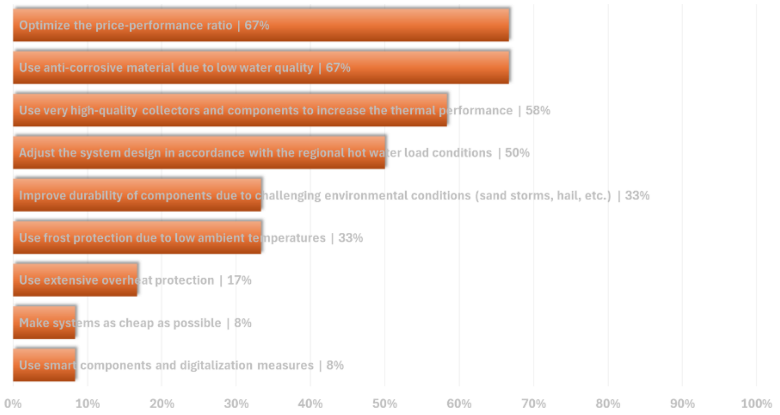


Figure 72. Techno-economic adaptions made to tailor products successfully to the target market(s) (Q20).

The main competitors and alternative technical solutions to provide hot water in target markets are gas-fired heaters, electric water heaters, and PV hot water systems as shown in Figure 73.

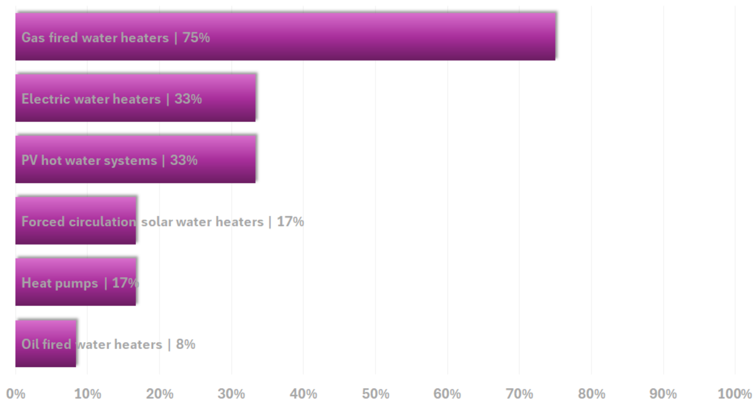


Figure 73. Competitors and alternative technical solutions to provide hot water in target market(s) (Q21).

Innovation and Market Outlook (Q22 – Q29): The most urgent tasks to make systems more competitive and reduce market barriers are price reduction, increased training and capacity building for installers and making systems easier to install, operate, and maintain, see Table 15.

Table 15. Tasks to make systems more competitive and reduce market barriers (Q20).

The 1st important	Price reduction (to achieve competitive energy prices) Increase training and capacity building for installers Make systems easier to install, operate and maintain
The 2nd important	Increase marketing activities (e.g., inform customers about energy savings and carbon reduction potential) Improve durability and reliability
The 3rd important	Offer innovative business models to end customers (e.g., selling energy) Simplify regulatory frameworks (e.g., building regulations) Improve standards and product certification
The 4th important	Offer additonal services (warranties, maintenance, etc.) to end customers Enhance subsidy schemes

For thermosyphon systems, the expectation of the future market is divided in three main categories. On the one hand, 58% of the manufacturers expect medium or high growth potential (with 25% expecting high growth), and 42% expect no or low growth potential, as shown in Figure 74.

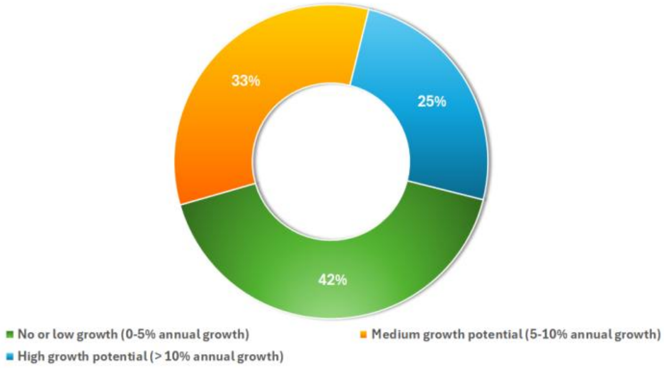


Figure 74. Market expectations (Q23).

As shown in Figure 75, the market regions with the highest growth potential are all located in Latin America and mostly overlap with the location of production. Only one company sees the highest growth potential outside the country of production.

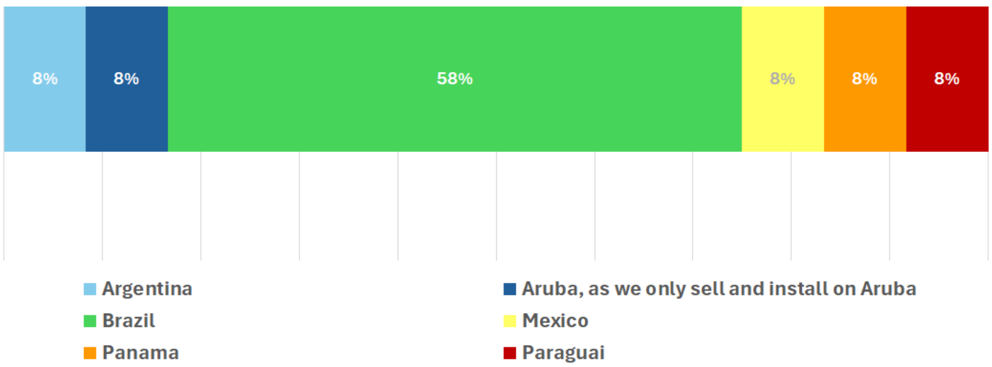


Figure 75. Market regions where manufacturers see most growth potential (Q24).

In response to requirements of recently introduced new technologies, the two main answers are product certification (75%) and testing according to standards (50%) as shown in Figure 76.

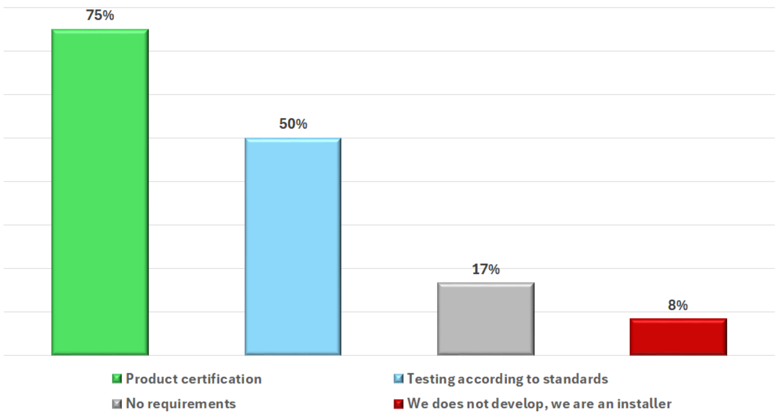


Figure 76. Requirement for development (Q25).

Discussion, conclusion and outlook

According to the market research and responses to the questionnaire, the following insights are most important to highlight:

- For most of the LAC region, countries have great development potential due to their excellent climatic conditions for installing solar thermosyphon heating systems but have major socio-economic obstacles to broader dissemination of the technology.
- Few LAC countries have local production (Mexico, Brazil, Barbados and Argentina), and most of them import products. Currently, manufacturers seem to predominantly focus on domestic marketing for their products. Therefore, there is an interesting development path both for national industries and trading of produced systems and raw materials across country borders and opening up markets with regards to international agreements.
- As far as the end customer is concerned, the most important requirements for purchasing thermosyphon systems are price, reliability and durability.
- In terms of competition, gas heaters are seen as the main competitor, even though most of the answered were from Brazil, where electric showers (instantaneous, without the use of accumulators) have a market share of 90%. Heat pumps, PVT and PV2Heat systems are very incipient in LAC, but in upcoming years, these technologies can be a very strong competitor to thermosyphon systems.
- Technological developments with regards to hybrid PVT, heat pump and PV2Heat systems could even boost the solar thermal market. Technological innovations are needed and together with local manufacturing and development, the solar thermal sector could further evolve, especially if taking the residential and industrial sector into consideration.
- To reduce the barriers of implementation, price is pointed out as one of the main factors, as well as ease of use and workforce training.
- The market expectations for thermosyphon systems are mixed. On the one hand side, 58% of the manufacturers expect medium or high growth potential, but 42% expect no or low growth potential. The solar thermal potential across the region is huge. There is a need to reach governments and address the need for sustainable heating solutions in the region, either to heat water or to supply space heating, cooling and industrial processes. It is possible to assume that when the market reaches 0,5 m^2 per capita the market is mostly saturated. Very few countries in the world have reached this number, but this situation is equivalent to taking a view out of the window and see one or two solar collectors on every roof. Even the large markets in Brazil and Mexico are both below 0,1 m^2/per capita, with only Barbados reaching 0,6 m^2/per capita. So, there is still a large way to go in LAC.
- As opposed to electricity, the use of heat is not directly billed as such. In electricity, a bill is directly correlated with how much electric energy we use. Most people are aware of how much electricity they use in a house or in a commerce. Heat is not billed directly, but rather a bill for the fuel or electricity used to heat the water or fluid is received. So almost nobody becomes aware of the heat needed. There are very few cases where user can mention a specific amount of hot water or an industry knows how much energy in the form of heat is required for a specific process. The fact that heat is not directly correlated to a cost causes a misperception on energy usage, especially when public policies are designed to support PV systems but not solar thermal systems. All in all, a distinct message to educate governments and end users on heat need and solar thermal solutions needs to be elaborated to foster market growth.

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3.9 Middle East and North Africa (Region #5)

Thermosyphon market and regional boundary conditions

Introduction: As there were no regional experts contributing to Subtask A and no companies from the MENA region who filled in the survey, this chapter comprises a desktop research and a summary of the contribution Khalid Salmi, SHAMCI Program Manager at RCREEE (Regional Center for Renewable Energy and Energy Efficiency) provided for Subtask D regarding Standards and Certification.

In countries such as Jordan, Lebanon, Palestinian Territories, Tunisia and Morocco solar thermal markets are dominated by thermosiphon systems. A typical solar thermosiphon system for residential application in the MENA country Morocco for example is equipped with 4 m² flat plate and enamelled steel tank volumes of 150 to 300 L. In Israel typical system sizes reach from 60 to 300 L with 2 to 4 m² collector area. Most commonly, there are direct thermosiphon systems with flat plate collectors as well as indirect thermosiphon systems with flat plate collectors in use. Imports from China often use evacuated tube systems [M1][https://euc-word-edit.officeapps.live.com/we/wordeditorframe.aspx?ui=de-DE&rs=en-US&wopisrc=https%3A%2F%2Faeeintecaustria-my.sharepoint.com%2Fpersonal%2Fd_tschopp_aee_at%2F_vti_bin%2Fwopi.ashx%2Ffiles%2F9a918d9cc7b1450989ae7b4eb57efe70&wdlor=c0388E783-15E8-4583-AF28-8F97B3C6827A&wdenableroaming=1&mscc=1&wdodb=1&hid=FD3565A1-E0D0-A000-8872-E0481D0F769B.0&uih=sharepointcom&wdlcid=de-DE&jsapi=1&jsapiver=v2&corrid=d25ec32c-6149-1134-9995-c88c1a3cc59b&usid=d25ec32c-6149-1134-9995-c88c1a3cc59b&newsession=1&sftc=1&uihit=docaspx&muv=1&cac=1&sams=1&mtf=1&sfp=1&sdp=1&hch=1&hwfh=1&dchat=1&sc={"pmo"%3A"https%3A%2F%2Faeeintecaustria-my.sharepoint.com"%2C"pmshare"%3Atrue}&ctp=LeastProtected&rct=Normal&wdorigin=Outlook-Body.Sharing.DirectLink.Copy&wdhostclicktime=1731965683627&instantedit=1&wopicomplete=1&wdredirectionreason=Unified_SingleFlushM2][M3].

Figure 77. Neom Tabuk, Saudi Arabia. Copyright GreenOneTec Solar Industries GmbH

Main applications: Applications are mainly for residential buildings, but solar thermal systems are also used in the hotel sector and in the public sector.

Market environment and challenges: Important markets of the Middle East and North African Region are Israel, Morocco, Lebanon, Palestinian Territories and Tunisia. Israel and the Palestinian Territories were within the ten markets with the highest market penetration per capita for the last couple of years according to the IEA SHC Solar Heat Worldwide market report [M15]. However, this was before the war between Israel and Hamas started in 2023. A few systems are also reported in Saudi Arabia, Egypt or Kuwait [M4, M5], in further countries like Iraq potential studies have been performed [M6, M7]. Besides the geopolitical challenges the region is facing, the market environment for solar hot water systems is further challenging because governments of the region sometimes rather focus on photovoltaic electricity production than solar thermal [M8].

Countries exporting to the MENA region are e. g. Greece, Spain and China. Israel, Lebanon and Tunisia have successfully built-up local production with regard to systems or components. Products with European standards are in place, especially for public installations. For imported products sometimes trained installers are lacking and therefore imported systems may fail or are badly maintained [M9].

From 2002 to 2008 there has been a large program to promote solar water heaters in Marocco (PROMASOL). The challenges were on the one hand to change existing habits with regard to energy use from propane gas to solar thermal water heaters, especially when the price of solar water heaters was more than sixfold the price of conventional water heating systems. Within the frame of the program support and training for local manufacturers and installation companies was provided because it was seen essential to produce and install according to certification standards. However, the aim of the national renewable energy strategy to reach 1.7 million SWH in 2020 has not been reached. [M9]

In Israel solar thermal obligations have been in place for decades. This strengthened the market and built-up local production capacity.

Since 2010/2011 the MENA region has faced a couple of political crises and conflicts that negatively affected the development of stable solar water heater markets. However, some non-profit organizations and international organizations started to use renewable energies and solar water heaters to not rely on official energy supply because public infrastructures partly are not functioning. Some regions stopped providing loans and incentives for solar water heaters, as people bought new televisions instead of solar water heaters. [M10,https://euc-word-edit.officeapps.live.com/we/wordeditorframe.aspx?ui=de-DE&rs=en-US&wopisrc=https%3A%2F%2Faeeintecaustria-my.sharepoint.com%2Fpersonal%2Fd_tschopp_aee_at%2F_vti_bin%2Fwopi.ashx%2Ffiles%2F9a918d9cc7b1450989ae7b4eb57efe70&wdlor=c0388E783-15E8-4583-AF28-8F97B3C6827A&wdenableroaming=1&mscc=1&wdodb=1&hid=FD3565A1-E0D0-A000-8872-E0481D0F769B.0&uih=sharepointcom&wdlcid=de-DE&jsapi=1&jsapiver=v2&corrid=d25ec32c-6149-1134-9995-c88c1a3cc59b&usid=d25ec32c-6149-1134-9995-c88c1a3cc59b&newsession=1&sftc=1&uihit=docaspx&muv=1&cac=1&sams=1&mtf=1&sfp=1&sdp=1&hch=1&hwfh=1&dchat=1&sc={"pmo"%3A"https%3A%2F%2Faeeintecaustria-my.sharepoint.com"%2C"pmshare"%3Atrue}&ctp=LeastProtected&rct=Normal&wdorigin=Outlook-Body.Sharing.DirectLink.Copy&wdhostclicktime=1731965683627&instantedit=1&wopicomplete=1&wdredirectionreason=Unified_SingleFlush M11]

Hot water load: According to the dissertation of Fatima Zohra Gargab on the “Technical-economic optimization and manufacture of a Moroccan solar water heater” the hot water consumption for a typical family in Morocco (with four persons) is assumed with 200 L. [M1]

Certification Schemes:

The Arab certification scheme SHAMCI (Solar Heating Arab Mark and Certification Initiative), inspired by European Solar Keymark, has been implemented in the region for the certification of solar thermal products. It was developed by the RCREEE the Regional Center for Renewable Energy and Energy Efficiency, in collaboration with the Arab Industrial Development and Mining Organization (AIDMO) and endorsed by the Arab Ministerial Council of Electricity (AMEC).

It was built around specific characteristics and needs of Arab states in the Middle East and North Africa. There are a couple of documents available on the website http://www.shamci.net/publications . The SHAMCI Network brings together 59 members from 22 Arab countries.

Egypt and Jordan are at the forefront of SHAMCI implementation. In Egypt it is officially recognised by the Ministry of Industry. The Egyptian Organization for Standardization and Quality (EOS) serves as the exclusive certification body responsible for evaluating manufacturers and importers based on SHAMCI requirements before products can enter the domestic market. This ensures high product reliability, durability as well as product performance and therefore strengthens Egypt’s SWH sector. The Jordan Standards and Metrology Organization (JSMO) adopted SHAMCI as a national certification scheme, establishing clear application procedures, fees, and a renewable two-year certification cycle.

The standardized quality assurance mechanisms provided by SHAMCI support consumer and investor confidence in the region that is essential for a long-term market growth.

Environmental conditions: Solar Resource: The MENA region is blessed with sun. The global horizontal irradiation covered in the SOLARGIS map for the MENA countries reaches from 1700 kWh/m² at the Mediterranean Sea to 2500 kWh/m² in the southern parts of the region.

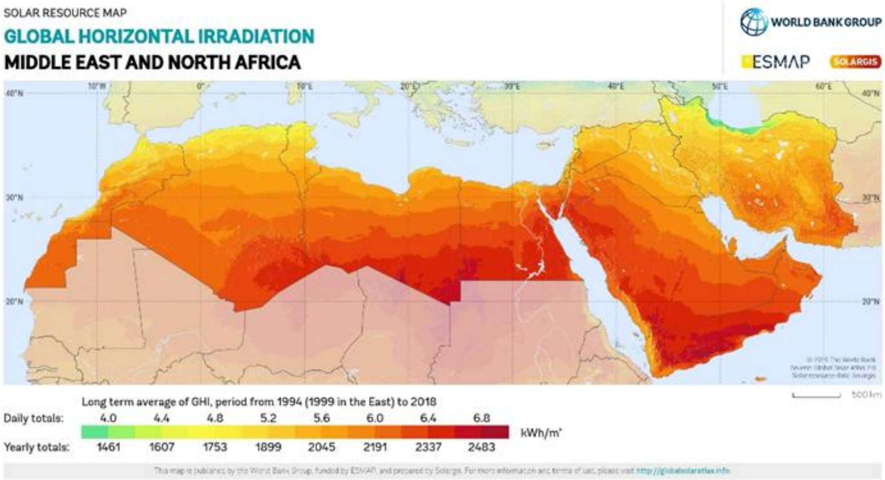

Figure 78. The MENA Region is one of the regions with very high solar irradiation Source: SOLARGIS [M12]

Climate Zones: There are three different climate zones, the arid, semi-arid and Mediterraneum climate zone. Arid climate zone (desert), mainly hot with temperatures up to 50 °C during days. During the night it can fall below freezing temperatures. Precipitation is below 250 mm per annum. The semi-arid climate is also hot but receives more precipitation than a desert. Precipitation is on average between 250 and 500 mm per year. The rain is usually enough to support some agriculture, but long droughts occur often. The Mediterranean climate has warm dry summers and mild, wet winters. The precipitation is on average lower than 900 mm per year. [M13]

Discussion, conclusion and outlook

On the one hand the MENA region sees countries that have built mature solar thermal markets (e.g. Jordan, Lebanon, Morocco, Israel) whereas in other countries like the Gulf region, Libya, Sudan or Yemen the adoption of solar thermal technologies remains very weak. Policy gaps, weak regulatory frameworks and the absence of certification schemes are some of the reasons for this.

As the region has set ambitious renewable targets to ensure energy security as well as economic growth, the potential for solar thermal systems adoption remains very high since the region is blessed with sun. For unlocking the potential reliable and cost-efficient solar thermal systems are essential, along with a harmonized and balanced quality framework that strengthens markets with regards to product and installation quality. With its regional network, SHAMCI could play a major role with regards to the regional solar thermal sector growth by spreading best practice examples and increasing country collaborations.

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3.10 North America (Region #6)

Thermosyphon market and regional boundary conditions

Introduction: This Chapter contains a market analysis of the United States, Canada and the Caribbean, with a focus on Puerto Rico. Following the classification of the Solar Heat Worldwide report (see Chapter 3), the markets of Mexico and Central America are included in Chapter 3.8 on Latin America and the Caribbean.

United States: The United States of America has approximately 12 solar thermal manufacturers who are actively engaged in the manufacture and sales of solar thermal systems. Of this group there are three subsets, domestic hot water, swimming pool heating and air/space heating. They are located all over the country but the largest are in Florida and California.

The mainland US predominantly requires freeze protected systems as the vast majority of the country faces freezing conditions at some point throughout the year. Therefore, direct thermosyphon systems are not used. To avoid freezing, most systems are forced circulation, indirect systems using a heat exchanger and a non-toxic heat transfer fluid or are designed to drain-back.

Hawaii is the exception, boasting a tropical climate, where solar thermal systems do not require freeze protection. However, thermosyphon systems are not common, as direct forced flow systems dominate this market due in part to architectural and aesthetic reasons.

Prices for systems vary considerably from region to region depending on climate, product availability, installer knowledge and type of home. According to a recent article published online, the costs of installing a residential solar domestic water heater is between $2,000 and $5,000 [N1].

The current US water heating market is $639 million annually, according to the data quoted by the US Solar Energy Industries Association, SEIA [N2]. The market is heavily focused on unglazed swimming pool heating collectors. It is estimated that there are 3.5 million residential pools that are heated in the US. Of this, 15% are heated by solar. Similarly, there are 240,000 commercially heated pools in the US of which 5% are heated by solar.

The US solar thermal market is small and is driven by incentives. The majority of the population does not know what solar thermal is and confuses it with solar PV. This has made it difficult for local manufacturers and installers, who struggle to differentiate themselves from a vastly larger and more developed PV market.

The ITC or Green Energy Tax credit, which is administered by the US federal government, is an incentive program for homeowners. It provides a 30% tax credit toward the purchase and installation of solar thermal systems [N3]. There are also many local and state incentives that are available, however these often change and can be difficult to find and access. DSIRE is a website run by N.C. State University that lists state incentives for renewable energy [N4].

Canada: The solar energy market in Canada is currently dominated by PV installations. However, the solar thermal market consists of commercial and residential swimming pool heating, and building-integrated air-preheating for commercial buildings. There are approximately six solar thermal manufacturers and distributors in Canada offering solar domestic hot water heating systems. All domestic hot water systems are indirect, freeze protected systems due to the freezing potential in the country. There is a potential market for direct seasonal solar domestic systems, but it has yet to be developed. Recent federal tax incentives for solar thermal systems have been introduced, and current test and rating requirements for site-assembled and packaged solar water heating systems are being revised to harmonize with the US and Europe, and to accelerate their deployment.

Puerto Rico: The Commonwealth of Puerto Rico is an island located in the Caribbean Sea with an area of land of 3,423.3 square miles and a population of 3.2 million [N5]. Puerto Rico is a United States territory, which means that its citizens are US citizens, the currency is the US dollar and government is closely linked to the U.S. federal government, but it is not a state and has certain autonomy. The climate is tropical without the risk of freezing, which makes it an ideal location for solar thermosyphon applications.

Puerto Rico has a well-established market for solar thermal, dating back to the 1970's. Several local manufacturers founded then are still around today including Universal Solar, and Tanagua, which are both second generation companies involved in the fabrication, assembly, sales and servicing of solar thermal systems. Other manufacturers on the island include Sun is Life and MC Green Solutions. These companies acquire components from the US, European and Chinese suppliers and assemble them in Puerto Rico. Starting in 2008 local manufacturers were provided with tax incentives for local manufacturing including, 4% income tax rate for 15 years and tax credits equal to 50% of their costs [N6]. These manufacturers compete with local retailers and installers who import complete systems from the US, Europe and China.

The predominant system configuration on the island is an open loop, direct thermosyphon system which is comprised of 2 m^2 of collector area and a 200 or 300L storage tank. The collectors typically use a selective surface despite the high solar irradiance which can sometimes lead to overheating and stagnation issues. These systems are installed on flat roofs on a 30° tilt angle.

The estimated market size is between 10,000 – 12,000 residential systems installed annually, based on information from the top 4 manufacturers. The primary focus for solar thermal companies in Puerto Rico is the residential market. None of the companies interviewed install larger forced flow systems for commercial or industrial applications. Tanagua has done installations on small hotels and guest houses using multiple residential systems plumbed together.

High electricity prices, 22.67 cents per kWh, which is 40% above the national US average [N7], and instability of the water and electricity grids has led to high adoption of solar thermal systems which can store and heat water without auxiliary power sources.

Prices for systems range from $2,000 - $6,000 USD installed, depending on the size and location of the installation. Installation costs range from $250 - $500 per system. Systems are sold directly by manufacturers, who have their own trained installers, or from local retailers offering a variety of products and systems. There are at least a dozen companies offering solar thermal products and services. Local big box stores, including Homedepot and Costco, carry and promote locally manufactured systems.

There are incentives available in Puerto Rico for the installation of solar thermal systems. LUMA, the local electrical utility provider, started offering a $550 rebate for the installation of an SRCC OG-100 certified solar collector in residential applications at the start of 2024 [N8]. There is currently no timeline for this rebate but according to a LUMA representative they have no plans to remove this incentive. LUMA is also working on a commercial/industrial incentive which would provide a rebate for larger installations. Details have not been finalized yet, but the rebate would be based on kWh savings.

Puerto Ricans can also take advantage of the ITC or Green Energy Tax credit, which is administered by the US federal government. This incentive allows homeowners to receive a 30% tax credit on the purchase and installation of solar thermal systems on their homes [N3].

None of the local manufacturers interviewed exported off island except in rare circumstances as they feel the market in Puerto Rico is robust enough for them.

R3 Program – CDBG-DR/MIT Recovery Funds program started in 2019 and was meant to provide funds to help Puerto Ricans rebuild after hurricane Maria decimated the island in 2017. There were many aspects to this program but one of them was the building of 30,000 new homes which would all be equipped with solar thermal systems and meet Energy Star for new homes criteria. While this program did not achieve its goal of building 30,000 new homes, there was significant building including 5,000 homes in the last two years all of which required the inclusion of solar thermal systems. The original R3 program closes at the end of 2024 but a new program replacing it will be coming into effect in early 2025.

Another Supplier in the Caribbean is Syrius Solar in Guadeloupe & Martinique. Syrius Solar is a French company established in 2013 with a head office in Montpellier France and subsidiaries in Guadeloupe and a factory in Martinique as well as in the south pacific. They specialize in thermosyphon systems designed for tropical marine climates [N9].

Market survey

Overview: Interviews were conducted with the top 4 manufacturers from Puerto Rico to estimate the market size (see previous Chapter). For the survey itself, there was only one response from North America, namely from one of the largest manufacturers of solar thermal systems in the United States.

Therefore, a detailed quantitative analysis of the survey outcome is not provided here, apart from the qualitative assessment of improvement tasks shown in Figure 79. The manufacturer rates increased efforts on marketing activities and subsidy schemes the highest, which is in line with the previous market analysis, stating that the market is small, driven by incentives and that most people do not know what solar thermal is (see above.)

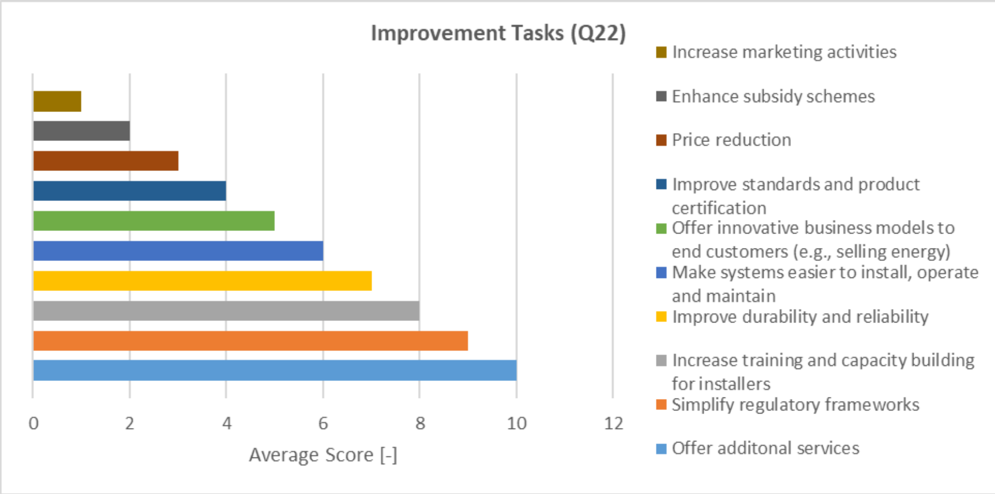

Figure 79. Improvement tasks (Q22).

Discussion, conclusion and outlook

Both for the United States and Canda, the market for solar thermal systems in general and for thermosyphon systems in particular is small, while both countries have more developed and vastly larger PV markets. Indirect systems are predominant in mainland US and Canda which face freezing conditions at some point throughout the year. Contrary to the US and Canada, Puerto Rico has a well-established market for thermosyphon systems due to a tropical climate without having the risk of freezing, high electricity prices, instability of the water and electricity grids and funding programmes aiming at rebuilding the country after hurricane Maria decimated the island in 2017.

The prospects for thermosyphon systems in the US and Canada remain meagre, with market activity expected to stay at low levels. Key factors to increase market chances are making the technology better known to the public and providing stable and accessible support schemes. In Canada, there is a potential market for direct seasonal solar domestic systems, but it has yet to be developed.

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[N6] Clean Energy Authority. Puerto Rico Solar Rebates and Incentives | Clean Energy Authority

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3.11 Oceania (Region #7)

Thermosyphon market and regional boundary conditions

Introduction: Oceania consists of 14 Countries/dependencies (see Figure 80) with a total population of 52.6 million persons. 50.2% of the population live in Australia, 19.6% in Papua New Guinea, 10.7 % in Western New Guinea (part of Indonesia) and 9.9% in New Zealand. The other 10% of the population is spread throughout smaller islands in the pacific.

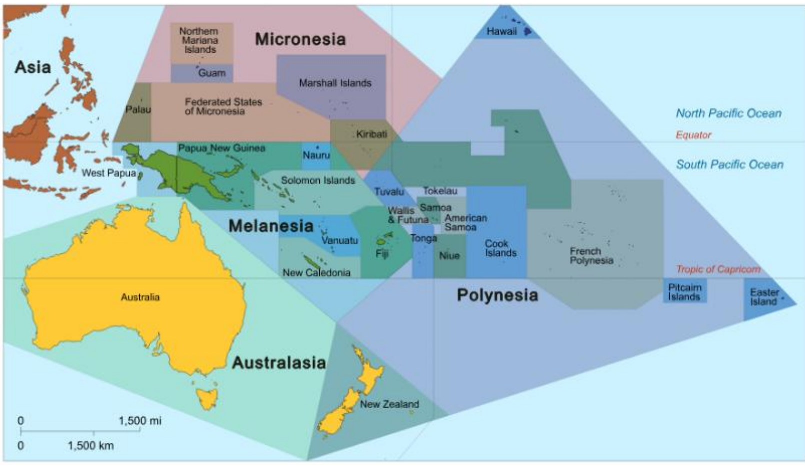
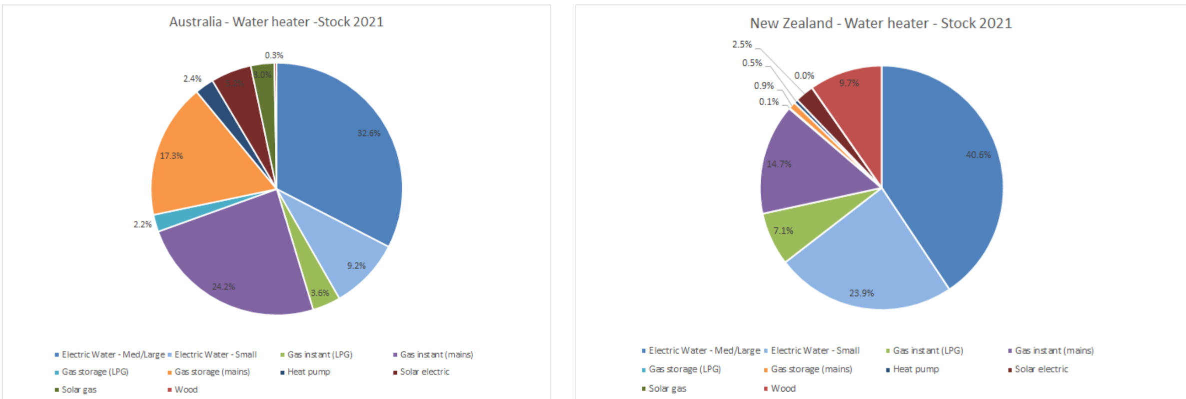


Figure 80. Oceania UN Geoscheme. Source: [O1].

Statistical data on water heating products and hot water energy consumption is not widely available in the Pacific and Papua New Guinea. Papua New Guinea has electricity network coverage to an estimated 21% of the population in 2021 [O2]. Consequently, only Australia and New Zealand have accessible data on water heating appliance sales and stock. Figure 81 illustrates the differences between the markets that have developed in these two countries. In Australia, 47.3% of water heaters are gas based and an additional 3% are gas boosted solar water heaters, whereas in New Zealand 64.6% of water heaters are electric water heaters and only 2.5% are solar electric. Heat pumps make up 2.4% of the stock in Australia and 0.5% in New Zealand.



(a) *(b)*

Figure 81. Water heating appliance sales and stock in the residential sector in Australia and New Zealand in 2021. Source: [O3].

Main applications: Thermosyphon solar water heaters in Australia are predominantly close-coupled systems where the tank sits above the collectors on the outside of the roof. Most collectors are of the flat-plate type as the tank is invariably pressurised making it more difficult to use evacuated tube collectors in a way that avoids water loss during glass breakage events while also minimising the risk of over-temperature due to stagnation. Figure 82 illustrates the type of system used in Australia. In Northern, warmer parts of Australia, systems sometimes circulate drinking water through the collector if the water quality is sufficient to avoid calcification in collector tubes. In cooler Southern regions or other areas where frost may occur the system typically includes a heat exchanger around the tank and treated water flows through the collector.

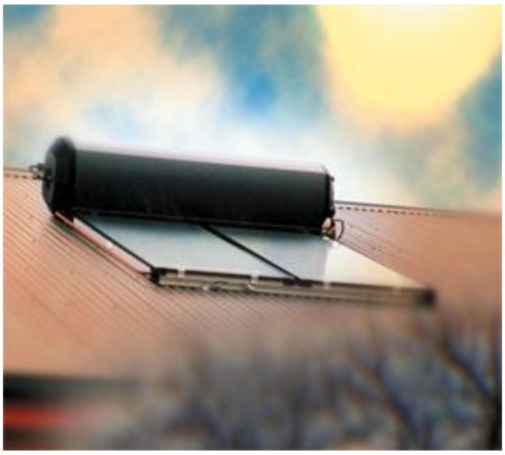


Figure 82. Close-coupled thermosyphon water heater typical for Australia.

Thermosyphon solar water heaters are typically made up of a 300 L tank with approximately 4 m^2 of collectors. This is illustrated in the survey responses to questions 10 and 11 at the end of this section. The tank often has a boost element part way up the tank to boost a backup volume by electricity in case of insufficient sunshine. In northern climates this type of system will provide 90% or more of a household's hot water needs. In southern climates it will provide more than 60% of hot water annually.

Solar water heaters make up 8.2% of the stock in Australia (5.2% electric boosted and 3% gas boosted) a total of approximately 890,000 products. It is estimated that approximately 350,000 (40%) of solar water heaters are thermosyphon circulation. In New Zealand there are about 50,000 solar water heaters, the majority of which are pumped systems. There is no data available on the number of solar water heaters installed in other countries of Oceania.

Main applications: Thermosyphon solar water heaters are mainly installed in residential single-family houses. Where larger systems are installed, they are invariably pumped circulation systems.

Market environment and challenges: Figure 83 illustrates the Australian market for solar water heaters over the past five decades. It can be seen that there have been a number of peaks and troughs, and the current market is declining gradually since the peak in the late 2000s. The peaks have generally been driven by market support schemes although the peak in the early 80's was in response to the oil crisis. Whilst many of the market support mechanisms are still in place over the past decade, household roof space is preferentially being used for PV thereby leaving less space for thermosyphon or pumped solar water heaters. At the same time, the cost of heat pump water heating technologies (which may receive a similar scope of incentives) has reduced significantly, and it appears that these are now dominating the market.

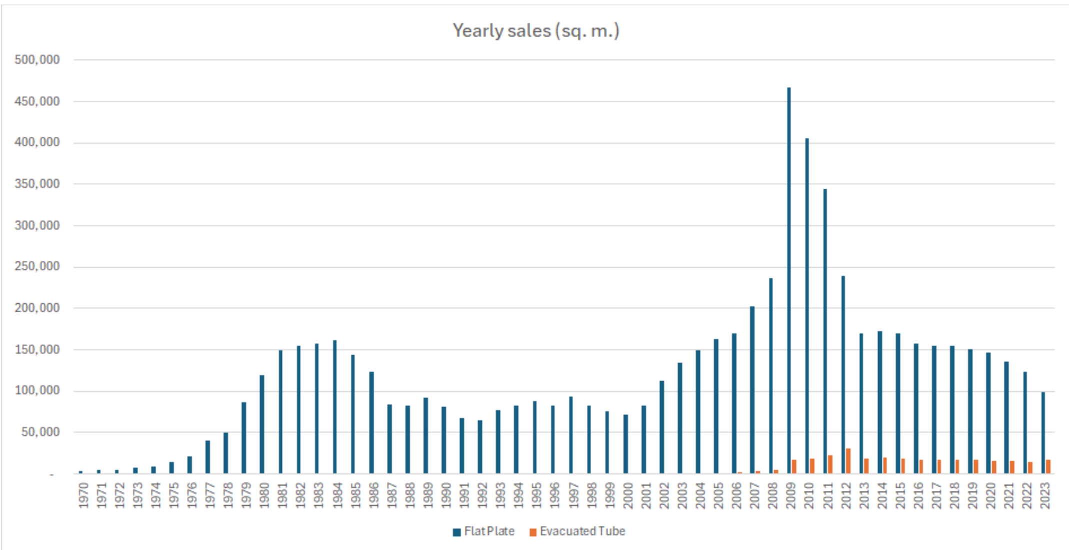


Figure 83. Annual sales of solar water heaters for the past 50 years in Australia. Source: David Ferrari and Ken Guthrie, based on data from the Australian Clean Energy Regulator.

One region of Australia, the State of Victoria has had a requirement for more sustainable new houses that has included the option of solar water heating for about two decades. However, the regulation was revised in late 2023 and heat pump water heaters are now the most likely low carbon water heater to be installed. The move to electrification and the preference to use available roof space for installing solar electricity for many householders means that the solar water heating market is reducing.

Meanwhile, Australia has the largest percentage of residential roof top PV installations globally. This is leading to overvoltage in distribution grids in residential areas which has led to responses that encourage electric water heating at times of high solar generation. These vary in effectiveness of savings for households versus protecting the grid operators from added costs. There is still a lot to be learnt in this developing situation.

Feed in tariffs have dropped dramatically so households are now looking to increase self-consumption rather than export. Consequently, there are a number of products that are being developed and marketed to increase the use of ‘excess PV generation’ for water heating. The control systems used for these can make a substantial impact on energy and running cost savings, as studied by Clift and Suehrcke [O4] who looked at different options. Yildiz [O5] has reported on a ‘Solarshift’ program to evaluate the opportunity to reduce PV export and running costs for households that is underway in the state of New South Wales.

Hot water load: Most solar water heaters are supplying loads of between 20 and 30 MJ per day for average household use. That is 100-150 L of hot water. However, the answers in the questionnaire below show that there are mainly 300 L systems on the Australian market.

Environmental conditions: Oceania has very good solar resources in most Countries, see Figure 84. Ambient temperatures are generally quite benign with few days of freezing temperatures. However, due to many clear sky conditions in Australia and New Zealand, systems often need to be designed to include frost protection.

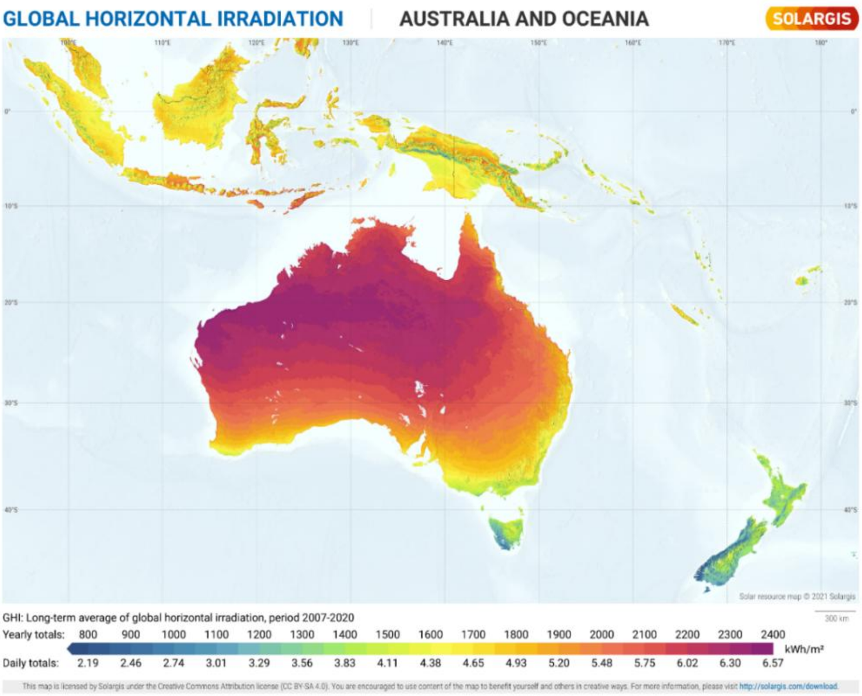


Figure 84. Global Horizontal Irradiation in Australia and Oceania. Source: [O6].

Subsidy schemes, promotion schemes, government policies: It is understood that, in Oceania, only Australia has significant subsidy schemes, these include:

- The Australian Government’s “Small-scale renewable energy systems scheme” [O7].
- State based white certificate schemes: Victorian Energy upgrades [O8] and NSW Energy savings scheme [O9].
- Solar Victoria State-based rebate scheme [O10] – similar schemes are replicated in South Australia and the Australian Capital Territory.

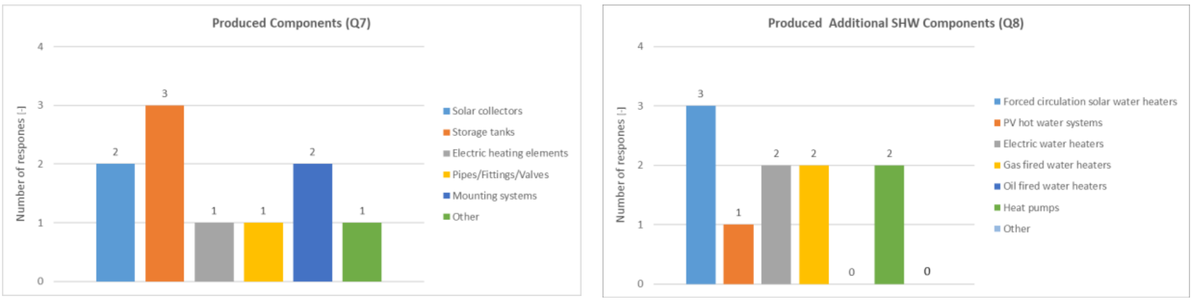
All these schemes require performance evaluation to AS/NZS 4234:2021 “Heated water systems — Calculation of energy consumption” and compliance with AS/NZS 2712-2007 “Solar and heat pump water heaters – Design and construction” so acts as a product certification scheme for all products sold in Australia.

Market survey

Overview: There were 3 responses to the survey from Oceania, all from Australia. The responses are illustrated in the diagrams following.

Production data (Q7 – Q12):

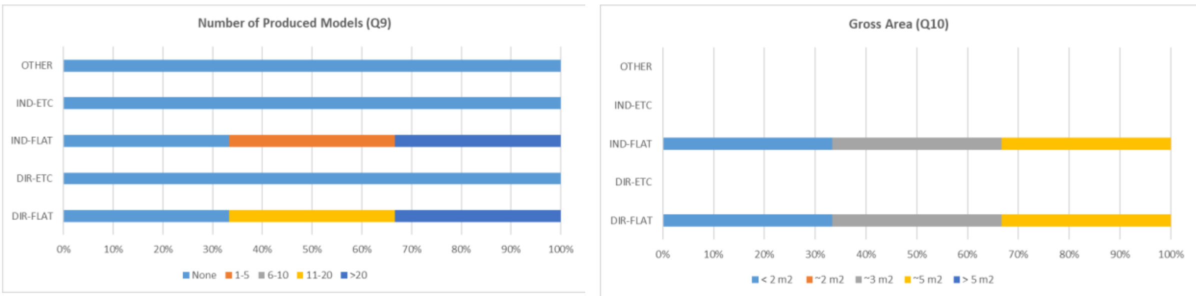
With regards to production data all three respondents mentioned the production of storage tanks, two had solar collectors and mounting systems respectively in their portfolio, and all respondents also sold forced circulation solar water heaters. Further additional SHW components mentioned were electric water heaters, gas fired water heaters and heat pumps.



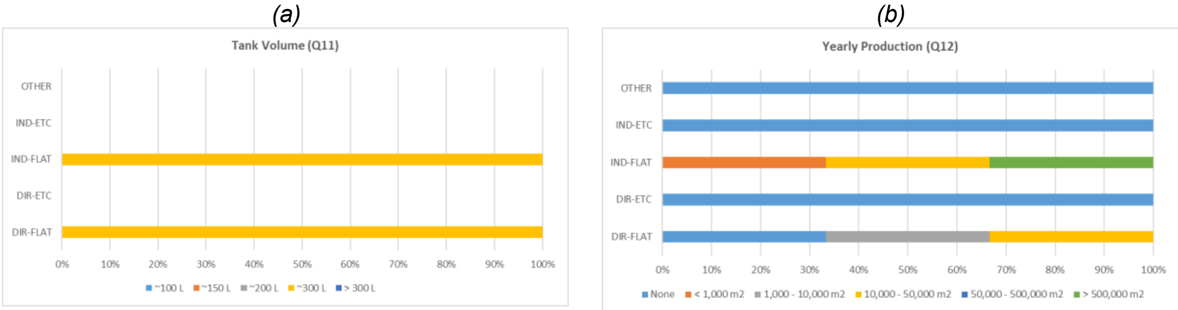
(a) *(b)*

Figure 85. Produced components (a) and additional SHW Components produced (b) (Q7-8).

The models produced are mainly indirect systems with flat plate collectors (IND-FLAT) and direct systems with flat plate collectors (DIR-FLAT) where water quality is sufficient. The number of models is rather high with 11-20 and >20 models for IND-FLAT and DIR-FLAT. Typical gross areas are <2m², 3m² and >5m² for both IND-FLAT and DIR-FLAT systems. The typical tank volume is 300 L (Figure 86).



(a) *(b)*



(c) *(d)*

Figure 86. Number of produced models, gross area, tank volume and yearly production (Q9-12).

Target markets and costs (Q13 – Q17):

In general, all of the world regions are target markets for Australian companies and one producer sells his products globally (to all of the indicated regions) (Figure 87). Two companies see the Australian market as the first biggest market, one the Indonesian market. Second biggest markets are New Zealand, USA and Africa. Third biggest markets for Australian companies are India, Papua New Guinea and Asia (Table 16).

The final customer prices are between $1,000-1,500 USD and >$2,500 USD (Figure 88).

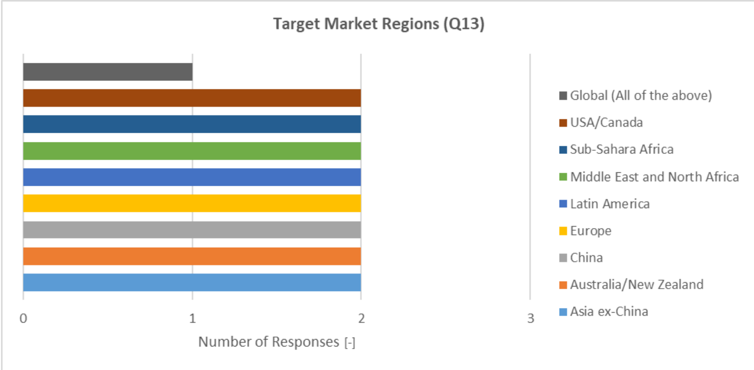


Figure 87. Target market regions (Q13).

Table 16. Biggest markets for Australian Manufacturers.

The 1st biggest market (3)	Australia (2) Indonesia (1)
The 2nd biggest market (3)	New Zealand (1) USA (1) Africa (1)
The 3rd biggest market (3)	India (1) Papua New Guinea (1) Asia (1)

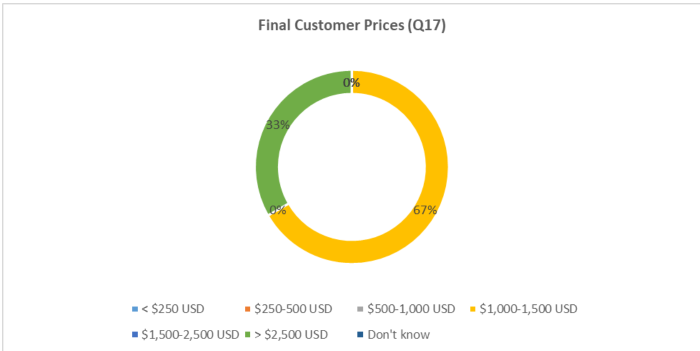


Figure 88. Final Customer Prices (Q17).

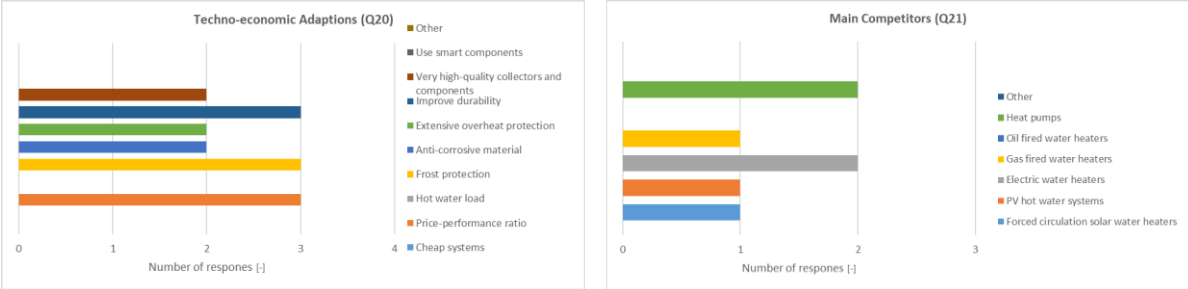
Product Placement / Business Models (Q18 – Q21):

Regarding end user requirements durability and reliability as well as systems easy to operate and maintain are seen as most important (Figure 89 (a)). Selling to wholesalers, to single installers, selling turnkey installations as well as maintenance and service packages were mentioned concerning (Q19) Distribution Channels (Figure 89 (b)).

(a) *(b)*

Figure 89. End User Requirements and Distribution Channels (Q18-19).

The price-performance ratio, improvement of durability and frost protection are seen as most important with regards to Techno-economic Adaptions. Main competitors are heat pumps and electric water heaters (Figure 90).



(a) (b)

Figure 90. Techno-economic Adaptions and Main Competitors (Q20-21).

Innovation and Market outlook (Q22 – Q29):

Together with price reduction, the manufacturers ranked improving standards and product certification highest, followed by increased marketing activities and the simplification of regulatory frameworks (Figure 91).

The market outlook is perceived as stable with two companies seeing no or low growth (0-5%) and one company seeing a medium growth potential (5-10%). The regions with highest growth potential are USA/Canada, China and Asia excl. China (Figure 92).

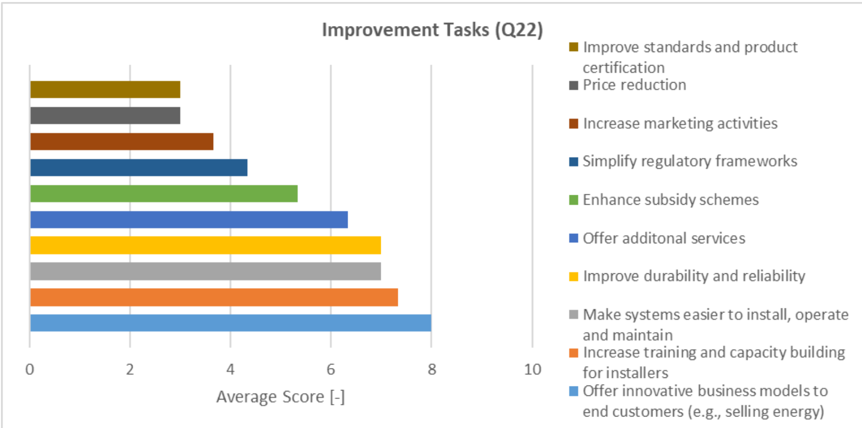


Figure 91. Improvement Tasks (Q22).

(a) *(b)*

Figure 92. Market Potential and Region Growth Potential (Q23-24).

Discussion, conclusion and outlook

Whilst the number of survey responses is limited, they suggest that:

- Most manufacturers are in the general water heating industry and supply gas and electric water heaters as well as solar water heaters.
- Direct and indirect flat plate systems are most common.
- Thermosyphon systems typically have a 300 L store and 3-5 m^2 of collector attached.

- Most manufacturers target international markets as well as local markets.
- Prices range from USD 1,000 to more than USD 2,500 per product. (Note that this seems low for the local market)
- Durability and reliability and ease of operation and maintenance are key end user requirements followed by ease of installation.
- The major marketing channel used is through wholesalers although a wide range is used by industry.
- Improved durability, frost protection and improved price performance ratio are the key technology improvements focussed on by manufacturers.
- Heat pumps and electric water heaters are the main competitors identified for thermosyphon water heaters.
- The key improvement tasks identified are price reduction and improving standards and product certification, followed by increased marketing activities and the simplification of regulatory frameworks.
- Low to medium growth is expected in the market.
- It is expected that regions which may have market growth will include USA/Canada, China and the rest of Asia.

This illustrates that the Australian market for Thermosyphon products is steady or in decline and manufacturers are targeting international markets. The main pressure in the marketplace is the move to electrification of heat and the competition with PV for available roof area as Australia has the highest rate of household roof top PV installation internationally. Therefore, it seems that the development of PV based water heating options are a likely way forward in Australia.

In the Pacific, the climate is generally more benign than in most of Australia so there should be good potential for thermosyphon products where hot water demand is high. However, at this stage it seems that the market is not well developed and consequently it is unlikely that installation expertise would be available to install thermosyphon water heaters. As there is a lot of air-conditioning used due to the climate it may be more likely that heat pumps would be more readily installed and maintained and if there is growth on rooftop PV there will be occasions of excess PV generation with no feed in tariff so indirect PV powered heat pump water heaters are possibly a future competitor.

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[O10] https://www.solar.vic.gov.au/hot-water-rebate

3.12 Sub-Sahara Africa (Region #8)

Thermosyphon market and regional boundary conditions

Sub-Sahara Africa comprises countries of the Southern African Development Community (SADC), as well as ECOWAS countries in West-Africa and countries of the East African Community. The population of Sub-Sahara African countries is about 1 billion people.

The SOLTRAIN initiative, aiming at the promotion and implementation of renewable heating and cooling in the SADC region supported by International Partnerships Austria, has been active in the SADC partner countries Botswana, Lesotho, Namibia, South Africa and Zimbabwe since 2009. The work done within the SOLTRAIN programme contributes to the information given below.

Main applications: The main applications of thermosyphon systems in Sub-Saharan Africa is for domestic hot water heating in school hostels, old age homes, low-cost housing developments, hotels and lodges and public institutions' infrastructure such as clinics and police stations, amongst others. In most cases, thermosyphon systems have a hot water storage tank of about 100 L to 300 L and a collector area of about 1 m² to about 4 m² respectively. They are installed either as a single unit or interconnected to meet the demand of the specific application. The presence of cabinet directives and National Renewable Energy Policies in some countries such as Namibia and Zimbabwe on the installation and replacement of solar water heating system on public institutions has resulted in a considerable growing number of thermosyphon solar water heating systems in public institutions, showing positive signs of these governments to decarbonize their energy sectors [S1] [S2].

The application of various technologies of thermosyphon systems is evident in Sub-Sahara Africa. Most commonly used are indirect water heaters with flat plates collectors or evacuated heat pipes, and direct water heating with flat plates or evacuated tubes. The use of unglazed collectors in some countries such as Namibia is primarily for pool heating. There have been attempts in some countries to make use of home-made thermosyphon systems, but their application is unpopular.

Market environment and challenges: The market situation varies country by country, and it is mostly driven by the policy landscape, standardisation, as well as awareness of the available technologies and their associated benefits and shortcomings. Namibia for example is characterised by high levels of solar radiation, especially in the coastal areas in the Southern area of the country. Most systems can easily reach stagnation, especially when they are operated at high irradiance levels. The low hot water energy demand during summer seasons when irradiance levels are high exacerbates the situation. Similarly, potential freezing temperatures pose a threat to the operation of the systems. However, this is usually mitigated by using glycol as the system working fluid in indirect thermosyphon systems. Furthermore, in some countries such as Namibia, the code of practice for industry players has prohibited the use of direct system due to freezing and quality of water [S3].

In terms of cost of technology, the cost varies depending on the technology type, the quality as well as the supplier. The most expensive thermosyphon system technologies are currently indirect glazed flat-plate collector systems. The general trend in the price dynamics for most thermosyphon systems in the last 10 years saw increasing prices, driven by high mobility and electricity cost, that influenced overall price dynamics, as well as the imbalance between demand and supply, as only few countries in the region manufacture these technologies and the systems must be imported.

Hot water load: The demand of hot water in Sub-Saharan Africa is high in various sectors, including domestic hot water. Measurements done in the frame of the SOLTRAIN project showed that hot the water demand in single family houses varied between 60 to 150 L per person and day. As soon as there is electricity, the share of electricity used for DHW preparation was about 25% to 33% for the houses monitored. It was interesting that the houses that used electricity for DHW preparation used less hot water compared to the houses using thermosyphon systems [S4]. The growing demand for housing as well as other accommodation sectors, leads to a higher demand for hot water thermal. The use of thermosyphon systems could therefore reduce the stress put on the electricity systems in the countries.

Environmental conditions: Figure 93 shows that desert, semi-arid and subtropical climates are prevalent in Sub-Sahara Africa. Desert climatic conditions are not conducive for evacuated tube systems due to very high temperatures most of the year. Figure 94 shows the Global Horizontal Irradiation for Sub-Saharan Africa with annual irradiation levels ranging from 1,600-2,400 kWh/m².

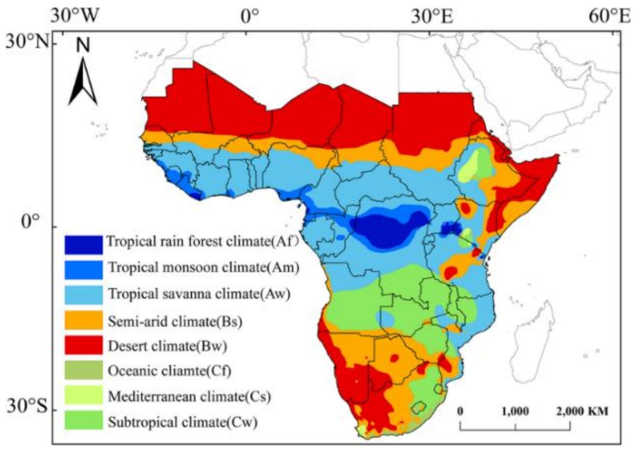


Figure 93. Climatic conditions for Sub-Saharan Africa. Source: [S5].

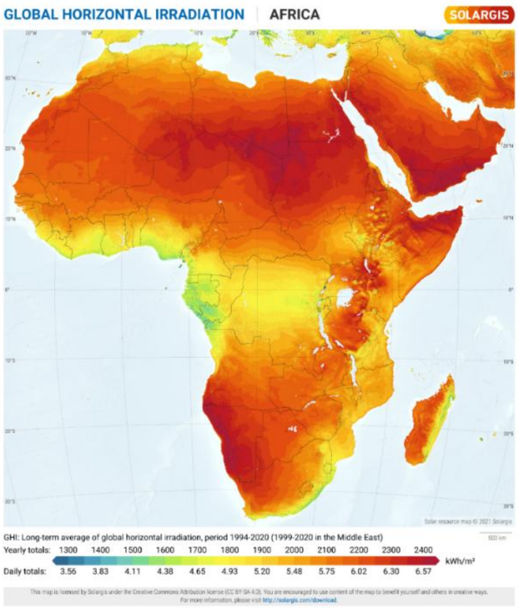


Figure 94. Global Horizontal Irradiation Map for Sub-Sahara Africa. Source: Solargis [S6].

Subsidy schemes, promotion schemes, government policies: Within Sub-Saharan Africa there are regional initiatives in line with international initiatives such as Energy Policies, Renewable Policies and Energy Efficiency Policies in the bid to reduce energy demand against deficit in renewable supply, e. g. for SOLTRAIN countries [S7-S18].

Product certification schemes, standards: There is no regional standard valid for all the countries in Sub-Saharan Africa region, although there are regional groupings such as Central Africa, East Africa, West Africa, and Southern Africa. Small Southern African Countries like Namibia or Lesotho in some cases adapt South African standards. Other, it is rather a country-by-country policy application. In the countries, the equipment that is sold in the private sector generally does not have the need to be certified. Implementations done in the frame of the SOLTRAIN initiative have to follow Solar Keymark certification schemes or similar product standards. Further, in some countries the need for certification arises when solar thermal equipment is included in a promotion regime or benefit.

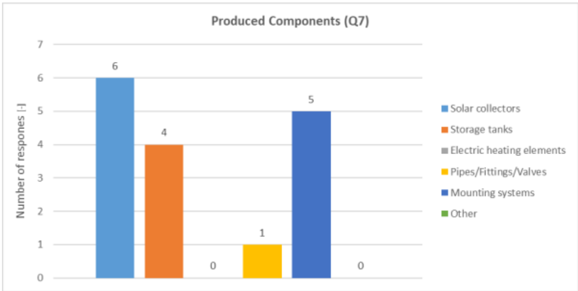
Most local standards are adopted from the following:

- ISO 9459-1: Solar Heating - Domestic Water Heating Systems Part 1: Performance Rating Procedure using Indoor Test Methods
- ISO 9459-2 Solar Heating - Domestic Water Heating Systems - Part 2: Outdoor Test Methods for System Performance Characterization and Yearly Performance Prediction of Solar

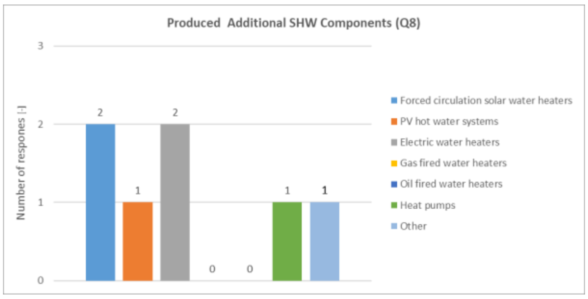
Market survey

Overview: Survey results from 6 manufacturers of thermosyphon systems were received from Botswana (3 answers), Namibia (2), South Africa (1) and Zimbabwe (1), countries from the SADC region. Obviously, there are many more companies in the growing market of Sub-Saharan Africa, but most manufacturers and distributors are very sensitive to sharing data. If there could be a government push that could be helpful to increase the contribution regarding data acquisition. In other regions of Sub-Saharan Africa the GN-SEC Centres East African Centre for Renewable Energy and Energy Efficiency (EACREEE1), ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE)2, The Centre for Renewable Energy and Energy Efficiency for Central Africa (CEREEAC[3])) are being established and giving confidence in these markets to share information in future.

Production data (Q7 – Q12): As shown in Figure 95 (a), all manufacturers of thermosyphon systems produce solar collectors, and most of them produce also mounting systems and storage tanks. Only a small share produces additional SHW components as shown in Figure 95 (b).



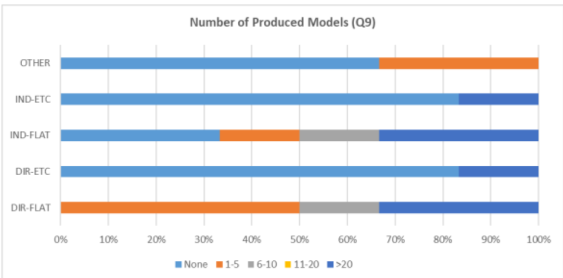
(a)



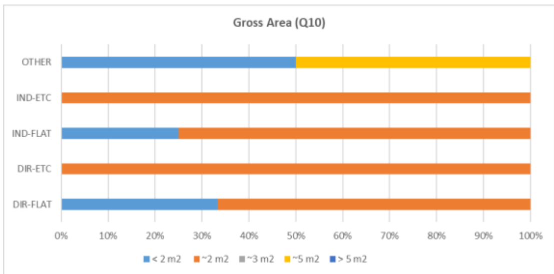
(b)

Figure 95. Produced components and Produced Additional SHW Components (Q7-8).

Figure 96 (a) – (d) show production data. The models most commonly produced are direct and indirect systems with flat-plate collectors (DIR-FLAT, IND-FLAT), see Figure (a). Most common system sizes are equipped with a 2 m² gross collector area and 200 L tank volume (Figure 96 (c)). Most manufacturers have production numbers below 10,000 m² per year (Figure 96 (d)).



(a)



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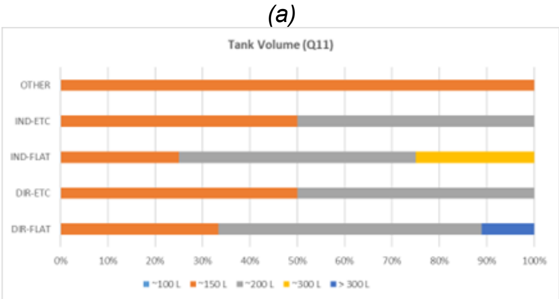
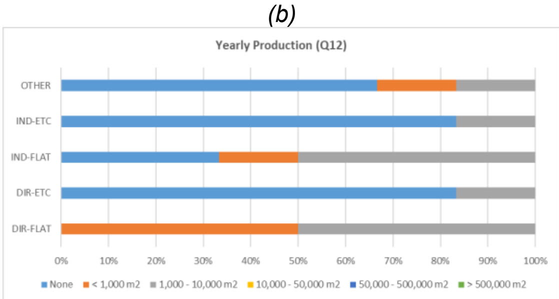


(c)



(d)

Figure 96. Number of Produced Models, Gross Area, Tank Volume and Yearly Production (Q9-12).

[1] https://www.eacreee.org/
[2] https://www.ecreee.org/
[3] https://www.cereeac.org/

Target markets and costs (Q13 – Q17): As shown in 2, the manufacturers exclusively sell within their local market region. This is also confirmed by Table 17, showing that the biggest markets coincide with the location of the production facility. Only two manufacturers export to other countries.

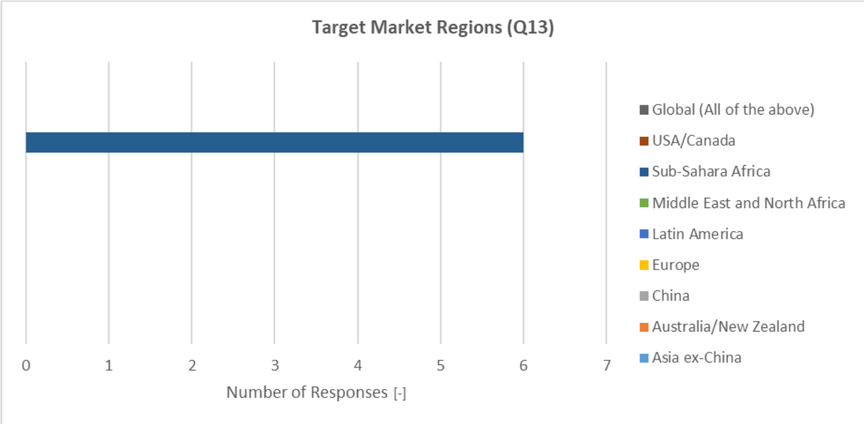


Figure 97. Target Market Regions (Q13).

Table 17. Biggest Markets in Sub-Sahara African Countries.

The 1st biggest market (6)	Botswana (3) Namibia (2) South Africa (1) Zimbabwe (1)
The 2nd biggest market (2)	Zimbabwe (2)
The 3rd biggest market (2)	Botswana (1) South Africa (1)

Figure 98 shows typical final customer prices with most of the systems being around $1,000-1,500 USD (50%).

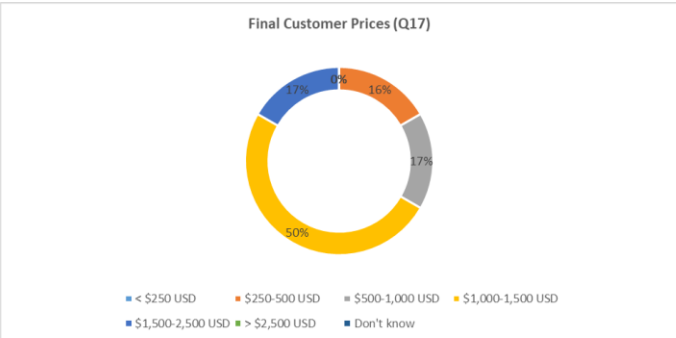
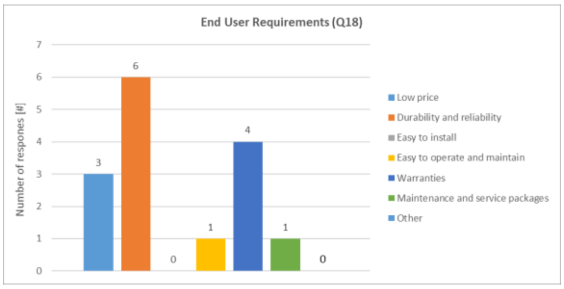
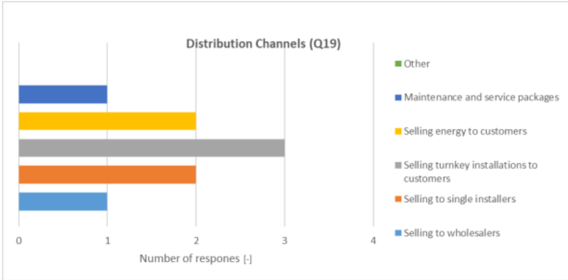


Figure 98. Final Consumer Prices (Q17).

Product Placement/ Business Models (Q18 – Q21): The main end use requirements are durability and reliability combined with warranties (Figure 99 (a)). Most manufacturers provide turnkey installations to customers (Figure 99 (b)).

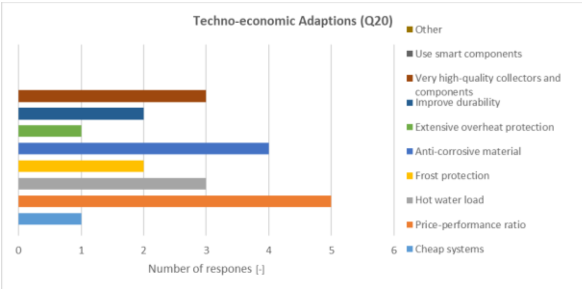


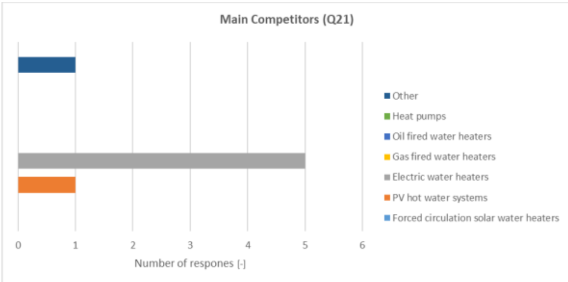


(a) (b)

Figure 99. End User Requirements and Distribution Channels (Q18-19).

As shown in Figure 100 (a), the major adaptions that Sub-Saharan manufacturers make are optimizing the price-performance ratio of their products. Main competitors are electric water heaters (Figure 100 (b)).





(a) (b)

Figure 100. Techno-economic adaptations and Main Competitors (Q20-21).

Innovation and Market outlook (Q22 – Q29): As shown in Figure 101, the most important improvement task is to increase training and capacity building for installers (score 3.6), with making systems easier to install, operate and maintain being the least important (score 9.2).

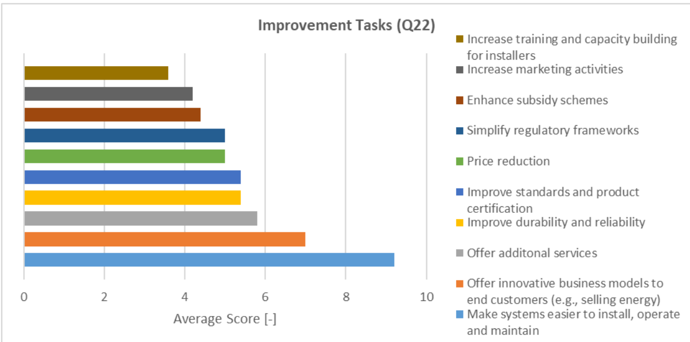
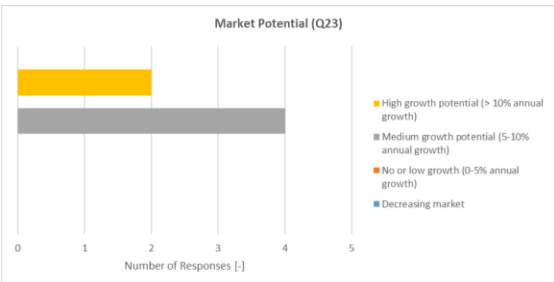
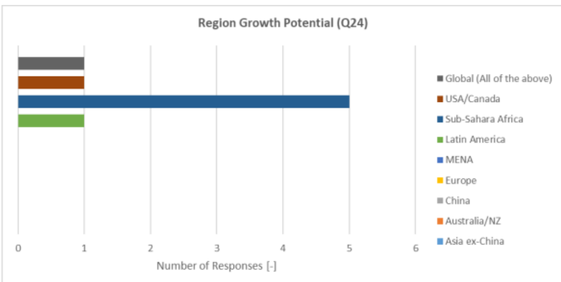


Figure 101. Improvement Tasks (Q22).

Figure 102 (a) shows that most companies expect a medium or high growth potential, focusing on the domestic markets in the Sub-Sahara region (Figure 102 (b)).





(a) (b)

Figure 102. Market Potential and Region Growth Potential (Q23-24).

Discussion, conclusion and outlook

- As only few countries have answered the survey the conclusions drawn focus on these countries. However, it is expected, that other Sub-Sahara African countries can benefit from the survey results as well.
- The typical system size in the surveyed countries is a system with a collector area of 2 m² and a tank volume of 150 to 200 L. The final system prices are rather high, mainly due to the lack of local production and the need to import from other countries.
- Together with warranties, durability and reliability are seen as the most important end user requirements. Further, capacity building is one of the most important improvement tasks, second important is increasing marketing activities followed by enhanced subsidy schemes.
- Two third of the survey participants see medium growth potential (5-10%) while one third even sees high growth potential (>10%) in the region. The local market is seen as most important market regarding the region growth potential showing the importance of strong local markets for regional growth and job creation.
- Measures to increase the market chances of thermosyphon systems are increased marketing activities, increasing reliability and durability as well as increasing the price performance ratio. Regulatory frameworks that have been adopted in some of the countries further support the application of solar thermosyphon systems and stimulate the markets.
- In general, there is great potential increase seen in the market as the deficit between supply and demand in Sub-Saharan Africa e.g. due to climate change effects on the hydropower stations [S19, S20] also affects the hot water production that still largely depends on electricity in many Sub-Sahara African countries. Further activities of local governments focus on energy efficiencies [S21] as well as the integration of renewable energy to the country energy mix to increase energy resilience and to reduce energy dependencies. In order to strengthen confidence in the market, government roll-out programs must be accompanied by capacity building and maintenance programs to ensure high quality and reliance. These measures could help to build mature markets and foster job creation.

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4 Market Analysis for PV Hot Water Systems

Figure 103. Photovoltaic to heat (PV2Heat) system. Photo: Bongani Xakaza, SANEDI, South Africa

4.1 Overview

According to the *IEA Renewables 2023* report, renewable electricity will be the fastest growing heat source in buildings between 2023 and 2028 and will increase by two-thirds globally. That would mean an increase by 2.2 EJ until 2028. In 2023, the increase of solar PV accounted for three-quarters of the renewable energy increase worldwide [P1].

This remarkable growth is mainly due to the low prices for solar photovoltaic (PV) panels, but also the reduction in installed system costs. PV panel efficiencies now stand at about 20% and above with new developments to even further increase efficiencies to 30% and beyond [P2]. In 2024, the price per Watt was less than 1 USD [P3]. Knowledge gains in optimized system and operation techniques increase energy use and efficiency. Using high exergy PV power supply for DHW becomes a viable alternative to traditional renewable energy sources like solar thermal water systems and biomass. It may be beneficial to use solar thermal collectors together with PV modules for electric boosting.

An overview of PV Hot Water technologies is given in detail in the IEA SHC Task 69 Report D.C3 “The Emergence of PV Hot Water Systems”. Here, a short summary of available technologies is given with a focus on available products and their market relevance.

4.2 Advantages of PV Hot Water

Photovoltaic water heating systems offer several advantages. The systems are very simple, and the price of the systems is increasingly less than the price for solar thermal thermosyphon systems. There is no piping necessary, only wiring. Therefore, the installation effort is minimized and there are no thermal losses through distribution and circulation lines. The tank does not have to be put on the rooftop but can be put anywhere in the house. There are no frost or stagnation issues because the systems inherently provide protection against frost and overheating, as they do not require water to circulate through externally mounted collectors. With grid-connected PV systems the self-consumption of solar photovoltaic electricity can be optimized. Further, it is possible to couple different sectors, like the heating and the electricity sector. Under low ambient temperature conditions, the efficiency of PV modules improves, and electricity generation is possible even under conditions of reduced solar irradiance. Consequently, PV water heating systems are better suited for use during shoulder seasons and winter periods, as well as in colder climates, compared to conventional solar thermal collector systems.

4.3 Challenges for PV Hot Water

The challenges include the initial capital investment required and complexities associated with system integration. This encompasses ensuring compatibility and efficient interaction between the system and existing household electrical demands, as well as its integration with the broader community infrastructure and the electric grid.

The efficiency of PV hot water systems is lower than for solar thermosiphon systems. If these systems do not include a maximum power point tracker for the PV module, the PV efficiency might be relatively low. Further, there are challenges with regards to the electrification of the heat sector, like the necessary upgrade of grid infrastructures with regards to grid connected systems.

Different technologies include PV hot water systems directly coupled to PV panels without grid connection, grid connected systems coupled with (smart) hot water tanks to increase PV self-consumption or systems connected with PV driven heat pumps that efficiently convert the electricity produced by photovoltaic panels into heat for DHW, space heating or for industrial processes. In Germany, a new solar heating concept for municipalities uses PV systems and heat pumps to provide solar heat for a district heating system.

4.4 Applications

4.4.1 PV2Heat Technologies

In areas with unreliable grid service, high connection costs, or low up-front capital, “photovoltaic to heat” (PV2Heat) systems represent a good alternative with regards to hot water production. Direct coupled PV2Heat technologies use the direct current produced by the photovoltaic panels directly to heat up water in a hot water tank, for example by means of a resistance heating element. That means minimal intermediary electronics are needed.

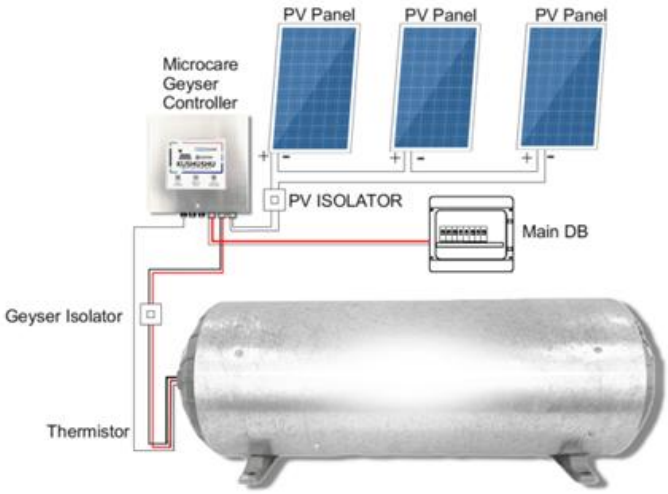

Figure 104. Schematic of a PV2Heat system from Microcare [P4]

One issue with direct-coupled PV2Heat water heaters is the inability to safely interrupt the high-voltage DC connection between the PV array and the heating element without inducing significant sparking. Such sparking can lead to damage of switching devices, such as relays, potentially compromising the tank's overtemperature protection mechanisms. This phenomenon arises from DC current arcing across control contactors (e.g., thermostats or relays), which can result in the contacts welding shut. This presents a serious safety risk, as the heating element cannot be deactivated while PV power is available. Consequently, this may lead to excessively high-water temperatures, posing a scalding hazard, or even catastrophic rupture of the tank in the event of pressure relief system failure [P4].

A viable mitigation strategy may be the use of alternating current (AC), which allows circuit interruption at zero current. However, this requires an inverter, which adds to the overall system cost.

4.4.2 Optimisation of PV self-consumption

Partially coupled PV2Heat technologies use the surplus of electricity produced by means of rooftop PV panels. These systems reach from a simple power export flow diverter/controller to more advanced ‘smart’ systems which interface with other household appliances, the grid, and even local networks of PV systems and households. A uniting feature of these technologies is that excess PV electricity must be available after all other electrical loads are met. In this situation, it can be advantageous to heat water rather than to export the electricity to the grid with low electricity prices. Further, from the energy provider’s perspective, it increases the stability of the grid. Besides direct coupled heating elements, PV driven heat pump water heaters are also able to shift peak loads and to heat up water tanks efficiently during daytime. Heating up water tanks can be seen as demand side management tool to provide ancillary services to the grid and will further increase with real-time pricing for grid-connected systems in place. Timers or central control schemes can be also used by service providers to intentionally shift the load profiles to better align with high levels of renewable electricity production and to avoid curtailment of renewable energy sources.

Solar combi-systems powered by PV use solar photovoltaic energy for both domestic hot water production as well as space heating in residential and commercial buildings. There are a few examples in Germany and Switzerland with PV systems covering 100% of the building's heat demand. In a few municipalities in Germany, PV systems are even used to supply hot water for the district heating systems [P3].

4.4.3 Hot Water from Grid PV

As another category of PV hot water, conventional electric water heaters can utilize PV electricity from the grid. This cannot be neglected in markets with high PV penetration and will presumably increase along with global PV penetration increase. Historically there have been 'controlled loads' to provide customers with low cost 'off-peak' electricity from fossil fuel generators. This 'off-peak' electricity was traditionally provided during night-times. It may be possible to repurpose and modernize these systems, where available, to instead selectively consume 'peak' solar generation of electricity. For example, 50% of Australian water heating is done through electric systems which makes up around 25 MWh of daily flexible demand in Australia's National Electricity Market. There is ongoing research to use this flexible demand and shift electric water heating into the middle of the day to soak up excess PV generation in the network through smart meters. Since current controlled load tariffs do not reflect the benefit of using excess PV energy in real time, the responsibility may fall onto retailers or regulators to come up with more equitable tariff structures. To guarantee consumer hot water amenity, further controls and two-way communication would be needed. One option would be to sell the hot water as a service by aggregated suppliers such as hot water tank and heat pump manufacturers. As larger players, these companies can develop and use sophisticated algorithms via cloud interfaces to maximize the value of this type of demand side management especially via the use and control of smart meters [P3].

4.5 Notable Markets

Important markets for PV2Heat systems are Australia, the United Kingdom, South Africa and China. But there are also small markets with positive developments, like in Austria.

4.5.1 Australia

Australia has a high penetration per capita with regards to installed photovoltaic systems, with more than 1 kWe installed capacity per person in 2024. In Australia, the production of hot water by means of electricity reaches about one third of the hot water market in the country. Optimization strategies for PV electricity self-consumption are in place, and hot water storage tanks further increase the share of self-consumption [P4]. As mentioned above, there is ongoing research in Australia with regards to further using the grid PV and demand side management strategies to avoid renewable energies curtailment.

An exemplary solution of direct use of solar PV in Australia is given below.

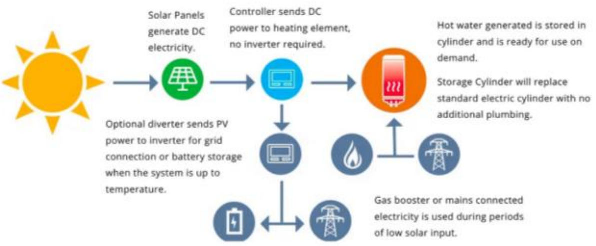

Figure 105. Solflow PV Direct Hot Water. Source: [P5]

4.5.2 United Kingdom

PV diverters have been developed predominately by manufacturers in the United Kingdom. The surplus energy produced by means of photovoltaic systems is directed to hot water storage tanks, underfloor heating, swimming pools, heat pumps, electrical devices or battery storages. The diverters serving hot water storage tanks are designed to work with existing electric hot water systems and immersion heaters. This means that it is not necessary to install a new system, the excess solar power is directed to the current water heater, turning surplus electrical energy into hot water. Exemplary manufacturers are Myenergi (https://www.myenergi.com) and marlec renewable power (https://www.marlec.co.uk). When the electricity produced by means of PV panels exceeds the consumption, thermal storage tanks are loaded.

Figure 106. Diverters to be used in households or for commercial use Source: [P6]

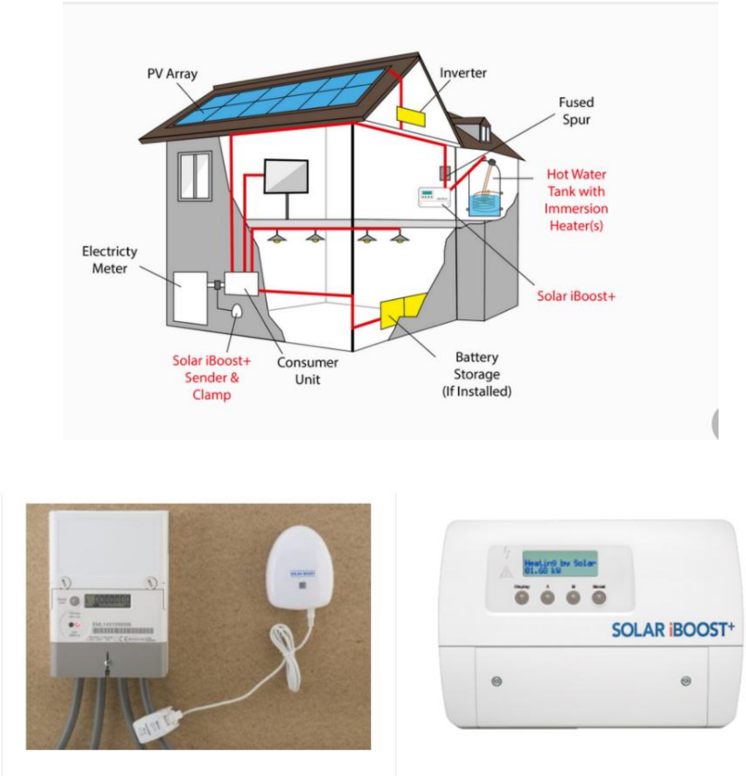

Figure 107. The Marlec system uses a sender and a clamp to detect surplus energy to deliver the energy to the immersion heater of an existing hot water tank. Source: [P7]

4.5.3 South Africa

In South Africa, PV2heat markets have developed since 2018, driven by decreasing costs of solar PV technologies and the ease of installation. Unlike traditional systems requiring insulated piping, PV2heat setups typically require only electrical wiring between the panels and the tank. These systems often include an AC heating element connected to the electricity grid to ensure water heating during periods of low sunlight. Primarily, PV2heat systems are used for residential domestic hot water production and are commonly installed in single-family homes, including free-standing houses, estate properties, multi-storey walk-ups, and apartment buildings. There is also a small share of installations on off-grid farms.

By the end of 2023, more than 34,000 systems have been installed with yearly growth rates ranging at about 40% from 2020 to 2023. One of the key factors driving the development is a regulation in place that states that no more than 50% of the hot water consumption in households be heated by energy produced from fossil energy sources [P8].

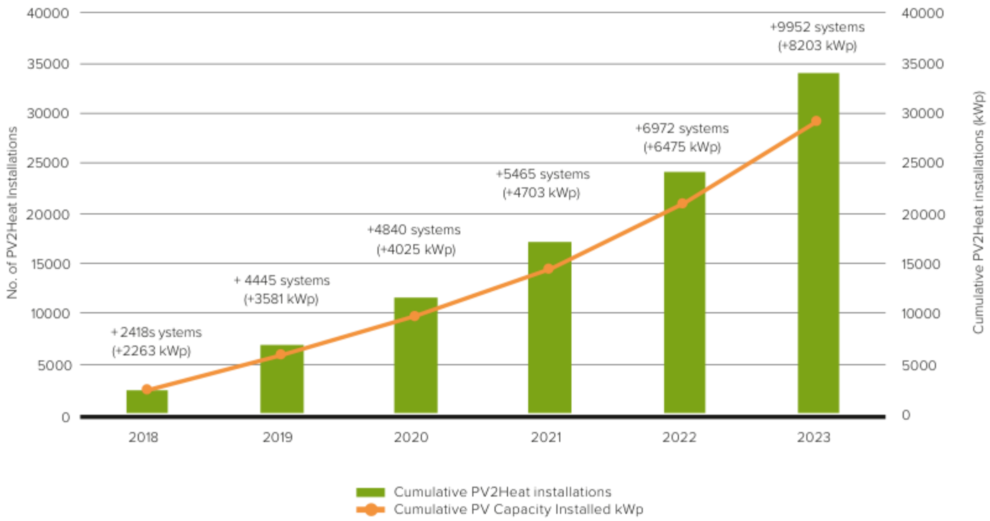

Figure 108. PV2heat market development in South Africa (2018-2023) Source: Lavhe Maluleke, Stellenbosch University, South Africa [P3]

Over the past 5 to 6 years, the solar PV water heating market has witnessed a flux of new entrants. However, many have either exited the market or undergone rebranding for various reasons. The most prominent systems currently available on the market includes the Elon and Geyserwise.

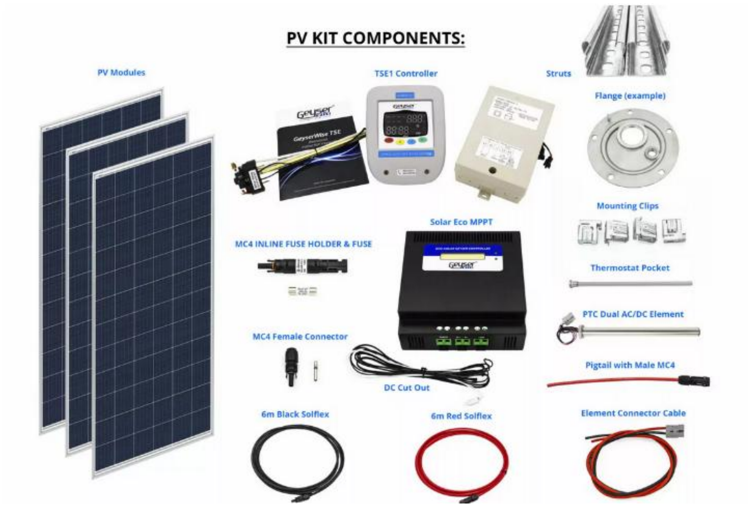

Figure 109. PV2Heat Kit Source: Geyserwise [P9]

In 2023 and early 2024, South Africa witnessed a significant increase in solar PV installations, driven by several factors, including declining costs of solar PV technology, strong government support, and growing energy insecurity caused by frequent load-shedding. A key aspect of this government support was the introduction of a solar energy tax credit in 2023, which was effective for one year. This incentive offered individuals a 25% tax rebate on newly purchased solar PV modules (up to R15 000). This incentive was designed to motivate investments in clean, sustainable electricity generation solutions. However, despite this progress, the industry still faces regulatory gaps concerning solar PV installations. Therefore, this surge also brought a wave of unqualified installers who often performed substandard installations, and this has a negative impact on the industry's reputation. To address these challenges, the development of innovative platforms such as the PV marketplace is underway, with its launch anticipated in early 2025. This specialized marketplace will link solar photovoltaic buyers with trusted installers in their local areas. All installers affiliated with the marketplace will undergo a rigorous vetting process before registration to verify their qualifications and reliability. This careful vetting aims to reduce risks and guarantee that customers receive genuine value, thereby enhancing the integrity and reputation of the solar PV industry.

While the exact number of installers is not definitively known, industry experts estimate that there are approximately 674 installers in their database.

4.5.4 China

PV Self-consumption hot water system

The SUNRAIN PV self-consumption hot water system comes with a PV module installed on the balcony or roof, and a water tank installed on each family bathroom. During the day, the PV module generates electricity, which is transmitted via cables to the water tank, eliminating the need for complex circulating pipelines, pumps, and valves. In high-floor buildings, split wall-mounted photovoltaic hot water systems are used, while in low-floor buildings, photovoltaic collection and distribution systems are used. Figure 110 below illustrates the SUNRAIN PV self-consumption hot water product, and Table 18 lists the specific parameters related to the tank and PV module.

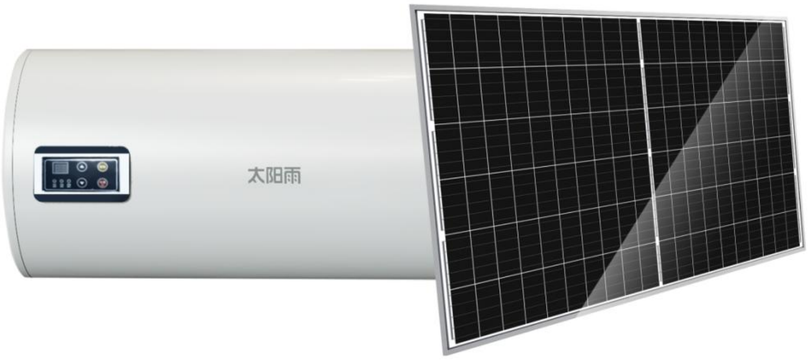

Figure 110. SUNRAIN PV Water Heater. Source: Sunrain [P10]

Table 18. Configuration parameters sheet for the SUNRAIN PV Water Heater.

Tank Data	Model	GW-60-2/0.4-2	GW-80-2/0.4-2
	AC Rated Voltage	220V	
	AC Rated Power	2000W	
	DC Rated Voltage	42V	
	DC Rated Power	400W	
	Rated Pressure	0.7MPa	
	Inner liner Material and Thickness	SPCC/2.0mm	
	Housing Material and Thickness	painted steel plate/0.4mm	
	Insulation Materials and Thickness, Density	PU/ 50mm, 32-38Kg/m^3	
	Protection Level	IPX4	
	Size	Φ468*730	Φ468*920
PV Module Data	Component Type	monocrystalline silicon	
	Rated Power	550W	
	Optimum Operating Voltage	41.96V	
	Optimum Operating Current	13.11A	
	Open-circuit Voltage	49.9V	
	Short-circuit Current	14A	
	Size	2278*1134*35mm	
	Weight	29.4kg*1 PCS	

PV and Grid Combined Heating Hot Water Systems

MICOE PV and grid combined hot water heating with intelligent switching is an innovative water heater that has high efficiency and energy-saving features. With the help of a photovoltaic module installed outdoors, this water heater generates DC electricity which is then directly supplied to a storage tank inside for heating; when the light is poor or the amount of hot water is insufficient, the utility power can be used to compensate. It consists of an advanced MPPT solar water heating controller (efficiency >99%) which is able to achieve intelligent switching, maximize the use of solar energy in order to save electricity, and implement triple leakage protection, two-stage over-temperature protection in order to protect the water heater from damage. PV heating is prioritized when the PV voltage is within the operating range of the controller; if the solar voltage falls below the controller's operating range, the controller will switch to mains heating until the water temperature reaches the maximum set temperature and stops heating. The hot water output rate exceeds 70%. The MICOE PV and grid combined hot water heating with intelligent switching is illustrated in Figure 111, showing the components and wiring paths in the system. The parameters of the products are listed in Table 19.

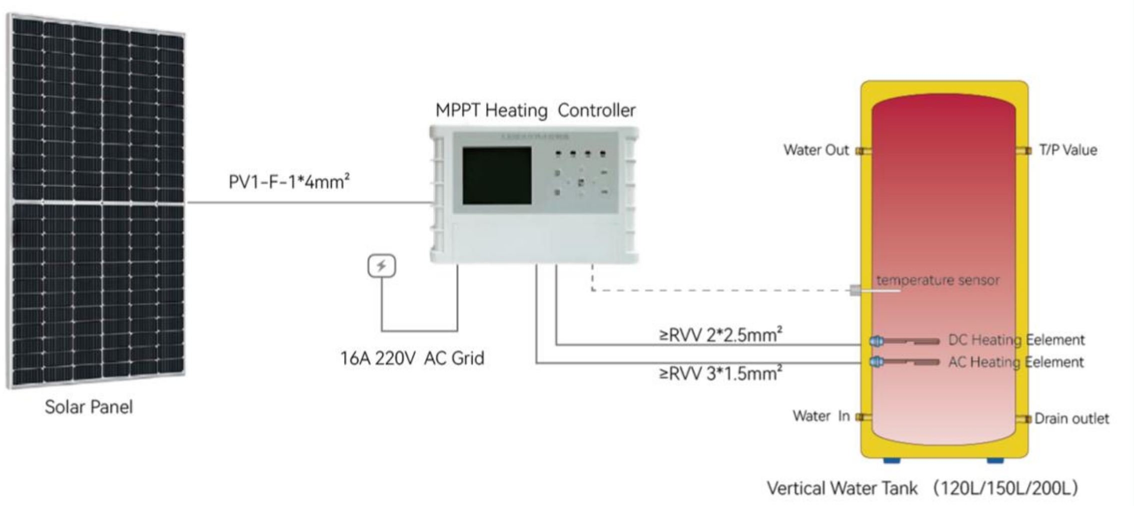

Figure 111. MICOE PV and Grid Combined Heating Hot Water Systems. Source: [P11]

Table 19. Configuration parameters sheet for the MICOE system.

Model	GL-120-2/2-1	GL-150-2/2-1	GL-200-2/2-1
Capacity	120L	150L	200L
PV Input Data			
Recommend PV Input Power	1100W	1650W	2200W
MPPT Operating Voltage Range	36Vdc~150Vdc		
PV numbers	550W*2 PCS	550W*3 PCS	550W*4 PCS
AC Electric Heater Data			
AC Rated Power	2000W		
AC Rated Voltage	230V		
DC Electric Heater Data			
DC Rated Power	2000W		
DC Rated Voltage	120V		
Tank Data			
Size	Φ450*1290	Φ520*1190	Φ520*1540
Temperature Setting Range	55℃~80℃		
Protection Function	Leakage protection, Over temperature Protection		
Inner Liner Material	Enamel		
Rated Pressure	0.7MPa		

The PV water heater market in China reached RMB 35 billion in 2023, a 10% increase over the previous year. As a result of technological advancements, PV water heaters have become more affordable, have improved in performance, and have met a variety of consumer needs. Smart products are gradually becoming the new favorites on the market, allowing remote control and monitoring via the Internet to improve the user's experience and to reduce energy consumption. In addition to market promotion, government support for PV water heaters includes technical research and development as well as standardization. An important characteristic of the market trend is its diversification and intelligence. Agricultural, commercial, and industrial applications of PV water heaters are widespread in China. The penetration rate of PV water heaters is increasing, especially in rural areas. PV water heater exports from China are on the rise, and international market demand is also gradually rising as the competitiveness of domestic products improves. Despite the broad market prospects, the industry is still facing several challenges, such as a lack of technological innovation, a lagging industrial upgrade, and a lack of market standardization.

China's PV water heater market has shown positive developments in terms of technology, policy, and market trends, but still needs to overcome some challenges in order to maintain sustained growth.

4.5.5 Other markets

There are small markets like for example the Austrian market, that have seen considerable market growth of PV Hot Water Technologies over the last years.

In Austria, the company my-PV GmbH for example offers PV driven solutions for hot water; electricity and hot water; electricity, hot water and heating; and electricity, hot water, heating and e-car with photovoltaics.

The company’s solutions support the increased self-consumption of the produced PV power and can be combined with battery storage and smart home solutions. Further the company offers solutions to also benefit from dynamic electricity tariffs. There are grid-connected solutions (diverter is needed) as well as autonomous off-grid solutions (DC elements without diverter) available.

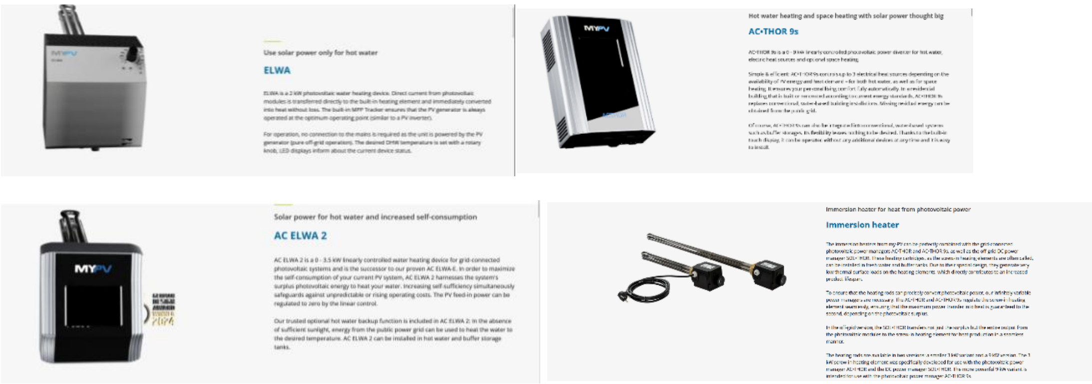

Figure 112. Examples of my-PV solutions for hot water, electricity and heating as well as e-car. Source: [P12]

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5 Discussion and Outlook

5.1 Thermosyphon solar water heating

Thermosyphon systems will likely continue a key role in the solar hot water market in the near future. The analysis showed a large regional diversification in terms of dominant technologies, market dynamics and boundaries. The key points can be summarized as follows:

Main applications: Across all regions, thermosyphon systems are mainly used in residential buildings, particularly for single-family homes in rural areas. There are some applications for multiple storey residential buildings in urban areas, for example in China and India, and applications in hotels, hospitals and public buildings as it is the case in Sub-Sahara Africa. As system sizes increase, indirect thermosyphon systems become more common or DHW supply is switched to pumped systems or alternative solutions (heat pumps, district heating, etc.) altogether. Urbanization is likely to take a toll on the thermosyphon market, as roof areas become scarce, aggregate DHW supply is enabled, and expectations regarding comfort grow, as it is the case in China.

System design: Direct systems are common in warmer climates in China, India, Latin America, Sub-Sahara Africa and the MENA region where there is no risk of freezing. In colder climates as in Europe, Japan or parts of China, indirect systems are prevalent. In China, most systems use evacuated tube collectors, especially in colder regions, whereas in Europe, flat plate collectors are dominant. These stark differences cannot be explained by environmental factors alone, and are presumably due to economic advantages in the mass production of evacuated tube collector systems, whereas highly industrialized areas favor more expensive flat-plate collector systems with higher life expectancy [8].

Market Dynamics, challenges and competitors: Most of Chinese manufacturers expect no or low growth market, while the market players in other regions, especially in Sub-Sahara Africa, Latin America and Europe's Mediterranean area are more optimistic. What stands out is that the Chinese market is under pressure from other renewable technologies. Almost all manufacturers are diversifying their product range by offering these technologies, which will most likely substantially affect the global market leading to economies of scale in production and distribution. This is much less the case in other regions, for example in Europe or Latin America, where joint production of solar thermal and PV products is uncommon. In some regions like Latin America (with gas-fired water heaters) and Sub-Sahra Africa (with electric water heaters), there is one dominant fossil-fuel based technology available, which would need wide-spread policy adaptions to crack its hegemony. Global barriers to more widespread adoption are the “fragile” reputation of the thermosyphon systems, with increasing marketing activities and improve durability and reliability, in addition to price reduction, seen as the top priorities to increase market penetration. Interestingly, price reductions are seen as the lowest challenge for Chinese manufacturers, which seem to have optimized mass production over the last decades.

Production and local value creation: Overall, the target markets for manufacturers are mostly domestic, with some local manufacturers like in Sub-Sahara Africa producing exclusively for local demand. China dominates global production and exports of thermosyphon systems. Chinese manufacturers almost exclusively supply the Chinese market and have other Asian countries as their main export markets. India also has a strong local industry. On a global scale, these two countries are the only ones with substantial production of evacuated tube collectors for thermosyphon systems. Other regions like Latin America and Sub-Sahara Africa have local production of flat-plate collector systems, which compete with imported products from China. European manufacturing is strongly export-oriented with flat-plate collector systems in the higher price range. The example of Puerto Rico shows how local manufacturing can be boosted with small and medium-sized enterprises. Starting in 2008, manufacturers were provided with tax incentives for local manufacturing, which lead to substantial growth of compagnies how acquire components from the US, European and Chinese suppliers and assemble them in Puerto Rico.

Hot Water Load: Daily hot water demand varies across regions, with a very high usage in Japan (~100 L/day) due to cultural bathing habits, and generally higher loads in urban areas and lower in rural regions. However, the actual hot water load does not translate to higher penetration of thermosyphon systems, as the hot water load is positively correlated with urbanization and industrialization, but thermosyphon systems experience adverse effects.

Environmental conditions: Thermosyphon systems thrive in high-irradiance regions, where there is a lower chance of freezing and high irradiance and warmer temperatures enhance the performance. In Europe’s Mediterranean region, moderate winters allow for year-round use. Overall, regional differences dictate system design, with flat plate collectors being better suited in moderate climates and evacuated tubes suited for variable or high-altitude environments.

Subsidy schemes, promotion schemes and government policies: Government-backed energy efficiency policies significantly impact adoption rates, and regions with active incentives see sustained market growth. China previously offered strong incentives for nearly two decades, but as the development is relatively mature, the subsidy mechanisms have been withdrawal since the 2010s. New building regulations require to install solar energy systems for all new buildings, independent of the technology. This shift towards technology-open policies targeting the building sector rather than offering specific incentives for thermosyphon systems will likely become more prominent around the globe, with increased pressure for thermosyphon systems from other renewable technologies.

Product certification schemes and standards: The adaption of standards vary globally. Europe follows Solar Keymark and ISO standards to ensure high product quality. India and Latin America have fewer mandatory regulations, leading to varying product quality. Lack of standardization in Africa and parts of Latin America affects export potential. Globally, stronger certification and performance testing could improve consumer trust, making thermosyphon systems more attractive in highly regulated, competitive markets.

Trends towards smart components: The integration of smart control, remote access via cell phone, and temperature visualization and monitoring on apps are major trends in incorporating digital technologies. These are especially prevalent in the Chinese and Indian market and are likely to rapidly expand to other markets.

Prices and cost saving potentials: Thermosyphon solar water heating systems exhibit considerable regional price variations due to differences in manufacturing costs, regulatory frameworks, and market demand. In low-cost manufacturing hubs such as China and India, typical system prices range are in $250-500 and $500-1000 ranges for standard sized thermosyphon system (with 150L tank and 2 m2 collector area), primarily due to economies of scale and inexpensive labor. In contrast, European markets, characterized by stringent efficiency standards and high-quality materials, see prices mostly in the $1,000–1,500 range. Latin American, the Middle East, and Sub-Saharan Africa position themselves in the mid-tier range, reflecting local economic conditions and supply chain limitations. Prices in Australia are among the highest worldwide, due to expensive system designs (almost exclusively indirect flat-plate collector systems), high quality, high labor costs and difficulties in large-scale adoption.

Although thermosyphon systems are a well-established technology, there is cost-saving potential in various areas. Firstly, cost-savings can be achieved through innovations. About two-thirds of the manufacturers reported to have introduced new technologies in the last five years. Major improvements are made in the field of smart technologies, but also regarding collector design (e.g., transparent insulation) and tanks (e.g., glass lined storage tanks due to water hardness). Simplified mounting structures, standardization and modular system designs allow for easier transportation and installation, lowering upfront costs, particularly in remote areas. Secondly, the mass production using economies of scale seems to be largely the case in China and partly in Europe and India, but less so in Latin America and Sub-Sahara Africa where there is substantial local demand. Thirdly, in some regions there is an insufficient regulatory framework, e.g., in Sub-Sahara Africa, where there is no regional standard valid for all the countries. This increases costs for certification and exports.

5.2 PV Hot water heating

Renewable electricity is expected to become the fastest-growing heat source in buildings between 2023 and 2028 according to the IEA, largely driven by rapid PV expansion. Falling costs, increasing efficiencies (above 20%, potentially up to 30%), and improved system designs are making PV-based water heating increasingly viable.

Advantages of PV hot water systems are their simplicity and cost-effectiveness. They are easy to install since they require only electrical wiring instead of piping. There are lower thermal losses compared to thermosyphon solar water heaters, and systems are resistant to frost and overheating. Flexible installation within buildings is another advantage besides the enhancement of self-consumption of solar electricity in countries with high PV penetrations to avoid curtailment of PV production. Further, PV hot water systems perform well in colder climates and during wintertime.

Key challenges include high upfront investment, system integration complexity, and lower efficiency compared to solar thermal systems. Additional issues involve grid integration, lack of optimization (e.g., without MPPT), and the need for grid infrastructure upgrades. Safety issues are another topic that must be considered well regarding the direct use of DC elements. Finally, there is a lack of knowledge about end-of-life procedures and recycling strategies.

System types include direct-coupled PV2Heat systems (off-grid), self-consumption optimization systems (with smart controls), PV-driven heat pumps and grid-connected solutions using PV electricity.

PV2Heat systems are particularly suitable for areas with unreliable electricity grids. In countries with high PV penetration surplus PV electricity can be used for water heating to increase self-consumption and support grid stability instead of curtailing PV production. In these cases, hot water tanks can act as flexible energy storage for demand-side management.

Key markets are Australia with high PV penetration and a focus on self-consumption and grid optimization, the United Kingdom where PV diverters are used to utilize surplus electricity, South Africa that saw rapid market growth between 2018 and 2023 due to energy insecurity and policy support and China as the largest and fast-growing market with strong government support and technological innovation. Other smaller markets like Austria are also growing, focusing on smart and integrated energy solutions.

Appendix

Abbreviations

DIR-FLAT	Direct system with flat plate collectors
DIR-ETC	Direct system with evacuated tube collectors
IEA SHC	International Energy Agency Solar Heating and Cooling
IND-FLAT	Indirect system with flat plate collectors
IND-ETC	Indirect system with evacuated tube collectors
LAC	Latin America and the Caribbean
MENA	Middle East and North Africa
SWH	Solar Water Heaters
DHW	Domestic Hot Water

List of Figures

List of Tables

References

Please note that additional region and technology specific literature and resources are given in the respective chapters of this report.

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