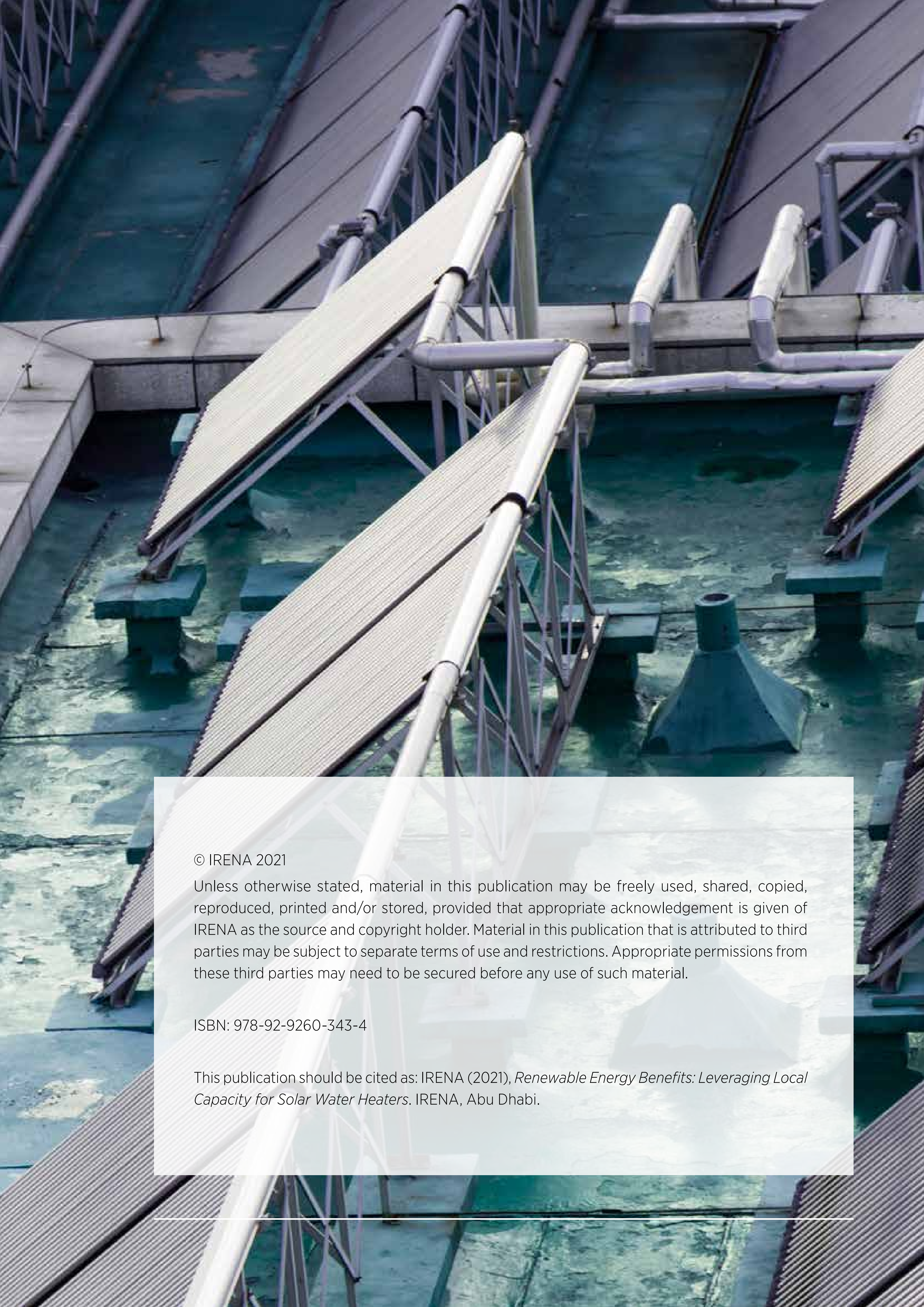
IRENA
International Renewable Energy Agency

RENEWABLE ENERGY BENEFITS

LEVERAGING LOCAL CAPACITY FOR SOLAR WATER HEATERS



ISBN: 978-92-9260-343-4

This publication should be cited as: IRENA (2021), *Renewable Energy Benefits: Leveraging Local Capacity for Solar Water Heaters*. IRENA, Abu Dhabi.

ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

ACKNOWLEDGEMENTS

This report was developed under the guidance of Rabia Ferroukhi (IRENA) and authored by Celia García-Baños (IRENA) with the support of Deloitte Advisory S.L.

The report greatly benefitted from valuable feedback and inputs from Diala Hawila, Ulrike Lehr and Michael Renner (IRENA).

The report benefited from the review by Jose María González Moya (APPA Renovables), Tahmina Mahmud and Olga Strietska-Ilina (ILO), Joumana Sayegh and Tony Gebrayel (LCEC), Deger Saygin (SHURA Energy Transition Center), Jesús García Martín (EU Energy Solutions), Darius Milcius (Lithuanian Energy Institute), Hanna Bartoszewick-Burczy (Institute of Power Engineering), Arslan Khalid (IRENA consultant), Leighton Waterman (formerly IRENA), Jinlei Feng, Abdullah Abou Ali and Sufyan Diab (IRENA) and leading companies from the private sector.

DISCLAIMER

TABLE OF CONTENTS

1. INTRODUCTION 8

2. SOLAR WATER HEATERS TODAY: AN OVERVIEW 9

2.1 Global and regional deployment 9

2.2 Policy instruments driving the deployment of solar water heaters 11

3. SOCIO-ECONOMIC VALUE CREATION FROM THE DEPLOYMENT OF SOLAR WATER HEATERS 17

3.1 Jobs 18

3.2 A closer look at the value chain 20

4. REQUIREMENTS FOR 10 000 SINGLE-FAMILY HOUSEHOLDS WITH RESIDENTIAL SOLAR WATER HEATERS 21

4.1 Overview of labour inputs 21

4.2 Procurement and manufacturing 22

4.3 Sales and distribution 27

4.4 Installation 28

4.5 Operation and maintenance 29

4.6 Decommissioning 31

5. CONCLUSIONS 33

Annex A. Solar water heater technologies 35

Annex B. Solar water heater components 37

REFERENCES 39

PHOTO CREDITS

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ABBREVIATIONS

ETC evacuated tube collector
FPC flat plate collector
GWth gigawatts thermal
ISO International Organization for Standardization
LCOH levelised cost of heat
MW megawatt
O&M operation and maintenance

LIST OF FIGURES, BOXES AND TABLES

Figure 2.1 ■ Global solar thermal capacity in operation, 2000-2019 ... 9

Figure 2.2 ■ Installed capacity in the ten countries that installed the most new solar water heaters in 2018 (MWth) ... 10

Figure 2.3 ■ Ten countries and territories that installed the most solar water heaters per 1 000 inhabitants in 2018 ... 10

Figure 2.4 ■ Ten countries and territories with the greatest cumulative installed capacity per 1 000 inhabitants in 2018 ... 11

Figure 3.1 ■ Employment in solar water heating and cooling by country in 2019 ... 18

Figure 3.2 ■ Value chain of solar water heaters ... 20

Figure 4.1 ■ Solar collector areas required for multi-family households, public facilities and industrial applications. ... 21

Figure 4.2 ■ Distribution of human resources required along the value chain ... 22

Figure 4.3 ■ Human resources required for procurement and manufacturing, by occupation ... 25

Figure 4.4 ■ Human resources required for sales and distribution, by occupation ... 28

Figure 4.5 ■ Human resources required for installation, by occupation ... 29

Figure 4.6 ■ Human resources required for maintenance, by occupation ... 30

Figure 4.7 ■ Human resources required for decommissioning, by occupation ... 31

Figure A.1 ■ Global market share of solar thermal heaters by application, system and technology ... 35

Figure A.2 ■ Differences between a thermosyphon system used to heat water directly (left) and a pumped indirect solar thermal system (right) ... 36

Figure B.1 ■ Heat exchanger configurations (internal, left; external, right) ... 38

Box 3.1 ■ Employment: Full-time equivalents and person-days ... 17

Box 4.1 ■ An overview of solar water heater manufacturers around the world ... 26

Box 4.2 ■ Maintenance activities ... 30

Box B.1 ■ Types of solar collectors ... 37

Table 4.1 ■ Materials required to manufacture the main components of two types of solar water heater (kg/unit) ... 23

Table 4.2 ■ Human resources required to manufacture main components of a solar water heater (person-days) ... 24

Table 4.3 ■ Equipment needed to manufacture components ... 26

Table 4.4 ■ Human resources required for sales and distribution, by activity ... 27

Table A.1 ■ Thermosyphon and pumped systems, direct and indirect ... 35

Table A.2 ■ Evacuated tube collectors vs flat plate collectors ... 36

About the Leveraging Local Capacity series

Renewable energy development can drive economic growth, create new jobs and enhance human health and welfare at the national level. The *Leveraging Local Capacity* series examines the kinds of jobs created and suggests ways to build on existing industries. Each study outlines the requirements along the entire value chain, particularly in terms of human resources and skills, to produce, install and operate plants or facilities based on a specific renewable energy technology.

The series of analyses also assesses the materials and equipment needed in each segment of the value chain, with a focus on identifying the potential for local value creation, and synergies with existing industries that could potentially leverage local capabilities.

To date, studies have been released on large-scale solar photovoltaic, onshore wind and offshore wind. The present report focuses on small-scale solar water heaters. Additional studies on more technologies are in preparation or planned.

The objective of the series is to inform assessments of the feasibility of procuring needed components and services domestically rather than from abroad. The studies can help decision makers identify ways to maximise domestic value creation by leveraging existing industries.

The series is part of IRENA's extensive research work on the impacts of renewable energy deployment during energy transitions, on-going since 2011. The initial focus on employment creation and skills was subsequently extended to cover other socio-economic elements such as gross domestic product, broader measures of welfare, local economic value creation, improved livelihoods and gender-differentiated impacts. These analyses, based on a solid quantitative modelling approach, include present-day global, regional and selected national impacts, as well as projections to 2030 and 2050. An additional dimension was added in the context of responses to the COVID-19 pandemic and its effects.

These and other reports can be downloaded from **www.irena.org/Publications**.

1. INTRODUCTION

Heating and cooling consume the most energy of all end uses, accounting for nearly half of global final energy consumption. Most of this is generated from fossil fuels. In 2019, fossil fuels and non-renewable electricity met more than 77% of heating and cooling demand (IRENA, IEA, REN21, 2020). The energy consumed for heating and cooling is thus a significant contributor to air pollution and carbon dioxide emissions: heating and cooling accounted for almost 40% of energy-related emissions in 2018, a share that has remained almost unchanged for the past decade, owing to the continued dominance of fossil fuels (IRENA, IEA, REN21, 2020).

Half of the energy consumed for heating and cooling is consumed in industrial processes, while another 46% is used in residential and commercial buildings – for space and water heating and, to a lesser extent, for cooking. The remainder is used in agriculture for greenhouse heating and for drying, soil heating and aquaculture (IRENA, IEA, REN21, 2020). Given that heating water accounts for about 18% of household energy use (US DOE, n.d.), on average, and that demand for hot water is growing with household incomes, the decarbonisation of heating and cooling in general, and water heating in particular is thus a key element of the on-going energy transition needed to limit the rise in global temperatures to well below 1.5°C (IRENA, IEA and REN21, 2018, 2020).

Solar thermal systems for water heating, or solar water heaters, represent a mature technology that has been successfully deployed in several developed and developing countries for more than 30 years. In countries like Barbados, Cyprus and Israel, 80 -90% of residential houses have domestic solar water heating systems on their roofs. The deployment of solar water heaters is particularly needed in countries that rely on fossil fuel imports to cover their heating needs, or where the use of electric boilers and heat pumps may strain the electricity system or be unaffordable to many households (ETSAP and IRENA, 2015). In South Africa, for instance, water heating with electricity and gas can account for 30-40% of the energy bill for a typical household (Hohne, Kusakana and Numbi, 2019).

The skills needed to manufacture, install and maintain a solar thermal system are easily transferable from occupations in manufacturing, construction and plumbing. Several countries, including Barbados, Brazil, China, Greece, Israel, South Africa, Tunisia and Turkey, have successfully developed local manufacturing capacity, thus creating jobs and spurring economic development. In most cases, the manufacturers are small to medium enterprises.

This report highlights opportunities to create local value by setting up a domestic industry around solar water heaters. It starts with the status of solar water heaters today, their main technologies and global installations and supporting policy mechanisms (Section 2). It then turns to the value creation and employment to be expected from solar water heater deployment (Section 3). Finally, it considers each segment of the relevant value chain more closely, focusing on human resources, skills and materials requirements (Section 4).

The scope of the analysis is as global as possible. Data were obtained through surveys and interviews with internationally recognised experts, and from desktop research of information published by leading companies and specialised institutions involved in solar thermal systems.[1] The report aims to deepen policy makers' understanding of the steps needed to develop a local market for solar water heaters, and the existing capabilities that can be leveraged to do so.

[1] A large number of stakeholders were interviewed and/or responded to questionnaires regarding the requirements for developing local capacity around solar water heaters. These included project developers, component manufacturers, service providers, energy authorities and representatives of national and global associations dedicated to solar water heaters or renewable energy in general. The study also draws on the public reports of relevant companies, including annual reports, technical specifications and equipment handbooks, and public price lists.

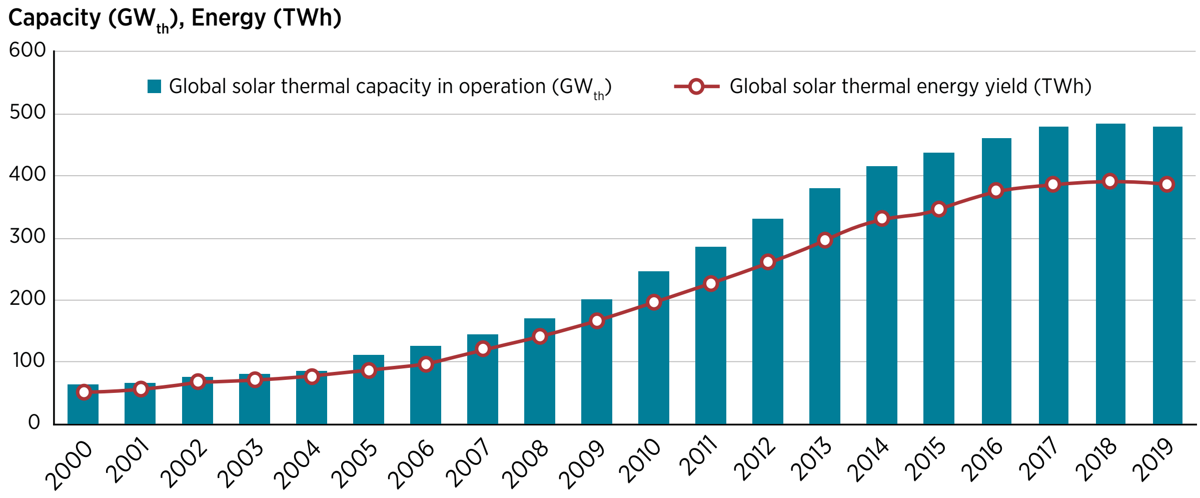
2. SOLAR WATER HEATERS TODAY: AN OVERVIEW

SWH are considered a mature technology; many collector types and system configurations exist that can be used in all climates (see Annex A for a more detailed overview of several types of solar water heaters). Their applications vary with the size of the building and its hot water needs. The potential for local value creation and local production varies by technology, as will be explained in Chapter 5.

2.1 Global and regional deployment

By the end of 2018, the world accounted for an installed solar thermal capacity[2] of 483 gigawatts thermal (GWth) (Figure 2.1) corresponding to 690 million square metres (m^2) of total installed collector area.[3] Installed collectors include both glazed and unglazed, for water and air. Most of the solar energy collected is used to heat water, though applications to heat and cool air exist. As of 2018, solar water heaters accounted for the bulk of installed capacity. In 2019, around 60% of the solar thermal systems installed were small-scale thermosiphon systems.[4] Large systems installed in multi-family buildings and establishments in the tourism and public sectors accounted for 28% of the total, followed by swimming pools, with 6%. Only about 3% of systems were for heating and cooling air (IEA-SHC, 2020).

Figure 2.1 ■ Global solar thermal capacity in operation, 2000-2019

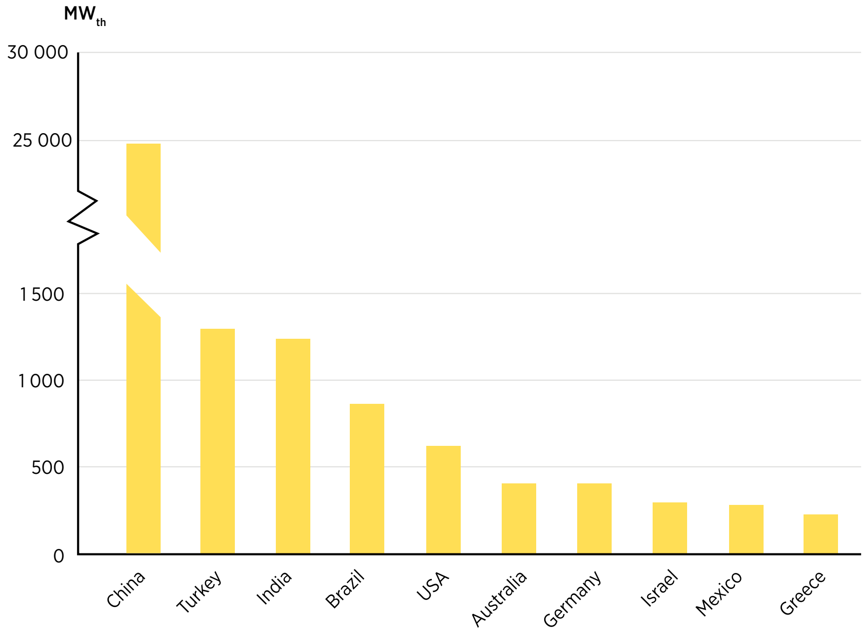


Source: Based on IEA-SHC (2020).
Note: The figures include unglazed and glazed water collectors.

China had the largest number of newly installed solar water heaters (glazed and unglazed), at almost 25 GWth in 2018, followed by Turkey and India with around 1.3 GWth. Brazil installed 875 megawatts thermal (MWth), and the United States, 623 MWth. Figure 2.2 shows the installed capacity by 2018 of the ten countries that installed the most solar water heaters in 2018 (MWth). Since China imbalances any cross-country comparison by its sheer size, looking at recent additions per capita and cumulative additions per capita completes the picture. For example, looking at newly installed solar water heaters per 1 000 inhabitants in 2018 reveals that several small countries and territories with smaller populations made important strides in deploying the technology (Figure 2.3). Resource potential cannot be the main driver of deployment, given that Denmark, a country with poor solar resources, ranks among the top ten.

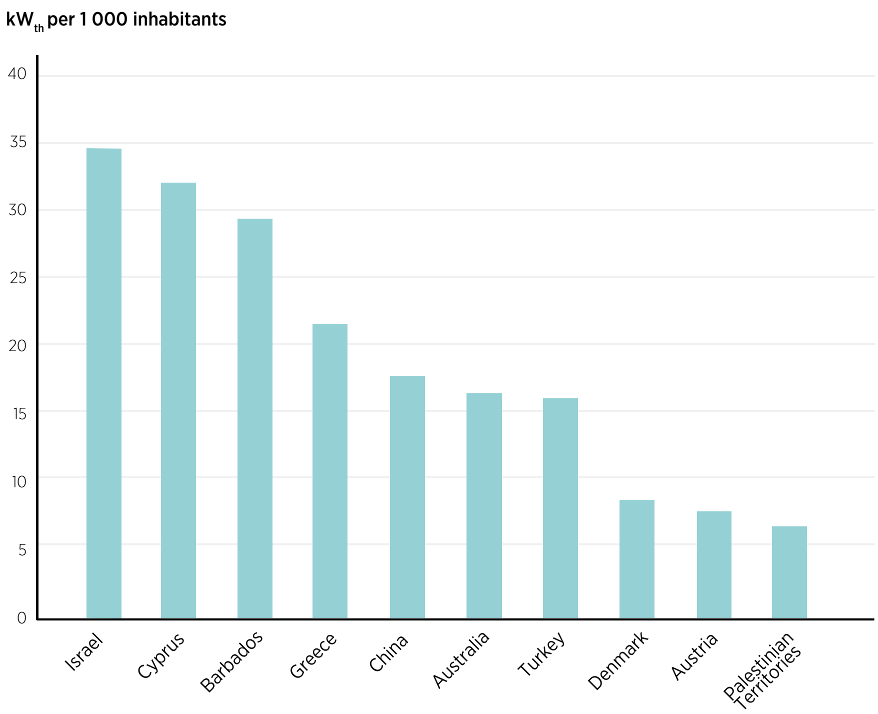
[2] This is solar thermal capacity for heating and cooling in general and is not limited to water heating.
[3] This was equivalent to 388 terawatt hours of annual solar thermal yield in 2017 and equates to ~700 watts thermal/m^2.
[4] A thermosiphon system is “a passive solar hot water system that relies on natural convection to circulate water through the collectors and to the tank. In this type of installation, the tank must be above the collector. As water in the collector heats, it becomes lighter and rises naturally into the tank above. Meanwhile, cooler water in the tank flows down pipes to the bottom of the collector, causing circulation throughout the system. The storage tank is attached to the top of the collector so that thermosiphoning can occur” (David Darling, n.d.).

Figure 2.2 ■ Installed capacity in the ten countries that installed the most new solar water heaters in 2018 (MWth)



Source: Based on IEA-SHC (2020).
Note: The figures include evacuated tube collectors, glazed and unglazed water collectors.

Figure 2.3 ■ Ten countries and territories that installed the most solar water heaters per 1 000 inhabitants in 2018



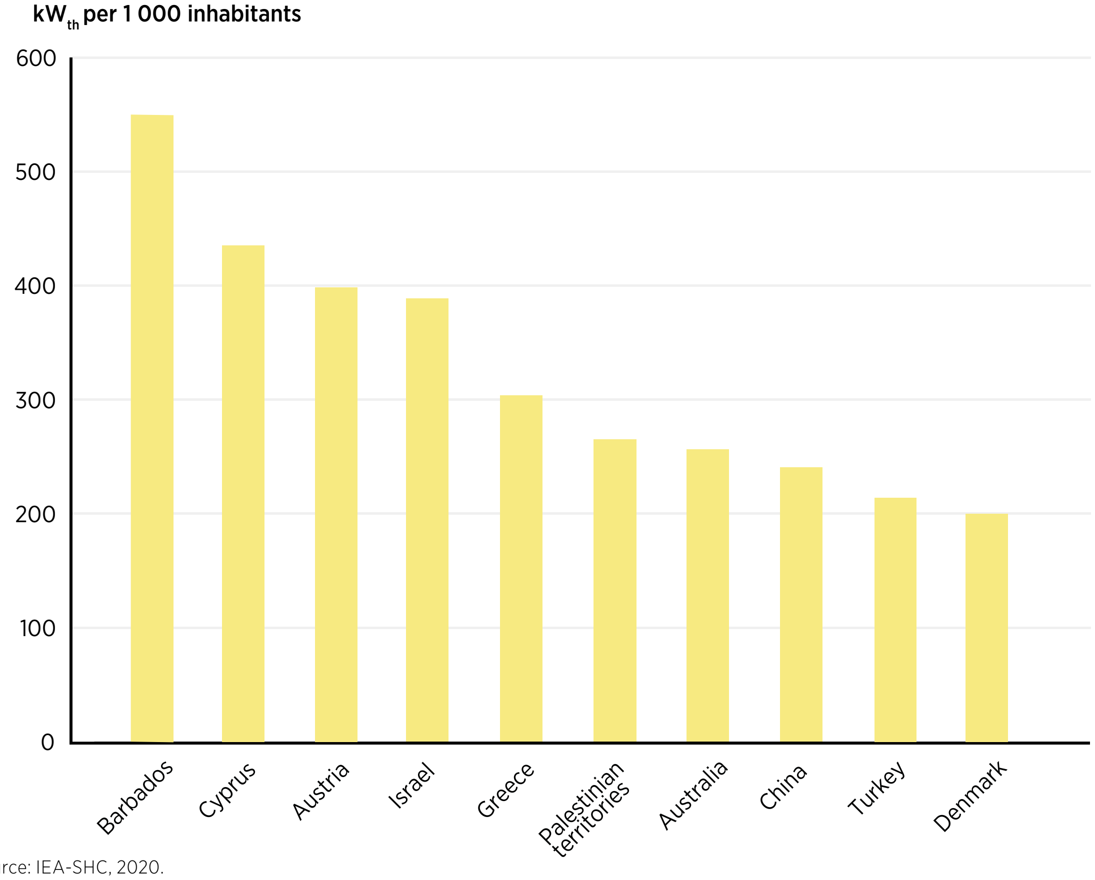
Source: IEA-SHC, 2020.
Note: The figures include evacuated tube collectors, glazed and unglazed water collectors.

The ten countries that added the most capacity per 1 000 inhabitants in 2018 were also the ones that had the greatest cumulative installed capacity per 1 000 inhabitants that same year (Figure 2.4), although in a different order. Barbados and Cyprus rank highest in this top ten, is due to resource scarcity, high prices of fossil fuel imports and/or limited access to alternative fuels – typical of island states.

2.2 Policy instruments driving the deployment of solar water heaters

Although often cost competitive, solar water heater deployment requires policy support. The barriers are manifold. For instance, low levels of awareness by households about modern hot water generating systems based on renewables hinders deployment. Homeowners tend to choose a known option. As a result, the deployment of solar water heaters has been largely supported by a mix of policies in many countries. These include direct policies such as targets, programmes, obligations and mandates, and financial incentives such as subsidies and low-interest loans to lighten the burden of the high initial cost (relative to cheaper alternatives such as gas boilers). In addition, enabling policies such as technical standards and certificates and training and retraining measures help create an enabling environment for the development of a solar water heater sector. Broader enabling policies are discussed in *Policies in a Time of Transition: Heating and Cooling* (IRENA, IEA and REN21, 2020).

Figure 2.4 ■ Ten countries and territories with the greatest cumulative installed capacity per 1 000 inhabitants in 2018



Source: IEA-SHC, 2020.
Note: The figures include evacuated tube collectors, glazed and unglazed water collectors.

Targets

Targets provide a clear indication of the intended deployment and timeline envisioned by the government. They inform industries and consumers alike, and often become key drivers of policy, investment and development. Targets for solar water heaters are set in terms of the number of systems, collector surface or thermal capacity.[5]

Ambitious solar thermal targets and low system prices have driven the impressive growth of solar water heaters in China. The country's 12th Five-Year Plan (2011-2015) included a target of installing 400 million m^2 of cumulative solar water collector surface. It was exceeded by more than 10.5%. By 2020, the end of the 13th Five-Year Plan period, this number was expected to have doubled to 800 million m^2 (NDRC, 2016).

In 2009, South Africa set a target of 1 million solar water heaters to be installed within five years (South Africa DOE, n.d.). Although supported by financial instruments, only about 400 000 systems were installed. In relative terms, solar thermal capacity still increased by more than 50% between 2010 and 2015. South Africa has since updated its target to 1.75 million systems by 2019 and 5 million by 2030 (IRENA, 2018).

In Lebanon, a 2020 target of 1 054 000 m^2 installed surface area was supported by financial mechanisms including favourable loans and cash-back applications (LCEC, 2016). By the end of 2015, the country had 683 133 m^2 installed surface area, and by the end of 2018, only around 150 000 m^2 had been added, far below the indicated target (IEA-SHC, 2020). The government has also set national targets for solar water heaters in the National Renewable Energy Action Plan, aiming for 1 716 835 m^2 by 2030 (IRENA, 2020a; UNDP, 2019).

[5] For a rough comparison, around 4 m^2 surface area is assumed to be equivalent to 2.8 KWth capacity.

Obligations and mandates

Obligations and mandates have been instrumental in encouraging the deployment of solar water heaters in many countries. Systems are most frequently installed in new or renovated buildings, often as mandated by building codes at the regional, national, subnational or municipal level.

The first country to mandate the installation of solar water heaters in new buildings was Israel, in the 1980s. Israel now has among the highest penetration rates of solar water heaters in the world. India's Energy Conservation Building Code of 2017 proposes that 20-40% of the hot water demand in new hotels and hospitals across the country, as well as in new buildings in regions with cold winters, should be met by solar systems. While compliance with the code is not mandatory, some states and municipalities use it to regulate construction. In 2009, Germany set an obligation for the use of renewable energy in buildings larger than 50 m^2. Heating (or cooling) energy requirements must be covered from renewable energies to an extent that varies according to the type of energy used, for instance, 15% for solar water heaters (BBSR-Energieeinsparung, n.d.).

Building codes and mandates are often regulated and put into practice at the municipal level of government. In China, for example, Shenzhen requires since 2010 that all new residential buildings with fewer than 12 floors install solar water heaters. In Brazil, many cities have established solar mandates. São Paulo, for example (since 2007), mandates that 40% of the energy needed to heat water in newly constructed buildings, both residential and commercial, should be solar. At the state level, Rio de Janeiro implemented a mandate in 2008 that all new and refurbished public buildings meet at least 40% of their water heating needs with solar energy (IRENA, 2015). Solar water heaters are also a requirement for new social housing projects, specifically under the Minha Casa, Minha Vida ("My House, My Life") programme. (IRENA, 2021).

Although building codes and mandates work well for new and refurbished buildings, financial incentives are often needed to upgrade existing buildings or to mitigate high upfront costs.

Financial incentives

In some cases, as in China and Turkey, the main driver for the deployment of solar water heaters is their competitive pricing, relative to the alternatives. They are seen to be most affordable in sunny regions where markets are well developed, featuring a large number of suppliers and easy payment options. But this is not the case in general, and financial incentives are still required to increase the cost competitiveness of solar water heaters compared to other solutions. Financial incentives include a range of grants, low-interest loans and tax incentives are most widely used in low-income countries where support is needed for the initial investment and where the alternatives (e.g., electricity, gas or diesel) are low cost, most often due to subsidies.

In South Africa, the National Energy Regulator allocated funds to marketing and incentives to support the target of installing 1 million solar water heaters within five years. The state utility company Eskom has subsidised purchases of registered solar water heaters since 2008. More than 122 000 systems were rolled out by the end of 2011, resulting in energy savings of approximately 60 gigawatt hours/year (Eskom, 2011).

In Tunisia, the government, supported by the United Nations Environment Programme, provided subsidies and concessional loans for solar water heaters to counter the market barrier imposed by their high upfront costs. Tunisia's solar programme, Programme national de promotion du solaire thermique en Tunisie, started a funding mechanism in 2005. In its first phase, focused on supplier lending, it supported a 20% subsidy of the capital costs of solar water heaters, a temporary interest rate subsidy (gradually phased out after 18 months) and credit repayable over five years.

Individual suppliers acted as indirect lenders and debt guarantors for consumers, while the Tunisian Electricity and Gas Company (Société Tunisienne de l'Électricité et du Gaz) collected loan repayments through utility bills. In its second phase, focused on consumer lending, it granted direct credit to households for solar water heater installation, relieving suppliers from debt liability. The company serves as a guarantor of household repayment. Bonuses of Tunisian dinar (TD) 200-400 (USD 150-300)[6] have replaced the 20% subsidy (CPI, 2012).

In Lebanon, the Ministry of Energy and Water and the Central Bank of Lebanon developed a national financing mechanism for solar water heaters that would support the achievement of the ambitious 2030 target. This offers subsidised loans at a 0% interest rate, in addition to a USD 200 subsidy for the first 7 500 loan applications. By the end of 2017, more than USD 1 450 000 had been injected into the market via the USD 200 grants. The mechanism has helped generate by the end of 2017 investments exceeding USD 135 million in solar water heaters in Lebanon (Ministry of Energy and Water/LCEC, 2019)

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[6] Currency conversion based on an exchange rate of TD 1.33 per USD in 2012.

Barbados has implemented financial incentives at times combined with mandates. The price of fossil fuels here is notably high. Solar water heaters rose in prominence back in the early 1970s after oil prices tripled in one year. The initial costs of a solar water heater could be recuperated in a few months. A tax exemption for the materials used to produce solar water heaters was introduced in 1974, reducing their cost by 20%. In the late 1970s, the government mandated the installation of solar water heaters in new government housing developments. In 1980, a tax benefit was introduced, making the full cost of installation tax deductible up to a maximum of USD 1 750. As a result, by 2009, there were around 45 000 solar water systems installed in Barbados (covering 40% of households) (US DOE, 2015; IRENA, 2014).

However, in many countries, fossil fuels and/or electricity are still subsidised, making it difficult for the solar water heating market to realise its potential. Reforming fossil fuel subsidies and putting a price on carbon can help level the playing field, although such steps may be politically difficult to implement.

In Sweden, a carbon tax was first introduced in 1991 at a rate of Sweden kronor (SEK) 250 (USD 41.4)[7] per tonne of fossil-fuel-based carbon dioxide emitted; by 2018, the tax was EUR 120 (USD 148)[8] per tonne (Sweden, 2018). Initially, the carbon tax had a positive effect on the solar heating market, with installations growing rapidly until around 2006. The market then started to decline slightly until 2011 when the decrease of installations became more acute. This decline is justified by the fact that the investment grant for solar heating systems was removed, prices for heat pumps decreased and there was a large increase in solar electricity (photovoltaic) (IEA-SHC, 2020).

7 Currency conversion based on an exchange rate of SEK 6.04 per USD in 1991.
8 Currency conversion based on an exchange rate of EUR 0.811 per USD in 2018.

Standards for solar water heaters

Technical standards are needed to support the creation of certifications and warranties, which in turn signal product quality to installers and consumers. Technical information such as product design details and service requirements must be provided. And where systems are produced locally, international standards for design requirements and testing methods should be applied. In the United States, inconsistencies in testing and rating requirements across states posed a challenge to manufacturers selling in more than one state (ACEEE, 2010). To support the development of a uniform, national standard for testing and rating solar equipment, the solar energy industry and a national consortium of utilities, state energy offices and regulatory bodies joined to lay the groundwork for the Solar Rating and Certification Corporation. At the state level, California's Solar Water Heating Programme, for example, requires residential customers to use the corporation's OG300-rated system in order to qualify for incentives. Standards also apply to larger systems (CPUC, n.d.).

In Lebanon, several technical standards apply to local manufacturers of solar water heaters. These include the Lebanese Norm NL EN 12975, NL EN 12976, NL EN 12977 and ISO (International Organization for Standardization) 9806-1-2. Standards for imported panels and tanks include Lebanese Norm NL EN 12975, in addition to product certifications such as ISO, ROHS (Restriction of Hazardous Substances) and TÜV (Technischer Überwachungsverein) (UNDP/CEDRO, 2015).

Training and retraining

Training and retraining programmes are critical for the proper, efficient and safe installation and maintenance of solar water heaters, and therefore play a key role in their deployment globally. Installing and maintaining these heaters involves a wide range of occupations (e.g., sales, engineering and plumbing) that could easily be fulfilled in relevant or cross-cutting sectors, with appropriate training and retraining.

In 2012, public and private actors in Mexico convened a working group to develop a standard installation process for solar water heaters. The Occupational Competency Standard EC0325 was published in May 2013 and used in the training and certification of 200 installers in 11 Mexican states (BMUB, 2015).

Since 2011 the Australian government has run a programme to train plumbers in installing and commissioning water heating systems (Australia, 2011).

3. SOCIO-ECONOMIC VALUE CREATION FROM THE DEPLOYMENT OF SOLAR WATER HEATERS

As countries move towards their renewable energy targets and ramp up efforts to reduce carbon emissions, heating water using renewable energy sources should be considered as a part of this effort. Estimates for the near future see the global market for solar water heaters cross USD 4 billion by 2024 (Global Market Insights, 2017). Next to the environmental benefits, this presents ample opportunities for socio-economic value creation and employment.

The deployment of renewable energy leads to jobs in different sectors, of different qualifications and duration. This study focuses on direct employment, which refers to employment that is generated directly by core activities without considering the intermediate inputs necessary to manufacture, install and operate solar water heaters. Other types of employment are indirect employment, including in upstream industries that supply and support core activities, or even more comprehensive induced employment, encompassing jobs resulting from additional income being spent on goods and services in the broader economy (such as food, clothing, transportation and entertainment).

Direct employment can be measured as the number of people needed to produce, install or maintain a solar water heater system of specific size and purpose. This analysis is based on a unit for a four-person household, comprising a 4 m^2 solar collector, one pump and a storage tank of 300 litres capacity. To make these numbers comparable across different renewable energy technologies and across economic sectors, they are converted to full-time equivalents (see Box 3.1) in the analysis presented in Chapter 4.

Box 3.1 ■ Employment: Full-time equivalents and person-days

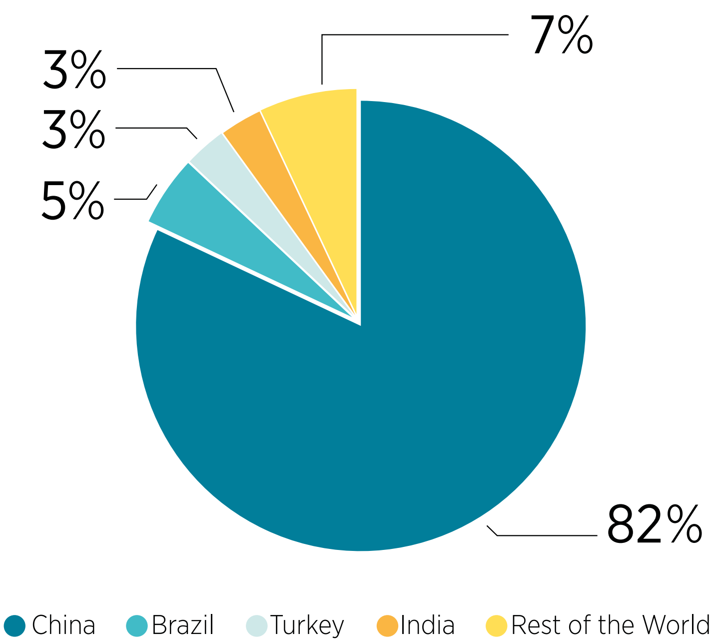
One full-time equivalent job is equal to one person working full time over the course of a year (specific definitions of how many hours per work week constitute full-time employment vary, depending on national legislation or local practice). This headcount is useful to compare jobs from renewable energy to labour market data, such as unemployment. Also, headcounts are a good measure for assessing training needs and capacity building.

Alternatively, employment can be measured in person-days. This measure reflects the amount of work done by one person working full time in one day. Person-days cumulate over time, so if the same person performs a task for two years, it is counted as one job, but two person-years. Person-years are most useful for estimating the amount of effort being devoted to a task over its lifetime.

3.1 Jobs

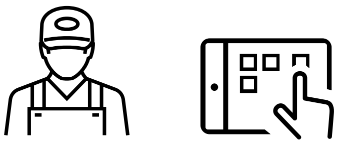
Worldwide employment (direct and indirect) in the solar heating and cooling sector was estimated at around 817 620 jobs in 2019. The largest number of jobs were in China, Brazil, Turkey and India. China accounted for about 83% of the global employment in the sector, with 670 000 jobs, followed by Brazil with 43 900 jobs, Turkey with 21 600 and India with 20 690 jobs (IRENA, 2020b) (Figure 3.1).

Figure 3.1 ■ Employment in solar water heating and cooling by country in 2019



Source: Based on IRENA (2020b).

As solar water heating involves a relatively simple technology (see section 2.1), local manufacturers – often small to medium enterprises – can produce, install and maintain the systems in most countries. Several countries (such as Argentina, Australia, Austria, Barbados, Brazil, China, Greece, Israel, Jordan, Lebanon, Spain, South Africa, Tunisia, Turkey and Uruguay) have successfully developed local industries, thus generating jobs and stimulating economic development. By 2015, Australia had almost 1 000 fulltime equivalent jobs in the solar water heating market according to Australia's Clean Energy Council, and Spain had 5 000 (IEA-SHC, 2015). In Lebanon, the number of companies involved in solar water heaters increased from 25 in 2005 to more than 170 by the end of 2017 (UNDP, 2019). A large percentage of the solar water heaters installed in Tunisia are also assembled there. Since the start of its programme, Tunisia has witnessed the establishment of seven domestic manufacturers and assemblers, and over 1 200 microenterprises working in installation and operation and maintenance (UNDP, 2019).

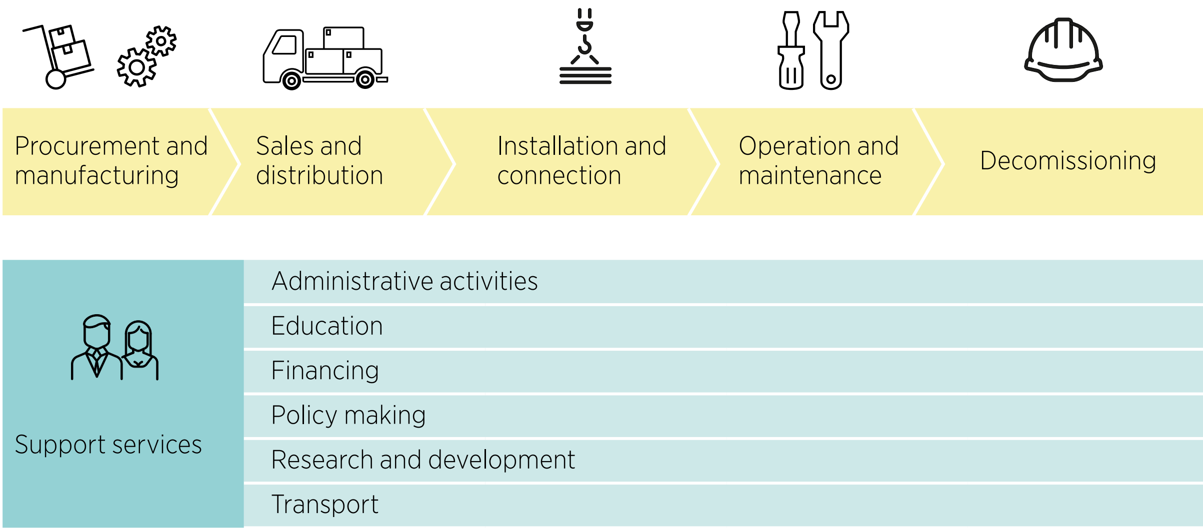


3.2 A closer look at the value chain

For a country adopting solar water heaters, the potential to generate income and create jobs depends on the extent to which solar water heater industries can leverage existing economic activities or create new ones. The potential to create value mostly lies in the following phases of the value chain: manufacturing, wholesale distribution, sales and installation, and maintenance and operation of solar water heaters. As with deployment, socio-economic value creation relies on the policies in place to develop the industry.

Designing policies to maximise local benefits from the deployment of solar water heaters requires a deep understanding of the requirements for labour, skills, materials and equipment. The following section provides a detailed assessment of such requirements. To better illustrate the needs with data, all numbers refer to a market serving 10 000 single-family (four-person) households. The assessment focuses on the core segments of the value chain: procurement of materials and manufacturing of equipment, sales and distribution, installation, operation and maintenance, and decommissioning of solar water heaters (Figure 3.2)[9].

Figure 3.2 ■ Value chain of solar water heaters



[9] Support services include administrative activities, education, financial services, policy making, research and development, and transport. Many of these activities can be developed locally, but their analysis is beyond the scope of this study.

4. REQUIREMENTS FOR 10 000 SINGLE-FAMILY HOUSEHOLDS WITH RESIDENTIAL SOLAR WATER HEATERS

This analysis is based on data from the residential sector, where most solar thermal heaters are deployed. Here, the requisite surface of the collector and the volume of the tank depend on the household usage of hot water. It is assumed that a four-member household uses about 300 litres of hot water per day[10]. For that quantity, a typical solar water heater system consists of a 4 m^2 solar collector, one pump and a storage tank of 300 litres capacity. Figure 4.1 estimates the solar collector areas needed for other applications.

4.1 Overview of labour inputs

The manufacturing, planning, installation and decommissioning of small-scale solar water heater systems for 10 000 single-family households[11] requires more than 460 000 person-days[12], and the labour requirements vary across the value chain. Operation and maintenance work is needed throughout the lifetime of a system and therefore represents a large chunk of the labour required (33%)[13].

As illustrated in Figure 4.2, installation (28%) and decommissioning (20%) are the next largest shares, followed by sales and distribution (10%) and procurement and manufacturing (9%). In other words, countries that do not manufacture equipment domestically can achieve job creation in other segments of the value chain. The bulk of the labour needed involves mostly low- to medium-level technical skills easily available in any country's workforce.

Figure 4.1 ■ Solar collector areas required for multi-family households, public facilities and industrial applications.

Source: Based on ESTIF (n.d.).

[10] Consumption varies based on the location of the household, inhabitants' lifestyles and other circumstances.

[11] This estimate is for 10 000 single-family households. The analysis assumes that the average surface of a solar water heater needed to obtain 1 MWth is 1 429 m^2 (IEA-SHC, 2018). Hence, servicing 10 000 single-family households would require 28 MWth, or 40 000 m^2.

[12] That is, direct jobs required throughout the lifetime of a solar water heater system (from manufacturing to decommissioning). Indirect and induced jobs are not included.

[13] The person-days required for the annual operation and maintenance of 10 000 single-family solar water heaters is estimated to be 7 680. Over a period of 20 years (considered the average life expectancy of these systems), the cumulative total is 153 600 person-days. As solar water heaters involve very mature technology, labour productivity is assumed to not improve over this period.

Figure 4.2 ■ **Distribution of human resources required along the value chain**

Typically, the value chain for any renewable energy project starts with project planning. However, solar water heaters are planned by the household itself. Using data provided by suppliers or installers, households can compare costs and benefits, including the expected return on investment at a household level. Once the decision to invest has been made, administrative tasks are typically undertaken at the individual household level. Such tasks include obtaining a permit or approval from the building owner to install the solar water heater (if required, especially in cases where the system is to be installed on a building rooftop), applying for and securing financing, and selecting the supplier.

Planning the installation of a solar water heater requires some technical knowledge and skills. The supplier/installer recommends the most suitable system and technology based on climatic conditions and, where applicable, the rooftop orientation, incline and shade coverage, etc. Other relevant information includes which equipment types are certified by the government as per recommended or enforced standards and specifications.

4.2 Procurement and manufacturing

Solar water heaters involve a relatively simple technology. Some of the main components – such as the collector, the pump or the storage tank – can be manufactured locally. This depends on three factors: government policies incentivising local value creation, the availability of raw materials and the presence of related industries. But markets can become overdeveloped. Where too much competition is driving prices below what is feasible for manufacturers (as in China), this may in fact discourage the further development of a domestic manufacturing industry.

The procurement and manufacturing of solar water heating systems involve the acquisition of the main components, intermediary products and raw materials. If these are not available locally, they are imported by the manufacturer.

As mentioned in Section 1, the composition of a solar water heater depends on the system used and generally consists of a solar collector, expansion vessel, pump and storage tank. Annex A provides a more detailed description.

The many types of solar heating systems utilise a wide variety of raw materials. Starting with the solar collector, the materials needed depend on the technology selected. Evacuated tube collectors (ETCs) currently dominate the market in China and account for about 70% of the worldwide market, while flat plate collectors (FPCs) dominate in Europe and elsewhere, and account for almost a quarter of the global market (IRENA, 2015; IEA-SHC, 2018).

- ETCs are a series of borosilicate glass tubes each containing a copper heat pipe, also coated with a black chrome selective coating. The heat pipes are connected to a copper manifold. The framework of the collector is made from stainless steel and rock wool is used for insulation.
- In FPCs, copper is used for the pipework attached to the underside of the absorber. The header pipe (manifold) is also made from copper. The absorber is enclosed within low-iron solar glass. Aluminium and stainless steel are the main materials used for the framework and back plate. Rock wool is used for thermal insulation.

Table 4.1 ■ Materials required to manufacture the main components of two types of solar water heater (kg/unit)

MATERIAL (KG)	Evacuated tube collector (ETC)				Flat plate collector (FPC)			
	Collector (absorber, famework, pipework and pipework insulation)	Pump and expansion vessel	Hot water tank	Total per unit	Collector (absorber, famework, pipework and pipework insulation)	Pump and expansion vessel	Hot water tank	Total per unit
Low-alloyed steel	80	4.7	91.74	176.44	128	4.7	91.74	224.44
Copper	43.82	0.625		43.905	43.28	0.625		43.905
Stainless steel	16	2.3	16.68	34.98	16.15	2.3	16.68	35.54
Glass tube (borosilicate)	56.8			56.8				0
Low-iron solar glass				0	36.48			36.48
Elastomere	16			16	16			16
Sheet rolling	11.2			11.2	11.28			11.28
Rock wool	8.12			8.12	9.72			9.72
Glass wool			8.34	8.34			8.34	8.34
Aluminium		0.05		0.05	15.72	0.05		15.77
Cast iron		3		3		3		3
Butyl acrylate		0.7		0.7		0.7		0.7
Alkyd Paint		0.07	0.42	0.49	0.28		0.42	0.7
Corrugated board		0.5		0.5		0.5		0.5
Polyvinyl chlorid		0.075		0.075		0.075	0.83	0.905
Polypropylene		0.025	0.83	0.855		0.025		0.025
Synthetic rubber		0.0175		0.0175		0.0175		0.0175

Source: Based on Greening and Azapagic (2014).
Note: A unit is considered to have 4 m2 collectors.

Furthermore, solar thermal systems may require the use of an electric pump and expansion vessel (the small tank that absorbs the expanding volume and limits the pressure of the circulating fluid), which predominantly are made from low-alloyed steel and coated with alkyd paint.[14] The solar collector and storage tank utilise steel and fibreglass insulated by glass wool (Greening and Azapagic, 2014). Table 4.1 lists the materials required to manufacture the main components of systems with both ETCs and FPCs. The analysis assumes a 4 m^2 solar collector, 25-litre expansion vessel, 100watt electric pump and 250-litre water storage tank.

[14] Alkyd paint, also called oil-based paint even though it contains no oil, is popular in applications that require a high-gloss, durable finish.

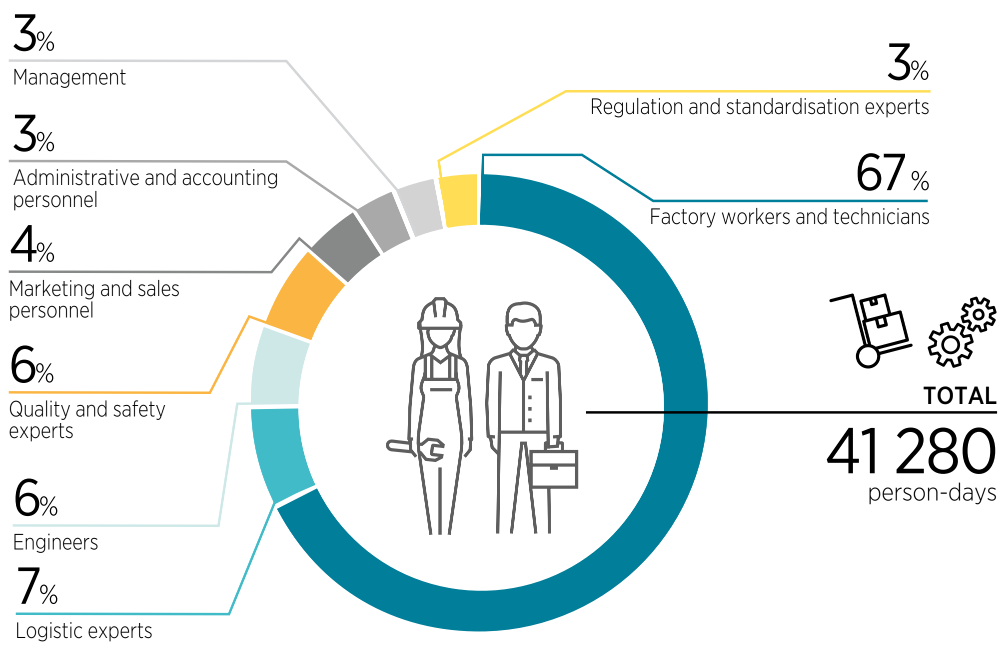
Manufacturing the main components needed for 10 000 households would require 41 280 person-days (Table 4.2), corresponding to less than 10% of the total requirements along the value chain. Out of all components, the manufacturing of the solar collector requires the most work, accounting for 18 000 person-days (44% of the total). The manufacturing of the storage tank requires another 14 400 person-days (35%), followed by the electric pump, which requires 8 800 person-days (21%).

Table 4.2 ■ Human resources required to manufacture main components of a solar water heater (person-days)

TYPE OF HUMAN RESOURCES	Solar collector	Pump	Storage tank	Total by occupation
Factory workers and technicians	12 000	6 000	9 600	**27 600**
Logistic experts	1 200	720	960	**2 880**
Engineers	1 200	480	960	**2 640**
Quality and safety experts	1 200	480	960	**2 640**
Marketing and sales personnel	720	480	480	**1 680**
Administrative and accounting personnel	720	240	480	**1 440**
Management	480	240	480	**1 200**
Regulation and standardisation experts	480	240	480	**1 200**
Total (as %)	**18 000** (44%)	**8 880** (21%)	**14 400** (35%)	**41 280**

Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters.

Figure 4.3 ■ Human resources required for procurement and manufacturing, by occupation



Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters. Due to rounding, percentages presented throughout this document may not precisely reflect the absolute figures.

Figure 4.3 shows the distribution of human resources required, by occupation, to manufacture the main components needed to equip 10 000 single-family households with solar water heating systems. The required workforce mostly consists of factory workers and technicians (67%) who can be easily hired locally. This is followed by logistics experts (7%), and engineers and quality and safety experts (which account for 6% each).

Manufacturing the main components of a solar water heating system requires specialised equipment and machinery (Table 4.3). It also requires equipment commonly used in other industries, such as machines for cutting, welding, washing, bending, melting and joining. Electronic and information technology tools are also used in automated manufacturing and assembly. Components are relatively easy to be transported, especially compared with other renewable technologies such as wind.

Table 4.3 ■ Equipment needed to manufacture components

Solar collector	Pumps	Storage tank
• Equipment to produce glass tubes: furnaces, moulds, coolers and cutting machines • Vacuum tubes production line, where the ends of the inner tubes are melted and welded • Vacuum tube coating line, to coat the inner tube • Vacuum tube cutting and rounding machines, to cut glass tubes • Vacuum machine, to generate vacuum inside tubes • Vacuum tube sealing machine, to seal tubes • Polishing and washing machines	• Sand patterns • Hydraulic presses • Polishing machines	• Welding machines (T.I.G or argon arc) • Solar tank rolling machines • Shearing machines • Cutting machines • Punching machines • Press benders • Test leakage machines • Foaming machines • Flattening machines • Sewing machines • Solar tank cover machines

Given the simplicity of the assembly and the manufacturing process of most of the pieces, the decision to do it locally might involve factors such as forecasted market demand (domestic, regional and international) and the level of competitiveness with exporting countries. Box 4.1 discusses some of the main manufacturers globally.

Box 4.1 ■ An overview of solar water heater manufacturers around the world

China has maintained its lead in the global solar heating industry for many years, as the biggest solar water heater producer since the late 1990s. Its largest companies – Sunrain Group, BTE Solar, Linuo Group, Himin Solar and Sunshore Solar – have integrated vertically to cover all stages of manufacturing. In 2017, the Chinese company Haier became the largest flat plate collector manufacturer worldwide by overtaking GREENoneTec (Austria) which had until then held the top position. Although most Chinese water collector production is of vacuum tube systems (evacuated tube collectors) that are installed domestically, an increasing number of companies offer both vacuum tube and flat plate collectors, and exports of all collectors have increased considerably in recent years.

The largest manufacturers of FPCs globally include GREENoneTec (Austria), BTE Solar (China), Five Star (China), Bosch Thermotechnik (Germany) and Dimas (Greece). Germany-based companies accounted for almost half of the top 19 FPC manufacturers in 2007, but by 2017 they made up only about one-quarter. Turkey and India are among the world's largest FPC manufacturers.

Although South Africa has seen a significant increase in the number of installers in recent years, its number of domestic manufacturers has declined due to rising competition from Chinese imports. In emerging markets, such as Lebanon, manufacturing is focused on tanks and stands, with almost 20 companies producing these components domestically.

Sources: REN21, 2013; UNDP/CEDRO, 2015; Solrico, 2017.

4.3 Sales and distribution

In the sales and distribution phase, distributors and wholesalers transport solar water heaters from manufacturers to households, creating many opportunities for value creation. In this analysis, the term wholesale refers to the purchase of solar water heaters from the manufacturers (including imports for imported equipment) and distribution involves the sale of systems to final customers using multiple channels. Distribution also encompasses the transport of solar water heaters from the warehouse to the installation site, including logistical arrangements.

Components can be conveyed in a typical pickup truck, with no special handling required apart from proper packaging to avoid breakage or scratching.

Selling and distributing solar water heating systems for 10 000 single-family households requires 44 160 person-days (around 10% of the total requirements along the value chain) (Table 4.4). The wholesale activity requires 30% of the total person-days, while the retail distribution of systems is the most labour-intensive activity, involving an estimated 30 960 person-days (70% of the total).

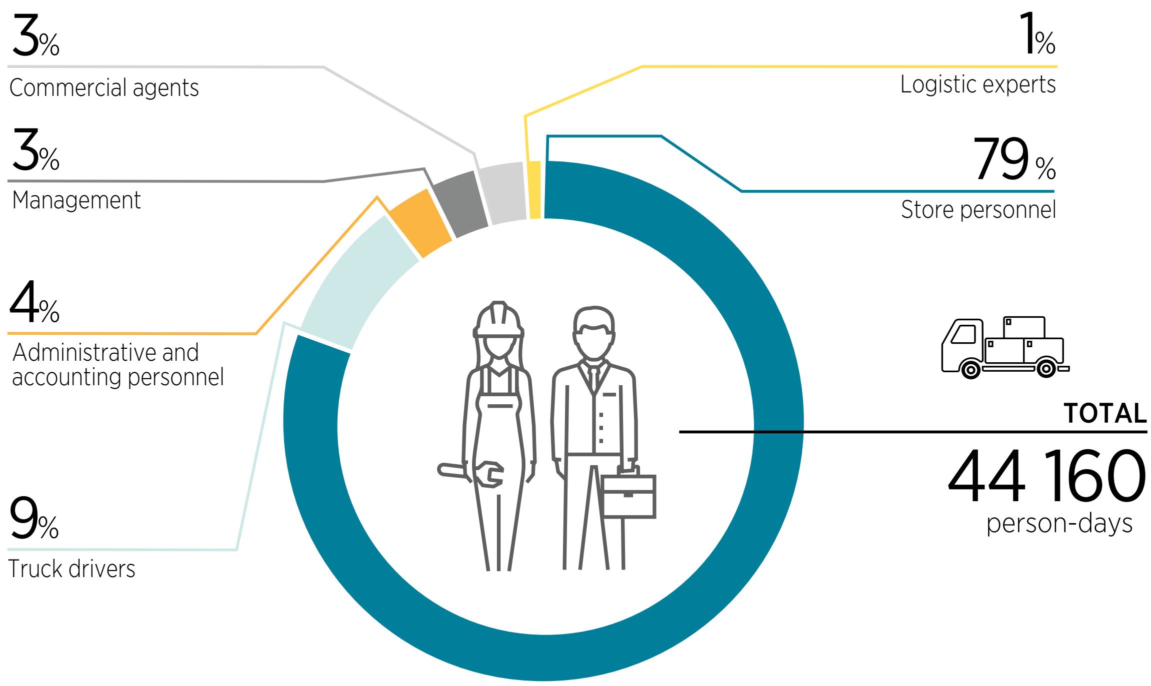
Table 4.4 ■ Human resources required for sales and distribution, by activity

TYPE OF HUMAN RESOURCES	Wholesale	Distribution	Total by occupation
Store personnel	7 440	27 600	**35 040**
Truck drivers	2 640	1 440	**4 080**
Administrative and accountant personnel	480	1 200	**1 680**
Management	960	480	**1 440**
Commercial agents	1 200	0	**1 200**
Procurement and logistic experts	240	240	**480**
Quality and safety experts	240	0	**240**
Total (as %)	**13 200** (30%)	**30 960** (70%)	**44 160**

Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters

In both cases, as illustrated in Figure 4.4, the bulk of labour requirements are fulfilled by store personnel (79% of the total), who may be low- or medium-skilled workers. This is followed by truck drivers, who account for 9% of the total and do not require a special permit. The remaining occupations are distributed almost evenly among administrative and accounting personnel, management and commercial agents (10% in total). The remaining share is taken by experts in procurement and logistics, and quality and safety. All of the above categories of workers can easily be recruited domestically and are found in every sector that has a sales and distribution segment.

Figure 4.4 ■ Human resources required for sales and distribution, by occupation



Source: IRENA analysis.
Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters.
Due to rounding, percentages presented throughout this document may not precisely reflect the absolute figures.

The equipment needed for distribution is the same as that needed for the wholesale transport of any shipment (i.e., trucks, trains, container ships or vessels for transporting the equipment and cranes for loading and unloading) as well as pickup trucks for the delivery of individual systems.

4.4 Installation

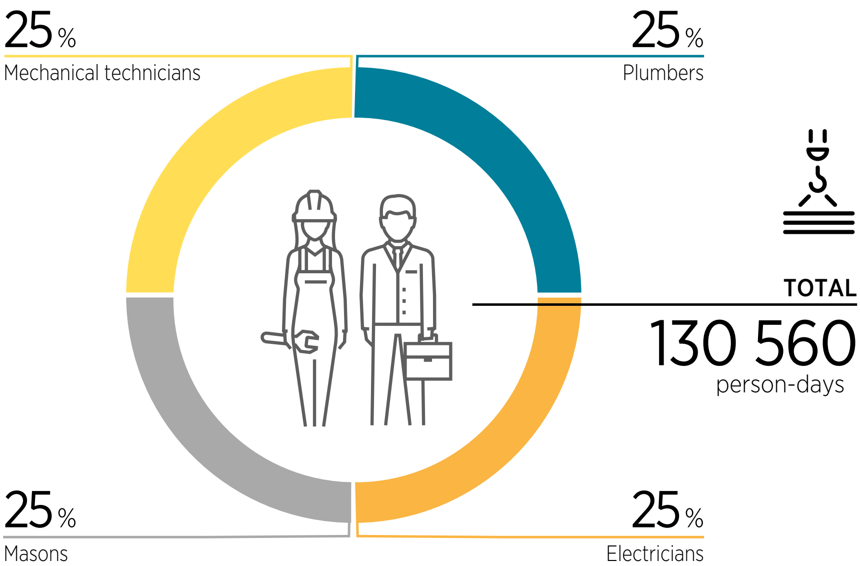
The installation and connection phase per unit can be finalised in a short period of time, but offers the bulk of job opportunities in the sector. The installation of appliances requires site preparation[15] and assembly of the equipment and connections for the valves, circulation pumps, control systems and thermostats. In general, the provider offers the installation and connection services.

Installing and connecting solar water heaters for 10 000 single-family households

[15] Roofs are the most common locations, and must be prepared carefully to avoid causing leaks or weakening the roof structure while anchoring components to it. The systems are often placed on supports or brackets. Ground mounting is sometimes required. For such installations, the lower edge of the collector should be at least one foot above the ground so it will not be obstructed by vegetation or soaked by standing water.

takes about 130 560 person-days (around 28% of the total requirements along the value chain). In terms of occupation, all the requirements are distributed equally among different types of technical personnel, including masons for the preparation of the site, plumbers to connect the pumping and water systems, electricians for the installation of control and electric systems and, finally, the mechanics needed for commissioning and start-up (32 640 person-days, each) (Figure 4.5).

Figure 4.5 ■ Human resources required for installation, by occupation



Source: IRENA analysis.
Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters.
Due to rounding, percentages presented throughout this document may not precisely reflect the absolute figures.

The materials and equipment needed for installation are easily available in every country. Equipment includes auxiliary tools (such as hammers, screws, screwdrivers or ladders), and electrical and electronic instrumentation and control systems used for system connection, start-up and troubleshooting.

4.5 Operation and maintenance

The operation and maintenance phase comprises the activities carried out throughout the operational lifetime of the project to ensure its uninterrupted functioning, including cleaning, technical control and other maintenance activities. While the operation of a system in a single-family household depends directly on the users, its maintenance requires qualified technicians.

All solar water heater systems have multiple components that can fail over the appliance's lifetime, and periodic inspection and maintenance procedures are a must to keep the systems functioning. However, unlike solar photovoltaic technologies, setting up a maintenance contract at the time of purchase and installation is a rare practice – especially for residential purposes – and maintenance is rarely conducted until the system's owner notices a problem (IRENA, 2015).

There is a set of maintenance activities that should be performed to identify any possible malfunction and achieve optimal performance levels (Box 4.2). These include checking the fluid pressure of the pump on a yearly basis and checking the pH levels and replacing the antifreeze fluid (Renewable Energy Hub, n.d.).

Box 4.2 ■ Maintenance activities

Periodic inspections and routine maintenance are required to ensure the optimal operation of solar water heaters. Some of the activities can be carried out directly by the user, but others require a qualified technician to prevent scaling, corrosion and freezing which can destroy the system and cause extensive damage. Also, from time to time, components – especially electric ones – may need repair or replacement. Maintenance activities include the following:

- Conduct a visual inspection on a regular basis (every 6-12 months).
- Clean the collector's surface and eliminate condensation and dirt from the collectors.
- Verify security valves.
- Verify that there are no water losses, or antifreeze leaks.
- Check the heat exchanger to look for corrosion and any unexpected deformation; the electric connections to identify leakages; and the metallic structure, screws and supporting brackets to identify corrosion and damage.
- Change the antifreeze liquid.
- Check the pumps.

Source: US DOE, n.d.b.

Operating and maintaining solar water heaters in 10 000 households would require 7 680 person-days per year. The total cumulative person-days over 20 years (the average lifetime of an appliance) account for about 33% of the labour requirements along the value chain[16]. The distribution of human resources needed is shown in Figure 4.6. Of the total person-days of labour, plumbers and electricians account for 34% each (2 640 person-days), and mechanical technicians account for 32% (2 400 person-days). In general, it is quite likely that the same technician has the skills and knowledge to resolve all mechanical, plumbing and electrical maintenance. The market can easily draw on construction and industry workers.

Figure 4.6 ■ Human resources required for maintenance, by occupation

Source: IRENA analysis.
Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters.

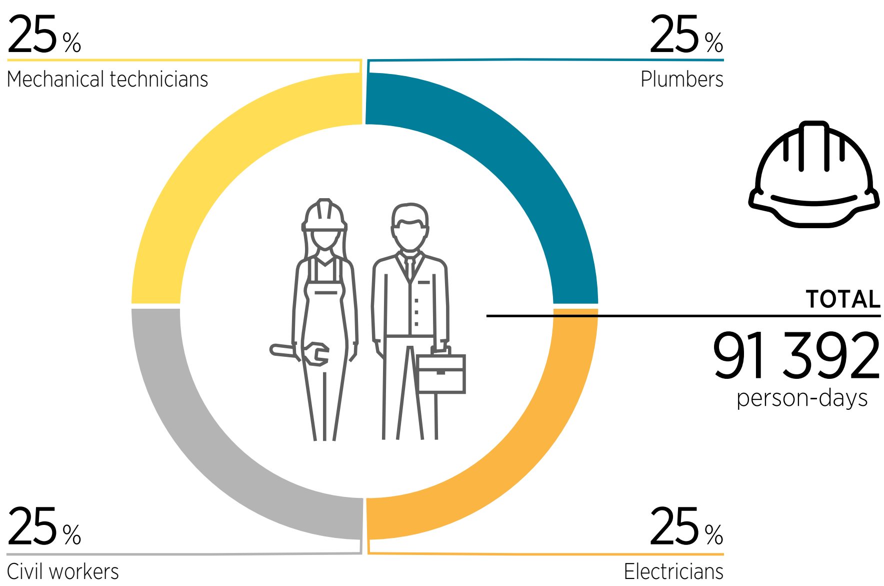
[16] The person-days required for each year of operation and maintenance is estimated to be 7 680. The total represents the cumulative jobs over 20 years (which is considered the average life expectancy of a system). Labour productivity is assumed to not improve over this period.

4.6 Decommissioning

A solar water heating system is expected to last more than 20 years; with maintenance, it should not lose efficiency. The decommissioning phase of the system takes place at the end of its operational lifetime (or when a house/building is decommissioned), when the components are essentially uninstalled, disposed of or recycled.

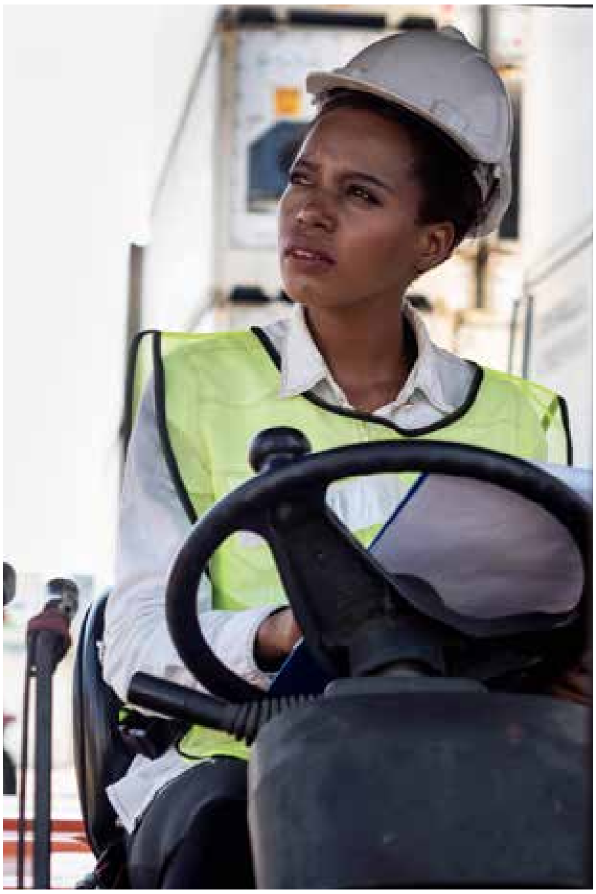
It may take close to 91 392 person-days to decommission 10 000 singlefamily solar water heating systems. The labour requirements are equally distributed among different occupations: plumbers, electricians, mechanical technicians and civil workers (25% each) (Figure 4.7)[17]. The decommissioning phase is the second-most labour-intensive phase, with 20% of the total requirements along the value chain. While this may not take place in most countries, there is great benefit from the considerable opportunity for local job creation in this sector. These activities are likely to be carried out by staff who are not highly qualified.

Figure 4.7 Human resources required for decommissioning, by occupation



Source: IRENA analysis.
Note: The figures are based on a scenario in which 10 000 single-family households are equipped with solar water heaters.

[17] This estimate includes only the task of dismounting the solar water heater and sending it to a landfill or treatment plant.



The equipment needed includes common, easily available tools such as screwdrivers and hammers. Cranes and ladders may be needed to access certain sites.

After the decommissioning of domestic solar water heater systems, most of the materials can be recycled: up to 90% of the aluminium, 41% of the copper, 62% of the steel and 62% of the glass used in ETCs can be recycled. Plastic and the remaining shares of the materials previously listed are landfilled. Propylene glycol is fully treated in wastewater treatment facilities. The methanol used in ETCs has to be sent to hazardous waste facilities for incineration (Greening and Azapagic, 2014). Recycling facilities are not always in place; if they were, this would offer additional employment opportunities.

5. CONCLUSIONS

Renewable sources of energy are key for the energy transition. It is widely acknowledged that the expansion of renewable energy not only supports climate goals and other environmental protection objectives, but also increases energy security, decreases dependence on fossil fuels and enables energy access. In addition, the deployment of systems that harness renewable energy supports economic growth, creates employment opportunities and enhances human welfare. Domestic value creation can be maximised by leveraging and enhancing capabilities in existing industries along the value chain, or developing them.

While efforts to deploy renewable-based systems have generally focused on power generation, there is a growing global consensus on the need to shift attention to end-use sectors. The transport and the heating and cooling sectors account for more than 30% and almost 50% of global energy consumption, respectively. Therefore, utilising renewables in these sectors is key to accelerating the pace of the global energy transition.

For heating and cooling, renewables are becoming increasingly cost-competitive relative to the alternatives, in particular for heating water. In contexts characterised by an insufficient energy supply and high reliance on fossil fuels, or where inefficient electric boilers are common and peak power loads need to be dropped, solar water heaters represent a promising solution. Their deployment is labour intensive, presenting opportunities for local job creation, and for the establishment of businesses focused on the sales, distribution and installation of systems. These opportunities for value creation are amplified by the fact that the requisite activities can build on existing capacity.

To maximise the domestic value created in the development of a solar water heater industry, policies and measures are needed to first stimulate demand for solar water heaters, and then to enhance capacity along the value chain.

On the demand side, the level of national- or local-level commitment to the energy transition sets the overall scope for the use of solar energy for water heating. While solar water heaters involve mature technology, their deployment is in some cases challenged by economic constraints such as relatively high upfront costs or long payback periods, and a lack of awareness of financial and other benefits. These barriers call for a wide range of policies, best in combination.

- The most common policies are those that support the cost-competitiveness of systems. Providing financial and fiscal incentives (subsidies, low interest loans, tax exemptions) can reduce the capital costs of solar water heaters. Meanwhile, reforming fossil fuel subsidies and putting a price on carbon can help level the playing field relative to fossil fuels. However, careful consideration of broader social and equity issues is necessary, particularly for low-income populations, for whom energy constitutes a larger share of household expenditures and whose budgets do not leave many options.
- Regulatory approaches such as mandates and obligations (e.g., building codes and standards) improve certainty in situations where economic incentives are sufficient to overcome existing barriers. Although they apply mostly to new buildings, they can also be introduced when refurbishing existing buildings. It is worth mentioning that the introduction of building codes also provides an opportunity to align energy efficiency with renewable energy requirements, which is key to achieving the energy transition.
- Measures to enhance consumer awareness of the benefits of solar water heaters are key to overcoming non-economic barriers. Equally important is providing information on the various systems and technologies available, and on the certified technologies and installers, so that both retailers and consumers can make informed decisions on the most suitable option. Public

awareness and acceptance are key prerequisites to the adoption of solar water heaters, especially in the absence of mandates and obligations, as this technology is mainly adopted at a household level. Effective ways to reach consumers include information and marketing campaigns that outline the benefits of solar water heaters. Where industry and government (especially if there are any financial and fiscal incentive programmes) can jointly promote such campaigns, this would increase the credibility of the industry and ensure the campaigns' success. The process might require the creation of specialised institutions or agencies.

On the supply side, policies and measures are needed to establish a conducive environment for the development of a domestic solar water heater industry. Such measures include the introduction of qualification requirements and standards, as well as education, training and certification to ensure the quality of the products manufactured and installed.

- A long-term vision is needed, and contributes to the creation of a stable and predictable environment that will attract market participants. Manufacturers, distributors and retailers all require a transparent, long-term view of the market's future in order to invest in it.
- Whether solar water heaters should be manufactured locally or be imported depends on the market potential of domestically produced solar water heaters (locally, regionally and globally) and existing capacity. In countries where relevant industries and service sectors already exist, efforts to develop a domestic supply chain for solar water heaters could leverage existing capacity. In countries where relevant industries do not exist, SWH give an opportunity to create the industry, if not nationally, regionally. Given the simplicity of the technology, local production would be an option.Therefore, an assessment of existing resources including labour, materials and equipment should be mapped against the requirements in each segment of the value chain.

Based on such analysis, opportunities for leveraging local labour markets and existing industries can be identified and policies and measures can be introduced to strengthen local capacities and maximise domestic value.

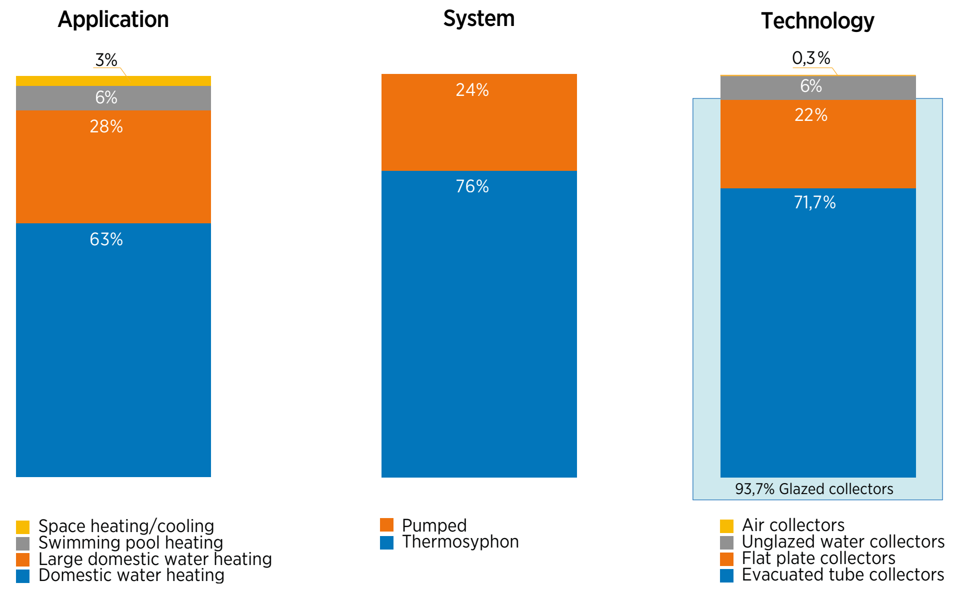
- Education, training and retraining policies are needed to meet the occupational and skills requirements of a solar water heater industry. The availability of such skilled workers as plumbers, electricians, technicians, retailers and others is critical. Prospects for local employment would be boosted by training programmes and certification schemes for those occupations. Moreover, involving both men and women in the employment opportunities along the various segments of the value chain would leverage an opportunity for gender empowerment and maximise livelihoods.
- A broad mix of policies and measures are needed to ensure the competitiveness of domestic firms. These include efforts towards industrial upgrading and supplier development; the creation of associations and networks among importers, producers and sellers; and the development of export markets. Quality improvement measures should be introduced, such as technical standards, product labels for systems and special certificates for installation contractors. Stringent standards for manufacturing and installation are not only of importance domestically, but also translate into a reputation for high-quality products beyond national borders, opening foreign markets.

The combination of policies, measures, instruments and approaches outlined here would need to be tailored to each context (national or local) to reflect specific circumstances (e.g., building stock, industrial heat demand, resources, etc.). The detailed look at value creation opportunities presented in this report can serve as a starting point for designing policies appropriate for each country.

Annex A. Solar water heater technologies

Solar thermal systems can be categorised according to their applications, the type of system used (thermosyphon or passive, versus pumped or active) and the technology of the solar collector (evacuated tube or flat plate collectors, unglazed water and air collectors). The global market share of each type is presented in Figure A.1.

Figure A.1 Global market share of solar thermal heaters by application, system and technology

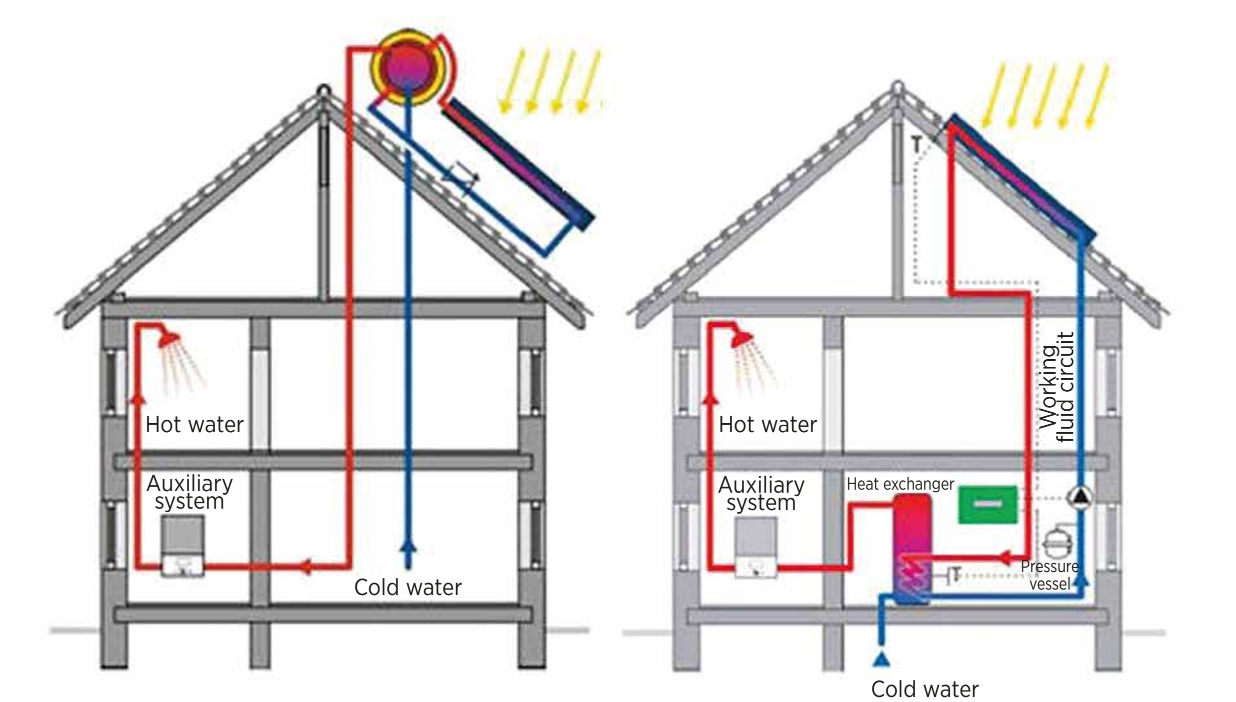


The choice of the system depends on specific needs and climatic conditions. Thermosyphon systems are less expensive as they do not require a pump, but they are not suitable for cooler climates since the tank is typically placed on top of the collector, and therefore subject to heat losses in cold weather (Table A.1). Both thermosyphon and pumped systems can be direct or indirect. In a direct system, heated water passes through the collector and the pump is controlled by sensors to regulate the water flow from the collector to the tank. Indirect pumped systems use two circulation loops. A closed-loop system runs the heat transfer fluid from the collector to a heat exchanger. In systems for residential applications, the heat exchanger is usually an immersed heat exchanger integrated in the storage tank.

Table A.1 Thermosyphon and pumped systems, direct and indirect

Thermosyphon (passive) system	Pumped (active) system
Thermosyphon systems use natural convection to drive the water from the solar collector to the hot water storage tank. The relatively cooler water from the bottom of the storage tank is circulated back into the solar collector (left side of Figure A.2). Thermosyphon systems are mainly used in warm climates, such as in southern China, Africa, South America, southern Europe and the Middle East and North Africa region. They are less suitable for cooler climates because of the high heat loss from external hot water stores and the danger of freezing during winter.	Pumped systems use a pump to circulate the heat fluid from the collector to the storage tank (right side of Figure A.2). They dominate the North American market, and account for more than half of the market in some cold climates.

Figure A.2 ■ Differences between a thermosyphon system used to heat water directly (left) and a pumped indirect solar thermal system (right)



If an external heat exchanger is used (e.g., in larger systems), a second pump is needed for the loop between the heat exchanger and the storage tank.

As for the solar collector, the widest deployed technologies are evacuated tube collectors (ETCs) and flat plate collectors (FPCs) (both glazed in principle, while unglazed collectors are normally used for swimming pools). ETCs are the most common, and are becoming even more prevalent as their production becomes more automated. Although ETCs are generally more expensive than FPCs, they are more efficient in cold climates due to their cylindrical shape that allows for efficient and maximum utilisation of solar energy (see Table A.2).

Table A.2 ■ Evacuated tube collectors vs flat plate collectors

Evacuated tube collectors (ETCs)	Flat plate collectors (FPCs)
ETCs use parallel rows of glass tubes, each of which contains either a heat pipe or another type of absorber, surrounded by a vacuum. This enables the prevention of heat loss through convection and radiation. As there is no air inside the tubes, thermal loss is minimal and the impact of ambient temperatures is also low.	FPCs consist of tubes carrying a fluid running through an insulated, weather-proof box with a dark absorber material and thermal insulation material on the backside that also prevents heat loss. FPCs are appropriate in warm climates, where they may be preferred, thanks to their relatively low cost.

Source: ETSAP and IRENA, 2015.

Annex B. Solar water heater components

Solar water heater pumping systems can be either active or passive. Active systems use pumps and controllers to circulate the fluid between the collector and the storage tank, while passive systems do not use pumps or controllers and comprehensively rely on gravity and the propensity of water to naturally circulate while being heated.

The main components of a solar water heating system include the solar collector and the balance of the system, which includes the collector-storage loop, the storage tank and, depending on the system type, heat exchanger(s), pump(s), auxiliary devices and/or controllers (IRENA, 2015)[18].

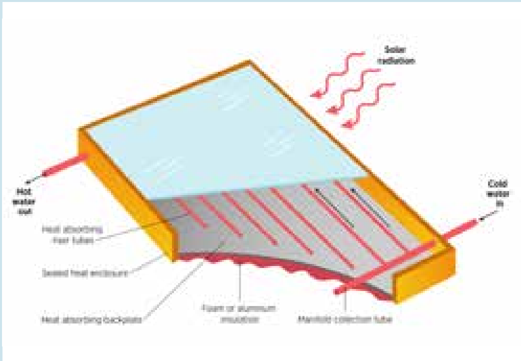
The solar water heater system includes the following equipment and components:

- Solar collectors absorb solar radiation, converting it into heat energy. The most common types used for residential applications are evacuated tube collectors, flat plate collectors and integral collector storage systems (Box B.1).

Box B.1 ■ Types of solar collectors

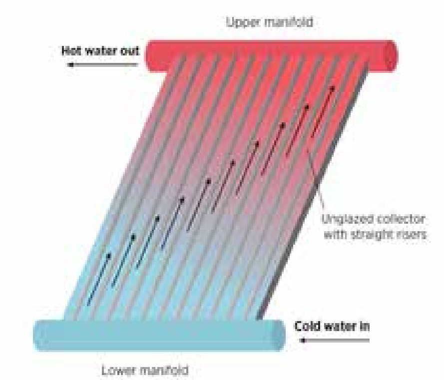
Solar water heaters can be classified according to the solar collector used. Their designs differ widely depending on the prevailing meteorological circumstances, heating and cooling demands, load profiles and costs.

- Flat plate collectors have a dark flat absorber (which is heated under the sunlight), a transparent cover to reduce losses, a liquid (water, glycol or a mixture) which conveys heat and metal tubes which transport the heated water.



- Evacuated tube collectors are the most common. In place of the metal tubes used in the flat plate system, glass tubes are inserted into one another, and a vacuum is created between them. This system is far more efficient, as the vacuum greatly reduces convection and conduction heat loss. The absorber can be made of metal or glass.

- Water unglazed systems are mainly used for swimming pools, and consist of black tubes made from rubber or plastic through which water passes. These are then heated by sunlight and the heat passes on to the water. This system is useful in heating large volumes of water, but is only capable of small increases in temperature. These systems are called "unglazed" as they have no glass cover, as do flat plate or evacuated tube collectors.



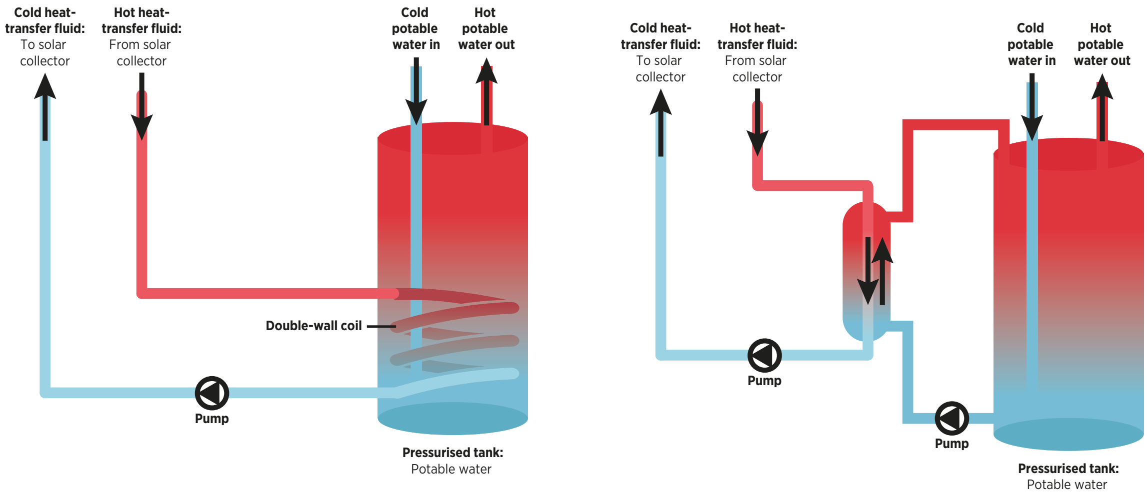
- Integral collector storage systems use both the collector and the accumulator to absorb solar heat; however, the accumulator is more likely to lose heat during the hours without sunlight. These systems are cheaper and are a good choice when hot water is needed in the evening hours.

Evacuated tube collectors account for over 70% of global systems, followed by flat plate collectors (with almost a quarter of the market) and unglazed water collectors (making up the remaining share) (IEA-SHC, 2018).

[18] For active systems, the balance of system and installation may each cost more than the collector. For passive systems, storage is most often integrated with the collector, and the balance of system costs are less.

- A primary circuit is a closed circuit which conveys heat from the collector to the storage tank, using a liquid (water or other fluid). Once the liquid is cooled, it is returned again to the collector to be reheated.
- A heat exchanger is a device used to transfer heat between the heated fluid coming from the collector and the stored water. Heat is conducted from the hotter fluid to the stored water through the metal walls that separate the two fluids in the exchanger (Marken, 2009). The heat exchanger may be either in or outside the tank.
- A storage tank is obviously needed to store the heated water. The heat exchanger may be in or outside this tank, and is mostly commonly inside. Cold water enters the lower part of the storage tank and its temperature rises when it comes in contact with the heat exchanger. As its temperature rises, its density is reduced; hot water then rises to the upper part of the storage tank. Storage tanks are usually anti-corrosive and thermally insulated.
- A secondary circuit conveys the hot water to its final use (clothes in washing machines, dishwashers, showers and wash basins) and the cold water from the supply to the storage tank.
- In active systems, a pump is used to circulate the fluid from the storage tank up to the collector. In passive systems, no pump is used, only natural convection: cooler water from the bottom of the storage tank returns to the solar collector naturally, as it is denser.
- A water expansion vessel is a small tank that absorbs the expanding volume and limits the pressure of the fluid circulating in the primary circuit.
- Pipes convey the liquids (water or not) in the primary and secondary circuits. They are made of copper or stainless steel, and are covered with a thermal insulator.

Figure B.1 ■ Heat exchanger configurations (internal, left; external, right)



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