Government of Nepal
Ministry of Energy, Water Resources and Irrigation
Alternative Energy Promotion Centre

ICIMOD

Solar Thermal Roadmap and Implementation Plan **FOR NEPAL**

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AEPC expresses our sincere gratitude to the sector experts and stakeholders for their technical contributions and insights for the development of the solar thermal roadmap and implementation plan for Nepal.

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Foreword

It is my honor to introduce the *Solar Thermal Roadmap and Implementation Plan for Nepal*, developed through a strategic partnership between the Alternative Energy Promotion Centre (AEPC) and the International Centre for Integrated Mountain Development (ICIMOD). This roadmap delineates a clear, phased approach for integrating solar thermal technologies into Nepal's energy mix, thereby enhancing energy security contributing to achieving our national objectives of Net Zero Emissions by 2045. By aligning technical pathways with policy frameworks and investment strategies, this document provides a comprehensive blueprint for stakeholders to deploy solar thermal solutions at scale, catalyze private-sector engagement, and foster socio-economic development. I trust that this roadmap will serve as an essential guide for government bodies, development partners, and industry alike, as we collectively pursue a resilient, low-carbon future for Nepal.

Solar thermal energy holds immense promise for Nepal, offering sustainable and efficient solutions for heating, cooling, and industrial processes across various sectors. This roadmap, developed through rigorous research, extensive stakeholder consultations, and inputs from technical and policy experts, provides a comprehensive strategy and outlines actionable pathways for integrating solar thermal energy into Nepal's energy framework. By leveraging the country's abundant solar resources, solar thermal technologies align closely with Nepal's commitments to achieving a low-carbon economy, increasing energy security, and fulfilling its targets under the Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action).

AEPC remains steadfast in its commitment to fostering innovative energy solutions and promoting multi-stakeholder collaboration to implement this roadmap effectively. The synergy between government institutions, private sector, development partners, and local communities will be instrumental in accelerating the adoption of solar thermal technologies. We are particularly grateful to ICIMOD for their technical expertise, regional insights, and dedication to sustainable development, which have been pivotal in shaping this initiative.

As we celebrate 28 years of service to the Nepali people, AEPC continues to champion clean, efficient, affordable, and modern energy solutions at the household, community, institutional and enterprise levels. Our work has significantly increased the share of renewable energy in Nepal's energy mix, reduced reliance on traditional biomass and imported fossil fuels, and promoted energy efficiency, thereby enhancing energy security and reducing greenhouse gas emissions. This Solar Thermal Roadmap now provides a clear, strategic framework to mainstream solar thermal technologies throughout Nepal's energy landscape and to guide our collective efforts in realizing a resilient, low-carbon future.

I wish to express my gratitude to all stakeholders who contributed to this roadmap: government agencies, private-sector partners, financial institutions, civil society organizations and end-users. I also extend special thanks to the dedicated teams at AEPC and ICIMOD for their tireless efforts and unwavering commitment to bringing this vital initiative to fruition.

Nawa Raj Dhakal
Executive Director

ICIMOD

Pema Gyamtsho Ph.D.
Director General

I am immensely pleased to present the *Solar Thermal Roadmap and Implementation Plan for Nepal*, developed in collaboration with the Alternative Energy Promotion Centre (AEPC). This document reflects a collective vision to harness solar thermal energy as a cornerstone of Nepal's sustainable energy future.

The roadmap was shaped through an extensive study and inclusive consultation, bringing together the expertise and perspectives of government agencies, development partners, and private sector stakeholders. These efforts have provided a robust foundation for identifying opportunities, addressing challenges, and laying out actionable pathways to advance solar thermal technologies in Nepal.

At ICIMOD, our mission is to build and share knowledge that drives regional policy and action and attracts investment that enables the diverse countries and communities of the Hindu Kush Himalaya (HKH) to transition to greener, more inclusive, and climate-resilient development. This roadmap serves as a testament to that mission. Supporting Nepal's transition to clean energy solutions demonstrates how knowledge and collaboration can prompt innovative approaches to address the pressing challenges of our time.

We are grateful to all partners for their invaluable contributions in this journey, from technical inputs to policy insights. I particularly commend the leadership of AEPC Nepal and the unwavering commitment of the ICIMOD team in steering this initiative forward.

I am confident that this roadmap will serve as a guiding document for policymakers, investors, and practitioners, driving tangible outcomes for Nepal's solar thermal energy sector. Let us continue to collaborate to put this vision into action, creating a brighter and more sustainable future for all.

Pema Gyamtsho, Ph.D.
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Acronyms

AEE INTEC	AEE – Institute for Sustainable Technologies
AEPC	Alternative Energy Promotion Centre of the Ministry of Energy, Water Resources and Irrigation
BYS	Balaju Yantra Shala
CDM	Clean Development Mechanism
CES	Center for Energy Studies, Institute of Engineering, Tribhuvan University
CER	Certified Emission Reduction
CREF	Central Renewable Energy Fund
CTEVT	Council for Technical Education and Vocational Training
ESCO	Energy Service Company
FNCCI	Federation of Nepalese Chamber of Commerce & Industries
FNCSI	Federation of Nepal Cottage & Small Industries
GESI	Gender Equality and Social Inclusion
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HAN	Hotel Association of Nepal
ICIMOD	International Centre for Integrated Mountain Development
IEA	International Energy Agency
IEA SHC	International Energy Agency, Solar Heating and Cooling Programme
IRENA	International Renewable Energy Agency
KFW	Kreditanstalt für Wiederaufbau Bank
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MOFE	Ministry of Forests and Environment
NAST	Nepal Academy of Science and Technology
NEEP	Nepal Energy Efficiency Program
NREP	Nepal Renewable Energy Programme
PV	Photovoltaic
R&D	Research and Development
REC	Renewable Energy Certificate
RETS	Renewable Energy Test Station
SHIP	Solar Heat for Industrial Processes
SME	Small and Medium-sized Enterprises
SWH	Solar Water Heater
STAN	Solar Thermal Association Nepal
UNCDF	United Nations Capital Development Fund
USA	United States of America
VAT	Value Added Tax

Technical terms and units

CO_2	carbon dioxide
°C	Degrees Celsius
EJ	Exajoule
GW	Gigawatt
GWh	Gigawatt hour
GW_{th}	Gigawatt thermal
Gt	Gigatons
kW	Kilowatt
kW_{th}	Kilowatt thermal
m^2	Square metre
m^3	Cubic metre
MW_{th}	Megawatt thermal
PJ	Petajoule
TWh	Terawatt hour
tCO_2/a	tons carbon dioxide per year
toe	tons of oil equivalent
%	Percent

Currencies

NPR	Nepalese Rupees
US$	United States Dollar

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1 Background

Nepal, with its abundant solar resources and growing energy demand, stands at an opportune juncture in its energy transition journey. As the country strives to enhance energy security, mitigate climate change impacts, and promote sustainable development, harnessing solar energy, particularly through solar thermal technologies, emerges as a promising solution to meet diverse energy needs across processes such as heating, cooling, and thermal industrial applications.

International Centre for Integrated Mountain Development (ICIMOD)'s Energy Intervention aims to foster a transition to renewable energy, holding the potential to create significant positive impacts on economic opportunities, job creation, gender empowerment, improved livelihoods, and enhanced resilience to climate change. Through knowledge generation, solution testing, and supporting scalable interventions, ICIMOD is working towards integrating renewable energy solutions that strengthen community resilience and business continuity across the Hindu Kush Himalaya.

Recognising the transformative potential of solar thermal technologies, ICIMOD, in collaboration with the Alternative Energy Promotion Centre (AEPC) under the Government of Nepal, is developing a comprehensive Solar Thermal Roadmap and Implementation Plan. This initiative seeks to chart a strategic course for the widespread adoption and integration of solar thermal technologies within Nepal's energy landscape, contributing to the country's long-term energy security, economic prosperity, and environmental sustainability.

The primary objective of this roadmap is to accelerate the implementation of solar thermal technology in Nepal for residential, commercial, and industrial uses. The roadmap aims to support Nepal's sustainable development and climate resilience objectives by setting clear targets and defining actionable steps to promote solar thermal technology, enhancing energy efficiency, reducing greenhouse gas emissions, and improving energy access.

Methodology
This Solar Thermal Roadmap and Implementation Plan was developed through a stakeholder-driven process that took place between June and December 2024. This approach involved extensive consultations with key stakeholders – government departments, academics, civil society organisations, industry delegates, and private sectors. The approach ensured that the roadmap is informed by diverse perspectives and aligns with national priorities for sustainable development and climate goals.

2 Executive Summary

Nepal aims to attain its net-zero emissions target by 2045 (Government of Nepal, 2021).

While the use of heating and cooling technologies constitutes about half of the total final energy consumption in the country (IEA, 2022), receive limited attention in the national energy policy. To attain a climate-neutral energy supply by 2045, it is crucial to transition to renewable energy sources for heating and cooling. A viable approach is the use of solar radiation to provide heating and cooling.

Nepal's diverse geography offers varying levels between 1,600 and 2,000 kWh/m² of annual global solar radiation and therefore has good potential for using solar energy in solar thermal systems. In 2022, Nepal ranked 41st out of 72 countries in terms of the total collector area installed, with an installed capacity of 210 MW_{th}, equivalent to 300,000 m² of collector area (IEA SHC, 2024).

This shows that Nepal already has a functional solar thermal sector, though it is largely focused on the installation of small thermosyphon systems for hot water preparation. Nevertheless, this is an excellent starting point for scaling up the use of solar energy in larger systems.

A comprehensive sector analysis, conducted in collaboration with numerous experts in Nepal as part of the preparation of this roadmap, concludes that with appropriate accompanying measures, Nepal could install more than 9 million m² of collector area, corresponding to a thermal capacity of 6.5 GW_{th}, by 2045.

The sectors with the highest potentials for solar thermal systems, ranked by potential are:

Sector	Collector area [m²]	No. of systems [-]	Solar energy yields [GWh.a]	Investments [Mill. NPR]	Avoided CO_2 [tCO_2/a]
Residential	7 600 000	1 950 000	5 992	267 046	2 034 710
Agriculture	500 000	20 000	394	20 270	133 863
Industry	490 000	7 000	386	29 797	131 185
Commerce and small and medium enterprises	275 000	14 000	217	22 297	73 624
Boarding schools, monasteries, and governmental institutions	208 100	6 300	164	11 249	55 714
Hotels and lodges	87 000	2 900	69	5 878	23 292
Hospitals and health centres	59 900	4 800	47	4 047	16 037
Steam cooking	30 000	50	24	1 014	8 032
Pilot systems	9 500	73	7	628	2 543
Total	**9 259 500**	**2 005 123**	**7 300**	**462 227**	**2 479 000**[1]

[1] Avoided CO_2 emissions according to Scenario 1 (See Chapter 10.1)

An annual solar yield of 7,300 GWh by 2045

If Nepal successfully achieves its roadmap goal in 2045, an annual solar yield of 7,300 GWh could be generated. Providing this amount of heat using electricity would require 8,111 GWh of electricity, considering the efficiencies. This figure is comparable to the total electricity generation from hydropower in 2021, which amounted to 9,667 GWh (IEA, 2022).

An average investment of NPR 23 billion per year

To build these solar thermal plants over the next 20 years, it would require an average investment of NPR 23 billion per year. This translates to an annual investment of only NPR 631 per capita.

13,000-14,000 full-time jobs by 2045

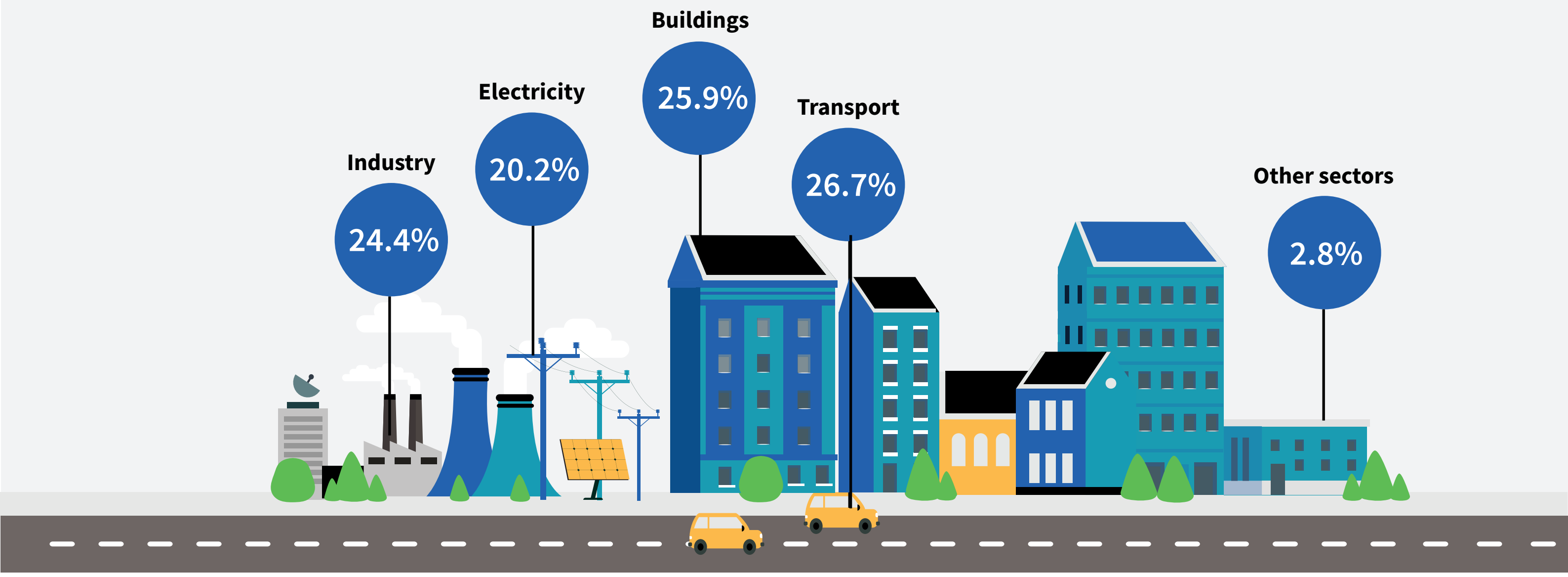
In addition to meeting energy goals, the installation of solar thermal systems can potentially create 1,400-1,500 full-time jobs by 2030, with the number increasing to 13,000-14,000 full-time jobs by 2045.

3 Importance of heating and cooling processes

When analysing the total global final energy consumption by sector — electricity, transportation, buildings, and industry —the electricity sector accounts for approximately 20% of total final energy consumption, while the transportation sector accounts for about 30%. The building and industry sectors, which are predominantly driven by heating and cooling needs, collectively account for approximately 50% of total final energy consumption (IEA, 2024).

Despite a 6% increase in annual heat consumption between 2017 and 2022 (IEA, 2024), the share of global **final energy consumption for heating and cooling** in the building and industry sectors has remained steady for many years **at around 50%** of total final energy consumption.

Figure 1: Total final energy consumption globally



According to the 2022 Renewables Report of the International Energy Agency (IEA), 53% and 44% of the total energy for heating, globally, is used for industrial processes and in buildings for space and water heating, respectively, while the remaining 7% is used in the agricultural sector.

The heating sector continues to be heavily reliant on fossil fuels. Apart from traditional biomass, only 13% of the global heating needs were met by modern renewables in 2022.

The IEA Renewables Report 2023 projects that the share of heat from renewable energy will increase by more than 40% (+12 EJ) globally between 2023 and 2028. However, this growth corresponds to only 70% of the projected global increase in total heat demand, leading to a rise in fossil fuel consumption for heat and associated CO_2 emissions (+5%/+0.6 Gt CO_2 in annual emissions).

This underscores the urgent need for a significant acceleration in the implementation of renewable energy sources to achieve international climate targets and reduce greenhouse gas emissions within the required timeframe.

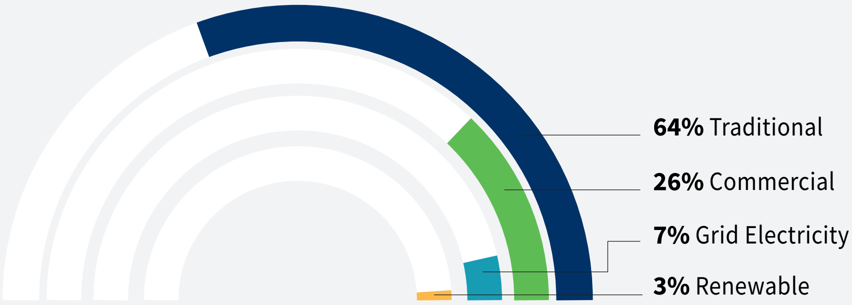
Meeting the demand for renewables in the heating and cooling sectors will require intensive utilisation of solar thermal energy, modern biomass applications, geothermal energy, and carbon-free electricity.

4 Energy consumption in Nepal

Nepal has no oil, gas, or coal reserves, and its energy sector is heavily reliant on traditional energy sources such as firewood, crop residues, and animal dung, mainly for domestic use (National Statistics Office, 2023).

Nepal's total energy consumption in 2023 amounted to 532.4 PJ (WECS, 2024).

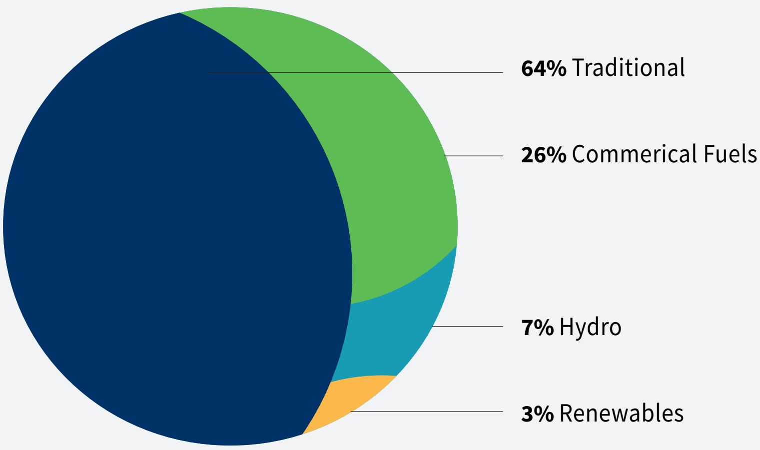
Figure 2: Nepal's total energy consumption by various sources in 2023 (WECS, 2024)



By 2023, 64% of Nepal's energy consumption came from traditional energy sources such as fuelwood, agricultural residues and animal dung. Commercial fuels such as coal, petrol, diesel, to name a few, contributed 26% of the total energy consumption, 7% came from grid electricity and 3% from renewable sources such as biogas, wind, solar and micro/pico hydro (WECS, 2024).

While fuelwood contributes as a major source of fuel in the residential, commercial and industrial sectors, fossil fuel (such as petrol and diesel) serves as the major source of fuel in the transportation and agricultural sector. Only the construction and mining sector is served majorly by electricity. However, among these sectors, the residential sector forms a major part of the national energy consumption at 61% of the total (WECS, 2024).

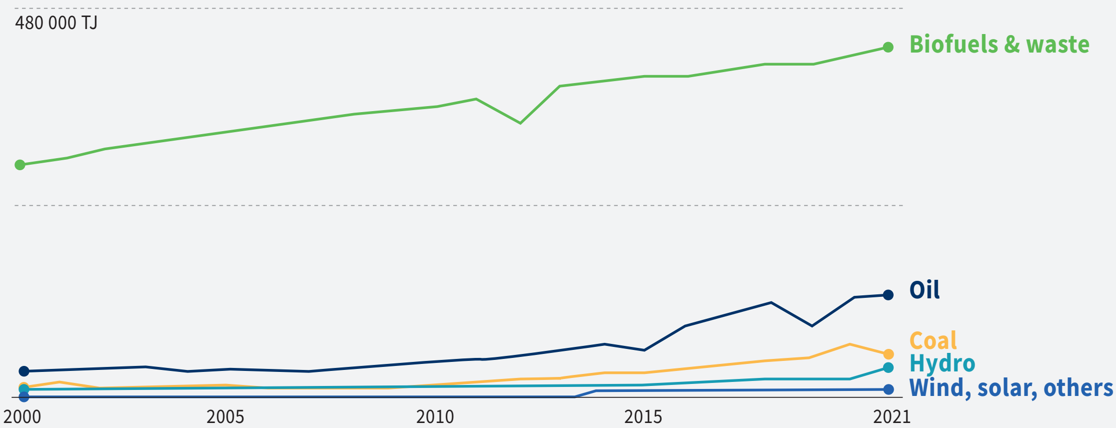
Figure 3: Total energy supply in Nepal in 2021



Source: International Energy Agency. License: CC BY 4.0

Looking back over two decades, between 2000 and 2021, Nepal's energy supply increased significantly across nearly all energy sources, with coal being the only exception, showing a slight decline in consumption in 2021.

Figure 4: Evolution of the total energy supply in Nepal from 2000–2021

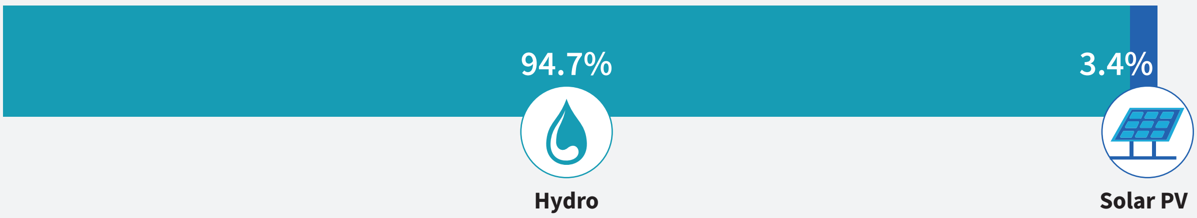


Source: International Energy Agency. License: CC BY 4.0

By 2024, 94.7% of Nepal's electricity was generated by hydropower and 3.4% by photovoltaic (PV) systems. The total electricity production in 2024 amounted to 12,681 GWh, with a strong growth trend in recent years (NEA, 2024).

As of February 2024, around 97.7% of the population in Nepal has access to electricity (Ministry of Finance, 2023/2024), with about 12% of the country's electricity being imported from India.

Figure 5: Renewable electricity generation in Nepal by source

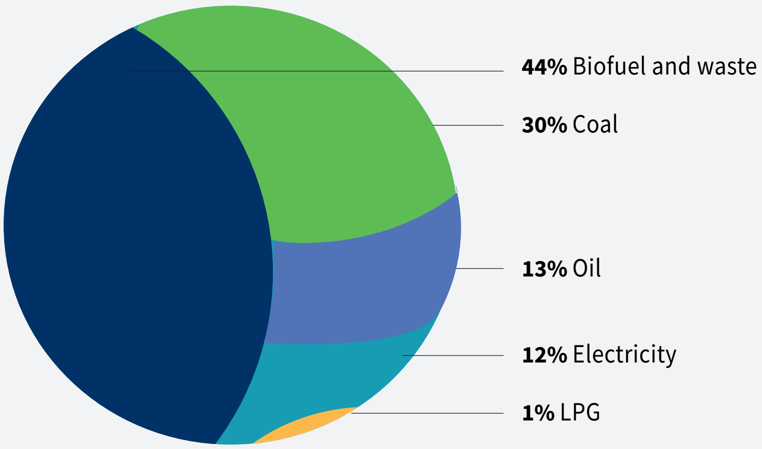


Source: NEA, 2024

Biomass, including wood and agricultural residues, is by far the most important primary energy source in Nepal for preparing hot water, heating buildings, drying agricultural goods, and cooking.

In the industrial sector, while biofuels and waste are important, the most frequently used energy source is coal, accounting for 30% of total final energy consumption in 2023 (WECS, 2024). When combining biofuels, coal and oil, these energy sources result in 88% of total final energy consumption in industry. Almost 100% of these energy sources are converted into heat for industrial processes, with a large proportion of this being low-temperature heat, which could also be supplied by solar thermal energy.

Figure 6: Final energy consumption in the industrial sector in 2023 (WECS, 2024)



Source: International Energy Agency. License: CC BY 4.0

Nepal is expected to reduce dependence on traditional and imported energy sources by increasing access to renewable energy. In 2023, the share of renewables in Nepal's final energy consumption stood at 3% (WECS, 2023), a figure expected to increase significantly in the coming years in both the electricity and heating sectors. Nepal aspires to minimise emissions and achieve net-zero emissions sustainably by 2045 (Government of Nepal, 2021). Solar thermal systems are one of the promising technologies for significantly increasing the share of renewable energy in the heating and cooling sectors.

The following chapters therefore establish the global context and outline the framework conditions necessary for the widespread adoption of solar thermal systems in Nepal.

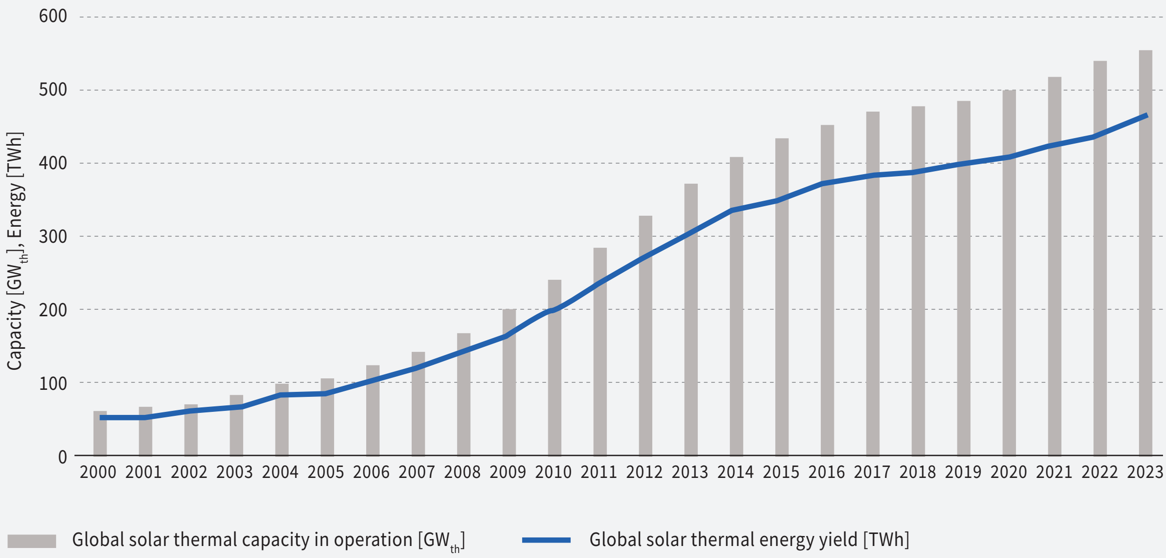
5 Status of the global use of solar thermal systems and prospects up to 2050

5.1 Global utilisation of solar thermal systems

By the end of 2023, approximately **122 million solar thermal systems were in operation**, with a total global capacity of 560 GW_{th}, equivalent to 800 million square metres of collector area. In 2023 alone, 18 GW_{th}, or 26 million m² of solar thermal collectors were installed and put into operation (IEA SHC, 2024).

The annual solar thermal energy yield of the global installed capacity amounted to 456 TWh (IEA SHC, 2024).

Figure 7: Global solar thermal capacity in operation and annual energy from 2000–2023 (IEA SHC, 2024)

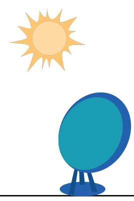


Environmental effects and contribution to climate goals

In 2023, the global solar thermal energy yield from all installed systems resulted in saving 49.1 million tons of oil and reducing 158.4 million tons of CO_2 emissions (IEA SHC, 2024). This underscores the substantial contribution of solar thermal technology in mitigating global greenhouse gas emissions and supporting Nepal's climate goals.

Jobs and economic impact

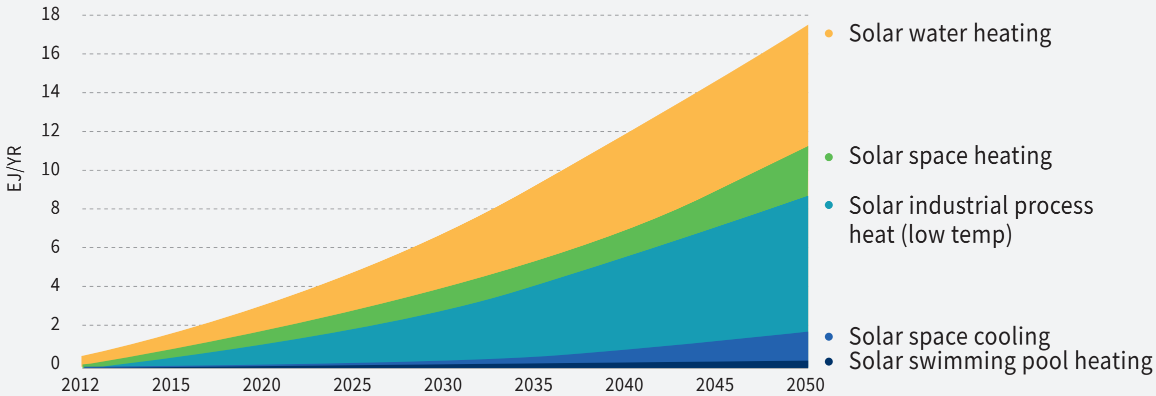
In 2022, the number of jobs in the production, installation, and maintenance of solar thermal systems was estimated to be 345,000 worldwide. The solar thermal industry's estimated worldwide turnover in 2022 was US$ 16.4 billion (IEA SHC, 2024).



5.2 The global outlook until 2050

The Technology Roadmap - Solar Heating and Cooling, published by IEA envisions that by 2050, solar energy could annually produce 18 EJ for heating and cooling. This includes 16.5 EJ for solar heating (more than 16% of total final energy use for low-temperature heat) and 1.5 EJ for solar cooling (nearly 17% of total energy use for cooling) (IEA, 2012).

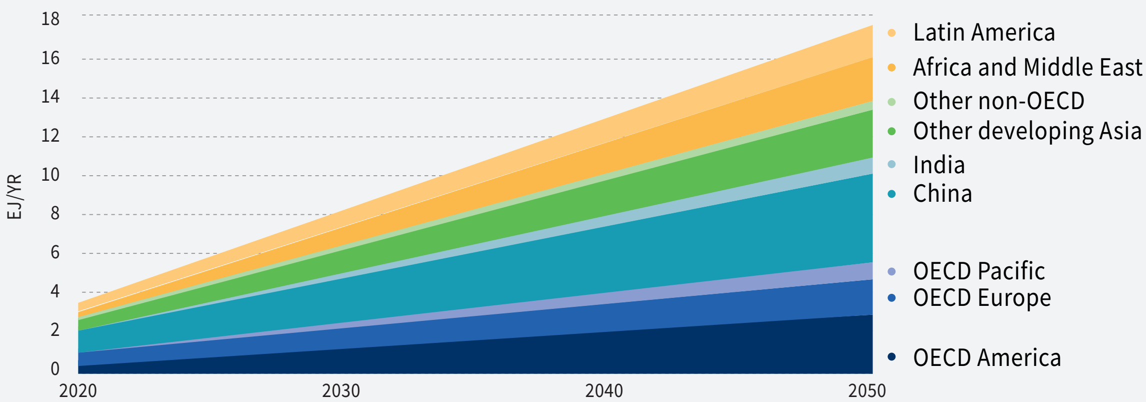
Figure 11: IEA Technology Roadmap vision of solar heating and cooling by sector (EJ/yr) (IEA, 2012)



- According to the IEA Technology Roadmap, solar collectors for **hot water and space heating in buildings** could achieve an installed capacity of nearly 3,500 GW_{th}, meeting around 8.9 EJ of annual energy demand for these purposes by 2050. By that time, solar hot water and space heating will account for 14% of energy use for space and water heating in buildings.
- Solar collectors for **low-temperature process heat in industry** could reach an installed capacity of 3,200 GW_{th}, producing around 7.2 EJ solar heat per year by 2050. By that time, solar process heat will account for 20% of energy use for low-temperature industrial heat.
- Solar heat for **cooling** could potentially contribute to 1.5 EJ per year from an installed capacity of more than 1,000 GW_{th} for cooling, accounting for nearly 17% of energy use for cooling by 2050.
- **Swimming pool heating** could reach an installed capacity of 200 GW_{th}, generating around 400 PJ of solar heat annually by 2050.

Figure 12 highlights the global applicability of solar heating and cooling. Asian countries are set to play a crucial role in the future. Beyond major players like China and India, the "Other Developing Asia" category, which includes nations like Nepal, shows significant potential for solar heating and cooling technologies

Figure 12: IEA- Technology Roadmap vision of solar heating and cooling by economic region (EJ/yr) (IEA, 2012)



5.3 Areas of application of solar thermal systems and potential in Nepal

Solar thermal systems have diverse uses, including heating domestic hot water, heating buildings, and providing process heat for industrial purposes or for drying agricultural crops. Additionally, solar thermal energy can provide cooling for air conditioning in buildings or preserving perishable goods.

The size of these systems ranges from very small systems designed for heating water in single-family homes to systems in the gigawatt range for industrial process heat[2].

Small-scale solar water heating systems and solar combi-systems (which combine hot water preparation and space heating for single-family houses, apartment buildings, hotels and public buildings) account for about 60% of the world's annual installations.

In Nepal, these same sectors – heating domestic hot water, space heating, and industries/agriculture – were identified as having the greatest potential for the use of solar thermal energy.

Figure 8: Small-scale thermosiphon systems for hot water preparation in Nepal.
Photo: Hans Schnitzer, AEE – INTEC

In addition to water heating, **solar heat for industrial processes** (SHIP) has gained increasing global interest. The total global number of SHIP plants is approximately 1,200 systems, with 1.4 million square metres of collector area and a capacity of 951 MW_{th} (IEA SHC, 2024). Globally, these systems are primarily plants for the mining, food, and beverage industries.

In Nepal, solar thermal plants used in industries could significantly reduce the import of fossil fuels. This is particularly important as 43% of Nepal's total final energy consumption in the industrial sector is currently derived from oil and coal (Refer to Figure 6).

A growing sector utilising solar thermal systems is horticulture and solar drying. These systems are increasingly being used to heat greenhouses for flower and vegetable cultivation and in facilities for drying agricultural products such as tea, fruits, and grains.

[2] 2 - 4m^2 collector area are very small systems for single-family homes· The worldwide biggest industrial application for a Aluminum refinery in Saudi Arabia has a collector area of 6 km^2, which corresponds to 1.5 GWth

Figure 9: Dairy San Antonio S.A. in Ecuador, 105 kW_{th}
Photo: Andrés Montero Izquierdo, Universidad de Cuenca, Ecuador

In regions with existing district heating infrastructure, **solar district heating (district heating infrastructure like district heating pipes, heat exchangers, and central heating systems in buildings)** plays a critical role in providing heating for communities and cities. By the end of 2023, there were a total of 336 solar district heating systems, with 1,908 MW_{th} capacity (2.73 million m²) in operation (IEA SHC, 2024).

Figure 10: The Zhongba solar district heating system in Tibet, China with 35,000 m² collector area (24 MW_{th}).
Photo: Sunrain, China

However, in Nepal, the short-term potential for solar district heating is limited due to the lack of necessary infrastructure. To lay the groundwork for this technology, it is recommended to first take measures to improve the energy efficiency of buildings that will be heated. The next step would involve developing the required infrastructure for solar district heating, such as district heating pipes and heat transfer stations.

6 Climatic conditions in Nepal

6.1 The solar resource

Nepal, with its abundant solar resources and growing energy demand, stands at a crucial juncture in its energy transition journey. As the country strives to enhance energy security, mitigate climate change impacts, and promote sustainable development, harnessing solar energy, particularly through solar thermal technologies, emerges as a promising solution to meet diverse energy needs across sectors such as heating, cooling, and industrial processes.

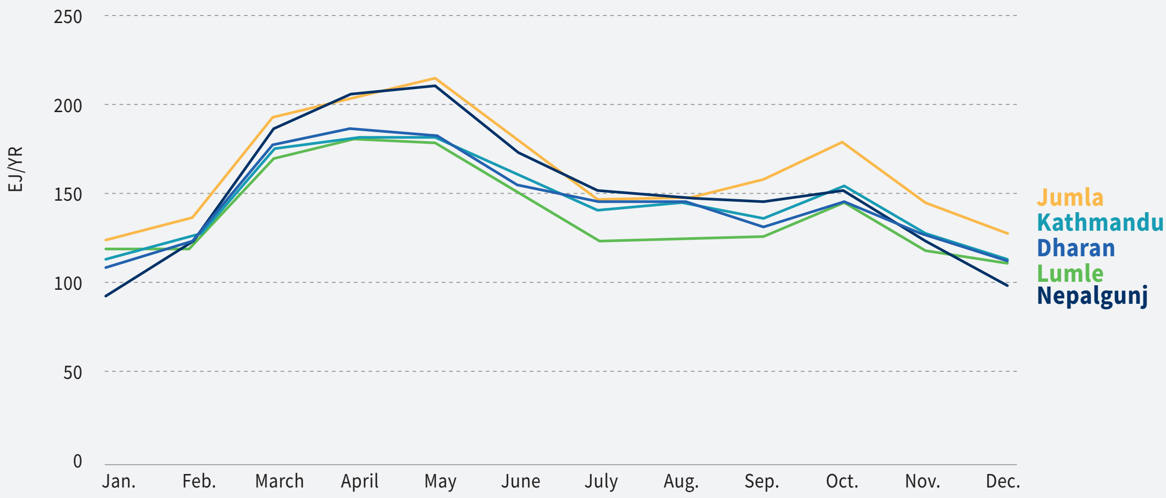
Nepal's diverse geography offers annual global solar radiation levels between 1,600 and 2,000 kWh/m². These levels exhibit seasonal variations, with higher solar radiation during the dry seasons (spring and autumn) and reduced levels during the monsoon season (June to September) due to cloud cover.

Despite these variations, Nepal's overall solar radiation is sufficient to support significant solar energy development, offering a sustainable and renewable energy source for the country.

Table 1: Average monthly values of global solar radiation on a horizontal surface in selected sites in Nepal (The World Bank, 2021)

	Kathmandu	Dharan	Jumla	Lumle	Nepalgunj
Latitude	27.70 N	26.49 N	29.15 N	28.29 N	28.05 N
	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²
Jan.	116	109	124	118	93
Feb.	125	122	136	122	124
March	173	175	192	169	186
April	182	185	200	179	203
May	180	181	214	178	210
June	159	154	182	152	173
July	141	143	145	124	151
Aug.	143	147	147	126	149
Sept.	135	132	157	125	144
Oct	153	145	177	143	153
Nov.	126	126	143	118	122
Dec.	113	113	127	111	100
Year	**1 745**	**1 731**	**1 944**	**1 667**	**1 807**

Figure 13: Average monthly global radiation in selected sites in Nepal in 2021



6.2 Air temperatures and frost

An important factor to consider when using solar thermal systems is the outside temperature, as it significantly affects the type of system that can be used. Due to the geographical location of Nepal, frost occurs in the winter months and especially in high mountain areas. In these areas, it is crucial to ensure that the solar thermal systems used are frost-resistant and capable of withstanding heavy snow loads.

7 Solar thermal energy utilisation in Nepal

7.1 Development of solar thermal energy utilisation in Nepal

According to a paper published by Tribhuvan University (Bajracharya & Shakya, 2003), the development of solar thermal conversion devices began in Nepal in the early 1960s. The first locally made Solar Water Heater (SWH) was installed on the premises of the Department of Mines and Geology, marking Nepal's first installation. However, another report indicates the first prototype SWH was manufactured in 1968 by Late Rev B.R. Saubolle and Asha Brothers in Kathmandu.

Further records indicate the Plumbing Division of Balaju Yantra Shala (BYS) began developing SWHs only after 1974. Following extensive experimentation and development, BYS supplied improved SWH systems to the hostel at Budhanilkantha School in 1975. This was the first unit installed for public use, which received a highly positive response from the public and sparked a growing market, attracting numerous manufacturers of solar water heaters for both domestic and commercial applications.

The development of SWHs received additional support from the then newly established Sanitary Section of the Mechanical Training Center in Balaju, with assistance from Helvetas, Switzerland (Bachmann & Waldvogel, 1990). Through continuous improvements in design, fabrication, and installation, combined with the efforts of private companies and technical institutes, the efficiency and performance of SWHs were significantly improved.

By 1992, the markets for SWHs had expanded, with 35 registered SWH manufacturers under the Department of Cottage and Small Industries and an additional 90 unregistered manufacturers operating in Kathmandu Valley alone (Bajracharya & Shakya, 2003). The market continued to grow steadily and between 2020 and 2023, an estimated 20,000 to 27,000 SWHs were installed annually (IEA SHC, 2024).

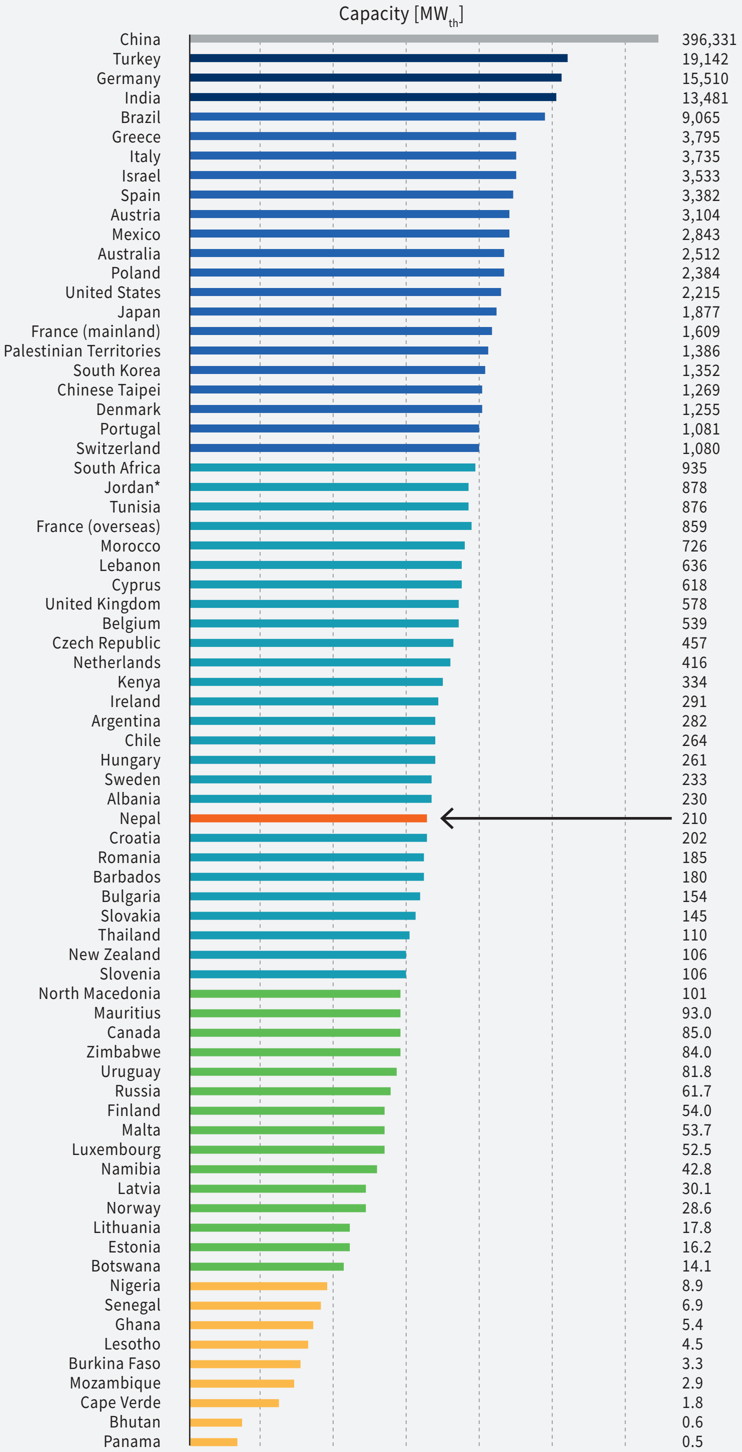
Figure 14: Solar water heater in Nepal
Photo: Trident Nepal Pvt. Ltd., Teku Kathmandu

7.2 Nepal's status in international comparison

This chapter compares Nepal's use of solar thermal systems with international benchmarks. This comparison is particularly important to ensure the targets set in the Solar Thermal Roadmap are both ambitious and realistic.

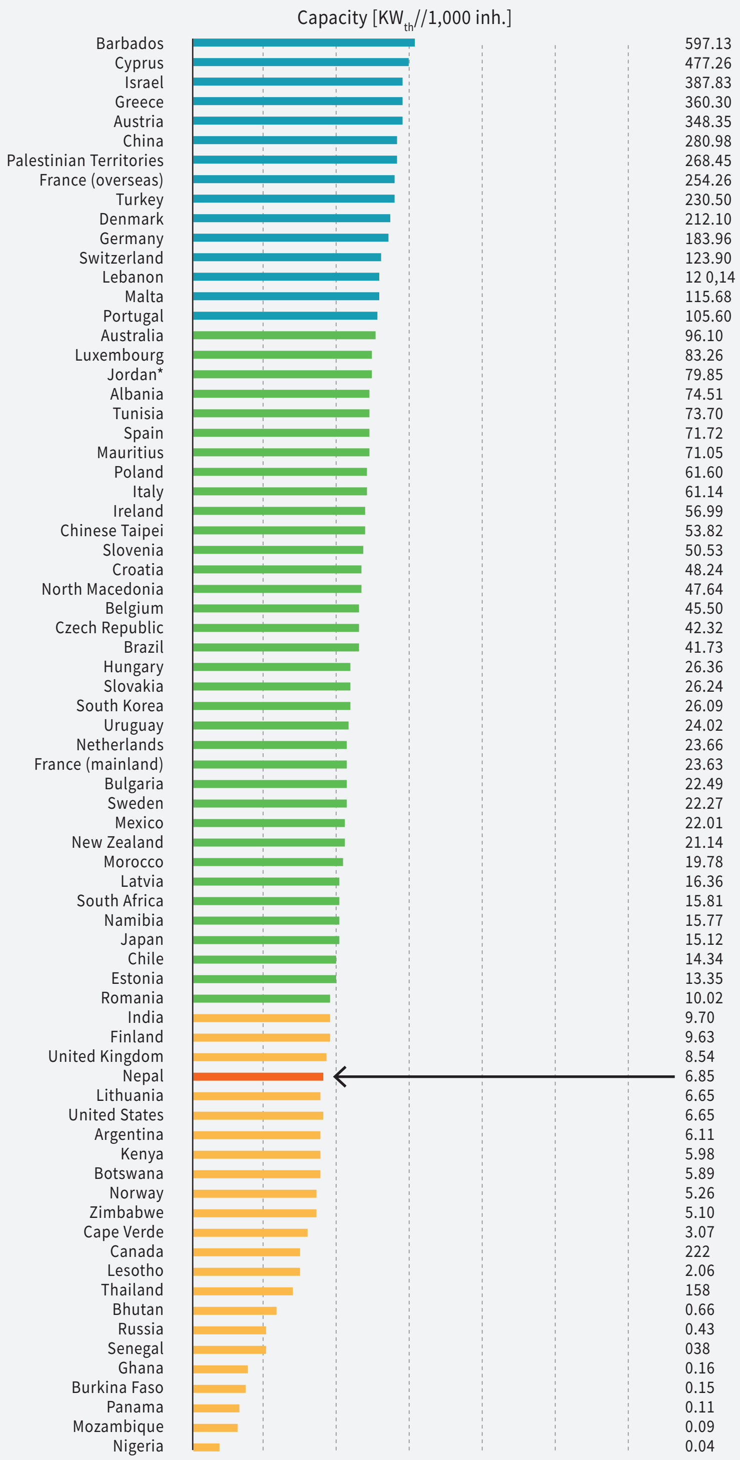
The following chart ranks 72 countries globally based on the total solar thermal capacity installed to date. The top five countries are China, Turkey, Germany, India and Brazil. Nepal ranks 41st, with an installed capacity of 210 MW_{th}, equivalent to 300,000 m^2 of collector area.

Figure 15: Cumulated capacity of glazed water collectors in 2022 (IEA SHC, 2024)



However, since the countries differ significantly in size and population, the absolute installed collector area or capacity is of limited significance. The market penetration or the degree of dissemination of the technology is better represented by the installed capacity per inhabitant. This is illustrated in Figure 16, which illustrates the cumulated capacity of glazed water collectors in 2022 per 1,000 inhabitants.

Figure 16: Cumulated capacity of glazed water collectors in 2022 per 1,000 inhabitants (IEA SHC, 2024)



This provides a completely different picture of the countries' rankings. Here, the top five countries are Barbados, Israel, Cyprus, Greece and Austria. China ranks 6th, while India is 51st, just three places ahead of Nepal, which ranks 54th (IEA SHC, 2024).

In 2022, the top five countries had an installed capacity of 600–350 kW_{th}/1000 inhabitants, equivalent to a collector area of 0.9–0.5 m^2 per inhabitant. Countries ranked between 6th and 10th place had an installed capacity between 280–212 kW_{th}/1000 inhabitants, corresponding to a collector area of 0.4 to 0.3 m^2 per inhabitant. Tunisia, in 20th place in 2022, has an installed collector area of 0.1 m^2/inhabitant installed.

In 2022, Nepal had a collector area of 0.01 m^2 per inhabitant. For Nepal to set ambitious targets for the use of solar thermal systems, it should draw inspiration from countries with a high level of market penetration.

With an ambitious programme well-supported by all stakeholders in Nepal, Nepal could realistically aim for an installation rate of 0.1–0.3 m^2/inhabitant between 2025 and 2045.

Table 2: Installed capacity per 1,000 inhabitants and collector area per inhabitant in selected countries in 2022 in relation to Global Solar Radiation and the Human Development Index (IEA SHC, 2024)

Country	kW_{th}/1000 inh.	m^2/Inhabitant	Global solar radiation kWh/m^2a[3]	Human Development Index 2022[4]
Barbados	597	0.9	2016	0.809
Austria	348	0.5	1126	0.926
China	280	0.4	1282	0.788
Turkey	230	0.3	1795	0.855
Lebanon	120	0.2	1935	0.723
Tunesia	73	0.1	1808	0.732
Namibia	15	0.02	2363	0.616
Nepal	7	0.01	1771	0.601

7.3 Collector technologies

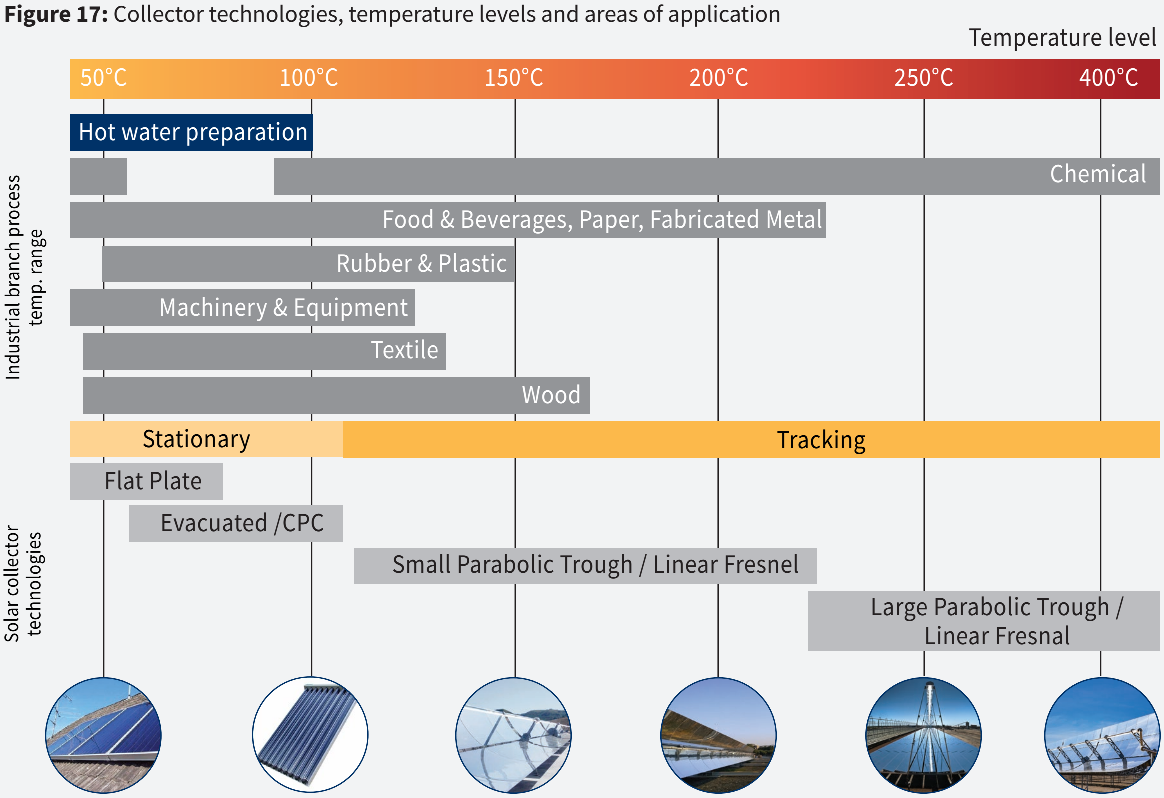
Depending on the required temperature level, different collector technologies are used for the application sectors outlined in this roadmap. For hot water preparation in the residential sector, as well as hotels, hospitals, and schools, temperatures of up to 80°C are required. In these cases, flat-plate collectors and evacuated tube collectors are commonly used.

For temperatures above 100°C, high vacuum flat-plate collectors, concentrating parabolic trough collectors or Linear Fresnel collectors can be used. These systems can achieve temperatures of up to 400°C.

The following figure provides an overview of these collectors, the temperature ranges they can achieve, and the main industry sectors in which they are utilised.

[3] Global radiation on the horizontal surface in selected cities.
[4] The UNDP Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions.

Figure 17: Collector technologies, temperature levels and areas of application



In addition to the collector technologies presented above, parabolic dish systems are another option. A parabolic dish system consists of a parabolic-shaped point focus concentrator, resembling a dish, that reflects solar radiation onto a receiver mounted at the focal point. These concentrators are mounted on a structure with a two-axis tracking system to follow the sun. The collected heat can either be converted into steam or utilised directly by a heat engine mounted on the receiver, which moves with the dish structure.

A relatively simple variant of this collector is the Scheffler reflector, which was specifically developed for solar cooking. It is most widespread in India.

The following figure shows a solar steam cooking system powered by five Scheffler dishes. These are installed at the Maharashtra Education Society in Pune, Maharashtra, for the Indian Army. Operating on turn-key along with a back-up boiler and cooking vessels, it is capable of preparing meals for 400–500 people (Sunrise CSP, n.d).

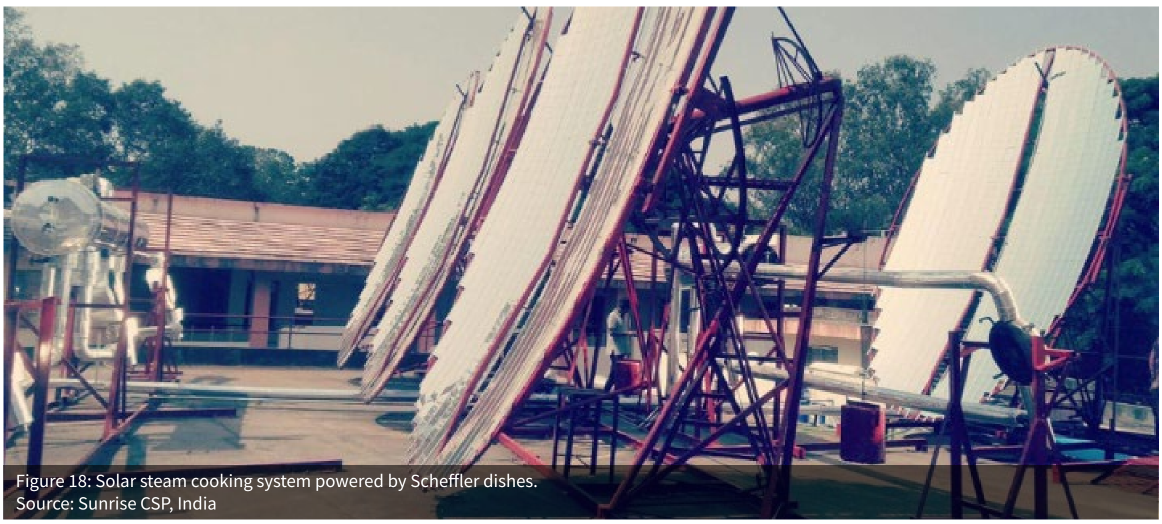


Figure 18: Solar steam cooking system powered by Scheffler dishes.
Source: Sunrise CSP, India

8 The Solar Thermal Vision 2045

The target for solar thermal systems installations by 2045 is based on stakeholder workshops held in June 2024, alongside detailed projections of population growth and energy demand until 2045. The vision for solar thermal energy focuses on achieving realistic market penetration targets by 2045, using successful countries with similar climatic conditions and human development indices as benchmarks.

8.1 Starting point and objectives for 2045

During the first stakeholder workshop held at ICIMOD on 18 July 2024, participants reviewed and discussed in detail Nepal's climatic conditions, data on population development, and data on the most important application sectors for solar thermal systems.

The discussion included the current status of solar thermal systems use. Between 2020 and 2023, 20,000– 27,000 solar hot water systems were installed annually, corresponding to an annual collector area of 50,000– 67,000 m^2. Majority of these systems are small thermosyphon systems, most of which are equipped with evacuated tube collectors (IEA SHC, 2024).

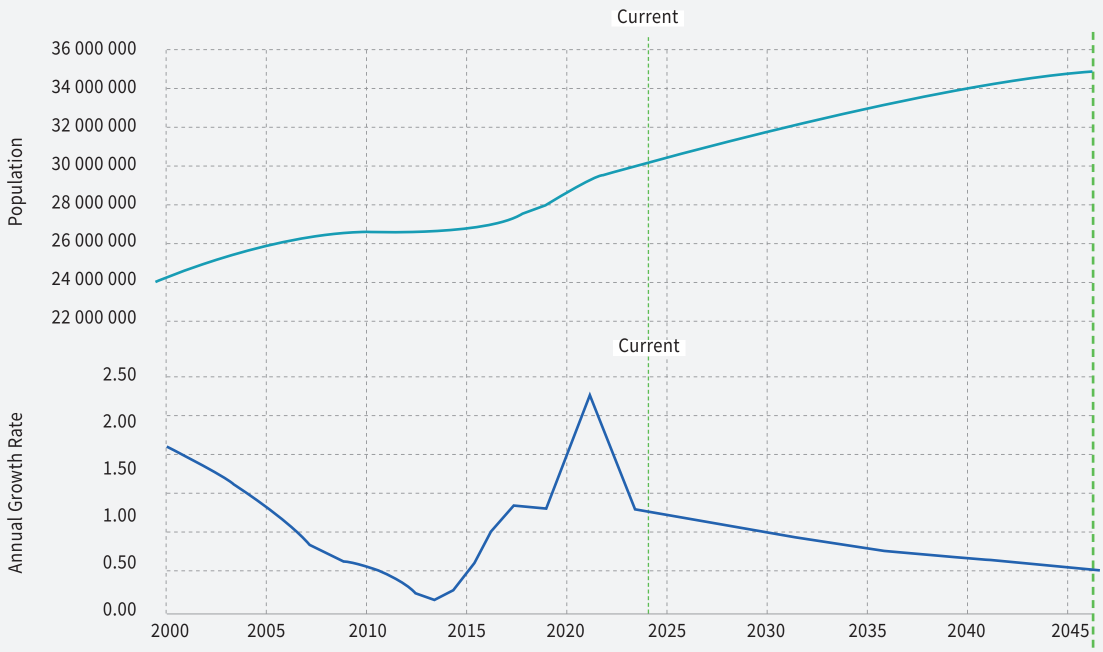
These annual installation rates highlight the presence of a functioning national solar industry, which can be built on in coming years.

Figure 19: Solar water heaters at Soaltee Westend Resort, Nagarkot
Photo: Werner Weiss, AEE INTEC

8.2 Nepal population growth

As the targeted solar thermal system installations are population-based, it is crucial to consider population development trends up to the target year 2045.

Figure 20: Nepal's population from 2000–2045 (United Nations, 2024)



In 2023, Nepal's population was approximately 30.9 million. Based on the United Nations World Population Prospects, this population is expected to grow to about 36.6 million by 2045. This forms the basis for the solar roadmap targets for 2045.

8.3 Objectives

Enhance energy security

Reduce dependence on imported fossil fuels by leveraging local solar resources and diversifying the energy mix

Promote economic developement

Create jobs and stimulate economic growth through the development and deployment of solar thermal technologies

Improve quality of life

Provide reliable and affordable energy for households, businesses, agriculture and industries

Mitigate climate change

Reduce greenhouse gas emissions and environmental impacts by replacing conventional energy sources with clean solar thermal energy

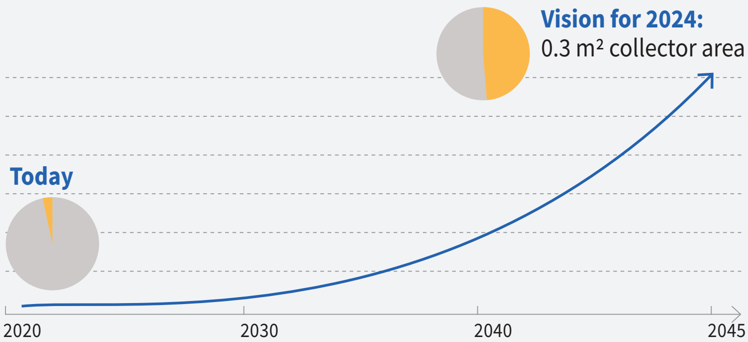
8.4 Vision Statement

Nepal aims to harness its solar energy potential toward widespread availability of affordable and reliable solar thermal technologies for key residential, commercial and industrial applications, which are currently heavily reliant on greenhouse gas emitting fossil fuels for energy supply.

Based on international benchmarks and an in-depth analysis of Nepal's environment, participants of the first stakeholder workshop concluded that a **target of 0.3 m^2 of collector area per inhabitant by 2045** would be realistic.

Given that Nepal's population is expected to grow to 36.6 million by 2045, achieving the installation target of 0.3 m^2 per inhabitant, would require the installation of approximately 11 million m^2 of collector area.

Figure 21: Market development based on the Solar Thermal Vision



9 Relevant sectors and potentials for solar thermal systems

To assess the feasibility of the Solar Thermal Vision target (installing 0.3 m^2 of collector area per inhabitant by 2045), the next step involves examining the potentials in relevant sectors and comparing them with the vision target.

The following chapters present the potential for solar thermal systems across various application sectors. **These potentials are based on the analysis of available statistical data, agreements of the discussions at the three stakeholder workshops, and expert assessment from the respective sectors.**

9.1 Residential sector

9.1 Residential sector	9.2 Hotels and lodges	9.3 Hospitals and health centres	9.4 Boarding schools, monasteries, and governmental institutions	9.5 Industry	9.6 Agriculture	9.7 Commerce and small and medium enterprises	9.8 Solar steam cooking	9.9 Sectors for pilot systems

The household or residential sector represents the greatest potential for installing solar thermal systems, given the daily demand for hot water for hygiene, laundry, and cooking.

According to the last census in 2021, there were 6,666,937 households in Nepal. With a population of around 30 million, this means an average of 4.5 people living in each household. By 2045, Nepal's population is expected to reach 36.6 million, resulting in a corresponding increase in the number of households. However, for the initial estimate of the potential, the current population is used.

Solar water heating systems

The household or residential sector represents the greatest potential for installing solar thermal systems, given the daily demand for hot water for hygiene, laundry, and cooking. Solar water heating systems are the easiest option to exploit in the residential sector.

Based on Nepal's income structure and population distribution, it is assumed that approximately **35% of the households can afford and are interested in installing a solar thermal system** with an average collector area of 3 m^2 (2.1 kW_{th}) over the next 20 years.

This estimate considers the lower demand for hot water in the southern region of Nepal (Terai), where 48% of the population resides. In Terai, an estimated 15% of the households will install solar thermal systems due to the high ambient temperatures year-round. For the remaining population in the central highlands and mountainous regions, it is anticipated that 55% of the households will install a solar thermal system by 2045.

9.1.1 Single-family homes

In 2021, there were around 6.6 million households in Nepal, of which around 5.27 million were single-family households and 1.33 million households were living in apartment buildings in cities and towns.

If 35% of single-family households install SWH systems, this results in approximately **1.9 million systems,** with a **total collector area of 5,700,000 m².**

TYPICAL SYSTEMS

Collector area	**2–4 m²**
Hot water storage size	**150–400 litres**
Collector type	**Flat-plate or evacuated tube collector**
Temperature range of the application	**60–80°C**
Number of systems by 2045	**1.9 million**

Further technical information can be found here: [IEA SHC | Task 69]

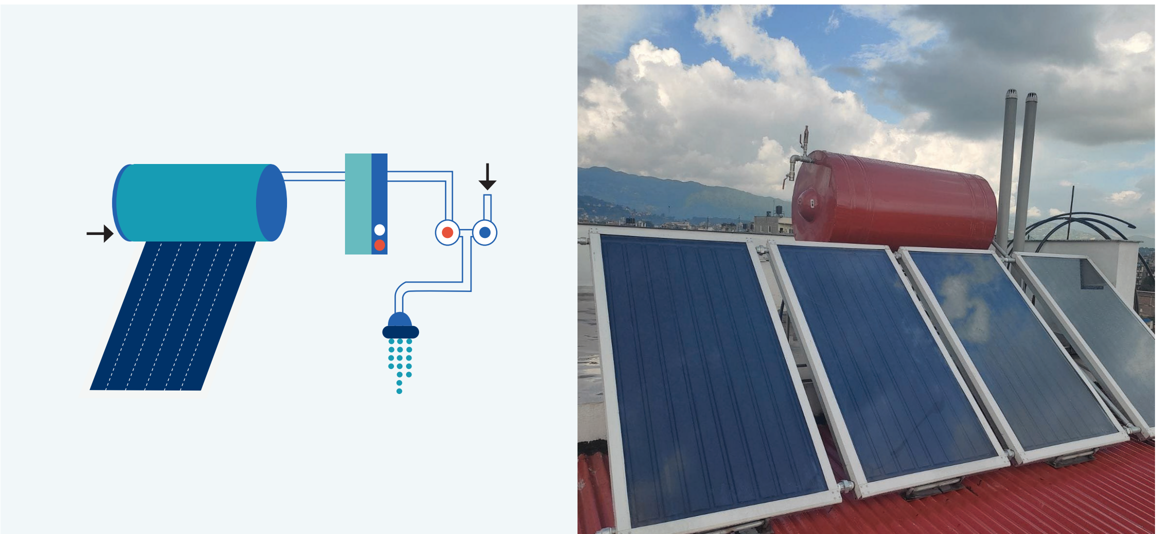


Figure 22: Small-scale Thermosiphon hot water system for single-family households in Nepal
Photo: Maharjan Metals, Nepal

9.1.2 Apartment buildings

In Nepal, there are 1.33 million households in apartment buildings, housing approximately 6 million people. For apartment buildings, an estimated 35% of households are expected to be equipped with solar thermal systems by 2045.

Assuming an average of 10 apartments per apartment building, this results in about **50,000 systems,** with an average of **40 m^2 collector area per system.**

The total area of these solar thermal systems in muliti-family buildings would be around 1.9 million m^2 of collector area.

TYPICAL SYSTEMS

Collector area	**20–100 m^2 (average 40m^2)**
Hot water storage size	**1,400–10,000 litres**
Collector type	**Flat-plate or evacuated tube collector**
Temperature range of the application	**60–80°C**
Number of systems by 2045	**50,000**

Further technical information can be found here: [IEA SHC | Task 45]

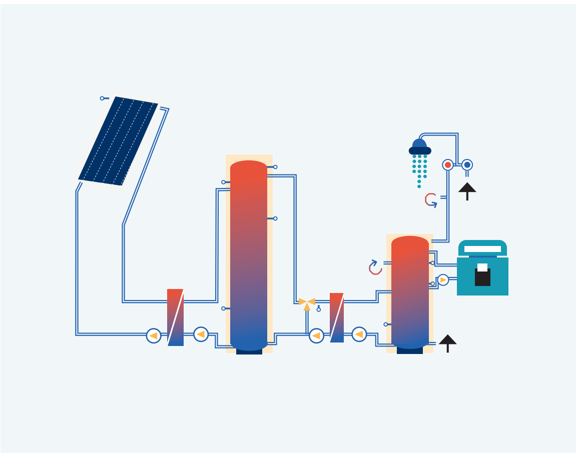


Figure 23: A pumped system for an apartment building

Apartment building in Nepal
Photo: Vie Tech Pvt. Ltd.

9.2 Hotels and lodges

In hotels and other accommodations, hot water is needed for showers, laundry, and dishwashing.

In 2023/2024 Economic Survey, the Ministry of Finance reported 182 registered star hotels with 17,073 beds and 1,234 registered tourist standard hotels (non-star, luxury heritage boutique hotels, lodges and resorts) with 37,297 beds. This brings the total number of beds in these accommodations to 54,370. The Hotel Association of Nepal (HAN) estimates there are about 26,000 more beds in standard hotels that are not centrally registered, but reported only at the provincial level, bringing the total number of beds in the hotel sector to around 80,000.

Beyond the hotel sector, other accommodations include homestays, teahouses, guesthouses, and bed-and-breakfasts. HAN estimates around 20,000 beds available in these accommodations equipped with the necessary sanitary infrastructure[5].

In hotels and other accommodations, hot water is needed for showers, laundry, and dish washing. To meet the daily hot water requirement with solar thermal systems, it is estimated that a 1–2 m^2 collector area per guest (bed) is required[6]. This means the hotel sector has the potential of around 1,400 systems with a total collector area of 72,000 m^2, assuming 60% of the potential will be utilised through special funding measures.

For homestays, teahouses, guesthouses and bed-and-breakfast accommodations, only 50% of these accommodations are expected to install solar thermal systems by 2045. This amounts to around 1,500 systems with a total collector area of 15,000 m^2 (average system size: 10 m^2)

All accommodations combined have a potential of about
2,900 systems with a **total collector area of 87,000 m^2.**

[5] Personal communication on 14 August 2024 with Tek B. Mahat, Chief Operating Officer, HAN
[6] This is the area required to heat 30-50 litres of water to 60°C on a day with average solar radiation of 600 Watts· For details, T-Sol simulation program· https://valentin-software·com/produkte/tsol/

Star hotels will primarily use pumped systems, while simpler accommodations may use thermosyphon systems, as shown in the figures below.

Figure 24: Solar installation at Mount Everest Base Camp (Pheriche)
Photo: Vie Tech Pvt. Ltd.

TYPICAL SYSTEMS

Collector area	**20–100 m² (average 50m²)**
Hot water storage size	**1,400–10,000 litres**
Collector type	**Flat-plate or evacuated tube collector**
Temperature range of the application	**60–80°C**
Number of systems by 2045	**2,900**

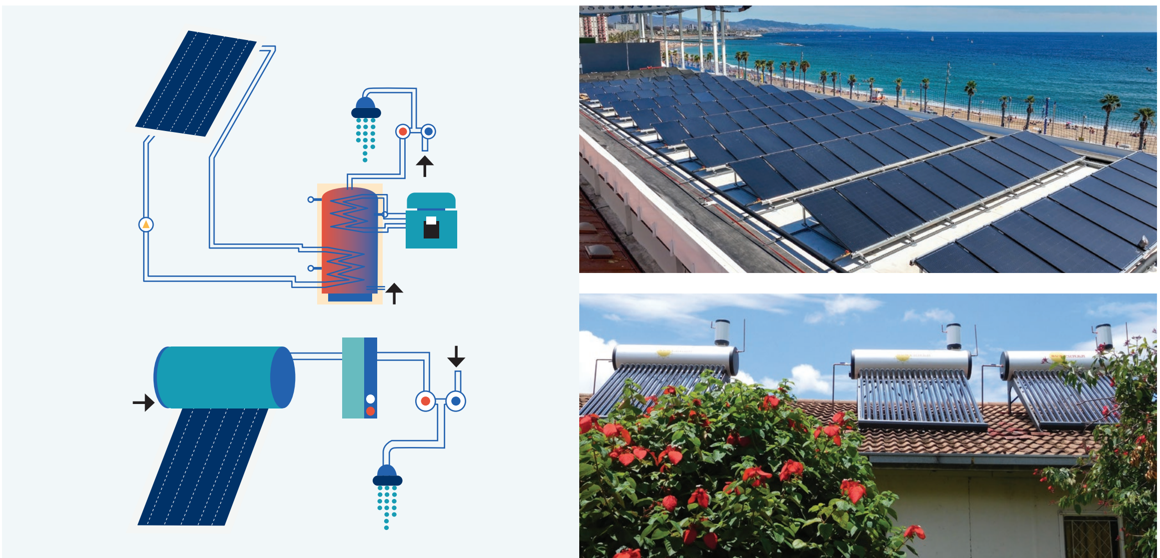


Figure 25: Pumped system (top) and thermosyphon system (bottom) for hotels and lodges.

9.3 Hospitals and health centres

These health facilities require hot water for hygiene (showers, cleaning), as well as laundry, cooking and dishwashing, particularly in hospitals.

Hospitals and health centres represent another sector with significant potential for solar thermal system use. These health facilities require hot water for hygiene (showers, cleaning), as well as laundry, cooking and dishwashing, particularly in hospitals.

According to the Ministry of Finance (see Table 3), as of February 2024, there are 7,858 health facilities in Nepal with a total bed capacity of 16,541.

Table 3: Health facilities in Nepal as of February 2024

Type of hospital	Number of hospitals
Public hospital	215
Primary health care centre	201
Subtotal - Hospitals	**416**
Health post	3 820
Ayurvedic dispensary	426
Basic health centre	3 196
Subtotal – Health centres	**7 442**
Total	**7 858**
Total bed capacity	**16 541**

Source: p.185, Economic Survey 2023/2024, Ministry of Finance

To estimate the potential for solar thermal systems in this sector, it is assumed that the 215 public hospitals, 201 primary health centres, and around 20 retirement homes will require hot water and are therefore relevant for estimating the potential.

Given the government's strong influence in the healthcare sector, it is assumed that a high proportion of these facilities would install solar thermal systems if appropriate support measures were in place. Assuming 70% of the aforementioned healthcare facilities will install solar thermal systems, this would result in a potential of 300 systems, with an average system size of 50 m^2 collector area.

For the 7,442 health posts and basic health centres, as well as some retirement homes, it is assumed that 60% (around 4,500 systems) have at least a small hot water demand. Therefore, these facilities would require only a system size of 10 m^2 per facility. This relatively lower percentage takes into account their limited financial resources and technical staff to initiate the construction of these systems.

Thus, by 2045,
an estimated 4,800 systems, with a **total collector area of 59,900 m^2,**
could be installed in the healthcare sector.

TYPICAL SYSTEMS FOR HOSPITALS

Collector area	**50–200 m^2 (average 50m^2)**
Hot water storage size	**3,500–20,000 litre**
Collector type	**Flat-plate or evacuated tube collector**
Temperature range of the application	**60–80°C**
Number of systems by 2045	**300**

TYPICAL SYSTEMS FOR HEALTH POSTS AND BASIC HEALTH CENTRES

Collector area	**5–20 m^2 (average 10m^2)**
Hot water storage size	**350–2,000 litre**
Collector type	**Flat-plate or evacuated tube collector**
Temperature range of the application	**60–80°C**
Number of systems by 2045	**4,500**

9.4 Boarding schools, monasteries, and governmental institutions

For schools with hot water demand, traditional/religious schools and institutional schools were considered. Monasteries/religious schools and governmental institutions (barracks, offices, etc.) are also assumed to have hot water needs.

In Nepal, there are a total of 35,876 schools (see below). Schools that have canteens or offer overnight accommodation (boarding schools) are suitable for solar thermal systems.

Table 4: Schools in Nepal

Community schools (Public)	**Traditional/ religious schools**	**Institutional schools** (Private)	**Total**
26 606	1 384	7 886	**35 876**

Source: p.197, Economic Survey 2023/2024, Ministry of Finance

Community schools, which generally do not require hot water, are not considered for solar thermal systems. However, schools with hot water demand, such as the 1,384 traditional/religious schools and 7,886 institutional schools were considered, assuming that 60% of each of these schools would install solar thermal systems. This results in a total of 5,500 systems.

Additionally, around 1,400 monasteries/religious schools and governmental institutions (barracks, offices, etc.) across the country are also assumed to have hot water needs. It is estimated that 60% of these facilities will install solar thermal systems, resulting in about 800 systems.

In total, the potential for solar thermal systems in this sector is approximately **6,300 solar thermal systems** with a **total collector area of around 208,000 m^2**.

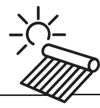


Figure 26: Pumped solar water heating system for a monastery in Bhutan
Photo: Werner Weiss, AEE – INTEC

TYPICAL SYSTEMS

Collector area	**10–100 m²**
Hot water storage size	**700–10,000 litres**
Collector type	**Flat-plate or evacuated tube collector**
Temperature range of the application	**60–80°C**
Number of systems by 2045	**6,300**

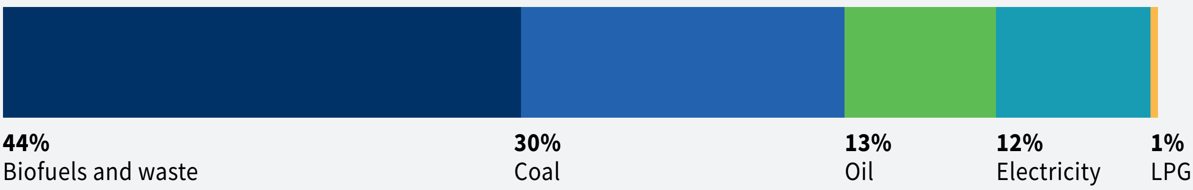
9.5 Industry

9.1 Residential sector	9.2 Hotels and lodges	9.3 Hospitals and health centres	9.4 Boarding schools, monasteries, and governmental institutions	9.5 Industry	9.6 Agriculture	9.7 Commerce and small and medium enterprises	9.8 Solar steam cooking	9.9 Sectors for pilot systems

Nepal's industrial sector is predominantly dependent on fossil fuels mainly used to generate process heat, highlighting a great potential for solar thermal systems in this sector.

Data from the WECS (2024) indicates that Nepal's industrial sector is predominantly dependent on fossil fuels, with oil and coal accounting for 45%[7] of the total final energy consumption. These fuels are mainly used to generate process heat, highlighting a great potential for solar thermal systems in this sector.

Figure 27: Final energy consumption in the industrial sector in 2023 (WECS, 2024).



[7] Coal, 30%, Petrol 2%, Diesel 10%, LPG 1%, Furnace oil 1% (WECS, 2024)

The energy demand per industry sector and the potential share of solar thermal systems are depicted in the table below. This data is sourced from the baseline study of selected sector industries (PACE, 2012)[8] to assess the potential for more efficient use of energy which was published in 2012 as part of the Nepal Energy Efficiency Programme (NEEP).

Table 5: Energy demand per industry sector in 2023 and possible share of solar thermal systems

Industry sector	**Electrical energy demand** [MWh]	**Thermal energy demand** [MWh]	**Solar thermal energy generation at 50% of total solar share in total thermal energy** [MWh]	**Required collector area** [m²]
Iron and steel	59 874	163 977		
Pulp and paper	30 759 083	140 665		
Brick	1 796	91 630		
Sectors relevant for solar thermal systems				
Beverage	15 300	15 451	7 726	9 538
Biscuit	3 571	15 718	7 859	9 702
Dairy	7 997	25 532	12 766	15 760
Instant noodles	3 957	65 356	32 678	40 343
Sugar	5 386	2 807	1 404	1 733
Vegetables and ghee	21 864	195 937	97 968	120 948
Soap and chemical	9 501	80 163	40 082	49 484
Other industries	50 000	400 000	200 000	246 914
Total relevant sectors	**117 576**	**800 964**	**400 482**	**494 422**
Total - all industry sectors	**30 938 329**	**1 197 236**	**400 482**	**494 422**

Source: Department of Industry, Nepal. (2024); FNCCI (2017); CASA Programme (2024)

The table clearly indicates that besides the pulp and paper industry, in almost all sectors, energy demand for heating exceeds that for electricity. With the exception of the iron and steel, pulp and paper, and brick sectors, the majority of these industries require either low-temperature (60–100°C) or medium-temperature heat of up to 250°C (IEA SHC, 2008). Only industrial sectors requiring low and medium-temperature heat for their processes were taken into account for the solar potential (see Table 5).

Studies and best practices documented by the IEA SHC (IEA SHC, 2016) show solar systems generated for industrial process heat can achieve solar coverage rates ranging from 30% to 85%. This formed the basis for the assumption that a solar coverage rate of 50% should be achieved for the systems to be installed in Nepal. This implies that solar thermal systems can provide 50% of the annual heat demand, with the remaining demand being met by back-up systems. To meet 50% of this heat requirement (solar share of the thermal energy) in the next 20 years, about 490,000 m^2 of collector area would be required.

Some best practice examples with high solar coverage rates are shown in Appendix 18.3.

The predominance of small and medium-sized companies in Nepal's industrial sector was taken into account when determining the number of systems to be built. The range of these systems varies from small systems of 50 m^2– 700 m^2 corresponding to 35 kW_{th}– 500 kW_{th} for SMEs up to the order of magnitude of 1– 5 MW_{th} (1,400– 7,000 m^2) for larger companies.

[8] At the time this roadmap was developed, this study was the only consistent dataset available for Nepal's industrial sector.

TYPICAL SYSTEMS

Collector area	**50–7,000 m² (35kW$_{th}$–5 MW$_{th}$)**
Hot water storage size	**3–700 m³**
Collector type	**Flat-plate, evacuated tube, parabolic trough or Fresnel collector**
Temperature range of the application	**60–250°C**
Number of systems by 2045	**5,000**

Figure 28: Pumped system with flat-plate collectors for the Golan Winery, Israel (left). A leading Swiss milk processing company uses 147 kWth (210 m²) of high vacuum flat-plate collectors for cheese production (right)

Photo: Tigi Ltd., Israel

Photo: TVP Solar, Switzerland

Figure 29: Parabolic trough collectors for one of the breweries of the Carlsberg Group in Salonika, Greece, Photo: Absolicon

Further technical information can be found here: [IEA SHC | Task 33](), [IEA SHC | Task 49]()

9.5.1 Cottage and small industries

According to the Federation of Nepal Cottage & Small Industries (FNCSI), there are around 100,000 micro-entrepreneurs in Nepal, with 35,000 of them registered as members of FNCSI. These enterprises typically employ between one and nine people[9].

A small subset of these micro-enterprises, primarily located in rural areas, operate in the food and textile sectors. These enterprises require heat to preserve food or dyeing natural fibres.

As there is no precise data on the exact number of such micro-enterprises and their limited financial capacity, the nationwide potential for solar thermal systems in this sector is estimated to range from **5,000 to 6,000 systems,** with a **total collector area of 20,000 m^2.**

Figure 30: Passive cabinet solar dryers in Zimbabwe. Domestic Solar Heating (left) and DTC, UZ (right)

TYPICAL SYSTEMS

Collector area	**3–10 m^2**
Hot water storage size	**200–1,000 litres**
Collector type	**Flat-plate and evacuated tube collector**
Temperature range of the application	**40–80°C**
Number of systems by 2045	**5,000–6,000**

[9] Information received at a stakeholder meeting with FNCSI representatives on 15 August 2024, in Kathmandu.

9.6 Agriculture

9.1 Residential sector | 9.2 Hotels and lodges | 9.3 Hospitals and health centres | 9.4 Boarding schools, monasteries, and governmental institutions | 9.5 Industry | 9.6 Agriculture | 9.7 Commerce and small and medium enterprises | 9.8 Solar steam cooking | 9.9 Sectors for pilot systems

About 30% of the total global energy is used in the agri-food sector, particularly thermal energy in both heating and cooling applications.

The agricultural and food processing industries are key sectors aligned closely with sustainable development goals, contributing significantly to rural development. About 30% of the total global energy is used in the agri-food sector, particularly thermal energy in both heating and cooling applications (Puri, 2022).

Research considers solar energy technologies as promising solutions to increase system flexibility while delivering mitigation benefits. Different types of solar heating and cooling systems can provide a wide range of desired operating temperatures, making them suitable for various applications in agricultural and food processing systems. The main applications of solar thermal energy systems in these industries include:
- solar air heaters for drying and dehydration processes
- solar water heaters for both heat and food processing systems
- solar cooking systems
- solar heating and cooling systems for maintaining greenhouse climate
- solar-powered cooling systems for both food processing and space cooling (Amir, 2022)

Potential in Nepal

The 2021 census shows that 50.1% of those engaged in any economic activity in Nepal are working in agriculture, forestry, and fishery (National Statistics Office, 2023). Despite this, the biggest obstacle to using solar technologies in agriculture is that farming in Nepal is largely subsistence-based. This dependency limits the potential for commercial solar drying, albeit in small systems. The current government subsidy programme for solar dryers has only seen modest demand further adding to this challenge.

Currently, agricultural drying in small-scale farms and businesses in Nepal has relied on traditional sun-drying methods, where goods like grain, pulses, and fruit are spread out on simple drying racks under direct sun. For medium-scale industries, coal-fired dryers are more common (Nepali Headlines, 2024).

In Nepal, there are three types of solar drying systems in use: i) Cabinet type for domestic use, ii) rack type for commercial use, and iii) tunnel type for industrial use (Joshi et.al., 2000)

Despite these challenges, the agricultural sector holds considerable potential for adopting solar thermal systems. By 2045, **an estimated 20,000 solar thermal systems** with an **average collector area of 25 m²** could be built for the agricultural sector[10].

[10] As there is no suitable database for the commercial agricultural sector available, the number of installations is an estimate based on the framework conditions described.

This potential can be realised if commercial farmers and small and medium-sized enterprises are made aware of the benefits of solar drying, companies actively offer this technology, and government support for solar dryer installations continue.

TYPICAL SYSTEMS

	Collector area	**10–1,000 m² (average size 25 m²)**
	Hot water storage size	**1–70 m³**
	Collector type	**Flat-plate, evacuated tube, air collector, greenhouse**
	Temperature range of the application	**40–250°C**
	Number of systems by 2045	**20,000**

Further technical information: [IEA SHC | Task 29]

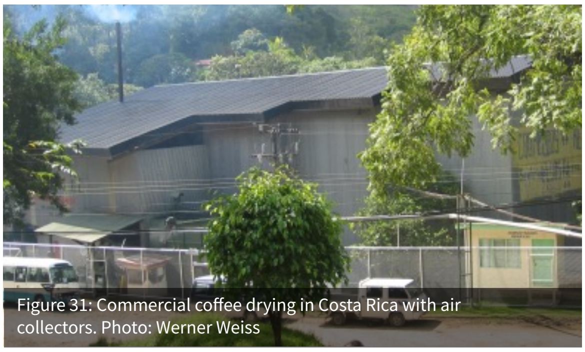


Figure 31: Commercial coffee drying in Costa Rica with air collectors. Photo: Werner Weiss

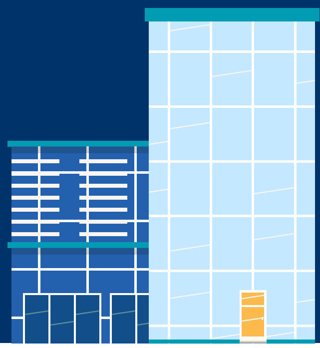
Figure 32: Solar greenhouses in Krugersdorp, Bosman van Zaal, South Africa

Figure 33: Herb dryer in Cuba. Photo: CONA

9.7 Commerce and small and medium enterprises

9.1 Residential sector	9.2 Hotels and lodges	9.3 Hospitals and health centres	9.4 Boarding schools, monasteries, and governmental institutions	9.5 Industry	9.6 Agriculture	9.7 Commerce and small and medium enterprises	9.8 Solar steam cooking	9.9 Sectors for pilot systems

Applications range from hot water production and process water for small businesses to space heating and solar cooling for office buildings.



Solar thermal systems offer a diverse range of applications for the commercial sector and small and medium enterprises (SMEs). These range from hot water production and process water for small businesses to space heating and solar cooling for office buildings.

The potential for the next 20 years for this sector is based on UNCDF (2020). According to this, Nepal had 923,356 micro, small, and medium enterprises (MSMEs) operating in 2018, with roughly half being registered. Among these enterprises, 69.3% are micro-enterprises, 25.2% small enterprises, and 5.5% medium-sized enterprises.

For estimating the potential adoption of solar thermal systems, only registered SMEs were used as the basis, totalling approximately 140,000 companies. Given the food, beverage and textile sectors have a low-temperature heat demand, it is estimated that around **10% of SMEs** will install solar thermal systems in the next 20 years.

TYPICAL SYSTEMS

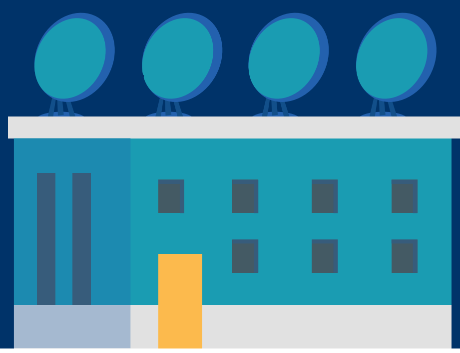
Collector area	**10–100 m^2**
Hot water storage size	**1–10 m^3**
Collector type	**Flat-plate, evacuated tube**
Temperature range of the application	**40–250°C**
Number of systems by 2045	**14,000**

Figure 34: Solar thermal air conditioning system with 2,579 m² collector area at the Caixa Geral de Depósitos (bank) in Lisbon, Portugal
Photo: SOLID

9.8 Solar steam cooking

9.1 Residential sector | 9.2 Hotels and lodges | 9.3 Hospitals and health centres | 9.4 Boarding schools, monasteries, and governmental institutions | 9.5 Industry | 9.6 Agriculture | 9.7 Commerce and small and medium enterprises | 9.8 Solar steam cooking | 9.9 Sectors for pilot systems

Solar cooking using steam have become an important in large kitchens.



Solar cooking using steam have become an important in large kitchens, particularly in temples, schools and army establishments, especially in India. Fixed focus type Scheffler concentrators are most widely used for different low- to medium- industrial process heat applications. These concentrators are available in the standard sizes of 8 m^2 and 16 m^2 (Bhambare, 2022).

A single Scheffler dish with a 16m^2 reflector can cook food for 125 people for approximately 240 days a year by generating 60 kg of steam per day (More, 2017).

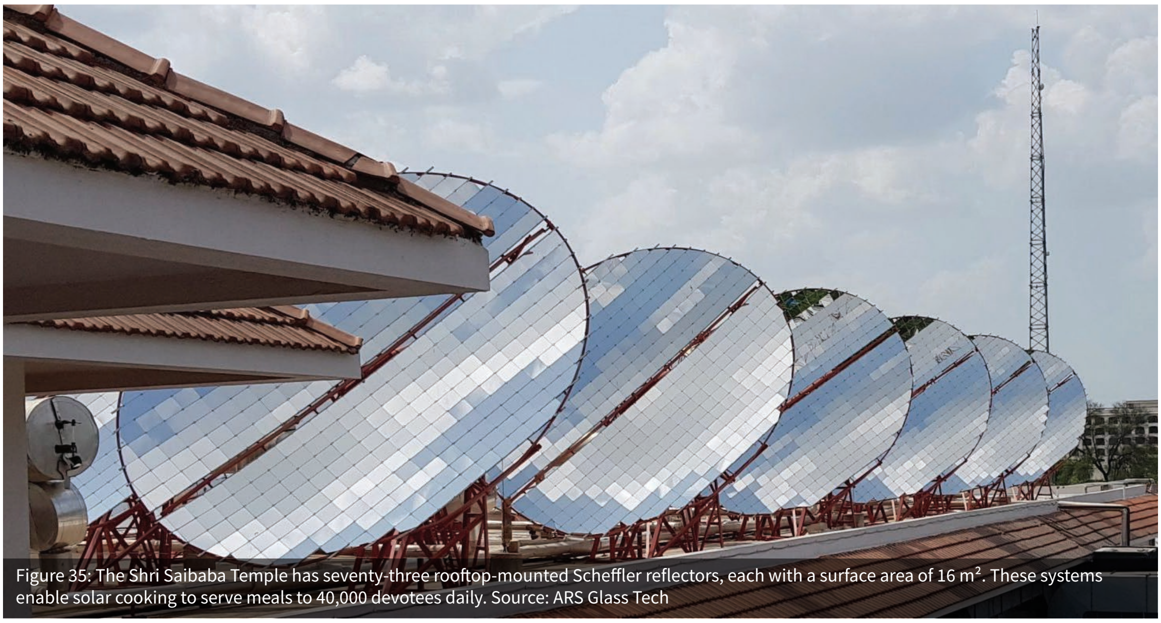


Figure 35: The Shri Saibaba Temple has seventy-three rooftop-mounted Scheffler reflectors, each with a surface area of 16 m^2. These systems enable solar cooking to serve meals to 40,000 devotees daily. Source: ARS Glass Tech

According to various sources, between 3,000 and 6,000 units of Scheffler dishes have been built globally to date, resulting in a total mirror surface area between 50,000 to 100,000 m^2. However, the vast majority of these systems have been installed in India. This shows that even in India, where the vast majority of global solar steam cooking systems have been built, the use of this technology remains relatively low.

In Nepal, solar steam cooking systems have been installed, but only in limited numbers, and data on the exact number of installations is not reported.

Based on the systems built in India to date, it appears to be realistic that a maximum of 50 kitchens – for ashrams, barracks or larger commercial kitchens – could be equipped with concentrators in Nepal. This corresponds to a **total receiver area of about 30,000 m^2**, with an average of 40 Scheffler dishes, or similar products, and a **combined collector area of about 600 m^2** per kitchen.

TYPICAL SYSTEMS

Collector area	**600 m^2**
Collector type	**Scheffler dishes or equivalent**
Temperature range of the application	**300°C**
Number of systems by 2045	**50**

9.9 Sectors for pilot systems

9.1 Residential sector	9.2 Hotels and lodges	9.3 Hospitals and health centres	9.4 Boarding schools, monasteries, and governmental institutions	9.5 Industry	9.6 Agriculture	9.7 Commerce and small and medium enterprises	9.8 Solar steam cooking	9.9 Sectors for pilot systems

It is recommended to build small pilot plants in the coming years in these sectors and thus build technical know-how.

The following sectors have limited potential for the use of solar thermal systems. The primary reason is the absence of necessary infrastructure in buildings (e.g., solar combi-systems for space heating or solar cooling) or urban infrastructure (solar district heating). For these sectors, it is therefore recommended to build small pilot plants in the coming years and thus build technical know-how.

9.9.1 Solar combi-systems for hot water and space heating

In the low-mountain and high-mountain regions, residential buildings and hotels typically lack central heating systems. Space heating is often provided by traditional biomass stoves or electric heaters, while most hotels and hospitals use air conditioners for heating during winter. Only a few households and commercial buildings have opted for heat pumps paired with photovoltaic systems.

In the medium term, there is considerable potential to use solar thermal systems for heating buildings in Nepal's mid-hills and inhabited high mountain regions. The prerequisite for this, however, would be to equip buildings with proper thermal insulation and a central heating system. These measures are recommended for adoption by the Human Settlements Committee.

Both air collectors and liquid-filled collectors can then be used to provide heat.

Further technical information can be found here: IEA SHC | Task 26

9.9.2 Solar district heating

Solar district heating could also have potential, particularly in urban areas of the low mountain range and in villages in the mountain regions where access to biomass is limited and electrical infrastructure is weak. These systems are most suitable in areas where outside temperatures are low in the winter months, and where are located close to each other and require heating for several months.

However, the necessary infrastructure for solar district heating is lacking. It would be worth considering setting up one or two small pilot systems that supply 10 to 30 well-insulated buildings with heat during the implementation period of this roadmap.

Further technical information can be found here: IEA SHC | Task 68, IEA SHC | Task 55

9.9.3 Solar air conditioning and cooling

The global market for cooling and refrigeration will continue to grow, particularly in the Global South. By 2050, 37% of the total electricity demand growth will be driven by air conditioning[11]. This presents significant potential for both solar thermal and PV-driven solar cooling and air conditioning systems.

The advantage of solar energy for cooling is that the supply (solar radiation) is available when the demand (cooling) is at a peak. In other words, cooling is most needed when the sun is shining. Solar thermal cooling is still a niche market, with over 2,000 systems deployed globally as of 2023. Small units, with a capacity lower than 20 kW, are becoming more compact (cheaper upfront costs), targeting the mass markets. Medium- to large-scale projects, with capacities of 30 kW to 2,000 kW, are dominated by engineered systems. Of the small and medium capacity (<350 kW) solar cooling systems worldwide, 70% are installed in Europe.

As with solar district heating, it is recommended to set up a small number of pilot plants during the implementation of the roadmap. However, local companies must first be trained to plan, install, and maintain such systems.

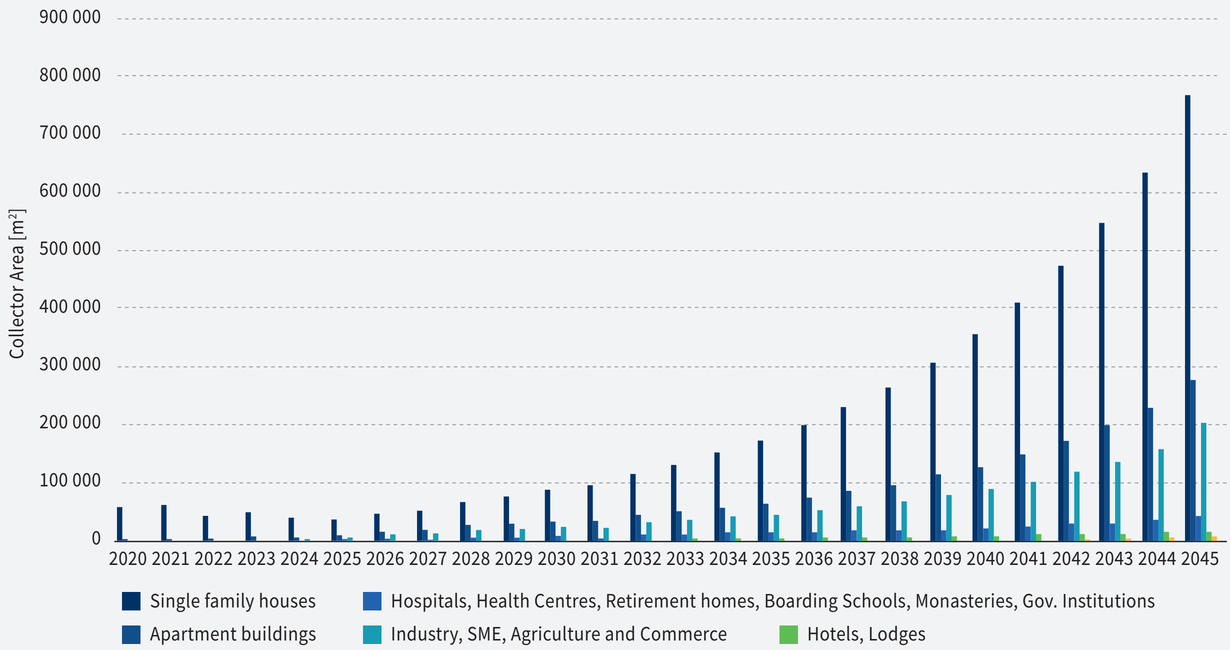
Further technical information can be found here: IEA SHC | Task 38, IEA SHC | Task 65

9.10 Annual installations and number of total installations per sector

As described in detail in the previous chapters, Tables 6 and 7 present the collector areas to be installed and the number of systems by sector.

The data indicate that the potential calculated on the basis of the sector analysis is slightly lower than the initial approximation for the solar thermal vision (refer to Chapter 8.4). The calculated potential of 9.26 million m^2 of collector area corresponds to around 0.26 m^2 of installed collector area per inhabitant in 2045, compared to the target value of 0.3 m^2 per inhabitant in the solar thermal vision.

Figure 36: Development of annual solar thermal installations per sector 2020–2045



[11] https://www.iea.org/reports/the-future-of-cooling

Table 6: Total number of total installations per sector

	Total number [-]	**Percentage of total** [%]	**Number for potential** [m²]	**Sytems** [-]	**Average size** [m²]	**Collector area** [m²]
Households single-family houses	5 330 000	35%	1 900 000	1 900 000	3	5 700 000
Households apartment buildings	1 330 000	35%	470 000	50 000	40	1 900 000
Hotels and lodges [beds]	100 000	58%	87 000	2 900	30	87 000
Hospitals, health centres, retirement homes	7 858	61%	4 800	4 800	12	59 900
Boarding Schools, monasteries, governmental institutions	10 670	60%	6 400	6 300	33	208 100
Industry - thermal energy demand relevant sectors **[MWh]**	800 964	50%	400 000	7 000	70	490 000
Agriculture				20 000	25	500 000
SMEs, commerce, cottage and small industries				10 000	28	275 000
Commercial cooking			50	50	600	30 000
Sectors for pilot systems						
Solar air conditioning and cooling				20	100	2 000
Solar space heating				50	20	1 000
Solar district heating				3	2 167	6 500
Total				**2 001 223**		**9 259 500**

Table 7: Annual installations and number of systems per sector 2020–2045

Year	Single-family houses	Apartment buildings	Hotels, lodges	Hospitals, health centres, schools, monasteries, government institutions	Industry, SMEs, agriculture, and commerce	Commercial cooking	Annual installations	Total collector area	Total installed capacity
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[MW^{th}]$
Until 2020	271 831	31 804	2 000	500	1 902		308 037	308 037	216
2020	60 685	3 498	549	473	1 694		66 898	375 000	263
2021	62 112	4 006	569	735	1 981		69 403	444 000	311
2022	42 545	5 259	417	771	1 846		50 838	495 000	347
2023	49 785	6 886	483	973	1 774		59 900	555 000	389
2024	41 694	6 586	663	1 088	2 975		53 006	608 000	426
2025	38 420	8 878	696	2 228	5 483		55 705	664 000	465
2026	45 617	16 286	725	2 320	11 182	600	76 731	741 000	519
2027	52 696	18 814	838	2 680	12 918	600	88 544	830 000	581
2028	61 347	21 902	975	3 120	15 038	600	102 983	933 000	653
2029	70 785	25 272	1 125	3 600	17 352	600	118 734	1 052 000	736
2030	81 796	29 203	1 300	4 160	20 051	600	137 110	1 190 000	833
2031	94 380	33 696	1 500	4 800	23 136	600	158 112	1 350 000	945
2032	109 324	39 031	1 738	5 560	26 799	900	183 351	1 530 000	1 071
2033	126 627	45 209	2 013	6 440	31 041	900	212 229	1 740 000	1 218
2034	146 289	52 229	2 325	7 440	35 861	900	245 044	1 990 000	1 393
2035	169 098	60 372	2 688	8 600	41 452	900	283 109	2 270 000	1 589
2036	195 839	69 919	3 113	9 960	48 007	900	327 737	2 600 000	1 820
2037	226 512	80 870	3 600	11 520	55 526	900	378 929	2 980 000	2 086
2038	262 691	93 787	4 175	13 360	64 395	1 200	439 608	3 420 000	2 394
2039	304 376	108 670	4 838	15 480	74 614	1 200	509 176	3 930 000	2 751
2040	352 352	125 798	5 600	17 920	86 374	1 200	589 245	4 520 000	3 164
2041	408 194	145 735	6 488	20 760	100 063	1 200	682 439	5 200 000	3 640
2042	472 687	168 761	7 513	24 040	115 873	1 800	790 673	5 990 000	4 193
2043	547 404	195 437	8 700	27 840	134 189	4 800	918 370	6 910 000	4 837
2044	633 919	226 325	10 075	32 240	155 397	4 800	1 062 756	7 970 000	5 579
2045	766 620	273 702	12 184	38 989	197 927	4 800	1 294 223	9 260 000	6 482
Total	**5 700 000**	**1 900 000**	**87 000**	**268 000**	**1 285 000**	**30 000**	**9 260 000**	**9 260 000**	**6 500**
No. of systems	**1 900 000**	**50 000**	**2 900**	**11 100**	**37 000**				

The data in the greyed-out years come from customs authorities and stakeholder estimates of locally manufactured systems. The data collection was carried out by ICIMOD in early 2024. All data for subsequent years are based on the simulation of sector potentials.

10 Energy savings and potential reduction in emissions

10.1 Potential reduction in electricity consumption

The solar yields and the corresponding reduction in electricity consumption that can be possible through the use of the solar thermal systems are presented in Tables 8 and 9, assuming the entire heating demand would be met using electricity instead of solar thermal systems.

Table 8 presents the solar yields and electricity savings that will be achieved from all solar thermal systems installed by 2030, in accordance with the roadmap targets. By 2030, the solar thermal plants built by 2030 are projected to save 1,000 GWh of electricity annually.

Table 9 presents the same results, but includes all solar thermal systems that will be installed by 2045. By 2045, all solar thermal plants built would save 8,111 GWh of electricity annually.

Table 8: Avoided annual electricity consumption due to solar thermal systems, 2030

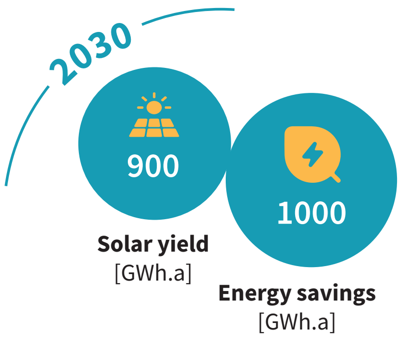


Table 9: Avoided annual electricity consumption due to solar thermal systems, 2045

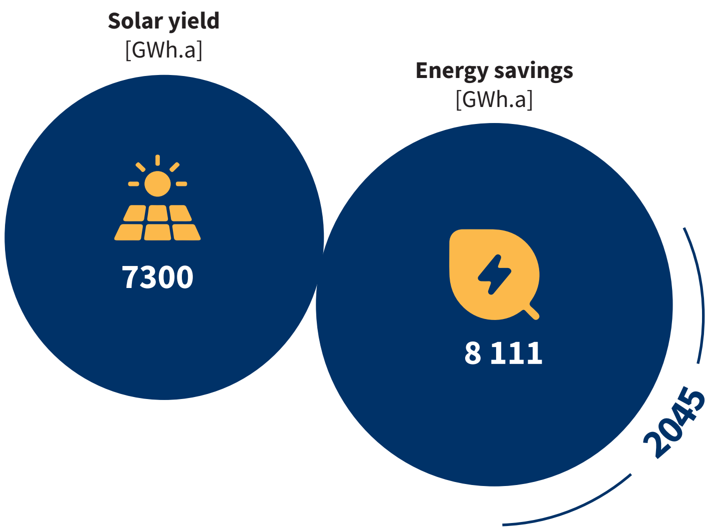


Table 10: Total cumulated collector area, installed capacity, solar yields, energy savings, and avoided CO_2 emissions until 2045

Year	Total collector area	Total installed capacity	Solar yield	Energy savings	Avoided CO_2 emissions Scenario 1	Avoided CO_2 emissions Scenario 2
	[m^2]	[MW_{th}]	[GWh.a]	[toe/a]	[tCO_2/a]	[tCO_2/a]
Until 2020	308 037	216	200	21 500	67 900	46 180
2020	375 000	263	300	32 200	101 700	69 300
2021	444 000	311	300	32 200	101 700	69 300
2022	495 000	347	400	43 000	135 900	92 400
2023	555 000	389	400	43 000	135 900	92 400
2024	608 000	426	500	53 700	169 700	115 500
2025	664 000	465	500	53 700	169 700	115 500
2026	741 000	519	600	64 500	203 800	138 500
2027	830 000	581	700	75 200	237 600	161 600
2028	933 000	653	700	75 200	237 600	161 600
2029	1 052 000	736	800	86 000	271 700	184 700
2030	1 190 000	833	900	96 700	305 500	207 800
2031	1 350 000	945	1 100	118 200	373 500	254 000
2032	1 530 000	1 071	1 200	129 000	407 600	277 100
2033	1 740 000	1 218	1 400	150 500	475 500	323 300
2034	1 990 000	1 393	1 600	172 000	543 400	369 400
2035	2 270 000	1 589	1 800	193 500	611 400	415 600
2036	2 600 000	1 820	2 000	215 000	679 300	461 800
2037	2 980 000	2 086	2 300	247 200	781 000	531 100
2038	3 420 000	2 394	2 700	290 200	916 900	623 400
2039	3 930 000	2 751	3 100	333 200	1 052 800	715 800
2040	4 520 000	3 164	3 600	386 900	1 222 400	831 200
2041	5 200 000	3 640	4 100	440 700	1 392 400	946 700
2042	5 990 000	4 193	4 700	505 200	1 596 200	1 085 200
2043	6 910 000	4 837	5 400	580 400	1 833 800	1 246 900
2044	7 970 000	5 579	6 300	677 100	2 139 300	1 454 700
2045	9 260 000	6 500	7 300	784 600	2 479 000	1 685 600

10.2 Solar yields and potential reduction in CO_2 emission

Table 10 presents the collector area installed for each year, the installed capacity, and the solar yields achieved. Additionally, the avoided CO_2 emissions are illustrated in two scenarios.

Scenario 1: Avoided CO_2 emissions in tons of oil equivalent, in relation to the energy savings achieved by solar thermal systems.

Scenario 2: Assumes without solar thermal systems, the required heat would be generated by: 50% electricity (88% domestic production through hydropower, 12% electricity imports from India), 30% biofuels and waste, and 20% oil (process heat in industry)[12].

The detailed methodological approach for calculating solar energy yields from the solar thermal systems and the resulting CO_2 emissions is documented in the appendix (See Chapter 18.2).

If the roadmap goal is achieved by 2045, the following outcomes are projected:
- Annual solar yield of 7,300 GWh
- Annual energy savings of 784,600 tons of oil

Avoided CO_2 emissions:
- Scenario 1: 2.48 million tons of CO_2
- Scenario 2[13]: 1.7 million tonnes of CO_2

[12] The percentage of electricity imported from India is assumed to remain constant· This is based on the electricity import share of 12% in 2023. Refer also to Chapter 5.
[13] The 12% of electricity imported from India was assumed to have come from power plants running on fossil fuels. In 2022, 75% of India's power plants were powered by either oil or gas. Source: https://www.laenderdaten.info/Asien/Indien/energiehaushalt.php

11 Investments required to implement the roadmap

The following table provides an overview of the investment required to implement the roadmap over the next 20 years.

Table 11: Investments required to implement the roadmap

Sector	System concepts and size of systems	Number of systems to be installed	Collector area to meet target	Estimated total cost	Estimated total cost
		[units]	[m²]	[Mill. NPR]	[Mill US$][14]
Single-family houses	Thermosyphon system 3m² collector area on average	1 900 000	5 700 000	238 668	1 766
Apartment buildings	Pumped system 20–100 m² average: 40 m² collector area	50 000	1 900 000	128 380	950
Hotels and lodges (Beds)	Pumped system 20–100 m² average: 50 m² collector area	2 900	87 000	5 878	44
Hospitals, health centres, retirement homes	Pumped systems 50–200 m² Thermosyphon systems 5–20 m²	4 800	59 900	4 047	30
Boarding schools, monasteries, government institutions	Pumped systems and thermosyphon systems 10–100 m²	6 300	208 100	11 249	83
Industry	Large pumped systems 50–1,000 m²	7 000	490 000	29 797	221
Agriculture	Solar air collector systems, Large pumped systems 20–1,000 m²	20 000	500 000	20 270	150
SMEs, commerce, cottage and small industries	Pumped solar water heating, cooling and air conditioning systems 20–100 m²	10 000	275 000	22 297	165
Commercial cooking	Fixed focus concentrators (CSP) 50 systems with 600m² each	50	30 000	1 014	7.5
Pilot systems					
Solar air conditioning and cooling		20	2 000	216	1.6
Solar space heating		50	1 000	61	0.5
Solar district heating		3	6 500	351	2.6
Total over 20 years		**2 001 123**	**9 260 000**	**462 227**	**3 420**
Average per year				**23 111**	**171**

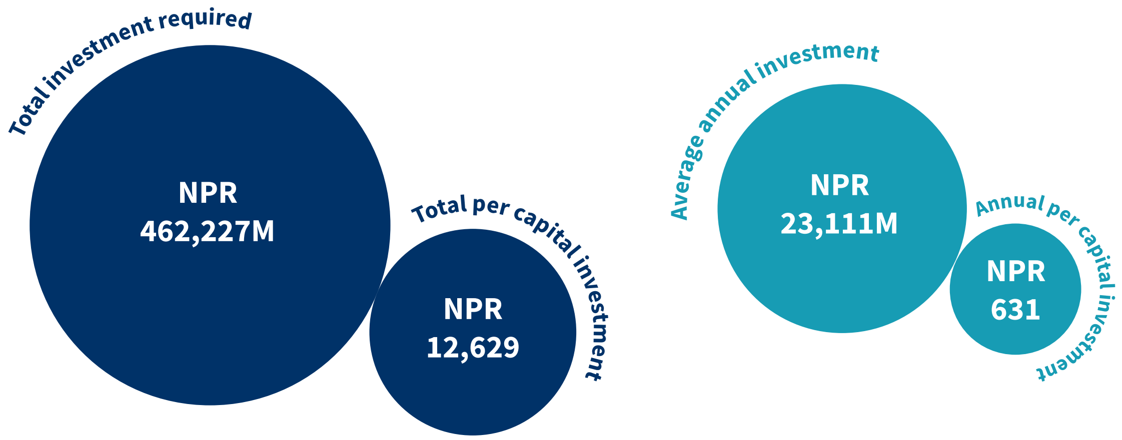
[14] Exchange rate: 1US$ is 0.0074 NPR, https://www.oanda.com/currency-converter/de/?from=NPR&to=EUR&amount=1

The underlying costs of thermosyphon systems, including installation, were collected from Nepalese companies in August 2024.

Since comprehensive costs for larger pumped solar thermal systems in Nepal are unavailable due to the lack of systems built, the investment costs of the larger pumped systems were estimated using the authors' international experience.

To achieve the target of installing 9.26 million square metres of collector area by 2045, a total investment of NPR 462,227 million (US$ 3,420 million) would be required. Spread over 20 years, this amounts to an average of NPR 23,111 million per year (US$ 171 million).

On a per capita basis, this amounts to a total investment of NPR 12,629 (US$ 93) over the 20-year implementation phase. Broken down further, the annual per capita investment required is only NPR 631 (US$ 4.7).



12 Jobs through solar heat in Nepal

The job calculation is based on an extensive literature review conducted for the IEA SHC Programme (IEA SHC, 2024), along with information provided by the China National Renewable Energy Centre, IRENA, and data collected from various country market reports. Based on this information, the following assumptions were made to estimate the number of full-time jobs:

a. Countries with high labour costs: Advanced automated production of flat-plate or evacuated tube collectors and heat storage, and markets with mainly pumped systems
Installation of complete systems with 133 m^2 solar collector area required per full-time job

b. Countries with low labour costs: Advanced automated production of evacuated tube collectors and heat storage, and market with mainly thermosiphon systems
Installation of complete systems with 87 m^2 solar collector area required per full-time job

c. Countries with low labour costs: Predominantly manual production of flat-plate collectors and hot water tanks, and market with mainly thermosiphon systems.
Installation of complete systems with 78 m^2 solar collector area required per full-time job

The criteria listed in category c) applies to Nepal, meaning one full-time job in 2024 requires the installation of 78 m^2 of collector area if the components (collectors, hot water tank and stand) are manufactured in the country. If the collectors and storage tanks are imported, about one-third of the value-added is accounted for by the exporting country. In the case of imported systems, the collector area increases to 104 m^2 per full-time job.

Table 12 presents two scenarios. Scenario 1 reflects the current reality, assuming 80% of all installed systems are imported and 20% are manufactured in Nepal (98.8 m^2/job). The second scenario assumes 50% of systems are manufactured in Nepal and 50% are imported (91 m^2/job). The numbers presented are full-time jobs and consider the production, installation, and maintenance of solar thermal systems.

Currently, around 500 full-time jobs in Nepal are generated through solar thermal system installations. Depending on the scenario, this could increase to 1,400–1,500 full-time jobs by 2030 and could rise further to 13,100–14,200 by 2045.

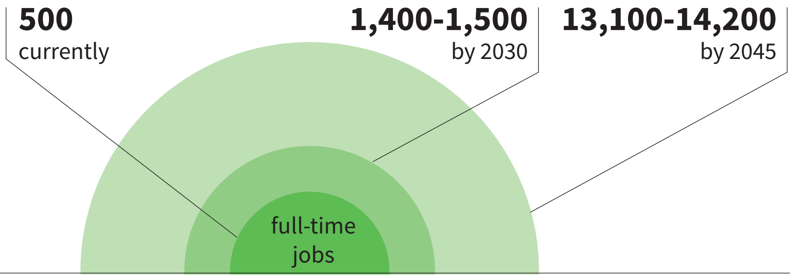
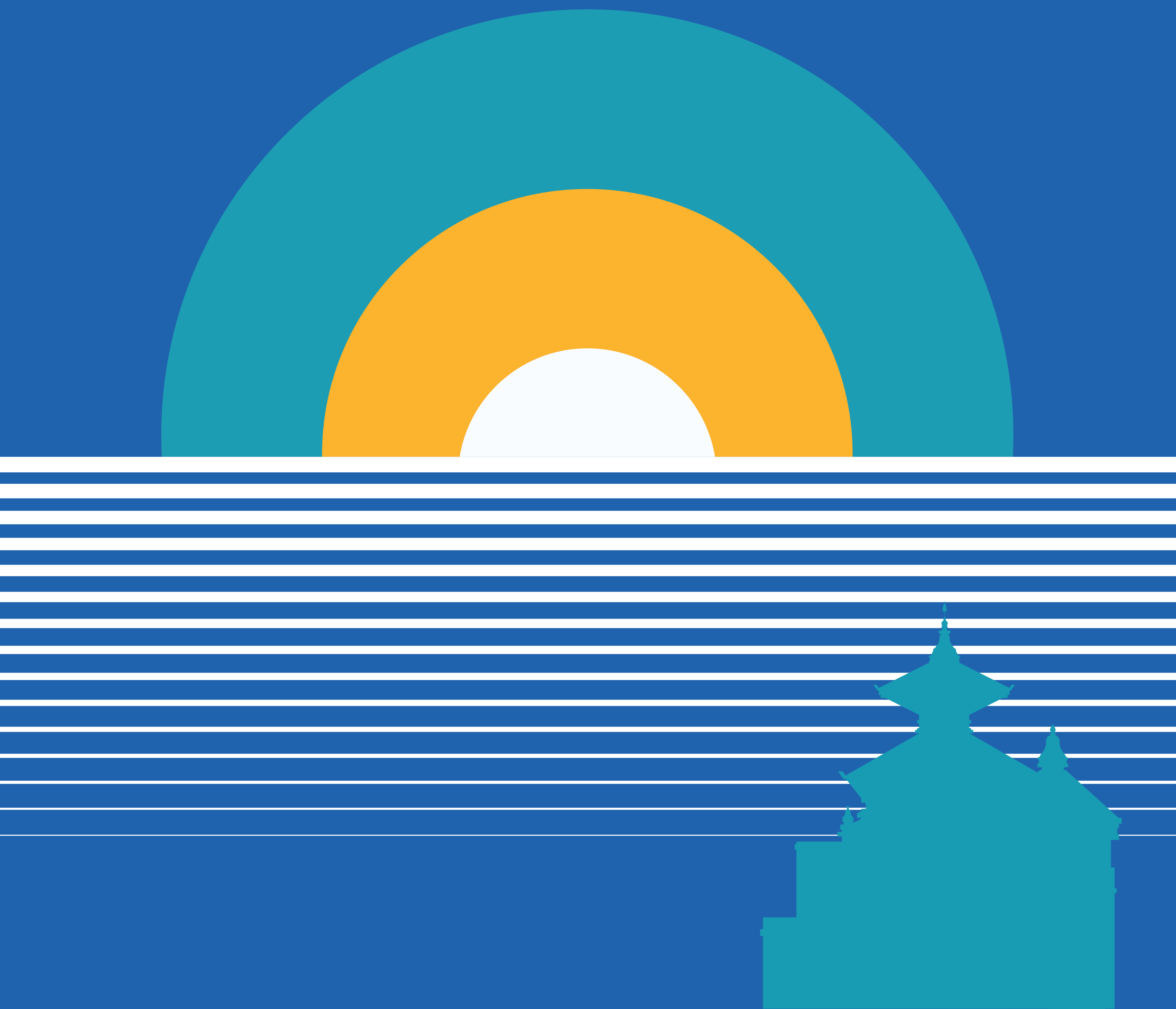


Figure 37: Heat storage production at Maharjan Metal Industries Pvt. Ltd. in Kathmandu, Nepal

Table 12: Full-time jobs in Nepal through solar thermal system installations

Year	Annual installations	Jobs: Scenario 1 80% import / 20% Nepal	Jobs: Scenario 2 50% import / 50% Nepal
	[m²]	[-]	[-]
2024	53 006	500	600
2025	55 705	600	600
2026	76 731	800	800
2027	88 544	900	1 000
2028	102 983	1 000	1 100
2029	118 734	1 200	1 300
2030	137 110	1 400	1 500
2031	158 112	1 600	1 700
2032	183 351	1 900	2 000
2033	212 229	2 100	2 300
2034	245 044	2 500	2 700
2035	283 109	2 900	3 100
2036	327 737	3 300	3 600
2037	378 929	3 800	4 200
2038	439 608	4 400	4 800
2039	509 176	5 200	5 600
2040	589 245	6 000	6 500
2041	682 439	6 900	7 500
2042	790 673	8 000	8 700
2043	918 370	9 300	10 100
2044	1 062 756	10 800	11 700
2045	1 294 223	**13 100**	**14 200**

13 Financing and support schemes



In countries that are leaders in the use of solar thermal systems, governments have implemented various political support measures, many of which have been maintained for years. The following list outlines some of the measures and the motivation behind them (Epp, 2013)[15].

Why do governments support solar thermal technology?

- Job creation: For example, the American Recovery and Reinvestment Act in USA
- Improving energy security
- Demand-side management: Solar water heaters save energy during peak load times (e.g., South Africa, Brazil, India)
- Achieve climate protection targets: Many European countries have national subsidy schemes and Renewable Energy Action Plans
- Reducing the annual subsidies for fossil fuels (eg., Barbados and Tunisia)
- Meeting increasing energy demand (eg., Solar India Mission)
- Reducing air pollution in cities (eg., Poland's subsidy programme)
- Implementing quality standards by mandating subsidy schemes (eg., China's first federal subsidy scheme)
- Improving efficiency by replacing existing solar water heaters (eg., Cyprus)
- Reducing the monthly energy bill of low-income families (eg., Berlin, Brazil, Turkey)

Where does the budget come from?

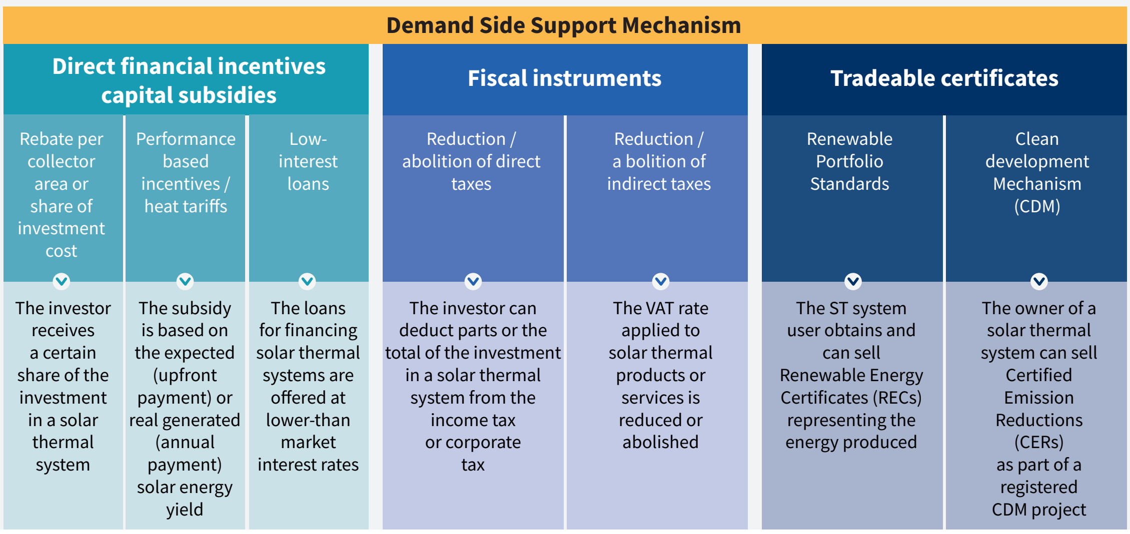
- Long-term scheme funding through developing Aid funds such as GEF, UNDP, GIZ, and Austrian Development Agency (eg., Namibia, Botswana, South Africa, Lesotho, Zimbabwe, Mozambique, Albania, Montenegro, Mexico)
- Levy on electricity bills (eg., Slovenia, USA, Cyprus, South Africa)
- Levy on gas bills (eg., California)
- European structural funds (Poland, Bulgaria, Serbia)
- Tax reduction schemes (eg., Chile, USA, France, Italy, Brazil)
- Renewable portfolio standards of utilities (eg., Brazil, USA)
- Certification trading (eg., Australia)
- Levy on import tax of new cars and air conditioning (eg., Tunisia)
- Removing subsidies on fossil-based energy sources such as electricity, gas, or oil (eg., Egypt, Barbados)
- Alternative Compliance Payments: Fees that US-based utilities must pay if they fail to meet the renewable portfolio standard (New Hampshire)

13.1 Demand-side support measures

The following figure illustrates various demand-side support mechanisms for solar thermal systems that have been successfully implemented in different countries. These measures are divided into three main categories: direct financial incentives, fiscal instruments, and tradeable certificates.

Each sub-category is briefly explained below and the pros and cons of each measure are described.

Figure 38: Classification of demand-side support measures



[15] This chapter is based on a lecture by Bärbel Epp from Solrico. See (Epp, 2013)

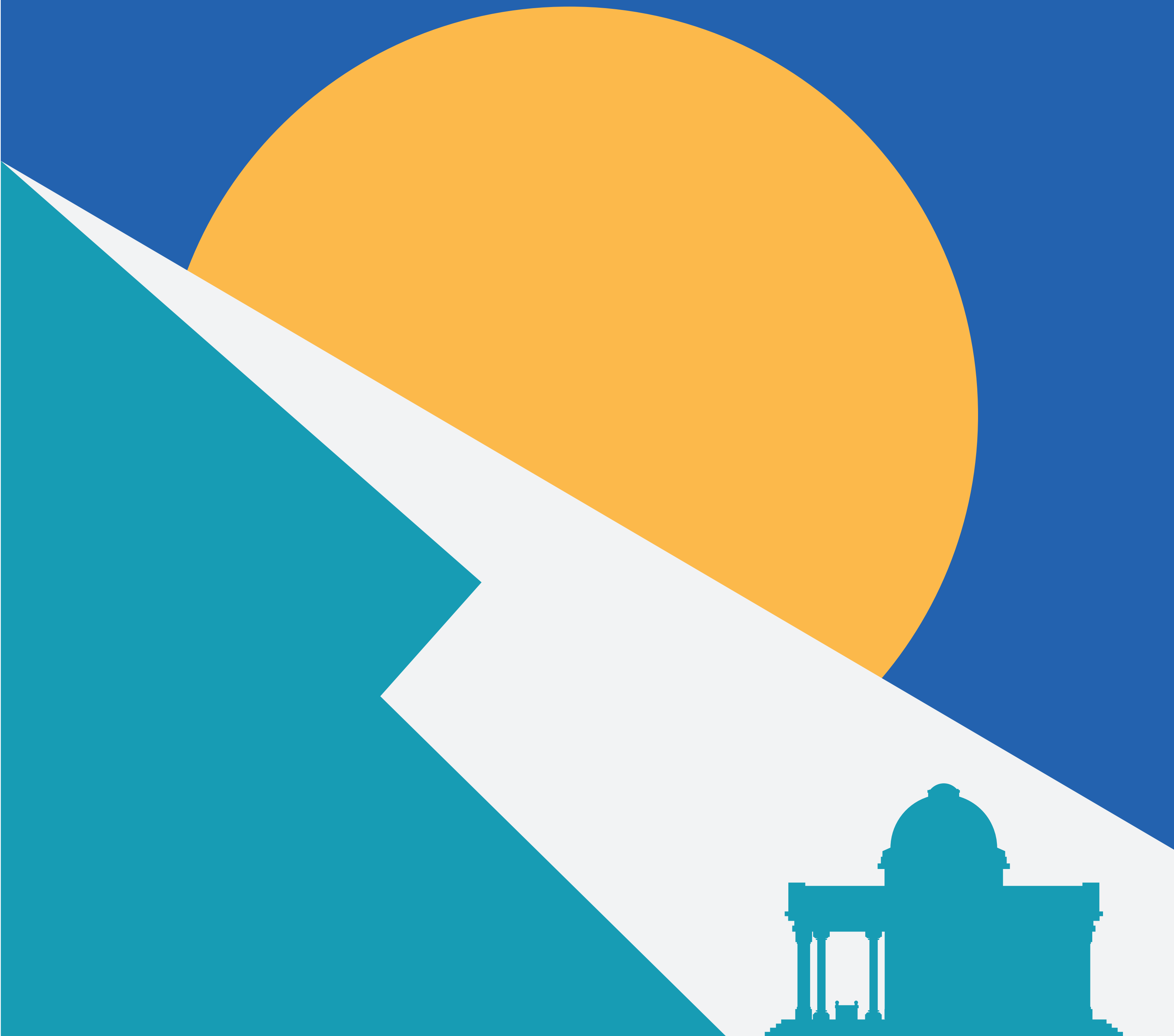
The following table presents the sub-categories of demand-side support mechanisms in detail, along with the advantages and disadvantages of the respective measures.

	Brief description	Pros	Cons
Rebates	Rebates are one of the most common subsidy schemes worldwide, where the investor receives a certain share of the investment in a solar thermal system from a public or private body (e.g. development cooperation).	• Lowers the overall investment costs for the end consumer immediately • Transparent and easy to understand by the customers • Can open different sources of funding outside the public budget • Increases reputation when the government financially supports investments in a certain technology	• Burden on the public budget • High risk for “stop and go” if dependent on annual public fund allocations • High administration burden with the application procedure (for clients and fadministrators) • Limited budget creates uncertainty, since the programme might be halted suddenly if the allocated budget is exhausted
Performance-based subsidies	Performance-based subsidies are based on the expected or real measured solar energy yield of the solar thermal system. Financial support is based on the calculated or actual measured solar yields. Due to the relatively high costs involved (either simulation of solar yields prior to construction or installation of appropriate measurement technology to record the annual real yield), performance-based subsidy schemes are only suitable for larger solar installations.	• Raises awareness about systems quality, performance, and maintenance • Increases investor confidence in solar thermal, suitable for commercial applications • Attracts third-party financers like Energy Service Companies (ESCOs) to offer guaranteed solar result contracts • Tariff level can be oriented to reach a certain payback time • Monitoring data helps identify performance irregularities	• Technical challenges in calculating or measuring delays in political decision and implementation • Complexity adds effort and costs in implementing the incentive programme • Additional costs for monitoring
Loans	Loans for financing solar thermal systems are offered at a lower-than-market interest rate.	• Eligible for both private and commercial customers • Can be combined with a rebate to a zero-investment decision for the investor • Rates of the low-interest loan can be paid by the monthly energy cost savings • Attracts ESCOs that profit from low-interest loans and sell solar heat to commercial customers	• Relatively high overhead costs for small loans for residential solar water heaters • Costly and time-consuming for lenders to collect the small monthly instalments of many residential clients • Only useful for medium-sized and larger systems

		• Smaller financial burden on public budgets than direct financial incentives • Receiving loans from banks makes solar thermal systems comparable to consumer product, like a TV or a car	
Reduction or abolition of indirect taxes	The VAT rate applied to solar thermal products and services is reduced or abolished.	• Immediately lowers the overall investment costs for the end consumer • Applies to both hardware (system) and services (installation) • Simple to apply without processing tax declarations • No additional allocation of public funds required, making it easier for public authorities or political bodies to support	• More relevant to private customers than commercial • Size of the incentive is limited to the VAT rate • May conflict with the government's target of increasing state tax revenues • No long-term investment security as VAT rate reductions or abolitions can be withdrawn by politicians at any time
Reduction or abolition of direct taxes	The investor can deduct parts or the total investment in a solar thermal system from the income or corporate taxes.	• No allocation of public budget is necessary, ensuring more credible long-term commitment of the government • Eligible to both private and commercial customers • No paper work for subsidy applications required before the investment • Lowers administrative burden than direct subsidies for administrator • No limitation to the number of accepted applications	• Does not lower the initial upfront investment, therefore not have the same psychological effect such as a direct grant, since the investor receives the payback with the next tax declaration • Socially unfair to low-income client groups who pay no or low taxes • Can conflict with the government's target of increasing state tax revenues • Impact depends on the level of taxation of the target group and general tax payment discipline
Renewable Energy Certificates (RECs)	The owner of a solar thermal system obtains certificates representing the energy saved or produced through the system that can be sold on the certificate market, typically driven by requirements for electric or gas utilities to meet a share of their sold energy with renewables.	• Neutral to public budget, adds no new costs to tax payers • Displaced energy from solar thermal systems is usually cheaper than solar electric systems, reducing utilities' costs for meeting quotas or portfolio standards • Lower-income residents and small businesses can profit from this scheme	• Certificate prices depend on the supply and demand, making it unstable • Revenues from certification trading are not predictable for the solar thermal investor and do not stimulate long-term investments in the sector • RECs in the residential sector require a kit-

		• For commercial metred systems, it raises awareness on system quality, performance, and maintenance	oriented market. Without this, solar thermal system suppliers would face high costs and significant efforts to have all system configurations tested by an independent test laboratory to determine the number of RECs a system receives within a certain climate zone.
Clean Development Mechanism (CDM)	The owner of a solar thermal system can sell Certified Emission Reductions as part of a registered CDM project.	• Create additional revenue streams without a burden to the host country's state budget • Small-scale residential systems can be bundled within a programme of activities, enabling individual projects using the same basic methods and monitoring technology, and to be funded by selling CDM's Certified Emission Reductions	• Certificate prices depend on supply and demand, making it unstable • Relatively complex and time-consuming application and approval procedures, often requiring specialised CDM project developers
Energy Service Company (ESCO)	ESCO plans, installs, maintains, and operates solar thermal systems. These systems are typically installed on the customer's building or property. The ESCO sells solar heat instead of solar thermal systems and signs long-term energy supply contracts with the clients.	• No upfront costs for users of the solar thermal system • Increases the confidence of potential heat consumers to invest in solar energy • Well-monitored and maintained systems since the client pay based on the delivered heat • Low-risk investment for the ESCO when focusing on creditworthy commercial customers or public institutions • Better return on investment when solar thermal system installation is bundled with other energy-improving measures	• High financial risk of long-term energy supply contracts makes it difficult for the ESCO to receive loan financing • High administrative burden due to the need for several contracts • Requires some scale to be profitable for investors • Lack of engineering capacity of the contractor to run and maintain large-scale solar thermal systems

14 Renewable Energy Subsidy Policy of Nepal



Nepal has implemented various policies to promote the expansion of renewable energy. In addition to general policies and its commitment to achieving CO_2 neutrality by 2045, the majority of policies focus on expanding the renewable electricity sector, particularly, hydropower and PV, and sustainable transportation, including the transition to electric vehicles.

Outlined below are the most important support schemes, which could potentially serve as the foundation for solar thermal systems support programmes.

Interest rate buydown support
This scheme provides a subsidy on the bank's interest rate, with upto 50% of the total interest on loans obtained for the project for a maximum of 5 years, or the interest buydown rate proposed by the applicant, whichever is lower.

Incentive based on energy generation
Provides incentives based on energy generation every four months. The maximum incentive is NPR 1.50 per unit of energy generated for a maximum of 5 years, or the incentive is based on the energy generated proposed by the applicant, whichever is lower.

Innovative sustainable energy projects
Provides financial support for innovative projects for up to NPR 10 million, covering 50% of the total cost or the financial support requested by the applicant, whichever is lower. This support is applicable to Solar PV net-metering connected to the grid, mini-grid system projects, and other renewable projects that contribute to the energy mix (NREP Nepal, n.d).

Despite these measures, Nepal lacks dedicated policies for the transition in the heating and cooling sector.

14.1 Other support measures, programmes, and policies

Additional renewable energy measure, programmes, and policies include:

- Renewable Energy Subsidy Policy of Nepal
- National Rural and Renewable Energy Programme (NRREP) of Nepal
- Rural Energy Policy of Nepal
- Promotion of Solar Energy in Rural and Semi-urban Regions of Nepal (DKTI)
- Innovative sustainable energy projects

15 Implementation of the Solar Thermal Roadmap

To achieve the targets set for 2045, it is essential to involve all relevant stakeholders and implement a comprehensive package of measures. This includes identifying relevant sectors and their potential for solar thermal systems, strengthening the solar thermal industry through training, developing new business models, and establishing financing instruments and legal frameworks for quality control.

In addition to these measures, monitoring the progress of the roadmap's implementation is crucial. Regular monitoring and annual reviews of the targets against the installed collector areas, enables prompt responses to any deviations from the set targets.

15.1 Components for successful implementation

To achieve the targets set for 2045, it is essential to involve all relevant stakeholders and implement a comprehensive package of measures. This includes identifying relevant sectors and their potential for solar thermal systems, strengthening the solar thermal industry through training, developing new business models, and establishing financing instruments and legal frameworks for quality control.

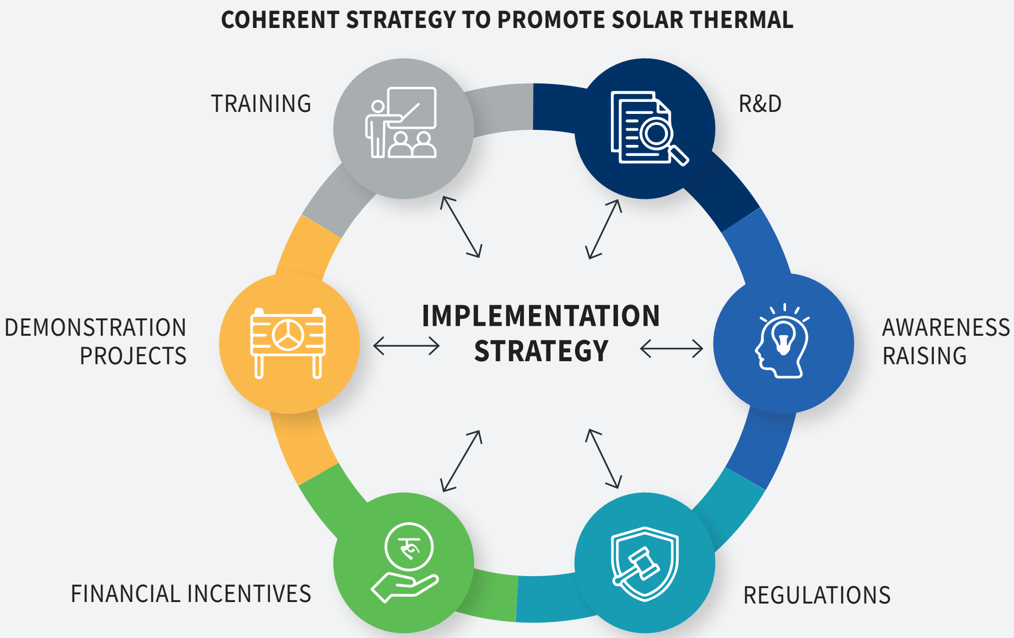
In addition to these measures, monitoring the progress of the roadmap's implementation is crucial. Regular monitoring and annual reviews of the targets against the installed collector areas, enables prompt responses to any deviations from the set targets.

Awareness raising: Raising awareness at all levels is crucial, as many individuals, policymakers, and industries remain unaware of the potential and wide-ranging applications of solar thermal technology.

Enhancing established applications: In areas where applications are already established, such as water heating with thermosyphon systems, the immediate focus should be on disseminating these systems. Simultaneously, efforts must be directed towards training additional specialists, ensuring quality assurance, and expanding local production capacities.

Initiating R&D and innovation: The next step involves initiating research, development, and innovation in areas of application where there are no demonstration systems in Nepal. For example, these could include larger pumped systems for hot water preparation in hotels and hospitals or the provision of process heat in the food and beverage industry.

Figure 39: Components for the successful implementation of a Solar Thermal Roadmap



Developing financial instruments: To ensure the medium- and long-term implementation of the roadmap in the medium, it is essential to develop financing instruments and non-monetary support measures.

Establishing technical regulations: Technical regulations are essential for the quality assurance of these systems. This includes establishing minimum standards for the production and import of solar thermal systems, setting installation requirements, and ensuring regular maintenance of the systems.

Identifying stakeholders: To achieve the roadmap's objectives, all the components mentioned above must be seamlessly integrated into the implementation process. Additionally, it is essential to clearly identify the stakeholders responsible for each component and outline their specific roles within the overall framework.

15.2 Key stakeholders for the implementation process

To successfully implement the roadmap, key stakeholders must collaborate closely and take on various roles. The government's role is particularly crucial in establishing the appropriate framework conditions and either leading the coordination of implementation directly or delegating this responsibility to a suitable organisation.

The following organisations and institutions have been identified as potenial key players in implementing the Solar Thermal Roadmap. This list is not exhaustive and can be expanded as needed.

AEPC	Alternative Energy Promotion Centre of the Ministry of Energy, Water Resources, and Irrigation
CES	Center for Energy Studies, Institute of Engineering, Tribhuvan University
CTEVT	Council for Technical Education and Vocational Training
FNCCI	Federation of Nepalese Chamber of Commerce & Industries
FNCSI	Federation of Nepal Cottage and Small Industries
HAN	Hotel Association of Nepal
ICIMOD	International Centre for Integrated Mountain Development
MoALD	Ministry of Agriculture and Livestock Development
MoEST	Ministry of Education, Science and Technology
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoHP	Ministry of Health and Population
NAST	Nepal Academy of Science and Technology
RETS	Renewable Energy Test Station
STAN	Solar Thermal Association Nepal

15.3 Measures and responsibilities

The following sections outline proposed measures for the first two years, along with key institutions responsible for implementing the roadmap. From the third year onward, additional measures must be taken, and those already implemented should be reviewed to assess their effectiveness. If necessary, adaptive measures must be undertaken.

15.3.1 Awareness campaign

The successful implementation of the Solar Thermal Roadmap largely depends on ensuring all target groups are well-informed about the benefits, possibilities, costs, and available support measures for solar thermal systems. Therefore, implementation measures should be accompanied by awareness campaigns from the very beginning. The awareness campaigns should prioritise and engage the participation of women and marginalised communities.

Key actions and initiatives
- Launch a comprehensive and targeted information campaign covering on all solar thermal applications
- Enhance public awareness of the advantages and possibilities of solar thermal systems

Target group	Measures	Milestones	Potential stakeholders
Overall public	• Media campaigns • Flyer distributions • Information booths • Newspaper, TV and radio broadcasts • Social media	**Year 1** • Developed targeted campaigns for different groups • Contract for implementation awarded to a suitable institution • Campaign launched **Years 1–3** • Campaign run • Impacts assessed • Campaign adjusted as necessary	• MoEWRI • ICIMOD • AEPC • Solar industry
Hotel Owners	• Targeted information workshops • Visits to demonstration plants	**Years 1–3** • Information workshops organised • Site visits to solar thermal systems in the hotel sector conducted	• HAN • AEPC • Solar industry
Hospitals, health centres, retirement homes	• Targeted information workshops • Visits to demonstration plants	**Years 1–3** • Information workshops organised • Site visits to solar thermal systems in the health sector conducted	• Ministry of Health and Population • AEPC • Solar industry
Schools	• Targeted information workshops • Visits to demonstration plants	**Years 1–3** • Information workshops organised • Conduct site visits to solar thermal systems in the education sector conducted	• Ministry of Education, Science and Technology • AEPC • Solar industry
Industry	• Targeted information workshops • Visits to demonstration plants	**Years 1–3** • Information workshops organised • Site visits to solar	• Ministry of Industry, Commerce and Supplies of Nepal • AEPC

Target group	Measures	Milestones	Potential stakeholders
		thermal systems in the industrial sector conducted	• FNCCI • FNCSI • Solar industry
Agriculture	• Targeted information workshops • Visits to demonstration plants	**Years 1–3** • Information workshops organised • Site visits to solar thermal systems in the agriculture sector conducted	• Ministry of Agriculture and Livestock Development • AEPC • Solar industry
Government institutions	• Promote solar thermal systems in government institutions, where applicable	**Years 1–3** • Information workshops organised • Site visits to solar thermal systems at government institutions conducted	• Government bodies of all levels • AEPC • Solar industry

15.3.2 Quality standards

A critical immediate measure is introducing binding quality criteria for both the components and the installation of the solar thermal systems. Currently, due to the absence of quality standards, poor-quality solar systems are being imported and locally manufactured, leading to systems with a short lifespan and moderate yields.

Key actions and initiatives

- Mandatory submission of solar keymark[16] test results for imported solar thermal systems
- For solar thermal systems manufactured in Nepal, the submission of a simple test report from a certified institution in Nepal
- Definition and mandatory introduction of minimum requirements for safety devices and solar thermal system installations
- Abolition or reduction of import duties upon the presentation of valid test certificates

Target group	Measures	Milestones	Potential stakeholders
Solar thermal industry	• Mandatory introduction of test certificates and national tests • Establish a simple component and system test for nationally manufactured solar thermal systems • Define minimum requirements for safety devices and solar thermal system installations • Introduce mandatory minimum requirements for safety devices and solar thermal system installations • Abolish or reduce import duties upon the presentation of test certificates	**Year 1** • Legal basis created • Test bench set up Minimum criteria defined and agreed with the solar industry **Year 2** All measures described are implemented	• Government • Import authorities • AEPC • Academic institutions and universities • Renewable Energy Test Station • Academic institutions and universities • Import authorities • Ministry of Finance

[16] Solar Keymark is a quality label for solar thermal products, especially solar collectors. For details see: https://keymark.eu and https://gscn.solar/

15.3.3 Training

For the successful implementation of the Solar Thermal Roadmap across all sectors, parallel to the awareness campaigns, training programmes for skilled workers that consider both gender equality and social inclusion (GESI) is essential. These trainings can play a critical role in informing and encouraging women engineers who have limited representation in the sector, to enhance their technical skills in solar thermal technology.

Key actions and initiatives

- Establish training programmes and begin capacity building
- Organise training programmes for technicians, engineers, and installers

Target group	Measures	Milestones	Potential stakeholders
CTEVT	• Train teachers • Develop curriculum	**Year 1** • First training course for teachers completed • Curriculum available	• Universities • Ministry of Education, Science and Technology • External international experts (if needed)
Installers	• Practical and theoretical training at two levels: • Level 1: Simple thermosiphon systems • Level 2: Pumped systems	**Years 1–3** • Accredited training programmes established	• CTEVT
Quality inspectors	• Train inspectors • Develop O&M standards	**Years 1–3** • Accredited training programmes established	• CTEVT
Engineers	• Develop a (master) course on solar thermal • Develop curriculum	**Year 1** • Curriculum development completed **Years 2–3** • (Master) course offered as part of the mechanical engineering degree programme.	• Universities

15.3.4 Demonstration and pilot systems for new sectors

Solar thermal systems already have a notable market presence in Nepal, particularly in the small systems (thermosyphon systems). However, for other applications presented in this roadmap, there are few or no examples of systems to date. To address this, it is proposed to establish demonstration plants for these new areas of application.

A limited number of pumped demonstration plants will be set up in various climate zones of Nepal for the following sectors:
- Apartment buildings
- Hotels and other accommodation
- Hospitals and health posts
- Schools
- Industry
- Agriculture

Additionally, pilot plants could established in the following areas:
- Solar combi-systems for domestic hot water and space heating (mountain regions)
- Solar cooling (Terai region)
- Small-scale solar district heating

The demonstration and pilot plants will serve several key functions:
- Building expertise through training for solar thermal companies
- Providing destinations for plant visits to showcase the functionality and benefits to sector representatives
- Demonstrating the performance of solar thermal plants, with comprehensive monitoring

Unlike small thermosyphon systems in the mass market, these systems will require subsidies, at least temporarily. This support programme could be based on the funding schemes described in Chapter 14.

Key actions and initiatives
- Building expertise and planning capacity
- Develop a support scheme for demonstration and pilot systems
- Constructing demonstration and pilot projects in key sectors
- Measure and analyse solar yields
- Utilise the constructed demonstration and pilot systems as excursion destinations to engage and persuade target groups

Target group	Measures	Milestones	Potential stakeholders
Solar industry	• Build expertise and planning capacity	**Year 1** • Pilot training courses for medium and large pumped solar thermal systems conducted **Years 2–3** • Standardisation of the training course and integration into regular vocational school training	• CTEVT • Center for Energy Studies • Tribhuvan University • External international experts if needed
Owners and operators of apartment buildings, hotels, hospitals, industry, schools, agriculture	• Develop a support scheme for demonstration and pilot systems	**Year 1** • Support programme is available • International donors contacted regarding funding	• Government • ICIMOD • Banks

Target group	Measures	Milestones	Potential stakeholders
		Year 2 • Support programme published	
Owners and operators of apartment buildings, hotels, hospitals, industry, schools, agriculture	• Select suitable demonstration and pilot projects • Install the systems • Monitoring and analysis of solar yields	**Year 1** • Feasibility studies conducted • Plant design and economic feasibility • Monitoring concept **Years 2–3** • First demonstration systems including monitoring are in operation • Measurement results evaluated and published	• ICIMOD • Center for Energy Studies • Tribhuvan University • Solar industry
Owners and operators of apartment buildings, hotels, hospitals, industry, schools, agriculture	• Plant visits for individual target groups	**Years 2–3** • Plant visits conducted	• AEPC • HAN • FNCCI • FNCSI • Solar industry

15.3.5 Research and development

An essential component in implementing the roadmap is the development of research and development capacities in Nepal. This can be achieved by strengthening R&D capacities in Nepal itself and increasing international coopertaion.

The increased R&D activities should aim to support the thermal solar industry in Nepal, particularly in product and system development, as well as system optimisation and adaptation to regional requirements.

A significant opportunity for international cooperation arises from ICIMOD's participation in IEA's Solar Heating and Cooling programme in 2024. This partnership allows all academic institutions and the solar industry in Nepal to participate free of charge in all IEA SHC research projects and to benefit from knowledge transfer activities offered through the IEA SHC Solar Academy.

Key actions and initiatives

- Establishment of institutionalised cooperation between universities and the solar industry
- Definition of a solar thermal research and innovation programme for the universities
- Establishment of cooperation with the IEA Solar Heating and Cooling Programme

Target group	Measures	Milestones	Potential stakeholders
• Universities • NAST	• Establish an industry network for collaborative research work with local universities	**Year 1** • Research and innovation interests defined and cooperation with the university sector formally established **Years 2–3** • First support measures by universities for solar industry initiated	• Solar industry
• Universities • NAST	• Provide research funding to research institutions and universities for research on application and optimisation	**Year 1** • Framework conditions and opportunities for solar thermal research clarified **Years 2-3** • First R&D projects defined and initiated	• Ministry of Education, Science and Technology
• Universities • NAST	• Establishing cooperation with the IEA SHC and Cooling Programme • Select an IEA SHC research project of interest to Nepal	**Year 1** • Contacted the chairman of the IEA SHC programme • Regular exchanges on research issues organised • On-site training in Nepal by IEA SHC experts conducted **Years 2-3** • Participation in one of the IEA SHC research projects	• ICIMOD

15.3.6 Monitoring progress of roadmap implementation

The progress of the roadmap's implementation across various sectors should be continuously documented and reviewed. The achievement of the annual targets for the installation of solar thermal systems must be reviewed annually, and the measures taken to implement them should be evaluated for effectiveness. If there are deviations from the targets, appropriate measures should be taken or existing measures adjusted to bring the implementation back on track.

It is recommended to publish an annual report on the status of the roadmap's implementation. This report should not only document the target reviews in terms of the installed solar systems in each sector but should also include an impact assessment.

Possible contents of the impact assessment

- Environmental impact: Reduction in carbon emissions and deforestation, improvements in air quality
- Economic impact: Job creation, energy cost savings, and growth of local industries
- Social Impact: Improved energy access, enhanced quality of life, and better health outcomes

Key actions and initiatives

- Institutionalisation of the review process for the roadmap implementation
- Publication of the annual report on the status of implementation

Target group	Measures	Milestones	Potential stakeholders
• MoEWRI • Provincial and local governments	• Institutionalisation of the review of the roadmap implementation	**Year 1** • A suitable institution to monitor implementation progress appointed • Data collection modalities determined	• AEPC • ICIMOD • External consulting from Nepal (if needed)
• MoEWRI • Provincial and local governments	• Annual detailed recording of installed solar thermal systems, broken down by sector	**Years 2–20** • Annual reports published	• AEPC • ICIMOD • External consulting from Nepal (if needed)
• MoEWRI • Provincial and local governments	• Compare annually installed solar thermal systems with the annual roadmap targets. If necessary, adapt the targets or implementation measures	**Years 2–20** • Annual confirmation or adjustment of the implementation measures taken	• AEPC • ICIMOD • External consulting from Nepal (if needed)
• MoEWRI • Provincial and local governments	• Identify areas where system performance can be improved under local operating conditions, considering the quality and environmental requirements	**Years 2–20** • Improvement measures implemented together with the local solar industry	• AEPC • ICIMOD • External consulting from Nepal (if needed)

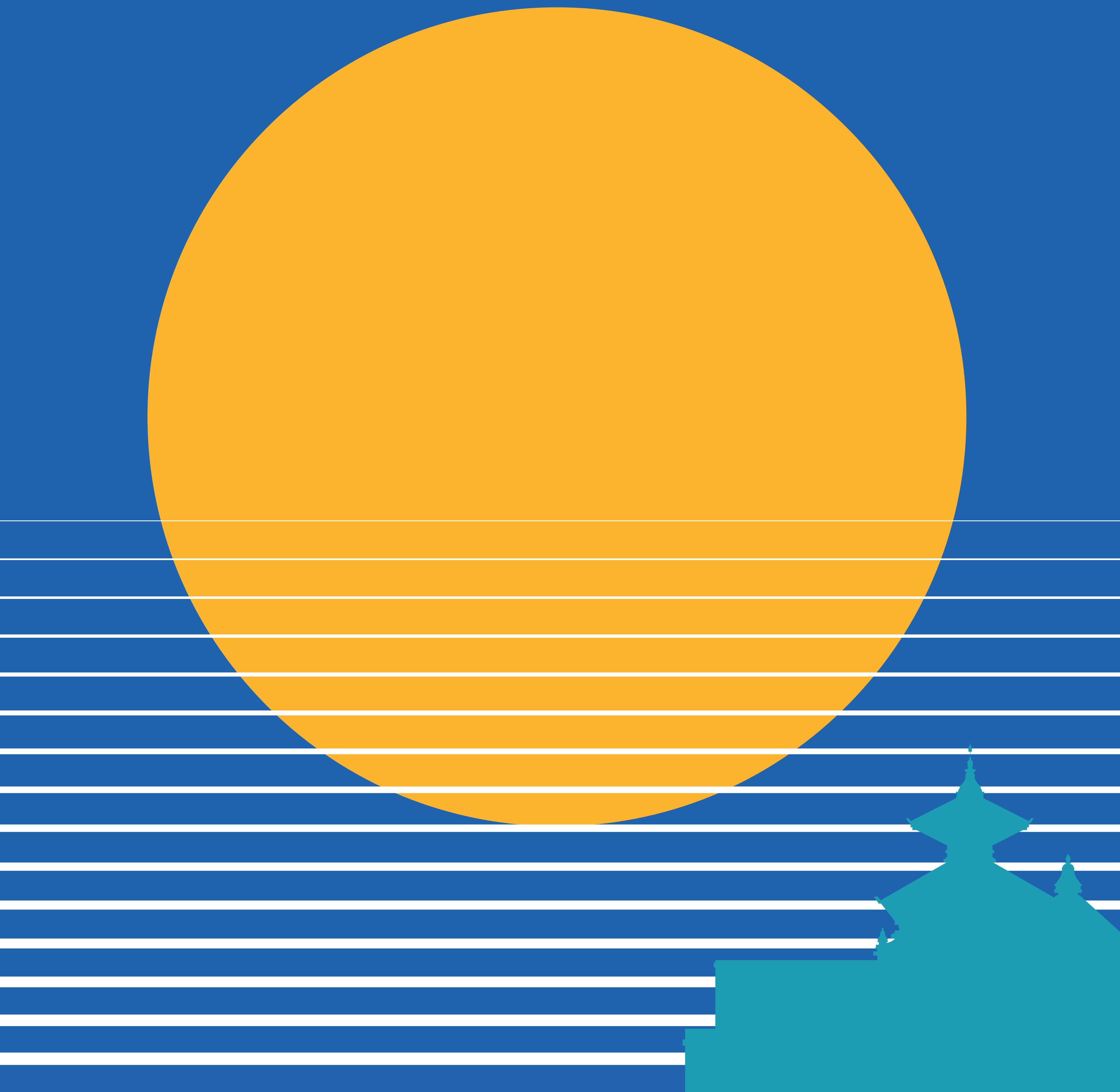
16 Institutions consulted

To ensure the framework conditions and objectives of the roadmap were as robust as possible, intensive consultations were held from 5 to 15 August 2024, with the institutions listed below, following the availability of the first draft. The feedback, data, assessments, and suggestions for changes provided by the interviewees were largely incorporated into the final version of the roadmap.

List of stakeholders

Key contact person	Designation	Organisation
Anil Maharjan	Director	Maharjan Metal Industries Pvt. Ltd.
Binod Kumar Sethia	Vice President	Vie Tech Pvt. Ltd.
Jagannath Poudel	Programme Manager	Federation of Nepal Cottage and Small Industries (FNCSI)
KR Khanal	President	Ultra Group Nepal Pvt Ltd
Krishna Prasad Parajuli	President	Solar Electric Manufacturer's Association Nepal (SEMAN)
Mukti Chhetri	NDC Focal Person	AEPC
Nawa Raj Dhakal	Executive Director	Alternative Energy Promotion Centre (AEPC)
Niraj Shrestha	Secretary	Solar Thermal Association Nepal (STAN)
Parmita Chapagain	Officer	Federation of Nepalese Chamber of Commerce & Industries (FNCCI)
Pragyan Regmi	Manager – Sustainable Banking	NMB Bank Limited
Satish Gautam	Team Leader, Renewable Energy for Rural Livelihood	United Nations Development Programme (UNDP)
Shaligram Bhandari	Senior Divisional Engineer	Ministry of Energy, Water Resources and Irrigation
Shree Raj Shakya	Director	Center for Energy Studies, Institute of Engineering, Tribhuvan University
Sushil Kumar Shrestha	Engineering Co-ordinator	Council For Technical Education and Vocational Training (CTEVT)
Suyesh Prajapati	Team Leader	Building Energy Efficiency Nepal, Minergy
Tek B. Mahat	Chief Operating Officer	Hotel Association of Nepal

17 References



AEE INTEC (2023), SHIP Plants Database, derived from https://ship-plants.info on 29.12.2024.

AEPC. (2004). *Solar water heating system database in Nepal,* Alternative Energy Promotion Centre (AEPC), Lalitpur, Nepal.

Amir, V. (2022). Solar energy advancements in agriculture and food production systems (Chapter 7).

Bachmann, A., & Waldvogel, H. (1990): *Solar water heaters in Nepal: Manufacture and installation, heating and cooling applications in agriculture and food processing systems*

Bajracharya, T. R., and Shakya, S. R. (2003). *Technology analysis of domestic solar water heater systems in Nepal: needs a revamp.* Paper presented at the Eight National Convention and FEISCA Regional Meet, 3–5 April 2003, Kathmandu, Nepal

Bhambare, P. S. (2022). *Design aspects of a fixed focus type Scheffler concentrator and its receiver for its utilization in thermal processing units*

CASA Programme. (2024). *Nepal dairy sector analysis report.* Retrieved from https://www.casaprogramme.com/wp-content/uploads/CASA-Nepal-DairySector-analysis-report.pdf

Department of Industry. (2023). *Industrial statistics: Fiscal Year 2079/080 (2022/2023).* Ministry of Industry, Commerce and Supplies, Tripureshwor, Kathmandu, Nepal

Epp, B. (2013). How to design a successful support scheme? Best practise and lessons learned. *Solrico.* Retrived from www.solrico.com

Federation of Nepalese Chambers of Commerce and Industry (FNCCI). (2017). *Fact sheet on renewable energy and low-carbon technologies.* Retrieved from https://www.eec-fncci.org/images/download/RHLt8-2017___fact_sheet_metal_copy.pdf

Government of Nepal. (2021): Nepal's *long-term strategy for net-zero emissions.* Kathmandu.

IEA. (2012). *Technology Roadmap – solar heating and cooling.* OECD/IEA, Paris.

IEA. (2022). Nepal electricity profile. Accessed 3 July 2024 from https://www.iea.org/countries/nepal/electricity

IEA. (2023). *Renewables 2022: Renewable analysis and forecasts to 2027.* OECD/IEA, Paris.

IEA. (2024). *Renewables 2023 – Analyses.* OECD/IEA, Paris.

IEA SHC. (2016). *Best practice: Solar process heat for industry.* IEA Solar Heating and Cooling Programme (Task 49). Retrieved from https://task49.iea-shc.org/Data/Sites/1/publications/IEA_Task49_Deliverable_C4_Best%20Practice-final-160528.pdf

IEA SHC (2008). *Process integration booklet.* IEA Solar Heating and Cooling Programme (Task 33). Retrieved from https://task33.iea-shc.org/Data/Sites/1/publications/Process_Integration_Booklet.pdf

IEA SHC. (2024). *Solar heat worldwide: Global market development and trends 2023, detailed market figures 2022.* Gleisdorf.

ICIMOD. (2023). Data collection by AEE INTEC for the IEA SHC *Solar Heat Worldwide Report,* Edition 2024. E-mail communication with Avishek Malla from ICIMOD

Joshi, C.B., et.al. (2000). Application of solar drying systems in rural Nepal. Paper presented at the World Renewable Energy Congress VI, Brighton, UK.

Ministry of Finance. (2024). *Economic survey, 2023/2024.* Retrieved from https://www.mof.gov.np/uploads/document/file/1717566409_Economic%20Survey%202080_81.pdf

More, A. M. (2017). Feasibility of solar steam cooking for 500 students using Scheffler Dishes at institute canteen.

National Statistics Office, (2023). *National Population and Housing Census 2021*: National report. Retrieved from https://censusnepal.cbs.gov.np/results/files/result-folder/National%20Report_English.pdf

NEA. (2024). *Nepal Electricity Authority, A Year in Review-Fiscal Year-2023/2024.* Kathmandu: Nepal Electricity Authority.

Nepali Headlines. (2024, April 5). Solar dryer installed. Retrieved from https://nepaliheadlines.com/solar-dryer-installed/

NREP Nepal. (n.d.). *SE Challenge Fund*. Retrieved from https://www.nrepnepal.com/se-challenge-fund/

PACE. (2012). *Baseline study of selected sector industries to assess the potentials for more efficient use of energy,* Kathmandu, Nepal. Retrieved from http://energyefficiency.gov.np/downloadthis/baseline_study_of_selected_sector_industries.pdf

Puri, M. (2022). Promoting sustainable agricultural food chains. *Sustainable Energy for All.* Retrieved from https://www.seforall.org/data-stories/promoting-sustainable-agricultural-food-chains

Sunrise CSP. (n.d.). *Indian Army, Pune, India.* Retrieved from https://sunrisecsp.com/indian-army-pune-india/

The World Bank. (2021). Solar energy atlas of Nepal. Washington D.C.

UNCDF (2020): Micro, Small and Medium-sized Enterprises, Access to Finance in Nepal, MSME Financing Series No. 3

United Nations. (2024). *World population prospects 2024.* United Nations Population Division. Retrieved from https://population.un.org/wpp/

WECS. (2024). *Energy Sector Synopsis Report.* Kathmandu: Water and Energy Commission Secretariat, Government of Nepal.

18 Appendix

18.1 Conversion factor from square metre collector area to capacity

In September 2004, representatives of the International Energy Agency's Solar Heating and Cooling Programme (IEA SHC) and major solar thermal trade associations agreed on an official recommendation for converting solar thermal collector area into installed capacity[17].

In this recommendation for solar thermal statistics, the installed capacity ([kW_{th}] - kilowatt thermal) is calculated by multiplying the aperture area of the solar collector [m^2] by the conversion factor 0.7 [kW_{th}/m^2]. This factor is applied uniformly to unglazed collectors, flat-plate collectors, and evacuated tube collectors.

This conversion factor has been used in all solar thermal statistics worldwide since 2004.

18.2 Methodological approach to obtain the solar yield and CO_2 emissions avoided

To determine the energy yield and CO_2 emissions avoided by the solar thermal systems, the methodology outlined in the Solar Heat Worldwide Report (IEA SHC, 2024) was applied. The following procedure was used:

- The cumulated collector area was allocated to the following sectors:
  - Single-family houses
  - Apartment buildings
  - Hotels, lodges
  - Hospitals and health centres
  - Industry and agriculture
- Reference systems were defined for each type of application (pumped or thermosiphon solar thermal system)
- The number of systems was determined based on the share of collector area for each application and the reference system.

In addition to the reference applications and systems above, reference collectors and reference climates were determined.

Based on these boundary conditions, simulations were then performed using T-Sol [T-Sol, Version 4.5 Expert, Valentin Energie software, www.valentin-software.com] to calculate the gross solar yields for each system. These gross solar yields refer to the solar collector heat output and do not include heat losses due to transmission piping or storage[18].

The amount of final energy saved was calculated from the gross solar yields, considering a utilisation rate of the auxiliary heating system of 0.8.

Finally, the avoided CO_2 emissions were calculated in two scenarios. To obtain the exact statement of the CO_2 emissions avoided, the energy sources to be replaced over the next 20 years would have to be determined. Since this could only be done in a very detailed survey, which goes beyond the scope of this roadmap, the avoided CO_2 emissions were calculated in two scenarios:

[17] https://www.iea-shc.org/press-releases/iea-shc-recommends-conversion-factor-07-kwthm2-for-statistics-on-concentrating-collectors

[18] Using gross solar yields for the energy calculations is based on a definition for Renewable Heat by EUROSTAT and IEA SHC. In editions of this report prior to 2011 solar yields calculated included heat losses through transmission piping and hence energy savings considered were about 5 to 15 % less depending on the system, the application and the climate.

Scenario 1: Final energy savings are expressed in tons of oil equivalent (toe): 1 toe = 11,630 kWh. The CO_2 emissions avoided by the solar thermal systems are quoted as kilograms of carbon dioxide equivalent ($kgCO_2e$) per ton of oil equivalent: 1 toe = 3.165 t CO_2e.[19] The emission factor only accounts for direct emissions.

Scenario 2: Assumed without solar thermal systems:

- 50% of heat would be generated by electricity (88% domestic production from hydropower and 12% by electricity imports from India)
- 30% would be generated by biofuels and waste
- 20% would be generated by oil (process heat in industry)

For the electricity mix (88% hydropower and 12% from oil-fired power plants), this results in carbon emissions of 106 gCO_2/kWh. The greenhouse gas emissions mix from various energy sources (hydropower, biofuels and waste, oil) result in 230,9 gCO_2/kWh

Table 13: Basic data for the calculation of CO_2 emissions in scenario 2

CO_2 emissions	**Conversion**	**gCO_2/kWh[20]**	**% of heat supply**
Hydropower plants (Nepal)	Electricity to heat	4	
Oil power plants (India)	Electricity to heat	855	50
Biofuels and waste	Biofuels and waste to heat	367	30
Oil	Crude oil to heat	339	20

18.3 Solar heat for industrial processes – best practices and studies

The Solar Heat in Industrial Processes (SHIP) market is experiencing steady global growth and holds significant potential. To demonstrate its feasibility and viability across various applications, best practice examples of SHIP systems with solar fractions between 30 and 90% are presented below. When selecting the systems, attention was paid to good global distribution and various industrial processes. The aim is to show that these systems have been built and used worldwide for a long time and can therefore serve as a good example for Nepal.

The information and data on the plants presented are taken from the SHIP Plants Database, which was compiled by AEE INTEC in cooperation with the IEA's Solar Heating and Cooling Program (AEE INTEC, 2023). The SHIP Plants Database serves this purpose by continuously tracking new systems, offering geo-referenced information, and presenting key performance indicators of SHIP plants.

All the data shown and significant more information on realised SHIP systems can be found under the following link: https://ship-plants.info

18.3.1 Best practices of SHIP systems with high solar fractions

The following table summarises the data of those best practice SHIP systems that are presented in more detail on the following pages.

Solar process heat system	**Moguntia Spice Making,** Austria	**Copper Mine "Gabriela Mistral",** Chile	**Milma Dairy,** India	**Laboratorios Liomont,** Mexico	**PepsiCo – Soft Drinks**, USA
Solar fraction	45 – 50%	85 – 100 %	40%	60%	50%

[19] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020
[20] https://www.leifiphysik.de/uebergreifend/fossile-energieversorgung/ausblick/emissionen-von-kraftwerken

Moguntia Spice Making, Austria

Moguntia Spice Making, Austria	Copper Mine “Gabriela Mistral”, Chile	Milma dairy, India	Laboratorios Liomont, Mexico	PepsiCo, USA

General information

A 220 m^2 solar thermal system and four 5,000 litre solar stratified storage tanks were installed on the premises of the Moguntia spice plant in Austria. The hot water produced is used for several cleaning and production processes. With the solar thermal system, Moguntia saves up to 50% of the energy required for hot water production and thus significantly improves its energy balance. Up to 110 litres of oil are saved per m^2 of collector surface per year.

- **Country** — Austria
- **Address** — Perlmooserstraße 19, 6322 Kirchbichl
- **Industry sector, NACE code** — Manufacture of other food products
- **Solar thermal system owner / operator** — Moguntia-Werke Gewürzindustrie GmbH
- **Year of operation start** — 2008

TECHNICAL PARAMETERS

Collector technology	**Flat plate**
Installed collector area (gross), m^2	**220**
Power, kW_{th}	**154**
Storage volume, m^3	**20**
Solar fraction	**45 – 50%**
Solar thermal energy used for	**Hot water for cleaning and production processes**

Copper Mine "Gabriela Mistral", Chile

Moguntia Spice Making, Austria	**Copper Mine "Gabriela Mistral", Chile**	Milma dairy, India	Laboratorios Liomont, Mexico	PepsiCo, USA

General information

Three solar process heat plants are currently in operation in the mining sector in Chile, providing heat for the electrolytic extraction of copper. One plant with parabolic trough collectors with a capacity of 2 MW_{th} is located in the "Minera El Tesoro", one in the "Constanza Mine" with 350 kW_{th} flat-plate collectors (solar fraction of 80%) and another in the "Minera Gabriela Mistral" with 39,000 m^2 flat-plate collectors (solar fraction of >80%). In the following table, the data of the Minera Gabriela Mistral are presented.

- **Country** Chile
- **Solar thermal system owner / operator** Codelco
- **Year of operation start** 2013

TECHNICAL PARAMETERS

Collector technology	**Flat plate**
Installed collector area (gross), m^2	**39,300**
Power, kW_{th}	**26**
Storage volume, m^3	**4,300**
Solar fraction	**85–100%**
Solar thermal energy used for	**Electro winning of copper**

Milma Dairy, India

Moguntia Spice Making, Austria	Copper Mine “Gabriela Mistral”, Chile	**Milma dairy, India**	Laboratorios Liomont, Mexico	PepsiCo, USA

General information

At the Milma dairy in the southern Indian city of Kannur, the milk processing processes have been powered by a solar thermal system since 2003. The system consists of 1,440 m^2 of flat-plate collectors in conjunction with a 60 m^3 hot water tank.

Country	India
Solar thermal system owner / operator	Milma dairy
Year of operation start	2003

TECHNICAL PARAMETERS

Collector technology	**Flat plate**
Installed collector area (gross), m^2	**220**
Power, kW_{th}	**1,440**
Storage volume, m^3	**60**
Solar fraction	**40%**
Solar thermal energy used for	**Pasteurisation of milk**

Laboratorios Liomont, Mexico

Moguntia Spice Making, Austria	Copper Mine "Gabriela Mistral", Chile	Milma dairy, India	**Laboratorios Liomont, Mexico**	PepsiCo, USA

General information

The company Laboratorios Liomont SA is engaged in the production of pharmaceutical raw materials and pharmaceutical preparations. A solar thermal system with 75 m^2 flat-plate collectors in conjunction with a 4 m^3 hot water tank was installed at the company in 2018. The system covers around 60% of the company's annual hot water requirements.

Country	Mexico
Solar thermal system owner / operator	LABORATORIOS LIOMONT SA DE CV
Year of operation start	2018

TECHNICAL PARAMETERS

Collector technology	**Flat plate**
Installed collector area (gross), m^2	**75**
Power, kW_{th}	**52.5**
Storage volume, m^3	**4**
Solar fraction	**60%**
Solar thermal energy used for	**Preheating of hot water**

PepsiCo, USA

Moguntia Spice Making, Austria	Copper Mine "Gabriela Mistral", Chile	Milma dairy, India	Laboratorios Liomont, Mexico	**PepsiCo, USA**

General information

PepsiCo operates a large plant in Tolleson in the Phoenix Metropolitan Area in Arizona, USA, for the production of the energy drink Gatorade.

In 2008, the PepsiCo Group ordered a solar thermal system to generate one million kWh of thermal energy per year for the production of Gatorade. The first plant was realised with a collector area of 893 m^2. More than 1,250 kWh/year per m^2 gross collector area was measured on the official heat meters of the local authorities. As a result, in 2010, an expansion of 2,568 m^2 was commissioned, followed by the third expansion stage in 2012 to the current size of 3,793 m^2.

- **Country** USA
- **Solar thermal system owner / operator** PepsiCo
- **Year of operation start** 2008

TECHNICAL PARAMETERS

Collector technology	**Flat plate**
Installed collector area (gross), m^2	**3,793**
Power, kW_{th}	**2.65**
Storage volume, m^3	**114**
Solar fraction	**50%**
Solar thermal energy used for	**The system preheats the production water for the soft drinks production upstream of the site's reverse osmosis plant**

18.3.2 Studies and reports

Publications of IEA SHC Task 64 on Solar Process Heat

The following publications of IEA SHC Task 64 can be found via the link shown below:

- Technology Position Paper
- Update on SHIP Technology Costs & SHIP Business and Financing Models
- Guidelines for Simulation Tools and Monitoring the Performance of SHIP Systems
- System/Component Modularization for SHIP Applications
- Integration Concepts and Design Guidelines
- Guideline for Yield Assessment in SHIP Plants

All reports can be downloaded here: https://task64.iea-shc.org/publications

Publications of IEA SHC Task 49 on Solar Heat Integration in Industrial Processes

The following publications of IEA SHC Task 64 can be found via the link shown below:

- Process integration and Process Intensification combined with solar process heat
- Best practice - Series of Case Study Reports from Demonstration Projects
- Potential studies on solar process heat worldwide

All reports can be downloaded here: https://task49.iea-shc.org/publications

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