

Strategic Research & Innovation Agenda for Solar Thermal Technologies





Secretariat for the European Solar Thermal Technology Panel of the RHC-ETIP

This document was prepared by the European Solar Thermal Technology Panel (ESTTP) of the European Technology and Innovation Platform on Renewable Heating & Cooling (RHC-ETIP), managed by Solar Heat Europe/ESTIF.

MAIN AUTHORS (in alphabetical order)

- **Andreas Häberle** (SPF-OST)
- **Andreas Hauer** (ZAE Bayern)
- **Christian Holter** (SOLID)
- **Christoph Brunner** (AEE Intec)
- **Daniel Mugnier** (Tecsol)
- **Guglielmo Cioni** (TVP Solar)
- **Harald Drück** (IGTE, Uni. Stuttgart)
- **Irene di Padua** (SHE)
- **Marco Calderoni** (R2M)
- **Marta Cañada** (Abora Solar)
- **Pedro Dias** (SHE)
- **Riccardo Fedrizzi** (EURAC)
- **Stephan Fischer** (IGTE, Uni. Stuttgart)
- **Werner Weiss** (AEE Intec)
- **Wim van Helden** (AEE Intec)

OTHER CONTRIBUTORS:

The members of the European Solar Thermal Technology Panel (ESTTP) of the European Technology and Innovation Platform on Renewable Heating & Cooling (RHC-ETIP).

ESTTP / Solar Heat Europe wishes to sincerely thank all those who submitted data and contributed to the collection of information.

EDITORS

- **Marco Calderoni** – R2M, ESTTP Chairman
- **Pedro Dias** – Solar Heat Europe / ESTTP Secretariat
- **Irene di Padua** – Solar Heat Europe / ESTTP Secretariat
- **Felix Kriedemann** – Solar Heat Europe / ESTTP Secretariat



Secretariat of the ESTTP of the RHC-ETIP (SHE)

2 place du champ de mars
B-1050 Brussels – Belgium

www.rhc-platform.org

info@rhc-platform.org

Manuscript completed in May 2022.

Brussels, © RHC-ETIP, 2022.

This document is available on the Internet at:

www.rhc-platform.org

All rights reserved. No part of this publication shall be reproduced, stored in a retrieval system, or transmitted by any means – electronic, mechanical, photocopying, recording, or otherwise – without written permission from the publisher.



The Secretariat of the European Technology and Innovation Platform on Renewable Heating and Cooling is a project that has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement N°825998.

Photographs: © Abora Solar, Absolicon, Austria Solar, Greek Solar Industry Association, GreenOneTec, NewHeat, SavoSolar, Solar Heat Europe, TVP Solar

Disclaimer

The opinions expressed in this document are the sole responsibility of the European Technology and Innovation Platform on Renewable Heating and Cooling and do not necessarily represent the official position of the European Commission. Reproduction and translation for non-commercial purposes are authorised, provided the source is acknowledge and the Editor is given prior notice and sent a copy.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	2
INTRODUCTION	3
CHAPTER 1 – SOLAR HEATING AND COOLING VISION	4
1.1 State of the Art	5
1.2 Market Trends	7
1.3 Technical and economic potential	8
CHAPTER 2 – TECHNOLOGICAL TARGETS AND INDICATORS	10
2.1 Ongoing research	11
2.2 Key performance Indicators (KPIs)	12
2.3 Potential Cost Reduction	14
CHAPTER 3 – RESEARCH PRIORITIES	15
A. TECHNOLOGIES	
TOPIC A.1 – Development of system components for solar district heating (SDH) and solar heat for industrial process (SHIP) including thermal storage (mid-high temperature/pressurised)	16
TOPIC A.2 – Demonstration projects for high temperature SHIP projects (<400°C)	17
TOPIC A.3 – Improved hybrid collectors, such as PVT	18
TOPIC A.4 – Developing prefabricated multifunctional solar façade systems	19
TOPIC A.5 – Developing ‘Solar-Active-Houses’ with high solar fraction	20
B. SYSTEM INTEGRATION	
TOPIC B.1 Integration of large solar thermal systems and storages process including thermal energy storage	21
TOPIC B.2 Integrated solutions for SHIP below 400°C	22
TOPIC B.3 Digitalisation	23
C. NON-TECHNOLOGICAL	
TOPIC C.1 Environmental legislation, and land availability for SDH	24
TOPIC C.2 – Developing new Business Models for Solar Thermal	26
Topic C.3 – Solar thermal resource mapping	27
CHAPTER 4 – IMPLEMENTATION PLAN	29
4.1 Budget requirements	30
4.2 Financing solar heating & cooling	31
4.3 Funding instruments	32
4.4 Recommendations	32
4.5 Requested Funding to implement the action plan	33
GLOSSARY	34

EXECUTIVE SUMMARY

The future of the energy system will have a dramatic impact on our life and that of coming generations, be it for its impact on climate, on economic growth or even on energy security. Recent events show also that the security of Europe, its economic stability and growth as well as its capacity to intervene in geopolitical matters is very much related to its energy security and, consequently, to its capacity to transition to renewable energy.

It is therefore natural that the European Union is increasing its ambition with regard to decarbonisation. While aiming to become carbon neutral by 2050, the European Union is also accelerating the transition, increasing the target of CO₂ reduction to 55% by 2030. In addition, the REPowerEU Plan is proposing concrete measures to reduce EU's dependency from imported fossil fuels. Which renewable energy, including solar (solar PV and solar thermal) playing an important role.

Today, more than just a couple of years ago, it is clear that renewable heating and cooling technology will play a vital role among the available options in the sustainable energy system, which will become more decentralised. This is evident also in proposals such as the review of the Energy Performance of Buildings Directive, which included a new concept for Zero-Emissions Buildings, based on in-loco supply of renewables. Solar thermal has two elements that make it essential for Zero-Emissions Buildings: its energy density and its integrated storage capacity. Being three times more efficient than solar PV, allows to make the best use of available rooftop area for residential and commercial applications (domestic hot water and/or space heating). Likewise, it should be a preferred option for available land area close to district heating networks or industries requiring solar heat for industrial processes. Regarding storage, one essential aspect that is usually disregarded is that solar thermal systems include always thermal energy storage. Hence, solar thermal prices (investment or LcoE) include always the storage capacity, which exceeds 185 GWh/a.

These aspects make solar heating and cooling an essential solution for a decarbonised and decentralised energy system. As a result, it will increase in relevance as an essential energy source in smart cities, smart industries and smart rural communities. Solar heating and cooling, besides being a decentralised and widely available energy source, it has also an important economic impact: approximately half the investment is allocated to the lower end of the value chain, generating jobs and economic growth at the local level. It is an extremely convenient heating source, based on a simple concept enhanced by cutting edge technology.

Thanks to technological progress solar thermal has become not only a better option for more traditional applications, such as domestic hot water production, but also an attractive alternative for new and more advanced applications such as industrial process heat.

Solar heating technology can have a strong impact in the market; however, to unlock its potential, technological development is urgently needed.

Therefore, experts from the solar heating and cooling sector have gathered together in the Solar Thermal Technology Panel of the Renewable Heating and Cooling Technology Platform and developed this technology roadmap that would help the sector to provide to the market the solutions to critical societal challenges. Hence challenges and solutions are addressed in greater detail in this roadmap.

Chapter 1 introduces the vision for solar heating & cooling, describing the state-of-the-art, market trends and the technical and economical potential.

Chapter 2 summarises the technological targets and indicators for different research & innovation priorities, including the Key Performance Indicators (KPI).

Chapter 3 describes the research priorities that are subdivided in: technologies, system integration and non-technical issues, presented in subsections A, B and C respectively.

Chapter 4 addresses the funding of research and innovation activities for solar heating and cooling.

INTRODUCTION

Nowadays, the final energy consumption in Europe is composed as follows: electricity is 20%, transport is 30% and heating and cooling is almost 50%, hence **heat is half** of the total energy consumed. Furthermore, the heating and cooling sector is responsible for 40% of the energy related CO₂ emissions¹ and solar thermal is among the renewable technologies which can substantially improve decarbonisation in this sector. With 389 GW_{th} installed worldwide, in 2020, solar thermal systems produced 479 TW_{th} which shows the potential of this technology.

In Europe, more than 10 million systems are currently installed, demonstrating how this technology is mature and is among the best options to reduce energy costs and boost decarbonisation.² During the last decade, solar district heating applications rapidly grew, and today more than 200 cities in Europe use solar thermal. The market for solar heat for industrial processes (SHIP) has also doubled in sized in the last few years, with record size installations coming up on a yearly basis.

Solar thermal has always been among the most acknowledged renewable energy sources by European citizens. This is because of several reasons:

- 1) Solar thermal is a no regret option, not producing emissions and easy to combine with several power and heat solutions (both renewables and fossil-based).
- 2) Its components are either reusable or recyclable, making these systems almost completely sustainable³.
- 3) It combines a low levelised cost of heat (LCoH) with short energy and carbon pay-back periods, stressing its relevance as a sustainable solution.

Solar thermal has experienced for decades a continuous increase in total installed capacity in Europe, reaching as of 2020, more than 37 GW_{th} of solar thermal collectors installed in Europe (corresponding to more than 54 million m²), and representing an estimate energy generation of 27 TW_{th}⁴. Such high value shows how concretely solar thermal is already contributing to EU's energy supply. And even though year-on-year sales have varied in recent years, along with other heating and renewable heat solutions, the solar thermal market faces a rebound since 2018 (with the obvious exception of 2020), with the market growth both in 2018 and 2019.

Furthermore, solar thermal has a good track record in terms of quality assurance. European solar thermal companies joined hands with research institutes to create the first quality mark for a renewable (or heating product) based on EN testing standards, the Solar Keymark. Thanks to this, solar thermal is a highly trustable technology, with many skilled local installers thanks to widespread training programs across the EU.

Today, strategies to achieve carbon neutrality emphasise the need for electrification, but such a path will require costly upgrades to distribution networks. While for mobility, this may be unavoidable, a fully carbon-neutral H&C sector is possible without increasing the electrical peak load by using currently available thermal renewable technologies.

A clear advantage of solar thermal in this context is that solar heat does not rely on the use of external network by providing thermal energy storage, both diurnal and seasonal. This technology can therefore support the decarbonisation of the power supply. For these and other reasons, solar thermal should be further deployed and new solutions using solar thermal for heating and cooling developed.

Solar thermal technologies will play a key role in the future energy system and significantly reduce energy costs and emissions. These applications are generated on-site and have the highest efficiency of all renewable technologies.

Most of the solar thermal systems installed in Europe are also manufactured in Europe and can provide both households with hot water at 60°C and industrial sites (such as breweries, paper mills or textile industry) with process heat (air, water or other fluids, steam) with low and medium temperature (reaching up to 400°C) solutions.

By reducing the cost of heat and by reducing CO₂ emissions, solar thermal is making living in a green world easier. The purpose of the input papers is to identify high-level RDI challenges to further deploy the potential of this promising technology.

¹ <https://www.iea.org/reports/renewables-2020/heat>

² <https://www.iea-shc.org/solar-heat-worldwide>

³ Recent studies, like the one by JRC on "Critical Raw Materials for Strategic Technologies and Sectors in the EU", highlight that 100% of components used for solar heat are recyclable.

⁴ Solar Heat Markets in Europe Trends and Market Statistics 2020, Solar Heat Europe, 2021

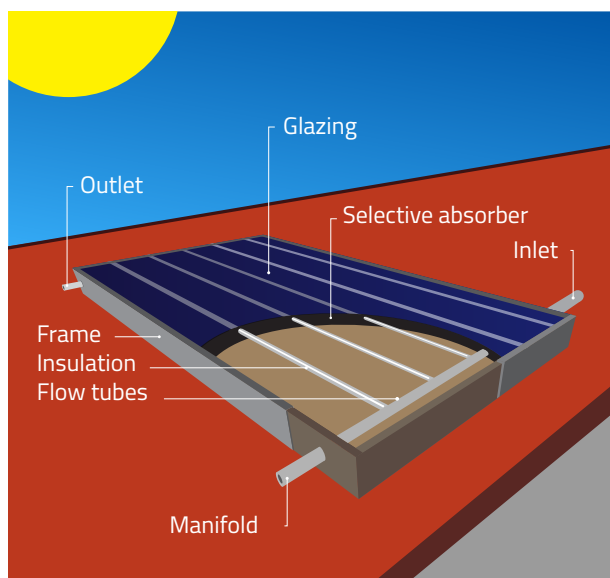
Chapter 1

SOLAR HEATING AND COOLING VISION

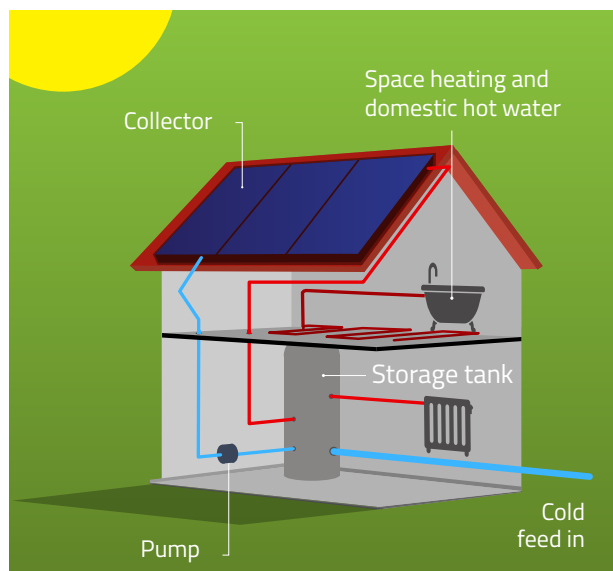


1.1 State of the Art

Solar thermal systems convert solar radiation into heat through an absorber, and then exchange this heat via a transfer medium. This transfer can be done in air, water or a mixture of water and glycol and, for higher temperature needs, with pressurised water or oil. The thermal energy produced is transferred to a storage tank, which is always a built-in feature of solar heating and cooling systems, regardless of their size and geographical location.

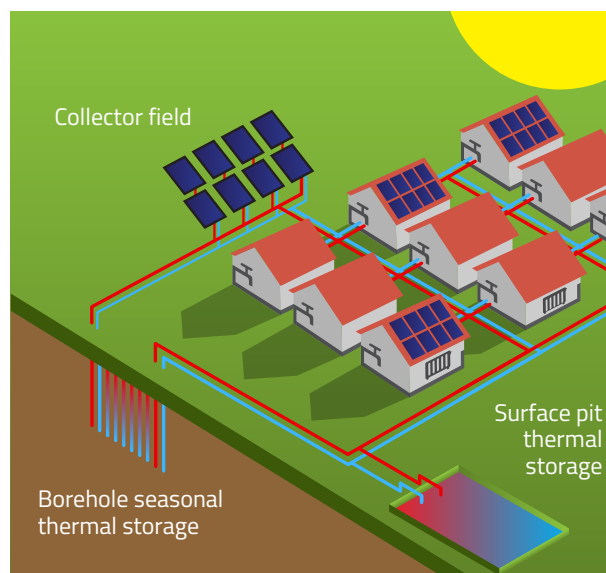


Indeed, solar thermal technologies are extremely flexible and can be used to warm up swimming pools and sanitary hot water, for space heating of both residential and non-residential buildings, or even for higher temperatures to decarbonise industrial heat processes with temperatures up to 400°C. These solutions range from small domestic systems (1.4 kW_{th} or 2m²) to medium-large large industrial plants (OVER 10 MW_{th} already existing), up to very large district heating installations (largest in Europe reaching 110 MW_{th}).



Furthermore, components of solar thermal collectors are of EU origin, and can almost entirely be reused or recycled. Considering that heat production through solar thermal does not produce emissions nor hazardous substances and consequently does not represent a risk for health or environment and since solar thermal can be combined with a myriad of other solutions (power or heat), solar thermal heat is clearly a no regret option.

Worldwide, most solar thermal systems are used for domestic hot water (DHW) production. However, the market has experienced a constant and robust increase of solar heat for industrial process (SHIP) plants and solar-assisted district heating (SDH) networks. Additionally, solar thermal at individual and large-scale level is easily compatible with other solutions, for both heat and power production.



Currently, typical applications of solar thermal technologies are:

- Domestic hot water preparation for single- and multi-family houses: these applications are usually done with thermosyphon or forced circulation systems, with typical solar fractions between 40-90% (meaning that solar energy covers these shares of the total heat demand). Temperature levels are between 40-60°C
- Space heating for single and multi-family houses with typical solar fractions between 15-40%, and for non-residential buildings and temperature level around 40°C
- Combi systems: combining DHW and space heating for single or multifamily houses
- District heating, with solar fractions going up to 50%, depending on the type of storage (seasonal to cope with summer-winter fluctuations, or storage for shorter periods) temperatures are usually between 40-100°C
- Low, medium, and high temperature heat for industrial process applications (through both solar heat and concentrated solar heat). Temperature can range from 40°C up to 400°C depending on the process
- Other applications, as Solar Thermal for swimming pools, Solar Active House, and Solar cooling applications.

The fact that solar thermal solutions do not produce polluting emissions contributes clearly to the reduction of greenhouse gas emissions and the improvement of air quality. For example, thermosyphon systems (e.g. individual solar collectors at building level) in Greece can save up to 1.5 tons of CO₂ per year which in Europe is the equivalent of the annual emissions of a combustion engine car.

Large-scale solar thermal applications have experienced a strong growth over the years:

- solar heat for industrial process (SHIP) is an expanding niche market with large potential for cost reductions in manufacturing. In 2018 alone, more than 100 industries installed solar thermal systems and the market already reached an annual installation rate of 0,5 GW. The industry sectors with the highest number of realized SHIP plants are the food and beverage industry and textile and pharmaceutical manufacturers⁵.
- solar district heating systems with and without large seasonal thermal energy storage represent over 1 GW_{th} of installed capacity in Denmark and new projects have been extending geographically over Europe, with new systems in Central Europe or even South-East Europe.
- large commercial and residential systems, ranging from collective systems used in multi-family homes, and applications in key segments such as hospitals, schools, and hotels.

Harvesting direct solar energy for heating of individual buildings has a very long history too, as part of the building architecture. As referred before, solar energy is today also extensively harvested in solar collectors for thermal uses, being the most common heating, though there are also relevant solutions for solar assisted thermally driven cooling.

Concentrating solar thermal uses solutions also used in CSP (such as Fresnel or parabolic trough) to produce higher temperatures, either for industrial uses, for cooling processes or even in district heating. Furthermore, combining PV with solar thermal in PVT (photovoltaic thermal) collectors⁶ is today an increasingly attractive option. PVT collectors convert solar radiation into usable thermal and electrical energy.

By combining electricity and heat generation within the same component, these technologies can reach a higher overall efficiency than solar photovoltaic (PV) or solar thermal alone.⁷ PVT technologies can differ substantially and be suitable for different temperature applications.

Compared to other technologies, solar thermal has some key specific strengths, as it:

- Is easy to integrate with other RES heating and electrical solutions, or with incumbent fossil systems, making it an enabler of sector integration and a facilitator of renovation processes.
- Can be considered as an energy efficiency measure since it always results in direct energy saving and faces similar challenges (e.g.: upfront investment, provide cost-savings rather than a direct return).
- Is a no regret infinite source of energy since it does not produce emissions and is easy to combine with other sources.
- Creates local jobs along the value chain (including distribution, planning, installation, and maintenance of solar systems).
- Is a scalable solution, deployed in all European member states and efficient in all types of climate and for different applications.
- Has no exposure to the volatility of energy prices (gas, electricity) and does not cause an increase of electricity demand, instead it helps to shave peak power demand.
- Allows a real self-consumption and increase both security of supply and energy independence.
- Provides a viable and reliable solution for direct renewable heat, decreasing the need for high exergy sources (electricity, gas) to be diverted to low exergy uses (space and water heating), hence reducing the burden on additional investments in infrastructure, being it for power or gas.

Solar heat provides clear benefits for local economies. In the European internal market, 90% of available solar thermal products are manufactured in Europe with European components. This solution not only produces clean energy locally, but it also creates new business and new jobs (including job-reconversion) at local and regional level. Furthermore, the European solar industry is an exporting sector, with annual net exports surpassing at times 1 billion Euros.

⁵ www.ship-plants.info

⁶ See IEA SHC || Task 60 || Application of PVT Collectors, 2018

⁷ Zenhäusern, Daniel, Evelyn Bamberger, and Aleksis Baggenstos. 2017. «PVT Wrap-Up: Energy Systems with Photovoltaic-Thermal Solar Collectors». Rapperswil, Switzerland: published by EnergieSchweiz. http://www.spf.ch/fileadmin/daten/publ/PVT_WrapUp_Final_EN.pdf

1.2 Market Trends

The EU aims to have a net-zero greenhouse gas emissions economy by 2050, as envisioned in the European Commission's 2050 long-term strategy⁸, to meet the EU's commitment under the Paris Agreement. While renewables have made an important contribution in this area, there is still a long way to go. This is related especially to the heating and cooling sector (RHC). More intensive deployment of RHC is possible. Already in 2018 about 98 Mtoe were provided by RHC (biomass, solar, geothermal, and ambient heat with heat pumps).

The plan of the EC, under the 32% overall target for RES is to reach 124 Mtoe by 2030 with an annual average increase of about 2.3%. Combined with a reduction in consumption due to efficiency measures in the building sector, this moderate rate will decarbonise 50% of H&C by 2040 and produce 155 Mtoe annually. This is clearly too little to achieve the above-mentioned goal of a net-zero greenhouse gas emissions economy by 2050.

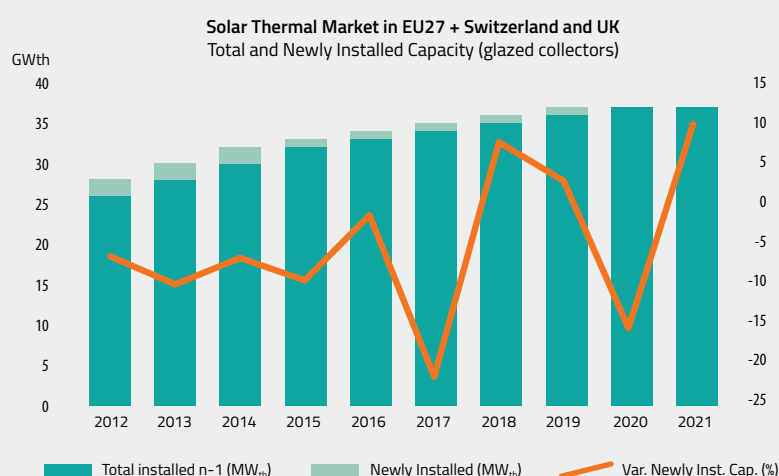
Solar thermal systems, which can be used in residential buildings, hotels, hospitals as well as in district heating systems and for the provision of industrial process heat, have the potential to make a major contribution to rapidly moving closer to the net-zero greenhouse gas emissions economy.

By the end of 2021, about 10.7 million solar thermal systems with an installed capacity of 37,8 GW_{th}, corresponding to a total of 54 million m² of collector area was in operation in Europe⁹. The solar thermal sector has been growing continuously for over four decades and generates annual a total of 27 TWh_{th}. Based on this annual energy generation, solar thermal for heating and cooling is the second most relevant renewable heat source after bioenergy.

in countries where the traditional mass markets for small-scale solar water heating systems for single-family houses and apartment buildings are under market pressure from heat pumps and photovoltaic systems. However, even in this market segment there are resilient countries, especially in Southern Europe, with countries such as Greece, Portugal or Cyprus showing a growth trend in recent years.

Besides the DHW use, space heating is another significant application, especially in central European member states. In Germany, approximately 50% of total installed collector area is for "combi systems" producing at same time thermal energy for DHW and space heating. In this specific sector the competition from heat pumps and solar PV systems is less significant since the peak in energy demand is mainly in winter when little solar irradiation is available, and solar PV is rather used for lighting and electric domestic appliances. Despite most of the market being represented by small-scale applications, solar heat use is growing in the number of MW_{th} scale systems for solar district heating and industrial applications. 23 large-scale solar thermal systems with about 160 MW_{th} (228 900 m²) were installed in Europe in 2019¹⁰.

Interest is also increasing throughout Europe in solar heat for industrial process (SHIP) systems. Several promising projects implemented range from small-scale demonstration plants to large systems in the MW_{th} scale. In 2021 a new record has been achieved for the largest SHIP plant in Europe in operation: a malting plant in France, with a capacity of 10 MW_{th}. The same year, also in France, started the construction of a 15 MW_{th} plant for a whey powder factory, while a 20 MW_{th} SHIP plant for a malting factory in Croatia has been contractualized.



In addition to the more traditional industrial sectors like food, beverage, textile, chemistry, and mining industry, in which solar thermal systems are commonly used, there are two new applications which are attracting more and more interest. One of these more recent applications, is the production of solar heat for flower and vegetable cultivation in greenhouses. The second application relates to the heating of gas pressure control systems, an interesting application which is already implemented in several systems in Germany.

Finally, the Photovoltaic Thermal (PVT) collector market developed very well in recent years in Europe and saw in 2019 a significant growth rate of 14%, corresponding to an increase of the yearly new installed capacity of 40.8 MW_{th} and 13,3 MW_{peak}. By the end of 2019, the worldwide installed PVT collector area was 1,166,888 m² (606 MW_{th}, 208 MW_{peak}), and 58% of this collector area was in Europe.

The main market segment for solar thermal in Europe is the residential sector, where this technology is mainly used in domestic hot water (DHW) systems. This market segment is experiencing challenging times, and this is especially evident

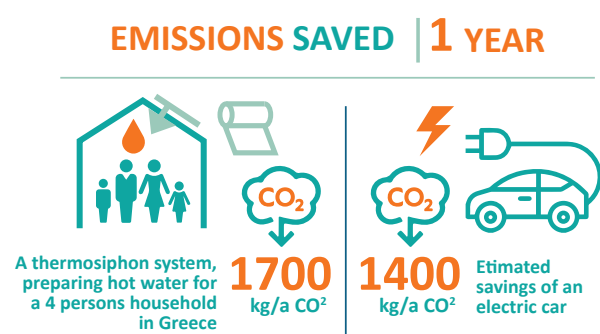
⁸ See European Union, Council of the European Union, 2020.

⁹ Preliminary Market Report 2021 - Solar heat Europe, ESTIF, 2022

¹⁰ Solar Heat Worldwide – Global market development and trends in 2019, W. Weiss and M. Spörk-Dür, IEA SHC 2020

1.3 Technical and economic potential

By effectively addressing the challenges listed in the following paragraph, solar thermal technologies will have a strong impact on the adoption of solar thermal technologies across different applications and a total solar energy supply equivalent to 31 000 toe¹¹ will be reached by 2040. An electric car can avoid approximately 1400kg CO₂/y compared to a single solar collector of 2.5m² size that can save up to 1700kg CO₂/y.¹² Such great impact will be reached if enough research and demonstration efforts will be directed to this technology, which is strongly acknowledged by the public as one of the 100% renewable heating technologies and is predominantly manufactured in Europe.



In a carbon neutral 2050 energy mix, renewable heating solutions are expected to take a prominent role. In fact, the decarbonisation of the heating and cooling sector will not be achieved without solar thermal, which in Europe is expected to cover at least 50% of the final energy demand for this sector. The European market is showing positive trends, and initial estimations for 2020 (pre-COVID) indicates strong growth rates in some of the largest markets and this is expected to continue in 2021.¹³

Solar thermal is the most efficient renewable energy sources. It converts the inexhaustible solar resource with an efficiency up to 70% (40–60% in most collectors), meaning that it is able to convert into thermal energy 70% of the solar energy received in the surface of the collector. As a reference, solar PV panels have an efficiency between 15 and 20%. The comparison with other heating solutions, such as heat pumps, presenting a COP from 1 to 5 (for ground-source heat pumps), would show an even larger difference, as a solar thermal system primary energy consumption (electricity for running the water pump) would lead to COPs of 60 and above.

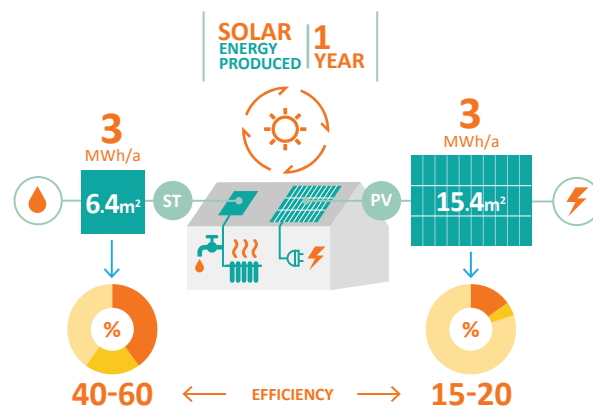
Currently there are 38 GW_{th} of solar heating capacity in Europe, with an estimated generation of around 27TWh_{th}. This represents over 10 million systems installed in Europe, with most of applications ranging between 40–70°C for domestic hot water and space heating for both residential and commercial buildings.

Nevertheless, solar heat can be used for a variety of applications: for example, solar-assisted district heating systems are commercially available, can reach sizes over 100 MW_{th}, and are particularly developed in Central and Northern Europe. The largest solar assisted district heating in the world is in the Danish city of Silkeborg where the solar thermal plant covers 100% of the summer heat demand of the city and 20% of the winter load, thanks to large seasonal thermal energy storage capacity.

As mentioned before, solar district heating (SDH) networks are an innovative and promising solutions which is more cost-effective than gas-based systems. However, the potential for this application is still underestimated and limited mostly to areas supplied with natural gas networks. In this context, the integration of solar heating and cooling with other renewable sources (be it for electricity or heat production) can also be an effective solution for peak shaving, especially when coupled with seasonal thermal storage.

Another growing reality is the one of solar heat for industrial process (SHIP), which shows already good results especially in areas as the food and beverage industry (breweries, dairies, etc), mining and textile processes.¹⁴

These solar thermal systems show great potential and are well suited for generating process heat, with good economics, but there is still a need for promoting further demonstration projects and feasibility studies.



Overall, large-scale systems need project finance and bankability tools, which implies, among other issues, standardisation, system validation and risk assessment procedures. In the last few years SHIP plants kept growing in Europe. From 2018 to 2020 they passed from 2MW_{th} to reaching the record size (in Europe) of 12MW_{th}. These plants were made by European companies for different industrial customers, from the agri-food sector to pulp and paper one.¹⁵

¹¹ In average this can be converted into 504 651 MW_{th} and 720 930 233 m²

¹² In average a solar thermal collector avoids 675 Kg CO₂/m² year and an electric car avoided 120 gr/Km. Comparing a single solar collector of 2.5 m² and a car with a Kms/year of 12000 km: 1 collector avoids 1688 Kg CO₂/collector year, and an electric car avoids 1440 Kg CO₂/year. Data from IEA SHC 2020

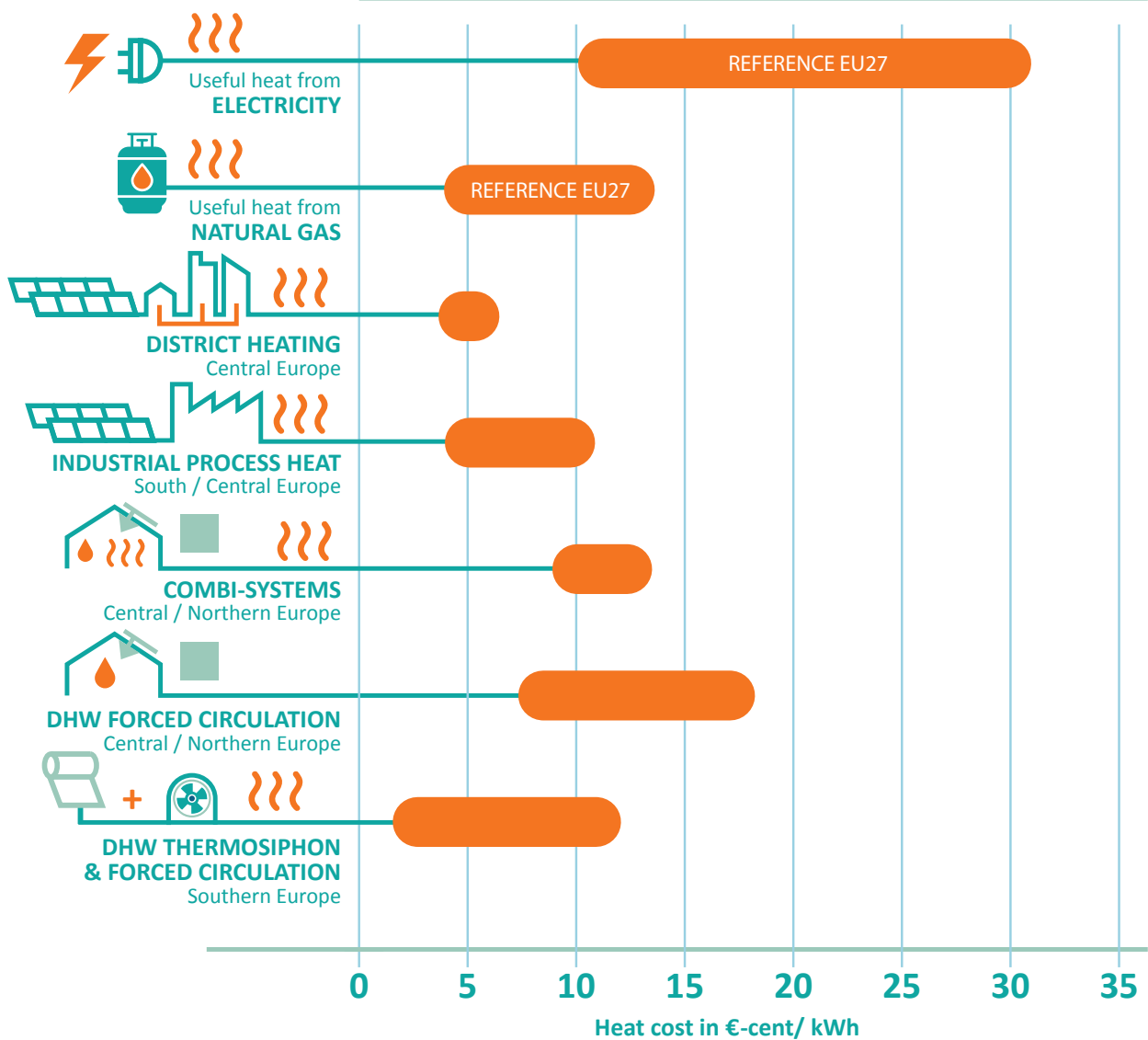
¹³ <https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2020.pdf>

¹⁴ During recent years the largest plant in Europe grew from 2 MW up to over 10 MW;

¹⁵ More information <http://www.ship-plants.info/>

Large-scale solar thermal systems can produce heat at a cost of around 20 to €30/MWh, compared to €28-35/MWh which is the full cost range for generating heat through gas boilers.¹⁶

LCOE (Levelised Cost of Energy) per kWh for different solar thermal applications



¹⁶ Solar Heat Worldwide 2020 – Global Market Development Trends in 2019: <https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2021.pdf>

Chapter 2

TECHNOLOGICAL TARGETS AND INDICATORS



2.1 Ongoing research

When assessing the ongoing research, it must be taken into account that the previous version of the Strategic Research Agenda for Solar Heating Cooling, focused on three main segments: Solar Active Houses (SAH), Solar Compact Hybrid Solutions (SCOHYS), and Solar Heat for Industrial Processes (SHIP).

Building decarbonisation is addressed mostly in SAH related projects, and the focus lays particularly on the integration of solar heat technologies in building façades. Looking at this segment, SAH are already available in the market but not yet as a standardised solution. Several projects¹⁷ are addressing key issues such as thermal storage and components (collectors, heat exchangers, façades) to improve SAH, however none of them is taking an integrated approach and additional projects will be needed to reach the goal of standardisation. In general, public funding is dedicated to nearly Zero Energy Buildings (nZEB) rather than SAH and private financing is still limited in this context, with little engagement and ambition from heating industries.

The second segment, hybrid systems (SCOHYS), is available in the market for domestic hot water (DHW) and space heating in both single- and multi-family houses. As showed by different projects¹⁸, multifamily houses applications reach competitive LCoH levels (€0,07/kWh for Austrian conditions). Like SAH, also SCOHYS projects put some emphasis on thermal storage solutions (PCM, thermochemical, sorption etc.) including seasonal one, bringing a positive impact on the overall sector.

Finally, as already mentioned, SHIP is a growing and expanding reality, with new technologies like high vacuum flat plate collectors reaching up to higher temperature and lowering costs for the application. The [Solarbrew](#) project reached €210/m² with a solar fraction of 19%; whilst for medium temperatures, [Fresh NRG](#) reached €412/m². Considering the technical lifetime of the systems, the target of 3-6 €cent/kWh for low temperature applications and 4-7€cent/kWh for medium ones can be reached under certain conditions. New large SHIP projects, such as [SHIP2FAIR](#) are expected to provide values between 2.5-3.5 €cent/kWh (with subsidies). Other initiatives, like [INSHIP](#) can provide additional opportunities for R&I investments in this area. SHIP applications for refrigeration and water treatment and evaporation are also being developed even though not so common yet. Additional information is available from the project [Solarpayback](#). The main barriers to a wide deployment of SHIP systems remain the competition from low price fossil fuels (as users tend to stick to business-as-usual solutions), the availability and/or cost of land or rooftop near relevant industries and still insufficient validated data on existing systems (track record).

Furthermore, industrial users require return on investments that are much shorter than what is possible (based only on savings of cheap fuels, without a clear carbon cost saving), for this reason a change in their mindset is needed to promote the deployment of renewable heat in the industrial sector. Besides solar process heat, also solar process refrigeration is being experimented in the [HyCool](#) project, where solar Fresnel collectors operate a hybrid thermal-electrical chiller.

Several projects are also addressing new collectors such as photovoltaic thermal (PVT) ones, and components (heat exchangers, controls etc.). Ongoing research on new materials (including nanotechnologies) can lead to a cost reduction and increase efficiency of solar thermal systems. The environmental impact of production can also be further reduced. New concepts including innovative design for concentrators, and novel concepts for thermal storage will also bring substantial improvements to the sector. These improvements will also promote sector coupling and reduce the need for new transmission grids, providing flexibility services both at product (hybrid collectors) and system level. This will greatly reduce the need for large infrastructure investments, required by a scenario of highly electrification of heat.

Finally, research is also looking at public and reliable solar irradiation maps, forecasting self-learning algorithms based on AI and methods that will simplify the feasibility and the design process of solar thermal plants and, afterwards, operation and control of the solar installations. Other ongoing research activities are related to the planning level (Solar Neighbourhood Planning), to integration in new and retrofitting of buildings including historical buildings and to standards and certification of solar thermal collectors and systems.

¹⁷ [THERMALCOND](#), [SCOOP](#), [SolSys](#), [COMTES](#), [HP-LP-SOLAR-FAÇADE](#), [ECOSS](#), [SARTEA](#), [STAID](#), [UniSto](#), [Tes4seT](#) had arelevant relation to SAH. Projects [HeizSolar \(DE\)](#) and [ECOSS \(FR\)](#) had a more direct contribution to the standardization goal, while projects such as [HP-LP-SOLAR-FAÇADE \(EU\)](#), [Tes4seT \(AT\)](#), [SCOOP \(EU\)](#) contributed to the cost reduction goal.

¹⁸ [PROSSIS2](#), [SAM.SSA](#), [MERITS](#), [TESse2b](#), [WPSol](#), [COMTES](#), [UniSto](#), [Tes4seT](#), [SysTHEff](#), [INSPIRE](#), [SYSTHEFF](#), [MACSHEEP](#), [HP-LP-SOLAR-FAÇADE](#). A few R&D initiatives focusing on cost reduction can be noted, such as [TEWISol \(DE\)](#), [Task 54 \(DE\)](#) and [Zeosol \(EU\)](#) and [SunHorizon](#)

2.2 Key performance Indicators (KPIs)

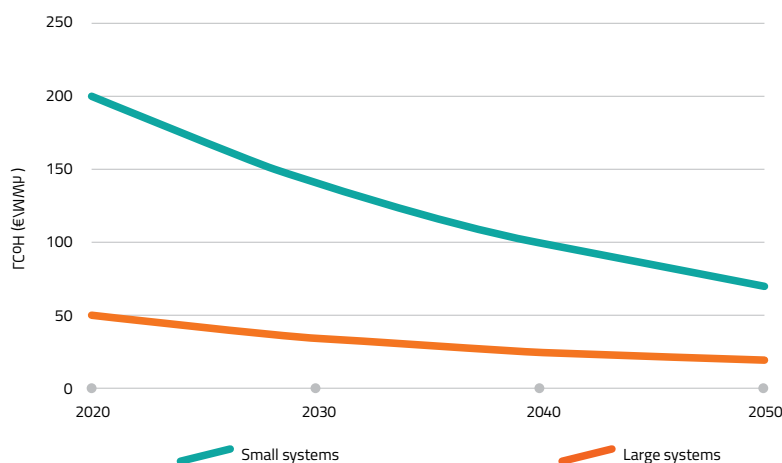
	Topic	Specific KPI at 2028	State of the KPI to date
SDH	Development of system components for SDH including thermal storage (mid-high temperature/pressurised)	1. Large solar thermal systems and storages will be integrated in medium and high temperature DH networks in large and medium size DH systems. Storages shall be developed, designed and used both for short-term (balancing heat between day and night) and for long-term (seasonal – shifting summer to winter).	Current experiences are mainly on medium-low temperature DH networks.
		2. System design rules established with solar thermal fraction in smart heating grids up to 40%.	5-10%
		3. Decentralized cooling and air-conditioning systems are integrated into at least 5 solar thermal district heating systems.	Unknown
SDH	Environmental legislation, and land availability for SDH	1. Better exploitation of available area through industrial symbiosis via DHC networks are showcased in at least 3 demonstration projects.	None
		2. Advanced concepts for sustainable use of land around cities and industrial areas (also with multi-use concepts for ground mounted systems combining solar heat with agriculture) for solar thermal energy have been conceived and validated with the support by regional energy planning.	None
SHIP	Demonstration projects for high temperature SHIP projects (<400°C)	1. Improved medium temperature applications both for pressurized hot water and for steam production (for Direct Steam Generation improved knowledge of two-phase flow-patterns is needed) with solar fraction > 40% and 40% yearly efficiency.	SF = 5-20% with yearly efficiency of 30%
		2. Integrated solutions combining low temperature solar process heating systems with other technologies (e.g. heat pumps, waste heat recovery, solar-trackers, heat driven processes, e.g. absorption cooling, power-2-heat, PVT) have been showcased.	Few experiences so far with HT HP, waste heat recovery, solar trackers, power-2-heat and PVT.
		3. Solar heat cost in the range of 3-6 €cent/kWh for SF of 40% by achieving investment costs of 300 €/m2 for low temperature SHIP systems (<100°C).	6-9 €cent/kWh for SF 5-20%
		4. Solar heat cost in the range of and 4-7 €cent/kWh for SF of 30% by achieving investment costs of 400 €/m2 for medium temperature SHIP systems (<400°C).	7-12 €cent/kWh for SF 5-10%
		5. By 2027, 1500 SHIP systems will be installed worldwide.	800 worldwide

SHIP	Development of system components for SHIP including thermal storage (mid-high temperature/pressurised)	1. Pre-manufactured solar thermal periphery units for SHIP plants (including piping, pumps, valves, storage, measurement devices and other armatures) will be at TLR 9 by 2027	Currently not available for SHIP
		2. Cost-efficient substructure concepts for industry roofs integration of concentrating solar thermal collectors will be available at <40 €/m ²	Currently not available in standardised way
		3. Lighter medium temperature collectors are developed.	T.B.D.
		4. New low temperature process technologies are addressed, such as thermal driven separation technologies - membrane distillation.	No experience so far
SHIP	Standards and certification schemes	1. Standards should be improved by including accelerated ageing tests for medium-temperature collectors.	Current standards do not include accelerated ageing tests.
		2. Dedicated certification schemes for SHIP will be available.	No specific certification scheme is available for SHIP.
PVT	Improved hybrid collectors, such as PVT	1. Develop appropriate testing standards and certification schemes for PVT. Standards should combine PV and T in one testing cycle at a reasonable cost for the manufacturer.	Currently Solar Keymark does not fully cover PVT.
		2. Reduce PVT collector costs, also by ensuring easy installation: Make the cost fall by a factor of 1.5 to 2.	1000 €/m ²
Buildings	Developing prefabricated multifunctional solar façade systems	1. To offer customizable architectural appearance.	Limited customization possible
		2. To implement a normative framework facilitating the integration of solar technologies in the construction sector, as uniform and international as possible.	Standards and regulation at EU level do not explicitly address building integration.
Buildings	Developing 'Solar-Active-Houses' with high solar fraction	1. SAH with at least 60% solar fraction will be standardized for newly built single-family and multi-family houses will be cost-competitive with other nearly zero-energy buildings, with solar heat at costs in the range of 12-16 €/kWh.	Not standardized, solar heat cost > 18 €/kWh
Financing	Developing new Business Models for Solar Thermal	1. Business models to integrate decentralized solar thermal systems into district heating grids will be available. Those should be shaped in a way that return temperatures from the heating system to solar collectors are as low as possible.	Feed-in of solar thermal heat into DH networks currently not common.
		2. "Heat as a service" business models for business customers have been improved.	First experiences exist but need to be standardised.
Data disposal	Solar thermal resource mapping and statistical data collection	1. Adoption of common resource assessment strategies	No common strategy currently available
		2. Increased share of identified deployable solar thermal technology across the EU	T.B.D.
Digital transition	Long term, third party verified performance data projects	1. Long-term monitoring and evaluation of existing SHIP systems publicly available for at least 30 systems.	Currently not available
		2. Increased solar thermal integration in energy policy in emerging and less mature markets	T.B.D.
		3. Cost regression development based on comprehensible statistical cost data	No statistical cost data available at EU level, but to some extent at local level (e.g., Member States)

2.3 Potential Cost Reduction

As presented before, solar thermal heating and cooling is used for many different applications from single family house applications for DHW or space heating, up to large-scale SHIP applications, solar cooling, or solar district heating (SDH). The energy costs for solar heat generated is as widespread as the application and depends on the application, the heat demand, the size of the system and the climate conditions of the location the solar thermal system is installed.

The graph below shows the current situation and which cost reduction could be achieved. The solar thermal levelised costs of heat (LCoH) are today in the range of 50€/MWh (for solar district heating systems) up to 200€/MWh hot (DHW and space heating) both located in mid European climate. All other LCoH for other systems are some were in between these two values.



The costs of both small and large systems can be significant reduced under the following boundary conditions:

1. Overheating protection limiting the temperature of the heat transfer fluid below 100°C results in lower investment costs of the heat transfer fluid loop and lower maintenance costs
2. Performance increase of components and overall systems results in a higher energy yield and thus lower LCoH even if the upfront investment for a better performing component and/or system is higher
3. Standardisation of the components, mechanical and hydraulic interfaces and over all systems. Standardisation reduces the costs all along the value chain from the production of the components up to the installation of the systems and in addition results in well installed systems with lower maintenance cost and a longer lifetime which lead to reduced LCoH
4. Long lasting components and systems with a longer lifetime result in a lower LCoH.

Chapter 3

RESEARCH PRIORITIES



A. TECHNOLOGIES

TOPIC A.1 - Development of system components for solar district heating (SDH) and solar heat for industrial process (SHIP) including thermal storage (mid-high temperature/pressurised)

Thermal energy storages can provide different functionalities for SDH and SHIP systems: they enable the increased use of solar energy and at the same time they provide flexibility, increase efficiency or provide drying. For the integration of solar energy, these systems can either store solar thermal heat directly or utilize PV electricity to run heat pumps (or chillers) and store this thermal energy (power-to-heat or power-to-cold) for flexible use.

For mid to high temperature levels several thermal energy storage technologies are available or under development. Large tank thermal storages, slightly over-pressurised, can provide heat up to about 130°C. Medium temperature phase change material (PCM) storages can store and provide heat for steam systems in industry, while high temperature sensible and thermochemical (TCM) storage technologies can store and provide high temperature heat for industry and for sector coupling.

For temperature range between 130°C and 200°C, which are very relevant to most industrial processes operating with steam as thermal energy vectors, steam storage is also being developed, and is expected to be a promising solution, given the high latent heat of evaporation of water. At these temperatures, effective thermal insulation is crucial to reduce losses. Double wall vacuum insulated tanks are being studied as a solution, and need to be demonstrated and upscaled to 1-10 m³ size.

The main development challenges of system components for SDH and SHIP applications are:

- Demonstrate slightly over-pressurised large tank thermal energy storages for solar heat in industrial processes.
- Further develop cost-effective and reliable phase change materials for medium temperatures and develop systems and components for their integration in SHIP systems.
- Demonstrate sensible high temperature TES systems for SHIP (concrete, metals, minerals and other materials).
- Materials and component development for thermochemical technologies for mid to high temperature SHIP (TRL between 4 and 6).
- Demonstration of pre-commercial, MWh scale, steam storage at 10-20 bar (final TRL8).
- Development of vacuum insulated tanks for higher temperature storage (final TRL 6-7).



A. TECHNOLOGIES

TOPIC A.2 - Demonstration projects for high temperature SHIP projects (<400°C)

Industrial players tend to be large heat and cold consumers; consequently, research and demonstration activities should focus on large-scale systems. More specifically, because a significant share of industrial processes operates at medium temperature levels, there is the need for improving medium temperature applications, both for pressurized hot water and for steam production.

Although some projects have already been launched (e.g. SHIP2FAIR for food industry), which aim to demonstrate the effectiveness of SHIP for specific industrial sectors, still there is a clear need for demonstration at scale, to build a meaningful portfolio of evidence and win the confidence of industrial users, and most of all build trust among existing renewable energy investors (such as funds having already experience in PV or wind projects).

In this respect it would be extremely effective to fund at least 4 demonstrations for SHIP plants, in 4 different industrial sectors (e.g. petrochemical, pharma, textile, paper), in the scale 1 to 5 MW each, with clear energy production yield (above 600 kWh/m²/y) and energy cost targets (below 50 €/MWh before incentives), dedicated in particular to mid to low irradiance regions. This would allow to demonstrate high replicability and impact throughout the EU.

Both direct and indirect steam generation are crucial for direct integration of the solar thermal energy into the industrial process. Further investigations about two-phase flow-patterns are needed in this regard. At system level, hybrid systems based on solar thermal and high temperature heat pumps need to be showcased and optimised. Developing cost-efficient substructure concepts for roof integration of concentrating and non-concentrating solar thermal collectors will enlarge the potential market for SHIP. Solar thermal units, including piping, pumps, valves, storage, measurement devices and other armatures should be improved by reducing the related planning and construction effort. This can be obtained with pre-manufactured units, as it was done already for low temperature residential applications, where such units are largely market available. For SHIP systems this step is still pending.

Finally, given the increasing size of developing and emerging countries' economies, process heat system technologies adapted to their specific conditions are needed. This can be achieved by development of standardized modular BoP units for a selection of system sizes (thermal power output), temperature levels and heat transfer fluids (water, water-/steam, thermal oil).

R&D in the SHIP sector means not only technology advancements but also improved tools and know-how. Extensive planning guidelines for different industry sectors and applications, conceived for 100% renewable energy supply concepts, have been identified as a major need, along with long-term monitoring and evaluation of existing SHIP systems. Research on the latter topic will increase quality of new systems and trust in the technology among potential customers.



A. TECHNOLOGIES

TOPIC A.3 - Improved hybrid collectors, such as PVT

PVT collectors' market is still under development, and these hybrid systems producing power and heat at the same time had a steady increase in the last few years. Nevertheless, some technical improvements are still needed to optimize their performances and reduce costs.

Research, development, and validation of new materials for PVT manufacturing will be needed to improve thermal performance and at the same time achieve that PV module bear. This is a challenge for both glazed and concentrated PVTs, due to the thermal constraints of some materials. Technological improvements should also be developed for PV-Thermal technology, with its special features (different from PV or Thermal separately) and ensure that these collectors are as durable or more than PV and/or solar thermal only collectors. Pilots and demonstration projects with monitoring and results communicated will make PVT systems cheaper and simpler to install.

The PVT segment will also need more demonstration of large-scale installation to monitor PVT also in solar thermal cooling applications, which are still under development although attractive. System optimization like local use vs grid injection, cold or hot storages combinations for large projects also needs study cases. PVT will improve thanks to the development of new low temperature district heating systems, where temperatures less than 60-80°C are being trailed and promoted as the future choice for expanding the decarbonization of heating and cooling. Finally, retrofitting existing DHNs with higher temperatures up to 100C is also to be explored with newly developed Vacuum PVT systems, which have the potential to increase energy yield per m2 by 30-50%. This significantly enables PVT coupled with heat pumps to play a role in distributed and centralized solutions.

Indeed, PVT has a major place to play in sector coupling. An emergent system is PVT plus heat pump, where the heat pump is doubly enhanced by solar: (i) thermal solar heat source + (ii) power-to-heat electrical source. And the PV part makes it natural to be linked to consumption (including electric vehicles) through digitalization, with weather forecast, management of real-time energy data and machine learning system optimisation; and daily or/and interseasonal (electrical and thermal) storage comes to enrich this subject.

To further promote this segment, it will be crucial to develop an appropriate standard on combined PVT testing (ISO, IEC and Solar Keymark) so that all in one testing batch can be achieved and subsequent design changes can be also covered at a lower cost and to tackle risks generated by combining the two technologies. Another option can be to adapt photovoltaic certification (IEC standards) to include different panel constructions (such as second glazing of glazed PVT collectors) while maintaining electrical safety.

The advantages of the cooling effect on PV production and reduced lifetime performance degradation in a PVT collector especially with heat pump deserve more work. LCA and recycling of PVT collectors deserve some attention although not different from PV and thermal existing solutions. Reducing PVT system costs through innovation and teaching is a topic especially vs PV only or PV + heat pump solution.

Awareness raising can be improved with specific labels for PVT solutions: Increase engineering students' awareness of PVT solutions by giving classes and tools for simulation, such as the ones found on PVT collector providers' websites. Inform PV and heat pump industries know about PVT's possibilities as a heat source and train their installers. More articles and communication disseminate best practices and cost-effective cases.



A. TECHNOLOGIES

TOPIC A.4 - Developing prefabricated multifunctional solar façade systems

The exploitation of locally available renewable energy sources such as solar thermal energy is not only desirable to reduce the import of high primary energy carriers on site but is also needed for the reliable and resilient operation of the grids by means of a wise integration with local storage and building energy management. In this context, the integration of solar thermal collectors in buildings' envelopes represents a valuable opportunity to support the transition of the current building stock to net-zero or positive energy buildings by harvesting solar energy to generate usable heat.

The integration of solar thermal or PV-Thermal collectors in the envelope is still not a consolidated practice in the construction sector and the level of market penetration is scarce, although the progressively increasing number of concepts being developed speaks for a growing interest for such solutions. Among the many potentially relevant areas of research, the few listed in the following are particularly relevant as they are cross cutting this niche market and represent crucial challenges to a wider adoption.

Development of technological solutions: the progress in solar envelope technologies is only partly driven by new materials entering the market as it is also pushed by advances in manufacturing and assembling of existing materials that result into new concepts, the improvement of existing technologies, and the design of new applications from conventional concepts (low TRL 4-5).

Prefabrication: solar envelope technologies are intrinsically systemic solutions designed for multifunctional performance, which require the collaboration of many stakeholders in the design, manufacturing, and construction processes of buildings. A systemic approach to prefabrication eases this challenge, moving as much as possible of such tasks in a controlled factory environment rather than on-site where a heavily hierarchised, categorised and standardized construction chain hinders professionals to collaborate around innovative solutions. In addition, prefabrication offers a huge opportunity to components manufacturers who can evolve and place higher added-value solutions on the market (mid TRL 6-8).

Development of packages of technologies: while more and more countries worldwide are adopting mandatory building energy codes to transform their stocks into net-zero- or plus-energy buildings in the short- to medium-term, there is need of packages of technologies which integrated operation is proven in a range of climate, social and economic conditions, and that cover energy demands based on locally available RES. By maximizing the utilization of the envelope surfaces and by prompting the synergic operation with storage and building, solar thermal and PV-Thermal solutions have the chance to effectively complement the renewable energy exploitation performed through technologies, such as heat pumps (mid TRL 6-8).

Harmonization of standards and norms: solar envelope systems must comply with both construction codes and energy industry norms. The resulting regulatory gaps and the lack of consolidated international standards create an unfavourable environment that may hinder planners, investors and clients from adopting these technologies (CSA projects).

Business models and construction process: the design, manufacture and installation of multifunctional facades are usually more complex and time-consuming activities compared to conventional solutions adopted in the construction sector. Roles and responsibilities, information and material fluxes, legal liability for the correct installation and operation, warranties and maintenance are relevant multi-faceted questions that must be cleared and planned before the commission. Innovative business models are needed to overcome such issues through a solid systemic approach to the design of buildings and their energy systems, where solar thermal and PVT are no longer addons but are integrated in the design and construction chains from the early stages. Once more, the development of new skills and high added-values services as well business opportunities are stimulated in the construction market (CSA and IA projects).

The conclusions drawn in this document are part of the work performed within the IEA-SHC Task56 - Building Integrated Solar Envelope Systems. <https://task56.iea-shc.org/>

A. TECHNOLOGIES

TOPIC A.5 - Developing 'Solar-Active-Houses' with high solar fraction

On global level the operation of buildings accounts for around 40 % of the primary energy consumption and approximately 25 % of the greenhouse gas emissions. In Europe buildings are responsible for 40 % of energy consumption and 36 % of CO₂ emissions. Additionally, large amounts of energy are embodied in the building's construction materials.

A significant reduction of the non-renewable energy consumption of buildings is an important goal of many countries and regions. As a step towards this goal the European Parliament and the Council already on 16. December 2002 agreed on the energy performance of buildings directive (EPBD; Directive 2002/91/EU).

According to the latest version of the European Building Directive, only "nearly zero energy buildings (NZEB)" that meet specific energy requirements from renewable energy sources at the site or in the immediate vicinity may be erected from 2021 onwards. Concerning the definition of nearly zero energy buildings it is quite important to perform the calculation of the energy balance of the building based on short time intervals, e.g. 15 minutes, as only by this approach a significant contribution towards real climate neutrality can be achieved¹⁹. Considering this, high solar thermal and solar electrical fraction can only be obtained if energy stores are an integral part of the building's energy system. This is exactly the case for Solar-Active-Houses (SAH).

Solar-Active-Houses (SAH)

Solar-Active-Houses (SAH) are energy efficient buildings with a solar thermal fraction of at least 50 %. If an additional photovoltaic system covers at least 50 % of the building's electricity demand these buildings are named Solar-Active-Houses Plus (SAH+). Hence the +; the "+" stands for the additional PV system. SAH and SAH+ are Nearly Zero Energy Buildings (NZEB), which fulfil the NZEB requirements by a good level of energy efficiency combined with a high share of solar thermal and in case of SAH+ also electrical energy. The Solar-Active-Houses Plus concept is also a key element of the Task 66 related to "Solar Energy Buildings" of the Solar Heating and Cooling Program (SHC) of the International Energy Agency (IEA) that will start on July 1, 2021 (<https://task66.iea-shc.org/>)

R&D Needs

To pave the way for the Solar-Active-Houses Plus concept becoming the building standard of the near future research and development activities are required focusing on improving the technical and environmental performance, the functionality and the aesthetic aspects of solar thermal and solar electricity systems for SAHs and SAH+ s as well as reducing the energy cost. In addition, it is enabling the SAH and SAH+ buildings supporting the electricity grid by offering additional grid related services like load shifting and peak shaving which avoid solar peaks in the electricity grid around noon. The aim is to develop SAHs and SAH+ as the most economical solution for NZEBs. The key objectives of R&D activities for implementing the SAH and SAH+ concept for both, new buildings and the refurbishment of existing buildings, are:

- development of reliable, well-functioning and aesthetical concepts for SAH and SAH+
- reduction of size of solar collector field and storage volume to ease the integration of SAH and SAH+ in existing building concepts
- reduction of solar heat costs of SAH with solar fraction of over 60% to the same level of solar heat costs of today's combi systems with 25% solar fraction
- elaborate and implement strategies for SAH+ providing positive features to electricity and heating grids
- development of technologies and concepts for the conversion of already existing buildings into SAH and SAH+ by means of solar refurbishment.
- development of the SAH and SAH+ concept, the design and the construction methods to a standard which can be used by the whole construction sector as nearly zero-energy building concept.

¹⁹ In order to characterize the impact of the building on the electrical and – if available thermal grid – in an appropriate way it is important to perform the calculations of the solar fractions based on short time intervals e.g. 15 minutes, and not on an energy balance over one complete year as it is e.g. the case for the definition of the German "Effizienzhaus-Plus". Using short time intervals to calculate the net energy balance is important, in order to reflect the fact that the electricity grid has no ability to store energy, so electricity fed into the grid is used immediately. As a result, electricity that is fed into the grid as excess photovoltaic energy in the summer, cannot be taken out of the grid again in the winter. Instead to cover electricity requirements in the winter, fossil fuel power stations have to be used. Calculating net values based on annual values therefore results in significantly lower equivalent carbon emission values than is actually the case.

B. SYSTEM INTEGRATION

TOPIC B.1 Integration of large solar thermal systems and storages process including thermal energy storage

Depending on the temperature level of the used heat, several large-scale TES technologies are applied for temperatures below or just above 100 °C, like aquifer TES (ATES), borehole TES (BTES), pit TES (PTES) or tank TES (TTES).

For the integration of storages with large solar thermal systems, the following challenges exist:

- Material and component development for higher temperature (up to 95 °C) for (very) large PTES, aimed at cost reduction for Central European conditions.
- Demonstration of large solar thermal systems coupled to large thermal storages in combination with other sources or with heat pumps for sector coupling (like power-to-heat) or industrial waste heat utilization.
- Need for new technical concepts and business models to integrate decentralized solar thermal systems into heating grids and for for thermo-electrical smart grids with integrated solar thermal systems
- New system design for increased solar thermal fractions in smart grids and system technology for optimised operations
- The integration of decentralized cooling and air-conditioning systems into solar thermal district heating systems

Another important topic is the development of small and medium scale solar thermally driven seasonal storage systems. Seasonal storage enables the utilisation in winter of cheap solar energy harvested in the summer period, avoiding the use of scarce renewable electricity in winter times.

Large parts of the buildings are not connected to a heating or DHC grid and therefore need local solutions for maximising the renewable share for heating and cooling. Part of the housing stock can be catered with heat pumps, but as these are electrically driven, they will add to the high load of the electricity grid in winter. This has to be balanced by technologies that move the surplus of renewables in summer to cover the demand in winter.

Thermochemical materials have the potential to enable this seasonal storage, but not yet in a cost-effective way. Development of cost-effective and reliable thermochemical materials, components and systems, including low-temperature heat storage (e.g. underground thermal energy storage) for efficient discharging, that enable seasonal solar thermal storage is one of the key challenges.



B. SYSTEM INTEGRATION

TOPIC B.2 Integrated solutions for SHIP below 400°C

Today, in many cases, SHIP solutions are stand-alone solutions supplying only a relatively small share of the total heat demand. This leads to fossil lock-in effects as the boiler house of industrial companies is only retrofitted after long time intervals. In stand-alone solutions, SHIP faces strong competition with other renewable or low CO₂ technologies such as excess heat, heat pumps and – increasingly – hydrogen (also but not only linked to electrification strategies). Concerning the challenges of the decarbonisation of the industrial heat demand, SHIP has to take the next step to integrated energy systems covering a significantly higher share of the heat demand compared to the status quo. Thus, other renewable technologies must not be seen as competitors but as partners of hybrid supply systems. We have to consider that electrified heat and green hydrogen have still very limited renewable capacity with still very small growth rates compared to the total expected demand. At the same time, other renewables as biomass face limited availability. In conclusion, SHIP has to play a major role in covering heat demand in low, medium, and high-temperature levels in these integrated energy systems. Therefore, research is necessary on different levels.

System integration

Besides the optimised design and operation of SHIP as part of multi-hybrid supply systems, there is a significant demand to increase the technical potential of solar supply in industry by adapting existing and developing innovative processes and supply technologies. This includes the following approaches:

- The radical adaptation of industrial processes and the integrated solar supply system by matching these to the concept of a solar reactor: by this, for example, the modular complexity of available solar integration concepts can be decreased, the control concept can be simplified, and the power demand for a supply system is reduced.
- Adapt existing, mainly electric-driven, but also develop new process technologies to enable low and medium solar heat supply with an increased potential for the combination with other renewable technologies: examples are the switch from batch to continuous processes but also process intensification approaches.
- Adapt and change supply systems in industry by the innovative combination of existing systems with SHIP: examples are the combination of steam-driven systems with SHIP.

System design

SHIP has to be combined with several renewable technologies leading to multi-hybrid supply systems covering a significant share of the overall industrial heat demand. The synergies of the different technologies will lead to lower heat generation costs and higher CO₂-emission mitigation.

The systems have to be designed with respect to different technical and technology-specific boundary conditions such as process temperature level, heat load profile and especially its seasonality, as well as the availability of solar irradiation and waste heat sources. Methodologies on efficient hydraulics and standardized design of components (type of collector, collector area, storage size, power of other technologies) are still not yet available and need to be developed. Modular design approaches will help to reduce the planning effort significantly and enable plug & play solutions. These concepts must be supported by innovative control strategies for multi-hybrid energy systems enabling renewable, efficient, reliable and low-cost heat supply.

Digitalization for optimized operation

The monitoring of integrated energy systems in industry raises new challenges. In future, there will be the need for automated monitoring of large-scale integrated energy systems and simple but effective fault detection methods to reduce downtimes and maximize renewable heat generation. Standard specifications for monitoring equipment will ensure quality assurance. The development of digital twins allows detailed monitoring, prediction control with suitable models and communication protocols. As the different technologies in multi-hybrid energy systems are in continuous interaction, new KPI's must be developed to evaluate the operation of such systems and highlighting multi-energy benefits.

Support in the phase of implementation

Standardization can play a key role in targeting a strong and fast market uptake of integrated energy systems. A standardized (technical and economic) project assessment for integrated energy systems will increase the chance of successful implementation and pave the path for new stakeholders. Especially investors need this as a basis for their risk assessment to make a decision for investment. The project assessment must include multi-energy benefits and innovative assessment criteria that price the value of decarbonisation. In addition, standards for commissioning procedures for integrated energy systems can play a major role in failure prevention and quality assurance.

Reaching out to high-temperature SHIP applications

While the main focus for the upcoming period will be on <400°C SHIP applications, global R&D activities on applications beyond 400°C should be monitored and supported as they will play an important role in further increasing the renewable share in the industrial heat sector. Therefore, high-temperature applications should be included in events like conferences and workshops. In addition, a group of interested experts working on this field should be formed to place the topic at an early stage and increase its visibility.

B. SYSTEM INTEGRATION

TOPIC B.3 Digitalisation

The European Energy system is in a transition towards clean energy and high efficiency. Digitalization is at the centre of this energy transition, and there affects solar thermal along the whole value chain (production, distribution, consumption, design, and planning) to keep solar thermal compatible on the digitalized market context and support the market increase. Digitalization will enable the management of real-time energy data through cost-efficient, robust, and scalable data collection and communication systems based on machine learning and data mining technologies. This plays a crucial role in optimizing energy conversion and distribution. Digitalization will ensure that solar thermal will play its full part in the decarbonization and inter-connection of key sectors (sector coupling).

Further digitalization influences the way energy is consumed by allowing engaging end-users to be aware of their energy use and turn their potential energy flexibility. Via simplifying the monitoring/performance assessment and system maintenance needs through visualization tools, insights into their energy use e.g. hourly intervals, are gained; thus, benchmarking with other consumers becomes possible, and energy savings can be suggested.

A digital twin's methodology is to support end-users to optimize consumption and design of energy supply systems. Using the digital twin method detailed simplified models for selected energy-relevant processes and renewable technologies are being developed and evaluated. Thus, a consumer like the industry is being supported in reducing cost and investment risk concerning solar thermal usage, and as a consequence the share of renewable energies in the industry should be significantly increased.

The planning process of solar thermal plants can be optimized by developing and applying various digital solutions, including big data approaches for data analysis (e.g. utilization of metering data for design processes), planning tools, sophisticated optimization, co-simulation methods etc. The development and harmonization of new and current standards need to be supported for the widespread use of innovative solar designs and applications in different sectors. At the same time, the effort for certification, testing and labelling needs to be reduced.

Addressing these points advancements in digitalization on the technology level will lead to radically lower costs, higher efficiency, better system design and integration, and enhanced operations. With regards to the whole energy system, research on system level is needed. The future energy system consists of a combination of multiple technologies with strong interdependencies, which require smart monitoring and control for optimal and efficient operation focusing on:

- A hybrid system with different renewable energy sources (solar thermal, heat pump, biomass, biogas, etc.)
- Energy supply under exergetic consideration
- New process technology concepts being supplied by solar thermal energy matching volatile solar sources with demand (e.g. continuous 24h supply, batch processes etc.)

Development and testing of technical and operational modelling, simulation and optimization of hybrid energy technologies and systems must identify the technological and systemic constraints. Digitalization will play a key role in this holistic approach.

Finally, automation in PVT industry would also need to be increased so that the cost of producing collectors can be reduced without giving up quality and durability. This industry has a lot of different requirements in equipment than PV and ST.



C. NON-TECHNOLOGICAL

TOPIC C.1 Environmental legislation, and land availability for SDH

SDH and SHIP systems will increase experience and lead to reduced planning and implementation periods. Design rules and thumb rules will be further developed and spread, particularly focussing on integration points. Commissioning rules of large-scale systems should be improved and further tested. Best practices in the field of industrial symbiosis via DHC networks will enable a better exploitation of available area and limit the risk connected to delocalization. Advanced concepts to support a sustainable and healthy use of land around cities and industrial areas for solar thermal energy shall be introduced. There is a large potential for further cost reduction in the same order of magnitude that has been seen in the wind and PV industry.

In principle, pre-loaded or restricted areas are to be preferred as reserved areas for solar thermal open spaces, provided that they sufficiently meet the technical application conditions of sufficient size and suitable orientation, proximity to heating networks and large consumers.

Examples of such **pre-loaded or restricted areas** are:

- old landfill areas
- Water protection areas
- Ancillary traffic areas on roads, railways and airports
- comparable areas that are neither available for commercial use nor residential buildings in any way and are also not permitted or suitable for agricultural use

If **such areas are not sufficiently available** and the use of grassland or agricultural land is necessary, an overall ecological concept must be drawn up:

Ground-mounted facilities offer the opportunity to achieve landscape and nature conservation goals in addition to sustainable energy generation. Many endangered species require undisturbed areas, fenced solar thermal open spaces can provide such spaces.

With regard to biodiversity areas, it has been observed that in collector areas, due to the low mowing cycles and the largely avoided other use, very favorable living conditions arise for both plants and animals, and that plants bloom, that abundant habitats for bees, butterflies and other insects are present, and that many small animals (pheasants, hares,...) find good shelter under collectors and that there are corresponding nesting and nesting and Retreat spaces are created. Combination use with agriculture can be, for example, the use of the site with the collectors for sheep or chicken husbandry or a corresponding design of the collector field, so that plant cultivation and harvesting are possible in between.

The overall ecological concept forms an integral part of plant planning when using grassland or agricultural land.

The criteria include the nature conservation and aesthetic design, including the development, within the facility and its immediate surroundings. The criteria are laid down in a functional specification, which is based on nature conservation regulations and species protection regulations.

1. Area eligibility criteria

- ST ground-mounted systems are to be built primarily on areas without higher value use and in the vicinity of a heating network or a larger heat sink with sufficient heat demand density (settlement area, industrial and commercial area).
- As a rule, conversion areas, areas along traffic routes (noise barriers), landfills, heaps, sealed soil areas or grassland and fallow grassland as well as agricultural land can be used. In the case of the latter grassland and agricultural areas, conflicts of use with agriculture as well as nature compatibility must be taken into account separately in the form of an overall ecological concept.
- Flat surfaces without shading and preferably with a compact cut are particularly suitable, for example to keep the costs for complicated system hydraulics, for fence systems and service routes low.
- Slopes up to a maximum inclination of 15° must have a suitable orientation between 90 degrees (east) and 270° (west). Northern slopes >5° inclination are usually unsuitable for ST ground-mounted systems.
- If possible, the open space should not be shaded or only to a small extent by vegetation, buildings or the topography of the terrain.

2. Technical-economic criteria

- ST ground-mounted systems should be implemented in close proximity to the central heating system and the heating network, as the specific costs and energy losses increase with the length of the transport pipe. Likewise, hydraulic integration into the heating network must be technically possible at the heat transfer point. In the presence of a heating network, the following distance rules can be used to narrow down the area designations in the first approximation:
 - With a grid peak output of 200 MW or more, suitable areas with a distance (as the crow flies) of less than 10 km to the nearest point of the grid are preferably to be used solar thermally,
 - with a peak grid output of more than 20 MW with a distance (as the crow flies) of less than 5 km to the next point,
 - in the case of a peak grid output of more than 5 MW, with a distance (as the crow flies) of less than 3 km to the next point,
 - for a peak grid output of more than 2 MW of less than 2 km,
 - for smaller heating networks, a distance of 1 km.

- If there is no heating network, the area-related heat demand density in particular is an important indicator for the basic grid suitability of a supply area and subsequently for the heating network integration of ST ground-mounted systems. Here, too, the spatial proximity to a potential heating network area is decisive for the economic efficiency of an ST ground-mounted system.
- ST ground-mounted plants have significant economies of scale: The specific costs decrease with increasing plant size, which means that larger plants can also be built economically further away from the feed-in point.
- For a high area yield, the inclination and orientation of the collectors must be optimized taking into account the conditions on site. For flat open spaces, a south orientation with an installation angle between 35 and 40 degrees is ideal. Slopes up to a maximum inclination of 15° must have a suitable orientation between 90 degrees (east) and 270° (west). Northern slopes >5° inclination are usually required for ST ground-mounted systems. unsuitable.
- Self-shading of the collectors due to too small row spacing as well as shading by vegetation, buildings or terrain topography have a yield-reducing effect and should be taken into account in the area selection and collector field planning.
- Further cost factors in connection with ST ground-mounted systems must be planned for the acquisition, lease, design and maintenance of the site. In particular, acquisition and lease costs can have a decisive influence on profitability and should be moderate.
- With regard to the costs for collector field installation, the nature of the substrate is important (concrete foundations vs. steel profiles, which can be driven quickly and cost-effectively into the ground by means of piling technology and easily dismantled)
- Various funding opportunities at state and federal level in the form of investment grants or discounted loans can increase profitability and should be used.



C. NON-TECHNOLOGICAL

TOPIC C.2 – Developing new Business Models for Solar Thermal

New business models and awareness raising programs tailored on customers are needed (e.g., targeting “Fair heat” or heat as a service). Such business models should base on high bankability of solar thermal projects, especially in the industrial sector, due to the very slow degradation of solar thermal collectors compared for example to PV. Those business models will also trigger efficient integration of solar thermal technology into the existing heat generation and distribution systems, making sure that return temperatures from the heating system to solar collectors are as low as possible. Feed-in of thermal energy in thermal networks shall be correctly valorised, among others by setting rules regarding feed-in temperatures, continuity of supply, minimum amount of purchased energy, certificate of renewable origin.

Small scale solar thermal

Solar thermal solutions are already quite successful as a distributed source of heat in small scale applications, to provide domestic hot water and space heating in residential buildings. These installations are mostly based on direct investment by the end user of the energy, who owns, operates, and maintains the equipment at his own expenses. The marketplace for small scale distributed solar thermal relies on specific drivers (e.g. environmental awareness, fuel savings, etc.) and financial incentives, to ease the burden of the initial investment, such as grants and soft loans, at a national and regional level.

The resulting business model, relies on a well-established network of retailers and installers, acting also as O&M service providers, and on a financial toolbox, mostly like the one dedicated to building and construction investments.

Recent years have seen a strong development of energy services, with energy distributors moving from their traditional commodity sale model (delivery of gas and electricity), towards more comprehensive energy services, including the supply and operations of equipment for a more rational energy use, efficiency, renewables, HVAC, etc, including solar PV and solar thermal packages for households. The associated financial services (operational leasing of equipment, or billing of locally generated energy) are a way forward to further develop the small-scale ST market segment. The SRA should provide increased support to the development of strong and harmonised schemes for energy labelling, product/system qualification (already existing, as well as new ones), to allow for enhanced financial and operational risk management tools.

Large scale solar thermal

In order to scale up ambitions and impact of solar thermal solutions, new market segments absolutely need to be targeted and supported, in particular for large scale applications such as Solar Heat for Industrial Process (SHIP) and Solar District Heating (SDH).

Upscaling solar thermal from domestic (kW) to industrial or utility scale (MW), requires a whole new set of financial and risk management tools, more similar to those in place for infrastructure project financing or real estate. In order to mobilise private, long term capital towards large scale deployments, it is crucial on one side to ensure sufficient returns on investments (around 7% IRR, unlevered), even better returns on equity invested (10-12% IRR, levered), as well as risk assessment and mitigation tools.

SRA should focus on these objectives by targeting resources towards:

- the development of EU harmonised standards in HPA (Heat Purchase Agreements),
- supporting of such standards with legislation to facilitate their adoption
- developing a legal framework for ESCo investments, based on well-established practice in the power sector
- initiating and facilitating the development of private capital pools dedicated to utility scale solar thermal, also mimicking best practices in the wind and power sector
- encouraging the development of insurance, re-insurance and other financial risk mitigation tools, dedicated to solar thermal
- developing an accredited performance data validation and certification framework for entire solar thermal plants, to go beyond today's single collector certification (see also next section C4).

All these actions will be targeted to make solar thermal utility scale plants to be considered an investment grade asset, accessing long term debt finance at competitive rates, and allowing institutional investors to allocate solar thermal equity investments in their portfolios, much the same way it is happening in renewable electricity.

C. NON-TECHNOLOGICAL

Topic C.3 – Solar thermal resource mapping

Knowledge of the spatial dimension of energy demands and renewable energy potentials is an essential basis for integrated (spatial) heat and energy planning. Hence, mapping of renewable energy sources for low-carbon heat and / or electricity production in high spatial resolution is one key aspect towards integrated spatial planning. Tools, methods and webservices to provide this kind of information for various user groups, from policy makers to energy planners, are approaching quickly on local, regional, national, and European levels. E.g., existing platforms on European level provide maps and related data for shallow geothermal, solar radiation, excess heat, on- and offshore wind, wave or biomass potentials and are already freely available for public usage or for the integration to national or local open government platforms and spatial data infrastructures.

Nevertheless, the spatial dimension of renewable energy potentials is just one part needed for integrated planning: To know, where energy sources for low-carbon technologies can be found need to be analysed in the context of where this energy might be best utilized for meeting local energy demands. For renewable electricity or renewable based liquid or gaseous fuels this issue is less critical due to the possibility of transporting or storing these forms of energy over long distances relatively easily and with few losses. By contrast, the distance between a heat supply system based on renewable sources such as solar thermal, geothermal heat pumps or excess heat emitters and an appropriate heat sink such as settlement areas, industrial consumers or district heating networks is crucial with regard to costs related to thermal losses or to the availability of suitable land, which is a scarce commodity, especially in the proximity of settlement areas.

Therefore, Objective of topic C.3 is to develop and implement (spatial) approaches for identifying and mapping suitable sites (land plots) for large-scale solar thermal installations in appropriate distance to settlements and / or existing district heating networks in high spatial resolution for EU member states). Existing spatial databases e.g., solar resource maps, digital elevation models, land cover, demographic data, settlement areas and building footprints as well as already existing derived information such as heat densities or potential district heating supply areas [*e.g., from the Heat Roadmap Europe or Hotmaps project*] shall be used, further processed and enriched with new spatial data that enable advanced solar thermal resource mapping considering both local availability of resources and affordable land as well as local demands of renewable heat. Advanced solar thermal resource mapping hence demands a profound spatial as well as technical and economic data basis which need to be gathered and processed.

Resource mapping comprises a key aspect for the integration of solar thermal resources in spatial energy planning and policy making and in assessing contributions to heating and cooling strategies as part of national climate action plans. A consistent high resolution solar resource mapping approach on local (city and community level) member state level as well as on EU-level is required to assess the full potential of solar thermal heating and cooling solutions. The data collection used for the assessment of the solar thermal resource availability must be harmonized based on existing solar radiation data, solar resource maps existing for cities and communities and also on performance data of operating systems for different applications. A harmonized approach would allow a common assessment of potential resources available to designers and policy makers in spatial energy planning.

In some cases, these are simply limited to very coarse measurement grids that do not account for local conditions such as mountain shading, elevation frequent fog in valley areas. In other cases (usually limited to municipal or urban plains), a more in-depth approach is taken, with detailed solar radiation maps created that consider local shading from vegetation or buildings. Currently, there are no established criteria associated with resource mapping dataset and methodology requirements. This results in different resource assessment datasets that are not comparable at the EU level, hindering detailed and harmonized spatial energy planning and policy decisions.

Key Actions

C.3.1 – Method development for advanced Solar thermal resource mapping and alignment with local energy demand to match resource and demand areas (heating and cooling) and facilitate spatial energy planning

C.3.2. – Data integration to existing European data platforms or development of a new dedicated spatial data platform in an open data format for visualisation (WMS) and data sharing in accordance with open data standards and principles.

C.3.2 – Promotion and dissemination strategies of solar thermal resources to policy makers, sustainable energy communities, end users and professionals in energy system design based on end use and potential applications.

C. NON-TECHNOLOGICAL

Topic C.4 Statistical data collection

Another important topic concerns the availability of cost data on solar thermal installations. It is currently difficult to make authoritative statements about the costs of solar installations in very different sizes and especially for different applications in the different member states. The goal of a detailed, standardized cost survey is the availability of precise cost data and the derived Levelized Cost of Solar Heat. This would allow reliable economic analyses in comparison to other technologies. It is also crucial that data collection and reporting about energy production yields includes always the output temperature levels, to account for this dimension (temperature), which is peculiar of solar thermal energy.

At present, very often only a small number of detailed data is available from individual solar thermal plants that have been built to date for comprehensive economic calculations. The available data very often do not show how the total costs are divided between the individual components and the planning and installation work. This means that, particularly in the case of large solar thermal plants for solar district heating and industrial applications at the planning stage or during policy implementation, only a very inadequate database can be used.

Key Actions

C.4.1 – Harmonized cost data collection for the main solar thermal applications in all EU member states to be able to calculate viable costs for levelized cost of solar heat.

C.4.2 – Harmonized statistical data collection methodologies and calculation/quantification of components, for solar heating and cooling systems, to further allow the solar thermal contributions to be accounted for (based on RES Directive calculation).



Chapter 4

IMPLEMENTATION PLAN



4.1 Budget requirements

The implementation of the Roadmap relies on various resources according to the R&I priorities and the specific needs of the technologies. Several mechanisms for supporting developments in solar thermal heating and cooling exist at European and national level. These mechanisms address different project stages and stem from different sources.

It must be noted that in recent years we have seen a reduction of dedicated funding for specific renewable heating and cooling technologies, including solar thermal. The priorities in terms of funding have been very much aligned with the SET-Plan²⁰. The SET Plan has so far penalized renewable heat technologies. In 2015, the Implementation Working Groups (IWGs) established under priority 1 “Being n.1 in renewables” only covered power generation, while renewable heat generation was excluded and covered only from the demand side (namely IWGs on positive energy districts and energy efficient buildings).

As a consequence of this approach, there weren’t any working groups addressing renewable heat. For instance, Deep geothermal and Concentrated Solar Power/Solar Thermal Electricity (CSP/STE) are focused on power generation.

The latter is a clear example of this ambiguity. A IWG is created for CSP/STE but solar thermal, with a market deployment in Europe ten-fold larger than CSP, is not covered. Solar thermal exclusively focus on renewable heat supply, CSP on electricity generation. Solar thermal is not covered by the work in this IWG, with only some aspects on concentrating solar being common to both technologies. Even if concentrated solar heat is growing in relevance, it is only one of the solutions among solar thermal technologies. And these concentrated solar heat technologies address low to medium temperature needs (up to 400°C), with temperature levels and system sizes much smaller than CSP.

In previous discussions related to the current SET-Plan (2015), the European Commission proposed to address renewable heat from the supply side, for instance in IWG5 and IWG6 (Buildings and Industry). While the involvement in such IWG is important, it does not cover essential aspects related to research & development on performance and costs for our technology: solar thermal (heating & cooling).

The fact is that the priorities reflected in Horizon 2020 (and even now in Horizon Europe) progressively evolved towards the priorities expressed in the SET-Plan and the proposals stemming from implementation working groups.

This means that one of the main requirements to the implementation of this strategic research agenda is reaching an increased funding allocation to renewable heating and cooling technologies, in this case solar thermal.

These technologies need to become higher priorities for funding from the European Commission (Horizon Europe) and Member States. The funding to be made available should cover both the supply side (renewable heat generation) and the demand side (system integration).

To push EU renewable heat generation forward, **the sector needs dedicated R&I funding and better representation in the revised EU SET Plan.**

The EU Solar Energy Strategy²¹ announced relevant R&I initiatives:

- “Through Horizon Europe, the EU will continue to support research and innovation to reduce the cost of **solar energy technologies**, while increasing their energy efficiency and their sustainability, including in the manufacturing stage. (...) The upcoming 2023–2024 work programme will include a **flagship initiative to support solar energy research and innovation**, focused inter alia on novel technologies, environmental and socio-economic sustainability, and integrated design”.
- “Also under Horizon Europe, the **European Partnership for Clean Energy Transition** will crowd in support from Member States, the energy industry and public organisations for research and innovation in solar energy over the 2021–2027 period”.
- “The collaboration with Member States can be further expanded by developing a common **solar energy research and innovation agenda** in the framework of the European Research Area. This initiative will build on the ongoing work of the **Strategic Energy Technology Plan**”.
- “The **Innovation Fund** will provide around EUR 25 billion of support over 2020–2030, depending on the carbon price, for the commercial demonstration of innovative low-carbon technologies, including solar energy”.

It is crucial that these initiatives specifically include and target all solar energy technologies, in particular solar heat, to “provide a level playing field for all solar technologies and do not favour one against the other²²”.

R&I funding with dedicated calls on renewable heat are needed to keep EU-based companies competitive. For speeding up the integration of solar heat in industry, it is required to increase substantially the investment in demonstration projects.

²⁰ Communication from the Commission, Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation [COM\(2015\) 6317 final](#)

²¹ Communication on EU solar energy strategy – [COM\(2022\)221](#), p. 15–16

²² Idem, p. 12

4.2 Financing solar heating & cooling

Economic and non-economic barriers hampering the uptake of renewable heating and cooling solutions, such as solar thermal, can be tackled by effective support policies.

In what concerns financing, there are two main factors to take into consideration:

- high upfront investment;
- levelised cost of energy.

High upfront investment

Projects using solar thermal energy are characterised by high capital costs and low operation costs. This represents a disadvantage for solar thermal when compared with other heating and cooling technologies, most commonly fossil fuels, which have a lower CAPEX, i.e., a much less investment intensive cost structure.

At the residential level, as well as for energy utilities or even industries, the cost structure of solar thermal projects – whether small or large scale – represents a significant obstacle to overcome. It is strongly dependent of the availability of capital and the costs of capital. Therefore, due to the predominance of CAPEX (over OPEX), any change on the cost of capital will have a significant impact on the economic and financial performance of the project.

In addition, there is less project data for renewable heating and cooling projects available for investors than there is for renewable power (e.g.: wind or solar photovoltaics). Such factors contribute to a higher perception of risk and therefore higher capital costs.

Levelised cost of energy

Solar thermal systems are competitive with any other solution within their lifetime. This means that they represent a good return on investment and present a low levelised cost of energy when the economic lifetime of the project is close to the technical lifetime of the system (most commonly beyond 20 years).

Nevertheless, in most cases, the economic lifetime attributed to the project is rather short. For instance, it is usual to find industrial companies looking for an economic lifetime matching their expectations for payback, which is rather short, often below five years. Under such conditions, the levelised cost of energy will be significantly higher and, most likely, not competitive with conventional fossil fuel alternatives.

Large scale solar thermal

Large solar thermal projects are certainly challenging to finance and call for specialised plans. High upfront investment, risk assessment and economic lifetime are among the special constraints inherent in the development of new solar thermal projects, which might impede the fast deployment of new solar thermal capacity. In addition, the substantial variability in the quality of solar thermal resources and the level of market maturity offers a variety of circumstances for solar thermal project developers. Therefore, in order to finance solar thermal projects, it is required to design the appropriate financing structure for each project.

Accelerated deployment of solar thermal heating and cooling on a broad scale necessitates expenditures that cannot rely simply on public finances. Therefore, private sector participation is vital. However, financial obstacles to the development of solar thermal projects in Europe exist and must be solved by early public backing of solar thermal development. In order to guarantee the security of big investments in solar thermal, it is also necessary to build a favourable framework.

In brief, the **main priorities in terms of financing** are risk mitigation measures, to reduce the cost of capital and other risk related costs (warrantees) and **direct financial support** in order to reduce the upfront investments and render these projects competitive within shorter economic lifetimes.



4.3 Funding instruments

The financing of solar heating & cooling, similarly to other renewable heat solutions, has been mainly centred on grant-based financing, especially when it comes to supporting breakthrough developments and demonstration projects that entail greater risk for investors. However, grants are typically intended to reduce the cost of capital.

The fact that grants can offer finance for project development (or even preliminary studies, including feasibility studies) at an early stage of the project might give benefits that considerably surpass the actual size of the grant. They can have a positive impact on the approval of the project, on facilitating the project financing process and reducing the capital cost.

Despite the fact that R&I grant-based funding is essential for early-stage technical development, it lacks the scale required to allow that demonstrations and pilot projects move beyond the financial “valley of death” and toward commercialization and industrial deployment. Instruments such as the Innovation Fund can provide some level of support to innovative solutions. Though there is the need for a large number of demonstration projects, namely when it refers to the decarbonisation of the industrial activities, as each industrial sector as intrinsic specificities that require a “demonstration project” type of approach.

The need for a fast deployment of renewable technologies, particularly renewable heating and cooling, require a strong commitment to funding a full range of R&I activities, covering different TRL levels, and enhancing a large number of demonstration projects. This is an essential condition to fill the gap between R&D funding and revenue support instruments such as renewable energy support schemes of Member States.

Further information can be found in the inventory of funding instruments developed by RHC-ETIP.

4.4 Recommendations

The European Solar Thermal Technology Panel (ESTTP) proposes the following recommendations:

- Prioritise grants as a funding instrument: the European Commission should continue to prioritise **grants as a key delivery tool for the demonstration** of novel renewable technology at scale. Grants are unrivalled in their ability to foster innovation throughout the whole value chain of a project. In the case of solar thermal energy, it is crucial not only to establish the viability of a certain technology, but also for the workforce to acquire significant skills and expertise that can be applied to projects with a larger proportion of private funding or other instruments.
- Explore new **blend financing instruments**: the use of grants should be enhanced by new instruments that can facilitate the increase of available funds. Grants that can be converted to loans create new options. This instrument provides public financial authorities with an innovative tool to aid innovation and reducing the risk associated with solar thermal energy technology, with the opportunity to earn loan interest. **Convertible grants** can be used to reduce the risk associated with such innovative projects and to promote market penetration, particularly in emerging markets. These can also be structured as **Revolving Funds**. Such blending finance approaches are a potentially effective alternative to grants for scaling innovation (particularly demonstration projects) in renewable heating and cooling. Innovative technologies will have more funding opportunities if regular grants are combined with convertible grants (non-interest bearing), and convertible loans (preferable to pure equity).
- Prioritise **up-front, risk-free, non-conditional funding**: as mentioned previously, solar thermal projects require high upfront investments. This means that grants, while including a milestone system to retain incentives for R&I projects, should allocate the large majority of the pay-outs upfront in order to mitigate the risk associated with the granted funds. There should remain a portion conditional to performance (energy production or GHG emissions reduction), though this should remain below one quarter of the total.

4.5 Requested Funding to implement the action plan

RHC-ETIP estimates that EUR 400 billion is the total investments required at the European level to substitute 50% of the yearly heating and cooling demand (200 Mtoe) from fossil fuels to renewables within the next 20 years. The related European R&D expenditure in the 2021-2027 period should amount to EUR 14 billion (50% industry, 25% EC, 25% MSs). The amount required for solar thermal corresponds to one eighth of this total, corresponding to **1.75 billion Euros**, that could generate a total of 17.5 billion Euros of investments²³, of which at least 25% could come from the EU R&D budget (i.e. Horizon Europe, Innovation Fund, and others), which amounts to EUR 438 million.



²³ RHC-ETIP estimations: each Euro spent for R&D therefore mobilises EUR 10 of investments.

GLOSSARY

ATES

Aquifer Thermal Energy Storage

BTES

Borehole Thermal Energy Storage

CAPEX

Capital Expenditures

COP

Coefficient of Performance

CSA

Coordination and support action

CSP

Concentrated Solar Power

DHC

District Heating and Cooling

DHC

District Heating

DHW

Domestic hot water

EC

European Commission

ESTTP

European Solar Thermal Technology Panel

EU

European Union

GW_{th}

Gigawatts thermal

IA

Innovation action

IEA

International Energy Agency

IEA-SHC

IEA Solar Heating and Cooling Implementing Agreement

IWG

Implementation Working Groups

KPI

Key Performance Indicators

LcoE

Levelised Cost of Energy

LCoH

Levelised cost of heat

MW_{th}

Megawatts thermal

nZEB

nearly Zero Energy Buildings

OPEX

Operating Expenditures

PCM

Phase change material

PTES

Pit Thermal Energy Storage

PVT

Photovoltaic & thermal

R&D

Research and development

R&I

Research and innovation

RES

Renewable Energy Sources

RHC

Renewable heating and cooling

RHC-ETIP

European Technology and Innovation Platform on Renewable Heating & Cooling

SAH

Solar Active Houses

SCOHYS

Solar Compact Hybrid Solutions

SDH

Solar-assisted district heating

SET-Plan

Strategic Energy Technologies Plan

SHC

Solar Heating and Cooling

SHIP

Solar heat for industrial processes

Solar PV

Solar Photovoltaics

SRIA

Strategic Research and Innovation Agenda

ST

Solar Thermal

STE

Solar Thermal Electricity

TCM

Thermochemical

TES

Thermal Energy Storage

TRL

Technology Readiness Level

TTES

Tank Thermal Energy Storage

TW_{th}

Terawatts thermal

WMS

Web Map Service

NOTES



EUROPEAN SOLAR THERMAL TECHNOLOGY PANEL



The Secretariat of the European Technology and Innovation Platform on Renewable Heating and Cooling is a project that has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement N°825998.

Follow us:  @EtipRhc #RHCETIP

Contact us: info@rhc-platform.org info@solarheateurope.eu

www.rhc-platform.org