Renewable industrial heat navigator brief

→ *Solar thermal solutions*

World Business Council *for Sustainable Development*

Preface

In today's rapidly evolving energy landscape, companies face increasing pressure to reduce carbon emissions, not only to meet regulatory requirements but also to stay competitive and align with growing stakeholder expectations. Across the globe, companies have been successful in lowering their carbon footprint by procuring renewable electricity and the renewable electricity market is quickly maturing. However, heat used in industrial processes continues to be predominantly generated by burning fossil fuels and transitioning to renewable heat marks the next major frontier to further reduce industrial companies' scope 1 and 2 emissions. Investment decisions in renewable heat solutions have thus become a critical lever to decarbonize industrial processes, reduce long-term energy costs, and enhance operational resilience.

To support companies in assessing the suitability of different renewable heat solutions for their operations, WBCSD is publishing a series of navigator briefs centering on technologically mature renewable heat solutions available in the market.[i] These briefs aim to provide companies with insights that allow them to make informed investment decisions, offering a clear understanding of how renewable heat solutions can deliver both environmental benefits and returns on investment. The briefs assess the impact of the analyzed renewable heat solutions on key areas of a company's business, including:

Strategy

→ Support broader business and sustainability goals by providing stable and competitively priced renewable heat *[refer to Business Summary, list of the key parameters]*

Risk

→ Major challenges and benefits of the solution through examples and experiences of companies from implemented projects. *[refer to Business Summary, key learnings from implemented projects]*

Operations

→ Key capabilities and potential of the solution including technical and other requirements necessary for a successful implementation. *[refer to key process parameters, key location parameters]*

Finance

→ Indicative cost details and commercial parameters to be considered when assessing investment into the solution. *[refer to key commercial parameters]*

Sustainability

→ How the solution lowers emissions, improves the company's environmental profile, and furthers its sustainability goals. *[refer to key location parameters, key commercial parameters, other parameters]*

Benchmarking and procurement

→ Examples of how peers are implementing innovative solutions and forming partnerships to drive sustainability and boost confidence in investment decisions. *[refer to key learnings from implemented projects]*

Environment, health and safety

→ Broad potential safety hazards to take appropriate safety measures for each of the solutions. *[refer to other parameters]*

Each brief is divided into four sections:

1. **Business Summary**, giving a high-level strategic overview of the factors that favor and limit each renewable heating solution, as well as key takeaways from projects installed by peers.
2. **Introduction**, providing a brief overview of the renewable heating solution.
3. A table with **key parameters** to be considered by companies when assessing the suitability of each renewable heat solution for their operations.
4. A table with **key learnings** from implemented projects showcasing the barriers overcome and the success factors that led to the implementation of the selected projects.

i) This series of briefs will cover technologies that are at Technology Readiness Level 7 and above, i.e. the prototypes of solutions have been demonstrated to work in operational environments.

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Source: SOLID. Solar thermal project in Turlock, California, USA with California Dairies Industries

Business Summary - Solar thermal

NON-CONCENTRATED SOLAR THERMAL

Up to

120°C

Hot water

1.6-1.9m²

of land per kW

€20-50

/MWh Levelized Cost of Heat

SUPPORTING FACTORS

- Carbon pricing and/or **available subsidies** on CAPEX
- **Financing models** that spread the CAPEX over long periods

- Location with high solar irradiance
- **Remote location** as solar thermal doesn't require grid connection

- **Year-round heat demand**

KEY COMMON SUCCESS FACTORS

- Availability of **land close to the facility**
- Availability of **capital subsidies** and/or **Heat-as-a-Service** financing models
- A **clear commitment to decarbonization** by the industrial company

SOLAR THERMAL FOR INDUSTRY

LIMITATIONS

- Large **upfront investment** if not using Heat-as-a-Service

- Availability of **suitable land**
- **Competition for space** with solar photovoltaics (PV)

- **Intermittence of heat production** (can be addressed with thermal storage)

CONCENTRATED SOLAR THERMAL

Up to

310°C

Steam

2.1-4.2m²

of land per kW

€30-70

/MWh Levelized Cost of Heat

01. Introduction

Solar thermal solutions use solar collectors to absorb sunlight and generate heat. They efficiently expose water or another fluid inside the collectors to the sun, heating it up to the desired temperature. The generated heat can then be used for residential and commercial heating, for district heating networks and industrial processes requiring hot water or steam at temperatures up to 400°C.

Currently, there are just under 1 GW_{th} of solar thermal solutions for industrial processes installed globally.[1] However, the potential of the technology is much greater. Estimates forecast it can supply up to 12% of the global final energy demand[2] and feature it as an important piece in the portfolio of renewable heating solutions needed to reach net-zero GHG emissions. According to the International Energy Agency (IEA), the deployment of solar thermal solutions in industry needs to accelerate rapidly and be up to 20 times faster during 2022-2028 than currently projected to have a chance at limiting global warming to 1.5°C.[3]

Solar thermal solutions come with several inherent advantages which make them attractive for some industrial applications. These are:

- → They provide fully decarbonized and renewable heat.
- → They do not use any fuel to generate heat, vastly reducing operational costs and avoiding fossil fuel, electricity, and biomass price fluctuations as well as supply shortages.
- → Under favorable conditions, they offer short payback periods of 3-5 years.
- → They do not require costly upgrades to local grid or other infrastructure and can be deployed in fully off-grid remote locations.
- → They can supply low, medium, or high-pressure steam at temperatures up to 400°C.

Did you know?

Solar PV uses sunlight to produce electricity while solar thermal generates heat. The heat generated by solar thermal solutions can be used directly in industrial processes without the need for additional equipment such as electric boilers or heat pumps.

Additionally, solar thermal covers roughly 2-3x less space for the same amount of energy produced in comparison to solar PV. On the other hand, solar PV has a large established market, lowering costs signficantly, and the electricity it generates can have other uses.

Source: Newheat. Aerial shot of the solar thermal project in Condat-sur-Vézère, France with Lecta Group

Types of solar thermal

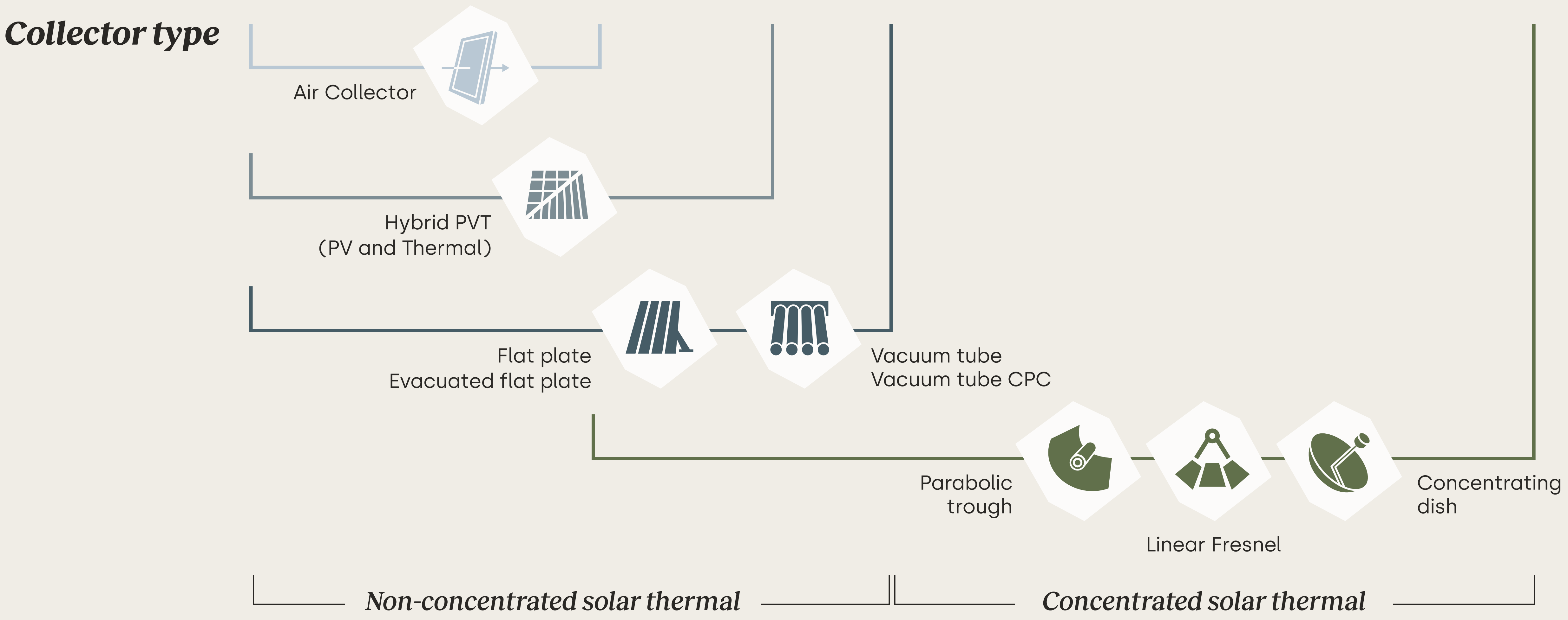
Solar thermal solutions encompass a variety of technologies that can be roughly split into two categories – non-concentrated and concentrated solar thermal solutions.[4]

- **Non-concentrated** solar thermal solutions are mostly suitable for lower temperature uses – such as preheating water – but are more cost and space efficient. They include flat plate collectors, evacuated tube collectors, and compound parabolic concentrator collectors.
- **Concentrated** solar thermal solutions concentrate direct sunlight into a specific point to generate heat at higher temperatures than their non-concentrated counterparts and can produce high pressure steam. They include parabolic trough and linear Fresnel solutions.

Additionally, solar thermal solutions can be paired with absorption chillers and other technologies to provide cooling to buildings and industrial processes. Finally, there are photovoltaic thermal (PVT) hybrid collectors producing both heat and electricity available on the market. However, this brief doesn't cover these solutions as their adoption for industrial processes is currently limited.

Figure 1: Types of solar thermal solutions and example industrial processes where they can supply heat

Industry	*0°C – 150°C*	*150°C – 400°C*
Chemicals	Boiling, drying	Distilling
Food and beverage	Boiling, drying, pasteurizing, washing	Frying
Mining	Copper electrolytic refining, mineral drying	Nitrate melting
Paper and pulp	Bleaching, drying	Wood processing
Textiles	Bleaching, washing	Dyeing



Source: Original figure designed by Solar Heat Europe and Solrico. Expanded and adjusted.

02. Key parameters for assessing *suitability of solar thermal*

The following parameters should be assessed in conjunction with each other to effectively evaluate suitability of solar thermal solutions. While each of them is important to be considered, generally, three main parameters are seen as crucial for assessing the commercial viability of solar thermal solutions. They are:

→ **Required temperature** (lower required temperature improves efficiency and lowers capital costs),

→ **Project size** (larger systems benefit from economies of scale), and

→ **Location** (high solar irradiance increases amount of heat generated and availability of land close to the industrial facility reduces the required investment).

Key process parameters	*Value*		*Context*
	Non-concentrated solar thermal	*Concentrated solar thermal*	
Supported temperature	Up to 180 °C with ideal applications under 120 °C	Up to 310 °C	◦ Concentrated solar thermal solutions can technically support temperatures up to 400°C, as evident from some projects in early development. Further specialized solutions reaching temperatures up to 1500°C are currently under research and development.[5]
Heat demand profile	◦ Year-round heat demand ◦ Heat demand during the daytime is ideal but thermal storage is commonly used to cover demand during other times of the day		◦ Solar thermal has high upfront investment costs and low operational costs. Increased utilization, especially during the summer months with the highest output potential, is key for commercial viability. ◦ Solar thermal heat generation is limited to daytime and without thermal storage requires up to 45-90 minutes after sunrise to reach desired temperatures, depending on the size of the installation.
Energy storage integration	◦ Primarily hot water storage tanks but other types of thermal storage are possible as well.		◦ Solar thermal solutions can cover up to 80% of energy demand when combined with thermal storage, compared to 20-30% without storage.
Process integration	◦ Optimal: Integration of heat supply directly at the industrial process ◦ Alternative: Integration of heat supply into existing steam or hot water network		◦ If using existing heat infrastructure, integration can be done in planned downtime without disrupting production. ◦ The integration at the industrial process allows optimizing the solar thermal solution to provide heat at the temperature required by that process which is usually lower than the heat network temperature. This increases efficiency and lowers needed capital investments but can be more complex than the integration into the existing heat network.
Waste heat utilization and hybridization	◦ Solar thermal can upgrade the available waste heat and be used to preheat water for a heat pump or boiler.		◦ The utilization of waste heat reduces the required capacity and the investment costs for the solar thermal solution. ◦ Waste heat can help deal with system inertia as it can be used to speed up the startup of the solar thermal plant after sunrise.

Key location parameters	Value		Context
	Non-concentrated solar thermal	Concentrated solar thermal	
Required space	1.6-1.9 m^2/kW	2.1-4.2 m^2/kW	◦ Solar thermal solutions can be generally installed on the ground as well as on roofs, such as most industrial roofs or parking area covers. Compared to solar PV, solar thermal collectors require 2-3x less space for the same energy output but generally require structures with higher load bearing capacity (up to 100kg/m^2). ◦ Larger ground installations can be combined with other land uses such as animal grazing.
Minimum plant size	In principle, there is no minimum plant size.		◦ Solutions range from less than 100kW to several hundred MW.
Distance between solar thermal plant and heat sink	◦ Up to 300 m – preferred ◦ Up to 500 m – feasible ◦ 500 m-1 km – needs further assessment		◦ Closer distances reduce heat losses and the cost of equipment. ◦ Distances above 1 km are technically possible and feasible for large plants but may be cost prohibitive for sub-MW plants.
Geographical location:	All around the world, with added advantage for locations with high solar irradiance level		◦ The geographical location and yearly solar irradiation roughly proportionally influence the commercials of the solutions. ◦ Operational projects are spread across the whole world. You can find their locations and specifications in **this database** published by AEE Intec. ◦ You can find approximate irradiation levels for your location on **this map** provided by the World Bank Group, Esmap, and Solargis.
◦ **Locations with high irradiance**	1700 – 2200 Global Horizontal Irradiance (GHI)	2000 – 2500 (Direct Normal Irradiance) DNI	◦ Example locations with high GHI and DNI include southwest of the United States, northern Africa, southern Europe and Australia. ◦ GHI is also high in India and Southeast Asia even though DNI is relatively low in these regions due to misty climate.
◦ **Other viable locations**	700 – 1700 GHI	1000 – 2000 DNI	◦ Example locations with medium GHI and DNI include east coast of the United States, central Europe, and northern China. ◦ Example locations with relatively low GHI and DNI include northern Europe.
Local infrastructure	No specific requirements		◦ Solar thermal solutions require only a negligible amount of electricity to operate (e.g. for remote control access) and can be implemented in fully off-grid settings without connection to any network.

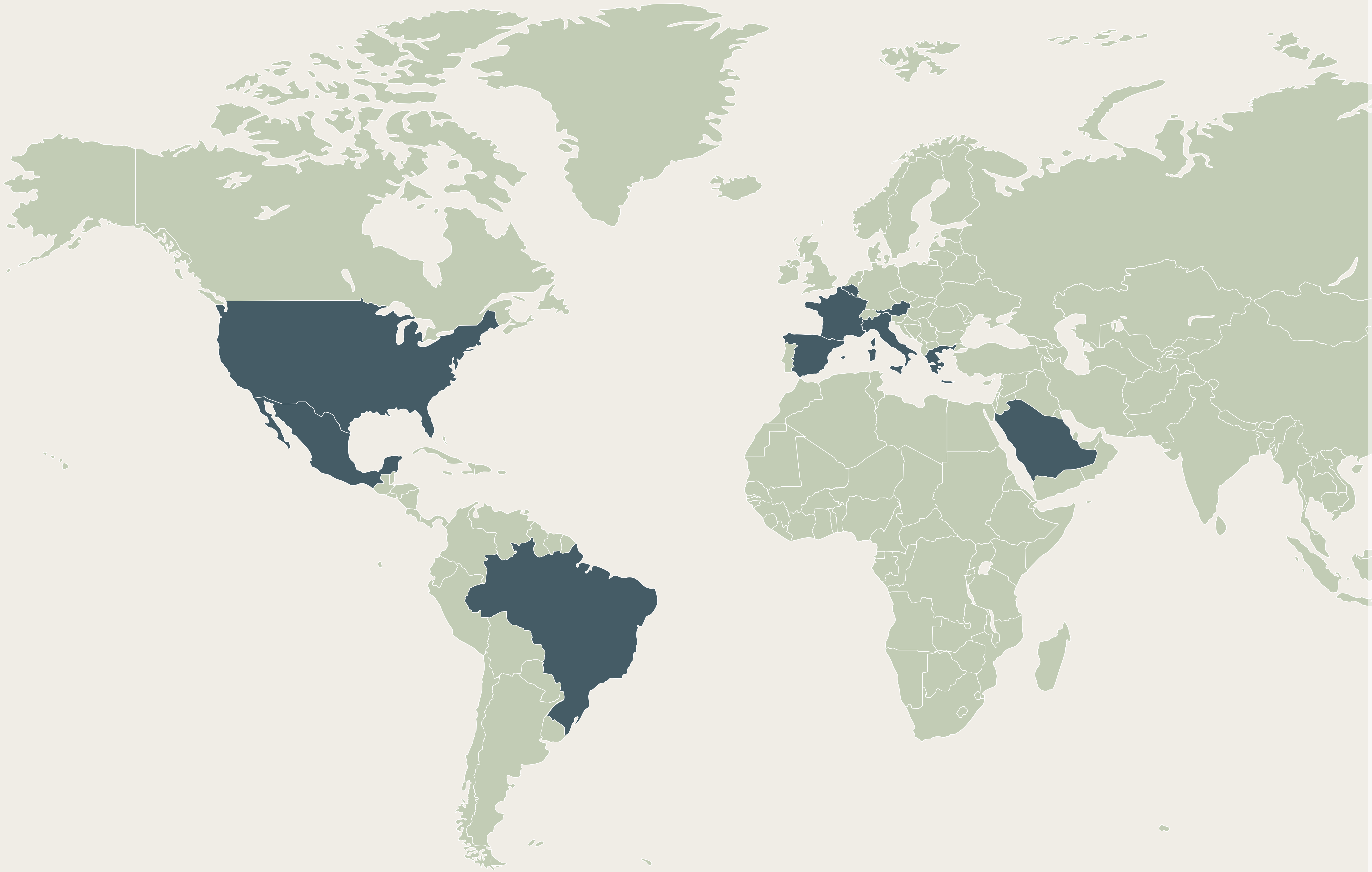
Solar thermal solutions have high upfront capital costs but minimal operational costs and long lifetime. They are therefore ideal for financing models such as **Heat-as-a-Service** which allow companies to avoid the capital expenditure and rather just pay for the supply of heat.

Key commercial parameters	Value		Context
	Non-concentrated solar thermal	Concentrated solar thermal	
Capital expenditure	400-1000 €/kW	600-1200 €/kW	↑ Inclusion of thermal storage ↑ Acquisition of land for the solar thermal solution ↑ Higher required temperatures ↑ Farther distance between solar thermal solution and heat sink ↑ Need for additional integration equipment ↓ Larger plants benefit from economies of scale as the additional equipment (other than the collectors) has a fixed price. ↓ Efficient project planning
Operational cost[6]	0.5-1% of CAPEX annually	0.5-3% of CAPEX annually	◦ Solar thermal solutions produce energy without any fuel. The operational costs are relatively small and are driven by operation and maintenance including the cleaning needs. They vary based on the environment, e.g. they can be higher in deserts due to the need to clean dust.
Levelized Cost of Heat	20-50 €/MWh	30-70 €/MWh[6]	◦ The exact LCOH depends on local irradiance, operating temperatures, heat requirements, lifetime of the plant, cost of financing, and other factors. ◦ You can find example scenarios of LCOH for several European locations in a **factsheet** prepared by Solar Heat Europe and Cepi.
Carbon savings when replacing:[7] **a) natural gas boilers** **b) coal-fired boilers**	◦ 205-250 kg CO_2-eq per MWh ◦ 319-450 kg CO_2-eq per MWh		◦ The lifecycle emissions of solar thermal solutions are only about 9-35 kg CO_2-eq per MWh[8] coming primarily from the manufacturing process and steel production, as the solutions do not emit any CO_2 during their operation.

Other parameters	*Value*		*Context*
	Non-concentrated solar thermal	*Concentrated solar thermal*	
Efficiency (ratio of irradiation to useful energy)	30-85% of solar irradiation transferred into useful heat	30-70 % of solar irradiation transferred into useful heat	The target process heat temperature and temperature of the liquid returning to the solar thermal solution are key parameters for the efficiency
Safety	No special precautions and generally safer than fossil fuel alternatives due to no combustion		Some solar thermal solutions use thermal oil instead of water to transfer heat which may pose a water pollution hazard in case of leakage
Lifetime	More than 25 years		

Source: Meriaura Energy, Solar thermal project in Nacozari de García, Mexico with Grupo México

03. Key learnings from *implemented projects*



Heineken – Engie – Solarlite-Azteq
FOOD & BEVERAGE
Seville, Spain

Lactalis Group – Newheat
FOOD & BEVERAGE
Verdun, France

Lecta Group – Newheat
PULP & PAPER
Condat-sur-Vézère, France

California Dairies Industries – SOLID
FOOD & BEVERAGE
Turlock, California, US

Ball – SOLID
PACKAGING
Fairfield, California, US

Avery Dennison – Solarlite-Azteq – Energynest
CHEMICALS
Turnhout, Belgium

AVL – SOLID
AUTOMOTIVE
Graz, Austria

Saudi Aramco – TVP Solar
OIL & GAS
Qurayyah, Saudi Arabia

Grupo México – Jorgensen - Meriaura Energy
MINING
Nacozari de García, Sonora, Mexico

Birra Peroni – Absolicon
FOOD & BEVERAGE
Bari, Italy

Carlsberg – Absolicon
FOOD & BEVERAGE
Sindos, Greece

Jean Larnaudie – TVP Solar
FOOD & BEVERAGE
Castelnau dAuzan, France

PepsiCo – TVP Solar
FOOD & BEVERAGE
Sete Lagoas, Minas Gerais, Brazil

Sigma Alimentos – Modulo Solar
FOOD & BEVERAGE
Iassa, Merida, Mexico

Volvo Group – Modulo Solar
AUTOMOTIVE
Tultitlan, Mexico

Project details	Decisive parameters	Barriers faced	Decisive success factors	Ease of process integration
30 MW$_{th}$ + 68 MWh hot water storage tank Heineken – Engie – Solarlite-Azteq **FOOD & BEVERAGE** Seville, Spain	→ Amount of **available space**. → **Subsidy** on the investment costs. → Solar thermal did not require any changes to the production line and the brewery, unlike electrification.	→ The **high CAPEX** investment cost was the major barrier in getting internal approval for the project. Engie secured a subsidy to make the project commercially attractive.	→ Heineken's strong corporate **commitment to reduce GHG emissions** and a clear roadmap to achieve net zero by 2025. → **Heat-as-a-service agreement** with Engie who financed the project and secured a subsidy.	→ Integration **with one connection point** to the existing steam network.
12 MW$_{th}$ + 3000 m^3 hot water storage tank Lactalis Group – Newheat **FOOD & BEVERAGE** Verdun, France	→ Solar thermal provides **long-term price stability** and independence from the fluctuations in the energy market, providing clear economic benefits. → **Emissions savings** compared to fossil fuels.	→ The **permitting process** including an archeological survey and a pipeline connection under a railway.	→ Lactalis's **commitment to carbon footprint reduction.** → The **heat-as-a-service agreement** enables Newheat to constantly optimize the management of the solution. → Financial assistance from the French government agencies.	→ The integration equipment needed to be **installed already before the beginning of the project** during the construction of the drying facilities.
3 MW$_{th}$ + 500 m^3 hot water storage tank Lecta Group – Newheat **PULP & PAPER** Condat-sur-Vézère, France	→ Available **land with limited alternative uses.** → Ideal target **process temperature** (<100°C). → High solar irradiance. → Emissions savings compared to fossil fuels.	→ Available **land was a former storage site** of hazardous material which needed to be sealed before installation began. → A **former utility bridge had to be restored** to connect the solar thermal plant and the facilities over a water stream.	→ **Solar thermal reduced the energy price** compared to fossil fuels alternatives. → The **heat-as-a-service agreement** enables Newheat to constantly optimize the management of the solution. → Financial assistance from the French government agencies.	→ Careful **planning mitigated the impact** of the integration onto the production.
2.8 MW$_{th}$ + 172.6 m^3 hot water storage tank California Dairies Industries – SOLID **FOOD & BEVERAGE** Turlock, California, US	→ The required **process temperature** (40-80°C) was ideal for flat plate solar thermal.	→ The **permitting processes** in California for the solar thermal and the pipeline connection to the facilities which runs under 6-lane railway.	→ **Identification of the correct integration point** for the solar thermal to maximize its efficiency. → **Close collaboration** with California Dairies Industries to minimize interference with existing processes.	→ **Thermal storage integration** mitigates the temperature variability of the supplied hot water and enables integration into existing control systems.

Project details		*Decisive parameters*	*Barriers faced*	*Decisive success factors*	*Ease of process integration*
2.8 MW_{th} + 106 m^3 hot water storage tank	Ball – SOLID PACKAGING Fairfield, California, US	→ Temperature **demand below 100°C** which is well suited for flat plate solar thermal. → The solar thermal solution can be extended with heat pumps to fully decarbonize the plant in the future.	→ The solar thermal solution came with a **new hot water loop replacing the old steam network** which reduced distribution losses from 30% to 5% but required deep technical understanding of Ball's thermal needs and controls.	→ The solar thermal solution was combined with a **heat-as-a-service agreement** shifting the project risk on the solar thermal provider who also financed the project and secured grants.	→ The new hot water loop needed integration of **new heat exchangers** complicating the integration process.
2.7 MW_{th} + 5 MWh thermal battery	Avery Dennison – Solarlite-Azteq – Energynest CHEMICALS Turnhout, Belgium	→ **Available space** for the concentrated solar thermal plant. → **High efficiency** of the solution and no need for energy conversion (heat-to-heat solution). → Combination with storage enables efficient use of all generated energy.	→ **Challenges with permitting** and insurance due to unfamiliar technology → **Supply chain issues** due to Suez Canal obstruction and COVID-19 pandemic extended the development time	→ Strong **decarbonization targets** by Avery Dennison. → The **long lifetime** of the solar thermal solution as well as the thermal battery. → Co-financing by the local community and grant reduced the financial risk to main stakeholders. → Consortium of several suppliers enabled sharing of risks and competencies.	→ Easy integration with **standard heat exchangers** as the system uses thermal oil which is used by Avery Dennison as well.
2 MW_{th} + 70 m^3 hot water storage tank + 650 kW^{th} solar cooling	AVL – SOLID AUTOMOTIVE Graz, Austria	→ Availability of **rooftop space.** → The solar thermal solution is able to comprehensively decarbonize the thermal demand by supplying the **process and space heating** all year round, as well as by providing **cooling in the summer.**	→ The implementation was combined with the **construction of a roof** over a previously uncovered car park which slowed down the development.	→ The **heat-as-a-service agreement** enabled lower recurring price of energy than a district heating alternative. → The solar thermal solution was accompanied by **energy efficiency and optimization** measures which helped increase the overall savings.	→ **Integration in existing network** while optimizing the distribution of the hot water and the industrial process.
1.8 MW_{th} (No storage)	Saudi Aramco – TVP Solar OIL & GAS Qurayyah, Saudi Arabia	→ The decarbonization potential of solar thermal even for **temperatures above 160°C.** → **Minimal efficiency losses** (only 15% annually) **from dust** covering the collectors without any cleaning.	→ COVID-19 lockdowns and **supply chain disruptions.**	→ Saudi Aramco's **commitment to decarbonization** of its operations.	→ Easy integration with **water-to-water heat exchangers.**

Project details	*Decisive parameters*	*Barriers faced*	*Decisive success factors*	*Ease of process integration*
830 kW$_{th}$ + 120 m^3 hot water storage tank Grupo México – Jorgensen - Meriaura Energy **MINING** Nacozari de García, Sonora, Mexico	→ **Emissions savings** provided by the solar thermal solution compared to the replaced diesel boilers. → **Remote mining location.**	→ **Limited barriers** due to previous experiences with similar projects.	→ Proper planning and **investment into project engineering.**	→ The integration included a **back-up electric boiler** and the conversion of existing heating infrastructure from steam to hot water.
460 kW$_{th}$ + 30 m^3 hot water storage tank Birra Peroni – Absolicon **FOOD & BEVERAGE** Bari, Italy	→ **Suitable industrial process** for the technology, as they required both hot water (75°C) and steam (4.4bar(g)). → Easily **accessible integration points.** → Available space. → High solar irradiance.	→ The system uses **passive pressurization** with nitrogen which took several days to fully optimize	→ The Birra Peroni's **commitment to the project** and their supportive involvement. → **Experience** from previous projects.	→ An **unused heat exchanger was available** on the pasteurizer equipment, allowing for seamless integration of the hot water without the need for any downtime. → Steam was integrated into **existing steam network.**
460 kW$_{th}$ (No storage) Carlsberg – Absolicon **FOOD & BEVERAGE** Sindos, Greece	→ High **solar irradiance.** → High **steam deman.** → Heat demand profile matching with the daily and yearly solar heat generation. → Available space.	→ It was **difficult to accurately predict head demand** of certain processes in the brewery due to lack of data. → Beer production line is **not continuous** and faces frequent starts and stops.	→ Using **proven technology** which demonstrated the feasibility of producing the steam at high pressure (4.5bar(g)).	→ Integrated into **existing steam network** without disturbing the customer's production during a planned downtime.
312 kW$_{th}$ (No storage) Jean Larnaudie – TVP Solar **FOOD & BEVERAGE** Castelnau d'Auzan, France	→ Heat **demand profile matches the solar thermal** supply (temperature up to 155°C). → Ease and **low cost of integration** for boiler preheating.	→ COVID-19 lockdowns and **supply chain** disruptions. → **Permitting** at local and regional level as the authorities lacked experience with industrial-scale solar thermal solutions.	→ Jean Larnaudie's **commitment to decarbonization** of process heat. → Availability of **public support.**	→ The integration into processes was more costly but greatly **increased the proportion of usable heat** from the solar thermal solution.

Project details		Decisive parameters	Barriers faced	Decisive success factors	Ease of process integration
250 kW$_{th}$ (No storage)	**PepsiCo – TVP Solar** **FOOD & BEVERAGE** Sete Lagoas, Minas Gerais, Brazil	→ Ideal **target temperature** (60-75°C) for preheating. → **Reduction** of the dependance on **natural gas**. → Reduction of CO_2 emissions.	→ **Lack of detailed historical data** about the heat demand. → **Leakage of fluid** (water) from the system increased the maintenance costs over the expected amount. → The solar thermal solution needs to be moved to the roof as the ground land is needed for production expansion.	→ **Short payback time** of 4 years. → **Avoided high inflation** of natural gas prices.	→ **Easy integration** with water-to-water heat exchangers. → The integration was done in the **planned downtime** and the development did not interfere with operation.
206 kW$_{th}$ +20m^3 hot water storage tank	**Sigma Alimentos – Modulo Solar** **FOOD & BEVERAGE** Iassa, Merida, Mexico	→ Energy **supply stability.** → Financial **savings**.	→ Need to **educate about the financial savings** provided over the whole lifetime of the project. → Concerns about solar thermal solutions by Sigma Alimentos' engineers.	→ Sigma Alimentos' **commitment to sustainability** and emissions reduction.	→ The **integration to the steam boiler** was complex.
96 kW$_{th}$ +10m^3 hot water storage tank	**Volvo Group – Modulo Solar** **AUTOMOTIVE** Tultitlan, Mexico	→ Energy **supply stability.** → Financial **savings.** → Elimination of natural gas and steam boilers to generate hot water.	→ Need to **educate about the financial savings** provided over the whole lifetime of the project.	→ Volvo Group's **commitment to sustainability** and emissions reduction. → The goal to **eliminate the use of natural gas.**	→ The existing steam boilers were uninstalled in parallel with the integration of the solar thermal solution to **ensure continuous operation** of the factory.

Annex: Links to external case studies

Project name	*Location*	*Link to case study*
Database with all operation solar thermal projects for industrial applications	Worldwide	→ https://energieatlas.aee-intec.at/index.php/view/map?repository=ship&project=ship_edit
Database of all active solar thermal suppliers	Worldwide	→ https://www.solar-payback.com/suppliers/
Examples of Solar Heat for Industrial Process plants across Europe	Europe	→ https://solarheateurope.eu/about-solar-heat/solar-heat-industrial-processes/
Solar Thermal at the Indianapolis International Airport	Indianapolis, USA	→ https://www.renewablethermal.org/iaa-case-study/
Solar Thermal at Boortmalt Malting Plant	Issoudun, France	→ https://www.renewablethermal.org/boortmalt-case-study/
Solar Thermal at Colgate-Palmolive Factory	Athens, Greece	→ https://www.renewablethermal.org/cp-absolicon-case-study/
Decarbonizing Process Heat at California Dairies, Inc. with Skyven Technologies	Visalia, California, USA; Turlock, California, USA	→ https://www.renewablethermal.org/skyven-cdi-case-study/
Sundrop Farms	Port Augusta, Australia	→ https://wbcsdpublications.org/wp-content/uploads/2020/07/WBCSD_Business_Case_Concentrated_solar_heat.pdf (p. 21) → https://www.aalborgcsp.com/projects/integrated-energy-systems/366mwth-integrated-energy-system-based-on-csp-australia
Petroleum Development Oman	Amal, Oman	→ https://wbcsdpublications.org/wp-content/uploads/2020/07/WBCSD_Business_Case_Concentrated_solar_heat.pdf (p.22)
ENEL Green Power	Stillwater, USA	→ https://wbcsdpublications.org/wp-content/uploads/2020/07/WBCSD_Business_Case_Concentrated_solar_heat.pdf (p. 23)

Glossary

CAPEX
Capital expenditure

DNI
Direct normal irradiance

GHG
Greenhouse gas

GHI
Global horizontal irradiance

IEA
International Energy Agency

IEA SHC
International Energy Agency Solar Heating and Cooling Programme

PV
Photovoltaic

PVT
Photovoltaic thermal

Endnotes

1. IEA SHC (2024), Solar Heat Worldwide, **https://doi.org/10.18777/ieashc-shww-2024-0001**

2. IEA SHC (2024), Technology Position Paper: Solar Heat for Industrial Processes (SHIP), **https://www.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task64-Technology-Position-Paper-SHIP-2024-01.pdf**

3. IEA (2024), Renewables 2023, **https://iea.blob.core.windows.net/assets/96d66a8b-d502-476b-ba94-54ffda84cf72/Renewables_2023.pdf**

4. For more technical details about the solar thermal technology see the publications by IEA SHC **Task64** and **Task49**.

5. See more information about very high temperature solar thermal solutions in the work by **SolarPACES Task IV**.

6. Values based on 'IEA SHC (2024), Update on SHIP Technology Costs & SHIP Business and Financing Models, **https://doi.org/10.18777/ieashc-task64-2024-0005**' and corroborated by contributing experts.

7. Values based on 'WBCSD, Concentrated solar heat, **https://wbcsdpublications.org/wp-content/uploads/2020/07/WBCSD_Business_Case_Concentrated_solar_heat.pdf**' and expanded by contributing experts.

8. Gabio-Thomas et al. (2023), Environmental impacts of solar thermal power plants used in industrial supply chains, **https://doi.org/10.1016/j.tsep.2023.101670**; Milousi et al. (2019), Evaluating the Environmental Performance of Solar Energy Systems Through a Combined Life Cycle Assessment and Cost Analysis, **https://doi.org/10.3390/su11092539**

Acknowledgements

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This navigator brief is the result of collaborative effort between WBCSD, representatives from WBCSD's Decarbonizing Heat workstream, and external subject matter experts. A range of stakeholders reviewed the drafts, ensuring that the publication broadly represents the majority perspective. WBCSD incorporated input and feedback from stakeholders in a balanced way. However, this does not mean that every member company or stakeholder agrees with every word or endorses the report. This publication has been prepared for general informational purposes only and is not intended to be relied upon as accounting, tax, legal, or other professional advice.

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