



How to investigate our energy consumption,
and the potential of SHIP technologies

Chapter 2

Why SHIP? Challenges and solutions

Even if solar thermal technologies such as flat plate, evacuated tubes, high vacuum flat plates, and linear Fresnel collectors are commercially available, Solar Heat for Industrial Processes (SHIP) remains in the early stages of development. The market of industrial heat remains heavily dependent on fossil fuels, while corporations remain reluctant to shift to carbon-free thermal energy systems despite their commitments to decarbonisation.

However, the dynamics of the market are changing: High and deeply volatile energy prices are shifting priorities towards the security and predictability of energy supply. Energy transition strategies relying upon energy carriers like natural gas appear frivolous today. The potential market for solar thermal is huge: Heat consumption in industry exceeded 27'000TWh (100EJ) globally in 2020¹. Around 35% of this, accounts for heat up to 200°C². That is 9'400TWh. An increase of 15% is expected by 2026³.

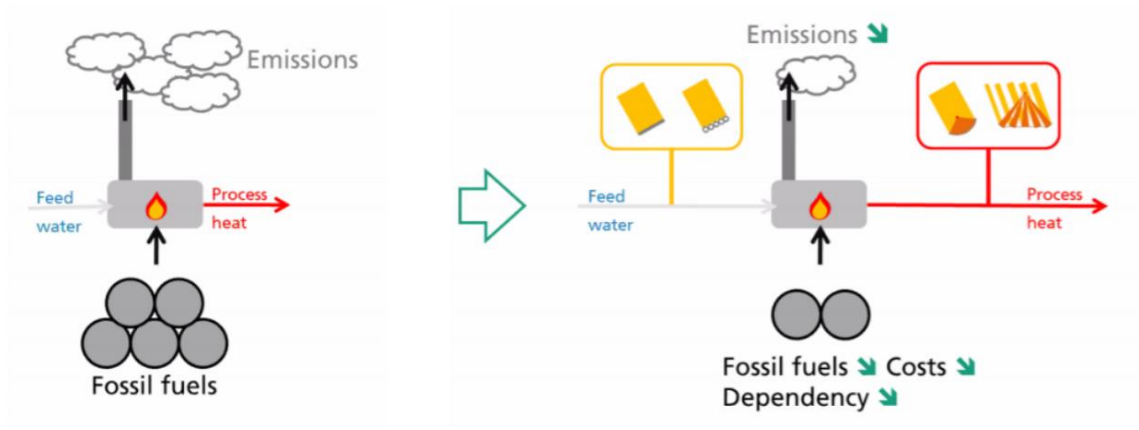
According to the trade association "Solar Heat Europe," SHIP has enormous growth potential, with 280 GWth deployment possible by 2030. One of SHIP's main advantages is its potential to ensure an affordable and constant price of heat during the system's lifetime, which is typically 25 years.

¹ 'Renewables 2021: Analysis & forecast to 2026', IEA, 12/2021, figure p.115

² Solar Payback, Solar Heat for Industry – Solar Payback, 2017

³ Renewables 2021, IEA report, 2021, p.125





Source : SOLID Solar Heat for Industry

Integrating solar heat into industries reduces fossil fuel dependency, costs, and emissions¹

Thanks to recent research and innovation activities, SHIP is overcoming its following main challenges:

- Low awareness and familiarisation among industrial users and energy consultants/ engineering companies
- Integration of SHIP in existing industrial processes

A number of solutions to face these challenges has been proposed. The SHIP2FAIR project has also contributed through:

- The development of easily replicable solutions to increase energy efficiency and lower process heat temperature.
- The development of suitable control strategies considering inertia effects, delays, the influence of radiation fluctuations, and susceptibility to oscillations.
- Tools validation by continuous feedback from real-operating systems.
- The development of training based on a practical methodology by extensively employing use-cases, letting users utilize the software directly within their local environment, thus achieving a tailored solution addressing users' local challenges.



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Solar thermal technologies and environmental impact

Solar thermal systems have significant advantages compared to fossil fuels: being cheaper, not producing any CO₂ emissions or pollutants during operation and being a renewable energy source are only a few.

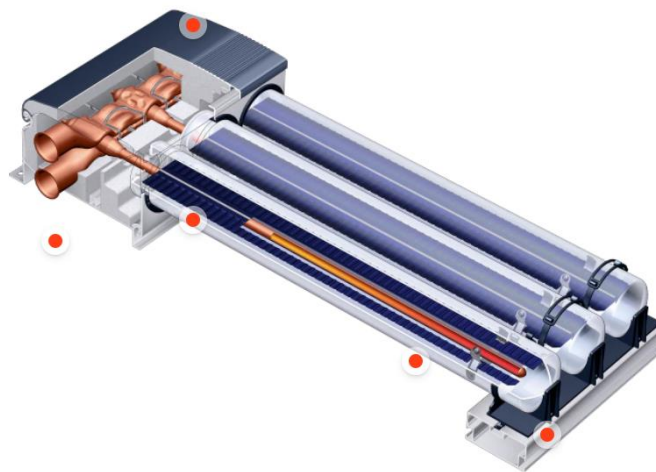
Three solar thermal technologies that have been studied and/or demonstrated under SHIP2FAIR are explained below.

- **Evacuated Tube Collectors**

Conventional simple flat-plate solar collectors were developed for use in sunny and warm climates. Their benefits however are greatly reduced when conditions become less favourable during cold, cloudy and windy days. Furthermore, weathering influences such as condensation and moisture will cause early deterioration of internal materials resulting in reduced performance and system failure. Evacuated heat pipe solar collectors (tubes) operate differently than the other collectors available on the market. These solar collectors consist of a heat pipe inside a vacuum-sealed tube. ETC have demonstrated that the combination of a selective surface and an effective convection suppressor can result in good performance at high temperatures. Vacuum acts as an insulator reducing any heat loss significantly to the surrounding atmosphere either through convection or through radiation, making the collector much more efficient than the internal insulating that flat plate collectors have to offer. With the assistance of this vacuum, evacuated tube collectors generally produce higher fluid temperatures.

The optimal orientation for this kind of panels is, as for a conventional flat plate collector, towards the equator.

In SHIP2FAIR project, we have chosen to use a Vitosol 300-TM developed by Viessmann. The absorber is located inside the tube, surrounded by a heat-insulating vacuum. The heat transfer medium does not flow directly through the tubes. This is because the Viessmann tube collectors work according to the heat pipe principle. The heat transfer fluid runs through the heat exchanger, also called the header. The process medium evaporates inside the heat pipe and transfers the heat to the heat transfer medium via the double pipe heat exchanger. This guarantees optimum heat transfer.



Internal view of the Vitosol 300-TM collector



To ensure high operational reliability and a long service life, Viessmann has developed ThermProtect – an automatic overheating protection system. It means that the collectors switch off when a certain temperature limit is reached. This occurs independently of the system configuration, the control settings and the installation position of the collectors.

With tube collectors, the heat pipe principle ensures the temperature-dependent shutdown. The solar energy evaporates the medium in the heat pipe, which liquefies again in the condenser. The resulting thermal energy is transferred to the system. ThermProtect here means that the medium can no longer condense at a temperature of 120 degrees Celsius. Therefore, this collector can provide hot water from 50°C up to 120°C.

This collector can be installed with a tilt angle as well as horizontally. In this case, the tilt angle is simulated by an internal rotation of the absorber.



Horizontal or tilt angle mounting

The heat produced by the collectors is transferred to the end user's process by a heat exchanger.

- **High Vacuum Solar Thermal Flat Plates (HVFPs): the MT-Power Panel for industrial applications**

The High Vacuum Flat Plates (HVFPs) are a unique, top performing non-concentrated solar thermal technology that has been developed and is owned by TVP Solar S.A. The company has industrialised HVFPs, which are now massively produced in its Italian manufacturing site under the **brand name 'MT-Power'**. Solar thermal systems based on MT-Power panels are modular allowing scaling up to tenths of MW and have been standardised for faster installation.



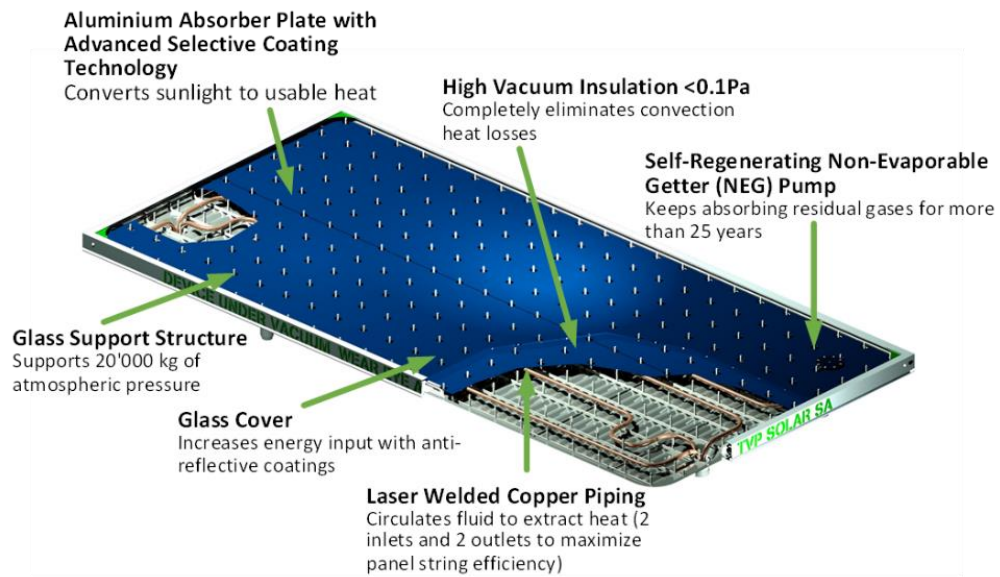


Figure: MT-Power panel: Simple, flat design with high-tech inside

MT-Power-based systems are suitable for the following industrial applications:

- ✓ Solar heat generation at temperatures between 60°C and 180°C
- ✓ Hot water production, or low pressure steam (up to 4bar)
- ✓ Installation on the ground or on the rooftop





Rooftop installation

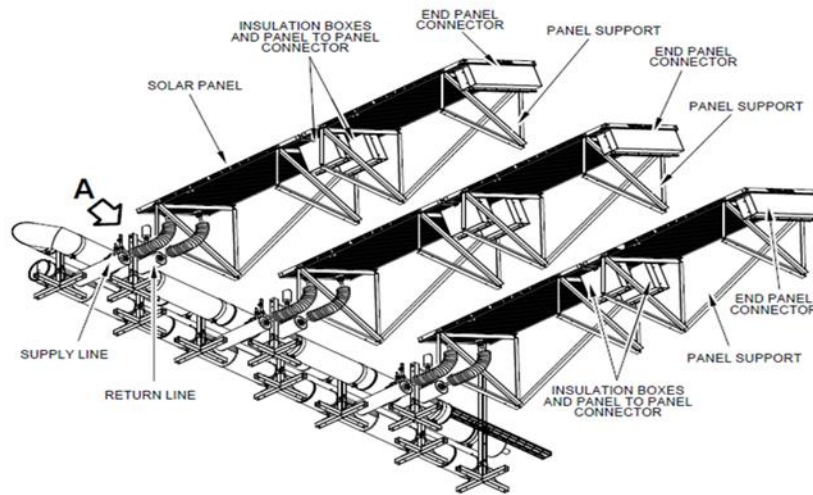
The range of temperature (60°C – 180°C) is particularly adapted to the following processes:

Target Sectors	Target Processes	
<ul style="list-style-type: none"> ✓ Food & beverage ✓ Pharmaceutical ✓ Chemical ✓ Oil & gas ✓ Pulp & paper ✓ Textile & leather ✓ Wood & wood products ✓ Automotive ✓ Non-ferrous metals ✓ Mining 	<ul style="list-style-type: none"> ✓ Boiling ✓ Pasteurizing ✓ Sterilizing ✓ Drying ✓ Cleaning ✓ Washing ✓ Bleaching 	<ul style="list-style-type: none"> ✓ Pickling ✓ Cooking ✓ Distilling ✓ Melting ✓ Dyeing ✓ Pre-heating ✓ Any process running at temperatures below 180°C

The MT-Power panels have been tested within EU-funded projects as well as in the free market. They:

- Demonstrate a top solar-to-heat energy conversion efficiency: 65% at 80°C; 45% at 180°C
- Generate heat at a lower cost than liquid or gaseous fossil fuels
- Reduce CO2 emissions
- Are simple to install and require minimal maintenance and no cleaning (minimal OPEX)
- Are easy to integrate and pose no risk to operation
- Have no moving parts and no concentration of sunlight
- Make use of direct sunlight, as well as diffuse light (e.g. cloudy days)
- Perform even when the glass cover is dirty
- Are SolarKeymark Certified up to 200°C
- Have a 25 year guarantee





Solar field assembly for MT-Power panels

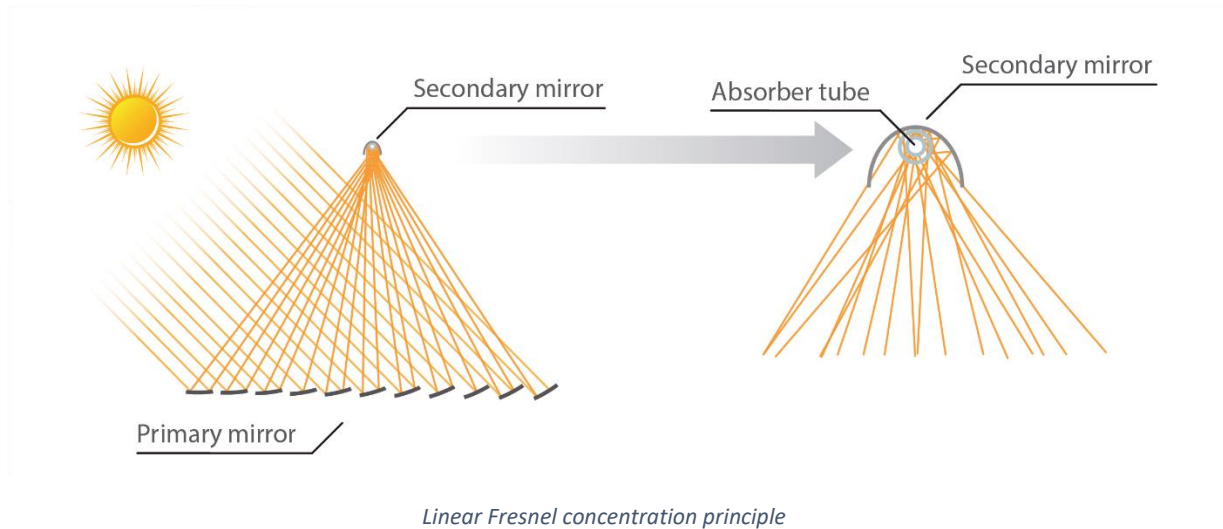
Economy:

- MT-Power system reduce the energy bills of the client, including operating and maintenance costs.
- Depending on the heat demand profile and available solar irradiation, as well as the use of thermal storage, a solar share of up to 70% can be achieved (% on the total heat generated).
- MT-Power systems reduce reliance on fossil fuels, enhance energy security and minimize the impact of increasing energy prices. Each kWh of solar heat substitutes 100% of the heat provided by conventional fuels.
- Direct reduction of CO₂ emissions: for example, 1 kWh of solar steam produced saves 216 g CO₂ emissions compared to burning natural gas.
- As a rule of thumb 1600m² of panels correspond to 1MW and require 3'000m² of space
- The extra load induced by the solar panels on the roof is approximately 70-80 kg/m²
- End user can choose to invest in a SHIP system (CAPEX) or the heat they consume (OPEX).

• **Fresnel Collector Technology**

The Fresnel collector technology consists of single-axis tracking rows of mirrors that automatically focus sunlight onto absorber tubes installed above the collector structure. Water is circulating inside these absorber tubes to collect heat, which is then turned into steam. A Fresnel collector field is built with the modules installed in series and rows to provide the desired heat output according to customer requirements.





The modularity of the collector has minimized static loads and low wind resistance and also allows installation on the roofs of factories. The system provides temperatures up to 400 °C and meets industrial heat requirements in which steam is the heat carrier. The collector can also be used with thermal oil or pressurized water as heat transfer fluids. Due to the industrial heating market still lagging behind in adopting clean technologies, Fresnel collector systems are a profitable alternative for reducing today's heavy reliance on fossil fuels.



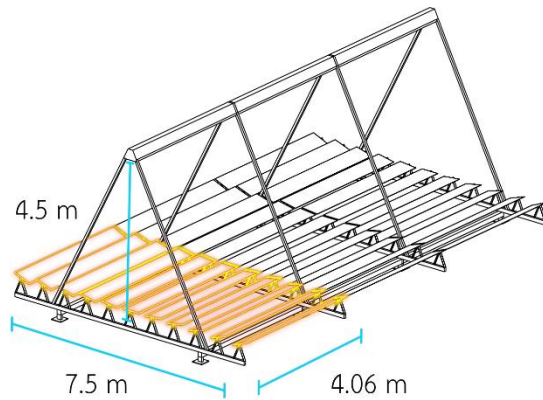
Rooftop installation



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The Fresnel collector is made of primary glass mirrors, a secondary reflector, and an evacuated absorber tube assembled on a metallic structure. A collector module has 4 metres in length and 7,5 metres in width, with the absorber tube positioned 4,5 m above ground level, as depicted in the images below.

Video - Industrial Solar Fresnel Collector: <https://youtu.be/CMImljBPImg>



Detailed view

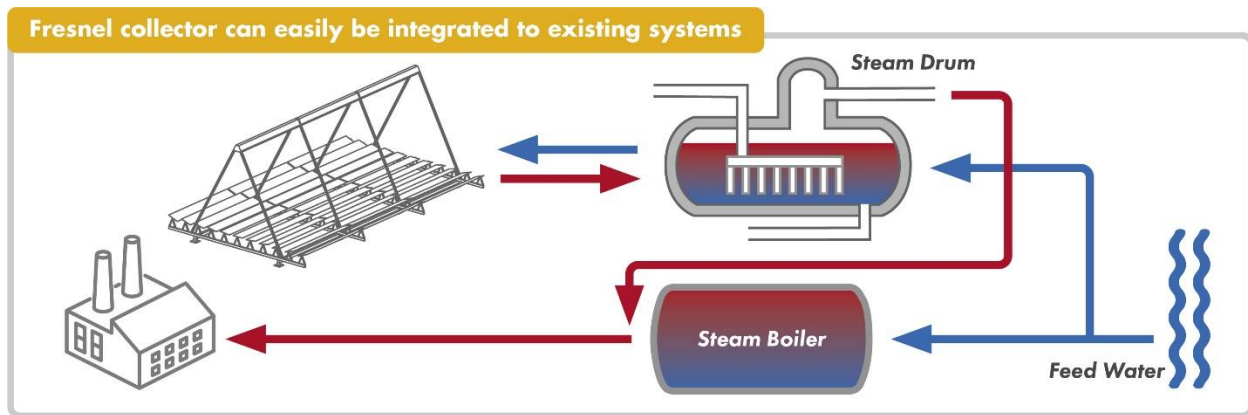
The technology is tested and validated within EU Research and Development funded projects as well as in the free market and presents the following unique advantages:

- Robust and modular size, allowing several MW installations
- No North-South alignment is needed
- 3000 square meters of ground area is enough to install a system with a peak heat output of 1 MW
- Allows precise temperature and power control
- Includes innovative features: very compact and precise tracking system able to bear high torques, lighter mirrors and a new generation of vacuum receivers
- Generates direct steam at pressures up to 40 bar (25 bar standard)
- Usage of other heat transfer mediums (e.g., thermal oil) allows high temperatures up to 400 °C
- Modular solution with less than 27 kg/m² can be easily integrated into industrial systems, including rooftop systems, to generate renewable heat from local renewable resources (the sun)

● Steam generation

A Fresnel solar steam generator consists of an array of Fresnel collectors, steam drums, insulated pipes and valves, and a control system. Water is pumped through the collector field and partially evaporated due to the concentrated solar radiation. The fluid then enters a steam drum, in which the steam is collected at the top, and the water is separated at the bottom. The produced steam is fed into the end user's steam network. The superheated water at the bottom of the steam drum is continuously circulated in the collector field.





Direct steam generation principle

The steam drum is an insulated vessel with a capacity proportional to the collector field peak power and compensates for short-term fluctuations in solar radiation caused by clouds. As steam is delivered to the production plant, feed water is pumped into the steam drum to maintain mass balance. The entire system works independently and uses data from a built-in weather station and solar radiation sensors. Further information about direct steam generation can be found in the videos below:

Video 1 - General overview: <https://youtu.be/1CatPf-xoC4>

Video 2 – Operation and Maintenance: https://youtu.be/kmkc_-bPaSM

Economy:

- The Fresnel technology reduces customers' energy bills, including operating and maintenance costs.
- Depending on the customer's demand profile and available solar irradiation, a solar share of 10% to 50% can be achieved (the percentage of the heat generated by solar energy in the customer's portfolio).
- With a + 25-year solar heat price cap, little O&M expenditures, and a free resource (solar irradiation), the technology can reduce reliance on fossil fuels and minimize the impact of increasing energy prices.
- Each kWh of solar-generated steam directly substitutes 100% of the heat provided by conventional fuels.
- Direct reduction of CO₂ emissions: for example, 1 kWh of solar steam produced saves 216 g CO₂ emissions compared to burning natural gas.



Potential Markets

The industry's wide range of heat demand and temperature levels presents an extremely attractive market for the utilization of solar process heat, particularly Fresnel technology. Examples of industries and processes are given below:

Industry	Process	Temperature (°C)
Dairy	Sterilisation	100–120
	Drying	120–180
Tinned food	Sterilisation	110–120
Textile	Drying, degreasing Dyeing	100–130
	Fixing	160–180
	Pressing	80–100
Paper	Bleaching	130–150
Chemical	Soaps	200–260
	Synthetic rubber Processing heat	150–200
		120–180
Meat	Cooking	90–100
Beverages	Steam grids	120–180
Timber by-products	Thermodiffusion beams	80–100
	Drying	60–100
	Preparation pulp	120–170
Bricks and blocks	Curing	60–140
Plastics	Preparation	120–140
	Distillation	140–150
	Separation	200–220
	Extension	140–160
	Drying	180–200
	Blending	120–140
Pharmaceutical	Sterilization	110–130

Economy:

- The cost of energy produced (€/kWh) in line with the European Strategic Energy Technology Plan requirements thanks to a high-performance increase and a great improvement in efficiency.
- Multi-criteria comparison must be developed to identify the most adequate heat exchanger network taking variations of solar heat, thermal storage, exergy, and thermo-economic principles into account in an optimization-based approach. This approach will enable clients to quantify how local savings obtained in the solar plant are transformed into global savings in the process.

