Accelerating the uptake of solar process heat through efficient finance and support schemes

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Abstract

The industrial sector worldwide is responsible for more than 20% of the total final energy consumption. Although Solar Heat for Industrial Process (SHIP) technologies have proven their technical and financial feasibility to supply a significant share of this demand, the deployment of such projects is far below the projected potential. The biggest lever to accelerate the uptake is not technological improvement but rather suitable financing schemes. This article provides an overview of the current situation of the industrial energy consumption linked to an assessment of financial challenges and risks for SHIP projects. The main financing challenges are examined in four aspects: i) missing general policy framework, ii) high project development costs, iii) investment constraints by end-users, and iv) risks and risk aversion factors. The article also examines existing financing solutions and business models from other sectors - such as the ESCO (Energy Service Company) model and presents case studies in which successful SHIP projects and policies were successfully implemented.

Keywords: solar process heat, SHIP, financing, business case, risk management.

1. Introduction

Heating is responsible for almost 50% of the total final energy demand worldwide and accordingly for around 40% of the total CO_2 emissions (Collier, 2018). However, despite that importance, the heating market is insufficiently addressed. For example, only 48 countries have targets for renewable heating and cooling compared to 146 countries with targets for renewable electricity (REN21, 2019). A major share of the heat demand accrues in the industrial sector which accounts for approximately 1/3 of the total energy (heat and power) of which around 74% are used for heating (Solar-Payback, 2018). Accordingly, industrial process heat is responsible for more than 20% of the total final energy consumption.

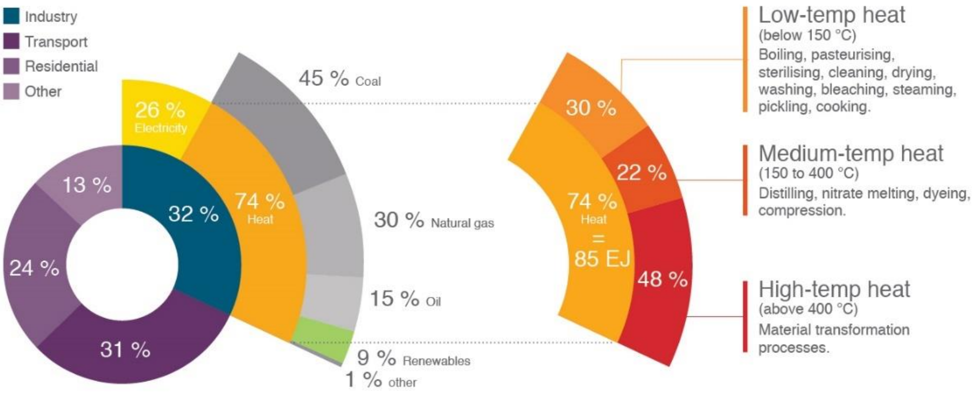

Figure 1: Total Final Energy Consumption 2014: 260 EJ (Solar-Payback, 2018)

Specific data on the share of renewable heat per sector is not available. Yet, in total, around 72% of the global heat demand is still supplied by the combustion of fossil fuels. In the industry, an even higher share is expected due to the comparatively high temperatures needed in industrial processes as well as the below-mentioned financing challenges. From the remaining renewable share, traditional biomass for cooking and heating accrues for the major part (Collier, 2018). As biomass and geothermal are ultimately constrained and full electrification of industrial heat is not realistic in the midterm, Solar Heat for Industrial Processes (SHIP) must play a major role to achieve the required decarbonization of the industrial production.

Various solar thermal technologies, which can cover a wide range of temperatures of up to 400 ºC, are available and

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already market-proven (Horta, 2015) while research for commercial applications in the industry for even higher temperatures is ongoing. Nevertheless, the growth rates of the SHIP market are unsatisfactory, even in markets where SHIP is feasible in terms of internal rate of return (IRR). Thus, besides the need for ongoing technological development, especially with respect to increased performance and lower costs, there are further non-technical market challenges that need to be addressed. A study conducted by (Collier, 2018) enumerated a list of economic barriers that prevent renewable heat from playing a major role in the decarbonization of the economy. While some of these challenges are valid for all kinds of renewables, some are only relevant for renewable heating. For SHIP specifically, there are four major obstacles that hamper the market growth, even in situations where SHIP is feasible due to energy costs and solar irradiation. These challenges are:

- General policy framework for renewable heat
- High project development costs
- Investment constraints by industrial end-users
- Risks and risk allocation

Solutions for each of them, such as financing models or support schemes, are available and have already been proven elsewhere. In order to accelerate the uptake of SHIP, these solutions need to be adapted to the specifications of the SHIP market. Technology providers need to adapt their business models or partner with financial institutions to offer full-fledged solutions while governments need to support the initial market development and create favorable market conditions.

In the next chapter, the financing challenges are examined in more detail while thereafter, solutions are described. In the end, existing examples of best practices are presented.

2. Financing challenges

2.1 Policy Framework

Renewable heat is still not on track to achieve its required contribution for the goals set in the Paris Agreement (IEA, 2017), this holds especially for industrial process heat. As mentioned above, only 48 countries have targets for renewable heating and cooling compared to 146 countries with targets for renewable electricity (IRENA et al., 2018). Most importantly, countries need to establish ambitious, concrete and verifiable long-term targets for renewable heat and translate them afterwards in sector-specific targets (IEA-RETD, 2015). These high-level targets will firstly induce the private market to build up the capacities required for implementation and secondly foster the implementation of detailed policy instruments. Various instruments, specifically for renewable heat considering the current market phase, are available and tested as described in (IEA-RETD, 2015) and shown below. It is important to explicitly address the industrial sector and design mechanisms that meet the specific industrial requirements, as it can be seen in the diagram below.

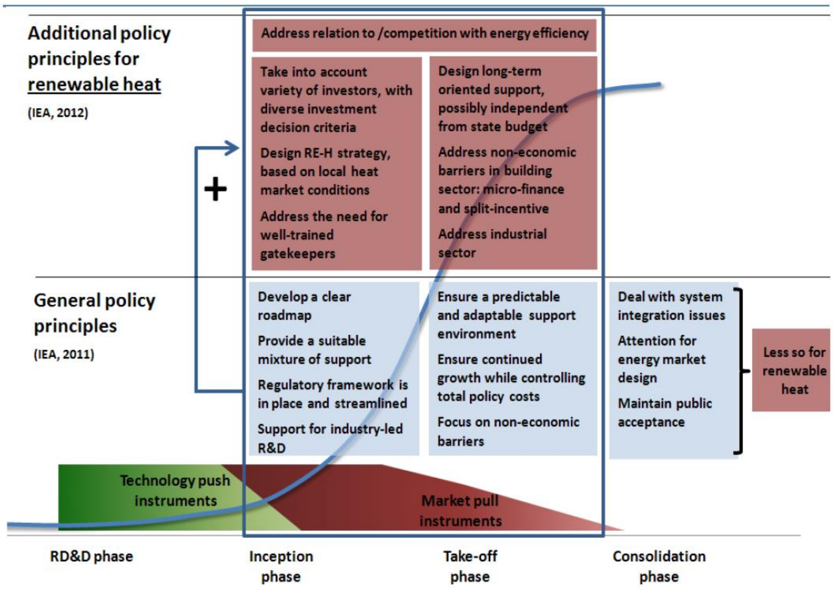

Figure 2: General and heat specific policy principles for renewable energies (Beerepoot, et al., 2012)

Solution: Set specific, ambitious and legally binding targets for renewable heat in general and for industry in specific and accelerate the implementation of concrete policy instruments to achieve them. Concrete measures with high impact on SHIP can be, inter alia:

- Improve availability of macro data for industrial heat demand (e.g. per specific sector / region / fuel).
- Adjust pricing of fossil fuels to foster renewable heat. This to current prices as well as to mid-term price predictions (e.g. 5 to 10 years).
- Foster demonstration plants (still, in most countries there is no commercial SHIP system in operation).
- Ease access to capital (e.g. soft loans)

2.2 High project development costs for solution providers or end-users

The development of SHIP projects is complex and thus costly. The major reasons are: i) insufficient availability (temporal resolution) and quality (temperature) of thermal energy consumption data (including forecast), which is needed for the optimal sizing of the collector field and components; ii) industrial end-user staff often have insufficient understanding of the technology, and iii) insufficient data availability on the required carrying capacity of industrial roofs. All this leads to increased costs which initially must be covered by the solution provider who will be able to recover them only if the project is implemented. While project development for a specific project can be feasible, there is always the risk for the developer that the project is not realized at all or taken by a competitor. Accordingly, project developers refrain from SHIP even when the market is attractive on a project level.

Solution: Public entities can engage in project development and thus lower the costs for developers. In addition, for companies with an energy consumption above a certain threshold, energy monitoring can be made mandatory.

2.3 Investment constraints

In industry, capital is constrained, especially for small and medium-sized companies (Richards et al., 2009). Thus, even when a project is feasible, e.g. the internal rate of return (IRR) exceeds the weighted average cost of capital (WACC), the project might still not be realized for various reasons. Firstly, even when the IRR is greater than the WACC there might still be other projects which are even more attractive. Secondly, companies often constrain their investments to their core business due to their greatest expertise in this sector, to gain market share and to maximize the use of existing resources. It is important to note that, while the first aspect, in which other projects have even higher IRR can be addressed by soft loans (e.g. subsidized interests due to carbon reduction effect of SHIP), the latter cannot.

Solution: Business models where the energy consumer does not need to cover the capital investment such as in Energy Service Companies (ESCO). To foster ESCO various measures can be undertaken, such as:

- Establishment of arbitration board and provision of standards and procedures.
- Ease access to capital for ESCOs.
- Implementation of public projects through ESCO models to accelerate market growth.
- Provide tax and customs incentives for ESCO when operating with renewables / energy efficiency.
- Provide options for securitization of ESCO projects to lower risks in case of customer default.

2.4 Risk aversion

There are various associated risks with SHIP projects which must be covered by one of the involved parties. For standard projects with capital investment by the energy consumer, the risks accrue mainly with the end-user. Subsequently, the major risks and potential mitigation measures are described:

Solar resource risk: The returns of a SHIP project are directly linked to the available solar resource. Even though the quality of available irradiation data has increased in recent years, measurements are mostly done in areas suitable for large power generation projects and not specifically for SHIP projects. Especially for concentrating solar technologies, as they require Direct Normal Irradiation (DNI), for which the available data has a greater uncertainty, the solar resource risk remains a major challenge. In-situ measurements in areas with high SHIP potential increase the quality of irradiation data and can thereby accelerate the SHIP market. However, due to the size of most SHIP projects, the costs for in situ measurements cannot be covered by individual projects.

Mitigation measures:

- Publicly funded measurement campaigns for solar irradiation in areas with great SHIP potential.

Operating costs: Even though the major share of the costs accrue with the capital investment, the running costs which are comprised of i) consumables (power and water), ii) spare parts, iii) operating staff and iv) third-party support effect the feasibility. For the end-consumer, these costs are difficult to estimate and become a risk.

Mitigation measures:

- Long maintenance contracts.
- Heat as a service (In this case the risk shifts from end-user to the ESCO provider which is most likely better positioned to quantify and mitigate the risk).

Performance risks: Until commissioning, the investor does not know whether the system meets the promised performance. Regardless of actual irradiation and operating costs, the total yield depends also on the performance under standard conditions (e.g. peak performance under reference conditions) and the downtimes of the system.

Mitigation measures:

- Public support for collecting and publishing third-party monitored performance data of SHIP plants with a long-term resolution (at least 12 months).
- Performance guarantees (referring to specific operating conditions).
- Minimum availability guarantees.
- Heat as a service (the risk shifts in this case from the end-user to the ESCO provider which is most likely better positioned to quantify and mitigate the risk).

Sizing risk: There is a risk of overproduction of solar heat beyond the storage capabilities which negatively affects the financial viability. The risk increases with larger solar shares and changes in production processes. Unlike power generation projects which operate under feed-in-tariffs or net-metering, renewable heat needs to be consumed on-site as storage capacity is limited. While part of that risks can be mitigated by a thorough assessment of the consumption (taking into consideration hourly consumption data), the risk of changes in production processes remains.

Mitigation measures:

- Comprehensive project development.

Future Energy Pricing: Underlying the feasibility assessment of SHIP systems is the expenditure with fuel-based heat generation which will drop in the future due to the integration of solar heat. In most countries where fossil fuels are not subsidized, the prices are indirectly linked to the fluctuating international oil prices. In comparison to electricity, there is a greater fluctuation of fuel-based heat supply and thus also future cashflows. In feed-in-tariff schemes for renewable electricity, for example, the future prices per MWh_{el} are even already defined.

Therefore, prices for fuel-based heat mostly vary more over time than the costs of electricity. These fluctuations add further risk to the project.

Mitigation measure:

- None in standard projects.
- Prince indexation in heat-as-a-service models, such as ESCO.

3. Building a market framework and innovative business models

Considering the previously mentioned challenges, there are different levels of promoting the implementation of SHIP technologies. Firstly, by implementing national-level policies and commitment to reducing carbon emissions, which should be broken down to sector-specific measures. Secondly, by developing market knowledge and capacity building regarding the industrial demand with matching SHIP technologies, which favors and accelerates project development. Finally, by fostering financing alternatives to implement such projects, which tackle the investment constraints and risks involved in SHIP projects.

3.1. Policies and support schemes

Although renewable heat policies are much less common than policies for renewable power generation, there are success stories that can be taken as references for other governments in order to incentivize the use of SHIP and other renewable heat supply. The map below indicates countries that have renewable heating and cooling policies in place, at least in some state-level (indicated by the hatched lines).

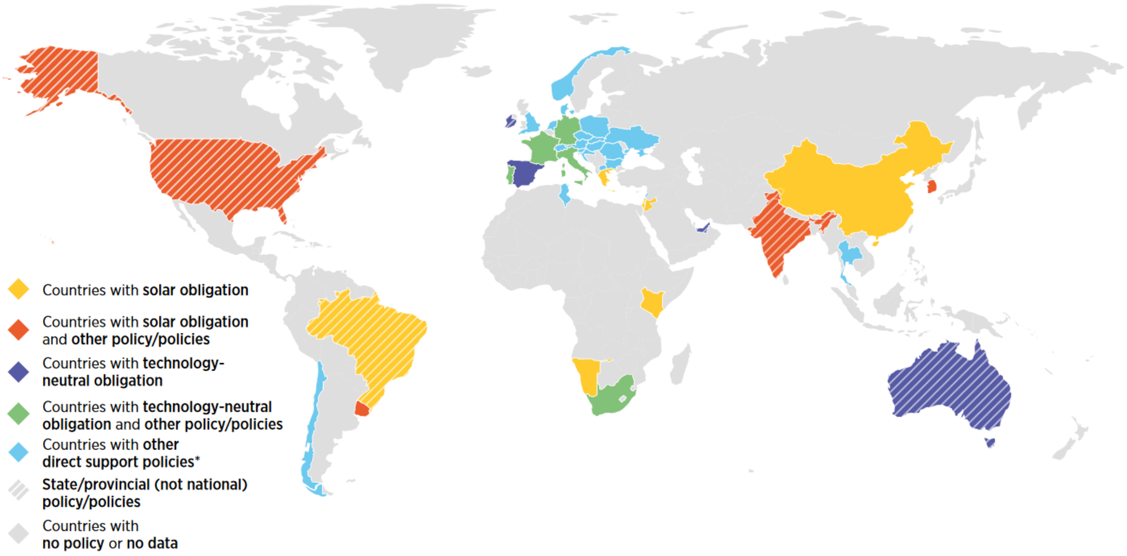

Figure 3 - Countries with renewable energy heating policies (IRENA et al., 2018)

Definition of quotas

In 2018, the European Union issued its latest directive to promote the use of energy from renewable sources and set a dynamic target of an annual increase of 1.3% for renewable heating and cooling until 2030 (EU, 2018). Although the actual value of 1,3% falls short in ambition, it indicates the market direction and is a long-term sign to the market.

Carbon taxes and trade

Another policy mechanism to support the rise of the SHIP market is the implementation of carbon taxes and carbon trading schemes. India in 2010 and Mexico in 2013 introduced related measures that are now equivalent to USD 6 and USD 3,5 per ton of CO_2 equivalent, respectively (IRENA et al., 2018). More recently, the South African government approved a carbon tax law which will come into force in different phases to charge R120 (equivalent to 7,65€) per ton of CO_2 equivalent (South Africa, 2019).

In 2005, the European Union implemented a CO_2 “cap and trade” scheme called EU ETS – Emissions Trading System, which works by limiting the amount of greenhouse gas emissions from heavy polluters such as manufacturing industry sectors and conventional power plants, and the saved emissions from some companies can be traded for other companies who would be above the threshold (EU, 2016). The price of the CO_2 emissions allowance has steadily increased in the last 3 years as shown in the graph below (Business Insider, 2019). To ensure that carbon taxes accelerate the uptake of SHIP or any other renewable process heat supply in the industry, it is important that, unlike in the current EU ETS scheme, all industrial sectors are included.

Figure 4 - CO2 European Emissions Allowance (Business Insider, 2019)

3.2 Capacity building and raising awareness

Insufficient capacities by solution providers and industrial end-users are still a constraint for SHIP. Capacity-building activities have been put in practice in African countries through the Southern African Solar Thermal Training and Demonstration Initiative (SOLTRAIN) in order to raise awareness and incentivize the deployment of solar thermal technologies, inter alia in the industrial sector. The program, funded by the Austrian Development Agency and the OECD Fund for International Development, contributes to unleashing the untapped potential of SHIP in the Agro-processing and Textile industries, among others (IRENA et al., 2018).

Another example of an international program focused on developing markets is the Solar Payback project which has a target to promoting the use of SHIP technologies across four partner countries: India, Brazil, Mexico, and South Africa. The program presented national SHIP potential studies for each partner country and is also helping to build reference projects. The final goal is to raise awareness and build capacity regarding technical and economic advantages of SHIP technologies, as well as to assist stakeholders and investors to access financing (Solar Payback, 2019).

3.3 Innovative business models

The main alternative to the direct acquisition of a SHIP installation is a "Heat as a Service" or ESCO approach.

ESCO – Energy Service Company

In this model, a local entity, often a so-called Special Purpose Vehicle (SPV), is created to invest in the SHIP project, operate it and sell the heat to the industrial customer (Putz, 2015). Thus, the ESCO takes a great part of the above-mentioned risks, especially regarding the solar resource, operation costs and performance risks associated with the SHIP projects. The contract agreement between the ESCO and the customer can take different shapes, depending on the preferences of each party. The main aspects to be considered, as compiled by the ESCO models report from the SHC Task 45 (Putz, 2015) and others, are mentioned below:

- The energy price, currency, as well as an eventual indexation to a reference for future price adjustments.
- The methodology for defining the plant performance with respect to varying factors (e.g. input and output temperatures).
- A monitoring and verification scheme as well as a procedure for stratification or an arbitration board.
- A minimum offtake which the industrial customer guarantees to procure on both a daily as well as an annual basis. This is especially relevant considering the commonly insufficient consumption data (see 2.2).
- Comprehensive definition of interfaces including inter alia supply of utilities (e.g. power, water, data connection required for operation), operation responsibilities, and insurances (also differentiating the SHIP plant and the industrial customer building).
- The financial status of the industrial customer and eventual guarantees by third parties (long-term security for the SPV to recover its investments).

- The balance sheet effects for the industrial customer when entering long-term heat supply agreements (optimization of tax effects for involved parties).

There are several variations of the above-described ESCO model such as “Build-Operate-Transfer” or the “Shared Savings”. In the first one, the operation time is typically shorter than in an ESCO contract. Thus, the end-user also profits from delayed expenditure and less performance risk, although carrying more operating risks in the long run (e.g. solar resource). In shared-savings contracts, which are more common in energy efficiency projects, the end-user and the operator share the savings obtained by the projects. As energy efficiency measures can be well linked to a SHIP project, this approach can also be an attractive alternative. Depending on the specific details, the contracts can be tailored to meet the requirements of each party. Another interesting alternative is the arrangement of long-term payments as they can reduce the burden of high-capital expenditures in the beginning.

Other possibilities to share risks and increase the attractiveness of SHIP projects for financial investors is the creation of project pooling, which would be comprised of selected business cases already developed to be implemented with long-term agreements. Therefore, special funds could be created to invest and manage a broader portfolio of SHIP projects, also sharing risks and best practices.

The ESCO model can overcome the challenge of investment constraints as explained above. Yet, also the ESCOs need access to capital. As such the ESCO concept is not new and widely applied already today in large fossil-based energy supply. These ESCO companies are often very large companies, with turnovers exceeding 100 million €/a, and low costs for capital. Yet, the companies establishing ESCO projects based on renewable heat are often rather small companies, establishing a new business model. Accordingly, to accelerate the market uptake of ESCOs with renewable heat the strength of the established player should be used. This could for example be achieved by a quota approach whereas each company offering ESCO services has to have a certain minimum share of renewable energy which is also increasing over time.

4. Case studies and future scenario

Although being in an infant phase, there are best practices of policy-related measures and innovative business models to accelerate the uptake of SHIP technologies which are presented below.

4.1 Successful policy measures

Solar Concentra – Spain

Spain is one of the leading countries worldwide in the development and implementation of solar concentrating technologies, having the largest global concentrated solar power installed capacity. From 2004 to 2012, the country implemented strong policies to promote solar technologies and created a national technological platform called Solar Concentra, which is a forum built from different players including the solar industry value chain, public administration agencies, technological centers, and universities. The initiative’s main objectives are: (i) provide a framework for the market development, (ii) foster cooperation and know-how transfer among members, (iii) enhance competitiveness via a strategic R&D agenda, and (iv) help public institutions to define and develop programs including solar thermal and concentrated solar technologies (PROTERMOSOLAR, 2019).

In one of its working groups, Solar Concentra developed a study focused on the Spanish potential SHIP market for medium temperature processes (between 100 °C and 400°C) in the industrial sector. The study called “Who is Who” delved into a more business development approach by applying a detailed filtering into three main aspects of the feasibility of SHIP projects: (1) availability of solar irradiation in a municipality level, (2) availability of low cost fossil fuel, and (3) industrial activity with suitable energy demand profile. The first filter applied a baseline of minimum direct solar irradiation (4.8 kWh/m²/a) and reduced the area of analysis to locations in which the SHIP installation can generate higher yields. The second filter evaluated the proximity and access to the natural gas grid, which in Spain is the cheapest source of fuel. Therefore, selecting locations more likely to have expensive fuels as they are far from the natural gas grid. The third filter used national statistical databases to select companies related to four previously selected strategic industrial sectors, namely Food and Beverage, Paper, Textile, and Agriculture and Cattle raising. In the second phase of the study, the Chemical, Mining, Wastewater Treatment, and Industrial Laundry sectors were added (Solar Concentra, 2017).

The outcome of the study included visual maps showing areas with higher density of industries presenting a high potential to implement SHIP projects, and a selected list of 200 companies for which solar energy could provide attractive industrial energy savings, both being valuable inputs for SHIP providers by reducing the high costs for project development (see 2.2). In a further step, the monitoring of operation data should be fostered in order that projects can be suitably sized more easily (see 2.3). This will benefit the implementation of any energy optimization measure and can be incentivized in various ways from soft (e.g. fiscal) to hard (mandatory) incentives.

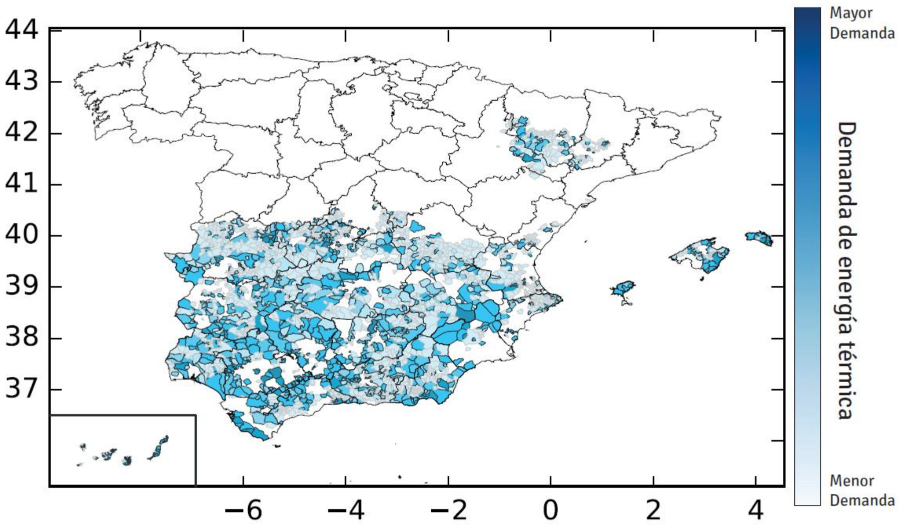

Figure 5 - Analysis of the heat demand in selected municipalities for the Food and Beverage sector (Solar Concentra, 2017)

Fonds Chaleur / France

In France, the ADEME (French Environment & Energy Management Agency) set up the "Fonds Chaleur" in 2009 as the major tool to reach the objective of 23% of renewable energy share in the national energy consumption by 2020 (38% in 2030). It addresses inter alia industrial heating, explicitly solar process heat. Between 2009 and 2017, ADEME spent 1.75 billion € for 4,273 projects of which 1,696 were solar thermal (detailed data on SHIP is not available). Selected projects receive a capital subsidy which is set in a case by case assessment and depends mainly on the geographical area (to account for irradiation), the minimum plant performance, the current costs for fossil fuel as well as a certain threshold of maximum eligible costs (ADEME, 2019).

One example of such an implemented project through the program is the Condat Paper mill, which came online in January 2019 in southwest France by the ESCO supplier NewHeat. The SHIP project has a capacity of 3.4 MW_{th} which is provided by 4,213 m^2 of flat plate collectors installed with single-axis tracking, coupled with a thermal storage of 500 m^3, and which supplies around 40% of the steam boiler pre-heating demand. The total project investment of 2.3 million euros was 61% co-funded by ADEME, and the ESCO sells heat at a fixed set price for the paper factory (SolarThermalWorld, 2019).

4.2 Solar Process Heating Projects

Japan Tobacco International / Jordan

In 2017, Japan Tobacco International (JTI) Manufacturing installed a Fresnel collector system with an aperture area of 1,254 m^2 on the roof of its facility in Jordan. The system generates steam at more than 200°C for the production processes as well as to power a double-effect absorption chiller. The solar steam generation technology and operating principle have already been described in detail by (Berger et al, 2016). The installation at JTI is important for two reasons. Firstly, it proves that already today, concentrating solar thermal technologies can commercially provide process heat at temperatures beyond 200°C, a range that cannot be reached by non-concentrating solar thermal collectors. Secondly, it shows that the generation of both heat and cold is viable, which further increases the market potential of solar thermal technologies in industrial applications.

4.3 Energy Service Companies / Heat-as-a-service cases

Pampa Elvira Solar / Chile

The Chilean copper producer Codelco has been benefitting from the largest SHIP installation in the country running in an ESCO model since 2013, which covers 80% of the mine's heat demand, mainly used for copper electrolytic refining. The system uses 43,920 m² of flat plate collectors with a thermal power capacity of 34 MW_{th} to generate hot water at 85°C, also coupled with a 4,300 m³ heat storage (Arcon-Sunmark, 2019). Pampa Elvira Solar is an SPV created to invest, install and operate the system in a 10-year agreement providing heat at a fixed price. Located in an extremely dry region in the Atacama desert, the collector field is dry-cleaned once a month and the plant operator is also responsible for the operation of the existent boiler station (SolarThermalWorld, 2013).

Bonilait Dairy / France

A combined biomass and solar process heat installation is in operation at the French dairy producer Bonilait Protéines to provide heat for drying milk and cleaning purposes at the factory. The solar field installed and operated by Dalkia in an ESCO model is comprised of 1,500 m² of flat plate collectors and generates heat at 80 °C, also coupled with a hot water thermal storage of 30 m³. When the solar irradiation is not enough to provide the expected temperature, the biomass boiler covers the remaining power demand, as the whole system is operated by Dalkia, although only solar heat is charged according to the ESCO contract (SolarThermalWorld, 2015).

With a larger implementation of such projects and the maturity of the SHIP market, these new financial tools will become standards within the investment institutions and funds, creating momentum for a larger adoption from industrial customers.

5. Summary

As industrial process heat accounts for approximately 20% of the total final energy demand, its decarbonization is of major importance. Yet, renewable heat, especially in the industry, is not on track and also insufficiently addressed by policy makers. As a complete switch to renewable electricity is not realistic, even in the mid-term, other renewables are required. Since geothermal and biomass are locally constrained, solar thermal energy needs to play a major role in the future industrial heat supply. However, despite SHIP projects having already proven their technical and financial viability, the market growth remains slow. Four major hurdles need to be tackled in order to accelerate the uptake of SHIP technologies: i) general policy framework for renewable heat, ii) high project development costs, iii) investment constraints by industrial end-users, and iv) risks and risk allocation are identified. For all these challenges, solutions are available and have been already proven. Countries need to set suitable targets for renewable heat, accelerate capacity building for solution providers and off-takers, support project development and, most importantly, accelerate the uptake of suitable financing schemes which consider the investment constraints by industrial end-users. For the industry, financing is especially important as companies have investment policies, which make the implementation of renewables more difficult compared to private persons or utilities.

Worldwide, various SHIP projects have already been implemented through an ESCO approach. For future research, a comprehensive assessment and comparison of these projects are required, especially with respect to technical best practices for monitoring and verification, contract standards as well as suitable support measures (e.g. guarantees). Thereby it is especially interesting to examine how existing, fossil based ESCOs, can be incentivized or enforced to switch to renewables.

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