Potential for Solar Process Heat in Germany - Suitable Industrial Sectors and Processes

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Abstract

The industrial sector represents a very promising application area for the further widespread of solar thermal technology, since it accounts for 30 % of the total final energy consumption in Germany and uses 75 % of its useful energy consumption as thermal energy. A review of existing potential studies in the field of solar process heat in combination with an analysis of the German industrial energy consumption leads to the selection of promising sectors and processes within industry. These are thoroughly analyzed regarding their potential for integration of solar thermal energy. Furthermore, a potential for the application of solar process heat in Germany is calculated. The results of this study facilitate the application of solar thermal energy in prioritized industrial sectors and processes.

1. Introduction

The final energy consumption in Germany accounted for 2,450 TWh in 2007 and the industry sector's share was 737 TWh, representing 30 %. The high importance of the industrial heat demand is proven by the fact that it accounts for 75 % of the industrial useful energy consumption, as shown in Figure 1. In the following chapters, the figures regarding the industrial heat demand are provided in terms of useful energy.

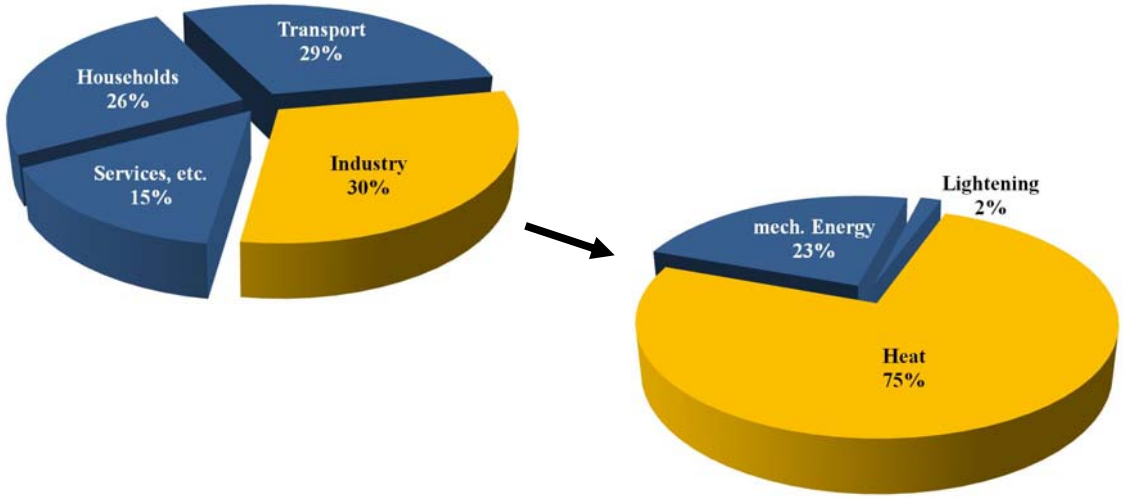

Fig. 1. Final energy consumption in Germany and useful energy consumption of the industrial sector in 2007 [1]

Both, the quantified potential for solar process heat in Germany and a qualitative analysis of the most promising industry sectors and processes is necessary to classify the feasibility for a further implementation of solar heating systems in industrial companies. Because no comprehensive potential study exists for Germany so far, the industry was analyzed in consideration of the results of previous studies. The results of these previous studies and the German energy statistics of the year 2007 were used to select the most promising industrial sectors and processes for the use of solar process heat.

2. Previous Potential Studies and its Results

Potential studies, which have been performed in the past for different countries or regions, identified several industrial sectors and processes as suitable for the application of solar heating systems. A subtask of IEA Task 33/IV summarized the main outcomes of the potential studies performed in different countries all over the world [2]. The existing studies differ significantly in the approach to quantify the potential for solar process heat. For example, some use the number of employees for the calculation, others determined available roof areas. One of the most comprehensive potential studies is the Austrian study PROMISE [3]. For this study the potential was calculated by a top-down approach using Austrian energy statistics. Questionnaires were used for the identification of promising sectors and processes. To gather more information about the energy demand and processes of industrial companies, 650 questionnaires were spread and 56 were returned. Because many of these questionnaires suffered by a lack of essential data only 32 questionnaires could finally be used. The following industry sectors were identified to be most promising for the application of solar thermal:

- Food products and beverages
- Textiles
- Rubber and plastic products
- Articles of concrete, cement and plaster

As mentioned by the authors of the study, only single answers were received for the sectors of paper and paper products as well as metal processing. These sectors were not identified to be promising for the application of solar process heat. Due to the lack of information about these sectors, this exclusion can be doubted. In the following, some of the main differences of other previous potential studies will be described. Only additional sectors to those identified in PROMISE will be mentioned in this paper. For the study “POSHIP – The Potential for Solar Heat for Industrial Processes” [4], which investigated the potential for solar process heat in Spain and Portugal, a bottom-up approach was used. This was done by a case by case analysis and an extrapolation to the whole sector. The following additional sectors were identified as promising:

- Tobacco products
- Leather and leather products
- Paper and paper products
- Chemicals and chemical products
- Motor vehicles and trailers

Further potential studies for Australia (state of Victoria only) [5], Italy [2], the Netherlands [6], Sweden [7], and Cyprus [8] partly supported the identified sectors, but only the sector of machinery and equipment was identified additionally. Within the project Procesol I and II [9], a potential study for Greece and Wallonia was conducted and the German industry sectors of food products and

beverages, paper and paper products and textiles were analyzed regarding their potential for solar process heat. The key sectors, which were identified by previous potential studies, are summarized in Table 1. The table indicates that some sectors like food products and beverages where identified as promising in nearly all executed potential studies, whereas others are only mentioned in a few studies.

Table 1. Results of previous potential studies adapted to German Classification of Economic Activities [10]

Industry sectors	Austria	Iberian Peninsula	Italy	Netherlands	Greece	Germany	Wallonia (Belgium)	Victoria (Australia)
Food products and beverages	x	x	x	x	x	x	x	x
Tobacco products		x	x		x		x	
Textiles	x	x	x	x	x	x	x	x
Leather and leather products		x	x		x			
Paper and paper products		x	x	x	x	x	x	x
Chemicals and chemical products		x	x		x		x	x
Rubber and plastic products	x							
Articles of concrete, cement and plaster	x							
Machinery and equipment								x
Motor vehicles and trailers	x	x	x		x			

A quantitative potential for solar process heat was estimated only in some of the studies described above. The results are displayed in Figure 2.

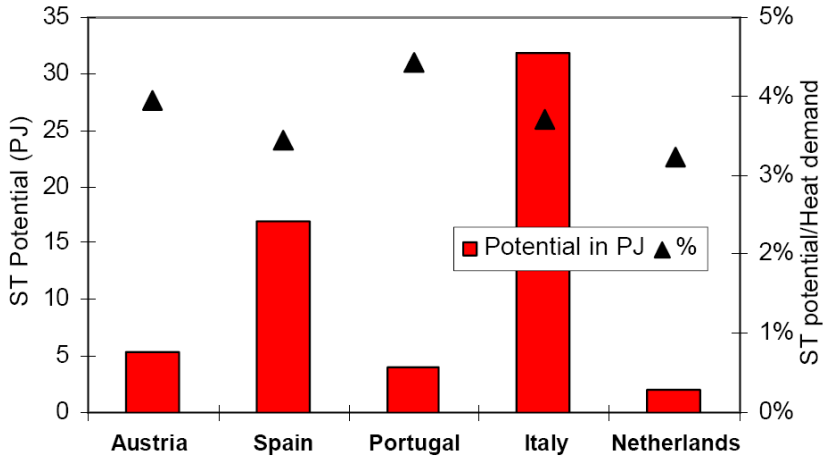

Figure 2. Solar process heat potential in selected European countries [2]

The figure shows that the calculated potentials are in a range between 3 and 4.5 % of the industrial heat demand in the particular region and is in the range of 60 PJ respectively 16.7 TWh for Austria, Spain, Portugal, Italy and the Netherlands.

3. The Potential for Solar Process Heat in Germany

Prior to the calculation of the potential for solar process heat in Germany, a decision is necessary which industry sectors should be considered. This decision is mainly based on the results of previous studies. In addition, the total amount and distribution of the heat demand of the mentioned sectors by temperature level is analyzed to determine their relevance. Of the sectors mentioned in Table 1, tobacco products and leather and leather products are excluded because of a very low relevance in Germany. Articles of concrete, cement and plaster is not considered due to the (very high) heat demand at high temperatures. One can assume that the small amount of low temperature heat used in this sector can be covered by heat recovery. The only industry sectors considered for this study which are not already mentioned in the chapter above are wood and wood products and fabricated metal products. This is due to the fact that these sectors have a reasonable heat demand at low temperatures and only little at high temperatures. Furthermore, some solar heating systems are already in operation at electroplating companies, which are part of fabricated metal products. This demonstrates the general feasibility of this sector for the application of solar process heat plants. Table 2 shows the selected sectors and a breakdown of their heat demand.

Table 2. Breakdown of heat demand for selected industry sectors [11]

Industry sector	**Process Heat**					**HW & SH**	**Sum**	**Share***
	< 100°C	**100°C..500°C**	**500°C..1000°C**	**>1000°C**	**Sum PH**			
Food products and beverages	9.4	11.6	0.0	0.0	21.1	7.3	28.3	**5.1%**
Textiles	2.9	0.0	0.0	0.0	2.9	2.1	5.0	**0.9%**
Wood and wood products	1.3	0.3	0.0	0.0	1.6	0.3	1.9	**0.3%**
Paper and paper products	3.0	11.1	0.0	0.0	14.1	2.9	17.0	**3.1%**
Chemicals and chemical products	15.4	24.0	51.2	12.6	103.2	8.3	111.5	**20.2%**
Rubber and plastic products	1.0	3.8	0.0	0.0	4.8	1.9	6.7	**1.2%**
Fabricated metal products	2.0	1.6	0.9	2.1	6.5	6.5	13.1	**2.4%**
Machinery and equipment	1.7	1.3	0.6	1.7	5.3	5.6	10.9	**2.0%**
Motor vehicles	3.0	2.3	1.1	3.1	9.5	9.9	19.4	**3.5%**
Sum:	**39.8**	**55.9**	**53.8**	**19.5**	**168.9**	**44.8**	**213.8**	
Share of industrial heat demand:	**7.2%**	**10.1%**	**9.7%**	**3.5%**	**30.6%**	**8.1%**	**38.7%**	

*of the industrial heat demand; all numbers without units in TWh; HW: hot water; SH: space heating

The table indicates that the sectors identified as promising for the application of solar process heat represent a substantial share of the industrial heat demand. In total, theses sectors consume nearly 40 % of the industrial heat demand in Germany including hot water and space heating. The heat demand for industrial processes as well as hot water generation and space heating are considered for this potential study as it is often not even possible to determine them separately in a certain industry. In many cases one heat distribution network provides the energy for the production process and the hot

water and space heating consumers. The sectors of chemicals and chemical products and food products and beverages have the highest shares of the low temperature heat demand. For the evaluation of the heat demand structure regarding the quantified potential for solar process heat, the temperature range of 100 °C to 500 °C has to be subdivided. Table 3 shows a breakdown of the temperature level up to 500 °C for chemicals and chemical products and food products and beverages and the entity of sectors. As this table is also based on another source, the numbers differ slightly from the ones in Table 2.

Table 3. Breakdown of the industrial heat demand without hot water/space heating up to 500°C [11/12]

	<100°C	100-150°C	150-200°C	200-250°C	250-300°C	300-500°C	Other
All sectors	12.7%	11.3%	4.1%	1.2%	0.8%	8.1%	61.9%
Food products and beverages	42.9%	40.7%	16.4%	0.0%	0.0%	0.0%	0.0%
Chemicals and chemical products	22.5%	9.2%	7.0%	6.1%	3.0%	8.0%	44.3%

To calculate the potential of solar heat for industry in Germany, the technical potential shall be determined in a first step by considering the process heat demand up to 250 °C as well as the demand for hot water and space heating. For food products and beverages and chemicals and chemical products the distribution of Table 3 was applied to the data of Table 2 to determine their heat demand up to 250 °C. For paper and paper products and wood and wood products the total heat demand for the range 100 °C to 500 °C was considered, since there is no heat demand above 200 °C within these sectors [13]. For rubber and plastic products, fabricated metal products, machinery and equipment and motor vehicles a share of about 17 % of the heat demand between 100 °C to 500 °C was considered. This is based on the figures for all industry sectors of Table 3. With these shares of the heat demand between 100 °C to 500 °C and the heat demand below 100 °C as well as the demand for hot water and space heating, a technical potential for solar heat for industry can be calculated to about 115 TWh/a. Further, the numbers in Table 3 indicate, that the most important temperature range for the application of solar process heat in Germany is below 150 °C. The share of the industrial heat demand in the temperature range of 150 °C to 250 °C is not negligible, but much smaller. Of course, the calculated technical potential cannot be covered with solar energy completely, but is further restricted. First of all, the process heat demand as well as the hot water and space heating demand can be reduced by energy efficiency measures like heat recovery. Furthermore, a fraction of the required heat has to be supplied by electricity for different reasons, and in many cases sufficient space is not available for the installation of solar heating systems.

Following [3], a share of 60 % of the technical potential for low and medium temperature processes cannot be used due to the restrictions mentioned above. Furthermore, an average solar fraction of 40 % is proposed. Applying these numbers to the technical potential of 115 TWh, the potential for solar heat in industry in Germany is about 18 TWh or 3.3 % of the total industrial heat demand. Although additional industry sectors were considered for the calculation of the potential, it is below the average of the results of previous studies which estimated potentials in a range of 3 to 4.5 %. This is based on the fact, that German industry has more high temperature processes than industry in countries like Austria and Spain due to a higher share of heavy industries like steel production. Nevertheless, the absolute number of 18 TWh represents in absolute figures by far the highest potential for solar process heat in European countries.

4. Promising Sectors for Solar Applications in Germany

In addition to the analysis of the heat demand of different sectors, the investigation of industrial processes in general can identify suitable points for integration of solar thermal energy. [2] and [3] identified industrial processes including cleaning, drying, evaporation and distillation, blanching, pasteurization, sterilization, cooking, melting, painting, and surface treatment as suitable areas of application. However, these processes are often not comparable for different industrial sectors, as some boundary conditions can vary in a wide range. For example, temperature and required time of washing processes depend very strongly on the treated product. Although these promising processes occur in nearly all industrial sectors, significant differences exist regarding the integration of solar heating systems. Although the mentioned processes are promising for solar heating application, a closer investigation of the promising industry sectors is necessary. The first results of this investigation are presented in the following.

4.1 Food Products and Beverages

The sector of food products and beverages was identified as promising in all previous potential studies. As mentioned in the last chapter, this sector has a large heat demand in the temperature range up to 150 °C. Common processes are pasteurization of liquid goods at 65 to 100 °C, cooking at 100 °C in meat processing, blanching of vegetables or meat at 65 to 95 °C, drying and evaporation at 40 to 130 °C in fruit and vegetable processing or cleaning of products and production facilities at 60 to 90 °C. Taking into account its big share of the industrial heat demand at low temperatures, the results of the previous studies and the variety of suitable processes, the food industry has a great potential for the use of solar thermal energy.

4.2 Textiles

As already shown, the heat demand of the textiles sector is limited to temperatures below 100 °C. Within the textile industry washing at 40 to 90 °C, drying and a large number of finishing processes like dyeing and bleaching at 70 to 100 °C or desizing at 80 to 90 °C are the main consumers of process heat. As a first guess, up to 25 to 50% [3] of heat needed in the textiles sector could be covered by solar thermal energy. This represents a large potential, although the share of the low temperature heat demand of the overall energy consumption of the German industry is quite low.

4.3 Paper and Paper Products

Within the pulp and paper industry, about two-thirds of the heat demand is needed at temperatures higher than 100 °C, which is unfavourable for solar heating systems containing standard components, but could in principle be provided with more advanced collector technologies. On the other hand, one-third is still consumed at advantageous temperatures below 100 °C for process heat, hot water and space heating. The preheating of boiler feed water represents a promising application for solar thermal energy in this industry sector, as steam is needed for drying of paper products. Furthermore, the share of energy cost is about 11 % of total manufacturing costs [14], which indicates the high importance of energy efficiency and the utilization of renewable energy in this sector.

4.4 Chemicals and Chemical Products

The chemical industry is one of the most important sectors of the German economy. The processes within the sector are very demanding regarding energy and resources. Energy costs are about 4 to 5 % of the total manufacturing costs. The German chemical industry accounts for 20 % of the final energy demand of German industry [15]. The heat demand plays a major role within this energy demand, and although a large amount is needed at high temperatures, there is still a considerable heat demand at low and medium temperatures as shown in Table 2 and 3. Potential processes for solar heat are especially bio-chemical processes with temperature levels about 37 °C as well as preheating and polymerisation processes [16].

4.5 Rubber and Plastic Products

According to [17], the German plastics processing industry has had an energy demand of 15.2 TWh in 2000. In [18] it is stated that about 40 % of the energy consumed is used for process heat applications. Table 2 shows that at least a reasonable share of this heat demand is needed at low and medium temperatures. Still many processes in the plastics industry require temperatures over 150 °C. Besides the supply of hot water and space heating, drying of plastic pellets is a potential process for solar thermal energy. The pellets are air-dried at temperatures from 50 to 150 °C to ensure quality during moulding.

4.6 Fabricated Metal Products

According to [19], the share of energy is only 0.3 to 1.6 % of the total manufacturing costs within the sector of fabricated metal products. Here, the heat demand plays a major role for the overall energy demand. [18] states a share of 45 % for the heat demand with respect to the total energy demand. Table 2 shows that a reasonable share is required at low and medium temperatures and the demand for hot water and space heating is quite high. The required heat is needed at low temperatures, especially for coating processes. For example, surfaces are etched in about 70 °C warm solutions and air-drying is an often used process that requires hot air with about 120 °C.

5. Conclusion

The heat demand plays a major role for the industrial energy demand as it accounts for 75 % of its useful energy consumption. This heat is needed in several industry sectors at low and medium temperatures, which is the major requirement for the utilisation of solar thermal energy. Some industry sectors like food products and beverages and textiles offer various options for the integration of solar process heat, whereas in others the utilization will be limited to a few processes. The major constraints for the application of solar heating systems in industry are the huge potential of energy efficiency measures, operational reasons and an absence of suitable roof area. Furthermore, guidelines for planning, installation and operation of large solar heating systems in industrial companies are not available today. If at least some of these constraints can be eliminated, a share of about 3.3 % respectively 18 TWh of the German industries heat demand could be covered by solar thermal energy.

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