IEA SHC Task 33 and SolarPACES Task IV: Solar Heat for Industrial Processes

Potential for Solar Heat in Industrial Processes

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1. Introduction

The goal of this report, developed in the framework of the IEA Solar Heating and Cooling Programme Task 33 and IEA SolarPACES Programme Task IV – Solar Heat for Industrial Processes (SHIP), is to highlight the potential use of solar thermal (ST) plants to provide heat for industrial applications. In order to fulfil this aim, several national potential studies were surveyed and compared with a focus on the key results and the methodologies applied.

The primary audience for this report are ***two target groups: the solar industry and policy makers***. In reading this report, the solar industry will learn of a relevant and so far unexploited market sector, industrial applications. Moreover, policy makers will realise that an adequate promotion of solar thermal should be done not only for the most “traditional” residential applications, but also for innovative applications, among which solar process heat stands out. ***This report can serve as a tool for developing national and local campaigns and policies on solar thermal energy for industrial uses***.

This booklet reports on the main outcomes of the potential studies performed in different countries all over the world and extrapolates these results to obtain an indicative figure of the potential application at the European level.

The country studies carried out in Austria, the Iberian Peninsula (Spain and Portugal), Italy and the Netherlands are included in this report as well as two regional studies (Wallonia for Belgium and Victoria for Australia) and two specific industrial sectors studies from Greece and Germany.

706 kW solar thermal plant for a dairy in Greece
(sources: CRES – Centre for Renewable Energy Sources, Solenergy Hellas S.A.)

840 kW solar thermal plant for a chemical industry in Egypt
(source: Fichtner Solar GmbH)

2. Potential for Solar Heat in Industrial Processes

2.1. Solar thermal for industrial applications

At the end of 2006, the installed solar thermal capacity worldwide[1] was about 118 GW_{th} (168 million m^2). Compared with 144 GW_{el} for wind, 69 GW_{el} for geothermal and 5,5 GW_{el} for photovoltaic, solar thermal has undoubtedly held a leading position among the renewable energy sources.

The majority of the solar thermal plants operating today provide hot water to households, for both sanitary purposes and space heating. Although the residential sector offers a huge potential for solar thermal applications, the industrial sector should not be ignored for two key reasons.

First, ***this sector shows a remarkable relevance, covering about 28% of the total primary energy consumption for final uses in EU25***[2].

Second, a significant share of the heat consumed in the industrial sector is in the low and medium temperature range. These two issues make the industrial sector a promising and suitable application for solar thermal energy.

Currently ***about 90 operating solar thermal plants for process heat are reported worldwide, with a total capacity of about 25 MW_{th} (35,000 m²)***. The plants distribution by sector and country are shown in the graphs below.

2.2. Main results

The 25 MW_{th} reported for the operating capacity of solar thermal plants in industry is a very small fraction (0.02%) of the total solar thermal capacity installed worldwide, which equals 118 GW_{th}, even though this comparison is not strictly correct from a methodological point of view. As a matter of fact, 118 GW_{th} is the result of a worldwide survey, while 24 MW_{th} is the output of a collection of built examples in 21 countries and not of a systematic review of the installed plants for industrial processes[3].

Even though the comparison is not scientifically correct, the difference between the two figures is huge. However, in spite of the current small contribution, the potential of using solar thermal for providing heat to industrial application is really relevant.

[1] W. Weiss, I. Bergmann, G. Faninger, Solar Heat Worldwide - Markets and contribution to the energy supply 2005, International Energy Agency 2007.
[2] Data for 2004, based on EUROSTAT statistics.
[3] For instance, China and Japan are not included in this collection.

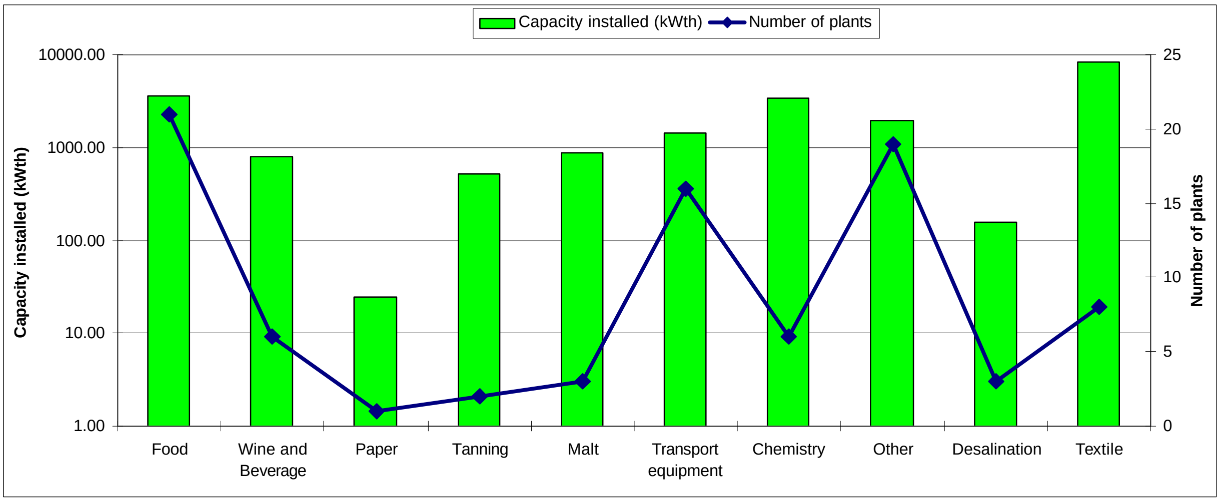

Figure 1. *Solar industrial process heat plants - distribution by industry sector. Reported within Task 33/IV as of October 2007.*

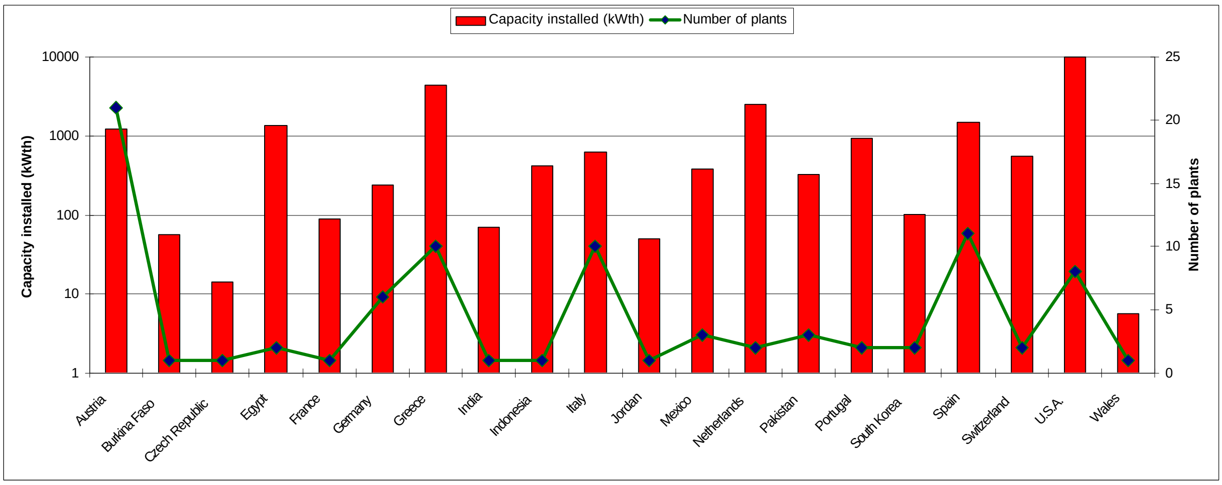

Figure 2. *Solar industrial process heat plants - distribution by country. Reported within Task 33/IV as of October 2007.*

The main results of the potential studies performed in several countries all over the world are summarised[4] with the key outcomes categorized by:

1. industrial heat demand by temperature range;
2. most suitable industry branches and processes for solar thermal use;
3. potential of application for solar thermal technologies in industry for several countries and at the European level.

[4] For information about the methodologies applied and the comparability of the results, please refer to paragraph 2.4.

2.2.1. Industrial heat demand by temperature range

Current data on the breakdown of industrial heat demand by different temperature ranges are not exhaustive in many countries. Therefore, the analysis of the performed potential studies has been useful to overcome this lack of information.

The recent study "ECOHEATCOOL"[5] reports that ***about 30% of the total industrial heat demand is required at temperatures below 100°C and 57% at temperatures below 400°C***.

Moreover, ***in several industrial sectors***, such as food, wine and beverage, transport equipment, machinery, textile, pulp and paper, ***the share of heat demand at low and medium temperature (below 250°C) is about, or even above, 60% of the total figure***. However, it should be highlighted that the pulp and paper sector uses primarily heat recovery systems and, therefore, even though the theoretical potential is high, the practical implementation of a solar thermal plant is not convenient in most of the cases.

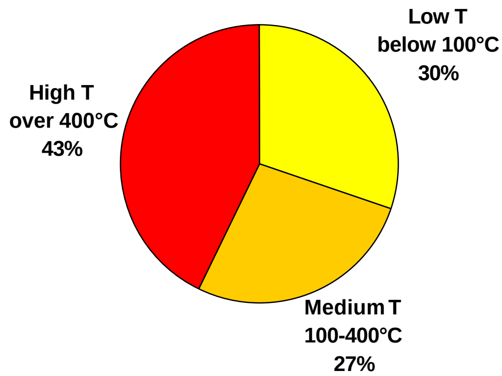

Figure 3. *Share of industrial heat demand by temperature level. Data for 2003, 32 countries: EU25 + Bulgaria, Romania, Turkey, Croatia, Iceland, Norway and Switzerland.*
(Source: ECOHEATCOOL (IEE ALTENER Project), The European Heat Market, Work Package 1, Final Report published by Euroheat & Power.)

As reported in the two figures above, the ECOHEATCOOL and POSHIP studies, though following quite different methodologies, come to results which are fully comparable[6]. In particular, the figures obtained from industry statistics are fully confirmed by the outcomes of the estimates done in the reported potential studies for solar process heat, for example in the POSHIP project.

Finally, it should be noted that quite often industrial processes exploit medium temperature heat by using steam as a heat carrier even though lower working temperatures would be sufficient. Therefore, ***in order to assess correctly the feasibility of the introduction of solar thermal in an industrial process, one should look at the actual temperature needed by the process itself and not at the temperature of the heat carrier being used***. ***Such an approach should be used not only for determining the implementation of solar thermal plants, but also for lowering the current process energy consumption***.

[5] ECOHEATCOOL (IEE ALTENER Project), www.ecoheatcool.org
[6] ECOHEATCOOL study is based on statistics from German industry transferred to the other Countries, while POSHIP is based on a bottom-up approach, starting from case studies.

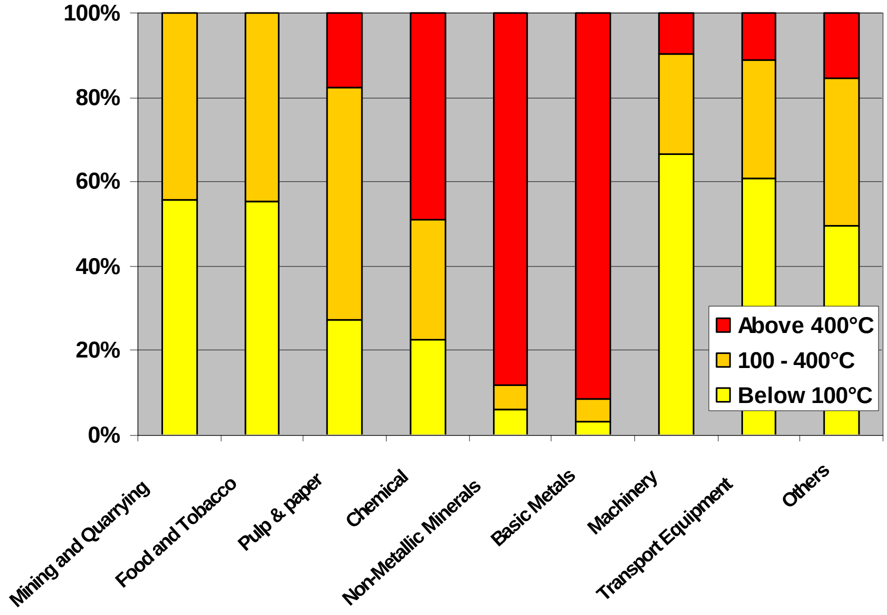

Figure 4. *Share of industrial heat demand by temperature level and industrial sector. Data for 2003, 32 countries: EU25 + Bulgaria, Romania, Turkey, Croatia, Iceland, Norway and Switzerland.*
(Source: ECOHEATCOOL (IEE ALTENER Project), The European Heat Market, Work Package 1, Final Report published by Euroheat & Power.)

Figure 5. *Share of industrial heat demand by temperature level for some industrial sectors which require low temperature heat. Data for 34 industries in the Iberian Peninsula.*
(Source: H. Schweiger et al., POSHIP, The Potential of Solar Heat for Industrial Processes, Final Report, 2001.)

2.2.2. Industrial sectors and processes

The second noteworthy outcome of this survey is the definition of the most suitable industrial sectors, where solar thermal heat could be fruitfully used.

In these sectors, the heat demand is remarkable and more or less continuous throughout the year. Furthermore, as described above, the temperature level required by some of the processes is compatible with the efficient operation of solar thermal collectors.

The key sectors are food (including wine and beverage), textile, transport equipment, metal and plastic treatment, and chemical. The areas of application with the most suitable industrial processes, include cleaning, drying, evaporation and distillation, blanching, pasteurisation, sterilisation, cooking, melting, painting, and surface treatment.

Finally, among the most promising applications ***space heating and cooling of factory buildings should be included as well***[7].

The relevance of each sector in regards to solar thermal market development also depends on the local industrial profile, for example, breweries represent an important industry in Austria and Germany, while dairies are important in Italy and Greece.

Table 1 provides an overview of the industrial sectors considered in the potential studies. The different sectors included should be carefully taken into account when comparing the outcomes of these studies as well as other technical and non-technical country specific parameters that directly affect the global figures.

2.2.3. The potential for solar process heat in the European Union

The results of the potential studies for different European countries are reported in Figure 6 and Table 2. The potential solar process heat estimated in the PROMISE[8] study for Austria reaches 5.4 PJ/year, while the Iberian Peninsula (Spain and Portugal) and the Italian studies show a potential of 21 PJ/year[9] and 32 PJ/year[10] respectively.

The study carried out for the Netherlands shows a quite lower potential (<2 PJ/year). The reason for this is because the hot water production up to only 60 °C was assessed in twelve industry branches thereby limiting the scope of the analysis.

7 Jaehnig, D., Weiss, W.: Space Heating of Industrial Buildings using underfloor heating systems, IEA SHC Task 33/IV, 2007

8 Müller, T. et al.: PROMISE – Produzieren mit Sonnenenergie, Potenzialstudie zur thermischen Solarenergienutzung in österreichischen Gewerbe - und Industriebetrieben within the Fabrik der Zukunft (BMVIT) Subprogram, Final report 2004

9 H. Schweiger et al., POSHIP (Project No. NNES-1999-0308), The Potential of Solar Heat for Industrial Processes, Final Report, 2001.

10 The solar thermal potential study for process heat in Italy was carried out in the framework of IEA Task 33/IV.

The potential studies available for other countries such as Germany, Greece and Belgium cannot be directly compared to the other countries because they are either regional studies or included only a few specific sectors, and therefore provide an incomplete picture.

Table 1. *Overview of the industrial sectors included in the different country potential studies.*

Industry sectors	Austria	Iberian Peninsula	Italy	Netherlands	Greece	Germany	Wallonia (Belgium)	Victoria (Australia)
Food products	X	X	X	X	X		X	X
Wines and beverages	X	X	X	X			X	X
Beer and malt		X	X	X		X	X	X
Tobacco products		X	X		X		X	
Textiles and textile products	X	X	X	X	X		X	X
Leather and leather products		X	X		X			
Pulp, paper and paper products		X	X	X	X	X	X	X
Chemicals and chemical products		X	X		X		X	X
Machinery and equipment								X
Transport equipment and auxiliary transport activities	X	X	X		X	X		
Other sectors	X				X		X	X

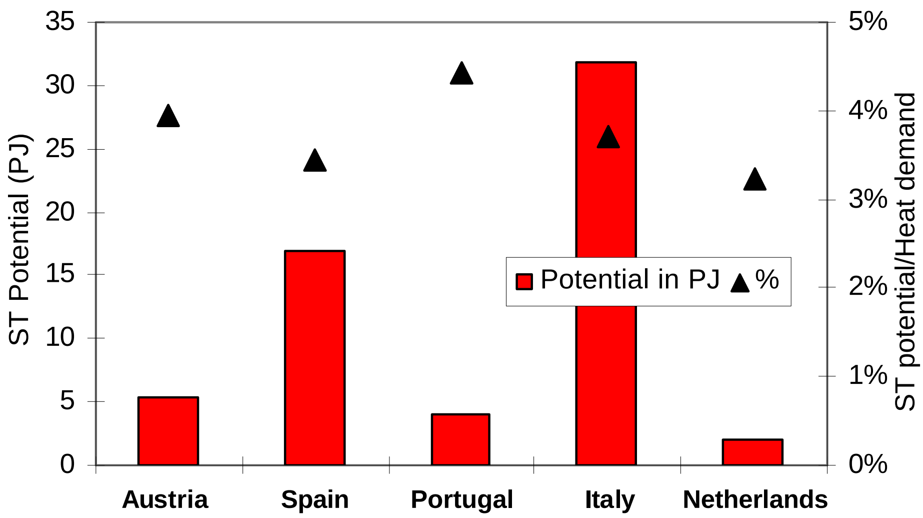

Figure 6. *Solar process heat potential in selected European countries [PJ/year].*

The scope of the Australian study was limited to the state of Victoria and includes both the commercial and service sectors. Focusing only on the industrial applications, the final potential figure is 9.47PJ/year. These results are not included in the summary table below because the goal of the survey was to calculate the potential at the European level.

In Table 2, the potential for the use of solar thermal in the industrial sector in different countries is reported in terms of delivered energy (PJ/year), capacity (GW_{th}) and collector area (Mio m^2). These potential figures are also compared to the corresponding industrial heat demand, in order to obtain the share of heat demand that could be covered by using solar thermal.

The results reported show that **<u>solar thermal systems could provide the industrial sector with 3÷4% of its heat demand in Austria, Italy, Portugal, Netherlands and Spain</u>**.

Extrapolating this result to the European Union (EU 25), considering an average share of 3.8%, ***the potential for solar thermal applications in industry reaches a value for heat production of 258 PJ/year.***

Table 2. *Industrial heat demand and solar process heat potential for selected countries and for EU25.*

Country	Industrial final energy consumption	Industrial heat demand (Final energy to heat demand conversion factor: 0.75)	Solar process heat potential at low & medium temperature	Solar process heat/ Industrial heat demand	Potential in terms of capacity	Potential in terms of collector area	Source of the data used for calculation (*)
	[PJ/year]	[PJ/year]	[PJ/year]		[GW_{th}]	[Mio m^2]	
Austria	264*	137	5.4	3.9%	3	4.3	Eurostat energy balances, year 1999; PROMISE project
Spain	-	493*	17.0	3.4%	5.5 - 7	8 - 10	POSHIP project
Portugal	-	90*	4.0	4.4%	1.3 - 1.7	1.9 - 2.5	POSHIP project
Italy	1,653*	857	31.8	3.7%	10	14.3	Eurostat energy balances, year 2000
Netherlands	89*	46	1.95	3.2%	0.5 - 0.7	0.8 - 1	Onderzoek naar het potentieel van zonthermische energie in de inustrie. (FEC for 12 branches only)
EU 25	***12,994****	***6,881***	***258.2***	***3.8%***	***100 - 125***	***143 - 180***	Eurostat energy balances, year 2002

The corresponding potential figures in terms of capacity and area have been calculated taking into account two possible yield values for the solar plants: 400 kWh/m^2 year and 500 kWh/m^2 year.

2.3. Expected impacts

What could be the impacts of this so far unexploited technology? The two main expected impacts are:

- contribution to EU targets for renewables; and
- job creation.

The EU heads of State and Government recently adopted an energy policy that does not simply aim to boost competitiveness and secure energy supply, but also aspires to save energy and promote climate-friendly energy sources. EU leaders set a firm target of cutting 20% of the EU's greenhouse gas emissions by 2020 and established a binding overall goal of 20% for renewable energy sources by 2020, compared to the present 6.5%.

Even though the detail targets have yet to be determined at both EU and national levels, some scenarios have already been prepared.

The most ambitious target for solar thermal, developed by ESTIF (European Solar Thermal Industry Federation), is to reach a level of 320 GW_{th} installed in 2020, meaning about 1 m^2 per capita and 19.7Mtoe/year of energy delivered[11].

According to the European Solar Thermal Technology Platform (ESTTP), the goal for 2030 is to have installed a total capacity of 960 GW_{th} by 2030.

Assuming that 10% of the calculated potential for solar heat in industrial applications were to be actually implemented within 2020, ***a total capacity between 10 and 12GW***

Following these assumptions, ***the industrial use of solar thermal energy could assure a market volume of 1000 MW_{th}/year, which would mean a 50% growth with respect to the current European annual solar market volume***, that equalled 2100 MW_{th} (almost 3 000 000 m^2) installed in 2006.

By exploiting this potential, 10 000-15 000 new jobs could be created by 2020. This figure represents a relevant share of the occupational target for the overall solar thermal sector, which according to the European Solar Thermal Technology Platform will be able to offer 224 000 full time jobs by 2020.

11 European Solar Thermal Industry Federation, "Solar Thermal Action Plan for Europe", www.estif.org

2.4. Methodological notes

Different methodological approaches were used within the surveyed studies. For Spain and Portugal, a bottom-up procedure was adopted, extrapolating the results of 34 case studies to the whole industry sector. In Austria, a top-down approach was used where the case studies only validated the outcomes of the previous calculations based on theoretical assumptions. The Italian methodology assumed the available surface as the main criterion for the solar potential assessment.

In spite of these methodological differences, some common steps were identified for performing a new country potential study:

- Define the most relevant and most suitable industrial sectors for the country under study.
- Assess the industrial heat demand by sector and by temperature range, focusing on low and medium temperature heat (e.g., up to 250°C).
- Calculate the technical potential including all the cases where the installation of a solar thermal system is assumed to be technically feasible; this step should take into account at least the following limitation factors:
    - available surface on roofs or façades
    - characteristics of the heat demand
    - heat demand at low temperature; here it is crucial to distinguish the heat carrier supply temperature (e.g., the steam temperature) and the working temperature actually needed by the process; if supply temperatures, which are most of the times much higher than working temperatures, are taken into account, the assessment of the potential for application of solar thermal in industry could be widely underestimated
    - technical possibility of coupling the solar thermal plant with the process
    - type of process (batch or continuous)
    - temperature of heat usage
    - availability of process heat storages (e.g. pools)
    - chances for heat recovery
    - availability of competing technologies
- Evaluate the techno-economic potential, where all the technical conditions are met and the economical feasibility is also assessed; this step should include the main following issues:
    - energy costs: historical trend and forecast for the future
    - investment and operation & maintenance costs
    - financing schemes from the public sector
    - assumptions on the main economic parameters for the calculations (pay back time, Internal Rate of Return, cost of kWh, etc.)

Table 3. *Overview of the methodological approaches used in the different potential studies.*

	ITALY	SPAIN AND PORTUGAL	AUSTRIA	NETHERLANDS
1. Heat demand				
Temperature range considered		up to 160ºC	up to 250ºC	only hot water up to 60ºC
Temperature used		process temperature		
2. Limitation by roof and façade area available considered				
	yes (statistical data on roof area)	yes (case by case analysis)	xxx generic restriction: xxx % of technical potential	
3. Technical constraints				
Difficulties of coupling solar system to processes				
Competing technologies			generic reduction of potential of xxx % supposed	
4. Economic parameters				
		case by case analysis specific parameters used for short term and medium term economic potential; result: not very relevant, as roof area is the main limiting factor		
5. Statistical approach				
	top-down	bottom-up approach: first case by case analysis, then extrapolation to whole sector	top-down	

3. Conclusion and recommended actions

Even though solar thermal is used today mainly for providing hot water to households and pools, the conducted survey clearly highlights that given its relevance in total final energy consumption, ***the industrial sector cannot be ignored***.

Moreover, a remarkable share of its heat demand is needed in the low and medium temperature range, and this is true particularly for certain industrial sectors (food – including wine and beverage, textile, transport equipment, metal and plastic treatment, chemical) and for several processes (cleaning, drying, evaporation and distillation, blanching, pasteurisation, sterilisation, cooking, melting, painting, surface treatment). Studies based on both industry statistics and on case studies performed for assessing the solar thermal potential in industrial applications came to consistent outcomes regarding the share of low and medium temperature heat required by the industrial branches noted above.

The analysis of the surveyed country potential studies also shows that, even though using quite different methodologies, the obtained figures are quite similar—***solar thermal could provide the industrial sector with 3÷4% of its heat demand***.

This result allows the extrapolation of the national figures to the European level—***solar thermal could provide 258 PJ/year of thermal energy to the EU25 industrial sector or an installed capacity of 100-125 GW_{th} (143÷180 Mio m^2)***.

Even assuming a quite conservative scenario for the penetration of solar thermal use in the industrial sector, its contribution for reaching the EU set targets for 2020 is significant.

Coming back to the two main target groups of this document, the message for the solar thermal national and European companies is: there is a relevant, promising, suitable and so far almost unexploited market sector for applying solar thermal technology. Therefore, **look at the most suitable and most representative industrial sectors in your country and exploit this potential**.

For policy makers and national and EU institutions, it is of utmost importance that **current policies for renewable development carefully consider, take into account, and promote with specific measures and policy tools, the industrial applications of solar thermal**.

The main recommended actions that the policy makers should take in order to support the development of a market for industrial applications of solar thermal are:

- Make economic incentives available for industries willing to invest in solar thermal. These incentives, aiming at reducing payback periods, could be provided by different schemes (e.g., low interest rate loans, tax reduction, direct financial support, third party financing, etc). To date, only local (e.g., at regional level) examples of these support schemes have been applied.

- Carry out demonstration and pilot solar thermal plants in industries, including advanced and innovative solutions, like small concentrating collectors.
- Provide information, by organising workshop and campaigns, to the industrial sectors involved to make them aware of several issues:
  - the real cost of heat production and use of conventional energy sources and their relevance in the total industry management cost; and
  - the benefits of using appropriate solar thermal technology.
- Support further research and innovation to improve technical maturity and reduce costs, especially for applications at higher temperatures.

Finally, regarding future improvements of this analysis, new and more complete studies are needed within the EU framework to assess the detailed potential at national and EU levels in the different industrial sector and expand the current data available to solar thermal companies and policy makers.

Appendix 1 – IEA Solar Heating and Cooling Programme

The *International Energy Agency* (IEA) is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) based in Paris. Established in 1974 after the first "oil shock," the IEA is committed to carrying out a comprehensive program of energy cooperation among its members and the Commission of the European Communities.

The IEA provides a legal framework, through IEA Implementing Agreements such as the *Solar Heating and Cooling Agreement*, for international collaboration in energy technology research and development (R&D) and deployment. This IEA experience has proved that such collaboration contributes significantly to faster technological progress, while reducing costs; to eliminating technological risks and duplication of efforts; and to creating numerous other benefits, such as swifter expansion of the knowledge base and easier harmonization of standards.

The *Solar Heating and Cooling Programme* was one of the first IEA Implementing Agreements to be established. Since 1977, its members have been collaborating to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. Current members are:

Australia	Finland	Portugal
Austria	France	Spain
Belgium	Italy	Sweden
Canada	Mexico	Switzerland
Denmark	Netherlands	United States
European Commission	New Zealand	
Germany	Norway	

A total of 39 Tasks have been initiated, 30 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition to the Task work, a number of special activities—Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops—have been undertaken.

The Tasks of the IEA Solar Heating and Cooling Programme, both underway and completed are as follows:

Current Tasks:

Task 32	*Advanced Storage Concepts for Solar and Low Energy Buildings*
Task 33	*Solar Heat for Industrial Processes*
Task 34	*Testing and Validation of Building Energy Simulation Tools*
Task 35	*PV/Thermal Solar Systems*
Task 36	*Solar Resource Knowledge Management*
Task 37	*Advanced Housing Renovation with Solar & Conservation*
Task 38	*Solar Assisted Cooling Systems*
Task 39	*Polymeric Materials for Solar Thermal Applications*

Completed Tasks:

Task 1	*Investigation of the Performance of Solar Heating and Cooling Systems*
Task 2	*Coordination of Solar Heating and Cooling R&D*
Task 3	*Performance Testing of Solar Collectors*
Task 4	*Development of an Insolation Handbook and Instrument Package*
Task 5	*Use of Existing Meteorological Information for Solar Energy Application*
Task 6	*Performance of Solar Systems Using Evacuated Collectors*
Task 7	*Central Solar Heating Plants with Seasonal Storage*
Task 8	*Passive and Hybrid Solar Low Energy Buildings*
Task 9	*Solar Radiation and Pyranometry Studies*
Task 10	*Solar Materials R&D*
Task 11	*Passive and Hybrid Solar Commercial Buildings*
Task 12	*Building Energy Analysis and Design Tools for Solar Applications*
Task 13	*Advance Solar Low Energy Buildings*
Task 14	*Advance Active Solar Energy Systems*
Task 16	*Photovoltaics in Buildings*
Task 17	*Measuring and Modeling Spectral Radiation*
Task 18	*Advanced Glazing and Associated Materials for Solar and Building Applications*
Task 19	*Solar Air Systems*
Task 20	*Solar Energy in Building Renovation*
Task 21	*Daylight in Buildings*
Task 23	*Optimization of Solar Energy Use in Large Buildings*
Task 22	*Building Energy Analysis Tools*
Task 24	*Solar Procurement*
Task 25	*Solar Assisted Air Conditioning of Buildings*
Task 26	*Solar Combisystems*
Task 28	*Solar Sustainable Housing*
Task 27	*Performance of Solar Facade Components*
Task 29	*Solar Crop Drying*
Task 31	*Daylighting Buildings in the 21st Century*

Completed Working Groups:

CSHPSS, ISOLDE, Materials in Solar Thermal Collectors, and the Evaluation of Task 13 Houses

To find Solar Heating and Cooling Programme publications and learn more about the Programme visit www.iea-shc.org or contact the SHC Executive Secretary, Pamela Murphy, e-mail: pmurphy@MorseAssociatesInc.com.

Appendix 2 – Task 33/IV Solar Heat for Industrial Processes

Task 33/IV was a collaborative project of the Solar Heating and Cooling Program and the SolarPACES program of the International Energy Agency (IEA) in which 16 institutes and 11 companies from Australia, Austria, Germany, Italy, Spain, Portugal, Mexico were involved. The aim of the project was the development of solar thermal plants for industrial process heat.

To reach this goal, studies on the potential for this technology were carried out for the countries involved, medium-temperature collectors were developed for the production of process heat up to a temperature of 250°C, and solutions were sought to the problems of integrating the solar heat system into industrial processes.

In addition, demonstration projects were realised in cooperation with the solar industry.

Knowledge was transferred to industry via industry newsletters, by holding relevant conferences as well as through the following four booklets:

- Design Guidelines - Solar Space Heating of Factory Buildings
- Medium Temperature Collectors
- Pilot Plants - Solar Heat for Industrial Processes
- Potential for Solar Heat in Industrial Processes

Further information: www.iea-shc.org/task33

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