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Demonstration of three large scale solar process heat applications with different solar thermal collector technologies

Dirk Pietruschka^{a*}, Roberto Fedrizzi^b,
Francesco Orioli^c, Robert Söll^d, Reiner Stauss^e

^aZAFH-NET, Schellingstraße 24, 70174 Stuttgart, Germany,

^bEURAC, Viale Druso 1, 39100 Bolzano, Italy, ^cSOLTIGUA, via Roma 54, 47035 Gambettola FC, Italy,

^dS.O.L.I.D., Puchstrasse 85, 8020 Graz, Austria, ^eSOLERA GmbH, Fuhrmannstraße 9, 72351 Geislingen-Binsdorf, Germany

Abstract

The recently started European FP7 Project InSun aims to demonstrate the reliability and efficiency of three different collector technologies suitable for industrial process heat supply in different climatic regions. The technologies demonstrated reach from improved flat-plate collectors for supply temperatures of up to 95°C in moderate northern Europe climate to tracked concentrating collectors (linear Fresnel collectors and parabolic trough collectors) for supply temperatures between 160 and 250°C in hot and dry Mediterranean climate in Italy and Spain. The main problem for a fast market development if this young and innovative technology is that a reliable performance of the production process has still a much higher priority for the industrial companies than energy savings reached. In consequence often only proven and standardized solutions are considered with payback times not longer than 3 to 5 years. Apart from the cost issue which changes with changing energy prices and the industrialization of the production process of the collectors, the reliability of the technology needs to be demonstrated. Here, intelligent control strategies for the integration in different industrial processes and methods for automated performance observations are required. These topics are given a high priority within the InSun project team with ZAFH-NET as coordinating research partner, EURAC as scientific research partner and Soltigua, Solid and Solera as industrial partners. This paper reports on the preliminary design of the three installations in terms of system layout, foreseen operating conditions and the industrial processes involved.

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* Corresponding author. Tel.: +49 -711-8926-2674; fax: +49 -711-8926-2891.
E-mail address: dirk.pietruschka@hft-stuttgart.de.

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1. Introduction

According to the Renewable Heating and Cooling European Technology Platform [1], around 50% of the energy consumption in Europe is due to heating and cooling used for domestic, tertiary and industrial purposes. Looking at the industrial and commercial 2/3 of the final energy consumption is spent for heating applications. At present solar thermal systems are mainly used for domestic hot water preparation and to support space heating systems in residential buildings; these systems are nearly state of the art and widespread in the building sector. On the other hand, in the industrial and tertiary sector, the active use of solar heat is so far not very common. The potential analysis for solar heat in industrial processes within Task 33 of the IEA [2] showed that in most industrial processes low and medium temperature is needed: more than 60% of the industry uses process heat with temperatures below 250°C [3], [4].

The main problem faced by engineers when dealing with large solar thermal collectors fields delivering heat to industrial processes is that a reliable performance of the production process is still much more important for the manufacturers than energy savings reached [5]. Apart of the cost issue, which changes with varying energy prices and the industrialization of the production process of the collectors, the reliability of the technology needs to be largely demonstrated. As one important step towards this goal, within the recently started European FP7 Project InSun three different types of collector systems each with a peak power of more than 1 MW are applied to different industrial processes and compared: improved flat plate collectors for an Austrian meat factory for steam pre-heating up to 95°C, tracked concentrating Fresnel collectors for an Italian brick drying factory at 200°C and parabolic trough collectors for milk powder production at 185°C in Spain. Each of these applications offers a high replication potential. The main aim of ‘InSun’ is to demonstrate the reliability and quality of large scale solar thermal systems for different types of industrial process heat applications on medium and higher temperature levels. Missing standards especially for concentrating collectors and the large uncertainty of system integration costs are the main bottlenecks for a fast system deployment in the industrial sector. Therefore, the project also aims to give a significant input to the standardization process in terms of construction, integration and dimensioning of this young and innovative technology.

Research tasks focus on the analysis and optimization of the integration process of the solar systems into the industrial processes and on the combined performance of the solar systems together with the industrial processes involved. To increase the reliability of large scale solar thermal systems covering a high fraction of the process heat (>20%) a permanent and automated monitoring system is needed. Therefore, internet based monitoring and analysis tools will be developed. These prototypes will be implemented in the demonstration systems and combined with innovative simulation based fault detection and predictive control tools.

Nomenclature

InSun Industrial Process Heat by Solar Collectors, FP 7 EU-Project, www.fp7-insun.eu

2. The InSun demonstration projects

The InSun project three demonstration partners are involved, BERGER Austria, Laterizi Gambettola SRL in Italy (SOLTIGUA) and Lacteas Cobreras in Spain. Fleischwaren Berger GmbH (BERGER) is a large meat and sausages producer in Austria with a daily production of 80 to 90 t final products. For Berger SOLID will install 1200 m² of their optimised flat plate collectors for feed water preheating of a steam generation process (95°C) and for heat supply of washing processes at lower temperatures. SOLTIGUA is the brand of Laterizi Gambettola SRL which are historically active in the construction business, especially in manufacturing hollow bricks, which are sold all over Italy. The company uses the brand “SOLTIGUA” for their activities in renewable energies, especially in designing and manufacturing concentrating collectors for industrial processes. They have developed parabolic trough and Fresnel collectors. Apart from this Laterizi Gambettola SRL still has a brick production with a production capacity of 100.000 tons/year. In the production process a huge amount of energy is required for the drying and burning process. Within InSun SOLTIGUA will install 2640 m² of Fresnel collectors on the roof of the brick fabrication for direct steam generation to support the brick drying process at temperatures of 180°C. Lacteas Cobreras S.A. (LACO) is a well known company in Spain with over 20 years’ experience within the dairy industry. In their dairy they produce apart from other milk products also milk powder. For the milk drying process a huge amount of heating energy at high temperature level 185°C hot air is required. The air is heated through a water steam to air heat exchanger. To reduce their energy gas consumption LACO plans to install 2040 m² of parabolic trough collectors provided by SOLERA supporting the milk drying process. All mentioned solar process heat demonstration projects have a huge replication potential in the food, chemical and other industries.

2.1. Demonstration site at BERGER

Fleischwaren Berger GmbH is a company located in Sieghartskirchen, Lower Austria with about 380 employees. The Production is approximately 80-90 tons of meat and sausage products per day.



Fig. 1. Production site at Berger Fleischwaren GmbH

Solar field details: For the processing of the delivered feed stock / raw material coming from the abattoirs, BERGER plans to install together with SOLID solar flat plate collectors with an overall area of ca. 1,122.5 m² on the south oriented roof of one production hall.. The produced thermal energy shall be mainly used for feed water preheating for steam boiler and the surplus heat shall be used for increasing the supply temperature within the heating water system up to 60°C. The feed water of the vapor vessel shall be preheated from approx. 40°C (the fresh water can be preheated by waste heat of compression chiller) up to 95°C. The steam is internally required for process heating – specifically for ham cooking. The hot water is required for drying the air conditioning systems – specifically in the climatic chamber and the maturation room for production of long-lasting sausages. The implementations at Berger concentrate on centralized water and steam production facilities that can be found in almost any industrial production site that uses thermal energy. Therefore, the system analyzed at Berger can be easily transferred to other sites and offers a high replication potential.

Expected energy yield and CO₂-savings: The heating capacity of the 1.125 m² solar collector field is approximately 650kW. The solar system is expected to deliver 520 MWh per year heating energy to the production process, which corresponds to a high specific collector yield of 460 kWh/m²a. This will reduce the heating oil demand of Berger by about 100,000 liters per year and reduces the CO₂ emissions by approximately 298 tons per year.

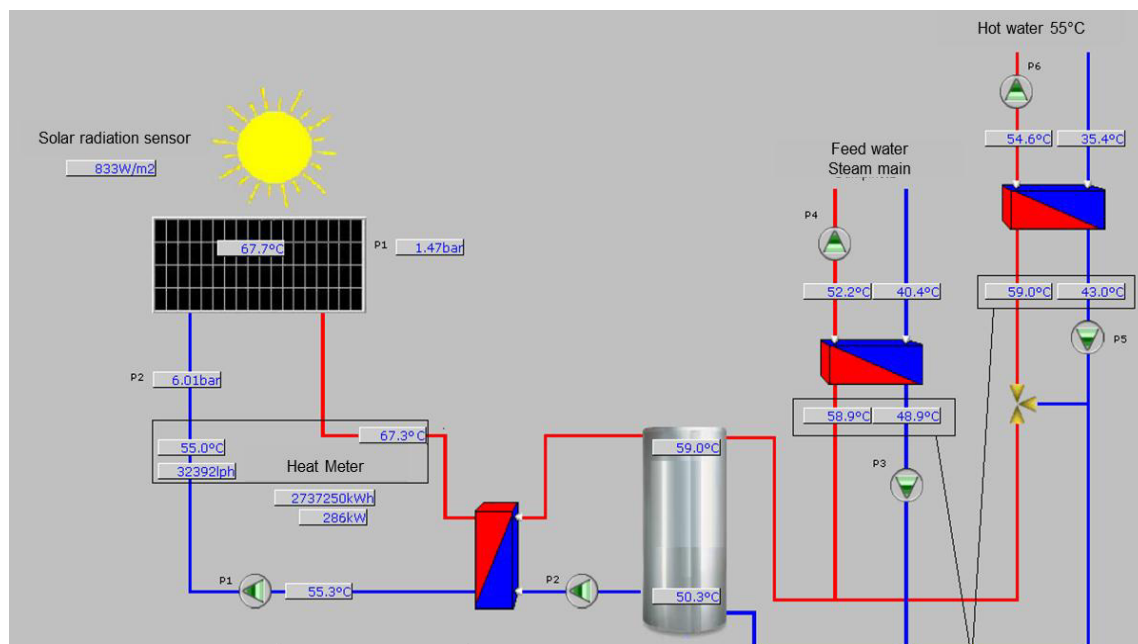


Fig. 2. Simplified hydraulic scheme of the planned solar system installation at Berger Fleischwaren GmbH

2.2. Demonstration site at Laterizi Gambettola SRL (SOLTIGUA)

The company Laterizi Gambettola SRL located in Gambettola, Italy, manufactures several types of clay brick, including highly insulating hollow clay blocks for external walls of buildings. . The manufacturing process involves a number of operations where heat is required, from brick extrusion, where hot water/steam is used to increase the raw material ductility, to wet brick drying and brick cooking.



Fig. 3. Production site at Laterizi Gambettola SRL (SOLTIGUA)

The Production process: The raw material is first processed and mixed, then it is extruded and the wet bricks go into the dryers. The total average consumption of the dryers is 2.2 MW at temperature levels of 200 to 260°C. Afterwards, the dry products are positioned on the kiln chariots and are then fired in the kiln. The kiln typically works 24 hours for 7 days per week and is shut off only for yearly maintenance. In the kiln a temperature of more than 900°C must be reached in order to complete the firing of the clay bricks. The high temperature is obtained with gas burners, which heat the air directly in the oven. The average thermal power consumption is roughly 4.5 MW. Total energy consumption on a typical year is around 41.8 GWh, 70% of which are used in the kiln and 30% in the dryers.

Solar field details: Fresnel collectors with a 2,640m² field size will be used to reach a total planned capacity of 1.2 MW at a steam outlet temperature of 180°C. Steam will be produced by two collectors' fields working in parallel, both directly (Direct Steam Generation) and indirectly (by a thermal oil solar circuit). In this way the two techniques will be compared and strong/weak points will be highlighted. The solar integration will take place mostly with a steam to air heat exchanger, by increasing up to 160°C the temperature of the ambient air used in the dryer, which will allow for more efficient operation and therefore for energy savings.

Expected energy yield and CO₂-savings: The heating capacity of the 2,640 m² solar collector field is 1,264 kW. The solar system working at 200/240°C is expected to deliver 1,200 MWh per year heating energy to the production process, which corresponds to a high specific collector yield of 450 kWh/m²a. This will reduce the gas demand of Laterizi Gambettola SRL by about 140,000 m³ per year and reduces the CO₂ emissions by approximately 340 tons per year.

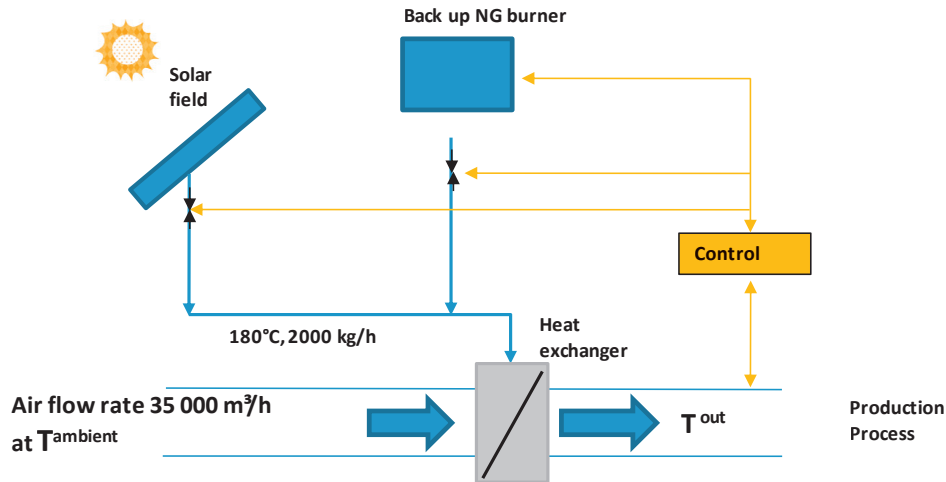


Fig. 4. Layout of the solar heat implementation at SOLTIGUA Italy

2.3. Demonstration site at Lácteos Cobreros S. A.

Lacteos Cobreros S.A. is a company with over 20 years' experience within the dairy and the transport industry (own transport fleet) and it is located in Castrogonzalo, Spain. The company has 45 employees.



Fig. 5. Production site at Lácteos Cobreros S. A. (Picture right: milk drying cyclone)

The production plant has enough capacity to cover all needs required by the cheese and dairy manufacturers. The production volume is over 4,000,000 liters of milk per month. Produced products are different kind of cheese (goat, sheep) in different versions and different kind of milk products (powder milk, concentrated milk, UHT goat milk and milk in bulk).

The production process: The milk is brought by trucks and stored in 50 000l storage barrel. Afterwards it is pre treated and split for various milk products. Inside the dryer is an atomizer, which is heated with the hot air (185 °C) provided by a steam-air heat exchanger. The quantity of the dried milk is

2,000 liter milk per hour. The highest energy consumption is required for the milk drying process with approximately a gas consumption of 35,000 kWh per day. The continuous process has permanent thermal power demand of approximately 1.5 MW for 24 hours a day. The following schematic shows the production and main flows.

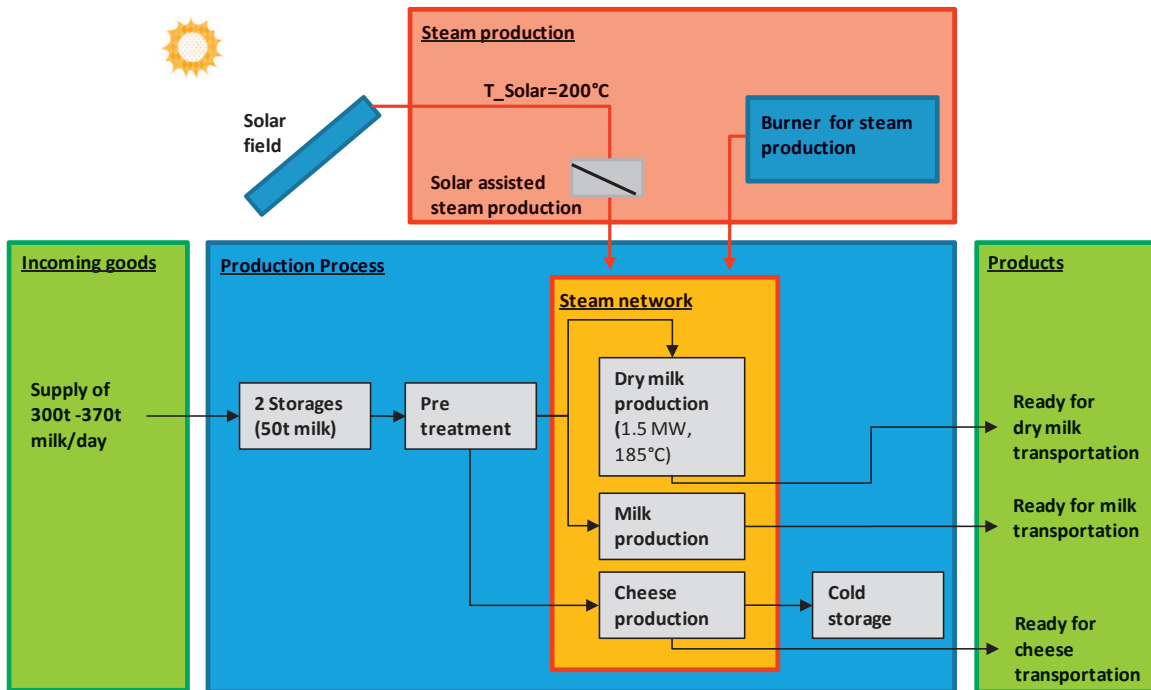


Fig. 6. Solar assisted steam generation at Lácteas, Spain

Solar field details: The planned solar field will be installed on some larger surrounding ground area of the property of Lácteas. The parabolic trough collectors with 2,040 m² total collector area will be operated with thermo oil at approximately 200°C collector outlet temperature. The hot thermo oil will be fed in an indirect steam generator to supply steam to the existing steam network supplying the steam to air heat exchanger heating up the drying air to 185°C. In times without milk drying the heat is fed into the steam network to supply heat for milk pasteurization, for washing processes and washing machines.

Expected energy yield and CO₂-savings: The heating capacity of the 2,040 m² solar collector field is 1 MW. The expected heating energy yield is approximately 1,064 MWh/year, which corresponds to a specific collector yield of 520 kWh/m²a. This will reduce the gas demand of Lácteas by about 120.000 m³ per year and reduces the CO₂ emissions by approx. 290 tons per year.

3. Simulation based fault detection and control optimization

A reliable and stable heat supply for the production processes involved has the highest priority for most industrial partners. As solar heating systems are not yet widely regarded as a reliable heating energy source the application of this technology often fails even before cost issues are discussed. To change this negative view, best practice demonstration projects are essential. However, a constant monitoring

including a permanent automated system observation including fault detection methods can also help to significantly increase the trust in the reliability of this young technology. Therefore, one main research task within InSun will be on the development and implementation of simulation based performance observation and fault detection methods. For larger solar fractions also simulation based predictive control tools are developed and tested. Internet based monitoring systems with central data collection and handling like the “ipsolar” software of SOLID are already applied by most of the larger collector and system providers and will build the basis for the application of such innovative methods as central server applications.

- **Online simulations for automated fault detection**

For the solar collector systems of the three demonstration sites dynamic simulation models are developed and used for automated system observation and fault detection. For this purpose, web access to the data acquisition systems is guaranteed by the demonstration partners. The principle of simulation based system performance observation is shown in Fig. 4Fig.

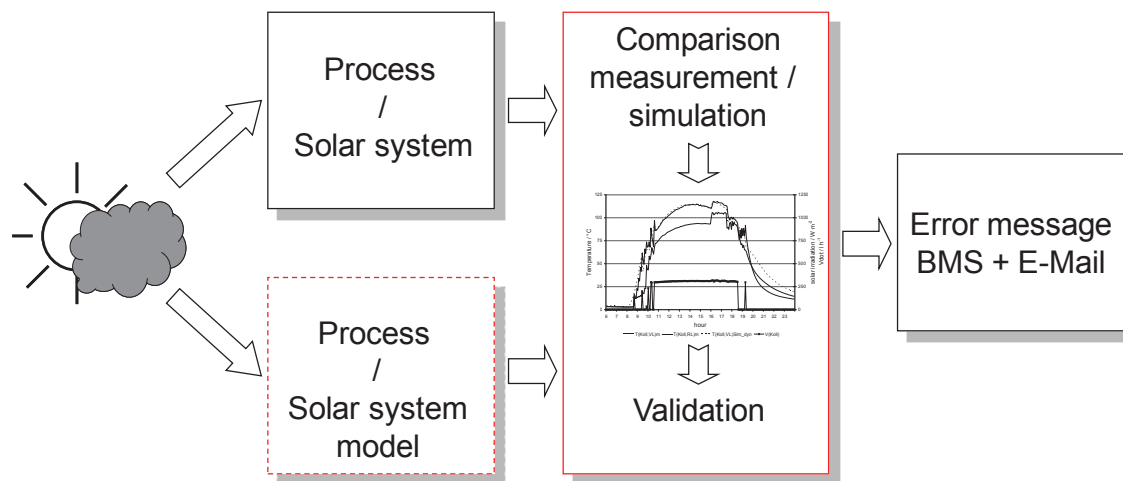


Fig. 7. Principle of a simulation based system performance observation

- **Simulation based predictive control**

If in future larger solar fractions (>20%) are reached, predictive control optimization tools using weather forecast data can be helpful to control the processes in order to maximize the solar contribution and to avoid stagnations in the large collector fields. Therefore, within InSun, zafh.net will test their simulation based predictive control methods on the demonstration plant of BERGER in Austria in cooperation with SOLID. The principle of this method is to control the processes according to the expected heating energy supply of the solar system which is predictable through the application of weather forecast data and the developed simulation models. The principle of the predictive control is shown in Fig. 5.

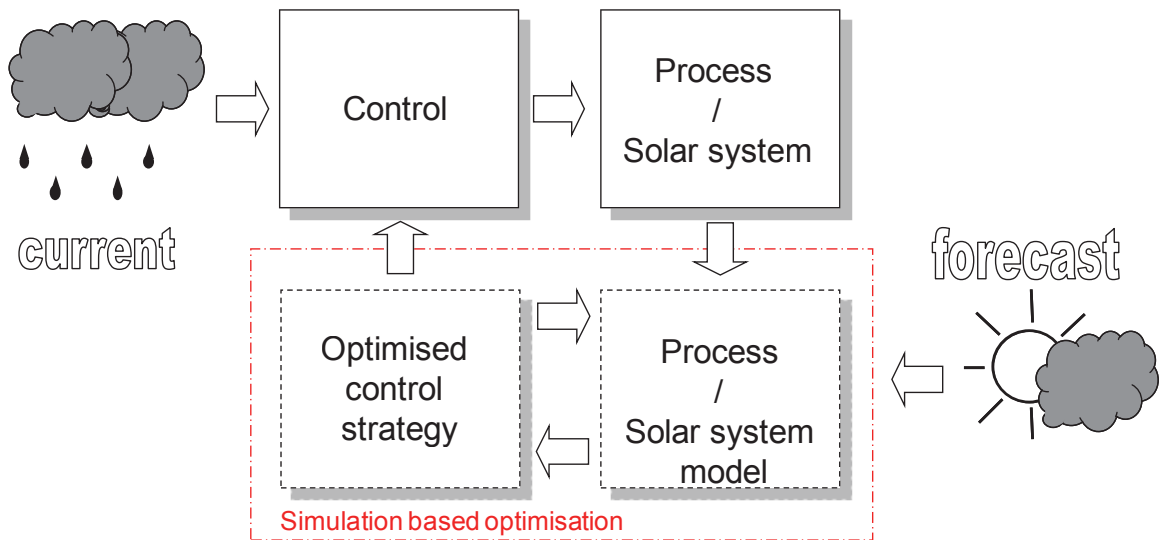


Fig. 8. Principle of simulation based predictive control optimization

4. Conclusions

A detailed analysis of the production processes is important to highlight on one hand the potentials for energy savings through internal heat recovery and through changes in the heat supply of some of the production processes involved. On the other hand, the process analysis delivers detailed load profiles of the different heat sinks, which are extremely important for the control design and the size of heat storages of the solar system. However, also changes in the production could help to increase the solar energy yield but are often extremely difficult to implement. Within InSun within a first intensive analysis phase the production processes of all three demonstration sites are analyzed in detail. This phase will be completed by end of 2012 and will help to improve the solar system design and the integration into the production processes involved. The first complete solar collector systems will be installed between end of 2012 and mid of 2013. Therefore, first monitoring data will be available starting from 2013 and will be published on the project web page (www.fp7-insun.eu). The development of simulation based automated performance observation and predictive control tools aim to increase the reliability and performance of large scale solar process heat application. Within InSun the potential of such tools will be demonstrated.

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References

- [1] RHC-ETP, “Common vision for the Renewable Heating and Cooling Sector in Europe”, public report, 2011.
- [2] C. Vannoni, R. Battisti, S. Drigo: “Potential for solar heat in industrial processes” prepared within Task 33 of the IEA-SHC programme and Task IV of the IEA SolarPACES programme, published by CIEMAT, 2008.
- [3] Feasibility assessment of Solar Process Heat Applications. C.Lauterbach, S.J.Rad, B. Schmitt, K. Vajen. Kassel : ISES Solar World Conference 2011, 2011.
- [4] Kalogirou, Soteris A. Solar Energy Engineering Processes and Systems. s.l. : Elsevier Inc., 2009.
- [5] Barriers to Solar Process Heat Applications. C. Faber, A. anthrakidis, M. Lanz, M. Rusack, F. Weis, M. Adam, S. Schramm. Kassel : ISES Solar World Conference 2011, 2011.