The Potential of Solar Process Heating in the Chemical Sector of Jordan

Martin Haagen, Dr. Mahmoud Al Najami, Jafar Al-Saqa, Lisa Willwerth

Abstract - Industry in Jordan accounts for approximately 20% of the final energy demand while around 60% of this industrial energy consumption is used for process heating. Renewable energy, especially solar, can contribute significantly to reduce the energy costs of Jordan industry, also in the chemical sector. With the first solar steam generation plant at RAM Pharma being in operation for more than 2 years also the technological feasibility has been proven in Jordan. To foster the widespread application of solar process heating in the chemical industry in Jordan a better understanding of the sector and its processes is needed. This paper (i) reviews the status of solar process heating, (ii) assesses the chemical sector in Jordan in general to identify key sub-sectors and (iii) examines a specific industry for its application potential of solar process heating.

Keywords: solar heat for industrial processes, Jordan, Chemical sector, energy, process heating

I. Introduction

On an aggregated level more than 60% of the industrial energy demand is thermal, mainly process heating, whereas electricity accounts only for around 40%. Thus, to achieve a climate and environmentally friendly production the industrial heat demand has to be addressed. In sun rich countries Solar Heat for Industrial Processes (SHIP) can contribute significantly to reduce the fuel consumption for industrial process heating.

There are various temperature classifications for industrial process heat demand. A reasonable approach for SHIP differentiates three ranges, referring to the technical limitations of solar thermal technologies, with low (< 100°C; non-concentrating collectors), medium (100° - 400°C; linear concentrating collectors) and high temperatures (> 400°C, point concentrating systems).

Martin Haagen, Industrial Solar GmbH, 79110 Freiburg, Germany; Tel.: +49 761 7671110; martin.haagen@industrial-solar.de

Dr. Mahmoud Al-Najami, RAM Pharma, 211-King Abdullah II Industrial Estate Sahab 11512, Tel: +962 64023950; info@rampharma.com

Jafar Al Saqa, RAM Pharma, 211-King Abdullah II Industrial Estate Sahab 11512, Tel: +962 64023950; info@rampharma.com

Lisa Willwerth, German Aerospace Center (DLR), 51147 Köln, Germany; Tel.: +49 2203 6012438; lisa.willwerth@dlr.de

So far only for the first two segments SHIP has been commercially applied. Concentrating solar thermal collectors use large reflective surfaces to concentrate the sunlight on an absorber where high temperatures are achieved. Due to the concentration only the direct sunlight can be used whereas non-concentrating technologies can use both, direct and diffuse irradiation.

As for the industry especially the medium temperature range is interesting and as Jordan also has very high direct irradiation this work focuses on the application of concentrating solar thermal technologies. A first SHIP system was already installed in Jordan at RAM pharmaceuticals in 2015.

The efficient integration of heat in the industrial processes is a major challenge when designing SHIP installations. Figure 1 below shows the major approaches whereas a comprehensive and detailed description can be found in [1].

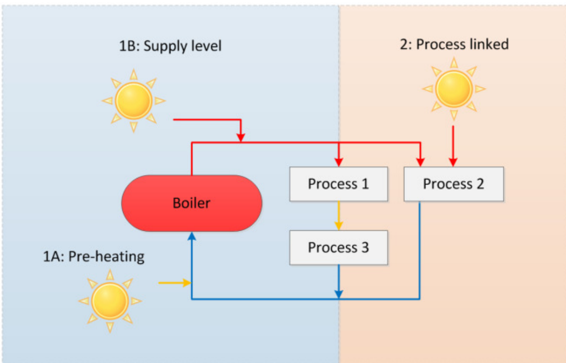

Figure 1: Integration options for solar heat in industrial processes

As mentioned above, temperatures of up to 400°C can be provided with commercially available linear concentrating collector technologies. While higher temperatures can be achieved with point-focusing system the technology is so far not commercially applied for industrial process heating. Still, there is research going on how also the high temperature section can be covered with solar thermal technologies.

1.1 SHIP experience in Jordan

Jordan was one of the first countries where solar steam generation was commercially used for an industrial application. In 2015 RAM Pharma installed linear concentrating Fresnel collectors with an aperture area of 400 m² and a thermal peak capacity of 223 kW.

Figure 2: Fresnel collector at RAM Pharma

The collector operates in Direct Steam Generation (DSG) mode, which means it evaporates water and feeds a two phase water-steam-mix to a steam drum. The steam drum separates the phases and acts as a buffer storage. While the collector field operates at variable pressures depending on the solar irradiation, steam is released to the consumer at their specific operation parameters at 6 bar_g. This is possible due to the buffer storage, which has a capacity of up to 14 bar_g. The design of the plant is described in [2].

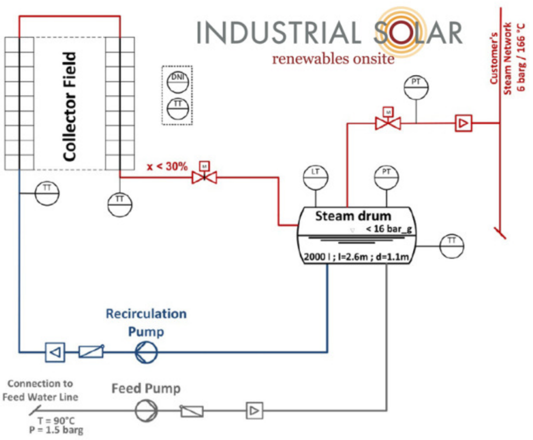

Figure 3: Simplified P&ID

The operation of the RAM Pharma process steam plant has been monitored in the SolSteam project [3]. A safe operation and stable steam supply was demonstrated. As can be seen from the following chart during periods of sunshine the collector provides an even more stable pressure within the steam supply line then the conventional fuel fired boiler during non-sunshine hours (see 06:00 to 08:00). This proves that the stability and reliability of the heat supply is actually improved through the solar steam generator. Also there is no negative interference between the steam supply of both systems. In periods of low solar irradiation e.g. clouds, the fossil boiler takes over steam supply without a break.

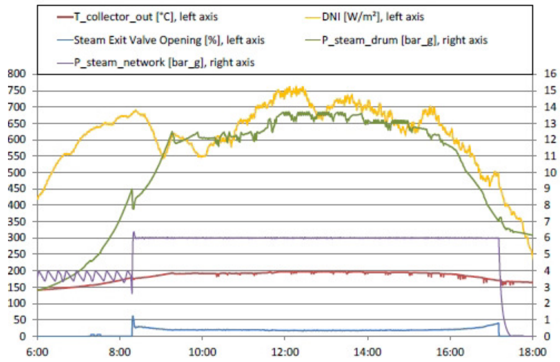

Figure 4: Collector performance on 19.06.2015

II. Energy consumption in the Jordanian chemical sector

The chemical sector is commonly identified as one of the sectors with the great potential for SHIP due to its large energy consumption in the low and medium temperature segment [4]. For Jordan the chemical sector, including mining and production of bulk chemical commodities as well as fertilizer production is also one of the major sectors with potash and phosphate derivatives, nitrogenous fertilizers, chlorides, bromines and Sulphur derivatives as the most important products. Unfortunately there is neither specific data on the energy consumption within the chemical sector of Jordan available nor are there specific targets for the use of renewable energy for industrial process heating.

2.1 Top-down approach for SHIP potential

For estimating the SHIP potential in a specific country and / or sector there are two major approaches. First, the macro-approach deducing the potential from aggregated energy data on the national level. Second, the micro-approach based on individual assessments of specific industrial companies. For the first the national data quality and availability is insufficient, for the second detailed company assessments are needed and data is commonly classified as confidential. Thus, only a very rough estimation can be made. Hiary [5] extrapolated data from a non-representative survey and found the total heat demand in the chemical sector in Jordan to be around 340 GWh. However, this number has to be questioned as (i) the survey was not representative and the chemical sector in Jordan has some very large energy consuming companies, (ii) classification of sectors was not following standardized terms; e.g. pharmaceuticals, plastics and rubber was listed separately. Thus, more work is needed to get a better understanding on the exact potential. For the time being the most interesting sectors can be identified in respect to their national importance namely potash, phosphate and bromine processing (all with high thermal

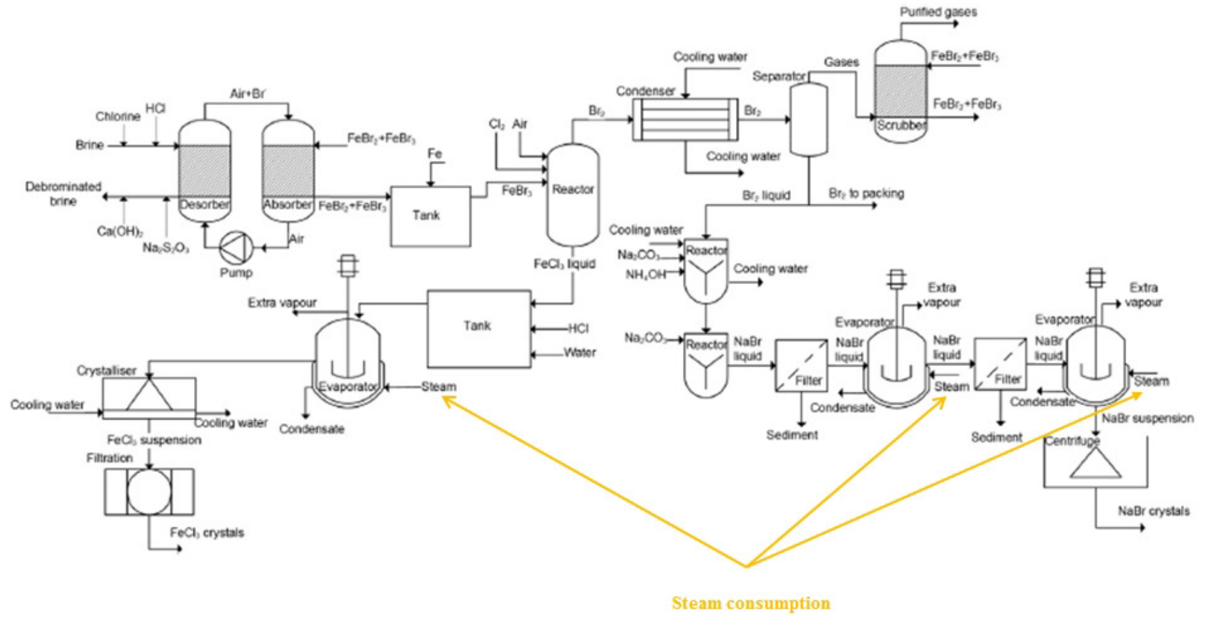

Figure 5: Bromine production flow chart [6], highlighting by the authors

energy demand in the medium temperature range) as well as fertilizer manufacturing. In addition, for smaller industries the manufacturing of resins, detergents or chlorine products offer also interesting opportunities to apply SHIP in Jordan.

2.2 Example of Bromine processing as a bottom-up approach

Within the scope of this paper no site assessments of individual chemical factories were undertaken due to limited resources and the challenge of using site specific date while respecting the confidentiality of the information. Nevertheless, since Jordan is one of the major producers of bromine worldwide, due to the Dead Sea, this application can be used as an example. Figure 5 shows the principal flowsheet of bromine production based on the assessment of a bromine facility in Ukraine. Medium pressure steam is mainly used at the various evaporators, (highlighted) and is commonly provided through fuel fired steam boilers.

At the same time, various exothermic processes within the facility allow waste heat recovery at lower temperatures. Reference [7] found a specific steam consumption of around 16 -20 tons per ton of bromine produced. The production capacity of Jordan Bromine industry exceeds 200,000 tons per year highlighting the large thermal energy demand which equals to an energy consumption of around 200 ktoe per year. With a solar fraction (solar provided heat / total heat consumed) of 25% solar process heating could already lower the specific fuel consumption by 50 ktoe per annum – within the bromine industry alone.

III. Conclusions and outlook

Industrial process heating is responsible for a large share of the total energy consumption and exceeds the power production in industry. Despite its importance it is commonly insufficient addressed by both private and public sector. The chemical sector has a very high thermal energy demand and accordingly a huge SHIP potential, especially in the segment of 100-400°C. In several of the chemical sub-sectors being present in Jordan SHIP there is also high energy demand in the medium temperature range. Thus, Jordan is well positioned to reduce its fuel consumption in the chemical sector through SHIP as (i) the country enjoys very high direct solar irradiation, (ii) there are already commercial project under operation and (iii) due to the high fuel prices SHIP is already financially interesting. To realize this potential better aggregated energy consumption data of the chemical sector is needed to better identify key sub-sectors. Moreover, also within individual facilities better data collection eases system design. In addition, it is helpful if clear targets are set by the policy makers and the necessary means are provided to achieve them.

Also R&D institutions play an important role as they can analyze and optimize energy consumption and integration opportunities for SHIP. For the more long term view important scientific questions are related to the use of point focusing systems, addressing temperature of 400 – 1,000°C, as well as for the use of electric heating based on solar photovoltaics.

ACKNOWLEDGMENTS

The monitoring of the plant from 2015 to 2017 within the frame of the project “SolSteam” is being funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) on the basis of a decision by the German Bundestag.

References

[1] B. Muster et. al., *Integration Guideline,* IEA SHC Task 49. 2015

[2] M. Berger et. al., *Solar Process Steam for a Pharmaceutical Company in Jordan*, SolarPaces 2015, AIP Conference Proceedings 1734, 100001 (2016).

[3] D. Krüger et. al., *Experiences with industrial solar process steam generation in Jordan*, SolarPaces 2016, AIP Conference Proceedings 1850, 180003 (2017).

[4] C. Lauterbach, *Potential, system analysis and preliminary design of low-temperature solar process heat systems,* Kassel University Press, Kassel 2014

[5] M. Hiary, *The Potential of Solar Process Heat in Jordan,* 2014

[6] S. Boldyryev, and P.S. Varbanov, *Low potential heat utilization of bromine plant via integration on process and Total Site levels,* Energy, vol. 90, No. 1, October 2015, pp. 47-55

[7] A. S. Mehta, *Ideas for process improvement emanating from audit of a bromine plant in the Greater Rann of Kutch,* Indian Journal of Chemical Technology, vol. 10, November 2003, pp. 644-653