Potential assessment in Mexico for solar process heat applications in food and textile industries

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Resumen

Industrial sector of Mexico is the second energy consumer, approximately 28% of the national consumption, according to the National Balance of Energy. A potential study carried out within the micro and small food and textile industries has established that they are using 68% of the total energy consumption as thermal energy, most supplied by liquefied gas and followed by natural gas and diesel. The processes use water and low pressure steam mainly at temperatures from 60 to 180 °C. In this context, solar concentrators, especially parabolic troughs, could give an important portion of the required thermal energy. The introduction in the country of a strategy change in the use of the energy is a formidable challenge. Beginning in the country with the erection of small parabolic trough plants in such industries could allow a technical and economic evolution of the technology and the benefits could be presented almost immediately. The methodology for the potential assessment for solar process heat applications in food and textile industries was based on the statistics from the National Balance of Energy, the National Directory of Economic Units and together with questionnaires, phone calls, workshops and in some cases personal interviews. According to such considerations, three scenarios were established and will be described within this paper in terms of the potential of the parabolic trough technology applied in the appropriated industries.
Keywords: Solar concentrators; Parabolic trough collectors; Industrial Process heat; Investment costs

Introduction

Mexico’s economy is strongly dependent on the energy sector. Abundant oil not only serves as fuel to power the economy, but also as a source of income for investment in social and economic development. However, the current energy policy of the country emphasizes the need for a more diversified energy portfolio, as a means to enhance future energy security and to avoid further environmental degradation. An interesting area where the energy is consumed at high levels is the industry. Mexico’s industrial sector is the second energy consumer, approximately 28% of the national consumption, according to the National Balance of Energy (2009) [1,2]. The industry of the transformation normally uses thermal energy inside its process; the conventional path to obtain such energy is commonly burning fossil fuels. At the international context potential studies performed in the past have identified that approximately between a 40 and 60% of that energy is dedicated for process heat and 30% of that heat is used to temperatures between 80 and 250 ºC. Particularly in Mexico a potential study carried out within the micro and small food and textile industries has established that they are using 68% of the total energy consumption as thermal energy, most supplied by liquefied gas and followed by natural gas and diesel [3]. The processes use water and low pressure steam mainly and the temperature requirements range from 60 to 180 ºC. The increase in the price and the eventual depletion of the fossil fuels outline the necessity to look for other forms of obtaining energy. An alternative form to avoid environmental degradation and to postpone the use of the fossil fuels is the use of the solar energy and particularly the concentrated solar energy. At the present day the concentrating solar technologies present an excellent potential to the electric power production and industrial process heat applications [4]. Among solar thermal concentrating technologies, parabolic trough is one of the most promising for both electrical and process heat production. In this context, the parabolic troughs, could give an important portion of the required thermal energy. In an industrial facility the parabolic trough solar system coupled to the conventional system of heat supply could make in several points like: direct joining to a specific process or the warm-up of water and even more steam generation. The introduction in the country of a strategy change in the use of the energy is a formidable challenge. Beginning in the country with the construction of small parabolic trough plants in such industries could allow a technical and economic maturation of the technology and the benefits could be presented almost immediately. The results documented in this paper could facilitate the application of solar thermal energy in the industrial sector.
Parabolic Trough Technology

At the present time Concentrating Solar Technologies (CST) are the most efficient and cost-effective way to generate electricity from the sun with a high potential of excellent application [4]. CST technologies are usually classified in three different concepts: towers, dishes and troughs. Tower system uses numerous two axis tracking mirrors called heliostats to concentrate sunlight onto a central receiver on the top of a tower. Dish system use parabolic dish concentrator to concentrate the light of the sun on a focal zone, reaching the highest concentration ratios, where a Stirling engine can be placed to generate electricity. Trough system use parabolic trough-shaped mirror reflectors linearly concentrate sunlight onto receiver tubes, heating a thermal transfer fluid which is then used to produce superheated steam and then used to generate electricity in a conventional turbine steam. Several hundreds of megawatts of CST capacity could be brought on-line within a few years and make an important contribution to the energy needs of the world [4]. Even though, the current tendencies of the CST present an excellent potential to the electric power production could be very interesting option to the process heat for industrial uses. Among solar thermal concentrating technologies, parabolic trough technology is one of the most promising in such sense. Parabolic troughs are made by bending a sheet of reflective material into a parabolic shape, see Fig. 1. A metal tube covered with a glass tube to reduce heat losses is placed along the focal line of the parabola. The solar energy is absorbed in a working fluid (heat-transfer oil, water or steam), which is then piped to a central location to produce electricity or simply heat to be used in an industrial process. Because the parabolic trough will reflect only direct-beam sunlight, it uses single-axis tracking system to keep it facing the sun. The Parabolic trough is the most mature technology to generate heat at temperatures up to 400 °C for solar thermal electricity or process heat applications. For testing purposes and for demonstration of the parabolic trough technology several prototypes have been developed by the Instituto de Investigaciones Electricas [5]. Each prototype includes a parabolic trough concentrator, mounted on a one-axis tracking structure. Anodized aluminum sheet with a solar reflectivity of 90% was used as reflective material. These prototypes were installed in different places and provided a lot information concerning to the operation and maintenance activities and the identification and establishment of mechanisms of collaboration with national industry to involve them in the technological development of parabolic trough components.
Solar Resource

For the thermal energy generation the fuel becomes an important factor and it determines the economy of the plant. The cost of the different fossil fuels constitutes a fundamental factor for the taking of decision on the localization of a conventional plant, in case of the parabolic trough system the “fuel” is free of cost. Solar energy in Mexico is an abundant resource distributed over the national territory. In general the knowledge of the renewable energy resources in the country is scarce, imprecise and of little benefit to promote their massive application, such is the case of solar radiation. However, many efforts have been carried out by different institutions in order to have better databases based on models that use monthly global horizontal radiation values (10 year average) and generating stochastically hourly Direct Normal Irradiance (DNI). The Instituto de Investigaciones Electricas using a Geographical Information System (GIS) prepared a database generated from most advanced modeling tools with input data from covering sky of satellite images [6]. Detailed exploration of the country to identify state by state the levels of average DNI (kWh/m²-year) was carried out. The analysis showed areas in the country with DNI levels between 2157 and 2800 kWh/m²-year at the northwest, central north and Yucatan peninsula.

Industrial Sector

The Mexican industrial sector of the country is the second energy consumer according to the National Balance of Energy 2009 [1]. The Production of Primary Energy was of 9853 PJ where the industrial sector consumed 28% of that energy being equivalent to 1284 PJ and it includes all the productive processes. The most intensive industrial branches in their majority correspond to the big industries of the country. In the Table 1 the type and quantity of the fuel consumed by the different industries are shown. The group of industries that compose the most intensive consumes near 60% (768PJ) of the total consumption of the industry.

The item “other branches” consumed 40% (515 PJ) of the energy of the sector and corresponds to the less intensive industries as: food, textile, wood, leather, ceramic products, among others. Of the 515 PJ, 49.9% corresponded to demanded electricity by the industries (257 PJ), this electricity later on is transformed in great measure to mechanical energy for specific uses and inclusive in many cases to thermal energy. The rest (258 PJ) corresponds to the consumption of fuel used by the less intensive industry inside their productive processes and associates. These processes include thermal energy, electricity autogeneración and fuels as inputs to the interior of their processes. The energy consumed by the industrial sector is based on the fossil fuels, with a marginal contribution of renewable energy (0.31 PJ) and its participation is located in the item of other branches.

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Trash of cane</th>
<th>Coal Coke</th>
<th>Oil Coke</th>
<th>Liquefied Gas</th>
<th>Diesel</th>
<th>Fuel oil</th>
<th>Dry gas</th>
<th>Electricity</th>
<th>Total</th>
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<tr>
<td>Total sector</td>
<td>5.49</td>
<td>87.32</td>
<td>40.81</td>
<td>129.44</td>
<td>39.49</td>
<td>51.75</td>
<td>84.07</td>
<td>478.7</td>
<td>365.77</td>
<td>1283.6</td>
</tr>
<tr>
<td>Intensive industry</td>
<td>5.42</td>
<td>83.99</td>
<td>40.81</td>
<td>96.22</td>
<td>6.81</td>
<td>29.79</td>
<td>58.24</td>
<td>338.37</td>
<td>108.43</td>
<td>768.08</td>
</tr>
<tr>
<td>%</td>
<td>98.72</td>
<td>96.19</td>
<td>100.00</td>
<td>74.34</td>
<td>17.24</td>
<td>57.57</td>
<td>69.28</td>
<td>70.69</td>
<td>29.64</td>
<td>59.84</td>
</tr>
<tr>
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<td>0.52</td>
<td>3.33</td>
<td>0.00</td>
<td>33.23</td>
<td>32.67</td>
<td>21.97</td>
<td>25.85</td>
<td>140.32</td>
<td>257.35</td>
<td>515.55</td>
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<tr>
<td>%</td>
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<td>3.81</td>
<td>0.00</td>
<td>25.67</td>
<td>82.73</td>
<td>42.45</td>
<td>30.75</td>
<td>29.31</td>
<td>70.36</td>
<td>40.16</td>
</tr>
</tbody>
</table>

Table 1. Energy consumption of the Mexican industrial sector, 2009 (PJ).
Methodology for the potential assessment

For this study only the potential is contemplated for the item other branches, see Table 1, where they are habitually classified the micro and small industry, excluding the intensive industry, generally with temperatures above the 300 °C. The methodology for the estimation of the potential for solar process heat applications in food and textile industries was based on the statistics from the National Balance of Energy published by the Energy Secretariat of Mexico, the National Directory of Economic Units issued by the National Institute of Statistics and Geography and together with questionnaires, phone calls, workshops and in some cases personal interviews with managers [3]. By means of statistics analysis and information gathered, three scenarios were established as follows:

- **Industrial theoretical potential**: potential in the whole less intensive industry that uses heat inside their productive processes considering that only 68% are using thermal energy. Also it is assumed that fuels used are: natural gas (9.2%), fuel oil (0.3%), diesel (2.5%) and liquified gas (87%), being excluded coal, trash cane, oil coke and oil coke. An average of DNI of 2000 kWh/m²-year is assumed and also an average efficiency of the parabolic trough of 50%.

- **Industrial technical potential**: potential in the less intensive industry that uses process heat but only considering micro and small industries of the food and textile branches (11505 micro and 5667 small industries). Other assumptions are similar to the theoretical potential, except that fuel used by these industries is liquified gas so that is the most popular (87%) at 15.8 USD/GJ.

- **Feasible technical potential**: potential in the less intensive industry that uses process heat, only considering micro and small industries of the food and textile branches, deduced from 50 answers received from contacted and strongly interested industries.

**Industrial theoretical potential**

This potential was estimated assuming that only 28.5 PJ of the energy industrial consumption which correspond to the less intensive branches could be used for the installation of solar concentrating parabolic trough technology, see Table 2. This assumption is based on the first approach of the introduction of small solar fields which are more appropriated so that solar concentrating parabolic trough plants would find application niches. It was also assumed that all industries possess portion of land available that would be covered with mirrors. Applying a yearly average value for solar radiation, a theoretical potential of around 6 million sq m of solar field area was obtained and investment of 1540 million USD, see Table 3. Nevertheless, these figures, although impressive, only proves that on the side demand, industries requiring thermal energy, land availability and the level of solar radiation (>2000 kWh/m²-year) are not limits to the generation of solar industrial process heat in Mexico.

**Industrial technical potential**

In this case all the micro and small industries (food and textile) were considered, assuming that they only consume liquefied gas (87% of the industries use this fuel) and 68% as thermal energy inside the processes where solar concentrating parabolic trough technology would substitute or simply backup the local boiler. In this scenario, the energy demand of 12.2 PJ (11505 micro and 5667 small) equivalent to useful energy of 2710 GWh per year could be covered by 2.7 million sq m of parabolic trough with investment about 650 million USD, see Table 4. These kind of industries usually invest in the purchase of fuel around of 153 million USD.

**Feasible Technical Potential**

In this scenario only micro and small industries of the food and textile
branches, deduced from 50 answers received from contacted and strongly interested industries were considered. Also is assumed that the companies would receive heat from solar energy (2920 hours of solar operation). Based on those considerations the following results were obtained. Total collection area of 75084 m² was obtained and the thermal power generated by the total solar field was 45051 kWt equivalents to 131.54 GWh/year. The total energy generated during the year would ascend to 0.47 PJ equivalents to 1.5 times of the energy consumed at the moment by the whole industry using as source the solar energy (0.31 PJ).

The total cost of investment for the installation of the systems would ascend to 17 million USD. The industries taken in account invest in fuel near 7.5 million USD per year being the liquified gas the fuel of more use. Based on the investment in solar equipment and annual payment in the purchase of fuel, the average period of simple capital recovery is approximately 2.3 years. It was not possible to really obtain a financial economic study because the companies were very cautious in the type of information that they provided.

**Conclusions**

In this paper the current situation of the Mexican energy sector was described. Also industries with more potential for implementing the parabolic trough technology were identified. Classification of industries of the country allowed an estimation of the market potential for solar process heat applications. An analysis based on the information published by the Mexican Energy Secretariat and other within the energy sector shows that the market potential for a segment of the industrial sector could be ascend to 0.47 PJ equivalent to 1.5 times of the energy consumed at the moment by the whole industry using as source the solar energy (0.31 PJ). At this segment the implementation of the parabolic trough technology could be through small installations running from several square meters to a hundred square meters useful thermal energy useful for productive activities. However, the
economics of the CST in general, is not yet attractive under the schemes currently prevailing in Mexico for the valuation of alternatives for energy generation. The perspective could change in the next years if it is possible to materialize projects that are under negotiation with the industry and actions supported by the government in terms of the regulatory framework so that renewables and especially solar energy have better opportunities for application.

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