Executive summary

Introduction

The use of solar concentrated energy in thermal applications has very little presence in Spain. In particular, the integration of solar thermal systems in district heating & cooling (DHC) networks is negligible. This study aims to demonstrate the viability of the solar concentrated energy in thermal applications, such as DHC networks. It can be an interesting solution in certain economic circumstances.

This report analyses the technical and economic feasibility of integrating a solar concentrated system in a DHC network. It has been chosen a reference network located in the region of Jaén (south of Spain). The study is performed by using public and available theoretical design data of the reference network, however it has been taken certain assumptions for those values that were not known.

Two different demands profiles have been assessed: a theoretical design demand that corresponds to the full capacity of the reference network, and a smaller initial demand adapted to the initial estimated network conditions.

This SDH reference network is a centralized system that supplies the heating (domestic hot water and heating) and cooling demands of a group of buildings (37.039 m^2) by biomass boilers and absorption chillers. This reference network has been chosen for several reasons:

- It has a favorable geographical location with significant direct solar irradiation.
- The possibility of simultaneously supplying the heating and cooling demands through solar energy.

The feasibility study also includes several dynamic simulations to analyze the performance of each proposed system to be integrated into the existing network. The results obtained are subjected to technical and economic criteria in order to select the optimal solution.

The procedure followed allows the optimization of the number of simulations to be carried out, as well as the identification of those solutions that are technically and economically feasible.

Methodology

The methodology involves the following steps:

1. Estimation of two different demand profiles to be supplied: a theoretical design demand that corresponds to the full capacity of the reference network, and a smaller initial demand adapted to the initial estimated network conditions. In both cases the demand is calculated by establishing certain previous hypotheses.

2. Selection of three different concentrated solar technologies and definition of their characteristics. Their technical parameters such as dimensions, efficiency, flow, etc. have been determined as an average value that represents each technology. They have been obtained from actual equipment data provided by some collectors manufacturers.

3. Design and implementation in a dynamic simulation program of the hydraulic system and the control system configuration of the plant, composed of the concentrated solar system integrated in the existing biomass system.

4. Determination of the variables that significantly influence the energetic performance of the facility. After assigning values to these variables and identifying all the possible combinations, there are 76 different solutions to be simulated. Energy efficiency of each of them is evaluated by analyzing solar fraction and solar energy production per m^2 variations.

5. The establishment of the technical feasibility criteria that allow the selection of the solutions that present the best energetic performance:

   - A minimum solar annual fraction of **15%.** Only those facilities with a significant energetic production are considered.

   - For each surface range, only are considered those facilities that, by increasing their accumulation ratio, increase their solar fraction at least **15%.**

   - For each accumulation ratio, only are considered those facilities that, by increasing their surface, decrease their production ratio less than **20%,** measured this loss with respect to the production peak value obtained for each accumulation ratio.

   After the simulations' results assessment, there are 14 installations that are technically feasible.

6. Economic analysis of the selected solutions through the comparison of the following cost effectiveness indicators: PB (Pay Back), IRR (Internal Return Rate), NPV (Net Present Value) and LCoHC (Levelized Cost of Heating/Cooling). This analysis is carried out from the point of view of two kinds of investors: end users and energy service companies (ESCOs).

7. The establishment of the economic criteria that allow the selection of the best technology solution:

   - PB < 15 years

   - IRR maximum

   - NPV > 0

8. Study of the selected solutions under various future economic scenarios such as fluctuations of biomass price, availability of grants and loans, etc. and assessment of their impact on the cost effectiveness indicators.

Results

The facilities that provide better technical and economic results according to the established criteria, and therefore presented as the best solutions are:

- For the design demand: an installation of **2.000 m^2** of linear Fresnel collectors (LFC) with a storage volume of **100 m^3**. It has a solar production of **891 kWh/m^2·year** and it provides a solar fraction of **34%**.
- For the current demand: an installation of **363 m^2** of parabolic through collectors (PCC) with a storage volume of **20 m^3**. It has a solar production of **963 kWh/m^2·year** and it provides a solar fraction of **41%**.

For the location of the solar field, it has been proposed an area that is adjacent to the building where the generation equipment is installed.

Some descriptive tables of the proposed location and the selected solutions are listed below.

<table>
<tr><th colspan="3">Proposed location for the solar collectors</th></tr>
<tr><td>Network location</td><td>Jaén</td><td rowspan="7"></td></tr>
<tr><td rowspan="2">Demand</td><td>Heating</td></tr>
<tr><td>Cooling</td></tr>
<tr><td>Installation type</td><td>Ground</td></tr>
<tr><td>Site</td><td>120 x 85 m area (10.200 m^2)</td></tr>
<tr><td>Image</td><td>Google Earth</td></tr>
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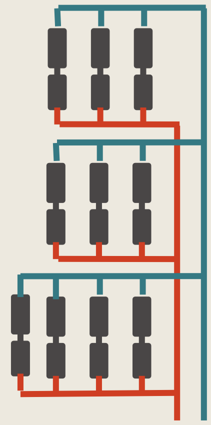
Table 1: Overview of the proposed location for the solar collectors.

Economic results of the selected solutions have been calculated under certain initial assumptions (biomass price index, solar heat price, etc.) and in the absence of funding or grants. Additionally, they are analysed under other circumstances obtaining cost effectiveness values significantly better than the initials.

The economic analysis also compares the solar energy generation cost, including the initial investment and all operating costs, only with the biomass fuel because in this case the solar system is integrated into an existing biomass plant. On the other hand, considering solar energy contribution in the design phase of a network could lead into a reduction in the installed power of the main facility. In that case, the comparison of the solar generation cost would be not only with the biomass price but also with all costs avoided by the solar system.

Linear Fresnel collectors solution – Design demand			
Collector type	Linear Fresnel		
Aperture area	2.000 m^2		
Land area	3.600 m^2		
Orientation	North-South		
Nº collectors	20		
Nº collectors in a battery	2		
Nº battery	10		
Network connexion	Parallel		
Hydraulic connexion	Horizontal	Solar fraction	34%
Accumulation volume	100 m^3	Production	1.782 MWh/year
Accumulation ratio	50 l/m^2	Production per m^2	891 kWh/m^2 year
End user Investment	896.341€	ESCO investment	746.951 €
Cost Effectiveness			
End user		**ESCO**	
Pay back	12 years	Pay back	11 years
IRR	6,7%	IRR	8,4%
VPN	258.817 €	VPN	372.384 €
LCoHC	53 €/MWh	LCoHC	41 €/MWh

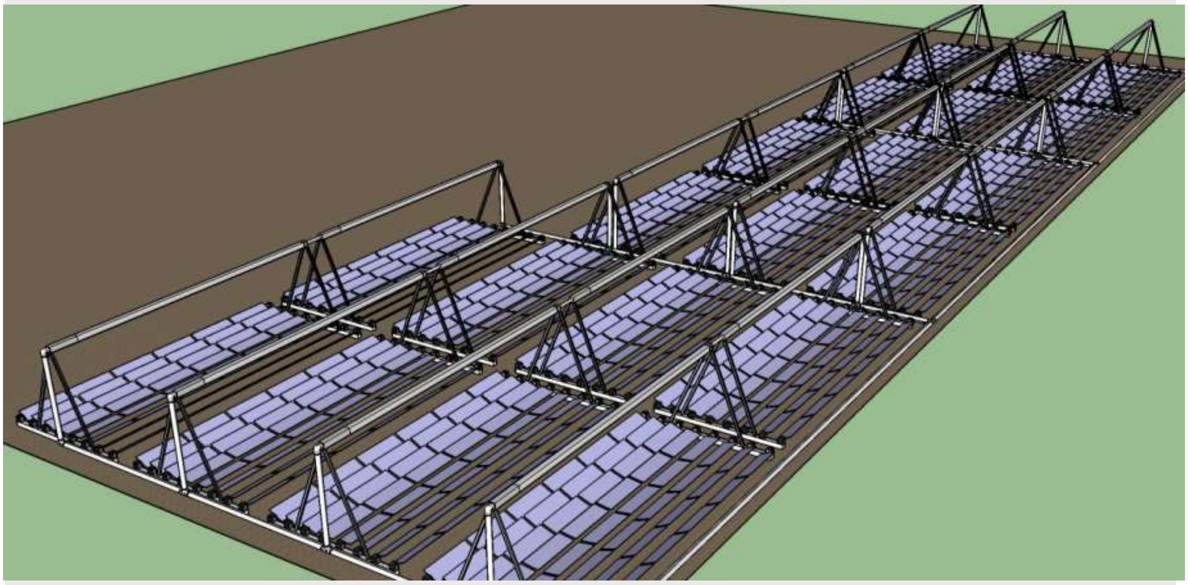
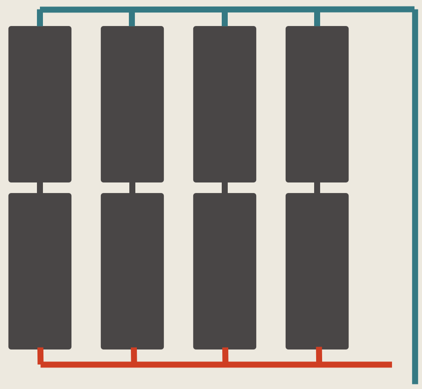


Table 2: Proposed linear Fresnel collectors solution. Design demand.

Parabolic through collectors solution – Initial demand			
Collector type	Parabolic through		
Aperture area	363 m^2		
Land area	982 m^2		
Orientation	North-South		
Nº collectors	8		
Nº collectors in a battery	2		
Nº battery	4		
Network connexion	Parallel		
Hydraulic connexion	Horizontal	Solar fraction	40%
Accumulation volume	20 m^3	Production	350 MWh/year
Accumulation ratio	50 l/m^2	Production per m^2	963 kWh/m^2year
End user Investment	199.561 €	ESCO investment	166.301 €

Cost Effectiveness			
End user		ESCO	
Pay back	8 years	Pay back	7 years
IRR	12,3 %	IRR	14,5%
VPN	214.400 €	VPN	230.474 €
LCoHC	66 €/MWh	LCoHC	51 €/MWh

Table 3: Proposed parabolic through collectors solution. Initial demand.