# Task 55 Towards the Integration of Large SHC Systems into DHC Networks

## Solar DH – network hydraulics and supply points

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|---|---|
| Subject: | Feasibility analysis of hybrid technologies for DHC including ST |
| Description: | Feasibility analysis of solar based PTC-ORC combined cooling and power plant |
| Date: | October 2020 |
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| Download possible at: | http://task55.iea-shc.org/fact-sheets |

## Introduction

The present factsheet summarizes the study *"Comparative Analysis and Design of Solar Based Parabolic Trough - ORC Cogeneration Plant for a Commercial Centre"* performed by the Universidad de Zaragoza (Spain) and published in 2020 [1]. Two novel solar based PTC-ORC cogeneration systems, producing power and cooling, were pre-designed, considering commercially available pieces of equipment, to cover the annual energy demands of a commercial centre located in Zaragoza (Spain). Their annual behaviour was analysed from technical, economic, and environmental viewpoints, proving their technical feasibility. Although the proposed solar based cogeneration systems were not competitive with a conventional system in which all the required electricity was purchased from the grid, the obtained results were promising and revealed the systems' potential interest and competitiveness in the short to medium term. Furthermore, from an environmental viewpoint the studied PTC-ORC systems presented considerable benefits, contributing significantly to the decarbonisation of the energy production, and achieving a very high renewable fraction.

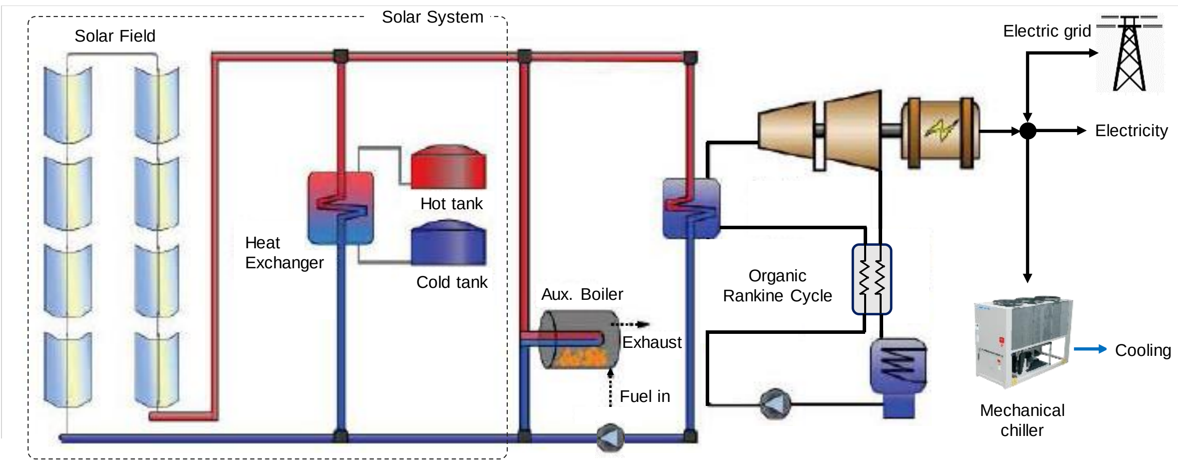


*Figure 1. Simplified diagram of the combined cooling and power systems analysed in the study (Source: [1])*

## Analysis highlights

Figure 1 depicts a simplified diagram of the analysed solar-based cogeneration systems that must attend the annual electricity and cooling demands of the commercial centre located in Zaragoza (Spain). Cooling is required for air conditioning throughout the year, even during winter months, to maintain comfortable indoor temperature conditions. The annual thermal cooling demand amounts to 6412 $MWh_t$. The annual electrical demand required for lighting, services, etc. (excluding the electricity consumption for cooling production in the mechanical chillers) amounts to 1370 $MWh_e$.

The proposed cogeneration systems consist of solar parabolic trough collectors integrated with thermal energy storage, an Organic Rankine Cycle, and vapor compression refrigeration chillers. A systematic procedure was applied to obtain the preliminary sizing of the plant components (see Table 1) considering commercially available pieces of equipment. System A is hybridized with a biomass boiler that supports the solar thermal production and allows full load operation of the ORC during all the solar system's operating time. System B, on the other hand, is not hybridised with biomass. For this reason, the installed capacities of the solar system and ORC are larger and it is considered that the ORC can operate at partial load, in order to produce the electrical requirements of the commercial centre (electricity for cooling production and electricity demand). Both systems were connected to the electrical grid, regarded as an auxiliary system, thereby selling the surplus electricity, and purchasing the required electricity when needed.

A detailed physical simulation of the operation of the system throughout the day and the year was performed, capturing its hourly, daily, and monthly dynamic behaviour, considering: (i) the variations of ambient temperature, solar radiation, and thermal energy production, among others; and (ii) the modelling of the different pieces of equipment based on technical data and investment costs of commercially available devices. Simplified economic and environmental analyses were also performed. The configuration without biomass hybridization (system B) was more economically interesting than the one with biomass boiler (system A), producing electricity at 0.1458 €/kWh, which is only 7% more expensive than the electricity purchase price in Spain. This was mainly due to the elimination of the purchase of biomass pellets, at the expense of the operational reliability provided by a dispatchable renewable energy source (i.e. biomass) and of a simpler operating strategy due to the partial load operation of the ORC in system B. Very high renewable fractions of almost 70% in system A and about 75% in system B were reached, obtaining a reduction of 85% of $CO_2$eq emissions in system A and carbon neutrality in the case of system B.

Future research effort is required in order to develop optimized cogeneration and trigeneration systems mainly driven by renewable energies in terms of: i) sizing, ii) more appropriate energy integration schemes considering the possibility of covering all energy services of a buildings (heating, cooling and electricity), implementing absorption chillers as well as thermal energy storage of heating and cooling produced, and iii) reducing the investment cost of these systems.

*Table 1. Solar based cogeneration systems. Technical data of components (Source: [1])*

| | Components | System A | System B |
|---|---|---|---|
| Solar system | Total aperture reflective area | 13,080 $m^2$ | 19,620 $m^2$ |
| | Land area | 32,375 $m^2$ | 52,610 $m^2$ |
| | Field thermal output power | 9.20 MWt | 13.79 MWt |
| | Solar thermal energy produced | 10,358 MWh/yr | 17,930 MWh/yr |
| | *Solar Collector* | | |
| | Model | Siemens SunField 6 | Siemens SunField 6 |
| | Orientation | North - South | North - South |
| | Tilt | 0° | 0° |
| | *Solar receiver* | | |
| | Model | Siemens UVAC 2010 | Siemens UVAC 2010 |
| | Heat Transfer Fluid | Therminol 66 | Therminol 66 |
| | Tsf,out-Tsf,in of receiver HTF | 214-121 °C | 214-121 °C |
| | *Thermal energy storage (TES)* | | |
| | Thermal energy capacity | 16.7 MWh | 32.6 MWh |
| | Tank volume | 356 $m^3$ | 696 $m^3$ |
| | Hours of storage | 6 hours | 6 hours |
| Biomass boiler | Thermal power | 2.8 $MW_t$ | - |
| | Energy efficiency (LHV basis) | 0.82 | - |
| | Biomass LHV | 15.5 MJ/kg | - |
| Mechanical chillers | Model | Cobalt W 153.3 | Cobalt W 153.3 |
| | Number of chillers | 3 | 3 |
| | Refrigerant | R134a | R134a |
| | Nominal cooling capacity per chiller | 1527 $kW_t$ | 1527 $kW_t$ |
| | Nominal electrical input power | 326 $kW_e$ | 326 $kW_e$ |
| | EER (nominal) | 4.68 | 4.68 |
| | Water temperature at condenser (in – out) | 30-35 °C | 30-35 °C |
| | Water temperature at evaporator (in – out) | 12-7 °C | 12-7 °C |
| Organic Rankine Cycle (ORC) | Type | Single pressure with regenerative preheating | Single pressure with regenerative preheating |
| | Number of ORCs | 1 | 1 |
| | Electric efficiency (full load) | 0.18 | 0.18 |
| | Nominal electrical power | 500 $kW_e$ | 978 $kW_e$ |
| | Thermal input power | 2.78 $MW_t$ | 5.43 $MW_t$ |

# Reference

[1] E. A. Pina, L. M. Serra, M. A. Lozano, Adrián Hernández and Ana Lázaro, "Comparative Analysis and Design of Solar Based Parabolic Trough - ORC Cogeneration Plant for a Commercial Centre". *Energies* 2020; 13, 4807; doi:10.3390/en13184807