Solar and heat pump systems. An analysis of several combinations in Mediterranean areas.

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Abstract

Recently the systems that combine solar thermal technology and heat pumps have been marketed to heat houses and produce domestic hot water. [1] This new combination of technologies is a welcome advancement, and need to be improved in the configuration. These systems will be cleaner as long as the electricity will improve the renewable energy fraction and they improve the efficiency. In Mediterranean areas, where there are less months of heating and higher temperatures, the solar thermal systems for heating have combined with water-water heat pump with a big storage tank can have better efficiency and less emissions than the geothermal heat pump system or a conventional heat pump.

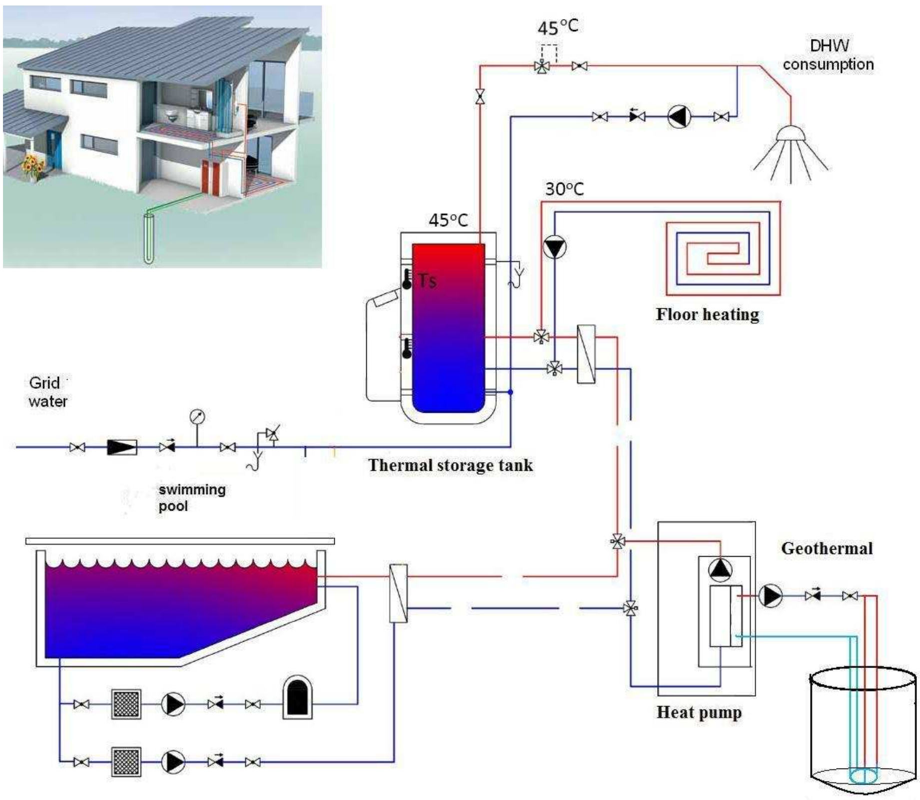

Fig. 1: Schematic diagram of a geothermal system with a heat pump [3] [5]

1. Introduction

The combination of solar-thermal collectors and heat pumps provides interesting possibilities for innovative and energy efficient heating systems with a high fraction of solar energy. Due to the rising cost of limited fossil resources, they are gaining more and more importance, even they are expensive. [2] Several configurations of solar systems have been studied combined with water condensation heat pumps. The functionality of these systems can lead to special operating conditions which significantly differ from conditions in standard solar systems, e.g. low collector temperatures below the dew point [3].

The cooler months when the external temperature is below the 7 ºC, the geothermal heat pump systems they have more efficiency than the standard heat pumps. The solar systems with water-water heat pump with a big storage tank have the same or better efficiency than the geothermal systems, with less CO_2 emissions at template climates.

The most efficient system in the north is using geothermal heat pumps with close loop, but it’s one of the most expensive configurations, because needs a big surface of pipes for the heat transfer with the ground. The biggest investment is the excavation (horizontal or vertical). The open loop systems are cheaper but have more barriers (environmental and jurisdictional). This systems they need a pit or a heating exchanger with a minimum invest of 8.000 € for a normal thermal demand. (See fig. 2)

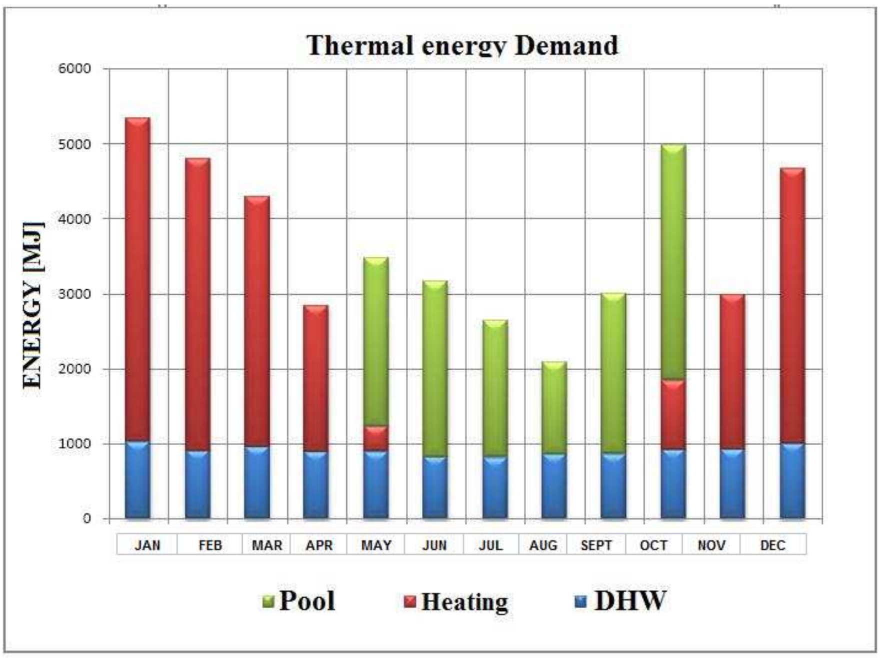

Fig. 2: Example of thermal demand in house of a Mediterranean area.

There are countries, like Spain, where it’s obliged to install a minimum quantity of solar panels for produce the DHW, between 0,5-1 square meter per person, to produce between the 30-70%, according to the solar radiation and external temperatures.

One interesting combination is for houses with swimming pool or with rain storage tank, where we can save the investment of the buffer storage tank using an isolated pool with thermal cover. There are various solar pool heating systems available, using the properly collectors. These systems cost little to run - the main cost is the electricity for the pump. Over the life of the system, the total cost will end up cheaper than systems that use big storage tanks and closer to the geothermal devices.

In Mediterranean areas many houses with pool or rain water storage tank have solar collectors for use the pool in autumn months. The heat can be dumped into a swimming pool the autumn months, and use the swimming pool like a big buffer tank in the cooler days, been more efficient than the geothermal systems. For cooler areas, we can arrive to freeze the pool; it has been studied than the water/ice latent heat storage tank to the heat pump extraction circuit has a bigger efficiency than the air systems, and the latent heat increase the storage energy capacity **[**4]**.**

2. Configuration of the solar HP heating system

The solar panels are unglazed, with a water-water heat pump, it's a fully integrated system: the heart of the system is the heat pump but solar energy provides energy to the evaporator side of the heat pump, either through a storage tank or directly, and when possible to the DHW tank and/or to the heating distribution system.

The storage tank is between 300-500 litters. The surface of the unglazed solar panels, because they are low efficiency is tree times bigger than a standard configuration with glazed panels, (4-6 m^2) nevertheless the cost its tree or four times cheaper, it depends of the quality and the brand. We will require from 25 to 50 square meters, depending on the size of the house and the thermal demand. These systems increase with solar energy the efficiency for DHW and space heating, during some month provides directly the DHW and heating necessities, and the 100 % of the pool demand, with a volume between 50-100 m^3.

The Heat pumps – Heating with air, solar energy with a Glazed collector - can cover up to a 75% of the thermal necessities (DHW and heating) about a 20% with solar energy and a 55% with the Heat pump, with a Seasonal COP of 4, consuming less of 25% of auxiliary energy from the electricity. **[5]**

The Heat pumps – Heating with air, solar energy with a Glazed collector - can cover up to a 70% of the thermal necessities (DHW, heating and pool) about a 32% with solar energy and a 48% with the Heat pump, with a Seasonal COP of 4, consuming less of 30% of auxiliary energy from the electricity. **[3]**

The Heat pumps – Heating with water, solar energy with unglazed collector – can cover up to 75% with more thermal necessities (DHW, heating and pool), with a 50% with solar energy and 20% with a Heat pump, with a Seasonal COP of 5, consuming less of 25% of auxiliary energy from the electricity. **[3]**

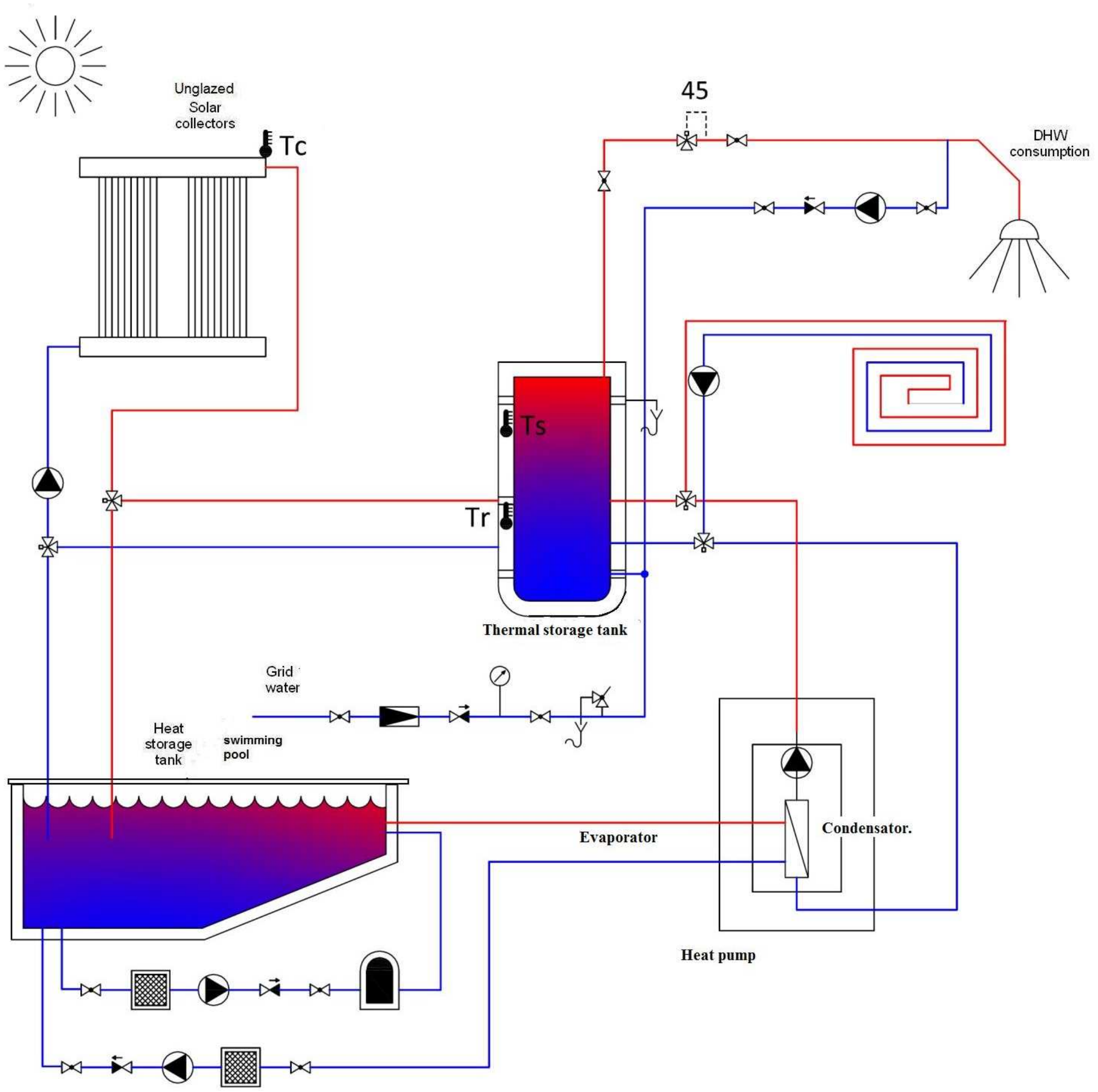

Fig. 3: Schematic diagram of the low cost solar thermal contribution system with a water heat pump [3]

The biggest problem is the low efficiency of the solar panels when they are working with differences of more than 20 ºC between the water and ambient temperature the efficiency it's falling down.

The advantage of this system it's than the water of the pool can go through the solar panels, saving pumps and heat exchangers, thus simplifying the system. The biggest disadvantage it's that we will need a bigger surface of solar collectors and use the heat pump all the winter, autumn and spring.

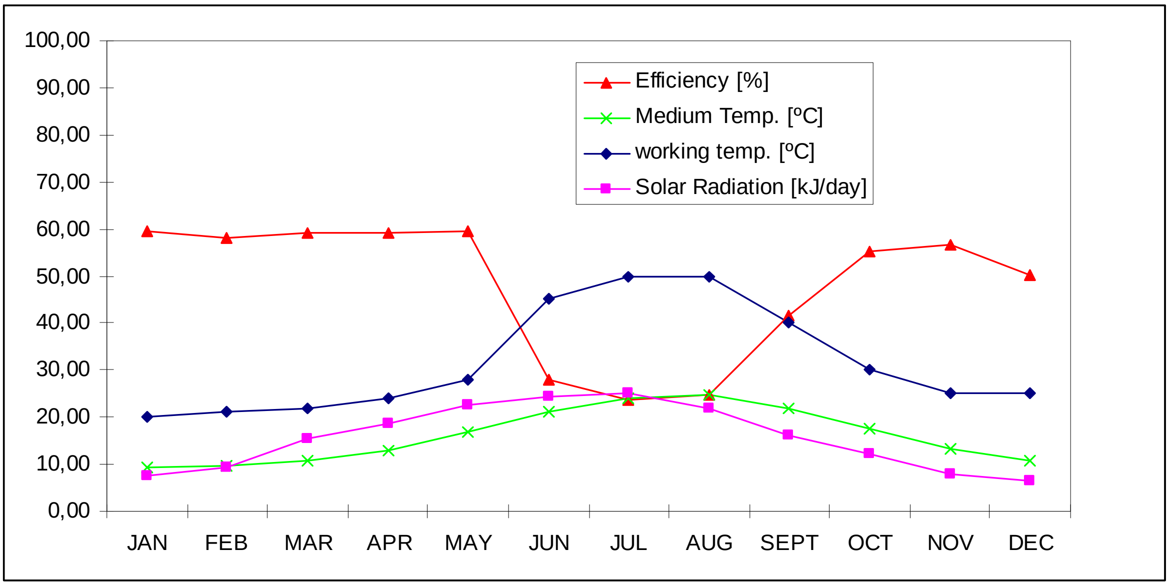

Fig. 4: Monthly temperatures, energy and efficiency at Balearic Islands

The solution for avoiding having a low averaged efficiency, find out the maximum efficiency for the solar panels to have the maximum solar energy gains, the unglazed panels are working usually with a difference of temperatures of less than 10 ºC, the pool will be usually in winter at 20 ºC and in spring and autumn at 25ºC, in summer they work close to 50 ºC, making a direct heat transfer to the DHW, working with a gradient temperature of 25 degrees. We can see at the figure number 3 than the efficiency at winter it's closer to 60% with a working temperature near 20 ºC, at summer it's near the 20% but we only need hot water and pool and the solar panels are working at 50 ºC. The pool's surface its part of the solar system, absorbing part of the radiation.

The standard solar panels work with gradient temperatures of more than 25 degrees all the year, because they transfer the energy to the DHW that it's more than 50 ºC. The result it's that the efficiency it's similar in both systems. These systems they need at summer a system for control overheating, due to the reduction of thermal necessities. Using absorption systems we can take profit of this energy for refrigeration application.

3. Results

Simulating the whole year system we reach different solar contributions, due to the efficiency of the system, the working temperature of the storage system, and the different COP of the heat pump. It has been simulated the minimum temperature of the pool, for the whether conditions at Balearic Island's, we have found out than the water-water heat pump with the unglazed panels has a higher efficiency than the air-water heat pump. The average temperature never goes down of 11 ºC, this validates the systems [3] in front of a geothermal heat pump of either close or open loop. There are some short time periods when the pool temperature decreases up to 9ºC, when the ambient temperature is -3ºC. For cooler areas, we can arrive to freeze the pool; it has been studied than the water/ice latent heat storage tank to the heat pump extraction circuit has a bigger efficiency than the air systems, and the latent heat increase the storage energy capacity [4].

Table 1. Stationary Coefficient of Performance with different HP combinations [3] [5]

COP	**Air-Water**	**Water-Water unglazed**	**Water-Water glazed**	**Geothermal**
Maximum	5,55	6,22	5,90	4,20
Minimum	2,12	2,85	2,79	3,83
Average	3,37 – 4,00	4,78	4,58	4,05

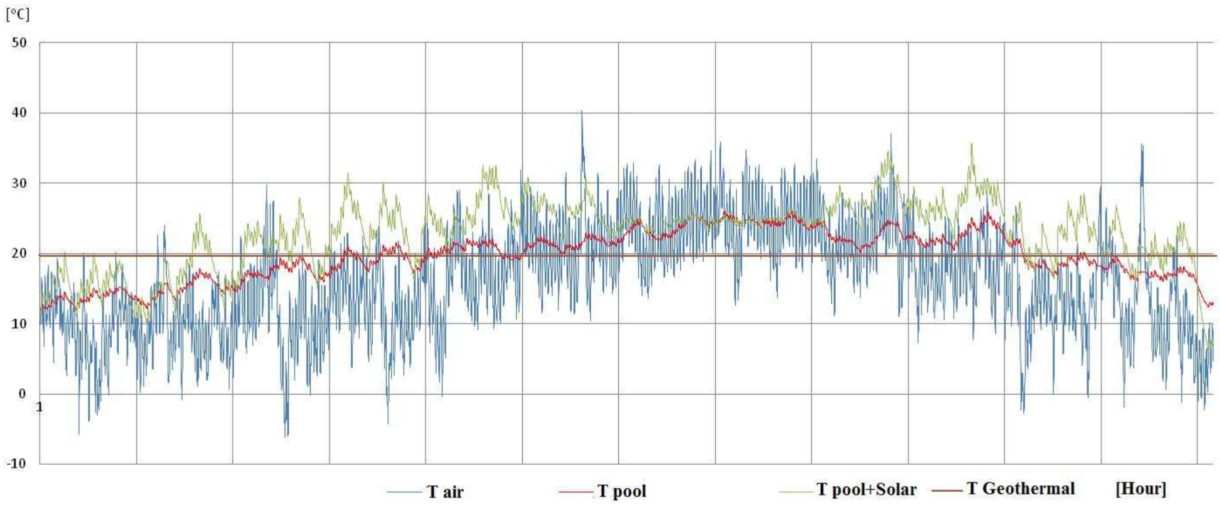

Fig. 5: Temperatures of the systems at Balearic Island's. [3][5]

The geothermal systems well design they work all the hours at the similar temperatures, with some degrees of difference, with a constant COP. The pool it's only 280 hours below the ambient temperature, less than the 3% of the time, with a Seasonal Coefficient of Performance near 5, depending of the model of the heat pump. The pool can be only used for swim at the end of March until the end of October, with temperatures up to 25ºC.

4. Conclusion

Solar heat pump systems are a good solution for family houses, where we can arrive to high comfort levels with very low energy consumption. There are a lot of systems to be improved for engineers and manufacturers of solar collectors and/or heat pumps. There is a need for the development of 'plug-and-play' or 'ready-to-install' system kit solutions, at least to avoid errors in dimensioning and assembling. To ensure energy efficient operation of such solutions, a control unit which continuously monitors the basic functions of the system including adequate system self-control strategies should be aspired.

The best option in the mediterranean areas from the energy saving and economical point of view it's use unglazed panels on instead to geothermal, with a 50% lees of investment with similar efficiency.

The unglazed panels combined with a pool or a big storage tank constitute a good system in Mediterranean areas, with similar efficiency to geothermal systems, and a lower cost, and simplifying the hydraulics and control systems with other solar systems.

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