CODEN STJSAO ISSN 0562-1887
ZX470/1592 UDK 62(05)=862=20=30

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

Andreu MOIA POL[1], Víctor MARTÍNEZ MOLL[1], Miquel ALOMAR BARCELÓ[1], Ramon PUJOL NADAL[1]

1) University of Balearic Islands, Physics department, Carretera Valldemossa km 7,5 E 07122 P. Mallorca (Spain)

andreu.moia@uib.es

Original Scientific Paper

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 needs to be improved in the configuration. These systems will be cleaner as long as the electricity will improve the renewable energy fraction and system efficiency. In Mediterranean areas, where there are fewer months of heating and higher temperatures, the solar thermal systems for heating have been combined with a water-water heat pump with a big storage tank which can have better efficiency and fewer emissions than the geothermal heat pump system or a conventional heat pump.

Solarni sustavi i dizalice topline. Analiza različitih kombinacija u Mediteranskim područjima

Izvorni znanstveni rad

U novije vrijeme sustavi koji kombiniraju solarnu toplinsku energiju i dizalice topline postaju komercijalno dostupni za grijanje kuća i pripremu potrošne tople vode. Ova kombinirana tehnologija predstavlja dobrodošli napredak, te zahtjeva dodatna poboljšanja. Ovi sustavi će biti energetski 'čistiji' sve dok električna energija poboljšava udjel iskorištenja obnovljivih izvora energije i iskorištenje sustava. U Mediteranskim područjima, gdje je tokom manje mjeseci potrebno grijanje i sa viši temperaturni raspon prevladava tokom godine, solarni toplinski sustavi su kombinirani sa voda-voda dizalicama topline uz korištenje velikog toplinskog spremnika, što ima veći stupanj iskorištenja i manje emisije u odnosu na geotermalni sustav dizalice topline ili konvencionalne dizalice topline.

Keywords

Solar Energy
Heat Pump
Geothermal

Ključne riječi

Solarna energija
Dizalice topline
Geotermalna energija

Primljeno (Received): 2012-04-12
Prihvaćeno (Accepted): 2012-10-02

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; moreover, 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].

In cooler months when the external temperature is below 7 ºC, the geothermal heat pump systems 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 a closed loop, but it's one of the most expensive configurations because it needs a big surface of pipes for 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). These systems need a pit or a heating exchanger with a minimum investment of 8.000 € for normal thermal demand. (See Fig. 2).

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

One interesting combination is for houses with a swimming pool or with a 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 proper 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 being cheaper than systems that use big storage tanks and is more comparable with the geothermal devices.

In Mediterranean areas, many houses with a pool or rain water storage tank have solar collectors for use in the pool in autumn months. The heat can be dumped into a swimming pool during the autumn months, and using the swimming pool like a big buffer tank in the cooler days, such a method has been more efficient than the geothermal systems. For cooler areas, we can eventually freeze the pool; research shows that the water/ice latent heat storage tank to the heat pump extraction circuit has greater efficiency than the air systems, and the latent heat increases the storage energy capacity [4].

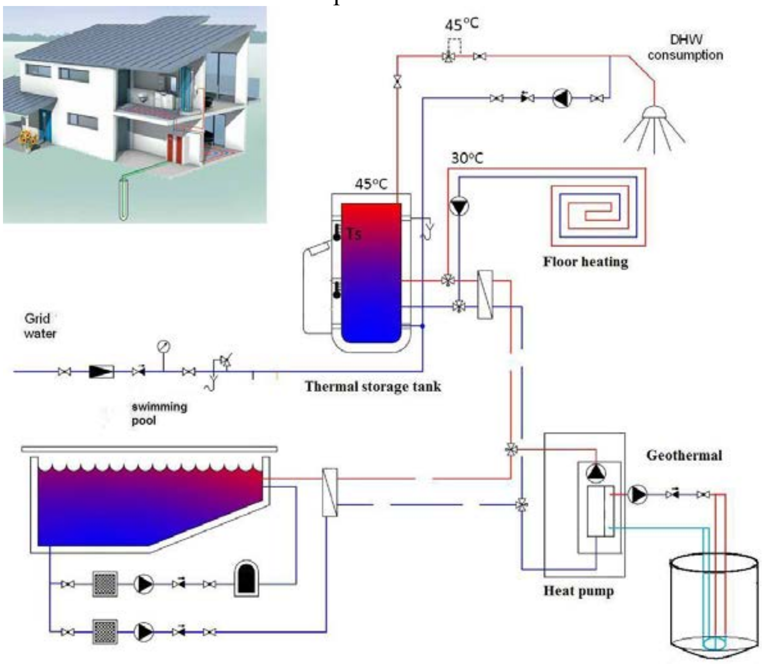

Figure 1. Schematic diagram of a geothermal system with a heat pump [3] [5].
Slika 1. Shematski prikaz geotermalnog sustava sa dizalicom topline [3], [5].

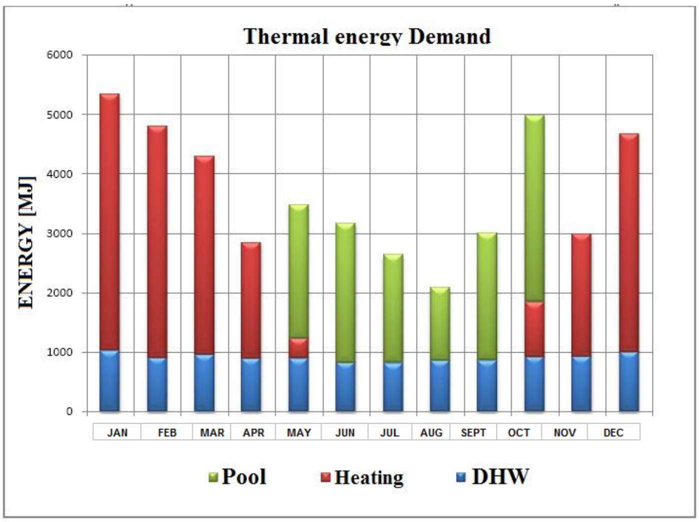

Figure 2: Example of thermal demand in house of a Mediterranean area.
Slika 2. Primjer potrebe za toplinskom energijom kuće u Mediteranskom području (Energija [MJ] po mjesecima).

2. Configuration of the solar HP heating system

The solar panels are unglazed, with a water-water heat pump, and it is 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 liters. The surface of the unglazed solar panels, because they are low efficiency, is three times bigger than the standard configuration with glazed panels (4-6 m^2), nevertheless the cost is three or four times cheaper, depending on 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 months directly providing the DHW and heating necessities, and 100 % of the pool demand, with a volume between 50-100 m^3.

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

The heat pumps – heating with air using solar energy with a glazed collector – can cover up to 70% of the thermal necessities (DHW, heating and pool), about 32% with solar energy and 48% with the heat pump, with a seasonal COP of 4, and consuming less than 30% of auxiliary energy from electricity. [3]

The heat pumps – heating with water using solar energy with an unglazed collector – can cover up to 75% with more thermal necessities (DHW, heating and pool), with 50% from solar energy and 20% from a heat pump, with a seasonal COP of 5, consuming less than 25% of auxiliary energy from electricity. [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, in which case their efficiency decreases.

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

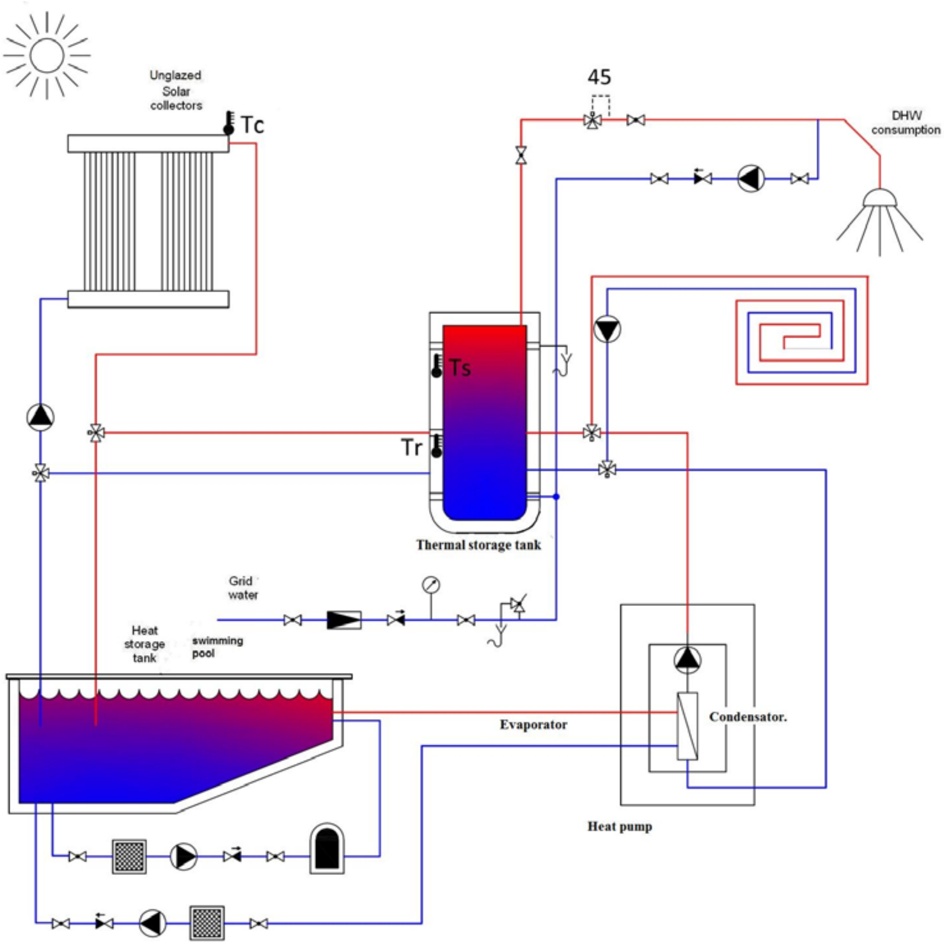

Figure 3 Schematic diagram of the low cost solar thermal contribution system with a water heat pump [3].

Slika 3. Shematski prikaz ekonomičnog solarnog toplinskog sustava sa dizalicom topline [3].

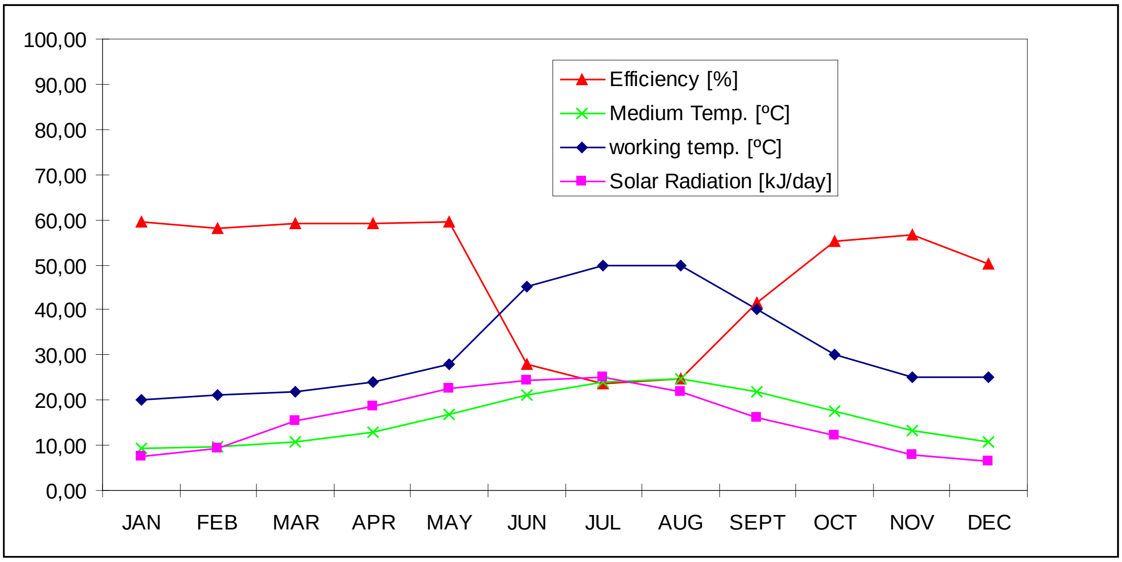

Figure 4. Monthly temperatures, energy and efficiency at Balearic Islands.

Slika 4. Mjesečne temperature [°C], iskoristivost sustava [%], i energija Sunčevog zračenja [kJ/dan] za Balearske otoke.

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

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

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. The minimum temperature of the pool has been simulated for the weather conditions on the Balearic Islands; we have found out that the water-water heat pump with the unglazed panels has a higher efficiency than the air-water heat pump. The average temperature never goes below 11 ºC, this validates the systems [3] before a geothermal heat pump of either closed or open loop. There are some short time periods when the pool temperature decreases to 9ºC, when the ambient temperature is -3ºC. For cooler areas, we can even freeze the pool; research has shown that the water/ice latent heat storage tank to the heat pump extraction circuit has a bigger efficiency than the air systems, and that the latent heat increases the storage energy capacity [4].

Table 1. Stationary Coefficient of Performance with different HP combinations [3] [5].
Tablica 1. Stacionarni toplinski množitelji (COP) postignuti sa različitim kombinacijama dizalica topline [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

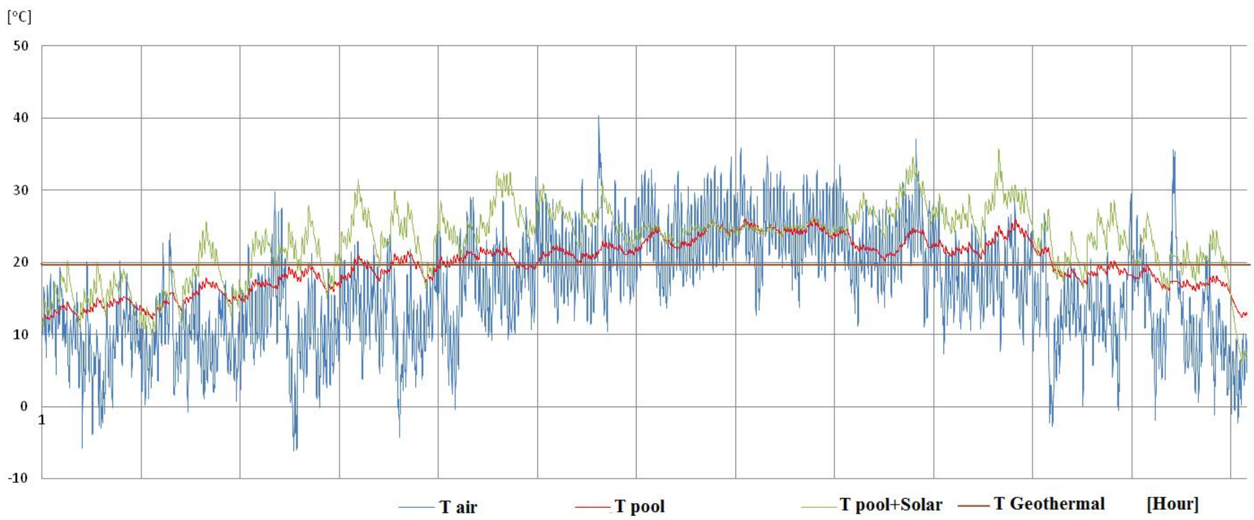

Figure 5. Temperatures of the systems at Balearic Islands. [3][5].
Slika 5. Satna raspodjela temperatura na Balearskim otocima [3], [5].

The geothermal systems are well designed and they work all hours at similar temperatures, with some degree of difference, and with a constant COP. The pool is only 280 hours below the ambient temperature less than 3% of the time, with a Seasonal Coefficient of Performance near 5, depending on the model of the heat pump. The pool can be only used for swimming from the end of March until the end of October, with temperatures up to 25ºC

4. Conclusions

Solar heat pump systems are a good solution for family houses, where we can achieve 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 to.

The best option in the Mediterranean areas from the energy saving and economical point of view is the use unglazed panels instead of geothermal, with 50% less 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, at a lower cost, and simplifying the hydraulics and control systems with other solar systems.

REFERENCES

[1] HADORN, JC; A new IEA SHC Task 44 & HPP Annex And analysis of several combinations for a low energy house. Proceedings of the Euro Sun 2010, Graz, Austria.

[2] FRANK, E; HALLER,M; HERKEL, S; RUSCHENBURG, J. Systematic Classification of Combined Solar Thermal and Heat Pump Systems. Proceedings of the Euro Sun 2010, Graz, Austria.

[3] MOIÀ POL, A;, ALOMAR BARCELÓ,M; PUJOL NADAL, R;, MARTÍNEZ MOLL,V. Domestic solar/heat pump heating systems with low and high efficiency collectors in Mediterranean areas. Proceedings of the Solar World Congress 2011, Kassel, Germany

[4] SONNLEITNER, M; TRINKL,C; WILFRIED, Z. In-situ investigation of a domestic solar/heat pump Heating system in a one-family house. Proceedings of the Euro Sun 2010, Graz, Austria

[5] Glen Dimplex Deutschland GmbH, ROTEX Heating Systems GmbH and Computer simulations by the Institute for Building Energetics at the University of Stuttgart.