Conference Proceedings

EuroSun 2016

Palma de Mallorca (Spain), 11– 14 October 2016

Study Case of Solar Thermal and Photovoltaic Heat Pump System for Different Cities in Turkey

Andreu Moià-Pol[1], Ramon Pujol-Nadal[1],Víctor Martínez-Moll[1], Nima Bonyadi[2], Derek Baker[2]

[1] University of Balearic Islands, Physics department, Mechanical Engineering Area (ME) Palma de Mallorca (Spain)

[2] Mechanical Engineering (ME) & Center for Solar Energy Research and Applications (GÜNAM), Middle East Technical University- METU, (TURKEY)

Abstract

The combination of solar thermal, photovoltaic, and heat pump technologies is a welcome advancement in countries with large solar resources such as Turkey. These systems could have similar efficiencies throughout the year for different locations in Turkey if we adjust the solar storage according to the weather conditions. In this paper, solar heating with a heat pump system for buildings have been designed to achieve different values of the fraction of primary energy saved using Flat Plate Collectors (FPC) and solar photovoltaic (PV) technology, and having a high system efficiency resulting in net zero energy for thermal production.

Keywords: *Solar thermal; heat pump; photovoltaic; geothermal; combisystems*.

1. Introduction

Turkey has large solar resources as shown in Figure 1 and a relatively large population. This country has the second largest newly installed solar thermal capacity worldwide in 2014, and this has made Turkey the largest European solar thermal market [1]. The solar combisystems are becoming popular for villas [1], where for arrive to a high comfort and efficiency we need a system with heating and Domestic Hot Water during all the year with a large solar systems.

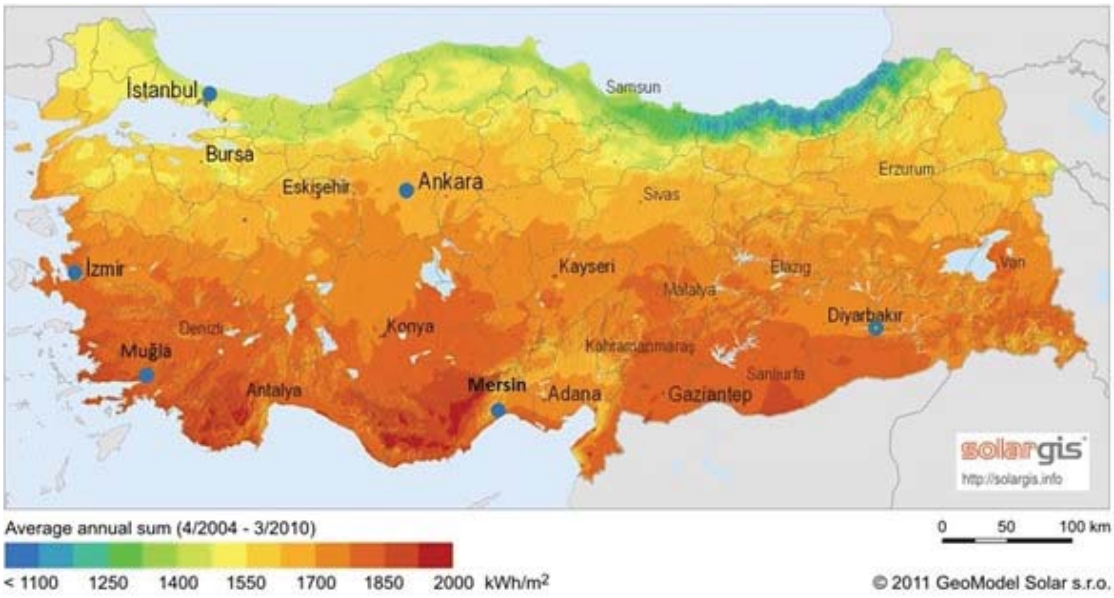

Fig. 1 Solar Radiation in Turkey and location of the studied cities. SolarGis [2]

doi:10.18086/eurosun.2016.04.22 Available at http://proceedings.ises.org

The actual prices of PV systems and mature technology of Flat Plate Collectors (FPCs) and water-to-water heat pump for ground-coupled applications have provided a new model: solar-electric heat pump assisted with solar-thermal collectors. These systems have been integrated in some software programs as Polysun. This article shows that these systems will be cheaper and easier to install than the shallow geothermal systems.

2. Description and results

Six different locations in Turkey (see Figure 1) have been simulated with FPC, PV and heat pumps (Water-water) as presented in Table 1. The used software Polysun [3] includes solar thermal, photovoltaics, heat pumps and geothermal systems. The PV system has been simulated as well with PVsyst[4] for adjust the power. The proposed system can operate with outside temperatures lower than 0ºC with a high solar fraction and with a high efficiency of the solar collector [5]. The storage is changing during the year according to the external temperature, in order to obtain higher efficiency from the thermal collector, PV and work with the maximum efficiency of the heat pump.

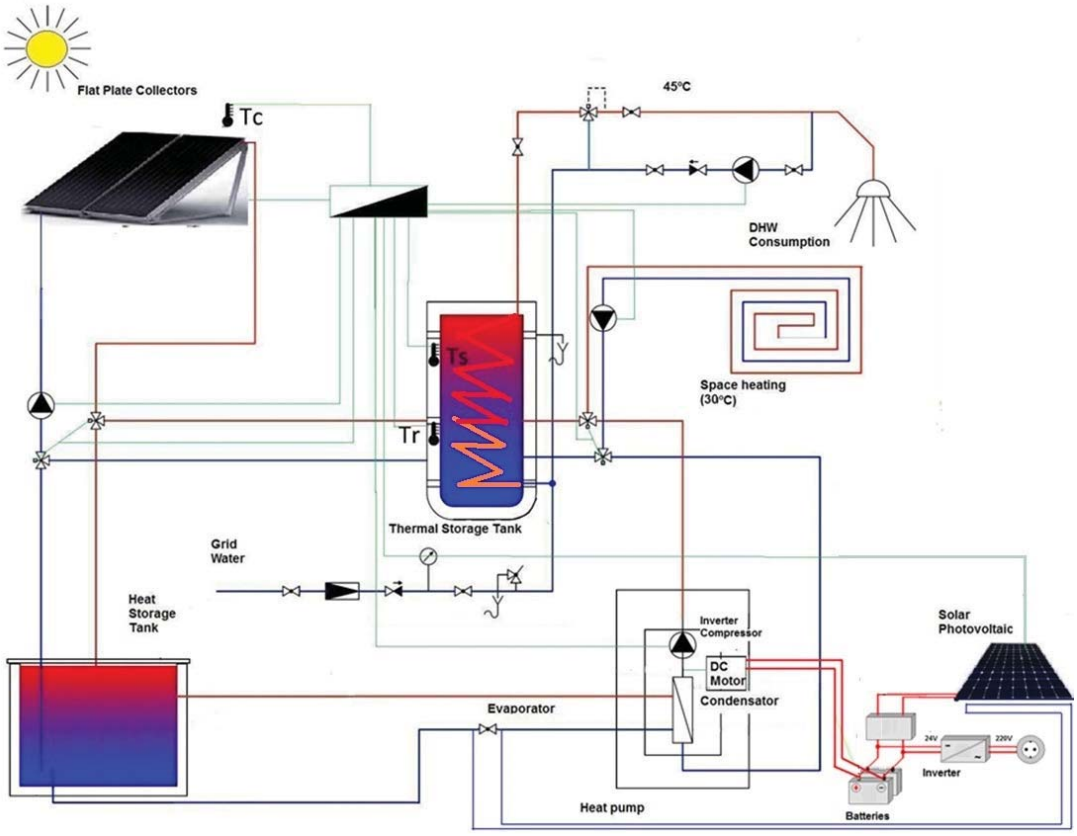

Fig. 2 : Simulation of the thermal system.

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. In Mediterranean areas many Villas with pool or rain water storage tank have solar collectors to use the pool in autumn months. The heat can be dumped into a swimming pool in the autumn months, and the swimming pool used like a big buffer tank in the cooler days, being more efficient than the geothermal systems [9].

ST Collector Efficiency $\eta = 0{,}807 - 3{,}075(Tm\text{-}Ta)/G - 0{,}022((Tm\text{-}Ta)/G)^2$ (eq. 1)
Coefficient of Performance Heat Pump = 4.2423+0.087 T (eq. 2) ($T_{max\ evap}$=15ºC)

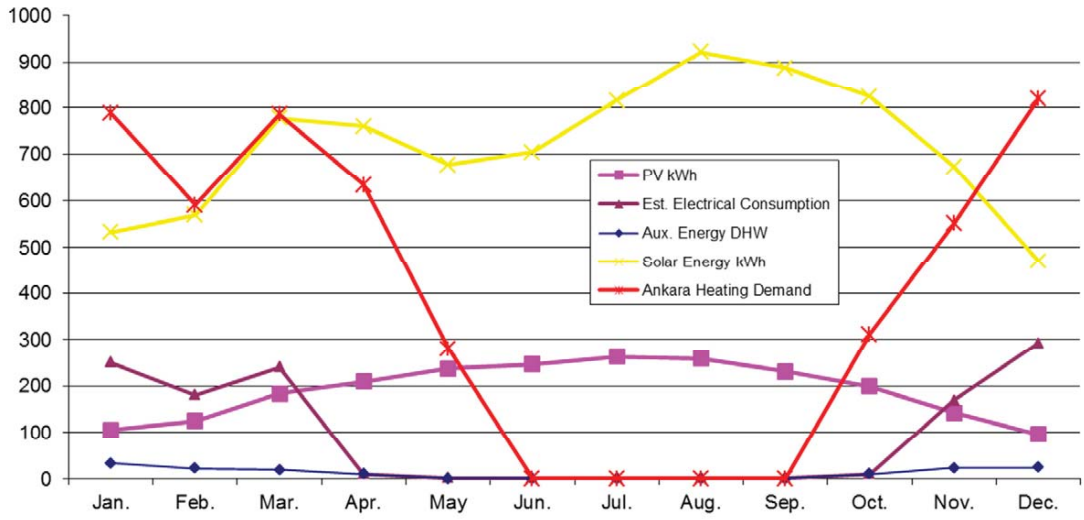

Fig. 3 : Annual Thermal demand (in kWh) with ST and PV production for Ankara

Simulating the whole year system we reach different solar fractions for the different locations, due to the efficiency of the system, the working temperature of the storage system, and the different COP of the heat pump. This system can have a very high Coefficient of Performance and adapt its efficiency to a variety of conditions. It is ideal for both cold and mild climates, and therefore for a country like Turkey with different weather conditions in the biggest cities.

Tab. 1: Results of one year simulation in three locations for DHW and Space Heating.

Location , Latitude	Thermal Energy Demand (kWh)	Solar Energy kWh/m^2	Electric Energy kWh	Solar Thermal Fraction	Average FPC Efficiency	PV installed power (Wp)	FPC (m^2)
Ankara, 39.9º	6370	1702	2284	88%	72%	1400	8
Mersin, 36.7º	3385	1486	524	93%	72%	360	6
Mugla,37.2º	4132	1798	1239	96%	74%	750	6
Izmir, 38.4º	3340	1697	1051	95%	74%	750	5
Diyarbakir, 37.9º	3993	1865	1423	96%	74%	750	5
Istanbul, 41º	2269	1486	529	94%	71%	520	4

There are some heat pump manufacturers that sell a hybrid air +PV system, and geothermal and air system for heating applications, in order to reduce the initial cost of the borehole and piping system, they have been analyzed, only shallow geothermal with PV. The size of the system is not very large for Turkey, and the maximum surface needed is less than 20m^2 if we take in account than these houses have a roof of 80 m^2 , these system fit perfectly. If there is any case without sufficient roof space, PVT technologies can be used, when it used for low temperatures with limited space is a good option, these collectors are good for low temperature heating systems, like fan coils or floor heating.

Recently, hybrid photovoltaic solar thermal collectors (PVT) became a topic of many research projects because of the possibility to gain heat and electricity simultaneously. PVT represents the alternative to separate PV panels and solar thermal collectors by integrating the two into one device [7]. Other studies have evaluated different possibilities to integrate PVT collectors in an air to water heat pump system and to compare the results with the combination of an air to water heat pump system together with a PV-system. The system P/S (PVT + heat pump in parallel and serial connection) in combination with a High Thermal Conductivity collector type turned out to be the most efficient and promising way to integrate uncovered PVT [8] collectors in a system at different locations. As the PVT collector serves essentially as a heat source for the heat pump (and is thus independent of solar radiation), the useful heat gains of the collectors occurs at the same time as heat is needed in winter. The rear insulation of the PVT collector is

in terms of best possible heat absorption from ambient air rather obstructive for such a system configuration.

FPC and PV with heat pump systems are a good solution for familiar households, both technologies are necessary in order to arrive to the future scenarios of zero emissions for net-zero energy building for Turkey.

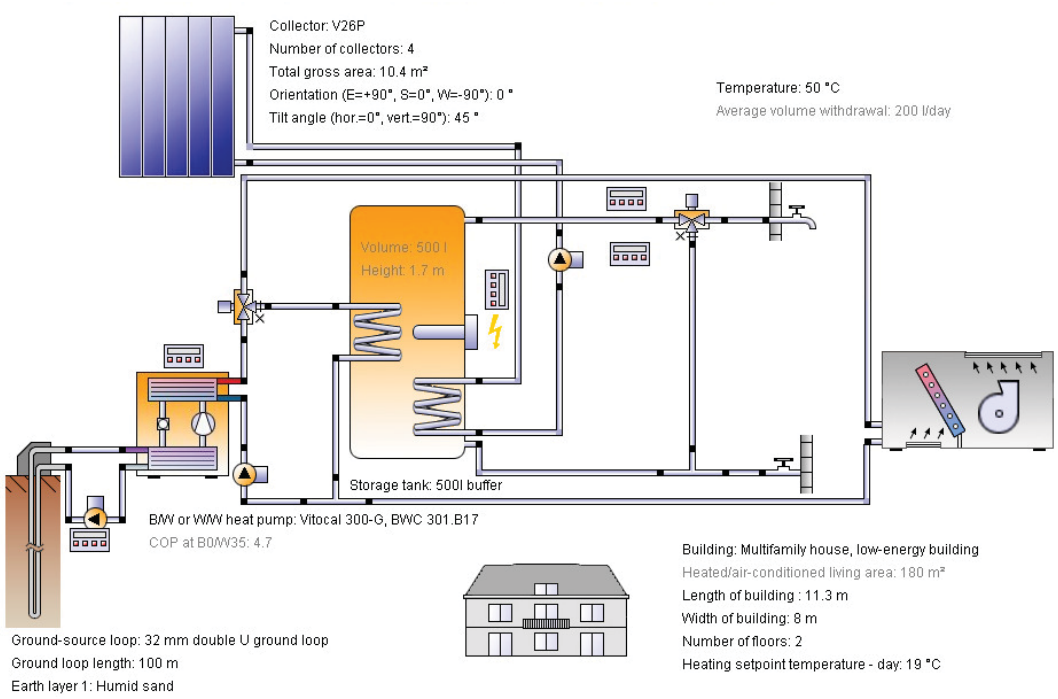

Fig. 4 : Diagram with Ground source+ Solar Thermal [3] for Istanbul.

The main problem of the geothermal is in some places the composition of the soil very uncertain, and the environmental barriers. They need a detailed geological analysis and sometimes they need some borehole, making the initial investment very high. In the analyzed case two boreholes of 120 meters were assumed. The results are presented in Table 2, standard commercial list prices of the different elements, the operational cost and maintenance hasn't been studied, supposing that is similar in both cases.

Tab. 2: Comparing cost of the system vs. Geothermal in Turkey

	Estimated cost		**Estimated cost**
Heat Pump + PV system	7 050 €	Heat Pump + PV system	7 050 €
Solar Thermal + Pipes	2 100 €	Borehole + Pipes	13 300 €
Thermal Storage Tanks	4 500 €	Thermal Tank	1 815 €
Total	**13 650 €**		**22 165 €**

The analyzed solar thermal-PV system is cheaper and has a similar efficiency than the Geothermal system, which gives an advantage. The only disadvantage will be for cooling, the geothermal will be easy to change in contrast with the Solar Heat Pump which will be needed a dry cooler or some auxiliary system in the heat pump in order to cool the house.

3. Conclusions

The analyzed solar thermal-PV system is cheaper and has a similar efficiency to the geothermal system, which gives an advantage. The only disadvantage will be for cooling, the geothermal will be easy to change in contrast with the Solar Heat Pump which will be needed a dry cooler or some auxiliary system in the heat pump in order to cool the house.

4. Acknowledgements

The authors acknowledge the financial support from Programa Pont “La Caixa”. Caixabank, S.A,”

5. References

[1]http://www.estif.org/
[2] http://solargis.info
[3] Polysun. http://velasolaris.com
[4] http://www.pvsyst.com/
[5] Andreu Moià-Pol, Víctor Martínez-Moll, Julian David Hertel,Rashid Nazmitdinov, Pavel Gladyshev. Solar and heat pump systems, analysis of several cases in Russia. Proceedings of the Solar World Congress 2015, Daegu, Korea.
[6] A. Moia-Pol, V. Martinez-Moll, R. Nazmitdinov, R. Pujol-Nadal. Study Case of Solar Thermal and Photovoltaic Heat Pump System for Different Weather Conditions. Aix-les-Bains. France. doi:10.18086/eurosun.2014.03.21
[7] A. Abdul-Zahra, T. Faßnacht, A. Wagner. Evaluation of the Combination of Hybrid Photovoltaic Solar Thermal Collectors with Air to Water Heat Pumps. Aix-les-Bains. France .EuroSun 2014.
[8] F. Ille, M. Adam, R. Radosavljevic, H. Wirth .Market and Simulation Analysis of PVT Applications for the Determination of New PVT Test Procedures. Aix-les-Bains. France. doi:10.18086/eurosun.2014.16.09
[9] Andreu Moià Pol, Víctor Martínez Moll, Miquel Alomar Barceló, Ramon Pujol Nadal. Solar and heat pump systems. An analysis of several combinations in Mediterranean areas. Proceedings of the Eurosun 2012, Rijeka, Croatia