Energy Supply In A Building Via A Photovoltaic-Thermal Power System

Saban Yilmaz, Hasan Riza Ozcalik, Erdal Kilic, Mustafa Aksu

Abstract: The fact that a PV-thermal energy system can supply energy for hot water and heating in a building is of vital importance for the proliferation of renewable energy sources. Central heating boilers are used in case of insufficient solar energy. This study mainly focuses on the planning of a PV-thermal power system for optimal energy supply in a building and a simulated performance analysis.

Index Terms: Renewable Energy, Solar Energy, Photovoltaic, PV/T, Thermal Energy.

1 Introduction

TRADITIONALLY, solar energy has been divided into two distinct but separate fields: solar thermal, where incoming radiation is converted into heat, and photovoltaics (PV), where solar energy is converted to electricity. Solar thermal systems have long been used for applications such as water heating, space heating and power generation. Photovoltaics, although it is a comparatively recent development, have also been applied to a large number of electricity generating applications, including watches, calculators and large power systems such as those used at the Sydney Olympic Village [1]. By and large the two technologies have, for the majority of their lives, remained as separate entities. In the late 1970's, however, a number of studies began to analyze incorporating photovoltaic and solar thermal into a single device, commonly referred to as Photovoltaic/Thermal (PV/T) solar collectors. The following are two benefits to PVT: First, the efficiency of PV cells can be increased by actively cooling them via a solar thermal system. Second, incorporation of both systems into a single unit may reduce the area dedicated to solar energy. It is well known that efficiency decreases with increasing temperature by approximately 0.5%/°C for mono and polycrystalline silicon PV-cells. In PV/T systems, the solar thermal is used to reduce the temperature of the PV-cells and thus improve their efficiency [2]. In the past 3-4 decades, the market of solar thermal and photovoltaic electricity generation has been growing rapidly. Technological developments were also seen in hybrid solar photovoltaic/thermal collectors and the associated systems. Generally speaking, a PV/T system integrates photovoltaic and solar thermal systems for the co-generation of electrical and thermal power from solar energy. A range of methods are available such as the choices of monocrystalline/polycrystalline/amorphous silicon (c-Si/pc-Si/a-Si) or thin-film solar cells, air/liquid/evaporative collectors, flat-plate/concentrator types, glazed/unglazed designs, natural/forced fluid flow, and stand-alone/building-integrated features. Accordingly, the systems range from PVT air and/or water heating system to hot-water supply through PV-integrated heat pump/pipe or combined heating and cooling and to actively cooled PV concentrator through the use of lens/reflectors. Engineering considerations can be mentioned in the selection of heat removal fluid, the collector type, the balance of system, the thermal to electrical yield ratio, the solar fraction, and so forth. These possess decisive effects on the system operating mode, working temperature, and energy performance [3]. This study focuses on planning the energy demand of a building at an optimal level of solar energy. Black Sea region, the region with the least radiation in Turkey, was chosen due to its climate to identify the effects of solar energy in severe conditions. In Figure 1, climate figures for the location where the building is located are given.

II. Solar System

Modelling was designed with Polysun and a combi boiler of 7.5 kW PV/T was selected as the energy source. Hot water, heating and electricity will be supplied for the 132 m2 house. Electricity surplus will be transferred to electricity network. System scheme is shown in Figure 2. Energy surplus of the building which demands 3500 kWh energy annually will be transferred to the network thanks to the on-grid system. 3 pieces of 2.1 kVA Anonymous inverters were planned. The building is a detached house of 132 square meters. 150 litres of 50^{o}C hot water is consumed daily.

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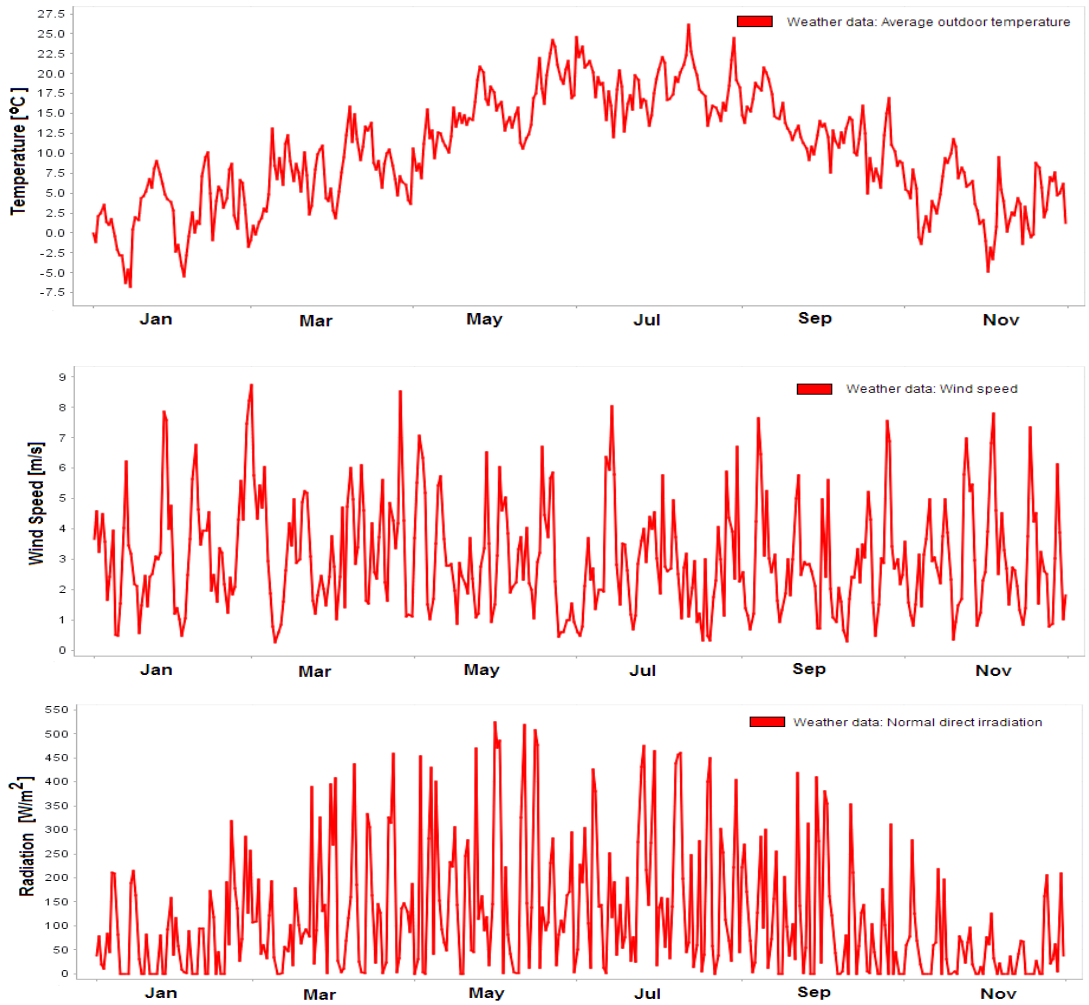

Fig. 1. *Climate values*

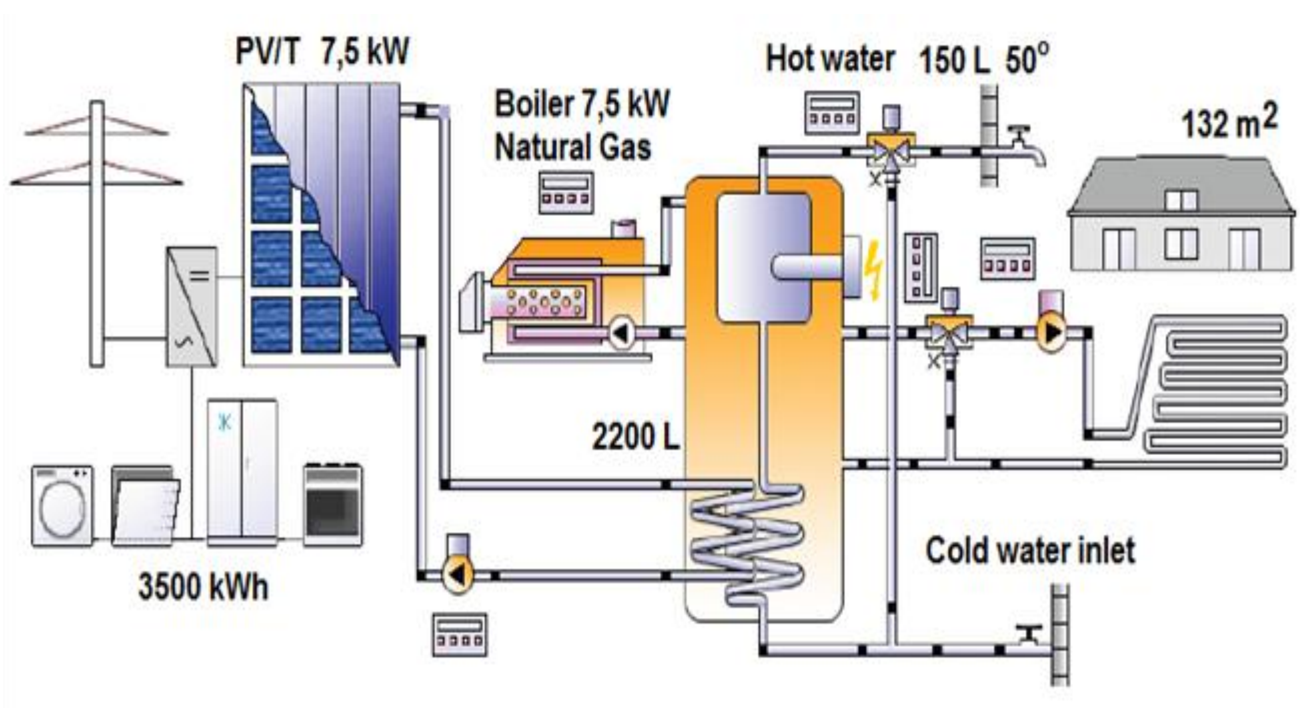

Fig.2. *System diagram*

III. PV/T

30 pieces of 250 W Dualsun monocrystalline PV/T panels were used in the system. Its nominal voltage is 30.7 V and nominal current is 8.15 A. Its efficiency is 15.4%. Total panel area is 49.2 m2 and installed power to supply the total electricity production is 7.5 kW. Panel properties are given in Table 1.

IV. Findings and Discussion

PV/T system and a gas fired boiler will supply energy for the building which demands 150 litres of 50oC hot water daily, 350 kWh of electricity monthly and 6822 kWh heating energy annually. Energy surplus will be transferred to the network. Monthly changes in the energy demand are displayed in Figure 3. Monthly temperature changes in different points of the system are shown in Figure 4. Monthly energy production via solar energy and gas fired boiler are given in Figure 5. A total of 13570 kWh energy is demanded by the building for heating, electricity and hot water annually. Solar energy provides 13045 kWh energy annually, most of which is used for electricity. Energy surplus is transferred to the network.

TABLE I. PANEL PROPERTIES

Brand Name	Dualsun
Model	DS 250 M
Cell type	Si-mono
Maximum Power (Pmax)	250 W
Nominal Voltage (Vmp)	30.7 V
Nominal Current (Imp)	8.15 A
Open Circuit Voltage(Voc)	38.5 V
Short Circuit Current (Isc)	8.55 A
Efficiency	15.4%
Maximum temperature	75 ^{o}C
Max. Pressure	10 bar
Length	1650 mm
Width	990 mm
Weight	19.1 kg

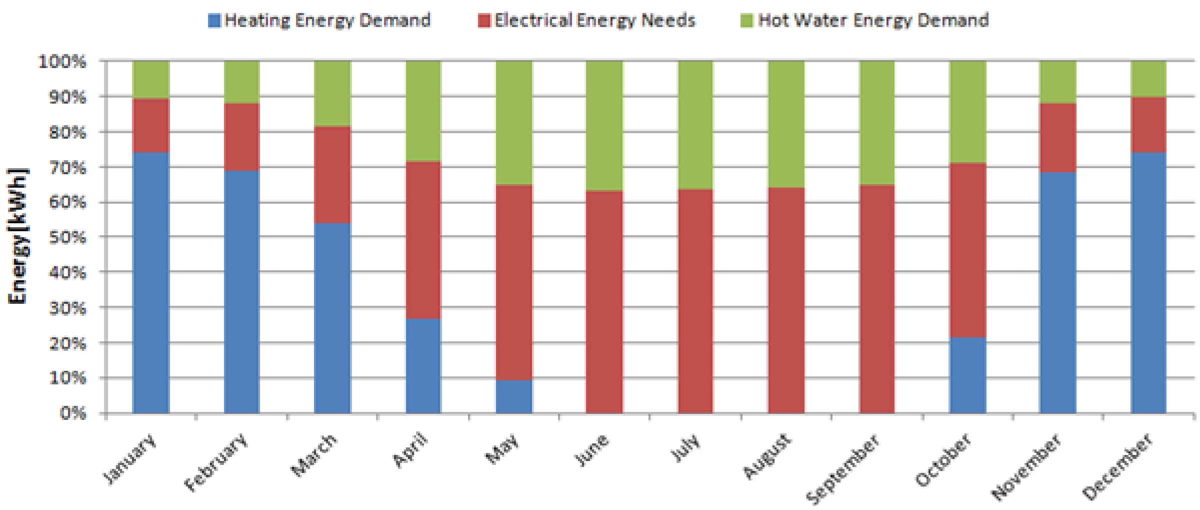

Fig. 3. *Changes in energy demand*

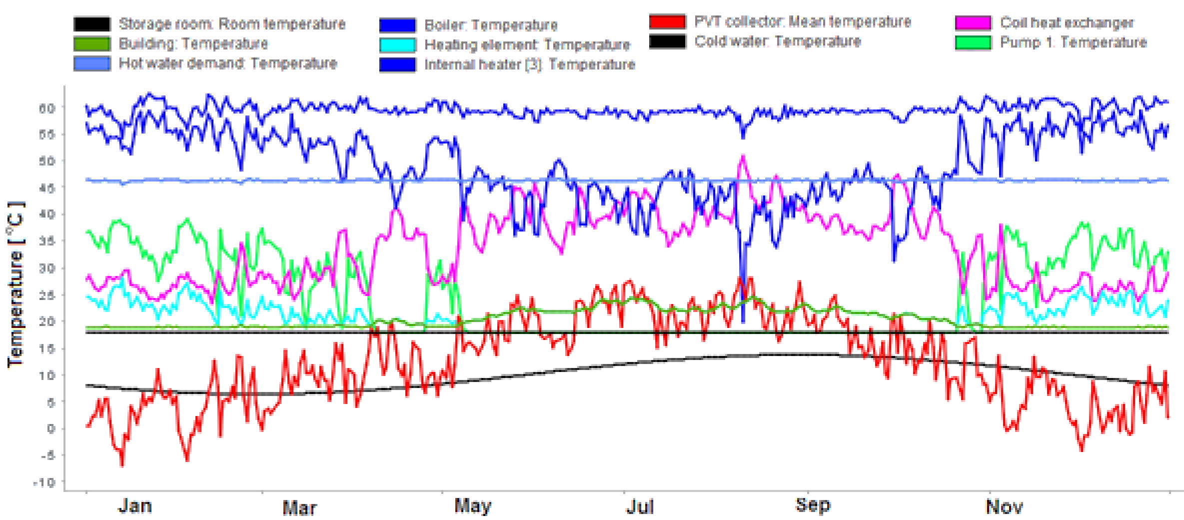

Fig. 4. *Temperature changes*

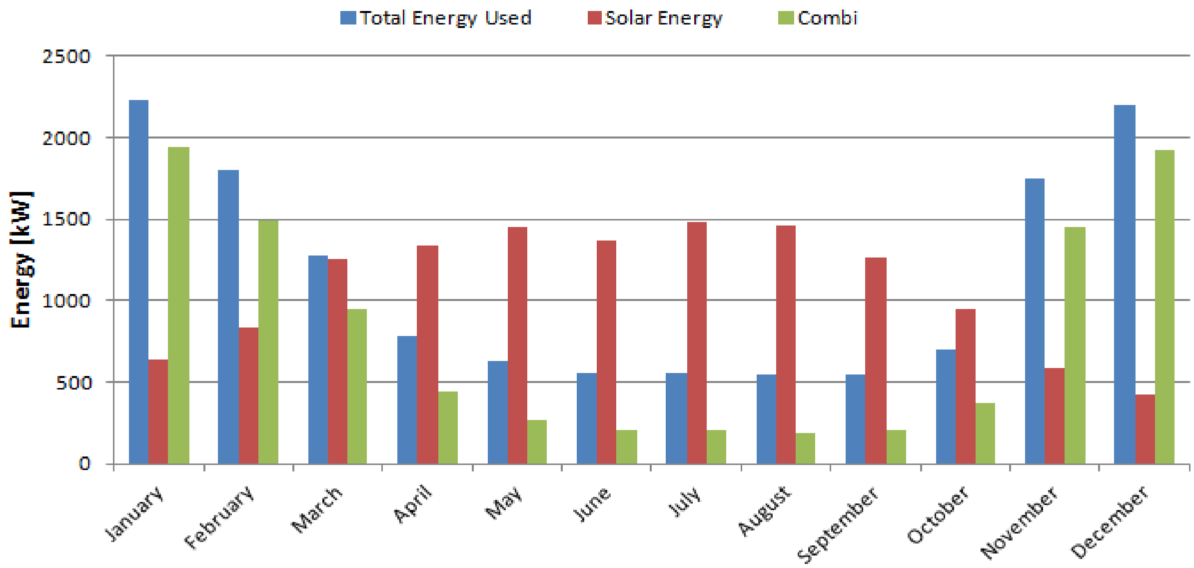

Fig. 5. *Monthly changes in energy*

V. Conclusion

PV/T systems supply energy for both electricity and hot water. PV/T hybrid systems are more productive compared to photovoltaic and solar collectors installed separately. In PV/T, PV system is cooled while hot water is heated, thus increasing the efficiency of PV system. In today's world, renewable energy sources gain importance each day and solar energy is a suitable option to supply energy for all demands of a building. More successful results can be obtained in Mediterranean region where radiation values and temperatures are high. When solar energy is insufficient, gas fired boilers, air conditioners and heat pumps may be used. It is concluded in this study that PV/T systems succeed in supplying hot water and heating for a building and that these systems must become more popular as Turkey usually benefits from solar energy to obtain hot water.

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