PHOTOVOLTAIC AND GEOTHERMAL INTEGRATION SYSTEM FOR GREENHOUSE HEATING: AN EXPERIMENTAL STUDY

Giacomo SCARASCIA MUGNOZZA, Simone PASCUZZI, Alexandros ANIFANTIS, Giuseppe VERDIANI
Department of Agro-environmental Sciences, "Aldo Moro" University of Bari,
Via Amendola 165/a, 70125 Bari, ITALY
e-mail: scarasci@agr.uniba.it; simone.pascuzzi@agr.uniba.it; a.s.anifantis@agr.uniba.it; giuseppeverdiani@hotmail.it

Keywords: greenhouse heating, renewable energy sources, hot water, low enthalpy energy

Introduction

Greenhouse crops are one of the most innovatory examples of modern agriculture and it is envisaged for them to expand more and more in future, especially in areas with unfavourable climatic conditions. They are one of the highest man-made forms of agricultural activity, because of the intense technological and bio-agronomic inputs in confined portions of the agricultural environment (Scarascia Mugnozza, 1995).

Energy consumption is one of the main cost factors in commercial greenhouses since high amounts of energy are used for greenhouse climate control in order to obtain good yields and high quality (Korner et al., 2004). The conventional greenhouse heating systems supplied from fossil fuel have a strong negative impact on agro-ecosystems (Scarascia Mugnozza, 1992).

Energy necessary to heat 1 m^2 of greenhouse area ranges from 500 to 2700 MJm^{-2} yr^{-1}, depending on the site, the cultivated plants, the greenhouse covering and the level of climate control.

The use of fossil fuel for greenhouse heating has a major impact on the cost and environmental sustainability of vegetable production.

The recent raise of prices of energy produced from fossil fuels has further increased productive costs of horticultural protected cultivations.

Many efforts have been made to reduce greenhouse energy consumption in greenhouse climate control, while interest has recently been aroused in alternative energy sources, which include renewable energy sources (Vox et al., 2006).

Renewable energy sources are particularly appropriate to ensure optimal microclimatic conditions for the growth of greenhouse crops and provide a major impetus to the ecological conversion of greenhouse heating systems (Ozgener, 2005; Scarascia Mugnozza, 2009). In this context, the greenhouse heating with geothermal heat pump result to be very convenient in terms of environmental and economic (Ozgener, 2010; Adaro et al., 1999).

Aim of the research was to assess the potential of the system in terms of energy production, efficiency and economy.

Materials and methods

The performance analysis of integrated photovoltaic and geothermal systems for greenhouse heating was investigated in an experimental study carried out at the University of Bari, Southern Italy.

Two experimental greenhouses with the same geometric and constructive characteristics (Fig. 1), have been realized, one of them heated and one unheated for comparison.

A 7.2 kW low enthalpy heat pump (Fig. 2) combined with a 120 m vertical double U-bend ground heat exchanger was installed in order to satisfy the thermal energy demand of 48m^2 single plastic skin greenhouse.

The electrical energy for heat pump operation is provided by an array of photovoltaic panels with a pick power of 1620 W.

The main physical and environmental parameters were measured over the winter period in order to analyze the energetic performance of the above mentioned integrated system for greenhouse heating (Fig. 3).

Figure 1. Experimental greenhouses.

Figure 2. Heat pump and boiler.

Figure 3. Heating system inside the greenhouse.

Particularly the thermal energy extracted from the soil, the electrical energy adsorbed by heat pump, the internal and external greenhouse air temperatures, the plant working fluid temperatures were measured and recorded continuously by suitable sensors connected to a data logger (Fig. 4).

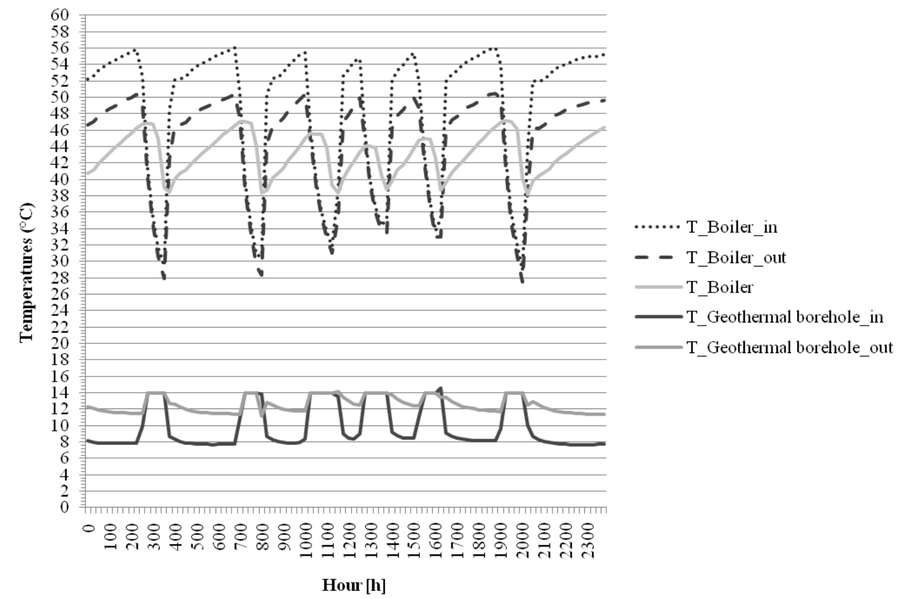

Figure 4. Heating system water temperatures on January 1, 2011.

Results

The heat pump turned 1620 kWh of electric energy in 6480 kWh of thermal energy during the three winter months of working (from December to February). In the same period the photovoltaic panels produced 2226 kWh of electrical energy. Then the electric energy required for heat pump operation was supplied entirely by photovoltaic panels.

The obtained results showed that the use of geothermal sources integrated with photovoltaic panels can supply the total heating energy demand of greenhouse. The 75% of the thermal energy (4860 kWh) was provided from the soil with an economy saving of 40% compared to the traditional heating systems.

The difference between the heating greenhouse and the external air temperatures was 6°C; moreover the difference between the heating and not heating greenhouse air temperatures was 8°C (Fig. 5).

As well know, due to the phenomenon of nocturnal thermal inversion the air temperature inside the not heated greenhouse was less than the external one, then the use of the heat pump has been useful both to avoid the nocturnal thermal inversion and to increase the air temperature inside the greenhouse.

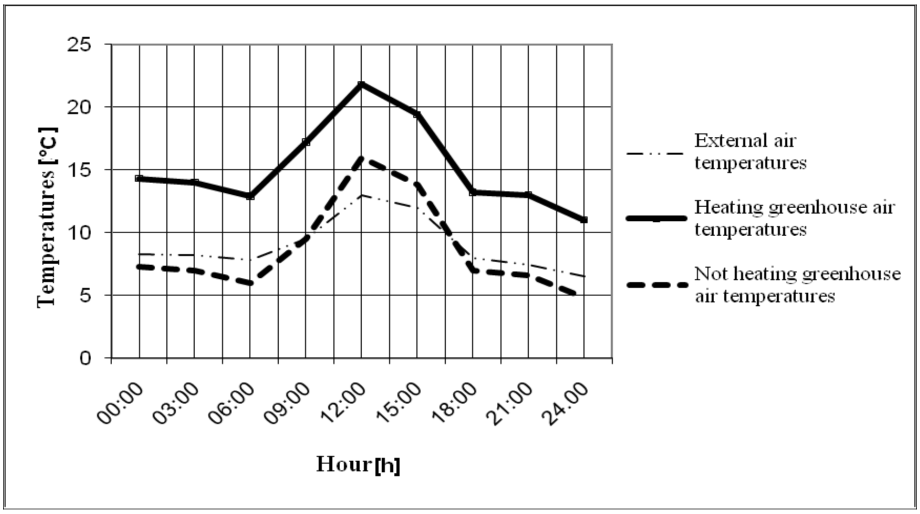

Figure 5. External and internal greenhouse air temperatures on January 1, 2011.

Discussion

The obtained results clearly show that the greenhouse energy demand can be effectively, efficiently and ecologically satisfied by the realized experimental system.

The coupling of heat pump with photovoltaic panels allowed to decrease the CO_2 emissions and to save primary energy of fossil fuels.

The environmental benefits of the realized system will be evaluated by life cycle assessment in the next step of the research.

References

[1] Adaro J. A., Galimberti P. D., Lema A. I., Fasulo A., Barral J. R., 1999, *Geothermal contribution to greenhouse heating*. Applied Energy 64: 241-249.

[2] Korner O., Bakker M.J., Heuvelink E., 2004, *Daily Temperature Integration: a Simulation Study to quantify Energy Consumption*. Biosyst. Eng. 87 (3): 67–77.

[3] Ozgener O, Hepbasli A., 2005, *Performance analysis of a solar assisted ground-source heat pump system for greenhouse heating: an experimental study*. Building and Environmen 40:1040–50.

[4] Ozgener O, 2010, *Use of solar assisted geothermal heat pump and small wind turbine systems for heating agricultural and residential buildings*. Energy 35:262–268 40:1040–50.

[5] Scarascia Mugnozza G., 1992, *Soluzioni costruttive e impiantistiche serricole a basso impatto ambientale*, Colture Protette n. 11.

[6] Scarascia Mugnozza G., 1995, *Sustainable greenhouse production in mediterranean climate: a case study in italy*, MEDIT 6 (4), 48-53.

[7] Scarascia Mugnozza G., Anifantis A., 2009, *Dal fotovoltaico al termico*, Colture Protette Vol. 6: 40-43.

[8] Vox G., Scarascia-Mugnozza G., Schettini E. 2006. *Photovoltaic solar cells and wind turbine for greenhouse climate control in Mediterranean areas*. Intl. Conf. Agricultural Engineering, AgEng2006 Bonn, Germany, 3-6 September 2006.