Journal of Agriculture and Environmental Sciences
June 2015, Vol. 4, No. 1, pp. 70-76
ISSN: 2334-2404 (Print), 2334-2412 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/jaes.v4n1a9
URL: http://dx.doi.org/10.15640/jaes.v4n1a9

Overview of Heating Greenhouses with Renewable Energy Sources a Case Study in Crete-Greece

John Vourdoubas[1]

Abstract

Heating greenhouses results in higher productivity and better quality of the produced crops mainly in Northern climates. Apart of conventional fuels already used for heating them, renewable energy sources are expected to play an important role in the near future. Among them solar energy, geothermal energy and biomass have been used in various greenhouses all over the world. A successful operation of a greenhouse cultivated with flowers during 2012-2014 in Crete-Greece heated with olive kernel wood proves that this solid fuel is a cheap energy source which can cover all the heating needs of the greenhouse lowering at the same time its CO2 emissions due to energy use. Olive kernel wood is an endogenous, renewable and CO2 neutral energy source in areas where olive trees grow. Additional installation of a Photovoltaic system in the greenhouse already heated with solid biomass in Crete will result in zeroing its CO2 emissions due to energy use in it. Since the heat demand in the greenhouse is much higher than the electricity demand, replacement of fossil fuel with a renewable fuel results in significant decrease of CO2 emissions due to energy use.

Keywords: Heating greenhouses, renewable energy sources, solar energy, geothermal energy, biomass, olive kernel wood

1. Introduction

Growth of high quality vegetables in greenhouses in Northern climates is connected with the creation of optimum growth conditions including optimum temperatures. Due to severe environmental problems caused by fossil fuels there is an increasing interest to use renewable endogenous energy resources for heating them particularly if they are cost effective. Among renewable energies the most important for providing the necessary heat in the greenhouses are solar energy, geothermal energy and biomass, (Sethi et.al., 2008, Vourdoubas, 2004) . In areas where olive trees grow a traditional fuel used for heating is the olive kernel wood which is a byproduct of the olive kernel oil producing industry. This solid fuel is used since many decades and its low price, local availability and good combustion characteristics make it very attractive. Therefore it is broadly used for heating in buildings, in small and medium enterprises and in greenhouses replacing heating and fuel oil (Vourdoubas, 1999). The severe economical crisis in Greece the last five years has increased substantially the price of heating oil which has resulted in its replacement with alternative fuels in many cases. In Crete-Greece the cultivation of many millions olive trees makes available the production of solid biomass based on olive trees like olive firewood, olive tree cuttings and olive kernel wood. Current price of olive kernel wood in Crete compared with its heating value makes it very attractive as substitute of fuel and heating oil. At the same time since olive kernel wood is a renewable energy source its use in greenhouses results in a large reduction of CO_2 emissions due to energy use in them. Greenhouses in Crete apart from using solid biomass for covering all their heating needs can also use solar energy with Photovoltaic cells for covering their electricity needs. Generation of electricity from PV cells is cost effective today and the legal framework in Greece for their use in greenhouses with net-metering exists.

[1] Lecturer , Technological Educational Institute of Crete , Department of Natural resources and environmental engineering , 3 Romanou str., 73133 , Chania ,Crete, Greece , tel: +30-28210-23070 , E-mail: vourdoubas@chania.teicrete.gr

2. Use of Various Renewable Energy Sources for Heating Greenhouses

Among various renewable energy sources, solar energy, geothermal energy and biomass have already been used for heating greenhouses. Solar energy has been used mainly with passive systems and energy storage (Santamouris et.al., 1994). Geothermal energy has been used directly (hot fluids with temperatures 50-100 °C (Bakos et.al., 1999) or indirectly with low enthalpy heat pumps (Esen et. al., 2013). Geothermal energy has also been used for cooling greenhouses during the summer with buried tubes inside the ground (Santamouris et.al.1995). Finally biomass has been used for heating greenhouses either in gaseous form (biogas) (Jaffrin et. al., 2003) or in solid form (various wood products and byproducts) (Vourdoubas, 1999). Heating needs of greenhouses depend on their construction, on the local climatic conditions and on the cultivated crop. The abovementioned renewable energy sources can cover part or all their heating needs. Which renewable energy source will be used depend on its availability, its relative price, the initial investment cost, the heating needs of the greenhouse and the possibility of covering part or all of them as well as from other factors. The combination of the abovementioned renewable energy sources can also result in covering all the heating needs of the greenhouse.

2.1. Solar Energy

Many types of passive solar systems have been used for heating greenhouses (Santamouris et.al, 1994). According to the characteristics of the heat storage system they are categorized as greenhouses with:

a) Heat stored in water
b) Heat stored as latent heat in various materials
c) Heat stored in rock bed
d) Heat stored in buried pipes

These passive solar systems can only cover part of the energy needs and can achieve temperatures 3-20 °C higher than the minimum outdoor temperature. A survey and evaluation of various heating technologies (Sethi et.al, 2008) proves that solar technologies can cover significant part of the heating needs of greenhouses. The operation for two years of an experimental passive solar greenhouse of 1,000 m^2 has shown energy gains equal to 35% of the annual heating requirements (Santamouris et.al, 1994). A literature investigation of various passive solar greenhouse classifies them in three categories according to the phase change materials used (Kurklu, 1998). These phase change materials (salt hydrates, paraffins, polyethylene glycol) can be used both for energy storage and humidity control in the greenhouses. Passive solar systems can also be used for covering the cooling needs of greenhouses (Santamouris, et.al., 1995, Chou et. al., 2004). The operation of a passive solar greenhouse with buried pipes has shown that it lowers the heating needs during the winter and its cooling needs during the summer. The investigation of the energy behavior of a greenhouse equipped with PV cells has been implemented in New Delhi , India (Nayak et.al. ,2008) . The PV cells were integrated in the south wall of the greenhouse and heat and electricity were generated. The heat was convected inside the greenhouse and the electricity was stored in batteries. The overall results during its operation were satisfactory. An exegetic analysis of a greenhouse cooled by an earth to air heat exchanger powered by a solar photovoltaic cell was studied in Izmir, Turkey (Yildiz, et.al. 2001). In this greenhouse significant part of its cooling requirements were covered by solar and geothermal energy.

2.2. Geothermal Energy

Geothermal energy can be used either directly utilizing warm fluid at approx 50-80°C or with low enthalpy heat pumps. A greenhouse heated with geothermal fluid of approx 100°C in Northern Greece has been used for cultivation of roses and an inside temperature of 20°C was required. The used geothermal fluid with mass flow rate of 42 tons/h and temperature of 95°C was maintaining an inside temperature of 20°C when the outside temperature was 7°C. The installed geothermal space-heating system of 2.26 MWth was covering all the heating needs of the greenhouse of 10.000 m^2 (Bakos et. al, 1999). Another greenhouse operating in Izmir, Turkey using a solar – assisted vertical ground – source heat pump has been reported by (Ozgener et.al, 2007). For ambient temperatures of 5.8-12.5°C the inside temperatures were 15.8-22.5°C. The COP of the heat pump was varying between 2 and 3.13 and it was proved that the heating system was operating satisfactorily without serious defects. A greenhouse heated with low enthalpy geothermal water with temperature of 28°C which was circulated in plastic pipes placed on the ground was studied in Argentina (Adaro et.al., 1999).

Experimental operations during three years period have shown satisfactory results regarding its space heating with low temperature geothermal water. The energy behaviour of a greenhouse equipped with a heat pump for heating, cooling and dehumidification was studied in Bangkok. The heat pump was achieving day temperature of 27 ^{o}C and night temperature of 18^{o}C having COP 1.2-4.0.

2.3. Biomass

The experimental investigation of a combined heated system with biogas, solar energy and ground-source heat pump has been reported in Elazig, Turkey (Esen et.al., 2013). Biogas was produced in situ using cow manure and the reactor was heated using solar energy. The project aimed to prove that a combination of various renewable energy sources like biogas, solar energy and low enthalpy geothermal energy can be used for the effective heating of a greenhouse. During the experimental operation of the greenhouse the outside air temperature was varying between 0^{o}C and 13^{o}C, the ground temperature between 8^{o}C-11^{o}C and the inside air temperature in the greenhouse was kept at 23^{o}C. The possibility of heating greenhouses with biogas with simultaneous enrichment of the inside air with CO_2 was investigated in France. The exhaust gases after burning the biogas were injected inside the greenhouse where roses were cultivated. During the experimental period of 24 months high productivity was obtained and the gains due to better productivity were higher than the heating cost reduction due to biogas use. This method offers the possibility of greenhouses construction nearby landfill sites and use of the produced biogas in the greenhouses. Heating greenhouses in Crete with olive kernel wood has been presented (Vourdoubas, 1999) as well as a multicriteria comparison of heating them with solar energy, geothermal energy and solid biomass (Vourdoubas, 2004). Possibilities for zeroing CO_2 emissions from greenhouses due to energy use has been presented (Vourdoubas , 2009) as well as the current use of olive kernel wood in Crete for heat production (Vourdoubas, 2015) . Renewable energy sources which have been used for covering energy needs in greenhouses are presented in table 1.

Table 1: Renewable Energy Sources which have been used for Heating Greenhouses

Energy source	Characteristics of the systems	Cover of heating needs	Cover of cooling needs
Solar energy	Heat storage in various materials	Partly	No
Solar energy	Heat storage in buried pipes	Partly	Partly
Geothermal energy	Hot fluid 50-80^{o}C circulated in pipes	All	No
Geothermal energy	Low enthalpy heat pump	All	All
Biomass (biogas)		All	No
Biomass (solid)	Hot water circulated in pipes	All	No

3. Characteristics of Olive Kernel Wood

Olive kernel wood is a byproduct of the olive kernel oil producing industry and its annual production in Crete Greece is approx 110,000 tons. Biomass fuels including olive kernel wood cover currently 8.5 % of the energy needs of Crete (Zografakis, 2005). Its current price is 0.08 €/kg and its heating value is 4,051 Kcal/kg (16.96MJ/Kg). It is easily transported from the production plant to the consumption site since its form is granular. In table 2 olive kernel wood chemical compositions is presented.

Table 2: Chemical Composition of Olive Kernel Wood

Water content	6.3%
Ash	8.0%
Organic matter	65.50%
Sulphur	0.11%
Total Carbon	45.30%
Hydrogen	5.17%
Nitrogen	1.33%
Oxygen	34.30%
Heating value	4.051Kcal/kg, 16.96MJ/Kg
Residual oil	2.44%
Residual hexane	≤10mg/kg
Chlorine	0.69%

The price of olive kernel wood is low compared with other energy sources in Crete. However its burning efficiency is lower than the corresponding efficiency of fuel or heating oil. In Table 3 the current price of olive kernel wood together with the prices of other energy sources in Crete are presented.

Table 3: Prices of Various Energy Sources in Crete

Energy source	Price (€/1000Kcal)	Efficiency (%)	Price (€/1000Kcal delivered)
Olive kernel wood	0,022	70	0,036
Fuel oil	0,045	90	0,050
Heating oil	0.095	90	0.106
Electricity	0,116	100	0,116
Electricity/heat pump	0,116	200-250	0,046- 0,058

4. Description of a Greenhouse in Crete Heated with Olive Kernel Wood

A commercial greenhouse in Chania Crete [35^{o}, 30`, 40`` N, 24$^{o}$ 01` 45`` E] for cultivation of flowers has been constructed and it used olive kernel wood as a fuel for covering all its heating needs during 2012-2014. The total area of the greenhouse is 3,300 m^2 and the required indoor temperature is 19^{o}C. The mean monthly average ambient temperature for Chania is presented in Table 4

Table 4: Monthly Average air Temperatures in Chania Crete

January	10,8^{o}C
February	11,0^{o}C
March	12,4^{o}C
April	15,8^{o}C
May	20,1^{o}C
June	24,7^{o}C
July	26,6^{o}C
August	25,9^{o}C
September	23,2^{o}C
October	19,4^{o}C
November	15,3^{o}C
December	12,4^{o}C

Heating of the greenhouse is required for many months during the year. The power of the heating system is 750 KW. The annual average consumption of olive Kernel wood the last three years is estimated at 220 tons/year with heating value of 8.91x10^9 Kcal (1,035,099 KWh). The average annual heat demand of the greenhouse is estimated at 220 KWh /m^2·year. The greenhouse is fully automatic including aeration, humidity and irrigation control as well as cooling during summer and it uses electricity for the operation of various machinery. The efficiency of the heating system and the hot water distribution system is estimated at 70% depending on the regular cleaning and maintenance of the boiler. Since the existing system covers all the heating needs of the greenhouse it does not use any additional heating system. The annual consumption of electricity is estimated at 48,500 KWh and it corresponds to a specific consumption of 14 KWh/m^2·year. The characteristics of the greenhouse are presented in Table 5

Table 5: Characteristics of the Greenhouse Heated with Olive Kernel Wood in Crete – Greece

Operation period	2012-2014
Area	3,300 m^2
Cultivated crop	Flowers
Inside air temperature	19 ^oC
Annual consumption of olive kernel wood	220 tons
Heating value of the used olive kernel wood Heat demand of the greenhouse	1,035,099 KWh 724,569 KWH
Power of the heating system	750 KW
Efficiency of the heating system	70%
Annual consumption of electricity	48,500 KWh
Total energy consumption	1,083,599 KWh
Total Specific energy consumption	318 KWh/m^2·year
Heating value of olive kernel wood	4,051 Kcal/Kg
CO_2 emissions avoided due to solid biomass use	279 tons CO_2/year
Specific gross heat consumption	214 KWh/ m^2·year
Specific electricity consumption	14 KWh/ m^2·year
Specific heat demand of the greenhouse	220 KWh/ m^2·year
Percentage of electricity to total energy consumed CO_2 emmisions due to electricity use	4.69 % 39 tons CO2 /year

5. Use of a Photovoltaic System for Zeroing the CO_2 Emissions in the Greenhouse Due to Energy Use

Since solid biomass is used instead of fossil fuels for heating the greenhouse, the only CO_2 emissions due to energy use are created because of the electricity consumption. Solar irradiance in Crete is rather high and the monthly and annual solar irradiance in Chania Crete is presented and in Table 6.

Table 6: Solar Irradiance in Chania – Creece Angle 30^o, KWh/m^2

January	83
February	97
March	128
April	152
May	183
June	191
July	208
August	207
September	172
October	127
November	107
December	83
TOTAL	1.738

The used electricity from the grid can be substituted with PV-solar electricity fed into the grid. Installation of a PV system in the abovementioned greenhouse connected with the grid can generate annually the same electricity that the greenhouse consumes. Therefore an offsetting of the fossil fuel generated electricity of the grid and used in the greenhouse can be obtained since the P.V. system will generate annually the same amount of electricity which will be fed in to the grid. It is estimated that a PV system with nominal power of 32.3 KWp in Crete can generate annually 48.500 KWh (Kagarakis, 1987) , Since the greenhouse uses the same amount of grid electricity that the PV system generates and feeds to the grid , there is not any net grid electricity consumed. Alternatively an autonomous PV system can generate the electricity consumed in the greenhouse but since electricity storage is needed the cost of such a system is substantially higher than in the previous case of the interconnected with the grid PV system. The cost of such a system in Greece currently is estimated at 45,000 Euros.

6. Environmental Considerations

Since olive kernel wood is a CO_2 neutral fuel its use for heating the abovementioned greenhouse results in less CO_2 emissions due to energy use. If instead of solid biomass, fuel oil was used then significant amounts of CO_2 were going to be emitted. It is estimated that if in the same greenhouse fuel oil was used it would result in the emissions of 279 tons of CO_2 annually. Additional CO_2 emissions are created due to the use of electricity in the greenhouse. It is estimated that 39 tons/year of CO_2 are emitted due to electricity consumption in it. Therefore the use of solid biomass and PV electricity in the greenhouse will save 318 tons of CO_2 annually, zeroing its emissions due to energy use.

7. Conclusions

Renewable energy sources are expected to find more applications in the daily life the coming years. Among then their use in heating greenhouses is going to increase since many of renewable energies technologies are cost effective and environmentally friendly. Various studies for using solar energy, geothermal energy and biomass have been implemented and various commercial applications already exist. Operation for three years (2012-2014) in Chania Crete Greece of a commercial greenhouse for flowers cultivation using olive kernel wood as fuel for covering all its heating needs has proved its reliability and profitability. Olive kernel wood, a local endogeneous and CO_2 neutral solid biomass source in Crete, is cheap compared with its heating value. Its current price in Crete is lower than the prices of other fuels including electricity. The investment cost of the described heating system is significantly lower than a corresponding heating system using low enthalpy geothermal heat pump which also can cover all the heating needs of the greenhouse. The fuel is easily transportable from the producing factory to the greenhouse and it is easily handlable. Electricity consumption corresponds to 4.69% of total annual energy needs of the greenhouse, therefore the demand of heat which corresponds to 95.31 % of the energy needs, is much higher than its electricity demand. The fact that a renewable and CO2 neutral energy source is used for heating the greenhouse results in a significant decrease of CO_2 emissions due to energy use. Future use of photovoltaic cells in the greenhouse will generate all the electricity which is demanded in it and the cost of such a system is not prohibitive. The combined use of solid biomass for heating and of solar-PV cells for electricity generation will result in the production of flowers with zero CO_2 emissions due to energy use.

References

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.

Bakos, G. C., Fidanidis, D, Tsagas, N. F. (1999). "Greenhouse heating using geothermal energy". Geothermics, 28, 759-765.R

Bargach , M.N., Tadili , R., Dahman , A.S. , Boukallouch . M. (2002) . "Survey of thermal performances of a solar system used for the heating of agricultural greenhouses in Morocco". Renewable energy, 20, 415-433.

Chou, S.K., Chua, K.J., Ho, J.C., Ooi, C.L. (2004). "On the study of an energy efficient greenhouse for heating, cooling and dehumidification applications". Applied Energy, 77, 355-373.

Esen, M., Yuksel , T. (2013). "Experimental evaluation of using various renewable energy sources for heating a greenhouse". Energy and Buildings, 65, 340–351A.**E SOLAR**

Ghosal, M.K., Tiwari, G.N. (2004). "Mathematical modeling for greenhouse heating by using thermal curtain and geothermal energy". Solar Energy,76, 603–613.

Jaffrin, A. , Bentounes ,N., Joan, A.M., Makhlouf, S. (2003). "Landfill biogas for heating greenhouses and providing Carbon Dioxide supplement for plant growth". Biosystems engineering, 86 , 113-123.

Kagarakis, K., (1987) " Photovoltaic Technology " Symmetria Publications , Athens , (In Greek).

Kurklu , A. , (1998). "Energy storage applications in greenhouses by means of phase change materials: a review", Renewable energy, 13, 89-103.**PURPOSES**

Nayak, S., Tiwari, G.N. (2008). "Energy and energy analysis of photovoltaic/thermal integrated with a solar greenhouse". Energy and Buildings, 40, 2015–2021.C

Ozgener,O., Hepbaslib, A. (2007). "A parametrical study on the energetic and exergetic assessment of a solar-assisted vertical ground-source heat pump system used for heating a greenhouse". Building and Environment, 42, 11–24.

Santamouris, M., Argiriou, A., Vallindras, M. (1994). "Design and operation of a low energy consumption passive solar agricultural greenhouse", Solar Energy, 52, 371-378.

Santamouris, M., Balaras, C.A., Dascalaki, E., Vallindras, M. (1994). "Passive solar agricultural greenhouse: A worldwide classification and evaluation of technologies and systems used for heating purposes', Solar Energy, 53, 411-426.

Santamouris , M., Mihalakopoulou ,G., Balaras , C.A. ,Argiriou , A., Asimakopoulos, D., Vallindras, M., (1995). "Use of buried pipes for energy conservation in cooling of agricultural greenhouse". Solar energy, 55, 111-124.

Sethi , V.P., Sharma , S.K. ,(2008) . "Survey and evaluation of heating technologies for worldwide agricultural greenhouse applications" .Solar Energy, 82, 832–859.AS

Vourdoubas, J., (1999), "Heating greenhouses in Crete using Biomass. The case of olive-Kernel wood", in the conference Energy and agriculture towards the third millennium, Athens, Greece.

Vourdoubas, J., (2004) "Comparison of greenhouse heating with geothermal energy, biomass and solar energy", in the conference "Geothermal energy applications in agriculture" Athens, Greece.

Vourdoubas, J., (2009). "Possibilities of zeroing CO_2 emissions due to energy use in greenhouses in Crete", Journal of agriculture and cattle breeding, 7, 66-73, (in Greek).

Vourdoubas, J., (2015), "Present and Future Uses of Biomass for Energy Generation in the Island of Crete – Greece"**,** Journal of Energy and Power Sources, in press.

Yildiz, A., Ozgener , O. , Ozgener, L. (2001). ,"Exergetic performance assessment of solar Photovoltaic cell assisted earth to air heat exchanger system for solar greenhouse cooling". Energy and Building, 43, 3154-3160.

Zografakis, N. (2005), "Crete: A preferential island for extensive applications of renewable energy sources in Europe and Mediterranean", in RE-islands conference, Brussels, 21/9/2005.

http://www.yr.no/place/Greece/Crete/Chania/statistics.html