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# Modelling of a novel Stand-Alone, Solar Driven Agriculture Greenhouse Integrated With Photo Voltaic /Thermal (PV/T) Panels

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## EXTENDED ABSTRACT

*This paper presents an analytical study of a new stand-alone agriculture greenhouse (GH) system. This system utilizes the excess solar radiation (more than that required by the plants for photosynthetic process) to generate electricity via a set of Photo Voltaic/Thermal (PV/T) units which are placed on the GH roof and south side. In addition to electricity generation, PV/Ts reduce the cooling load of the GH and help the system to be naturally ventilated. The system recovers the GH air humidity, including the plants transpiration, and uses it as irrigating water. Two coupled mathematical models are developed using MATLAB. The first model calculates the absorbed and transmitted solar radiation by/through each GH surface for a Clear Sky Day. The results of the first model are used as inputs to the second one that predicts the GH performance (GH surfaces and air temperatures, air relative humidity, air velocity, water production, electricity production and power consumption). These models are applied on climate conditions of Zagazig city, Sharqia, Egypt. The results show that the system presents a good solution for water shortage in Egypt as it has the ability to provide suitable climate conditions for plant growth (high quality and quantity) and produce enough water for irrigation purposes.*

### Mathematical Models

*The mathematical modelling is divided into two parts; the first model is developed to calculate solar radiation absorbed and transmitted by/through each GH covers. Solar radiation is calculated based on Clear Day Solar Flux Model [1]. Based on GH geometry and solar radiation angles the shading factor, which represents the percentage of the part of component area that exposed to solar radiation to the total area, is calculated. According to thermal and physical properties of each component and based on shading factor absorbed and transmitted total incident solar radiation is calculated instantaneously using a code written in MATLAB.*

*The second model predicts the performance of the GH using the results of the solar radiation model. A transient one dimensional mathematical thermal model based on mass and heat transfer is developed to predict GH surfaces' temperatures, circulating air conditions (temperature and relative humidity) at different positions, water production, power consumption for cooling system and power generation from PV/T & TPV panels. Each GH wall is considered isothermal surface and the ground is considered adiabatic surface. Figs. 1&2, [2&3].*

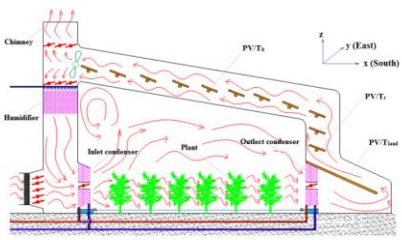



*Figure 1. Conceptual configuration of the solar driven GH*

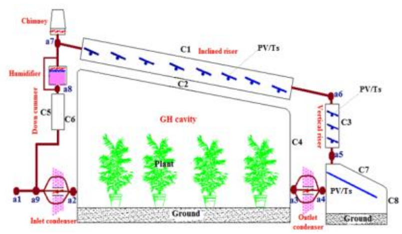
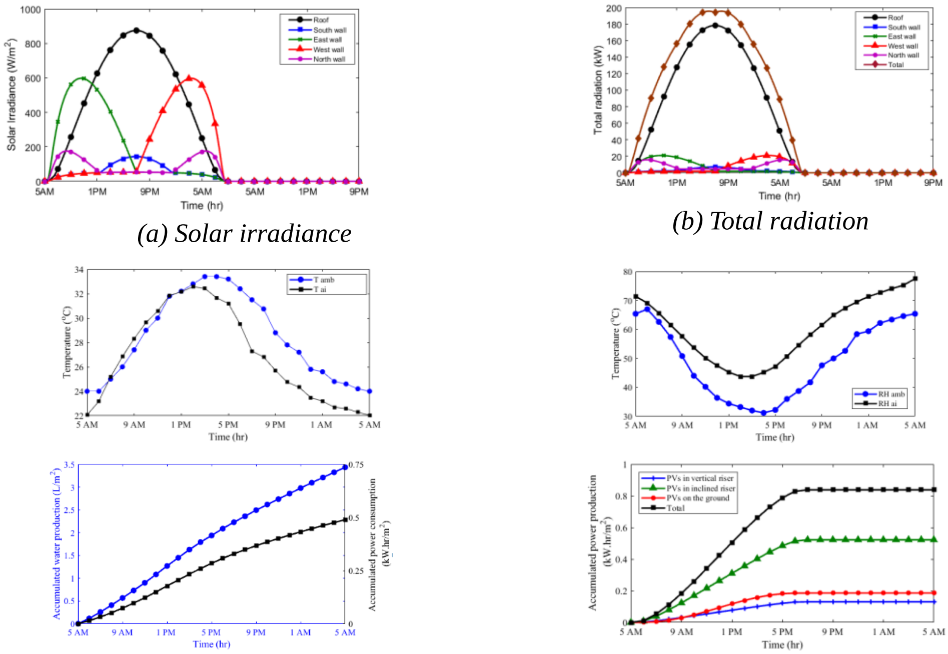



*Figure 2. Mathematical model of the GH system*

### Results and Discussion

*In order to provide plants with sufficient solar radiation required for photosynthesis, solar radiation transmitted into GH cavity via each GH surface is calculated instantaneously. For 21$^{st}$ June (maximum radiation day), the results showed that GH roof is the dominant cover for transmitting solar radiation into GH cavity. The irradiance of GH roof is about twice that of east or west wall (Fig.3 (a)). Figure 3 (a) is an only indication to the availability of solar radiation, but Figure 3 (b) presents the total solar radiation transmitted into GH cavity via each wall. It shows that about 90% of the total solar radiation transmitted comes from GH roof.*

*In addition to solar radiation, climate conditions and irrigating water are two essential factors for plant growth. To provide suitable conditions inside GH cavity, temperature and relative humidity are calculated instantaneously based on the developed thermal model. Ambient conditions for a typical day of maximum radiation in Zagazig, Egypt, are obtained based on the average values of last five years (2014-208), (Fig.3) [4].*




Solar radiation transmitted into GH cavity

*(a) Solar irradiance* *(b) Total radiation*

GH cavity conditions

Power and Water production

*Figure 3. Results for a typical day of maximum radiation in Zagazig, Egypt*

**Conclusions**

*This paper presents an analytical investigation for a newly developed stand-alone solar driven agricultural GH. This system utilizes the extra solar radiation (above that required by the plants photosynthetic processes) to generate electricity (using a set of TPVs and PV/Ts) and produce water for irrigation (using HDH process). Two coupled mathematical models are developed to predict GH performance for climate conditions of a typical day of 21st June as a maximum radiation day in Zagazig, Egypt. From the results it is concluded that:*

*a. Plants need only about 50% of available solar radiation and the other half could be used in this system to generate electricity and irrigating water.*

*b. The optimum percentage of area which can be equipped with TPVs is 75% of the roof area.*

*c. The system can provide a suitable climate for different plants growth.*

*d. The system can produce 3.5 L/m2.day of water with power consumption of 0.5 kW.hr/m2.day.*

*e. The system can generate 0.9 kW.hr/m2.day of electricity.*

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