Athens Institute for Education and Research
ATINER

ATINER's Conference Paper Series
AGR2017-2312

Selection of Photovoltaic Systems to the Greenhouses

Eugenio Romantchik
Professor
Autonomous University of Chapingo
Mexico

Eduardo Rios
Professor
Autonomous University of Chapingo
Mexico

An Introduction to ATINER's Conference Paper Series

ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. This paper has been peer reviewed by at least two academic members of ATINER.

Dr. Gregory T. Papanikos
President
Athens Institute for Education and Research

This paper should be cited as follows:

Romantchik, E. and Rios, E. (2017). **"Selection of Photovoltaic Systems to the Greenhouses",** Athens: ATINER'S Conference Paper Series, No: **AGR2017-2312.**

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209 Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm

ISSN: 2241-2891
16/11/2017

Selection of Photovoltaic Systems to the Greenhouses

Eugenio Romantchik

Eduardo Rios

Abstract

The high level of contamination that emanates from the production of electricity generated from fossil fuels has led to the search for new energy alternatives, including photovoltaic systems (PVS). Currently, the application of PVS in agricultural greenhouses presents difficulties. Greenhouses use a wide variety of electrical equipment depending on its level of technification, this translates into a photovoltaic system design specific to each one and entails an exhaustive selection of the components, therefore, a design cannot be applied from no way to two different greenhouses. In Mexico, electricity tariffs increased annually from 4.4 to 27% from 2003 to 2013. This research shows an algorithm for the selection of photovoltaic systems based on the geographic location, soil surface, electric charges and crop type, it shows the factors that influence the costs of photovoltaic systems for greenhouses. Results are useful for decision making. Experimentally, the results of the algorithm were validated by an off-grid system with battery bank for an irrigation system.

Keywords: Algorithm, Greenhouse equipment, Off-grid system Photovoltaics.

Introduction

Unavoidably, an agricultural greenhouse requires the use of electrical energy to generate optimal environmental conditions and increase crop production. The amount of this energy depends on the processes carried out in each greenhouse, eg heating, cooling, ventilation, irrigation, lighting, shade (Cuce et al., 2016; Ozkan et al., 2011). Solar radiation is a free energy source that can be used to satisfy those processes. The cost of electric power in the agricultural sector increases every year, Li et al. (2017) analyzed the economic performance of photovoltaic greenhouses and their electricity rates and recommended the use of photovoltaics for their short return on investment time.

Numerous experiments and studies have demonstrated the technical feasibility of installing photovoltaic systems in greenhouses (Yildiz et al., 2011; Beccali et al., 2014; Nayak and Tiwari, 2010). Nakoul et al. (2014) simulated the performance of a photovoltaic generator and concluded that the main factor for selecting the components of the system is the amount of energy used. However, there are still some problems to solve to implement photovoltaic systems, according to Cossu et al. (2014) and Carlini et al. (2012) the variation of the intensity of the solar radiation prevents an optimum performance in different places. In addition Mekhilef et al. (2013) says that the variation of the electric charges between each greenhouse prevents to reproduce the photovoltaic systems. In this sense, scientific methods are known to calculate the energy generated by a photovoltaic array (Pérez-Alonso et al., 2012; Almonacid et al., 2011). And some others to design and size them, (see Table 1), however, none are developed to service the greenhouse equipment in the agricultural sector and according to the studies of Osisioma et al. (2017) these techniques are highly complex and have a high computational cost.

Table 1. *Some Disadvantages of Scientific Methods to Design PV Systems*

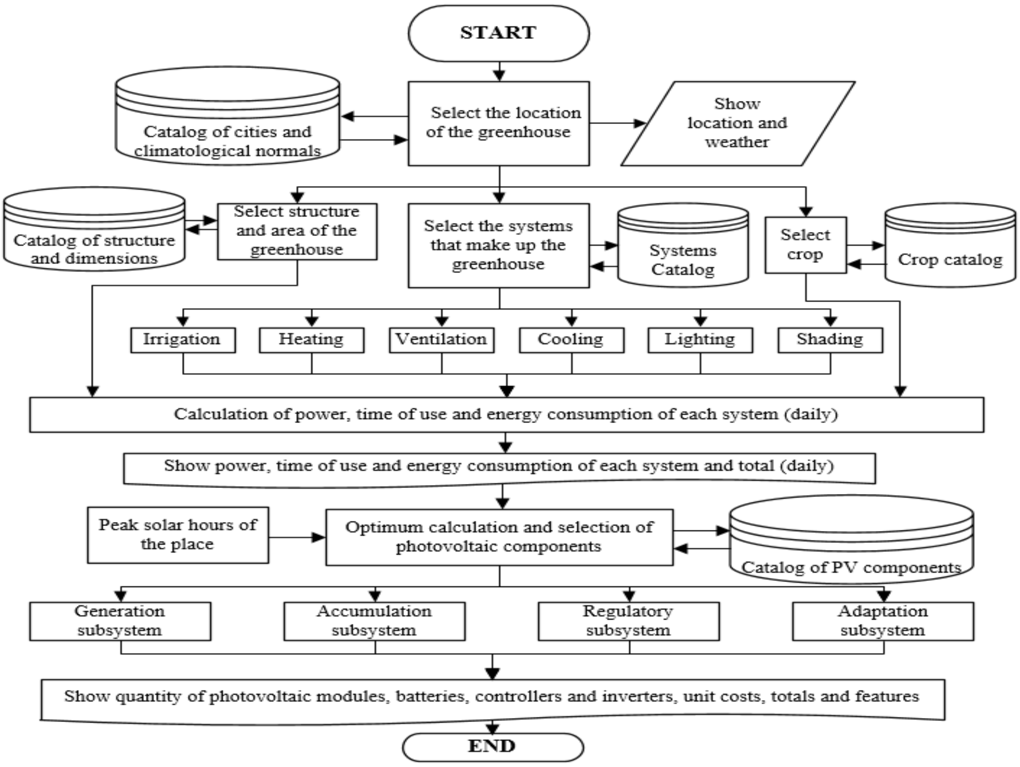
Author	**Country**	**Design methods**	**Disadvantages**
Chauhan and Saini (2017)	India	Discrete harmony search (DHS) algorithm	This model only applies to rural households with four types of renewable energy.
Ibrahim et al. (2017)	Malaysia	The proposed technique uses an accurate objective function as well as a fast simulation algorithm.	The mathematical model is not reproducible under conditions different from those of the experiment.
Okoye and Solyali (2017)	Turkey	Optimization model based on integer programming.	It is focused on stand-alone PV systems in the residential sector and not applies for greenhouses.
Belmili et al. (2014)	Algeria	Techno-economic analysis with object-oriented programming.	Hybrid systems are obtained (solar-wind) and increase the complexity of the system and its components.

The above problems are addressed in the present work whose main objective is to develop a tool based on an algorithm with specialized databases in greenhouses to select the technical characteristics and number of the components of the photovoltaic system (solar panels, current inverters, batteries power accumulators and load controllers). It is expected that the results of this research will be useful for its application during the design phase of any greenhouse.

Methodology

In Belmili et al. (2014) proposed an algorithm to size hybrid systems (PV-wind), and Nelson et al. (2006) developed a program to analyze economically the same type of system. In this work, a methodology is developed that addresses both issues (sizing and costs) and using only applied photovoltaic energy in greenhouses, reducing the complexity of the proposed systems and increasing their reliability. This is done in the following stages: 1) Development of the algorithm of calculation and selection, 2) Development of databases, 3) Software development, 4) Validation of results through experimental cases.

Figure 1. *Graphical Representation of the Developed Algorithm for Selecting PV Components*



Development of the Algorithm

Figure 1 shows the algorithm developed in this research. It can distinguish the four inputs to start the process of selecting the components of the photovoltaic system that satisfies the demands of a greenhouse: 1) the geographical location of the installation, 2) the greenhouse surface, 3) process systems that compose the greenhouse, 4) type of crop. The two main calculations that are described in the algorithm are the total energy consumed daily E_{tot} in kWh/day by the greenhouse and the calculation of components and their costs.E_{tot} must be at least equal to energy produced by photovoltaic system and it is calculated using eq. 1. Where: E_i: is the energy consumed by each process system (irrigation, heating, ventilation, cooling, lighting and shading) in $kWh/day$and is a function of the greenhouse area. The most representative systems with the highest energy demand in any agricultural greenhouse are heating, cooling and irrigation. The equations 2-4 calculate the electric energy of equipment for each of them. This value is obtained by multiplying $E_i$by the power of equipment by hours of use (t_{use}).

$$E_{tot} = \sum E_i = E_{heating} + E_{cooling} + E_{irrigation} + E_{lighting} + E_{shading} + E_{accesories} \quad \text{Eq. 1}$$

When the heating system is carried out using heat pumps and the heat loss is through the cover of the greenhouse, eq. 2 calculates the power in kW. Where Q: heat loss in $kcal/h$, COP: pump coefficient performance, 3412: conversion factor, C: specific heat air in$kcal/kg°C$, w_a: specific air weight in kg/m^3, A_g: greenhouse area in m^2,H_w: height of walls in m, R: air renewals per hour, $t_i - t_o$: difference of indoor and outdoor temperature in$°C$. For the irrigation system: the electric power of the water pumps (P_{pumps}) is calculated in kW by eq. 3, where A_g: greenhouse area in m^2, K_p: pipe expenditure factor, Q_e: mass flow of irrigation system in m^3/s, H_d: dynamic load in m, ρ: density of water in kg/m^3, g: acceleration of gravity in m/s^2,E_r: spacing between rows, E_e: spacing between emitters in m, 746: conversion factor, $\eta_p$hydraulic efficiency of the pump and η_m: electric efficiency of the motor. The pad-fan system is the most used for cooling greenhouses and requires air extraction fans and pumps to recirculate water in the wet pad. Nelson (1998) presents a method to select the power of this equipment according to the area of the greenhouse, altitude above sea level, and difference in temperature of the air circulating inside the greenhouse. $E_{cooling}$ is the electrical energy in kWh consumed and calculated with eq. 4, where P_{fans} and $P_{w,pumps}$ are the electric power of fans and water pumps in kW.

$$E_{heating} = t_{use}P_{bc} = t_{use}\frac{Q}{COP*3412} = t_{use}\frac{Cw_a[A_gH_w]R(t_i - t_o)}{COP*3412} \quad \text{Eq. 2}$$

$$E_{irrigation} = t_{use}P_{pumps} = t_{use}\frac{A_gK_p\, Q_e\, H_d\, \rho g}{E_rE_e746\, \eta_p\eta_m} \text{Eq. 3}$$

$$E_{cooling=}t_{use}(P_{fans} + P_{w,pumps)} \quad \text{Eq. 4}$$

Once the amount of electrical energy needed in the greenhouse is known, the number of solar panels (N_{sp}) is calculated by means of eq. 5 (Ibáñez et al., 2004). Where F_s: over sizing factor (10%), P_{panel}: unit power of solar panels in W, R_T: thermal performance (85 - 90%), PSH: peak sun hours (it is a hypothetical constant solar irradiance of 1000 W/m^2 during one hour), η_{ec}: efficiency in electric conductors, η_{cc}: charge controller efficiency, η_I: inverter efficiency and η_b: coulombic efficiency in batteries.

$$N_{sp} = \frac{(1+F_s)E_{tot}}{P_{panel}\, R_T\, PSH\, \eta_{ec}\eta_{cc}\eta_I\eta_b} \qquad \text{Eq. 5}$$

$$E_{prod} = N_{sp}P_{sp}R_T\, PSH \text{Eq. 6}$$

$$E_{accu} = \frac{F_s[N_D E_{tot}]}{D_d} \qquad \text{Eq. 7}$$

$$N_{cc} = \frac{F_{cc}I_{sc}N_{sp}}{I_{reg}} \qquad \text{Eq. 8}$$

$$I_{máx} \geq 1.25 * \left(\frac{P_{inv}}{V_{min} * \eta_{inv}}\right) \qquad \text{Eq. 9}$$

The energy produced by the solar panels, E_{prod} in kWh, can be obtained with eq. 6. Eq. 7 calculates the energy that will be accumulated in the battery bank, E_{accu}; where F_s: security design factor, N_D: number of autonomy days, D_d: depth of discharge of batteries. Then eq. 8 calculates the number of charge controllers, N_{cc}; where F_{cc}: safety factor (1.25), I_{sc}: short circuit current of each panel in $amperes\ A$, I_{reg}: is the current of the commercial charge controller. Finally, the power of the inverter will be proportional to the installed power of the solar panels, eq. 9 is used to calculate the current between the batteries and the inverter,$I_{máx}$in A, whereP_{inv}: nominal inverter power inkW, V_{min}: minimum inverter operating voltage in V and η_{inv}: inverter efficiency.

Development of Databases

For the execution of the algorithm five databases were elaborated, namely: 1) climatic conditions of different geographic sites (average values of solar resource [PSH], dry and wet bulb temperatures, wind speed and relative humidity), 2) greenhouse types and surfaces (building structures and greenhouse size), 3) electrical equipment (electric motors, water pumps, fans, blowers, extractors, agitators, solenoid valves, sensors, controllers, etc.), 4) types of crops (species and their optimum temperatures), 5) photovoltaic equipment (solar panels, inverters, batteries and charge controllers).Within catalogs of photovoltaic equipment the most important data of each component were integrated, [W], voltage [V], current [A], commercial brands and their costs.

Development of Software

Software and the user interface were developed in order to any interested agricultural producer can calculate a photovoltaic system for him greenhouse in a simple and free way. It is available on line at http://sistemas.chapingo.mx/empresas/SICF.

Validation of Results

Using developed software, were obtained the components of an off-grid photovoltaic system (3.6kW) with battery bank and installed in an experimental greenhouse at the Autonomous University of Chapingo, Mexico (where PSH = 5.5) in order to validate the results.

Findings/Results

Analysis of the Impact Factors on Investment Costs for Making Decisions

In order to make decisions about which type of photovoltaic system to install (grid or off-grid) the developed algorithm was used to make comparisons of total initial investment costs. The variables were: greenhouse area (A_g), energy produced (E_{prod}), amount of solar resource [PSH] and type of crop. In the first case (Figure 2), it shows the costs of on-grid photovoltaic systems for an irrigation system in three identical greenhouses with the same type of crop but under different intensity of solar radiation, ie in different geographic locations. It is found that the initial investment cost increases when smaller solar resources are available to meet the same energy demands. It is possible to exemplify this situation in countries like Spain and Mexico where the average solar resource is of 3.3 and 5.5 PSH respectively, the photovoltaic system would be more economic in the second site. Xue (2017) stressed the importance of performing economic analyzes to implement photovoltaics in greenhouses. Belmili et al. (2013) studied the total lifecycle costs of isolated hybrid systems, however, he did not study the factors influencing the initial costs. The cost comparison in this study complements this criterion.

In the second case (Figure 3), it is intended to supply electrical energy to pad-fan cooling systems of three identical greenhouses with different crops and located at the same site. It is shown that the impact of the crop type on the total cost depends on the energy produced by the photovoltaic system. In this case the temperature at which the cooling system is started is considered as the main parameter. Amir Vadiee and Martin (2012) states that the lower the optimum temperature of the crop, the longer the operation time of the cooling system during the day. It is verified from the results of Figure 3 that the crop with the lowest optimum temperature has the most expensive photovoltaic system, also the cost difference using different crops can be 31%. In the third case (Figure 4), it is considered to feed a heating system with an isolated photovoltaic system with batteries. This is the most costly scenario possible since heating is the most energy-intensive system (Bayrakci and Kocar, 2012), and the isolated system is the most expensive and complex, so it is not economically advisable. According to Brudermann et al. (2013) high costs such as those obtained in Figure 4 represent the main objection of a farmer to use photovoltaic technology. From the previous cases, the following Table 2 compares the costs of a photovoltaic system for a greenhouse soil surface of 1750 m^2 and a solar resource of 3 PSH.

Figure 2. *Influence of Solar Resource over Costs*

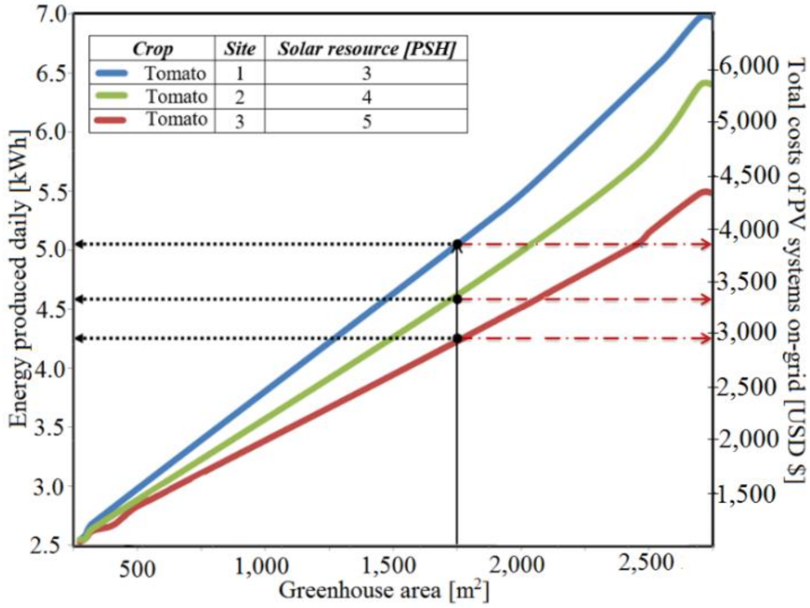


Figure 3. *Influence of Type of Crop over Costs*

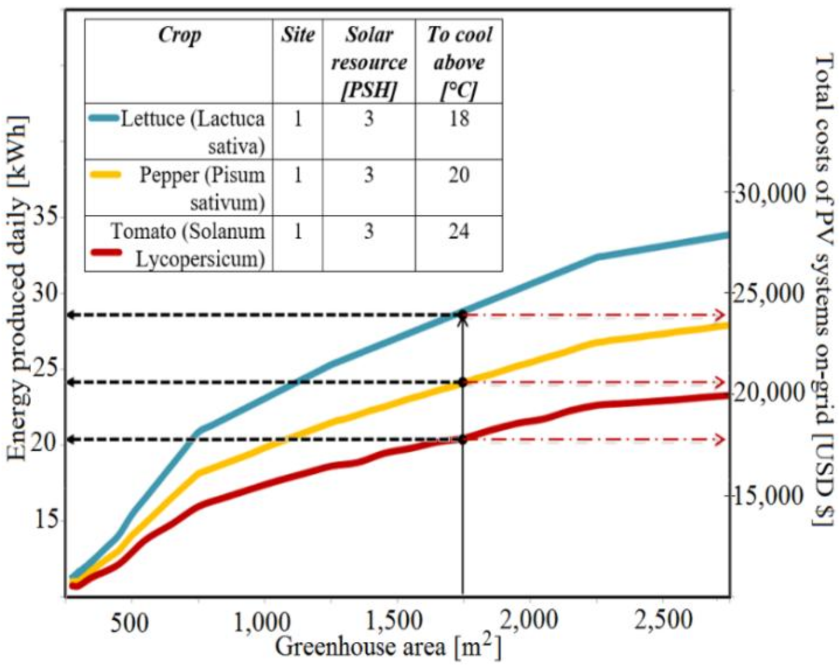


Figure 4. *Influence of Type of Photovoltaic System over Costs*

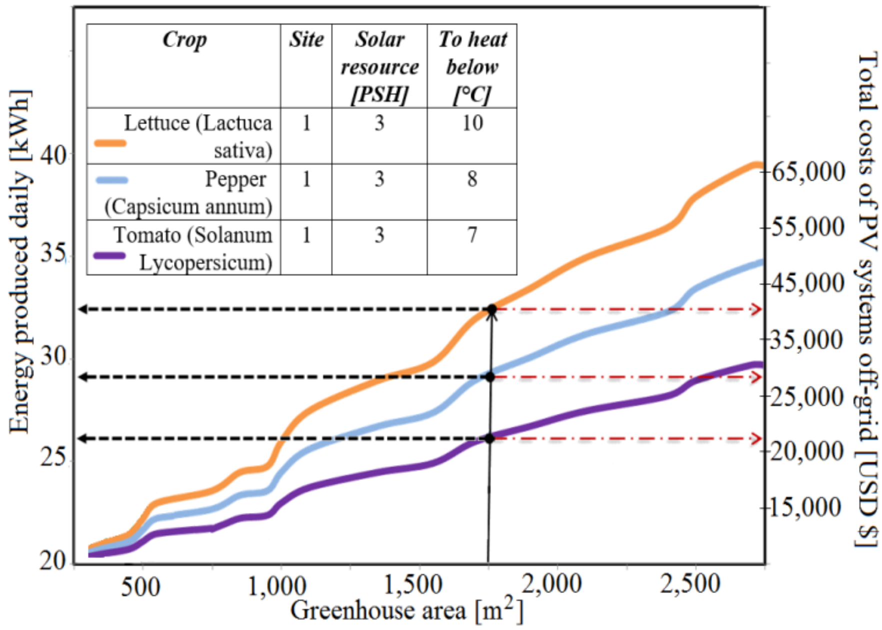


Table 2. *PV Systems for Different Processes with High Energy Demand in a Greenhouse (Surface Soil: 1750m*^{2}*, PSH: 3, Crop: Tomato*

	Irrigation	***Cooling***	***Heating***
Type of PVS	On-grid	On-grid	Off-grid
Energy produced	5.1 kWh	20.2 kWh	26.2 kWh
Investment cost	$3,850	$17,720	$21,040

The above analysis can help to make better economic choices in the initial design stage according to the energy needs of each greenhouse. Once the type of installation is selected, the software is used for a specific case and the components of the photovoltaic system are obtained: Experimental study: It consists of off-grid photovoltaic system to supply electric energy for irrigation system of a greenhouse of 6,165 m^2 in central region of Mexico (5.5 PSH), it is composed of 2 pumps 2.2 kW each one and an agitator of 1.1 kW. Software results were (Figure 5): 16 solar panels that generates total power of 3.68 kWp, 2 charge controllers of 80 A, 12 batteries of 1800 Ah and an inverter/charger of 7 kW. The PV system was installed and monitored. Average daily energy production was 22.4 kWh in summer and 14.5 kWh in winter (december). The daily energy consumption was 5.9 kWh per day. Although the system produces on average 18 kWh, it was oversized in order to achieve three days of autonomy.

Figure 5. (Left) *Irrigation System and Solar Panels* (Right) *Components Selected by Developed Algorithm*

Discussion

The major problems of photovoltaics in agricultural greenhouses, according to the study of Gonçalves and Vasconelos (2017) are: high initial cost and geographical conditions (solar irradiation), and limitations in the availability of systems on the market. In this work, these problems were addressed in greenhouses by creating databases to facilitate access to information, by studying the initial investment cost factors and the creation of an algorithm that uses solar radiation data from the site of installation. The analysis of the initial investment costs was qualitative and not quantitative, since the price trend of photovoltaic components is decreasing according to Strupeit and Neij (2017). Kelley et al. (2010) quantitatively estimated the costs of photovoltaic systems for different U.S.A. cities, however today they are no longer in force. The algorithm gave results of an oversized photovoltaic system to supply energy to the irrigation system, some related cases like Helal et al. (2008) and Jones et al. (2016) show that this fact is necessary for irrigation or water pumping systems but warn that entails a significant increase in the initial cost of investment.

Conclusions

The developed algorithm calculate on-grid and off-grid systems, it can be reproducible for different solar radiation conditions to those shown in this work, it saves time in the search of the components of the PV system because these are taken from the elaborated catalogs. Criteria for making decisions were established in the design phase of the greenhouse according to the initial investment costs. To do so, was analyzed the impact of three factors on the cost of photovoltaic systems in greenhouses with different surface, which are: 1) the solar resource of the site (solar radiation) 2) type of crop and 3) the type of photovoltaic system (on or off grid). The costs are higher in places with low solar radiation. The cost analysis also showed that in the case of cooling systems, the investment costs is strongly influenced by the type of crop in the greenhouse. It is not advisable to use off-grid photovoltaics for systems with high energy demand such as heating because the costs are prohibitive compared to systems connected to the grid. To validate the developed algorithm, a greenhouse photovoltaic system was installed, results of energy production and cost analysis highlight the importance of a correct selection of photovoltaic systems in greenhouses.

References

Almonacid, F., Rus, C., Pérez-Higueras, P., Hontoria, L. Calculation of the energy provided by a PV generator. Comparative study: conventional methods vs. artificial neural networks. Energy 2011; 36(1):375-84. DOI=10.1016/j.energy.2010.10.028.

Bayrakci, Asiye Gül and Günnur, Koçar. Utilization of renewable energies in Turkey's agriculture, Renewable and Sustainable Energy Reviews, Volume 16, Issue 1, January 2012, Pages 618-633, ISSN 1364-0321. DOI=10.1016/j.rser.2011.08.027.

Beccali, M., Cellura, M., Finocchiaro, P., Guarino, F., Longo, S., Nocke, B. Life cycle performance assessment of small solar thermal cooling systems and conventional plants assisted with photovoltaics. Sol Energy 2014; 104:93-102.DOI = http://dx.doi.org/10.1016/j.solener .2013. 10.016.

Belmilli, H., Almi, M. F., Bendib, B. Bolouma, S. A Computer Program Development for Sizing Stand-alone Photovoltaic-Wind Hybrid Systems, Energy Procedia, Volume 36, 2013, Pages 546-557, ISSN 1876-6102. DOI= 10.1016/j.egypro.2013.07.063.

Belmili, H., Haddadi, M., Bacha, S., Almi, M.F., Bendib, B., 2014. Sizing stand-alone photovoltaic–wind hybrid system: techno-economic analysis and optimization. Renew. Sust. Energy Rev. 30, 821–832. DOI= https://doi.org/10.1016/j.rser.2013.11.011.

Brudermann, Thomas, Kathrin Reinsberger, Anita Orthofer, Martin Kislinger, Alfred Posch. Photovoltaics in agriculture: A case study on decision making of farmers, Energy Policy, Volume 61, October 2013, Pages 96-103, ISSN 0301-4215. DOI=http://dx.doi.org/ 10.1016/j.enpol.2013.06.081.

Carlini, M., Honorati, T., Castellucci, S. Photovoltaic greenhouses: comparison of optical and thermal behaviour for energy savings. Math Probl Eng 2012; 2012 Article ID 743764. DOI:10.1155/2012/743764.

Chauhan, A. and Saini, R. P. Size optimization and demand response of a stand-alone integrated renewable energy system, Energy, Volume 124, 1 April 2017, Pages 59-73, ISSN 0360-5442. DOI= http://bit.ly/2huCpXr.

Cossu, M., Murgia, L., Ledda, L., Deligios, P. A., Sirigu, A., Chessa, F., Pazzona, A. Solar radiation distribution inside a greenhouse with south-oriented photovoltaic roofs and effects on crop productivity. Appl. Energy 2014; 133:89-100. DOI: 10.1016/j.apenergy.2014.07.070.

Cuce, E., Harjunowibowo, D., Mert Cuce, P. Renewable and sustainable energy saving strategies for greenhouse systems: A comprehensive review, Renewable and Sustainable Energy Reviews, Volume 64, October 2016, Pages 34-59, ISSN 1364-0321. DOI= http://bit.ly/2mtlPfQ.

Ezinwanne, O., Fu Zhongwen, Li Zhijun. Energy Performance and Cost Comparison of MPPT Techniques for Photovoltaics and other Applications, Energy Procedia, Volume 107, February 2017, Pages 297-303, ISSN 1876-6102. DOI= 10.1016/j.egypro.2016.12.156.

Gonçalves, Priscila and Vasconcelos Sampaio, Mario Orestes Aguirre González. Photovoltaic solar energy: Conceptual framework, Renewable and Sustainable Energy Reviews, Volume 74, July 2017, Pages 590-601, ISSN 1364-0321. DOI=https://doi.org/10.1016/j.rser.2017. 02.081.

Helal, A. M., S. A. Al-Malek, E. S. Al-Katheeri. Economic feasibility of alternative designs of a PV-RO desalination unit for remote areas in the United Arab Emirates, Desalination 221 (1-3) (2008) 1-16. DOI=10.1016/j.desal.2007.01.064.

Ibáñez, P. M., Rosell P., J. R. and Rosell U., J. I. 2004. Tecnología Solar. Colección Energías Renovables [Solar Technology Renewable Energy Collection] 1ª Ed, Mundi-prensa, España. 259-344 pp. ISBN: 84-8476-199-1.

Ibrahim, Anwar Ibrahim, Tamer, Khatib, Azah, Mohamed. Optimal sizing of a standalone photovoltaic system for remote housing electrification using numerical algorithm and improved system models, Energy, Volume 126, 1 May 2017, Pages 392-403, ISSN 0360-5442. DOI= http://bit.ly/2z5Kj4B.

Jones, M. A., I. Odeh, M. Haddad, A. H. Mohammad, J. C. Quinn. Economic analysis of photovoltaic (PV) powered water pumping and desalination without energy storage for agriculture, Desalination, Volume 387, 1 June 2016, Pages 35-45, ISSN 0011-9164. DOI= http://bit.ly/2ilh9V2.

Leah C. Kelley, Eric Gilbertson, Anwar Sheikh, Steven D. Eppinger, Steven Dubowsky. On the feasibility of solar-powered irrigation, Renewable and Sustainable Energy Reviews, Volume 14, Issue 9, December 2010, Pages 2669-2682, ISSN 1364-0321. DOI=doi:10.1016/j.rser.2010.07.061.

Li, Changsheng, Haiyu, Wang, Hong, Miao, Bin, Ye. The economic and social performance of integrated photovoltaic and agricultural greenhouses systems: Case study in China, Applied Energy, Volume 190, 15 March 2017, Pages 204-212, ISSN 0306-2619. DOI= http://bit.ly/2iYuG4n.

Mekhilef, S., Faramarzi, S. Z., Saidur, R., Salam, Z. The application of solar technologies for sustainable development of agricultural sector. Renew Sustain Energy Rev 2013; 18:583-94.DOI= http://bit.ly/2yM5rJ7.

Nakoul, Z., Bibi-Triki, N., Kherrous, A. (2014) Optimization of a Solar Photovoltaic Applied to Greenhouses, Physics Procedia, Volume 55, 2014, Pages 383-389, ISSN 1875-3892. DOI:10.1016/j.phpro.2014.07.055.

Nayak, S., Tiwari, G. N. Energy metrics of photovoltaic/thermal and earth air heat exchanger integrated greenhouse for different climatic conditions of India. Appl. Energy 2010; 87:2984-93. DOI:10.1016/j.apenergy.2010.04.010.

Nelson V. P. 1998. Greenhouse operation and management. 5th ed. Prentice Hall, pp. 144-154. ISBN-13: 978-0133746877.

Nelson D. B., Nehrir, M. H., Wang, C. Unit sizing and cost analysis of stand-alone hybrid wind/PV/fuel cell power generation systems, Renewable Energy, Volume 31, Issue 10, August 2006, Pages 1641-1656, ISSN 0960-1481. DOI= https://doi.org/10.1016/j.jtice.2016.07.047.

Okoye, C. O. and Solyali, O. Optimal sizing of stand-alone photovoltaic systems in residential buildings, Energy, Volume 126, 1 May 2017, Pages 573-584, ISSN 0360-5442. DOI= http://bit.ly/2zKNaPJ.

Ozkan, B., Figen Ceylan, R., Kizilay, H. Energy inputs and crop yield relationships in greenhouse winter crop tomato production, Renewable Energy, Volume 36, Issue 11, 2011, Pages 3217-3221, ISSN 0960-1481. DOI= 10.1016/j.renene.2011.03.042.

Pérez-Alonso, J., Pérez-García, M., Pasamontes-Romera, M., Callejón-Ferre, A. J. Performance analysis and neural modelling of a greenhouse integrated photovoltaic system. Renew Sustain Energy Rev 2012; 16(7):4675-85. DOI=http://dx.doi.org/10.1016/j.rser.2012.04.002.

Strupeit, Lars and Lena Neij. Cost dynamics in the deployment of photovoltaics: Insights from the German market for building-sited systems, Renewable and Sustainable Energy Reviews, Volume 69, March 2017, Pages 948-960, ISSN 1364-0321. DOI= https://doi.org/10.1016/j.rser.2016.11.095.

Vadiee, A. and Viktoria, M. Energy management in horticultural applications through the closed greenhouse concept, state of the art, Renewable and Sustainable Energy Reviews, Volume 16, Issue 7, September 2012, Pages 5087-5100, ISSN 1364-0321. DOI= 10.1016/j.rser.2012.04.022.

Xue, J. Photovoltaic agriculture - New opportunity for photovoltaic applications in China, Renewable and Sustainable Energy Reviews, Volume 73, June 2017, Pages 1-9, ISSN 1364-0321. DOI= http://bit.ly/2A22Vmc.

Yildiz, A., Ozgener, O., Ozgener, L. Exergetic performance assessment of solar photovoltaic cell (PV) assisted earth to air heat exchanger (EAHE) system for solar greenhouse cooling. Energy Build 2011; 43:3154-60. DOI=10.1016/j.enbuild.2011.08.013.