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Integrating mechanical control systems and nanotechnology for enhanced energy efficiency in renewable-poured smart greenhouses

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With increasing global challenges of climate change and water shortage, the need for new and advanced agricultural technologies beyond the conventional approaches is crucial. This project will create an "energy-smart greenhouse" that combines the latest nanotechnology and protected cultivation to establish the optimal growing environment with minimal energy requirements. The article deals with solar power control and optimization in greenhouses, which is an increasing topic among scholars. An east-west oriented small-scale solar greenhouse system is set up in Baghdad (33.3 o N, 34.4 o E). The solar thermal is placed on the roof of the green house where it is closely monitored. The paper examines how solar power can be intelligently integrated into greenhouse processes with reference being made to the increase in efficiency of energy. There have been attempts to increase climate control in the greenhouse to ensure that there are appropriate temperatures that would support the growth of plants. The findings reveal the possibility of solar energy to help in the use of sustainable agricultural methods through improved performance of green houses.

Keywords: Greenhouse; SWH; Nanotechnology; Solar energy.

1. INTRODUCTION

Due to the high request for effective and accurate sensors, research is ongoing for new elements and greenhouse technology is first used around 200 years ago in the process of gardening in Iraq; this is later encouraged as compared to the rest of the world. The greenhouse space in Iraq has increased significantly in comparison with the previous decade; it has been caused by a combination of diverse factors including paying more attention to gardening and raising the financial contributions. This can be attributed to the fact that greenhouses facilitate the cultivation of food throughout a varying time. It is especially relevant in those regions where the agricultural practice cannot take place because of the bad weather. Iraq has a hot and dry climate [1]. Greenhouse gas (GHG) business is one of the worst products that consume a lot of energy as well as one of the major causes of global warming. In order to eliminate that issue and confront the challenge, the most logical choice is not to disregard the issue of energy conservation and substitute the conventional sources with renewable ones. It has been demonstrated in recent years that agricultural greenhouses may incorporate solar electricity. Research on the improvement and assessment of solar thermal, photovoltaic (PVT), and solar energy system architectures and thermal collector systems [2-4]. Expanding farm goods is necessary to address hunger and people's food needs. Crop production has been organized in greenhouses. By regulating the temperature, air moisture, light intensity, soil moisture, carbon dioxide content, and wind speed, experts manage the greenhouse's productivity. Each of these elements is important and interconnected. In order to provide different environmental conditions for every plant, researchers have been forced to use a variety of monitoring techniques to feed people, all agricultural products must grow.

Crops are grown in conservatories. Greenhouse experts manage plant yields by regulating environmental factors such as temperature, humidity, light intensity, soil moisture, CO2 levels, and wind speed. You can't separate and ignore any of these factors. In order to provide each plant with a wide range of environmental conditions, researchers employ a plethora of monitoring techniques [5]. As the temperature of a PV module rises, its electrical power decreases more rapidly. Running the PV module at relatively low temperatures, achieved by reducing the excess heat, may thus keep its performance to a minimum. It is possible to dissipate the thermal energy associated with a PV module by passing a cold fluid (often water or air) over or under it. Numerous applications exist for the fluid's thermal energy. The abbreviation "PV/T" describes this type of system. Reducing the temperature of the PV module can improve electrical efficiency[6, 7]. A new method for photovoltaic integrated systems using greenhouses and solar thermal units has been shown to be suitable for usage in rural, isolated, desert, and industrial areas. One viable strategy for studying renewable energy sources is solar power, which is both affordable and emission-free[8]. The photovoltaic module with the greenhouse covering maximizes land productivity with little surface area. Theoretical, practical, and experimental research on greenhouses and PV/T has been abundant in recent years [9, 10]. Optimal temperature management and energy use reductions are possible with the help of active and passive technologies, such as appropriately controlled equipment and current covering materials [11]. New methods for enhancing the thermal and optical performance of greenhouses and photovoltaic systems have been introduced by recent developments in nanotechnology. Because of their capacity to improve light transmission, block harmful UV radiation, and minimize heat losses, nanomaterials like silica (SiO_2), titanium dioxide (TiO_2), and zinc oxide (ZnO) nanoparticles have been extensively studied as additives in greenhouse covering materials. It has been demonstrated that adding nanoparticles to polymer films greatly enhances the stability of greenhouse microclimates by lowering internal temperature swings and boosting crops' access to photosynthetically active radiation (PAR) [12]. Additionally, in solar thermal systems, nanofluids have proven to have better thermal properties than traditional fluids. Because nanofluids have better convective heat transfer properties and higher thermal conductivity, their use in solar collectors increases heat transfer efficiency. According to studies, using nanofluids in solar water heating systems, such as Al2O3-water and CuO-water mixtures, can boost thermal efficiency by up to 15–25% when compared to conventional working fluids [13]. Nanotechnology has been used in photovoltaic applications to increase panel durability and efficiency. TiO_2 and SiO_2-based nano-coatings have anti-reflective and self-cleaning qualities that lower dust buildup and optical losses on PV surfaces. In arid and dusty regions like Iraq, where dust deposition severely impairs photovoltaic performance, this is especially crucial. Nano-coated PV panels maintain higher electrical output and minimize efficiency losses due to surface contamination, according to experimental studies [14]. .A promising approach to increasing system efficiency, lowering thermal losses, and raising crop productivity in challenging climates is the incorporation of nanotechnology into greenhouse solar energy systems. The role of renewable energy in sustainable agricultural development can thus be strengthened by integrating nanomaterial-based solutions into smart greenhouse designs, which can further optimize energy utilization and environmental control. The production and use of reduced graphene oxide (rGO) nanocomposites, which have been enhanced with metal and metal oxide nanoparticles, to optimize solar cell performance [15].Their application in creating GO:TiO_2 hybrid photoanodes using anthocyanin dye derived by red cabbage, and varying in length of the SiNWs, is studied to create solar cells [16,17] photo-voltaic properties of SiNWs solar cells are studied in their various lengths [18]. The contribution of this paper is to provide a greenhouse with an ideal climate for plant growth throughout the year using clean energy sources at the lowest feasible cost and under the farmer's easy supervision. All day long, the control system gives us data that we can use to fine-tune the greenhouse's ventilation, cooling, heating, and humidity levels, as well as to create the optimal circumstances for plant growth.

2. EXPERIMENTAL WORK

This paper outlines the experimental setup for an integrated solar energy system, highlighting critical components such as the solar water heater, cooling system, voltage control unit, and control system, all of which are integral to the development process. As shown by Figure 1, the length, width and height of the described greenhouse is 80 cm, 120 cm, respectively, and has a total count of 96 plants divided into 6 sections. The greenhouse given has a solar heater (capacity 5-litre) that is used to warm the soil thus facilitating plant growth. It uses solar water heaters that have panels (Hi-MO 7 -cell) that are normally placed on sunny roofs where they harness solar energy and thus heat water in a cylindrical tank. These contemporary heaters have the temperature, water level sensors and the cold-water insulation. The chosen type of solar panels is the Monocrystalline Silicon type with the efficiency of approximately 16.9%. Solar thermal technology also capitalizes on the use of solar collectors to make the most out of the energy, which can be done in different contexts such as the timber seasoning process or even heating a greenhouse and also in industrial drying. The DC output of the solar panels is converted to AC which is used to power whatever needs it and a battery is charged in daylight hours to use as power at night, the voltage and current of which are kept stable by a parameter controller. Also, the greenhouse has a cooling system comprising three fans, which use 25 Watts, to circulate air. To measure the sun radiation experimentally the TES-1333 digital solar power meter will capture the solar radiation of 0-2000 W/m^2 with a fine resolution and accuracy, and the DT9205A digital multi meter will measure the voltage and current of DC [19,20].

Figure 1 Greenhouse with Solar water heater system accompanies.

Different solar power measurement systems and control systems are mentioned in this work, drawing the attention to such important devices as TES-1333 solar power meter, which is able to measure solar radiation between 0 to 2000 W/m 2 with a resolution of 0.1 W/m 2, and the DT9205A multimeter, which could be used to measure DC voltage and DC current. Important hardware is the Arduino Mega board with ATmega 2560 microcontroller, the MAX 6675 Amplifier of thermocouple signals, the 4 Channel Relay of high voltage loads, a Soil Moisture Sensor, a DHT22 Digital Humidity and Temperature Sensor, and Thermocouple Type K. Illustrative figures are also provided in the document to enhance understanding of the workings of devices and the way they are connected. The system will incorporate a solar heater to warm the soil and water to use in drip irrigation and three fans used on the left side to circulate air in the greenhouse. An example of this is a solar panel, measuring 106 cm by 63 cm, which produces 100 watts of electricity through the use of sunlight, a motor is fitted so that the angle can be adjusted to allow the panel maximum exposure to the Baghdad latitudes in summer. The humidity of more than 60 percent and temperature of more than 25 degrees Celsius are conditions of the environment that are needed to sustain adequate cooling and crops in the green house. In an effort to enhance efficiency of the panel, water cooling is done in a network of iron tubes and then reused in a home cooling system. The solar panel produces DC with fluctuating voltage that is converted to an AC power of 24 volt through an inverter, which is enough to operate all appliances in the greenhouse with 0.3A. Also, the second solar panel is 70 cm by 42 cm generating 50 watts which is placed northeast with a southwest tilt of 35 degrees to get the most sunlight during summer. The greenhouse is equipped with lights and sensors linked to an Arduino control system that activates the fans collectively when internal temperatures exceed 25 °C or humidity surpasses 60%, conditions favorable for optimal crop cultivation. A charging regulator is also utilized to standardize the solar panel's DC output, ensuring efficient operation of all equipment [21-25].

Figure 2 Greenhouse with Control system.

3. RESULTS AND DISCUSSION

We tested the temperature of the hot water that came out of the solar heater. Figures (3) and (4) show how the ambient air temperature and solar radiation impact the theoretical temperatures. With a margin of error of about 1%, the theoretical temperature seems to be greater than the actual temperature. The precision of the temperature measuring equipment and the occurrence of partial shadowing on the solar heater are the causes of this. As the ambient air temperature and radiation level rise, we find that both the actual and theoretical temperatures rise as well. Figure 3 shows that when the sun's rays get more intense and concentrate on the solar heater for an extended period of time, the water temperature rises [26].

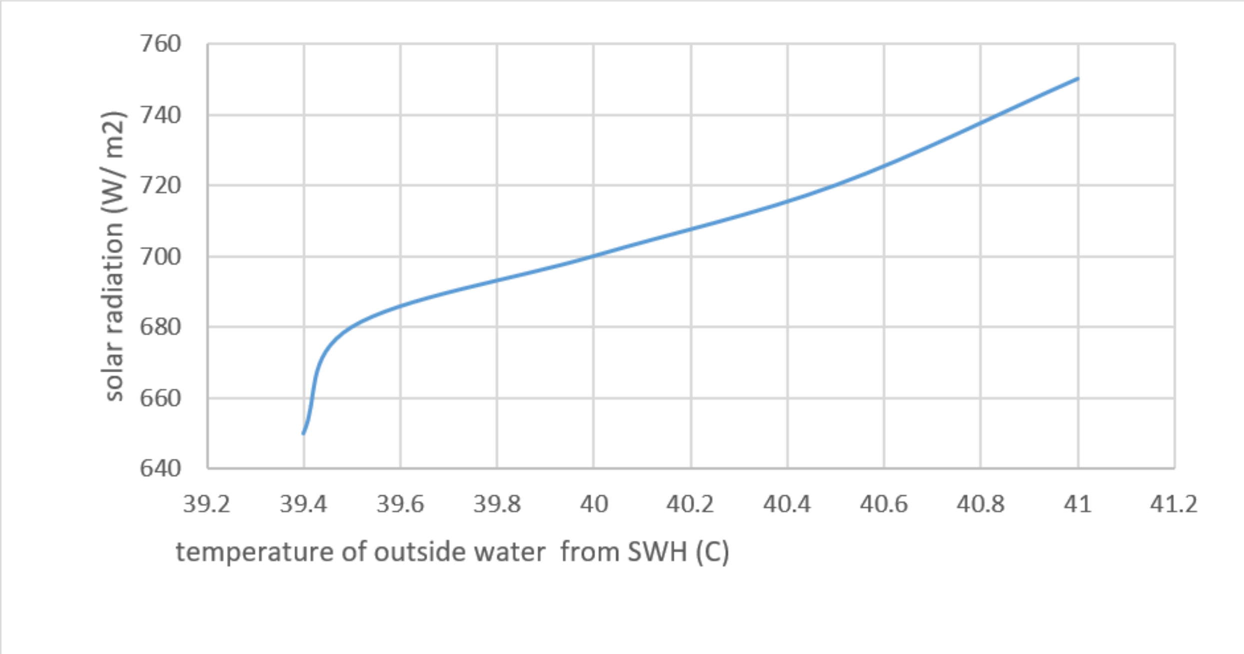

Figure 3 Solar radiation Relationship with outside water temperature from SWH.

As shown in Figure 4, the soil temperature within the greenhouse is quite high due to the high water temperature that emerged from the solar heater utilized for winter irrigation. The diagram shows how the temperatures of water, air, and plants interact with solar radiation in a greenhouse. This finding further supports the idea that solar radiation serves a crucial heating role by raising the average temperatures of water, air, and plants when its intensity is raised. The variations in the air, plants, and water temperatures are used to highlight the environmental factors that determine the heat of plants. This study can be used to enhance greenhouse constructions and utilize more of solar energy to warm water. Recognizing daily temperature fluctuations also requires a grasp of temperature variations throughout the day, such as differences between morning and afternoon. This study highlights the significance of studying the impact of sun radiation on greenhouse temperatures in order to encourage more effective farming methods [27,28].

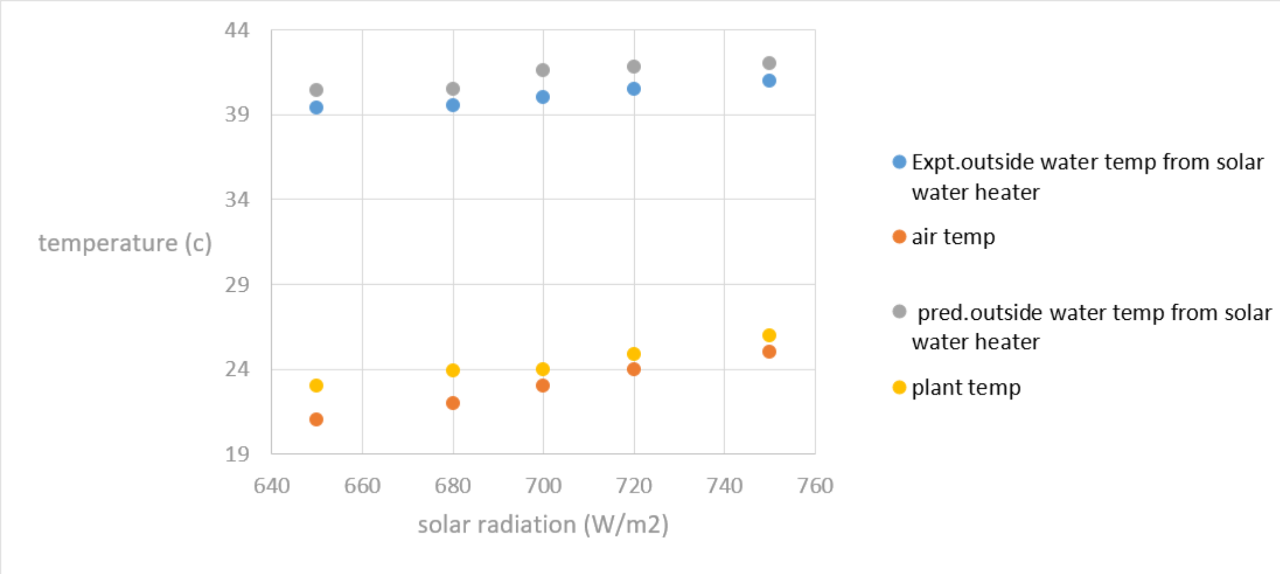

Figure 4 Temperatures Variation of air, water, and plant with solar radiation.

Figure 5 reveals that the overall low humidity levels in Iraq (15-42%), as discussed in the text, are brought to light on June 10, 2023, when it is discussed in relation to the hourly variance in both indoor and outdoor humidity. Humidity in the greenhouse is typically higher than in the ambient air, as shown in Figure 5, which is evidence of the greenhouse's ability to retain moisture, which is good for plant growth. The fact that humidity varies throughout the day means that we are supposed to examine the relationship between the rate of evaporation and such variables as temperature and sunshine. Increased relative humidity could be beneficial to certain crops, but excess moisture can cause activities such as fungal proliferation hence one should keep a check on the same. To enhance agriculture in the harsh environment in Iraq it is important to keep a check on the humidity in green houses. Further research is recommended to study and have more knowledge on how to control greenhouse conditions [29-31].

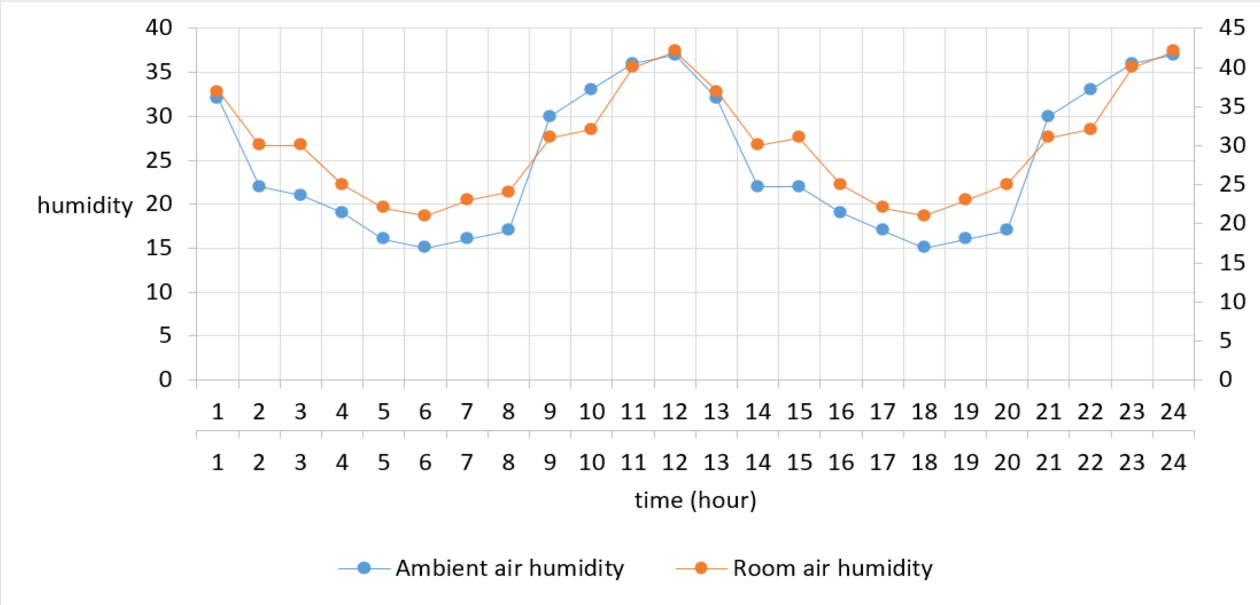

Figure 5 Greenhouse and outdoor humidity levels are measured hourly on June 10, 2023.

Figure 6 illustrates that cell temperature and solar radiation impact load and open voltage. When cell temperature increases, the voltage also falls. As solar radiation increases, the voltage decreases, resulting in maximum load and open-circuit voltages of 15.6 at 4 PM and 18.4 at 9 PM, respectively.

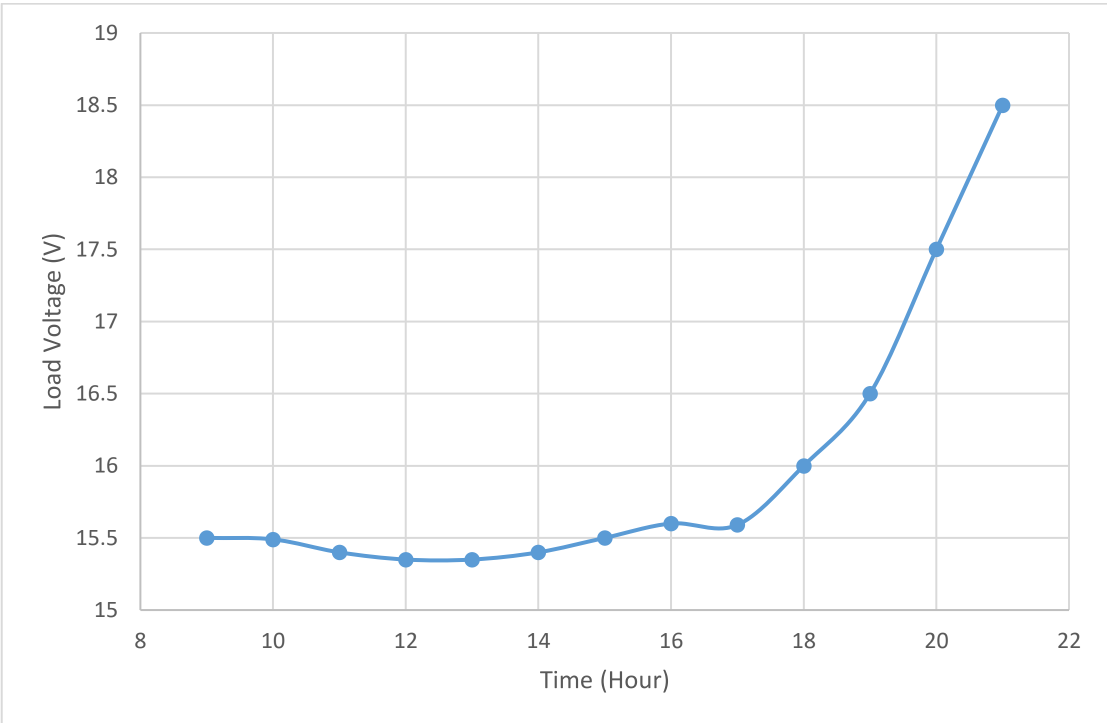

Figure 6 Voltage variation of the load on an hourly basis.

The relationship between the variation in radiation intensity and the voltage produced by the solar panel is seen in Figure 7. A clear connection between them has been identified. Solar voltage is generated when solar radiation is present. When the sun's rays hit 800 Kw /m2 midday, the voltage dropped to 22 volts.

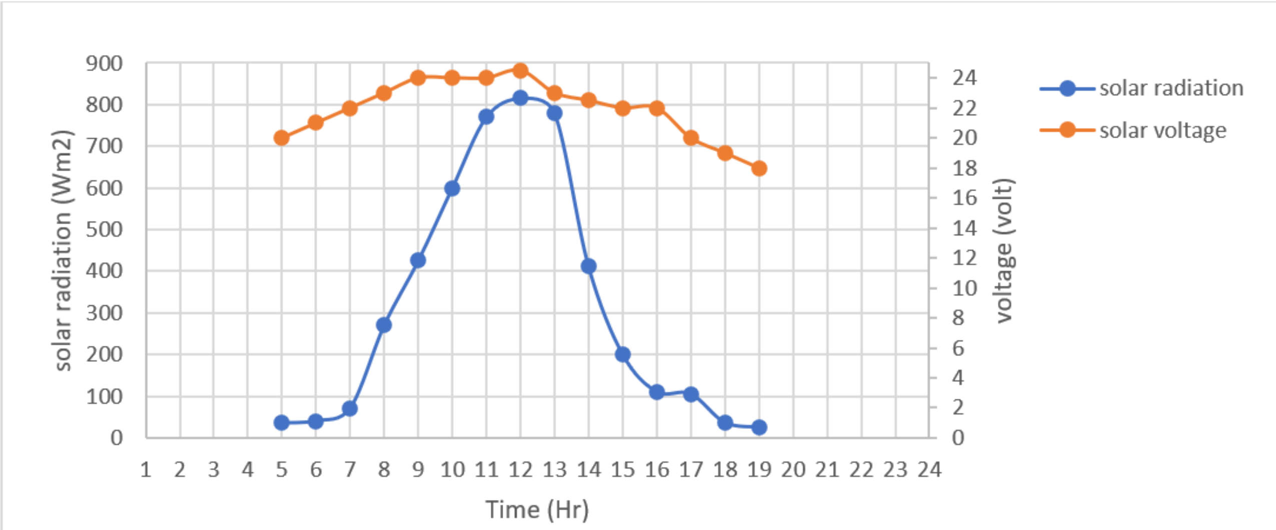

Figure 7 The greenhouse's hourly solar voltage variation with solar radiation on June 10, 2023.

Figure 8 illustrates the correlation between solar panel temperature and efficiency, highlighting the importance of the cooling system in preserving solar panel performance. It appears that the cooling system is successful in reducing the temperature of the solar panel from 60 °C to 50 °C in the previous curve, as the efficiency drops to 60 °C when the panel temperature rises. The maximum efficiency that the panel can achieve under standard conditions is 19%. Keeping the solar panel's efficiency steady at around 3%. The results shown in Figure 8 demonstrate how photovoltaic electrical efficiency is highly dependent on operating temperature, with a discernible decline in efficiency as PV temperature rises. This behavior highlights how crucial it is for photovoltaic systems operating in hot climates to have efficient thermal management techniques. According to earlier research, cutting-edge cooling techniques, like nanofluid-based cooling systems, greatly improve heat transfer when compared to traditional cooling techniques, which lowers PV operating temperatures and boosts electrical efficiency [19,20,21]. Thus, incorporating cooling solutions based on nanomaterials is a promising way to improve the performance of the suggested solar-poared greenhouse system in the future.

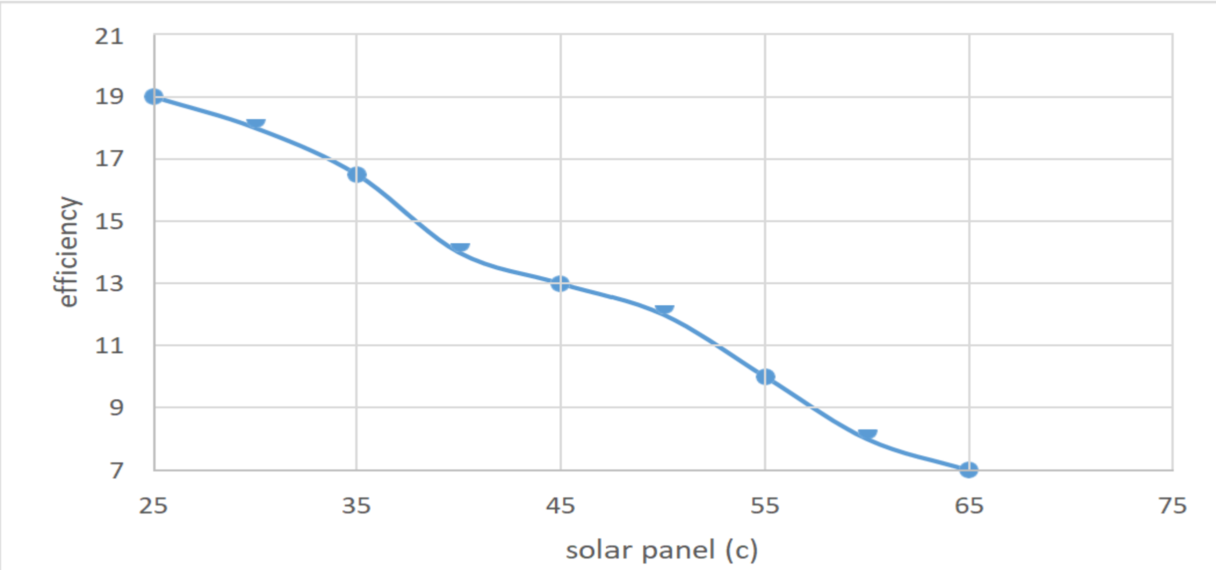

Figure 8 Temperature PV with efficiency.

4. CONCLUSIONS

Improving the circumstances that prevent the spread of greenhouse gases in Iraq's climate was the primary goal of this study. The most common issue is lowering the greenhouse's high temperature, which becomes particularly problematic in the middle of the day. Using renewable solar energy, we were able to tackle this problem in an eco-friendly way. From this investigation, we can deduce the following:

1. The use of fans to remove air from the greenhouse helped lower the extremely high humidity levels within.
2. Lowering the temperature within the greenhouse by 60% and facilitating plant development are both achieved through the employment of an intelligent technology that controls the climate.
3. The soil temperature inside the greenhouse is increased by approximately 5 °C when the solar heater is used to heat it.

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