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Development and Performance Evaluation of a Low-cost Solar Greenhouse Dryer

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Abstract

The greenhouse effect is a process that involves trapping the solar radiation that's coming from the sun. A greenhouse is a structure made of glass that's designed to provide a certain environment for the plants. Its main objective is to provide the plants with the necessary conditions to grow well. Although this type of technology is centuries old, it's still being used in the country. The agriculture sector is India's backbone and contributes to the country's economic growth. A new technology is needed that can help enhance the performance of the farming systems. Among the most prevalent types of such technology is the green house. Due to the country's semi-arid climate, greenhouse cultivation is expected to grow significantly in India. Unfortunately, since the government doesn't provide financial support for the construction of these structures, the farmers have to build their own greenhouses. This study is aimed at developing a low-cost greenhouse structure. It is found that the cost of proposed low-cost greenhouse is 2.617 times less than that of conventional greenhouse.

Major Findings: *Greenhouses enable plant development in harsh or arid climates, making them effective for farming. Integration of technology like sensors benefits the environment. The proposed low-cost greenhouse is 2.617 times cheaper than standard designs, making it suitable for resource-scarce settings.*

Keywords: *Greenhouse Dryer, Renewable Energy, Relative Humidity, Solar Energy*

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1.0 Introduction

Current energy sources such as coal, oil, and gas are considered to be the main factors that contribute to the global energy crisis. It is impossible for developing countries to reap the benefits of these sources because of the limited nature of these resources. On the contrary, they are instead shifting their focus to renewable energy sources. Aside from the sun, other renewable energy sources such as rain, wind, and waves can also be utilized to generate electricity. Solar power, which has the ability to provide a significant amount of power, is recognised as one of these. Solar energy is a type of renewable energy that is captured from sunlight and transformed to both heat and electricity as a sustainable resource as opposed to customary fossil fuels To make the most use of this abundant source several solar devices such as Solar Air Heaters (SAHs) which use solar energy to heat air for space heating or industrial purposes, solar Photovoltaic (PV) panels which convert sunlight directly into electricity, and greenhouse dryer that uses solar heat to dry the agricultural products; it helps the human towards dependency of fossil fuels and helps the environment by promoting environmentally friendly practices. They are great in combating the energy necessities by conserving the environment[1-3].

As the global population continues to rise, one of the most significant contributors to the instability of the global food supply is the growing number of people all over the world. Food storage plays a pivotal role in ensuring adequate nutrition worldwide, as keeping provisions in their original state maintains vital nutrients. While customary techniques like heat transfer dry crops post-harvest, preventing damage, innovative convection methods could optimize the process. Complex seasonal fluctuations and global disparities in access make long-term preservation paramount, as temporary surpluses must suffice distant shortfalls. Though harvesting yields sustained sustenance, clever containment counteracts concern of coming calamities compelling consumption before crops could otherwise last. With ingenuity and vigilance, varieties of victuals may voyage varied venues, voicing values of viability and vivacity for all.

There are several methods for improving the quality of food by lowering their content in moisture. One of them is solar drying. The natural process is to spread the crops which need to be dried on the floor and leave them for some time under the full sun. This approach could help to eliminate any horrible organisms that tend to be in plants. This one is also a less-practicing process because it harms the environment less. The process that is most efficient in improving the quality of the dry products they grow involves the use of the greenhouse with no fossil fuels. The house uses less energy and can be more sustainable. Also, using it could help produce better products that will take up less space. The most useful type of greenhouse is the one made of glass. The house of such a type could be used for growing plants that require certain conditions. The greenhouse process or the greenhouse effect could be defined as the major cause and the only process which can be introduced and can be implemented in the solar drying process. In its essence, it helps the drying box save its heat by trapping the solar radiations with it. The houses that are used for the plants are rather small and can be stored anywhere, but not in industrial-sized buildings. The mini greenhouses are cold frames. The warming contents are produced and maintained in the small house. A great example of the use of a commercial glass greenhouse is its design for growing vegetables and fruits. The process regulates that once the crops that are being used for drying are placed or grown in the greenhouse, the ventilation system at the foot of the facility will be opened and the air from the exterior of the greenhouse will be taken into it. The glass house, besides, is equipped with lights and computer-controlling systems. These systems can improve the condition of the plants by testing their specific conditions of relative humidity of air, environmental air temperature, and vapor-pressure deficits[4-11].

A greenhouse or hothouse is a building that's usually made from glass that's specifically intended to grow plants. They are typically smaller than those used for commercial or industrial purposes, and can normally accommodate them in a warm state. A cold frame is a type of mini greenhouse that's similar in purpose but is made up of a frame, and is not reinforced by any type of light. A glasshouse is frequently used to grow spring planting vegetables, and there is a large range of equipment available to it to allow it to take care of its different plant species. Its lights and cooling systems are all computer controlled. These types of growers may also record the actual conditions of the plants, including their air temperature and relative humidity, to ensure that the plants grow to their optimal potential. There is a risk that less crops are produced. The idea was first mentioned as

early as the Romans. The Roman emperor Tiberius loved eating cucumbers. The fruits were grown from a variety of artificial methods and were placed in heated containers to keep them warm during the night. Allegedly, the fruits were kept in houses or frames that were covered with thick sheets of oil-based selenite that the Romans had no idea of using. Greenhouses were frequently a difficulty initially, owing to a deficiency of heating. A greenhouse was built with a heated roof around 1681 in the United Kingdom and is considered the 1st of its kind. The construction of greenhouses was growing as technology improved in the 17th century. One of the most notable structures that featured this type of structure was the Versailles palace, which measured 150 meters long. The first contemporary greenhouse was built in the Netherlands in the 18th century by a French botanist named Charles Lucien Bonaparte. Due to the popularity of botany, universities started to build greenhouses. Greenhouses were initially brought to the world's attention by the French, who built orangeries that were designed to keep fruit trees from freezing. With the rise in popularity of pineapples, an increased number of pits were constructed. At some point in time, gigantic glasshouses were also constructed all over the world simultaneously. The term "palm house" refers to these kinds of structures, which are distinguished by their height in comparison to that of palm trees. There was also a history of greenhouses being found in public parks and gardens. Through the utilization of iron and glass, a wide variety of buildings, including palm houses, were constructed during the 19th century. Large establishments, such as train stations, frequently called for the construction of buildings of this kind. Numerous big greenhouses were constructed during the 19th century. Japan was the country that 1st built a greenhouse in the year 1880. During the 20th century and the 1960s, the use and design of geodesic domes led to the development of new types of greenhouses. Various companies were also known to make hoop houses, which are similar to greenhouses but made from various materials. The decrease in building expenses also led to the establishment of numerous small farms and garden centers. In the 1970s, the introduction of UV-Inhibitors led to the development of new materials that improve the film's resistance to ultraviolet radiation. This also led to the increase in the usable life of the greenhouse. Also beginning in the 1980s and continuing into the 1990s, gutter-shaped greenhouses became more popular. The type of greenhouse structures usually found in commercial and industrial settings are gutter-connected greenhouses, which are also commonly used for storing vegetables and flowers. The use of gutter-connected structures is commonly known to have some solar radiation penetration through its walls. This type of structure may then increase the temperature within a greenhouse. Unlike the other types of greenhouses, this type of structure does not have natural convection, which may then raise the temperature within it. Screens can cut the greenhouse's heat consumption by 8%, according to multiple studies. Regarding this, one study indicated that screens with a high coefficient of reflection might reduce the heat demand of the greenhouse by around 8%. One more thing that could help reduce the greenhouse's energy usage is a surface that is dyed. This type of material, which is also transparent, may help decrease the greenhouse's humidity levels. A greenhouse must be able to control its temperature and humidity. It must also utilize ventilation to keep pests and diseases out. This technique can be carried out through the use of fans and vents. Plastic coverings that allow light to enter a greenhouse can also be used to prevent pests and diseases from spreading. During times of relative abundance, solar energy can be captured by capturing the solar energy coming from the greenhouse. Also, livestock waste can be used to heat the greenhouse. This process can be performed by placing a chicken coop inside a greenhouse. Yet another process that the structure can use to cool itself is by opening its windows when they become too hot. This feature allows the greenhouse to either do it manually or through an automatic process. For this method, the windows can be controllers or by an automatic shade house. An example of an automatic operator is the use of a window controller that opens or closes the windows as the weather dictates. The use of electronic controllers is the most common process of cooling the structure. Although this approach is straightforward, it can become complicated when used to larger operations. A shade can also be placed over the windows, which helps the windows in the greenhouse to cast a shade as a form of cooling the greenhouse. Another process that cools the greenhouse is the use of a shade house. One method of cooling the greenhouse is by having a shade house that is placed over the windows. The other is by the use of the garlic ventilation systems that are found on glass greenhouse roofs. For example, the IFTS greenhouse uses grow lights in their greenhouse to produce high light to the plant, increasing yields in

the process. The glass greenhouse, for example, in this case may use glasses mega beam. It has been known for over a century that adding more carbon dioxide to the air can increase plant growth by 1100 ppm. Along with the development of new tools for carbon dioxide buildup, this method was brought to the Netherlands. By raising a greenhouse's carbon and temperature, high-quality secondary metabolites can be created. This process can also work to lower the greenhouse's water consumption. Thus, by increasing the carbon dioxide of the greenhouse, the plants can meet their need for carbon by reducing the greenhouse's flow. Placed near a plant with several byproducts, a commercial greenhouse can help the plant and the environment. Through this process, a refinery can reduce its greenhouse gas emissions by 70%. Aside from boosting the plant's growth rate, this process can also help a nursery increase its production of tomatoes by about 70%. Only this method can be used if the greenhouse has a limit on the amount of carbon dioxide it can emit. These structures are commonly made out of plastic and are commonly used for commercial purposes. Commercial greenhouses, which are usually high-tech facilities that are used for the production of vegetables and flowers, are also commonly made out of glass. These types of structures can be controlled through a computer. Modern domestic designs commonly feature large glass panes that are 730mm x 1422mm thick. This type of construction is ideal for large greenhouse sizes due to the amount of support it requires. Another type of greenhouse that is commonly referred to as the Dutch Light is a structure that has sloping sides[12-16].

Janjai, Khamvongsa built a PV-mounted greenhouse that has a black concrete floor[17]. It features a 44-meter-square floor area, and it has a layer of polycarbonate sheets that cover its outer surface. The greenhouse's cooling system was powered by a 53W panel. The researchers tested the greenhouse's performance by loading 150 kilograms of fresh chillies.

They found that the greenhouse's dryer dried the vegetables upto 10% of their moisture content. The average duration of this process is around 2 to 3.5 days. In order to find out how the greenhouse design and different elements impact the onion's mass transfer coefficient Kumar and Tiwari examined the impacts on the weight of the onions[18]. They experimented with a number of different circumstances, including drying in the bright sun, naturally occurring convection, and forced convection. According to the findings of the study, the different mass transfer coefficients that occur during the cooking of onions have the potential to influence the overall performance of a greenhouse gas dryer and its overall effectiveness. To reach a maximum drying ability of 100 kilogrammes under forced mode, the designers of the greenhouse dryer, Barnwal and Tiwari, developed a hybrid photovoltaic or thermal model using a 30° roof design[19]. In their study, Nayak and Tiwari conducted an investigation on the energy and exergy characteristics of the greenhouse[20]. Next, in order to make a greenhouse that is environmentally friendly, they incorporated a photovoltaic or thermal collector and a greenhouse dryer. The designers were successful in exceeding the exergy efficiency of the greenhouse by around 4%. Janjai, Lamlert conducted a simulation and experimental study on the effectiveness of the greenhouse dryer when it was used to dry longan and bananas[21].

The greenhouse dried fruit had a sweeter flavour and a more vibrant colour as compared to other dried items. In Saudi Arabia, built a greenhouse dryer that was designed to evaluate its thermal performance[22]. The framework of the structure is made of aluminium, and it is inclined at a 30° angle after construction, which allowed it to have a roof that has a vertical. Two plywood boxes were placed inside the facility to maintain its air flow rate. Jitjack, Thepa constructed 2 greenhouses using area-enhanced panels[23]. These structures, were tested in different conditions, such as the presence of rubber sheets and an empty greenhouse. The system's efficiency increased by 15%. In Morocco, Belloulid, Hamdi experimented with creating 30 cylindrical cakes out of dewatered sludge samples[24]. These models were used to illustrate the many characteristics of the plant. The size of the greenhouse's solar dryer, which was 60 centimeters wide, was also equipped with a transparent sheet. A volume reduction of 80% was accomplished by the plant during both the warm and cold seasons. Morad, El-Shazly built three solar tunnel dryers that are powered by an electric motor and have a transparent plastic film that's attached to them[25]. The continuous fan operation and the plant's air flow allowed them to achieve a good drying condition. They tested the temperature control system of a greenhouse.

The purpose of a greenhouse is to cultivate plants in an artificially controlled setting. Producing fruits and vegetables is only one example of the many crops that

can benefit from this kind of system. Even though there have been several successes in agriculture, India's yields are lower than those of other nations. This means that the country needs to improve its agricultural development to become an economic power. One of the most effective ways to improve the efficiency of our farming systems is by adopting a new technology known as the green house. Although this is centuries old, it's still being used in the country. The semi-arid environment of the country maximises the potential of this type of infrastructure. Building greenhouses is not subsidised by the Indian government, which is a major letdown. This has forced the farmers to build their own facilities. In order to provide low-cost greenhouse structures, a study has been conducted.

2.0 Construction of Low-cost Greenhouse

Figure 1 shows the line diagram of low-cost greenhouse. Iron rods, PVC pipes, green net, PVC electrical conduits, polythene sheet *etc.* are the required materials to construct the low-cost greenhouse. Table 1 shows the parameters of low-cost greenhouse. Table 2 shows the cost of labor and material required for conventional greenhouse (30 feet x 10 feet). Table 3 shows the cost of labor and material required for low-cost greenhouse (30 feet x 10 feet). After construction it is found that the cost of conventional greenhouse is 2.617 time higher than that of proposed low-cost greenhouse. The inside view of a cheap greenhouse is shown in Figure 2.

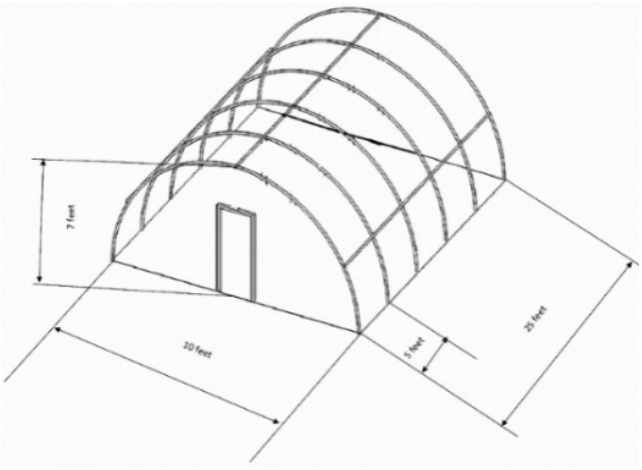


Figure 1. Line diagram of low-cost greenhouse.



Figure 2. Inner view of low-cost greenhouse.

Table 1. Parameters of low-cost greenhouse

Parameters	Dimensions
Overall dimensions of low-cost greenhouse of area	30 feet x 10 feet
Length of greenhouse	30 feet
Width of greenhouse	10 feet
Distance between side poles	5 feet
Depth of foundation	1.5 feet
Top height	7 feet

Table 2. Cost of labor and material required for conventional greenhouse (30 feet x 10 feet)

S. No.	Items	Quantity	Cost
1	Angle iron bar	500 kg	35000/-
2	Door	1	4000/-
3	Welding	-	5000/-
4	Green net	70 x 30	5000/-
5	Building material	Bricks, cement *etc.*	10000/-
6	Labor cost	-	7000/-
7	Material loading	-	4000/-
8	Nut and bolt	50	1000/-
9	Net connector	250 feet	3000/-
Total cost in Rs.			74000/-

3.0 Results and Discussions

Figure 3 shows the variations of relative humidity with respect to time (hr) for the two clear days in summer. It is evident that the effect of relative humidity at dawn is high; it gradually decreases up to a minimum range, and then increases until sunset. It is found that the relative humidity inside greenhouse was less compare to outside greenhouse.

Table 3. Cost of labor and material required for low-cost greenhouse (30 feet x 10 feet)

S. No.	Items	Quantity	Cost
1	Iron rod	12	6000/-
2	PVC pipe	150 feet	2240/-
3	PVC pipe (small)	140 feet	1350/-
4	Door	1	2700/-
5	Green net	1	1750/-
6	Building material	Bricks, cement *etc.*	7500/-
7	Rope	1 kg	170/-
8	Labor cost (4 days)	-	5450/-
9	Welding	-	150/-
10	Loading	-	1000/-
Total cost in Rs.			28310/-

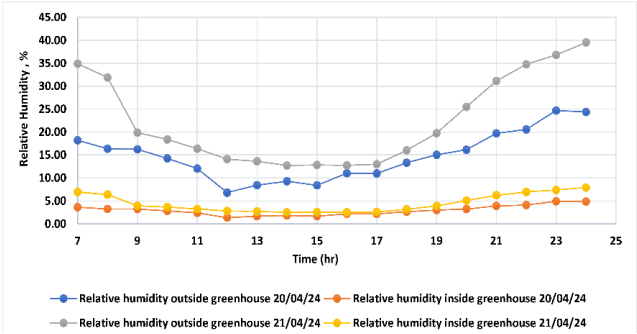


Figure 3. Indoor and outdoor greenhouse relative humidity comparison.

Figure 4 shows the variations of air temperature with respect to time (hr) for the two clear days in summer. It is evident that the effect of air temperature at dawn is less; it gradually increases up to a maximum range, and then decreases until sunset. It is found that the air temperature inside greenhouse was significant less compare to outside greenhouse.

Figure 5 clearly shows the variations of wind speed with respect to time (hr) for the two clear days in summer. It is evident that the effect of wind speed at dawn is less; it gradually increases and decreases in every hour. It is found that the wind speed inside greenhouse was less compare to outside greenhouse.

Figure 6 shows the variations of global radiation with respect to time (hr) for the two clear days in summer. It is evident that the effect of global radiation at dawn is less; it gradually increases up to a maximum range, and then decreases until sunset. It is found that the global radiation inside greenhouse was significant less compare to outside greenhouse.

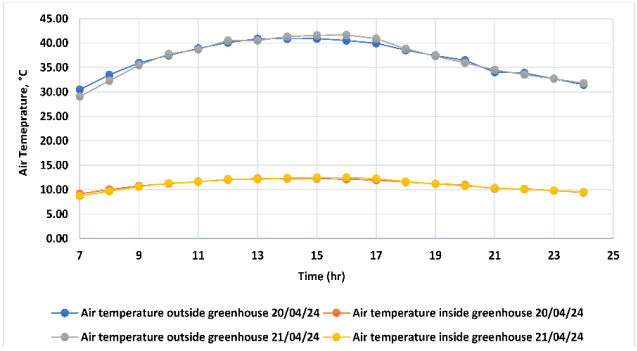


Figure 4. Comparison of air temperature of outside greenhouse and inside greenhouse.

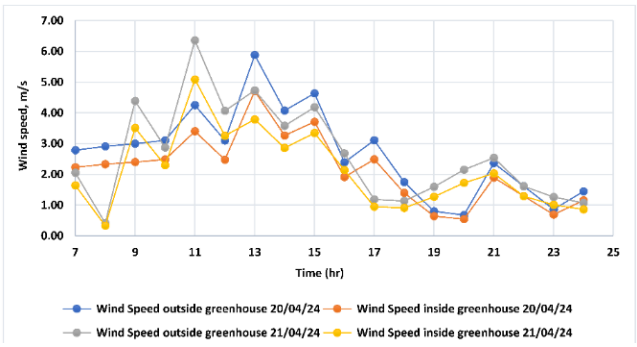


Figure 5. Comparison of wind speed of outside greenhouse and inside greenhouse.

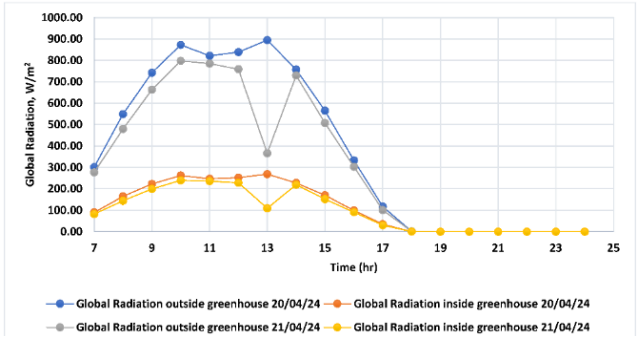


Figure 6. Comparison of global radiation of outside greenhouse and inside greenhouse.

4.0 Conclusion

Greenhouses are always a better option for farming in rough or extreme terrains. They have shown remarkable results in plant growth in the adverse environments.

Creating a habitable environment inside our biosphere is not easy. There are many challenges which arise only after the altering of the ambient environment for the plants. With the help of sensors and technology, these hurdles can be ignored up to a certain limit. Greenhouses can be a good alternative with such scarce resources available. In the aridest regions also, greenhouses have shown promising results. Greenhouse farming has turned the pace of agriculture in such areas. Such controlled farms are a good solution to extreme climatic conditions and rising food demands all over the globe. It is found that the cost of proposed low-cost greenhouse is 2.617 times less than that of conventional greenhouse.

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