Journal of Science and Technology
ISSN: 2456-5660 Volume 06, Issue 01, Jan-February 2021

www.jst.org.in *DOI: https://doi.org/10.46243/jst.2021.v6.i1.pp118-125*

Design of a Solar Modified Greenhouse Prototype

Mr. Aditya Arvind Yadav[1], Mr. Akshay Vijay Yadav[2], Dr. Jaydeep Bagi[3], Mr. Pravin A Prabhu[4]

[1](M. Tech, Department of Energy Technology, Shivaji University, Kolhapur, India)
[2](Design & Development Executive, Décor Home India Pvt. Ltd, Navi Mumbai, India)
[3](Director, Department of Technology, Shivaji University, Kolhapur, India)
[4](Co-ordinator, Department of Energy Technology, Shivaji University, Kolhapur, India)
[1]Corresponding Author: adiyadav821@gmail.com

To Cite this Article
Mr. Aditya Arvind Yadav, Mr. Akshay Vijay Yadav, Dr. Jaydeep Bagi and Mr. Pravin A Prabhu, "Design of a Solar Modified Greenhouse Prototype", Journal of Science and Technology, Vol. 06, Issue 01, Jan-February 2021, pp118-125

Article Info
Received: 27-08-2020 Revised: 10-12-2020 Accepted: 15-12-2020 Published: 27-12-2020

Abstract: *In India there are variety of crops and fruits produced every year. The process of drying in India is generally performed in direct solar radiation also known as solar drying, but this method is not effective. The higher content of moisture in the crops and fruits damage on large scale. Thus, moisture content should be controlled by an effective way to avoid further loss of crops and fruits. The innovative technique i.e. Solar Greenhouse can be an effective way to avoid loss of crops and fruits, thereby improving the lifecycle. In this study the design parameter of solar modified greenhouse prototype is discussed. The various parameters in the design of greenhouse are glazing materials, energy conservation, ventilation methods and solar orientation. With the help of solar modified greenhouse prototype, it is possible to carry out experimental validation for drying of crops and fruits assisted with Phase Change Material as a Thermal Energy Storage.*

Keywords*: Solar Greenhouse, Drying, Post-harvesting, Phase Change Material, Thermal Energy Storage*

I. Introduction

India is amongst one of the largest fruits and vegetables producing countries in the world. As per ranking India is second largest producers of grains, fruits and vegetables. The global annual production of fruits and vegetables is estimated to be 392 and 486 million tons every year. Every year nearly 40 to 50% of the entire crop production gets damaged due to improper post harvesting method. The major damage of the crops is due to moisture content present in the crop. Due to presence of high moisture content in the crops the growth of microorganism takes place. The higher rate of microorganisms degrades the crops to higher extent within a minimum time span. Therefore, drying process is very essential to maintain the optimum level of moisture content to minimize the post harvesting losses. Thus, drying is the process of maintaining the safer or optimum moisture content in the grain to prevent it from self-degradation due to microorganisms. The drying process can be either done by mechanical drying process and by renewable energy i.e. solar energy drying. As far as mechanical drying is considered there is a large-scale energy consumption during drying process, which is not a cost-effective solution. Thus, solar energy can be utilized for drying of grains, fruits and vegetables during sunshine hours, whereas use of Phase Change Material can enhance the drying process during non-sunshine hours.[1] & [2]

II. Basic Principle and Need of Solar Greenhouse

The earth receives nearly 1.8×10^{17} W of total incoming solar radiation at the top of the atmosphere at the top of the atmosphere. The total solar power reception on the land area in India is about 5000 trillion kWh per year. India receives nearly about 250 to 300 clear sunny days. The average solar radiations incident is in the range of 4 to 7 kWh per m2. Thus, sun provides unlimited supply of energy. The solar energy is the inexhaustible source of energy. The energy received from sun is intermittent in nature. Therefore, it is very essential to develop economic and efficient solar thermal energy storage (STES) devices which will store solar energy. The basic idea of solar thermal energy storage (STES) system is to provide storage of thermal energy at time when solar energy is abundantly available and to provide it whenever it is required.[1]

Solar Greenhouses are designed to collect the solar energy during the day time and utilizing the same energy during non-sunshine hours. The solar greenhouses can be either stand alone structure or can be attached to the house. The basic principle involved in solar greenhouse is as follows: -

1. The glazing material provided should gain maximum solar radiation during sunshine hours.
2. Proper insulation material should be incorporated where there is no direct solar radiation to trap the heat by radiation.
3. The glazing material should have minimum heat loss.
4. The solar greenhouse should rely on natural ventilation for maximum period of time.

III. Design of a Solar Greenhouse

The various aspects taken into consideration while designing a solar greenhouse prototype are as follows: -

1. Glazing materials
2. Energy Conservation
   A. Floor heating system
   B. Insulation materials
3. Ventilation methods
4. Solar Orientation

1. Glazing Materials

The glazing material utilized for solar greenhouse prototype should allow maximum solar radiations to enter into the greenhouse. Another important parameter that should be taken into consideration is heat loss, the heat loss by the walls of the solar greenhouse should be as minimum as possible. Therefore, the material selected for glazing should have maximum absorptivity and minimum reflexivity. The most commonly used glazing material involve rough surface glass, double layered rigid plastic, fibre glass, clear glass. The thin plastic foil is most widely utilized glazing materials for solar green house. The plastic foil can provide direct and diffuse solar radiation incident on the glazing materials. The commonly used glazing materials are as given below: -

Table 1. Commonly used glazing materials [5]

Sr. No	Glazing Materials	Light Transmission	R-Value	Disadvantages
1.	Glass- Single Layer	85 to 90%	0.9	1. Can be easily broken 2. Cannot withstand excess weight 3. Requires many supports
2.	Glass- Double Layer	70 to 75%	1.5- 2	1. Heavy weight 2. Requires precise installation
3.	Polyethylene- Single Layer	80 to 90%	0.87	1. Cannot withstand excess weight 2. Transmission decreases with time 3. Has an ability of sagging and shrinking in hot and cold weather respectively.
4.	Polyethylene-Double Layer	60 to 80%	1.5-1.7	1. Cannot withstand excess weight 2. Transmission decreases with time 3. Has an ability of sagging and shrinking in hot and cold weather respectively.
5.	Polyethylene-Corrugated High Density	70 to 75%	2.5 to 3	NA

6.	Fiber reinforced plastic (FRP)	85 to 90%	0.8	1. Light transmission decreases over a period of time
7.	Polycarbonate-Double wall rigid plastic	83%	1.6-1.7	1. Have a translucent property 2. Expensive
8.	Polycarbonate film-Triple and quad wall rigidplastic	75%	1.8-2	1. Have a translucent property 2. Expensive

2. *Energy Conservation*

The Energy Conservation is the most important parameter in the solar greenhouse. The proper solar thermal heat storage materials should be incorporated at the base of the solar greenhouse. The common heat storage materials include rocks, concrete, excess burnt bricks, etc. The North side of the solar greenhouse should be insulated to avoid losses. The extra thickness on North wall provides the thermal insulation as well. The use of Phase Change Materials can also enhance the heat storage on greater extent. The commonly used Phase Change Materials (PCM) for Thermal Energy Storage (TES) inside the greenhouse are Paraffin,Sodium thiosulfate pentahydrate,Glauber's salt (sodium sulphate decahydrate), etc.

The basic working of Phase Change Materials (PCM) is that it absorbs heat i.e. incident by the solar radiations, and when the adequate amount of heat is gained the solid state of PCM is converted to liquid state thereby storing the heat energy during phase change. During the non-sunshine hours the heat gained by the phase change materials is released. Due to release of the heat energy the liquid phase of the PCM is again converted back to the solid phase. Thus, PCM acts as a Thermal Energy Storage (TES). The PCM can be effectively implemented in either floor heating system i.e. at the base level of the greenhouse or it can be also used in place of insulation materials at the North wall.[3] &[6]

3. *Ventilation methods*

The ventilation is one of the most important parameters in designing of the greenhouse. The air exchange rate plays an important role as far as humidity is concerned. The ventilation can be either classified into free ventilation or forced ventilation. The free ventilation is a one in which the direct use of the air surrounding the greenhouse is utilized, whereas the forced ventilation includes the draft fan or blower fans that are attached to the greenhouse with proper supply of the electrical accessories. The Solar PV attached blower fans can also be a better option.[4]

4. *Solar Orientation*

The solar orientation is the most important parameter in greenhouse design. The obstruction in the path of the greenhouse should be removed as maximum as possible. The greenhouse should be south oriented for maximum solar radiation gain. The roof inclination angle should be between 15 to 25° to capture 90% of solar radiation incident on to the surface of the greenhouse. The North wall of the greenhouse should be well insulated so as to avoid the heat loss. The figure below elaborates the solar orientation on the greenhouse.[5]

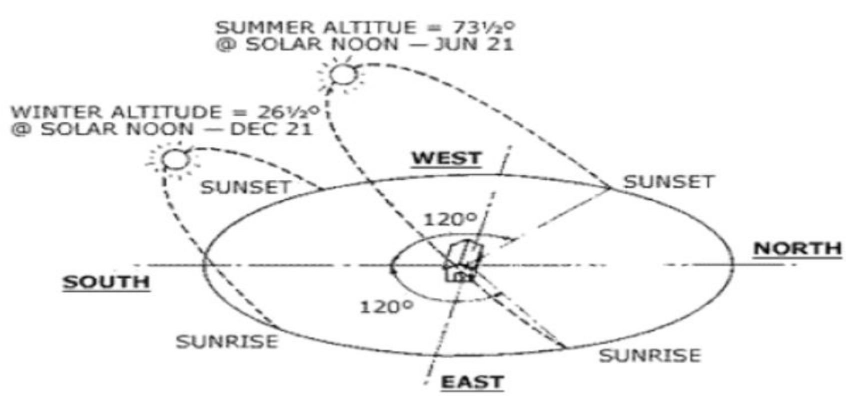

Figure 1: - Solar Orientation on greenhouse

IV. Result and Discussion

For designing of the solar modified greenhouse SOLIDWORKS software was utilized. The overall design was divided into number of several steps as follows: -

1. Design of Frame 1
2. Design of Frame 2
3. Design of PCM Tray
4. Design of Tray- Net Assembly

1. Design of Frame 1

The frame 1 consist of a rectangular arrangement consisting of a four rectangular square tube each of dimension 20×20×2 mm. The overall length for four quantity is 660mm respectively. Similarly, four rectangular square tube of dimension 20×20×2 mm is incorporated. The overall length for four quantity is 290mm. The frame also consists of a tray-net holding assembly and a PCM tray holding assembly. The tray-net holding assembly consists of a L-shaped rod of length 25×25× 4 mm. The overall length of a tray-net holding assembly and PCM-tray holding setup for four quantity is 1000mm. The distance of PCM holding tray from the bottom is 80mm, whereas the distance between tray-net holding assembly and PCM holding tray is 50mm respectively.

The upper frame consists of a four rectangular square tube each of dimension 20×20×2 mm. The overall length of the upper frame is 1000mm respectively. The base of the greenhouse is equipped with stand of dimension 20×20×2 mm at four corners of dimension 50mm respectively. The material used for the frame 1 is plain carbon steel. The detailed drawing of design of frame 1 is illustrated in figure below: -

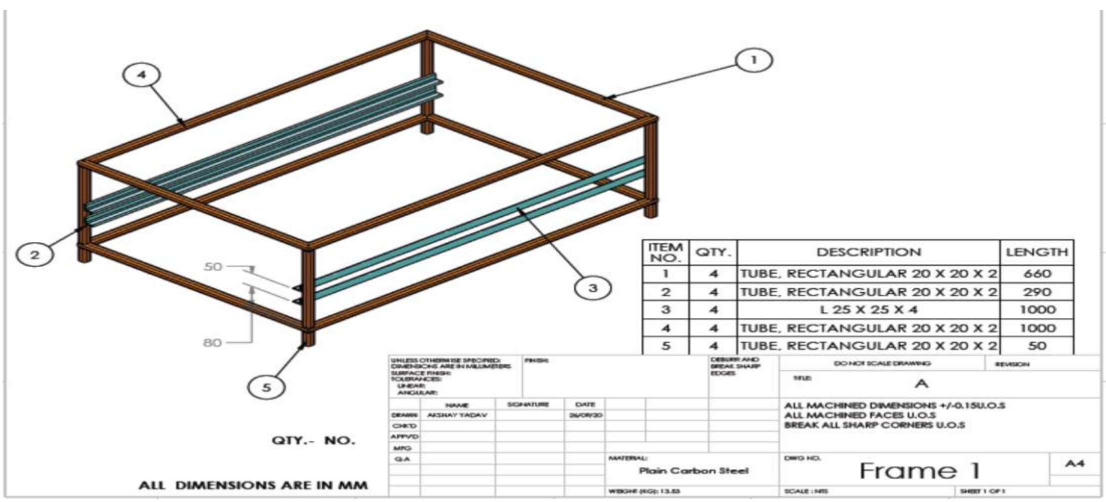

Figure 2. Detailed Design of Frame 1

2. Design of Frame 2

The Frame 2 consists of a upper triangular roof section, all the frame is designed in L-shaped arrangement. The L-shaped rod with dimension 25×25×3 mm of quantity 2 each of length 1000m is used across lengthwise. The base length of the triangular frame is designed with a L- shaped rod of dimension 25×25×3 mm of quantity 2 each of length 660mm is used. The sides of the triangular frame are designed with a L- shaped rod of dimension 25×25×3 mm with dimension 350.466mm for 2 quantity and 345.47 mm for 2 quantity is incorporated. The apex of the triangular frame is designed with a L- shaped rod of dimension 25×25×3 mm with dimension of 997.64 mm with 2 quantity is utilized. The angle between the base of the triangle and the side is kept between 15^o to 25^o respectively depending upon the latitude of the place where the actual experimental setup is tested. The detailed drawing of design of frame 2 is illustrated in figure below

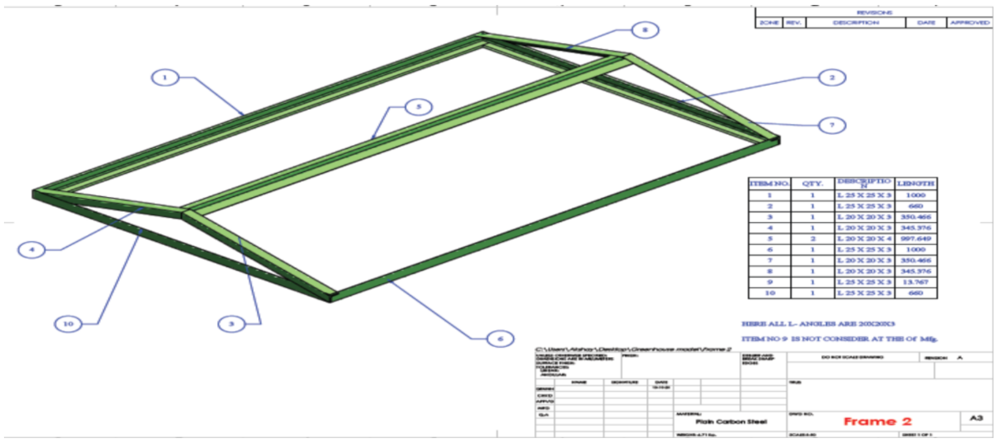

Figure 3. Detailed Design of Frame 2

3. Design of PCM Tray

The PCM Tray consists of a rectangular tray arrangement. It is lowermost tray in the greenhouse prototype. It is 600×600 mm with height of 25mm from the base plate. The PCM tray and the base plate is designed in plain carbon steel to sustain the temperature increment when the PCM changes its phase from solid state to liquid state. The detailed drawing of design PCM tray is illustrated in figure below

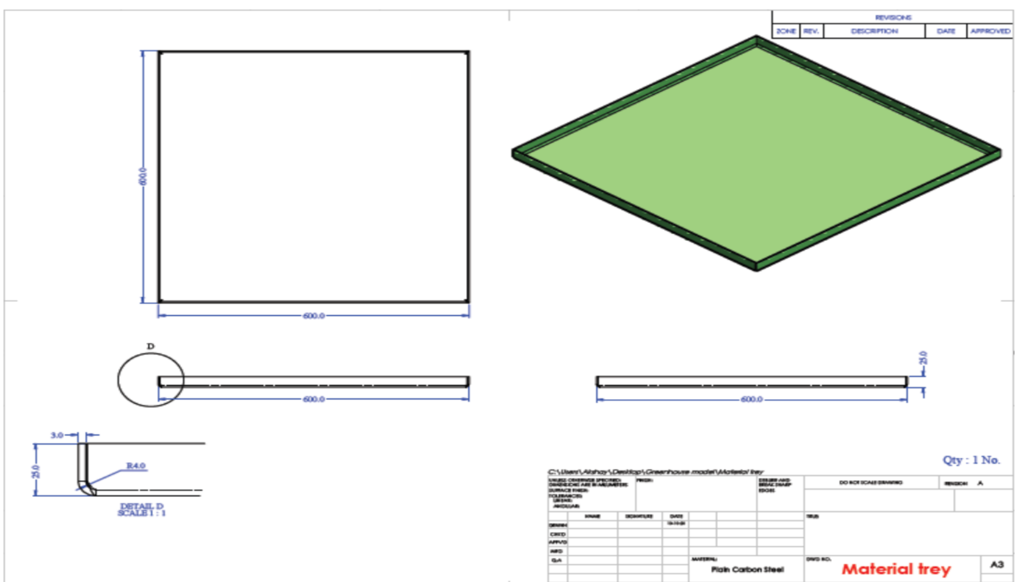

Figure 4. Detailed Design of PCM Tray

4. Design of Tray- Net Assembly

The tray equipped for drying purpose is designed initially with L shaped bar of dimensions25×25×4 mm of 2 quantity each of length 900 mm. Similarly, other two smaller sides of a rectangular tray with L shaped bar of dimensions 25×25×4 mm of length 600mm are used. The detailed drawing of design of Tray-Net assembly is illustrated in figure below

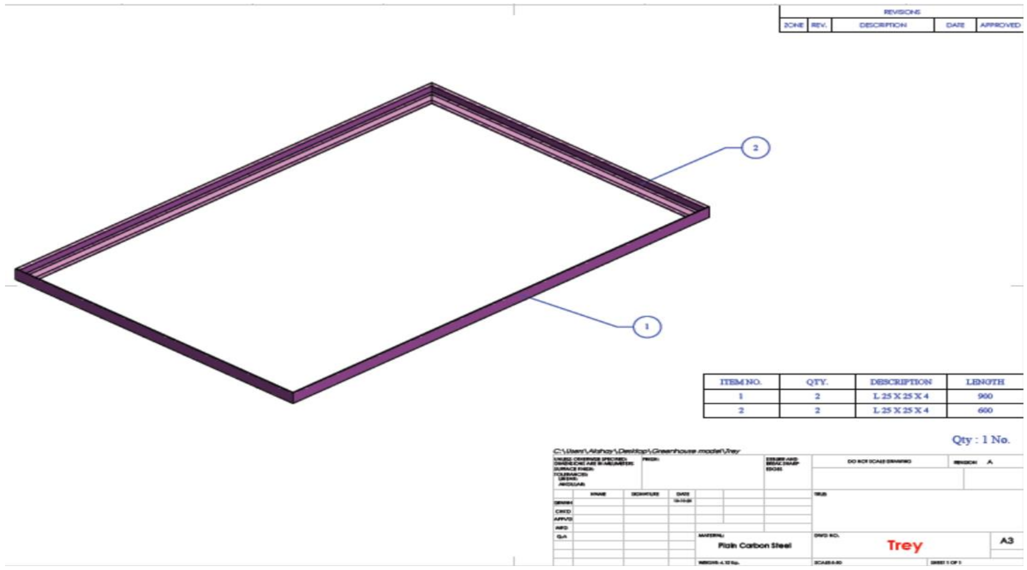

Figure 5. Detailed Design of Tray

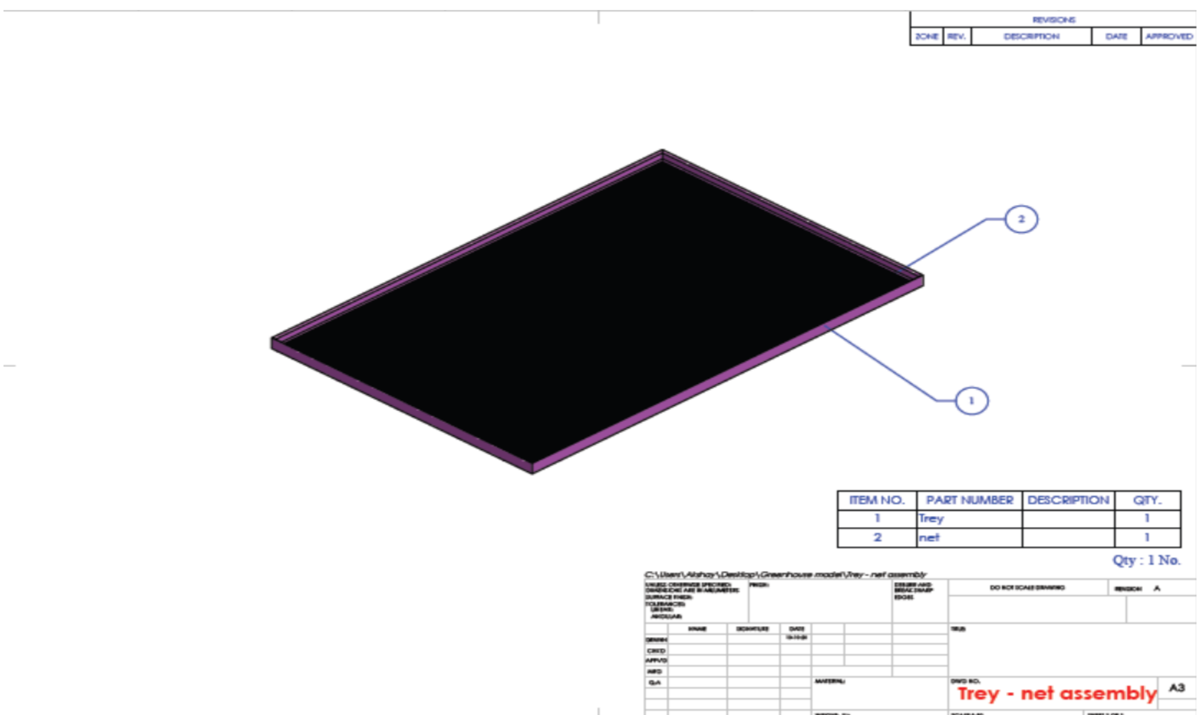

Figure 6. Detailed Design of Tray-Net Assembly

The detailed assembly of Modified Solar Greenhouse prototype is shown in figure below

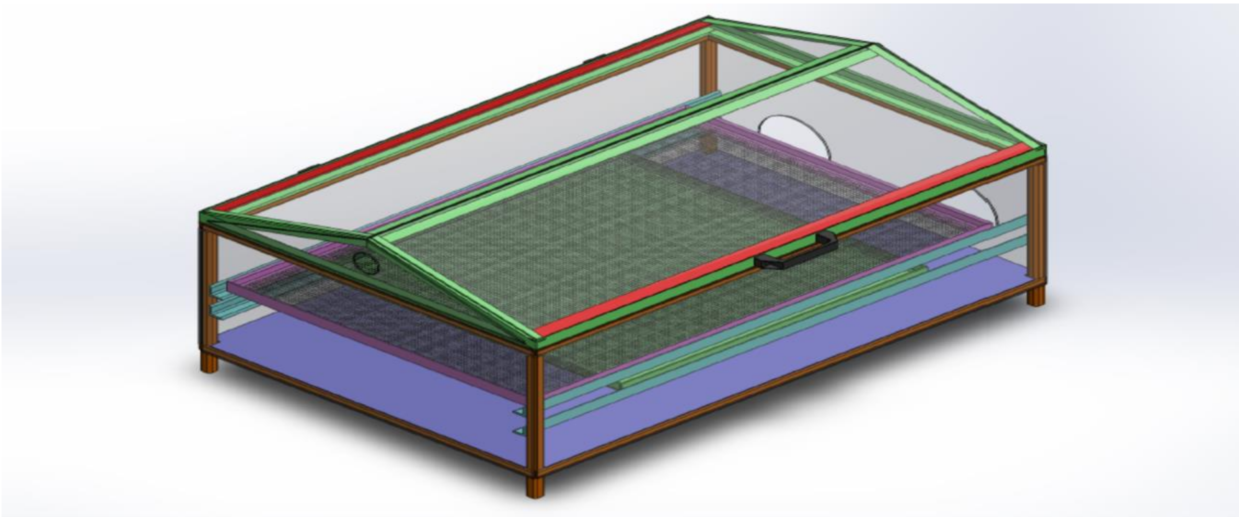

Figure 7. Detailed Assembly of Modified Solar Greenhouse prototype

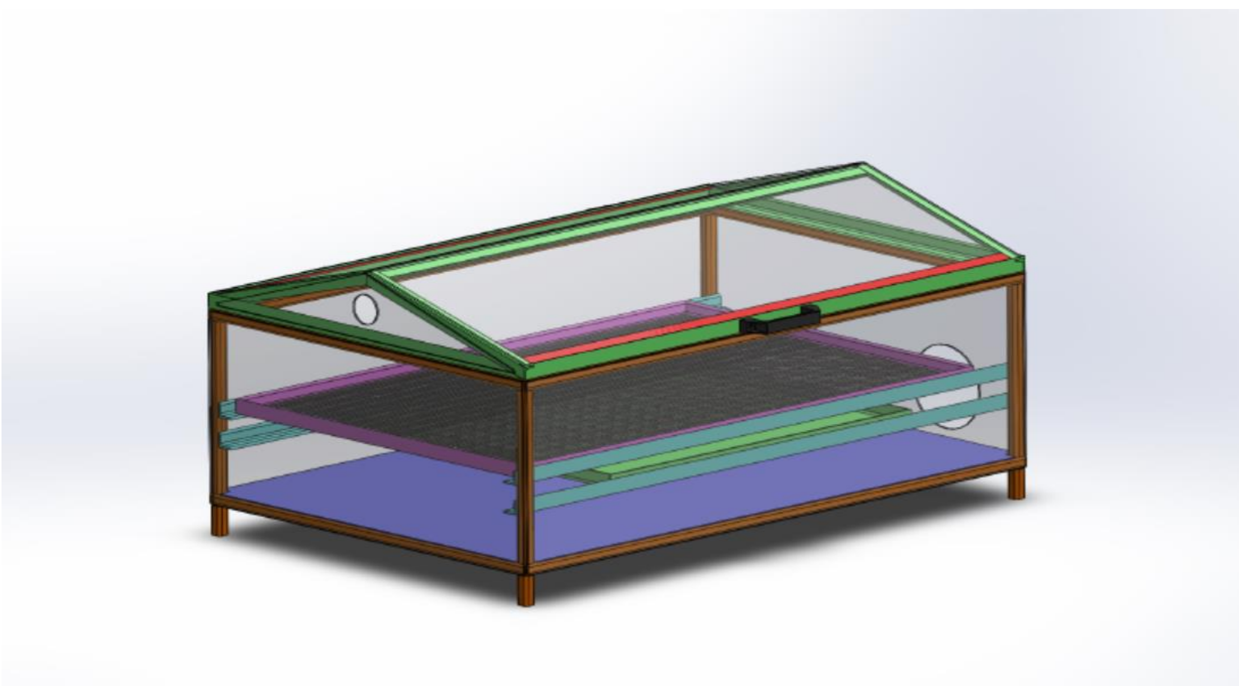

Figure 8. Detailed Assembly of Modified Solar Greenhouse prototype

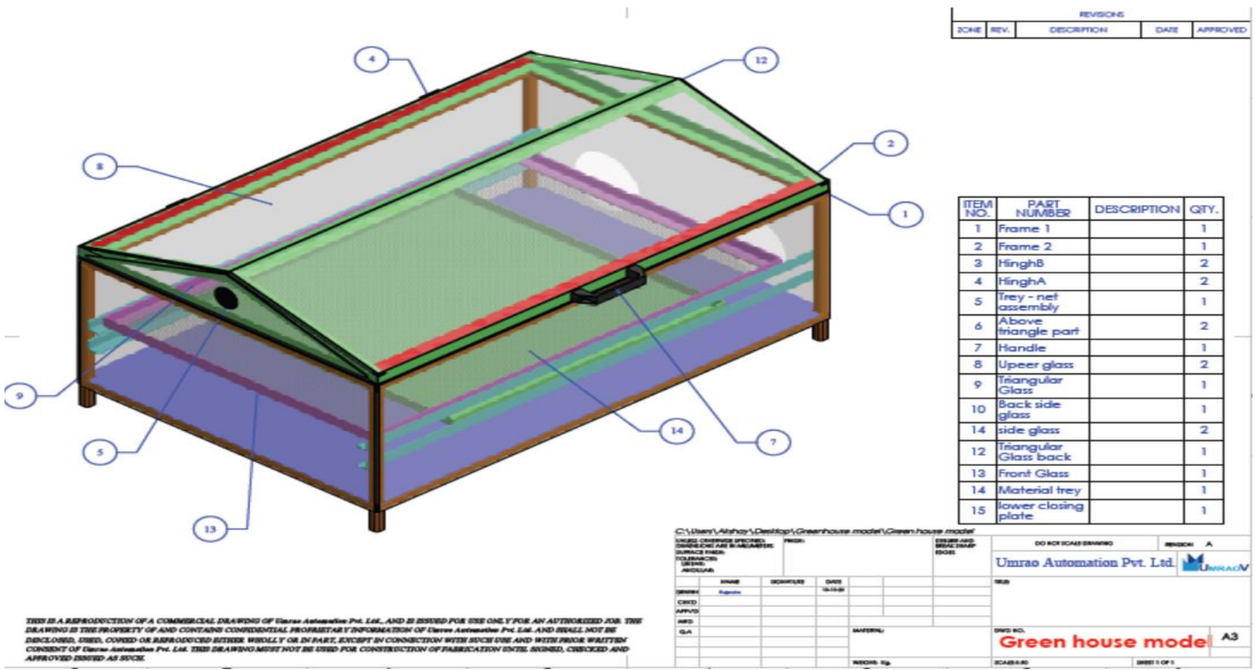

Figure 9. Detailed Assembly of Modified Solar Greenhouse prototype

V. Conclusion

The drying process is one the most important step in post-harvesting of the crops is considered. India is amongst one of the largest fruits and vegetables producing countries in the world. As per ranking India is second largest producers of grains, fruits and vegetables. The global annual production of fruits and vegetables is estimated to be 392 and 486 million tons every year. Every year nearly 40 to 50% of the entire crop production gets damaged due to improper post harvesting method. The major loss of crops due to presence of moisture content in the crops, the moisture content of major crops grown in India can be reduced to desired level by utilizing the solar radiation. The major problem with the direct solar drying is that drying process is not been optimum, some of the grains are not properly dried. The major problem faced during non-sunshine hours is that the grains are not dried at all. Therefore, to resolve the problem of drying the above study of modified solar greenhouse experimental prototype test model has been undertaken. The use of Phase Change Material (PCM) as Thermal Energy Storage (TES) has been adopted in the design of the modified solar greenhouse. The PCM assisted modified solar greenhouse can work during non-sunshine hours which will enhance the efficiency of the modified solar greenhouse.

References

[1] Prakash O, Kumar A, Laguri V. Performance of modified greenhouse dryer with thermal energy storage. Energy Reports 2016; 2:155 –162.
[2] Rajesh. K, Karuppasamy K. Performance evaluation of solar greenhouse dryer for drying herbals. International Journal oF Engineering Sciences & Management Research (IJESMR) 2016;3(6):70–77.
[3] Ebangu BO, Dintwa E, Motsamai O. Development of a Cost-effective Design of a P-V Ventilated Greenhouse Solar Dryer for Commercial Preservation of Tomatoes in a Rural Setting. Advances in Technology Innovation 2019; 4(4):222-233.
[4] Hassanien RHE, Li M, Dong Lin W. Advanced applications of solar energy in agricultural greenhouses. Renewable and Sustainable Energy Reviews 2016;54: 989–1001.
[5] List HR. Solar Greenhouses. 2008; 9140:1–27.
[6] Prabhu PA, Shinde NN, Patil PS. Review of phase change materials for thermal energy storage applications. International Journal of Engineering Research and Applications 2012; 2(3):871-875.