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Application of Solar Energy in the Development of Micro Weather for Agriculture Greenhouses

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ABSTRACT:

The objective of this work is to help in the improvement of the microclimate of the greenhouse by designing a heating system based on solar thermal energy in order to keep the productivity of a certain crop remain constant throughout the year. The design of the greenhouse itself will be modeled in the graphical editor of Simulink Matlab that is a block diagram designated for multi-domain simulation and model based designs. Simulink does have a special tool which is Simscape that involves a library that will further help us design physical systems for instance the thermal model one.

Keywords: Greenhouse, Solar heating system, Thermal energy storage, climate, heat transfer, Simulink, Simscape, crops, tomatoes, Gembloux Greenhouse Dynamic Model.

INTRODUCTION:

Solar heat technologies do vary and have big impacts on the productivity of agriculture if they were well implemented into greenhouses. There are various types of thermal heat storages technologies: sensible heat storage, latent heat storage, and thermo- chemical heat storage. Each type does have its own benefits and in parallel some constraints to be taken into consideration before selecting the adequate technology. The Madhya Pradesh region is well known by various types of agricultural cultivations and uses a lot of greenhouses but the majority of them are either old based greenhouses that use thermal plastic covers to maintain a certain scale of temperature or they are based on fuels which are conventional energy sources and harm the sustainability of our environment. The M.p. Green Plan concerns the improvement of the agricultural sector in M.P. since it is contributing into the gross national product by 19 %, with 15% from agriculture and 4% from agro-industry. The sector of agriculture plays a major role in the development of M.P. and especially in improving the societal since 80% of rural inhabitants depend on agriculture to generate their daily revenues.The green strategy consists of building blocks: Make agriculture the pillar of growth of M.P. in the next decade. Adopt aggregation as an organizing model for agriculture. Improve all types of agriculture' sectors including the modern and traditional agricultures. Improve the private sector (private investments).Engagement of all sectors into the development of agriculture. Focus on a sustainable agriculture. In order to improve the sustainability of agricultural sector nationally and contribute into the feasibility and success of the M.P.

Literature review:

1 A Review on Application of Solar Energy in Agriculture Sector by Narendra Nath Saxena 2021: This paper suggests that solar energy may offer a long-term solution to many of the world's current issues, including climate change, energy shortages, atmospheric conservation, and drought. Farmers in the United States, the European Union, and Asian countries are at the forefront of adopting A Review on Application of Solar Energy in Agriculture Sector. However, despite the fact that this technology has numerous advantages, as demonstrated in this article, most farmers on the African continent are less accepting of solar systems for agriculture. The African continent also benefits from increasing solar radiation and has 60% of the world's productive land. Solar power is suitable for agricultural applications such as electrical shielding, threshing, aerating, grinding, drainage, purification, and so on. Solar energy is now widely used by Indian farmers in the water sector, especially in irrigation systems, for their agricultural. Despite this, farmers believe that the initial cost of solar water pump systems is more than the cost of a diesel water recirculating pump, but neither system considers production or maintenance expenses.

2 Solar Technology in Agriculture WRITTEN BY Ghulam Hasnain Tariq, Muhammad Ashraf and Umar Sohaib Hasnain 2020: Solar energy-based agriculture farms can easily accomplish energy requirements and reduce cost production. Utilization of solar energy at agricultural farms includes different types of machinery and equipment depending on task to accomplish by using different characteristics of solar energy like heating or converted in some other form of energy, such electrical or chemical. These applications include solar thermal and electric devices such as solar spraying machine, solar greenhouse heating, solar crop dryers, solar water pumps, ventilation for livestock, solar irrigation pumps, solar electricity etc. These solar energy equipped machineries also include radio frequency solar controlled sowing and spreading of seeds. Solar energy is a trustful and reliable source to compensate all requirements of energy for future.

3 Modelling the thermal performance of a naturally ventilated greenhouse in Zimbabwe using a dynamic greenhouse climate model by E. Mashonjowa et al 2013

The Gembloux Dynamic Greenhouse Climate Model (GDGCM), previously validated for a tomato crop in European greenhouses, was adapted to simulate the microclimate in a naturally ventilated Zimbabwean greenhouse containing a rose crop. The GDGCM consists of a system of differential equations based on the heat and mass balances of the layers of a greenhouse, and were worked out within the Transient System Simulation (TRNSYS) program. Modified sub-models to calculate the greenhouse air renewal rates and crop canopy resistance to water vapour transfer were introduced. Numerical results obtained using the model were compared to experimental measurements carried out in a full-scale commercial naturally ventilated Azrom type greenhouse with a rose crop. The simulated results showed good agreement with the observed values of all parameters for most parts of the day. For the period of observation the mean standard errors between the predicted and experimental greenhouse air temperature and relative humidity, canopy temperature and crop transpiration were 1.8 C, 14.8%, 1.9 C and 14.2 W m2 , respectively, in winter and 1.3 C, 8.6%, 1.6 C and 21.8 W/m2 ,

4 Computational Modeling of the Thermal Behavior of a Greenhouse by Bruno Lebre 2021: This article studies different greenhouse structures by computational simulation using Energy Plus and Design Builder. First, a comparison was performed between the computational results and the measured values from a greenhouse prototype at different operating conditions. Overall, the comparison shows that the computational tool can provide a reasonable prediction of the greenhouse thermal behavior, depending on the differences between the weather data modelled and observed. An outdoor air temperature difference of 16 ◦C can cause a difference of about 10 ◦C between the air temperature predicted and measured inside the greenhouse.

5 Effects of a solar heating system on the microclimate of an agricultural greenhouse. Application on zucchini by N. Arbaoui. 2023 This work focuses on studying experimentally the effect of a solar heating system (SHS) on the microclimate of an agricultural greenhouse. This heating system is a combination of a copper tube placed between the double roof glazing and a sensible heat storage system. This installation is based on the daily thermal conversion of solar energy and its storage for night restitution. This experimentation also includes a second control greenhouse (G_C) without any heating system that allows comparison at different stages of crops growth under the agricultural greenhouses.

Methodology: In the problem of analysing the greenhouse heating system, we need to consider this two-parameter list: The situation outside the greenhouse including air temperature, humidity, solar radiation, speed of the wind. The inside situation including the air temperature, humidity, soil temperature and the heating energy relieved (as for example the solar heating energy integrated)

The Greenhouse parameters: The greenhouse pilot that will be experienced for heating purposes is located in Jabalpur-patan of the region of latitudeof 79.98andlongitude of 23.18 mabove the sea. The site has a warm dry climate with a yearly average temperature of 21.9 °C according to the NASA Surface meteorology and Solar Energy data . In addition, the greenhouse is approximately a 30m*40m area base and a 2.5m height .

The Vegetation: Tomatoes Growing and Harvest Information Because tomatoes do require a long warming growing season, and its roots need consistently warm days and nights and a warmer soil before proceeding the planting day and night, we decided to select it as vegetation to be planted in our greenhouse. In addition to this, the climate conditions of the site (Jabalpur-patan)

Table Tomatoes Growing and Harvest Information

Temperature	
Germination	15℃ -29 ℃
For Growth	21 ℃ -24 ℃
Measurement	
Space between plants in rows	0.11 m
Root depth	0.20m-1.82m
Height	0.9m-1.22m

Thermal Parameters Before digging into the thermal and heat transfer analysis of the parameters of the greenhouses, it is necessary to set up the thermal and radiation parameters for each of the soil, cover, vegetation, and air.

Table 2 Thermal and Radial Parameters of the Greenhouse different Subsystems.

Soil characteristics	First layer	Second layer	Third layer	Fourth layer
Thermal conductivity (W m-1 K-1)	0.15	0.76	1.38	2
Layer thickness (m)	0.05	0.1	0.15	0.2
Density (kg m-3)	2000	2000	2000	2000
Heat capacity of soil (kJ kg-1 K-1)	0.8	0.8	0.8	0.8

Cover characteristics, 200 µm diffused polyethylene	
Thermal conductivity (W m-2 K-1)	4.5
Vegetation characteristics (tomatoes)	
specific heat capacity of tomatoes (kJ kg-1 K-1)	3.98
Air characteristics	
Humid air density (kg m-3)	0.99
Volumetric heat capacity of humid air (kJ m-3 K-1	**1**
Latent heat of condensation of water (kJ kg-1)	2442
Inside air velocity (m s-1)	0.34

Mathematical Modeling

In order to be able to solve the climate problem inside the greenhouse, it is necessary to take into account various parameters and that will directly influence the crop's growth. The physical processes involved in describing the microclimate of the greenhouse can be schematized according to the figure below:

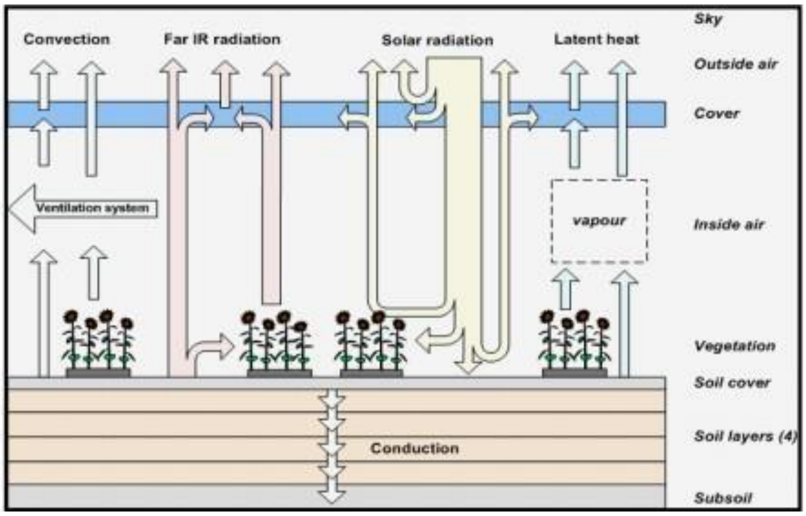

Figure 4.1 Gembloux Greenhouse Dynamic Model

- Cover: The material used for covering the greenhouse is polyethylene, its thermodynamic properties and material have to be homogeneous.
- Crop: The vegetation used need to have a uniform density and uniform temperature through the system.
- Air: It is considered homogeneous throughout the greenhouse and has a unique heat capacity.
- Soil: The layers of the soil, as we will be referring to three sub-layers need to be homogenous in term of organic elements in order to assume a uniform heat capacity and temperature through the layer or the subsystem.

Qin-Qout = Instantaneous variation of the greenhouse generated energy

the thermal equations that describe the heat energy exchanges occurring inside in the greenhouse are as follow:

Table 4.1 Nomenclature

i	inside air	R	radiative flux
e	external air	S	Solar radiation
c	cover	V	convective exchange
w	inside air mass vapor	L	Latent flux density
v	vegetation	C	Thermal capacity
s	soil surface	A	total area
s0,s1,s2,s3	layers of soil	D	Conductive flux density
M	density	P	propotion

For radiative, convective, conductive equations, refer to appendix B for heat transfer equations.

The initial conditions:

Tc=Ti+TV+Te=0

Energy equilibrium for the cover:

$$C_c \frac{\mathrm{dT}_c}{\mathrm{dt}} = (\mathrm{Q_{Rvc}} + Q_{Rsc}) \frac{\mathrm{As}}{\mathrm{Ac}} + Q_{Vci} + Q_{Lci} - Q_{Vce} - Q_{Lce} + Q_{Sc}$$

Energy equilibrium for the interior air:

$$C_a \frac{\mathrm{Vol}}{A_s} * \frac{\mathrm{dT}_i}{\mathrm{dt}} = \mathrm{Q_{Vsi}} + Q_{Vvi} - \frac{\mathrm{Ac}}{\mathrm{As}} Q_{Vci} - Q_{dryair} + Q_{heatingsys}$$

- Q_{dryair} : Thermic flux of dry air
- $Q_{heatingsys}$: The heat flux due to the heating system (to be added when the solar system is added to the greenhouse)

Mass equilibrium equation for the water in the inside air:

$$C_{Lat} \frac{\mathrm{Vol}}{A_s} * \frac{\mathrm{dW}_i}{\mathrm{dt}} = \mathrm{Q_{lsi}} + Q_{lvi} - \frac{\mathrm{Ac}}{\mathrm{As}} Q_{lci} - Q_{watervapour}$$

- : Thermic flux of water vapour

Energy equilibrium for the vegetation:

$$C_v M_v \frac{\mathrm{d}T_v}{\mathrm{dt}} = \mathrm{Q_{Rsv}} - Q_{Rvc} - Q_{Lvi} + Q_{Sv}$$

Energy equilibrium for the soil surface:

$$Q_{Ss} - (1 - P_v) Q_{Rsc} - P_v Q_{Rsv} + \mathrm{Q_{Vsi}} + Q_{Lsi} - Q_{Ds1} = 0$$

Energy equilibrium for the soil' layers:

First soil layer: $\frac{\mathrm{d}T_{s1}}{\mathrm{dt}} = \frac{Q_{Ds1}}{\rho_{s1} C_{s1} l_1} - \frac{Q_{Ds2}}{\rho_{s2} C_{s2} l_2}$ (8)

Second soil layer: $\frac{\mathrm{d}T_{s2}}{\mathrm{dt}} = \frac{Q_{Ds2}}{\rho_{s2} C_{s2} l_2} - \frac{Q_{Ds3}}{\rho_{s3} C_{s3} l_3}$ (9)

Third soil layer: $\frac{\mathrm{d}T_{s3}}{\mathrm{dt}} = \frac{Q_{Ds3} - Q_{Dunderground}}{\rho_{s3} C_{s3} l_3}$ (10)

As stated before, in equation (1), the thermal global balance can be described by only one equation which means the supplies mince the losses will be equal to the instantaneous internal energy.

Energy supplies will then concern the solar one: + $Q_{Sc} + Q_{Sv}\ Q_{Ss}$ positive during the day and null during the night, then the $Q_{heatingsys}$ as stated in (3) can be added to the ∑Supplies. The losses are stated in the Fig. 4.1.

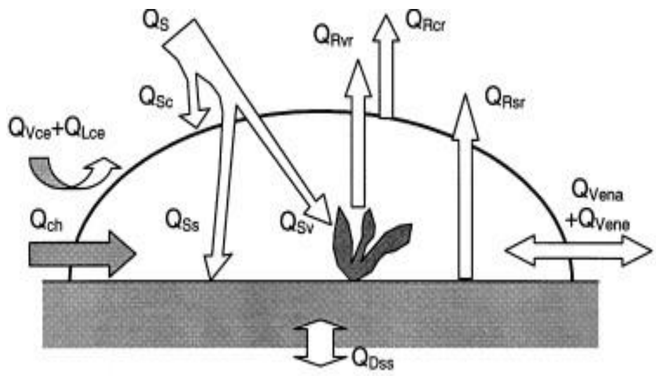

Figure 4.2 Overview of the heat exchange flux inside the greenhouse.

As the energy equilibrium equation of the inside air is the one that consists of the heat energy needed to heat the greenhouse, we will mainly focus on it in order to calculate the energy needed for heating the greenhouse to reach the microclimate conditions needed for the harvest and growth of tomatoes in the area concerned. In the energy balance of inside air (3), only the convective heat transfer is not negligible, it is assumed that the solar radiation entering the greenhouse is almost zero in order to simplify the solution of the heat transfer equations. For the temperature of soil layer 1, we need to set up an initial value for the temperature of underground layers for soil and this is going to be assumed to be 13°C for the winter season .

Table 4.2 Monthly Averaged Air Temperature at 10m above the Surface of the Earth (°C)

Monthly air temperature 10 m above the surface of the earth												
Last 20year average data												
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL AVG
13	14.7	16.8	18	20.1	23.2	26.6	26.6	24.1	20.9	17.4	14.4	19.65
9.82	11.1	12.8	13.9	15.8	18.9	22.1	22.3	20.4	17.6	14.3	15.5	16.21
16.8	18.7	21	22.2	24.4	27.6	31.6	31.4	28.5	24.6	20.7	17.8	23.775

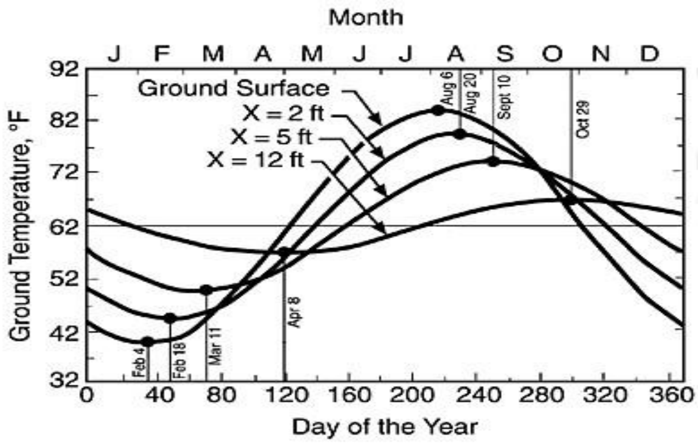

Figure 4.3 Seasonal soil temperature change as a function of depth below ground surface for an average moist soil .

The equation (7), (8), (9) are first order differential equations solved using analytical methods. For the temperature inside air of the greenhouse is solved using Euler Method assuming

$T_c = T_i = T_v = T_e = 0$

The temperature variation for soil 1 with time is then: $T_{s1}(t) = 13°C + e^{-\frac{h}{\rho c_p L}t}$

The temperature variation for soil 2 with time is then: $T_{s2}(t) = 11°C + e^{-\frac{h}{\rho c_p L}t}$

The temperature variation for soil 3 with time is then: $T_{s3}(t) = 9°C + e^{-\frac{h}{\rho c_p L}t}$

Same thing will be done for T inside air. For Toutside air, referring to , we may use the sine function to model the daily temperature variation by setting some parameters. The equation that model this is as follow:

$y = ((x - C)) + D$

$$A = \frac{(T_{max} - T_{min})}{2}, B = 2\pi/12, C(phase) = 0, D = T_{min} + A$$

By setting the parameters to the adequate values by referring to for NASA meteorological data for the site that is used for experiment at 26m elevation from the sea, the function becomes

$$T_e = 3.15 \sin\left(\frac{2\pi t}{24}\right) + 14.65$$

For December, the occurring lowest temperature at night is 11.5 °C and the highest one is 17.8°C, for this, the equation that model temperature in December for the sitetargeted is: 4.2

Gembloux Greenhouse Dynamic Model Results

Using Matlab, I was able to solve plot the Temperature variations for the subsystems: soil layers at different depths (0.2 m, 0.15 m, 0.10 m), inside air, and outsideair in order to identify the gaps occurring between each subsystems and not only that, be able to identify the subsystems that essentially needs a heating system in order to improve the overall climate of the greenhouse. The figure below sums up the plots, there is a label describing what subsystem the plot refers to:

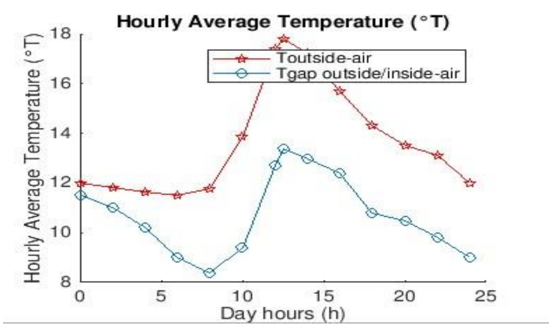

Figure 4.4 gap between Te and Ti.

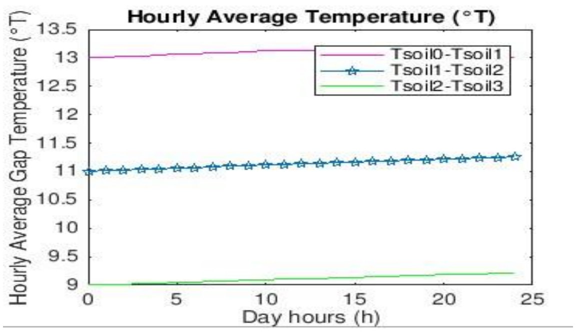

Figure 4.5 gap for the soil' layers 3/2, 2/1, 1.

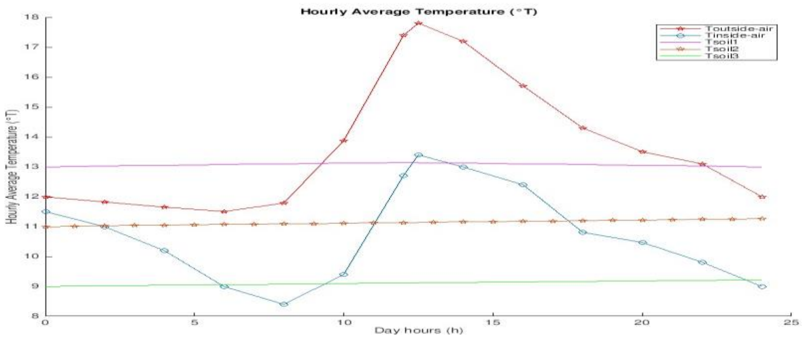

Figure 4.6 Hourly time variation of soil' layers (0.2 meters, 0.15 meters, 0.1 meters) temperatures, inside air temperature, and outside air temperatures

The average temperatures gap for the soil' layers 3/2, 2/2, 1 are respectively: 9°C, 11 °C, and 13°C. The average temperature for the external air is: 14.4 °C. The average gap temperature between internal air and external air is: 10.719 °C. In order to heat up the inside air to a temperature of 18 °C, mathematical analysis results show that an energy of 90 Wh/m² is needed to reach that goal, which means a total energy of **Q_h=108000 Wh** is required.

Simulink Matlab Simulink is a block diagram environment integrated with MATLAB that provides its user with multidomain simulation and Model based design. Simulink provides a graphical editor that you can use to build in the model you want by taking out the features from the customizable block library, and then proceed to the modelling solvers and simulation dynamic systems. In addition, there is an important feature called "Simscape" that enables the user to build in physical models in Simulink graphical editor. Simscape in opposite of Simulink contains additional constructs to specific physical modeling, for instance:

Mechanical building blocks , Electrical building blocks ;Magnetic building blocks Hydraulic building blocks , Thermal building blocks

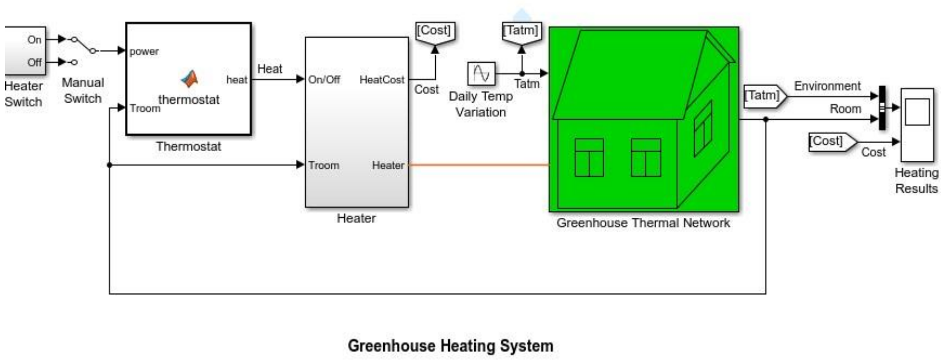

Figure 4.7 Overview of the Greenhouse Thermal Model as it was Built on Simulink Matlab.

Reading the details on Simulink limitation, we found out that Simulink physical block cannot handle complex models as it is the case for the greenhouse (many layers, diverse temperatures all over the greenhouse), this means Simulink can only handle lumped parameters model by assuming constant temperature across the building. This is problematic as it didn't allow us to have clear and logical simulations.

In Addition to this issue, the Matlab Simulink doesn't allow to configure the area of the building or the greenhouse, it only considers the whole block as a rectangle, it doesn't allow also to set up the distances between each layers (soil layers, vegetation, inside air, cover).

HEATING SOLUTIONS

In winter seasons, the temperatures of the site that is located in the latitude23.18/longitude 79.93drop to approximately 9.82 °C in January and 11.1 °C in February. As stated before in Table 1, the needed temperatures inside the greenhouse to maintain the appropriate microclimate conditions are between 15°C and 29°C for germination and between 21°C and 24°C for growth. In order to heat up the inside air to a temperature of 18 °C, mathematical analysis results show that a total energy of **Q_h=832.25 kWh** is required. In our capstone project, we will mainly use solar energy as main source for heating up the greenhouse, for that, it is compulsory to specify some important solar data and parameters such as the average diffuse radiation incident for the site concerned, the optimum tilt of solar panels. According to [17], the monthly averaged diffuse radiation incident on a horizontal surface in the site with latitude23.18/longitude 79.93for December **is 5.30 kWh/m²/day**. Rather than this, it is important to know the solar angle or optimum tilt of the solar thermal panels that are going to be used. To reach a high efficiency and to be able to increase the energy output of solar collectors, it is preferable to have a tracking. To help the farmers, researches have been done to find the optimum tilt angle of collectors by means of mathematical analysis. Using the solar angle calculated as provided by, the optimum angle that can be

taken into consideration while placing the solar collectors on the site concerned is 36° during winter time:

Jabalpur Optimum Tilt of Solar collector by Month

Jan	Feb	Mar	Apr	May	Jun
51°(0.89rad)	59°(1.02rad)	67°91.16rad)	75°(1.30rad)	83°(1.44rad)	89°(1.55rad)
Jul	Aug	Sep	Oct	Nov	Dec
83°(1.44rad)	75°(1.30rad)	67°(1.16rad)	59°(1.02rad)	51°(0.89rad)	44°9(0.76rad)

Figure 5.1 Solar angle calculations for the region of jabalpur.

The surface area that we will need of solar thermal collectors assuming the efficiency of the type of panel used is going to be calculated using the formula that will be further used in the upcoming subsections:

$$A = \frac{Q_{heating}}{\eta * Average\ diffuse\ irradiation} = \frac{832.25\ kWh}{\eta * 5.30 \frac{kWh}{m^2}/day}$$

There are four main categories of solar water heaters or collectors:

- Low Temperature Unglazed Collectors
- Concentrating Collectors
- Flat Plate Collectors
- Evacuated Tube Collectors
- Selective Absorbers

SENSIBLE HEATING SYSTEM USING FLAT COLLECTORS

Overview on Flat Collectors Flat collectors are preferably used over evacuated tubes as they overheat easily when installed flat not on the roof of the greenhouse, more maintenance cost comparing to flat collectors.

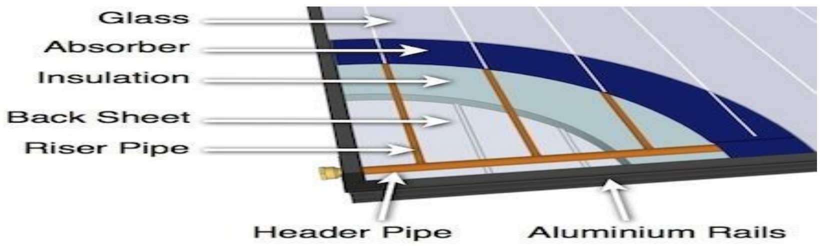

Figure 5.2 Flat Plate Collectors Main Components

System Design

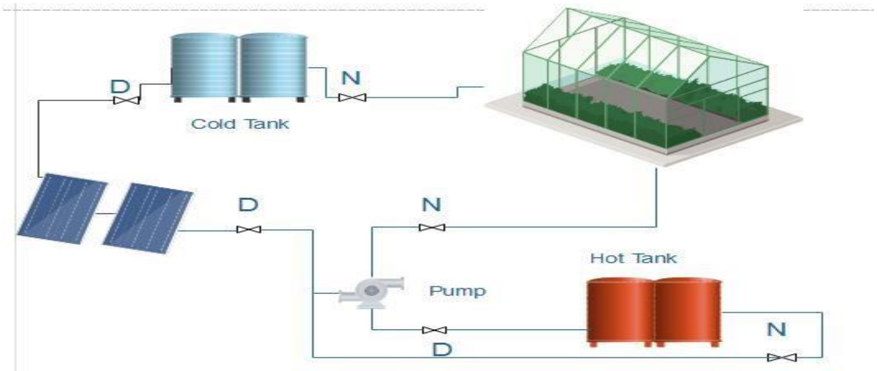

Figure 5.3 Design of the Greenhouse Heating System Using eDraw (For both Flat Plate and Evacuated Tube Collectors).

1. Cold water tank of 1m3
2. Flat solar collectors inclined by an angle of 36 degrees.
3. Hot water tank of $1m^3$
4. Polybutylene tubes+ valves+ fans+ one water pump

During the day, the valves for cold water as it is shown in the figure are open and the valves for night are closed, letting the flow of cold water coming from the blue tank to the solar collectors ensured by the pump, the hot water tank stores then the hot water that is saved for night heating. The circulation of water is closed, which means that the cold water tank are used for both recuperation and supply during the day.

Overview on Evacuated Tube Collectors

evacuated tube collectors are composed of four components:

evacuated tube (absorbs solar to heat), heat pipe (mainly deals with transferring the heat), manifold (the insulator of the header pipe) and mounting frame. The figure below shows an overview of the evacuated tube collector:

Figure 5.4 Evacuated Tube Collectors Showing its Main Components .

System Design:

Underground Heating System

Polybutylene pipes (k=10.17 W/m²K)are going to be opted for in underfloor heating as they ensure long durability prevents the metallic components of the system from corrosion throughout the usage time. To work asoxygen barriers for the system, the pipes should be of type “barrier” .

Before moving to the calculation part, and how much area of pipes is needed for the heating system, we need to know by how much the soil heat energy is contributing into the increase of ambient air’s temperature of the whole system, we refer to equation (3) and also the data generated in Fig.4.6 :

Table 5.1 data generated of heat

Qhsoil	3200 W
Q_i	7000 W
Ratio	46%

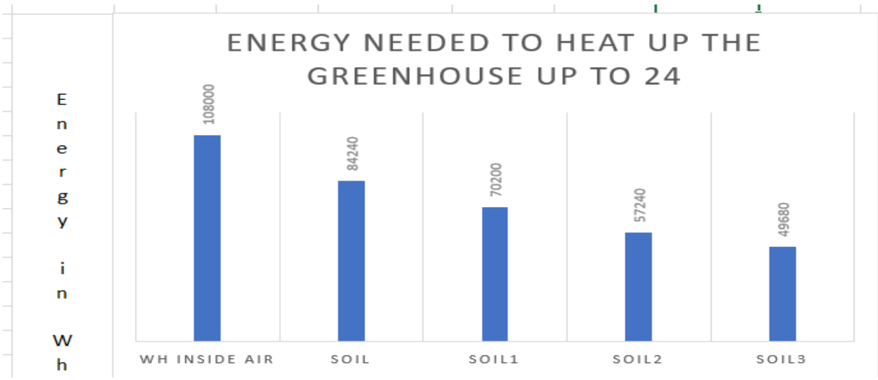

Figure 5.6 Different Soil Layers Energy Needed to Heat up The inside Air of the Greenhouse to 24°C.

DIVERSE SOLAR HEATING SOLUTIONS

Underfloor Heating Using Flat Plate Collectors :

The pipe are is given by: $\pi * d * l = 3.14 * 0.02m * 50m = 3.14m^2$

The number of pipes needed to cover up the heating of 988 m² of soil considering a gap of 20 cm and 46% of inside air is:

$$n = \frac{A}{2*3.14} = 157\ polybutylene\ pipes$$ of 50 m

157 pipes are needed to cover the demand of the greenhouse in terms of soil heating.

Now it is necessary to calculate the needed area of solar collectors (either selective or flat solar collectors) required to reach the required Q energy needed to heat the soil and the ambient air.

Cp = 4.19 kJ/kg.K ρ= 1000 kg/m³ Ti = 5 °C Tf = 30 °C Q= 49680 Wh.

Therefore, the volume of tank required is:

$Q = Cp * \rho * V * (Tf - Ti) = 4.19 * 1000 * (30-5) * V$: $V \approx 1m^3$

the efficiency of flat plate collectors for a temperature difference of 25°C is approximately 60%, the needed area of solar collectors can be calculated using the formula discussed before:

$$A = \frac{49.68\ kWh}{0.6 * 5.30 \frac{kWh}{m^2}/day} = 15.62\ m^2$$

$$\sqrt{15.62} = 4\ m$$

We need approximately 15.62 m² of flat collectors in order to heat up the soil and 46% of the greenhouse of area 1200 m². the aperture area of a flat collector is 2.3 m², this means we need approximately 7 flat plate collectors.

The Needed Components for Underfloor Heating Using Flat Plate Collectors.

Figure 6.1 The Needed Components for Underfloor Heating Using Flat Plate Collectors.

7 flat plate collectors of an aperture area of 2.3 m²

157 of polybutylene pipes of 50 m and 0.02 m diameter

pump+2 fans+2 water tanks of 1m3

Underfloor Heating Using Evacuated Tube Collectors

The number of pipes needed to cover up the heating of 988 m² of soil considering a gap of 20 cm and 46% of inside air is:

$$n = \frac{A}{2*3.14} = 157\ polybutylene\ pipes$$ of 50 m

157 pipes are needed to cover the demand of the greenhouse in terms of soil heating.

Now it is necessary to calculate the needed area of solar collectors (either selective or flat solar collectors) required to reach the required Q energy needed to heat the soil and the ambient air.

Cp = 4.19 kJ/kg.K ρ= 1000 kg/m^3 Ti = 5 °C Tf = 30 °C Q= 49680 Wh.

Therefore, the volume of tank required is:

Q= Cp * ρ * V * (Tf - Ti) = 4.19* 1000 * (30-5)*V : V≈ 1m^3

According to , the efficiency of evacuated tube collectors for a temperature difference of 25°C is approximately 80%, the needed area of evacuated tube solar collectors can be calculated using the formula discussed before:

$$A = \frac{49.68\ kWh}{0.8*5.30\frac{kWh}{m^2}/day} = 11.72\ m^2$$

$\sqrt{11.72} = 3.42\ m$

We need approximately 11.72 m² of evacuated tube collectors in order to heat up the soil and 46% of the greenhouse of area 1200 m². According to , the aperture area of evacuated tube collectors is 2.83 m², this means we need approximately 4 evacuated tube collectors.

Needed Components for Underfloor Heating Using Evacuated Tube Collectors .

Figure 6.2 The Needed Components for Underfloor Heating Using Evacuated Tube Collectors.

4 evacuated tube collectors of an aperture area of 2.83 m²

157 of polybutylene pipes of 50 m and 0.02 m diameter

pump+2 fans+2 water tanks of 1m3

On floor Heating Using Flat Plate Collectors

The heating of the soil layer 0 can cover up to 78% of the heating goals of the ambient air. As stated before, the energy requirement to heat the ambient air to 24 °C during day and night in winter time is: 108000 Wh. Therefore, the needed heat supplied by the soil heating system is: 84240 Wh.

Now that we opted for onfloor heating systems, we need to make sure to higher the gap between pipes to facilitate the growth and germination of the greenhouse. We will consider a gap of 40 cm.

The pipe are is given by: $\pi * d * l$ = 3.14 ∗ 0.02m ∗ 50m = 3.14m^2

The number of pipes needed to cover up the heating of 988 m² of soil considering a gap of 20 cm and 78% of inside air is:

$$n = \frac{A}{3*3.14} = 105\ polybutylene\ pipes$$ of 50 m

105 pipes are needed to cover the demand of the greenhouse in terms of soil heating.

Now it is necessary to calculate the needed area of solar collectors (either selective or flat solar collectors) required to reach the required Q energy needed to heat the soil and the ambient air.

- Cp = 4.19 kJ/kg.K ρ= 1000 kg/m^3 Ti = 5 °C Tf = 30 °C Q= 84240 Wh.

Therefore, the volume of tank required is:

- Q= Cp * ρ * V * (Tf - Ti) = 4.19* 1000 * (30-5)*V V≈ 1m^3

According to , the efficiency of flat plate collectors for a temperature difference of 25°C is approximately 60%, the needed area of solar collectors can be calculated using the formula discussed before:

- $A= \frac{84.24\ kWh}{0.6*5.30\frac{kWh}{m^2}/day} = 26.5\ m^2$
- $\sqrt{26.5} = 5.14\ m$

We need approximately 26.5 m² of flat collectors in order to heat up the soil and 78% of the greenhouse of area 1200 m². According to , the aperture area of a flat collector is 2.3 m², this means we need approximately 12 flat plate collectors.

The Needed Components for On floor Heating Using Flat Plate Collectors

Figure 6.3 The Needed Components for On floor Heating Using Flat Plate Collectors

- 12 flat plate collectors of an aperture area of 2.3 m²
- 157 of polybutylene pipes of 105 m and 0.02 m diameter
- pump+2 fans+2 water tanks of 1m3

On floor Heating Using Evacuated Tube Collectors

The heating of the soil layer 0 can cover up to 78% of the heating goals of the ambient air. As stated before, the energy requirement to heat the ambient air to 24 °C during day and night in winter time is: 108000 Wh. Therefore, the needed heat supplied by the soil heating system is: 84240 Wh.

Now that we opted for on floor heating systems, we need to make sure to higher the gap between pipes to facilitate the grow and germination of the greenhouse. We will consider a gap of 40 cm.

The pipe are is given by: $\pi * d * l = 3.14 * 0.02m * 50m = 3.14m^2$ The number of pipes needed to cover up the heating of 988 m² of soil considering a gap of 20 cm and 78% of inside air is:

$$n = \frac{A}{3*3.14} = 105\ polybutylene\ pipes$$ of 50 m

105 pipes are needed to cover the demand of the greenhouse in terms of soil heating. Now it is necessary to calculate the needed area of solar collectors (either selective or flat solar collectors) required to reach the required Q energy needed to heat the soil and the ambient air.

- Cp = 4.19 kJ/kg.K
- ρ= 1000 kg/m^3
- Ti = 5 °C
- Tf = 30 °C
- Q= 84240 Wh.

Therefore, the volume of tank required is:

- Q= Cp * ρ * V * (Tf - Ti) = 4.19* 1000 * (30-5)*V
- V≈ 1m^3

According to [21], the efficiency of flat plate collectors for a temperature difference of 25°C is approximately 60%, the needed area of solar collectors can be calculated using the formula discussed before:

- $A= \frac{84.24\ kWh}{0.8*5.30\frac{kWh}{m^2}/day}$ = 19.9 m²

$$\sqrt{26.5} = 4.46\ m$$ •

The Needed Components for On floor Heating Using Evacuated Tube Collectors.

Figure 6.4 The Needed Components for On floor Heating Using Evacuated Tube Collectors.

- 7 evacuated tube collectors of an aperture area of 2.83 m²
- 105 of polybutylene pipes of 50 m and 0.02 m diameter
- pump+2 fans+2 water tanks of 1m3

ENERGY SAVINGS AND CO_2 EMISSIONS

The investments cost for heating up the greenhouse during cold times in M.P. is approximately 5000Rs. /day which is very high if assuming the daily net incomes for a farmer in the region of M.P. is moderate. the mass of CO_2 emitted per liter of diesel is approximately 2.68 kg/l. For heating up an area of 1200 m², we need approximately 60ltr of diesel per day which results in 160.80 kg of CO2 emitted per day. Mass of CO2 emitted per liter of diesel per day: 2.86*60= 160.8 kg of CO2 emitted per day.

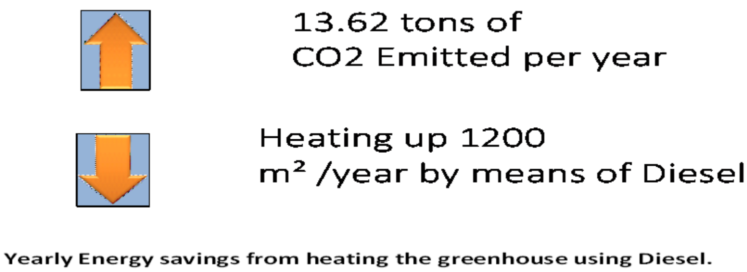

Figure 6.5 Yearly Energy savings from heating the greenhouse using Diesel.

- Heat of combustion for diesel is : 45 MJ/kg
- 1 liter of diesel weighs : 0.850 kg /l
- The energy savings from combustion: 45*0.850*60*30*3= 206550 MJ/year.
- The cost savings from combustion: 60*30*3*94=169200 RS/year.

COST ANALYSIS

The tables below describe the cost analysis of the four systems excluding the maintenance cost and installation fees that will be added once the optimum and efficient heating system is selected:

UNDERFLOOR HEATING USING FLAT PLATE COLLECTORS		
Energy contribution	49680 Wh	
	UNITS	PRICE/UNIT
Flat Plate Collectors	7	46244.88
Pump 1kW	1	3360
Polybutylene pipes 50 m 0.02 m diameter	157	702.8
Water of 1m3	2	1199
Fans	2	1999
Total Cost	443809.76 Rs	

Underfloor Heating Using Evacuated Tube Collectors		
Energy contribution	49680 Wh	
	UNITS	PRICE/UNIT
Evacuated Tube Collectors	4	76140.8
Pump 1kW	1	3360
Polybutylene pipes 50 m 0.02 m diameter	157	702.8
Water of 1m3	2	1199
Fans	2	1999
Total Cost	424658.8 Rs	

Onfloor Heating Using Flat Plate Collectors		
Energy contribution	84240 Wh	
	UNITS	PRICE/UNIT
Flat Plate Collectors	12	46244.88
Pump 1kW	1	3360
Polybutylene pipes 50 m 0.02 m diameter	105	702.8
Water of 1m3	2	1199
Fans	2	1999
Total Cost	638488.56 Rs	

ONFLOOR HEATING USING EVACUATED TUBE COLLECTORS		
Energy contribution	84240 Wh	
	UNITS	PRICE/UNIT
Flat Plate Collectors	7	76140.8
Pump 1kW	1	3360
Polybutylene pipes 50 m 0.02 m diameter	105	702.8
Water of 1m3	2	1199
Fans	2	1999
Total Cost	616535.6 Rs	

Underfloor Heating Using Flat Plate Collectors		
Energy contribution	84240 Wh	
	UNITS	PRICE/UNIT
Flat Plate Collectors	12	46244.88
Pump 1kW	1	3360
Polybutylene pipes 50 m 0.02 m diameter	157	702.8
Water of 1m3	2	1199
Fans	2	1999
Total Cost	669002.219 Rs	

Underfloor Heating Using Evacuated Tube Collectors		
Energy contribution	84240 Wh	
	UNITS	PRICE/UNIT
Evacuated Tube Collectors	7	76140.8
Pump 1kW	1	3360
Polybutylenepipes 50 m 0.02 m diameter	157	702.8
Water of 1m3	2	1199
Fans	2	1999
Total Cost	636528.852 Rs	

COMPARISON OF DIFFERENT HEATING SYSTEMS COST COVERING78% OF INSIDE AIR ENERGY		
	FLAT PLATE COLLECTOR	EVACUATED TUBE COLLECTORS
Under floor Heating	669002.219	636528.852
On floor Heating	638488.56	616535.6

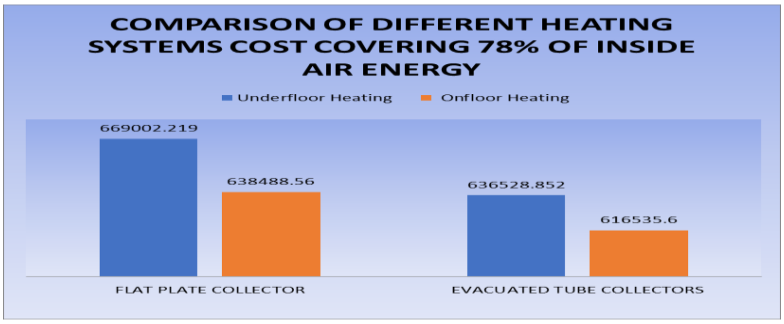

Figure 7.1 Comparison on the Basis of Expenses assuming the same Energy Output.

After setting up the energy output of underfloor heating to 78% of heating the inside air instead of 46% to allow comparison between the different heating scenarios, it is now shown or proven that opting for on-floor heating using evacuated tube collectors and polybutylene pipes might be a good option for farmers in the region of M.P.,excluding the maintenance and installation. The total expenses of the apparatus needed to heat up a 0.12 ha greenhouse is: 616535.6 **Rs**

CONCLUSION

The investment cost for heating up the greenhouse for the duration of cold times in Madhya Pradesh is about 5000Rs./day which could be very essential. In order to enhance the micro-weather of the greenhouse and to contribute into the protection and sustainability of the device, 4 heating structures have been opted to cover the heating of the ambient air in the greenhouse up to 78% throughout wintry weather time. After modeling the greenhouse, and putting in place heat exchange equations, we were capable of discover the energy necessities to warmness up the inner air to an average temperature of 24 °C after solving differential equations. Based totally at the calculations generated we had been capable of pick on-ground heating device the usage of poly -butylene pipes and evacuated tube collectors because the maximum green and most effective option.

FUTURE SCOPE

Solar energy has a vital scope in agriculture field specially in vegetable and fruits and flower farming. the use of solar energy can reduce the running cost for farmers. This work provides a way to establish the forecast and planning for application of solar technology for green house farming. This work can be further extent for more vegetables and fruits. some more heat storage element like phase change material with solar thermal devices can be implement in order to get heating. More work can be done on other segment like dairy, fishing and food storage and processing units. More methodologies like simulation analytical analysis and protype physical modelling can be use in order to optimize the performance of solar energy in green house farming.

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