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Designing New Model of Flat Plate Solar Water Heating Systems For Greenhouses in Erbil, Iraq

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Master of Science

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Designing New Model of Flat Plate Solar Water Heating Systems For Greenhouses in Erbil, Iraq

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Dalshad Majeed Rasheed

DEDICATION

This thesis is dedicated to my Parents and my top supporter, my wife in the beginning and my brothers. Without you, this thesis would never come true.

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Designing New Model of Flat Plate Solar Water Heating Systems For Greenhouses in Erbil, Iraq

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Thermal analysis was used to examine the feasibility of utilizing a solar water heating systems for greenhouse heating in this investigation. Land heat storage is a major factor in this scheme. Some types of resources, such as electricity, are studied in this thesis, to see how they can be decreased in consumption in Erbil district, and the goals of the current project are to implement a system that requires a minimum amount of electricity for greenhouse heating. In order to preheat the soil and air, as well as build a dense polypropylene greenhouse firstly have been done a small hole in the soil to a depth of 0.3 m. A custom greenhouse system was constructed, and flat solar panels were employed to observe the effect. In this system two storage tanks and an equipment which reduces the water hardness was used. In addition to this, solar irradiation properties in Erbil City was also given in this study. Results indicate that this heating system is advantageous for use in Erbil City, Iraq.

Keywords: Greenhouse, TRANSYS16, Flat plate solar collector, Sun Power

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LIST OF ABBREVIATIONS

C : Collector

D : Diameter

B : Beam

⊥ : Perpendicular

G : Ground

|| : Parallel

O : Outlet

I : Inlet

LIST OF SYMBOLS

Z	: Zenith angle
G	: Incidence angle of reflect radiation
Γ	: Surface azimuth angle
Δ	: Declination
H	: Collector efficiency
M	: Dynamic fluid viscosity
T	: Transmittance
V	: Specific volume
D	: Incidence angle of diffuse radiation
Θ	: Incidence angle of beam radiation
Σ	: Stefan Boltzmann constant
A	: Transmittance of initially unpolarized

1. INTRODUCTION

1.1 OVERALL

The release of fossil fuel into the atmosphere has resulted in many environmental issues. If fossil fuels are burned, then the atmosphere is surely harmed and plays a significant role in the phenomenon of global warming, as proven in the figure (1.1). Alternate energy sources do not rely on non-renewable resources.

Figure 1.1: Air emissions due to fossil fuel combustion

In several ways, there are several other options that could be used to provide sustainable electricity outside of fossil fuels, including hydro, biomass, and geothermal, as well as solar. There are good and bad points of it, to consider. When it comes to vast amounts of green resources, there are several problems. The other major problem with green energy is supply efficiency. renewable energy also is a type of solar and/ geothermal power Historic fossil fuel costs are well in excess of existing wind power. Latest technologies and large capital costs are contributing to this because of this, on the other hand, solar energy is free, since no have tax for using it, It is almost unlimited. The planet receives the equivalent of energy from the sun in an hour, because of recent technological advances and the reduced cost of construction, the global community has been paying attention to solar energy. Soon to be the preferred energy. It may be used for various applications such as domestic hot water heating, space heating, distillation of salt water, solar thermal electricity, solar cooking, and as well as solar power for generating steam for a heat engine. in this analysis, solar heating has been used to heat the room.

Sustainable, clean, environmentally friendly, and nonpolluting are a few of the benefits of solar energy. It has a long economic value, needs minimal upkeep, has almost no expense, and uses almost no resources. Geographical and seasonal factors may favor or limit the use of solar power. There is no sunlight at night.

A low cost Seasonal Solar Soil Heat Storage (SSSHS) system used for greenhouse heating was invented and investigated. With soil heat storage technology, the solar energy stored in soil under greenhouse can be utilized to reduce the energy demand of extreme cold and consecutive overcast weather in winter. Unlike conventional underground heat systems, heat pumps are not needed in this system and so the cost is drastically reduced [1].

Greenhouse heating Experiments were carried out in two identical polyethylene tunnel type greenhouses, each with 15 m2 ground area. Rocks were filled in two canals excavated and insulated in the soil of one of the greenhouses. Greenhouse air was pushed through the rock-bed by a centrifugal fan with 1100 m3/h air flow rate and controlled by two thermostats when the energy storage or release was required [2].

In the currnet study ,Over winter, Erbil gets its heat from natural gas, which produces global warming and air pollution. To overcome these issues, energy pollution and scarcity of power, the usage of solar water heating systems is highly recommended.

1.2 AN EFFECTIVE SOLAR WATER HEATING SYSTEM

1.2.1 Overall

Many areas of the world now depend on solar energy for their energy needs because it is a sustainable source of energy. Heating water directly using the using solar rays is one of the easiest and most direct ways to utilize solar energy. A solar water heater has a thermal storage tank that uses an enclosed collector. More heat from the absorber via panel is transferred to the pipes, in figure (1.2) show Solar systems use flat plate collectors as a creative way to obtain solar energy.

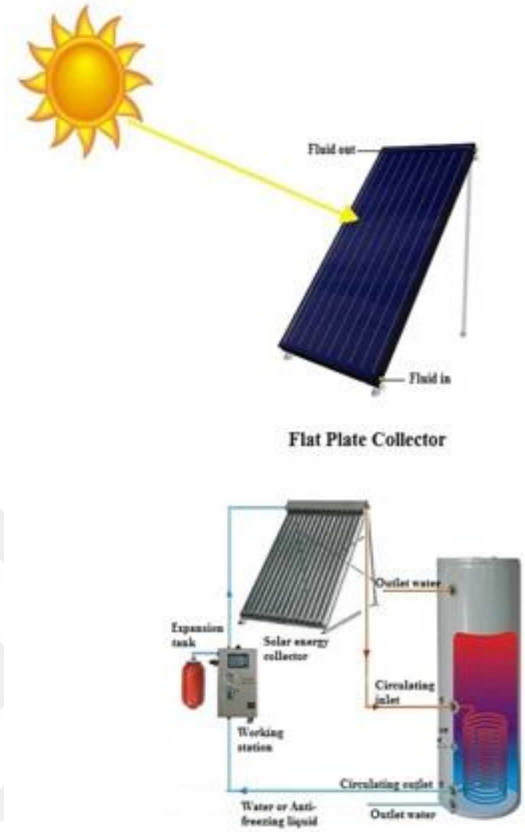


Figure 1.2: Solar systems use flat plate collectors as a creative way to obtain solar energy

1.2.2 COLLECTOR OF FLAT PLATE

Flat-plate collector is most often used for preparing hot water and room heating They are suitable for applications that range from atmospheric to about 100 C^{o}. Figure (1.3) representing Collector of flat plate, the heat transfer liquid circulates in, and heat insulation on top, and a translucent panel below, also known as surface or flat-plate collectors, utilize both horizontal and vertical solar radiation, are less costly, less complicated, and need no monitoring of the sky than FPC systems. transparent cover transmits solar radiation to the absorber. here it is thermally absorbed. We want a strong thermal conductivity to move the accumulated in the absorber pipes to the fluid heat reservoir. Ordinarily, an anti-corrosive water glycol blend is used as a heating fluid [3]. The fluid in the collector helps shield it from freezing. Absorbing all the radiant energy from all angles, flat-plate collectors aren't essential for tracking the light. Similarly-oriented collectors capture the same amount of energy but are placed flat on a ground, the flat plate collector would absorb more solar energy than the collector that is loaded with an angle.

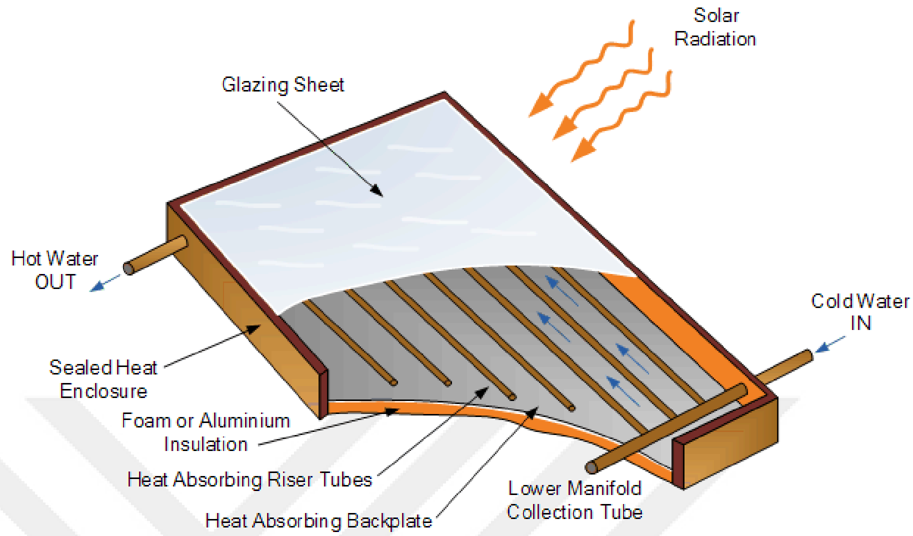


Figure 1.3: Collector of flat plate

1.3 REVIEW OF THE LITERATURE

1.3.1 Overall

The research would then outline the latest research that has been done in commercial-sized solar heating systems, present theory, demonstrate instances, and include explanations on alternative ways to successfully implement systems, and proposals The literature about solar heating simulation applications would be revisited.

1.3.2 THEORY ON HOW TO IMPLEMENT A SOLAR WATER HEATING SYSTEM

Computational analysis to create a theoretical model of a SWHs with respect to tank surface region, storage tank length, piping capacity, and mass movement, built a mathematical model to obtain data on temperature. Raising the surface area of the flat plate collector would lead to a rise in water temperature, while increasing the tank depth would cause a decrease, and increasing the pipe size may cause a decrease Utilizing flat plate collectors for domestic or commercial or industrial water heating makes it really common today's solar water heating (SWH) [4] .

The model incorporates a (Half Sine) power law to measure the thermal fluctuation in the storage tank and estimate the extra heat supplied by the light. Based on these findings, the designer is seen to be more than able to do accurate and capable of performing economic analysis on any device proposal [5].

Examined the relationship between brine flow and spiral jacketed heat exchanger output in solar domestic water tanks. increasing the brine flow rate causes a greater heat transfer coefficient in the spiral direction, leading to lower stratification in the storage tank and to higher efficiency Measurement of the solar glazed plate collectors with the use of tanks for thermal storage of heat will demonstrate the poor thermal efficiency of the collector [6].

In this study observed that the temperature ranges of the storage tank rises with the volume of the tanks, however when space is increased, the maximum and minimum temperatures also decrease[7]. solar water heating systems cut natural gas usage by 60.18%, and prevent emissions of approximately 7418.17 kg [8]. Solar energy may be used in the winter season to heat the water. discovered the productivity of the device increases in the winter, which is connected to the usage of solar air heat for residential purposes in Baghdad [9].

1.3.3 A SCIENTIFIC DESCRIPTION OF SOLAR WATER HEATING SYSTEMS

Used an alternative SWHs that would allow to get hot water from SWH, as long as this system can feeding hot water above a set temp.. If the system is unable to feeding hot-water above the set temp., then electric water-heater be used, then founded that SWH can feeding hot water 80% of time, and the rested 20% will be feeded by electric water-heater[10].

The link between collector and S-tank in SWHs is that when the capacity of S-tank raises then efficiency of collector will increase too in link with performance of these system [11].

Integrated collector-based plane water heaters are being constructed in the southern part of Tunisia. To deliver hot water, they assessed the storage's energy effectiveness. To obtain a value of 70% on this kind of solar collector, will want to use a storage tank [12].

Active solar heating involves a pump or motor as a source. 13% of the device utilizes solar energy to fuel and is free of charge, while the monitoring system was 19% [13]. A less than 1m² passive solar water heating device utilizing mostly off the shelf components, The achieve temp. in temperate weather via this collector was observed as 75°C with inner temperature was founded of 25°C. The made to measure solar water heater was found to be ideal for domestic applications as well. The overall performance of this machine was measured as 26.28% [14].

TRNSYS software was used to accomplish this feat. Flat plate collectors are used in a system of 600 litres holding tanks. The weather data of Baghdad is used to model the TRNSYS. For the

winter months, an extra heater supplies hot water to the system. During the months of December and February, the maximum auxiliary energy was needed (between 1,025 and 1,000 megajoules per month) [15].
omprepared [simulated] to go through simulations in 2014, using just four solar water heaters in four separate cities, and using the TRNSYS calculation, the storage tank temperatures were within 1% of an annual average year's climate change, In Dublin, Ireland a commercial scale device equipped with an automatic sub-thermost and a draw-off and the operation of an auxiliary immersion heater [16].
In this study, maximum collector outlet temperature was measured at a collector outlet temperature of 70.4 C°, and the water at the bottom of the tank was 59.9 C°. Larger contact surface region, growing tube conductivity, and increasing collector reliability improves and extends the series flat plate collector's capability[17].
As a means of decreasing heat loss and improving solar collector performance, a study was conducted to combine low temperature heat storage and heat pumps [18].
Investigated the seasonal thermal storage in combination with heat pump and low-temp. heating systems, then found a appropriate size for thermal E-storage and collector-area [19].

1.3.4 A BRIEF OVERVIEW OF THE THEORETICAL AND EXPERIMENTAL ASPECTS OF SOLAR WATER HEATING

In Tunisia with (Austria) used to demonstrate the need of heat insulation on greenhouse structures (studied and demonstrated in Adrar, Tunisia), is also recommended for locations that experience very high temperatures (Algeria). Essentially, the SWHS consisted of a solar collector tank and a water reservoir. Since it was an experiment, the glass and absorber's temperatures should be varied in the molding phase According to the research, an 80 degree temperature is achieved after two hours of a fire starting at 80C. We examined the impact of detoxification on theory. This machine was 32.89% effective [20].
Tubes of water on a flat plate collector showed that an median heat loss coefficient of 0.68 W/m².°C occurred in the experimental setup, although a theoretical average loss of 0.65 W/m².C° was noted when the optimum solar heat rate was found to be 785 W [21].

Straight design was found to yield improved thermal efficiency results from an experimental and numerical study, as seen by the results from experimental and numerical research and simulation [22].

The authors claim to have empirically and the experiment proved theoretically that they obtained more power from a rectangular flow heaters as opposed to circular pipes, to obtain better collector performance, flow rates must also rise with rising, and the mass of waste generated must also fall. Then, waste water temperature is decreased by flow [23].

The overall flow ratio with a double-glazed reflective board, an experiment and theory study show that efficiency of a traditional and uninsulated solar collector is increased significantly [24].

1.3.5 Inferred by experimentation:

Major findings derived from historical studies of the literary reference are:

1- Many people prefer using solar flat-plate collectors for household water heating.
2- Higher efficiencies are almost often used with processes that employ forced ventilation.
3- It's feasible to use in cities that have a similar atmosphere to Erbil, such as Baghdad.

2. A REVIEW OF THEORETICAL CONCEPTS

2.1 AN EXTENSIVE SYSTEM OF MATH MODELS

2.1.1 Overall

For heating purposes, warm water is an energy-intensive process. Substantial amounts of energy are required in most parts of the country for space heating and for hot water generation, so calculating the heating load is essential in the design of a solar heating system.

Heating loads are the thermal resources used to keep a greenhouse warm in the winter.

2.1.2 THE TOTAL OF ALL HEATING LOADS

Heat loss generally means the transition of an item to its atmosphere is described as a "heat loss." heat loss may take place in either of the following three ways: conduction, convection, and radiation:

1- Technology is passed across buildings, ceilings, and the ground.
2- letting in and blowing out air

The following calculations are used to find the total heating requirements for, heating is provided as (heating may be lost through): external wall, internal wall, and the roof or floor [25].

$$Q_{Tloss} = A * U_o\left(T_{input} - T_{output} \right) \tag{3.1}$$

where Q_{Tloss}: is the overall heat loss, A: is the spaces of area and T_{input} and T_{output} :are the outdoor and indoor temp, respectively, (U_o) :is the total (Heat Transfer Coefficient) .

$$U_o = \frac{1}{R_{total}} \tag{3.2}$$

$$R_{total} = \frac{1}{h_i} + \frac{1}{h_o} + \frac{\Delta x}{k} \tag{3.3}$$

Value, R_{total} is: the resistance, h_i are the layer thickness of the material wall, and (k) is: the thermal conductivity, so heat loss by water flow is given in standard units:

$$Q_{Tloss} = \dot{m}_{mass} * \left(h_{output} - h_{input} \right) \quad (3.4)$$

Where, $(\dot{m}_{mass}) = \frac{\tilde{V}}{V}$ (3.5)

Can be substituted to get the $\dot{m}_a$ molar mass of an incompressible $\tilde{V}$ fluid flow (rate) V for the molar flow, h_{out} and h_{in} enthalpy.

2.1.3 Monitoring Pipes Concept

To determine (pipe size): needed for various water flow rates and depending on the fig. (2.1). To begin, evaluate the water mass flow rate $(\dot{m}_w)$, that is denoted by the following:

$$\dot{m}_w = \frac{Q_{loss}}{(T_{wo} - T_{wi}) * Cp_w} \quad (3.6)$$

Absolute heat loss QT_{loss} from the exterior walls, cp_w internal walls, door, floor, and infiltration, (T_{wo})door, and via the roof is (T_{wi}).

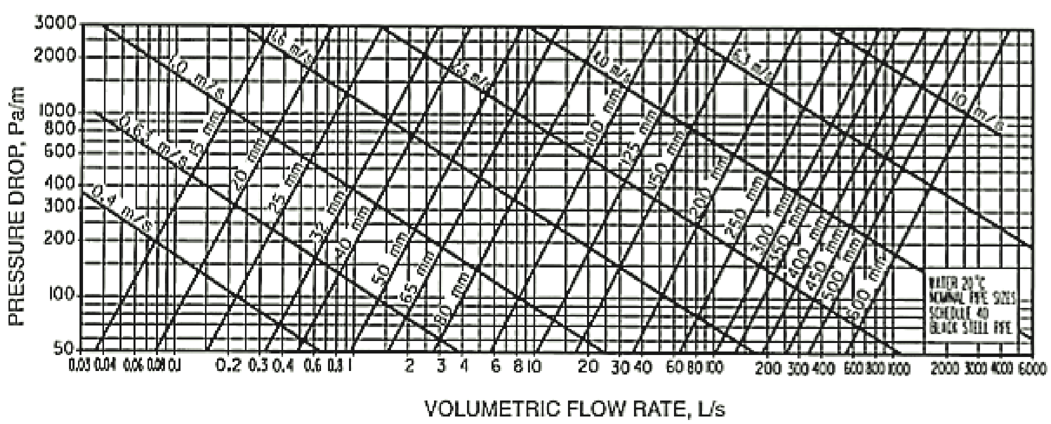


Figure 2.1: A source of rapid heating and system failure (Schedule 40). [26]

2.1.4 Total Sun Radiation

There are three major kinds of solar radiation: direct, diffuse, and refracted. In addition to radiation absorbed directly from the sun, there is diffuse solar radiation denotedI_b, which is the fraction of the radiation that is dispersed by the environment. The sunlight that has been scattered by the ozone is called dispersed solar radiation. The amount of diffuse solar radiation hitting a surface is given the symbolI_d. The radiated solar energy that is returned to the surface after being absorbed by other objects is denoted by I. Complete solar radiation follows these guidelines:

1- Entire uniformity of surface temperature

2- The combination of long-wave and short-wave irradiation.

3- Heat propagation on the inside of the stone.

4- Ground reflection, ρ_g, the reflected heat for a tropical or hot-humid area, (0.2 for ground) [27].

5- Bought for no purpose other than K_T, 'accessibility' to achieve marketing objectives (0.7).

The surface azimuth, γ, is set to zero owing to the south being magnetic [28]. in total solar radiation, direct, diffuse, and reflecting solar radiation on the ground for an hour is computed below:

$$I_T = R_b\, I_b + \left(\frac{1-\cos\beta}{2}\right)\; I\rho_g + \left(\frac{\cos\beta+1}{2}\right) I_d \tag{3.7}$$

Here R_b is the angle of beam radiation on a defined by the geometric factor, is zenith θ as tan θ_z equals raise the following:

$$R_b = \frac{\cos\theta}{\cos\theta_z} \tag{3.8}$$

To figure out how much power is radiates in parallel (cos θ and cos θ_z), here need to know the normal and the incidence of the beam to find θ_z, which is the solution of the beam radiation equation (3.2).

$$\cos\theta = \cos\beta \sin\emptyset \sin\delta - \sin\beta \cos\gamma \sin\delta \cos\emptyset + \cos\beta \cos\omega \cos\emptyset \cos\delta + \sin\gamma \sin\omega \sin\beta \cos\delta + \cos\gamma \cos\omega \cos\delta \sin\beta \tag{3.9}$$

$$\cos\theta_z = \cos\omega \cos\emptyset \cos\delta + \sin\delta \sin\emptyset \tag{3.10}$$

Here β is: the surface inclination, as shown from the horizontal and optimal inclination in winter is set at negative (declination) north, and inclination from the meridian has a 0-180 degree range as seen in the figure to the left (2.2).

2.2 Reflected Radiation From The Ground

The Earth is radiating solar power I, can be measured as

$$I = K_T * I_o \tag{3.11}$$

In an extraterrestrial location, I_o can measure the horizontal radiation for an hour at the beginning of an hour on Earth:

$$I_o = \frac{3600 * 12 * G_{sc}}{3.14} \left(0.033 \cos \frac{n * 360}{365} + 1\right) \left[\cos\delta \cos\emptyset \ (\sin \omega_2 - \sin\omega_1) + \frac{(\omega_2 - \omega_1) * 3.14}{180} \sin\emptyset \sin\delta \right] \tag{3.12}$$

A rough estimate of the solar energy flux, in units of G_{sc}, (joules per square meter per second) applied at mean solar surface-terrestrial ray incident on a horizontal surface for one hour to earth-sun distance of a one Earth sphere, which is G/m2 in relation to one meter [29].

For Erbil city (36.2063o N), latitude $\emptyset$, is the angular inclination north or south of the equator, north positive, and declination is the angular direction of the radiation sunlight at solar in the afternoon (like, when the sun rays is on the Local Meridian), north positive, respecting to equator's axis, and can be calculated :

$$[\ \delta\ ] = \sin\left(\frac{n + 284}{365} * 360\right) * 23.45 \tag{3.13}$$

Theangle (ω), is the angular-movement of the sun (east or west) of the local meridian caused by the planet rotating on its axis at a rate of 15° revolutions per hour; mornings are negative, afternoons are positive, and limits: (ω_1) and (ω_2) signify a interval other than an hours.

$$[\ \omega\ ] = (\ st - 12) * 15 \tag{3.14}$$

What is called (ST), or (solar time) defined as a time depends on what latitude are in relation to the sun.

$$ST = E + (L_{st} - L_{loc}) * 4 + Std \qquad (3.15)$$

Here the local time is: specified, meridian time is Utc. Equation is : L_{st}, Erbil's longitude is L_{loc} 43°, or, instead, for Erbil, it is the longitude coordinate provided as the equation of time: in the W in degrees.

$$E = (0.0000751 + \cos B * 0.0018681 - \sin B * 0.0320771 - \cos 2B * 0.0146151 - \sin 2B * 0.040891) * 229.12 \qquad (3.16)$$

(B) may be said to be constant

$$B = (n - 1)\frac{360}{365} \qquad (3.17)$$

2.3 Solar Irradiance, Which Diffuses Out

A diffuse amount of solar radiation I_d, is normally distributed through the sky, and it is described as follows:

$$I_d = I * \left(0.9511 - K_T * 0.1604 + 4.388 * {K_T}^2 - {K_T}^3 * 16.638 + {K_T}^4 * 12.336\right) \qquad (3.18)$$

For $0.22 < K_T \leq 0.8$

2.4 Polarized Dispersed Radiation

It can be derived from the following equation: (I_b) can be derived from the below Eq. :

$$[\,I_{Dispersed}] = I - I_{diffuse} \qquad (3.19)$$

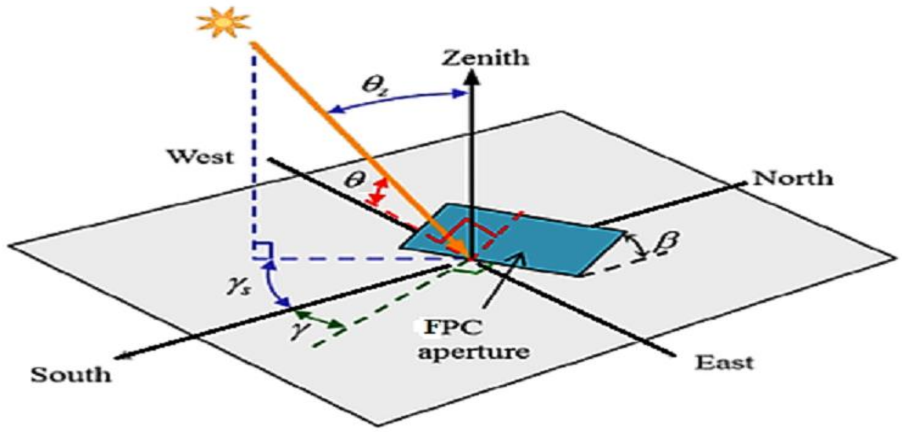


Figure 2.2: A zenith, a sighting, an inclined surface, an incidence, a surface inclination, and a sun angle are often referred to as angular angles.

2.5 The Amount Of Energy Collected By A Flat Plate Solar Collector Expanded.

The point at which the entire inlet fluid is at its optimum heat transfer temperature is when a solar collector is at the most efficient. Energetic return (Q_u), is equal to the collector removal factor (F_R), multiplied by the overall allowable output.

$$Q_u = F_R A_c \ [S - U_L(T_i - T_a)] \tag{3.20}$$

When A_c is the collector field, S is the total water temperature, U_L is the water's heat capacity, T_i is the water's temperature, and T_a is the air temperature.

2.5.1 Total Coefficient of Loss

The total coefficient of loss the collector, U_{Loss} can be calculated using the below Eq. :

$$U_{Loss} = U_b + U_e + U_t \tag{3.21}$$

Here U_b, U_t and U_e are the coefficient of bottom losses , top-of-side losses, and the coefficient of Edge loss, respectively.

For the sake of loss calculation

$$U_t = \left(\frac{1}{h_w} + \frac{N}{\left[\frac{T_{Pm} - T_a}{Nf + f}\right] * \frac{C}{T_{Pm}}^{e}} \right)^{-1} + \frac{\sigma * \left(T_{pm}{}^{2} + T_a{}^{2}\right) * (T_{pm} + T_a)}{\frac{1}{0.00591 * Nh_w + \varepsilon_p} + \frac{f + 2N + 0.133 * \varepsilon_p - 1}{\varepsilon_g} - N} \quad (3.22)$$

$$C = (1 - 0.000051 * \beta^2) * 520 \quad (3.23)$$

For [(0°) < β < (70°)] , [(70°) < β < (90°)] use[β = (70°)]

$$f = (0.089 * h_w + 1 - 0.1166 * h_w * \varepsilon_p)(0.0786 * N + 1) \quad (3.24)$$

$$e = \left(1 - \frac{100}{T_{Pm}}\right) * 0.430 \quad (3.25)$$

$$h_w = \frac{8.6 * V^{0.6}}{L^{0.4}} \quad (3.26)$$

For a given value of N for the number of glass plates, T_{pm} is the value of the ambient temperature, T_a is the air temperature rise per minute, the coefficient σ is the Stefan Boltzmann Constant, h_w is the ratio of the wind velocity to the rate of plate movement through the water per cubed volume of glass, and V is the room volume velocity in meters ε_p and ε_g. There is something unique about there.

back tension,

$$U_b = \frac{K_b}{L_b} \quad (3.27)$$

Degradation or degradation factor,

$$U_e = \frac{(p * L_e) * \left({}^{K_e}/{}_{L_e}\right)}{A_c} \quad (3.28)$$

The thermal conductance (p) of the back insulation (K_b) is to air is equal to the thermal conductivity (K_e) to air. Thickness of the back and edge insulation (L_b) is often called perimeter (L_e).

2.5.2 To Provide For Collector Heat Removal

It is easier to describe a quantity that is equal to the collector's real useful energy gain and the collector's useful energy gain if the whole collector surface were at fluid inlet temperature. This is known as the "collector heat removal element F_R, and it is denoted as:

$$F_{Removal} = [\, F' * \; F'' \,] \tag{3.29}$$

When the CF and the Cf mean collector factor and flow are given, the flux inlet can be calculated as below:

$$F'' = \frac{\dot{m} * Cp}{A_c * U_L * F'}\left[1 - e^{-\frac{A_c * U_L * F'}{\dot{m} * Cp}}\right] \tag{3.30}$$

$$[\, F'] = \frac{{}^{1}\!/_{U_L}}{W * \left[\frac{1}{F * U_L * [(W - D) + D]} + \frac{1}{\pi * Dh_{fi}} + \frac{1}{c_b}\right]} \tag{3.31}$$

Equation to the effectiveness of a fin: W: is the tube-spacing, D is the tube-diameter, C_b: is the conductance, h_{fi} : is the heat transfer coefficient, and F: is a number obtained as follows:

$$F = \frac{\left[\frac{m}{2} * \; (W - D)\right] * \tanh}{\frac{m}{2} * \; (W - D)} \tag{3.32}$$

$$m = \sqrt{\frac{U_L}{t_p \, k_p}} \tag{3.33}$$

k_p and t_p are dimensionless quantities, but they may be referred to as simply as "p" or "k" for the thermal conductivity of the plate.

To calculate Re_D, firstly should calculateh h_{fi}.

$$\mathrm{Re_D} = \frac{\mathrm{VD}}{\mathrm{v}} = \frac{4\ \dot{\mathrm{m}}_{\mathrm{w}}}{\mathrm{D\mu\ \pi}} \quad (3.34)$$

The $\dot{m}_w$ mass-flow density (the number of grains of water per second per second passing) of where μ is the viscosity (grains per second) After laminar flow is created and requirements are satisfied, the necessary heat transfer can be established as:

$$\mathrm{Nu_D} = \frac{\mathrm{h_{fi}D}}{\mathrm{k}} = 4.36 \quad (3.35)$$

Where Pr is constant and does not change with respect to the flow direction of heat transfer, Nusselt's number $\mathrm{Nu_D}$ is constant, and Reynolds' number Pr is independent of axiality

But smooth steady, or well-developed circular flow of turbulent media has a value of Nusselt.

$$\mathrm{Nu_D} = \mathrm{Pr}^{0.4}\ 0.023\mathrm{Re_D}^{0.8} \quad (3.36)$$

The connection is used for heating about, [$0.6 \leq \mathrm{Pr} \leq 160$], [$\mathrm{Re_D} \geq 10\ 000$], and [$\frac{L}{D} \geq 10$].

$$[\ \mathrm{h_{fi}}\ ] = \frac{\mathrm{Nu_D k_w}}{\mathrm{D}} \quad (3.37)$$

μ, pr and k_w can be founded from table [25]

2.5.3 Solar Radiation Absorbed

The absorbe S-radiation ‘ S ‘ can be calculatas below Eq. :

$$[\ \mathrm{S}\ ] = \mathrm{I_d} * (\tau\alpha)_\mathrm{d} * \left(\frac{1+\cos\beta}{2}\right) + (\tau\alpha)_\mathrm{g} * \mathrm{I\rho_g} * \left(\frac{1-\cos\beta}{2}\right) + \mathrm{R_b} * \mathrm{I_b} * (\tau\alpha)_\mathrm{b} \quad (3.38)$$

Here[(1−cos β)/2] , and [(1+ cos β)/2] are the VF ‘’ view vactor from the collector to the earth and the view factors from the collector to the sky, respectively multiplied by the required Transmittance absorptance [τα] product. The Subscripts d, g and b denote Diffuse, Ground light, and Ray, respectively. The following equation can be used to calculate the transmittance absorptance product:

For beam,

$$(\tau\alpha)_b = 1.01\ \tau\alpha \tag{3.39}$$

The solar absorptance α is and the transmittance of a single cover, if a solar collector has an absorption layer on its surface, and τ

$$\tau = \tau_r \tau_a \tag{3.40}$$

$$[\ \tau_a] = \exp\left(-\frac{L_g * \ K_g}{\cos\theta_2}\right) \tag{3.41}$$

Where the subscript an indicates that only assimilation loss have been taken into account. [K_g] is: the extinction-coefficient, which is roughly [32 m −1] for glass with a strong iron-Oxide contented (greenish-cast of the edge), so[L_g] is: the thickness of the glass mask.

Aspect the angle [θ_2] is: proportional to the Indices of refraction, this is due to the Rule of Refractions, Snell's principle

$$\theta_2 = \sin^{-1}\left(\frac{\sin\theta_1}{n_i}\right) \tag{3.42}$$

And τ_r is the original unpolarized radiation transmittance, which is the sum of the transmittances of the two elements perpendicular-unpolarized radiation,[$r_\perp$] and parallel-unpolarized radiation [$r_{\|}$], while element (r) is: the representation of unpolarized-radiation.

$$[\tau\ _r] = \frac{1}{2} * \left(\frac{(1-r\ _\perp)}{(r\ _\perp+1)} + \frac{(1-r\ _{\|})}{(1+r\ _{\|})}\right) \tag{3.43}$$

$$[\ r\ _\perp] = \frac{\sin^2 * (\theta\ _2 - \theta\ _1)}{\sin^2 * (\theta\ _2 + \theta\ _1\ )} \tag{3.44}$$

$$[r\ _{\|}] = \frac{\tan^2 * (\theta\ _2 - \theta\ _1)}{\tan^2 * (\theta\ _2\ + \theta\ _1)} \tag{3.45}$$

For- diffuse:

$$[(\tau\alpha)\ _d] = \tau\alpha * 1.01 \tag{3.46}$$

These Eq.'s (3.40) to (3.45) can be said three times but in exchange for using $[\theta_1]$ and $[\theta_2]$, Which are: mean the angles of (Isotropic Diffuse Radiation), instead θ will be mentioned as θ_{d1} and θ_{d2}, respectively.

$$[\theta_{d1}] = [\ 0.001497 * \beta^2\ ] + [\ 59.7 - 0.1388 * \beta\ \ ] \tag{3.47}$$

And for ground,

$$(\ \tau\alpha\ )_{ground} = \tau\alpha * 1.01 \tag{3.48}$$

The angles of isotropic radiation, we'll use θ_1 and θ_2. But, instead of that, the calculations (3.40) to (3.45) are used using θ_{g1} and θ_{g2}, which are: (Isotropic Reflected Radiation), and they are given as angles:

$$\theta_{g1} = 0.002693\beta^2 + 90\ - 0.5788\beta \tag{3.49}$$

2.6 Efficiency of Solar Collectors

It is said that the usable energy benefit of a FPC is determined by the ratio of its direct-to-sun receiver efficiency (Q_u) and collector area (η):

$$\eta = \frac{Q_u}{A_c I_T} \tag{3.50}$$

2.7 Temperature Of The Average Plate

When a collector is generating usable energy, the temperature of the mean is often higher than the solvent. For liquid heat exchangers, the temperature differential is seldom important, whereas for air heaters, on the other hand, it may be significant. Although we cannot say with absolute certainty the usable heat capacity of a collector, we may quantify the mean plate temperature with the use of this formula:

$$T_{pm} = T_{wi} + (1 - F_R)\frac{Q_u/A_c}{F_R U_L} \tag{3.51}$$

Let us calculate the first approximation of the mean plate temperature $T_{wi} + 10$ °C. Then let us check if it matches with that calculated by the equation, but treat the result as the absolute truth, allowing for measurement error.

2.8 Calculation Experiment

To estimate the amount of solar heating and hot water available for a greenhouse, experimentally find the net energy gain from the system:

$$Q_s = \dot{m} * Cp_w * (T_{Wout} - T_{Win}) \qquad (3.52)$$

The total amount of -Kerosene needed in liters to produced kJ of Heat is determined as below, [30]

1 liter of Kerose = 37600 kJ of heat.

The next step, is to calculate the sum of CO_2 produced by a heat output in KW_h, as below,

1 k_g of carbon dioxied =Amount of of heat from keros $KW_h \times 0.26$

3. PRACTICAL ASPECTS

3.1 STUDY BY EXPERIMENT

3.1.1 Overall

The Erbil Solar Water Heating device is composed of flat plate collectors installed on the facility's roof. may also be referred to as facing the south in a 60° angle, flat-plate solar collectors accomputers located on the 1st floor of the Erbil research building, with the tubes water heat exchangers buried under the flooring Water was made to flow both within and outside the device as well. It also included an irrigation piping device with sensors, temperature sensors, flow sensors, a motorized three-way valve, and an electromagnet actuator system, which regulated the irrigation of the house in accordance with water hardness. Via the DESIGM INSIGHT, all divese data from the temp., flow-meter, and pressure-sensors could be viewed on a computer screen.

3.1.2 The Chosen Place Room

A SWHs was located in Erbil-Iraq at the Technical Institute (36.2°N, 44°L). Notice that the greenhouse has dimensions of 5.0 meters wide, 5.0 meters long, and 3.25 meters tall, and desigen the greenhouse room by glass as bellow in fig. (3.2).

Figure 3.1: An image of the GH

the external walls is made-up Glass, outside to inside walls, The dimensions of the Glass for width are 1 centemeter , and for the others walls same that .The floor dim. is 5.0 meter $\times$ 5.0 meter and consiste of some materials of Stone and Sand, then the roof is Polygonal each one dim. is 3.0 meter $\times$ 5.0 meter and made-up Glass too.

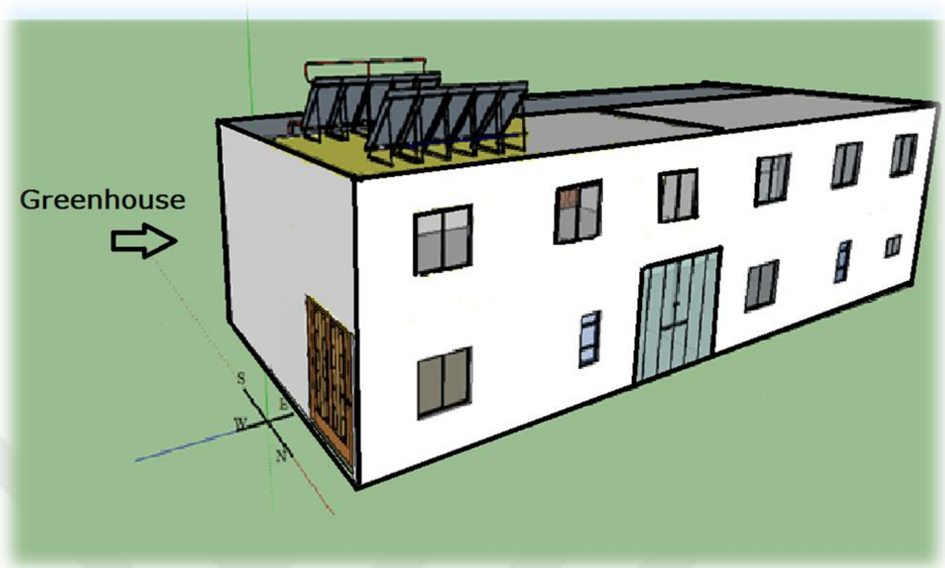


Figure 3.2: The design chosen by the flat plate collector building's designers

3.1.3 Solar Collector With Flat Plate

In Erbil research center building mounted on the roof 10 panels of FPSC positioned in two rows (five by five) parallel to each other , puted at angle 60 degrees to the horizontal, face to the south, (each $2m^2$ in area) and the rows are linked together with each other, and attached to the vertical as seen in the drawing (3.3). They use type the Wikosun 2020/Ti2340+ technologies, which have features as strong as well as quick as these by using effective copper. This collector is of a rigid, lightweight, robust and glass-reinforced aluminium construction, as well as is equipped with a rail and is wrapped across the rear wall with 40 mm of 40 microporous mineral wool ($70kg/m^3$). This pipelayer has a set of four 22 mm copper pipes that link to each other on one end by the parallel intake and outtake manifolds. The 3.2 mm protective glass covers the flat plate assembly. This collector operates at a maximum pressure of 10 bar and achieves a working temperature of 208 °C, thus maintaining a maximum efficiency from (80.2 to 93) percentage.

Figure 3.3: Using unglazed steel in photovoltaic solar collectors

3.1.4 Tanks For Storage

The two different configurations tanks used in this study, first type style WBO(1005 UNO), with a working pressure of 16 bar and a maximum temperature of 130 °C, as well as indirect tank storage as shows in Figure (3.4). Both tanks are packed with water, with a total of 1000 litters capacity and each has a separate heat exchanger, one lower and one at the top. It's a tank with a depth of 790 mm and a height of 2,000 mm, there is 100mm of insulation. There are 2 other plugs for heaters of electrical. The lower heat exchanger has a total surface area of 19.8 m^2 and can hold a lower quantity of liquid, whereas the higher one has a capacity of 13.3 m^2 and can hold an equal amount of liquid. This lowers the temperature in the upper part of the tank and serves as a heat exchanger between the two tanks.

Figure 3.4: Two tanks were used for the project

There are two additional connectors on the hot water-storage tanks. One is for hot water supply to Greenhouse and the second cold water reterun from Greenhouse. The storage tank using a temperature sensor at the top of the tank to mesure the storage tank temp. and this sensor connect with the control board. In addition, inspection flanges are located at the bottom of the S-tanks to avoid accumulation of sludge, Then these tanks also have a check-valve pressure to regulates the pressure inside these tanks as seen above in Fig. (3.4).

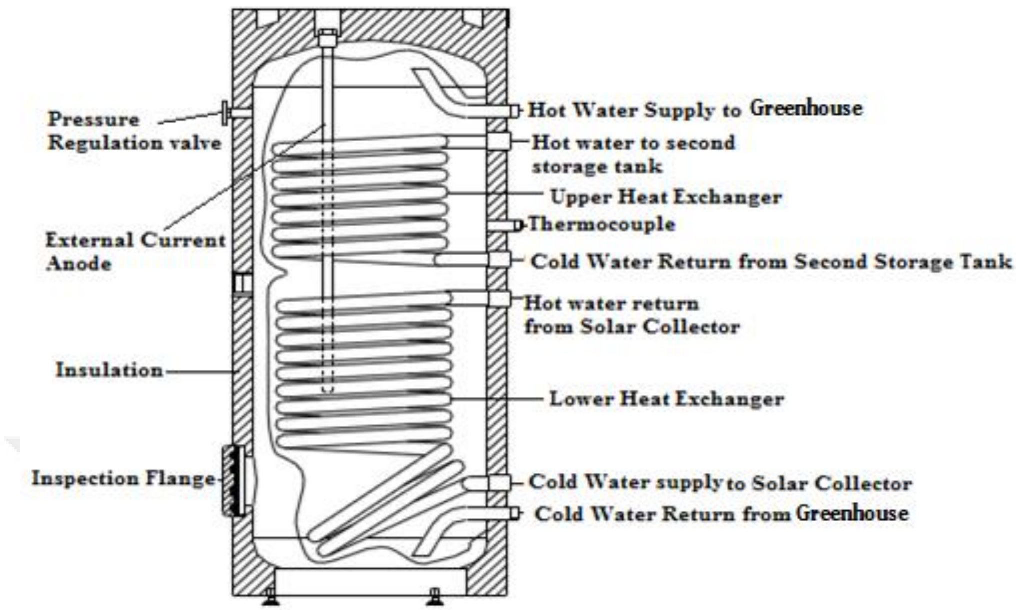


Figure 3.5: Side view of the reservoir

3.1.5 Water Softener For Home Usage

The softener water function is treated the water coming fron the source or from water flow wells. After treatment the water pumped to steel storage tanke and store the treated water here, mean which would be filtered before being used, and poured into the steel tank to be treated with water capacity of 1.3 m^3/hr. water softener removes the magnesium and calcium ions, and replaced of sodium ions.

Figure 3.6: Reverse osmosis system

3.1.6 System Of Piping

Used black steel pipe of 25.4 mm (1 inch) diameter, isolated with fiberglass was used in this method to keep the pipe warm. It was essential to secure the external pipes as well, since they were made of glass and sheathed in fiberglass to keep them free of the elements.

3.1.7 Vessel For Expansion

This illustrates a tank, which is connected to the solar water heating device in the third picture, (3.7). As the system pressure drops below the lowest, the pump's reservoir volume, water begins to flow into the tank. The water that is practical to use has been stockpiled. when the device pressure within the pressure chamber is at its highest, the centrifugal pump will switch will turn off The tank is almost complete. Returning water to the pressure pushes it further into the system. Water use efficiency has been measured and logged with a ZMET Hydro tank, with minimal start-up time required. Even, the expansion-vessel diameter is 380 mm, and 505 mm high, with volume 50 litters, also the max. operating P is10 bar.

Figure 3.7: Tubular ceramic-vessel

3.1.8 System of Pumping

These pumps are needed to maintain the water flowing in the SWHs. This system has 3 pumps: first pump between the 1st S-tank to the S-collectors, seconed pump between two storage tanks, and the last pump circulation the hot water from the S-tank to the GH, then cold water return to storage tank. The pumps have three speeds, as seen in the illustration, which are Low speed, medium speed, and fast speed as shows in Fig. (3.8).

Figure 3.8: Alternating water-pump

3.1.9 Measuring Flow

This graph represents the results of this analysis, it displays a flow meter. This flow sensor monitors the steady flow of hot water. The cable from the controller to the data monitor connects the two units together. Figure (3.14) shows the usage of four sensors, the first and second are set before the S-collectors, so third flow-sensor is placed after the S-tanks, and the last one is placed before the Greenhouse pipe. This sensor-type (QVE310), so its measures reliability is decrease than-2%.

Figure 3.9: Temperature flow-sensor

3.1.10 Sensor Of Temperature

Used 2 kinds of temp. sensors first (SIEMENS Type-QAP21.2 cable temperature sensor) investigation: Figure a (3.10) The cable is constructed of stainless steel and is tied to a nickel-plated pipe fitting on the outside wall. seconed type QAE26.9 this instrument is submerged in the liquid and measurements are obtained as the temperature of the liquid nears 25 degrees Celsius show in Figure b (3.10) Such a sensor is rendered with a stem inserted into a stainless steel tubing.

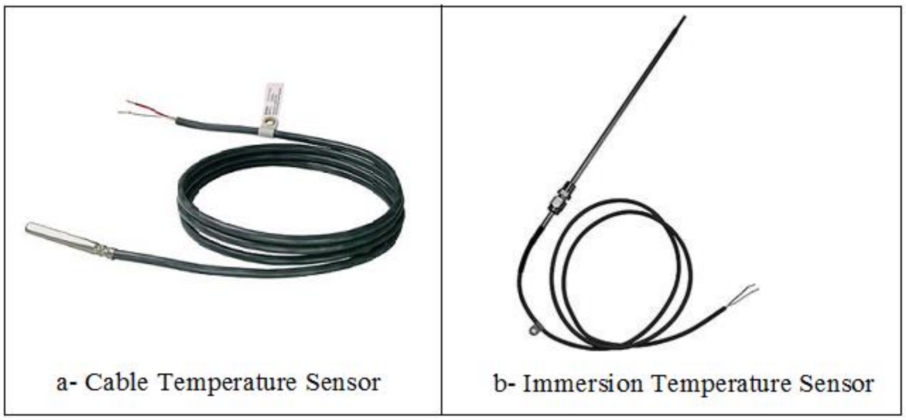


Figure 3.10: Capillary thermometers

3.1.11 Actuator Electrometric

Three-way valves are normally controlled by an electromechanical actuators. AC or DC is used to produce the appropriate amount of torque for any number of phases, depending on the application. The actuation system used was made by SIESMANNEL and is set to 13.6 mm/second, refer to "actuator speeds" (3.11).

Figure 3.11: Electrometric actuator

An actuator connect with three pipes: storage tanks, greenhouse pipe, and return pipe in the current design. If the actuator is set to position (0), it is considered "off". Conversely, if it is set to position (1), it is "on". If the room temperature rises above the desired level, the actuator can close the flow between the greenhouse supply and return pipes and begin delivering water to the Greenhouse again.

3.1.12 Sensor Of Pressure

SIEMENS Type QBE102-P10 is the pressure sensor, as shown in figure (3.12), mesure the pressure to control the system , The pressure sensor's measurement tolerance is ±0.4% of scale with 0% accuracy. Figure (3.14) has three pressure sensors used in advance of the solar collectors, the 1st before the storage tanks, the second part is between the S-tanks and the third part is used before the GH room.

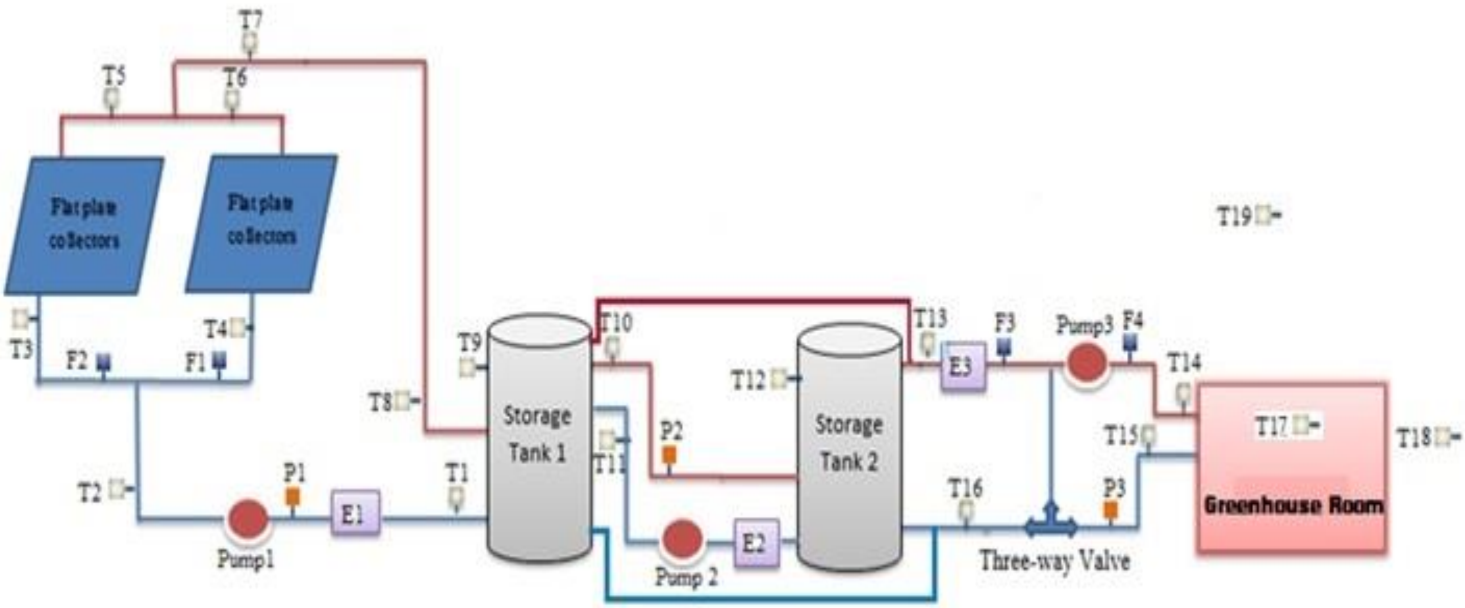
Figure 3.12: An air pressure-sensor

3.1.13 Electricity Meter

kilowatt-hour battery meter This research uses a Siemens UH65-series ultrasonic temperature and air conditioning energy-efficiency meter in the fig. (3.13). Three different kinds of meters are required; the 1st is placed between the S-collectors and the 1st S-tank, the seconed are used to measure their distance from the Greenhouse, and the third is situated between the two storage tanks

Figure 3.13: Cap acoustic power analysis

Diagram (3.14) illustrates all the devices in the framework with the flow meters and pressure sensors highlighted. Figure (3.15) displays all of the outputs of the software DESIGT, and figure (3.16) depicts the solar heating design.



T1 Storage tank1 outlet temperature
T2 Main Solar inlet temperature
T3 First row collector inlet temperature
T4 Second row collector inlet temperature
T5 First row collector outlet temperature
T6 Second row collector outlet temperature
T7 Main Solar outlet temperature
T8 Storage tank1 inlet temperature
T9 Storage tank1 temperature
T10 Storage tank2 inlet temperature
T11 Storage tank2 outlet temperature
T12 Storage tank2 temperature
T13 Storage tanks outlet temperature
T14 Room inlet temperature
T15 Room outlet temperature
T16 Storage tanks inlet temperature
T17 Room temperature
T18 Corridor temperature
T19 Ambient temperature
F1 First row solar water flowrate
F2 Second row solar water flowrate
F3 Storage tank water flowrate
F4 Room water flowrate
P1 Solar water pressure
P2 Storage tanks water pressure
P3 Room water pressure
E1 Solar energy meter
E2 Storage tank energy meter
E3 Room energy meter

Figure 3.14: Electronic diagram of a SWH circulatory function

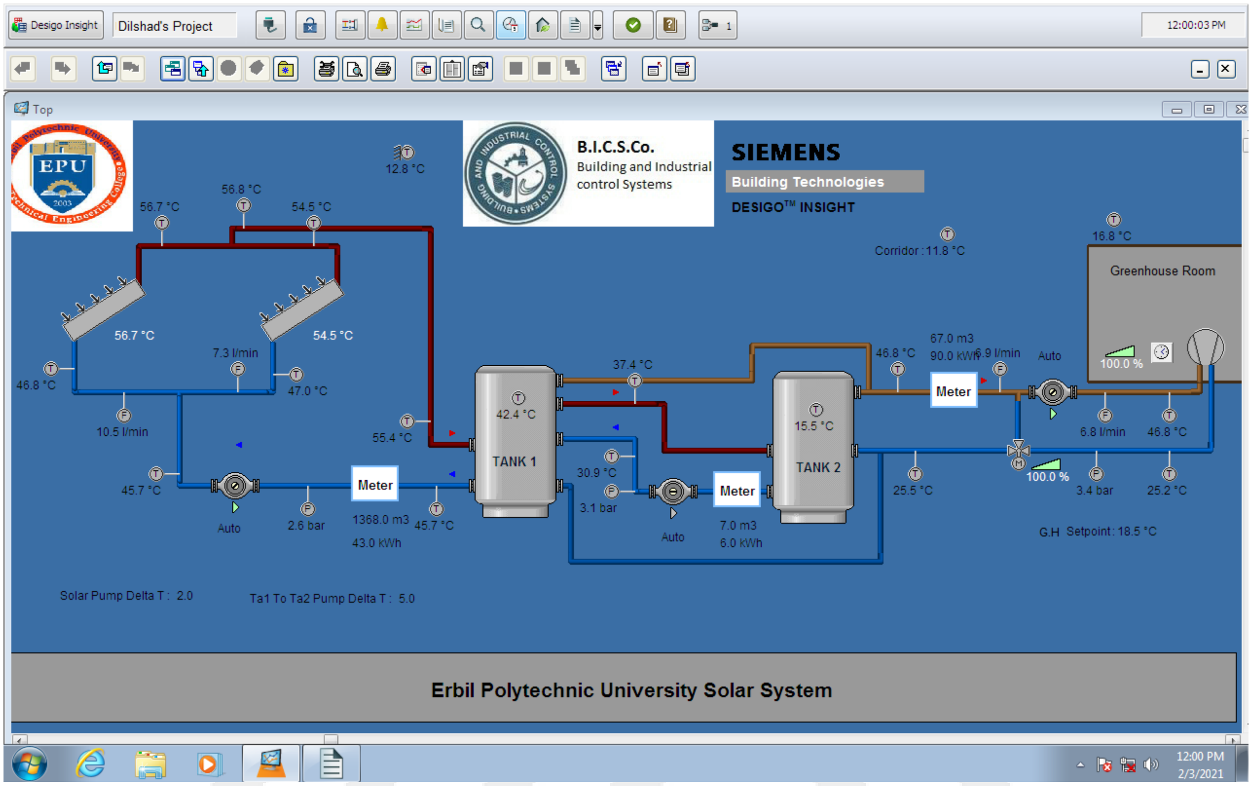


Figure 3.15: Photograph of the latest release of the product under development

3.1.14 Procedure For Experimentation

The first step in creating a solar water heater is to determine the heating demand for this building, the total heating requirement was 23.6 kW. Complete heating and cooling load was then was then applied, then flow rate was measured, resulting in the pipe diameter. He chose a pipe diameter of 25.4mm (1") and a length of 33m . At long last, the entire all was linked together in the following manner: Turn-on the softener residential water unit and then pumped, so let the steel-T fill when the treated water:

1- Make sure the device is completely saturated before the predetermined system pressure is reached.
2- To enable the safety-vented components to vent, open all the solar collectors, storage tanks, and supply piping as much as possible.
3- Before filling the system, we should make sure there is no air inside the piping in the system, and then cap all the protection valves.

4- Storing hot water in the first S-tank will prevent it from entering the Greenhouse.

And the circulation circuit such that the lower heat exchanger is kept moist (3.16). during the pumping phase, the heat in the S-tank will transfer from the solar absorber plate to the water inside the ST, which will be heated and returned to the lower heat exchanger. This is a self-reinventing device.

Once the water in the first storage tank is at 50°C, the pump between the two tanks will then activates, and heat from the first storage tank will then flows into the two storage tank, so the water in the two storage tank will be cooled, and then returns to the first storage tank for further heat exchange to take place. This is a self-per petrifying device.

Switch on the monitor and then open the software DESIGO 8 hours after the next to enable 8:00 a. Every single piece of data is attached to this machine, which appears every fifteen minutes in this application.

To go into the Greenhouse, the two tank temperatures must be greater than 50 degrees Celsius. Hot water flows from the two large storage tanks to the Greenhouse, via a system of pipes, to provide the heating needed for the Greenhouse. The heated water will be distributed underneath the space through the floor channels, while the pump draws cold air through the channels and expels the warmed air out into the outside world. If the space is being heated, the water in the storage tanks would rise and flow through the pipes to the cooling system.

At the set temperature of the air, the return-water valve in the Greenhouse will close and open the other to return the greenhouse water to the tanks, and until the room has dropped below that temperature, the return-water pump will re-operate.

However, this process operates only throughout the day and can take up to eight hours. In the Greenhouse, some sections shut down between the hours of four in the evening and early in the morning to maintain heat.

Wastewater can circulate naturally between the solar reservoir and the tank, from when the storage tank begins to finish as long as the storage temperature is constant.

1- For low- to moderate cloudiness, except where the water outflow from the solar panels is 2°C higher than the in the water inlets.
2- To stop water being frozen during the night and when the weather is under 4°C

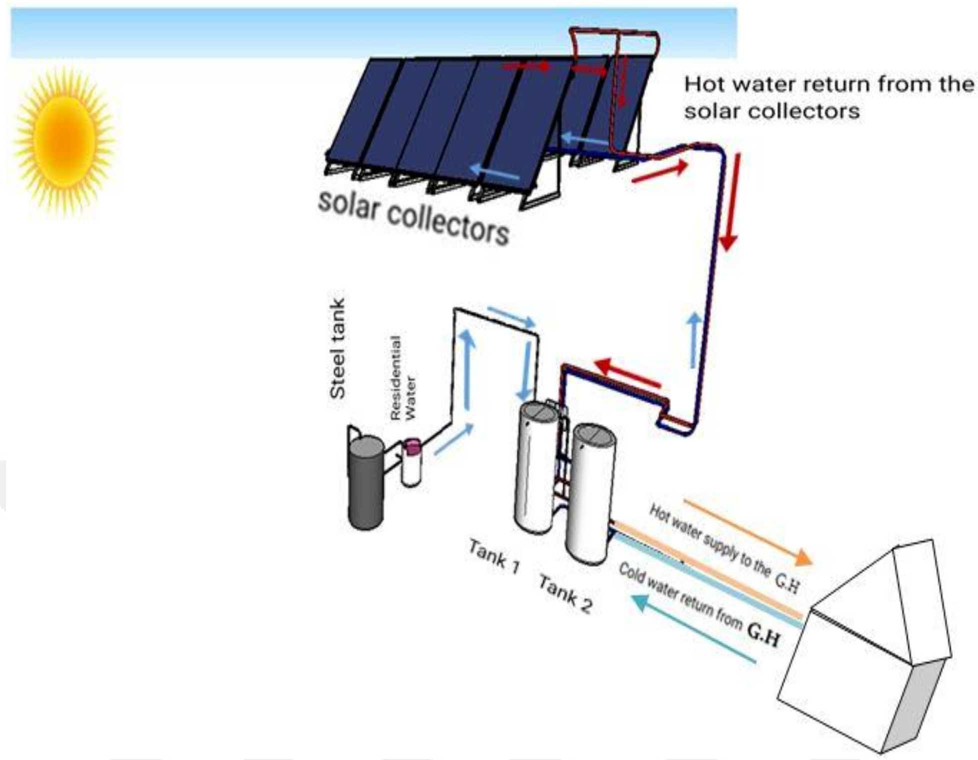


Figure 3.16: It has been created using the Schematic of a solar heating device, which operates at 1:1 size.

3.2 SIMULATION OF TRNSYS

3.2.1 Overall

The TRNSYS was created using the pseudo-steady state program. Modeling with TRNSYS permits the system elements to be interconnected in whatever way the system configuration. as estimated that incorporates a mathematical model for each device part, the analysis concludes that TRNSYS is a short-duration modular simulation software with a variable structure [31].

3.2.2 Program For TRNSYS Simulation

Complex thermal structures can be modeled using the TRNSYS simulator. Each aspect is scrutinized separately. generic factor is characterized using a simulation-dependent model: TRNSYS “TYPE” describes a series of simulation-dependent variables and parameters. This behaviour changes over time, which is how the transient issues are dealt with in this scheme. The following parts discuss the TRNSYS model, as well as other factor models that have been applied to examine the current city's results.

The TRNSYS 16 model illustrates the device operation as seen in Figure (3.17). This model consists of TMY2 reader Type 15 with a Type 56 reader for local weather and room length of dimensions 5.20 by 4.90 by 3.25 by mounted. This flat collector is oriented to the solar cell collector that is mounted at a 60° angle to the south, and attached to the rest of the solar panel Type-B. This SC is linked to the water tank Type-534, which is 2-meter-tall and has 2 inner heat exchangers with a volume of 1000L, so the pumps uses a single speed differential thermostat Type 115. When the solar water tank water outlet is elevated to 2°, the differential thermostats switches on the pump, however if the tank temperature drops below this level, the differential thermostats turns it off. Due to this section of the machine being exposed to the light, the water becomes hot and then heats the tank.

A Type 114-3 hot water pump serves to pump water from the reservoir to the Greenhouse type tank Type 56. the thermost Type 108 thermometer is connected to a heating/cooling schedule which measures the room temperature every hour When the room temperature is below 22°C, the Flowrate switch opens the loops; if it rises above this level, the LineSwitches are shut down at 4:00 p. A thermost equation, called Equa, Is responsible for supplying a signal to two elements, one of which is a Type 108, the other a Type 517 To use thermostat when the Type 514 is not accessible, an electrical heater is needed. a psychometric map brings in dry-in-heating and relative humidity to calculate room heat load form Type 33. Additional features include the ability to display the device output as graphs, as well as the plotters, plus reports may be output as either as curves or data files in a variety of formats.

There can find the TRYS software details and implementation procedures below:

1- Also in the diagram figure (3.18), the first step is to pump cold water from the storage tank up to the heat exchanger. The water would be heated in the heat exchanger, and then the heated again to return to the storage tank.

2- When the stored water warms up, it will pass into the heat exchanger, and after that the water in the collectors has been drained, it will be circulated back to the storage tank.

3- If the water within the tank gets to 50 degrees, the hot, so the hot water in the Greenhouse will be circulated through the Heat Exchanger, and it will be made much hotter. The water in the holding tank would gradually returns to its former temperature.

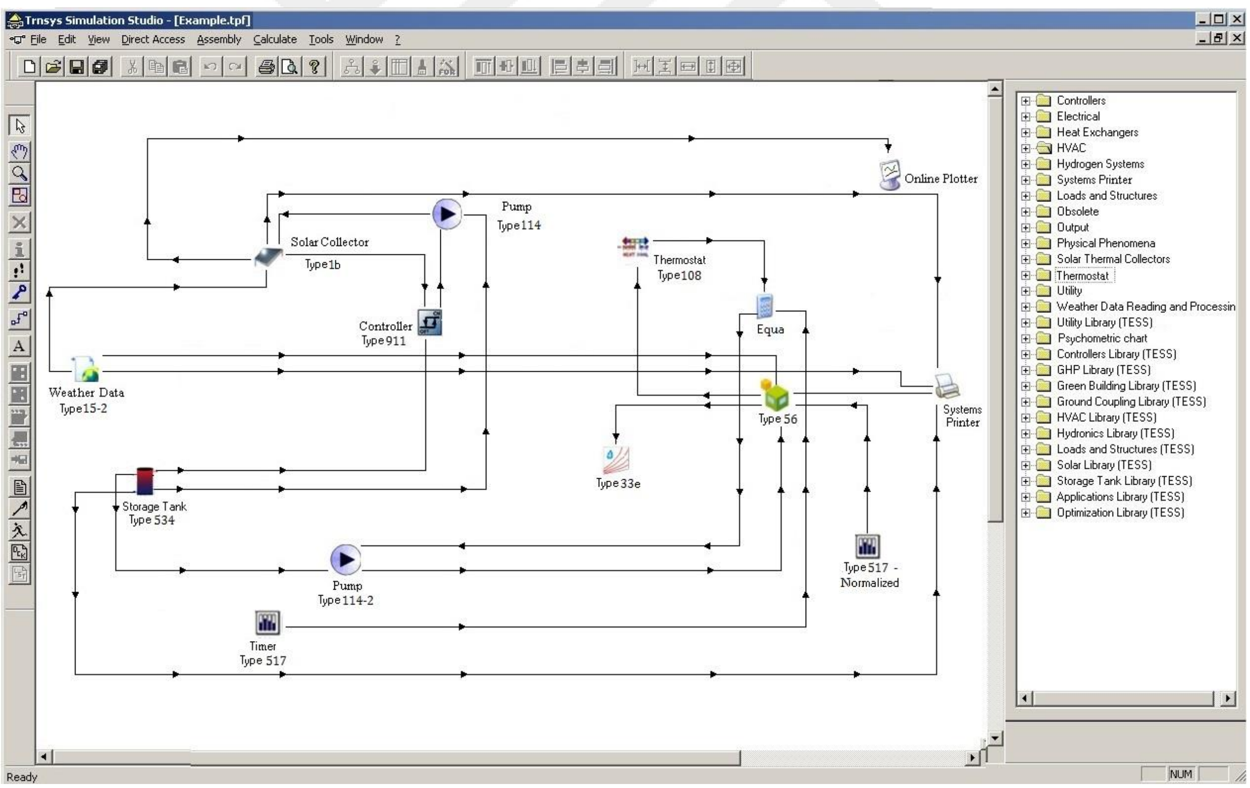


Figure 3.17: TRNSYS model schematic diagram used to simulate solar heating systems

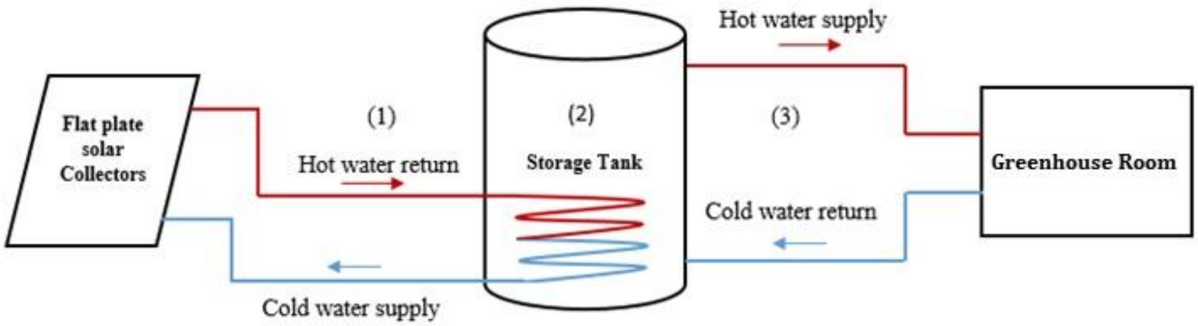


Figure 3.18: An innovative heating and cooling method developed by this TRNS is using solar water heat.

3.2.3 Model For Verification:

Many colleges, schools, as well as academic institutes, have been built in the city of Erbil, the buildings are in use from 8:00 a.m to 16:00 p.m during the winter season months, so they require more of heat. Then the electricity is not supplied in Erbil city for 24 hours a day, due to of the cold weathers, so they use diesel or electric heaters. Electricity generates revenue, and produces air pollution and while burnt will produced the CO_2, nitrogen oxide, sulfur dioxide, and so on.

A solar water heating device is commonly recommended as the simplest way to get around these issues because it reduces electricity use and prices, while being environment-friendly.

Verification must be performed after the experimental system has been completed and experimental data has been obtained. The validation is achieved using the TRNS model, which examines experimental data via simulation TRNS, and the effects of the analysis.

The simulated results are contrasted with TRNS, and the results are seen to be nearly identical in Figure (3.19). This graph illustrates the experimental and forecast collector water temperature from January 2021 compared to that of January 2011.

Some data gathered by the machine and the TRNS software are presented in the Table (1.1) and second Table (1.2).

3.2.4 TRNSYS Program Results

All of the program's findings are remarkably similar to those previously found. In this way, the solar water heating device is subjected to five seasons of trial (laboratory testing) over a 30-minute cycle every day. This year was hectic" (October, November December, January, February).

The typical solar thermal system temperature change for October, November, December, January, and February are shows in fig. (3.20) and (3.24) respectively. depicted as 3 degrees above, and 3 degrees above normal At sunrise and sunset, the minimum temperature differential is minimal, and the highest occurs at solar midday, while at solar radiation is the average.

Figure (3.25) is for the average of October, November, December, and January. The mean water temperature observed was (102.4 °C) ,(102.4 °C), (96.3 °C), (80.9 °C), (89.4 °C), and (77.8 °C), respectively, and the lowest value for the times of day is in the morning and evening. It may be deduced from these findings that the room load temperatures are satisfactory for all seasons of the year can be met from these water exit temperatures.

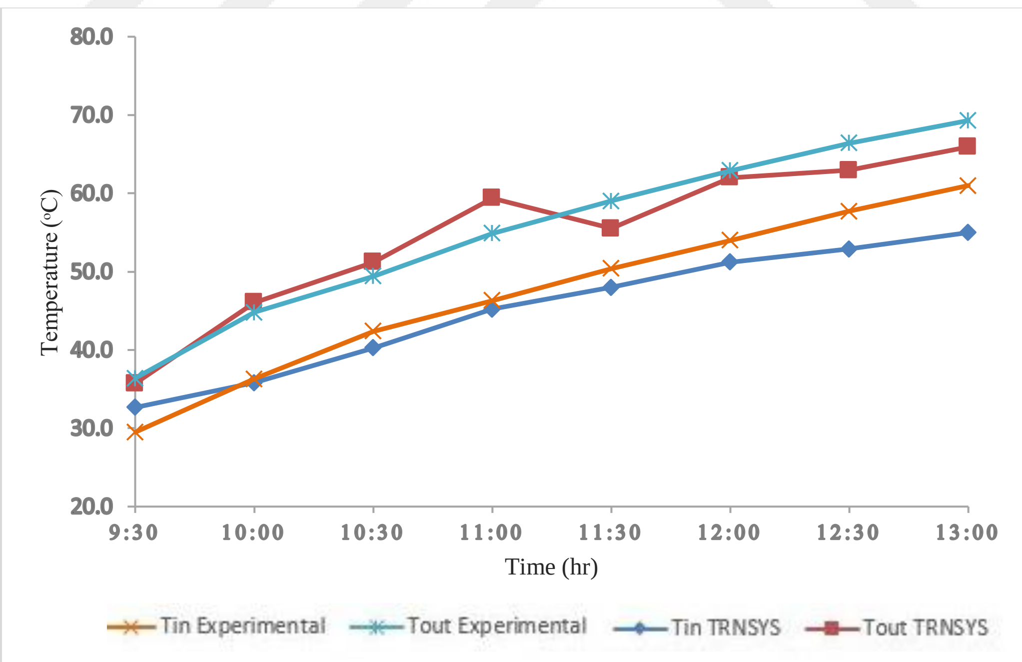


Figure 3.19: Temperature of the proposed solar system and the actual inlet and necessary water flow in January- 2021

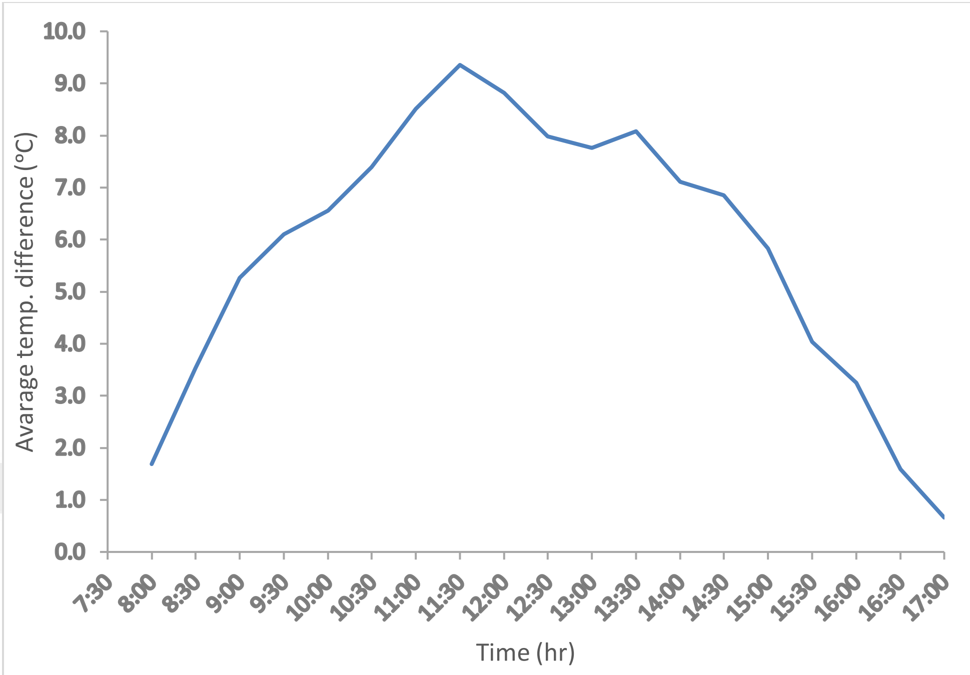


Figure 3.20: In October 2020, average solar energy gap

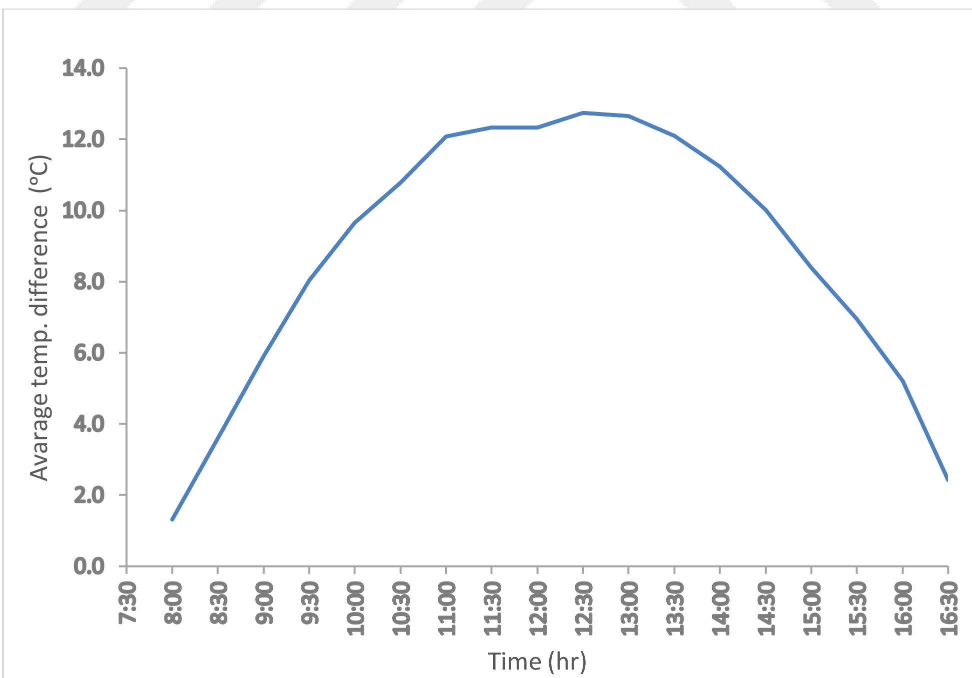


Figure 3.21: The approximate variation in the temperature between the solar collector in November 2020 and November of this year

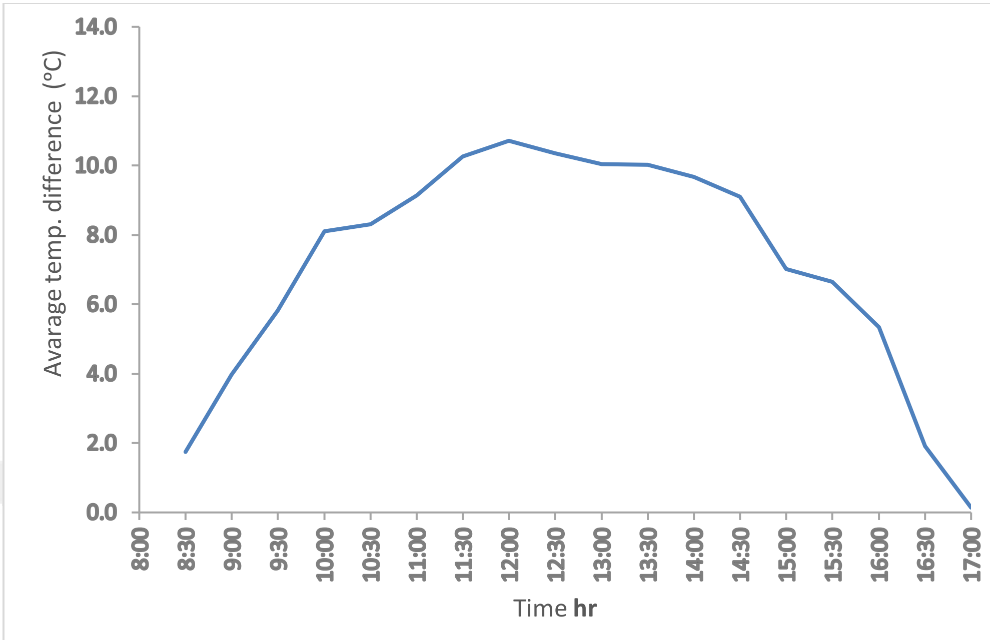


Figure 3.22: In December 2020, the average temperature difference between solar collectors

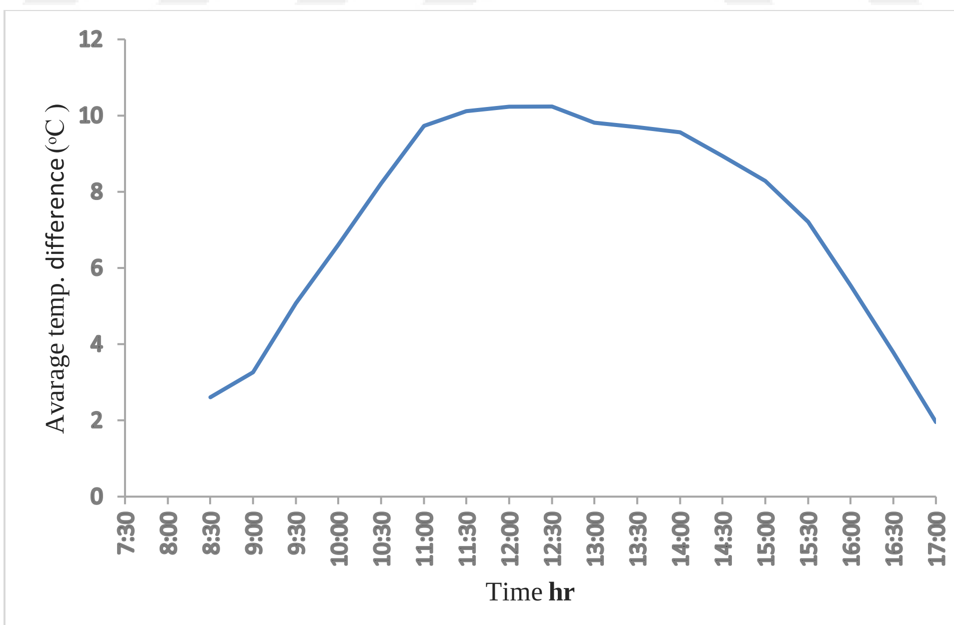


Figure 3.23: In January- 2021, the solar collector's average temperature differential

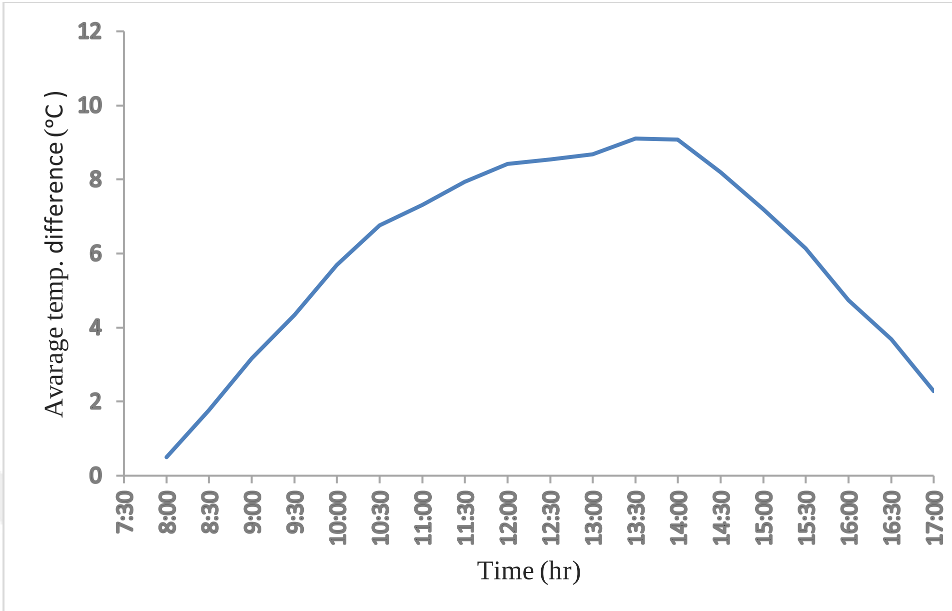


Figure 3.24: In February-2021, Solar collector temperature differential

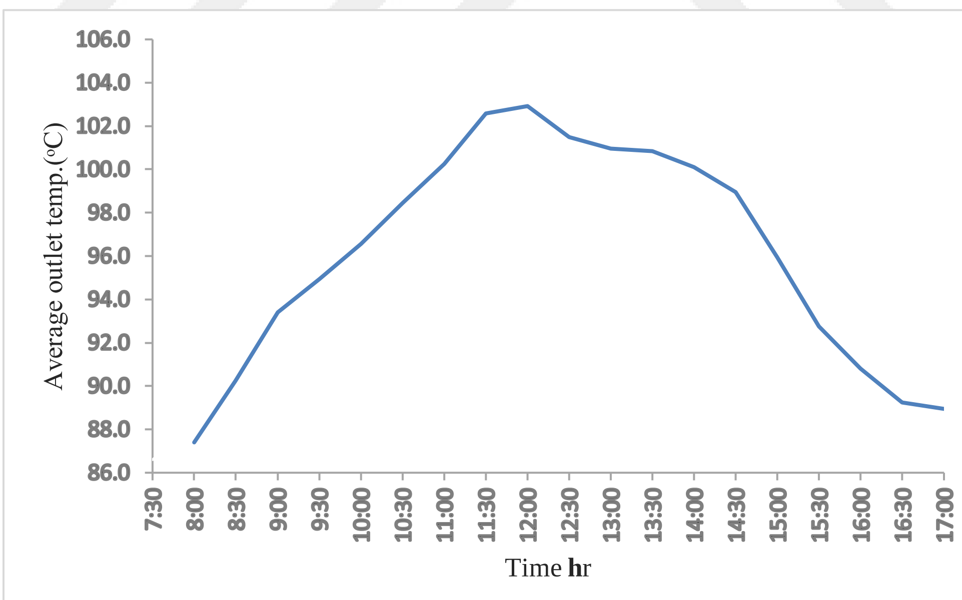


Figure 3.25: In October 2020, Average temperature of solar collector's outlet water

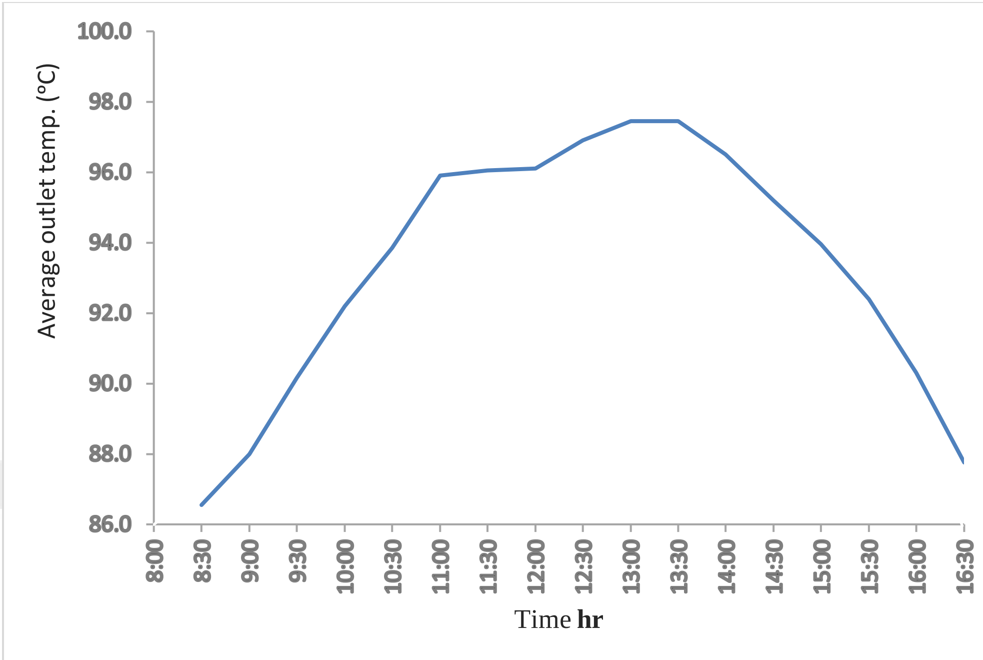


Figure 3.26: In November- 2020, Average temperature of the solar collector's outlet water

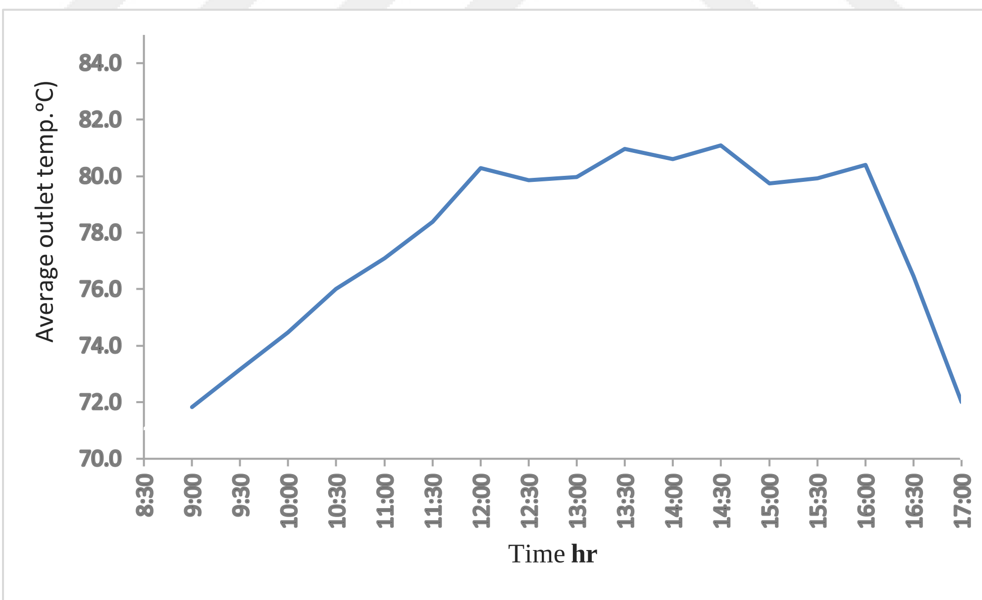


Figure 3.27: In December- 2020, Average temperature of the solar collector's outlet water

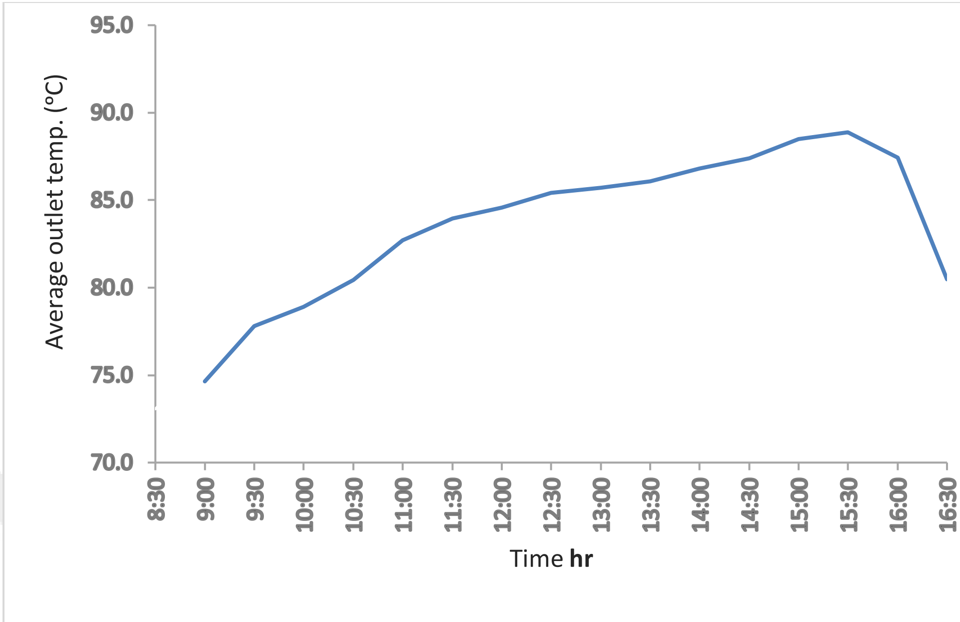


Figure 3.28: In January- 2021 Average temperature of solar collector's outlet water

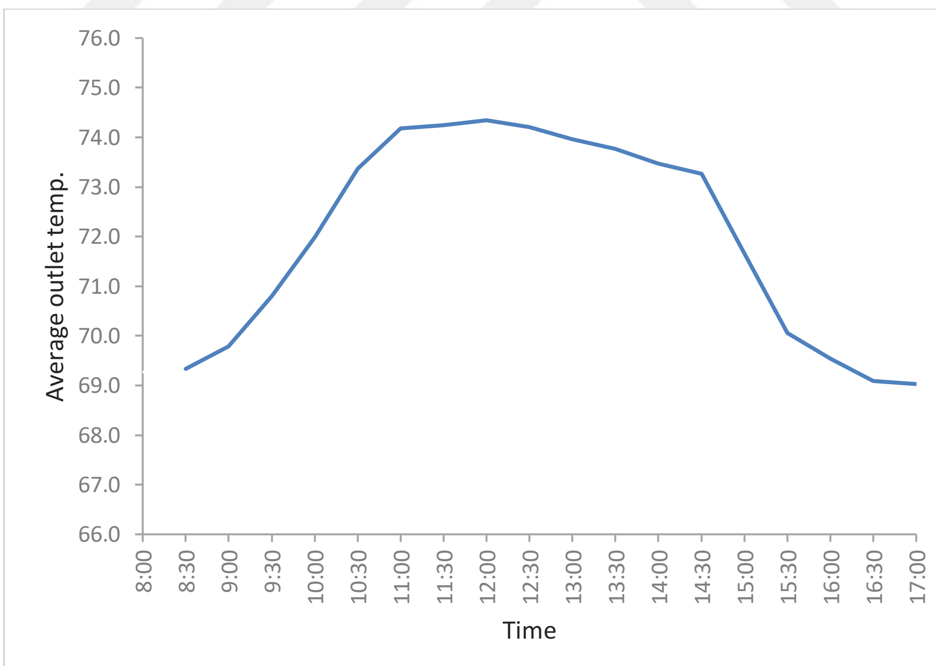


Figure 3.29: In February- 2021, Average temperature of solar collector's outlet water

Table 1.1: In 1th of February- 2021 estimate Experimental data

Time	Inlet temp in Storage Tank1	Outlet temp in Storage Tnk1	Inlet temp in Solar	Outlet temp in Solar	Water flow Rate in Solar
09:30	33	28.1	28.4	37	15.3
10:00	42.4	35.5	35.5	45.7	15.3
10:30	47.4	39.5	35.5	45.7	15.3
11:00	50.0	41.8	45.8	54.6	15.2
11:30	51.3	43	47.3	58.7	15.2
12:00	53.1	44.1	53	62.5	15.2
12:30	53.1	45	56	66.1	15.2
13:00	55.4	47.2	60	68.4	15.3

Table 1.2: In 1th of January- 2021 estimate data by TRNSYS program'

Time	Inlet Temp in Solar	Outlet Temp in Solar	water Flow rate in Solar	Room heating load
09:30	32.9	35.8	918	19457.0
10:00	36.8	46.4	918	19269.3
10:30	38.5	50	918	19239.3
11:00	45.2	59.4	918	18862.0
11:30	47.1	53	918	18872.0
12:00	49.4	60	918	18459.0
12:30	51.2	62	918	17695.4
13:00	55	65.6	918	17685.4

4. DISCUSSION AND RESULTS

Solar water heating would have an energy-saving solution, thus reducing the amount of kerosene and diesel, emissions of CO_2. the estimate of 17% for global horizontal radiation for seventeen cities in the world during the last ten years and a seventeen year span in Erbil and that location's intermediate monthly percentage is shown in figure (4.1). The figure shows that even in winter season, then Erbil has a good solar radiation domain from 250 W/m2 to 540 W/m2, in the horizontal surface area [32].These three diagrams (4.2) ,(3) and (4) results our experimental of the ST temp. composed by the system and (Ta) for bellow months in 28th of January-2021, 1th of February-2021, and 4th of February-2021, respectively. for 1st of February data are as follows: The storage tank's temperature reached 52°C for day 2 of use on the 28th of January (and this was above the temperature of hot water which was stored at this time at 5°C with a higher solar irradiation), because it is easier to heat the room to a lower temperature the next morning (early in the day than the late at noon with high radiation levels and high temperatures). for the 1st of February and the 4th since the atmospheric temperature and sunlight are higher than on January 28, the tank water would also rise. The average temperature of 1st February is 13.5°C, and the highest for the month of the year is only prior to the 4th of the year, with the water stored in the tanks at 55.4°C, Figures (4.5), (6), and (7) represent the room's heating and solar load expected for 28th of January, 1st, and 4th of February. The coldest night of the experiment, for minimum temperature of 3 degrees Celsius as the machine's starting time was at 5 p.m. throughout the evening, and the room maintains the same temperature during the day, the device is operating at the full load at 8 a.m. As the sun is at its lowest at the time of the day, the heating load from the collectors is their height. In the graph, the results demonstrate that solar water heating device would be able to provide at least 7 hours of heating for a water volume that has previously been 8 hours exposed to the ambient air in the sunlight. See Figure (4.6): On the first of February, the room's would shut off after eight degrees of heat to help us save energy at 3:00 p.m. The machine demonstrates that the capability of dealing with the heat from 7 hours of sunlight and around 10kJ of solar collector load at any given time. When the solar heating device is operational, the appliance will provide all the necessary water with just air at temperatures of around 14°C ,Fig. (4.8) and (4.9) shown the values provided here represent the estimated heating loads for our room from 9:00 a.m to 4:00 p.m for the winter season based on TRNSYS software, Figure (4.10) illustrates the amount of solar heat obtained, room heating, and additional heat that is required to match it. the findings suggest that there is no need for a heat pump unless it is in certain months, except for in the beginning towards the end of the year. But for the three months December, January, and February above-mentioned needed to using the keros heater with a rate of (8% , 14% and 14%) of heating loads for our room required, respectively.Then effect of using the SC on volume of kerose used to ride the heating loads for our room required as shows in fig. (4.11) illustrates the relationship between annual production and use of kerosene , In January heating loads about (195 litters) would be needed, but on an annual basis it will be reduced to that amount (27 litters). Mean just 14% of the loading room heating must be recovered through using kerose heaters.Without the aid of the solar water system, the ton of CO_2 is represented by burning fuel; here's how much it will be by utilizing it. According to this model, when the solar water heating method is implemented, CO_2 emissions would decrease. applying the solar-heating machine, compared to just 72.4 kg of carbon dioxide in state 1058.4 kg of carbon dioxide in the space produces 93% CO_2 savings for the household The net percentage of carbon dioxide emissions will decline to zero over the next four months, and then stabilize. One an experimental analysis of the current values with those of Bolaji and Abiala 2012 is included in this figure (4.13). There are positive outcomes, which suggests that the mean water temperature is proportional to atmospheric temperature. It got much more energy in the morning but considerably less in the afternoons while the solar radiation was minimal. Then when compeare the max. water temp. and max. Ta in our present work are (72.8°C) and (18.8°C), respectively, however when compear that with Bolaji and Abiala Auther in 2012 ,are (83.5°C) and (34.5°C), respectively been mentioned in source [21].

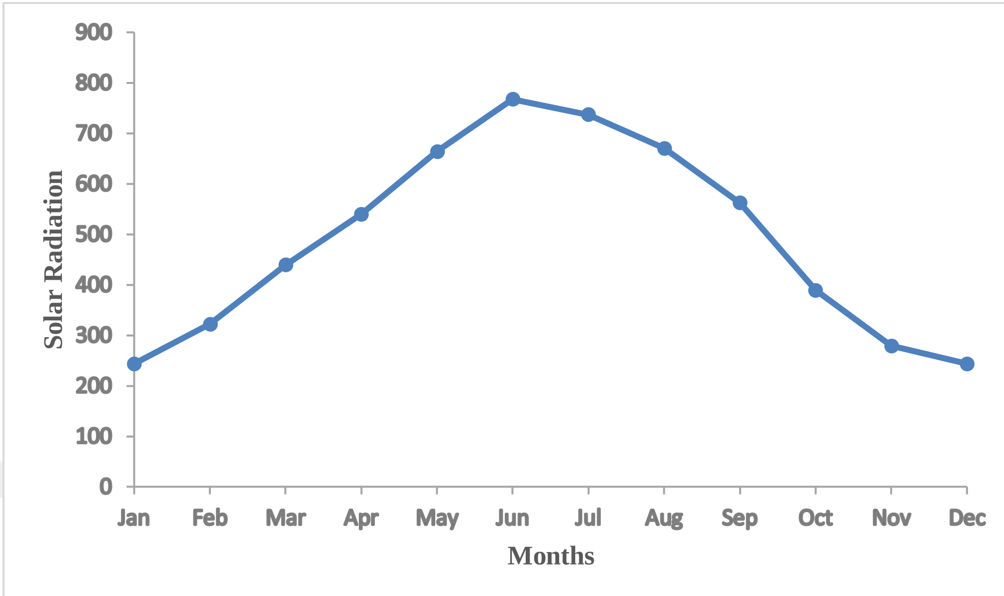


Figure 4.1: Average monthly solar radiation

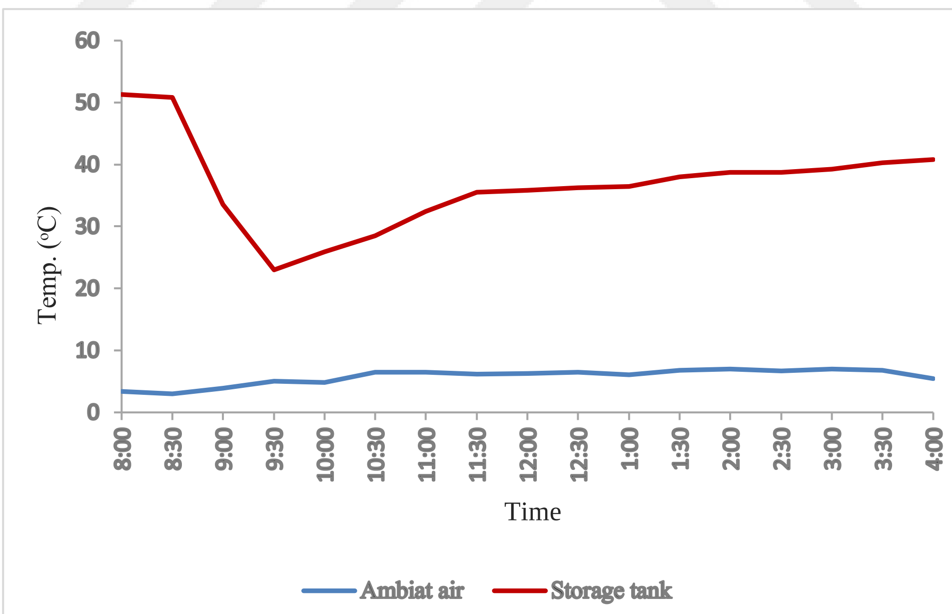


Figure 4.2: In 27th of January- 2021, estimate ambient tank temperature

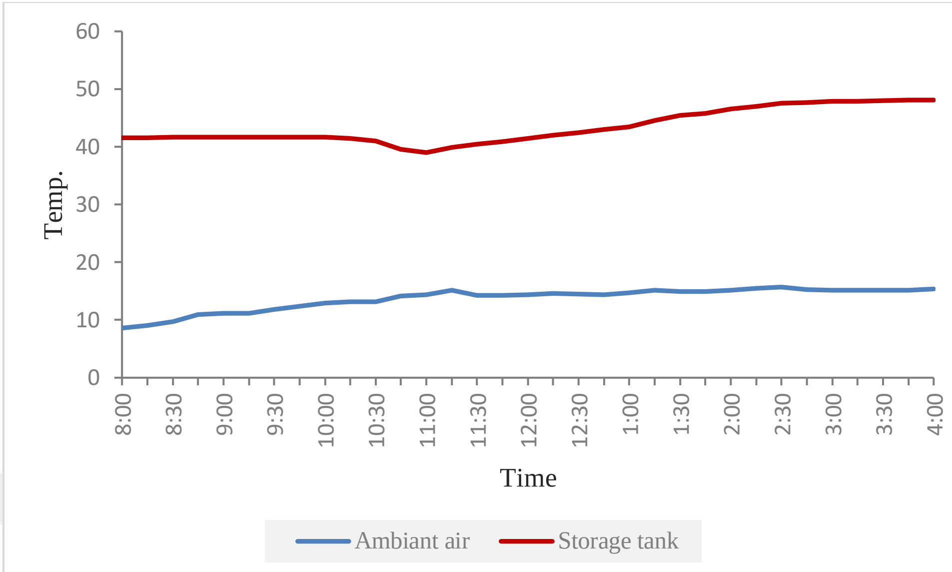


Figure 4.3: In 1st of February- 2021, estimate ambient tank temperature

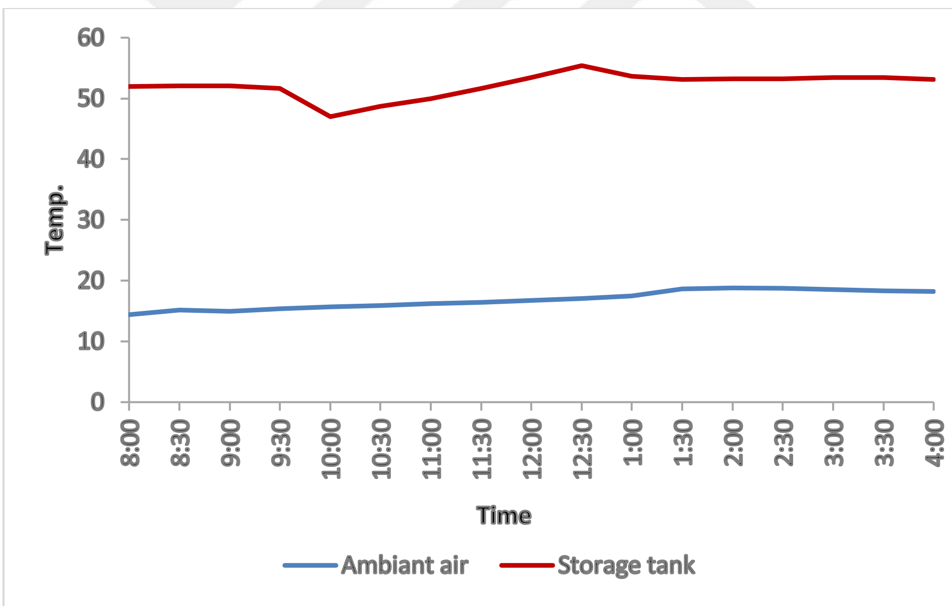


Figure 4.4: In 4th of February- 2021, estimate ambient air and storage tank temperature

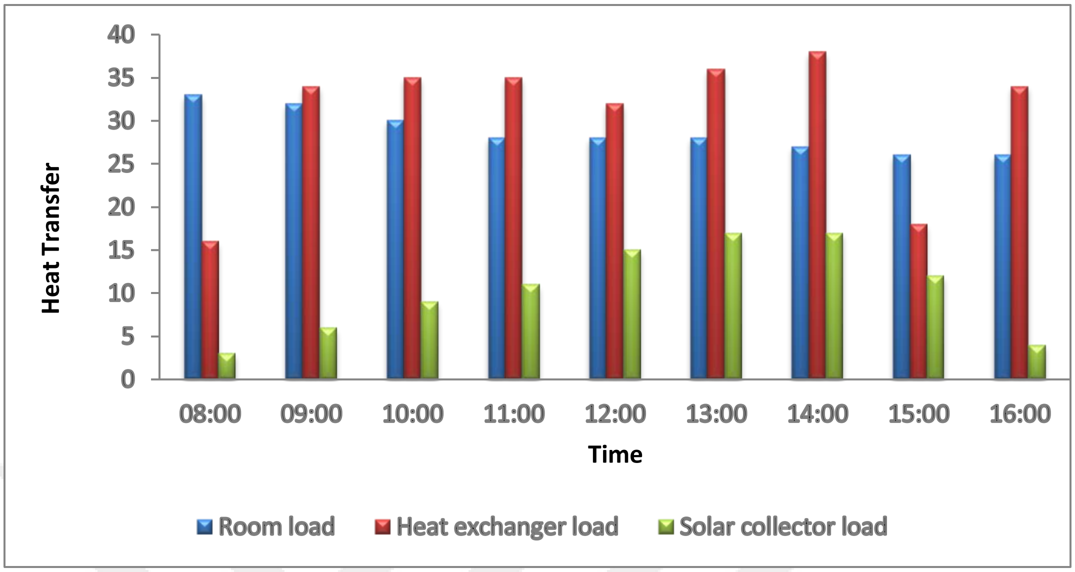


Figure 4.5: In 28th of January- 2021, estimate the heating loads (room, heat exchanger and solar collector)

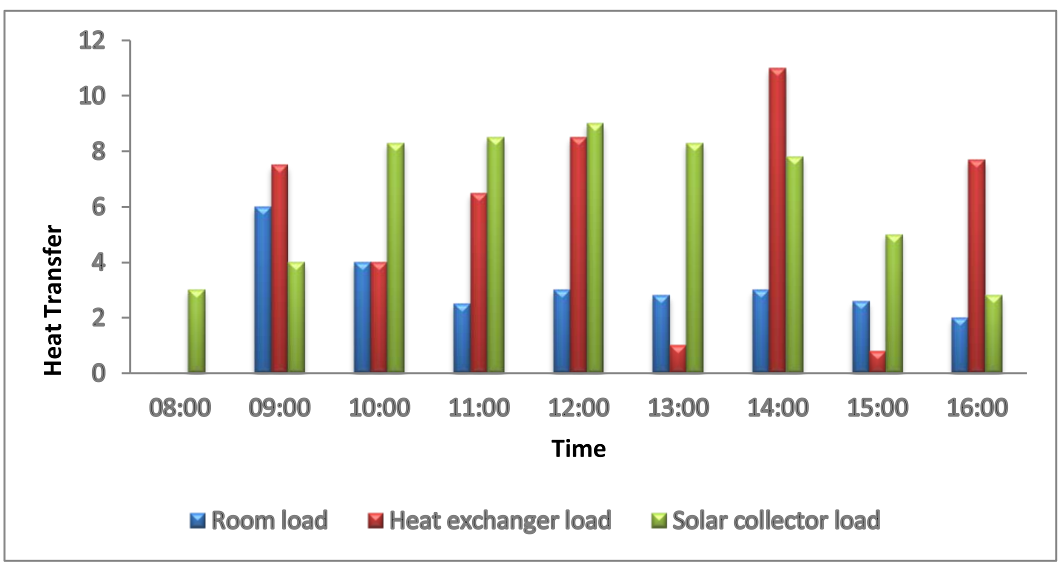


Figure 4.6: In 1th of February- 2021, Measure the total heating capacity, heating load, and solar collector load

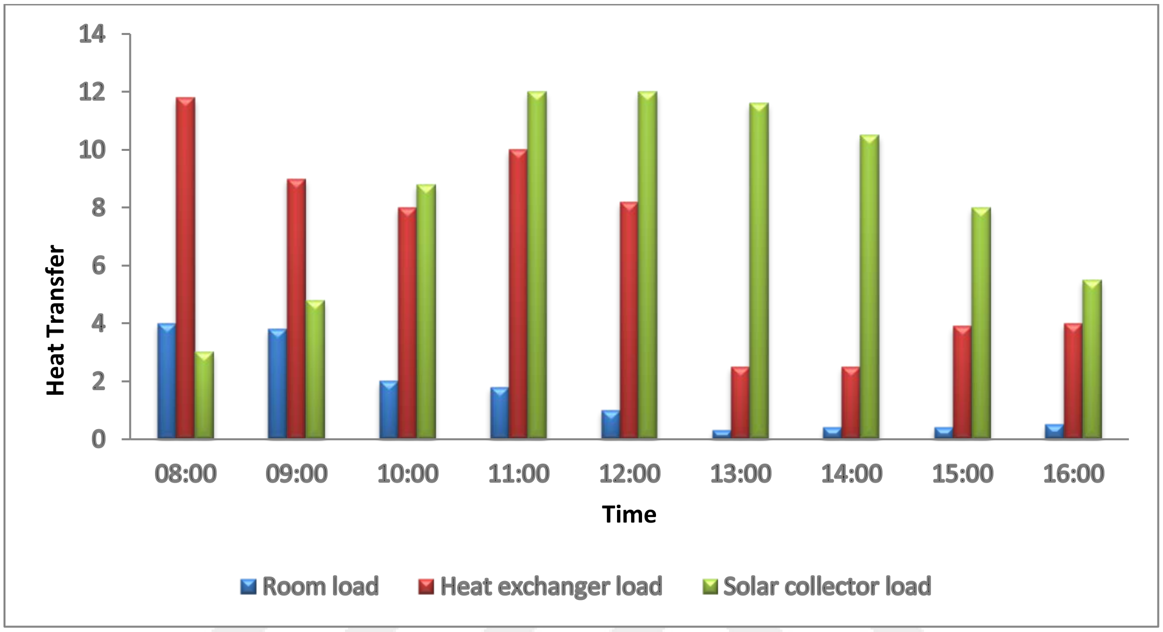


Figure 4.7: In 4th of February- 2021, Determine of loads for (room, Heat Exchanger, and Solar Collector)

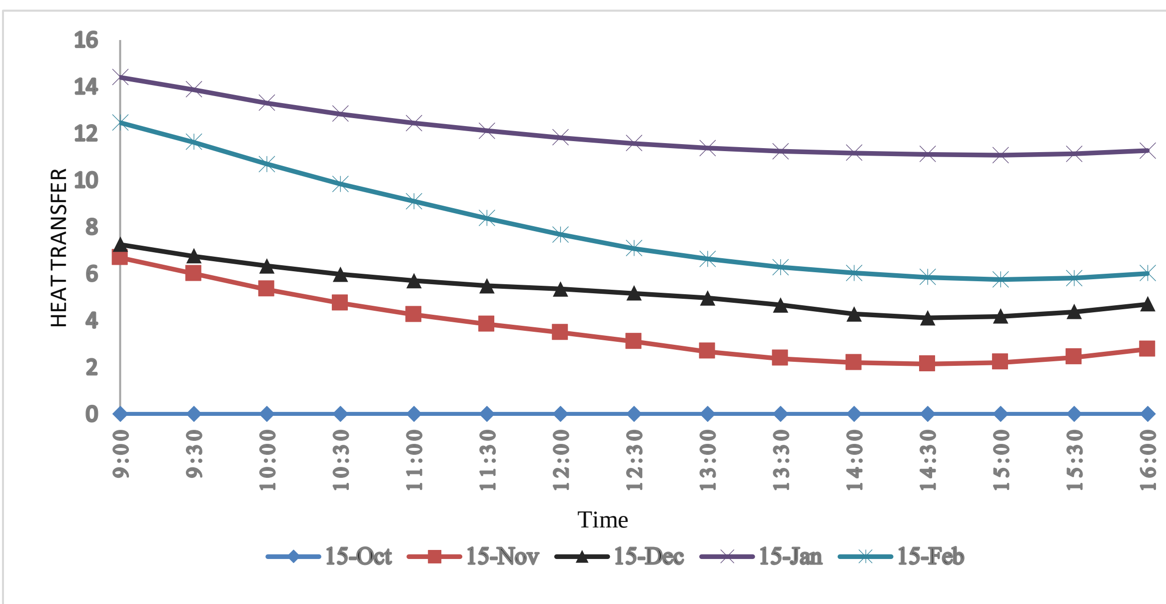


Figure 4.8: Calculation of the theoretical room heating load

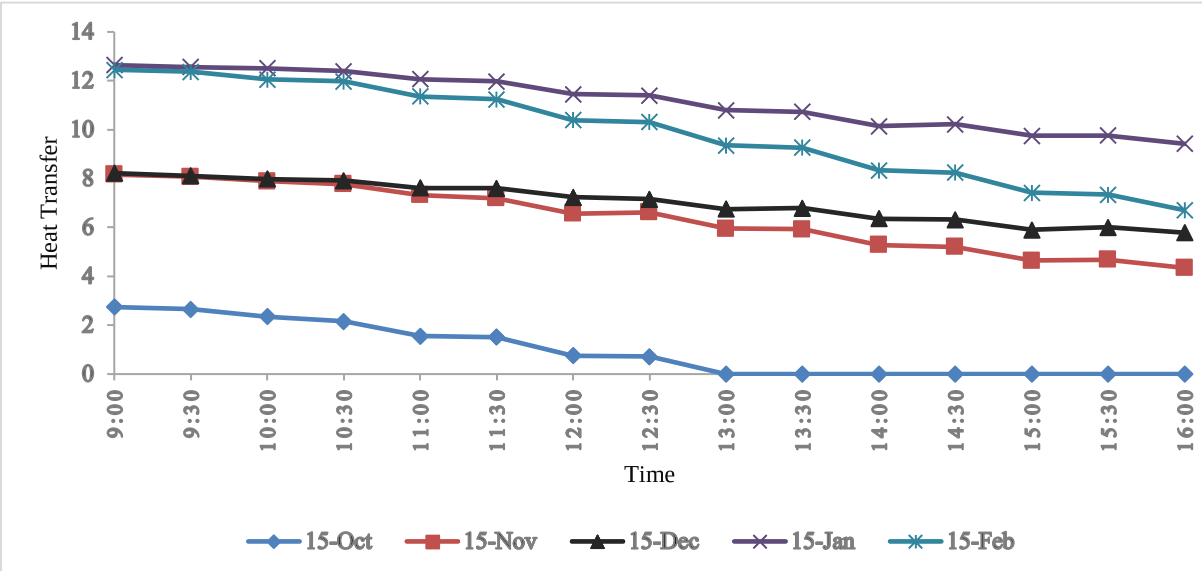


Figure 4.9: TRNSYS was used to simulate the heating load in a building.

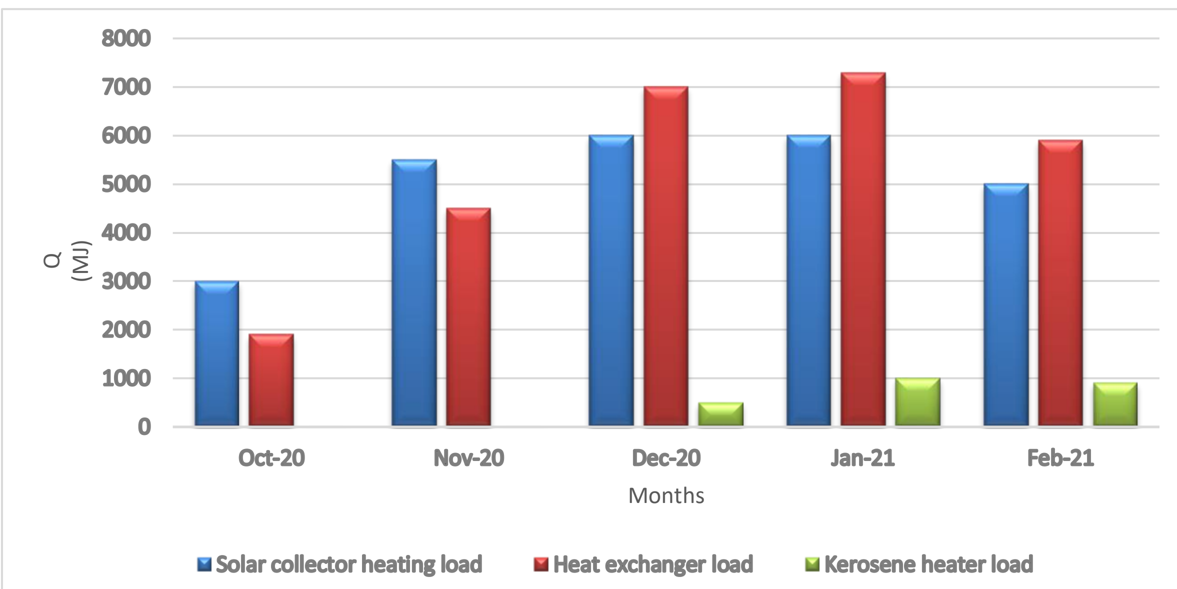


Figure 4.10: For five months' estimate amount of heat by heaters to recover the room's heating load

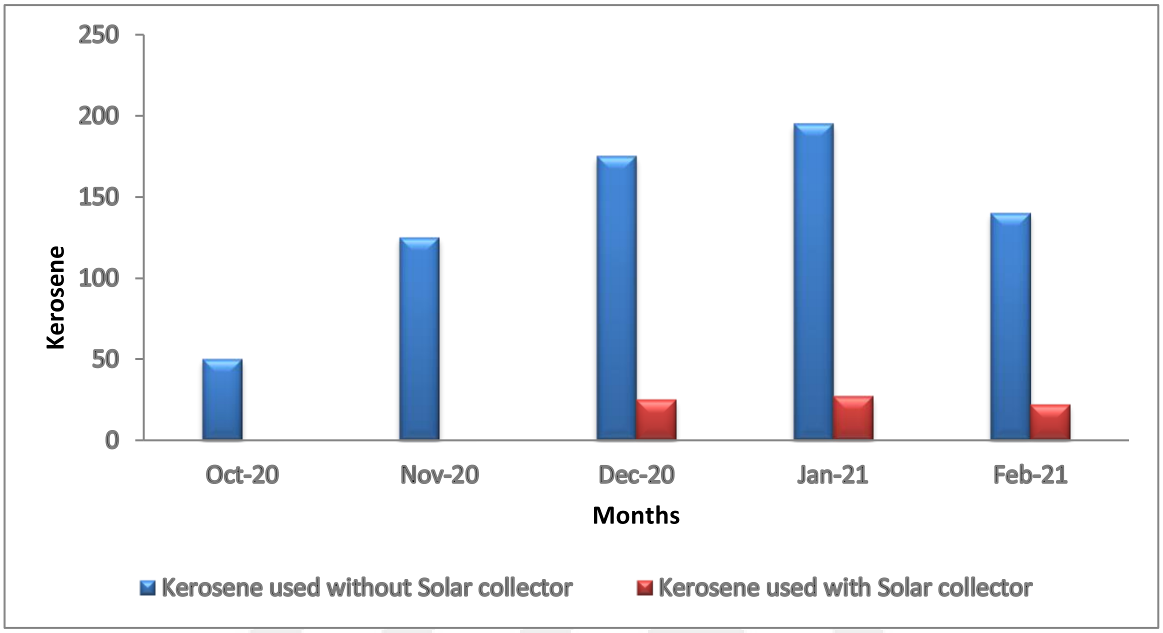


Figure 4.11: Kerosene litters used for five months with and with-out the solar collector

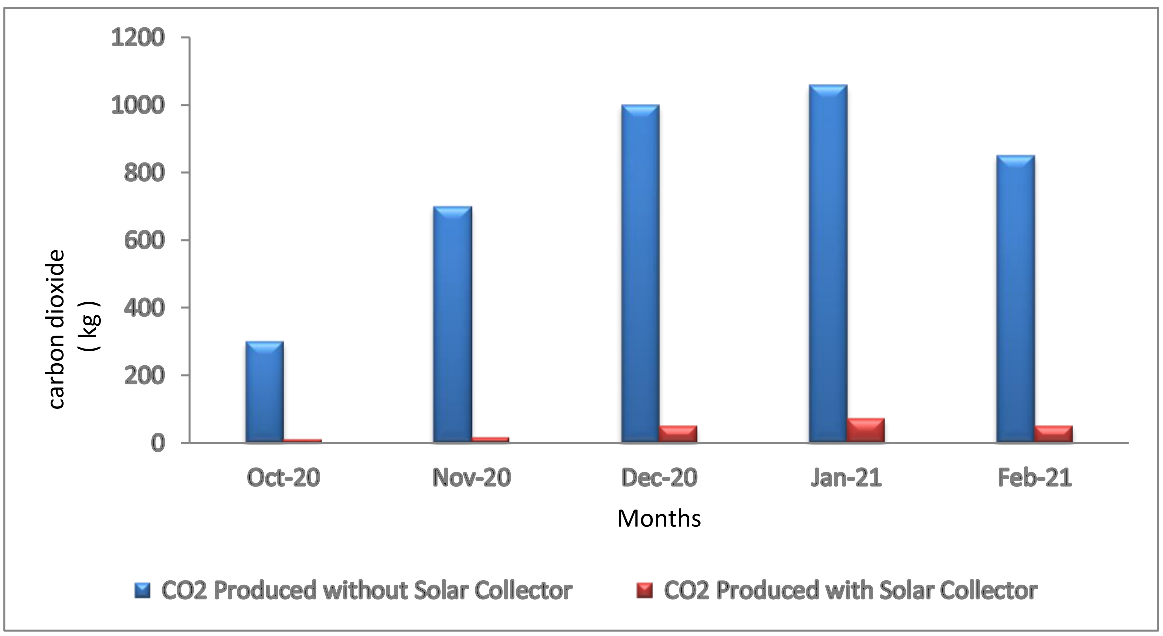


Figure 4.12: CO_2 emissions per kg for five months with and with-out the solar collector

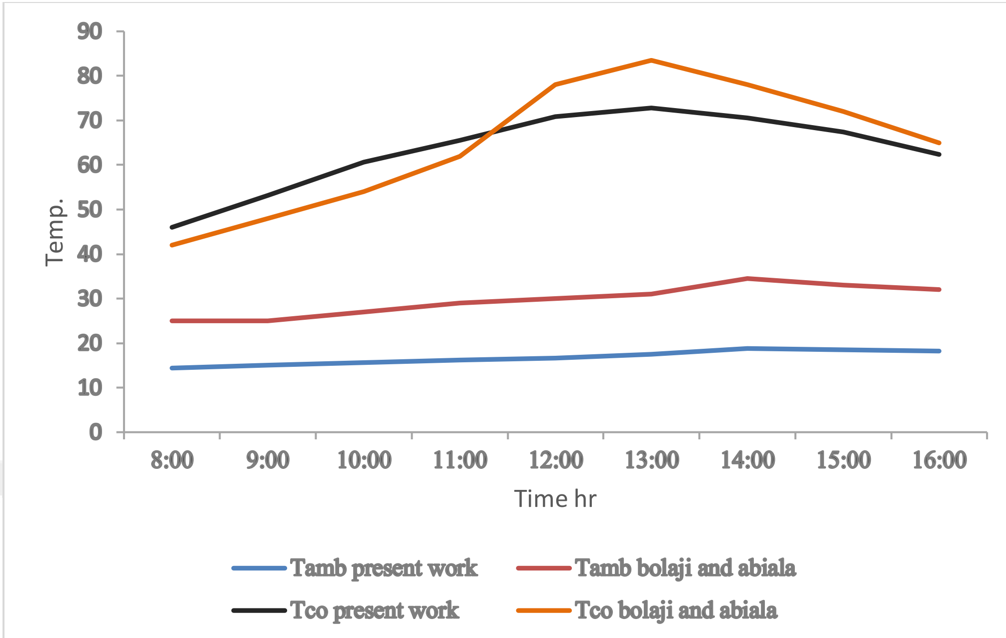


Figure 4.13: The current paper by Bolaji and Abiala compares our current study to that by Bolam in 2012 [21]

5. CONCLUSIONS AND SUGGESTIONS

5.1 CONCLUSION

A wide variety of different experimental research, as well as a few computer simulations, were performed on the heating load in Erbil to yield the following conclusions;

1. These flat plate collectors will operate in solar heating systems in Erbil on the hottest clear day of the year in the country (50.7°C).
2. It proved to be effective in bringing together experimental and simulation data.
3. Assumes that from 9:00 a.m to 5:00 p.m Erbil's has just about 92% of the electricity throughout the one month for December, so it includes the power demand for 92.4%, 86.4%, and 86% of December, January, and February.
4. Experimental evidence shows that for least cloudy and coldest weather (3°C) shows that the device will heat water to cover 8 hours of a working day
5. It has been shown that this device has cut down the amount of CO_2 emissions in Erbil and improved the kerosene's quality. In December, utilizing the method, the amount of keros is around 8% whereas in relation to without using is 12% , and for January and February, the total amount without the device is 7% compared to 4% of the original CO_2 production, Others monthes there's no need for CO_2 pollution. This would delay global warming.
6. An agreement between this study and other similar works reported in the literature was found.

7.

5.2 SUGGESTIONS

The following are recommended comparisons to further improve and enhance the comparison:

1. We should Add Elements to the ST and meters electrice joinet to the board control part, due to take detials the of energy amount and needed add the energy from the system to overcome the building instead of greenhouse heat load, that mean change the time working from 8:00 a.m to 4:00 p.m and change (8 h to 24 h).
2. We study effected of SC area (50%) (75%) (100%) on the overall heating load consumption.
3. Looking for the effective parameters of the temperature distribution using a set of sensors embedded in the tank and studying it with precision.
4. A contrast with the flat plate solar heating device using different collector models is warranted, but may be misleading.
5. It should be noted that this is a local study and different results can be obtained in other locations and under different experimental conditions.

REFERENCES

[1] Zhang, Liang, et al. "A low cost seasonal solar soil heat storage system for greenhouse heating: Design and pilot study." Applied Energy 156 (2015): 213-222.

[2] Kürklü, Ahmet, Sefai Bilgin, and Burhan Özkan. "A study on the solar energy storing rock-bed to heat a polyethylene tunnel type greenhouse." Renewable Energy 28.5 (2003): 683-697.

[3] Kalogirou S. A., (2004) "Solar thermal collectors and applications". Department of Mechanical Engineering, Higher Technical Institute, P.O. Box 20423, Nicosia 2152, Cyprus, *Progress in Energy and Combustion Science* 30 (2004) 231–295.

[4] Bin Ramli A. A., (2010) "Theoretical Analysis of Solar Water Heating System". *Thesis submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Mechanical Engineering*, Faculty of Mechanical Engineering .University of Malaysia Pahang.

[5] Ali M. H., (2010) "Solar Thermal Water Heating for Domestic or Industrial Application (New Trend Modeling)". University of Technology 2195. *Eng. & Tech. Journal*, Vol.28, No.11.

[6] Baek S. M., Nam J. H., Kim Charn-Jung, (2011) "Effect the Brine Flowrate on the Performance of Spiral-Jacketed Thermal Storage Tank used for Domestic Solar Hot Water Systems: A Computational Fluid Dynamics Study". *Applied Thermal Engineering* 31 (2011) 2716-2725.

[7] Kim K. H., Kim G. D., and Han C H., (2013), "A Performance Assessment of Solar Flat Plate Collector System with Heat Storage Tank". International Journal of Mining, *Metallurgy & Mechanical Engineering (IJMMME)* Volume 1, Issue 5 (2013) ISSN 2320-4052; EISSN 2320-4060.

[8] Hernández M. B., (2013) "Solar Heat use for Hot Water and Heating Preparation in a Residential Building". *Vilnius Gediminas Technical University*, Faculty of Environmental Engineering, Vilnius.

[9] Khuder A. H., (2013), "Study The Use Of Solar Energy For Heating Buildings In Baghdad City". Journal of Engineering and Development, Vol. 17, No.6, December 2013, ISSN 1813-7822.

[10] Sadrin S., Hossain M., Mohit E., (2009), ''Alternative Solar WATER Heater for Domestic purpose'' . Submitted to the Department of computer Science and Engineering of BRAC University, August.

[11] Comakli K., Cakir U., Kaya M., Bakirci K., (2012), "Relation between Collector and Storage Tank Size in Solar Heating system". *Energy Conversion and Management* 63 (2012) 112-117.

[12] Ben Slama R. and Tunisia I. G., (2010) "Experimentation of a Plane Solar Integrated Collector Storage Water Heater". *International Renewable Energy Congress,* November 5-7, – Sousse, Tunisia.

[13] Siyal E. Z. A., Rajput I., (2010), "Fabrication and analysis of passive solar water heating system".

[14] Samo S. R., Siyal A. A., Siyal Z. A. and Jatoi Abdul Rahman, (2012) " Analysis of an Active and Passive Solar Water Heating System". *Sixteenth International Water Technology Conference,* IWTC 16, Istanbul, Turkey.

[15] Mohammed M.N., Alghoul M.A., Abulqasem Kh., Alshrif.Mustafa, Kh.Glaisa, P.Ooshaksaraei, M.Yahya, A.Zaharim and K.Sopian, (2011), "TRNSYS Simulation of Solar Water Heating System in Iraq". Energy Research Institute, University Kebangsaan Malaysia, *Proceedings of the 4th WSEAS international conference on Energy and development - environment - biomedicine*, MALAYSIA.

[16] Lisboa P. A. and Fonseca-Costa M. A., (2014), "Simulating the Performance of Solar Water Heating Systems". *Journal of Energy and Power Engineering* 8 (2014) 636-645.

[17] Ayompe L.M. and Duffy A., (2013) "Analysis of the thermal performance of a solar water heating system with flat plate collectors in a temperate climate". *Applied Thermal Engineering,* 58 (2013), 447-454.

[18] Sridharan M., Prasanna N., SivaPrakash E., VaradhaRajan R., (2014), "Experimental Investigation on Series Solar Flat Plate Collectors with Variable Mass Flow Rates". *International Journal of Innovative Research in Science*, Engineering and Technology. International Conference on Innovations in Engineering and Technology. Volume 3,(2014), 2347-6710.

[19] Hesaraki A., Sture H., Fariborz H., (2014) "Energy-Efficient and Sustainable Heating System for Buildings: Combining seasonal heat storage with heat pumps and low-temperature heating systems". Department of Civil and Architectural Engineering, KTH – Royal Institute of Technology, Stockholm, Sweden. The 10th *international Energy Conference* (IEC).

[20] Bannaceur S., Draoui B., Benhamou M., Bennamoun L., (2012) "Experimental Study and Modeling the Behavior of a Solar Water Heater Tested At the Region of Adrar, Algeria".1Department of Mechanical Engineering, University of Béchar, Algeria. *International Journal of Advanced Renewable Energy Research*. Vol. 1, Issue. 8, (2012), 460-466.

[21] Bolaji B. O. and Abiala I., (2012) "Theoretical and Experimental Analyses of Heat Transfer in a Flat-Plate Solar Collect". Department of Mechanical Engineering, College of Engineering, Federal University of Agriculture, Abeokua, Nigeria. *Walalilac Journal*, volume 9, No.3, 239-248.

[22] Karanth K. V., Madhwesh N, Kumar S., Manjunath M.S. (2015), "Numerical and Experimental Study of a Solar Water Heater for Enhancement in Thermal Performance". Department of Mechanical & Mfg. Engineering, Manipal Institute of Technology, Manipal, Karnataka, India International Journal of Research in Engineering and Technology, Volume: 04.issue (3) (2015), 2321-7308.

[23] Chii-Dong Ho, Tsung-Ching Chen, Chen-jung Tsai, (2010) "Experimental and Theoretical studies of recyclic flat-plate solar water heaters equipped with rectangle conduits". *Energy and Opto-Electronic Materials Research Center*, Department of Chemical and Materials Engineering , Tamkang University, 151 ying-Chaun road, Tamasui. *Renewable Energy* 35 (10) 2279-2287.

[24] Nikolic N., Lukic N., (2015), "Theoretical and experimental investigation of the thermal performance of a double exposure flat-plate solar collector". Faculty of Engineering, University of Kragujivac, Sester Janjic6, 34000 Kragujivac, Serbia. *Solar Energy* 119(2015) 100-113.

[25] Incropera F. P., Dewitt D. P., (2007), Theodore I. Bergman and Aderienne S. Lavine, "Fundamentals of Heat and Mass Transfer".

[26] ASHRAE, (2013), Fundamentals Handbook (SI) .pp 22.7.

[27] Shukla K.N., Rangnekar S., Sudhakar K.,(2015), "Comparative study of isotropic and anisotropic sky models to estimate solar radiation incident on tilted surface". A case study for Bhopal, India”. Energy Reports PP.96-133.

[28] Duffie J. A. and Bekman W. A., (2013) "Solar Engineering of Thermal Process", fourth edition, *Solar Energy Laboratory*, University of Wisconsin-Madison.

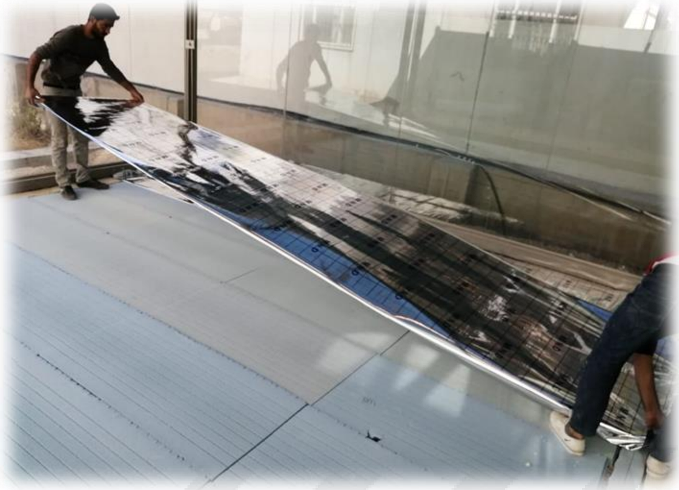
[29] Klein, S. A. and Hurlbut C. S., (1977), "Calculation of Monthly Average Insolation on Tilted Surfaces". *Solar Energy*, 19th edition, 325.

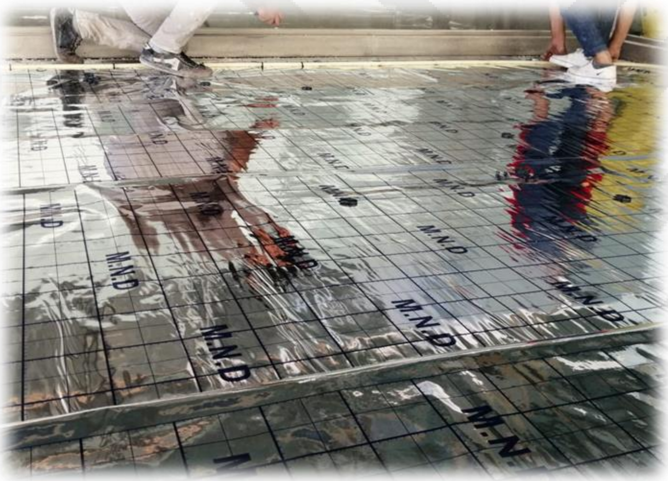
[30] Demirel Y., 2012, "Energy (production, conversion, Storage, conservation and coupling)" Energy, Green Energy and Technology, DOI: 4471-2372, Springer-Verlag London Limited, 27-70.

[31] Klein S. A., Beckman W. A., Mitchel J.W., Duffie J. A., Duffie N.A., and Freeman T. L., (1998) "TRNSYS Manual" , *University of Wisconsin*.

[32] Tadors M.T.Y., Mustafa M.A.M., M. Abdel-Wahab, (2014), "Estimation of the Global Horizontal Solar Radiation in Iraq". *International journal of emerging technology and advanced engineering*, ISSN 2250-2459,ISO 9001:2008, Certified Journal, Volume 4, (2014), 2250-2459.

APPENDIX A. PHOTOS OF THE EXPERIMENTAL WORK OF THE THESIS

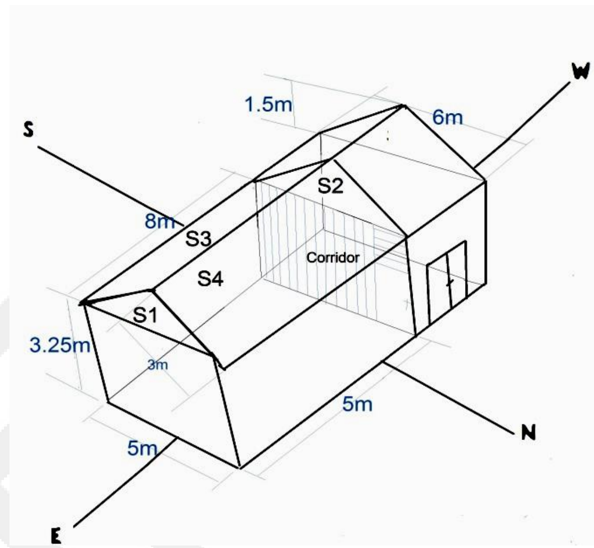




APPENDIX B. CALCULATION DETAILS

1- Heating Load Estimation

To calculate room heating load, there are some assumption made:



1. Room inside temperature (21 °C).
2. Outside temperature (-2 °C).
3. Inside unconditioned space (11.8°C).
4. 25, December, 2020, 12 p.m.
5. Greenhouse Room dimension = (5× 5 × 3.25) m³
6. The greenhouse beside the building.
7. Sensible heat transfer load in G.H room

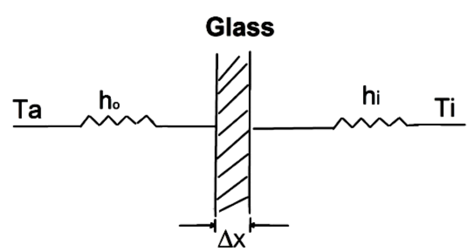
   $Q_{s=}\ m^{\cdot}\ cp\ (Twi - Two)$

8. Heat transfer from ground inside G.H room $Q_{g=hi\ Ag\ (Tg-Tr\ )}$

9. Total loss heat transfer Q_{Tloss}

walls:

North Direction:



Area $_{North}$ = length * high

= 5 * 3.25 = 16.2 m^2

$Q_{North=}\ U\ A\ (Ti - To)$

$$U_{North} = \frac{\mathbf{1}}{\boldsymbol{R_{North}}} = \begin{array}{l} R_{North} = \dfrac{1}{h_i} + \dfrac{\Delta x}{k_{Glass}} + \dfrac{1}{h_o} \\ = \dfrac{1}{8.32} + \dfrac{0.1}{0.96} + \dfrac{1}{34.1} = 0.25 \end{array}$$

$$U_{North} = \frac{1}{0.25} = 4 \ \ W/m^2.\text{°C}$$

$$Q_{North} = 4 * 16.2 * \left(21 - (-2)\right)$$

= 1490 W = 1.490 KW

South Direction:

Area $_{South}$ = length * high

= 5 * 3.25 = 16.2 m^2

$$Q_{South} = U\,A\,(Ti - To)$$

$$U_{South} = \frac{1}{R_{South}} =$$

$$R_{South} = \frac{1}{h_i} + \frac{\Delta x}{k_{Glass}} + \frac{1}{h_o}$$

$$= \frac{1}{8.32} + \frac{0.1}{0.96} + \frac{1}{30.9} = 0.253$$

$$U_{South} = \frac{1}{0.253} = 3.95 \ \ W/m^2.\text{°C}$$

$$Q_{South} = 3.95 * 16.2 * \left(21 - (-2)\right)$$

= 1471 W = 1.471 KW

East Direction:

Area $_{East}$ = length * high

= 5 * 3.25 = 16.2 m^2

$Q_{East=}\ U\,A\,(Ti{-}To)$

$U_{\ East} = \dfrac{1}{R_{East}} =$

$R_{East} = \dfrac{1}{h_i} + \dfrac{\Delta x}{k_{Glass}} + \dfrac{1}{h_o}$

$= \dfrac{1}{8.32} + \dfrac{0.1}{0.96} + \dfrac{1}{32.4} = 0.25$

$U_{\,East} = \dfrac{1}{0.25} = 4\ \ W/m^2.\,°\mathrm{C}$

$Q_{East} = 4 * 16.2 * \left(21 - (-2)\right)$

= 1490 W = 1.490 KW

West Direction:

Area $_{West}$ = length * high

= 5 * 3.25 = 16.2 m^2

$T_{Corridor=11.8\,°\,C}$

$T_{Ambint=\,-2\,°\,C}$

$Q_{West=}\ U\,A\,(Ti{-}To)$

$T_{i=21\,°\,C}$

$U_{\ West} = \dfrac{1}{R_{West}} =$

$R_{West} = \dfrac{1}{h_i} + \dfrac{\Delta x}{k_{Glass}} + \dfrac{1}{h_i}$

$= \dfrac{1}{8.32} + \dfrac{0.01}{0.96} + \dfrac{1}{8.32} = 0.25$

$U_{\,West} = \dfrac{1}{0.25} = 4\ \ W/m^2.\,°\mathrm{C}$

$Q_{West} = 4 * 16.2 * \left(21 - (11.8 - 2)\right)$

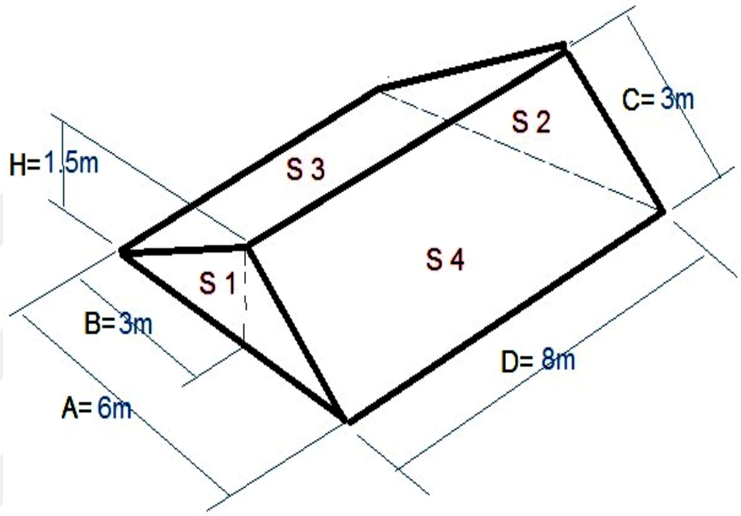
= 7257 W = 0.7257 KW

$$Q_{Total\ Directions} = Q_N + Q_S + Q_E + Q_W$$

$$= 1.49 + 1.471 + 1.49 + 0.7257$$

$$= 5.1767\ KW$$

Roof:



$$A_{Section\ 1} = \frac{1}{2} * \frac{A}{2} * \text{high} * 2$$

$$= \frac{1}{2} * \frac{6}{2} * 1.5 * 2 = 4.5\ m^2$$

$$R = \frac{1}{h_i} + \frac{\Delta x}{k_{Glass}} + \frac{1}{h_o}$$

$$= \frac{1}{8.32} + \frac{0.1}{0.96} + \frac{1}{32.4} = 0.25$$

$$U_{Section1} = \frac{1}{R_{S1}} = \frac{1}{0.25} = 4\ W/m^2.°C$$

$$Q_{S1} = U * \text{Area} * (T_{in} - T_{out})$$

$$= 4 * 4.5 * \left(21 - (-2)\right) = 414\ W = 0.414\ kW$$

$$A_{Section\ 2} = A_{Section1} = 4.5\ m^2$$

$$R = \frac{1}{h_i} + \frac{\Delta x}{k_{Glass}} + \frac{1}{h_i}$$

$$= \frac{1}{8.32} + \frac{0.1}{0.96} + \frac{1}{8.32} = 0.34$$

$$U_{Section2} = \frac{1}{R_{S2}} = \frac{1}{0.34} = 3\ W/m^2.°C$$

$$Q_{S2} = U * \text{Area} * (T_{in} - T_{out})$$

$$= 3 * 4.5 * \left(21 - (11.8 - 2)\right) = 151\ w = 0.151\ kW$$

$$A_{Section\ 3} = D * C$$

$$= 8 * 3 = 24\ m^2$$

$$R = \frac{1}{h_i} + \frac{\Delta x}{k_{Glass}} + \frac{1}{h_o} = \frac{1}{8.32} + \frac{0.1}{0.96} + \frac{1}{30.9} = 0.253$$

$$U_{Section3} = \frac{1}{R_{S3}} = \frac{1}{0.253} = 4\ W/m^2.°C$$

$$Q_{S1} = U * \text{Area} * (T_{in} - T_{out})$$

$$= 4 * 24 * \left(21 - (-2)\right) = 2208\ W = 2.208\ KW$$

$A_{Section\ 4} = A_{Section\ 3}$ = 24 m^2

$$R = \frac{1}{h_i} + \frac{\Delta x}{k_{Glass}} + \frac{1}{h_o} = \frac{1}{8.32} + \frac{0.1}{0.96} + \frac{1}{34.1} = 0.25$$

$$U_{Section4} = \frac{1}{R_{S4}} = \frac{1}{0.25} = 4\ W/m^2.°C$$

$$Q_{S4} = U * \text{Area} * (T_{in} - T_{out})$$

$$= 4 * 24 * \left(21 - (-2)\right) = 2208\ W = 2.208\ KW$$

$Q_{Roof\ Total} = Q_{S1} + Q_{S2} + Q_{S3} + Q_{S4}$ = 0.414 + 0.151 + 2.208 + 2.208 = 4.981 KW

= 4981 W

Floor:

Area = length * high

= 5 * 5 = 25 m^2

$$R = \frac{1}{h_i} + \frac{\Delta x}{k_{Cork}} + \frac{\Delta x}{k_{Nylon}} + \frac{\Delta x}{k_{Sand}} + \frac{\Delta x}{k_{Limestone}} + \frac{1}{h_i}$$

$$= \frac{1}{8.32} + \frac{0.02}{0.04} + \frac{0.002}{0.36} + \frac{0.02}{2.05} + \frac{0.03}{2.22} + \frac{1}{8.32} = 0.76$$

$$U_{Roof} = \frac{1}{R_{Roof}} = \frac{1}{0.76} = 13.16\ W/m^2.°C$$

$$Q_{Floor} = U * \text{Area} * (T_{in} - T_{out})$$

$$= 13.16 * 25 * (21 + 2) = 7567\ W$$

= 7.567 KW

Infiltration:

Volume = Length* Height * Width

= 5 * 3.25 * 5 = 81.25 m^3

1air change per hour

$$\frac{m^3}{hr} = 1 * 81.25 = 81.25 \frac{m^3}{hr} * \frac{1000}{3600} = 22.57 \frac{Lt}{sec} = 0.02257 \frac{m^3}{sec}$$

Outside temperature = -2°C &76% relative humidity→ $h_{out} = -0.31\ kJ/kg$

Inside temperature = 21°C &50% relative humidity→ $h_{in} = 40.747 kJ/kg$

$$v = 0.761\ m^3/kg$$

$$\dot{m}_a = \frac{\tilde{V}}{v} = \frac{0.02257}{0.761} = 0.030\ kg/sec$$

$$Q_{Inf} = m_a\ (h_{in} - h_{out})$$

$$= 0.030 * \left(40.747 - (-0.31)\right) = 1.231\ KW = 1231\ W$$

2-Pipe Design

$$\dot{m}_w = \frac{QT_{loss}}{Cp_w * (T_{wo} - T_{wi})}$$

$$= \frac{1.4}{4.18 * (10)} = 0.033\ kg/s$$

$$\tilde{V} = \frac{\dot{m}_w}{\rho} = \frac{0.033}{1000} = 3.3 * 10^{-5}\ m^3/sec = 0.33\ \ lt/sec$$

From figure (3-1) determine pipe diameter

There are three diameter located in the line of volumetric flowrate, which they are:

$$40\ mm = \frac{40}{25.4} = 1.575"$$

$$32\ mm = \frac{32}{25.4} = 1.259"$$

$$25\ mm = \frac{25}{25.4} = 0.984"$$

$$20\ mm = \frac{20}{25.4} = 0.787"$$

Because all diameters are less than 2", choose the pipe diameter which is located at the line of velocity ≤ 1.2 m/sec. Therefore; for Heat Exchanger unit of (1.4 Kw) the pipe diameter is 25 mm (0.984").

Sensible heat transfer load in G.H room

$$Q_{s=}\ m^{\cdot}\ cp\ (Twi-Two)$$

= 0.033 * 4.18 * (40.4 – 20)

= 2.81 KW

Heat transfer from ground inside G.H room

$$Q_{g=hi\ Ag\ (Tg-Tr\ )}$$

= 8.32 * (5 * 5) (30-21)

= 1.878 KW

$$QT_{loss} = Q_{Total\ Direction} + Q_{Roof} + Q_{Floor} + Q_{Inf} + Q_{\ g} + Q_{\ s}$$

$$= 5.176 + 4.981 + 7.567 + 1.231 + 1.878 + 2.810$$

$$= 23.6\ KW$$

3- Total Solar Radiation Estimation

Estimating total solar radiation for Erbil city at 12:00 pm for 21st December, $\emptyset = 36°\ N$, $L_{loc} = 44°\ E$

From table (2-1) $n = 21 + 334 = 355$

$$\delta = 23.45 \sin\left(360 \frac{284 + n}{365}\right) = 23.45 \sin\left(360 \frac{284 + 355}{365}\right) = -23.45^o$$

$$B = (n - 1)\frac{360}{365} = (355 - 1)\frac{360}{365} = 349.15$$

$$E = 229.2(0.000075 + 0.001868 \cos B - 0.032077\ sinB - 0.014615 \cos 2B - 0.04089 \sin 2B)$$

$$E = 229.2(0.000075 + 0.001868 \cos(349.15) - 0.032077 \sin(349.15) - 0.014615 \cos(2 * 349.15) - 0.04089 \sin(2 * 349.15)) = 2.17\ min$$

For Erbil city Utc+3 or,

$$L_{st} = 15^o\left(\frac{L_{loc}}{15^o}\right) = 15^o * 3 = 45^o\ E$$

$$ST = Std + 4\,(L_{st} - L_{loc}) + E$$

$$= 12 + \frac{[4\,(-45 - (-44)) + 2.17]}{60} = 11.9695\ hr = 11{:}58\ Am$$

$$\omega = 15\,(ST - 12) = 15(11.9695 - 12) = -0.456^o$$

$$\beta = /\emptyset - \delta/ = /36 - (-23.45)/ = 59.45^o \cong \mathbf{60^o}$$

$$cos\theta_z = cos\emptyset\ cos\delta\ cos\omega + sin\emptyset\ sin\delta$$

$$= \cos(36)\ cos\delta \cos(-0.456) + \sin(36) \sin(-23.45) = 0.508$$

$$\theta_z = 59.45^o$$

$$cos\theta = sin\delta\ sin\emptyset\ cos\,\beta - sin\,\delta\ cos\emptyset\ sin\beta\ cos\gamma + cos\delta\ cos\emptyset\ cos\beta\ cos\omega + cos\delta\ sin\beta\ cos\gamma\ cos\omega + cos\delta\ sin\beta\ sin\gamma\ sin\omega$$

$$= \sin(-23.45)\sin(36)\,cos(60) - sin\,(-23.45)\cos(36)\sin(60)\cos(0) + \cos(-23.45)\cos(36)\cos(60)\cos(-0.456) + \cos(-23.45)\sin(60)\cos(0)\cos(-0.456) + \cos(-23.45)\sin(60)\sin(0)\sin(-0.456) = 0.999927$$

$$\theta = 0.6909^o$$

$$R_b = \frac{cos\theta}{cos\ \theta_z} = \frac{0.999927}{0.508} = 1.967$$

At (12:30 Pm): $\omega_2 = 15(12.4965 - 12) = 7.0425°$

At (11:30 Pm): $\omega_1 = 15(11.4095 - 12) = -7.9575°$

$$I_o = \frac{12 * 3600}{\pi} G_{sc} \left(1 + 0.033 \cos\frac{360\ n}{365}\right) * \left[cos\emptyset\ cos\delta\ (\sin\omega_2 - sin\omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180}\ sin\emptyset\ sin\delta\right]$$

$$I_o = \frac{12*3600}{\pi} 1367 \left(1 + 0.033 \cos\frac{360*355}{365}\right) * \left[\cos(36)\cos(-23.45)\left(\sin(7.0425) - \sin(-7.9575)\right) + \frac{\pi(7.0425-(-7.9575)}{180} \sin(36)\sin(-23.45)\right] = 2.583$$

MJ/m^2

$I = K_T * I_o = 0.7 * 2.583 = 1.807$ MJ/m^2

$$I_d = I * \left(0.9511 - 0.1604 * K_T + 4.388 * {K_T}^2 - 16.638 * {K_T}^3 + 12.336 * {K_T}^4\right)$$

$I_d = 1.807 * (0.9511 - 0.1604 * (0.7) + 4.388 * (0.7^2) - 16.638 * (0.7^3) + 12.336 * (0.7^4)) = 0.441$

MJ/m^2

$I_b = I - I_d = 1.807 - 0.441 = 1.366$ MJ/m^2

$$I_T = I_b R_b + I_d\left(\frac{1 + cos\beta}{2}\right) + I\rho_g\left(\frac{1 - cos\beta}{2}\right)$$

$$I_T = (1.366 * 1.967) + \left(0.441\left(\frac{1+\cos(60)}{2}\right)\right) + \left(1.807 * 0.2\left(\frac{1-\cos(60)}{2}\right)\right)$$

$= 3.33$ MJ/m^2 $= 925.16$ W/ m^2

4- Solar Collector Efficiency Overall loss coefficient: Input data:

parameter	Value
V	$5\ m/s$
ε_p	0.88
ε_g	0.95
T_{pm}	$342.2\ K$
T_a	$271K$
K_b	$0.045\ W/m.\ ℃$
L_b	$0.04\ m$
K_e	$0.04\ W/m.\ ℃$
L_e	$0.03\ m$
k_p	$401\ W/m.\ ℃$
t_p	$0.5\ mm$
W	$0.15\ m$
D	$0.022\ m$

$$L = \sqrt[3]{room\ volume} = \sqrt[3]{14.5 * 7 * 3.5} = 7.08\ m$$

$$h_w = \frac{8.6\ V^{0.6}}{L^{0.4}} = \frac{8.6 * 5^{0.6}}{7.08^{0.4}} = 10.324\ \ W/m^2.\ ℃$$

$$f = (1 + 0.089h_w - 0.1166h_w\varepsilon_p)(1 + 0.0786\ N)$$

$$= \big(1 + (0.089 * 10.324) - 0.1166(10.324 * 0.88)\big)(1 + 0.0786 * 1) = 0.927$$

$$C = 520(1 - 0.000051\beta^2)$$

$$= 520(1 - 0.000051(60)^2) = 424.528$$

$$e = 0.430\left(1 - \frac{100}{T_{pm}}\right) = 0.430\left(1 - \frac{100}{359.6}\right) = 0.3104$$

$$U_t = \left(\frac{N}{\frac{C}{T_{pm}}\left[\frac{T_{pm} - T_a}{N+f}\right]^e} + \frac{1}{h_w} \right)^{-1} + \frac{\sigma(T_{pm} + T_a)({T_{pm}}^2 + {T_a}^2)}{\frac{1}{\varepsilon_p + 0.00591\, N h_w} + \frac{2N + f - 1 + 0.133\varepsilon_p}{\varepsilon_g} - N}$$

$$= \left(\frac{1}{\frac{424.528}{342.2}\left[\frac{342.2 - 279}{1 + 0.927}\right]^{0.3104}} + \frac{1}{10.324} \right)^{-1} + \frac{5.67 * 10^{-8}(342.2 + 279)(342.2^2 + 279^2)}{\frac{1}{0.88 + 0.00591 * 1 * 10.324} + \frac{2 * 1 + 0.927 - 1 + 0.133 * 0.88}{0.95} - 1}$$

$$= 5.927 \ W/m.℃$$

$$U_b = \frac{K_b}{L_b} = \frac{0.045}{0.04} = 1.125 \ W/m.℃$$

$$U_e = \frac{\left({K_e}/{L_e}\right) * (p * L_e)}{A_c} = \frac{\left({0.04}/{0.03}\right) * (2 * (2 + 1) * 0.096)}{20} = 0.0384 \ W/m.℃$$

$$U_L = U_t + U_b + U_e$$

$$= 5.927 + 1.125 + 0.0384 = 7.09 \ W/m.℃$$

5- Collector Heat Removal Factor:

$$m = \sqrt{\frac{U_L}{k_p \, t_p}} = \sqrt{\frac{7.09}{401 * 5 * 10^{-4}}} = 5.947$$

$$F = \frac{\tanh[m(W - D)/2]}{m(W - D)/2} = \frac{\tanh[5.947(0.15 - 0.022)/2]}{5.947(0.15 - 0.022)/2} = 0.954$$

$$T_w = \frac{T_{wo} + T_{wi}}{2} = \frac{340.6 + 329.4}{2} = 335 \ k$$

$$\dot{m}_w = \frac{total \ mass \ flowrate}{no \ of \ tube} = \frac{0.25}{4} = 0.0625 \ kg/sec$$

From Incropera *et. al*, 2007, Table(A-6),properties of saturated water, $\mu = 10.49 * 10^{-6} N.s/m^2$, $Pr = 0.916$, $k_w = 22 ** 10^{-6} W/m.℃$

$$Re_D = \frac{4\,\dot{m}_w}{\pi D \mu} = \frac{4 * 0.06}{\pi * 0.022 * 10.49 * 10^{-6}}$$

$$= 344819.6 \; > 2300 \; (turbulant\ flow)$$

$$Nu_D = 0.023 {Re_D}^{0.8}\, Pr^{0.4} = 0.023(344819.6)^{0.8}\,(0.916)^{0.4} = 597.805$$

$$h_{fi} = \frac{Nu_D\, k_w}{D} = \frac{597.805 * \; 22 * 10^{-3}}{0.022} = 597.805\ W/m^2.℃$$

$$F' = \frac{{}^{1}/_{U_L}}{W\left[\frac{1}{U_L[D + (W - D)F]} + \frac{1}{C_b} + \frac{1}{\pi D h_{fi}}\right]}$$

$$= \frac{{}^{1}/_{7.09}}{0.15\left[\frac{1}{7.09[0.022 + (0.15 - 0.022)0.954]} + \frac{1}{\infty} + \frac{1}{\pi * 0.022 * 597.805}\right]}$$

$$= 0.938$$

$$F'' = \frac{\dot{m}\ Cp}{A_c U_L F'}\left[1 - e^{-\frac{A_c U_L F'}{\dot{m}\ Cp}}\right] = \frac{0.0625 * 4190}{20 * 7.486 * 0.938}\left[1 - e^{-\frac{20*7.486*0.938}{0.0625*4190}}\right]$$

$$F'' = 0.784$$

$$F_R = F' * F'' = 0.9346 * 0.784 = 0.735$$

6- Absorbed Solar Radiation:

$$\theta_2 = \sin^{-1}\left(\frac{\sin\theta_1}{n_i}\right) = \sin^{-1}\left(\frac{\sin 0.6909}{1.526}\right) = 0.453°$$

$$\tau_a = \exp\left(-\frac{K_g L_g}{\cos\theta_2}\right) = \exp\left(-\frac{32 * 0.0023}{\cos(0.453)}\right) = 0.929$$

$$r_{\parallel} = \frac{tan^2(\theta_2 - \theta_1)}{tan^2(\theta_2 + \theta_1)} = \frac{tan^2\,(0.453 - 0.6909)}{tan^2\,(0.453 + 0.6909)} = 0.043$$

$$r_{\perp} = \frac{sin^2(\theta_2 - \theta_1)}{sin^2(\theta_2 + \theta_1)} = \frac{sin^2\,(0.453 - 0.6909)}{sin^2\,(0.453 + 0.6909)} = 0.043$$

$$\tau_r = \frac{1}{2}\left(\frac{1-r_{\parallel}}{1+r_{\parallel}} + \frac{1-r_{\perp}}{1+r_{\perp}}\right) = \frac{1}{2}\left(\frac{1-0.043}{1+0.043} + \frac{1-0.043}{1+0.043}\right) = 0.917$$

$$\tau = \tau_a \tau_r = 0.929 * 0.917 = 0.8524$$

$$(\tau\alpha)_b = 1.01\,\tau\alpha = 1.01 * 0.8524 * 0.95 = 0.809$$

$$\theta_{d1} = 59.7 - 0.1388\beta + 0.001497\beta^2 = 59.7 - 0.1388(60) + 0.001497(60)^2$$

$$\theta_{d1} = 56.76^{o}$$

$$\theta_{d2} = \sin^{-1}\left(\frac{\sin\theta_{d1}}{n_i}\right) = \sin^{-1}\left(\frac{\sin 56.76}{1.526}\right) = 33.236^{o}$$

$$\tau_a = \exp\left(-\frac{K_g L_g}{\cos\theta_{d2}}\right) = \exp\left(-\frac{32 * 0.0023}{\cos(56.76)}\right) = 0.9157$$

$$r_{\parallel} = \frac{tan^2(\theta_{d2} - \theta_{d1})}{tan^2(\theta_{d2} + \theta_{d1})} = \frac{tan^2(33.236 - 56.76)}{tan^2(33.236 + 56.76)} = 9.236 * 10^{-10}$$

$$r_{\perp} = \frac{sin^2(\theta_{d2} - \theta_{d1})}{sin^2(\theta_{d2} + \theta_{d1})} = \frac{sin^2(33.236 - 56.76)}{sin^2(33.236 + 56.76)} = 0.159$$

$$\tau_r = \frac{1}{2}\left(\frac{1-r_{\parallel}}{1+r_{\parallel}} + \frac{1-r_{\perp}}{1+r_{\perp}}\right) = \frac{1}{2}\left(\frac{1-9.236 * 10^{-10}}{1+9.236 * 10^{-10}} + \frac{1-0.159}{1+0.159}\right) = 0.863$$

$$\tau = \tau_a \tau_r = 0.9157 * 0.863 = 0.79$$

$$(\tau\alpha)_d = 1.01\,\tau\alpha = 1.01 * 0.79 * 0.95 = 0.758$$

$$\theta_{g1} = 90 - 0.5788\beta + 0.002693\beta^2 = 90 - 0.5788(60) + 0.002693(60)^2$$
$$\theta_{g1} = 64.956^{o}$$

$$\theta_{g2} = \sin^{-1}\left(\frac{\sin\theta_{g1}}{n_i}\right) = \sin^{-1}\left(\frac{\sin 64.956}{1.526}\right) = 36.419^{o}$$

$$\tau_a = \exp\left(-\frac{K_g L_g}{\cos\theta_{g2}}\right) = \exp\left(-\frac{32 * 0.0023}{\cos(36.419)}\right) = 0.913$$

$$r_{\parallel} = \frac{tan^2(\theta_{g2} - \theta_{g1})}{tan^2(\theta_{g2} + \theta_{g1})} = \frac{tan^2(36.419 - 64.956)}{tan^2(36.419 + 64.956)} = 0.0119$$

$$r_{\perp} = \frac{sin^2(\theta_{g2} - \theta_{g1})}{sin^2(\theta_{g2} + \theta_{g1})} = \frac{sin^2(36.419 - 64.956)}{sin^2(36.419 + 64.956)} = 0.237$$

$$\tau_r = \frac{1}{2}\left(\frac{1 - r_{\parallel}}{1 + r_{\parallel}} + \frac{1 - r_{\perp}}{1 + r_{\perp}}\right) = \frac{1}{2}\left(\frac{1 - 0.0119}{1 + 0.0119} + \frac{1 - 0.237}{1 + 0.237}\right) = 0.796$$

$$\tau = \tau_a \tau_r = 0.913 * 796 = 0.727$$

$$(\tau\alpha)_g = 1.01\,\tau\alpha = 1.01 * 0.727 * 0.95 = 0.698$$

$$S = I_b R_b (\tau\alpha)_b + I_d (\tau\alpha)_d \left(\frac{1 + cos\beta}{2}\right) + I\rho_g\,(\tau\alpha)_g \left(\frac{1 - cos\beta}{2}\right)$$

$$= (1.366 * 1.967 * 0.809) + \left(0.441 * 0.775\left(\frac{1+\cos(60)}{2}\right)\right) + \left(1.807 * 0.2 * 0.698 * \left(\frac{1-\cos(60)}{2}\right)\right) = 2.511$$

MJ/m^2

7- Actual Useful Energy Gain for Flat Plate Solar Collector:

$$Q_u = A_c\, F_R\, [S - U_L(T_i - T_a)]$$

$$= 20 * 0.735\left[2.511 - \left(7.09(329.4 - 279) * \frac{3600}{10^6}\right)\right] = 18.0157 \text{ MJ/m}^2$$

8- Solar Collector Efficiency:

$$\eta = \frac{Q_u}{A_c I_T} = \frac{18.0157}{20 * 3.33} = 0.27 = 27\,\%$$

9- Mean plate Temperature:

$$T_{pm} = T_{wi} + \frac{Q_u/A_c}{F_R U_L}(1 - F_R)$$

$$T_{pm} = 329.4 + \frac{\left(\left(18.0157 * \frac{10^6}{3600}\right) / 20\right)}{0.735 * 7.09}(1 - 0.735) = 342.2℃$$

Experimental Calculation:

For calculating experimentally solar collector useful heat energy gain, and heating load from heat exchanger, can be found as:

1- For calculating solar collector heating load for 4th February at 12:00 pm from experimental data:

$$Q_u = \dot{m}\ Cp\ (T_{wo} - T_{wi}) = 0.25 * 4.2 * (52.5 - 43.3) = 9.66\ kW$$

2- For calculating Heat Exchanger load for 4th February at 12:00 pm from experimental data:

$$Q_u = \dot{m}\ Cp\ (T_{wi} - T_{wo}) = 0.112 * 4.2 * (51.1 - 26.3) = 11.67 kW$$

3- From results of TRNSYS program, let take January as an example:

Solar collector heating load = 6325 MJ

Heat Exchanger heating load = 73272 MJ

∴ heat needed from kerosene heater = 7327.2 – 6325 = 1002.2 MJ.

1 litter of kerosene produced 37600 KJ of heat.

That is mean for January= $\frac{73272}{37600} = 194.9 = 195$ litter of kerosene.

4- CO_2 emission without using solar water heating system can be found as:

7327173.5 kJ = 4070.7 KWh

1 kg CO_2 =KWh of heat from kerosene x 0.26

= 4070.7*0.26 = 1058.38 Kg of CO_2.