SOLAR WATER HEATER SYSTEMS
FOR COMMERCIAL BUILDINGS

By
Nazarul bin Nordin
(13277)

Dissertation submitted in partial fulfillment of
The requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

SEPTEMBER 2013

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

SOLAR WATER HEATER SYSTEMS
FOR COMMERCIAL BUILDINGS

By

Nazarul bin Nordin

Project Dissertation is submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirements for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

( )

Universiti Teknologi PETRONAS
Tronoh, Perak

September 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(NAZARUL BIN NORDIN)

ABSTRACT

This proposal outlines the background of the project entitled "Solar Water Heater Systems for Commercial Buildings". Over the past years, considerable much of a progress has been made in looking for alternative energy such as solar energy itself as the main non-renewable sources that people nowadays depending on, the oil is depleted from day to day. As the research for this renewable energy of solar is carried on, researcher is trying to find the efficiency (energy saving generated) from the Solar Water Heating System.

The purpose of this study is to investigate the energy saving generated using the solar water heating system in heating water to decrease the dependence on conventional heater based on real times using updated weather data simulated by TRNSYS program. The other purpose is to properly size the system installed to have optimum performances.

The research papers regarding the application and study of solar water heating in collecting solar energy are presented in the second chapter. As in most of the researches, the studies are more focusing on the system of Solar Water Heating in region of Malaysia, particularly in Ipoh. Thus, in this project, two mains aspects in determining the relevancy of using the solar to heat the water in commercial uses is going to be simulated

The methodology is proposed in which the deep and details literature review on past research on the topic related to come out with the proper comparison based on the past research conducted by other researchers worldwide. As addition, the planning of project has been done in the Gantt chart in the Appendix.

ACKNOWLEDGEMENT

First and foremost, I praise to God for His guidance and blessings throughout the entire course of the Final Year Project I (FYP I) and Final Year Project II (FYP II). I would also like to sincerely thank University Teknologi PETRONAS (UTP) and in particular, Mechanical Engineering Department for providing me with the wonderful opportunity to fulfill my requirement for Bachelor of Engineering (Hons) in Mechanical Engineering. With the opportunity, I had clearly gained extra knowledge in mechanical field.

I would like to express my deepest appreciation to my Final Year Project Supervisor, Assoc. Prof Dr. Morteza Khalaji Assadi for the overall Final Year Project's plan. Thank you for giving me the maximum opportunity to obtain useful information related to my field of studies.Thanks to the examiners, Dr. Shaharin Anwar Sulaiman and Dr. Hussain Hammud Ja'afer Al Kayiem for all the knowledge shared; and also to all lecturers and staffs for the continuous help, support and guidance to overcome the challenges faced, from the beginning of this project until the end.

Special thanks to Mr Arief from SolarMate (M) Sdn. Bhd. For all the data and knowledge shared specially regarding the solar hot water industry. Also, I would like to take this opportunity to thanks to Final Year Project's Coordinator, Dr Azmi bin Abdul Wahab for keeping the supervision in a great control.

Finally, deepest gratitude goes to all my fellow colleagues, friends and family who gave me great inspirations to complete the project.

TABLE OF CONTENTS

CERTIFICATION . . . . **ii**

ABSTRACT . . . . **iv**

ACKNOWLEDGEMENT . . . . **v**

TABLE OF CONTENT . . . . **vi**

LIST OF FIGURES . . . . **vii**

LIST OF TABLES . . . . **vii**

CHAPTER 1: INTRODUCTION **1**

1.1. Background of study 1

1.2. Problem Statements 3

1.3. Objectives and Scope of Study. 3

1.4 Scope of Study. 3

1.5 Relevancy of the project. 4

CHAPTER 2: LITERATURE REVIEW **5**

2.1 Conventional Water Heater Vs Solar Hot Water Heater Usage 5

2.2 Economy and Financial Perspective. 6

2.3 Solar Water Heating System. 7

2.4 TRNSYS Simulation of Solar Hot Water System. 11

2.5 Transient System Simulation Program. 12

2.6 System Sizing. 17

2.7 Solar Collector Orientation Angle 18

CHAPTER 3: RESEARCH METHODOLOGY . . . 20

3.1. Project Flow Chart 20

3.2 Project Activities 20

3.3 Project Gantt chart. 21

3.4 Data Gathering 23

3.4.1 Solar Hot Water Manufacturer Product Specs 23

3.4.2 Average Solar Radiation data in Ipoh 24

3.4.3 Hotel Information 25

3.5 Tools and Equipment used 27

3.6 Modeling and Simulation of the System 28

3.6.1 System Description and Parameter Calculation 28

3.6.2 TRNSYS Simulation Modeling 28

CHAPTER 4: RESULT AND DISCUSSION . . . 31

4.1 Energy Saving Calculation. 31

4.2 Optimization of the System Sizing 33

CHAPTER 5: CONCLUSION 33

REFERENCES 34

List of Figures

Figure 1: Three forms of solar energy conversion. 01

Figure 2: Picture of an evacuated tube collector. 13

Figure 3: Cross section of an evacuated tubes collector. 13

Figure 4: Schematic of heat exchanger. 14

Figure 5: i nodes of the stratified storage tanks. 15

Figure 6: Incidence angle of the flat plate collector. 18

Figure 7: The variation of angle and intensity of solar radiation on a surface. .18

Figure 8: Tilt and orientation angle of the solar collector. 19

Figure 9: Impiana Hotel located in Ipoh. 25

Figure 10: Average flow of hot water draw profile on all days. . . .27

Figure 11: System schematic of Solar Hot Water System (SHWS). . . .28

Figure12: TRNSYS modeling for schematic system chosen.. . . .30

Figure 13: Simulation results Graph of the system modelled. . . .32

List of Tables

Table 1: Project work description. 20

Table 2: Gant Chart22

Table 3: Evacuated tube solar collector specification
From Solar Mate (M) Sdn. Bhd. 23

Table 4: Weather data of Ipoh from Meteorological
Department of Malaysia. 24

Table 5: The data on number of rooms of the hotel25

Table 6: Average flow rate of hot water draw hourly on average day. . .26

CHAPTER 1
INTRODUCTION

1.1) Background of Study

As the human life expands, energy demands are continuously increasing rapidly as the development of the industrial. The main source of the energy used nowadays which is the fossil fuel is extremely limited to deal with the worldwide demand and has been causing series of environmental problems. Thus, the search for alternative green energy resources has been drawing a lot of interest in the research.

Solar energy, as the most abundant resources all over the world as reported that amount of solar energy received from Sun every year is reaching to 1×10^{18} kW.h. It is almost ten thousand times human energy consumption annually [1]. Three forms of solar energy conversion as illustrated in the Figure 1.1, is the electricity, chemical fuel and heat. Mostly, the devices such as thermal collector is used to convert the solar energy into the heat energy for direct use at low temperatures (<300°C)[2]. There also many application in solar thermal which has been utilized to cut down the dependence of human toward fossil fuel in residence by using solar absorber for home appliances uses such as to heat the water .

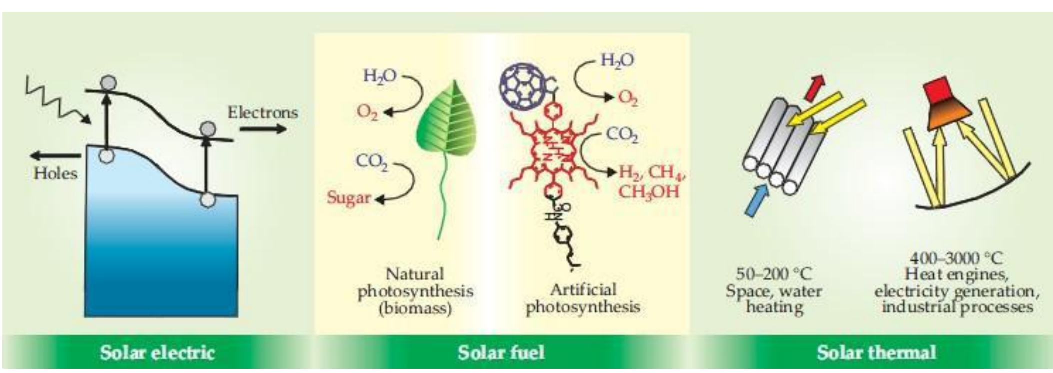


Figure 1: Three forms of solar energy conversion [2]

As the prices of all conventional energy sources for heating including oil, natural gas, propane and electricity have been increasingly rapidly over the past decade, the trend of these increment in prices is projected to continue-increasing. So, renewable energy sources are becoming viable in supplying energy to be used in daily life purposes. Several reasons why the renewable energy is viable are they do not require as many ongoing operational costs. In given time, the energy saving it produced can cover for the high initial capital for its system.

Nowadays, over one third of energy is used in water heating in US. By using Solar Water Heating Systems, it can supply 60% or more of the required heat to hotel purposes. In ASEAN, Solar Hot Water Heating Systems have started its popularity in energy saving due to its increasing population and concerns for the environmental issue. Solar Hot Water Heating System in Malaysia is not an exception given that Malaysia itself has abundant resources of solar energy throughout the year. Particularly nowadays, Solar Hot Water Heating is installed in commercializes and industrial purposes due to its capability to save energy in heating water.

However, the amount of heat produced by the system depends on many factors such as weather condition, solar radiation amounts, system efficiency and hot water draw profile. Thus, a case study in conducted on the viability of the system installed in Ipoh, Malaysia to see whether it is viable enough to installed by comparing the energy saving produced.

1.2) Problem Statement

In industry purposes, the solar required is much higher energy to be considered cost saving. In Malaysia nowadays, there are plenty of solar manufacturers and system provider for solar system installation mainly for the solar hot water heating systems. The efficiency or the viability of the system installed cannot be justified alone by the manufacture system. The weather data of the particular place and the hot water draw profile must be taken into account.

- What is the energy saving that the Solar Hot Water can give in Ipoh (particularly) weather condition (solar radiation amount)?

1.3) Objectives

The objective of this study is as stated below:

1. To investigate the energy saving generated in heating water by using the solar water heating system (specifically by Solar Mate Sdn. Bhd) based on real time weather data of Ipoh (local solar radiation), and hot water draw profile using energy simulation software of TRNSYS.
2. To develop a simulation model using Transient Systems Simulation Program, TRNSYS
3. To optimize the system sizing based on the hot water draw profile of the hotel

1.4) Scope of Study

1. Research on the recent technology system of the solar heating water system and how the system work

2. Study about the climate data for different region in Malaysia

3. The hotel how water draw profile

3. Research on the usage of simulation software TRNSYS capability in simulating the energy saving of solar heating water system in commercial uses

1.5) Relevancy of project

This study is relevant because from this study, the formation of the precipitation can be observed, and the results can also be used to calculate saving generated by comparing energy generated by the system or reduction in real electricity bills

Feasibility of the Project

The research work will cover two semesters starting from May 2013 to January 2013 which is sufficient to collect data and analyze the result. This study is planned to be started in FYP II and yes, it can be completed within the time frame as this study do not need complicated preparations, only the study and paper review which can be obtained and accessed by the internet and library in UTP. Lastly, this project can definitely be done within the time frame

CHAPTER 2
LITERATURE REVIEW

In order to fully understand the steps to complete this project, the study has been done on the simulation of the transient system which is Solar Heating Water System, through various sources internet journal, research papers, previous Final Year Students Projects and etc. The theory of the system components and energy calculation method also has been finding to complete the projects on successfully.

2.1) Conventional Water Heater VS Solar Hot Water Heater Usage

Throughout the decade, the solar hot water system is being used by people domestically to heat their water in order to reduce the dependency on the conventional water heater which used oil, natural gas as main energy sources to heat the water. By time, the fuel is increasing in prices and using solar to reduce the bills is proper way to harness the free energy which means lower electricity and oil use as a fuel. On average, heating water using solar system can reduces the bill from 50%-80%. [28].From Commonwealth Solar Hot Water Awarded Residential Projects Database, approximately up to 10,000 kBTU/yr-20,000 kBTU/yr of energy for system size range from 50-200 sq ft2 is saved annually.

Utilizing the solar how water system also gives the planet a lot of benefits. Solar hot water system is the same like solar-electric which helps to reducing the CO_2 emissions as conventional water heater use more energy to heat water. According to the engineers at the University of Wisconsin's Solar Energy Laboratory, such a 6,400 KWh of electricity is spent for four-person household with electric water heater. Assuming the typical power plant having 30% of efficiency, it means that an electric water heater is responsible for the emission of 8 tons of CO_2 annually which almost doubled the amount of CO_2 release by a typical modern automobile. From research that has been conducted, for example the analysis of solar domestic hot water system in Toronto show GHG emission is reduce up until 75% as the system is used [15]

Analyst also believes that the usage of conventional water heaters produces, annually, total CO_2 of the residential water heaters at North America approximately equal to CO_2 produced by the all cars and light trucks around the continent.

According to the study by the EESI (Environmental and energy study institute), total of 1.5 million solar water heater already in use in United States homes and businesses and estimates that almost 40% of homes in united states haves sufficient sunlight radiation access.[28]

2.2) Economy and Financial Perspective

- Cost Payback

At initial cost, the implementation and installation of the system can be quiet expensive. But in time, the benefit and profit it produced can be interested. Statistically, 100 flat plate collectors installed in Proximity Hotel, in North Carolina expected to get pay back within 5 years' time and Confederate Place Hotel in Canada save 10,000 dollar per year and expected payback cost in 3.5 years due to the increasing fuel price [29]. Most of the installed system even has a higher cost, it cost is covered within 5 years only

- Incentives

Government also plays its role in promoting the people to install the solar water system to their daily appliances. In United States, The U.S. Department of Energy and the North Carolina Solar Center has an DSIRE (Database of State Incentives for Renewables and Efficiency) to promote the implemented of the renewable energy

In Massachusetts, there are funding and program for encouraging people to implement the solar water system .Among them is;

- Massachusetts Clean Energy Center's Commonwealth Solar Hot Water Programs – Grants for residential and commercial solar hot water installations, and grants for commercial-scale feasibility studies. MassCEC has reserved $10 million of funding for the Commonwealth Solar Hot Water program, which will last until the end of 2016.
- Federal Tax Credit - A 30 per cent federal Investment Tax Credit (ITC) for qualified residential and commercial projects

The U.S. Department of Energy and the North Carolina Solar Center has a DSIRE (Database of State Incentives for Renewables and Efficiency) to promote the implemented of the renewable energy. For Malaysia, still there is no incentives program found for the personal installation. [29]

2.3) Solar Heating Water System

- System available

In Solar Heating Water System provide in the market now days, there are lots of configurations of the system and each system has different advantages and disadvantages. The system showed below is the Solar Domestic Hot Water system in the market. They are divided into several groups depending on two characteristics: [13]

Direct (Open Loop) VS Indirect (Closed Loop)

And

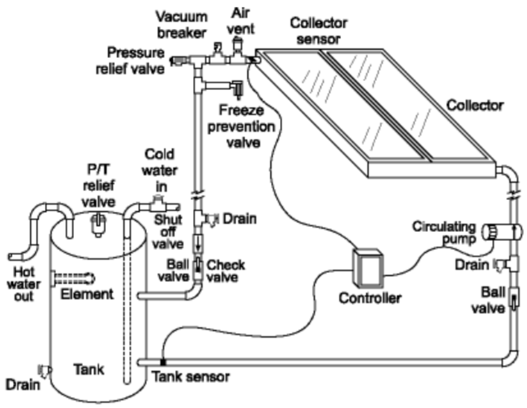
Passive VS Active

Direct or open loop is the system whereby the water you used is the water being heated **and Indirect or closed loop** is the system whereby the heat exchanger is used to transfer the heat from the solar collector fluid to the water in the main storage tank. The collector fluid is made from varies fluid, usually plain water or propylene glycol. The **Passive** means that the transfer of heat from the water is natural convection thus no outside energy is used to flow the water while **Active** means that there is pump(outside energy) is used to move fluids around in the system loop.

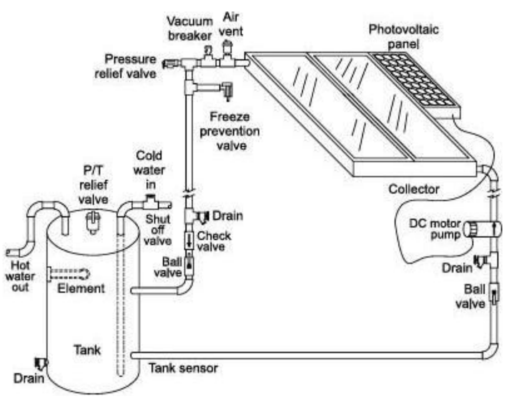
Different combinations of these two main characteristic produced the following major classifications of solar domestic hot water systems.

1. Direct (Open Loop) Active

a. Differential controller operated pump systems

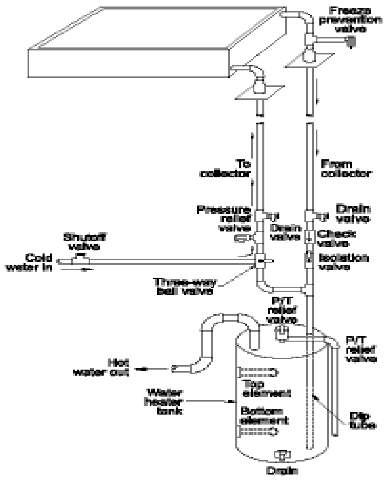


b. Photovoltaic operated systems

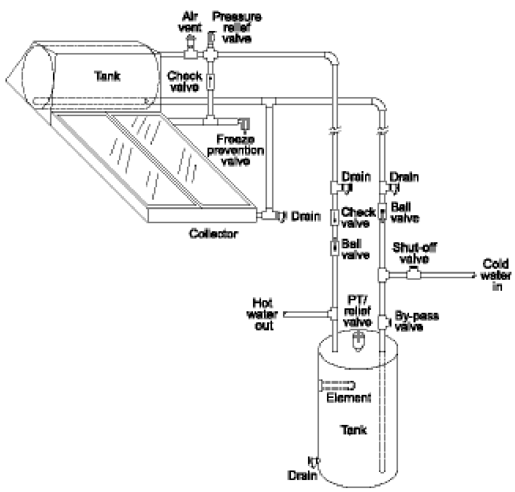


2. Direct (Open Loop) Passive

a. Integrated Collector Systems

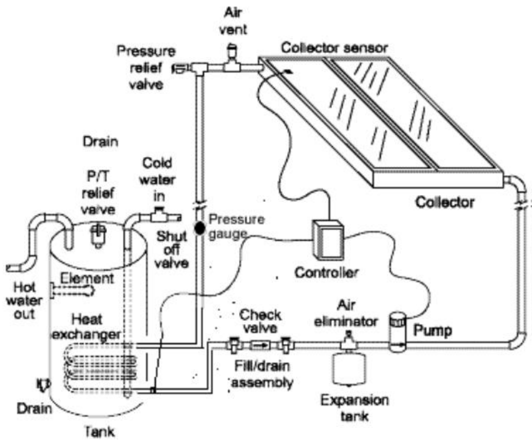


b. Thermo siphon Systems

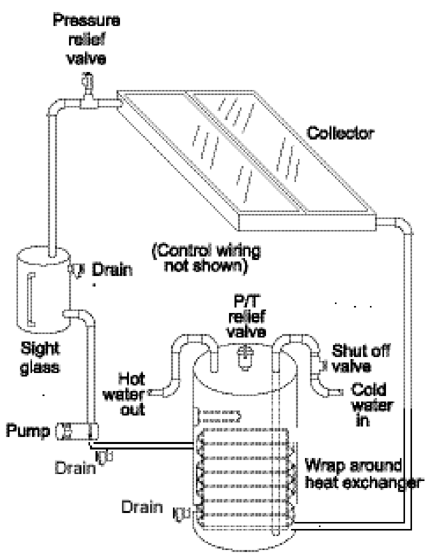


3. Indirect (Closed Loop) Active

a. Indirect controller operated pump systems



b. Drain back Systems



2.4) TRNSYS Simulation of Solar Hot Water System

There a lot of simulation of the Solar Domestic Hot Water system had done by numerous of researcher to see the pattern of how the solar system behaves for particular designed system.

To see the behavior of the system, researchers have to use experimental method in order to see the "actual" pattern on the system for example if we want to know the efficiency of the solar collector. However, using the experimental method could takes a long times. By using simulation, the output of the system can be expected if all the input parameter used is accurate.

Among the simulation done by the researcher using TRNSYS software:

i. Simulation Model In TRNSYS Of A Solar House From Brasov, Romania [24] simulates the energy analysis profile throughout the solar house which is provide with solar energy located in Tran Silvia University campus. The result show remarkable advantages on energy saving of the auxiliary heating energy components

ii. TRNSYS Simulation Of Solar Water Heating System In Iraq [30] paper show the verification of the direct solar water heating system of the hot water demand of 25 person using the auxiliary electric heater to analyzed it. The simulation proves that about 69% of annual solar fraction can be covered by the system.

iii. Solar Domestic Hot Water System Analysis Using TRNSYS [15] analyses the sensitivity analysis and system simulation of the Net Zero Energy Healthy Housing in Toronto. The sensitivity analyses study the electricity consumption of various components and GHG emissions annually. The study shows system gives 80% of reduction in electricity demand cost and GHG emissions compared to old system. The paper also stated that conventional water heater electricity demand increase with the hot water demand increases. For 100 liters of daily hot water demand, 479 kWh is needed.

2.5) Transient Systems Simulation Program

TRNSYS is software which has an ability to simulate transient and steady state system with a modular structure. Using the concept of equation solving program based on standard numerical techniques, this software recognizes a system description language in which the user specified it using the interactive component that make the system and the manner how are they being connected to each other. TRNSYS library have many components commonly used in the thermal and electrical energy systems, as well as the components to handle the input from outside the system such as weather data or other time-dependent forcing functions and output result. The modular natures of this software give its user the flexibility to alter and add new components to existing TRNSYS library. TRNSYS is really suitable to analyses the system whose behavior is changing over the time. For energy simulation system which is a transient system, TRNSYS has been used by engineers and researchers all over the world. Main applications of TRNSYS include: solar system (solar thermal and photovoltaic systems), low energy buildings and HVAC system, renewable energy systems, cogeneration, fuels cells [31].

The TRNSYS engine will calls the system components during the simulation at each time step based on the input file, called the deck file, until the iteration of the system's equation is solved. [31]

- Evacuated Tube Solar Collectors

This type of system features parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for commercial applications.

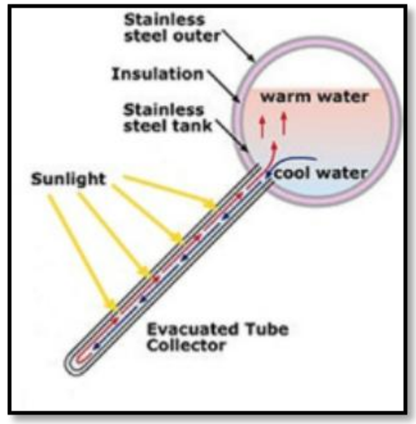


Figure 2: Picture of an evacuated tube collector *Figure 3: Cross section of evacuated tubes collector*

Mathematical model

The characteristic of each module determine the thermal performance of the collector array. The efficiency of solar collector is given:

$$\eta_{col} = \dot{m}.c_p(T_{out\ col} - T_{in\ col}) \,/\, A_{col}\, I_t \qquad (1)$$

Where:

$\eta_{col=}$ collectors efficiency

$\dot{m}$ = flow rate

C_p= fluid specific heat

$T_{out\ col}$ = outlet temperature of fluid from collector

$T_{in\ col}$= inlet temperature of fluid to collector

A_{col}= Collector area

I_t= Global radiation incident on the solar collector

- Heat Exchanger

Mathematical model

The capacitance of each side of the heat exchanger is calculated according to the following four equations:

$C_c = m_c\ C_{pc}$ (2)

$C_h = m_h\ C_{ph}$ (3)

C_{max}=maximum C_h and C_c (4)

C_{min}=minimum C_h and C_c (5)

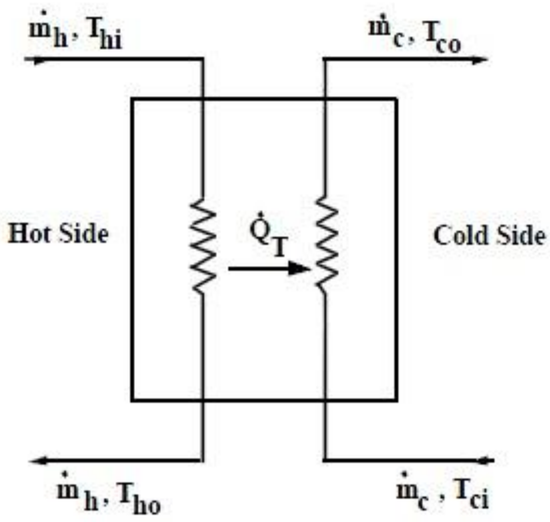


Figure 4: Schematic of heat exchanger

For counter flow configuration, the following expression used to calculate the heat exchanger effectiveness at each time step:

$$\varepsilon = \frac{1 - \exp\left(-\frac{UA}{C_{min}}\left(1-\frac{C_{min}}{C_{max}}\right)\right)}{1 - \left(\frac{C_{min}}{C_{max}}\right)\exp\left(-\frac{UA}{C_{min}}\left(1-\frac{C_{min}}{C_{max}}\right)\right)} \qquad (6)$$

Where:

Cc =capacity rate of fluid on cold side, mcCpc

Ch= capacity rate of fluid on hot side, mhCph

Cmax =maximum capacity rate

Cmin =minimum capacity rate

Cpc =specific heat of cold side fluid

Cph =specific heat of hot side fluid

ε= heat exchanger effectiveness

QT =total heat transfer rate across heat exchanger

Qmax =the maximum heat transfer rate across exchanger

UA =overall heat transfer coefficient of exchanger

N =number of shell passes

➢ Stratified Storage Tank

Mathematical model

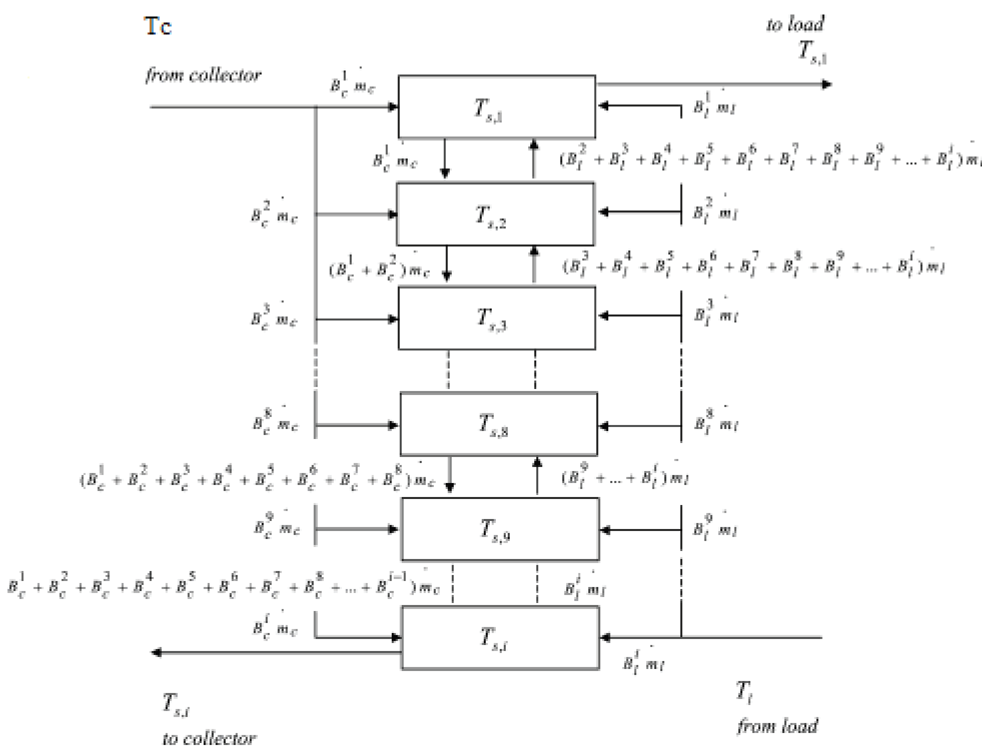


Figure 5: i nodes of the stratified storage tanks

B_c^i is a collector control function, which can be defined to identify which node receives water

From the collector: [31]

$$B_c^i = \begin{cases} 1 & if \quad T_{s,i-1} \rangle T_c \rangle T_{s,i} \\ 0 & other \end{cases} \quad (7)$$

B_l^i is a load return control function, which can be denote to identify which node receives water returning from the floor heating system.[31]

$$B_l^i = \begin{cases} 1 & if \quad T_{s,i} \rangle T_L \rangle T_{s,i+1} \\ 0 & other \end{cases} \quad (8)$$

The net flow between nodes can be either up or down depending upon the magnitudes of the collector and load. Flow rates and the values of the two control functions at any particular instant. It is convenient to define a mixed flow rate that represents the net flow into node i from node i − 1, excluding the effects of flow, if any, directly into the node from load.

$$\gamma_i = m_h \sum_{j=1}^{i-1} B_c^j - m_l \sum_{j=i+1}^{N} B_l^i \quad (9)$$

An energy balance on node i can be expressed as [31]:

$$m\, c_{p,i}(dT_{s,i}/dt) = U_i\, A_i\,(T_a - T_{s,i}) + B_c^i\, m_h\, cp_i(T_c - T_{s,i}) + B_l^i\, m_l\, cp_i(T_L - T_{s,i})$$

$$+\begin{cases} \gamma_i\, cp_i\,(T_{s,i} - T_{s,i+1}) & \text{if } \gamma_i < 0 \\ \gamma_i\, cp_i\,(T_{s,i-1} - T_{s,i}) & \text{if } \gamma_i > 0 \end{cases} \qquad (10)$$

2.6) System Sizing

As manufactures providing the proposal to install the solar heating water system at domestic level, they used an estimation of water draw profile. However, when the installation is at the hotel, the manufactures cannot estimate the water draw because of the large system. If we know the hot water draw profile, it can help to "properly-size" the system so that the system installed can be fully utilized. The collector area, the storage tank volume and flow rate must be properly sizes to get the optimum size of the system and generally, there is rule-of-thumb can be used to initially sized the system. Based on a study on solar hot water system design criteria, the SHWS optimized supposed to have area of collector of 0.8, 1.0 and 1.2 m^2 per occupant for hot water consumption of 40, 50 and 60 liters per occupants. [30]. The following is the rule-of-thumb suggested to size solar hot water system according to research in Faculty of Sciences and Techniques of University of La Rochelle [22];

i. Daily consumption of hot water.

   C_{max}(m) = (consumption/day/person)x(number of places)

ii. Surface area of the collector.

   The International standard requires $60 < C\ (m) / A < 100$

iii. Storage tank:

   The International standard requires $0.8 < V_s / C\ (m) < 1.2$

iv. Sizing of the hydraulic circuit.

   The flow rate is given by the following expression:

   $Q_{total} + q_{collector} \times A$

   Where $q_{collector}$ is the flow rate of the working fluid per square meter of collector.

2.7) Solar Collector Orientation Angle

For flat plate collectors, the incident angle of the sun ray hitting is different and varies throughout the day. It varies with time because of the sun path pattern causing the variation of solar radiation energy reaching the collector surfaces. The intensity of solar radiation decreases as the incident angle of the sun radiation is getting bigger. Figure 6 show the incident angle of flat plate collector and Figure 7 show the variation of angle and its intensity as the incident angle changes.

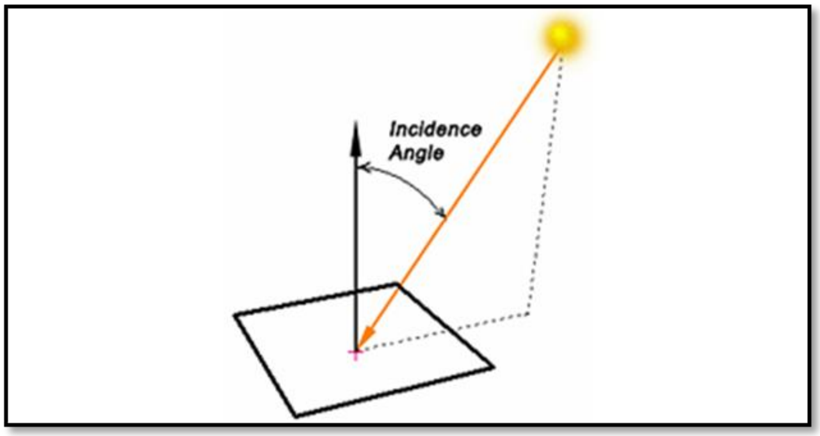


Figure 6: Incidence angle of the flat plate collector

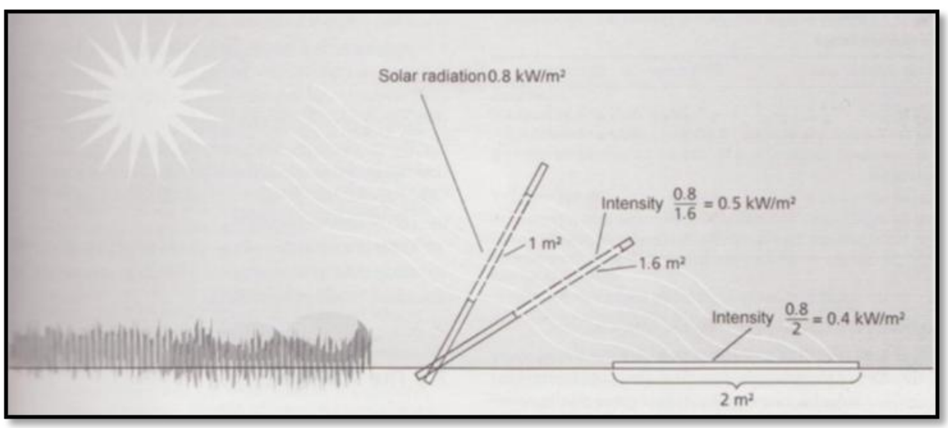


Figure 7: The variation of angle and intensity of solar radiation on a surface [8]

The solar reach the collector surface (flat plate) is decreasing when the orientation deviates more from the south direction and the optimum tilt. To obtain as much as solar radiation available at certain location, the exact orientation and tilt angle based on latitude can be decided. For location in Northern part of the Earth, the collector must be facing south and the tilt angle is the best at the latitude value of that particular location or 10-15 less than the latitude. [8]

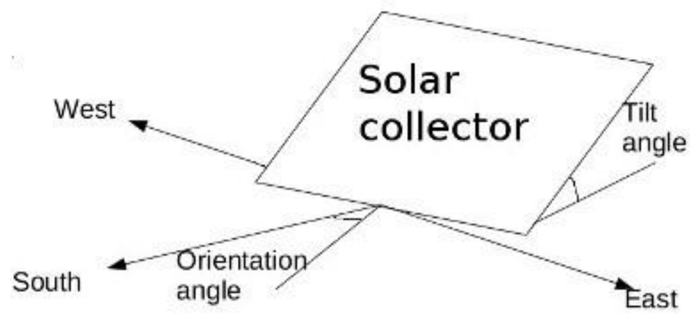


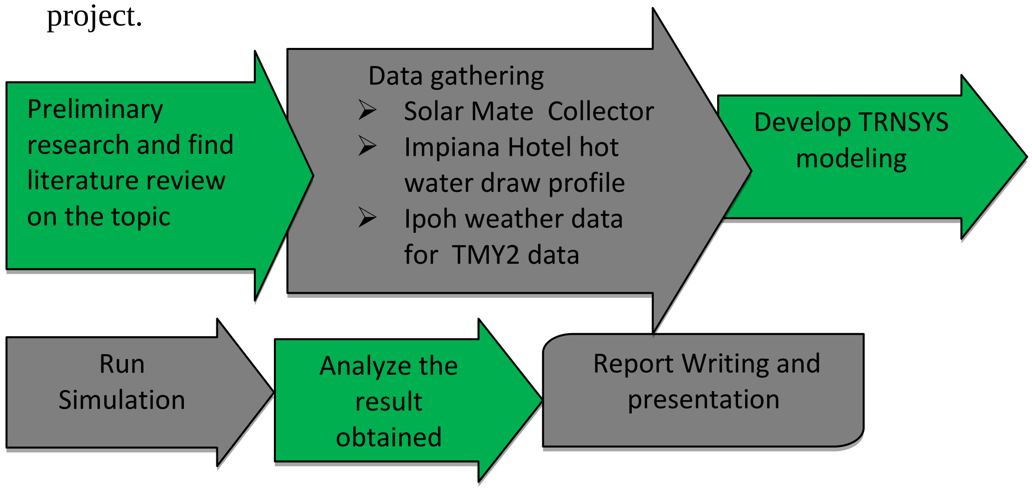
Figure 8: Tilt and orientation angle of the solar collector

Different season gives different optimum tilt and orientation for the solar collector because of the changing in sun path in a day [10]. There is exact calculation method to determine the exact orientation based on real time but it is not will be an attention in this study.

CHAPTER 3
RESEARCH METHODOLOGY

3.1) PROJECT FLOW CHART

There are some steps and procedures that are taken by the author to do this project. Figure 3.1 below is the methodology that the author uses to conduct this project.



3.2) PROJECT ACTIVITIES

Each stage of the methodology used to complete the project is described in detail in Table 1. The project activities will show a clearer picture on how the project is carried on throughout the completion.

Table 1: Project work description

METHODOLOGY	DESCRIPTIONS
Literature Review and Preliminary Research	Deep study regarding the solar radiation, the technology of Solar Water heating System, and the factor of affecting the effectiveness of the system is perform as well as the energy saving calculation method from solar.
Data Gathering	Collection and data gathering of the three main types of data needed for the

	simulation such as the specification of the manufactures Solar collector, solar radiation of Ipoh and hot water draw profile of the Impiana Hotel.
TRNSYS modelling development	The TRNSYS software is self-taught using the manual guide and TRNSYS model of the solar heating water system is develop using the commonly used existing components of the TRNSYS.
Simulation run and Result analysis	The system model is run for simulation and trouble shoot process is carried out to fix the error in the modelling. The result from the simulation is analysed to determine the energy saving obtained from the system configuration input. The result achieved will be discussed more in Chapter 4.
Final documentation	Outcomes of the project from the beginning will be documented for the future references.

3.3) Gantt Chart

The Gantt chart for the project is built for the guideline of timeline as show in the Table 2. The Gantt chart function is to monitor the project progress so that it will always on the schedule. The Gantt chart is flexible and can be changed from time to time depends on project's needs.

Below is the Gant chart that the author uses for this project. The duration for this project is approximately 40 day, starting from doing the preliminary research until the report writing and the documentation.

The Table 2 below shows the Gantt chart of the project.

No	Steps	Day																												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26-37	38	39	40
1	**Preliminary Research**	■	■	■	■	■																								
2	**Data Gathering** • **Manufactures product Specification** • **Weather data (solar radiation) in Ipoh** • **Hotel hot water draw profile**						■	■	■	■	■	■	■	■	■															
3	**TRNSYS learning**								■	■	■	■	■	■	■	■	■	■												
4	**Model TRNSYS development**										■	■	■	■	■	■	■	■	■	■										
5	**Simulation run And trouble shoot**																		■	■	■	■	■	■	■	■	■			
6	**Data analysis**																										■	■	■	
7	**Report Writing**																		■	■	■	■	■	■	■	■	■	■	■	■
8	**Presentation and Dissertation**																									■	■	■	■	■

3.4) DATA GATHERING

Data collection of the parameters listed is research and collected.

1. Monthly water cold temperature in Malaysia
2. The recent technology of the solar heating water system specification and configuration.
3. Average solar radiation is collected from the Minister of Meteorology of Malaysia
4. Hot water draw profile of Impiana Hotel in Ipoh were observed and collected

The data gathered has the major part as input of the TRNSYS simulation modelling to simulate the model the system installation behaviour

3.4.1) Solar How Water Manufacturers product Specification

- The specification is put as parameter in the TRNSYS simulation and obtained from the Malaysian Solar Hot Water manufacturer

- Evacuated tube:

TECHNICAL SPECIFICATIONS OF SOLAR COLLECTORS

DESCRIPTION	VACUUM TUBE
Length	1800mm
Outer tube diameter	Ø58mm
Inner tube diameter	Ø47mm
Material	Borosilicate Glass 3.3
Selective coating	Cu--SS--N/AL
Absorbance	≥0.93
Transmittance	≥0.89
Vacuum	5×10^{-3} Pa
Daily Solar absorbance	7.9 MJ/m2
Working pressure	0.7MPa

DESCRIPTION	VACUUM HEAT PIPE
Heat conducting pipe material	Copper
Heat conducting fin	Aluminium
Thermostability	≥250
Heat transfer coefficient	≥220 W
Isothermal performance	≤0.2°C
Length	1700mm

Table 3: Evacuated tube solar collector specification from Solar Mate(M) Sdn. Bhd.

3.4.2) Average solar radiation data in Ipoh

The data of solar radiation in Ipoh can be obtained from the Meteorological Department of Malaysia. The data intended to being used is the latest one from year 2011 converted from raw data (in Microsoft Excel) format into the TMy2 data format. TMY2 data format is the data format which can be read by the TRNSYS software for the simulation to run.

Currently in TRNSYS 17 version, the TMY2 data format for Ipoh region is not yet available. The author planned to use the actual data of the simulation region (Ipoh region) in order to get more accurate result on how much energy can be generated from solar hot water system if implemented on Ipoh area. The data needed from the Meteorological Department is in the hourly reading. It cost about RM 960. So, it is not feasible for the author to continue the uses of Ipoh data. The author decides to uses TMY2 weather data from Penang, Bayan Lepas as it is the closest weather data available in TRNSYS 17 weather library.

Records of Mean Daily Global Radiation							
Unit : MJm-2							
Month	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Year							
2010	17.84	18.77	18.69	17.61	16.79	13.48	18.24
2011	18.19	17.20	17.87	17.53	15.99	15.30	17.59
2012	19.01	18.05	17.95	17.31	17.92	15.35	18.12
Total	55.04	54.02	54.51	52.45	50.70	44.13	53.95
Average	18.34667	18.00667	18.17	17.48333	16.9	14.71	17.98333

Records of Mean Daily Global Radiation						
Unit : MJm-2						
Month	Jan.	Feb.	Mar.	Apr.	May	Jun.
Year						
2010	17.40	20.87	21.07	19.63	19.05	17.71
2011	15.12	20.16	17.85	18.70	18.39	18.76
2012	17.43	19.84	18.37	19.03	18.03	19.14
Total	49.95	60.87	57.29	57.36	55.47	55.61
Average	16.65	20.29	19.09667	19.12	18.49	18.53667

Table 4: Weather data of Ipoh from Meteorological Department of Malaysia

3.4.3) Hotel information- IMPIANA HOTEL in Ipoh

Figure 9: Impiana Hotel located in Ipoh

From the data gathering made by interviewing the staff and manager of the Impiana Hotel, the following is the information on the hotel. For the installation of solar collector, approximately there are 1350 m^2 of roof top area which more than enough space for the system installation.

Type of Rooms	No. of Rooms	Size (m^2)
Deluxe	99	24
Club	66	24
Premier	18	38
Suite	16	68
Royal Suite	1	280
TOTAL	200	

Table 5: The data on number of rooms of the hotel

The most important data for the project to obtain is the hot water draw profile of the hotel in average days. To be used as major input for the simulation

Methodically, for hotel or system which does not having water draw profile:-

1) Water flow rate readings

2) Temperature of the flow rate readings

This information must be collected to create the hot water draw profile. For Impiana Hotel, there is already having the readings of the daily hot water draw profile. The following table show the reading of the hot water draw profile reading in 24 hours. The reading is taken in 10 minutes interval. The reading for 1 hour average is calculated in the table for TRNSYS input.

TIME	minutes							
hour	10	20	30	40	50	60	total(GPH)	average(GPM)
1	0.8	0.6	0.7	1.1	0.6	0.7	4.5	0.75
2	0.8	0.55	0.5	0.7	0.55	0.4	3.5	0.58
3	0.5	0.4	0.35	0.4	0.45	0.45	2.55	0.43
4	0.4	0.4	0.35	0.35	0.7	0.6	2.8	0.47
5	0.45	0.4	0.45	0.45	0.45	0.45	2.65	0.44
6	0.45	0.5	0.55	0.6	0.6	0.6	3.3	0.55
7	0.75	1.2	1.4	1.45	1.8	2	8.6	1.43
8	2.5	4.05	3.85	4.05	3.5	3.5	21.45	3.58
9	4	4	3.2	3.75	3.3	3.75	22	3.67
10	2.5	2.3	1.85	1.6	1.3	1.5	11.05	1.84
11	1.6	2.3	2.25	2.1	1.95	2.4	12.6	2.10
12	2.5	1.25	1.2	0.9	1.1	1.5	8.45	1.41
13	1.65	1.65	1.5	1.35	1.6	1.7	9.45	1.58
14	1.55	0.95	1.2	1.4	0.5	0.5	6.1	1.02
15	1.2	1.25	1.7	1.5	1.1	1.35	8.1	1.35
16	0.8	0.75	0.6	1.05	1.2	0.9	5.3	0.88
17	0.8	1.2	1.25	0.7	1.1	1.1	6.15	1.03
18	1.2	1	0.7	1.2	0.7	0.65	5.45	0.91
19	0.8	1	1	1.1	1.05	0.8	5.75	0.96
20	1.15	1.1	1.55	1.6	1.3	1.6	8.3	1.38
21	0.95	1.4	1.4	2.05	2.1	2.35	10.25	1.71
22	1.6	1.15	0.95	1.65	2.1	2.35	9.8	1.63
23	1.8	1.8	2	1.3	1.2	2.2	10.3	1.72
24	1.55	1.4	1.1	1	1.05	1.1	7.2	1.20
					Total		195.6	32.60

Table 6: Average flow rate of hot water draw hourly on average day

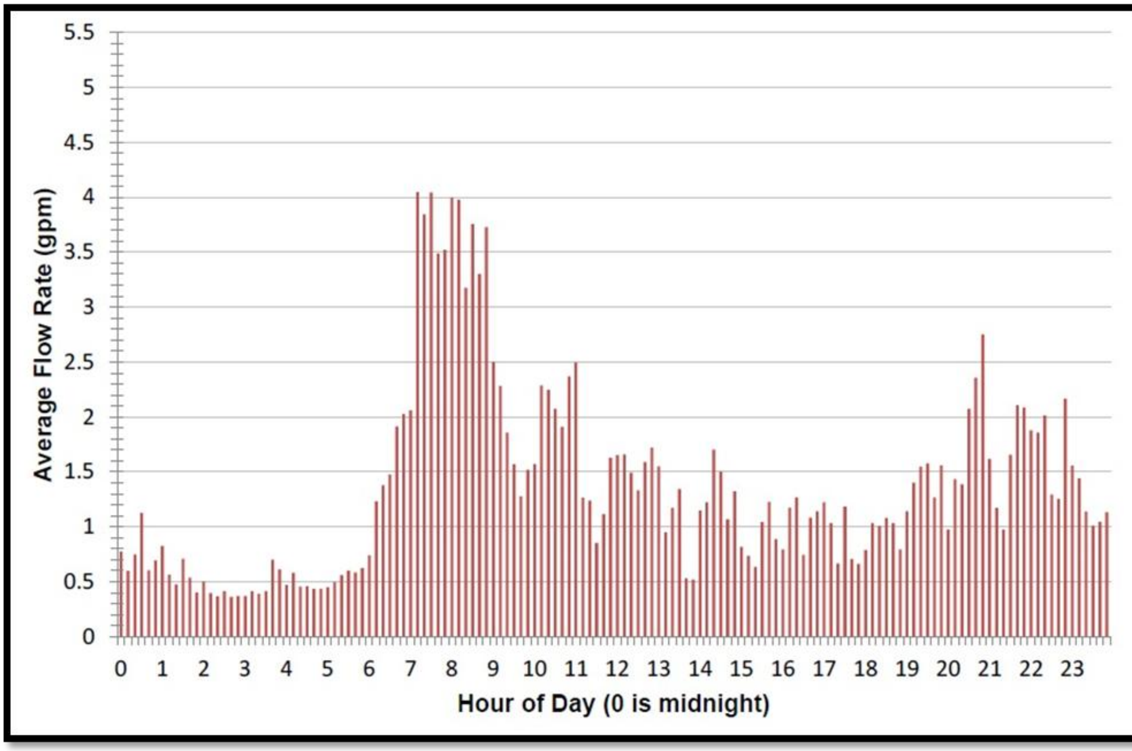


Figure 10: Average flow of hot water draw profile on all days

Figure 10 show that the peak hour rate for the average daily hot water draw profile is on between 7am – 9am and 8pm – 9pm. There are 2 peak hour rates but the first peak hour rate is considered as the required flow rate by the hotel water system to supply. The data of this hot water draw profile will be put into the time forcing component of TRNSYS to simulate the different of hot water volume demand over the time in a day basis.

3.5) TOOLS AND EQUIPMENT

The author uses some tools and software to finish up the project of Solar Heating Water System simulation.

1) Microsoft Excel

- Microsoft Excel is used to calculate the average of the hot water draw from the Impiana hotel. Simple mathematics formula is used in the Excel to help the author.

2) TRNSYS 17 simulation software

3.6) MODELLING AND SIMULATION OF THE SYSTEM

3.6.1) System Description and Parameter calculation

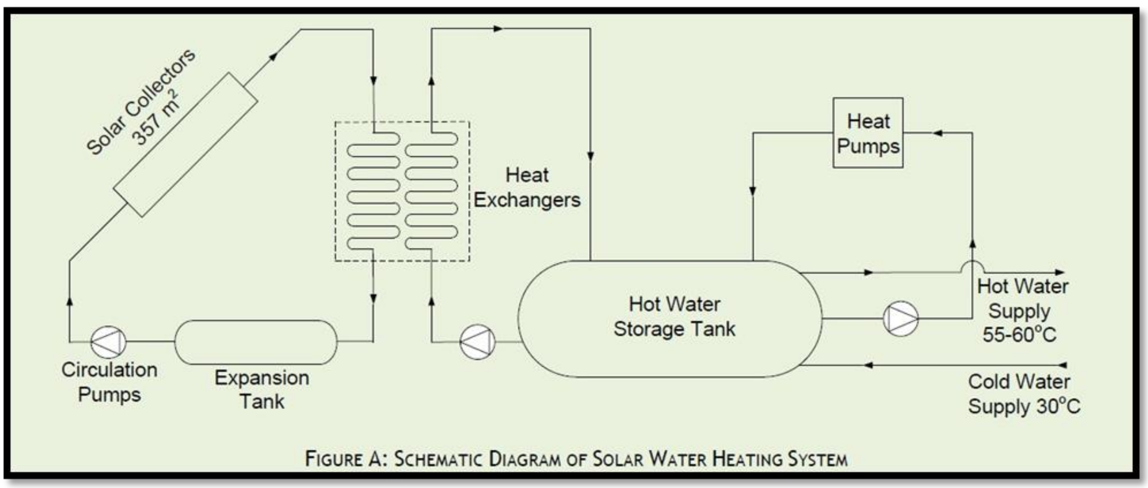


Figure 11: System schematic of Solar Hot Water System (SHWS)

3.6.2) TRNSYS Simulation Modeling

- **Parameter calculation**

Tank storage volume.

One person standard how water storage is 30 Liter.

Impiana Hotel= 200 rooms

Assume 100 occupancy (2 people/rooms);

Volume= 30L x 200 (2) =12,000 L

Solar Collector Area.

Rule of thumb is $1m^2$ of solar collector for 50L of water.

(12,000L / 50L)= 240 m^2 of solar collector area.

Flow rate of solar collector.

Rule of thumb is Total Area x 0.02 L/s

= 240 m^2 x 0.02= 4.8 L/s

The initial value based on rule of thumb of Storage Tank, Solar Collector Area and Flow Rate of Solar Collector is the input to the simulation modeling before the optimization took place**.**

Also, throughout the project completion, several assumptions must be made to simplify the calculation:

1) Person = 8~10 gallons/day of HOT WATER (not mixed) for shower

2) Shower temp 34~38 deg C

3) Ambient water 25~27 deg C

4) Heat loss negligible through the pipe system (insulated)

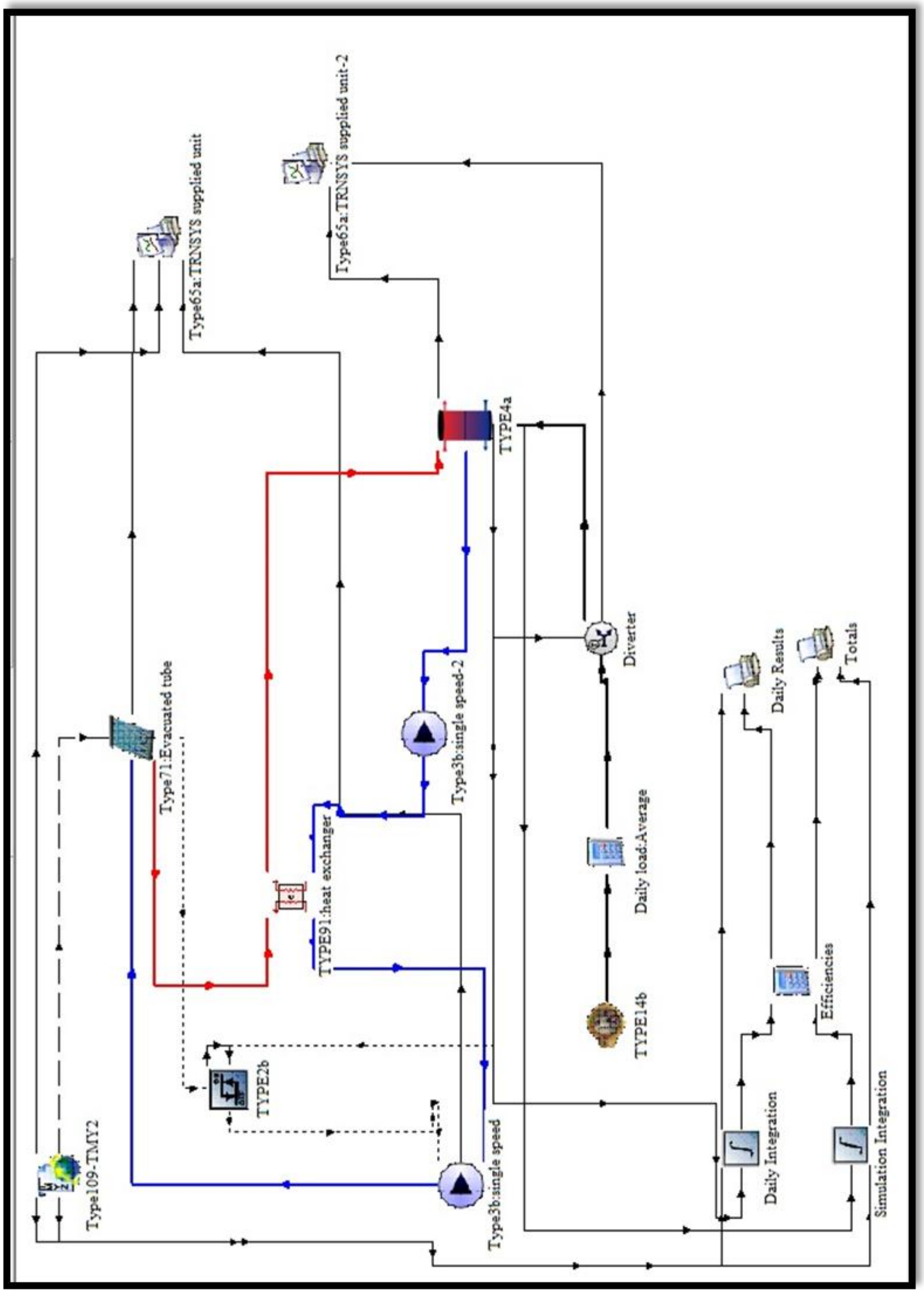


Figure12: TRNSYS modeling for schematic system chosen

CHAPTER 4
RESULT & DISCUSSION

4.1) Energy saving calculation:

Using equation of **$Q= (mc_p \Delta T)/3600$;** to know heat energy saved.

Example, $m_{flow\ rate}$ =200 liter/hr

Temp inlet= 26 °C – cold water

Temp outlet=67 °C

c_{p} , specific heat= 4.19

So, Q= [200 liter/hr x 4.19 x (67-26)]/3600= 9.5439 kWh

To get money value, multiply with electricity taarif, 0.32 cents per kWh.

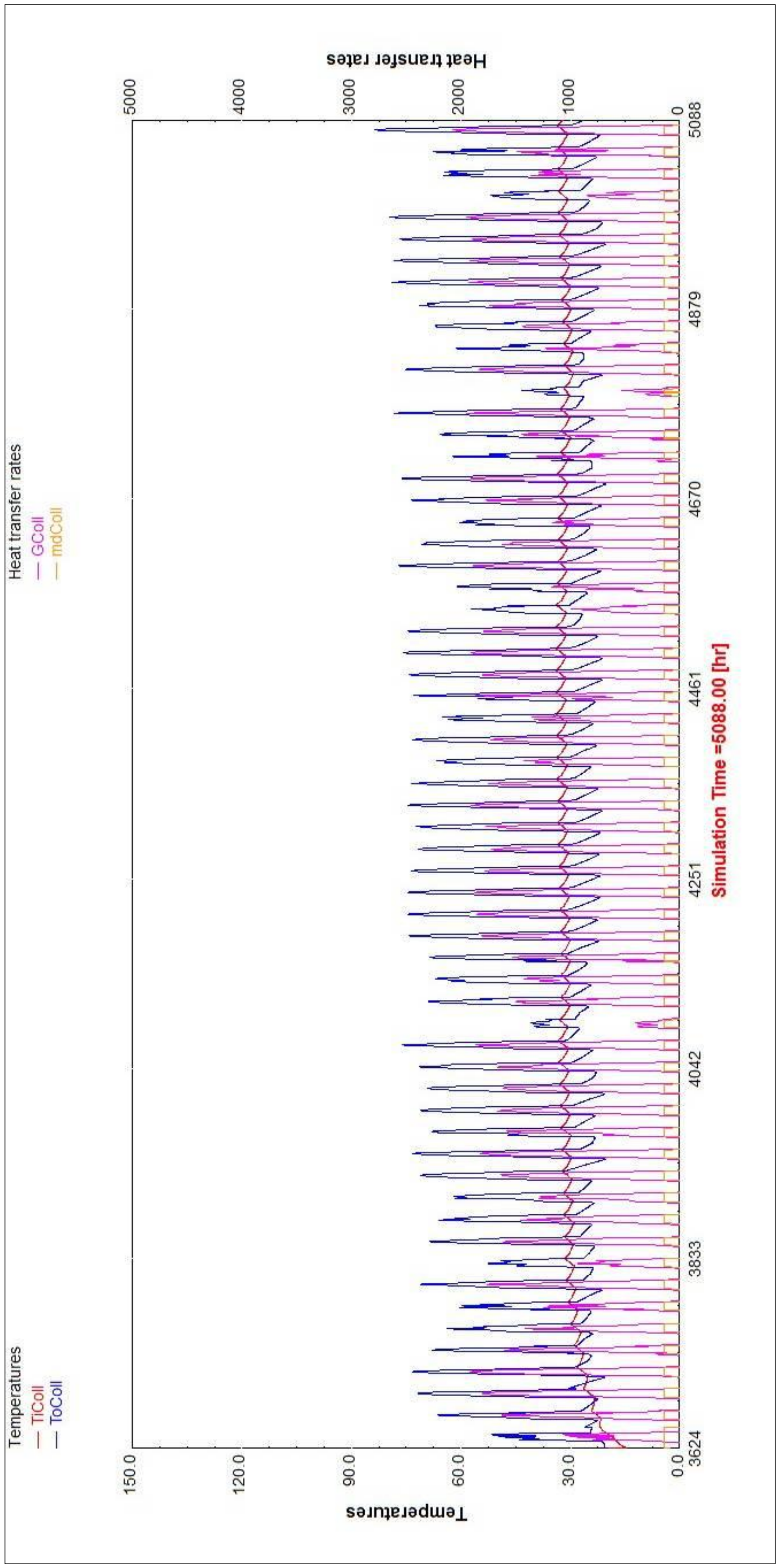


Figure 13: Simulation results Graph of the system modeled

CHAPTER 5
CONCLUSIONS

As stated in the objective and problem statement of the project, this project would help to determine the efficiency of the solar heating water system use to heat the water and generate the energy saving thus the cost saving also can be estimated before the system is installed. By using the real time weather data, the consecutive result simulated will give the accurate estimation compare weather data in the TRNSYS itself as it is does not represent the data of the real time weather data collected. And the actual hot water water draw profile could be use to properly sized the system as it can lower the initial cost of the installment and optimize the performance of the solar heating water system itself.

REFERENCES

[1]. J. M. Jefferson. “Global Climate Change and the Challenges for Renewable Energy”. Florence, Italy, 1998 (Pergamon), P. 1-7

[2]. N. S. Lewis, G. W. Crabtree, eds., “Basic Research Needs for Solar Energy Utilization: Report

[8] M. N. B. Othman, "Design and Development of Innovative Solar Water Heater," Universiti Teknologi Petronas, Tronoh, Perak 2010.

[10] E. A. Handoyo, "The Optimal tilt angle of a solar collector," presented at the International Conference on Sustainable Energy Engineering and Application [ICSEEA], 2012.

[13] W. Byrd. (2009, 20 November 2013). Types of Solar Domestic Hot Water Systems. 1-5. Available: www.lacleantech.net

[15] G. S. G. a. A. S.Fung, "Solar Domestic Hot Water System Analysis Using TRNSYS," Department of Mechanical and Industrial Engineering, Ryerson University, Ontario,Canada, 2012.

[22] R. D. M.Ahmad, M.Ajdour, M. El Metoui and R. Belarbi, "PREVIS 1.0:Easy Software for simulation and sizing of solar water heating system," Faculty of Sciences and Techniques, University of La Rochelle, France, 2007.

[24] C.Serban, "SIMULATION MODEL IN TRNSYS OF A SOLAR HOUSE FROM BRAŞOV,ROMANIA," Department of Renewable Energy Systems and Recycling, University of Braşov, Transilvania, 2011.

[28] (2011, 20 December 2013). SolarHotWater. Available: http://www.builtwellsolar.com/solarhotwater.html

[29] Hasek, G. (2009, March). Future Looks Brighter for Solar Hot Water Heating Systems at Hotels. Green Lodging News. Retrieved from http://www.greenerbuildings.com/feature/2009/03/18/solar-hot-water-heating-hotels?page=0%2C0

[30] Michaelides, I.M., & Wilson, D.R. (1996). Optimum Design Criteria for solar hot water systems. Renewable Energy, 9 (1-4), 649-652

[31]TRNSYS, University of Wisconsin, 16 November 2009, http://sel.me.wisc.edu/trnsys