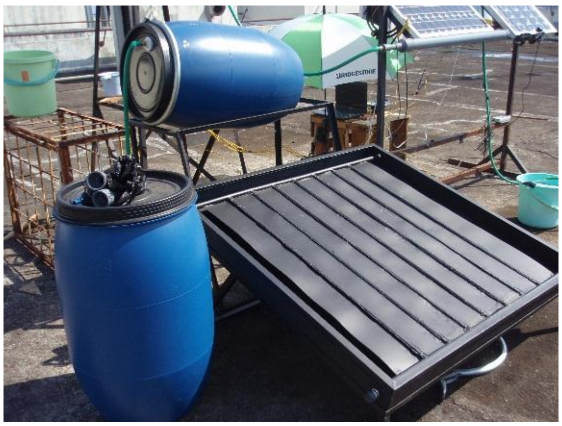
Solar energy in Indonesia

An internship report on solar water heaters and sustainable energy technologies in the area of Bandung.

By Kaj Pegels

8th of January 2014



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Preface

This report is part of the internship that I followed at the Institut Teknologi Bandung (ITB). The ITB is a technical university located in the city Bandung in Indonesia. The internship was part of the second year of the master program Sustainable Energy Technology at the University of Twente. During my internship I was supervised by Dr. Halim Abdurrachim who is one of the lecturers at the ITB and also my supervisor at the University of Twente (UT) Dr. Angele Reinders supported me during the internship.

On the 12th of August I left the Netherlands for my 4 month long internship. The main topic of my internship was solar energy and in specific solar water heaters. I had an individual assignment in which I made a model to simulate a solar water heater and I also did research which was mainly on the knowledge on solar water heaters and sustainable energy technologies of Indonesians living in a rural area and Indonesian students.

I choose to go to Indonesia because I really wanted to go to a developing country in South East Asia. Since I was born in the Philippines I have always been interested in going to a country in this part of the world. Therefor going to Indonesia for my study was a real good opportunity. The internship taught me a lot about my background. By going to Indonesia I learned a lot about the way that people live in this part of the world. Their culture, the climate and the country by itself are so different from the Netherlands and other western European countries.

I could not have fulfilled my internship at the ITB successfully without the help of other people. First I would like to thank my supervisor from the UT Dr. A.H.M.E. Reinders for getting me into contact with the ITB and for supporting me while I was there. I would like to thank Lambok Siregar for preparing me to go to Indonesia by teaching me some of the Indonesian language. Thanks to MSc Hans Veldhuis for giving me the data on the solar irradiation in Jayapura. Also special thanks to my college student Juan Carlo Sidabutar who has really helped me to get accustomed to the Indonesian way of living and for all his help during my internship. I would like to thank the other students at the department of thermal engineering where I worked most of the time which helped me in a number of cases and were a pleasant company. Furthermore I would like to thank the students at the Universitas Islam Negeri who helped me during my research there. Last but not least I would really like to thank my supervisor Dr. H. Abdurrachim at the ITB for guiding me during my stay in Indonesia and for all of his help during my project.

Summary

This report gives the results which have been obtained during the four month long internship project. The project took place in the region of Bandung which lies in West Java in Indonesia. The project consisted of two separate parts. The main topic of both parts are solar water heaters. This summary will shortly describe the contents of the project and will give the results which have been obtained.

In the first part of the project a model has been made of a solar water heater. The model is used to determine the area of the solar collector which is suitable for the project specific study case. The solar water heater which has been modelled is based on a solar water heater of which the performance characteristics were already determined. Also the solar water heater had two sources for heating up the water. Namely by the sun, as all solar water heaters do, but also by a built in oven to burn fuels which are locally available like wood or paper. The model has been made in the program MATLAB version R2013a. The outcome of the model is the temperature of the water inside of the solar water heater's storage tank during five days of using the solar water heater. Furthermore the model also gives the amount of fuel which had to be burned in order to keep the water temperature inside of the storage tank above 37 ℃, which is the minimum water temperature for showering, when the amount of available solar energy is too low. The model needs different input data namely the solar irradiance of five consecutive days, the user profile of the consumer using the warm water from the solar water heater during that five days and the lower heating value of the fuels which had to be burned. To determine the solar collector area three scenarios have been created for the model. The three scenarios differed in the size of the solar collector area (1, 2 and 3 m^2), the available solar irradiance and the location where the solar water heater would be placed. The important benchmark of simulations was the minimum water temperature for taking a shower which was 37 ℃.

The results of the solar water heater point out that the choice for a specific solar collector area size is not an exact science. A solar collector with a size of 2 m^2 is chosen for this project. With this collector size the frequency with which the water temperature is below the minimum water temperature is relatively low and the same holds for the fuel costs which are relatively low as well. For a collector size of 3 m^2 this would be even lower but it is assumed that this collector size will not be economically valuable.

In the second part of the project a small research has been done in the village Banjaran and at the university Universitas Islam Negeri (UIN). In Banjaran a questionnaire has been done and a field inventory and at the UIN a questionnaire was done. In Banjaran the questionnaire was done to find out if there is any need for solar water heaters and what the people their knowledge is on sustainable energy technologies. The conclusion of the research is that there is no need for solar water heaters in Banjaran. The performance of a solar water heater is not in line with the yearly water use profile of the people in Banjaran. The technology is new to the people and also warm water is seen as a luxury instead of a necessity. Sustainable energy technologies are new to the people of Banjaran. Thinking about the source of the energy that they use and the effects by using these energy sources to the environment is not of a concern to them.

The research done by the field inventory showed that solar water heaters can be produced in Banjaran by metal workshops. A price indication for the production costs has not been found. Therefor it cannot be said whether or not there is a business case for the production of solar water heaters in Banjaran. The production of solar water heaters can be done locally and also part of the materials can be bought locally as well.

The goal of the questionnaire at the UIN was to find out if there is any knowledge on solar water heater technology and if there is any knowledge on sustainable energy technologies. A large part of the students at the UIN know what a solar water heater is. There seems to be a knowledge difference on solar water heater technology between the different faculties. The questionnaire did not point out what the students their knowledge on solar water heaters is because the questions in the questionnaire were not adequate. The questionnaire was not designed for students but for the people in the village Banjaran. This made the questionnaire inadequate.

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1 Introduction

The subject of this project is sustainable energy technology and in specific solar energy. The human population has a significant impact on planet earth. Every day huge amounts of fossil fuels like natural gas and petroleum are being consumed. The creation of some of these fossil fuels took millions and millions of years. The earth's supply is limited and by the rate that fossil fuels are being used nowadays future generations might come into serious problems regarding their energy supply. Not only is the depletion of fossil fuels a serious threat for the worlds growing energy demand but also the pollution created by burning these fuels has serious environmental effects. These effects are witnessed both locally and globally. For example the air pollution coming from the chimneys of coal power plants which pollutes the air locally. The rise of the earth's surface air temperature which causes climate changes and a rising sea level are both global effects.

By using sustainable energy technologies like solar energy the usage of fossil fuels can be reduced significantly. In Europe one can see there is a growing tendency towards these energy sources. While driving car across the Netherlands one can see solar panels on the roof of one of the residences at almost every street. In the Netherlands the usage of sustainable energy sources are a growing trend but can the same also be seen in Indonesia?

The differences between a developed country like the Netherlands and a less developed country like Indonesia are vast. The climate, the economical state and the culture all differ. In this project which takes place in the city Bandung and the surroundings which lies in West Java in Indonesia a solar water heater, which is a device that heats up water by using solar energy, will be modelled by using the program MATLAB (version R2013a) and for a specific case the area size of the solar collector of the solar water heater will be determined. Also a small research has been done at two locations. The first location was the village Banjaran which lies in a rural area to the south of Bandung. Here research was done on the need for solar water heaters and on the knowledge on sustainable energy technologies of the people living in Banjaran. Also it has been determined if solar water heaters can be made locally in Banjaran and if there is a possible business case for local solar water heater production. The second location was at the university Universitas Islam Negeri which lies in the east of Bandung. Here research has been done on the students their knowledge on solar water heaters and sustainable energy technologies.

This report is divided into two parts. In the first part the model which is made to simulate a solar water heater will be discussed. First a literature study is done on solar water heater technology. After that the model which has been made to simulate the solar water heater will be discussed. Finally the simulations will be done, the results will be obtained and a conclusion will be given. The second part will discuss the research which has been done. First the research methods will be discussed and also a short summary on how the actual research took place will be given. After that the results which have been obtained will be given and will be discussed. Finally a conclusion on the research will be given.

2 Problem definition

Warm water has many uses. It can be used for cleaning or for heating. There are many ways to obtain warm water. For example a residence can be connected to the district heating where the warm water is generated by a combined heat and power cycle. Something which can be seen in numerous of cities in the Netherlands. Warm water can also be obtained by geothermal energy which for example is a common energy source in Indonesia where there is a lot of volcanic activity and therefor many hot springs can be found. The focus of this project is the production of warm water by using a so called solar water heater. A solar water heater can be used by a single household and is a sustainable way to create warm water. The power of the sun is used to heat up the water and therefore no (fossil) fuels have to be burned.

The project will be divided in two parts. In the first part a scenario has been assumed which resembles the conditions of a village in a rural area. Based on this scenario the size of a solar water heater for the village will be determined by doing some simulations. The second part consists of a small research in the village Banjaran and the Islamic university the Universitas Islam Negeri (UIN). The following three research questions will be answered by doing the research.

1. *Is there any need for solar water heaters in Banjaran?*
2. *Is there any knowledge on sustainable/green energy technologies?*
3. *Is there any knowledge on solar water heaters at the Universitas Islam Negeri?*

3 Methodology

The first step in this project is to do a literature research on solar water heaters. After the literature study a mathematical model will be made of a specific solar water heater. After some simulations with the mathematical model the size of the solar water heater will be determined. For the research also a literature study will be done on how to do a research in a developing country. After the literature study the research will be done by visiting two sites namely the village Banjaran and the university UIN. At the UIN a questionnaire will be done and in Banjaran both a questionnaire and a field inventory will be done. Finally the report will be presented in two separate parts. The first part consists of the solar water heater model and the simulations and the second part consists of the research which has been done.

Part I: Simulation

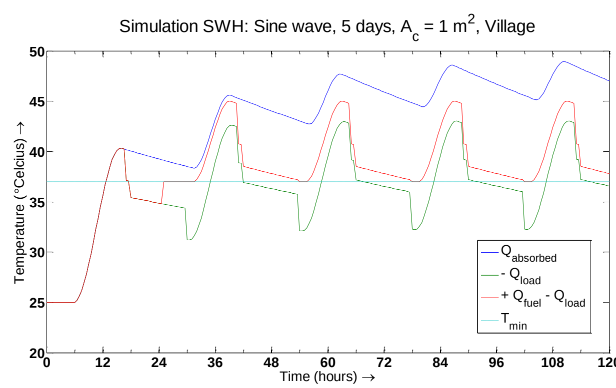
```
for t=0:k-1


    % Different CASES
    if Qs(t+1) == 0 && qload(t+1) == 0
        if Tstor(t+1) == T_amb
        % Qabsorbed + Qloss
        Qu = 0;
        Qloss = 0 ; % W

        else

        % Qabsorbed + Qloss
        Qu = 0 ;
        Qloss = Rtot*(Tstor(t+1)-T_amb) ; % W

        end
```



4 Introduction part 1

Utilizing the power of the sun for our daily needs is nothing new. Solar energy is the driving force for our planet. Solar energy can be used in many ways. To heat up water, to dry food or to create electricity are among the appliances of solar energy. This project focusses on solar water heaters. These devices are used to heat up cold water by the power of the sun in order to use it as shower water or cleaning water. Solar water heaters are used all over the world. In America, the Netherlands but also in the developing world. In principle the technology is really simple and can be made in most places by using local materials. Also the technology is not that expensive. This makes solar water heaters a relatively good technology to use in developing countries. There are different types of solar water heaters. For consumer use there are two main types of solar water heater collector technology. Solar water heaters with flat-plate collectors are the simplest technology. Here the heat absorber is a flat plate with copper or metal tubing to transport the water. The technology which is more common to use nowadays are evacuated-tube solar collectors. This technology is more expensive but also has a higher efficiency than flat-plate collectors. Furthermore the solar water heater can be a passive or an active system which means that the water circulation is regulated either by natural circulation or by a pumping system respectively. In developing countries the type of solar water heaters which are being used most often especially in rural areas are solar water heaters with flat-plate collectors and a passive system because they are relatively cheap, can be made locally and are simple. The type of solar water heater which will be simulated in this project is a passive flat-plate solar collector as well. In the following chapters the system which will be simulated will be explained in more detail. After that the solar water heater will be simulated and from these simulations the sizing of the solar water heater will be determined.

4.1 Introduction on the system

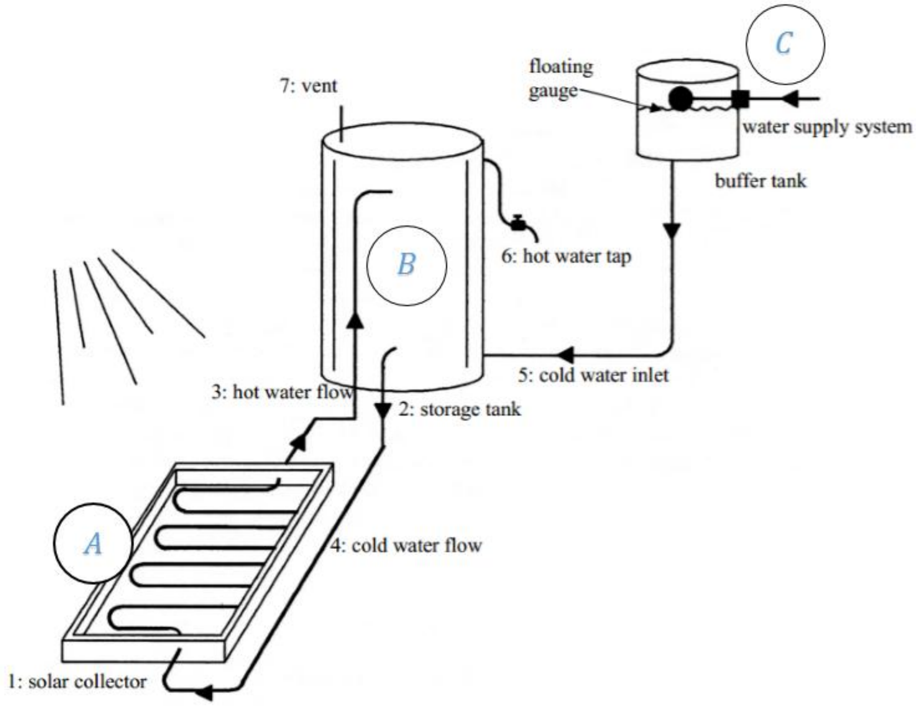


Figure 1 Schematic of a solar water heater (BACIBO, 2004)

Figure 1 gives a schematic of a solar water heater. The main components of the systems are a cold water reservoir (C), a solar collector (A), the stove and the warm water storage tank (B) which is placed within the stove. The focus of this project is on components A and B. In short the working principles of both of these components will be explained.

4.1.1 Solar collector

Figure 2 shows an exploded view of a solar collector. This is the part of the solar water heater where the heat is collected from the sun and transferred to the water. By placing the solar collector 0.4 m under the storage tank (Vanderhulst, Lanser, Bergmeyer, Foeth, & Albers, 1990) and with an inclination the water can flow via natural circulation. Water can be heated up to 60 ℃ or 80 ℃ (Julian Chen, 2011).

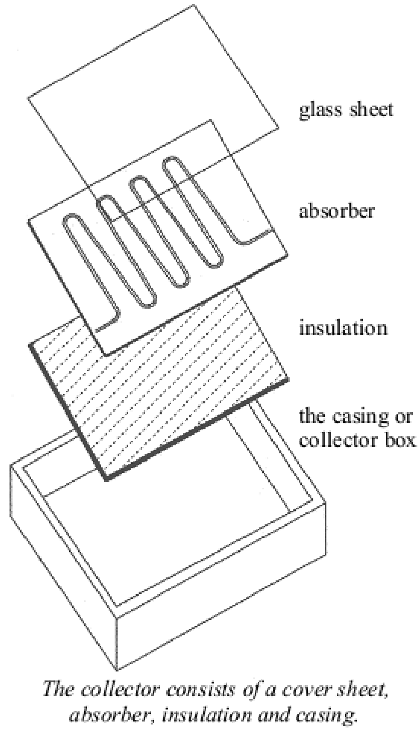


Figure 2 Solar collector

Three aspects of a solar collector are important with respect to its functioning (Engbers, 2002). The first aspect is absorption. Most of the radiance of the sun should be absorbed by the collector and heat loss by radiation of the solar collector should be as low as possible. The second aspect is reflection. The absorber should reflect as less as possible and the front plate should reflect the infrared light emitted by the absorber which creates a greenhouse effect in the solar collector box. The third aspect is isolation. Heat loss by conduction and convection should be minimized.

For this project a flat plate solar collector will be modelled. The ITB already has experience with this kind of solar collectors. Figure 3 gives an example of the type of solar collector which will be modelled. The focus of the project will be on determining the area size of the solar collector by using a model to calculate the water temperature within the storage tank.

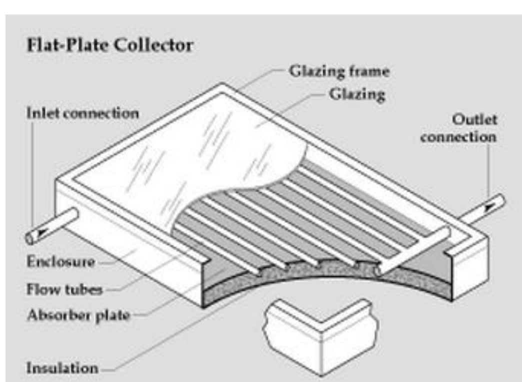


Figure 3 Flat panel solar collector, source: http://www.your-solar-energy-home.com/FlatPlateCollectors.html

4.1.2 Stove and storage tank

The storage tank setup for this project is not the typical setup. The storage tank will be placed in a stove, see Figure 4. The classical design exists of a storage tank only. The functions of the storage tank is to store the hot water and to be able to supply hot water on demand. The main design criteria's for the storage tank are the storage volume and the insolation. The storage tank for this project has a double function. It will function as a storage tank but also as a heat exchanger. When using the stove by burning local wastes like wood the water in the storage tank can be heated the whole day and is not depending anymore on solar energy alone. For this project the dimensions of the storage tank and stove are already fixed.

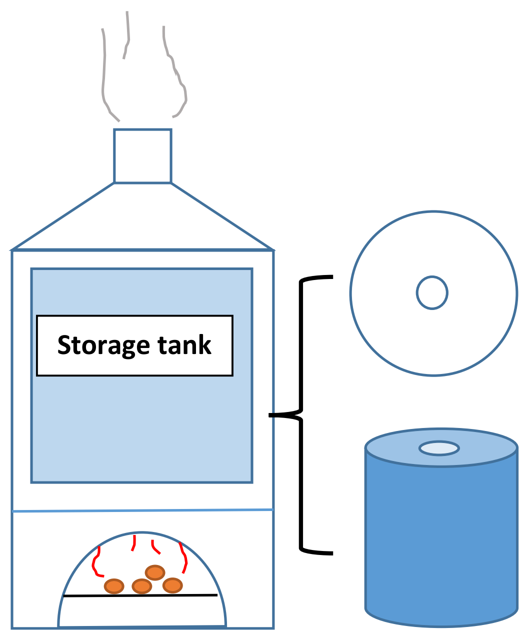


Figure 4 Storage tank in the stove

5 Modelling of the SWH

Under the supervision of Dr. Halim Abdurrachim numerous of projects have been done on solar energy technology as well as for solar water heater technology. Because of this the solar water heater which will be modelled for this project is similar to a solar water heater which was fabricated earlier. Therefor important design parameters like the solar collector's performance graph are known. Calculations, derivations and simulations are done in the following chapters. In the previous chapters it was already explained that the solar water heater exists of numerous of components, is used by people and the sun is the primary energy source driving the system. Therefor to model such a system these aspects need to be taken into account. The expected result of this chapter will be the area size of the solar collector (the absorber) which is needed to collect a certain amount of solar energy to heat up the water.

5.1 Energy balance of the solar water heater

To determine the suitable area size of the solar collector an energy balance has to be solved. Figure 5 shows the energy flows in the system. The solar collector absorbs solar energy (Q_s). The water will be heated and will start to circulate. Hot water then enters the storage tank. Here the water will be mixed with cooler water. The storage tank loses energy by conduction and natural convection (Q_{loss}) to the environment. Fuel for the stove will heat up the water when the temperature is to low (Q_{fuel}). Warm water will be used by the users (Q_{load}).

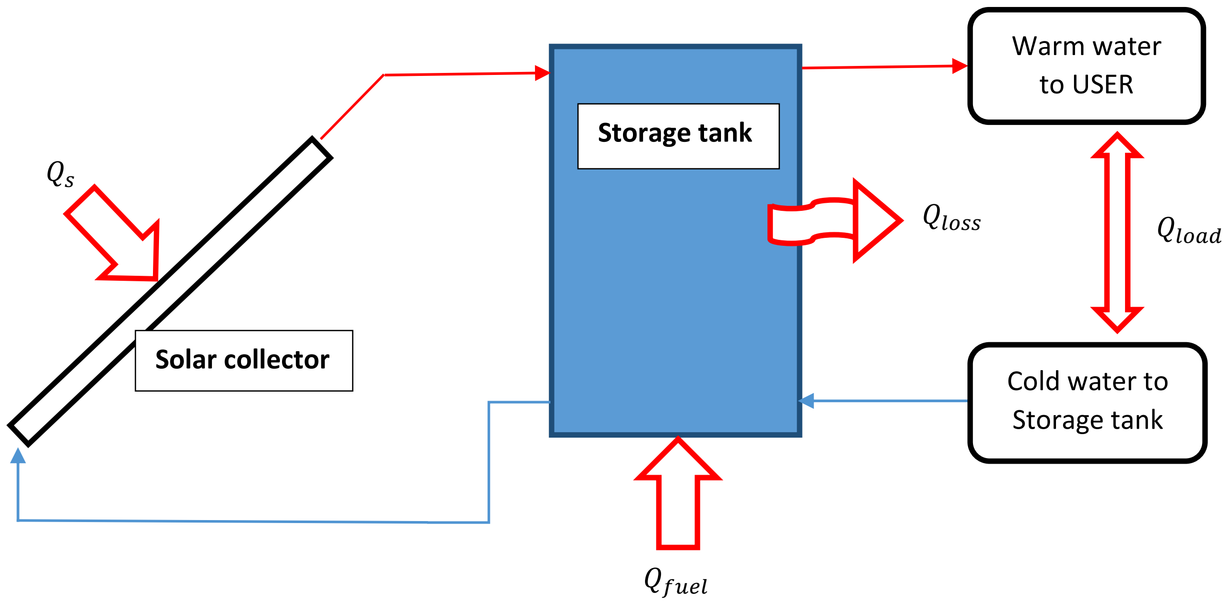


Figure 5 Energy flows of the SWH

The energy balance equation for the storage tank is given by:

$$Q_{storage\ tank} = Q_{absorbed} + Q_{fuel} - Q_{load} - Q_{loss} \qquad (5.1\text{-}1)$$

With,

$Q_{storage\ tank} = The\ energy\ input\ into\ the\ storage\ tank, (J)$

$Q_{absorbed} = The\ energy\ absorbed\ by\ the\ solar\ collector\ and\ added\ to\ the\ storage\ tank,\ (J)$

$Q_{fuel} = The\ energy\ input\ due\ to\ the\ burning\ of\ a\ fuel\ in\ the\ stove, (J)$

$Q_{load} = The\ energy\ output\ of\ the\ storage\ tank\ by\ usage\ of\ warm\ water, (J)$

$Q_{loss} = The\ energy\ loss\ of\ the\ storage\ tank\ to\ the\ environment, (J)$

By solving equation (5.1-1) the temperature within the storage tank can be determined by assuming a certain area size of the solar collector. In the following chapters the terms in the energy balance will be explained and determined where possible.

5.2 Absorbed energy

The energy which is absorbed by the collector ($Q_{absorbed}$) can be determined by using the performance curve of the solar collector. The performance curve used in this project is given by (Lim, 1989).

The performance curve of a solar collector is given by the following function (Anderson, 1983):

$$\eta_c = F_R \tau \alpha - F_R U_L \frac{T_{in} - T_{amb}}{q_s} \qquad (5.2\text{-}1)$$

With,

$\eta_c = The\ collector\ efficiency, (-)$

$T_{in} = The\ temperature\ of\ the\ water\ from\ the\ storage\ tank\ going\ into\ the\ collector, (°C)$

$T_{amb} = The\ temperature\ of\ the\ surroundings, (°C)$

$q_s = The\ solar\ irradiance, (W/m^2)$

$\tau = The\ transmissivity\ of\ the\ collector\ for\ the\ given\ solar\ irradiance, (-)$

$\alpha = The\ absorptivity\ of\ the\ collector\ for\ the\ given\ solar\ irradiance, (-)$

$F_R = The\ collector's\ heat\ removal\ factor, (-)$

$U_L = The\ collector's\ overall\ heat\ transfer\ coefficient, (W/m^2 \cdot °C)$

According to the performance curve the efficiency of the solar collector depends on the ratio $\frac{T_{in}-T_{amb}}{q_s}$ while the factors $F_R \tau \alpha$ and $F_R U_L$ stay constant.

The performance curve of the solar collector in this project is given by:

$$\eta_c = 0.645 - 15 \cdot \frac{T_{in} - T_{amb}}{q_s} \qquad (5.2\text{-}2)$$

In Figure 6 the performance curve is given.

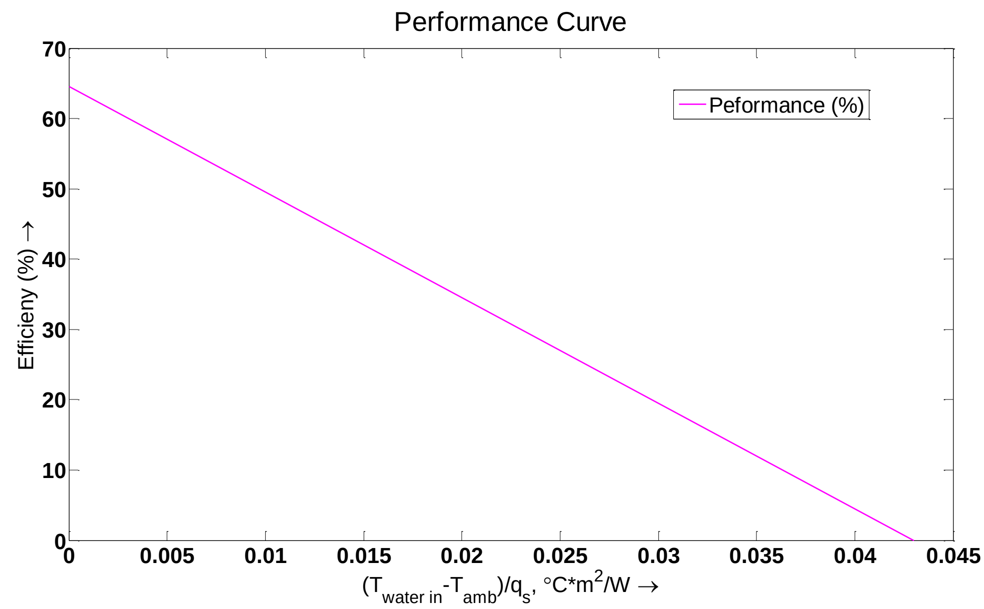


Figure 6 Performance Curve: solar collector

Because equation (5.2-2) does not contain any unknowns the efficiency of the collector (η_c) can be determined. Then the energy which will be absorbed by the solar collector ($Q_{absorbed}$) can be determined by using the following equation:

$$Q_{absorbed} = q_s \cdot A_c \cdot \eta_c \cdot dt \qquad (5.2\text{-}3)$$

With

$A_c = The\ area\ of\ the\ solar\ collector, (m^2)$

$q_s = The\ solar\ irradiance, (W/m^2)$

$\eta_c = The\ collector\ efficiency, (-)$

$dt = The\ change\ in\ time, (seconds)$

In the introduction, see Chapter 5, it was told that (A_c) is the design parameter which has to be calculated for this assignment. By assuming an A_c the water temperature in the storage tank can be determined and based on these results a suitable solar collector area can be determined.

5.3 Solar irradiance

The sun is the main power source driving the solar water heater. To determine the energy input to the solar water heater data on the solar irradiance (W/m^2) should be known. Since the solar irradiance is different every day an average of for example of the past five years, could be used to have a clear picture on the amount of solar irradiance which will be available. Also during the rainy season it can rain all day and the amount of solar irradiance is very low thus the solar water heater will not be applicable without the use of an external energy source like using the stove as in this assignment.

For the solar irradiance three models will be used for the simulations. The models will consist of five full days of solar irradiance. This will give a clear picture of the water temperature inside the storage tank during an extended period of time. The first model will represent a period with a clear sky. This will be modeled by using a sine wave function. The second model is obtained from solar irradiance data of a test site in Jayapura the capital city of Papua on the island of New Guinea. This data was collected in the month of July and is used because of the fact that it is in Indonesia and there is a relatively long period of time of solar irradiation data available. The third solar irradiance model is also based on a sine wave function only this time the first day represents a cloudless day and the four consecutive days represent clouded days.

5.3.1 Solar irradiance model: Sine wave

The solar irradiance during a cloudless day can be modelled by using a sine wave function. In Indonesia the sunrise is around six am. At approximately twelve am the sun is at its highest point and at six pm it will be sunset. The following function has been used to model the solar irradiance.

$$q_s = q_s^{max} \cdot \sin\big((\pi \cdot (t-6))/12\big) \qquad (5.3\text{-}1)$$

With,

$q_s = The\ solar\ irradiance\ at\ time\ is\ t, (W/m^2)$

$q_s^{max} = The\ maximum\ amount\ of\ solar\ irradiance, (W/m^2)$

$t = The\ time\ from\ 6\ am\ until\ 6\ pm, (time\ in\ hours)$

The figure below, Figure 7, shows the solar irradiance during one day. For simulating more than one day the same graph applies only repeated. The solar irradiance during night time will be set to zero. During the day the maximum amount of solar irradiance (q_s^{max}) will be 800 W/m^2.

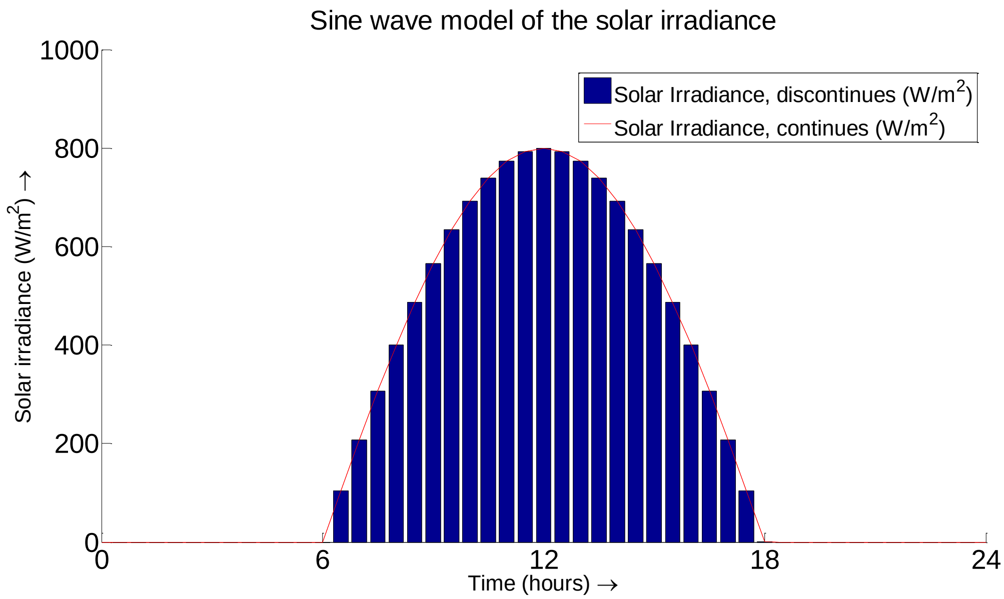


Figure 7 Solar irradiance: Sine wave model

5.3.2 Solar irradiance model: Jayapura

The Jayapura solar irradiance data was obtained from MSc. Hans Veldhuis who is a PhD-student at the University of Twente. The data contained the global horizontal irradiance during the whole month of July 2013 in Jayapura. Every minute a measurement has been taken. The global horizontal irradiance (w/m^2) is the direct and diffuse solar irradiance on a surface horizontal to the surface of the earth. For the simulations solar irradiance measurements of the 11th until the 15th of July will be used. Figure 8 shows the solar irradiance during that period of time.

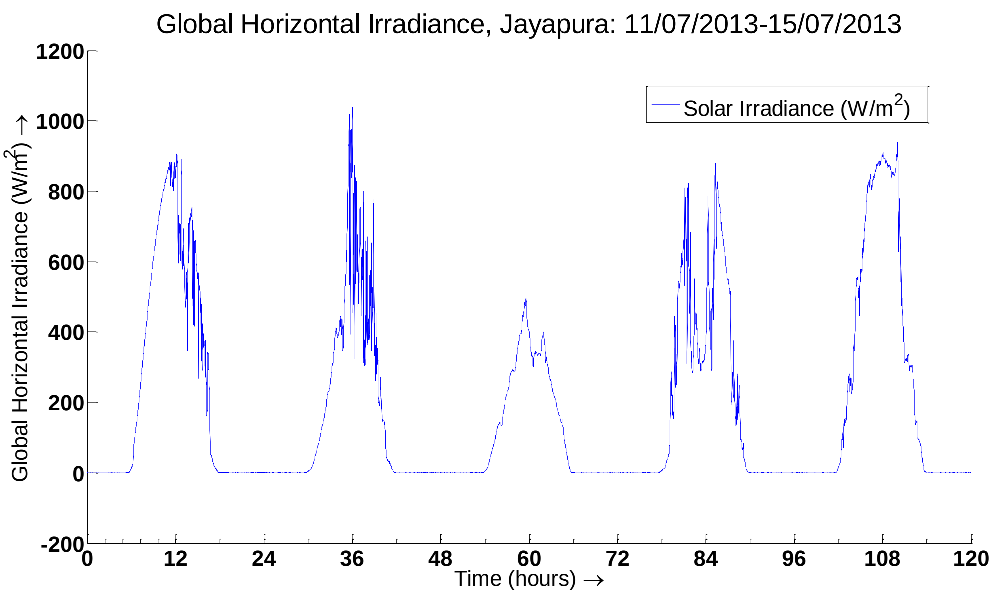


Figure 8 Solar irradiance: Jayapura model

5.3.3 Solar irradiance mode: Modified sine wave

The modified sine wave gives the solar irradiation of one cloudless day followed by four consecutive clouded days. The modified sine wave is made by the same way as the sine wave model of Chapter 5.3.1. The only difference is that the maximum solar irradiance for day two until five will be 200 (W/m^2). Figure 9 gives the solar irradiance of the modified sine wave.

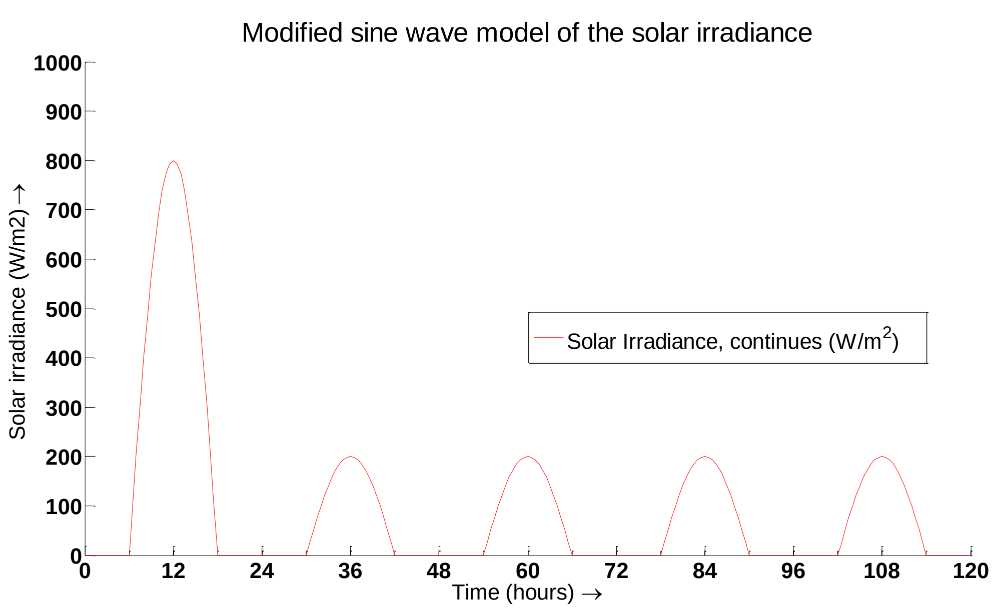


Figure 9 Solar irradiance: modified sine wave model

5.4 Heat loss

The cylindrical storage tank will be insulated but some heat loss is inevitable. For the simulation it is assumed that heat loss will occur only at the sidewalls. Figure 10 gives a cross-section of the wall of the storage tank. Equation (5.4-1) gives the heat loss as a function of the temperature of the stored water and equation (5.4-2) gives the total amount of heat loss.

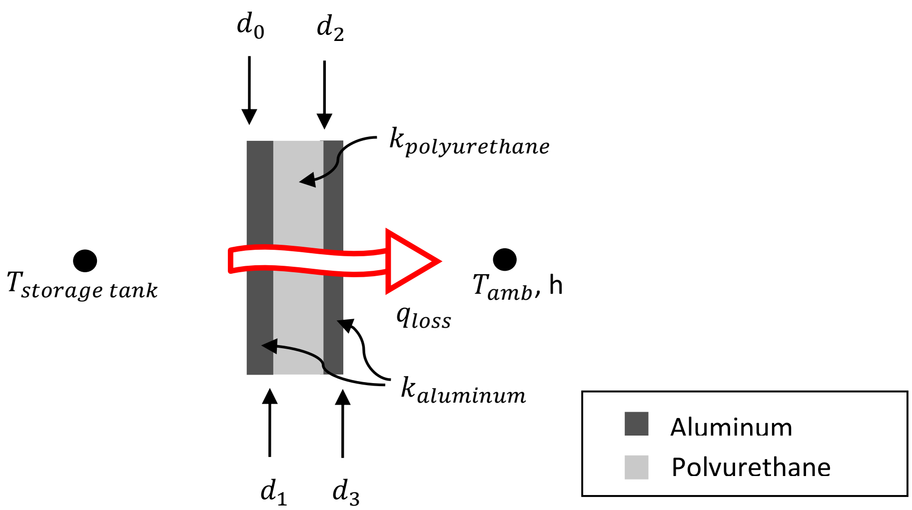


Figure 10 Cross-section of the storage tank

$$q_{loss} = \frac{(T_{storage\ tank} - T_{amb})}{\frac{\ln d_2/d_1}{2\pi H \cdot k_{polyurethane}} + \frac{\ln d_1/d_0}{2\pi H \cdot k_{aluminum}} + \frac{\ln d_3/d_2}{2\pi H \cdot k_{aluminum}} + \frac{1}{2\pi r H \cdot h}} \quad (5.4\text{-}1)$$

$$Q_{loss} = q_{loss} \cdot dt \quad (5.4\text{-}2)$$

With,

$k_{aluminum} = The\ constant\ of\ thermal\ conductivity\ of\ aluminum, (W/m \cdot °C)$

$k_{polyurethane} = The\ constant\ of\ thermal\ conductivity\ of\ polyurethane, (W/m \cdot °C)$

$h = The\ constant\ of\ convective\ heat\ loss, (W/m^2 \cdot °C)$

$d_n = The\ diameter\ of\ each\ section\ n\ of\ the\ storage\ tank\ wall, (m)$

$H = The\ height\ of\ the\ storage\ tank, (m)$

$q_{loss} = The\ energy\ flux\ lossed\ to\ the\ environment\ by\ the\ storage\ tank, (W)$

$Q_{loss} = The\ energy\ loss\ of\ the\ storage\ tank\ to\ the\ environment, in\ (J)$

$dt = The\ change\ in\ time, (seconds)$

$T_{storage\ tank} = The\ temperature\ of\ the\ warm\ water\ in\ the\ storage\ tank, (°C)$

$T_{amb} = The\ temperature\ of\ the\ surroundings, (°C)$

Table 1 shows the constants which have been used in the simulation. The thermal and conductive coefficients are assumptions and the length units have been found by measuring the actual storage tank.

Table 1 Heat loss parameters

Property	*Value*
$k_{aluminum}$	205 $W/m\cdot$°C (engineering toolbox, 2013)
$k_{polyurethane}$	0.02 $W/m\cdot$°C (engineering toolbox, 2013)
h	100 $W/m^2\cdot$°C (Moran & Shapiro, 2007)
d_0	$44.3\ cm$
d_1	$44.5\ cm$
d_2	$48.5\ cm$
d_3	$49.5\ cm$
H	$100\ cm$

5.5 Load

A solar water heater will not stand idle but will be used. After asking around some of the students at the ITB it was concluded that warm water usage in villages will mainly be for showering. Cleaning the house or doing the dishes is done with cold water. For the loading profile for the solar water heater some assumptions have been made.

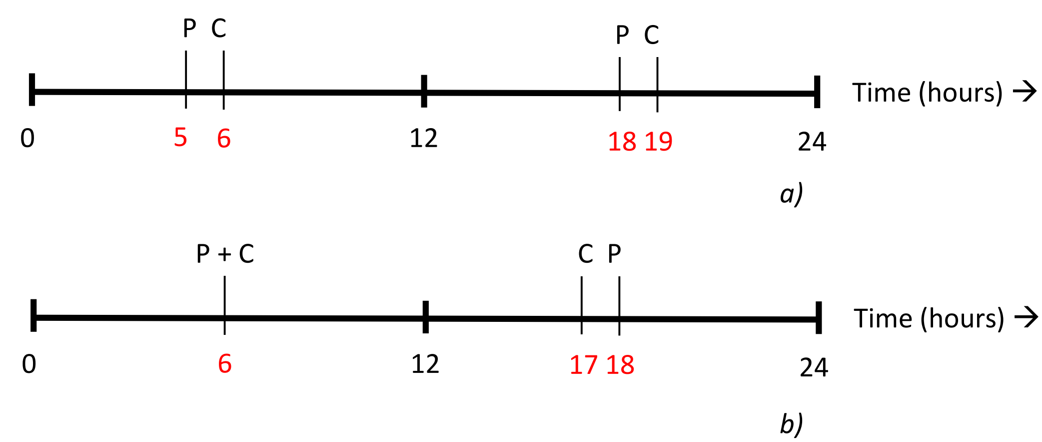


Figure 11 Timeline showering: Children (C) and Parents (P), a) City b) Village

The solar water heater will be used by one family. The family consists of a mother, a father and three children. After having spoken to Carlo Sidabutar who is a student at the ITB it was concluded that the family members shower two times a day. Once in the morning before going to school or to work and once in the evening after coming back from school and work. Figure 11 gives two timelines for when the shower will be used. One is in an urban area and the other is in a rural area. The difference is made because of the fact that in the urban area the time to travel to the work and back will take more time on average therefor they wake up earlier and it will take more time for them to get back home. Children have school from 7 am in the morning therefor they will shower around 6 am.

In Indonesia a lot of people use a so called gayung, which is a small water bucket, instead of a shower head for showering. For this model it is assumed that the people use such a gayung and for one shower they use about twenty times this gayung filled with one liter of water. The total water usage is scaled down because the solar water heater (SWH) which is modelled in this project has a smaller storage tank. A storage tank of 300 liter is enough for a normal family (according to Dr. Ir. Halim Abdurrachim). The storage tank size in this project is approximately 140 liter. Scaling down gives the following factor: $f = 140/300$. Table 2 gives the loading profile of both the City and Village profile.

Table 2 Loading profile: hot water usage

	Water usage (liter)	
Time (hour)	*Village*	*City*
5		$40 \cdot \mathrm{f}$
6	$100 \cdot \mathrm{f}$	$60 \cdot \mathrm{f}$
17	$60 \cdot \mathrm{f}$	
18	$40 \cdot \mathrm{f}$	$40 \cdot \mathrm{f}$
19		$60 \cdot \mathrm{f}$
Total	$200 \cdot \mathrm{f}$	$200 \cdot \mathrm{f}$

The following equation is used to determine the energy loss by using warm water from the tank.

$$Q_{load} = M_{load} \cdot c_p \cdot (T_{storage\ tank} - T_{amb}) \tag{5.5-1}$$

With,

$M_{load} = The\ amount\ of\ water\ used\ and\ refilled, (kg)$

$Q_{load} = The\ energy\ lost\ by\ using\ the\ warm\ water, (J)$

$T_{storage\ tank} = The\ temperature\ of\ the\ warm\ water\ in\ the\ storage\ tank, (°\mathrm{C})$

$c_p = The\ heat\ capacity\ of\ water, (J/kg \cdot K)$

$T_{amb} = The\ temperature\ of\ the\ surroundings, (°\mathrm{C})$

5.6 Fuel

The minimum amount of fuel which is needed for the SWH is based on the minimum temperature of the water in the storage tank. For the minimum temperature see Appendix I. The amount of fuel which is needed depends on the solar irradiance, the water usage, the efficiency of the oven and the fuel type. The solar irradiance and the water usage have been discussed in Chapter 5.3 and Chapter 5.5 respectively.

5.6.1 Fuel type

Local materials will be used as fuel. Materials which can be used are paper, leaves, crops residues and wood. Table 3 shows the materials which are used for this model. The lower heating values (LHV) have been obtained from (ECN; Phyllis2, 2013).

Table 3 LHV of fuels

Material type	*Material*	*Lower heating value* (MJ/kg)
Wood	Teak	18.90
Paper	Newspaper	18.39
Rice husk	Rice husk	14.99
Leaves	Palm tree leaves	19.66

5.6.2 Fuel calculations

As mentioned before the amount of fuel which is needed depends on the minimum water temperature in the storage tank. For the model it is assumed that fuel will be used when the temperature of the water becomes lower than the minimum temperature. The following equation is used to determine the amount of energy which is needed.

$$Q_{fuel}^{t} = M \cdot c_p \cdot (T_{min} - T_{Storage\ Tank}^{t+1}) \quad (5.6\text{-}1)$$

With,

$Q_{fuel}^{t} = The\ fuel\ energy\ needed\ at\ time\ t, (J)$

$M = The\ amount\ of\ water\ in\ the\ storage\ tank, (kg)$

$T_{min} = The\ minimum\ temperature\ of\ the\ water\ in\ the\ storage\ tank, (℃)$

$T_{storage\ tank}^{t+1} = The\ temperature\ of\ the\ water\ in\ the\ storage\ tank\ at\ time\ t+1, (℃)$

To determine the amount of fuel which has to be used the following formula has been used.

$$M_{type} = \frac{Qfuel/\eta_{stove}}{LHV_{type}} \quad (5.6\text{-}2)$$

With,

$Qfuel = The\ fuel\ energy\ needed, (J)$

$\eta_{stove} = The\ efficiency\ of\ the\ stove, (-)$

$LHV_{type} = The\ lower\ heating\ value\ of\ the\ material\ type, (kJ/kg)$

$M_{type} = The\ mass\ needed\ of\ a\ material\ type, (kg)$

$type = The\ type\ of\ material;\ either\ wood, paper, rice\ husk\ or\ leaves$

The efficiency of the stove depends on many factors, the temperature of the water in the storage tank, the heat generated by the fuel which is burned. For this model it has been assumed that the efficiency will be constant. No literature data was found on the average efficiency of a simple stove as the one in this system. Therefor an efficiency of 15 % has been assumed.

5.7 Water temperature in the Storage tank

To determine the temperature in the storage tank equation (5.1-1) needs to be solved first. After that the following equation needs to be solved:

$$Q_{storage\ tank} = M \cdot c_p \cdot (T_{storage\ tank,new} - T_{storage\ tank,old}) \tag{5.7-1}$$

With,

$M = The\ mass\ of\ the\ water\ inside\ the\ storage\ tank, (kg)$

$c_p = The\ heat\ capacity\ of\ water, (J/kg \cdot K)$

$T_{storage\ tank,new} = The\ new\ water\ temperature\ in\ the\ storage\ tank, (°C)$

$T_{storage\ tank,old} = The\ old\ water\ temperature\ in\ the\ storage\ tank, (°C)$

Rewriting equation (5.7-1) gives a relation for the new temperature of the water in the storage tank:

$$T_{storage\ tank,new} = Q_{storage\ tank}/(M \cdot c_p) + T_{storage\ tank,old} \tag{5.7-2}$$

In reality the water temperature in the storage tank is not a uniform temperature. But in this simple model it is assumed that it is so.

6 Simulations

In the previous chapter the energy balance which is used for the simulations was explained. The simulations will be done by using the program MATLAB R2013a. Appendix II gives the process flow diagram of the simulations by using MATLAB. For the simulations the main design parameter is the size of the solar collector.

Due to the complexity of the system which exists of different system inputs namely the solar irradiance, the user loading, and fuel usage it was decided to simulate specific scenarios. In Table 4 the different simulation scenarios are given.

Table 4 Simulation scenarios, simulation of 5 days

Scenario (#)	*Solar collector area (A_c)*	*Solar irradiance model (q_s)*	*Location (Q_{load})*
1	1	Sine wave, Jayapura, Modified sine wave	Village
2	2	Sine wave, Jayapura, Modified sine wave	Village, City
3	3	Sine wave, Jayapura, Modified sine wave	Village

For the simulations the temperature of the water in the storage tank will be simulated for a period of five days. This will give a better idea on what the water temperature will be during an extended period of time. An import parameter for the simulations is the minimum water temperature of the water in the storage tank. This temperature indicates the water temperature which is preferred for having a shower. It is assumed that this temperature is about 37 °C ($T_{minimum}$), see Appendix I.

6.1 Summary of the system parameters

Table 5 gives a summary of the system parameters which have been used for the model.

Table 5 System parameters

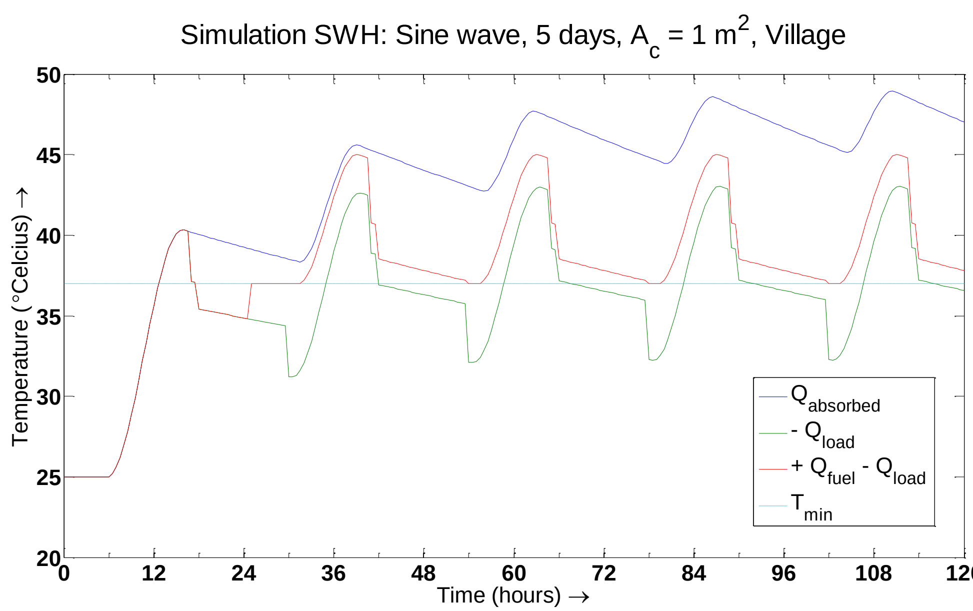
System parameters
$R_{tot} = 1.46\ W/°\text{C}$, $T_{ambient} = 25\ °\text{C}$, $T_{minimum} = 37\ °\text{C}$, $M_{water} = 138.89\ \text{kg}$, $A_{solar\ collector} = 1, 2, 3\ m^2$, $c_p = 4.18\ kJ/(kg \cdot °\text{C})$, $LHV_{wood} = 18.9\ MJ/kg$, $LHV_{paper} = 18.39\ MJ/kg$, $LHV_{leaves} = 19.7\ MJ/kg$, $LHV_{husk} = 15.0\ MJ/kg$, $\eta_{stove} = 15\ \%$

6.2 Results

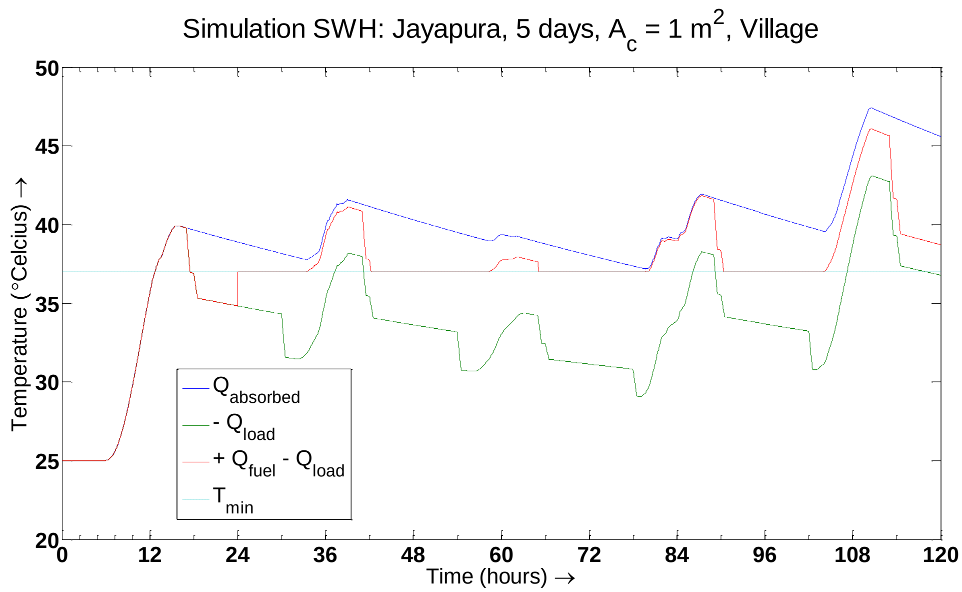
In the following subchapters the results of all scenarios are given and will be discussed. As can be seen in for example Figure 12 each graph looks similar. In every graph the blue line represents the temperature of the storage water after a period of time due to the solar irradiance which is absorbed ($Q_{absorbed}$), see also Chapter 5.3 on the different solar irradiance models. Besides the blue line there are multiple of other lines drawn in the same graph showing what happens to the storage water temperature when another system variable is taken into account as well. For example when there is heat loss in the system due to showering (Q_{load}) or when there is also fuel burned in the stove (Q_{fuel}) in order to keep the water temperature at the appropriate shower temperature.

6.2.1 Scenario 1: Solar collector area ($\boldsymbol{A_c}$) is 1 $\boldsymbol{m^2}$

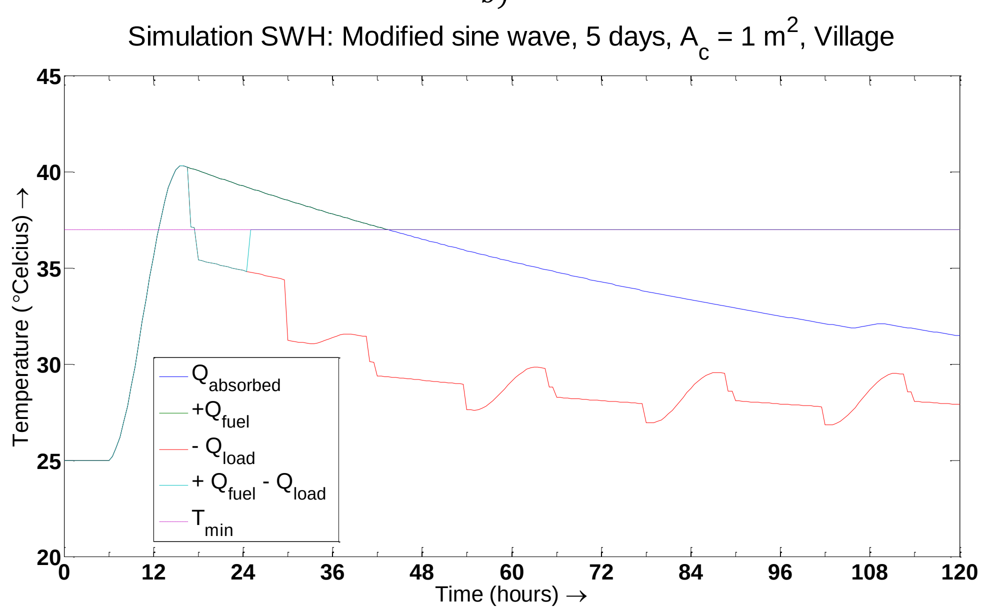
In the figure below the results are given for the first scenario. As can be seen from Figure 12 a), b) and c) the modeled solar irradiance has a significant impact on the water temperature.



a)



b)



c)

Figure 12 Results scenario 1. Solar irradiance model: a) Sine wave, b) Jayapura, c) Modified sine wave

Focusing on $Q_{absorbed}$ in the graph a), b) and c). For all irradiation models it can be seen that the water temperature increases by approximately 15 ℃ in the first day (0-24 hours). At some point the amount of solar irradiation will not be enough to increase the water temperature and there will only be heat loss to the environment (Q_{loss}) as can be seen by the moderate declination of the water temperate until the solar irradiation is high enough again to heat up the water. After the first day the different solar irradiation models also give a different water temperature development. Taking a look at the sine wave model, Figure 12 graph a), it can be seen that the increase in temperature in the consecutive four days, which is about 10 ℃ in four days, is relatively small compared to the first day even though the solar irradiation is the same as in the first day. On the fourth day, at time is 72 hours, the pattern of temperature increase and decrease is repeating. This is as expected since the solar irradiation is a constant pattern as well. The maximum temperature of the water will be around 49 °C. Looking at the Jayapura irradiation model, Figure 12 graph b), it can be seen that the development of the water temperature is not as regular as for the sine wave model. This is as expected because of the fluctuations in solar irradiance. In Figure 13 the water temperature and the solar irradiance are shown. It explains the irregular temperature increase and it shows why the temperature increase each day differs quite a lot because of the differences in solar irradiance. Still the maximum water temperature gets around 47 °C. Looking at Figure 12 graph c) the simulation with the modified sine wave shows that after the first day the solar irradiance is not enough, except for the last day, to increase the water temperature. Thus simulating a sunny day followed by four consecutive clouded days and the maximum water temperature is around 40 °C.

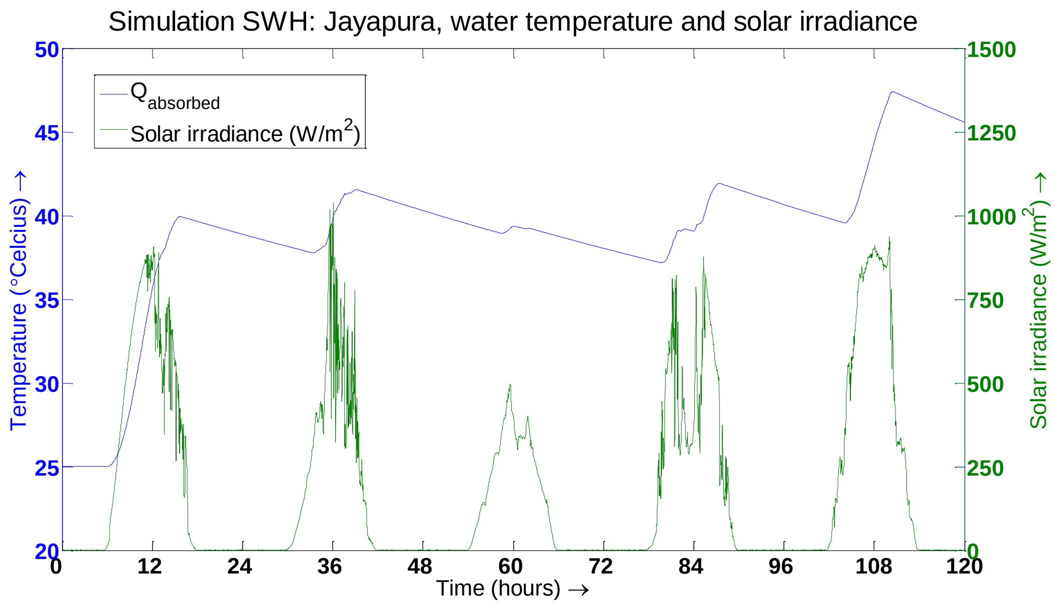


Figure 13 Jayapura: water temperature and solar irradiance

The solar water heater (SWH) system is not only for heating water but also for using this heated water. As was explained before the graphs in **Figure 12** also show what happens to the system with different kinds of inputs, either heat is withdrawn and/or added to the system.

Now the graphs in **Figure 12** will be further compared. An import benchmark is the minimum water temperature, T_{min} = 37 °C, of the stored water which is drawn as a horizontal dashed line in each graph.

6.2.1.1 Q_{load}

Taking a look at the $+Q_{load}$ line, see also Chapter 5.5, in which the use phase is added to the model causes a temperature decrease at constant intervals. People take a shower in the morning and in the evening. This causes a consecutive steep temperature decrease. For the sine wave, Jayapura and the modified sine wave simulation the maximum temperature decrease during this period is about 10.57 °C, 8.08 °C and 9.03 °C respectively. In both the simulation of Jayapura and the modified sine wave, respectively **Figure 12** b) and c), it can be seen that the temperature of the water is below T_{min} during the better part of the use phase. The sine wave simulation, **Figure 12** a), shows that the water temperature is only below T_{min} during the morning shower, not taking into account the first day which is the startup day of the solar water heater.

6.2.1.2 $\boldsymbol{Q_{load}}$ and $\boldsymbol{Q_{fuel}}$

In Chapter 4.1 the concept of the solar water heater system was explained. Besides the sun as energy source the solar water heater can use a fuel (Q_{fuel}) as energy source as well. In Figure 12 line $+Q_{fuel} - Q_{load}$ simulates what happens when heat is added to the system by using a fuel source. In Chapter 5.6 the fuel model was explained. In the figure it can be seen that the temperature of the water does not get below the minimum temperature of 37 ℃ after the first day. Table 6 shows the amount of fuel that is needed for each model in Figure 12 per day.

Table 6 SWH simulations: average amount of fuel needed a day

Model	*Input/Output*	*Wood (kg)*	*Paper (kg)*	*Leaves (kg)*	*Rice husk (kg)*
Sine wave	Q_{fuel}/Q_{load}	0 .8	0.8	0.8	1.0
Jayapura	Q_{fuel}/Q_{load}	1.2	1.2	1.2	1.5
Modified sine wave	Q_{fuel}/Q_{load}	1.8	1.9	1.8	2.3
Modified sine wave	$Q_{fuel}/-$	0.4	0.4	0.8	0.4

The table shows that the amount of fuel which is needed in Jayapura is in between of the amount of fuel that is needed in between both of the sinusoidal models. It is clear that for example obtaining 0.8 kg of paper is something else than obtaining 0.8 kg of wood.

The model of the modified sine wave, Figure 12 graph c), is the only model which is modelled with Q_{fuel} and without Q_{load} because it is the only model which gets below 37 ℃ when the only system input is the solar irradiation ($Q_{absorbed}$). It can be seen that before the end of the second day (time is 48 hours) the temperature gets below T_{min}. The amount of fuel which is needed a day for this simulation can be found in Table 6.

6.2.2 Scenario 2 and 3: Solar Collector area $(\boldsymbol{A_c})$ is 2 $\boldsymbol{m^2}$ and 3 $\boldsymbol{m^2}$

In the second and third scenario the same simulations have been done as in scenario 1. Besides these simulations also simulations were done with another loading profile, see Chapter 5.5 for both loading profiles Village and City. *Appendix III* shows the result of all simulations. As can be seen the graphs with the loading profile Village are similar in geometry as to the simulations shown in Figure 12 only moved up in temperature which is as expected since the solar irradiance which is absorbed ($Q_{absorbed}$) has increased whereas the other model variables were not changed. For example Figure 14 shows the water temperature for the different solar collector sizes when only solar irradiation ($Q_{absorbed}$) is taken into account. Each collector area size causes a similar profile only shifted to another temperature. The maximum temperature for the 1 m^2, 2 m^2 and 3 m^2 solar collector area is respectively 47.8 ℃, 53.8 ℃ and 57.1 ℃. Thus increasing the collector size also increases the maximum water temperature which is reached. Next a closer look will be taken at the effect of the different loading profiles, the fuel usage and the maximum temperature and average temperature for some of the simulations.

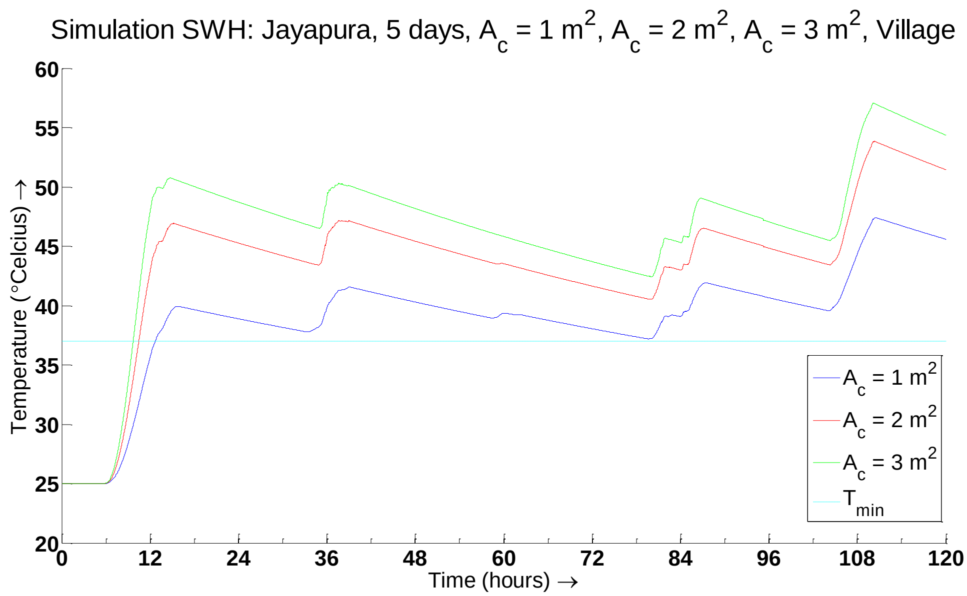


Figure 14 Comparison solar collector area: Jayapura

6.2.2.1 Village and City model

Figure 15 gives the results of the different loading profiles (City and Village) for the solar irradiance in Jayapura. For both models the temperature drops and increases at the same intervals each day. Also from the figure it can be seen that the maximum and minimum water temperature for each loading profile is approximately the same. From this it can be obtained that the different time of water usage does not have a significant effect. Table 7 gives the amount of fuel which has to be used for both load profiles in order to keep the storage water temperature above 37 ℃. The results are almost similar which shows again that the effect on the time of usage is not significant. Therefore it has been decided to use only the load profile Village for scenario 1 and scenario 3.

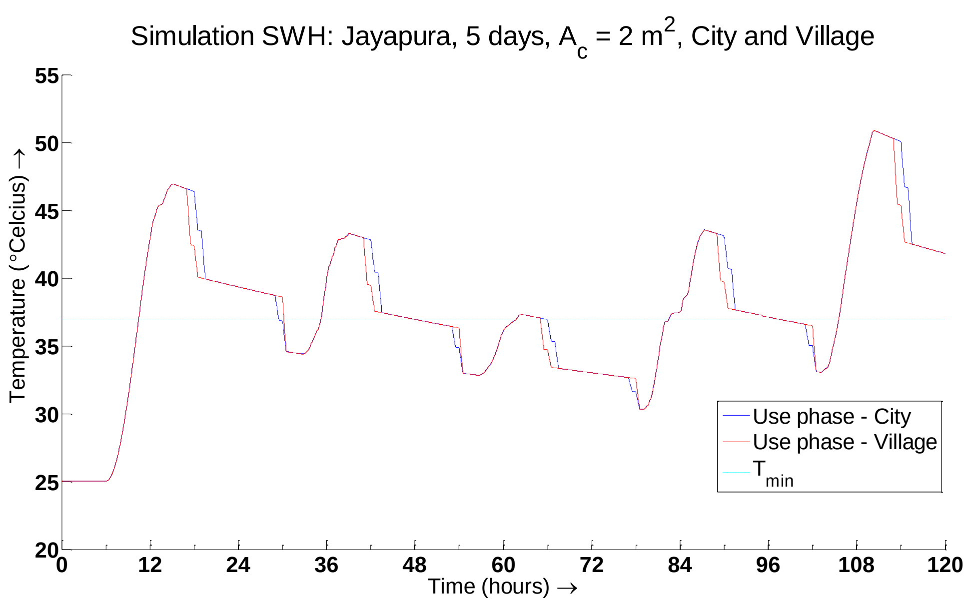


Figure 15 Comparison loading profiles: Jayapura

Table 7 Comparison fuel use, City and Village: Jayapura

	Fuel type	Wood (kg)	Paper (kg)	Leaves (kg)	Rice husk (kg)
Loading profile	City	4.08	4.19	3.92	5.15
	Village	4.08	4.20	3.93	5.15

6.2.2.2 Comparison normal use models

During normal use of the system the solar water heater will be used (Q_{load}) and fuel (Q_{fuel}) will be used to keep the temperature of the water high enough. Table 8 gives the maximum temperature and fuel use, only for the amount of wood, for all of the solar irradiation models and for each scenario shown in the graphs in Figure 12 and *Appendix III* as line "$+Q_{fuel} - Q_{load}$". Furthermore Table 8 gives the maximum water temperature (T_{max}) in the storage tank as well as the average water temperature ($T_{average}$) when only the solar irradiation ($Q_{absorbed}$) is used in the simulation, see also Figure 12 a), b) and c), Figure III-II a), c) and e) and Figure III-III a), b) and c) in *Appendix III*.

Table 8 Results, irradiation model and solar collector area: fuel, maximum water temperature ($\boldsymbol{T_{max}}$) and average water temperature ($\boldsymbol{T_{average}}$)

Irradiation model →		***Sine wave***			***Jayapura***			***Modified sine wave***	
Solar collector area (m^2) ↓	*Fuel use (kg)*	T_{max} *(°C)*	$T_{average}$ *(°C)*	*Fuel use (kg)*	T_{max} *(°C)*	$T_{average}$ *(°C)*	*Fuel use (kg)*	T_{max} *(°C)*	$T_{average}$ *(°C)*
1	0.80	48.96	42.73	1.20	47.42	38.96	1.80	40.31	34.29
2	0.39	53.16	47.42	0.82	53.85	43.65	1.66	47.60	38.58
3	0.19	55.05	49.62	0.61	57.07	46.23	1.60	51.61	41.05

From Table 8 it can clearly be seen what the effect of a larger collector size is. The maximum and average water temperature increases and the amount of fuel which is needed decreases. Furthermore the solar irradiation model which is used influences the results significantly. Comparing the fuel usage of Jayapura to both of the sine wave models it can be seen that it lies somewhere in between. Increasing the collector area size from 1 m^2 to 2 m^2 has more effect than increasing it from 2 m^2 to 3 m^2 this is also because the solar collector area is not doubled.

Taking a close look at the solar irradiation models, see also Chapter 5.3, it can be seen that the trend for the results in Table 8, differ. For the sine wave model which represents a cloudless period it can be seen that by increasing the solar collector area size the fuel use decreases significantly. This does not apply for the maximum water temperature which is obtained. The difference between the smallest and biggest collector size is approximately 6 °C. The same holds for the average temperature which is approximately 7 °C. For the Jayapura solar irradiation model the fuel usage also decreases significantly but not as much as for the sine wave model. The temperature difference between a solar collector area of 1 m^2 and 3 m^2 for the maximum and average temperature respectively is approximately 10 °C and 7 °C. In the modified sine wave model which represents a cloudless day followed by four clouded days the fuel use is a lot higher than the other models but the amount of fuel which is needed does not decrease as significantly as for the other models. The maximum and average temperature differences are respectively 11 °C and 7 °C.

For all of the solar irradiation models the difference of the average temperature was approximately 7 °C. From this it can be concluded that the different solar irradiance models do not affect the average water temperature significantly when the size of the solar collector area is increased. Another relation which can be observed from the table between the solar irradiance and the solar collector area is that if the average and maximum temperature is higher the fuel which is needed decreases more steep when the collector area is increased.

6.3 Conclusion

Based on the results which are obtained in this paragraph a solar collector area will be chosen. Three solar collector sizes were simulated: 1 m^2, 2 m^2 and 3 m^2. The most important benchmark for choosing the collector area is the minimum water temperature of 37 °C (T_{min}). In Chapter 6.2.1 it was shown that the different solar irradiance models have a significant effect on the water temperature. Thus influencing the solar water heater system on a day to day base. Chapter 6.2.2.1 showed that the different loading profiles gave similar results and therefore it was decided to use only one of the loading profiles to further simulate the water usage.

When the solar water heater system is used (a loading) the water temperature gets below T_{min} for all simulated solar collector areas. Looking at the results for a solar collector area of 1 m^2 the water temperature is below T_{min} for more than half of the time and thus fuel will be needed to keep the water temperature above T_{min}. Only for the solar collector size of 3 m^2 the temperature is above T_{min} for the better part of the time. Increasing the solar collector size also showed that the shape of the water temperature profile stays more or less the same but only increases in temperature level. Furthermore the average temperature increased by about 7 °C for every solar irradiation model by increasing the solar collector size by 1 m^2.

The minimum amount of fuel that will be needed reduces significantly when the collector size is increased. The amount that reduces is significantly different for each solar irradiation model.

Choosing a suitable solar collector area size is not an exact science. The results which are obtained show that the solar water heater model can be influenced significantly by many parameters like for example the solar irradiation. Also many parameters have been assumed by an educated guess. Moreover a suitable solar collector area also depends on the costs of the collector and the fuel which is available. Using a large collector will increase the costs but decreases the need for fuel and thus the fuel costs. Also which type of fuel will be available and in what amount. Since both of these aspects have not been researched the decision on which collector size is suitable cannot be based upon it. The question about costs will be very important in Indonesia since it is a developing country where prices are very important and long term investments are not specifically the first choice.

Taking all of the results of the simulations into account the solar collector size of 2 m^2 will be appropriate for this project. Based on normal usage of the solar water heater, water from the solar water heater will be used and fuel will be needed, the water temperature will be below the minimum temperature for the collector size of 1 m^2 to often unless a relatively large amount of fuel is used. For the collector size of 2 m^2 this is far less and also less fuel will be needed. The size of the collector must be increased and will cost more but it is assumed that this will be within limits. For the collector size of 3 m^2 the system will be even more autonomous and use less fuel. The change in fuel consumption from 2 m^2 to 3 m^2 is not as big as for 1 m^2 to 2 m^2 and is therefore less effective. Therefore the increase of collector size from 2 m^2 to 3 m^2 is assumed not to be economically valuable. Thus a collector size of 2 m^2 is chosen for this project.

End of part 1 of the report

Part II: Research

7 Introduction part 2

The second part of the project consisted of a small research. The first part discussed a model to determine the solar collector size of a solar water heater given a certain amount of solar irradiance. The second part focusses on the application of solar water heaters in real life. Research has been done at two locations. The first location is the village Banjaran which lies to the south of Bandung and is a rural area. The second location is the university Universitas Islam Negeri (UIN) which is an Islamic university and lies in the east of Bandung. The research focusses on the following three questions.

1. *Is there any need for solar water heaters in Banjaran?*
2. *Is there any knowledge on sustainable/green energy technologies?*
3. *Is there any knowledge on solar water heaters at the Universitas Islam Negeri?*

Solar water heaters have numerous of advantages. The available solar energy is for free. After the initial investment the costs for running the device are very low. No pollution is created. And since there is plenty of solar energy available in Indonesia why don't they use the technology on a broad scale? This has to be answered by research question one and three. The second research question comes from the author's study background. Doing a master program on sustainable energy technologies and the fact that renewable energy technologies are a hot topic in Europe for the past years has made it interesting to see whether or not this topic is of any interest in Indonesia. If Europe switches over to use more and more of renewable energy sources this will have a significant impact. Indonesia is a developing country. The need for energy will increase as development takes place and since the country consists of more than 240 million people it will have a significant impact if this country uses renewable energy sources or not at all.

In the following paragraph the research method will be explained. After that the methods of research will be further discussed and finally the results of the research will be given.

8 Research method

The method of research has been based upon the theory given by (Desai & Potter, 2006). Because of the limited amount of time and the language barrier it has been decided to do a questionnaire survey and a field inventory. The questionnaire will give answer to specific questions and from this the research questions given in the previous chapter can be answered. Besides doing a questionnaire a field inventory will be done in Banjaran. The field inventory will show whether or not solar water heaters can be produced locally in a village. If this is the case then the local production of solar water heaters can be an interesting business case for local startup companies. In the following two chapters the questionnaire which has been made for this research will be discussed as well as the field inventory.

9 Questionnaire

To answer the research questions given in Chapter 7 a questionnaire has been made. The questionnaire is a structured questionnaire. Which means that most of the questions have a specific answer. The first questions are general questions about the people their background. After that the questions will be on their (warm) water usage. After which follows some questions about solar water heater technology. And the last questions are on renewable/green energy. While making the questionnaire extra care was taken to make it applicable and understandable for people that are living in a village. For example asking people where they would use warm water for was not a reasonable question. Because in Indonesia warm water is only used for showering and not for doing the dishes or cleaning the house. After handing out the questionnaires an answer to the research questions will be sought. In Appendix IV and Appendix V the questionnaire which has been made for this research can be found respectively in English and Bahasa Indonesia. The English version was made by the author and the translation has been made by a number of fellow students.

As was mentioned before the questionnaire will be held at two location. In the village Banjaran and at the university UIN. Under the following two headings the procedure of doing the questionnaires is described. Since both of the locations asked for a different approach they will be discussed separately.

9.1 Banjaran

The research in Banjaran was done on the 20th of November (2013). A lot of help was given by fellow student Juan Carlo Sidabutar (Carlo) who is an Indonesian. Doing the research here without a translator or spokesperson is virtually impossible. The local villager does not understand English. Furthermore instead of giving the questionnaire to the people to fill it in most of the questionnaires were held by telling the questions and giving the possible answers. The approach of the translator was to have a friendly chat with the people instead of giving them the feeling that they were interrogated. The answers given by the people where translated and written down by Carlo. This on itself brings along some insecurity to the results which have been obtained. Carlo might have manipulated the results unwillingly or not. Also the interpretation of the question as stated in the questionnaire might have been different from the way that the translator interpreted them. Before the questionnaires were held there was a close consult about the questionnaire between the author and the translator. The fact that both have worked together for three months prior and that their way of thinking is similar in many ways it is assumed that the answers that were given are indeed correctly interpreted and documented. Three of the questionnaires were filled in by the villagers themselves. Figure 16 shows some high school students that are filling in the questionnaire. The questionnaire was given to a random sample.

Figure 16 High school students filling in the questionnaire in Banjaran

9.2 Universitas Islam Negeri

On the 21st of November (2013) research was done at the Universtas Islam Negeri (UIN). Together with Carlo and a couple of students of the UIN, who are also interested in solar energy technology, the questionnaire was spread at the campus of UIN. Figure 17 shows the people that were involved in giving the questionnaire to the students at the UIN.

Figure 17 Questionnaire at the Universitas Islam Negeri

The approach for giving the questionnaire to the students was different then to the villagers in Banjaran. Here the questionnaires were given to the students and filled in by themselves. By this approach it was possible to give many questionnaires at the same time, see also Figure 18.

Figure 18 Students filling in the questionnaire at the Faculty of Science and Technology

The university has more faculties. To answer the research questions people of three different faculties were given the questionnaire.

10 Field inventory

To find out whether or not a solar water heater could be produced locally in Banjaran a field inventory has been done. The main advantage of local production is that it helps stimulating the economy by creating job opportunities for both the production of and the after sales service for the product. Also the usage of local materials will stimulate the economy of the village. The field inventory will focus on the following two aspects. Are the materials needed to build a solar water heater available in Banjaran and can a solar water be manufactured locally? Appendix VI shows the two lists which were made in order to document the data for the field inventory. Figure 24 in Appendix VI shows the main materials which are needed for the solar water heater. This list of materials was put together by reading the instruction manual on building a solar water heater as explained in (BACIBO, 2004). In the instruction manual the collector box is made of wood. In Bandung and surroundings this material type is not suitable, according to the experience that the ITB has with solar water heater technology, and therefore the collector box has to be made from metal. Figure 25 in Appendix VI gives the field inventory list on manufacturing the solar water heater. Since the main parts of the solar water heater need metal manufacturing the list only contains this data. Both lists in Appendix VI show the number of times a certain material or manufacturing step was found. Also the price is an important aspect. And for manufacturing the quality of the manufacturing is important to indicate the durability of the solar water heater.

The field inventory was done on the same day as the day that the questionnaire was done in Banjaran. When driving through Banjaran by car possible shops were localized and either visited immediately or on the way back. Just like for the questionnaire Carlo questioned the shop owners about the available materials and the manufacturing capabilities, see Figure 19. Figure 20 shows some of the equipment and some of the stock material, like metal tubes, of the second workshop which was visited. And Figure 21 shows two of the workers at the first metal workshop working on some metal tubes.

Figure 19 Field inventory: Carlo (on the right) talking to the owner of a metal workshop

Figure 20 Field inventory: equipment and stock at the second metal workshop

Figure 21 Field inventory: workers working at the first metal workshop

11 Results

The results of the research done in both Banjaran and at the UIN are given here. In Banjaran eleven questionnaires were done by a random sample and at the UIN 32 questionnaires were done at three different faculties. At the UIN the questionnaires were filled in at or near of three different faculty buildings. The first faculty building that was visited was the Faculty of Science and Technology (FST), the second faculty building that was visited was the Faculty of Educational Studies (FES) and the last faculty building that was visited was the Faculty building of Psychology (FP). It is most likely that the students sitting here and who filled in the questionnaire had their background in that faculty.

11.1 Results Questionnaire

The table in Appendix VII shows the results of all questionnaires in Banjaran and UIN. The results are given by a, b, c, d ,e or f depending on the amount of possible choices per question and where a is the first given answer and f the last given answer. Some questions provided more possible answers and a couple of questions asked for an explanation. The results of all questionnaires will be discussed here by the following four subjects; general, (warm) water usage, solar water heater, sustainable energy. After these results are given they will be further elaborated.

11.1.1 Banjaran

11.1.1.1 General

Accept for the oldest age category (71 years and older) all ages were represented in the questionnaires. The age category of 10-20 years and 31-50 years were represented most, both by approximately 37 percent. Everyone had the same religion which is the Islam. 64 percent of the people live in a house with 4-6 persons.

11.1.1.2 Water usage

All of the persons use a gayung for showering (a gayung is a little bucket to scoop the water from a water tank). And only one person uses both a gayung and a shower head. 70 percent of the people shower two times a day. More than half of the people shower 11-15 minutes. The others shower less than this time. None of the questioned people lived with older people in their house. Little more than half of the questioned people lived with a baby in their residence and two thirds of them use warm water one up to four times a day for the baby. To heat up water 82 percent have used gas and 18 percent used a stove.

Currently 36 percent of the people have access to warm water in their residence. Of the people that do not have access to warm water half of them do not know if they plan to get warm water. A third is not planning to get warm water and 17 percent is planning to get warm water access. Also none of them has ever lived in a residence with warm water access. Of the people that have warm water access two thirds of them use it once or twice a day and one third uses it three to four times a day. Also half of them have connection to warm water all the time and half of them have only part time connection. During rainy season half of the people are neutral on the importance of warm water for showering. About 20 percent does not think warm water for showering is important during the rainy season at all and 36 percent thinks it is important to have warm water for showering. During the dry season no one thinks that warm water for showering is important.

11.1.1.3 Solar water heater

Of the people that were questioned 82 percent did not know what a solar water heater is. After having explained what a solar water heater is and how they work almost half of the people indicate that they are not interested in buying a solar water heater and almost all indicate that they rather buy a system that heats up water by another energy source but the sun.

All of the persons that do know what a solar water heater is (18 percent) indicate that they have a friend or relative who owns a solar water heater. Asking the people more about the device gave the following results. None of them knows the main components of a solar water heater. Half of the persons indicate that the solar water heater will not work when there is no sun and half of the persons do not know. For guessing the lifetime of the device they say it will be around one to five years. None of the questioned that knows about solar water heaters indicate that they ever considered buying a solar water heater.

Of the questioned people almost three quarter (73 percent) of the people indicate that they have free space around their house with a lot of sun. Asking them if it is important to pay attention to the effect of the season (rain season or dry season) on the systems performance before purchasing the device shows that 40 percent says it is of neutral importance, 40 percent thinks it is not to not really important and the rest think it is important.

11.1.1.4 Sustainable energy

None of the people has ever heard of the terms renewable or green energy. After explaining this concept 50 percent indicates that they have heard of solar energy. 30 percent has ever heard about geothermal energy and 30 percent knows about hydro power. Asking them if they would consider using a renewable energy source instead of a traditional energy source three quarters indicate that they don’t know and the rest says that they don’t want to use it.

11.1.2 UIN

11.1.2.1 General

The questionnaire was given to students and therefor the people were around 20 years old. They are all higher educated people. And all have the Islam as religion. Two third of the people live in a residence with 4-6 persons.

11.1.2.2 Water usage

Just like in Banjaran all of the people use a gayung for showering and a small percentage (16 percent) also uses a shower head. 84 percent showers for 2 times a day and more than half of the people shower about 6-10 minutes. One quarter of the people live in a residence with older people and all of them use warm water for at least one to four times a day. 44 percent of the people live in a residence with a baby and 79 percent of them uses warm water. To heat up water 88 percent use gas as a fuel and no one uses a solar water heater.

Little more than half of the people have access to warm water in their current residence and 94 percent uses warm water once or twice a day. 30 percent has access to warm water all the time. Of the people that do not have access to warm water 62 percent plan to get warm water access. About half of the people have lived in a residence with warm water access and 29 percent thinks that it is important to get warm water access again.

During the rainy season 30 percent indicates that it is important to have warm water for showering and 44 percent is neutral on the use of warm water. During the dry season no one thinks that warm water for showering is important and a third thinks it is not important at all.

11.1.2.3 Solar water heater

38 percent of the people don't know what a solar water heater is and after explaining what a solar water heater is half of them would consider to buy such a device. 42 percent indicates to prefer to buy a solar water heater to heat up water instead of a stove or another device.

Of the people that do know what a solar water heater is (62 percent) three quarter of them do not own a solar water heater themselves or know someone that has one and one quarter knows someone who has the device. About half of the people indicate to know what the main components of a solar water heater system are. Asking them whether or not a solar water heater will work when there is no sun 15 percent indicates that it will work, 55 percent thinks that it will not work and 30 percent does not know if it will work or not. 42 percent guessed that the life time of a solar water heater is 1-5 years, 37 percent says that it is 6-10 years, and 20 percent thinks that it is 11 years and longer. 60 percent of the people indicate to have never considered buying a solar water heater.

70 percent has free space around their house for placing a solar water heater. More than half of the people think that it is important to pay attention to the performance differences of the device during the rainy and dry season.

11.1.2.4 Sustainable energy

34 percent of the people has heard of the terms sustainable or green energy. Most of these people indicate solar energy as a sustainable energy as well as wind energy, geothermal and bio energy. Also 82 percent indicate to consider using a sustainable energy source instead of the classical energy sources.

Of the people that have never heard of sustainable or green energy most indicate to have heard of solar energy as a sustainable energy source. Some have heard of wind energy, geothermal energy and bio energy. 47 percent considers to use a sustainable energy source, 16 percent does not consider to do so and 37 percent does not know.

11.2 Elaborating the results

By looking at the results of the questionnaires, see the previous subchapter, and the observations which have been made during the research the results will be further elaborated according to the research questions given in the introduction, see also Chapter 7.

11.2.1 Banjaran

11.2.1.1 Research question 1

Is there any need for solar water heaters in Banjaran?

First it was determined whether or not the people use a lot of water. Using a gayung is less effective than using a shower head and since all of the people use a gayung the water usage for showering in Banjaran is not optimal and more water will be needed because a lot of water is wasted. The people shower two times a day and for a time of 11-15 minutes. This means that there is a certain water capacity needed for a person every day. If a family would want to purchase a solar water heater their shower habits will affect the water capacity that the solar water heater should have. A bigger water capacity will mean a more expansive solar water heater. This can be a serious bottleneck for purchasing a solar water heater. Since a solar water heater can cost from 11 million IDR up to 20 million IDR. And according to (Salary Explorer, 2013) the average Indonesian income is around 5 million IDR. Thus for people living in a village which on average also do not have a high income the cost of a solar water heater is a lot of money.

Even more important to know is whether or not the people have a need for warm water. First it was asked whether or not the people use warm water for specific family members. In the questionnaires there was no one who lived with older people. Therefor it is not clear if this part of the population in Banjaran needs warm water. Half of the questionnaires indicated that the people lived with a baby and a significant part of these people indicated that the baby needs warm water up to 4 times a day. From the two population categories given above there is at least one group that needs warm water every day. This can be obtained by using a solar water heater. Obviously the amount of warm water that a baby needs is relatively small and the time that it will be a baby is only temporarily, therefor this population group alone probably does not give enough of a reason to purchase a solar water heater.

People have indicated to use both gas and another fuel like wood to heat up water. The gas will cost money but fuel like wood can be obtained for free but is limited available. And since gas is quite cheap in Indonesia this might not be seen as a problem.

A significant part of the people (more than 30 percent) already have access to warm water in their residence. This means that having warm water access is common and therefor expanding the amount of people that have connection to warm water by introducing solar water heaters will not be a problem.

Of the people that do not have warm water access none of them every lived in a residence with warm water connection. A small part is planning to get warm water access. This means that there is a possibility for solar water heaters to be introduced.

From the people that have warm water connection half of them indicates to have the connection part time. Since solar water heater technology also does not guarantee a connection to warm water all the time this does not have to be a bottleneck. For the people that have warm water connection all the time the warm water insecurity of a solar water heater could be a bottleneck of the device.

One of the important aspect of (warm) water usage is the differences during the two season. When it is dry season the solar water heater can function optimally but during that period the people indicate to have no need for warm water for showering. Both the people that have and do not have warm water access indicate this. From the author's own experience it can be said that showering with cold water at a warm place in Indonesia is comfortable, for example in Jakarta. And the same is indicated by the people in Banjaran. During the rainy season people indicate that warm water for showering is important. Unfortunately during this period the performance of a solar water heater is much lower than in the dry season. There might be long periods without warm water from the device. So the all year round performance of solar water heaters is not in line with the warm water needs that the people in Banjaran have.

On the knowledge on solar water heaters most people indicate to know nothing about them. For people that live in rural areas, like Banjaran, it is hard to understand how a solar water heater works and the threshold for adopting new things is really high. This means that the advantages of a solar water heater must be significant and the way the technology will be introduced, for example by a seller they know very well, will play an important role for the success of the technology.

A small part of the people know what a solar water heater is because of their friends or relatives. But more knowledge on solar water heaters except for their existence there is not. They never considered to buy one themselves. This does indicate that solar water heater technology is not something the people have not heard of but real interest for it there is not.

Before purchasing the device it must be known whether or not the device is suitable to place at one's house. Three quarter of the people indicate that they have suitable space for it. So introducing the technology on a broad scale in Banjaran is possible.

11.2.1.2 Research question 2

Is there any knowledge on sustainable/green energy technologies in Banjaran?

At first all of the people indicate to never have heard of sustainable or green energy. Later a third indicated to know about green energy sources like hydro power and geothermal energy. After explaining the term green energy and its benefits they still did not understand it and are reluctant to consider using one of these energy types. The concept of green energy and a sustainable living is new to them and something that has not crossed their mind before.

11.2.2 UIN

11.2.2.1 Research question 2

Is there any knowledge on sustainable/green energy technologies at the Universitas Islam Negeri?

34 percent of the students indicate to have heard about the terms renewable or green energy. On average they also gave a good explanation of the term. For example one student explained it as follows, "renewable energy is an energy that is not depleted." When looking at the different faculties it can be seen that the FST has the highest percentage of people that heard about sustainable or green energy. After that comes the Faculty of Psychology (FP) with 29 percent and last comes the Faculty of Educational Sciences (FES) with 17 percent. That the FST has the highest percentage is as expected because energy (heat or electricity) is an important subject when it comes to technology.

Both the students that do and do not know about sustainable energy technologies have heard about these types of energy technologies like for example wind energy. This shows that even though they do not know of this category of energy sources they know of their existence.

Of the students that have heard about sustainable energy sources before a high percentage (84) indicates that they would consider using one of these energy sources instead of the classical way by burning coal or gas.

And of the students that did not know about sustainable energy a much smaller percentage (47) considers to use these energy sources. The main reason for this is because the questionnaire stated that these energy types are more expansive.

11.2.2.2 Research question 3

Is there any knowledge on solar water heaters at the Universitas Islam Negeri?

A significant part of the students that filled in the questionnaire know what a solar water heater is. The highest percentage that know about the device was found at the FP (with 86 percent), after that comes the FST (with 74 percent) and at the FES no one knew about the device. It was expected that the highest percentage of students at the FST would know about these devices because of the interest of these students in technology and for example also in this technology.

To determine whether or not the students that said to know solar water heaters also know more about these machines other than what they look like more questions had to be filled in. Half of the students indicated to know the main components of a solar water heater. Unfortunately there was no more detailed question about this to clarify this statement. Asking them if a solar water heater would work when there is no solar energy available was a bit of a trick question. Some of the students indicate that they do not know, either or not because they have never used the device themselves. Most of the students indicate that the device will not work mainly because there is no solar energy to heat up the water. Only 15 percent had it right by saying yes only they gave no good reason for it. The answer is that the solar water heater will still work if there is no sunlight since someone can still withdraw warm water from it if the water was heated up before. But it depends also on how people have interpreted the word 'work'.

Letting the students guess what the life time of a solar water heater is most students guessed that this would be 1-5 years and only five percent guessed that it would be more than 20 years. For example solar water heaters that were placed in Florida (USA) in the 1920s still worked after 80 years of installment (Julian Chen, 2011).

A little bit more than half of the people indicate that the performance difference of the solar water heater during the rainy and the dry season is important to consider before purchasing the device. This is the correct answer because there can be a lot of difference in terms of available solar energy to heat up the water and the user demand for warm water. If both the demand for warm water and the availability of warm water are not in line with each other than it might not be a good decision to buy the device.

11.3 Results field inventory

The fill in tables made for the field inventory on both the materials needed for and the manufacturing of a solar water heater where found not to be suitable for the field inventory, see Appendix VI. In total seven metal workshops where found and all of these workshops worked according to the same principles.

The metal workshops are able to construct the whole solar water heater. They are able to do all of the manufacturing steps which are needed for the metal parts as well as the other production steps like painting the heat absorber black and gluing the glass or plastic cover on the metal solar collector box. Figure 22 shows one of the workers at the first metal workshop which was visited doing some welding on a metal tube. And Figure 23 shows some metal constructions at another workshop which have been painted as well. Besides manufacturing with metal they are able to buy all of the materials which are needed when they are not in their stock. Table 17 in Appendix $VIII$ shows the availability of the materials at three of the metal workshops. From this it can be obtained that most of the materials are not in stock and have to be bought.

Figure 22 Worker at the first metal workshop welding metal tubes

Figure 23 Painted metal frames at one of the metal workshops

The workshops can purchase all of the materials which are not in stock as well as building the whole solar water heater. In order to let a metal workshop built a solar water heater a list of materials as well as the construction (technical) drawings have to be submitted to the shop. The workshop will then go to the market to obtain the pricing of all materials. One of the workshops indicated that some of the materials would be in stock, other materials could be purchased locally, like insulation material, and other materials, like the copper tubes, would have to be purchased in Bandung which is the nearest city. Purchasing most of the material locally would benefit the economy of Banjaran. Also transportation of the material from Bandung would be relatively expansive. With the total price of all materials and the estimated production costs the workshop will give a price for the total project. After some price negotiations the deal can be sealed and a certain amount of the price has to be paid up front.

The research pointed out that solar water heaters can be produced locally by metal workshops and some of the materials can be obtained locally. Depending on the production size the production of solar water heaters locally could create job opportunities.

12 Discussion

With the results given in the previous chapter, Chapter 11, the results will be further discussed. Here the main findings of the research will be given as well as a reflection on the research.

12.1 Main findings

The main findings of both the questionnaire and the field inventory are given here. The main findings of the research done by the questionnaire are collected under the following three topics; 1- water needs, 2- solar water heater knowledge 3- sustainable energy knowledge. The findings will be represented in a list.

12.1.1 Questionnaires

12.1.1.1 Banjaran

The main findings from the questionnaires in Banjaran.

1. **Water needs**
   - ❖ Warm water is only used for showering.
   - ❖ There is a daily need for warm water for specific family members, like for example babies.
   - ❖ The people indicated to have used unsustainable energy sources for heating up water.
   - ❖ Already a significant part of Banjaran has access to warm water.
   - ❖ The people that do not have access to warm water have never had it. Warm water is still a luxury good.
   - ❖ The part time warm water access of solar water heaters can be a bottleneck for some of the people in Banjaran.
   - ❖ The year round performance of solar water heaters is opposite to the people their needs for warm water.
2. **Solar water heater**
   - ❖ There is little to no knowledge on solar water heater technologies in Banjaran.
   - ❖ Most residences have a suitable place for solar water heaters around their residence making it possible to introduce solar water heaters on a broad scale in Banjaran.
3. **Knowledge on sustainable/green energy technologies**
   - ❖ The concept of sustainable/green energy technologies is new to the villagers of Banjaran.

12.1.1.2 Universitas Islam Negeri

The main findings from the questionnaires at the Universitas Islam Negeri.

1. **Solar water heater**
   - ❖ Most students (64 percent) know what a solar water heater is.
   - ❖ There is a difference in knowledge on solar water heaters between the students of the different faculties.
   - ❖ 31 percent claim to know the main components of a solar water heater.
   - ❖ The questions asked to find out more about their knowledge on solar water heaters were not adequate.
   - ❖ A little bit more than half of the students understand that the performance of the device differs per season.
2. **Knowledge on sustainable/green energy technologies**
   - ❖ A significant part of the students have heard about the terms sustainable or green energy.

- ❖ The Faculty of Science and Technology is the faculty with the highest percentage of the students that have heard about sustainable or green energy.
- ❖ Besides solar energy which was the topic of the first part of the questionnaire the students also know about other sustainable energy technologies like wind energy.

12.1.2 Field inventory in Banjaran

The main findings of the field inventory in Banjaran.

- ❖ Local metal workshops can purchase all the materials which are needed for the solar water heater.
- ❖ The whole solar water heater can be built by the metal workshops
- ❖ The materials needed for the solar water heater which are not in stock can be purchased locally or in the city nearby (Bandung)
- ❖ The price for the solar water heater can be determined after the metal workshop has obtained a list of all the materials and the construction steps which are needed.

12.2 Reflection on the research

Reflecting on the research which was done in Banjaran there are some points of attention. The questionnaire focused on two main subjects, solar water heaters and sustainable energy technologies. This might have been too much after finding out that both subjects where new to most of the people. The questionnaire had a lot of questions. Therefor it took quite some time to do one questionnaire which also limited the amount of questionnaires which could be done. More days could have been spent in Banjaran to increase the sample size. The random sample might not have been random and representative for the population in Banjaran. There were a relatively large percentage of students and people working in a shop.

The questionnaire which was used for the research at the UIN was made for another target group and one of the research questions differed. Therefor the questionnaire was not adequate for the research. Given more time the questionnaire would have been modified to be appropriate for the students. The questionnaire took a lot of time for most of the students to fill in. It took between 15 and 45 minutes to fill in. Also the questionnaire had questions on a topic, water usage, which was not part of one of the research questions. Furthermore many students filled in some of the questions which were not meant for them. This might indicate that the questionnaire was unclear. The students at the UIN were capable to speak reasonably English therefor the research methodology which would have been suitable to do here as well is interviewing. This might have given less interviewees than the amount of questionnaires but could have been more qualitative.

Reflecting on the field inventory which was also done in Banjaran the metal workshops indicated that they could purchase all of the materials. For the local production of solar water heaters it is important to know where the materials can be bought, locally or not, and how much it will cost to buy these. Given more time this could have been found out as well. Also the workshop owners claimed that the whole solar water heater could be produced in their workshop. To insure that they can the construction drawings of a solar water heater could have been shown to them in order to determine if they could have built the whole device.

13 Conclusion

By looking at the results, see Chapter 11, the discussion, see Chapter 12, and the observations which have been made during the research an answer to the research questions given in the introduction, see Chapter 7, will be given here as well as the conclusion to the field inventory in Banjaran.

The first research question is as follows:

1. *Is there any need for solar water heaters in Banjaran?*

The results of the research done in Banjaran point out that there is no need for solar water heaters in Banjaran. The performance of the device is not in line with the warm water needs of the people. Warm water for showering is still seen as a luxury and is therefore not a real need. The technology is new for the people in Banjaran and they themselves see no need to adopt the technology instead of using the classical ways of heating water.

The second research question is as follows:

2. *Is there any knowledge on sustainable/green energy technologies?*

Sustainable or green energy technologies are new to the people of Banjaran. The people live a simple live in which their daily activities keep them more than occupied. Thinking about the source of the energy that they use and the effect of using these energy sources is not of a concern to them.

Sustainable or green energy technologies are not new to the students at the Universitas Islam Negeri. There is a knowledge difference between the different faculties which was expected because there might be only some studies that focus on energy technologies. A significant part of the students have heard of more types of sustainable energy technologies like wind energy and geothermal energy besides solar energy which was the type of sustainable energy technology which was a topic in the questionnaire.

And the third research question:

3. *Is there any knowledge on solar water heaters at the Universitas Islam Negeri?*

A large part of the students at the UIN know what a solar water heater is. There seems to be a difference in their knowledge on solar water heaters between the students of the different faculties. The technical faculty was not the faculty with the highest percentage of students that had heard of solar water heaters. This was not as expected since it was assumed that these students were most interested in these kind of technologies and would therefor on average know more about sustainable energy technologies. The questionnaire did not point out what the students their knowledge level on solar water heater technology is because the questions were not adequate. Overall the questionnaire was not designed for students but for the people in the village Banjaran. This made the questionnaire inadequate.

Field inventory

The research done by the field inventory showed that solar water heaters can be produced in Banjaran by metal workshops. Thus the production of solar water heaters can be done locally and part of the materials can be bought locally as well. For a possible business case for the production of solar water heaters in Banjaran one of the metal workshops can be contracted for doing the production and it is also possible to let them collect the necessary materials.

End of part 2 of the report

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Appendix I

An important parameter for the solar water heater is the temperature of the water in the storage tank. The size of the solar collector will be based on the temperature of the water in the storage tank. If this temperature is to low the solar collector area should be increased to increase the energy which will be absorbed and/or more fuel has to be burned in the stove. According to (Cheng-Li & Meng-Chieh, 2005) the average preferred shower temperature in a test in Taiwan is about 38.5 ℃ and the preferred shower temperature in Japan is 40.5 ℃. Because Indonesia lies on the equator and has a tropical climate it is assumed the preferred water temperature for showering is a little bit lower than in Taiwan which lies in the subtropical zone. Thus for the simulations a water temperature above 37 ℃ is preferred. This means that when the temperature will go below 37 ℃ the stove has to be used and/or the size of the solar collector has to be bigger.

Appendix II

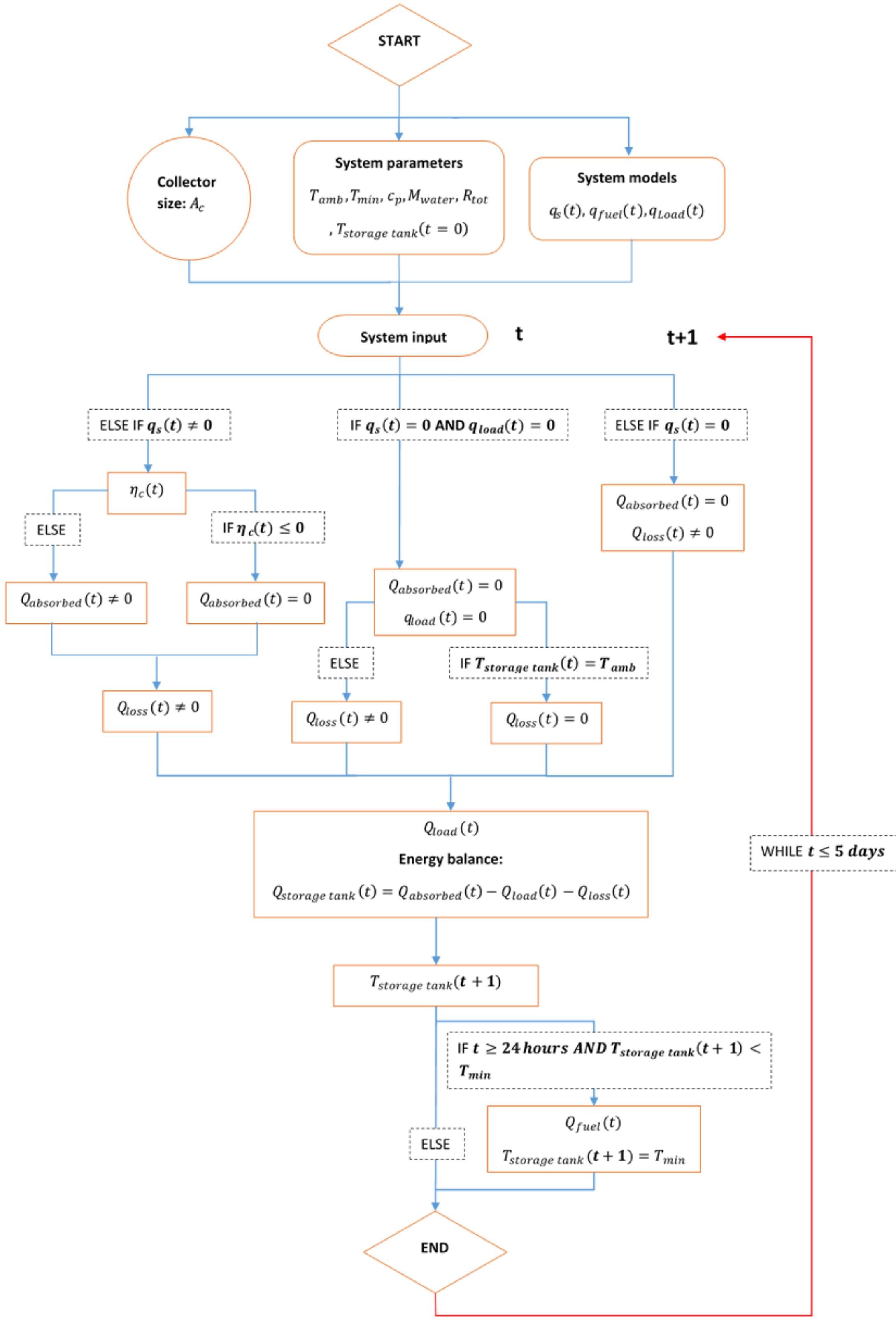
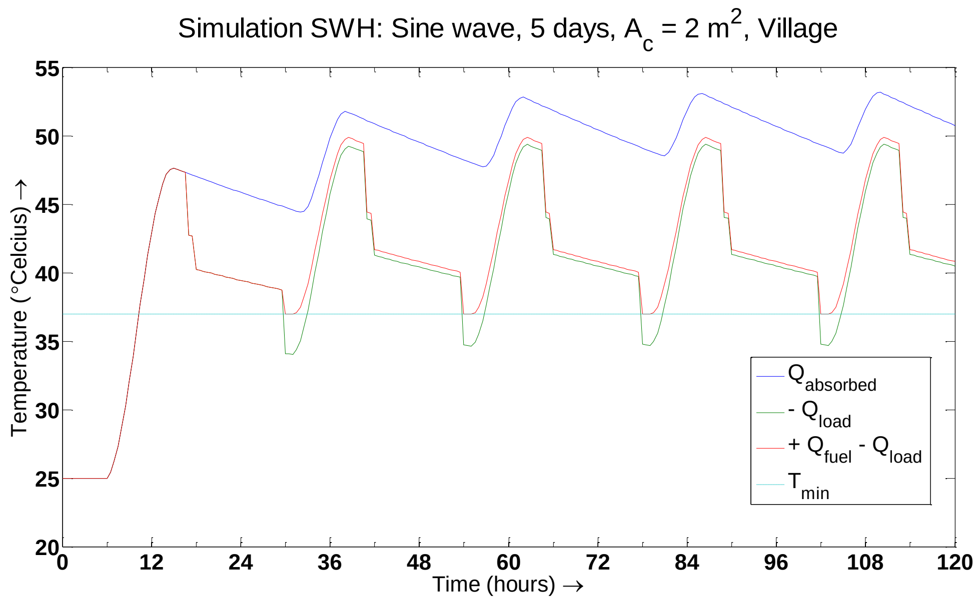
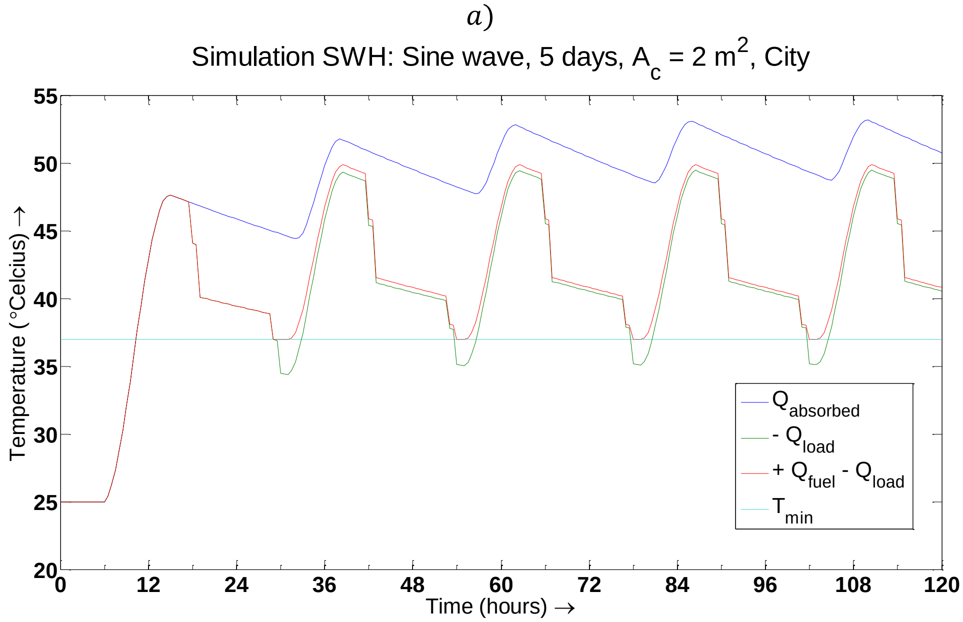


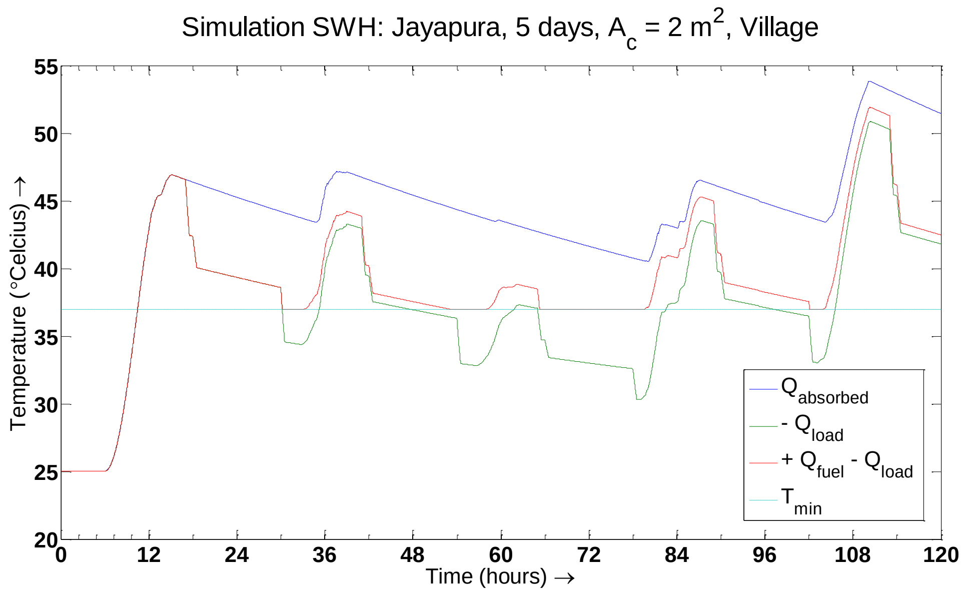
Figure II-I Process flow diagram of the SWH in MATLAB R2013a


Simulation SWH: Sine wave, 5 days, A_c = 2 m^2, Village
Temperature (°Celcius) →
Time (hours) →
55
50
45
40
35
30
25
20
0
12
24
36
48
60
72
84
96
108
120
$Q_{absorbed}$
- Q_{load}
+ Q_{fuel} - Q_{load}
T_{min}

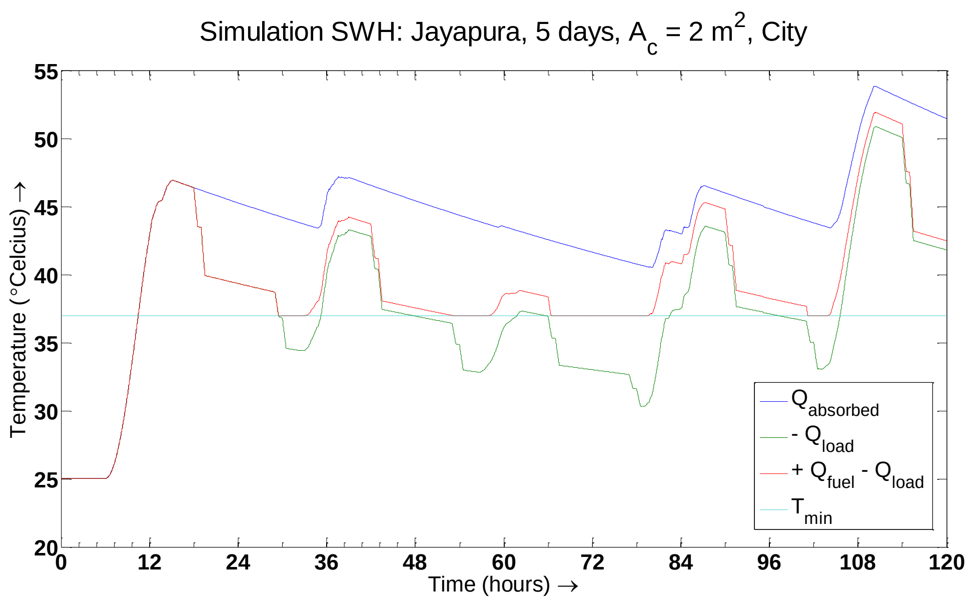
a)


Simulation SWH: Sine wave, 5 days, A_c = 2 m^2, City
Temperature (°Celcius) →
Time (hours) →
55
50
45
40
35
30
25
20
0
12
24
36
48
60
72
84
96
108
120
$Q_{absorbed}$
- Q_{load}
+ Q_{fuel} - Q_{load}
T_{min}

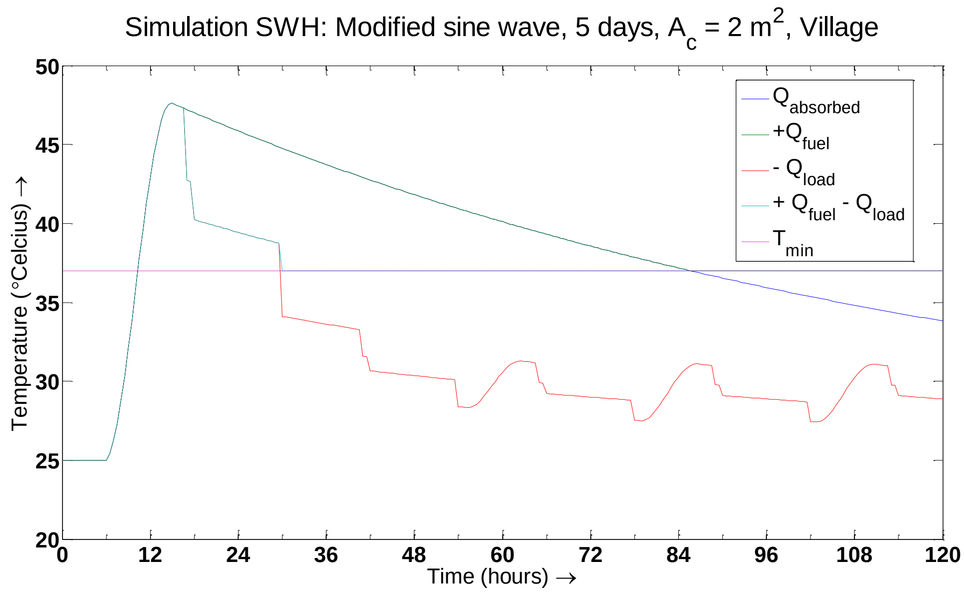
b)


Simulation SWH: Jayapura, 5 days, A_c = 2 m^2, Village
Temperature (°Celcius) →
Time (hours) →
55
50
45
40
35
30
25
20
0
12
24
36
48
60
72
84
96
108
120
Q_absorbed
- Q_load
+ Q_fuel - Q_load
T_min

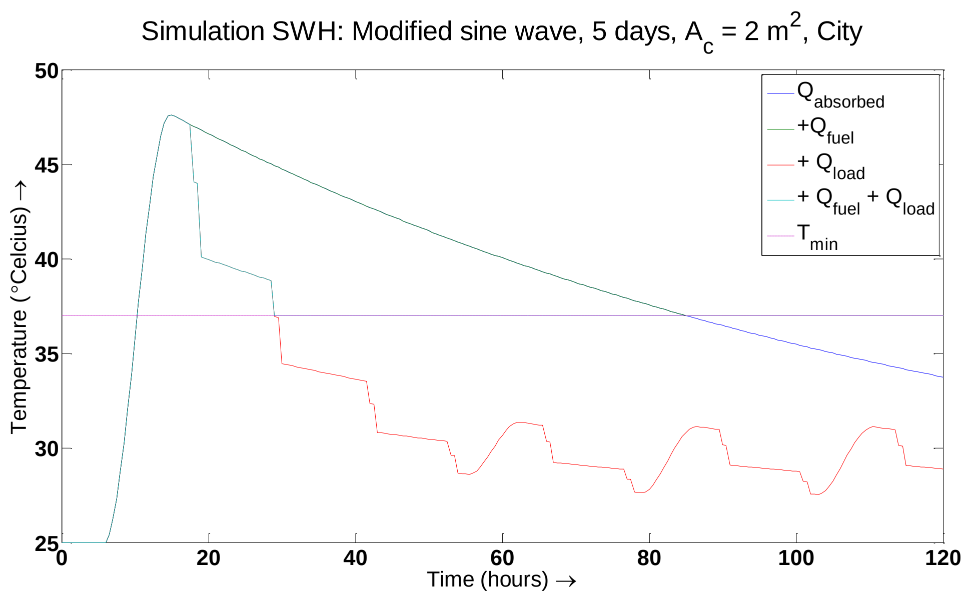
$c)$


Simulation SWH: Jayapura, 5 days, A_c = 2 m^2, City
Temperature (°Celcius) →
Time (hours) →
55
50
45
40
35
30
25
20
0
12
24
36
48
60
72
84
96
108
120
Q_absorbed
- Q_load
+ Q_fuel - Q_load
T_min

$d)$

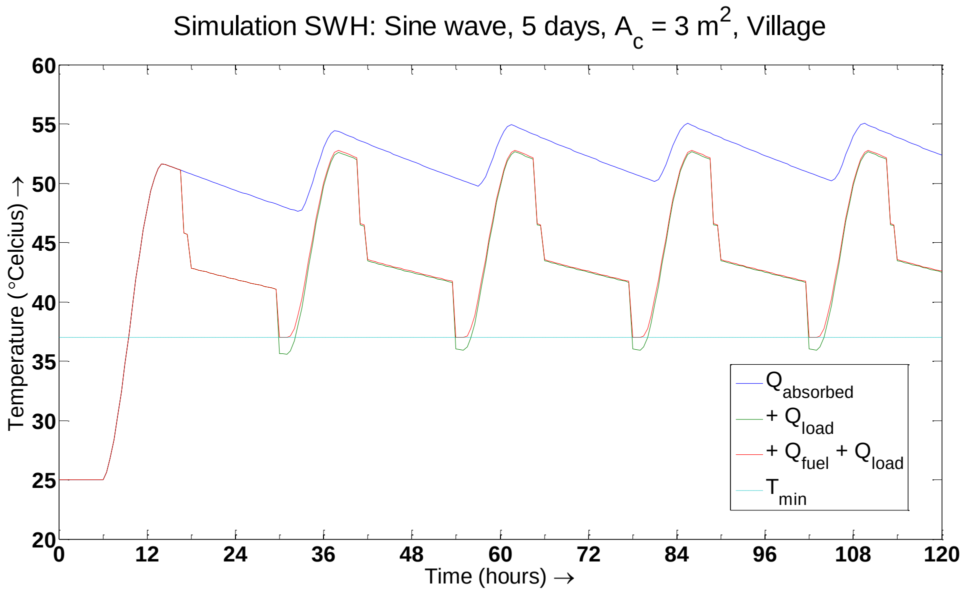


e)

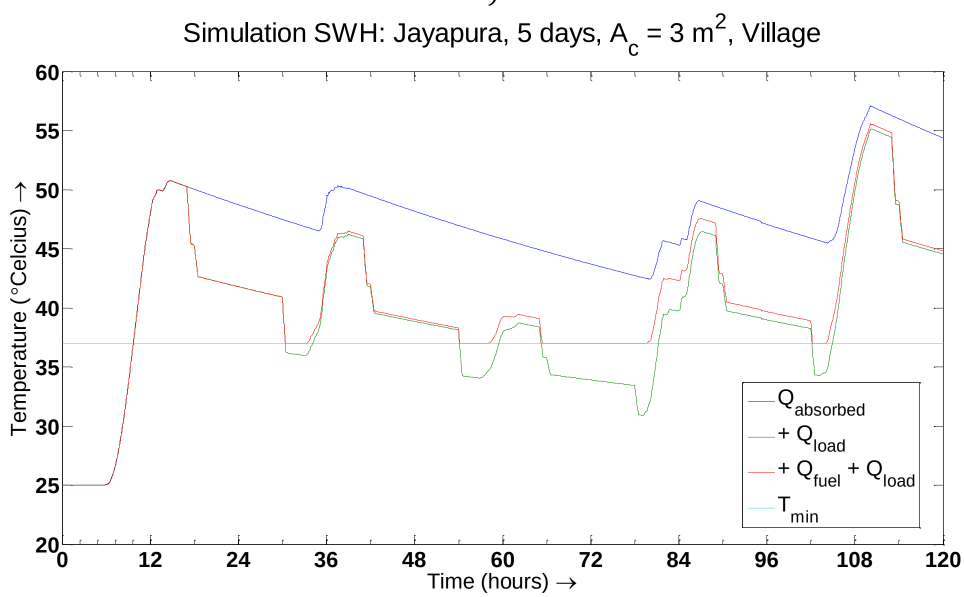


f)

Figure III-II Results scenario 2. Respectively Village and City loading profile. Solar irradiance model: a), b) Sine wave, c), d) Jayapura , e), f) Modified sine wave


Simulation SWH: Sine wave, 5 days, $A_c = 3\ m^2$, Village
Temperature (°Celcius) →
Time (hours) →
60
55
50
45
40
35
30
25
20
0
12
24
36
48
60
72
84
96
108
120
$Q_{absorbed}$
$+ Q_{load}$
$+ Q_{fuel} + Q_{load}$
T_{min}

a)


Simulation SWH: Jayapura, 5 days, $A_c = 3\ m^2$, Village
Temperature (°Celcius) →
Time (hours) →
60
55
50
45
40
35
30
25
20
0
12
24
36
48
60
72
84
96
108
120
$Q_{absorbed}$
$+ Q_{load}$
$+ Q_{fuel} + Q_{load}$
T_{min}

b)

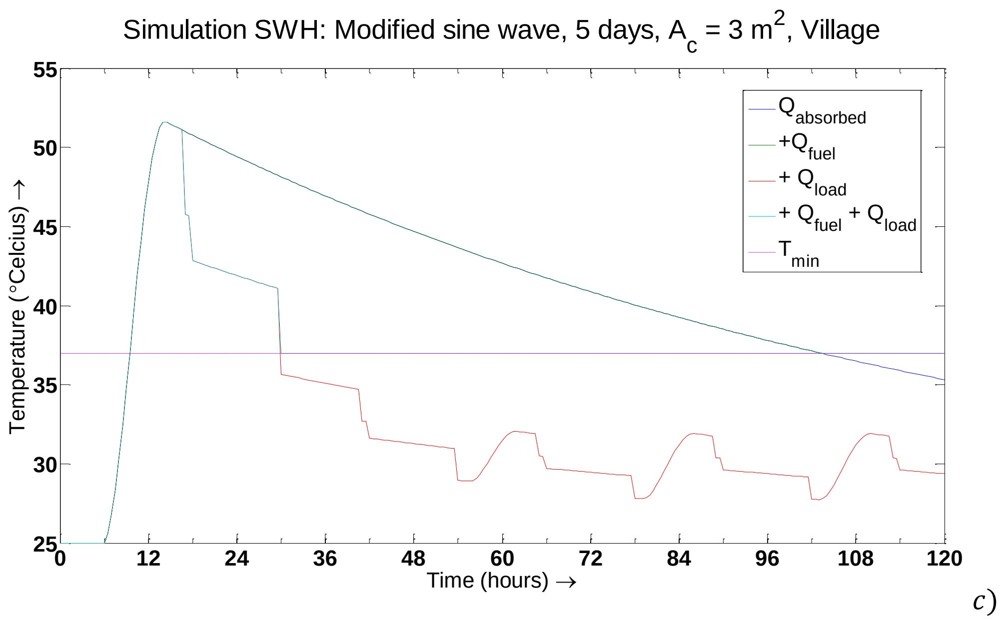


Figure III-III Results scenario 3. Solar irradiance model: a) Sinewave, b) Jayapura, c) Modified sine wave

Appendix *IV*

QUESTIONNAIRE

THIS QUESTIONNAIRE IS STRICTLY CONFIDENTIONAL AND IS FOR STUDY RELATED PURPOSES ONLY

My name is Kaj Pegels and I am following a master program at the University of Twente in the Netherlands. My master program is about sustainable/renewable energy. Characteristics of these energy sources is that they are available in abundance and they are environmentally non-polluting. Currently I am doing an internship for my study at the Institute Teknologi Bandung. My internship assignment is to make a mathematical model of a device which creates warm water by using the energy from the sun (a so called solar water heater). Also I am conducting a small research on this technology by this I am trying to find out whether or not there is any demand for such a device in rural areas (villages like Banjaran), if the device can be made cheap locally and if people have heard about sustainable/renewable energy. If you have questions or if some of the questions in this questionnaire are unclear please ask me. Thank you for your time and effort.

Contact details: email k.j.r.pegels@student.utwente.nl, tel. 0812 963 73862

<u>Questions</u>

1. What is your name?

---

2. What is your age?

○ 10-20 years

○ 21-30 years

○ 31-50 years

○ 51-70 years

○ 71-older

3. What is your profession?

---

4. What is your religion?

- ◯ Islam
- ◯ Catholicism
- ◯ Protestantism
- ◯ Hinduism
- ◯ Buddhism

5. With how many persons do you live together?

- ◯ 1-3 persons
- ◯ 4-6 persons
- ◯ More than 6 persons

<u>The following questions are on the usage of warm water.</u>

6. Do you use a gayung or a shower head for showering?

- ◯ Gayung
- ◯ Showerhead
- ◯ Both

7. How many times a day do you shower?

- ◯ 1
- ◯ 2
- ◯ 3 or more

8. For how long do you take a shower?

- ◯ 0-5 minutes
- ◯ 6-10 minutes
- ◯ 11-15 minutes
- ◯ 16-20 minutes

◯ Longer than 20 minutes

9. Do you live with old people in your residence?

◯ Yes

◯ No

10. If so, do they use warm water and how often a day?

◯ No

◯ Yes, 1-4 times a day

◯ Yes, 5-8 times a day

◯ Yes, more than 8 times a day

◯ Yes, I don't know how many times a day

11. Are there any babies in your residence?

◯ Yes

◯ No

12. If so, do they use warm water and how often a day?

◯ No

◯ Yes, 1-4 times a day

◯ Yes, 5-8 times a day

◯ Yes, more than 8 times a day

◯ Yes, I don't know how many times a day

13. The following is a list of methods to heat up cold water. Which of these methods have you used?

◯ Gas boiler

◯ Stove

◯ Solar water heater

◯ Other(s), namely:

----

14. Do you have access to warm water in your current residence?

◯ Yes

◯ No

If question 14 was answered with *yes* continue with part B. Otherwise continue with question 15.

15. Do you plan to get warm water access?

◯ Yes

◯ No

◯ I don't know

16. Have you ever lived in a residence with warm water connection?

◯ Yes

◯ No

If question 16 was answered with *yes* continue with question 17. Or else continue with part C.

17. How important is it for you to get warm water access again?

◯	◯	◯	◯	◯
Not important	Not really important	Neutral	Important	Very important

Continue with part C.

B

18. How many times a day do you use warm water?

◯ 1-2

◯ 3-4

◯ 5-6

◯ More than 6 times a day

19. Do you have warm water connection all the time?

◯ Yes

◯ No

◯ Only part time

C

20. During rainy season how important is warm water for showering?

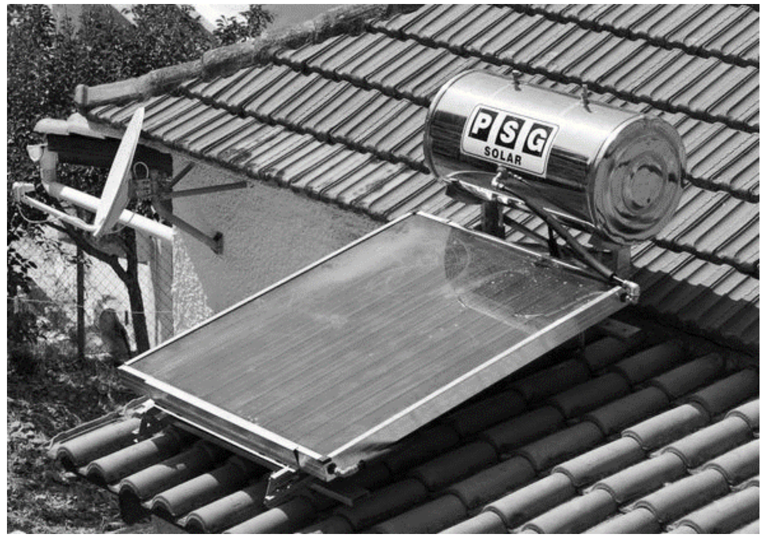
◯	◯	◯	◯	◯
Not important	Not really important	Neutral	Important	Very important

21. During dry season how important is warm water for showering?

◯	◯	◯	◯	◯
Not important	Not really important	Neutral	Important	Very important

The following questions are on solar water heaters.

The figures below give 2 examples of a solar water heater



22. Do you know what a solar water heater is?

◯ Yes

◯ No

If question 22 was answered with *no* continue with part D. Otherwise continue with question 23.

23. Do you own a solar water heater or have a friend or relative who owns a solar water heater?

◯ Yes, I own a solar water heater

◯ Yes, a friend or relative of mine owns a solar water heater

No, I don't own a solar water heater and neither do I have friends or relatives that own one.

24. Do you know the main components of a solar water heater?

◯ Yes

◯ No

25. Will the solar water heater work when there is no sun?

◯ Yes

◯ No

◯ I don't know

Also explain why?

----

26. Guess the lifetime of a solar water heater?

◯ 1-5

◯ 6-10

◯ 10-20

◯ More than 20 years

27. Have you ever considered buying a solar water heater?

◯ Yes

◯ No

Also explain why?

Continue with part E.

D

Description of a solar water heater:

A solar water heater is a device which uses the energy from the sun to heat up water and to store the warm water. Warm water which can be used for example for showering. The main components of a simple solar water heater are a solar collector, which collects the heat, a storage tank, to store the warm water and to supply the warm water to the user, and a cold water reservoir, which is needed to keep the storage tank filled with water. The device is not maintenance intensive and does not need a fuel like wood to heat up the water. The disadvantages of a solar water heater is the limited storage capacity, the time it takes to heat up the water and the dependency on the solar energy which will be available.

28. Having read the short description of a solar water heater would you consider buying such a device?

◯ Yes

◯ No

◯ I don't know

Also explain why?

----

29. Would you prefer buying a warm water system working on solar energy or on another energy source like gas or wood (for a boiler)?

◯ System on solar energy

◯ System on a other energy source

◯ I don't know

E

30. Do you have free space around or on top of your residence with a lot of sun?

◯ Yes

◯ No

◯ I don't know

31. During the rainy season the warm water capacity of the solar water heater can be much lower than in the dry season. Before purchasing such a device you think this is an important characteristic of the device to pay attention to?

◯	◯	◯	◯	◯
Not important	Not really important	Neutral	Important	Very important

The following questions are on renewable/green energy.

32. Have you ever heard of the terms renewable energy or green energy?

◯ Yes

◯ No

If question 32 was answer with *no* continue with part F. Otherwise continue with question 33.

33. Could you explain the meaning of the terms renewable/green energy?

----

34. The following list shows different kinds of renewable energy sources. Check the boxes of the energy sources that you know.

☐ Wind Energy

☐ Solar Energy

☐ Geothermal Energy

☐ Bio Energy

☐ Hydro power

☐ Other(s), namely:

----

35. Would you consider using one of the types of energy listed in question 34?

◯ Yes

◯ No

◯ I don't know

Also explain why?

End of the questionnaire

F

Explanation of renewable or green energy:

Renewable or green energy sources are energy sources that do not deplete. An example of such an energy source is the power from the sun, solar energy. There is plenty of sunlight, the sun is available for everyone and it is for free. Other energy sources like oil which are heavily used in the car industry are limited available. Furthermore renewable energy sources are environmental friendly and for this reason they are also called green energy sources. For example the solar energy does not pollute the earth whereas burning oil causes toxic exhaust gases.

36. The following list shows different kinds of renewable energy sources. Check the boxes of the energy sources that you know.

☐ Wind Energy

☐ Solar Energy

☐ Geothermal Energy

☐ Bio Energy

☐ Hydro power

☐ Other(s), namely:

----

37. Would you consider to use one of these types of energy knowing that they are more expensive but environmental more friendly and sustainable?

◯ Yes

◯ No

◯ I don't know

Also explain why?

End of the questionnaire

Appendix V

KUISIONER

KUISIONER INI DIGUNAKAN UNTUK KEPENTINGAN STUDI SEMATA

Nama saya Kaj Pegels dan saya sedang mengambil program master/S2 di University of Twente di Belanda. Program master saya adalah tentang *sustainable energy* atau yang dikenal sebagai energi terbarukan. Karakteristik dari sumber energi jenis ini adalah mereka tersedia dimana-mana dan dan ramah lingkungan karena tidak mencemari lingkungan. Saat ini saya sedang menjalani program internship di Institut Teknologi Bandung atau ITB. Proyek saya dalam program internship ini adalah membuat model matematika dari sebuah alat yang menghasilkan air panas / air hangat dengan memanfaatkan energi dari matahari, yang biasa dikenal dengan Pemanas air tenaga surya. Saya juga melakukan penelitian lebih lanjut mengenai hal tersebut terkait teknologi tersebut, dan saya juga mencoba untuk mengetahui apakah alat seperti ini digunakan atau ingin digunakan di daerah pedesaan (misal seperti di Banjaran), apakah alat seperti ini dapat dibuat dengan mudah dan murah dengan memanfaatkan workshop yang tersediaa di sekitar, dan apakah orang-orang tersebut pernah mendengar tentang *sustainable energy* / energi terbarukan. Apabilka anda mempunyai pertanyaan atau ada dari pertanyaan kuisioner yang diberikan tidk jelas, anda dapat menanyakannya kepada saya. Terima kasih untuk waktu dan kesediannya untuk mengisi kuisioner. Terima kasih.

email : k.j.r.pegels@student.utwente.nl, tel. 0812 963 73862

Questions

1. Siapa nama anda?

---

2. Berapa umur anda?

- ○ 10-20 tahun
- ○ 21-30 tahun
- ○ 31-50 tahun
- ○ 51-70 tahun
- ○ Lebih dari 71 tahun

3. Apakah pekerjaan anda?

---

4. Apakah agama yang anda anut?

- ◯ Islam
- ◯ Katolik
- ◯ Protestan
- ◯ Hindu
- ◯ Buddha

5. Berapakah jumlah orang yang tinggal dirumah anda?

- ◯ 1-3 orang
- ◯ 4-6 orang
- ◯ Lebih dari 6 orang

Pertanyaan berikut merupakan pertanyaan terkait dengan penggunaan air hangat.

6. Apakah anda menggunakan gayung atau shower untuk mandi?

- ◯ Gayung
- ◯ Shower
- ◯ Keduanya

7. Berapa kali anda mandi dalam satu hari?

- ◯ 1
- ◯ 2
- ◯ 3 atau lebih

8. Berapa lama biasanya anda mandi?

- ◯ 0-5 menit
- ◯ 6-10 menit
- ◯ 11-15 menit

○ 16-20 menit

○ Lebih dari 20 menit

9. Apakah anda juga tinggal dengan orang yang berusia lanjut di tempat tinggal anda (misal kakek/nenek anda)?

○ Ya

○ Tidak

10. Jika Ya, apakah mereka menggunakan air hangat saat mandi? Dan berapa kali dalam sehari mereka menggunakannya?

○ No

○ Ya, 1-4 kali sehari

○ Ya, 5-8 kali sehari

○ Ya, lebih dari 8 kali sehari

○ Yes, namun tidak mengetahui berapa kali sehari

11. Apakah ada anak usia 5 taun ke bawah yang tinggal bersama anda?

○ Ya

○ Tidak

12. Jika Ya, apakah mereka menggunakan air hangat saat mandi? Dan berapa kali dalam sehari mereka menggunakannya?

○ Tidak

○ Ya, 1-4 kali sehari

○ Ya, 5-8 kali sehari

○ Ya, lebih dari 8 kali sehari

○ Yes, namun tidak mengetahui berapa kali sehari

13. Berikut ini adalah metode untuk memanaskan air sebelum mandi. Metode mana dari berikut ini yang pernah anda gunakan?

- Kompor gas
- Tungku/ Kompor dengan kayu bakar
- Pemanas air tenaga surya
- Lainnya …

---

14. Apakah anda biasa menggunakan air hangat di tempat tinggal anda?

- Ya
- Tidak

Jika pertanyaan nomor 14 dijawab dengan "*ya*" lanjutkan bagian B. Jika tidak, lanjutkan ke pertanyaan nomor 15.

15. Apakah anda berencana untuk mendapatkan akses untuk air hangat?

- Ya
- Tidak
- Saya tidak tahu

16. Pernahkah anda tinggal dirumah yang memiliki fasilitas air hangat?

- Ya
- Tidak

Jika jawaban untuk pertanyaan nomor 16 adalah *"Ya"*, lanjutkan. Jika tidak, lanjutkan ke bagian part C

17. Seberapa pentingkah bagi anda untuk mendapatkan fasilitas air hangat?

◯ Tidak penting	◯ Tidak terlalu penting	◯ Netral	◯ Penting	◯ Sangat penting

Lanjutkan ke bagian C.

B

18. Berapa kali dalam satu hari anda menggunakan air hangat?

- ◯ 1-2 kali
- ◯ 3-4 kali
- ◯ 5-6 kali
- ◯ Lebih dari 6 kali

19. Apakah anda bisa mendapatkan air hangat setiap saat dirumah anda?

- ◯ Ya
- ◯ Tidak
- ◯ Kadang-kadang

C

20. Selama musim hujan, seberapa penting bagi anda untuk mandi dengan air hangat?

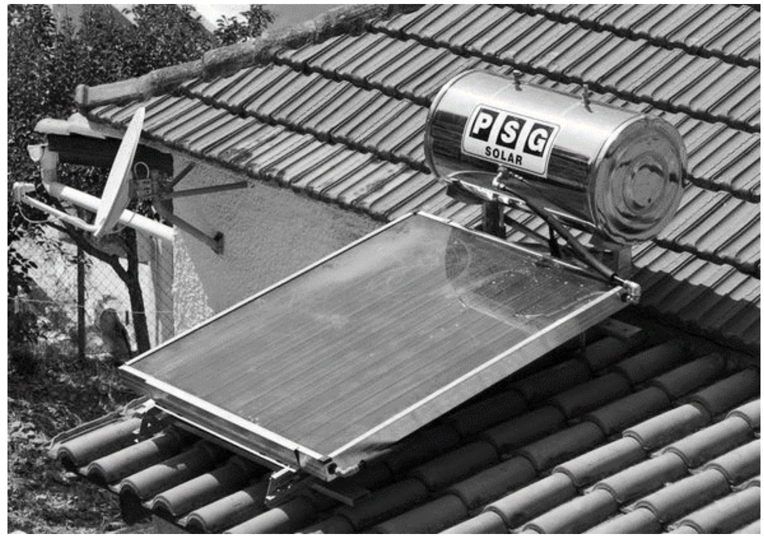
◯	◯	◯	◯	◯
Tidak penting	Tidak terlalu penting	Netral	Penting	Sangat penting

21. Selama musim kemarau, seberapa penting bagi anda untuk mandi dengan air hangat?

◯	◯	◯	◯	◯
Tidak penting	Tidak terlalu penting	Netral	Penting	Sangat penting

<u>Pertanyaan berikut ini adalah pada pemanas air tenaga surya.</u>

Gambar berikut merupakan dua contoh dari pemanas air tenaga surya / solar water heater



22. Apakah anda tahu tentang pemanas air tenaga surya?

◯ Ya

◯ Tidak

Jika pertanyaan nomor 22 dijawab dengan "*tidak*" lanjutkan pada bagian D. Jika menjawab ya, lanjutkan ke pertanyaan nomor 23.

23. Apakah anda memiliki pemanas air tenaga surya? Adakah teman/kerabat yang memilikinya

◯ Ya, saya memiliki pemanas air tenaga surya

◯ Ya, teman/kerabat saya memiliki pemanas air tenaga surya

◯ Tidak kedua-duanya

24. Apakah anda tahu komponen utama dari sebuah pemanas air tenaga surya?

◯ Ya

◯ Tidak

25. Apakah pemanas air tenaga surya dapat bekerja saat tidak ada matahari?

◯ Ya

◯ Tidak

◯ Tidak tahu

Mengapa begitu?

----

26. Berapa lama kira-kira umur sebuah pemanas surya tenaga matahari menurut anda?

◯ 1-5

◯ 6-10

◯ 10-20

◯ Lebih dari 20 tahun

27. Apakah pernah terpikir oleh anda untuk membeli pemanas air tenaga surya?

◯ Ya

◯ Tidak

Mengapa begitu?

Lanjutkan ke bagian E.

D

Penjelasan mengenai permanas air tenaga surya:

Permanas air tenaga surya adalah alat yang memanfaatkan energy yang berasal dari matahari dan menggunakannya untuk memanskan air, dan juga kemudian untuk menyimpannya. Kemudian air panas/hangat tersebut dapat digunakan untuk keperluan mandi misalnya. Komponen utama dari sebuah solar water heater adalah solar kolektor, yang berfungsi untuk mengumpulkan panas, tangki penyimpanan untuk menyimpan air yang telah dipanaskan dan mengalirkan air tersebut ke keran-keran, dan tangki air dingin yang digunakan untuk mengisi storage tank dengan air biasa. Alat ini tidak memerlukan perawatan atau maintenance yang bersifat rutin dan juga tidak memerlukan bahan bakar,misalnya seperti kayu atau minyak tanah,dsb. Salah satu keterbatasan yang ada pada pemanas air *tenaga surya adalah kapasitas dari tangki maupun dari pemanas air itu sendiri, waktu yang diperlukan untuk memanaskan air dan ketergantungan akan ketersediaan energi matahari.*

28. Setelah membaca penjelasan singkat mengenai pemanas air surya, apakah anda tertarik untuk membeli/memakainya?

◯ Ya

◯ Tidak

◯ Tidak tahu

Mengapa begitu?

----

29. Manakah yang anda pilih, apakah anda akan membeli pemanas air dengan tenaga surya atau membeli pemanas air dengan sumber tenaga lain,misal dengan tenaga gas elpiji/kayu untuk memanaskan air?

◯ Pemanas air dengan sumber energi matahari

◯ Pemanas dengan sumber energi lain

◯ Tidak tahu

E

30. Apakah anda memiliki tempat/area kosong yang tersinari matahari secara terus menerus di rumah anda?

◯ Ya

◯ Tidak

◯ Tidak tahu

31. Biasanya, suhu air yang dihasilkan pemanas air pada musim hujan lebih rendah dibandingkan dengan saat musim kemarau. Apakah hal tersebut menjadi salah satu pertimbangan pentingbagi anda sebelum membeli dan dalam pemilihan jenis pemanas air?

○ Tidak Penting ○ Tidak terlalu penting ○ Biasa Saja ○ Penting ○ Sangat Penting

Pertanyaan berikut terkait energi terbarukan / green energy.

32. Apakah anda pernah mendengar tentang energi terbarukan / *green energy*?

○ Ya

○ Tidak

Apabila pertanyaan no 32 dijawab 'Tidak' lanjutkan dengan bagian F. Apabila tidak, lanjutkan ke pertanyaan no 33

33. Dapatkah anda menjelaskan tentang energi terbarukan / *green energy* menurut pandangan anda?

----

34. Berikut adalah beberapa sumber dari energi terbarukan, manakah diantara daftar tersebut yang anda tahu?.

□ Energi Angin

□ Energi Matahari

□ Energi Panas Bumi

□ Bio Massa

□ Energi Hidro

☐ Lainnya, sebutkan

----

35. Apakah anda berminat untuk menggunakan sumber energi seperti yang telah disebutkan pada pertanyaan no 34?

◯ Ya

◯ Tidak

◯ Tidak Tahu

Mengapa begitu?

Selesai!!

F

Penjelasan mengenai energi terbarukan:

Energi terbarukan atau green energy adalah energi yang apabila digunakan terus menerus tidak akan pernah habis. Salah satunya adalah energi yang bersumber dari matahari, yaitu energi matahari. Cahaya matahari ada di mana-mana di sekitar kita dan kita dapat menggunakannya tanpa harus mengeluarkan biaya atau gratis. Sumber energi lain yang biasa digunakan di industri bukanlah energi terbarukan dan juga jumlahnya sangatlah terbatas. Energi terbarukan juga dikenal sebagai energi yang ramah lingkungan dan hal itu pulalah yang menyebabkan energi terbarukan sering disebut green energy. Sebagai contoh penggunaan energi matahari tidak mencemarkan lingkungan seperti penggunaakn bahan bakar fosil sebagai sumber energi.

36. Berikut adalah beberapa sumber dari energi terbarukan, manakah diantara daftar tersebut yang anda tahu?.

☐ Energi Angin

☐ Energi Matahari

☐ Energi Panas Bumi

☐ Bio Massa

☐ Energi Hidro

☐ Lainnya, sebutkan:

----

37. Apakah anda akan menggunakan peralatan yang menggunakan sumber energi terbarukan walaupun harganya lebih mahal tetapi ramah lingkungan, tidak merusak kesehatan dan tak pernah habis?

◯ Ya

◯ Tidak

◯ Tidak Tahu

Mengapa begitu?

Selesai!!

Appendix VI

Field Inventory - Materials

System part	Component	Part/material	Times found	Amount/type	Price
SC	Absorber/Metal box	Galvanized iron plate			
SC	Absorber	Copper tube			
SC	Absorber	Galvanized iron tube			
SC	Absorber	Iron wire			
SC	Absorber	Pop rivets			
SC	Absorber	Solder lamp			
SC	Absorber	flux			
SC	Absorber	a tin red lead paint			
SC	Absorber	primer			
SC	Absorber	a tin dull blackboard paint			
SC	Cover plate	Glass cover plate			
SC	Cover plate	Plastic cover plate			
SC/ST	Insulation material	Wool			
SC/ST	Insulation material	Coconut fiber			
SC/ST	Insulation material	Polyurethane			
SC/ST	Insulation material	Saw dust			
SC/ST	Insulation material	Kapok (Cotton)			
ST	Cover plate	flat/corrugated galvanised sheets			
ST/B	Drum/resevoir	metal drum (oil, diesel drum)			
ST	Drum	Plastic tank			
B	Resevoir	Plastic tub			
B	Resevoir	metal drum			
B	Resevoir	washing tub			
B	Resevoir	floating gauge			

Figure 24 Field inventory: materials

Field inventory - Manufacturing

Manufacturing	Times found	Price	Quality
Welding			
Bending			
Soldering			

Figure 25 Field inventory: manufacturing

Appendix VII

Banjaran

Table 9 Questionnaire, Banjaran: general questions

	Questions		
Questionnaire	Q2	Q4	Q5
1	c	a	b
2	d	a	b
3	a	a	b
4	c	a	a
5	c	a	b
6	b	a	b
7	b	a	b
8	a	a	a
9	a	a	b
10	a	a	a
11	c	a	a
<u>Answers</u>			
Times "a"	4	11	4
Times "b"	2	0	7
Times "c"	4	0	0
Times "d"	1		
Times "e"	0		

Table 10 Questionnaire, Banjaran: (warm) water use questions

	Questions															
Questionnaire	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21
1	a	b	c	b	a	b	a	-	b	c	b	-			c	a
2	a	b	c	b	a	a	b	ab	b	-	b				b	a
3	a	b	c	b	a	a	b	a	a				a	c	d	b
4	a	c	e	b	a	b	a	a	b	b	b				d	a
5	a	b	d	b	a	a	b	a	b	a	b				d	a
6	a	c	b	b	a	a	a	b	b	c	b				c	a
7	a	a	a	b	a	a	a	a	b	b	b				d	a
8	a	b	c	b	a	b	a	a	a				-	a	c	b
9	a	b	b	b	a	a	b	a	a				b	a	c	a
10	c	b	b	b	a	b	a	a	a				a	c	c	a
11	a	b	c	b	a	b	a	a	b	c	b				a	a
<u>Answers</u>																
Times "a"	10	1	1	0	11	6	7	9	4	1	0	0	2	2	1	9
Times "b"	0	7	3	11	0	5	4	2	7	2	6	0	1	0	1	2
Times "c"	1	2	5		0		0	0		3		0	0	2	5	0

Times "d"				0		0	0				0	0		4	0
Times "e"				0		0					0			0	0

Table 11 Questionnaire, Banjaran: solar water heater questions

	Questions									
Questionnaire	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31
1	b						c	b	a	b
2	b						c	b	a	b
3	b						b	b	b	b
4	b						b	b	b	a
5	a	b	b	c	a	b			b	c
6	b						c	b	a	c
7	a	b	b	b	a	b			a	d
8	b						b	c	a	c
9	b						a	b	a	d
10	b						a	b	a	c
11	b						b	b	a	-
Answers										
Times "a"	2	0	0	0	2	0	2	0	8	1
Times "b"	9	2	2	1	0	2	4	8	3	3
Times "c"		0		1	0		3	1	0	4
Times "d"					0					2
Times "e"										0

Table 12 Questionnaire, Banjaran: sustainable energy questions

	Questions					
Questionnaire	Q32	Q33	Q34	Q35	Q36	Q37
1	b				e	c
2	b				non	c
3	b				non	b
4	b				b	c
5	b				bc	c
6	b				e	b
7	b				e	c
8	b				b	c
9	b				b	c
10	b				b	c
11	b				c	b
Answers						
Times "a"	0				0	0
Times "b"	11				5	3
Times "c"	0				2	8

Times "d"	0	0
Times "e"	0	3

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Table 13 Questionnaire, UIN: general questions

	Questions		
Questionnaire	Q2	Q4	Q5
FST - 1	a	a	c
FST- 2	b	a	b
FST - 3	a	a	b
FST - 4	a	a	b
FST - 5	a	a	b
FST - 6	b	a	a
FST - 7	b	a	c
FST - 8	a	a	b
FST - 9	a	a	b
FST - 10	a	a	b
FST - 11	a	a	b
FST - 12	a	a	c
FST - 13	b	a	b
FST - 14	a	a	b
FST - 15	b	a	b
FST - 16	a	a	b
FST - 17	a	a	a
FST - 18	a	a	a
FST - 19	b	a	a
FES - 20	a	a	b
FES - 21	a	a	b
FES - 22	a	a	b
FES - 23	a	a	b
FES - 24	a	a	c
FES - 25	a	a	a
FP - 26	a	a	b
FP - 27	b	a	c
FP - 28	b	a	c
FP - 29	b	a	b
FP - 30	a	a	b
FP - 31	a	a	b
FP - 32	b	a	b
Answers			
Times "a"	22	32	5
Times "b"	10	0	21
Times "c"	0	0	6

Times "d"	0
Times "e"	0

Table 14 Questionnaire, UIN: (warm) water use questions

	Questions															
Questionnaire	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21
FST - 1	a	b	b	a	a	a	b	a	a				-	-	b	b
FST- 2	a	b	b	a	e	b	a	a	b	-	a	c			c	a
FST - 3	a	b	b	b	a	b	a	a	a				a	a	e	b
FST - 4	a	b	b	b	a	a	e	a	a				a	c	d	b
FST - 5	a	a	c	b	a	b	a	a	a				a	c	c	c
FST - 6	a	b	e	b	a	b	a	a	b	b	b				c	a
FST - 7	a	a	c	a	e	a	e	a	a				-	-	d	b
FST - 8	a	b	b	b	a	a	a	a	a				a	a	b	a
FST - 9	a	b	d	b	a	b	-	a	a				a	c	d	c
FST - 10	c	b	c	b	a	b	-	a	a				a	b	b	a
FST - 11	a	b	b	a	e	b	a	a	a				a	a	c	a
FST - 12	a	b	b	a	e	a	e	a	a				a	c	d	c
FST - 13	a	b	c	a	b	a	b	ab	b	a	b	d			e	b
FST - 14	a	b	c	b	a	a	a	a	b	a	a	b			-	-
FST - 15	a	b	b	b	a	a	b	a	b	a	a	c			d	b
FST - 16	a	b	b	b	e	b	e	a	a				a	c	c	c
FST - 17	a	a	b	a	a	b		a	b	a	b				d	c
FST - 18	c	b	b	b	a	b	a	a	b	b	b		a	c	c	b
FST - 19	a	b	b	b		b	b	ab	b						c	a
FES - 20	c	b	d	b	a	a	e	a	b	b	a	c			c	b
FES - 21	a	b	b	b	a	a	b	b	a				a	c	c	c
FES - 22	a	b	b	b	e	a	b	a	a				b	a	c	c
FES - 23	a	b	c	b	a	b	a	a	a				a	a	c	b
FES - 24	c	b	e	a	b	b	b	a	a				a	c	-	-
FES - 25	a	c	b	b	a	b	a	a	a				a	c	b	a
FP - 26	a	b	b	b	a	a	b	a	b	a	a	b			b	a
FP - 27	a	b	c	b	a	b	a	a	b	a	a	d			d	a
FP - 28	a	a	e	b	a	a	b	a	b	a	b				a	b
FP - 29	c	b	a	b	a	b	a	d	a				a	c	c	b
FP - 30	a	b	b	b	a	b	a	a	b	b	b				b	b
FP - 31	a	b	b	b	a	b	a	a	b	a	b				c	c
FP - 32	a	b	c	b	a	a	a	a	b	b	b				b	a
Answers																
Times "a"	27	4	1	8	23	14	15	30	17	8	6	0	15	5	1	10
Times "b"	0	27	18	24	2	18	9	3	15	5	7	2	1	1	7	12
Times "c"	5	1	8		0		0	0		0		3	0	10	13	8

Times "d"			2		0		0	1				2	0		7	0
Times "e"			3		6		2					0			2	0

Table 15 Questionnaire, UIN: solar water heater questions

	Questions									
Questionnaire	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31
FST - 1	a	c	b	c	b	b			a	d
FST- 2	b						b	b	a	c
FST - 3	a	c	b	c	a	b			b	c
FST - 4	a	c	a	b	a	b			a	d
FST - 5	a	c	b	b	c	b			a	c
FST - 6	b						c	c	a	c
FST - 7	a	c	a	b	a	a			a	d
FST - 8	a	c	b	a	a	b			a	c
FST - 9	a	c	a	b	a	b			b	d
FST - 10	a	c	a	c	d	b			b	b
FST - 11	a	b	a	a	c	b			a	d
FST - 12	a	c	b	c	b	a			a	c
FST - 13	a	c	a	b	a	a			a	d
FST - 14	a	c	b	b	-	b			a	d
FST - 15	b						a	a	a	d
FST - 16	a	c	b	b	b	b			c	c
FST - 17	b						a	a	a	c
FST - 18	b						a	a	a	b
FST - 19	a	c	a	b	a	a			b	d
FES - 20	b						c	c	c	c
FES - 21	b						a	c	b	d
FES - 22	b						c	b	a	c
FES - 23	b						c	b	a	b
FES - 24	b						a	a	a	d
FES - 25	b						b	c	b	c
FP - 26	a	b	b	c	b	a			a	d
FP - 27	a	b	a	a	c	b			c	c
FP - 28	a	b	b	c	a	a			a	d
FP - 29	a	b	a	b	b	b			a	d
FP - 30	a	c	b	b	b	a			-	-
FP - 31	a	c	b	b	b	a			a	d
FP - 32	b						a	a	a	d
Answers										
Times "a"	20	0	9	3	8	8	6	5	22	0
Times "b"	12	5	11	11	7	12	2	3	6	3
Times "c"		14		6	3		4	4	3	12
Times "d"					1					16
Times "e"										0

Table 16 Questionnaire, UIN: sustainable energy questions

	Questions					
Questionnaire	Q32	Q33	Q34	Q35	Q36	Q37
FST - 1	a		bd	a		
FST- 2	b				b	a
FST - 3	b				b	a
FST - 4	a		bd	a		
FST - 5	a		abc	a		
FST - 6	b				b	-
FST - 7	b				ab	a
FST - 8	a		abc	a		
FST - 9	a		ab	c		
FST - 10	b		b	b		
FST - 11	a		abcde	a		
FST - 12	b				b	b
FST - 13	a		b	a		
FST - 14	a		bce	a		
FST - 15	b				b	a
FST - 16	b				bc	c
FST - 17	b				d	c
FST - 18	b				b	b
FST - 19	b				abc	a
FES - 20	b				b	c
FES - 21	b				e	c
FES - 22	b				ab	a
FES - 23	b				ab	a
FES - 24	a		bf			
FES - 25	b				b	c
FP - 26	b				abcd	a
FP - 27	b				b	c
FP - 28	b				e	b
FP - 29	b				b	c
FP - 30	b				b	a
FP - 31	a		d	a		
FP - 32	a		af	a		
<u>Answers</u>						
Times "a"	11		5	9	5	9
Times "b"	21		10	1	17	3
Times "c"	0		4	1	3	7
Times "d"	0		4		2	
Times "e"	0		2		0	
Times "f"			2			

Appendix $VIII$

Table 17 Field inventory Banjaran: availability materials

System part	Component	Part/material	Workshop 1	Workshop 2	Workshop 3
Solar collector (SC)	Absorber/Metal box	Galvanized iron plate	-	-	-
SC	Absorber	Copper tube	-	-	-
SC	Absorber	Galvanized iron tube	-	-	-
SC	Absorber	Iron wire	+	+	+
SC	Absorber	Pop rivets	+	+	+
SC	Absorber	Solder lamp	+	+	+
SC	Absorber	flux	+	+	+
SC	Absorber	a tin red lead paint	/	+	/
SC	Absorber	primer	-	+	+
SC	Absorber	a tin dull blackboard paint	-	+	+
SC	Cover plate	Glass cover plate	-	-	-
SC	Cover plate	Plastic cover plate	-	-	-
SC/Storage Tank (ST)	Insulation material	Wool	+	-	-
SC/ST	Insulation material	Coconut fiber	+	-	-
SC/ST	Insulation material	Polyurethane	+	-	-
SC/ST	Insulation material	Saw dust	/	/	/
SC/ST	Insulation material	Kapok (Cotton)	+	+	-
ST	Cover plate	flat/corrugated galvanised sheets	-	-	-
ST/Buffer (B)	Drum/resevoir	metal drum (oil, diesel drum)	-	-	-
ST	Drum	Plastic tank	-	-	-
B	Resevoir	Plastic tub	-	-	-
B	Resevoir	metal drum	-	-	-
B	Resevoir	washing tub	-	-	-
B	Resevoir	floating gauge	-	-	-
+ Available - To order / Unknown					