DESIGN, OPTIMIZATION AND PERFORMANCE EVALUATION OF A SOLAR HEAT COLLECTOR TROUGH AUTOMATED DATA ACQUIZITION SYSTEM

A project submitted to the Department of Mechanical Engineering for the partial fulfillment of the degree of B.Sc. in Mechanical Engineering

Submitted by

Nashid Ibne Shahid	200818010
Mustahseen Mobashwer Indaleeb	200918042
Dewan Akramul Haque	200918045

Supervised by

Dr. Engr. Md, Alamgir Hossain, PhD

Assistant Professor

Department of Mechanical Engineering

MILITARY INSTITUTE OF SCIENCE & TECHNOLOGY (MIST)

Mirpur Cantonment, Dhaka-1216

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STUDENT DECLARATION

We hereby declare that, this thesis and project paper is our original research work on "Design, Optimization and Performance Evaluation of a Solar Heat Collector Trough Automated Data Acquisition System". However contribution of others involved are indicated clearly with due reference. This paper is solely for academic purpose and was not submitted elsewhere for the award of any degree or as a publication.

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Nashid Ibne Shahid

Student No: 200818010

____

Dewan Akramul Haque

Student No: 200918045

____

Mustahseen Mobashwer Indaleeb

Student No: 200918042

SUPERVISOR CERTIFICATION

This is to certify that, Nashid Ibne Shahid, Student ID: 200818010; Mustahseen Mobashwer Indaleeb, Student ID: 200918042; Dewan Akramul Haque, Student ID: 200918045 have completed their undergraduate project and thesis entitled "Design, Optimization and Performance Evaluation of a Solar Heat Collector Trough Automated Data Acquisition System". This project and thesis work embodies original work under my supervision.

____

Dr. Engr. Md. Alamgir Hossain, PhD
Assistant Professor,
Department of Mechanical Engineering,
Military Institute of Science and Technology,
Mirpur Cantonment, Dhaka- 1216.
Date: December 2012

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The Authors.

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ABSTRACT

From the very beginning of the 21st century, the world is craving towards technological advancement. Every continent, every country is fighting for their survival through technology to make their future predictable and safe. Eventually, with the up rising demand of energy, the span of reserved petroleum started to reduce. Throughout the world, price of the petroleum products started to rise rapidly. At this stage researchers started to think about an alternative option as the source of energy. Thus the concept of solar energy came. At present Solar energy is termed as one of the most effective and reliable Renewable energy sources (RESs).

The rapid evolution of renewable energy sources during the last two decades resulted in the installation of many solar power units. The production of electricity from renewable energy technologies is mounting much faster than the electric power supply as a whole. Solar power is among the fastest emergent segments of the renewable energy market. Centralized solar power is produced on large farms and fed into an electrical grid. Globally, grid-connected solar capacity increased an average of 60 percent annually from 2004 to 2009, faster than any other energy source. Today, however, solar power still accounts for less than one-half of one percent of the world's power output.

This solar power can be utilized to conserve energy in various ways. Solar heat collector system is one of it. A good reason to use Solar Heat Collector System(SWHS) instead of conventional energy based systems, is that it offsets those greenhouse gases that would have been generated had the water been heated by electric power or natural gas.

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NOMENCLATURES

AM1 = Refers to Sun directly overhead.

AM2 = When Zenith angle (ϕ_z) is 60^o

AMO = Radiation outside earth's atmosphere.

ASTM A123 = A model of "American Society for Testing Materials".

CFC = Chlorofluorocarbon.

CRES = Corrosion Resistant Steel.

CSIR = Centre for Scientific & Industrial Research.

DNES = Department of Non-conventional Energy Sources.

EF = Energy Factor number.

Eskom/ESCOM = Electricity Supply Commission.

FHR = First Hour Rate.

GHG = Green House Gas.

GWh = Giga Watt Hour.

GWth= Giga Watt thermal

HCFC = Hydro chlorofluorocarbon.

HPWH = Heat pump water Heater.

ICS = Incident command System.

IEA = International Energy Agency.

I_{sc} = Solar Constant.

kW = Kilo Watt.

REDA = Renewable Energy Development Agency.

REN 21= Renewable Energy policy Network for 21^{st} century.

REP = Renewable Energy Policy.

RES = Renewable energy Sources.

SESSA 5010 = A project of Solar Energy Society of Southern Africa.

SHC= Solar Heat Collector

SWHS = Solar Water Heating system.

UV = Ultra Violet.

W/m^2 = Watt per meter square.

WRC = World radiation Centre.

δ = Sun declination.

Θ_s = Solar Elevation Angle.

Ψ = Solar Azimuth Angle.

ϕ_z = Zenith Angle.

Chapter 1

INTRODUCTION

1.1 IMPORTANCE OF SHC

1.2 APPLICATION IN REAL LIFE

1.3 PURPOSE OF THE PROJECT

1.1 IMPORTANCE OF SOLAR HEAT COLLECTOR

Small-scale renewable energy applications can contribute considerably to global climate protection while playing an important role in improving the quality of life in the developing world. Solar heat collector (SHC) is particularly promising; it is one of the simplest and least expensive ways to harness renewable energy and can be comparatively cost-effective for reducing greenhouse gas (GHG) emissions. With financial and other types of support via carbon trading mechanisms, SWH technology could be a valuable component of climate change mitigation efforts.

Solar water heating contributes to economic development in a number of ways. For example, without the need for highly capital-intensive manufacturing equipment, SHC systems are made in many developing nations, small and large alike. As such, substantial new job opportunities in manufacturing, retail sales, and business administration, as well as system design, installation, and maintenance can result from greater adoption of SHC technology. Additional local economic benefits include substantial savings of conventional fuel costs, with payback periods of three years or less in some locations.

1.2 APPLICATION IN REAL LIFE

Domestic solar water heaters for residential and commercial applications are one of the simplest and often among the most cost-effective renewable energy technologies. Using materials that are locally available in many countries, SHC systems can be constructed without highly sophisticated or tremendously expensive manufacturing technology. Yet, their simplicity belies their potential to contribute substantially to global Green House Gas(GHG) reduction efforts. Today, while billions of dollars are being poured into research and development of highly sophisticated, state-of-the-art energy technologies, solar water heating – one of the simplest and oldest renewable energy technologies – continues to prove its value in many parts of the world.

As a Scandinavian country, the climate of Bangladesh is more suitable to utilize the solar power in Water heating field. By using Solar Heat Collector System (SHCS), we can reduce our power generation as well as consumption resulting a cost effective power sector. Using Solar Heat Collector System, abundant electricity can be saved which is traditionally used in the electric heaters.

Solar water heating system can be extensively used to disinfect water, provide continuous supply of warm water for household applications, laboratory works, cleaning purposes, in industrial plants and other daily usages.

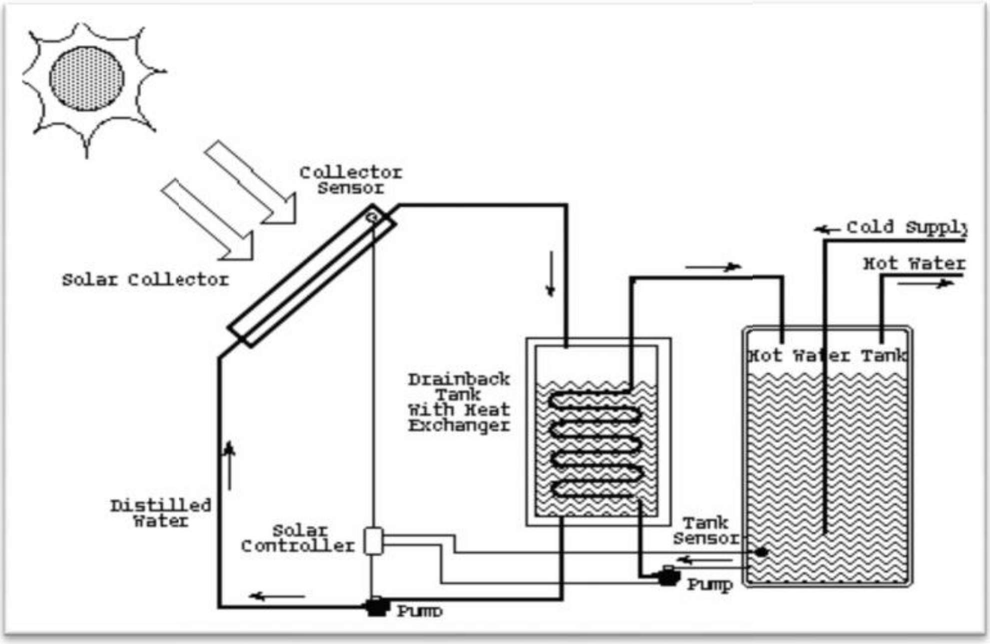

Figure 1.1: Traditional Drain-back hot water system [1]

1.3 PURPOSE OF THE PROJECT

Being an under-developed country, Bangladesh is facing a huge power shortage. A large amount of national currency is being expensed everyday to mitigate this demand. Thus, our development in power sector is so minimal that hardly helps our economy to rise.

So we need to invent some alternative systems using Renewable Energy Sources (RES) to minimize our fuel expense. The electric water heater is been used widely in our country to increase the temperature of water and get a continuous supply of warm water. It needs a huge amount of electricity to run these traditional electric heaters.

The sole purpose of this project is to make a model solar heat collector system having the feature of warming water up to required temperature and providing a continuous supply of warm water. The objective of making such a system is to get the maximum advantage at minimum possible cost. It will allow lower class and lower middle class people to afford it very easily if it can be produced industrially. Conserving solar heat is also a major purpose of our project.

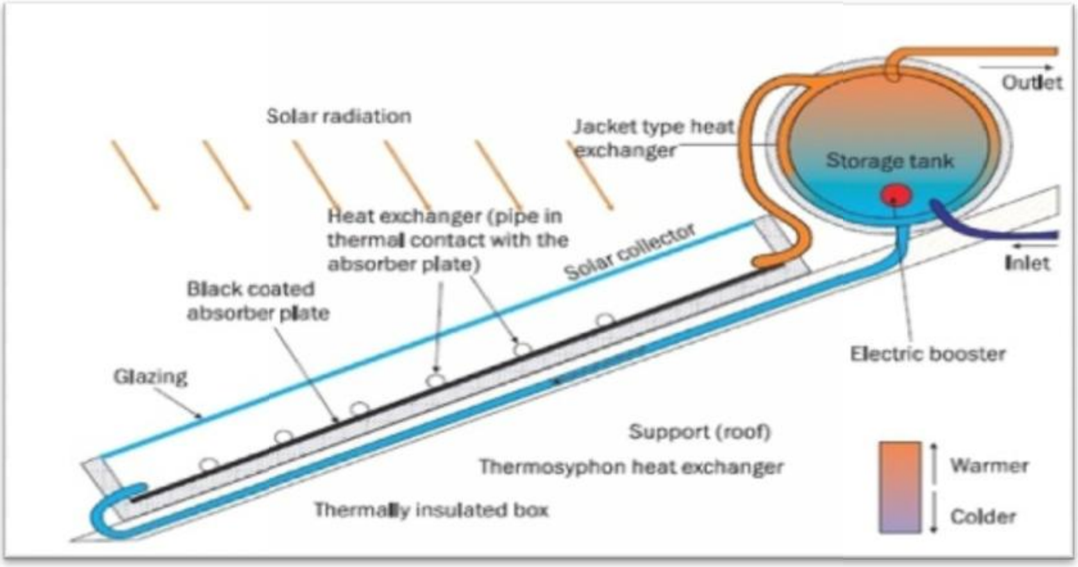

Figure 1.2: Diagrammatic representation of working of solar heat collector [2]

1.4 THESIS OUTLINE

The thesis comprises nine chapters. First chapter covers the importance application and purpose of the project. Second chapter gives a comprehensive description of solar water heater in the global and Indian sub-continent aspect. The chapter three covers a literature review on types, method of choosing and residential water heaters. A short description on solar sun path is also included. Chapter four contains design and construction of the device. The data acquisition system is discussed in chapter five. A detailed data analysis is shown in chapter six. Result analysis is covered in chapter seven. Chapter eight comprises discussion and conclusion which is followed by recommendations in chapter nine.

Chapter 2

SOLAR WATER HEATER: GLOBAL ASPECT AND INDIAN SUB-CONTINENT

2.1 INTRODUCTION

Most of the hot water demand in various applications is met by heating water through conventional energy, that is, electric geysers running on largely fossil power or natural gas based heating systems. Apart from being highly polluting, conventional electric heaters consume only a percentage of the actual electricity that is dispatched from the power plants across long transmission distances, which have large transmission losses. A good reason to use SWHS instead of conventional energy based systems, is that it offsets those greenhouse gases that would have been generated had the water been heated by electric power or natural gas. Most of the times, water heating (especially in the domestic sector) coincides with the peak load timings of the grid. This results in higher peak loads if most of the hot water demand is being met from conventional electric heaters. From the point of view of demand side management, it becomes indispensable to adopt non-conventional energy-based and energy efficient technologies, which can generate hot water with minimal requirements and dependence on fossil fuels, thereby contributing to shaving off the peak load. On the industrial front, a major portion of thermal energy requirements in the sector lies in the temperature range of 50 °C– 250 °C, which corresponds to the low/medium temperature range of solar thermal systems. These include dairy, food processing, textiles, hotels, edible oil, chemical, marine chemicals, bulk drug, breweries, and distilleries. Many of these industries also use hot water in the range of 70 °C– 90 °C [3]. These requirements are presently met primarily by combustion of fossil fuels like coal, lignite, and fuel oil. Solar energy, being abundant and widespread in its availability, makes it one of the most attractive sources of energies. Tapping this energy will not only help in bridging the gap between demand and supply of electricity but shall also save money in the long run. A 100 liter capacity SWHS can replace an electric geyser for residential use and may save approximately 1500 units of electricity, annually, under Indian Sub-continent conditions. Thus, a typical family can save 70%–80% on electricity or fuel bills by replacing its conventional water heater with a solar water heating system. It has also been estimated that a 100 liters per day system installed in an industry can save close to 140 liters of diesel in a year. So also, usage of solar water heater to supply pre-heated boiler feed water can help saving 70%–80% of fuel bills. Reduction of pollution and preservation of environmental health are some of the co-benefits of this technology. This is probably why the use of solar energy for water heating has become one of the largest applications of solar thermal systems today. Based on the abovementioned equivalence (100 lpd system saves 1500 units of electricity)[3], it is estimated that in generating the same amount of electricity from a coal-based power plant, 1.5 tones of CO2 is released into atmosphere annually [3]. One million SWHSs installed in homes will, therefore, result in reduction of 1.5 million tones of CO2 emission into the atmosphere. Clearly, SWHS is one of the most cost effective, viable, and sustainable options available for hot water generation today.

2.2 GLOBAL ASPECT

The demand of SWHSs has been increasing significantly in the few past decades and studies have shown that SWHS installations are increasing throughout the world. As a result, the global solar market achieved a growth rate of 15% in 2007. Solar thermal energy for domestic heating purposes is common all over the world with significant market penetration in Australia, China, Europe, Israel, Turkey, and Brazil. The existing capacity of solar water heaters across the globe has increased from 125 Gigawatt-thermal (GWth) to 180 GWth in a span of two years (2007–2009) [4]. China and Germany are the world leaders in terms of the number of SWHS installations. They are followed by Turkey, Brazil, and India in that order. In terms of existing capacity, China is still the leader, followed by Turkey, Germany, Japan, and Greece. Globally, China and the European Union are the two largest markets for solar water heaters. At the end of 2008, the solar thermal capacity worldwide, in operation, was 171 GWth, of which almost 59% (101 GWth) took place in China. Provisional numbers suggest that 2008 witnessed further 42% growth in the Chinese market (IEA 2009). An interesting example of successful replacement of existing heating systems with SWHS is that of South Africa's as it has a number of learning worthy of emulation. Although it does not figure among the top 5 achievers of the world in SWHS installations, South Africa has abundant sunshine and the average daily solar radiation is between 4.5 kWh/m^2 and 6.5 kWh/m^2 [4]. It is relatively predictable and well distributed throughout the country, with some regional variations. The country has an established manufacturing infrastructure for SWHSs. The South African experience with SWHS can be chronologically phased as below.

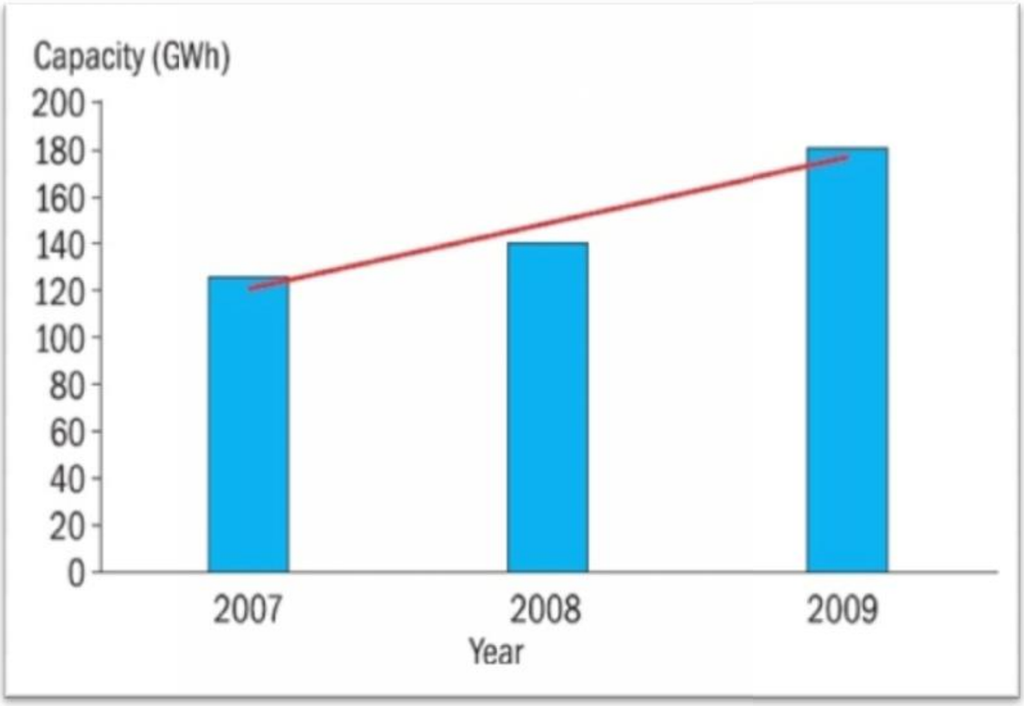

Figure 2.1: Trend in capacity addition of solar water heating systems (2007-09) [5]

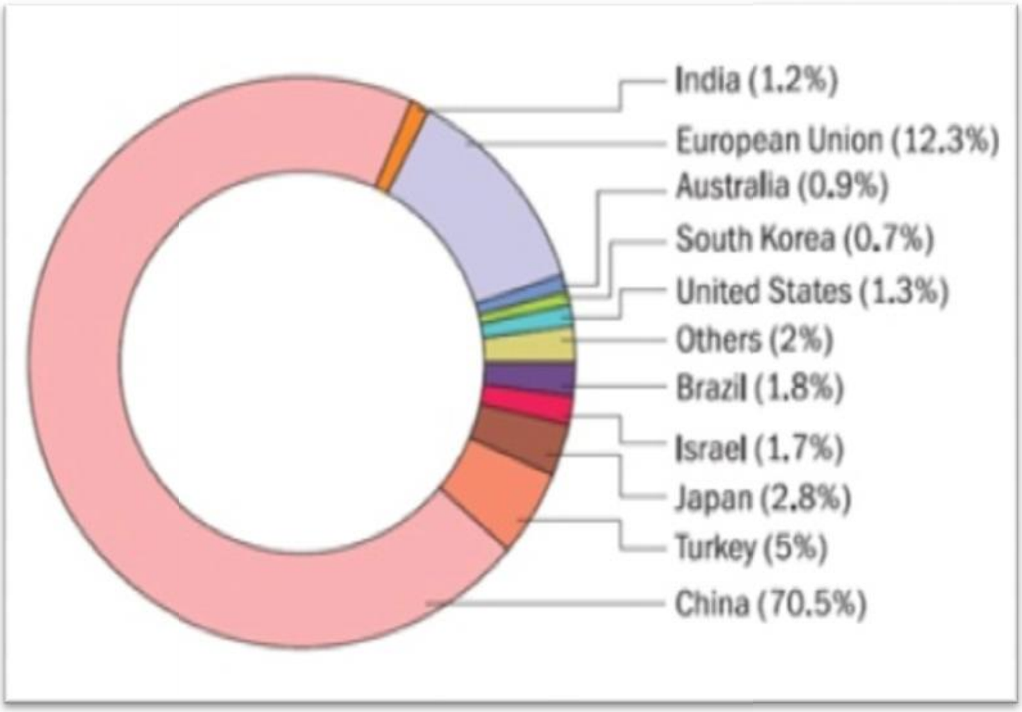

Figure 2.2: Global picture of SWHS in 2008 [6]

1. **Phase 1 (1978–1983):** This phase was marked by the widespread acceptance and installation of SWHs. The government supported the promotion of SWHs with the Centre for Scientific and Industrial

Research (CSIR), which developed effective communication strategies and projects by motivating home-owners to install them. Home owners would pay, either with a home improvement loan, or through cash. The SWH market grew mostly among the middle-to high-income customers. In 1983, about 27 000 m2 of solar collectors were produced. In that year, the SWH communication project of the CSIR came to an end and the market collapsed and has not yet recovered.

2. **Phase 2 (1984–2003):** The collapse of the SWH market happened during this period. SWH installations dropped and annual glazed collector installations were about half of what they had been in the previous phase.
3. **Phase 3 (post–2003)**: The White Paper on the Renewable Energy Policy of the Republic of South Africa, prepared by the Department of Minerals and Energy, Pretoria in 2003 gave a new perspective and created renewed interest in the field. The city of Cape Town has taken the initiative to supporting RE and ensuring that 10% of the households have SWH systems by 2010. For this, it has initiated a number of activities to promote the technology such as drafting a bylaw to promote SWHS, to retrofit low-income homes with SWHS, and so on.

The SWHS industry in the country is currently experiencing a revival. The media have begun covering the industry extensively. SESSA5010 is another project, which installed subsidized SWH and collected data for a detailed assessment of the technology. At the SWH workshop held at the International Conference on the Domestic Use of Energy in Cape Town in April 2007, Eskom11 presented its new approach to solar water heating and its inclusion into Eskom's Demand Side Management Program. In June 2007, the Eskom Board approved the investment of R 2 billion 12 to be made over five years. This is expected to have a positive impact on the SWH industry in South Africa. China, on the other hand, continues to dominate the global solar hot water industry. Chinese companies manufactured 28 million m2 of systems in 2009, representing 80% of global solar hot water heating output, the dominant manufacturer being Human Solar Energy. Although the European solar hot water heating industry has been marked by acquisitions and mergers among leading players in that market, it has managed to show a healthy growth of more than 12% annually during 2001–07, and a shift toward increased use of systems for space heating in addition to hot water. World-over, the residential sector has the largest market share in the solar water heater market. Majority of the SWHSs are installed in urban areas. An estimated 70 million households worldwide now employ solar hot water heating by sector [4].

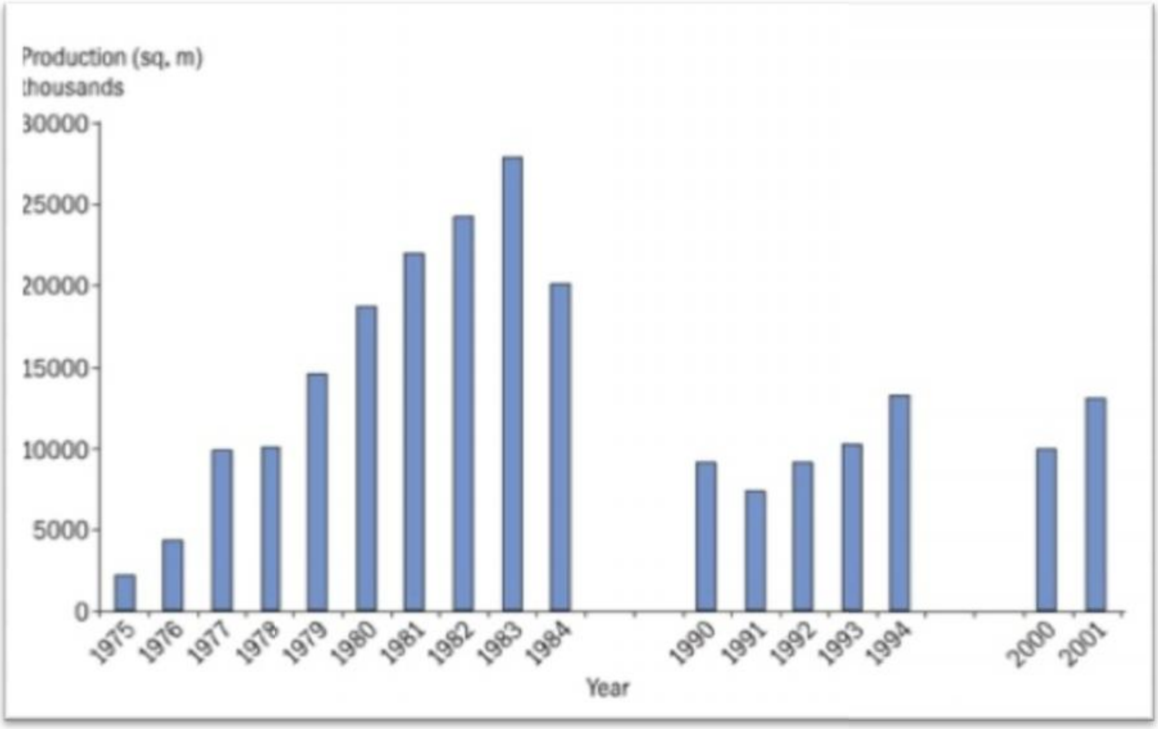

Figure 2.3: Solar collector production in 1975-2001 [6]

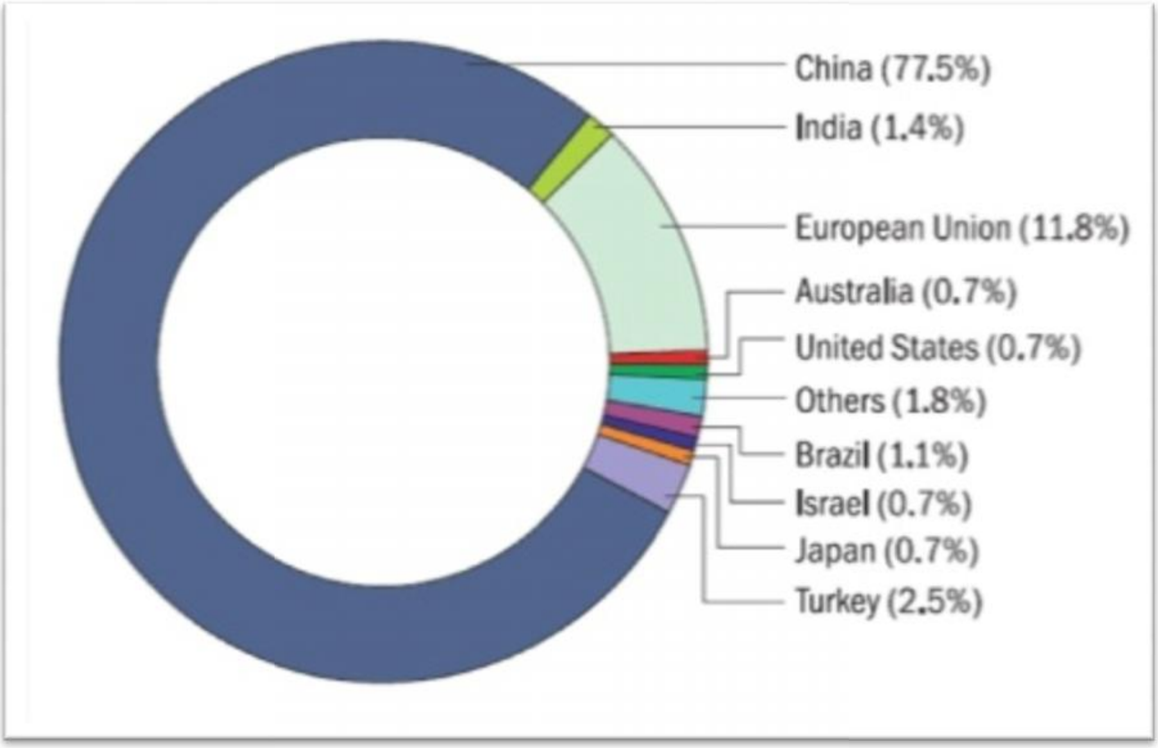

Figure 2.4: Global capacity addition in 2008 [5]

2.3 INDIAN SUB-CONTINENT ASPECT

In Indian Sub-continent, the first serious attempts to deploy the technology were made with the formation of the Department of Non Conventional Energy Sources (DNES) 21 in 1982 in India, though the history of research and pilot-demonstration go back to the 1960s. The continuing increases in electricity tariffs as well as problems associated with the electricity supply such as outages and voltage fluctuations have forced users to look for alternate means of which solar hot water system is one of the options. Most parts of Indian Sub-continent receive high amount of solar radiation, which makes solar water heating an attractive and viable option. Today, Indian Sub-continent ranks fifth in terms of the number of SWHSs installation, accounting for 1.4% of the total heating capacity through solar water heaters around the world 22 (REN21 Global Status Report 2010). As per industry estimates, currently, almost 70%–80% of the SWHS sales occur in the residential sector. In the year 2001, almost 80% of the SWH installations in Indian Sub-continent were in the commercial and industrial sectors. Since then, the residential sector has overtaken commercial and industrial sectors and has become the main driver of growth of SWHS in Indian Sub-continent. More than 95% of these households are located in the urban areas. Diffusion of SWHSs in industrial sector is limited and scattered

Table 2.1: Monthly Solar radiation at different locations of Bangladesh (kWh/m^2.day period, 1988-1998) [7]

Month	Dhaka	Rajshahi	Sylhet	Chittagong	Barishal	Khulna
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.19
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.79	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97

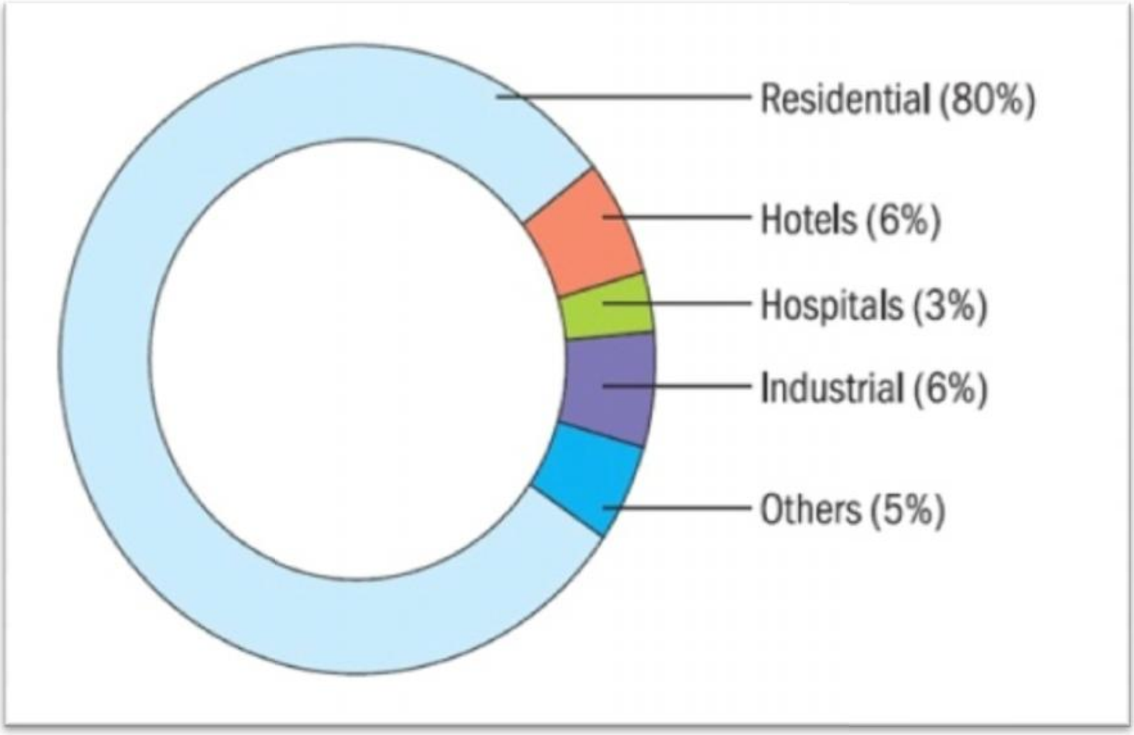

Figure 2.5: SWHS installation in Indian Sub-continent in different sectors [5]

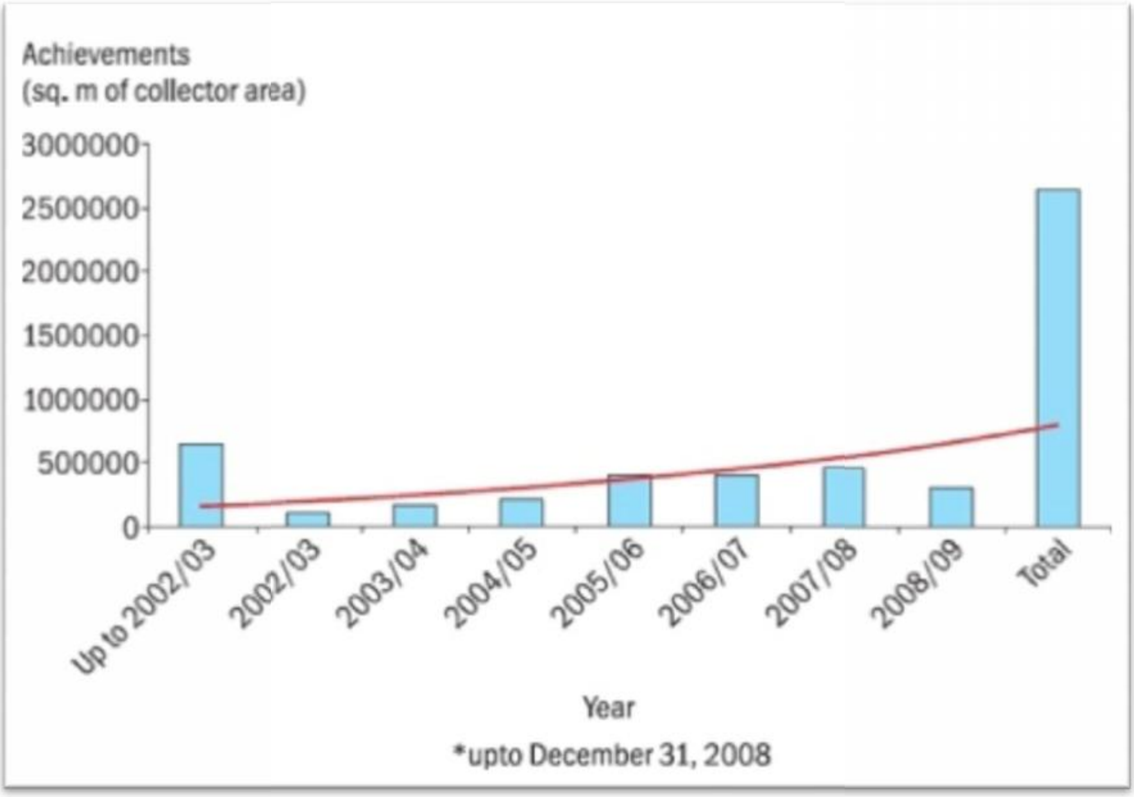

Figure 2.6: Total SWHS installations in Indian Sub-continent [8]

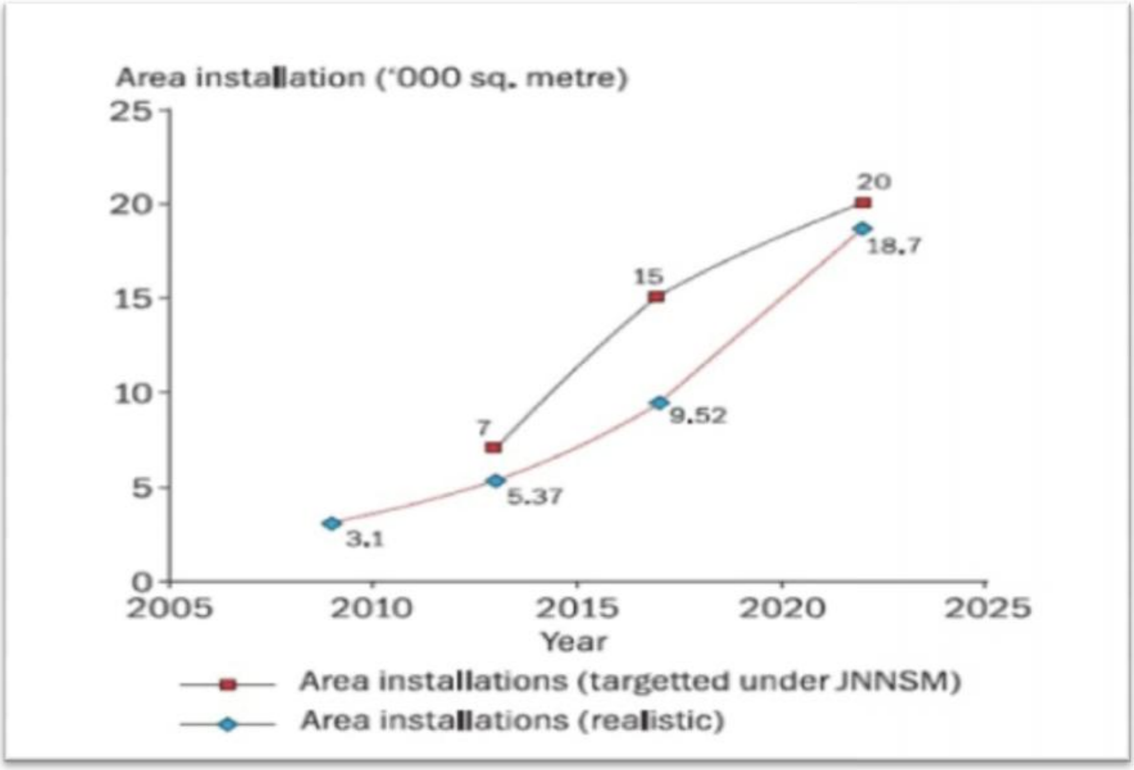

Figure 2.7: Estimated vs. current scenario up to 2022 in Indian Sub-continent [9]

Chapter 3

LITERATURE REVIEW

3.1 INTRODUCTION

3.2 TYPES OF SOLAR WATER HEATER

3.3 CHOOSING A WATER-HEATING METHOD

3.4 TYPES OF SWH FOR RESIDENTIAL APPLICATION

3.5 ACTIVE SOLAR HEATING SYSTEMS

3.6 ESTIMATION ON SUN PATH

3.1 INTRODUCTION

Sun is a sphere of intensely hot gaseous matter. The solar energy strikes our planet a mere 8 min and 20 s after leaving the giant furnace, the sun, which is far away. The sun has an effective blackbody temperature of 5762 K. The temperature in the central region is much higher. In effect the sun is a continuous fusion reactor in which hydrogen is turned into helium. The sun's total energy output is 63 MW/m^2. This energy radiates outwards at all directions. Only a tiny fraction of the total radiation emitted is intercepted by the earth. However, even with this small fraction it is estimated that 30 min of solar radiation falling on earth is equal to the world energy demand for one year. Man realized that a good use of solar energy is in his benefits from the prehistoric times. The Greek historian Xenophon in his 'memorabilia' records some of the teachings of the Greek Philosopher Socrates (470–399 BC) regarding the correct orientation of dwellings in order to have houses which were cool in summer and warm in winter. Since prehistory, the sun has dried and preserved man's food. It has also evaporated sea water to yield salt. Since man began to reason, he has recognized the sun as a motive power behind every natural phenomenon. This is why many of the prehistoric tribes considered Sun as 'God'. Many scripts of ancient Egypt say that the Great Pyramid, one of the man's greatest engineering achievements, was built as a stairway to the sun. Basically, all the forms of energy in the world as we know it are solar in origin. Oil, coal, natural gas and woods were originally produced by photosynthetic processes, followed by complex chemical reactions in which decaying vegetation was subjected to very high temperatures and pressures over a long period of time. Even the wind and tide energy have a solar origin since they are caused by differences in temperature in various regions of the earth [10]. The greatest advantage of solar energy as compared with other forms of energy is that it is clean and can be supplied without any environmental pollution. Over the past century fossil fuels have provided most of our energy because these are much cheaper and more convenient than energy from alternative energy sources, and until recently environmental pollution has been of little concern. But the main problem is that proved reserves of oil and gas, at current rates of consumption, would be adequate to meet demand for another 40 and 60 years, respectively. The reserves for coal are in better situation as they would be adequate for at least the next 250 years [11]. If we try to see the implications of these limited reserves we will be faced with a situation in which the price of fuels will be accelerating as the reserves are decreased. Considering that the price of oil has become firmly established as the price leader for all fuel prices then the conclusion is that energy prices will increase over the next decades at something greater than the rate of inflation or even more. In addition to this is also the concern about the environmental pollution caused by the burning of the fossil fuels. In addition to the thousands of ways in which the sun's energy has been used by both nature and man through time, to grow food or dry clothes, it has also been deliberately harnessed to perform a number of other jobs. Solar energy is used to heat and cool buildings (both active and passive), to heat water for domestic and industrial uses, to heat swimming pools, to power refrigerators, to operate engines and pumps, to desalinate water for drinking purposes, to generate electricity, for chemistry applications, and many more. There are many alternative energy sources which can be used instead of fossil fuels. The decision as to what type of energy source should be utilized must, in each case, is made on the basis of economic, environmental and safety considerations. Because of the desirable environmental and safety aspects it is widely believed that solar energy should be utilized instead of other alternative energy forms, even when the costs involved are slightly higher [12]. In the aspect of Bangladesh, we do not have many reserve of petroleum. We have a good reserve of natural gases and coal. However the reserve is reducing day by day and the research on renewable energy is in a great dimension now in Bangladesh. The aspect of this project was to reduce the consumption of fuel or electricity which is consumed in domestic and industrial use of hot water supplies. On that basis, it can be told clearly that the necessity to develop an efficient solar water heater (SWH) is the demand of the era now. The subsequent development will show the progress of a solar water heater development stage by stage.

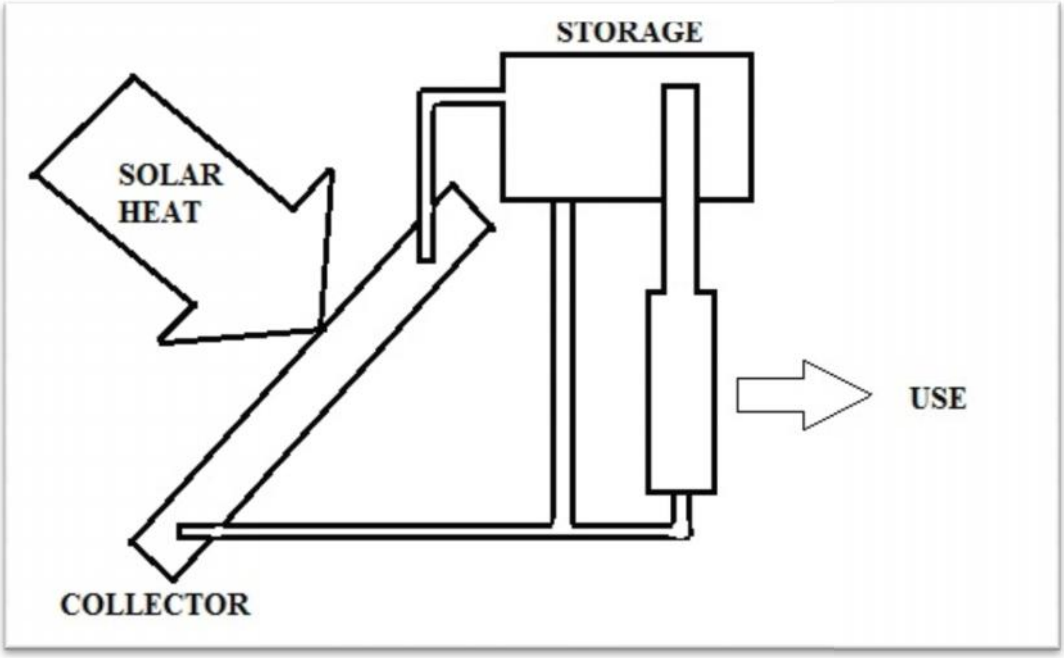

Figure 3.1: Block diagram of a solar water heating system

3.2 TYPES OF SOLAR WATER HEATER

A water heater uses a heating source to raise the temperature of incoming cold water from a municipal main or well. The heated water is stored in a tank and distributed on demand to showers, bathtubs, sinks and other water-using equipment in the home. Several types of water heaters are available:

1. Storage tank water heaters
2. Tank less water heaters
3. Integrated space heating systems
4. Solar water heaters
5. Heat pump water heaters
6. Conventional Gas water heaters
7. Electric Water Heaters

3.2.1 Storage Tank Water Heaters

Storage tank water heaters are by far the most common type used in Canada. These systems heat and store water in a tank so that hot water is available to the home at any time. As hot water is drawn from the top of the tank, cold water enters the bottom of the tank and is heated. The heating source can be electricity, gas or oil. More efficient storage tank water heaters can perform as much as 40 percent better than conventional models [13]. An energy-efficient model will typically have one or more of the following features:

1. Extra tank insulation for better heat retention and less standby loss (loss of
   Heat through the walls of the tank)
2. A better heat exchanger to transfer more heat from the energy source to the water
3. Factory-installed heat traps, which allow water to flow into the tank but prevent unwanted flow of hot water out of the tank.

Energy-efficient gas-fired storage tank water heaters may include additional design features [13]. Such as:

1. Electronic ignition, which saves energy by eliminating the need for a continuous pilot light powered exhaust.
2. Improved control of flue baffle and flue damper, which reduces heat loss through the flue vent.
3. Condensing heat exchangers, which greatly improve the overall efficiency.
4. Oil-fired water heaters with state-of-the-art burners, which offer high-efficiency performance and minimal stack losses.

3.2.2 Tank less Water Heaters

These systems (also known as demand or instantaneous water heaters) do not have a storage tank. They heat water only when it is needed, thus avoiding standby heat loss through tank walls and water pipes. The most basic units consist of either an electric element or a gas burner surrounded by flowing water.

Tank less water heaters are usually installed to serve a specific need near the point of use, such as under a kitchen sink. Depending on overall water usage, they may not have the capacity to supply an entire home with hot water. For this reason, they are often used as booster heaters to supplement another water heating system.

A relatively new tank less technology – the low-mass water heater – is capable of supplying much more hot water to the home. These systems are typically gas-fired with electronic ignition and power exhaust. This makes them more efficient than conventional tank less heaters. They can be connected to an external storage tank if necessary [13].

3.2.3 Integrated Space Water Heating Systems

Integrated space water heating systems combine the household heating requirement with the household hot water needs, saving money on total system installation. A single boiler is used, requiring only one combustion burner and one vent. Often these systems employ an insulated external storage tank with a high-efficiency low-mass boiler to heat the water, which then passes through a fan coil (as in a car radiator). The system then blows the heat around the house in a warm air distribution system, like a conventional furnace.

For integrated systems that do not use high efficiency boilers, the initial cost saving is soon eliminated by very low seasonal efficiency. The heater is sized to produce enough heat to warm a house on the coldest winter day. However, in the spring, summer and fall, when no heating is required, the same heater heats domestic hot water only. The effect is an oversized water heater that operates for several months of the year with a low heating demand – and low efficiency, as a result.

One type of integrated system that has been around for many years, particularly in the Maritime Provinces, is a fuel-fired hot water boiler with a tank less coil water heater that uses a heat exchanger in the boiler to heat tap water but without a separate storage tank. The water flows through a coil inside the boiler whenever a hot water faucet is turned on. The drawback is that this system is dramatically less efficient in warmer months, when space heating is not required, as the boiler water must be kept hot all the time [13].

3.2.4 Solar Water Heaters

Solar water heaters use the sun's energy to heat water. Active solar systems, on the other hand, use pumps and controls to move the heated water from the collector to the storage tank. In areas where the temperature drops below freezing, the fluid in the collectors is usually antifreeze, which is then run through a heat exchanger to heat the household water.

Solar systems can supply up to 50 percent of the energy needed to heat water for an average household (depending on climate conditions and water use). Since energy from the sun is free, solar water heaters can significantly reduce a household's water heating costs – savings that in turn can offset the higher purchase and installation costs of a solar system [14].

3.2.5 Heat Pump Water Heaters

Heat pump water heater (HPWH) technology uses electricity to move heat from one place to another instead of generating heat directly.

To understand the concept of heat pumps, imagine a refrigerator working in reverse. While a refrigerator removes heat from an enclosed box and expels that heat to the surrounding air, a HPWH takes the heat from surrounding air and transfers it to water in an enclosed tank.

A low-pressure liquid refrigerant is vaporized in the heat pump's evaporator and passed into the compressor. As the pressure of the refrigerant increases, so does its temperature. The heated refrigerant runs through a condenser coil within the storage tank, transferring heat to the water stored there. As the refrigerant delivers its heat to the water, it cools and condenses, and then passes through an expansion valve where the pressure is reduced and the cycle starts over [14].

3.2.6 Conventional Gas Water Heaters

These water heaters are very reliable and ready when you need them. Natural gas water heaters recuperate up to 40 percent quicker than electric models. Gas water heaters have higher efficiency ratings than electric water heaters of the equivalent storage capacity. So, it may be conceivable to meet your water-heating demands with a gas unit that has a smaller storage tank than an electric unit with the same rating. Gas water heaters shouldn't be insulated atop or within about 8 inches of the bottom of the tank.

Except for some reasonably new but minor gains in the area of insulation and energy efficiency, conventional gas water heaters have remained almost unaltered over the years. These water heaters can waste water as they have to reheat water in the tank as it cools down [14].

3.2.7 Electric Water Heaters

Electric prices dropped in the '50s, making electric water heaters more appealing. Installation and initial cost was also cheaper than solar hot water heaters.

As previously noted, electric hot water heaters are also slow to recover when compared with gas water heaters. Nevertheless upkeep of the electric water heater is easier as it involves very little maintenance. Electric Tank less Water Heaters are really small in size and therefore can be installed just about anywhere, even beneath a sink! The cost ranges between $700 - $800 and increases in cost as size increases. Electric tank less water heaters drag a lot of power and will call for multiple electric circuits and or heavier cable, which increases installation prices [14].

So as you can surmise, each type of water heater has pros and cons, with the tank less water heater gaining in acceptance and popularity.

3.3 CHOOSING A WATER-HEATING METHOD

When it comes to water-heater selection, experts say two considerations are the key: a unit's fuel type and first-hour rate (FHR). Consider both, say experts, but focus most on a unit's FHR the number of gallons of hot water that can be produced in the first hour to avoid the disappointment of running out of hot water. The FHR, which is listed in each model's list of specifications, is based on the hot water stored in the tank plus the amount of incoming cold water that can be heated in an hour. This is important for peak periods of use such as getting everyone showered first thing in the morning.

When you turn on a faucet, cold water enters the water heater's tank as hot water flows into the pipe. If the rate of flow out of the tank exceeds the water heater's capacity to heat the cold water flowing in to replace it, the temperature of the tank will start to fall putting out first tepid, then cold water.

To find your specific FHR requirement, think about the time of day when your household uses the most water. Online calculators and charts can assist you in calculating this number; see our Useful Links page for some helpful formulas. Then narrow your water-heater selection to models with an FHR specification that meets your requirements. Two 50-gallon water heaters may have quite different FHR ratings. Note that water heaters often gain in energy efficiency at the expense of recovery rate, so don't skip this crucial specification [14].

A unit's EF or federal energy-factor number, which indicates how efficiently a water heater converts fuel into hot water, can also be a useful tool. The higher the EF is, rating the better, with numbers generally ranging from 0.5 to 2.4. (Note: solar water heaters use a rating called the solar fraction, with 0.5 being the requirement for Energy Star certification.) Need to compare two water heaters that use the same fuel? Start by narrowing your choice to the water heaters with an FHR that meets your needs, and then look for the highest EF rating [15].

Consumers should also give some thought to their preferred fuel: solar, natural gas, propane, oil or electricity. It's important to acknowledge that most people replacing an existing water heater will be limited to the fuel type they're currently using, generally natural gas or electricity. The old rule of thumb was that it could be worth switching to a less costly fuel only if you plan to stay in your home for 10 years or longer. Now experts are starting to calculate cost savings in terms of return on investment -- with investing in an energy-efficient water heater offering better returns than most other choices [16].

Overall, experts say electric water heaters are less expensive and more efficient than gas water heaters, which lose some heat from the necessary venting. However, natural-gas rates are so much lower than electricity rates in many parts of the country that a gas water heater can still be the more cost-effective choice. Gas units also heat water faster than electric models, so you'll have more hot water available for times of peak usage. This also means consumers can get by with a smaller tank on a gas water heater. Still even under the umbrella of gas and electric there are many nuances. Water heaters can be categorized into several types, often used in combination:

Solar water heaters are currently the most energy-efficient option. You can offset costs by taking advantage of a federal tax credit of up to 30 percent of the cost and installation expense (with no price cap) until 2016 [16]. This tax credit applies to existing homes as well as new construction. Cost effectiveness depends much more on local fuel costs and additional state and local incentives than on your area's climate, with a payback period as short as three or four years in some areas. Solar water heaters can also last indefinitely since they can always be repaired. Often they're used in combination with a storage-tank water heater and tank less water heater, to compensate for a string of cloudy days.

Storage-tank water heaters heat water in a tank where it's stored until needed. The most popular consumer option, storage-tank water heaters are the least expensive units to buy and install. On average, experts say they last 10 years (13 for gas models) before a tank typically leaks and the unit must be replaced. Tank-style water heaters can also be combined with other types for extra storage or as backups (since a very small tank plus a pump can keep a tank less water heater from wasting water or shooting out slugs of cold water). Gas storage-tank water heaters cost more than electric models initially and require more labor to install, but in most parts of the country these appliances cost only about a third as much to operate. Currently, a few gas storage-tank models meet Energy Star standards.

Electric heat pump water heaters, also called hybrid water heaters, are the newest and most energy-efficient type of electric water heater. It's also important to note that this is the only type of electric water heater that qualifies for a federal tax credit of 30 percent of the installed cost (with a $1,500 cap), when added to an existing primary residence by the end of 2010 [17]. These units add a heat pump to a regular tank-style electric water heater (using the heat in ambient air as long as it is 45 degrees Fahrenheit or higher) to heat water. Consumers can buy a heat-pump add-on to use with the electric water heater they already have or buy a hybrid water heater that includes the heat pump. Experts say these appliances can be a good choice for all-electric homes.

Gas condensing water heaters are the most efficient type of gas water heater, building a condenser into a gas storage-tank model or a gas tank less model. This type of water heater, compared with other gas water heaters, can cut the cost of heating water by 30 percent and the initial cost is partly offset by the 30 percent federal tax credit. This type of unit provides nonstop hot water at 3 to 5 gallons per minute, so consumers never run out of hot water [17].

Tank less water heaters, often called on-demand water heaters, save energy by not heating water until it's needed. Since there's no storage tank, they also save space. Tank less water heaters last longer than tank-style water heaters (15 to 20 years), often carry longer warranties, and can be repaired easily. Gas tank less water heaters that meet Energy Star standards qualify for a 30 percent tax credit for 2010. Tank less water heaters can replace a tank-style water heater, but installation is easier and more cost-effective for new construction though the tax credit doesn't apply then. One thing to note: Even gas-fueled tank less heaters require an electrical outlet for operation, which means consumers won't have access to hot water in the event of a power failure.

Point-of-use water heaters, also called instantaneous heaters, are small water heaters, tank less or semi-tank less, that provide instant hot water to a specific sink or shower. They're often used in conjunction with a bigger water heater of any of the other types, or in an out-building where consumers just need hot water. Point-of-use water heaters are especially useful for faucets or shower heads located far away from the main water heater and can minimize water use for those who don't have a recirculation system that keeps hot water flowing through the pipes all the time [18].

Lastly, all current models have to meet these standards, so that statement doesn't differentiate one water heater from another. Instead, experts and users suggest contemplating your preferred fuel type and then comparing energy-factor (EF) specification for the water heaters that have the size and FHR you need.

3.4 SWH FOR RESIDENTIAL APPLICATION

3.4.1 Flat-Plate Collector

Glazed flat-plate collectors are insulated, weather-proofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors - typically used for solar pool heating - have a dark absorber plate, made of metal or polymer, without a cover or enclosure [13].

3.4.2 ICS Systems

ICS (also known as batch) systems, feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. These systems should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather. Because the water storage is on the roof, these systems typically weigh over 400 kilograms when filled with water [13].

3.4.3 Evacuated-tube solar collectors

These collectors feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits eradicative heat loss. These high-temperature collectors are used more frequently for commercial applications as their high temperatures are inappropriate for the majority of mid-temperature solar water heating applications [13]

3.5 ACTIVE SOLAR HEATING SYSTEMS

3.5.1 Direct Open Loop Circulation Systems

In these systems a pump circulates household water through the collectors and into the home. Direct Open Loop Circulation Systems work well in climates where it rarely freezes [13].

3.5.2 Indirect Closed Loop Circulation Systems

Pumps circulate a heat-transfer fluid through the collectors and a heat exchanger. This process heats the water that then flows into the home. These systems are popular in climates prone to freezing temperatures. The heat transfer fluid (antifreeze) is usually a glycol-water mixture with the glycol concentration depending on the expected minimum temperature. The glycol is usually food-grade propylene-based so that it is non-toxic [13].

3.6 ESTIMATION ON SUN PATH

The path of the sun across the sky changes with the time of a day. This changes the travel path inside the solar container. This change can be measured by sun path charts.

Sun path charts can be plotted either in Cartesian (rectangular) or Polar coordinates.
Cartesian coordinates where the solar elevation is plotted on X axis and the azimuth is plotted on the Y axis. Polar coordinates are based on a circle where the solar elevation is read on the various concentric circles, from 0° to 90° degrees, the azimuth is the angle going around the circle from 0° to 360° degrees, the horizon is represented by the outermost circle, at the periphery. The azimuth angle indicates the direction of the sun in the horizontal plain from a given location. The various trajectories of the sun in the sky are bounded by those of the 21st day (equinox) of each month from December 21 until June 21. The geometrical position of the sun relative to a location is specified by an altitude angle and an azimuth angle of a coordinate centered at the point of observation on earth. It is customary to set the reference coordinate in the cardinal directions.

The *solar altitude* angle is the angle measured between the line drawn towards the sun from a point on earth and the horizontal surface. The *solar azimuth* angle is the angle the projection of the line to the sun makes with the southern direction. The *zenith angle* of the sun is the angle between the line to the sun makes with the zenith and the direction perpendicular to the earth. These angles can be shown as the following figure:

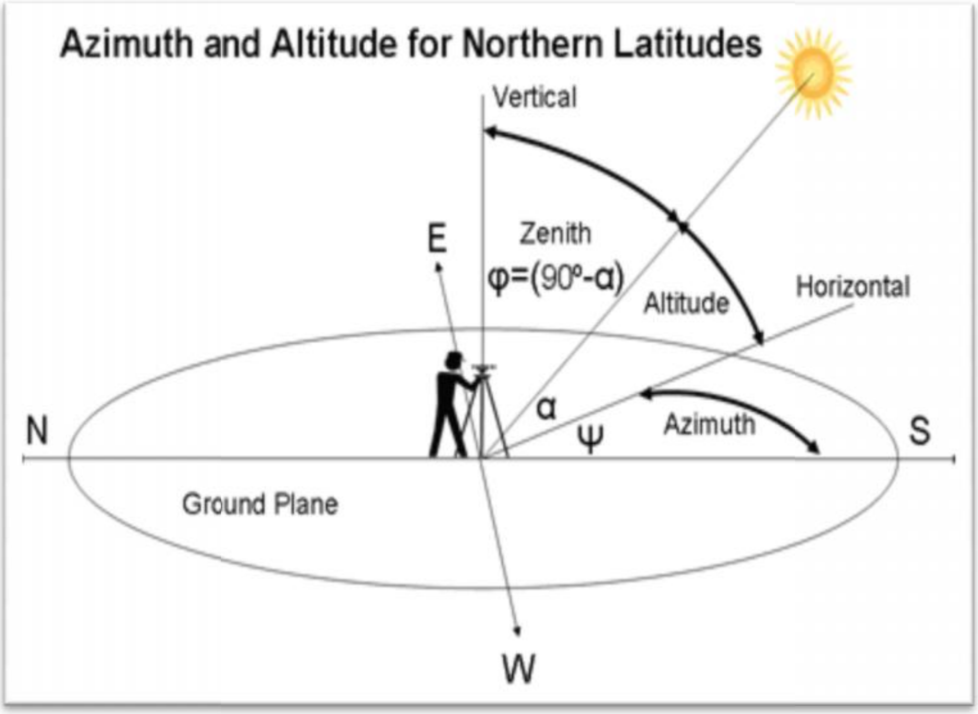

Figure 3.2: Altitude, Azimuth and Zenith Angle (sunearthtools.com)

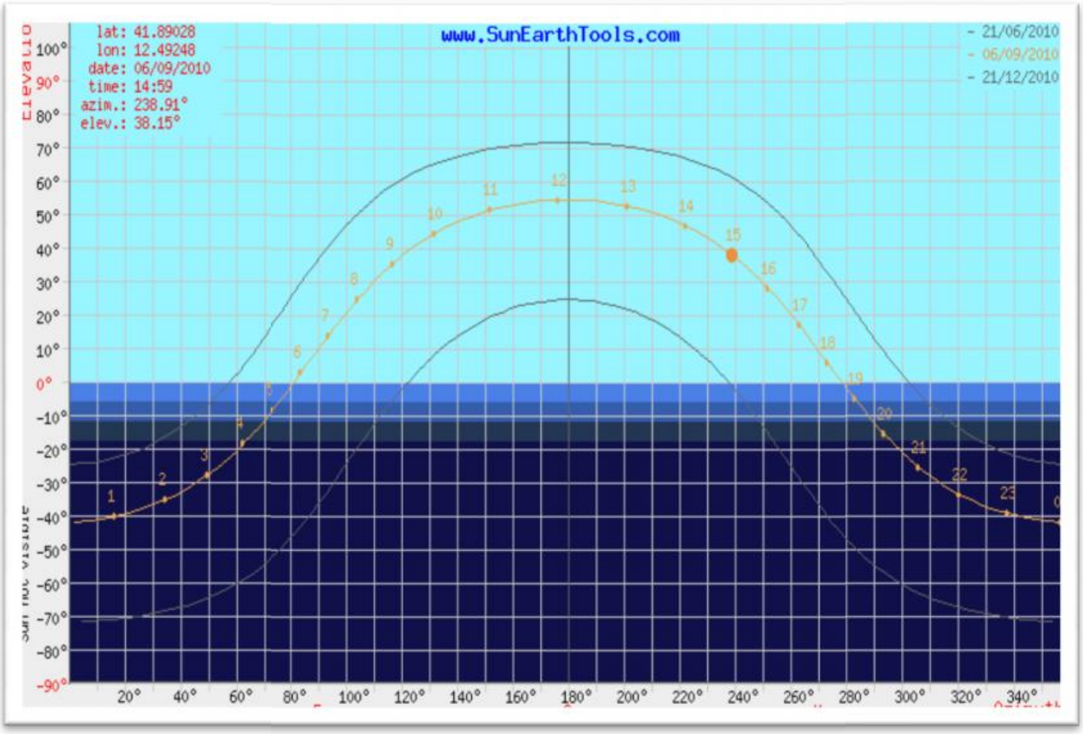

Figure 3.3: Sun chart in Cartesian Coordinates (sunearthtools.com)

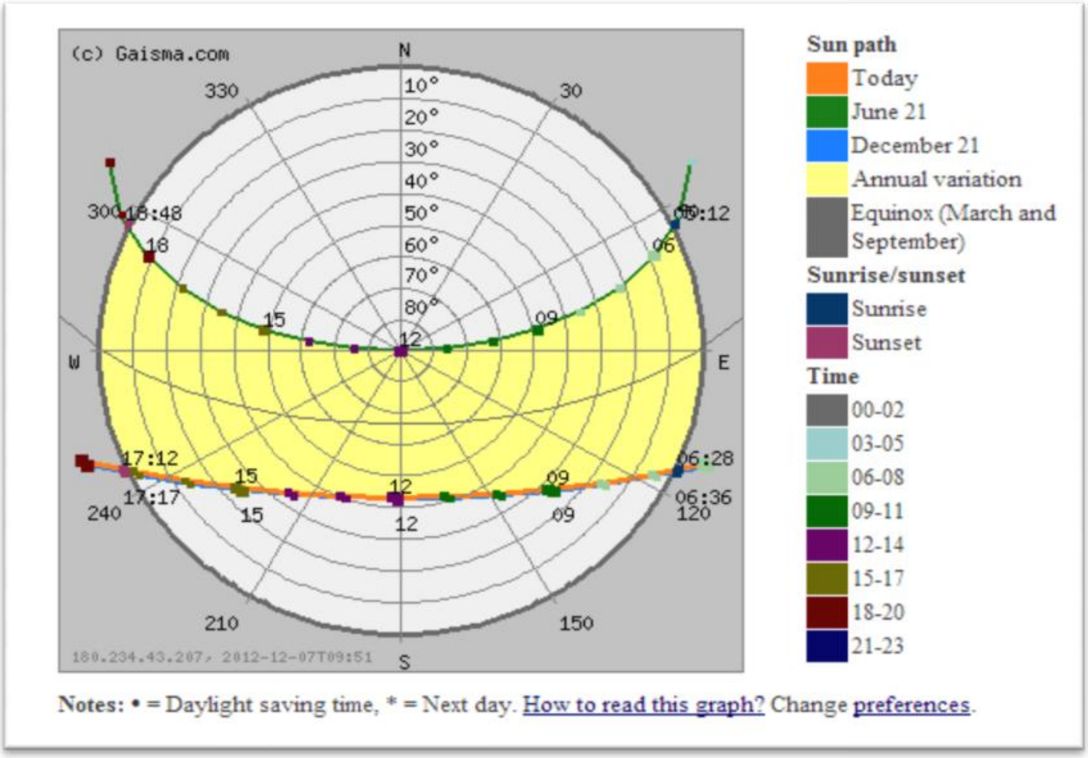

Figure 3.4: Sun chart in Polar Coordinates for Dhaka, 2012
(sunearthtools.com)

Table 3.1: Solar Angles for July 7 and 8, 2010

Time	Altitude Angle (degrees)		Azimuth Angle (degrees)	
	7 July	**8 July**	**7 July**	**8 July**
12:00	88.63	88.52	34.72	33.50
13:00	76.94	76.96	-87.84	-87.33
14:00	63.22	63.24	-93.46	-93.20
15:00	49.55	49.57	-97.53	-97.35
16:00	36.01	36.02	-101.48	-101.33
17:00	22.67	22.67	-105.58	-105.58

Chapter 4

DESIGN AND CONSTRUCTION

4.1 MATERIAL SELECTION

4.1.1 Introduction

Considering the cost, availability and suitability we have tried to incorporate the best possible and suitable materials in our collectors. For selecting the materials, we managed to maintain some requirements needed. They are:

1. Materials used outdoors shall be sunlight/UV-resistant and listed for outdoor locations.
2. Materials shall be designed to withstand the temperatures to which they are exposed.
3. Dissimilar metals that have galvanic action (such as steel and copper) shall be isolated from one another.
4. Only stainless steel fasteners shall be used to secure collectors. Stainless steel bolts shall be coated with an anti-seize lubricant to prevent galling and allow for removal during system maintenance or repair.
5. If the collectors are building-mounted, materials in direct contact with aluminum-frames shall be aluminum, stainless steel or outdoor rated nonmetallic materials designed for collector mounting.
6. Structural members shall be either:

    a. Aluminum
    b. Hot-dip galvanized steel per ASTM A123 equivalent or better.
    c. Coated or painted steel (not allowed in marine environments)
    d. Stainless steel (recommended for marine environments)
    e. Outdoor rated nonmetallic materials designed for collector mounting.
    f. Outdoor rated pressure treated lumber or laminated beams:
        - Shall be installed using roofing flashing methods to prevent water pooling and UV exposure on top surface.
        - Shall not be installed in direct contact with roofing material, soil or where exposed to extended periods of pooled water.

4.1.2 Specification

We have designed our collector into three parts. They are selected separately with respect to their materials. They are:

1. Frame
2. Transparent clear glass/plastic sheet.
3. Fins

1. Frame:

Frame is the rectangular box shaped structure having fins attached inside of it. It helps the water to flow through it. It has got two pipes attached to two opposite ends, having the inlet and outlet of the collector. We managed to design our frame with some different materials having different properties. They are given below chronologically:

a. **Copper (Cu)-** Evaluating all the properties of copper relating its heat conductivity, we selected copper as the base material of our collector frame. The low hardness of copper partly explains its high electrical conductivity (59.6×10^6 S/m) and thus also high thermal conductivity, which is the second highest among pure metals at room temperature. But due to the high ductility and low hardness of copper, it can not withstand the high pressure and force of water flowing through the collector. Besides that, the cost of Cu makes it harder to produce a cost effective collector. So it had to eliminate.

b. **Aluminium (Al)-** Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminum metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the passivation phenomenon. Aluminium is a relatively soft, durable, lightweight, ductile and malleable metal. It is nonmagnetic and does not easily ignite. Though it is one of the abundant and heat conducting material but due to its softness and low ductility, we had to eliminate it as well.

c. **Stainless Steel-** Stainless steel does not readily corrode, rust or stain with water as ordinary steel does, but despite the name it is not fully stain-proof, most notably under low oxygen, high salinity, or poor circulation environments. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed. It has all the suitable properties we needed and according to our criteria except one and that is Cost. It is expensive due to its production procedure and that is why we cannot select it.

d. **Mild Steel-** Mild steel, also called plain-carbon steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel contains 0.16–0.29% carbon; making it malleable and ductile, but it cannot be hardened by heat treatment. Mild steel has a relatively low tensile strength, but it is cheap and malleable. Evaluating all the properties of it, we finally decided to select Mild steel for our collector frame.

2. <u>Transparent clear glass or plastic sheet:</u>

a. Transparent Plastic Sheet is a versatile product which provides solutions for many indoor areas. It can be easily formed and fabricated using various techniques. The main characteristic of Transparent Plastic Sheet is that it gives high clarity, and the anti-glare property provides impact resistance. It is also useful in stopping fires spreading and withstands most chemical agents.
b. The main benefit of Transparent Plastic Sheeting is its ability to be formed using thermoform, and can also be bent hot or cold. It has high light transmission with water clear clarity, and the anti-glare finish on one side eliminates reflection.
c. On the other hand Greenhouse glass traps heat energy in the same way that Earth's atmosphere keeps the planet warm through light wave transformation and through convection of the air inside the greenhouse. They convert it to heat energy, which cannot escape through the glass. Thus the flowing water inside the collector will get warmer by the trapped heat. But use of glass has some limitations compared to the plastic sheets. They are:

(1) Glass is typically an easily breakable (brittle) material compared to the tougher plastic.
(2) Glass is basically a heavier material compared to the lighter plastic materials.
(3) Plastics are more malleable than the solid glass material.

Hence we have chosen clear transparent plastic sheet having more strengths and less brittleness than glass which will help to resist the pressure of the pump and the weight of water on it.

3. **Fins:**
   a. Fins are one of the necessary and important part of our collector. It will be attached inside the collector frame to guide the water flow to achieve the maximum travel distance inside the collector. It will help the water to remain inside the collector for maximum possible time gaining maximum heat. It must be a good heat conducting material preferably metal. We can select various materials evaluating all the properties in favor of the working condition.
   b. Similar to the collector frame, we evaluated many metals like Copper, Aluminium, Stainless steel, Mild steel, Cast iron etc. But finally we came up with Mild steel for its good heat conducting capability, better strength, toughness, rigidity and low cost.

4.2 COLLECTOR DESIGN

4.2.1 Introduction

As per the requirements of the project, the main focus was to increase the absorption of sun's energy by water through the container. So, not very shiny and heat conductive material was to be used as the material of the containers to be designed. This would increase the absorption of sun's energy by the container which would increase the absorption of heat energy by the water passing inside the container. So, water could be heated inside the container by solar energy. This chapter includes the designing criteria, designing process of the container to be made and the modifications needed to improve their thermal performance.

4.2.2 Design Criteria

The design criteria for the container was-

1. The container material is appreciated to be matted to enhance refractive capability.
2. The material must be able to conserve the heat for as much time as possible.
3. The shape of the container must be such that the solar rays can incise on the container for maximum time.
4. It must have some kind of insulation to minimize the heat loss.
5. The container must allow maximum amount of solar ray to enter inside the container.
6. The container must hold at least 50 liters of water.

Fulfilling these criteria, the material and shape of the solar container was determined.

Figure 4.1: Top surface of our collector

4.2.3 Specification

The robust containers specification is discussed below.

Table 4.1: Specification of the container.

Container	
Shape	Rectangular
Material	Mild Steel
Capacity	60 liters
Height	2 inch
Length	48 inch
Width	36 inch
Thickness of the metal sheet	3 mm

4.2.4 Modifications

To improve efficiency of the solar water heater, several modifications have been made to conventional solar water heater design.

1. **Modification 1**: A lot of heat is lost from water when we use conductive material at the bottom of the container through conduction. To minimize this heat loss we used transparent plastic at the bottom.
2. **Modification 2:** To increase the travel path of water in the container we used mild steel fin attached with it. It increases the time water travel inside the container. So water gets more time to absorb heat from the container surface.
3. **Modification 3:** To increase the heat absorption by the container we painted the top surface in 'black'.

4.2.5 Conclusion

The designs of the containers were made according to the initial idea of the project i.e. to increase the absorption of sun's energy. To facilitate the heat absorption and insulation of the container, suitable modifications were made. The designs and modifications were made based on the theoretical assumptions. While experimenting, in some cases variations were found. To improve these deficiencies, further modifications were made until suitable results were found.

4.3 SELECTION OF HEAT TRANSFER FLUID

4.3.1 Introduction

For transporting the heat from the sun are carried away by the fluid flowing inside the closed loop of our system. Fluid having a good heat absorbing capability should be selected in this case. We initially thought to select a refrigerant to use in this aspect which can transfer the heat at it's maximum level. Thinking of all the preferable fluid we finally selected our best possible heat transfer fluid.

4.3.2 Design Criteria

The design criteria of fluid selection are given below:

1. Fluid must be of antifreeze and non-volatile in properties.
2. Fluid is preferable to be in liquid form and possess good heat absorbing ability.
3. It must flow properly and smoothly.
4. Antifreeze solution shall be inhibited propylene glycol mixed with distilled water. As an alternative, glycerin antifreeze may be used. But Antifreeze solution shall be rated for usage up to 300 °F (149 °C) minimum which will be tough for us.
5. Antifreeze solutions may become corrosive over time if not properly maintained.

4.3.3 Selection

1. **Refrigerant:** The ideal refrigerant has favorable thermodynamic properties, is noncorrosive to mechanical components, and is safe (including nontoxic, nonflammable, and environmentally benign). The desired thermodynamic properties are a boiling point somewhat below the target temperature, a high heat of vaporization, a moderate density in liquid form, a relatively high density in gaseous form, and a high critical temperature. Since boiling point and gas density are affected by pressure, refrigerants may be made more suitable for a particular application by choice of operating pressure. The inert nature of many CFCs and HCFCs, while having the benefit of making them nonflammable and nontoxic, contributes to their stability in the atmosphere, and their corresponding global warming potential and ozone depletion potential. In the order of ozone depletion potential, it is generally from highest to lowest, Bromochloroflurocarbon such as Halon, CFCs then HCFCs. But a refrigerant is a substance used in a heat cycle usually including, for enhanced efficiency, a reversible phase transition from a liquid to a gas which is completely against our criteria. So we cannot select any of the refrigerants.

2. **Water:** Water is good heat carrying fluid having a wide range of temperature to sustain its phase. As water is abundant in nature and costs less, we decided to use it as our working fluid. Water takes up

the heat absorbed by the mild steel container and through the transparent glass sheet and transfer it through the outlet.

4.3.4 Conclusion

Heat transfer from the sunlight to the working fluid completely depends on the efficiency of transferring heat of the fluid. Fine selection of this working fluid needs to be done before manufacturing the whole system because upon it, the whole system's work ability and efficiency depends. Hence by selecting water as the heat conducting fluid, we enhanced our systems effectiveness and efficiency.

4.4 SELECTION OF STAND MATERIAL

4.4.1 Introduction

We have to design a metal stand to support the container. It should be able to rotate to locate the sun to increase efficiency of the solar water heater. It should be strong enough to hold the container when it is full of water. It should be able to rotate desired degree with full water.

4.4.2 Design Criteria

The design criteria for the stand was-

1. It should be strong enough to bear the total load of the container with full Water.
2. It should have freedom to rotate at certain degree.
3. It should have stability when the container is moving.
4. It should have a shaft to hold the gear for power transmission.
5. It should have a shelf to hold the motor.

Fulfilling all these criteria, the material and the design of the stand is determined.

Figure 4.2: Stand used to support the collector

4.4.3 Design Criteria for Power Transmission

The design criteria for power transmission was-

1. It should have enough power to bear the load of the container at full.
2. It should be able to rotate to degree of some point and then back to initial place after some time.
3. It should be able to rotate the container step by step with time.

Fulfilling all these criteria, the motor and gear are chosen.

4.4.4 Specification

The specification of the transmission are described below.

Table 4.2: Specification of power transmission

Power Transmission	
Motor	DC motor (120W, 12 V)
Transmission	Gear & Pinion
Battery	12 V

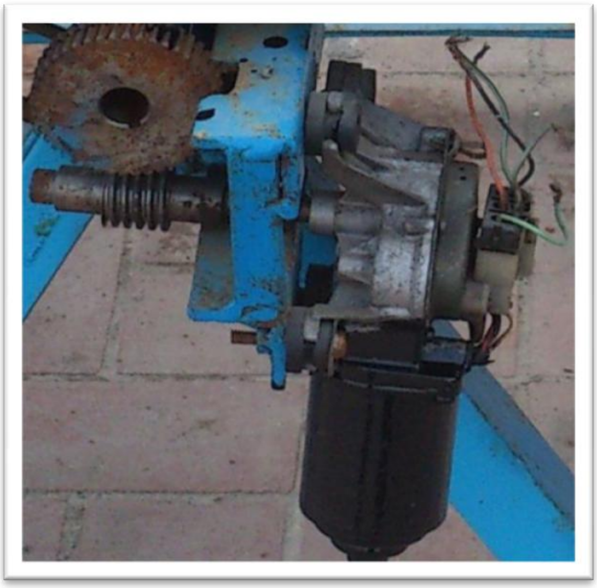

Figure 4.3: DC motor used to rotate the collector in order to track the sun

4.4.5 Conclusion

The design of the stand and power transmission were made according to initial criteria to enhance the performance of solar water heater. The designs and modifications were made by theoretical assumptions.

4.5 DESIGN OF WATER SUPPLY SYSTEM

4.5.1 Introduction

To supply water we have to design and install a water supply system to the solar water heater design. It is very important system to our solar water heater design. It could be open and closed system. The design includes what type of container, piping, joints, pump, we will use. The design will also have to be heat insulated and water leak proof.

4.5.2 The Tank

The design criteria for the water tank was-

1. The tank should contain minimum 60 liter of water.
2. Plumbing should be easy on the tank.
3. It should handle hot water.
4. It should be high enough to give high head to the water to flow into the container.

5. It should be easily filled up from the outside.

Fulfilling these criteria, the material and size of the tank is determined.

4.5.3 Pipes and Ducts

The criteria for the piping was-

1. Piping should be able handle water pressures that pump gives.
2. It should be able to handle hot water.
3. It should be leak proof.
4. It should be insulated.
5. It should be flexible enough to move.

Fulfilling these criteria, the material and length of piping is determined.

4.5.4 The Pump

The design criteria for the pump was-

i. The pump should create much pressure head to make water able to flow inside the container and to the tank.
ii. It should consume less energy.
iii. It should give certain pressure to the system that the pressure does not cause any leakage on the system.
iv. The pressure caused by the pump should not damage the fins.
v. It should be light enough to move.

Fulfilling all these criteria, the horse power of the pump is determined.

4.5.5 Specification

The specification of the tank, pipes and pump are discussed below.

Table 4.3: Specification of tank

Tank	
Capacity	60 liters
Material	Plastic
Height from the ground	5 feet

Figure 4.4: Tank used

Table 4.4: Specification of pipes

Pipes	
Material (for normal piping)	Rubber
Material (for elbow and T joints)	Iron
Material (for joints)	Iron and Plastic
Valves	Ball valve

Table 4.5: Specification of pump

Pump	
Model	JSW/10M
Horse Power	1 HP
Voltage	220V
Power	.75kW
Maximum Head	38m
IP	44

Figure 4.5: Pump used

4.5.6 Modification

1. **Modification 1:** Joining of a rubber and a steel valve is tricky. To join these two we used threaded steel pipe between them.
2. **Modification 2:** To join the rubber pipe at the tank we used steel connector and steel ball valves.
3. **Modification 3:** To control the flow from and to the tank, we used ball valve taps.
4. **Modification 4:** To control the flow from the pump, we used a ball valve on the outflow line.

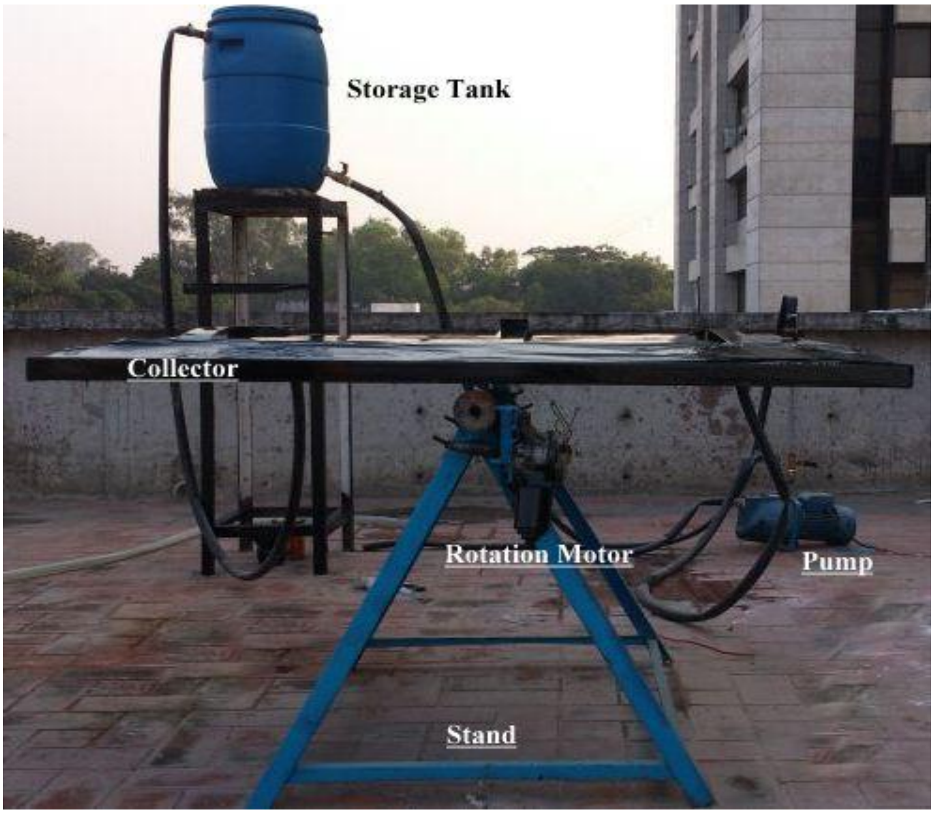

Fig 4.6: Overall set up

4.5.7 Conclusion

The design of the supply system was made for performance and efficiency. To leak proof the system silica gel and thin rubber gauges were used. To control the power of the pump some valves were used. While experimenting, some discrepancies were found in the system. They were eliminated by making further modifications of the system.

Chapter 5

DATA ACQUISITION

5.1 INTRODUCTION

5.2 IMPORTANCE OF DAQ's

5.3 COMPONENTS USED

5.1 INTRODUCTION

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:

Sensors that convert physical parameters to electrical signals.

Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.

Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Data acquisition applications are controlled by software programs developed using various general purpose programming languages such as BASIC, C, Fortran, Java, Lisp, Pascal [19].

5.2 IMPORTANCE OF DAQ's:

Data acquisition has become a significant process in order to maintain data controlling of any individual project or system. The wide spread usage of it is prevailing only due to it's smooth and comfort application.

A Data Acquisition System is comprised of three parts; an I/O sub-system, a host computer and the controlling software. However, some systems, such as the Power DNA Cube running a stand alone. Linux application combine the I/O sub-system and the host CPU in the same package. These systems are often referred to as embedded DAQ system.

DAQ requires detailed knowledge of meteorological data of the place where the system will be installed, because the corresponding energy production is highly influenced by the climate condition. Thus, is essential to develop techniques that will aid in assessing the available RES potential at the area of interest resulting in minimum system cost and maximum operation reliability under intermittent energy production conditions Additionally, because of the yearly variation of the climatic conditions, statistical processing of a large volume of data available from past years is required in order to derive accurate models of the RES resources. Thus, the usually applied data organization in text files is inefficient and the development of automate Database Management Systems is indispensable [19].

Automatic data-acquisition systems are currently used for both monitoring system performance and control of its operation. The obtained information can be used to evaluate the plant efficiency during long periods and to optimize future systems in terms of performance and reliability.

5.3 COMPONENTS USED:

5.3.1 Temperature Sensor

Sensors detect physical phenomena and convert these to corresponding electrical signals that are relatively easy to measure. Sensors that do not produce an electrical signal naturally are supplemented with electronics to produce the measurable signal. Several temperature sensor types [20] are available, each with its own strengths and weaknesses. DAPs are intended to work with any sort of sensor that delivers a measurable electrical signal.

1. Temperature sensor types:

    a. Thermocouples.
    b. RTDs
    c. Thermistors
    d. Infrared
    e. Solid state
    f. Bimetallic.

    a. **Thermocouples:** These sensors depend on differences in charge mobility in two dissimilar metals to produce a potential difference. The developed potentials are small, but measurable. Thermocouples are rugged, and tolerate a wide range of temperatures, but they have many drawbacks, including low signal levels, long-term stability, and noise. Their response time tends to be very slow, but this often results from the packaging more than the device physics.The measurement is actually temperature difference, not anabsolute temperature level, so a supplementary measurement is required to establish the reference temperature. The resulting temperature correction is called cold junction compensation. Despite their limitations, thermocouples are used with success in a variety of applications. You can obtain moderate accuracy using standard device curves with no calibration. Careful calibration can improve accuracy to within a degree C or so.

b. **RTD:** RTDs, short for "resistive thermal devices," are built basically the same way as wire-wound or thin-film resistors, but using materials with relatively high levels of resistivity variation as a function of temperature. They are generally between thermocouples and thermistors in terms of speed, ruggedness, signal level and temperature range. If not severely stressed, they have good long term stability. They cost more, but offer superior linearity and good accuracy using standard curves without calibration. With individual device calibration, the accuracy is even better.

   Though most common metals exhibit RTD effects, platinum alloys have the best range and performance, and are by far the most popular.

c. **Thermistors:** Negative temperature coefficient thermistors, the ones commonly used for temperature measurements, change resistance dramatically in response to temperature changes, but they have some limitations. They are vulnerable to physical damage and chemical contamination for example, water can cause problems. They require careful protective packaging, and this often limits how they can be used. Response is moderately fast, but typically limited because of the packaging. The thermal characteristics are highly nonlinear, so you must apply corrections that differ for every device type. For full accuracy you must calibrate. They have a limited range compared to other thermal sensors. For the temperature where liquid water can exist can perform very well.

d. **Infrared:** These sensors are very useful for measuring extreme temperatures through a viewing port, under conditions that would rapidly destroy other sensor types. The accuracy, stability, and repeatability are not very good, so they need a lot of attention. The receiver/converter electronics scale the signal to convenient levels for acquisition and recording.

e. **Solid state:** These devices use the thermal properties of semiconductor junction voltages to detect temperature. These devices are appealing because sensor, power-gain amplifiers, and "linearization" can be fabricated on the same chip. The drawbacks are that the operating range of the electronics limits the sensing range, and any calibration other than offset adjustment is impractical. These are extremely handy for measuring ambient temperatures around circuit boards, and popular for "cold junction compensation" in combination with thermocouples. Accuracy is moderate.

f. **Bimetallic:** We mention this one only in passing. A sensor bonded to a bimetallic strip senses strain in proportion to temperature changes. This is too bulky, slow, and vulnerable to mechanical and electrical interference for most applications, but compatible.

5.3.2 Selecting the Sensors

Evaluating all the properties like availability, sustainability, longevity, temperature sensitivity, and cost we managed to apply a temperature sensor named LM32. The LM32 is a digital temperature sensor that measures 3 temperature zones and has a single-wire interface Sensor Path bus. Sensor Path data is pulse width encoded, thereby allowing the LM32 to be easily connected to many general purpose micro-controllers. Several Winbond Electronics Super I/O products include a fully integrated Sensor Path master, that when connected to an LM32 can realize a hardware monitor function that includes limit checking for measured values, autonomous fan speed control and many other functions. Though initially we selected thermocouple as our final sensor but due to environmental suitability and measurement advantage, we selected LM32 replacing T type thermocouple.

5.3.3 LM32

The LM32 [21]measures the temperature of its own die as well as two external devices such as a processor thermal diode or a diode connected transistor. The LM32 can resolve temperatures up to 255°C and down to -256°C. The operating temperature range of the LM32 is 0°C to +125°C. The address programming pin allows two LM32s to be placed on one Sensor Path bus.

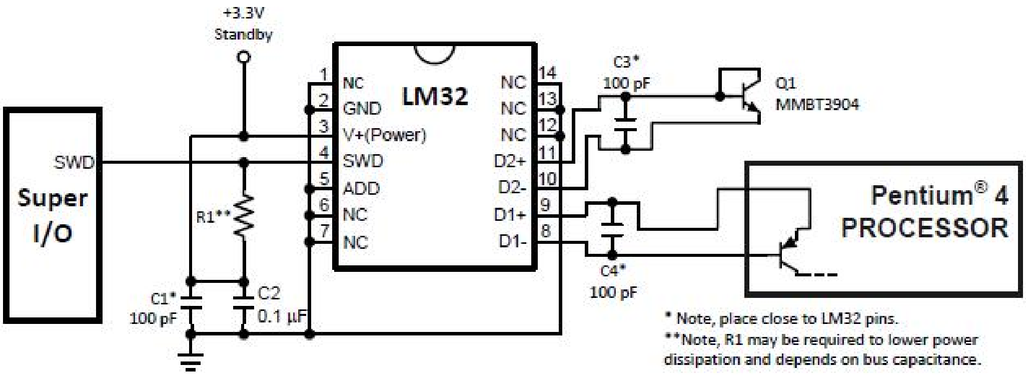

Figure 5.1: Typical application of LM32.

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Table 5.1: Key specification of LM32

		VALUE	UNIT
Temperature Sensor Accuracy		±3 °C (max)	
Temperature Range:			
	LM32 junction	0 °C to +85 °C	
	Remote Temp Accuracy	0 °C to +100 °C	
Power Supply Voltage		+3.0 V to +3.6	V
Average Power Supply Current		0.5 mA (typ)	
Conversion Time (all Channels)		22.5ms to 1456ms	

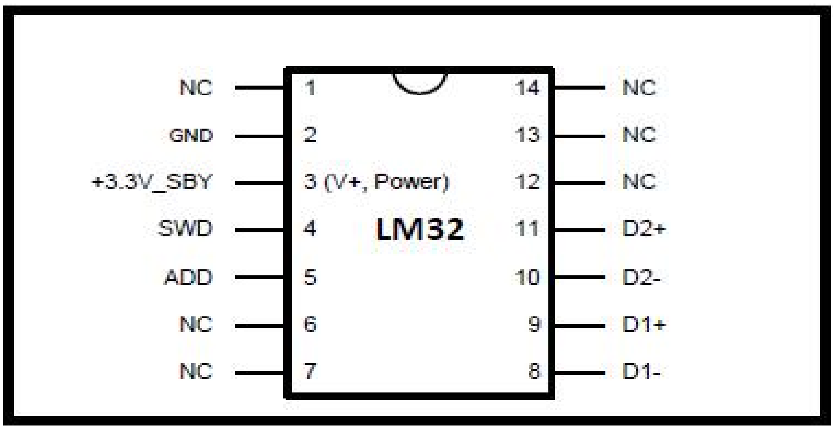

Figure 5.2: Connection diagram of LM32

Table 5.2: Pin description of LM32.

Pin Number	Pin Name	Description	Typical Connection
1, 6, 7,12, 13, 14	NC	No Connect	May be tied to V+, GND or left floating
2	GND	Ground	System ground
3	V+/+3.3V_SBY	Positive power supply pin	Connected system 3.3 V standby power and to a 0.1 µF bypass capacitor in parallel with 100 pF. A bulk capacitance of approximately 10 µF needs to be in the near vicinity of the LM32.
4	SWD	SensorPath Bus line; Open-drain output	Super I/O, Pull-up resistor, 1.6k
5	ADD	Digital input - device number select input for the serial bus device number	Pull-up to 3.3 V or pull-down to GND resistor, 10k; must never be left floating
8, 10	D1-, D2-	Thermal diode analog voltage output and negative monitoring input	Remote Thermal Diode cathode (THERM_DC) - Diode 1 should always be connected to the processor thermal diode. Diode 2 may be connected to an MMBT3904 or GPU thermal diode. A 100 pF capacitor should be connected between respective D- and D+ for noise filtering.
9, 11	D1+, D2+	Thermal diode analog current output and positive monitoring input	Remote Thermal Diode anode (THERM_DA) - Diode 1 should always be connected to the processor thermal diode. Diode 2 may be connected to an MMBT3904 or GPU thermal diode. A 100 pF capacitor should be connected between respective D- and D+ for noise filtering.

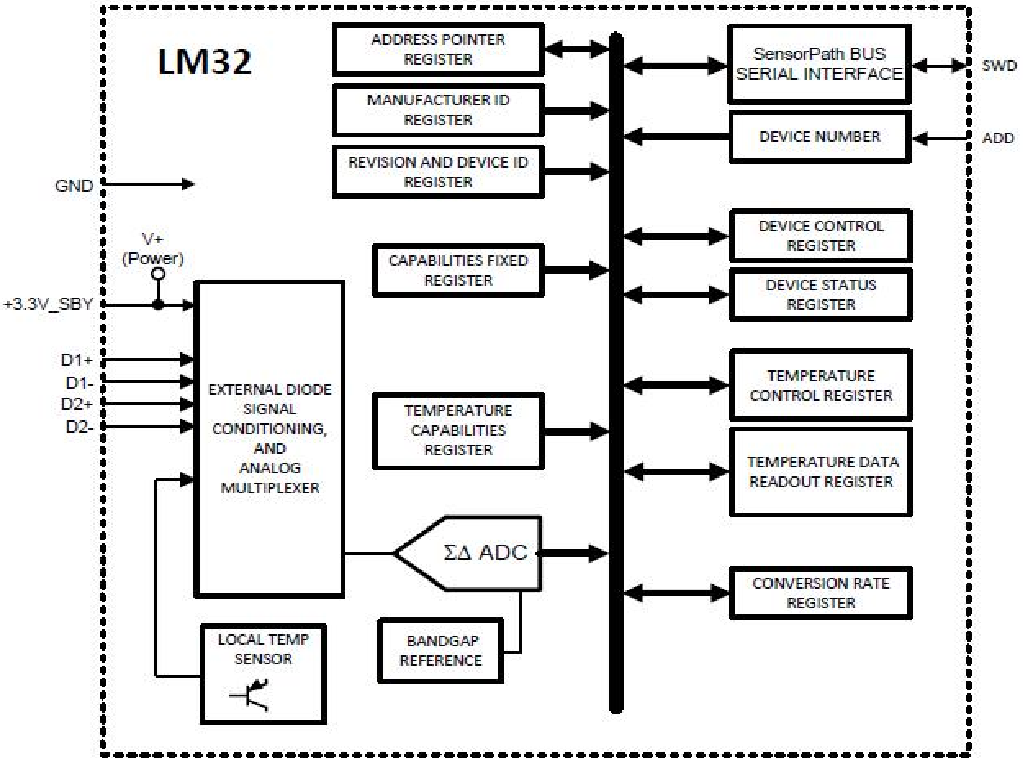

Figure 5.3: block diagram of LM32.

5.3.4 Microcontroller used (ATMEGA 8)

The ATmega8 [22] is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1 MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed.

The ATmega8 provides the following features: 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes of EEPROM, 1K byte of SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, a 6-channel ADC (eight channels in TQFP and MLF packages) where four (six) channels have 10-bit accuracy eight channels in TQFP and MLF packages) where four (six) channels have 10-bit accuracy.

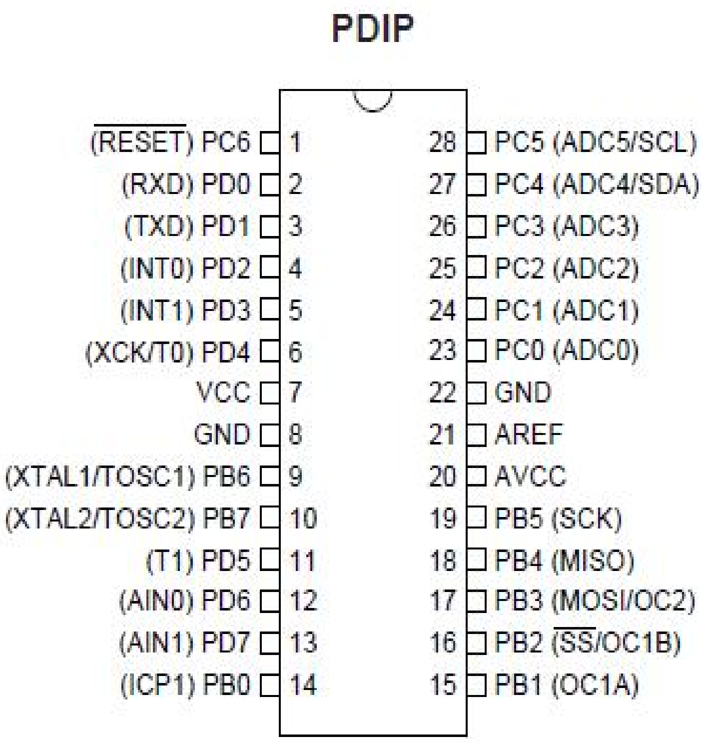

Figure 5.4: PIN configuration of ATMEGA 8

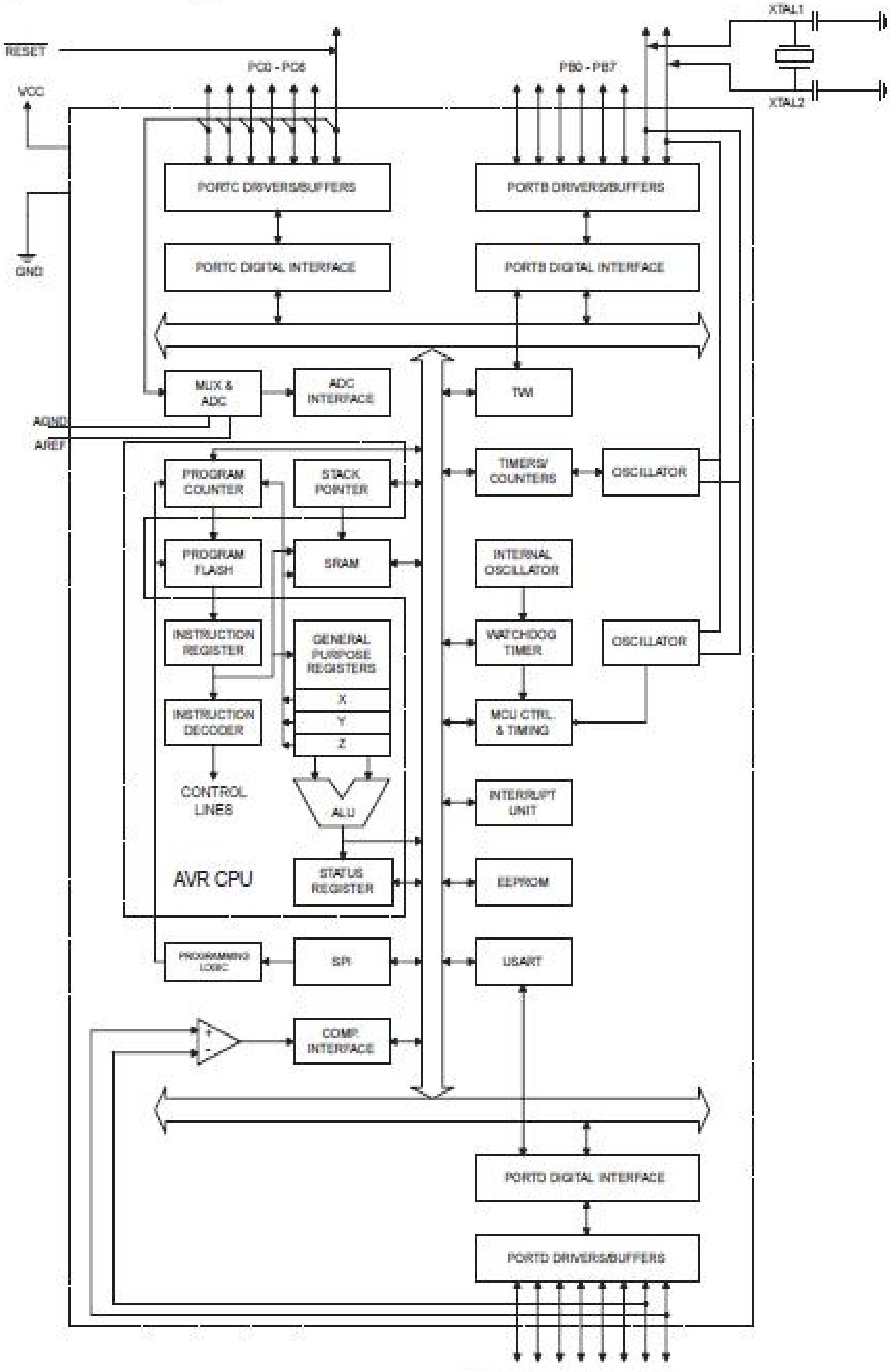

Figure 5.5: Block diagram of ATMEGA 8 [22]

5.3.5 MAX232 (IC)

The MAX232 [23] is an integrated circuit, first created by Maxim Integrated Products, that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals.

The drivers provide RS-232 voltage level outputs (approx. ± 7.5 V) from a single + 5 V supply via on-chip charge pumps and external capacitors. This makes it useful for implementing RS-232 in devices that otherwise do not need any voltages outside the 0 V to + 5 V range, as power supplydesign does not need to be made more complicated just for driving the RS-232 in this case.

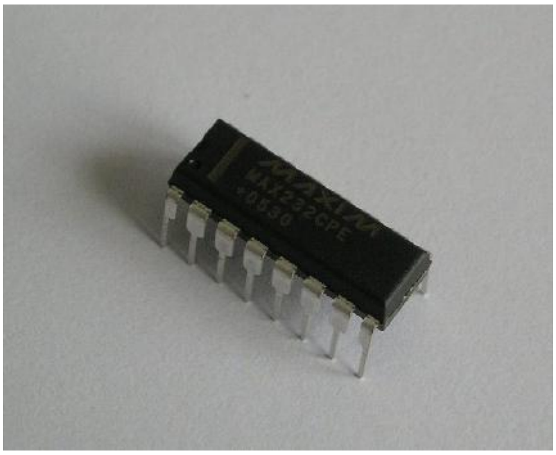

Figure 5.6: A MAX232 IC [23]

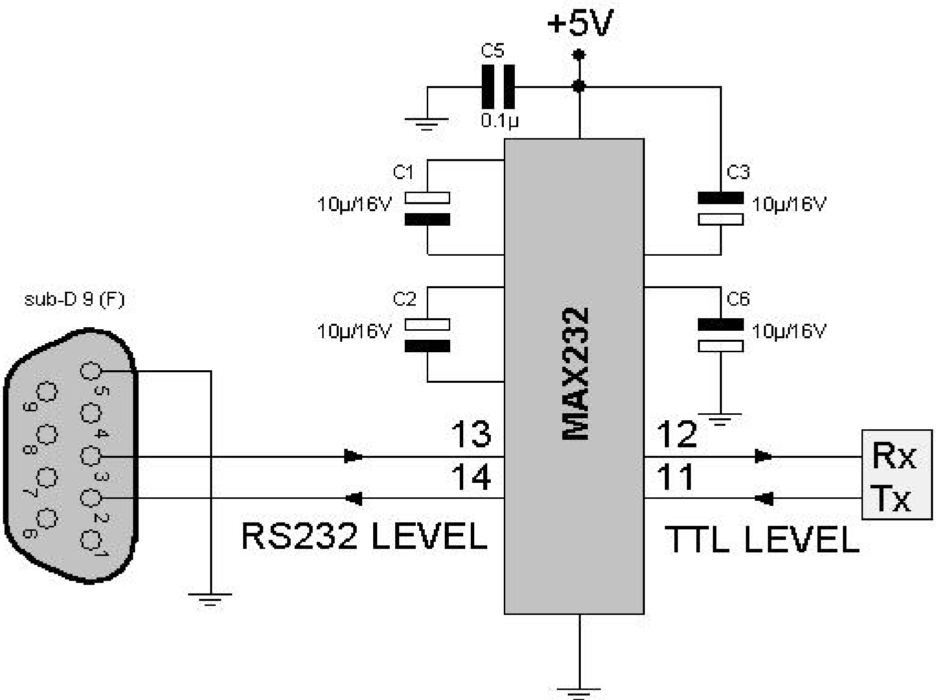

Figure 5.7: MAX232 Serial controller circuit.

The features of MAX232 are:

1. Input voltage levels are compatible with standard CMOS levels
2. Output voltage levels are compatible with EIA/TIA-232-E levels
3. Single supply voltage: 5V
4. Low input current: 0.1μA at TA= 25 °C
5. Output current: 24mA
6. Latching current not less than 450mA at TA= 25°C

5.3.6 USB to RS232 converter

The USB to RS232 Converter board [24] is a PIC microcontroller based device that receives a USB signal from a PC and converts the signal to an RS232 output. The output signal can be sent to any one of three serial ports. Devices which may be connected to the RS232 ports include the ASI Inc. X-Y Stage, the Olympus Z-Focus, and the Mai Tai LASER.

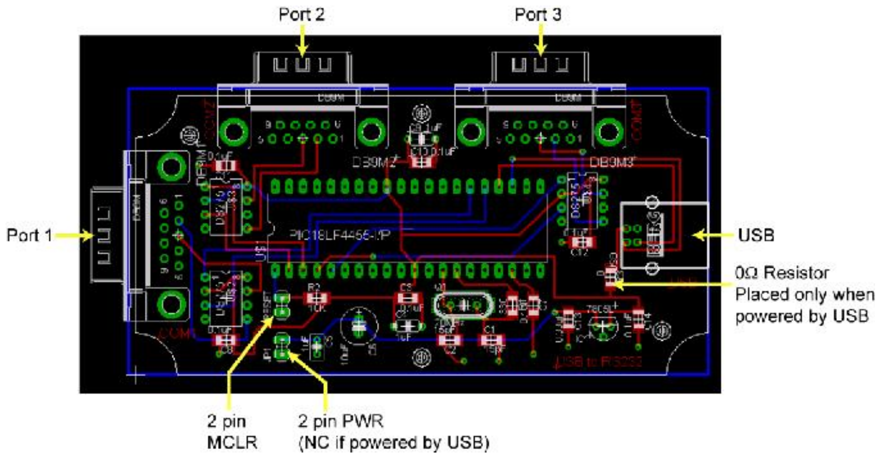

Figure 5.8: Current PCB layout of USB to RS232 converter

5.3.7 Data acquisition of this project

Placing the temperature sensor LM32 above the inlet and outlet piping of our collector, we connect it to the microcontroller ATMEGA 8. After the connection is made, the ATMEGA 8 is serially connected to the IC microprocessor MAX232 to evaluate the voltage difference which is transformed by the microcontroller. Several resistance having different values are to be placed to manage the voltage being uniform. The connection is then done by the USB to RS232 converter to the Computer to finalize the interface. The interface is based on 8-bit microcontroller operating at 1MHz. The ATMEGA32 is programmed using C language. The visualization of the data acquisition system results on the computer (PC) requires the implementation of a graphic interface. The desktop application was developed using Visual Studio 2010. It has a communication control that provides access to the serial port for communication purposes. The desktop application is used to further process, display and store the collected data on the PC's disk. The whole circuit diagram of our DAQ is given below:

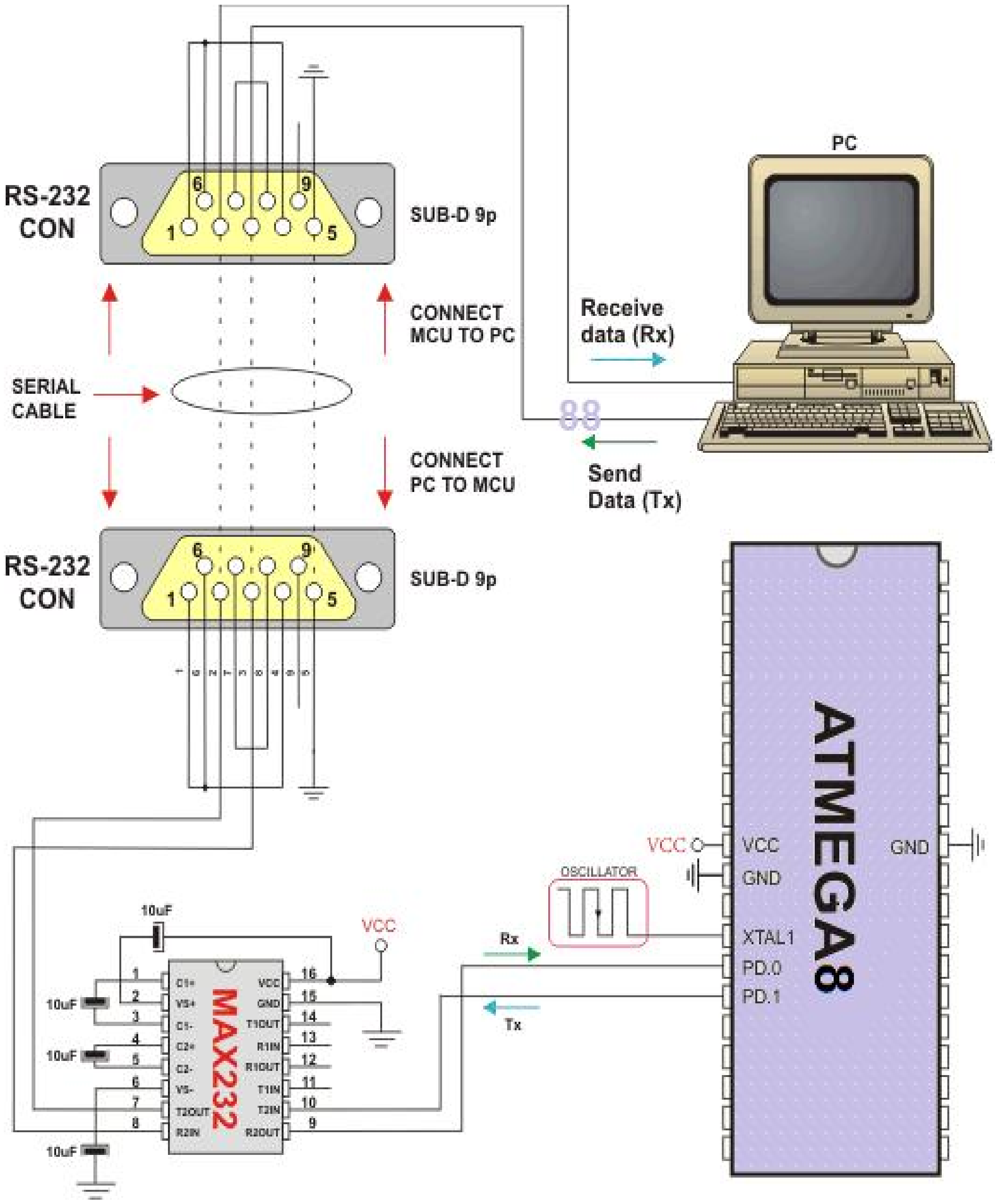

Figure 5.9: Data acquisition circuit of the whole system.

Chapter 6

DATA ANALYSIS

6.1 INTRODUCTION

6.2 EXPERIMENT IN DETAIL

6.1 INTRODUCTION

Experiments were performed throughout the year after modifications were made to the initial designs. According to the results found in every data collection, more modifications were made to find out the optimum design of the solar container.

Bangladesh is situated between 20.30-26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. Daily Average of Bright Sunshine Hours at Dhaka City is listed in the following table:

Table 6.1: Daily Average of Bright Sunshine Hours at Dhaka City [25]

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	**7.55**	**9.13**	**6.03**

Emphasis was given to use the maximum possible solar energy to be used for the experiments to be conducted. Weather conditions were another important factor to be considered. Bright and sunny weather was preferred for the experiments.

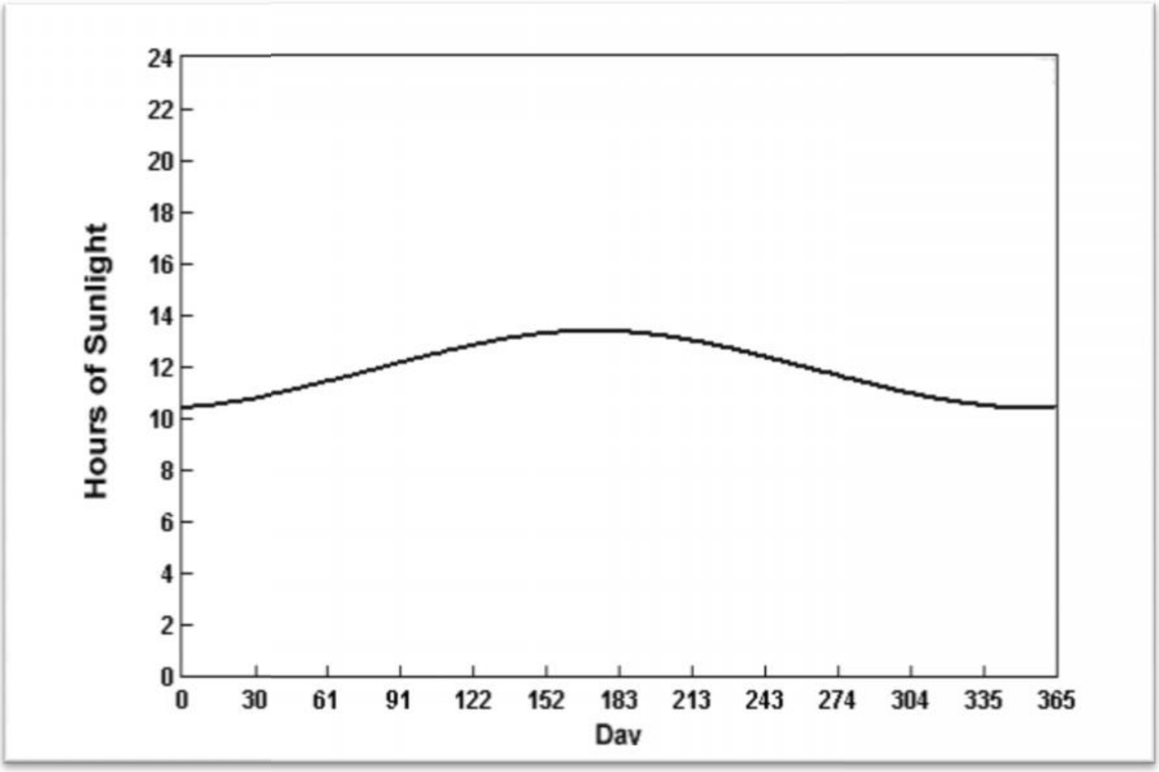

Figure 6.1: The amount of hours of sunlight in Bangladesh.[26]

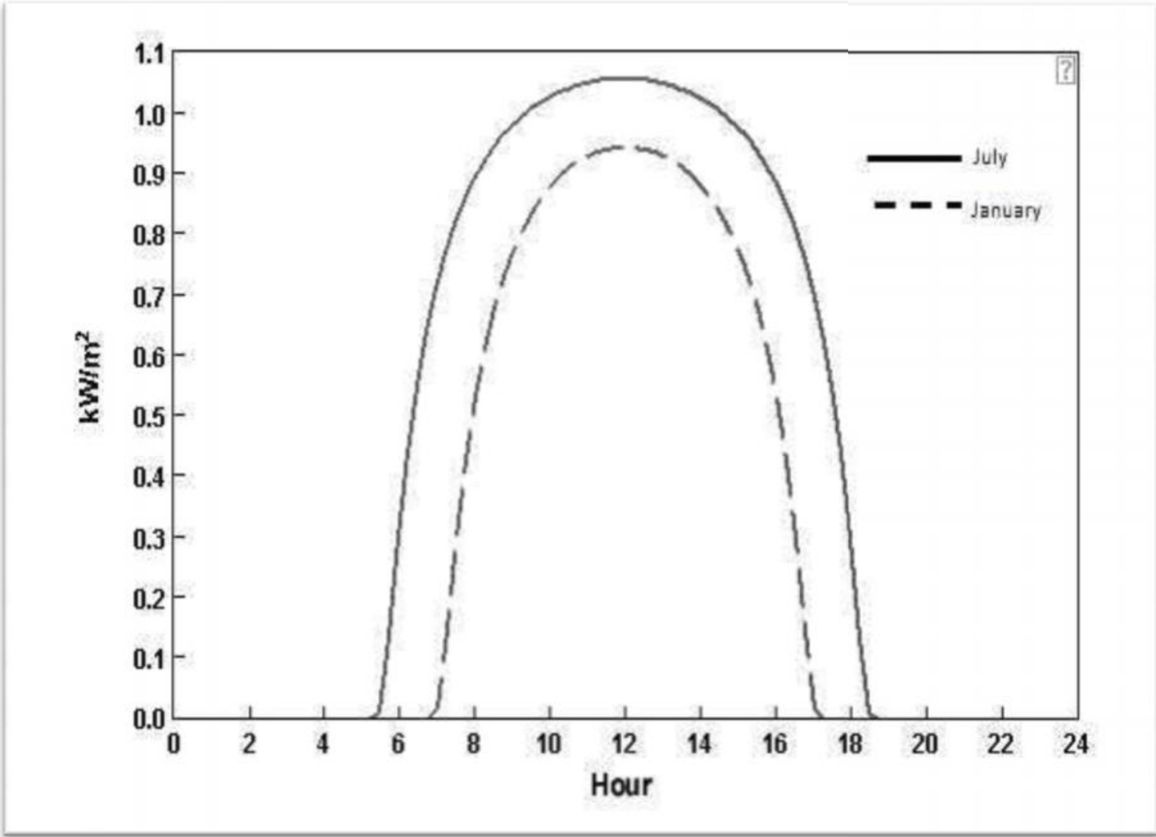

Figure 6.2: The highest and lowest intensity in direct radiation in W/m^2 [26]

6.2 EXPERIMENTS IN DETAIL

The data is taken in some stages. According to the weather of our country, we have divided our data collection into two parts. They are:

1. Data taken in summer season
2. Data taken in winter season

Now depending on the position and structure of our collector we have again divided the data collection into four subgroups. They are:

1. Data taken when the collector is static and horizontal to the ground.
2. Data taken when the collector is moving by the motor.
3. Data taken with the reflector present(moving the collector)

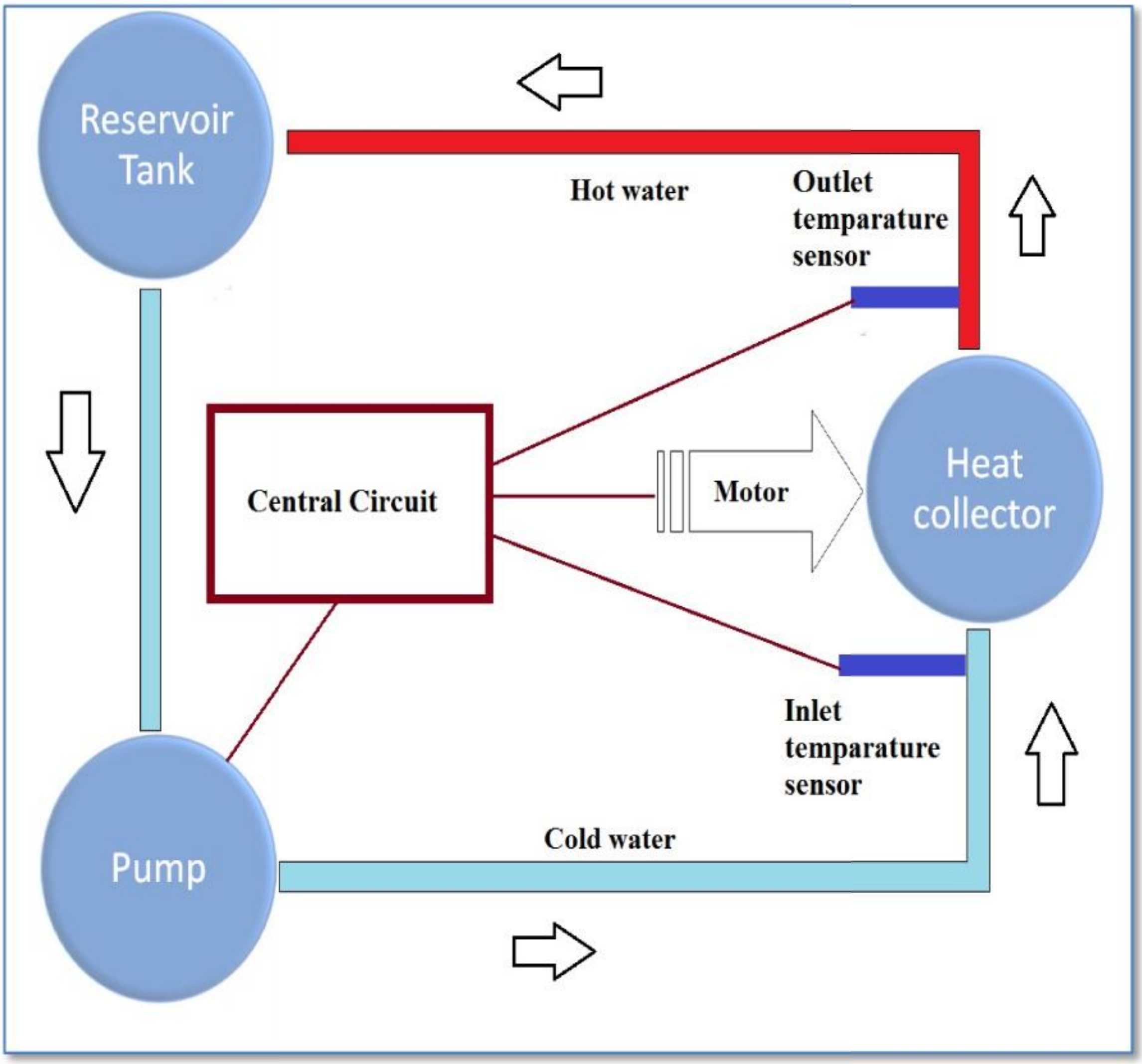

Figure 6.3: Diagram of full system

6.2.1 Data taken in summer season

1. **Experiment no 1**: Time: 7th July, 2012

The day was sunny. Collector was surrounded with heat insulators. From 1000 Hrs, preheating started and data was taken from 1200 Hrs. Pump was ran every after 15 Minutes during the cycle. Single pass (60±5) liter water was heated. Collector was static.

Table 6.2: Observed data against time for Experiment 1.

Obs. No.	Time	Inlet Temperature (^{o} C)	Outlet Temperature (^{o} C)
1.	12.00 pm	25.5	32.5
2.	12.15 pm	29	35
3.	12.30 pm	31.5	39
4.	12.45 pm	33	42.5
5.	13.00 am	35	45
6.	13.15 pm	36.5	49
7.	13.30 pm	38	52.5
8.	13.45 pm	41	56
9.	14.00 pm	44	61.5
10.	14.15 pm	46.5	63
11.	14.30 pm	49	65.5

From the data table 6.2 the following graph can be drawn-

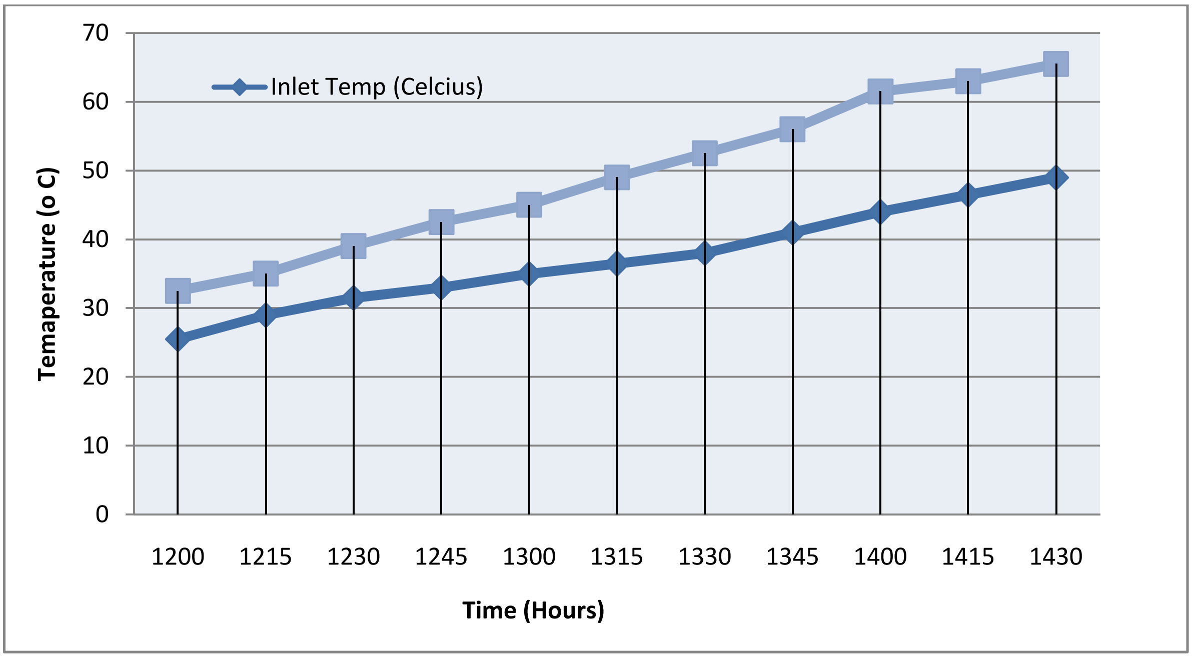

Figure 6.4: Temperature variation with time for experiment 1.

2. Experiment no 2: Time- 18th August, 2012

The day was sunny. Collector was surrounded with heat insulators. From 1000 Hrs, preheating started and data was taken from 1200 Hrs. Pump was ran every after 15 Minutes during the cycle. Single pass (60±5) liter water was heated. Collector was moving.

Table 6.3: Observed data against time for Experiment 2.

Obs. No.	Time	Inlet Temperature (^{o}C)	Outlet Temperature (^{o}C)
1.	12.00 pm	24	27
2.	12.15 pm	26	29.5
3.	12.30 pm	29	32
4.	12.45 pm	32	36.5
5.	13.00 am	35.5	41
6.	13.15 pm	37	44.5
7.	13.30 pm	41	48
8.	13.45 pm	45.5	53
9.	14.00 pm	48.5	58
10.	14.15 pm	52	62.5
11.	14.30 pm	57.7	66

From the data table 6.3 the following graph can be drawn-

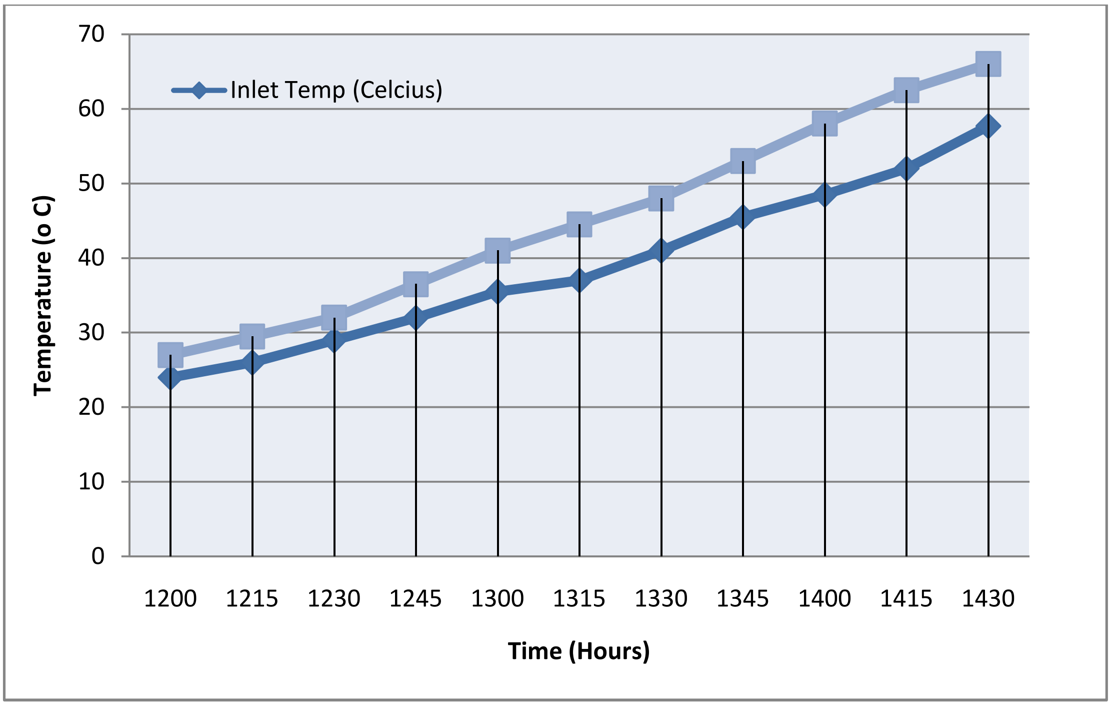

Figure 6.5: Temperature variation with time for experiment 2.

3. **Experiment no 3:** Time- 18th August, 2012

Collector was surrounded with heat insulators. From 1000 Hrs, preheating started and data was taken from 1200 Hrs. Pump was ran every after 15 Minutes during the cycle. Single pass (60±5) liter water was heated. Collector was moving with reflector.

Table6.4: Observed data against time for Experiment 3.

Obs. No.	Time	Inlet Temperature (^{o}C)	Outlet Temperature (^{o}C)
1.	12.00 pm	28	32
2.	12.15 pm	31	37
3.	12.30 pm	33	41.5
4.	12.45 pm	36.5	45.5
5.	13.00 am	41	48
6.	13.15 pm	43	53
7.	13.30 pm	45.5	57
8.	13.45 pm	49	61.5
9.	14.00 pm	53	66
10.	14.15 pm	59	70.5
11.	14.30 pm	63.5	76

From the data table 6.4, the following graph can be drawn-

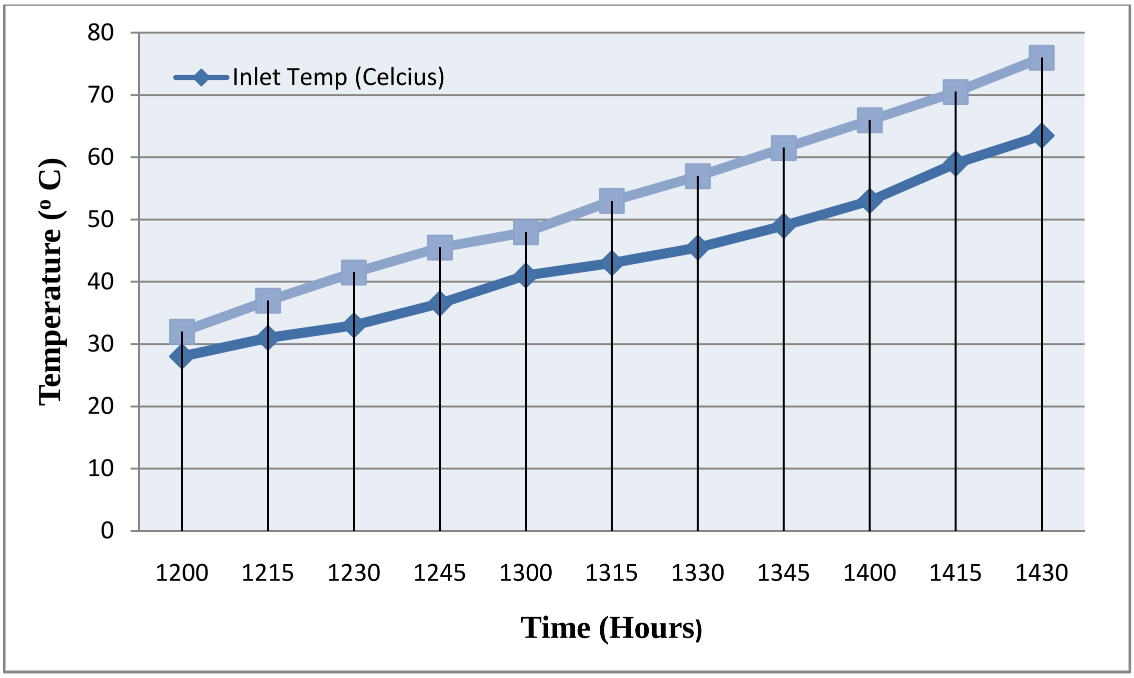

Figure 6.6: Temperature variation with time for experiment 3

5.2.2 Data taken in winter season

1. **Experiment no 4**: Time- 27th Nov, 2012
   The day was sunny with little fog. Collector was surrounded with heat insulators. From 1000 Hrs, preheating started. Pump was ran every after 15 Minutes during the cycle. Single pass (60±5) liter water was heated. Collector was static.

Table 6.5: Observed data against time for Experiment 4.

Obs. No.	Time	Inlet Temperature (^{o} C)	Outlet Temperature (^{o} C)
1.	12.00 pm	22.5	25
2.	12.15 pm	24	27.5
3.	12.30 pm	26.5	29.5
4.	12.45 pm	29	33
5.	13.00 am	31	37
6.	13.15 pm	32.5	41
7.	13.30 pm	34	43.5
8.	13.45 pm	37	45
9.	14.00 pm	39.5	48.5
10.	14.15 pm	41.5	51
11.	14.30 pm	44.5	53.5

From the data table 6.5, the following graph can be drawn-

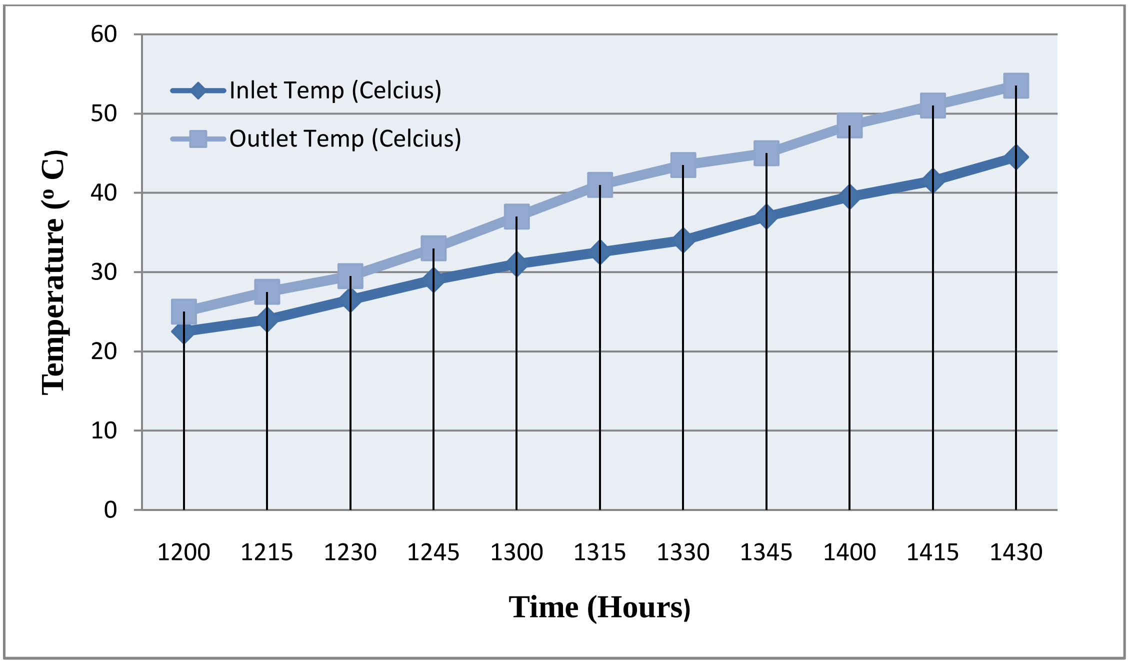

Figure 6.7: Temperature variation with time for experiment 4

2. **Experiment no 5:** Time- 28th Nov, 2012
   The day was sunny. Collector was surrounded with heat insulators. From 1000 Hrs, preheating started and data was taken from 1200 Hrs Pump was ran every after 15 Minutes during the cycle. Single pass (60±5) liter water was heated. Collector was moving.

Table 6.6: Observed data against time for Experiment 5.

Obs. No.	Time	Inlet Temperature (^{o}C)	Outlet Temperature (^{o}C)
1.	12.00 pm	23.5	27
2.	12.15 pm	25	31
3.	12.30 pm	28	33
4.	12.45 pm	30.5	34.5
5.	13.00 am	34	36.5
6.	13.15 pm	37	39
7.	13.30 pm	39	41
8.	13.45 pm	42	43.5
9.	14.00 pm	44.5	47
10.	14.15 pm	46	50.5
11.	14.30 pm	48.5	54

From the data table 6.6, the following graph can be drawn-

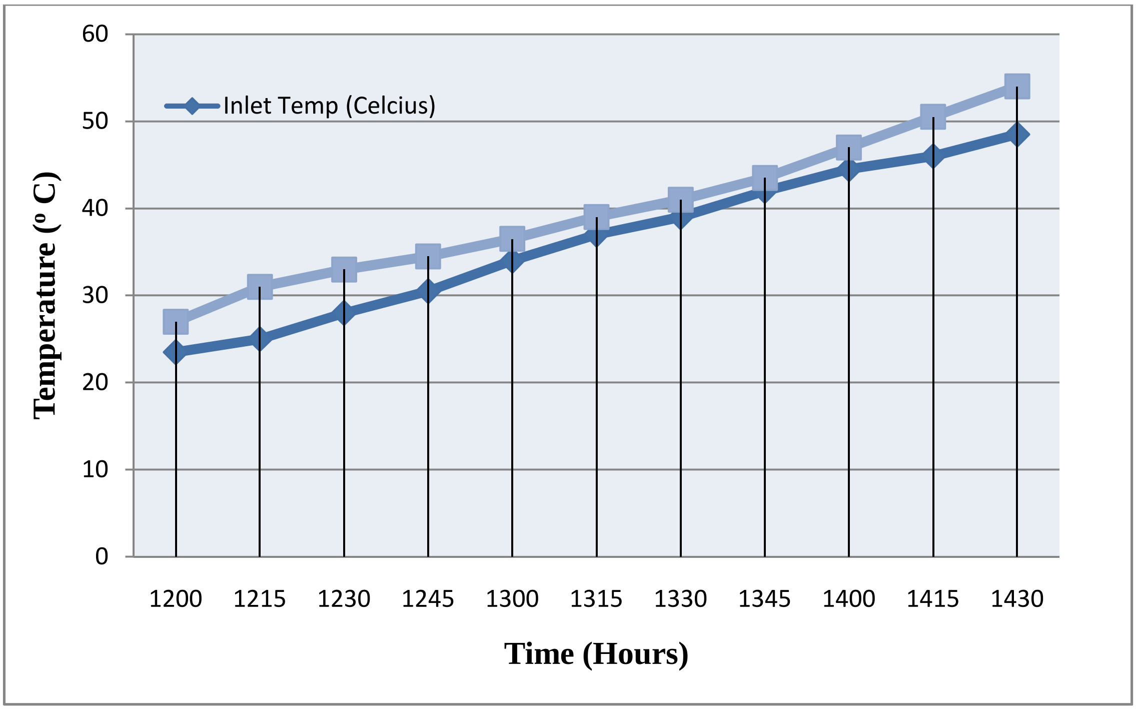

Figure 6.8: Temperature variation with time for experiment 5

3. **Experiment no 6**: Time- 29th Nov, 2012
The day was sunny. Collector was surrounded with heat insulators. From 1000 Hrs, preheating started and data was taken from 1200 Hrs. Pump was ran every after 15 Minutes during the cycle. Single pass (60±5) liter water was heated. Collector was moving with reflector.

Table 6.7: Observed data against time for Experiment 6.

Obs. No.	Time	Inlet Temperature (^{o} C)	Outlet Temperature (^{o} C)
1.	12.00 pm	23	25.5
2.	12.15 pm	24.5	27
3.	12.30 pm	27	31
4.	12.45 pm	29	33.5
5.	13.00 am	30.5	36
6.	13.15 pm	33	39.5
7.	13.30 pm	35	42.5
8.	13.45 pm	38	46
9.	14.00 pm	41	49.5
10.	14.15 pm	43.5	52.5
11.	14.30 pm	47	56

From the data table 6.7, the following graph can be drawn-

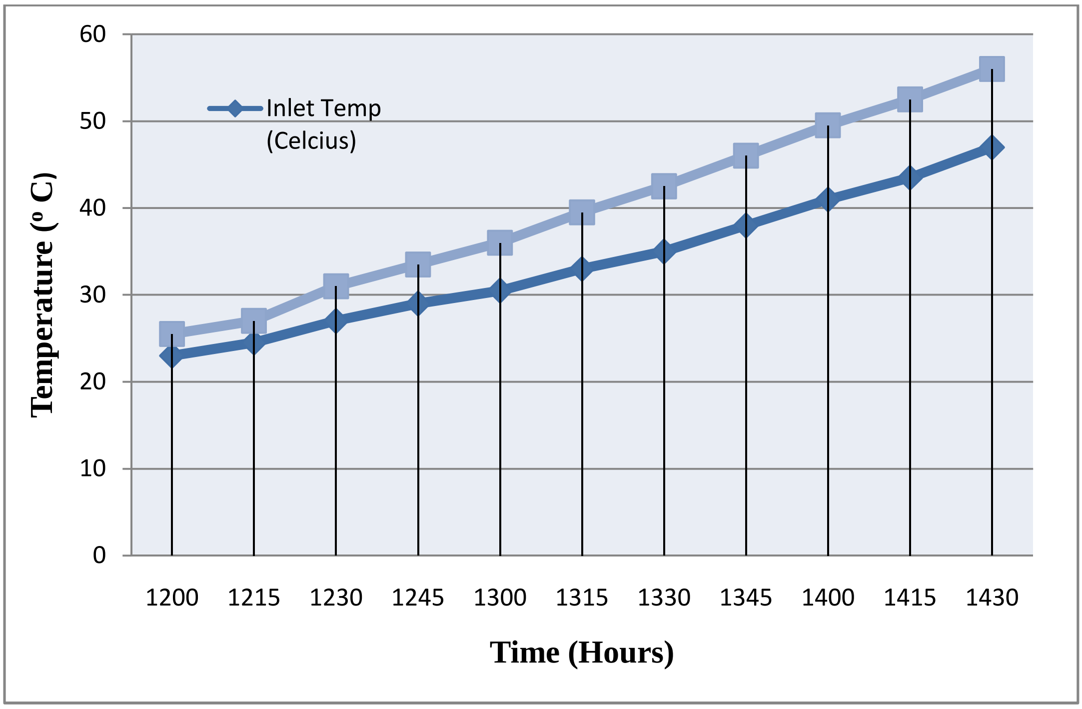

Figure 6.9: Temperature variation with time for experiment 6

Chapter 7

RESULT ANALYSIS

7.1 INTRODUCTION

7.2 ANALYSIS OF RESULT

7.3 CONCLUSION

7.1 INTRODUCTION

This chapter includes discussion about the results found during experiment at summer and winter time while the heater was static and moving position. Here we also compared the results found at the experiments.

7.2 ANALYSIS OF RESULT

We have done our experiment in two parts_

1. Experiment at summer;
2. Experiment at winter;

From the experiment 1, 2 and 3 (see section 6.2.1) at summer season, following graph was found for outlet temperatures-

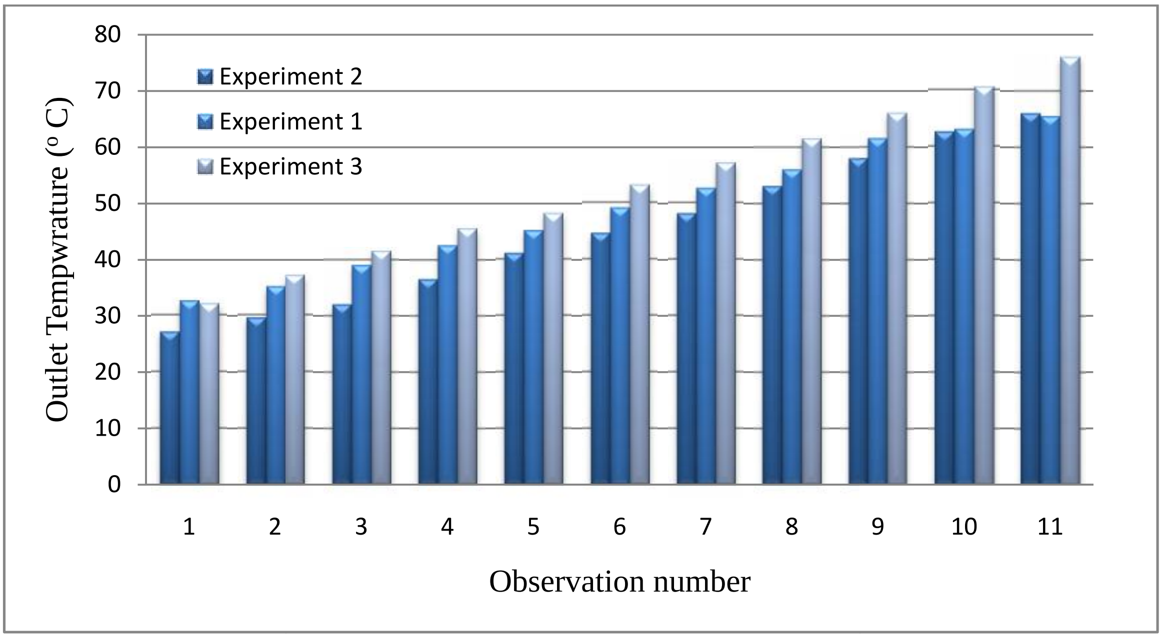

Figure 7.1: Comparing outlet temperatures from experiment 1, 2 and 3

For the inlet temperature sets the graph is like below:

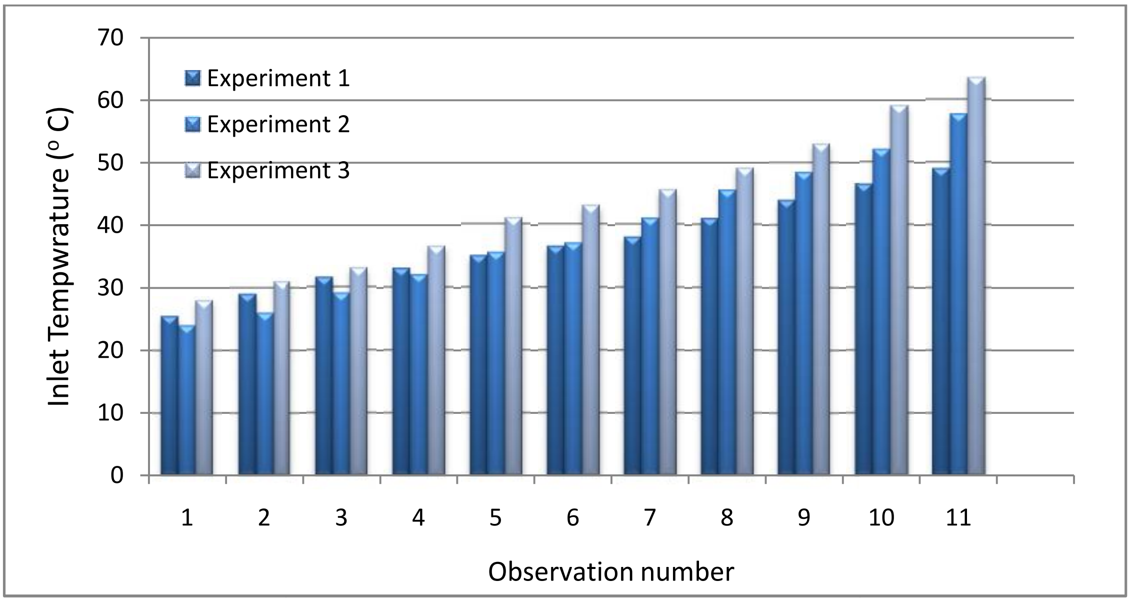

Figure 7.2: Comparing inlet temperatures from experiment 1, 2 and 3

From the outlet temperature graph, it was seen that, the water temperature was continuously raised until at an average of 70°C. We get the highest heated temperature of the water 76°C when the collector with the reflector while tracking the sun.

By plotting the output data found in experiment 4, 5 and 6 (see section 6.2.2) we get following graph for winter season in case of outlet temperatures-

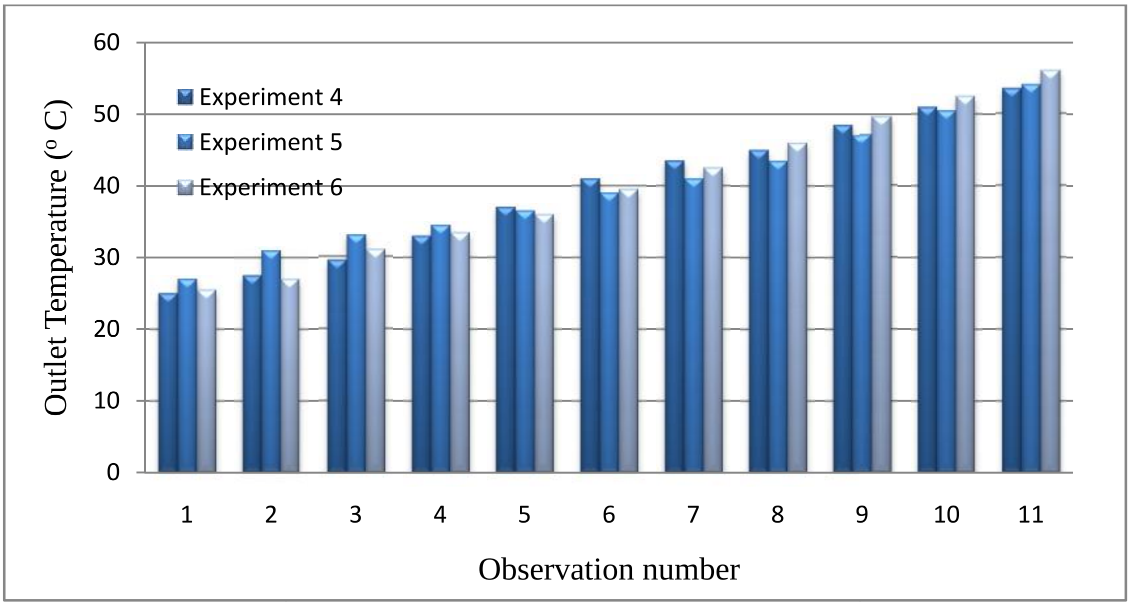

Figure 7.3: Comparing outlet temperatures from experiment 4, 5 and 6

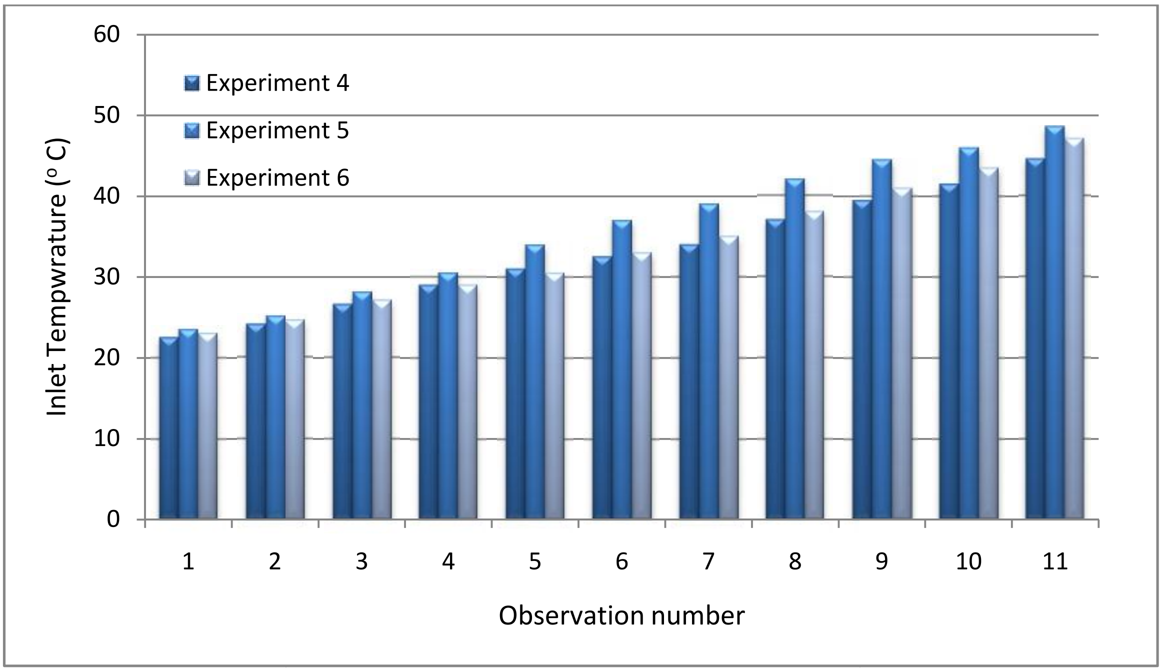

Figure 7.4: Comparing inlet temperatures from experiment 4, 5 and 6

From the outlet temperature graph, it was seen that, the water temperature was continuously raised until at an average of 54.5°C. We get the highest heated temperature of the water 56°C when the collector with the reflector while tracking the sun.

Point to be noted is the maximum temperature increment rate is gained in rotation with the reflector. So both in summer and in winter we preferred to develop from static to rotation with reflector.

Comparing between the data found with container with reflector while tracking the sun, we get the maximum temperature of the water as follows-

During summer (see experiment 3 under section 4.2.1): 76°C

During winter (see experiment 6 under section 4.2.2): 56°C

Plotting the two output data set of experiment 3 and experiment 6, we get the following graph-

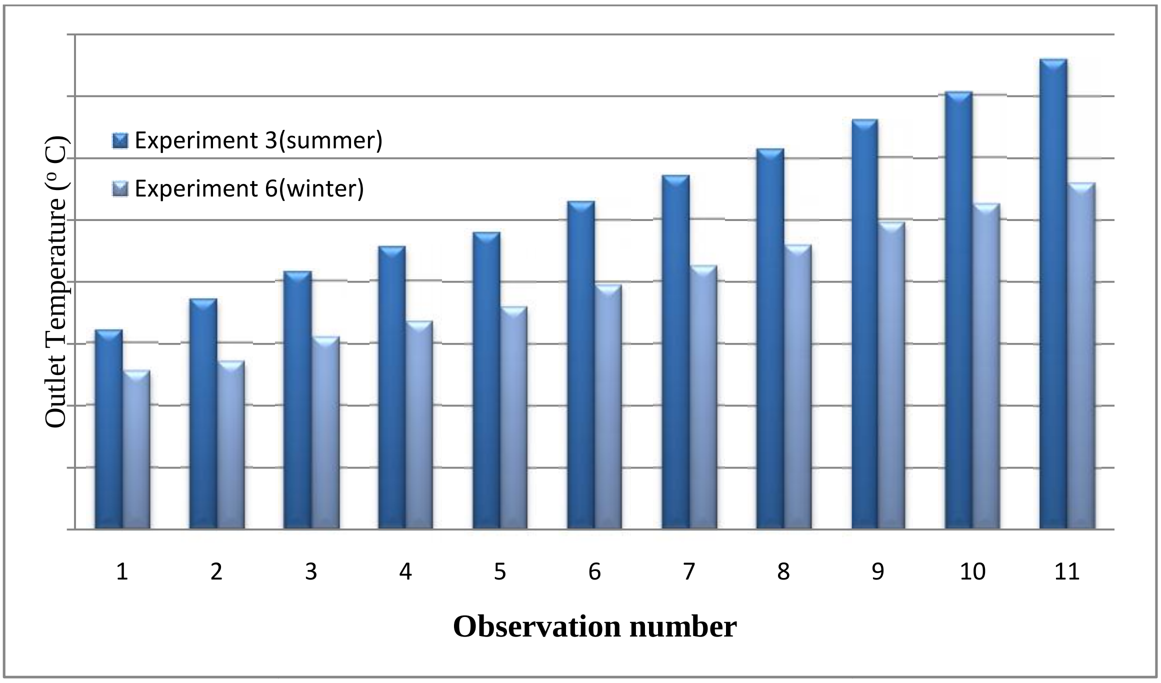

Figure 7.5: Comparing the values from moving collector between summer and winter

From the graph, we see the difference of temperature rising of water during the summer and winter season.

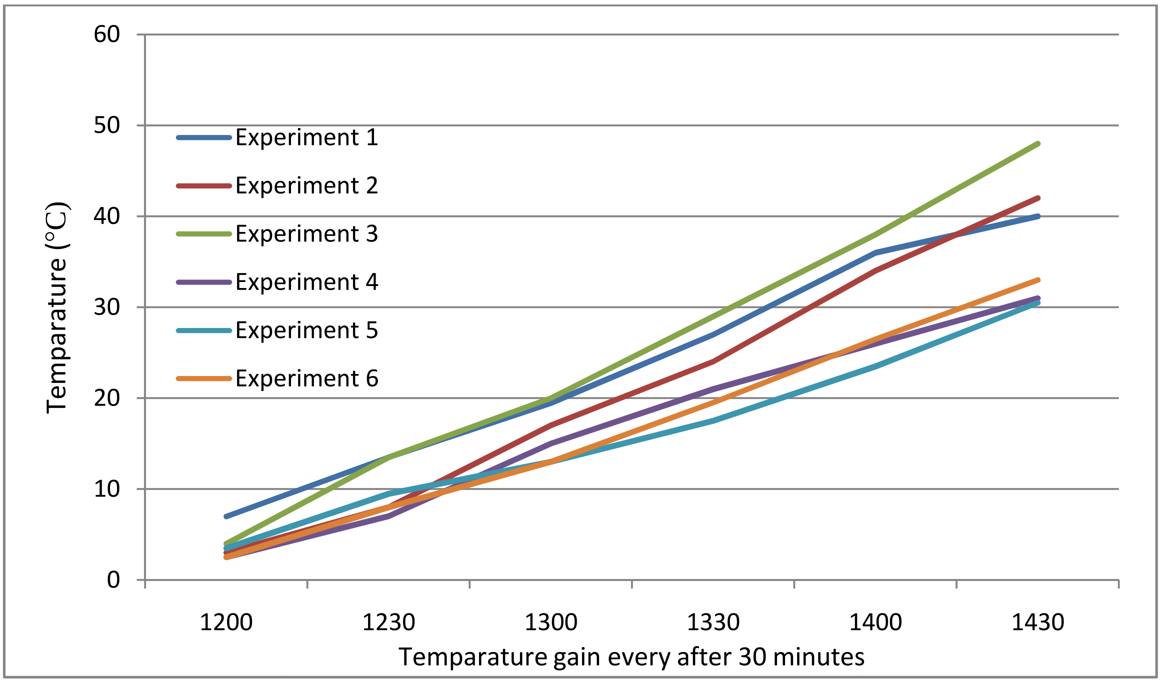

Figure 7.7: Comparing the temperature gain of all experiments every after 30 minutes.

7.3 CONCLUSION

The finally developed solar water heater system's performance was satisfactory as it could raise the temperature of the water maximum 76°C at the summer and 56°C at the winter. We also calculate the following data:

Table 7.1: Highest possible time to get 60±5 liter water in summer at 24°C day temperature

No.	Requirement	Temperature required (°C)	Lowest temperature gain in summer	Temperature Difference (°C)	Time to get the supply (Minutes)
1.	Kitchen	50	8	26	97.5
2.	Bath	40	8	16	60
3.	Industry	70	8	46	172.5

Table 7.2: Highest possible time to get 60±5 liter water in winter at 22.5°C day temperature

No.	Requirement	Temperature required (°C)	Lowest temperature gain in summer	Temperature Difference (°C)	Time to get the supply (Minutes)
1.	Kitchen	50	7	27.5	117.9
2.	Bath	40	7	17.5	75
3.	Industry	70	7	47.5	203.6

From figure 7.7 it is to be conclude that highest temperature gain is in experiment 3 (moving with reflector in summer), In case of winter, most preferable is experiment 6 (moving with reflector in winter). So this ways are always adopted in development.

Chapter 8

DISCUSSION AND CONCLUSSION

8.1 ADVANTAGES OF THE SWH

The overall project was carried out intending to build up an efficient solar water heater. In the summer the heater supplied water of 73 Celsius highest in close loop. So without the help of consuming other energy that temperature was gained. We can mark that a remarkable achievement for the set up. The advantages of the developed solar container were-

1. The solar water heater is capable of operation in all climates.
2. The SWH doesn't have any area based restriction.
3. The designed capacity is 30 liter approximately and can be increased if built bigger in a single pass of water.
4. Capable to perform in both close and open loop of water.
5. The bottom fiber is capable of passing sun rays through bottom.
6. If this type of SWH can be made in a large scale, it can supply water for industrial purpose.
7. Under continuous bombardment of sun, the SWH can heat water in a very short interval of time (typically in 2-3 hours).
8. The SWH is environment friendly and can be proved effective in the present energy crisis situation.
9. The SWH is cost effective in long term applications compared to other temporary arrangements of water heating.
10. The SWH is simple to manufacture and can be further developed to increase the efficiency.

8.2 LIMITATIONS OF THE SWH

The limitations of the developed solar container were-

1. Continuous presence of sun was mandatory for the SWH to heat water.
2. When water is expanded due to heat, the SWH has to release some water through drain line. So loss of water is there.
3. The rotation axis is not a 3 dimensional system.
4. Water pump consumes some electrical energy.
5. The microprocessor circuit needs a 5V battery which needs to be recharged after time interval.
6. The water takes some time to be heated up. So continuous flow is not possible.

8.3 CONCLUSION

During the days of development of the project, we faced some problems in different stages. But all those were overcome through modifications and implementations. At an overall view, we found the solar water heater has a good capability to heat water both in summer and in winter. We intended to keep the whole collector in an air tight case or container and to take another set of data. But we couldn’t do that due to shortage of time. However the performance generated was a satisfactory one and we could get what we wanted in a moderate effort. We will be looking forward to see its further development

Chapter 9

RECOMMENDATIONS

9.1 RECOMMENDATIONS

9.1 RECOMMENDATIONS

Though we got a good temperature from the SWH, there is always a scope of improvement. The construction work suggests a further development as follows:

1. The overall setup if possible should be operated inside a air tight chamber. That would ensure more temperature rise.
2. The stand was driven by a gear and pinion. Instead a stepper motor is suggested if possible
3. A rotation in 3 axis is more desirable.
4. The container was made of mild steel. A better heat conductor is recommended.
5. The pipes were restricting water flow while pump ran, so its better if steel pipe is used instead of rubber pipe.
6. A mirror reflector instead of steel reflector might give much improved result.
7. If possible, fluid with more heat capacity can be used.
8. The frame might be built up of lighter material to reduce the load on motor.
9. If possible the surface area should be increased which will ensure more heat absorption.
10. Treated water instead of raw water is suggested to prevent corrosion inside the heater.

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APPENDICES

A.1. DAQs

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Text;
using System.Windows.Forms;
using System.IO.Ports;
using System.Threading;

namespace serialCommunication
{


    public partial class Form1 : Form
    {
        SerialPort _serialPort;
        // delegate is used to write to a UI control from a non-UI thread
        private delegate void SetTextDeleg(string text);
        public Form1()
        {
            InitializeComponent();
        }

        private void Form1_Load(object sender, EventArgs e)
        {
            // all of the options for a serial device
            // can be sent through the constructor of the SerialPort class
            // PortName = "COM1", Baud Rate = 19200, Parity = None,
            // Data Bits = 8, Stop Bits = One, Handshake = None
            _serialPort = new SerialPort("COM10", 9600, Parity.None, 8,
StopBits.One);
            _serialPort.Handshake = Handshake.None;
            _serialPort.DataReceived += new
SerialDataReceivedEventHandler(sp_DataReceived);
            _serialPort.ReadTimeout = 500;
            _serialPort.WriteTimeout = 500;
            _serialPort.Open();
```

```
        }
        void sp_DataReceived(object sender, SerialDataReceivedEventArgs e)
        {
            Thread.Sleep(50);
            char[] data = new char[100];
            try
            {
                _serialPort.Read(data, 0, 10);

            }
            catch (Exception ex)
            {
            }
            string s = new String(data);
            this.BeginInvoke(new SetTextDeleg(si_DataReceived), new object[] { s
});
        }

        private void si_DataReceived(string data)
        {
            textBox2.Text = data;
        }

        private void button1_Click(object sender, EventArgs e)
        {
            // Makes sure serial port is open before trying to write
            try
            {
                if (!_serialPort.IsOpen)
                    _serialPort.Open();
                String x;
                x = textBox1.Text;
                _serialPort.Write(x + "\r\n");
            }
            catch (Exception ex)
            {
                MessageBox.Show("Error opening/writing to serial port :: " +
ex.Message, "Error!");
            }
        }
```

```
        private void textBox1_TextChanged(object sender, EventArgs e)
        {

        }
    }
}
```

A.2. DAQs (microcontroller section)

```
char uart_rd;

void main() {
  UART1_Init(9600);              // Initialize UART module at 9600 bps
  Delay_ms(100);                 // Wait for UART module to stabilize

  while (1) {                    // Endless loop
    uart_rd = ADC_read(0);
     UART1_Write(uart_rd);       // and send data via UART
    delay(2000);
    }
  }
```

A.3. Microcontroller for rotating motor

A.3.1. Assembly Coding

```
L293D_A   equ P2.0       ;L293D A - Positive of Motor
L293D_B   equ P2.1       ;L293D B - Negative of Motor
L293D_E   equ P2.2       ;L293D E - Enable pin of IC

        org 0H
Main:
        acall rotate_f    ;Rotate motor forward
        acall delay       ;Let the motor rotate
        acall break       ;Stop the motor
        acall delay       ;Wait for some time
        acall rotate_b    ;Rotate motor backward
```

```
        acall delay        ;Let the motor rotate
        acall break        ;Stop the motor
        acall delay        ;Wait for some time
        sjmp  Main         ;Do this in loop

rotate_f:
        setb  L293D_A      ;Make Positive of motor 1
        clr   L293D_B      ;Make negative of motor 0
        setb  L293D_E      ;Enable to run the motor
        ret                ;Return from routine

rotate_b:
        clr   L293D_A      ;Make positive of motor 0
        setb  L293D_B      ;Make negative of motor 1
        setb  L293D_E      ;Enable to run the motor
        ret                ;Return from routine

break:
        clr   L293D_A      ;Make Positive of motor 0
        clr   L293D_B      ;Make negative of motor 0
        clr   L293D_E      ;Disable the o/p
        ret                ;Return from routine

delay:                     ;Some Delay
        mov   r7,#20H
back:   mov   r6,#FFH
back1:  mov   r5,#FFH
here:   djnz  r5, here
        djnz  r6, back1
        djnz  r7, back
        ret
```

A.3.2. C programming.

```
#include <AT89X51.H>#define L293D_A P2_0        //Positive of motor
#define L293D_B P2_1        //Negative of motor
```

```
#define L293D_E P2_2        //Enable of L293D

// Function Prototypes
void rotate_f(void);        //Forward run funtion
void rotate_b(void);        //Backward run function
void breaks(void);          //Motor stop function
void delay(void);           //Some delay

void main(){                //Our main function
  while(1){                 //Infinite loop
        rotate_f();         //Run forward
        delay();            //Some delay
        breaks();           //Stop
        delay();            //Some delay
        rotate_b();         //Run Backwards
        delay();            //Some delay
        breaks();           //Stop
        delay();            //Some delay
    }                       //Do this infinitely
}

void rotate_f(){
    L293D_A = 1;            //Make positive of motor 1
    L293D_B = 0;            //Make negative of motor 0
    L293D_E = 1;            //Enable L293D
}

void rotate_b(){
    L293D_A = 0;            //Make positive of motor 0
    L293D_B = 1;            //Make negative of motor 1
    L293D_E = 1;            //Enable L293D
}

void breaks(){
    L293D_A = 0;            //Make positive of motor 0
    L293D_B = 0;            //Make negative of motor 0
    L293D_E = 0;            //Disable L293D
}

void delay(){               //Some delay...
```

```
unsigned char i,j,k;
for(i=0;i<0x20;i++)
    for(j=0;j<255;j++)
            for(k=0;k<255;k++);
```