DESIGN AND CONSTRUCTION OF A COST-EFFECTIVE SOLAR WATER HEATER

A thesis

by

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SONARGAON UNIVERSITY (SU)

MAY, 2025

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APPROVAL

This is to certify that the project **"Design and Construction of a Cost-effective Solar Water Heater" ,** by Md. Tahmid Hasan, ID: ME2103025470; Md. Mustakim Billah Shuchok, ID: ME2103025474; Md. Bappy Parvez, ID: ME2103025243; Madhob Chandra Roy, ID: ME2103025547; Md. Mehedi Hasan, ID: ME2103025469; has been carried out under our supervision. The project has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science (B.SC.) in Mechanical Engineering of year 2025 and has been approved as to its style and contents.

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DECLARATION

We do hereby solemnly declare that we have carried out the work presented here in this project report and have not been previously submitted to any University/ Organization for the award of any degree or certificate

We hereby ensure that the works prevented here do not breach any existing copyright.

We further indemnify the university against any loss or damage arising from breach of the foregoing obligation.

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ACKNOWLEDGEMENT

First, we started in the name of almighty Allah. This thesis is accomplished under the supervision of **Navid Inan,** Lecturer, Department of Mechanical, Sonargaon University. It is a great pleasure to acknowledge our profound gratitude and respect to our supervisor for this consistent guidance, encouragement, helpful suggestions, constructive criticism, and endless patience throughout the progress of this work. The successful completion of this thesis would not have been possible without his persistent motivation and continuous guidance.

The authors are also grateful to **Prof. Md. Mostofa Hossain**, Head of the Department of Mechanical Engineering, and all respected teachers of the Mechanical Engineering Department for their co-operation and significant help in completing the thesis work successfully.

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ABSTARCT

The Cost-Effective Low Energy Consumption Solar Water Heater is an innovative solution that utilizes solar energy to heat water efficiently and sustainably. This system is designed with flat plate collectors that capture sunlight and transfer the absorbed heat to water flowing through copper pipes. A motorized pump circulates water from a storage tank to the solar collector, where it is heated and returned to the insulated hot water tank for usage. The design uses locally available materials and simplified manufacturing techniques to reduce overall costs, making it an affordable option for residential and commercial use. Unlike conventional water heaters, it requires minimal electricity, primarily for pump operation, resulting in low energy consumption and significant cost savings. This solar water heater is ideal for regions with limited wood, coal, or gas access, providing a reliable and eco-friendly alternative. Its sustainable design contributes to reduced carbon emissions and promotes green energy adoption.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This Project is intended to design a water heating system using solar technology. Various design and manufacturing constraints exist, but the most general and efficient method would be used here. It includes a thorough study of the mechanism of solar water heaters. The heater would be manufactured after designing such a mechanism, and the results would be presented. Solar energy technology is used in various places in different ways. It is used to produce electricity, and it provides energy that is used to cook food. Solar systems are designed so that water can be heated to any temperature. But at domestic levels, water can be heated up to 60 ºC. Evacuated solar and glazed plate heaters are the most common solar-powered water heaters worldwide. Some of the systems are active, and others are passive. Active systems are divided into direct and indirect solar systems. In this Project, an indirect solar system will be designed. The mechanism of our solar heater will resemble that shown in Figure 1.

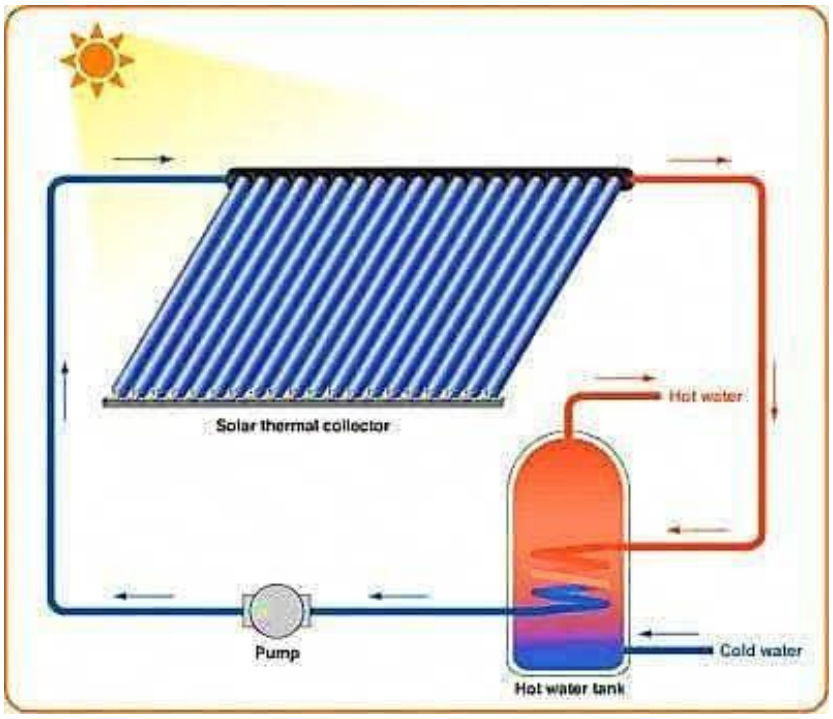


Figure 1.1: Solar Water Heater Mechanism

The world relies heavily on fossil fuels for most of its energy demands, which has caused much harm to the Earth. The increase in greenhouse gas levels in the atmosphere is mainly due to the combustion of fossil fuels as a source of energy. This has caused global

warming, leading to climate change, floods, forest fires, rising sea levels, and melting glaciers. These are just some consequences of our over-reliance on fossil fuels for energy demands. Solar energy provides an alternative and environmentally friendly energy source to the fossil fuels used for our energy needs. Over the last few decades, solar energy systems have gained more recognition because they can provide energy at a low long-term cost and minimal environmental damage.

Researchers have developed several techniques for harnessing solar energy, including applications for space heating, water heating, electricity generation, etc. Solar energy is generated by the fusion of hydrogen atoms in the Sun. This fusion reaction results in the release of high-energy particles called gamma rays. Gamma rays are transmitted as electromagnetic radiation to the Earth, about 150 million kilometres from the Sun. Electromagnetic radiation comes in three forms: infrared rays, visible light, and ultraviolet rays. Solar energy reaching the Earth's surface can be harnessed directly using photovoltaics (solar cells) and solar concentrators. Photovoltaics are used for electricity generation, while solar concentrators are used as a thermal energy source. The utilization of solar energy collectors (concentrators) to transform radiation into heat energy is the basis of the solar water heating technology. A simple solar water heater consists of a collector, a tank, and a flow channel through which the working fluid is transported.

1.2 Problem Statement

Considering the epileptic nature of electric power supply in our country, the reliance on solar applications for water heating will lead to better service reliability for hot water needs. It will have minimal negative impact on the environment. This would reduce the reliance on electric heaters, which have higher operational costs and depend on fossil fuels as a primary energy source.

1.3 Motivation for the Study

Much research has gone into solar energy over the past few decades. This is primarily because of the increased worldwide acknowledgement of the environmental effects that the use of fossil fuel as an energy source comes with. This current Study will result in the design and construction of a portable solar water heating system that will provide hot water. Using locally sourced materials would reduce the financial resources required compared to the imported materials. With this system, our country is going through a recession and a pandemic, which has further impacted the nation's economy. The

availability of locally made solar water heating systems would help boost the local economy and curb the importation rate.

1.4 Objective

This Project aims to design and construct a portable solar water heater. The objectives are

- To design and construct a Cost-Effective Energy Consumption Solar Water Heater.
- To minimize electricity consumption and reduce energy costs.
- To harness solar energy for efficient water heating.

1.5 Structure of the Project

This Project is organized as follows:

Chapter 1 Introduction: The first chapter contains the statement of the introduction, problem statement, motivation of our Study, objectives, and the project outline.

Chapter 2 Literature Review: Chapter two contains an introduction, about solar water heater theory, types of solar water heaters, a literature review part, and a summary.

Chapter 3 Hardware and Software Analysis: Chapter three describes the theoretical model. Here we mainly discuss the proposed system about Hardware.

Chapter 4 Methodology: Chapter four deals with our project methodology, working steps, block diagram, structural design, and working principle.

Chapter 5 Result and Discussion: Chapter five deals with our project discussion, the results of our advantages, and our project application study.

Chapter 6 Conclusion: Chapter six is all about our project conclusion and future scope.

CHAPTER 2
LITERATURE REVIEW

This section includes topics related to cost-effective Energy Consumption Solar Water Heater systems. These provide a sampling of problems appropriate for applying a Cost-Effective Energy Consumption Solar Water Heater. The references are summarized below. System are included. These provide a sampling of problems appropriate for application of Cost Effective Low Energy Consumption Solar Water Heater. The references are summarized below.

2.2 What is a Solar Water Heater

A solar water heater converts sunlight into renewable energy for water heating using a solar thermal collector. Solar water heating systems are comprised of various technologies used worldwide, and their use is increasing. In a "close-coupled SWH system the Storage Tank is horizontally mounted immediately above the solar collectors on the roof. No pumping is required as the hot water naturally rises into the tank through thermo-siphon flow. In a "pump-circulated" system, the storage tank is ground – or floor–mounted and below the collectors' level; a circulating pump moves water or heat transfer fluid between the tank and the collector.

A Solar Water Heater is a device that provides hot water for bathing, washing, cleaning, etc., using solar energy. It is generally installed on the terrace, where sunlight is available and heats water during the daytime. It is stored in an insulated storage tank for use when required, including in the morning. We are blessed with Solar Energy in abundance at no cost. The solar radiation incident on the surface of the Earth can be conveniently utilized for the benefit of human society. One of the popular devices that harnesses the solar energy is a solar hot water system (SHWS). A solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water. The solar energy incident on the absorber panel coated with the selected coating transfers to the riser pipes underneath the absorber panel. The water passing through the risers gets heated and delivered to the storage tank. The recirculation of the same water through the absorber panel in the collector raises the temperature to 80 °C (Maximum) on a good sunny day.
The total system with solar collector, storage tank, and pipelines is called a solar hot water system. Solar water heating systems are divided into two categories. They are a closed

loop system and an open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from bore wells or freezing temperatures in the cold regions.

2.3 Types of Solar Water Heaters

Solar water heaters can be either active or passive. An active system uses an electric pump to circulate the heat transfer fluid; a passive system has no pump. The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sunlight available at the site, proper installation, and the tilt angle and orientation of the collectors. Solar water heaters are also characterized as open loop (also called "direct") or closed loop (also called "indirect"). An open-loop system circulates household (potable) water through the collector. A closed-loop system uses a heat-transfer fluid (water or diluted antifreeze, for example) to collect heat and a heat exchanger to transfer the heat to household water.

2.3.1 Active Systems

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. They are usually more expensive than passive systems but are also more efficient. Active systems are generally easier to retrofit than passive systems because their storage tanks do not need to be installed above or close to the collectors. But they will not function in a power outage because they use electricity. Active systems range in price from about $2,000 to $4,000 installed.

2.3.2 Open-Loop Active Systems

Open-loop active systems use pumps to circulate household water through the collectors. This design is efficient and lowers operating costs, but is not appropriate if your water is hard or acidic because scale and corrosion quickly turn off the system. These open-loop systems are popular in non-freezing climates such as Hawaii. They should never be installed in climates that experience freezing temperatures for sustained periods. You can install them in mild but occasionally freezing climates, but you must consider freeze protection. Recirculation systems are a specific type of open-loop system that provides freeze protection. They use the system pump to circulate warm water from storage tanks through collectors and exposed piping when temperatures approach freezing. Consider recirculation systems where mild freezes occur at least once or twice a year. Activating the freeze protection more frequently wastes electricity and stored heat. Of course, when the

power is out, the pump will not work, and the system will freeze. To guard against this, a freeze valve can be installed to provide additional protection if the pump doesn't operate. The valve dribbles warmer water through the collector to prevent freezing in freezing weather.

2.3.3 Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Double-walled heat exchangers prevent contamination of household water. Some codes require double walls when the heat transfer fluid is anything other than household water. Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection. However, glycol antifreeze systems are a bit more expensive to buy and install, and the glycol must be checked each year and changed every 3 to 10 years, depending on glycol quality and system temperatures. Drain back systems use water as the heat transfer fluid in the collector loop. A pump circulates the water through the collectors. The water drains by gravity to the storage tank and heat exchanger; there are no valves to fail. When the pumps are off, the collectors are empty, which assures freeze protection and also allows the system to turn off if the water in the storage tank becomes too hot.

2.3.4 Passive Systems

Passive systems move household water or a heat-transfer fluid through the system without pumps. Passive systems have no electric components to break. This makes them generally more reliable, easier to maintain, and possibly longer lasting than active systems. Passive systems can be less expensive than active systems, but they can also be less efficient. Installed costs for passive systems range from about $1,000 to $3,000, depending on whether it is a simple batch heater or a sophisticated thermosiphon system

2.4 Literature Review

The solar energy the Earth receives in a day is far greater than humans' total energy in the same period. Eighteen days of the incident's solar radiation on Earth would give an equivalent amount of energy compared to all the planet's reserves of natural gas, coal, and oil (Union of concerned scientists, 2015). Solar radiation contains about 1,300 watts per square meter outside the Earth's atmosphere. A third of this gets reflected into space once it reaches the Earth's atmosphere, and the rest travels toward the surface of the Earth. Every square meter receives about 4.2 kilowatt-hours of solar energy daily (Union of Concerned Scientists, 2015).

Although the amount of solar energy the Earth receives daily is greater than that used by humans, the intensity of this solar energy or radiation incident on the Earth's surface depends on some factors. These factors include the geographic location and its inherent climate, the weather patterns or seasons, and the time of day. At specific periods within the year, the Earth is near the Sun, because the Earth revolves elliptically around the Sun. When the Earth is nearer the Sun, its surface receives more solar radiation. Earth's rotation around the Sun is on a tilted axis of 23.5°, which plays a role in determining the incident radiation at a given location. The Earth's tilted rotation brings about longer days in the northern hemisphere. Conversely, the southern hemisphere has longer days for the six months after the fall equinox. The southern parts of the United Kingdom and other middle latitudes get higher amounts of radiation during summer due to the longer days.

However, during winter, regions around the middle latitude receive lower amounts of solar energy because the solar rays are incident at a tilted angle during winter in middle latitude regions (Office of Energy Efficiency and Renewable Energy, 2013). The intensity of the solar radiation received on the Earth's surface depends on the angle the Sun's rays make with the Earth's surface. This angle ranges from 0°, when the Sun is just above the skyline, to 90°, when the Sun is directly overhead. The greatest incredibility of solar radiation striking the Earth's surface can be observed at solar noon. This is when the Sun is at its highest position (90°) in the sky, on a clear, cloudless day (Energy Information Administration, 2020). At angles less than 90°, the solar rays travel longer distances through the atmosphere, making them less intense when they reach the Earth's surface.

As solar rays travel through the Earth's atmosphere, some get absorbed or reflected, and others get scattered. Various elements, such as the air molecules, water vapor, the clouds, dust particles, and volcanoes, influence whether the solar rays get absorbed, reflected, or

scattered. Based on this, solar radiation is classified into two components: diffuse and direct beam solar radiation. Direct beam rays reach the Earth's surface without being diffused. Diffuse rays get scattered, absorbed, or reflected by the dust particles, air molecules, or water vapour in the Earth's atmosphere (Adefarati & Bansal, 2019).

When the solar collector of an SWH is inclined, the diffuse rays striking it comprise the sky diffuse radiation, and a third component of solar radiation: Ground reflected radiation (Ineichen et al., 1990). The ground reflected radiation reflects off the Earth's surface and strikes the collector. The direct radiation gets affected by atmospheric conditions; on a clear, dry day, it can reduce by up to 10% and during thick, cloudy days, by up to 100% (Office of Energy Efficiency and Renewable Energy, 2013). Global solar radiation is the total amount of solar energy the Earth's surface receives, equivalent to the sum of the diffuse, direct beam, and ground-reflected radiation.

While concentrating solar systems require direct beam solar radiation to function correctly, the flat-plate collector system functions properly with diffuse and direct beam solar radiation (Energy Information Administration, 2020). Scientific researchers record the number of solar radiation incidents in specific locations at various periods during the year. These values estimate the amount of solar radiation incident in other places with similar latitudes and local weather. Solar energy measurements are usually expressed as the total amount of solar radiation on a horizontal surface or the total solar radiation on a surface tracking the Sun. Solar radiation data is traditionally represented as kilowatt-hours per square meter (Office of Energy Efficiency and Renewable Energy, 2013).

2.5 Summary

We tried to do this Project by reading the above literature, and we have made our Project successful by reducing the mistakes from last year's Project.

CHAPTER 3

HARDWARE AND SOFTWARE ANALYSIS

3.1 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics.



Figure 3.1: SMPS

Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on, and full-dissipation, and spends very little time in the high-dissipation transitions, which minimizes wasted energy. A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an essential advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. Switching regulators are replaced with linear regulators when higher efficiency, smaller size, or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter, turning it on and off at frequencies between 20 kHz and 200 kHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

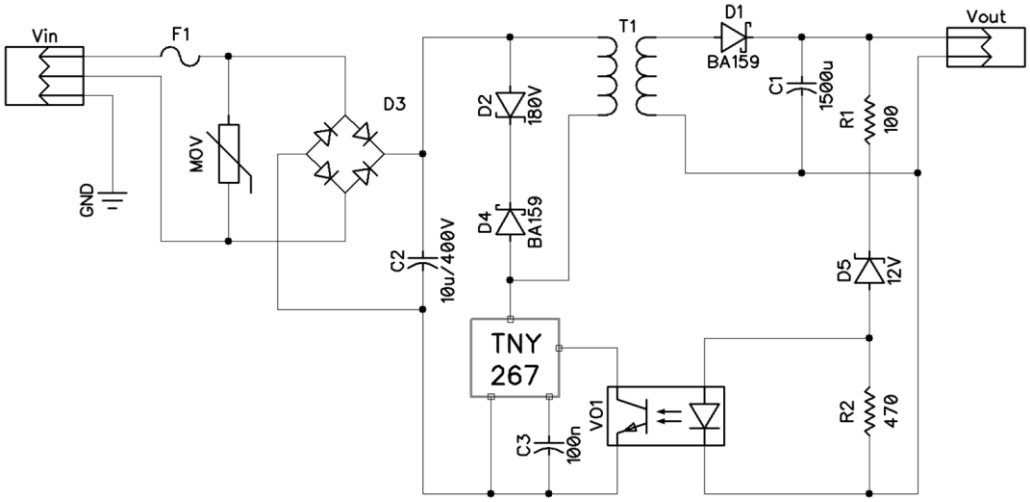


Figure 3.2: Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned on. The continuous switching of the capacitor maintains the voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) regulator, followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pinouts, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer. There are different circuit configurations known as topologies, each having unique characteristics, advantages, and modes of operation, which determine how the input power is transferred to the output. Most commonly used topologies, such as flyback, push-pull, half bridge, and full bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer, and the power conversion is provided by the inductive energy transfer.

Advantages of switched-mode power supplies

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density

Disadvantages

- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment, such as computers, sensitive electronics, battery-operated devices, and other equipment requiring high efficiency.

Switch Mode Power Supply

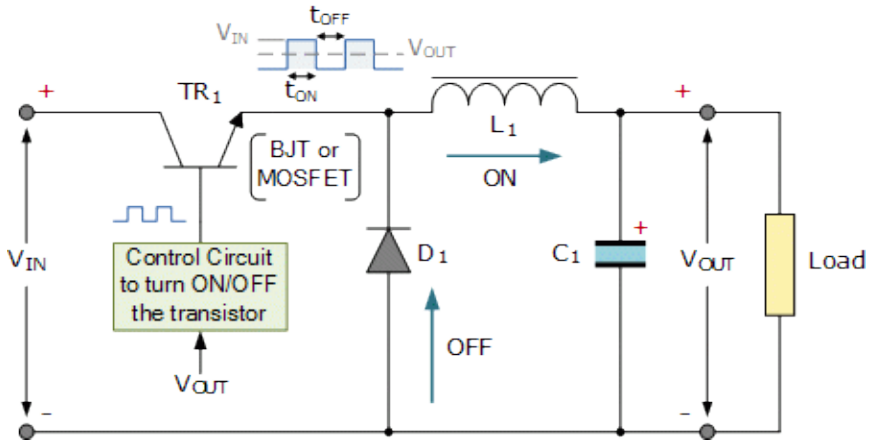


Figure 3.3: SMPS Diagram

Linear voltage IC regulators have been the basis of power supply designs for many years, as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent circuits made from discrete components such as a zener diode and a resistor, transistors, and even op-amps. The most popular linear and fixed output voltage regulator types are the 78… positive output voltage series, and the 79… negative output voltage series. These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 to about 24 volts for use in many electronic circuits.

A wide range of these three-terminal fixed voltage regulators is available, each with built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available, and they provide output voltage which is continually variable from just above zero to a few volts below its maximum voltage output. Most DC Power supplies comprise a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, and a filter circuit to remove any ripple content from the rectified d.c. Producing a suitably smooth d.c. Voltage, and some form of voltage regulator or stabiliser circuit, either linear or switching, to ensure the correct regulation of the power supply's output voltage under varying load conditions. Then a typical DC Power supply would look something like this:

Typical DC Power Supply

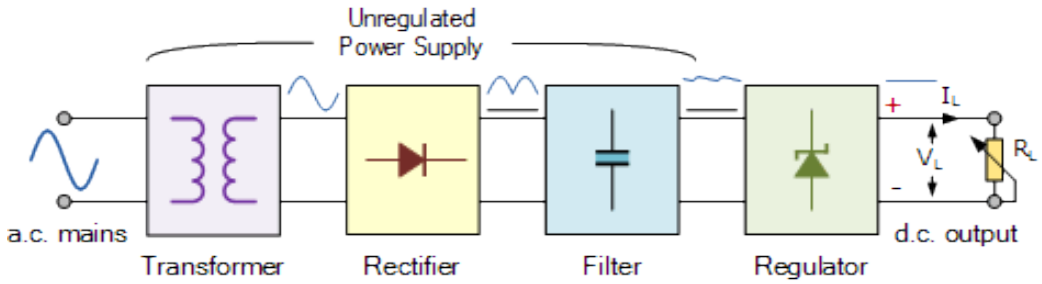


Figure 3.4: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could have a single zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, an output capacitor, and some feedback resistors to set the output voltage.

3.2 Plastic Pipe

Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances that can flow liquids and gases (fluids), slurries, powders, and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members.

Product Description

Table 1: Description of Plastic Pipe

Product Name:	Clear PVC tubing
Material:	pvc
Size:	From 1/8inch (ID 3mm) to 2 inches (ID 50mm)
Wall Thickness:	From 1mm to 4mm
Color:	Clear / blue / red / yellow / black / green / orange etc.
Working Pressure:	from 2bar (30psi) to 4bar (60psi)
Temperature Range:	From -5 to 65 degrees C.
Length/roll	10m, 20m, 30m, 50m/roll or other.

Application

Suitable for low-pressure transfer of various Fluids and air, such as fuel, water, light chemicals, oxygen, gas for watering systems, peristaltic pumps, electrical and thermal insulation, analytical systems in plant equipment, laboratories, watering systems, and many other low-pressure industry applications.



Figure 3.5: Plastic Pipe

3.3 Digital Thermometer

A thermometer is a device that measures temperature or a temperature gradient (the degree of hotness or coldness of an object). A thermometer has two essential elements: a temperature sensor (e.g., the bulb of a mercury-in-glass thermometer or the pyrometric sensor in an infrared thermometer), in which some change occurs with a change in temperature.



Figure 3.6: Digital Temperature Sensor

Some means of converting this change into a numerical value (e.g., the visible scale that is marked on a mercury-in-glass thermometer or the digital readout on an infrared model).

Thermometers are widely used in technology and industry to monitor processes, in meteorology, in medicine, and in scientific research. Some of the principles of the thermometer were known to Greek philosophers two thousand years ago. As Henry Carrington Bolton (1900) noted, the thermometer's "development from a crude toy to an instrument of precision occupied more than a century, and its early history is encumbered with erroneous statements that have been reiterated with such dogmatism that they have received the false stamp of authority."

The Italian physician Santorio Santorio (Sanctorius, 1561-1636) is commonly credited with the invention of the first thermometer, but its standardization was completed through the 17th and 18th centuries. In the first decades of the 18th century in the Dutch Republic, Daniel Gabriel Fahrenheit made two revolutionary breakthroughs in the history of thermometry. He invented the mercury-in-glass thermometer (the first widely used, accurate, practical thermometer) and the Fahrenheit scale (the first standardized temperature scale to be widely used).



Figure 3.7: Digital Temperature Sensor Display

Specification

- Temperature range: -50~ +110°C
- Using environment: Temperature: -5~ +50°C Humidity: 5%~80%
- Accuracy: ±1°C
- Size: 47*28*14mm
- Weight: 22g
- Color: Black and white

3.4 Pump Motor

This is a low-cost, small-sized Submersible Pump Motor that can be operated from a 2.5 ~ 6V power supply. It can take up to 120 liters per hour with very low current consumption of 220mA. Just connect the tube pipe to the motor outlet, submerge it in water, and power it. Make sure that the water level is always higher than the motor. A dry run may damage the motor due to heating, and it will also produce noise.This is a low cost, small size Submersible Pump Motor which can be operated from a 2.5 ~ 6V power supply. It can take up to 120 litters per hour with very low current consumption of 220mA. Just connect tube pipe to the motor outlet, submerge it in water and power it. Make sure that the water level is always higher than the motor. Dry run may damage the motor due to heating and it will also produce noise.



Figure 3.8: Pump Motor

Feature

- Operating Current: 130~220mA
- Flow Rate: 80 ~ 120 L/H
- Maximum Lift: 40 ~ 110 mm
- Continuous Working Life: 500 hours
- Driving Model: DC, Magnetic Driving
- Material: Engineering Plastic
- Outlet Outside Diameter: 7.5 mm
- Outlet Inside Diameter: 5 mm

3.5 Resistor

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at times, act to

lower voltage levels within circuits. Resistors may have fixed resistances or variable resistances, such as those found in thermostats, visitors, trimmers, photo resistors, hamsters, and potentiometers. The current through a resistor is directly proportional to the voltage across the resistor's terminals. This relationship is represented by Ohm's law



Figure 3.9: Resistor

Theory of operation

The behavior of an ideal resistor is dictated by the relationship specified by Ohm's law:

$$V = I.R$$

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I), where the constant of proportionality is the resistance (R).

Equivalently, Ohm's law can be stated:

$$I = V/R$$

This formulation states that the current (I) is proportional to the voltage (V) and inversely proportional to the resistance (R). This is directly used in practical computations. For example, if a 300-ohm resistor is attached across the terminals of a12 12-volt battery, then a current of 12 / 300 = 0.04 amperes flows through that resistor.

3.6 Copper Tube

Copper tubing is most often used for heating systems and as a refrigerant line in HVAC systems. Copper tubing is slowly being replaced by PEX tubing in hot and cold water applications. There are two basic types of copper tubing: soft copper and rigid copper. Copper tubing is joined using a flare connection, compression connection, pressed connection, or solder. Copper offers a high level but is becoming very costly.corrosion resistance but is becoming very costly.

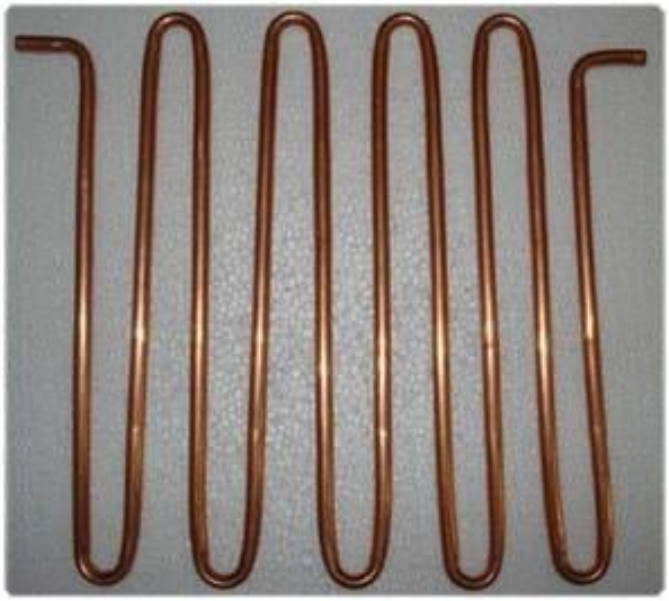


Figure 3.10: Copper Tube

Types of Copper Tube:

Soft copper

Soft (or ductile) copper tubing can be bent easily to travel around obstacles in the tubing path. While the work hardening of the drawing process used to size the tubing makes the copper stiff or rigid, it is carefully annealed to make it soft again; it is, therefore, more expensive to produce than non-annealed, rigid copper tubing. It can be joined by any of the three methods used for rigid copper, and it is the only type of copper tubing suitable for flare connections. Soft copper is the most popular choice for refrigerant lines in *split-system* HYPERLINK "https://en.wikipedia.org/wiki/Air_conditioner"air conditioners and heat pumps.at pumps.

Rigid copper

Rigid copper is a popular choice for water lines. Rigid or "Hard" copper tubing is generally called "pipe". Copper "piping" is referred to by nominal pipe size, or the inner diameter. It is joined using a solder/sweat, roll grooved, compression, or crimped/pressed connection. Rigid copper, rigid due to the work hardening of the drawing process, cannot be bent and must use *elbow fittings* to go around corners or obstacles. If heated and allowed to cool in an annealing process, rigid copper will become soft and can be bent/formed without cracking. to go around corners or around obstacles. If heated and

allowed to cool in a process called annealing, rigid copper will become soft and can be bent/formed without cracking.

As a heat exchanger

Heat exchangers transfer heat to achieve the desired heating or cooling. An important design aspect of heat exchanger technology is the selection of appropriate materials to conduct and transfer heat fast and efficiently. Copper has many desirable properties for thermally efficient and durable heat exchangers. First and foremost, copper is an excellent conductor of heat. This means that copper's high HYPERLINK "https://en.wikipedia.org/wiki/Thermal_conductivity"thermal conductivity allows heat to pass through it quickly. Other desirable properties of copper in heat exchangers include its allows heat to pass through it quickly. Other desirable properties of copper in heat exchangers include its corrosion resistance, biofouling resistance, maximum allowable stress and internal pressure, creep rupture strength, fatigue strength, hardness, thermal expansion, specific heat, antimicrobial properties, tensile strength, yield strength, high melting point, alloy, ease of fabrication, and ease of joining. The combination of these properties enable copper to be specified for heat exchangers in industrial facilities, HVAC systems, vehicular coolers and radiators, and as heat sinks to cool computers, disk drives, televisions, computer monitors, and other electronic equipment. Copper is also incorporated into the bottoms of high-quality cookware because the metal conducts heat quickly and distributes it evenly.corrosion resistance, biofouling resistance, maximum allowable stress and internal pressure, creep rupture strength, fatigue strength, hardness, thermal expansion, specific heat, antimicrobial properties, tensile strength, yield strength, high melting point, alloy, ease of fabrication, and ease of joining. The combination of these properties enables copper to be specified for heat exchangers in industrial facilities, HVAC systems, vehicular coolers and radiators, and as heat sinks to cool computers, disk drives, televisions, computer monitors, and other electronic equipment. Copper is also incorporated into the bottoms of high-quality cookware because the metal conducts heat quickly and distributes it evenly.

3.7 Easy EDA

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share publicly and privately, and discuss , simulations and printed circuit boards. Other features include the creation of a bill of materials, Gerber files and pick and place files and documentary outputs in PDF, PNG and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.schematics, simulations , and printed circuit boards. Other features include the creation of a bill of materials, Gerber files , pick and place files, and documentary outputs in PDF, PNG, and SVG formats. EasyEDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits, and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

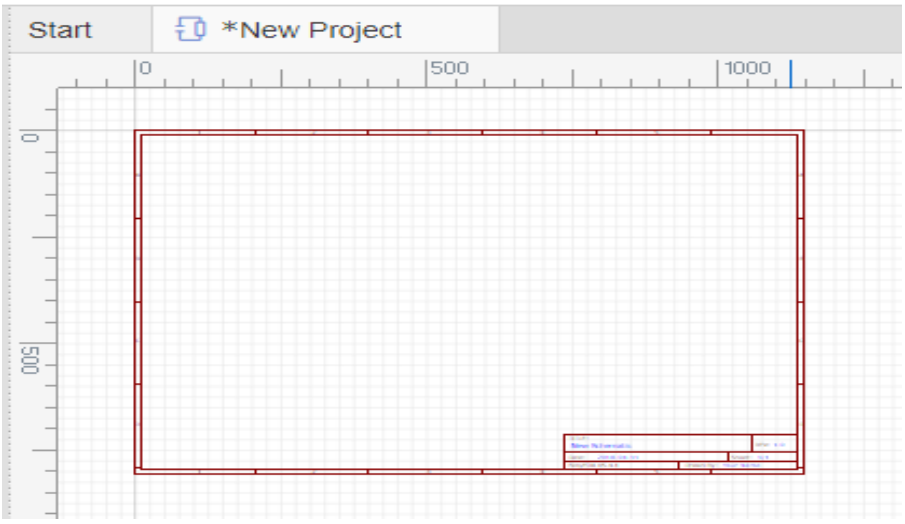


Figure 3.11: Easy EDA Software Interface

Subscription-free membership is offered to the public, plus a limited number of private projects. The number of private projects can be increased by contributing high-quality public projects, schematic symbols, and PCB footprints, and/or by paying a monthly subscription. Registered users can download Gerber files from the tool free of charge, but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third-party tools.Subscription-free membership is offered for public plus a limited number of private projects. The number of private projects can be increased by contributing high quality public projects, schematic symbols, and PCB footprints and/or by paying a monthly subscription.Registered users can download Gerber

files from the tool free of charge; but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third party tools.

CHAPTER 4
METHODOLOGY

4.1 Our methodologies for the Project

Our methodologies for the Project

- Creating an idea for designing and constructing a cost-effective **Energy Consumption Solar Water Heater**. And developing a block diagram & structural diagram to know which components we need to build.**Cost Effective Low Energy Consumption Solar Water Heater**. And designing a block diagram & structural diagram to know which components we need to construct it.
- Collecting all the components of our system.
- Setting up all the components in a PCB board & then soldering. Lastly, assembling all the blocks in a board and running the system & for checking purposes.

4.2 Working Step Chart

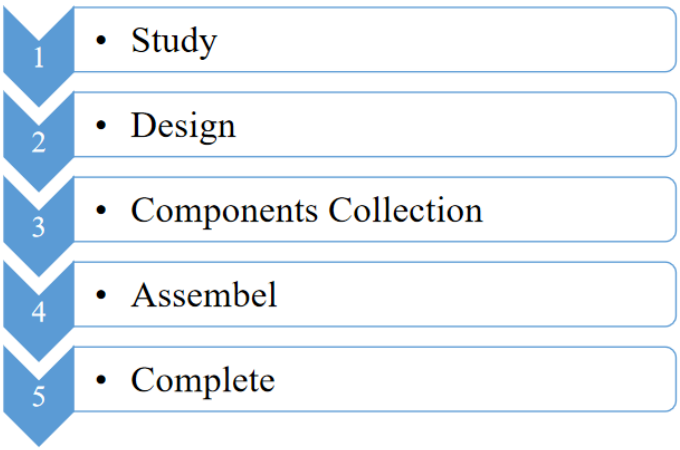


Figure 4.1: Working Step Chart

4.3 Block Diagram

The whole project works by taking power from the supply voltage and feeding it to a power supply, or an SMPS module. The SMPS converts the 220V AC to a pure DC of 5V 5Amp. We will use this 5V DC output from the SMPS to run our controller, motor, and other units.

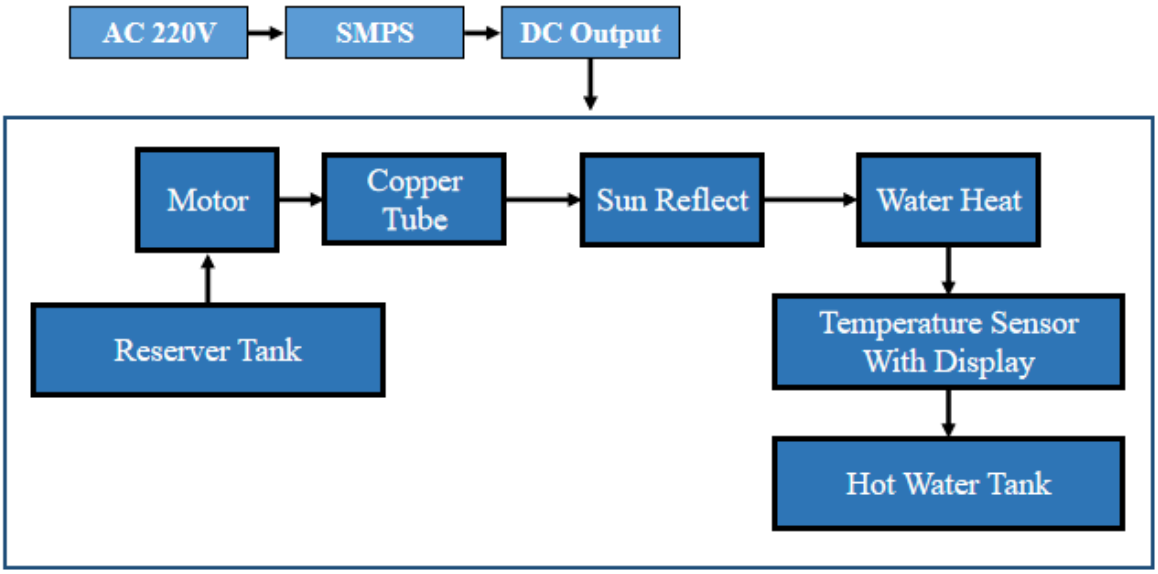


Figure 4.2: Block Diagram of Our System

4.4 Structural Design

The schematic diagram here represents the electrical circuit and the components of the Project. Here we have used standardized symbols and lines.

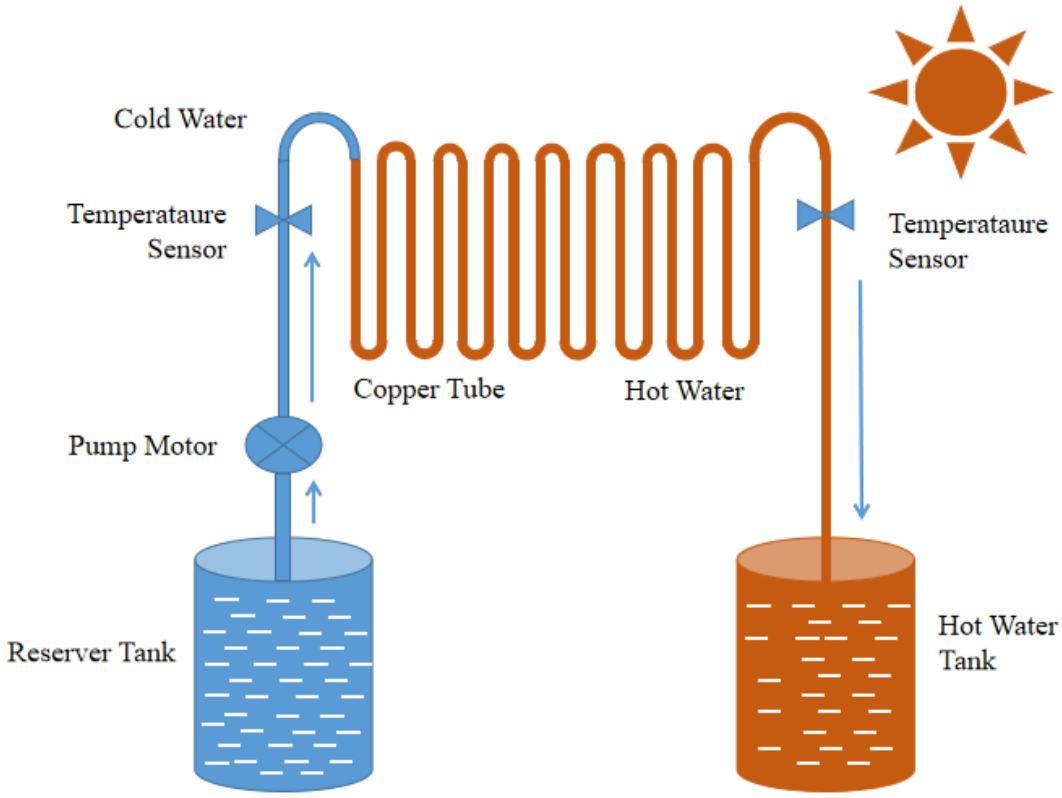


Figure 4.3: Structural Diagram of our Project

4.5 Circuit Design

In this part, we show our project circuit design and connect our instrument through standard wire.

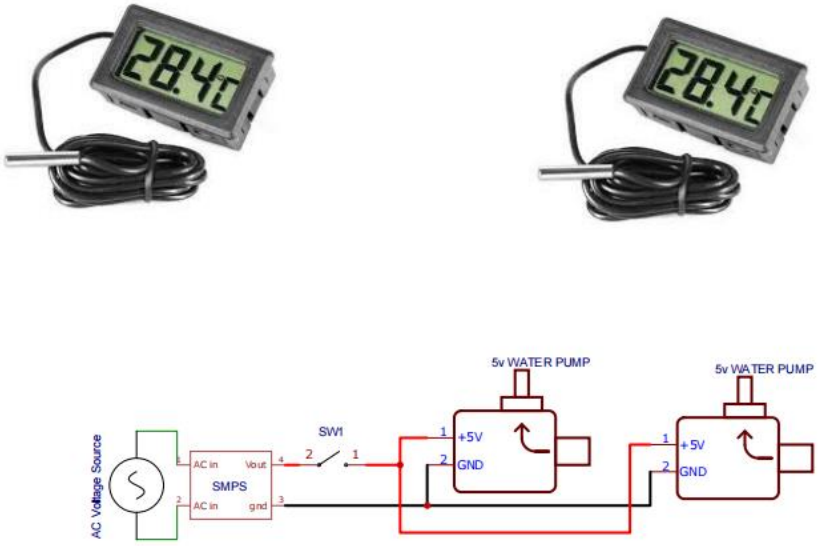


Figure 4.4: Circuit Design of our Project

4.6 Working Principle

Our main power supply for this system is AC 220 volts. This power is connected to the SMPS. The primary function of SMPS is to convert AC to DC. We need DC power since all our instruments in this Project are DC. This SMPS will supply a fixed 5V DC, 5Amp in this system. Here we use a pump motor, copper tube, reserve tank, hot water tank, etc.

The Cost-Effective Energy Consumption Solar Water Heater operates by harnessing solar energy to heat water efficiently. Water from the reserve tank is pumped into the system using a motorized pump. As the water enters, its temperature is monitored using a temperature sensor, which displays real-time readings. The water then flows through copper tubes exposed to sunlight, where it is heated due to copper's excellent thermal conductivity. The heated water is transferred to an insulated storage tank for future use, maintaining its warmth. This system is energy-efficient, environmentally friendly, and reduces dependency on traditional heating methods.

4.7 Our Final Project View



Figure 4.5: Our Final Project Overview

CHAPTER 5
RESULT ANALYSIS

5.1 Discussion

While working on our project, we faced some difficulties as it is a very complex system, but the results we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and taken necessary notes for future improvements. Future recommendations include improving system design and wiring, and adding features for more efficient operation.

The Cost-Effective Low Energy Consumption Solar Water Heater demonstrates an efficient method for harnessing solar energy to heat water sustainably. Using a submersible pump, copper tube, and temperature monitoring system, the Project effectively circulates water, absorbs solar heat, and stores heated water for future use. Using locally available materials reduces construction costs, making it affordable and accessible. Real-time temperature monitoring ensures effective heat transfer, while the insulated storage tank maintains water temperature. This system lowers electricity consumption and minimizes environmental impact by reducing carbon emissions and promoting renewable energy solutions in everyday applications.

5.2 Result

Temperature Data:

Cold Water: T cold = 31.5 c

Hot Water: T hot = 52.6 c

ΔT (Temperature Difference)

ΔT = T hot – T cold = 52.6 – 31.5 = 21.1 c

To calculate the **heat transfer rate** (i.e., **power in watts** required to heat water), we use:

$Q^{\cdot} = m^{\cdot} c \cdot \Delta T$

Where:

- $Q^{\cdot}$ = heat transfer rate (W)

- $\dot{m}$ = mass flow rate (kg/s)
- c = specific heat of water = **4184 J/kg°C**
- ΔT = temperature change = **21.1°C**

Step 1: Convert Flow Rate to kg/s

Flow rate = 2 liters/min

$\dot{m}$=2 L/min 60/2 = 0.0333kg/s

Step 2: Apply Formula

$\dot{Q}$=0.0333·4184·21.1=2946.6 W≈2.95 kW

☑ **Final Answer:**

Heat transfer rate ≈ 2.95 kilowatts (kW)

After finally completing this Project, we ran it & we observed the output of this Project. We can see that it is working well as expected. After making our project, we observe it very carefully. It works as we desire. Our project gives perfect output, and all equipment works perfectly. We checked how much it worked and got an ideal production from this project.

- Finally, we have completed our Project successfully & checked our Project. It's running accurately according to our objective.
- At first, we start our system.
- The following are the outputs of our Project.
- Efficiently heats water using solar energy with minimal power consumption.
- The submersible pump ensures smooth water flow from the reserve tank.
- Copper tube effectively transfers solar heat to the water.
- Heated water is stored safely in the insulated hot water tank.
- Real-time temperature monitoring enhances user awareness.
- Reliable performance with low maintenance requirements.

5.3 Advantage

There are undoubtedly many advantages of our Project, and some of the major ones have been given below -

- Solar water heating is a free process.
- Water heating with solar is healthy
- Solar cookers make no noise.
- A solar water heating system is portable.
- Power cuts are not an issue
- Cost-effectiveness
- Reduce energy waste
- No Oil consumption.
- Simple construction
- Ease of operation.

5.4 Limitation

It is a demo project, so we found some limitations. In the Future, we will work to reduce this kind of limitation. These limitations are -

- This Project can now be used only for small-scale purposes
- No energy backup.
- Efficiency is reduced during cloudy or rainy days.
- It takes longer to heat water than electric heaters.

5.5 Application

Some of the application areas of the Project have been pointed out below:

- It can be used for Water heating
- Heating water for commercial purposes.
- Water Purification
- Hotels and Resorts Hot Water Systems
- Off-grid Water Heating Solutions

CHAPTER 6
CONCLUSION

6.1 Conclusion

The Cost-Effective Energy Consumption Solar Water Heater is a sustainable and eco-friendly solution that utilizes solar energy to heat water. Integrating components such as a submersible pump, copper tubes, temperature sensors, and an insulated hot water storage tank ensures efficient water heating with minimal electricity consumption. Solar radiation is absorbed by the copper tubes, which are excellent conductors of heat, allowing water to reach the desired temperature as it flows through the system. The heated water is then stored in a well-insulated tank, ensuring its availability for extended periods without significant heat loss.

One of the primary advantages of this system is its low operational cost, as it relies predominantly on solar energy, reducing electricity bills and dependency on fossil fuels. Furthermore, its environmentally friendly design helps decrease carbon emissions, promoting sustainable energy use. The system's design also incorporates locally available materials, making it cost-effective and accessible for various communities, especially in remote or off-grid areas.

While there are some limitations, such as dependency on sunlight and space requirements for installation, the benefits far outweigh these challenges. Overall, this solar water heater is a reliable, cost-effective, and sustainable solution that supports clean energy initiatives and reduces environmental impact.

6.2 Future Scope

We are thinking about adding many features to our project in the Future to achieve more desirable outcomes. Some of the steps that we are thinking about taking are given below:

- In future development, this project can be developed by a Microcontroller Unit.
- In the Future, I will try to apply it in the real field.
- In the Future, we will add an extra power system.
- In the Future, develop an IoT system controlled by our Project

REFERENCE

[1] Abdunnabi, M., Rohuma, I., Endya, E., & Belal, E. (2018). Review on solar water heating in Libya.

[2] Adefarati, T., & Bansal, R. C. (2019). Energizing Renewable Energy Systems and Distribution Generation. In Pathways to a Smarter Power System (pp. 29–65). Elsevier.

[3] Alternative Energy Tutorials. (2015). Solar Flat Plate Collectors for Solar Hot Water.

[4] API Energy. (n.d.). Active Vented System. Retrieved September 29, 2020

[5] Atia, D. M., Fahmy, F. H., Ahmed, N. M., & Dorrah, H. T. (2012). Optimal sizing of a solar water heating system based on a genetic algorithm for an aquaculture system. Mathematical and Computer Modelling, 55(3–4), 1436–1449.

[6] Azom. (2005). Aluminium - Specifications, Properties, Classifications and Classes.

[7] Barry, C. (2018). thermal properties of glass fiber thread. B&W FIBERGLASS NEWS, 1.

[8] Dean, J. (n.d.). Domestic Hot Water Assessment Guidelines (Fact Sheet), Saving Energy In Commercial Buildings, NREL (National Renewable Energy Laboratory). Retrieved May 19, 2020,

[9] Eagle Stainless. (n.d.). Characteristics of Stainless Steel. Retrieved September 27, 2020

[10] Ekpo, J., & Enyinna, P. (2017). Design and Construction of a Solar Water Heater for Environmental Sustainability. British Journal of Applied Science & Technology, 20(3), 1–15.