



(RESEARCH ARTICLE)



## Comparative analysis of solar heaters and heat exchangers in residential water heating

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### Abstract

This research shows the comparative analysis between the solar heater and the heat exchanger efficiency. This is used for water heating in this project to show the use of this for residential purposes. The efficiency of these two is calculated in this project which helps to know the efficiency of each model in the water heating purpose. In this research process, a suitable set of comparisons has been drawn between the heat exchanger and water heater that have been worked on based on the effective solar energy. Effective energy usage provides a suitable beneficial impact in Favor of using this residential water heating system of heat exchangers. Detailed information has been represented in the background sections along with rationale aspects where the issues along with their remedies have been depicted.

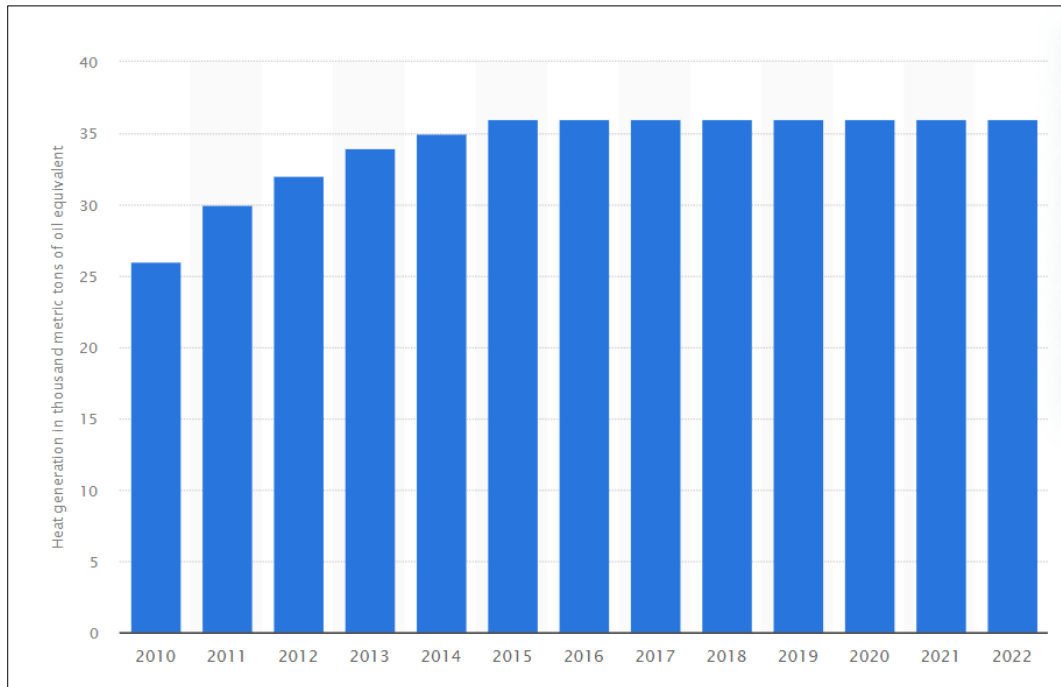
**Keywords:** Heat exchangers; Solar heater; Residential water heating systems; Solar Panel Angle; Temperature.

### 1. Introduction

In this present era, the rapid transformation towards suitable energy sources has been increasing rapidly which creates a huge demand for using solar-based components in the daily lifestyles of underlying human beings. Thus, the deployment of solar heaters and heat exchangers comes into real-life contexts that serve all the requirements of the people, especially for residential purposes. The effectiveness of using solar heaters supports the aspect of almost "60%" less energy used to heat the water as compared to the other energy sources. The same also used less "35%" of the energy in space heating whereas heat exchangers also serve the purpose of regulating the fluid temperature in the overall processing systems.

Based on analysing the overall graph, it has been observed that the usage of solar components in its present era has been used rapidly for almost "36000 metric tonnes" in 2022 [1]. The usage has been drastically enhanced by almost "40%" as compared to the usage in 2010. In the residential processes, the usage of heat exchangers lies in reducing the microbial to develop products safe for further aspects of consumption to prevent spoilage [2].

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**Figure 1** Analyzing the energy extracted from active solar heating in the UK until 2022

### 1.1. Problem Statement

Enhanced cases of CO<sub>2</sub> emissions require to be resolved in such a manner so that an endless amount of energy has been saved throughout the research contexts based on adopting solar heaters and heat exchangers [13]. Analyzing the overall residential cases, it has been observed that in many residential buildings, the modern processes of heating have been done by introducing solar heaters along with heat exchangers that replicate the economic opportunity in the overall research cases. Heating the water for domestic purposes of heating using solar energy is considered to be a neutral and simple method of saving energy as compared to others. The same has opposed the excessive usage of fossil fuels based on maintaining their reserves.

#### *Aim and Objectives*

The main aim of the overall research process lies in introducing the effective usage of heat exchangers and solar heaters so that the residential water processes have been economical based on using renewable energy sources as compared to the traditional process.

This research process includes some research objectives, that includes

- To identify the issues faced in the traditional after-heating systems that have been eliminated based on using solar heaters and heat exchangers
- To analyse effective comparison between solar heaters and heat exchangers along with their usage, especially in the residential areas
- To evaluate the energy efficiency process of solar heaters and heat exchangers in the water heating processes
- To recommend the enhanced usages of sustainability that have been introduced based on suitable sources of energy of solar-based water heating systems

### 1.2. Research Questions

- What are the issues identified in the traditional heating process that requires to be eliminated based on introducing the usage of solar heaters and heat exchangers?
- What is the suitable comparison that has been drawn between heat exchangers and solar heaters?
- How to evaluate the energy efficiency of residential heating systems based on solar water heaters?
- What are the mitigation strategies adopted to reduce the implications of the traditional water heaters by solar-based water heating systems of solar heaters and heat exchangers?

### 1.3. Rationale

The main issue is the excessive usage of fossil fuels creates issues in the excessive emission of CO<sub>2</sub> in the surrounding atmosphere which also causes significant challenges for the people living in the surrounding arena [14]. Thus, effective applications of solar heaters and heat exchangers have been used so that it helps in saving energy from an economic point of view.

This is the main issue as of now, as the reserve of fossil fuel has been decreasing day by day based on excessive usage of the same for residential purposes.

The research process sheds light on accomplishing the usage of a renewable set of energy sources so that the effective matter of sustainability has been preserved throughout the environment [15]. The issue faced in improving energy efficiency has been resolved based on the effective usage of solar heaters in residential buildings.

### 1.4. Summary

Based on analysing the overall aspects, it can be stated that detailed information regarding the solar heat exchangers and heaters has been portrayed in this process. Issues faced by traditional water heating systems have also been discussed along with the benefits of introducing solar-based water heating systems.

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## 2. Literature Review

### 2.1. Introduction

The project has been providing data about the solar heater and the heat exchanger process and also describing the analysis process. According to the data, this has been a process that has been implemented with the solar water heating system. Hence it has been also used for the heat exchanging process and helps to transfer the solar energy absorbed in solar collectors to potable water. Based on this researcher has been provided with various objectives which have been related to the study and their analysis process. Hence their researcher has been providing the various data which has been essential for the project and also describing those data.

### 2.2. Working principle of the solar heater and heat exchanger

#### 2.2.1. Solar heater

The solar heater is known as the "solar thermal system" which collects the sun's radiation and converts that into heat. This device is used for heating tasks and has no impact on the environment. The collector of the solar heater is used to collect the sun's radiation which is then converted into heat. This heat is then transferred to the water tank by the circulating pump. The thermal regulator of the solar heater gets triggered when the collector is hotter than the tank water. This exchange is triggered by the thermal regulator, density variance, due to the "low density" the "hot water" moves from the solar heater to the tank, and due to the high density the cold water moves downward from the tank to the solar heater.



**Figure 2** Solar heater model

The above image shows the solar heater model, the collector, and the tank is present in the above image. The collector collects the sun's radiation and the tank stores the water. Due to the variance in density, the cold water with high density moves downward from the tank to the collector and the hot water goes upward from the collector to the tank.

There were various studies from [56-59] Patel Anand et al. [60] HD Chaudhary et al. [61-73] Anand Patel et. al performing thermal performance by varying geometries of solar collector or by doing comparative analysis of parameters to enhance heat transfer efficiency and renewability in a solar heater.

### 2.2.2. Heat exchanger

The “heat exchanger” is used to transfer heat from one medium to another medium. This heat exchanger converts the heat of the “solar-heated water” to the water that is being used for residential purposes. The “hot fluid” and the “cold fluid”, two distinct fluid streams, move through separate channels within the heat exchanger. The terms “hot and cold” are merely used to describe how differences in the temperatures of the two fluids. A temperature difference between the fluids should fuel the heat transmission. Naturally, heat transfers from the hotter to the colder fluid. The two fluids go through tubes or channels that are divided by a conducting substance, usually made of metal, that acts as the heat transfer surface [2]. The effective transfer of heat between the fluids is ensured by this conducting substance. Due to its increased temperature, the hot fluid releases thermal energy as it moves along its channel or tube.



**Figure 3** Heat exchanger

The cold fluid on the other side absorbs this energy when it passes through the separating material. The “hot fluid” delivers off heat to the “cold fluid”, while the “cold fluid” delivers off “heat to the hot fluid”. The exchange continues until the temperature difference between the two fluids becomes insignificant, or until equilibrium is reached. Fluids can flow in parallel or counterflow in heat exchanger designs [3]. While both “fluids flow” in the identical path during “parallel flow”, they flow in different paths during “counterflow”. Since they maintain a greater temperature difference between the fluids during the heat exchange process, counterflow designs are frequently more effective. The design, the materials employed, and the flow rates of the fluids all have an impact on a heat exchanger’s efficiency.

### 2.3. Use of solar heater and heat exchanger in water heating

Capturing solar heat, this solar heater and heat exchanger system circulates a heat-transfer fluid through the collectors. The accumulated heat is then transferred to the water that needs to be heated via the heat exchanger after the heated fluid has been pushed there to an appropriate heat exchanger. A “plate heat exchanger” is a typical design for heating water. This consists of numerous plates with tiny channels for the fluid to travel through. The heat exchanger is situated such that heating the water you want to heat will be accomplished effectively. Both the water supply system and the circulation system for solar collectors are connected to the “heat exchanger” [4]. On one flank of the “heat exchanger”, the “heat-transfer fluid” from the “solar collectors” enters, heating the water on the opposite side. The two fluids are kept apart by the heat exchanger while yet enabling heat to move between them. Track the temperature of the heated water and a temperature sensor is placed on the heat exchanger’s exit. The solar controller is placed to control the water circulation and to move the fluid from one area to another area. This is used to heat the water and to use that for various tasks. The use of this technology helps to heat water and to use that for residential purposes [5].

### 2.4. Cost Efficiency of the Solar Heater and Heat Exchangers

The cost efficiency of the “Solar heater and heater exchangers” depends on various factors and it has also been included with the installation cost, operational cost, and energy savings process [23].

#### 2.4.1. Initial installation cost

The cost efficiency of solar heat and heater exchangers can be affected by the initial investment required for installation. This has been included in the cost of purchasing and install process of the solar panels. Mainly installation process of the solar heater and the heat exchangers cost is higher than the traditional heating system [24].

#### 2.4.2. Operational cost:

“Solar heaters and heater exchangers” have lower operational costs compared to conventional heating processes. Once the installation process has been completed this uses the sunlight and generates the heat, this is free and also a sustainable energy [25].



**Figure 4** Solar Heater and Heat Exchangers

#### 2.4.3. Energy savings:

“Solar heat and heater exchangers” provide essential energy savings over time, this energy-saving process has been dependent on multiple factors like system size, systems work efficiency of the element, and their different types of climate conditions [26].

#### 2.4.4. Return on investment (ROI):

The process of the “solar heaters and heater exchangers” can be evaluated based on the return on investment. The ROI considers the initial installation cost and the energy savings over the lifespan of the system [27]. The payback period for solar heat and heater exchangers can range from multiple years to decades, depending on the specific system and energy consumption. Once the system has paid for itself through energy savings, the ongoing savings can contribute to long-term cost efficiency.

### 2.5. Linkage to Objectives

This project has been containing the aim of the effectiveness of the usage of heat exchangers and solar heaters. According to the data, researchers has been identify the various issues in the traditional after-heating process that are eliminated using solar heaters and heat exchangers. Analyze and differentiate the effectiveness of solar heaters and heat exchangers with their usage, specially provided in residential areas. It also helps to create the energy efficiency process of the solar heaters and heat exchangers in the process of water heating. It also recommended the improved usage of sustainability those are introduced researchers to the various suitable sources of energy and also indued with the solar-based water heating system. Here researcher has been providing various essential data via their research process, those data help to provide various information regarding the solar heater and heater exchanger.

### 2.6. Literature gap

During the research, the researcher has been encountering various issues which have been creating cause a lack f time, lack of proper data, and team members not doing their work efficiently. During the analysis process, the researcher found errors in their model, which has been the reason for the literature gap.

## 2.7. Summary

The efficacy of using heat exchangers and sun heaters has been the focus of this project. The statistics show that researchers have identified several problems with the conventional after-heating procedure that can be resolved by using solar heaters and heat exchangers. Examine and distinguish between the efficiency of solar heaters and heat exchangers used, particularly in residential settings. Additionally, it contributes to the development of solar heaters and heat exchangers that are energy efficient. Additionally, it encouraged researchers to use sustainability more effectively by introducing them to a variety of viable energy sources and introducing them to solar-powered water heating systems.

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## 3. Material and methods

### 3.1. Research Philosophy

Effective selection of the research philosophy requires to be done in such a manner so that the objectives of the research have been fulfilled throughout the research contexts. Among several research philosophies, "**positivism research philosophy**" has been taken in this research process so that an effective comparison between the two aspects of solar heaters and heat exchangers has been done effectively [21]. The identified philosophy enhances the knowledge of the overall research processes so that the renewable set of sources has been used throughout the research.

### 3.2. Research Design

Research design has been regarded as one of the processes that entail a systematic set of ways based on maintaining effective protocol and framework. This research process has used "**explanatory research design**" where the effectiveness of sustainability has been achieved regarding the usage of solar-based water heating systems [22]. This research design provides a suitable relationship along with the cause-and-effect aspects so that high-end performance has been ensured in this regard. Effective energy efficiency also has been achieved based on the solar-based water heating systems that have been regarded as a suitable set of sources in the renewable energy process.

### 3.3. Research Approach

The research approach provides extensive support to achieve the aim of the research processes so that the quality of the research has been enhanced. Between the two research approaches, the "**inductive research approach**" has been taken in these processes as this approach supports new ideas by using solar heaters and heat exchangers as compared to the traditional electric heater-based process. This approach helps in extracting new information that creates suitable benefits for the associated human beings.

### 3.4. Research Strategy

The researcher has used here "**Action-Oriented**" research strategy, this is a collaborative research process for the participants and the community. This research strategy has been focused on developing actionable solutions to real-world problems. It is involved with the stakeholders and their research findings also provide the findings to inform and guide regarding making decisions. This research strategy has been containing the various key elements for this particular strategy [28]. Those are- "**Collaboration**", "**Problem-solving orientation**", "**Participatory approach**", "**Action and change**", "**Reflexivity**". The action-oriented search strategy is a dynamic and iterative process. This process has been creating the aim that to generate the knowledge and solutions, that are applied to solving real-world problems. Here researcher has been using the "Solidworks" software for developing the model and the analysis process. Hence research uses various analysis methods for the model analysis and development process.

### 3.5. Data Collection

The practice of acquiring data from sources that have already been used and gathered by others is referred to as tertiary data collection. In research and analysis, this kind of data collection is frequently used to supplement primary and secondary data sources [29]. The following steps are often involved in gathering tertiary data:

- **Identify the study objective:** Establish the precise data or insights required and specify the research topic or inquiry.
- **Establish the data requirements:** List the precise variables or data pieces required to meet the research purpose [30].
- **Look for sources that already exist:** Conduct a thorough search to find sites that are pertinent and already have the information you're looking for. These sources can consist of academic journals, government papers, business databases, published research projects, and others [31].



**Figure 5** Tertiary data collection method

- **Determine the credibility, dependability, and relevance of the sources:** verify that the sources have been chosen to fit the data and offer accurate and reliable information by evaluating their quality and relevance.
- **Choose the best sources:** Consider the reliability, usefulness, and accessibility of chosen sources before selection [32].
- **Extract the data:** Take specific variables or data components from the sources you've chosen. This could entail downloading data files from online databases, manually extracting data from reports or papers, or utilizing data scraping technologies to gather data from websites [33].

### 3.6. Data analysis

The data analysis process is meticulously inspecting, cleaning, altering, and evaluating data to discover pertinent insights, patterns, and trends [34]. A well-structured data analysis process, whether in the context of business, research, or investigations, aids in making informed judgments. The following is a general description of the data analysis process:

#### 3.6.1. Define the objectives and questions

Clearly define the objectives of your data analysis. What do you want to achieve or learn? Make specific inquiries that you want the information to assist you in resolving [35].

#### 3.6.2. Data Collection

Obtain important data from many sources while ensuring its accuracy and integrity. This can be accomplished via databases, spreadsheets, APIs, sensors, surveys, and other appropriate technologies [36].

#### 3.6.3. Data preprocessing and cleaning

Remove errors, duplicate records, inconsistent data, and superfluous information from the data by cleaning it. As soon as you can, deal with missing values and outliers [37].

#### 3.6.4. Data Exploration

Visualize and explore the data to get a rudimentary understanding of its make-up, distribution, and patterns. This helps in creating hypotheses and finding possible insights [38].

#### 3.6.5. Feature Engineering

Feature engineering is the process of creating new features from already existing data to increase relevance and predictability. It might be essential to do this by scaling, merging, or aggregating the variables [39].

### 3.6.6. Data transformation

Normalize or standardize the data to ensure that variables are on a consistent scale. This is especially important for machine learning algorithms that rely on numerical inputs [40].

### 3.6.7. Statistical Analysis

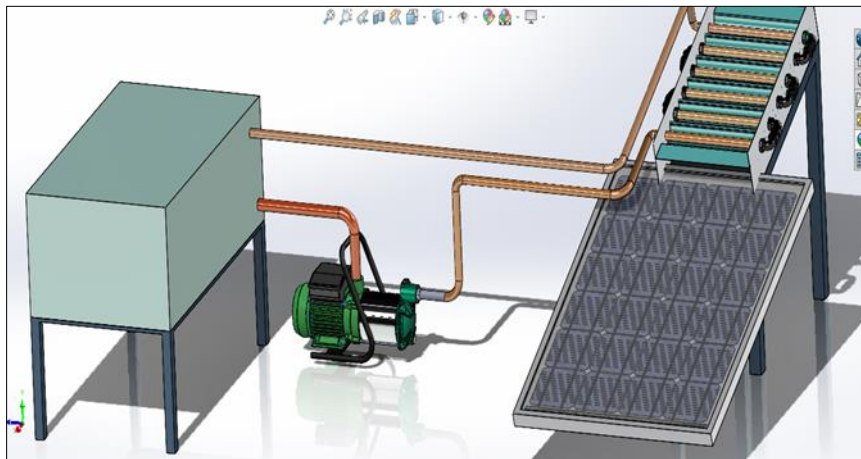
It has been discovering correlations, trends, and relationships between variables, employing exploratory data analysis. In this, it is possible to utilize measures of central tendency, dispersion, and hypothesis testing [42].

## 3.7. Feasibility

An approach for assessing a research study's viability and practicality is called research feasibility. It entails assessing many elements that could influence the execution of a research project successfully. The following are some typical steps in the research feasibility method:

- **Define the research objectives:** Clearly define the research objectives. The proposed research study's goals and objectives should be stated in this manner. This aids in identifying the precise elements that require feasibility evaluation [41].
- **Evaluate the research question:** Assess the research topic to make sure it is pertinent, significant, and able to be addressed by the planned study. Think about the study question's potential impact and how it fits into the corpus of existing knowledge.
- **Assess the research design:** Evaluate the suggested research design, taking into account the methodology, research approach, and data-gathering techniques. Take into account the design's suitability for answering the research issue and the accessibility of the resources needed for its implementation.
- **Analyze the resources:** Consider whether the time, money, people, and equipment required to carry out the research study are all readily available. Determine whether there are enough resources available and whether they can be used wisely to accomplish the project.
- **Take ethical considerations into account:** Evaluate the research study's ethical implications, taking into account both any potential dangers and participant benefits. Determine if the study can be carried out ethically and whether the required ethical permissions can be obtained [43].

## 4. Results

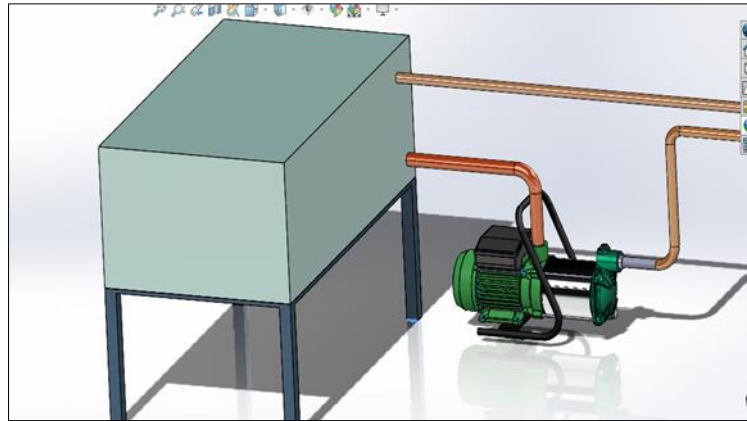


**Figure 6** Final view of the model

The “final view of the solar heater” and the “heat exchanger model” is represented in this stage. This uses sunlight to increase the temperature of the water and the analysis is performed on the model that shows the efficiency of the model.

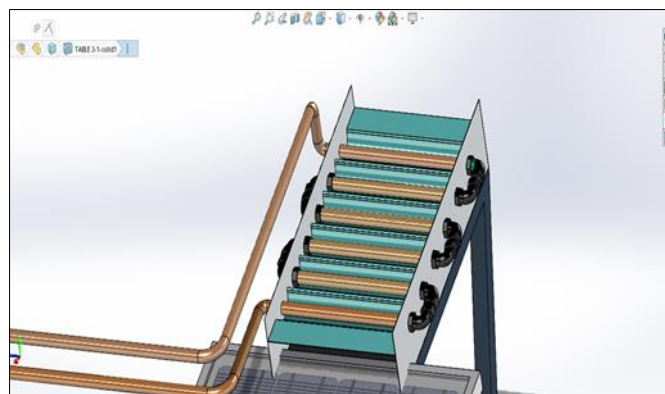
The efficiency of this model depends on the efficiency of the solar panel or the collector to collect the sunlight. The efficiency of the model can be increased by changing the angle of the panel with time [6]. The panel angle is important to collect the rays of the sun these rays are used to heat the water.





**Figure 7** Water tank

The above image shows the tank generated in this project which is used to store the water. The cold water is passed to the solar heater and the heat exchanger and then the water is heated up and comes back to the tank. The tank works as the storage of water. When the water in the tank is cold the density of the water is high, and the water in the collector and heat exchanger is hot with low density. Due to this, the water flows in the system and the tank's cold water gets hotter.



**Figure 8** Heat Exchanger

The heat exchanger model is used to convert the temperature from one element to another element. The flow of water is done in the model and the water becomes hot during the flow through the heat exchanger. The cold water comes to the heat exchanger and then the water is heated up and moved back to the tank. The efficiency of the heat exchanger depends on the loss while working. This loss arises during the flow of water from the tank to the heat exchanger [7].

## 5. Discussion

The efficiency of the "solar heater" and the "heat exchanger" is analyzed in this project which shows the efficient way of heating water. The "solar heater" collects the ray of the sun and then converts that into heat. In order to function and transmit heat, heat exchangers often need an external energy source, such as gas or electricity. Costs for continuous operations may result from this. A heat exchanger's efficiency might alter depending on its size, design, and energy source. Even though modern designs can be highly energy-efficient, some energy will inevitably be lost throughout the heat transfer process [8]. Heat exchangers are dependable all year round since they can consistently deliver hot water regardless of the weather. Due to the necessity for machinery like a boiler, installing a heat exchanger could require extra room, and good ventilation is crucial. Compared to a "solar water heater", installation expenses may be higher. A heat exchanger's effect on the environment is influenced by the energy source it uses [9].

Solar water heaters are more environmentally friendly and have lower recurring energy expenses because sunlight is their main energy source. In sunny climates, solar water heaters can be quite effective since they use solar energy directly. On days that are overcast or wet, their effectiveness could, however, decline. In times of limited sunlight, solar

water heaters may offer slightly erratic hot water. This problem can be solved by integrating backup systems. Solar panels or collectors must be installed on roofs or other open spaces with good sunshine exposure to use solar water heaters. Despite possible greater initial installation costs, there may be long-term energy savings. Solar water heaters are environmentally benign since they use a renewable energy source and emit less greenhouse gases [10]. "Solar heaters and heat exchangers" for increasing heat may both efficiently heat water for domestic use. The decision is based on variables like a preferred energy source, initial outlay, space availability, and considerations for the environment. A solar water heater is more environmentally friendly and can eventually result in cost savings, especially in sunny areas, as opposed to a heat exchanger, which provides steady hot water but may include ongoing energy bills. The importance of introducing the usage of solar heaters has been depicted in this process as it saves excessive energy usage as compared to traditional water heaters [19]. Solar water heaters provide the required hot water for bathing, cleaning and washing based on the requirements of the domestic set of usage [20].

### *Future Work*

Evaluating the benefits of solar-based water heating systems entails sustainability based on analysing the nanofluids that provide suitable benefits to the overall thermal energy systems [6]. It is also required to implement the nanofluids in thermal applications so that positive cases of suitability have been encountered in the heating process. Analysing the wide usage of solar-based water heating systems all across the country, it accumulates almost "USD 5.57 billion" in 2022 which is also expected to be increased to almost "9.56 billion USD" in 2032 [16]. Enhancing the matter of suitability will be done based on implementing the stable set of nanofluids with the optimum concentrations that provide a positive set of results in the overall assessments. The same also helps in enhancing the economic feasibility in such a manner that effective applications have been achieved in this regard.

Hot water supply has been regarded as a greater set of relevance to countering the effects of climate change based on the integration with solar collectors in the residential hot water systems so extensive enhancement of efficiency has been witnessed in this regard [17]. Mismatches cases of issues have been witnessed by the proponent of water consumption along with the energy supply so that effective beneficial impacts have been extracted in this regard. It is also important to focus on storing the latent heat based on accomplishing the phase change materials so that effective domestic usage has been witnessed in this regard [18]. Moreover, it is also important to add some additional impairments based on introducing the hybrid set of photovoltaic and thermal solar panels so that the encountered issues will be resolved shortly.

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## **6. Conclusion**

Based on analysing the overall research it can be stated that a suitable set of comparative analyses has been done in this specific research process so that suitable decision-making statements have been drawn out of it. Introducing heat exchanger systems in the water heating processes, especially in residential areas portrays that the transfer of energy has been done based on the absorption of the solar collectors to the potable water.. The same also reduces the consumption of fossil fuels in such amounts so that a suitable set of reserves also has been initiated throughout the research process.

It is important to focus on suitable integration of the thermal systems with the existing processes so that the deployed modern systems work efficiently as compared to the others.. On the other hand, the usage of the heat exchanger lies in regulating the temperature of the associated fluid to fulfil the requirements of the pasteurization and filling operations. The same also helps in reducing the amount of microbial to make the product safe throughout the research process.

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