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Experimental Investigations of solar chimney performance

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PREFACE

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Guiding Example

Experimental Investigations of solar chimney performance

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DEDICATION

We would want to express our gratitude to the Almighty God for his guidance in writing this book. Strength, mental power, protection, and abilities, as well as providing us with a healthy life. This research is dedicated to our loving parents, who have always been a source of inspiration and strength when we felt like giving up, and who continue to provide moral, financial, spiritual, emotional, and other forms of support. To our siblings and sisters, relatives, mentors, friends, and classmates who encouraged us to finish this study through their words of advice and encouragement. Finally, we provide a you for all of these.

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ABSTRACT

The aim of this study is to assess the feasibility and performance of a solar chimney power plant in generating electricity from solar energy. Through analysis of collected data including temperature variations, power output, and airflow rate, the project evaluates the system's efficiency and potential. The results indicate that the solar chimney power plant efficiently harnesses solar energy for electricity generation. Temperature sensors provide valuable insights into temperature changes, allowing for optimization of the plant's efficiency. DC current and voltage sensors accurately measure turbine power output, enabling precise monitoring and control. The study finds that turbine power output correlates directly with temperature differences between the collector and chimney. Higher temperature differentials lead to increased power generation. Airflow sensor data contributes to evaluating system efficiency and performance, identifying any airflow restrictions or inefficiencies. Based on these findings, it can be concluded that the solar chimney power plant, with its specified dimensions and sensor setup, shows promising potential for sustainable energy production. This project highlights a dependable and environmentally friendly alternative for generating electricity in the field of renewable energy. The insights gained from this study provide a basis for future research and development in solar chimney power plants, aiming to further enhance their efficiency and power output. This project contributes to advancing cleaner and more sustainable energy solutions, supporting the shift towards a greener future.

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LIST OF ACRONYMS/ABBREVIATIONS

Rc	Collector radius
$\hbar ci$	Collector inlet height
$\hbar co$	Collector outlet height
$\hbar c$	Collector height at distance r from inlet
xD	Turbine pressure drop ratio
ηt	Turbine efficiency
Δpt	Pressure drop available to the turbine
$Rc\hbar$	Chimney radius
$Hc\hbar$	Chimney height
Δpf	Pressure drop due to friction in the chimney
P	Power generated

Chapter one

1. INTRODUCTION

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1.1 INTRODUCTION

In recent years, the world has witnessed an increase in global demand for clean and sustainable energy sources. As traditional fossil fuel reserves continue to deplete and concerns about the environmental impact of greenhouse gas emissions rise, the exploration of alternative energy technologies has become paramount. One of the most efficient technologies is the solar energy

Solar energy, as a form of renewable energy, has gained significant attention and importance in recent years due to its immense potential to address the world's energy needs in a sustainable and environmentally friendly manner. Solar power is derived from the sun's radiant light and heat, which is harnessed through various technologies to generate electricity or provide heat for a wide range of applications as shown in figure 1-1.

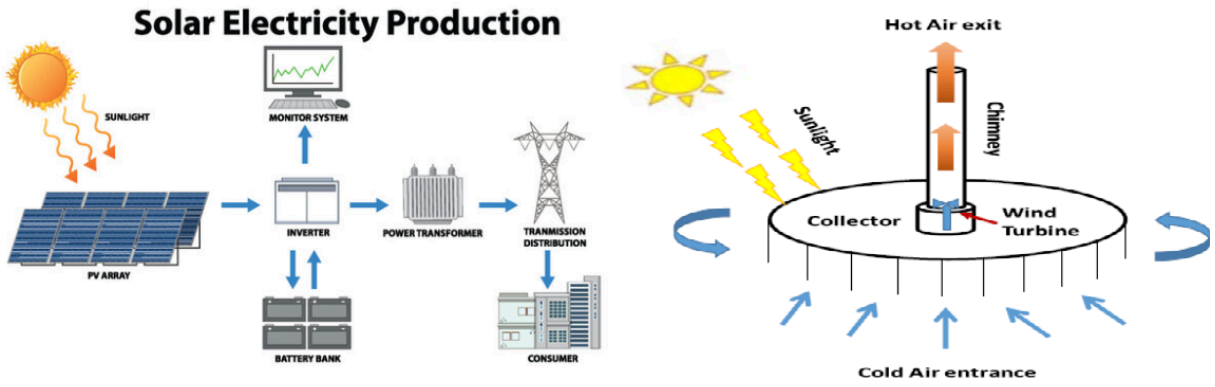


Figure 1-1: solar energy resources and technologies

Solar renewable energy is based on the fundamental principle of converting sunlight into usable energy. The sun, a virtually inexhaustible source of power, emits an enormous amount of energy

in the form of electromagnetic radiation. By capturing and harnessing this energy, solar technologies offer a clean and sustainable alternative to traditional fossil fuel-based energy sources, Solar energy offers numerous advantages that make it a compelling choice for renewable energy generation. Firstly, it is an abundant resource available across the globe, enabling wide-scale deployment in various geographical locations. Additionally, solar power is a clean energy source, producing no greenhouse gas emissions or air pollutants during operation. This helps combat climate change and reduce environmental pollution, contributing to a healthier and more sustainable, Photovoltaic (PV) systems are one of the most common methods used to convert solar energy into electricity. These systems utilize solar panels composed of semiconductor materials, such as silicon, which absorb photons from sunlight and release electrons, generating an electric current. The electricity produced can be used directly or stored in batteries for later use.

Among these technologies, solar chimneys have emerged as a promising solution for harnessing renewable energy through the principles of natural convection as any solar energy resource the solar chimneys produce no greenhouse gas emissions or air pollution. This makes them an environmentally friendly alternative to coal, oil, and natural gas power plants, which are major contributors to climate change and air pollution. Additionally, solar chimneys can be built in remote areas where access to electricity is limited, providing a reliable source of power to off-grid communities.

1.2 History

The idea of using solar chimneys to generate electricity was first proposed by Isidoro Cabanyes in 1903. Cabanyes, a Spanish engineer, suggested using a large glass roof to collect solar heat and a tall chimney to create a draft that would drive a turbine. However, this concept was not widely pursued at the time due to the availability of cheap fossil fuels and the lack of efficient materials and technologies for capturing and converting solar energy. In the 1970s, during the oil crisis, interest in renewable energy sources was renewed, and the concept of solar chimneys was revisited.

In 1975, Jörg Schlaich, a German structural engineer, proposed a design for a solar chimney that would use a greenhouse to collect solar heat and a tall chimney to create an updraft. Schlaich's design was based on the principle of the greenhouse effect, where sunlight passes through a transparent material and is absorbed by the ground, which then emits infrared radiation that is trapped by the greenhouse's walls. This process heats the air inside the greenhouse, creating a temperature difference between the air inside and outside the greenhouse, which drives an updraft in the chimney.

In the early 2000s, several pilot projects were built to test the feasibility of solar chimneys as a renewable energy source. One of the most notable projects was the Manzanares Solar Chimney in Spain as shown in figure 1-2 , which was completed in 1982. The Manzanares Solar Chimney was a 195-meter-tall tower with a 10,000-square-meter greenhouse at its base. The tower was used to generate electricity by driving a turbine with the updraft created by the temperature difference between the air inside and outside the greenhouse. The project was successful in demonstrating the feasibility of solar chimneys as a renewable energy source, but it was not economically viable due to the high cost of construction and maintenance.[1]



Figure 1-2: Solar chimney power plant in Manzanares.

In the 2010s, interest in solar chimneys was renewed with the development of new materials and technologies that made them more cost-effective. In 2016, a company called Hyper Solar announced plans to build a solar chimney in California that would be capable of generating 200 megawatts of electricity. The project was expected to cost $1.5 billion and would be the largest solar chimney in the world. However, as of 2022, the project has not been completed, and it is unclear if it will ever be built As shown in figure 1-3.

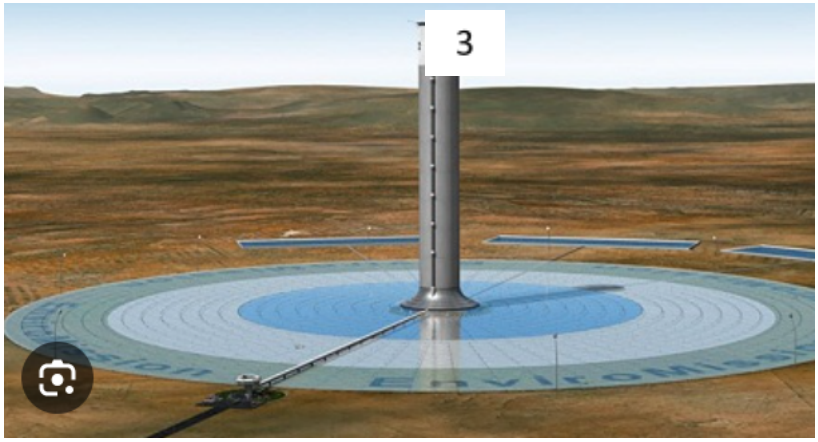


Figure 1-3: Solar chimney power plant in California

1.2.1 Current Status and Future Prospects

Solar chimneys have the potential to be a significant source of renewable energy, but there are still several technical and economic challenges that need to be addressed. One of the main challenges is the high cost of construction and maintenance, which makes solar chimneys less competitive with other renewable energy sources such as solar panels and wind turbines. Another challenge is the limited geographic range of solar chimneys, as they require a large amount of land and a specific climate to be effective. Despite these challenges, there is still interest in solar chimneys as a renewable energy source, and research and development efforts are ongoing to improve their efficiency and reduce their cost. One promising development is the use of new materials such as carbon nanotubes and graphene, which have the potential to make solar chimneys more cost-effective and efficient. Additionally, advances in computer modeling and

simulation are helping researchers better understand the complex fluid dynamics and heat transfer processes that occur in solar chimneys, which could lead to further improvements in their design and performance. In conclusion, solar chimneys have a long and storied history, dating back to the late 19th century. While they have the potential to be a significant source of renewable energy, there are still several technical and economic challenges that need to be addressed. However, with ongoing research and development efforts, solar chimneys could play an important role in the transition to a more sustainable energy future.

1.3 PROCESS

The concept behind a solar chimney is relatively simple. A tall vertical tower, usually several hundred meters in height, is constructed with a large transparent roof or greenhouse-like structure at its base. This roof allows sunlight to penetrate and heat the air inside, creating a temperature gradient. As the air warms, it becomes less dense than the surrounding cooler air, causing it to rise. This upward movement sets in motion a natural convection process, creating a continuous flow of air through the chimney. The airflow inside the solar chimney can be harnessed to generate electricity. At the base of the tower, one or more turbines are strategically placed to capture the airflow and convert it into mechanical energy. The turbines, connected to generators, produce electricity as they rotate, making the system capable of generating power on a significant scale. As shown in figure 1-4. [3]

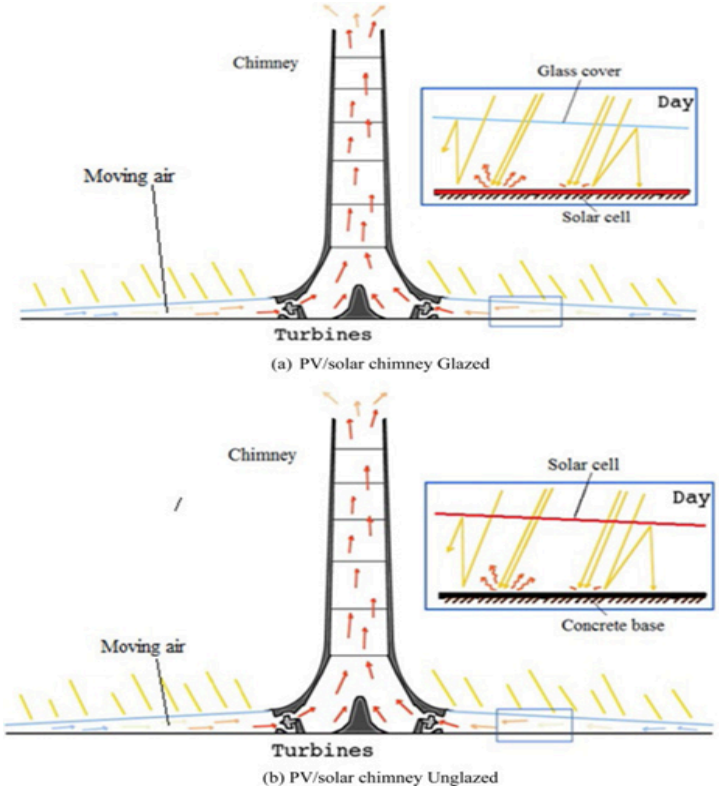


Figure 1-4: Solar chimney power plant process.

1.4 DEFINITION

A solar chimney, also known as a solar updraft tower or solar thermal chimney, is a type of renewable energy technology that utilizes the principle of natural convection to generate electricity. It consists of a tall vertical tower with a large transparent roof or greenhouse-like structure at its base. The functioning of a solar chimney is based on the temperature difference created by solar radiation. Sunlight enters the transparent roof, heating the air underneath. As the air heats up, it becomes less dense and begins to rise. This creates an upward airflow inside the chimney, which sets in motion a natural convection process. At the base of the tower, one or more turbines are placed strategically to capture the airflow and convert it into mechanical energy As shown in figure 1-5. The turbines are connected to generators, which produce electricity as they rotate. The continuous flow of air driven by the temperature difference between the heated air inside the chimney and the cooler ambient air outside allows for a continuous generation of power. [4]

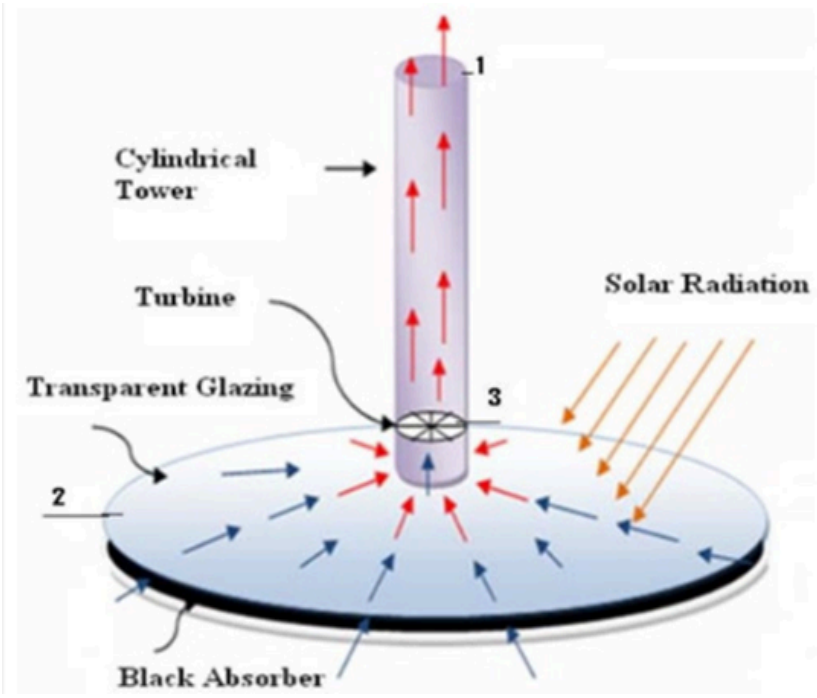


Figure 1-5: Basic solar chimney power plant.

1.5 ADVANTAGES

1.5.1 Renewable Energy Source

Solar chimneys harness the virtually inexhaustible supply of solar energy, converting sunlight into electricity through a combination of greenhouse effect and updraft processes. This reliance on a perpetually available resource ensures a continuous and sustainable power supply, mitigating concerns about resource depletion and environmental degradation associated with finite fossil fuel reserves. .[5]

1.5.2 Minimal Environmental Impact

Unlike fossil fuel power plants, solar chimneys produce electricity without burning fossil fuels or emitting pollutants such as carbon dioxide, sulfur dioxide, nitrogen oxides, or particulate matter. This results in significantly lower environmental impact and helps mitigate climate change. .[5]

1.5.3 Low Operating Costs

Once constructed, solar chimneys boast minimal ongoing expenses. Unlike conventional power plants that rely on costly fuel procurement and transportation, solar chimneys operate predominantly through passive solar heating and natural convection, eliminating the need for fuel inputs and their associated costs. Furthermore, their simplified design and reliance on well-established engineering principles contribute to lower maintenance requirements, resulting in significant cost savings over their operational lifespan. .[6]

1.5.4 Long Lifespan

Solar chimneys are engineered for durability and longevity, with robust designs capable of withstanding the rigors of long-term operation in diverse climatic conditions. Through routine maintenance and periodic upgrades, solar chimneys can sustain reliable electricity generation for decades, providing a resilient and dependable energy infrastructure that delivers lasting benefits to communities and economies. .[6]

1.5.5 Potential for Hybrid Systems

Solar chimneys offer versatility and compatibility with other renewable energy technologies, presenting opportunities for hybrid energy systems that combine multiple energy sources to maximize efficiency, reliability, and energy output. Whether integrating with photovoltaic panels to capture additional solar energy or coupling with wind turbines to capitalize on complementary wind patterns, solar chimneys can enhance overall energy generation capacity and grid stability, particularly in regions with abundant renewable resources.[6]

1.6 DISADVANTAGES

1.6.1 Weather Dependency

Solar chimneys rely on solar radiation to generate the temperature differential necessary for airflow and power generation. Consequently, their performance can be affected by weather conditions such as cloud cover, seasonal variations, and diurnal changes in sunlight intensity. Extended periods of overcast weather or low solar irradiance may result in reduced electricity output, impacting reliability and energy predictability.[7]

1.6.2 Technological Complexity

Solar chimneys involve complex engineering and design considerations, requiring specialized expertise in areas such as thermodynamics, structural engineering, and fluid dynamics. The integration of multiple components, such as the solar collector, chimney structure, and power generation system, presents technical challenges in terms of optimization, operation, and maintenance. Ensuring the reliable and safe operation of solar chimneys may require ongoing research, development, and innovation.[7]

1.6.3 Design of solar chimney

To ensure the safety, enhanced power output, and operational efficiency of solar chimney power plants (SCPPs), it's imperative to optimize the design of the chimney, prioritizing structural integrity while maximizing airflow and heat exchange. This involves careful material selection, reinforcement strategies, and structural analysis to withstand environmental stresses. Additionally, power output can be enhanced through innovative collector designs and streamlined airflow pathways. Robust opeal safety measures and risk management protocols are essential for reliable operation, alongside thorough assessments of environmental impacts and commercial viability. Critical design parameters such as collector area, chimney height, and turbine pressure drop must be optimized through computational modeling and simulation analyses to maximize energy conversion efficiency and overall plant performance,

ensuring steady development and commercial application amidst evolving threats and changing environmental conditions.[8]

1.7 Types

1.7.1 HSCPP System:

The HSCPP system, as depicted in Figure 1-6, integrates the operational principles and technologies of both a conventional SCPP and a CT. Its components include a SC (200 m height, 10 m diameter), a collector (250 m diameter), and a bidirectional turbine. Positioned at the base of the collector is a seawater pool (30 m diameter). The collector's height varies from 6 m at the entrance to 12 m at the chimney base. All dimensions and components are illustrated in Figure 1-6. The turbine is situated at ground level beneath the chimney. Gutters along the chimney's inner walls channel desalinated water to an external reservoir via connected pipes. Water sprinklers are installed at the chimney's top section, supplied by an external pump drawing water from a reservoir. The seawater pool, centrally located under the chimney, is equipped with water pipes sourcing water from an external reservoir. The chimney and base are constructed of concrete, while the collector's rooftop is composed of glass. The bidirectional turbine enables energy capture in both directions.[9]

1.7.1.1 CT mode

The CT mode of operation, as illustrated in Figure 1-6, requires specific system components: the chimney, turbine, and water sprinklers. Unlike the SCPP mode, the CT operates at nighttime, independent of solar irradiation. Its operation begins by spraying cool water mist onto the hot, dry air at the chimney's top. This rapid evaporation cools the air, increasing its density and pressure at the chimney's apex, thus driving airflow downwards. Similar to the SCPP mode, the velocity of ascending air within the chimney is dictated by the temperature disparity between the interior and exterior environments. As air descends, it engages with the turbine to generate electricity before exiting into the collector area. Figure 1-6 illustrates the airflow direction during this mode. The efficacy of the CT mode hinges on ambient air temperature and

humidity, discussed in detail in subsequent sections. Transitioning between SCPP and CT modes is facilitated by the bidirectional turbine, which adjusts its spinning direction based on airflow. Consequently, the HSCPP operates as SCPP during daylight hours and as CT at night, offering continuous electricity and desalinated water production, contingent upon favorable weather conditions. This operational flexibility contributes to enhanced system utilization and efficiency compared to conventional SCPP designs, accompanied by a notable reduction in the Levelized Cost of Electricity (LCOE).[9]

1.7.1.2 SCPP mode

The SCPP mode, as illustrated in Figure 1-6, functions by utilizing solar irradiation intercepted at the collector's surface. This solar energy heats the air beneath the collector, causing an increase in temperature and a decrease in density. Consequently, the air's kinetic velocity rises along the sloped roof. This increased velocity allows for expansion of the air as it flows from sector one to two over the seawater pool. As the air traverses the seawater pool, it becomes humid due to the interaction with the seawater. Throughout the day, with the intensification of solar radiation, the air beneath the collector experiences an exponential temperature increase, further expanding over the seawater pool. This creates a pressure differential between the bottom and top of the SCPP, propelling the hot and humid air upwards towards the chimney. As the humid air ascends, its temperature decreases, leading to water desalination on the chimney's inner walls. Concurrently, the hot air interacts with a turbine situated within the chimney, generating electricity. The velocity of the ascending air within the chimney is determined by the temperature difference between the interior and exterior of the chimney. Subsequently, the air exits the chimney into the surrounding environment. The flow direction within the system, encompassing the entrance, collector, seawater pool, turbine, and chimney, is depicted in Figure 1-6. The color-coded arrows in the figure indicate the temperature progression of the air as it moves through the system. As daytime progresses, with increasing temperature and solar radiation, the production of desalinated water and electricity is expected to peak around noon, gradually diminishing in the afternoon as temperature and solar radiation

decline, ultimately ceasing at sunset. The SCPP's operation is inherently tied to solar irradiation, limiting its functionality to daytime only.[9]

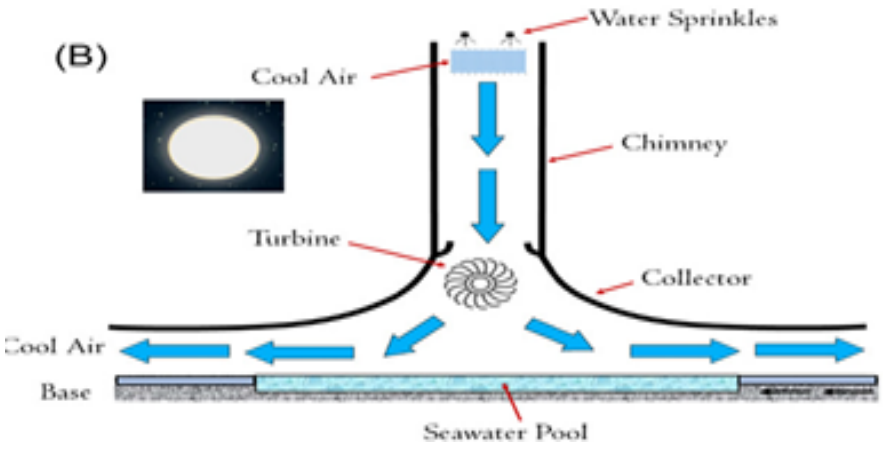


Figure 1-6: Schematic operation with physical dimensions of the proposed hybrid solar chimney

1.7.2 Solar Chimney for space cooling and thermal comfort

The concept of thermal comfort encompasses more than just space heating; it involves space conditioning, which is the integrated operation technique for controlling air temperature, humidity, and air quality. Solar chimneys and integrated approaches can be used to achieve this. The underground temperature is typically lower than the annual average air temperature in summer but higher in winter. At depths of 2-3 meters, the average underground temperature is around 20-25˚C. For instance, in Omaha, Nebraska, the geothermal soil temperature was found to be 12˚C when the outdoor temperature was 31˚C (Wang et al., 2004). Wang et al. (2004) conducted an experiment where they cooled room air using geothermal temperature and obtained satisfactory results. Many researchers, such as Bansal, Sodha, Mathur, Sawhany, and Thanu, have been working on Earth-to-Air Heat Exchangers (EAHE). EAHE systems can work satisfactorily for up to 7-8 hours, after which the Coefficient of Performance (COP) decreases, and the ground requires recharging time, which is a limitation of EAHE. This geothermal heat exchange system is known as an Earth-to-Air Heat Exchanger (EAHE). Maerefat and Haghighi (2010) used this technology integrated with a solar chimney for passive cooling and ventilation of buildings, as shown in Figure 1-7.[10]

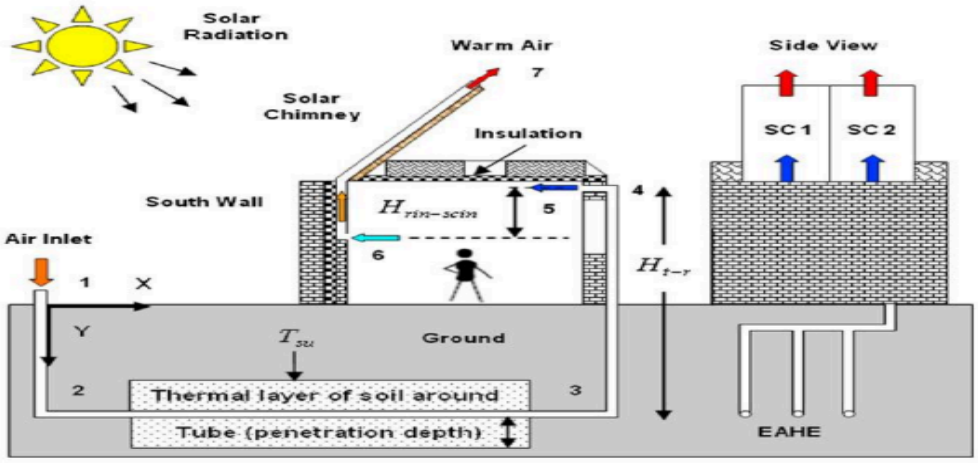


Figure 1-7: Schematic diagram of integrated earth to air heat exchanger and solar chimney.

1.7.3 Solar Chimney for space heating and ventilation

Gan (1998) demonstrated the versatility of the trombe wall by controlling the positions of dampers, allowing it to function effectively in both winter and summer seasons. The trombe wall was constructed on a south-facing wall using concrete and masonry, with the exterior covered in glazed glass and painted black. Three holes were incorporated into the design, with two positioned at the bottom and top of the masonry wall. A damper was installed in the top hole to close it during the summer and open it during the winter. Another damper was placed at the exit opening of the chimney to close it during the winter and open it during the summer.Wang et al. (2005) proposed the use of single-pass and double-pass roof solar collectors for space heating and natural ventilation. The dampers were used to control the application mode, with the "1 close 2 open" position indicating that hot air was circulated into the room, representing the space heating mode. For natural ventilation, the damper positions were reversed. The double-pass configuration involved two layers of glazing, with the flow position being in series for space heating and parallel for ventilation mode. The performance of the double-pass roof solar collector was found to be approximately 10% higher than that of the single-pass collector, indicating the effectiveness of the glazing as shown in figure 1-8.[10]

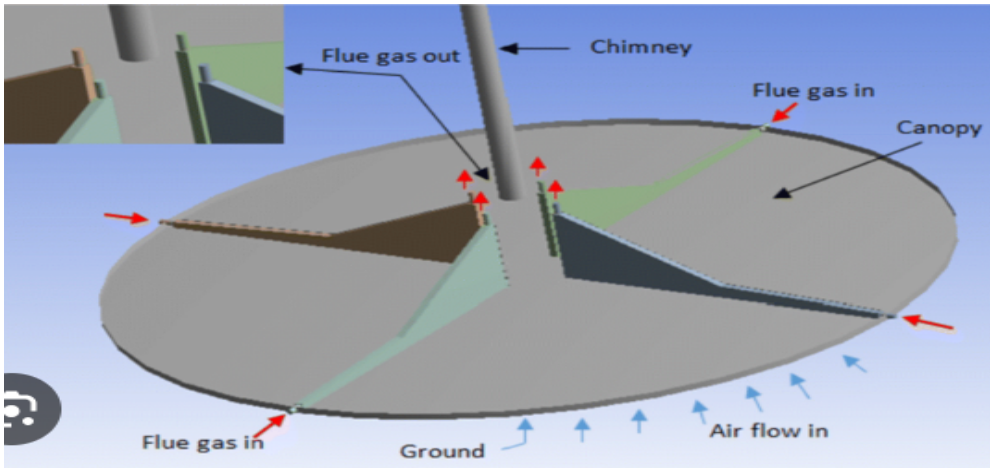


Figure 1-8: Schematic diagram of heating and ventilation in solar chimney.

2.DESGIN OF SOLAR CHIMENY

2.1 Formulas and equations

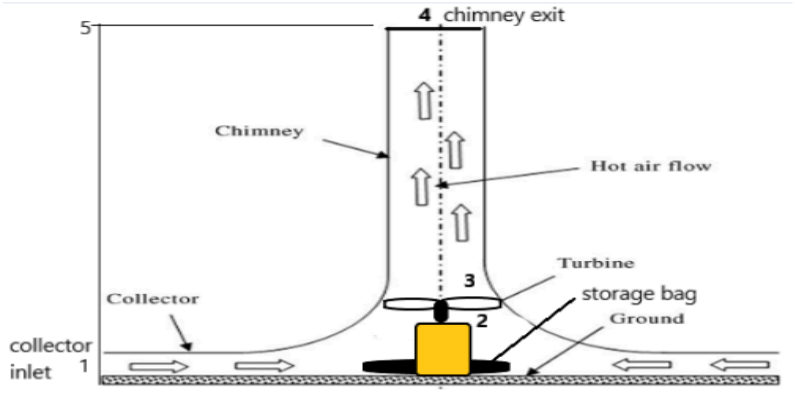
The total heat input is;

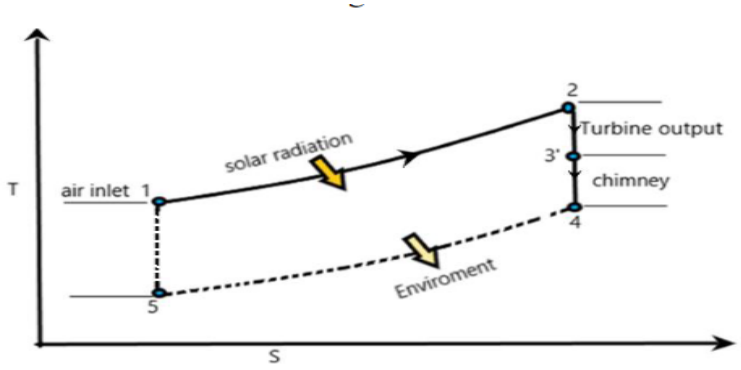
$Qi = \dot{m} \times (h2 - h1) = \dot{m}(T2 - T1)$ [1]

The Expansion energy to lift the air up to state 4:

$Plift = \dot{m} \times g \times Hchim$

The energy exchange is isentropic, since the friction and heat transfer are negligible. Then the value of enthalpy (Δh) can be equated to the amount of air that has descended down in the atmosphere after having been cooled from chimney exit temperature. So, the enthalpy change in the chimney becomes; [11]





$\Delta h = g \times \Delta Hchim = Cp \times (T1 - T5)$ [1]

Then the turbine shaft power becomes;

$Pshaft = \dot{m} \times Cp \times (T2 - T3) - \dot{m} \times Cp \times (T1 - T5)$

$$\frac{\partial(\rho V_r^2)}{\partial r} = -\frac{\partial P}{\partial r} + \frac{\partial \tau_r}{\partial r} + \rho g$$

Pressure difference can be written as;

$$\Delta p_{tot} = g \times \int_0^{Hchim} (\rho_2 - \rho_4) dH$$

The pressure difference can be re-written as;

$\Delta ptot = g \times (\rho 2 - \rho 4) \times Hchim$

The useful driving pressure is;

$Pt = \Delta ptot - Pf$

$$V_2 = \frac{G(\tau \times \alpha) \times A_{gz} - \beta(\Delta T_a \times A_{gz})}{\rho_{air} A_{chim} c_p (\Delta T)}$$

Then, $\Delta T_a = (T_{pm} - T_1)$

i. Mean plate temperature (T_{pm})

$$T_{pm} = T_1 - \frac{Q_{useful}}{A_{gz} \times \beta \times F_R} \times (1 - F_R)$$

ii. Collector Heat removal factor (F_R)

$$F_R = \frac{\dot{m} \times C_P}{A_{gz} \times \beta} \left(1 - \exp\left(\frac{A_{gz} \times \beta \times F'}{\dot{m} \times C_P}\right)\right)$$

$Pout = \eta tur \times Pt \times V2 \times Agz$ [1]

2.2 DESGIN OF SOLAR CHIMENY

2.2.1 Solar chimney power plant in Manzanares

-The Solar Chimney Power Plant in Manzanares was constructed in the early 1980s as a joint project between the German aerospace agency DLR (Deutsches Zentrum für Luft- und Raumfahrt) and the Spanish government. It operated as a test facility to explore the feasibility and efficiency of solar chimney technology.

Design: The plant consisted of three main components: a large greenhouse collector, a tall chimney, and a turbine generator system. The greenhouse collector was a large, transparent structure that absorbed solar radiation. The air inside the greenhouse heated up due to the greenhouse effect.

Chimney: The chimney was a tall, hollow tower located at the center of the greenhouse. It extended vertically upward from the center of the greenhouse to create a temperature gradient. As the air inside the greenhouse heated up, it became less dense and rose towards the top of the chimney.

Turbine Generator: At the base of the chimney, there was a turbine generator system. As the hot air rose through the chimney, it passed through the turbine, causing it to spin. The spinning turbine then generated electricity.

Operation: During daylight hours, sunlight would heat the air inside the greenhouse, creating a temperature difference between the bottom and the top of the chimney. This temperature gradient caused air to flow through the chimney, driving the turbine and generating electricity. The chimney acted as a natural draft chimney, utilizing the principle of convection to create airflow.

Output: The Manzanares Solar Chimney Power Plant had a relatively low power output compared to other conventional power plants. It was primarily an experimental facility and was not designed for large-scale commercial electricity generation.

History: The Solar Chimney Power Plant in Manzanares was constructed in the early 1980s as a joint project between the German aerospace agency DLR (Deutsches Zentrum für Luft- und Raumfahrt) and the Spanish government. It operated as a test facility to explore the feasibility and efficiency of solar chimney technology. [12]

Tower height	194 m
Tower diameter	10 m
Collector diameter	244 m
Collector area	40,000 m^2 membrane, 6,000 m^2 glass
Collector height	1.80 m
Collector weight	5.5 kg/m^2 (without glass)
Tower weight	125t

Table 2-1: Chimney Dimensions



Figure 2-1: Manzanares solar chimney power plant.

2.2.2 Solar chimney power plant in Jinsha wan (China)

In December 2010, a tower in Jinsha wan in Inner Mongolia, China started operation, producing 200 kilowatts. The 1.38 billion RMB (USD 208 million) project was started in May 2009. It was intended to cover 277 hectares (680 acres) and produce 27.5 MW by 2013, but had to be scaled back. The solar chimney plant was expected to improve the climate by covering loose sand, restraining sandstorms.[29] Critics have said that the 50m tall tower is too short to work properly and that it was a mistake to use glass in metal frames for the collector, as many of them cracked and shattered in the heat. So they replaced it with solar panels

For purpose of more studies regarding these kinds of power plants, an experimental sample was built in University of Jinsha wan, in 2010. [12]

The chimney height is 60 m and the collector has 50 m diameter. The collector angle must be designed in a way that the most possible heat could be absorbed, Jinsha wan city has the attitude of 36º, 68´ and longitude of 48º, 45´. [12]

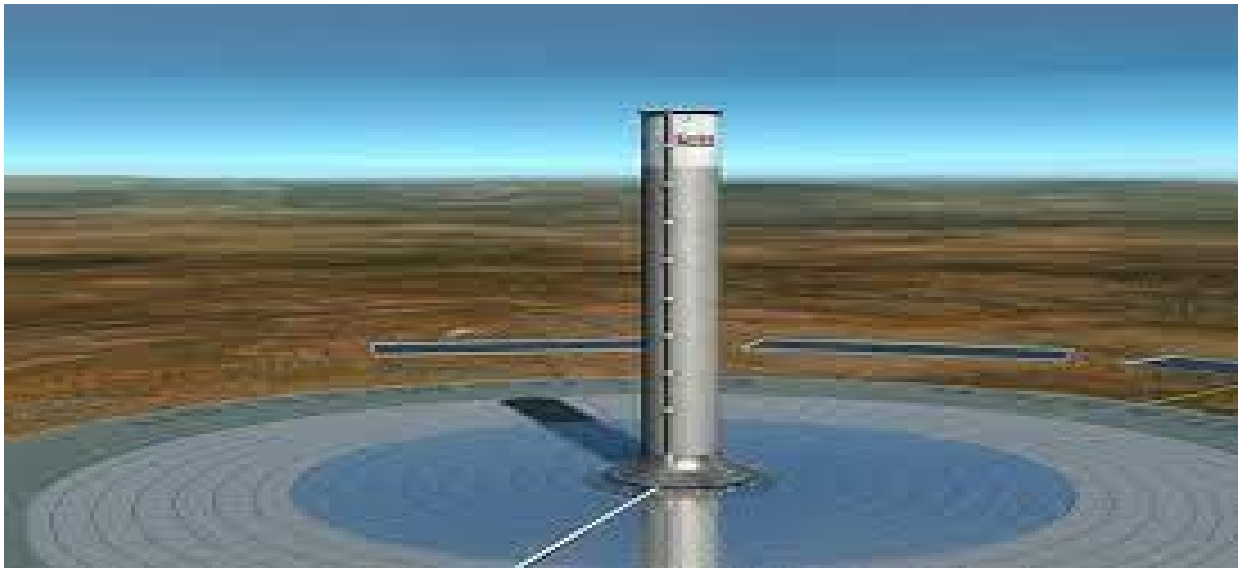


Figure 2-2: Jinsha wan solar chimney power plant.

2.2.3 Influence of main plant dimensions on power output

2.2.3.1 Chimney parameters

Rch	Chimney radius
Hch	Chimney height
Δpf	Pressure drop due to friction in the chimney
P	Power generated

Table 2-2: Chimney parameters.

Figure 2.5 illustrates a comparable trend, wherein the power output demonstrates an almost linear rise from 20MW for smaller chimney radii (20m). This progression occurs because a larger chimney cross-section permits greater airflow. The power output peaks at 145MW when the radius reaches 165m, before experiencing a slight decline for chimney radii up to 200m. Notably, this peak remains relatively consistent, indicating that a power output exceeding 140MW could be achieved for any chimney radius falling within the 120m to 200m range.

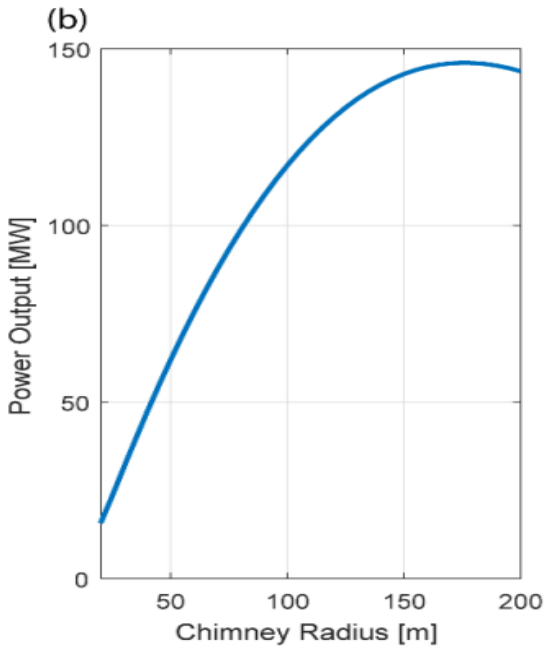


Figure 2-3: Relation between chimney radius and power output.

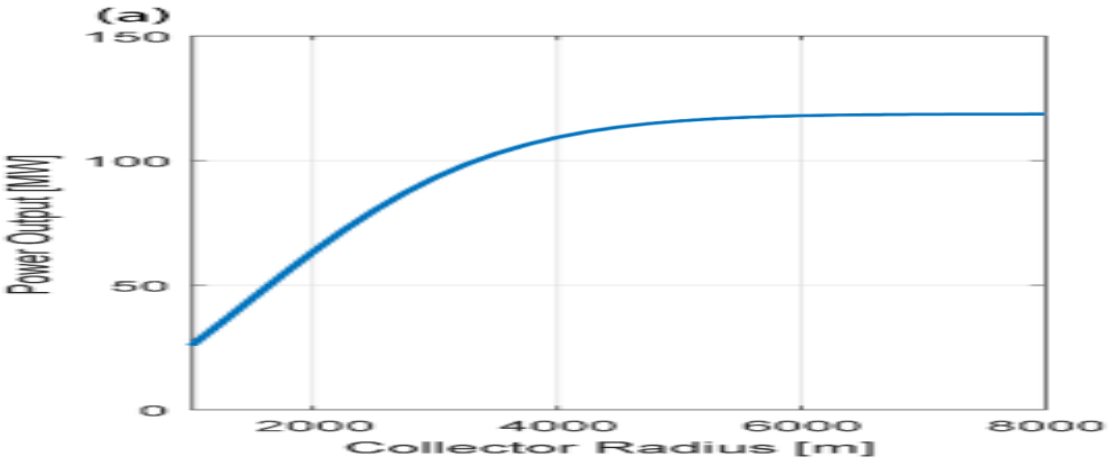
2.2.3.2 Collectors Parameters

Rc	Collector radius
hci	Collector inlet height
hco	Collector outlet height
hc	Collector height at distance r from inlet

Table 2-3: Collectors Parameters.

In this segment, we delve into the impact of the overall dimensions of the Solar Chimney Power Plant (SCPP) on its power generation capacity. Figure 2.4 illustrates this relationship, revealing a noticeable rise in power output. For instance, the output escalates from 25MW when the collector radius is 1000m to 115MW when the radius expands to 8000m. This escalation follows a nearly linear trend up to a radius of approximately 3000m. This linear progression occurs because a larger collector area allows for greater heat absorption. Notably, while the increase in power output aligns closely with the collector radius, it doesn't exhibit the same linear correlation with the area (which increases with the square of the collector radius). As the

collector radius exceeds 5000m, the power output reaches a plateau, indicating diminishing returns beyond this threshold. This suggests that, while holding other dimensions constant, enlarging the collector beyond a certain size yields progressively smaller gains in power output.[12]



2.2.3.3 Turbine Parameters

x	Turbine pressure drop ratio
ηt	Turbine efficiency
Δpt	Pressure drop available to the turbine

Table 2-4: Turbine Parameters.

The turbine pressure drop is a crucial factor in predicting power output. While its optimal value and its interactions with other variables have been explored, they continue to be debated [14]. Thus, the initial part of this study methodically examined how turbine pressure drop, power output, and other factors interrelate. In the case of the facility with standard dimensions and environmental settings, the turbine pressure drops, denoted as x, ranged from 0.6 to 0.95, with corresponding power outputs computed. According to Figure 3, the results suggest that the maximum power output occurs at a pressure drop of approximately 0.8, with a decrease in power of no more than 8% when x is between 0.7 and 0.9 [13]

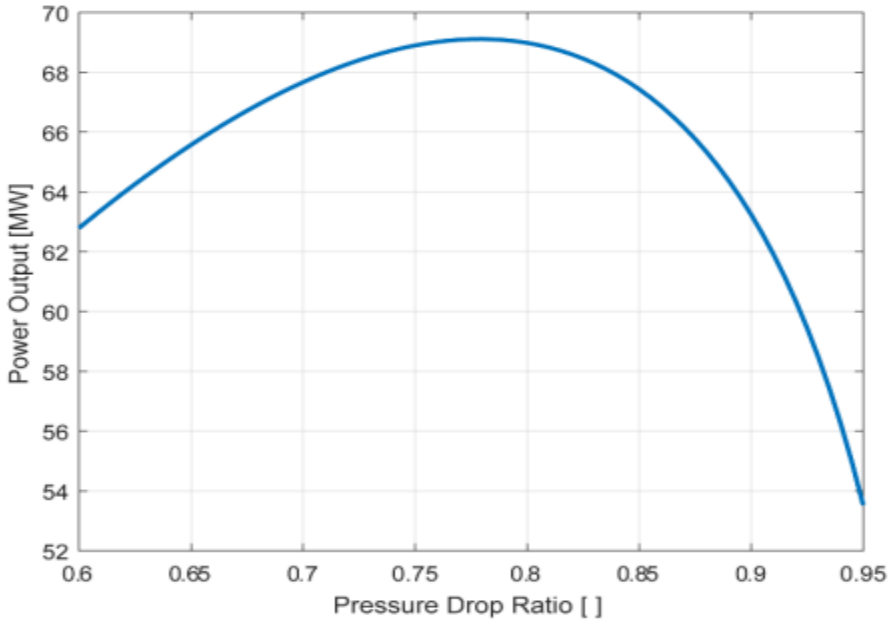


Figure 2-4: Relation between power output and pressure drop ratio.

2.2.3.4 Power Output Relation

Pout= v Ac ΔPt ηtg. [10]

Ac= cross sectional area of chimney.

V= velocity of air, m/s.

ΔPt= pressure difference across the turbine, kPa.

ηtg= efficiency of the turbine generator system.

2.2.3.5 Conclusion

-The generation of electricity grows linearly with increases in both collector and chimney radius until it stabilizes or peaks.

-The power output displays a quadratic increase with the height of the chimney, underscoring the importance of incorporating tall chimneys in plant designs.

-It is crucial to achieve a precise balance between the collector size and the chimney radius for any given chimney height.

-The collector radius needs to be sufficiently large to allow the air temperature to equalize with the surrounding canopy and ground, yet extending the radius further does not yield additional advantages.

-Smaller chimney widths restrict airflow, thus capping the power output; chimneys with a radius of up to 200 meters are required to achieve a power output of 900 MW. [13]

2.3 MATRIEAL SELECTION

2.3.1 Glass Solar panel of solar chimney

A photovoltaic (PV) module, also known as a PV panel or solar panel, consists of photovoltaic cells arranged within a frame to produce energy. These panels harness sunlight to produce direct current (DC) electricity. A single solar panel is referred to as a PV panel, while a group of these panels is known as an array. These arrays deliver solar power to electrical devices.

Each module's power output is assessed under standard test conditions (STC), although actual field output may differ. Output power typically varies from 100 to 365 Watts (W). The efficiency of a module is crucial as it influences the physical size of the panel for the same power output; for example, a 230 W module at 8% efficiency would be twice the size of one at 16% efficiency. Some solar modules on the market now surpass 24% efficiency. Currently, the highest solar module efficiency achieved in commercial products is approximately 21.5%, which is generally lower than the efficiencies of the individual cells when tested separately. The most efficient mass-produced solar modules have power densities up to 175 W/m^2 (16.22 W/ft^2). [14]

2.3.1.1 Solar Panel Cost

Cost is often the initial factor people evaluate when selecting solar panels. The price of a solar panel is influenced by several aspects, including its power capacity (measured in Watts), physical dimensions, brand, material quality, durability, and any relevant certifications.

While cost is a significant consideration, it should not be the sole criterion. Opting for the cheapest solar panel might compromise efficiency and long-term value. Selecting solar panels is a decision that carries risks; however, considering their extended lifespan of over 30 years, it is more crucial to invest in a high-quality system rather than simply choosing the least expensive option. [4]

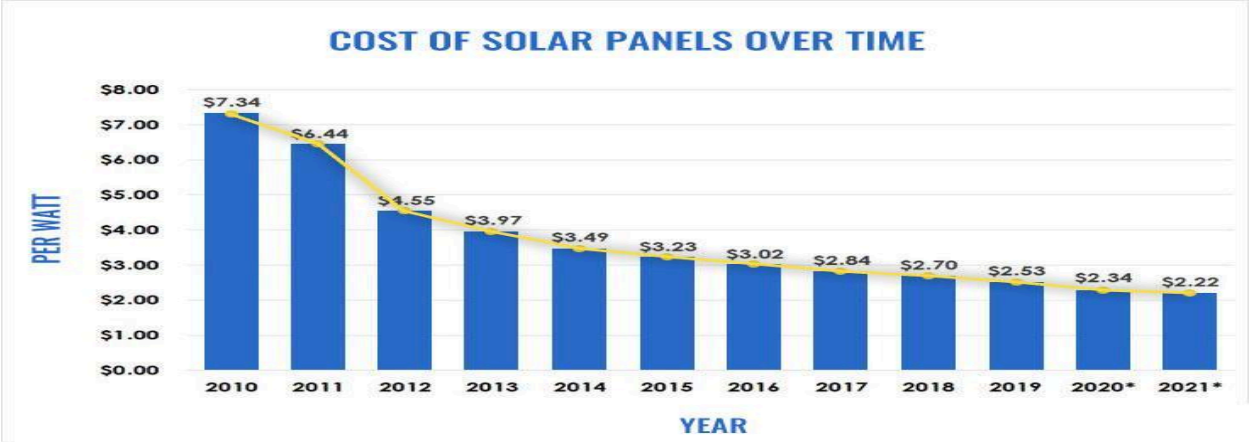


Figure 2-5: Cost of solar panels over time.

2.3.1.2 Solar Panel Quality

This considers the manufacturing process and the quality of materials used in constructing the solar panel. Manufacturers vary in the types of panels they produce, differing in quality, price, and efficiency. Some manufacturers are vertically integrated, overseeing every stage of production. These companies prioritize quality control and heavily invest in research and development (R&D). Other manufacturers focus solely on assembling panels and typically do not produce their own cells or invest in R&D. They rely more on manual labor than on automation, resulting in the most cost-effective panels. [14]

2.3.1.3 Energy Efficiency

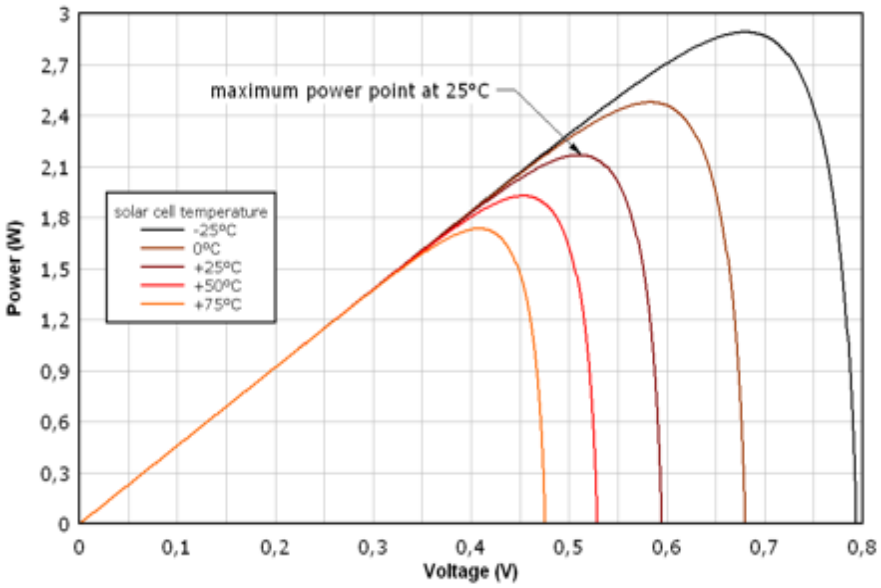
In recent years, the efficiency of solar panels h 24 nificantly increased, rising from an average conversion rate of about 15% of sunlight into usable energy to approximately 20%. Some high-efficiency solar panels can achieve conversion rates as high as nearly 23%.

Paly	18% efficiency
Mono	19% efficiency
HJT N-Type	22% efficiency
IBC	22.5% efficiency

Table 2-5: Energy Efficiency.

2.3.1.4 Temperature Coefficient

The effect of heat on the operational efficiency of solar panels post-installation is significant, as overheating can hasten their aging. A lower efficiency loss per degree Celsius is preferable because the semiconductors within solar panels are particularly susceptible to high temperatures. Manufacturing standards indicate that the optimal operating temperature for photovoltaic solar panels is 25°C (77°F). [15]



The solar panel's power loss can be calculated as follows

65degC – 25degC = 40degC

40degC x -0.5% = 20%

Therefore, panel power loss = 20% x 250W = 50W

Therefore, panel power = 200W [15]

2.3.1.5 Types of Solar Cells

Monocrystalline silicon is known for its high efficiency and strong heat tolerance, requiring less space. Polycrystalline (or multi-crystalline) silicon solar panels have become the preferred option for residential installations due to their effectiveness and affordability. Additionally, there are amorphous (or thin-film) silicon cells, which use the least silicon but are less efficient. Compared to an amorphous panel, a crystalline panel will be smaller for the same wattage output. [16]

2.3.1.5.1 Monocrystalline

Monocrystalline solar cells are made from single crystalline silicon. They are very distinctive in their appearance as they are often colored, and the cells hold a cylindrical shape. In order to keep the costs low and performance at optimal levels, manufacturers cut out the four sides of the monocrystalline cells. This gives them their recognizable appearance. [16]

Advantages

They have the highest level of efficiency at 15-20%.

They require less space compared to other types due to their high efficiency.

Manufacturers state that this form of solar cell lasts the longest, with most giving them a 25-year warranty.

They perform better in low levels of sunlight, making them ideal for cloudy areas. [6]

Disadvantages

Here are some of the disadvantages to monocrystalline solar cells

They are the most expensive solar cells on the market, and so not in everyone's price range

The performance levels tend to suffer from an increase in temperature. However, it is a small loss when compared to other forms of solar cell.

There is a lot of waste material when the silicon is cut during manufacture. [16]

2.3.1.5.2 Polycrystalline Solar Cells

Polycrystalline solar panels were first introduced to the market in 1981. Unlike monocrystalline cells, which require cutting on all four sides, polycrystalline cells are made by melting silicon and pouring it into square molds, resulting in perfectly shaped square cells.

Advantages:

The production process is less expensive and sir 27 :han that of monocrystalline cells.

This method reduces silicon waste.

Polycrystalline cells are less adversely affected by high temperatures, enhancing their appeal in warmer regions due to their lower cost. [17]

Disadvantages:

The efficiency of polycrystalline cells ranges only from 13-16% because of the lower purity levels of silicon, making them less efficient compared to other types on the market.

They yield lower output rates, necessitating more roof space for installation, which makes them less space-efficient. [17]

2.3.1.5.3 Thin Film Solar Cells

The efficiency of thin film solar cells varies significantly, ranging from 7% to 13%, depending on the technology used. Since 2002, there has been a substantial increase in both the knowledge and popularity of thin film solar cells, which has spurred advancements in research and development. As a result, future models of thin film solar cells are anticipated to achieve efficiency rates between 10% and 16%.

Advantages:

Thin film solar cells can be made flexible, which makes them suitable for a variety of applications and building types.

They are easier to mass-produce, which could make them more cost-effective than crystalline solar cells. [17]

Disadvantages:

Thin film solar cells are not ideal for residential 28 ıe to their large space requirements.

Their low space efficiency may lead to additional costs for supplementary components such as support structures and cables.

They generally have a shorter lifespan and consequently shorter warranty periods. [17]

2.4 TURBINE SELECTION

2.4.1 Solar Power Plant Turbines

These turbines generate electricity by harnessing thermal energy from solar radiation. Solar arrays concentrate solar radiation onto a small receiving area where the solar energy is transformed into heat. This heat is absorbed by a working fluid which powers a gas or steam turbine cycle to produce electricity. [18]

2.4.1.1 Turbine Design of the SCPP

Literature on solar chimneys provides limited information regarding the factors that influence turbine efficiency, often merely assuming efficiency values ranging from 40-80%, as noted by Bäckström & Gannon and Mullett. This study introduces a new methodology for the redesign of solar chimney turbines, utilizing the Matrix Throughflow Method (MTFM). The MTFM, a tool for two-dimensional analysis, is typically used in the design of axial flow turbines and fans.

2.4.1.2 Simulation Model

The solar chimney power plant operates on fundamental physics principles. The heating collector functions as an air heater utilizing solar energy, with heat transfer principles used to forecast performance. In the analysis of the chimney, heat transfer is overlooked, but the buoyancy force (a concept from fluid mechanics) is considered. Turbomachinery theories are employed to design and analyze the turbine.

Rotational speed (Ω)	100 rpm
Air velocity	9 m/s
Inlet total pressure	92930 pa
Inlet total temperature	29 ; k
Total head rise	90 pa
Outer diameter	5 m
Numbers of blades	4

Table 2-6: Simulation Model.

2.4.2 Axial flow turbine

2.4.2.1 Advantages

Transform Unutilized Land into Productive Areas: Large-scale solar turbine operations require expansive arrays of PV panels, which necessitate substantial land areas that receive uninterrupted sunlight, typically found in barren locales like deserts.

Produce Clean Energy: Solar turbines operate without burning fossil fuels; they rely solely on sunlight, thus producing energy without a carbon footprint.

Eliminate Fuel Costs: Since sunlight is freely available, it helps reduce the operational costs of solar power plants and mitigates the impact of fluctuating prices for traditional fuels.

Enhance Efficiency of Traditional Power Plants: Solar turbines or Concentrated Solar Power (CSP) systems can augment the efficiency of conventional fossil fuel power plants by raising the temperature of the working fluid with solar thermal energy.

2.4.2.2 Disadvantages

Weather Dependence: Solar energy is inherently intermittent, requiring solar turbines to frequently start up and reheat to maintain optimal performance.

Limitations in Heat Capacity: The transmission fluids used in current solar turbines cannot be heated beyond 752°F. However, this limitation can be addressed by positioning the turbine on a tall tower and directing mirrors to concentrate sunlight directly onto the steam boiler, bypassing the need for transmission fluid in pipes. [17]

2.5 PHASE CHANGE IN SOLAR CHIMNEY

Paraffin Experimental studies on the impact of latent heat storage (LHS) on a solar chimney (SC) pilot were conducted. These experiments, which were performed with and without phase change material (PCM), measured variables such as temperature and velocity to evaluate the performance of the solar chimney.

Paraffin wax served as the PCM in a prototype SC, featuring a 3-meter chimney height and a 3-meter collector diameter, located at the University of Tehran campus. The findings indicated that the peak absorber surface temperature reached 72°C with PCM, compared to 69°C in a conventional solar chimney (CSC). Additionally, the maximum air velocity was slightly higher in the PCM-equipped system at 2 m/s, compared to 1.9 m/s in the CSC.

The incorporation of the LHS system resulted in an average mass flow rate increase of approximately 8.33% in the pilot, thereby enhancing the overall performance of the solar chimney.

Paraffin, utilized in these experiments, was sourced from Shanghai YiYang Instrument Co., Ltd. (Shanghai, China), with a minimum purity of 98% and industrial-grade quality. Its thermophysical properties, detailed in Table 2.8, include high heat storage capacity, excellent chemical stability, minimal corrosion, and affordability. [19]

Table 1

Thermophysical properties of paraffin.

Material	Melting Point (°C)	Density of Liquid Phase (g/cm^3)	Density of Solid Phase (g/cm^3)	Specific Heat ($kJ/m^3 \cdot K$)	Thermal Conductivity ($W/m \cdot K$)
Paraffin	60–64	0.768	0.900	1635	0.405

Table 2-7: Thermophysical properties of paraffin.

Chapter Three

3.EXPERM [32] AL ANALYSIS

3.1 Introduction

The solar chimney power plant is an innovative renewable energy technology that utilizes solar energy to produce electricity. This study aims to assess the effectiveness and efficiency of such a plant featuring a chimney height ranging from 1 to 3 meters and a collector with a diameter of 5 meters.

Operating on the principle of convection, this plant comprises three primary components: a solar collector, a tall chimney, and a turbine. The collector, a large circular area, absorbs solar radiation, converting it into heat energy. Positioned vertically above the collector, the chimney creates a thermal updraft zone, while the turbine, located at its base, transforms thermal energy into mechanical energy, ultimately generating electricity.

This experimental analysis seeks to evaluate the plant's performance across different weather conditions and varying levels of solar radiation. Key parameters to be assessed include temperature distribution within the collector, airflow velocity in the chimney, and turbine power output. By conducting this investigation, we aim to gain insights into the efficiency and viability of the solar chimney power plant design, contributing to its further development and optimization as a renewable energy technology.

Overall, this study will yield valuable data on the operational performance and potential of the solar chimney power plant, potentially influencing the advancement and widespread adoption of renewable energy solutions.

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Fig 3.1 Experimental setup of Solar Chimney Plant

The current power output from the solar power plant is modest, prompting a detailed examination of the factors that impact its performance. Through experimental modeling, a generalized mathematical framework has been developed to enhance the plant's power generation capability based on existing configurations. This approach focuses on identifying key variables within the design of the experimental solar chimney power plant setup that significantly influence its performance. By comparing dependent and independent factors, the aim is to optimize the setup's capacity to generate power effectively.

3.2 System Description

The solar chimney power plant utilizes solar energy to generate electricity through a combination of a tall chimney and a large collector. The chimney's main role is to create a temperature differential using the greenhouse effect. Sunlight passes through the collector's plastic material, heating the trapped air inside. This heated air rises naturally due to convection, creating an updraft in the chimney. The height of the chimney is critical in maintaining the desired airflow is chosen for the chimney due to its durability and heat resistance. A black coating enhances solar radiation absorption, ensuring higher temperatures within the chimney. PVC also offers cost-effectiveness and ease of construction, being widely available and lightweight. The collector, made from 0.80 mm greenhouse plastic material, facilitates efficient absorption of solar energy. This translucent material allows sunlight to penetrate while minimizing heat loss. The greenhouse effect inside the collector heats the air, causing it to rise towards the chimney. As the heated air moves up the chimney, it drives a turbine or generator at its base. The turbine's rotation converts the updraft's kinetic energy into electrical energy, thereby generating electricity. This power can serve various purposes, from residential use to industrial applications or integration into the electrical grid. The solar chimney power plant project offers numerous benefits. It harnesses renewable solar energy, making it sustainable and eco-friendly. The choice of materials like PVC for the chimney and greenhouse plastic for the collector ensures affordability and straightforward maintenance. The system's simplicity allows for easy scalability and adaptation to diverse geographical and climatic conditions.

3.2.1 Pressure Measurement (Adafruit BMP280):

- Connect the BMP280 pressure sensor to the ESP32 via I2C communication (SCL to GPIO22, SDA to GPIO21).
- Place the sensor where it can accurately measure atmospheric pressure inside the solar chimney.
- Type: Barometric pressure and temperature sensor
- - Interface: I2C/SPI
- - Pressure Range: 300-1100 hPa
- - Temperature Range: -40 to +85°C
- - Resolution: 0.16 Pa, 0.01°C
- - Power Supply: 1.71-3.6V

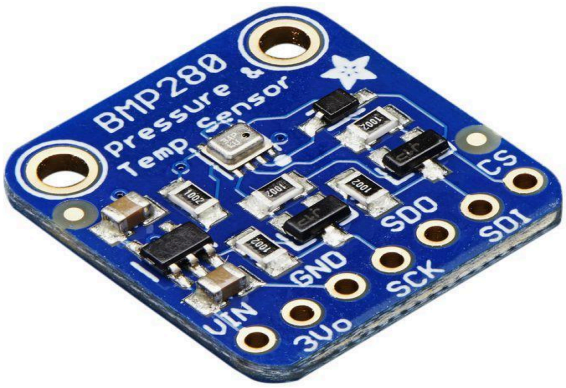

Fig 3.2 Adafruit pressure sensor

3.2.2 Temperature Measurement (DS18B20):

- Connect each of the 14 DS18B20 temperature sensors to the ESP32 using the One Wire protocol. Use a pull-up resistor (4.7kΩ) between the data line and VCC for each sensor.
- Place the temperature sensors at strategic points within the solar chimney setup (e.g., at the base, mid-height, top of the chimney, and around the collector).
- Type: Digital temperature sensor
- - Interface: 1-Wire
- - Temperature Range: -55 to +125°C
- - Accuracy: ±0.5°C from -10 to +85°C
- - Resolution: Programmable 9-12 bits
- - Power Supply: 3.0-5.5V



Fig 3.3 DS18B20

3.2.3 Rotational Speed Measurement (100ppr Rotary Encoder):

- Connect the two 100ppr rotary encoders to the ESP32. Assign appropriate GPIO pins for the encoder signals (e.g., CLK and DT pins).
- Mount the rotary encoders on the turbine to measure rotational speed.
- Consists of 100 transparent and opaque segments.
- Rotates to create a pattern of light and dark pulses.
- IR LED: Emits infrared light.
- - Photodetector: Detects light passing through the disk's slots.
- - Output Signals: Generates pulses corresponding to the disk's rotation.
- - Pins: Typically, 4 pins for power, ground, and two output signals (A and B) for direction and speed sensing.
- Combined Operation
- - IR LED shines light through the rotating encoder disk.
- - Photodetector captures light through slots, generating electrical pulses.
- - Output: Pulses are read by a microcontroller to determine position, speed, and direction of rotation.



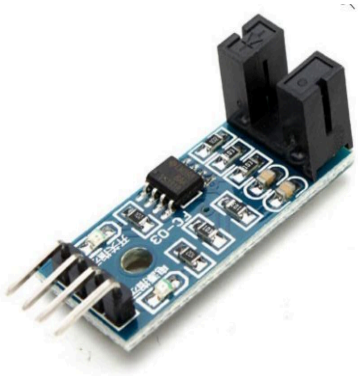



Fig 3.4 100ppr Rotary Encoder **Fig 3.5 Wind Turbine**

3.2.4 Current and Voltage Measurement (INA219):

- Connect the INA219 current/voltage sensor to the ESP32 via I2C (SCL to GPIO22, SDA to GPIO21).
- Integrate the INA219 into the circuit to monitor the power output of the turbine.
- Type: Bi-directional current/power monitor
- - Interface: I2C
- - Voltage Range: 0-26V
- - Current Range: ±3.2A
- - Resolution: 0.8mA
- - Power Supply: 3-5V

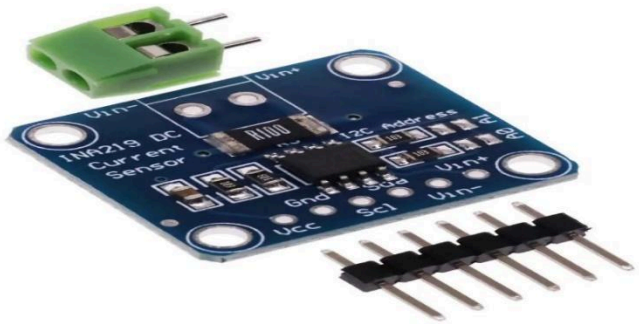

Fig 3.6 INA219

3.2.5 ESP32 Microcontroller:

- Program the ESP32 to read data from all sensors and send it via Bluetooth to the phone.
- Ensure the ESP32 is powered and connected to a stable power source.
- Core: Dual-core 32-bit LX6 microprocessor
- - Clock Speed: Up to 240 MHz
- - Memory: 520 KB SRAM
- - Connectivity: Wi-Fi, Bluetooth 4.2 BLE
- - GPIO Pins: 34
- - Operating Voltage: 3.0-3.6V



Fig 3.7 ESP32 Microcontroller

3.2.6 Bluetooth Communication:

- Pair the ESP32 with the phone via oth.
- Use a suitable app on the phone (e rial Bluetooth Terminal) to receive and log data transmitted from the ESP32.

3.2.7 System connections:

The box contains all components.

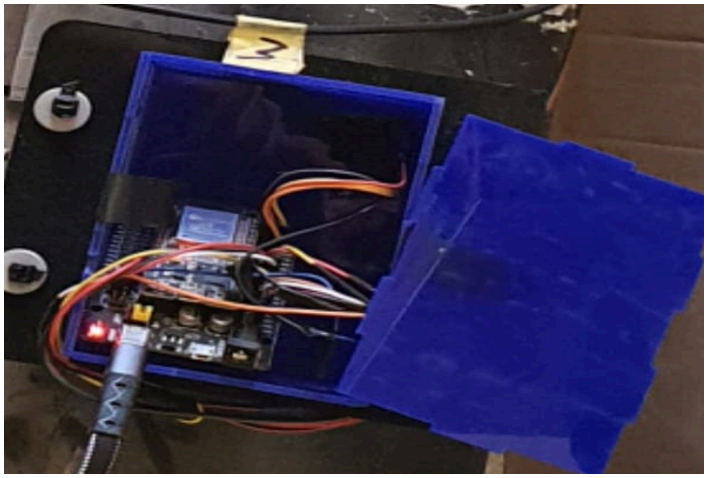

Fig 3.8 System connections

3.2.8 Power bank:



Fig 3.9 Power bank

3.2.9 Electric generator connected to the turbine:



Fig 3.10 Electric generator

3.2.10 Octagonal solar collector:

A collector with a diameter of 5 meters is employed, which is made of 0.80 mm greenhouse plastic material, it consists of wooden frame and 0.80 mm greenhouse Plastic with 89% - 90% Light Transmission % ,25% Diffused Light.



Fig 3.11 PVC Solar Collector

3.2.11 PVC material coated with black color:

The system consists of a chimney with a height ranging from 1 to 3 meters, constructed using PVC material coated with black to enhance solar absorption.



Fig 3.12 PVC Material

3.2.12 Wooden frame:

The collector consists of 8 wooden frames assembled together to make the octagonal shape.



Fig 3.13 Wooden frame

3.2.13 Micro SD Card Reader Module:

Typically supports Micro SD. Often uses a standard USB interface for connection to devices like computers and smartphones. Allows for data transfer between the Micro SD card and the connected device.

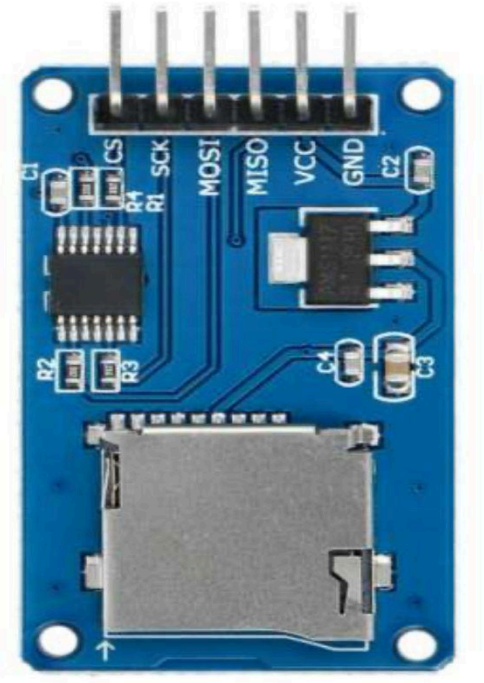

Fig 3.14 Micro SD Card Reader Module

3.3 RESULTS AND DISCUSSION

3.3.1 solar chimney at 1m height:

Date	Time	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	RPM1	Current	Voltage	Pressure
6/30/2024	8:03:53	24.9	24.8	24.7	24.5	24.4	24.4	24.2	24.3	24.2	24.1	17	1	0.3	100.5
6/30/2024	8:18:53	24.8	24.6	24.4	24.3	24.4	24.4	24.3	24.4	24.3	24.4	18	1	0.3	100.5
6/30/2024	8:33:53	25	25.1	25	24.8	24.8	24.7	24.4	24.4	24.4	24.4	20	0.9	0.4	100.5
6/30/2024	8:48:53	25.1	25	25.1	24.8	24.5	24.5	24.4	24.7	24.4	24.2	21	1.1	0.5	100.5
6/30/2024	9:03:53	25.2	25.1	25	24.6	24.3	24.4	24.7	24.5	24.7	24.5	20	1.2	0.6	100.6
6/30/2024	9:18:53	25.2	25.1	25.1	25.1	24.8	24.7	24.5	24.4	24.5	24.4	23	1.1	0.7	100.6
6/30/2024	9:33:53	25.3	25.2	25.1	25	24.8	24.7	24.4	24.7	24.4	24.7	24	1.2	0.7	100.6
6/30/2024	9:48:53	25.4	25.4	25.1	25.1	24.6	24.5	24.7	24.7	24.7	24.7	25	1.1	0.7	100.7
6/30/2024	10:03:53	25.4	25.3	25.2	25.1	25.1	25	24.7	24.5	24.7	24.5	26	1.1	0.6	100.7
6/30/2024	10:18:53	25.5	25.4	25.4	25.2	25	25	24.5	25	24.5	25	27	1.2	0.6	100.7
6/30/2024	10:33:53	25.5	25.4	25.3	25.4	25.1	25	25	25	25	25	27	1.1	0.6	100.5
6/30/2024	10:48:53	25.4	25.4	25.4	25.3	25.1	25	25	25	25	25	28	0.8	0.6	100.6
6/30/2024	11:03:53	25.6	25.5	25.4	25.4	25.2	25.2	25	25	25.2	25	29	0.7	0.5	100.5
6/30/2024	11:18:53	25.6	25.3	25.4	25.4	25.4	25.4	25	25.2	25	25.2	30	0.9	0.7	100.5
6/30/2024	11:33:53	25.6	25.5	25.5	25.4	25.3	25.2	25.2	25.4	25.1	25.4	30	1.1	0.6	100.5
6/30/2024	11:48:53	25.6	25.1	25.3	25.6	25.4	25.2	25.4	25.2	25.4	25.2	32	1.3	0.6	100.5
6/30/2024	12:03:53	26.1	26	25.5	26.1	25.4	25.3	25.2	25.2	25.2	25.2	30	1.2	0.6	100.5
6/30/2024	12:18:53	26.0	26.0	25.1	26.0	25.4	25.4	25.2	25.3	25.2	25.3	31.0	1.2	0.6	100.5
6/30/2024	12:33:53	26.2	26.2	26	26.2	25.6	25.4	25.3	25.4	25.3	25.4	32.0	1.1	0.5	100.4
6/30/2024	12:48:53	26.3	26.3	26.0	26.3	26.1	26	25.4	25.4	25.4	25.4	33.0	1.1	0.5	100.5
6/30/2024	13:03:53	27.0	26.8	26.2	27.0	26.0	26.0	25.4	26.0	25.4	26.0	34.0	1.1	0.6	100.5
6/30/2024	13:18:53	27.4	27.2	26.3	27.4	26.2	26.1	26	26.1	26	26.0	35.0	1.1	0.7	100.5
6/30/2024	13:33:53	28.1	27.9	26.8	28.1	26.3	26.3	26.0	26.3	26.0	26.3	38.0	1.2	0.7	100.5
6/30/2024	13:47:53	28.5	28.3	27.2	28.5	27.0	27.2	26.1	25.7	26.1	25.7	39.0	1.4	0.7	100.5
6/30/2024	14:03:53	29.0	28.8	27.9	29.0	27.4	27.2	26.3	26.2	26.3	26.2	38.0	1.3	0.6	100.5
6/30/2024	14:18:53	30.1	29.5	28.3	30.1	28.1	28.0	27.2	27.3	27.2	27.3	37.0	1.2	0.6	100.3
6/30/2024	14:33:53	30.5	30.1	28.8	30.5	28.5	28.3	28.2	28.1	28.2	28.1	37.0	1.3	0.6	100.4
6/30/2024	14:48:53	30.5	30.2	29.5	30.5	30.2	30.2	30.2	30.0	30.2	30.0	36.0	1.4	0.6	100.3
6/30/2024	15:03:53	30.6	30.3	30.6	30.6	30.3	30.3	30.2	30.0	30.2	30.0	35.0	1.4	0.5	100.7
6/30/2024	15:18:53	30.1	30.1	30.1	30.1	30.7	30.2	30.4	30.5	30.4	30.5	34.0	1.3	0.7	100.7
6/30/2024	15:33:53	30.2	30.2	30.2	30.2	30.4	30.2	30.2	30.4	30.2	30.4	33.0	1.2	0.6	100.7
6/30/2024	15:48:53	30.1	30.0	30.0	30.1	30.2	29.8	30.0	30.1	30.0	30.1	32.0	1.1	0.6	100.5
6/30/2024	16:03:53	30.1	30.0	30.0	30.1	29.8	29.7	29.5	29.7	29.5	29.7	32.0	1.1	0.6	100.6
6/30/2024	16:18:53	30.0	30.0	28.6	30.0	29.7	27.8	29.5	29.4	29.5	29.4	33.0	1.0	0.5	100.5
6/30/2024	16:33:53	28.7	28.6	28.6	28.7	27.8	27.9	27.9	28	27.9	28	31.0	1.0	0.5	100.5
6/30/2024	16:47:15	28.6	28.6	28.2	28.6	27.9	27.8	27.7	27.9	27.7	27.9	30.0	1.1	0.6	100.5
6/30/2024	17:03:53	28.3	28.2	28.2	28.3	27.8	27.9	27.8	27.7	27.8	27.7	29.0	1.2	0.6	100.5
6/30/2024	17:18:53	28.3	28.2	27.8	28.3	27.9	26.9	27.9	27.7	27.9	27.7	25.0	1.1	0.6	100.5
6/30/2024	17:33:53	27.7	27.8	27.4	27.7	26.9	26.6	26.6	26.6	26.6	26.6	22.0	1.1	0.6	100.5
6/30/2024	17:48:53	27.5	27.4	27.8	27.5	26.6	27.8	26.4	26.4	26.4	26.4	24.0	1.1	0.4	100.7
6/30/2024	18:03:53	28.1	27.8	28	28.1	27.8	27.5	27	26.5	27	26.5	23.0	0.8	0.4	100.7
6/30/2024	18:18:53	28.1	28	27.8	28.1	27.5	26.3	26.3	26.3	26.3	26.3	22.0	0.7	0.4	100.7
6/30/2024	18:33:53	27.8	27.8	27.5	27.4	26.3	26	26	26	26	26	22.0	0.9	0.4	100.5
6/30/2024	18:47:15	27.6	27.5	26.3	26.3	26	26	26	26	26	26	23.0	0.9	0.3	100.6
6/30/2024	19:03:53	26.4	26.3	26	26	26	25.2	25.2	25.2	25.1	25.2	21.0	0.8	0.3	100.5
6/30/2024	19:18:53	26.1	26	26	26.1	25.2	24.9	24.9	24.9	24.9	24.9	20.0	0.7	0.3	100.5
6/30/2024	19:33:53	25.3	25.2	25.2	25.1	24.9	24.9	24.8	24.8	24.7	24.8	18.0	0.9	0.3	100.5
6/30/2024	19:48:53	25.2	25.1	24.9	25	24.9	24.8	24.7	24.7	24.7	24.7	15.0	0.9	0.3	100.5

Table 3-1: solar chimney at 1m heigh.

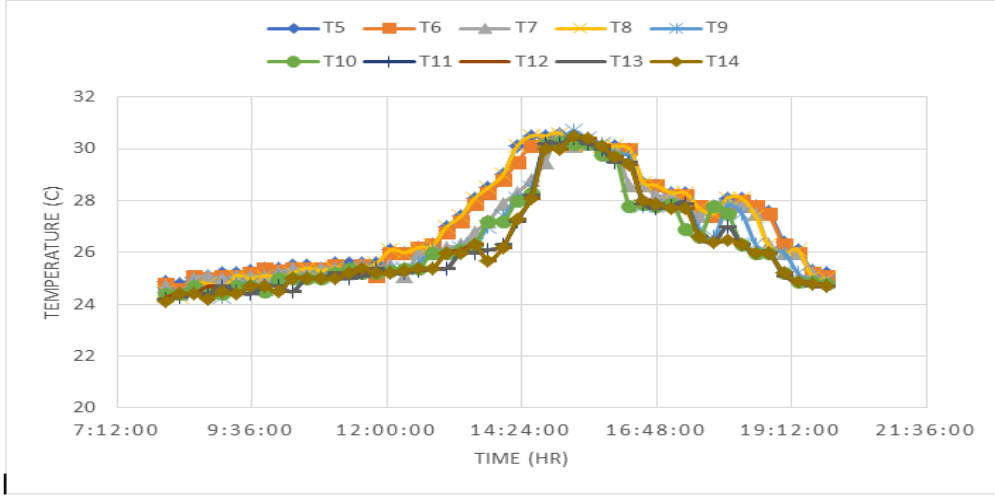

Fig 3.15 Temperatures to time graph for 1 m height

3.3.2 solar chimney at 2m height:

Date	Time	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	RPM1	Current	Voltage	Pressure
6/29/2024	9:02:15	26.9	26.5	26.3	26.8	26.7	25.9	25.9	25.9	25.4	25.8	25.8	25.6	33	1.1	0.7	100.3
6/29/2024	9:17:15	28.1	27.9	27.7	27.5	27.5	27.2	26.9	26.8	26.6	26.6	26.5	26.4	35	1.1	0.8	100.4
6/29/2024	9:32:15	28.2	28.2	28.2	28.2	28.2	28.2	27.8	27.8	27.8	26.9	26.9	26.8	35	1.1	0.7	100.3
6/29/2024	9:47:15	28.4	28.3	28.3	28.6	28.5	28.6	27.9	27.8	27.9	27.7	27.7	27.6	36	1.3	0.7	100.4
6/29/2024	10:02:15	28.4	28.4	28.3	28.2	28.3	27.9	27.8	27.9	27.8	27.7	27.8	27.8	37	1.2	0.8	100.3
6/29/2024	10:17:15	28.7	28.8	28.6	28.6	28.3	28.1	27.9	28.1	27.7	27.9	27.8	28.1	39	1.1	0.7	100.4
6/29/2024	10:32:15	28.8	28.8	28.7	28.5	28.6	28.2	27.8	28.2	27.9	28	28.1	28.1	38	1.2	0.8	100.3
6/29/2024	10:47:15	29	29.1	29	28.5	28.5	28.2	27.9	28.2	28	28	28.1	28.1	39	1.1	0.9	100.4
6/29/2024	11:02:15	29.4	29.4	29.2	29.1	29.2	28.4	28.1	28.4	28	28.1	28.1	28.3	40	1.1	0.9	100.5
6/29/2024	11:17:15	29.3	29.4	29.3	29.2	29.2	28.4	28.3	28.4	28.1	28.1	28.3	28.2	43	1.2	0.8	100.5
6/29/2024	11:32:15	29.5	29.6	29.5	29.1	29.1	28.5	28.2	28.5	28.1	28.3	28.2	28.3	42	1.1	0.8	100.5
6/29/2024	11:47:15	29.7	29.7	29.6	29.1	29	28.7	28.4	28.7	28.3	28.4	28.3	28.4	45	1.3	0.7	100.4
6/29/2024	12:02:15	29.6	29.7	29.7	29.4	29.4	28.8	28.5	28.8	28.4	28.3	28.4	28.6	46	1	0.8	100.5
6/29/2024	12:17:15	29.8	29.9	28.8	29.7	29.7	28.8	28.6	28.8	28.3	28.8	28.6	28.7	47	0.9	0.9	100.5
6/29/2024	12:32:15	29.9	29.9	28.8	29.8	29.8	28.9	28.7	28.9	28.8	29	28.7	28.9	48	1.1	0.8	100.5
6/29/2024	12:47:15	30	30.1	30.1	30	29.8	29.5	29.1	29.5	29	29.1	28.9	28.9	50	1.3	0.8	100.5
6/29/2024	13:02:15	29.9	30.1	30.1	29.9	29.6	29.4	29.6	29.4	29.1	29.2	28.9	28.8	50	1.4	0.9	100.5
6/29/2024	13:17:15	30.2	30.2	30.2	30.2	29.4	29.3	29.2	29.2	29.2	29.1	29.0	28.9	51.0	1.5	1.0	100.5
6/29/2024	13:32:15	31.0	30.9	30.8	29.8	29.7	29.6	29.6	29.5	29.6	29.5	29.2	29.1	53.0	1.4	0.9	100.4
6/29/2024	13:47:15	31.2	31.0	30.9	30.9	30.8	30.8	30.7	30.7	30.6	30.5	30.5	30.1	53.0	1.3	0.8	100.5
6/29/2024	14:02:15	32.1	32.6	32.5	31.5	31.3	31.4	31.4	31.5	31.4	31.5	31.4	30.8	55.0	1.4	0.8	100.5
6/29/2024	14:17:15	32.9	32.7	32.6	32.5	32.1	32.0	32.1	32.0	32.1	32.0	32.1	32.0	55.0	1.5	0.8	100.5
6/29/2024	14:32:15	33.9	33.7	33.2	33.3	33.4	33.3	33.2	33.2	33.3	33.2	33.2	33.1	57.0	1.4	0.7	100.5
6/29/2024	14:47:15	33.2	33.1	33.3	33.2	33.6	33.7	33.6	33.7	33.6	33.7	33.6	33.5	56.0	1.4	0.7	100.5
6/29/2024	15:02:15	33.2	33.2	32.9	32.9	32.3	32.2	32.1	32.2	32.1	32.2	32.1	32.1	55.0	1.3	0.8	100.5
6/29/2024	15:17:15	33.1	33.0	32.8	32.7	32.5	32.5	32.4	32.3	32.2	32.3	32.2	32.0	54.0	1.2	0.8	100.3
6/29/2024	15:32:15	32.3	32.4	32.4	32.2	32.1	32.0	32.1	32.1	32.0	32.1	32.0	32.1	52.0	1.3	0.7	100.4
6/29/2024	15:47:15	32.2	32.1	32.0	32.1	32.1	32.1	32.2	32.0	31.9	32.0	31.9	31.7	51.0	1.4	0.8	100.3
6/29/2024	16:02:15	32.1	32.1	32.0	31.8	31.6	31.5	31.3	31.2	31.2	31.2	31.2	31.0	49.0	1.4	0.8	100.4
6/29/2024	16:17:15	31.5	30.9	31.1	31.0	30.9	30.8	30.7	30.5	30.4	30.5	30.4	30.4	51.0	1.3	0.8	100.3
6/29/2024	16:32:15	31.6	31.0	31.1	30.7	30.6	30.5	30.4	30.4	30.2	30.4	30.2	30.1	52.0	1.2	0.7	100.4
6/29/2024	16:47:15	31.0	30.8	30.7	30.4	30.3	30.2	30.2	30.1	30.0	30.1	30.0	29.7	49.0	1.1	0.8	100.5
6/29/2024	17:02:15	30.1	30.1	30.1	30.0	29.8	29.9	29.8	29.7	29.5	29.7	29.5	29.4	48.0	1.1	0.8	100.3
6/29/2024	17:17:15	30.0	30.1	30.0	29.9	29.8	29.7	29.7	29.6	29.5	29.4	29.3	29.1	45.0	1.0	0.7	100.4
6/29/2024	17:32:15	28.8	28.8	28.7	28.5	28.6	28.2	27.8	28.2	27.9	28	28.1	28.1	45.0	1.0	0.7	100.3
6/29/2024	17:47:15	28.7	28.8	28.6	28.6	28.3	28.1	27.9	28.1	27.7	27.9	27.8	28.1	43.0	1.1	0.6	100.4
6/29/2024	18:02:15	28.4	28.4	28.3	28.2	28.3	27.9	27.8	27.9	27.8	27.7	27.8	27.8	44.0	1.2	0.6	100.3
6/29/2024	18:17:15	28.4	28.3	28.3	28.6	28.5	28.6	27.9	27.8	27.9	27.7	27.7	27.6	42.0	1.1	0.6	100.4
6/29/2024	18:32:15	28.1	27.9	27.7	27.5	27.5	27.2	26.9	26.8	26.6	26.6	26.5	26.4	41.0	1.1	0.6	100.5
6/29/2024	18:47:15	27.9	27.8	27.5	27.5	27.3	27.2	26.6	26.7	26.4	26.4	26.3	26.1	39.0	1.1	0.7	100.5

Table 3-2: solar chimney at 2m heigh.

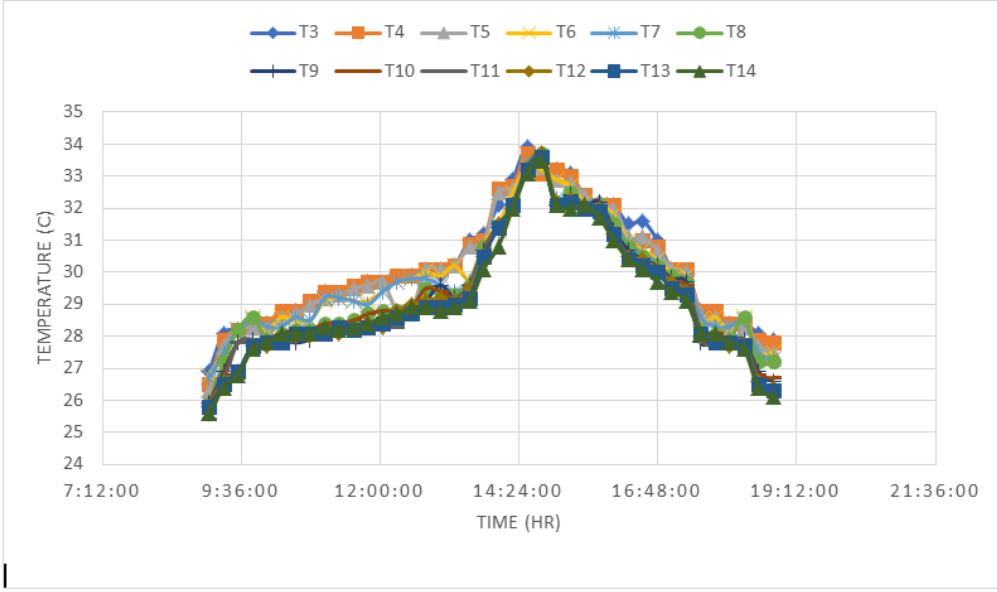

Fig 3.16 Temperatures to time graph for 2m height

3.3.3 solar chimney at 3m height:

Date	Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	RPM1	RPM2	Current	Voltage	ressure
27/6/202	13:14:32	30.2	30.1	30.1	30.0	29.8	29.5	29.4	29.3	29.2	29.2	29.2	29.1	29.0	28.9	40	26	1.1	0.7	100.5
27/6/202	13:29:32	31.2	31.1	31.0	30.9	30.8	29.8	29.7	29.6	29.6	29.5	29.6	29.5	29.2	29.1	51	34	1.1	0.8	100.5
27/6/202	13:44:32	32.2	31.4	31.2	31.0	30.9	30.9	30.8	30.8	30.7	30.7	30.6	30.5	30.5	30.1	55	36	1.2	0.8	100.5
27/6/202	13:59:32	33.4	32.5	32.1	32.6	32.5	31.5	31.3	31.4	31.4	31.5	31.4	31.5	31.4	30.8	66	44	1.3	0.9	100.5
27/6/202	14:14:32	33.8	33.1	32.9	32.7	32.6	32.5	32.1	32.0	32.1	32.0	32.1	32.0	32.1	32.0	69	46	1.5	0.9	100.5
27/6/202	14:29:32	34.3	34.2	33.9	33.7	33.2	33.3	33.4	33.3	33.2	33.2	33.3	33.2	33.2	33.1	71	47	1.9	0.9	100.5
27/6/202	14:44:32	33.4	33.3	33.2	33.1	33.3	33.2	33.6	33.7	33.6	33.7	33.6	33.7	33.6	33.5	67	43	1.8	1.0	100.5
27/6/202	14:59	33.2	33.2	33.2	33.2	32.9	32.9	32.3	32.2	32.1	32.2	32.1	32.2	32.1	32.1	65	42	1.7	1.1	100.6
27/6/202	15:14:32	33.3	33.2	33.1	33.0	32.8	32.7	32.5	32.5	32.4	32.3	32.2	32.3	32.2	32.0	63	42	1.6	1.0	100.6
27/6/202	15:29:32	32.5	32.4	32.3	32.4	32.4	32.2	32.1	32.0	32.1	32.1	32.0	32.1	32.0	32.1	65	40	1.4	1.0	100.6
27/6/202	15:44:32	32.5	32.3	32.2	32.1	32.0	32.1	32.1	32.1	32.2	32.0	31.9	32.0	31.9	31.7	61	41	1.3	1.0	100.5
27/6/202	15:59:32	31.9	32.0	32.1	32.1	32.0	31.8	31.6	31.5	31.3	31.2	31.2	31.2	31.2	31.0	57	35	1.3	0.9	100.5
27/6/202	16:14:32	31.8	31.7	31.5	30.9	31.1	31.0	30.9	30.8	30.7	30.5	30.4	30.5	30.4	30.4	55	33	1.2	0.8	100.5
27/6/202	16:29:32	32.0	31.9	31.6	31.0	31.1	30.7	30.6	30.5	30.4	30.4	30.2	30.4	30.2	30.1	57	34	1.1	0.9	100.5
27/6/202	16:44:32	31.0	31.0	31.0	30.8	30.7	30.4	30.3	30.2	30.2	30.1	30.0	30.1	30.0	29.7	54	30	1.2	0.8	100.5
27/6/202	16:59:32	30.2	30.1	30.1	30.1	30.1	30.0	29.8	29.9	29.8	29.7	29.5	29.7	29.5	29.4	51	29	1.1	0.7	100.5
27/6/202	17:14:32	30.1	30.0	30.0	30.1	30.0	29.9	29.8	29.7	29.7	29.6	29.5	29.4	29.3	29.1	50	27	1.0	0.7	100.4

Table 3-3: solar chimney at 3m heigh.

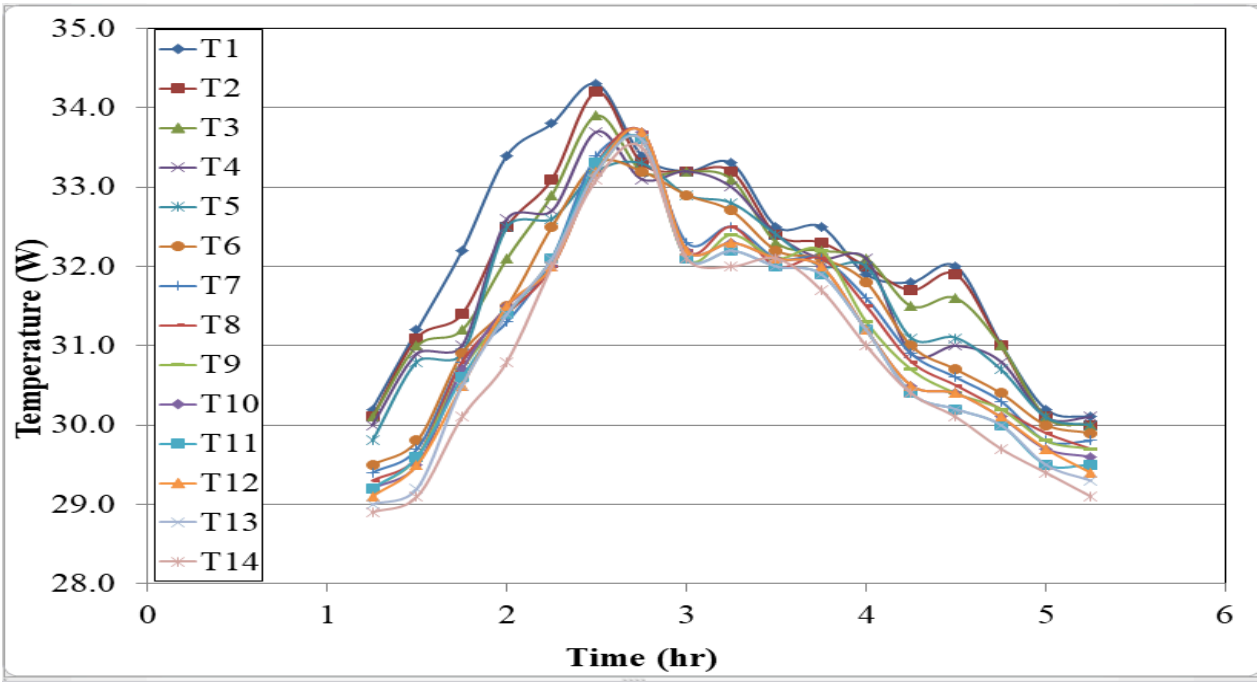

Fig 3.17 Temperatures to time graph for 3m height

Chapter four

4. CONCLUSION

In this project, a solar chimney power plant was designed and built with a chimney height of 3 meters and a collector octagonal diameter of 5 meters. The project demonstrated a successful conversion of solar energy into power. Temperature sensors placed at regular intervals along the collector and chimney provided crucial data on temperature gradients, optimizing plant efficiency. Temperature variations were monitored using DS18B20 sensors placed at 0.5 meter intervals along collector and the chimney. Additionally, DC current and voltage sensors were used to measure turbine power output, while an air flow sensor assessed airflow exiting the chimney, enabling precise system control.

Analysis of collected data revealed a direct relationship between turbine power output and temperature difference between collector and chimney. Maximizing this temperature differential is the key of enhancing energy production. The air flow sensor provided vital data on chimney airflow, identifying inefficiencies and guiding system adjustments to improve overall performance.

In conclusion, this solar chimney power plant, with its specified dimensions and sensor setup, shows promising potential for sustainable energy production. It offers a reliable, environmentally friendly alternative for electricity generation, contributing valuable insights to renewable energy research and development.

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