ACADEMICIA

ISSN: 2249-7137 Vol. 11, Issue 10, October 2021 Impact Factor: SJIF 2021 = 7.492

ACADEMICIA
An International Multidisciplinary Research Journal
(Double Blind Refereed & Peer Reviewed Journal)

DOI: 10.5958/2249-7137.2021.02094.2

# A LOOK AT HOW SOLAR CHIMNEY INTEGRATED SYSTEMS MAY BE USED FOR ROOM HEATING AND COOLING

**Dr. Aniket Kumar*; R.K. Jain**; Mr. Hamid Ali*****

[1, 3]School of Electronics Electrical & Mechanical Engineering,
Faculty of Engineering and Technology,
Shobhit Institute of Engineering and Technology,
(Deemed to be University), Meerut, INDIA
Email id: aniket.kumar@shobhituniversity.ac.in, [3]hamid.ali@shobhituniversity.ac.in

**School of Humanities, Physical & Mathematical Sciences,
Faculty of Engineering and Technology,
Shobhit Institute of Engineering and Technology,
(Deemed to be University), Meerut, INDIA
Email id: Rakesh.jain@shobhituniversity.ac.in

## ABSTRACT

*In the residential sector, traditional indoor climate comfort systems account for a significant portion of energy usage. Passive design is a method of lowering building energy demand by reducing the amount of electricity used by mechanical systems. Solar chimneys are an unique passive architecture that uses solar energy to build up stack pressure as natural draught components. The installation of a solar chimney increases the efficiency of domestic space heating and cooling while also lowering greenhouse gas emissions. This article gives a summary of current developments in the field of solar chimney research. To enhance the degree of thermal comfort, the building industry has a propensity to use integrated solar chimney designs. The most frequent solar chimney-based integrated setups were summarized in this article. In addition, each system's difficult elements and suggestions were discussed. Combined energy systems based on solar chimneys have long been considered as effective green building design solutions. Each system has its own set of advantages and disadvantages, and there is no universal standard for ranking these systems in order of performance. More trials are needed to address issues that may arise in their commercial uses. More research is needed in order to create optimization methods and control systems. A desired control system reacts to residents'* *demands in an unobtrusive manner, allowing them to alter a state if it is deemed thermally unpleasant, and provides quick feedback.*

**KEYWORDS:** *Solar Chimney Earth-Air Heat Exchanger Phase Change Material (PCM) Cooling Cavity Water Spraying System Trombe Wall.*

## 1. INTRODUCTION

Buildings account for a significant portion of global and regional energy consumption. Heating and cooling account for a broad range of percentages of total building energy consumption, ranging from 18 percent to 73 percent globally. Researchers were worried about new methods for decreasing energy consumption in building design a few decades ago. Bioclimatic design, for example, entails the use of energy-saving methods in building construction in conjunction with the use of renewable energy sources such as solar energy [1]. One difficult issue is achieving thermal comfort via bioclimatic architecture. It has a large overall environmental effect and may contribute considerably to climate change. All structures were naturally ventilated until the advent of modern mechanical systems. Since energy and the environment have become two major concerns in building design, scientists have taken a keen interest in reviving old architecture. The solar chimney (SC) is one of the earliest passive ventilation techniques. It has been used for millennia, most notably by the Persians in the Middle East and the Romans in Europe. It is a new design that maximizes ventilation effect by generating a significant temperature increase in the chimney in order to allow solar radiation to pass through Solar chimneys, Trombe walls, and double-skin facades all work in the same way because they are open chambers that use insolation to induce air flow. The Trombe wall is a huge structure that is primarily used to heat the building.

However, with the right adjustments, cooling may be accomplished as well. Solar chimneys are mostly used to improve night ventilation, although they may also be utilized during the day. They may be connected to the building's walls or placed on the roof. The most frequent chimney design is vertical. However, it has a detrimental effect on the building's aesthetics. As a result, laying the collector along the roof slope is both less expensive and less visible. The use of a solar chimney is not restricted to residential or commercial structures. For livestock housing, Rahman and Chu suggested a natural draft chimney instead of artificial ventilation. Reduced ventilation costs resulted in increased chicken production efficiency and profitability. Industrial locations have distinct design elements and comfort criteria, which are outside the scope of this article. According to the literature review, there is a substantial amount of literature on SC. There has been a rising interest in implementing new methods that take use of solar chimney integrated systems in recent years. Integrated space heating/cooling systems have been the subject of a few studies. As a result, the goal of this paper is to contribute to recent advancements in solar chimney use for building ventilation.

Furthermore, it demonstrates the potential and efficacy of future solar chimney-based integrated systems [2]. The section is organized in a logical order, beginning with an overview of the analytical and numerical advances of solar chimneys and ending with references to experimental research in the area. Section 3.1 contains a detailed description of the EAHX-SC system; Section 3.2 discusses PCM-enhanced solar chimneys; discusses water consuming systems based on SCs; and Section 3.4 concludes with a brief report on PV-based solar chimneys. . Solar chimney independent building applications The use of wind or sun energy for ventilation became outdated in the twentieth century as mechanical ventilation systems became more widely available and people's lifestyles changed. As a consequence, prior to the 1980s, solar chimney research and development was rather restricted. The issue of decreasing greenhouse gas emissions and the necessity for effective ventilation has reawakened interest in solar chimneys in recent decades. Many current studies focus on model experiments and theoretical examinations to investigate the effects of solar chimney design, orientation, and climatic factors on ventilation performance. The primary goal of most solar chimney research was to improve natural ventilation by using various design factors. The breadth of the chimney, stack height, chimney orientation, and absorber materials, for example, were all of practical concern. According to Khanal and Lei's study, the majority of works in this field were based on pure experiments or an experimental method combined with numerical modeling. The experimental findings of Afonso and Oliveira revealed that the breadth of the chimney had a greater impact on ventilation rate than its height.

According to Mather and Mathura the optimal absorber inclination angle ranges between 40° and 60° depending on the location latitude. While Hamdy and Fikry discovered that the optimal tilt angle of a solar collector needed to give the greatest ventilation efficiency for their experimental model was 60°, Mathur and Mathur showed that this inclination angle was about 45°. For winter applications, the optimal tilt angle results in a small increase in chimney air flow rate, thus it may not be worth the risk of building instability. The increased ventilation rate during the summer months, on the other hand, is noteworthy, and choices must be taken with care. Ong [10] created a mathematical model of a wall-type solar chimney that was stable. The model anticipated the solar chimney's thermal performance as well as the velocity of air flow down the chimney. For chimneys with a gap-to-height ratio smaller than 1:10, analytical modeling of velocity and temperature profiles in the chimney demonstrated excellent agreement with previous tests. It seems that obtaining steady state radiation is challenging due to the variable nature of solar irradiation. Mart and HerasCelemin developed a dynamic model for assessing the solar chimney's performance using real-time meteorological data. The SC's potential for providing nighttime ventilation in Mediterranean regions was also discussed. Lee and Strand investigated the effects of chimney height, absorber wall solar absorption, glass cover solar transmittance, and air gap width under various climate conditions. Among the four input factors, it found out that the air gap width had the least effect on ventilation improvement. A tiny solar chimney with an absorber length smaller than 1 m was proposed by Mathur and Bansal. Because it could be integrated in a normal window without requiring significant structural changes, the system installation took precedence over the previous designs. Their thorough study also showed that when the air gap was expanded, the airflow rate rose. The air volume supplied to or withdrawn from a place (usually a room or home) divided by the volume of the space is measured in air change per hour (ACH). The temperature would approach the ambient if the amount of air supplied to the interior areas was adequate. Natural ventilation offers thermal comfort for occupancy at an ambient temperature of 20–26 °C [3]. There is no universal formula for determining the ideal ACH for a naturally ventilated home. The fact that ACH is dependent on a variety of architectural factors such as building layout, resident count, and building purpose makes it a difficult component to manage. The majority of the research [did not use an optimum number to calculate its value.

Computational fluid dynamic (CFD) techniques grew in popularity in solar chimney research as rapid numerical systems were developed. In most cases, CFD gives all essential flow statistics throughout the whole area of interest. Pressure fluctuations and heat distribution in the chimney are of practical relevance in the case of a solar chimney. Laminar flow algorithms were created to model airflow and heat transfer in the solar chimney before the introduction of commercial software packages. The solar chimney's flow characteristics are more akin to a turbulent flow regime. The accurate description of turbulence modeling in the literature is given special attention. k − models are believed to present more accurate forecasts of velocity and temperature profiles\sas reported by experiments. The k models outperformed the other models for boundary layer flows under unfavorable pressure gradients, according to this study. As a result, they have become the primary research technique in solar chimney studies. In contrast to a one-dimensional approach, a multi-dimensional analysis supported by the CFD technique can capture prevailing flow phenomena like reverseflow. When air entrainment happens at the chimney outlet and air penetrates lower into the chimney, reverse flow occurs. Reverse flow through the solar chimney should be avoided because it reduces the flow rate, which is undesirable for ventilation. Khanal and developed an inclined passive wall solar chimney design with an inclined passive wall (glazing) and a vertical active wall (absorber) to avoid reverse flow (IPWSC). The research confirmed that there is an optimal chimney height-to-gap ratio for suppressing reverse flow and inducing maximum ventilation rate [3].

## 2. DISCUSSION

### *2.1.APPLICATION:*

Solar chimney, in contrast to natural stack ventilation methods that may result in a poor stack effect, is clearly more promising. because it enhances the temperature differential between inside and outside Increasing solar gain is one way to do this. One of the most significant advantages of a SC is that it may be utilized forth need for cooling and the supply of cooling in space is referred to as space cooling. The insulation is in full swing. Solar chimneys are usually thought to be inappropriate for residential use. areas with low levels of solar radiation or hot, dry climates However, by combining a wall and a roof solar chimney, AboulNaga and Abdrabboh [enhanced the chimney night ventilation efficiency. The air flow rate was three times higher than that of a normal person. Rooftop solar chimney on its own The system was placed on a single home in the United States.Al-Ain is a city in the United Arab Emirates. The height of the ideal wall chimney in relation to the with an intake height of 3.45 m, the maximum air flow rate (almost 2.3 m /s 3) was achieved. a distance of 0.15 m for a flat volume, an ACH number of up to 26 was obtained. It is sufficient to overcome the significant cooling load for aim a hot environment, construction is necessary. Rachapradit Khedari, Rachapradit Kediri, Rachapradit Kediri, Rachapradit Khedari, Rachapradit Khedari, in a single-room home (25 $m^3$) with an air conditioner (AC), there is a chimney. Bangkok is the capital of Thailand. The home with the solar chimney had a lower average temperature. Compared to a standard AC, an AC consumes 10–20 percent less electricity. House. The size of the solar chimney aperture was utilized to regulate the ventilation rate. An experimental study revealed that a 5 $cm^2$ opening for When used with an air conditioner, the SC unit was the most efficient. A SC was built on the top of a 12 m3 cabin room by Imran, Jalil. Iraq. The chimney was 2 m wide and long, with three distinct airflows.50, 100, and 150 mm gap thicknesses The ideal inclination angle into get the greatest air flow rate, the angle was set to 60°. The system has the potential to cause This area requires 4–35 air changes each hour. It may be put to good use as a storage area. Mechanical ventilation is not required for cooling. Figure 1 shows the Structure of double pass roof solar collector. (a) Space heating mode (b) Natural ventilation mode. Dampers are indicated by Latin numerals- Tuyeres are indicated by Roman numerals- AC1 air channel 1- AC2 air channel 2- IP insulation plate- AP absorber plate- GC glass cover [4].

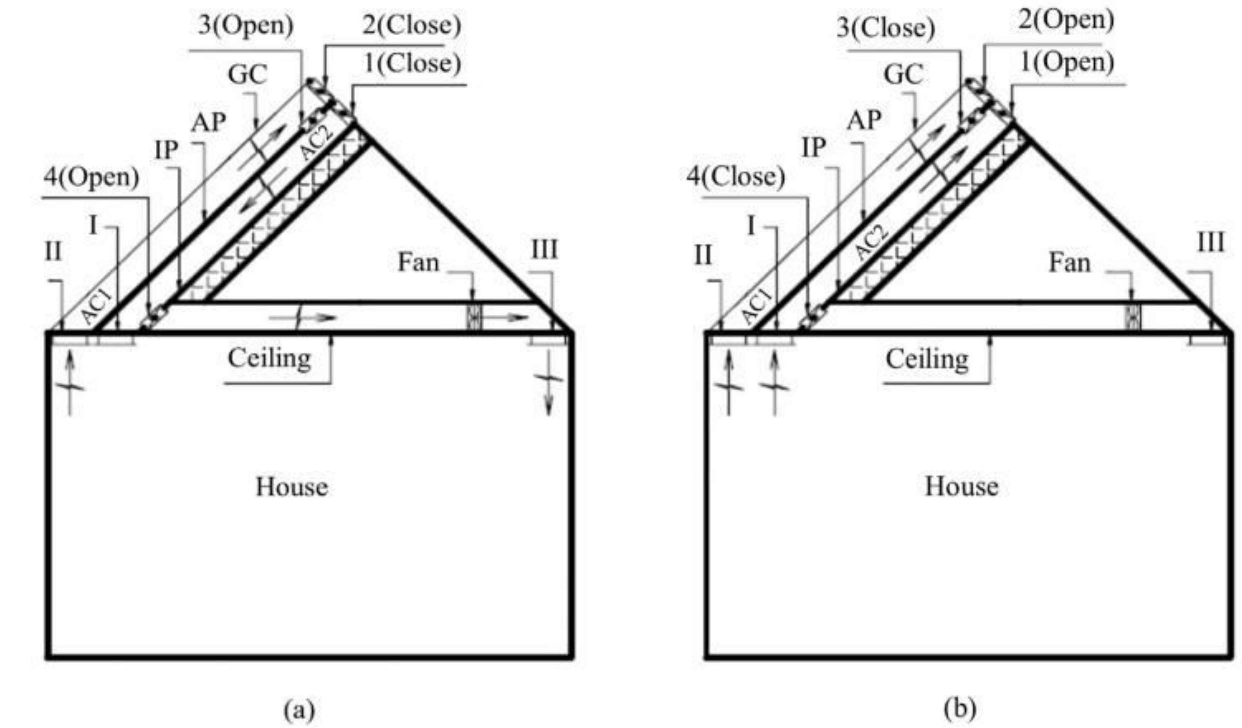


**Figure 1: Structure Of Double Pass Roof Solar Collector. (A) Space Heating Mode (B) Natural Ventilation Mode. Dampers Are Indicated By Latin Numerals- Tuyeres Are Indicated By Roman Numerals- AC1 Air Channel 1- AC2 Air Channel 2- IP Insulation Plate- AP Absorber Plate- GC Glass Cover.**

*2.2. ADVANTAGE:*

Solar chimney, in contrast to natural stack ventilation methods that may result in a poor stack effect, is clearly more promising. because it enhances the temperature differential between inside and outside Increasing solar gain is one way to do this. One of the most significant advantages of a SC is that it may be utilized forth need for cooling and the supply of cooling in space is referred to as space cooling. The insulation is in full swing. Solar chimneys are usually thought to be inappropriate for residential use. Areas with low levels of solar radiation or hot, dry climates However, By combining a wall and a roof solar chimney, AboulNaga and Abdrabboh enhanced the chimney night ventilation efficiency. TheThe air flow rate was three times higher than that of a normal person. Rooftop solar chimney on its own The system was placed on a single home in the United States.Al-Ain is a city in the United Arab Emirates[5]. The height of the ideal wall chimney in relation with an intake height of 3.45 m, the maximum air flow rate (almost 2.3 m /s 3) was achieved. a distance of 0.15 m. For a flat volume, an ACH number of up to 26 was obtained.(321 meters)3 It is sufficient to overcome the significant cooling load for aIn a hot environment, construction is necessaryRachapradit Khedari, Rachapradit Kediri, Rachapradit [6] Khedari, Rachapradit Kediri, Rachapradit Khedari,In a single-room home (25 m )3 with an air conditioner (AC), there is a chimney.Bangkok is the capital of Thailand. The home with the solar chimney had a lower average temperature. Compared to a standard AC, an AC consumes 10–20 percent less electricity house. The size of the solar chimney aperture was utilized to regulate the ventilation. rate. An experimental study revealed that a 5 cm2 opening for When used with an air conditioner, the SC unit was the most efficient. A SC was built on the top of a 12 m3 cabin room by Imran, chimney was 2 m wide and long, with three distinct airflows.50, 100, and 150 mm gap thicknesses The ideal inclination angle isTo get the greatest air flow rate, the angle was set to 60°. The system has the potential to causeThis area requires 4–35 air changes each hour. It may be put to good use as a storage area. Mechanical ventilation is not required for cooling [7].

*2.3. WORKING:*

According to the studies described above, the bulk of solar chimney research focused on passive cooling. However, in certain areas, space heating is more important than natural cooling, particularly during the winter. Because SC works better for space cooling, there are few SC applications for space heating in the literature. The use of a solar chimney for space heating was shown by Haghighi and Maerefat. They demonstrated a computer simulation of natural convection in a 2D chamber with a chilly exterior environment. The numerical modeling was compared to previous experimental and numerical studies published in the literature. A parametric analysis was also conducted to obtain a better understanding of the factors that affect ACH and room air temperature. The findings indicated that optimizing the air gap, inlet, and outlet sizes resulted in a maximum ACH of 0.2 m for a space measuring 4.0 m 4.0 m 3.125 m without air in filtering. The effect of ambient air temperature on ACH is likewise shown to be insignificant. Furthermore, the system seemed to be capable of delivering a pleasant interior environment despite a low solar intensity of 215 W/m 2 and a low ambient temperature of 5 °C. The SC systems previously described were just cooling or heating devices. The use of SC for both space heating and cooling is a unique design. Zhai, Dai [28] proposed a feasible configuration that may decrease heating and cooling demand throughout the year without adding complexity to the system. They looked at a single-pass roof solar collector and a double-pass roof solar collector that were both placed on a single typical Chinese common home. Roof solar collectors were solar air collectors with a single or double pass that were placed on the building's roof. The double pass roof solar collector, which was created by combining a double pass solar air collector with the building's southern roof. Dampers 1, 2, 3, and 4 were placed to transition between space heating and natural ventilation in the winter and summer, respectively. Indoor air may enter air channel 1 (AC1) via tuber II, acquiring heat from sun radiation, by shutting dampers 1 and 2 and then opening dampers 3 and 4. Then it goes into air channel 2 (AC2), where the absorber plate heats it up. It pours into the air duct once tuyere I am closed. The heated air is blown into the room by the fan via tuyere III. The space is naturally ventilated thanks to the reverse cycle. Indoor air enters air channels 1 and 2 via tuyeres I and II, respectively, by shutting dampers 3 and 4 and opening dampers 1 and 2. Because the air in the channel heats up and rises, the stack effect will ultimately appear. The findings revealed that a two pass roof solar collector performed better for both room heating and natural ventilation. It has a 10 percent better immediate efficiency than a single pass roof solar collector. A number of papers in the literature have been examined. Various research techniques to handle different elements of a SC design may be found in the literature.

Application for Author Location Methodology is a key argument. Performance at high inclination degrees and gap widths (major findings/observations)Thailand • In a hot humid environment, a comparison of air velocity and temperature distribution in the SC with dry air and wet air Modeling of CFD numerically[8] • With the exception of a slight increase in air temperature, increasing the air relative humidity reduces air velocity at the inlet and outlet of the chimney • The air temperature distribution is relatively similar to the dry-air model • A small opening height-to-gap ratio of 0.25 is recommended for SCs with moist air hang, he Cooling of the space To explore SC airflow rate, a plume model based on energy balances and thermal boundary layer theory is being developed. Modeling and analysis • Unlike previous analytical models, the plume model considers both vertical and horizontal density changes throughout the chimney. Six experimental data sets were selected for plume model validation. For reasonably high velocity circumstances, a turbulent boundary layer may be added to the plume model to enhance it even further. The plume model produced encouraging results in terms of forecasting SC air flow rate and indicating the presence of the ideal chimney gap width. The model's inability to anticipate complex flow phenomena such as reverse flow is one of its limitations. Solar chimney independent building applications as space heating or cooling methods were discussed in the preceding introduction. For at least two reasons, the effectiveness of a natural ventilation system is directly dependent on the residents. First and foremost, the inhabitants must be warm and comfortable. Second, they are likely to have some influence over the system. Integration of solar chimney with other technologies is recommended to significantly improve its performance for the aim of increasing interior thermal comfort. The goal of this article is to go through the most popular solar chimney-based integrated systems.

In most cases, integrated systems were followed by a consideration of their basic features and suggestions for improving the system in order to create a more sustainable future. Pipes placed several meters under the earth, using soil as a natural consistent temperature source, are an innovative way to circulate air throughout the structure. The earth's undisturbed temperature refers to the temperature of the soil 2–3 meters under the surface, which is mostly stable. In the winter, this temperature is greater than the surface temperature, and in the summer, it is lower. An earth air heat exchanger (EAHX)[9] is a technology that may be used to improve ventilation via a cooling or heating effect. Mihalakakou and Santamouris proposed a comprehensive numerical model for predicting EAHX thermal performance. Their model was created in the TRNSYS environment and could be used for future study with ease. The pipe length, pipe radius, air velocity, soil depth, and the temperature differential between ambient air and soil all have a significant influence on EAHX performance. The heat transfer capacity may be increased by increasing the burial depth and length of the pipes, as well as lowering the airflow rate. According to Bansal and Misra, the material of underground pipes had no effect on EAHX performance, thus a less expensive piping material is acceptable. To simulate the EAHX, Ramrez-Dávila and created a three-dimensional finite volume CFD algorithm. Three climatic conditions were studied: one with severe heat in the summer and low temperatures in the winter (Ciudad Juárez, Chihuahua), another with moderate weather (Mexico City), and the third with hot weather (Merida, Yucatán). For the cities of Cads. Juárez, México City, and Mérida, simulations were performed for sand, silt, and clay soil textures, respectively. According to them, the EAHX potential for space heating and natural ventilation may be quite different. In Cads. Juárez and México City, the average air temperature decreased by 6.6 and 3.2 degrees Celsius in the summer and increased by 2.1 and 2.7 degrees Celsius in the winter, respectively. Mérida EAHX winter thermal performance, on the other hand, was superior to its cooling effect [10].

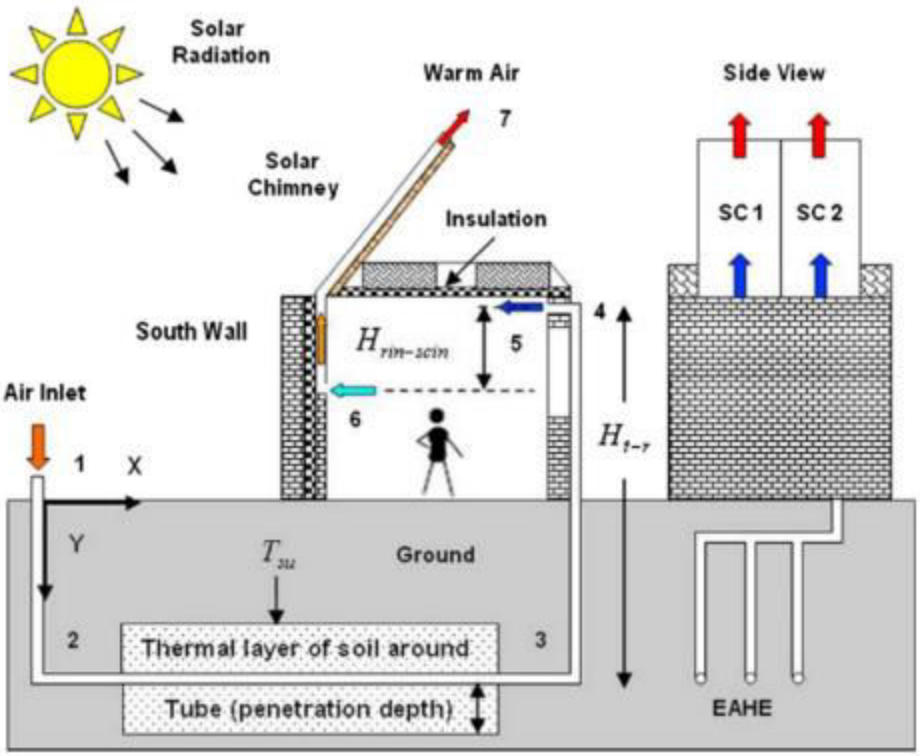


**Figure 2: Schematic diagram of integrated earth-air heat exchanger and solar chim.**

## 3. CONCLUSION

The use of a solar chimney as a passive technique to improve natural ventilation and therefore decrease the demand for supplemental energy for thermal comfort is highly recommended. Solar chimneys have been widely researched computationally and experimentally during the past several decades. Solar chimneys are ineffective in hot, dry, or humid climates, as well as in areas with little insulation. As a result, research into the creation of a combination system may be an option. To combine solar and geothermal energy, a solar chimney with an earth-air heat exchanger is recommended. The system is chosen primarily because it can provide room heating in the winter and cooling in the summer. Its application, however, is highly reliant on the latitude and altitude of the site, as well as the soil type, water table, soil moisture, and structure design. A model that is optimized based on parametric analyses of the coupled system would disclose even more about the system's efficacy. Further study, including the impact of ice formation in the winter, dynamic functioning, and real-world experimental settings, is needed to fully comprehend the system's performance.PCM has been studied for heating and cooling applications in buildings since the 1930s. Because PCM can only affect these factors, the temperature of the air and surrounding surfaces are the main parameters of human comfort needs for PCM-technology. The study on incorporating PCM with a solar chimney was discussed in this article. PCM's ability to minimize temperature variations, particularly peak temperatures, makes it a good choice for solar chimney construction. The incorporation of PCM in SC is the simplest and most cost-effective of the suggested setups. Further study on the selection of the appropriate PCM for the system is needed. Because appropriate ventilation is a top priority, the designer is keen to develop a situation in which an EAHXSC system is equipped with PCM in future study. It should be emphasized that in order to convince building users, the performance of a PCM-enhanced SC should be evaluated in real-world scenarios. As a result, it seems that further research in this area is required.

Solar chimney-based water-consumption systems are best suited to areas with a hot and dry environment. The system may be configured in a variety of ways. Water-consuming systems substantially improve the solar chimney's thermal efficiency. The absence of adequate accessible water resources to satisfy water demands within an area is the most significant drawback for broad public usage of the linked system. As a result, designing the least-water-consuming and most-optimized system is a difficult task.In the literature, hybrid photovoltaic-thermal (PV/T) systems have received a lot of attention. Combining photovoltaic panels with a roof solar chimney is a novel concept. The system's capacity to improve ventilation while also generating energy makes it a suitable design. The suggested systems' architecture includes uncontrollable factors such as weather and local attitudes. Physical processes are involved, and they are complex. Furthermore, key factors like as wind pressures, interior temperatures, and building leaks may all be subject to significant error. The first law of thermodynamics or energy analysis was used to examine all of the aforementioned integrated systems. Energy efficiencies, on the other hand, are unable to tell us how close a system's performance is to perfection. Energy analysis reveals the possibility of better matching the energy supply and demand. N. Monghasemi, A. Vadiee Renewable and Sustainable Energy Reviews Exergy may also be thought of as a meeting point for energy, the environment, and the economy. This may be a good chance for research to compare SC integrated systems based on energy analysis. The investigation of these systems is still under progress. As a result, there is no strict judgment at this level to determine which system is better. It is determined that each system has its own set of advantages and disadvantages that may be appropriate for one area but not for another.

**REFERENCES**

**1.** N. Monghasemi and A. Vadiee, “A review of solar chimney integrated systems for space heating and cooling application,” *Renewable and Sustainable Energy Reviews*. 2018.

**2.** Y. Gao, J. Liu, X. Yuan, K. Zhang, Y. Yang, and Y. Wang, “Air-conditioning system with underfloor air distribution integrated solar chimney in data center,” in *Procedia Engineering*, 2017.

**3.** L. Zuo, Y. Yuan, Z. Li, and Y. Zheng, “Experimental research on solar chimneys integrated with seawater desalination under practical weather condition,” *Desalination*, 2012.

**4.** M. A. Aurybi, S. I. Gilani, H. H. Al-Kayiem, and A. A. Ismaeel, “Mathematical evaluation of solar chimney power plant collector, integrated with external heat source for non-interrupted power generation," *Sustain. Energy Technol. Assessments*, 2018.

**5.** Y. Wang, Z. Fang, L. Zhu, Z. Yang, J. Wang, and L. Han, "Study on the integrated utilization of seawater by solar chimney," *Taiyangneng Xuebao/Acta Energiae Solaris Sin.*, 2006.

**6.** S. Lal and S. C. Kaushik, "CFD simulation studies on integrated approach of solar chimney and borehole heat exchanger for building space conditioning," *Period. Polytech. Mech. Eng.*, 2018.

**7.** Z. L. Fang, J. G. Kong, L. Zhu, Y. P. Wang, and Q. W. Huang, "Property of airflow under collector of integrated solar chimney system," *Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/Journal Tianjin Univ. Sci. Technol.*, 2008.

**8.** O. Manca, S. Nardini, P. Romano, and E. Mihailov, "Numerical investigation of thermal and fluid dynamic behavior of solar chimney building systems," *J. Chem. Technol. Metall.*, 2014.

**9.** G. Quesada, D. Rousse, Y. Dutil, M. Badache, and S. Hallé, "A comprehensive review of solar facades. Opaque solar facades," *Renewable and Sustainable Energy Reviews*. 2012.

**10.** S. Lal, S. C. Kaushik, and P. K. Bhargav, "Solar chimney: A sustainable approach for ventilation and building space conditioning," *Int. J. Dev. Sustain.*, 2013.