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<https://doi.org/10.5109/6625729>

出版情報 : Evergreen. 9 (4), pp.1181–1202, 2022–12. 九州大学グリーンテクノロジー研究教育センター

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Review of Hybrid Photovoltaic- Air Updraft Solar Application: Present and Proposed state Models

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(Received October 2, 2022; Revised December 12, 2022; accepted December 15, 2022).

Abstract: Similar to any solar conversion application into electrical power, the photovoltaic panel performance is suffering from the high temperature and when it is mounted in hot-dry climates. One method to overcome these setbacks is to marry the PV panel with a solar air updraft system, which led to a decline in its temperature by upgrading the air mass flow facing the PV-panel. This paper presents a comprehensive review of the hybrid Photovoltaic- Air Updraft Solar models. The review presents and discusses the compounds and experimental and theoretical studies that were carried out on the existing PV- solar air updraft models. In addition, the paper proposed a new solar air updraft technique by coupling the PV panel with a swirling air generator. The proposed model is simple and more efficient than the conventional solar air updraft design, leading to higher PV panel cooling performance.

Keywords: Solar Artificial Vortex Engine, Solar radiation, Solar Air Updraft Technology, Hybrid Photovoltaic - Air Updraft.

1. Overview

Man has been utilizing solar energy—the light and heat that the sun emits—since the dawn of time through a variety of continually developing technologies. Other ways to use solar energy include the thermal energy from the sun, whether for direct heating or as part of a mechanical conversion process for movement or electrical energy or to generate electricity through photovoltaic phenomena using photovoltaic panels¹⁻⁴). In addition to architectural designs that rely on the use of solar energy, which are techniques that can significantly contribute to solving some of the most pressing problems the world is currently experiencing⁵). Because they have the least detrimental impact on the environment, renewable energy sources like hydropower, wind, and solar are appealing to nations all over the world⁶). Renewable energy⁷⁻¹¹) sources are a very important resource in the present and future eras, so many researchers seek to develop and improve well-known energy sources such as solar energy^{5,12-19}) and wind energy²⁰⁻²⁹).

In this research, a hybrid integrated PV Panel integrated with a solar air updraft system is reviewed; the first section presented the concept of PV solar cells and the most important influences on the efficiency of energy productivity by presenting a group of previous studies. The second part is the concept of Hybrid Solar Chimney-PV in terms of the applications and uses of the system by presenting previous studies by a group of researchers.

Either in the third part clarify the concept of Solar Vortex Engine SVE also by reviewing previous studies. In the fourth section, the research presents its conclusions in light of previous studies. In the conclusion, the research presents the proposed model with a summary of the research.

2. Solar panel technology and cooling methods

The solar cell, or photovoltaic, was called a "solar battery" in the early days of its manufacture, but it has a completely different meaning now³⁰). A system that uses the photovoltaic effect to directly convert solar energy into electrical energy. Its main component is a silicon layer, to which additional impurities have been introduced to give it some electrical qualities. The bottom layer, known as P, has the ability to absorb electrons thanks to the boron element. When solar radiation hits the top layer, electrons release energy that varies with the solar radiation's strength. As one of the auxiliary alternatives to conventional energy sources like petroleum, coal, gas, and their derivatives, which are finite in nature and subject to depletion due to their massive depletion, solar cells are crucial for providing spacecraft and satellites with electrical energy they require. That causes environmental contamination, has a life expectancy of up to 30 years, and the primary barrier to its utilization is the cost of manufacture. Fig. 1 shows a semiconductor device (PN

junction) that converts light energy (photons) to electrical energy (DC)³¹⁾.

It offers the advantage of not having any moving parts that may fail. As a consequence, it works over satellites with great efficiency, especially as it does not require maintenance, repairs, or fuel because it operates silently, although dirt on the solar cells caused by pollution or dust reduces their performance, necessitating periodic cleaning^{32–36)}. Solar cells can be divided into three types, as follows:

❖ **Monocrystalline solar cells:** These are cells constructed from a single crystal of silicon, and their efficiency ranges from 11 to 16%, suggesting that the cells absorb 1000 watts per square meter of sunlight on a bright day near the equator. One square meter of these cells, for example, absorbs solar energy with this efficiency, creating between 110 and 160 watts, which is quite efficient when compared to other types, but it is economically expensive.

❖ **Polycrystalline solar cells** are silicon wafers scraped from cylindrical silicon crystals, which are then chemically treated in furnaces to improve their electrical properties before being coated with anti-reflection coatings to absorb sunlight with high efficiency. This kind has a 9–13% efficiency, making it less efficient than monocrystalline but economically less costly.

❖ **Amorphous solar cells:** These cells are made using a basic process in which silicon is coated in thin layers on glass or plastic surfaces; however, their efficiency is less than 3 to 6% and their prices are lower as well. It is best suited for applications that require 40 W or less, and its efficiency and cost are lower than those of the preceding kinds.

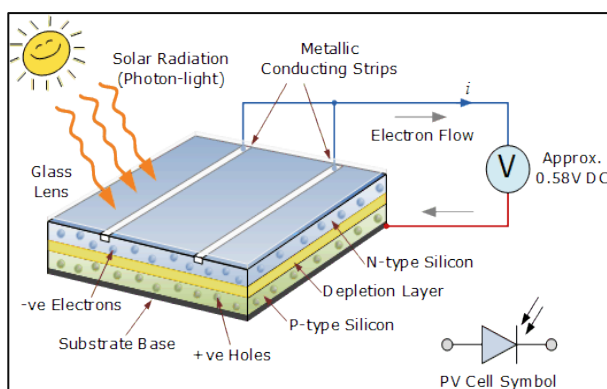


Fig. 1: Photovoltaic cell in detail³¹⁾

The electrical behavior of a PV cell resembles that of a diode because of the p-n junction of a semiconductor material that is sensitive to sunlight as the guiding physical principle. It is theoretically possible to describe the perfect solar cell as an anti-parallel current source for a diode Fig. 2³⁷⁾. Light exposure causes a direct current to be created, which changes linearly with the amount of solar energy. Shunt resistance and another series are two ways to enhance the model.

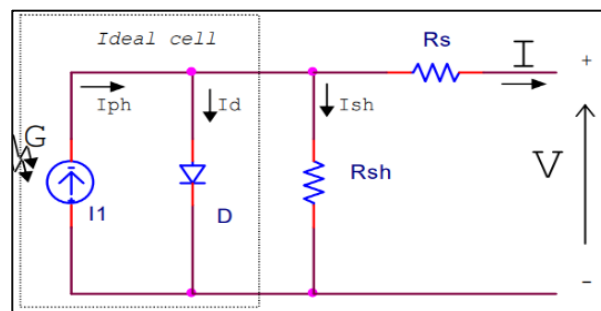


Fig. 2: PV cell equivalent circuit.³⁷⁾

The efficiency of PV solar cells is affected by many conditions that affect the performance of the cell, such as dust, the angle at which the solar panels are directed, the conditions in which the PV solar cells are manufactured, and temperature, where the temperature has the greatest impact on the performance of the cell. So, when the temperature of the PV cell rises, this leads to a decrease in the efficiency of the cell and a decrease in the energy produced, in addition to reducing the cell's lifespan, especially the longer the period in which the cell remains at temperatures above the normal limit. While cells depend only on the light in the production of electrical energy. So, researchers seek to reduce the temperature impact because it cannot be disposed of as shown in Fig. 3.

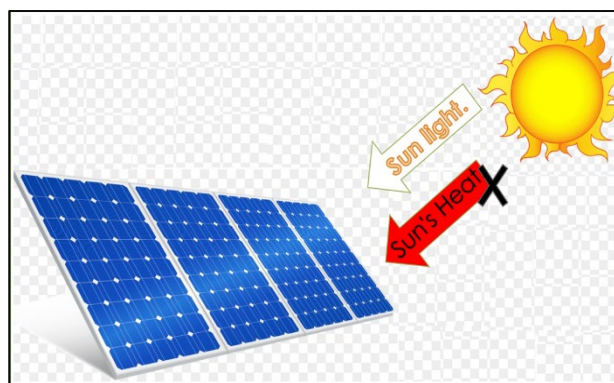


Fig. 3: Solar cells and solar emissions

V.Jafari Fesharaki³⁸⁾, found a relationship between PV efficiency and temperatures. Using simulation that relied on a set of equations " $I(t) = 1000 + 500\sin(t/5)$ " including equation as shown in Fig.4. The efficiency of the PV panel decreases as the temperature increases, as shown in Fig. 4, thus it is an inverse relationship. This is due to the fact that when the current increases somewhat and the cell's voltage falls even further, the production capacity and efficiency drop. Depending on the technology, different solar cells have different effects on heat. Therefore, many researchers worked on and sought to study the cooling of photovoltaic cells in various ways.

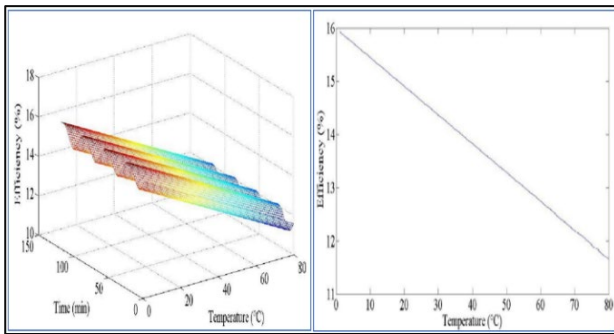


Fig. 4: Relationship of photovoltaic efficiency and temperature ³⁸⁾

The methods of cooling solar cells were classified into three main sections, including ^{39,40)}: PVT Air, PVT Liquid, and PVT Hybrid, as shown in Fig.5. This study will highlight the previous studies of PVT Air because it concerns research trends in improving the performance of PV-panels.

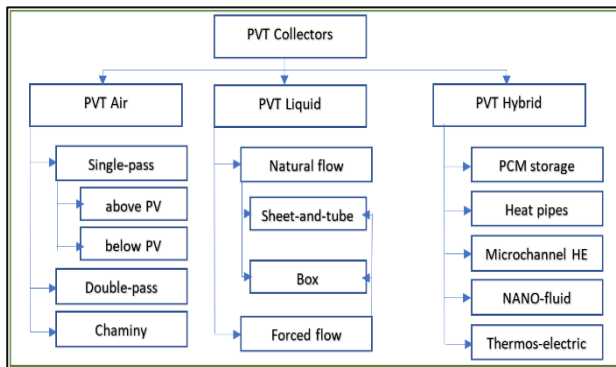


Fig. 5: PV cooling technologies.

H.G. Teo and Hawlader ⁴¹⁾ worked on a photovoltaic module active cooling system. Where he worked on effectively cooling the photovoltaic cells through the design and manufacture of the hybrid solar system, photovoltaic or thermal (PV / T) and experimentally tested it. A good agreement was reached between the simulation program and the experimental data after the task was accomplished using software simulation. On the rear of the photovoltaic panel was a parallel array of ducts that had an inlet/outlet manifold connected to them. This manifold was built for the even dispersion of airflow. Experiments were carried out both with and without the use of active cooling. When the system was run in the active cooling state, the panel achieved a clear decrease in temperatures, which led to an increase in the PV efficiency between 12% to 14%, compared to efficiency values ranging between 8-9% before the system was turned on, which is illustrated in Fig.6.

A hybrid PV/T system produces both electrical and thermal energy. The investigation showed that adopting an active cooling method had a positive impact. Even while the PV module could operate at 68°C without cooling, its electrical efficiency plummeted to only 8.6 %.

Blower-cooled PV modules may be kept at 38°C while still achieving an electrical efficiency of 12-5 %. Aside from that, the appropriate flow rate was discovered in this research as well. The maximum heat from the PV module may be absorbed with an airflow rate of 0.055 kg/s. Beyond this point, neither the thermal nor the electrical energy is impacted. In order to save energy, you may use this information to determine the appropriate power rating for the blower.

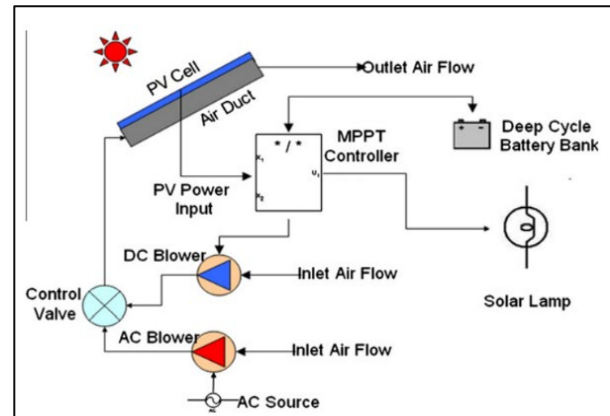


Fig. 6: PV cooling system ⁴¹⁾

According to Fig. 7, electrical efficiency appears to be more stable than thermal efficiency. The average range of electrical efficiency is between 10.1% and 11.0%. The system's thermal efficiency, which is around 40% greater, is substantially higher than its electrical efficiency. This demonstrated that the majority of solar energy is transformed into heat, and the experiment's thermal efficiency resulted in a considerable difference from electrical efficiency. The hybrid system's overall efficiency ranges from 50 to 70%.

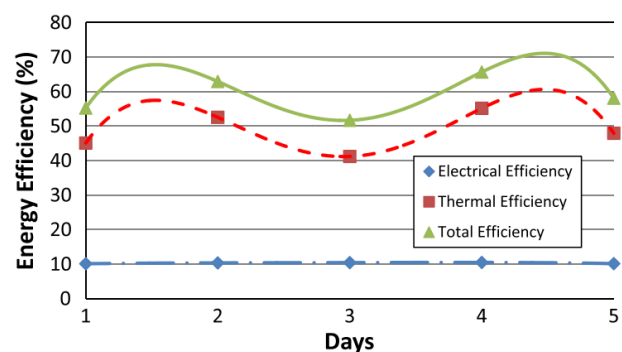


Fig. 7: a five-day evaluation of the effectiveness of thermal and electrical systems ⁴¹⁾.

Peyvand Valeh-E-Sheyda ⁴²⁾ conducted an experimental study in indoor conditions using air and water as two-phase fluids in a set of rectangular micro-channels with a hydraulic diameter of ($D = 0.667 \times 10^{-3}$ m). The flow rate of the liquid was 0.04 m/s, while the surface velocity ranges for the gas were 0 to 3.27 m/s. The performance of

the PV cell in phases of slug and transitional slug flow and annular flow is the main topic of this work. Illustration of two-phase flow in PV cell microchannels for decreasing gas-liquid temperatures. In terms of PV cell cooling, the two-phase working fluid was contrasted with the single-phase. Additionally, it was explored how much more heat might be removed from PV/T panels using slug flow. The experimental findings show that the proposed hybrid system may greatly increase the output power of PV solar cells. An increase in output power of up to 38% was reported by combining PV with microchannels. Fig. 8 shows the general design used in this study, which contains a set of tubes for PV cooling.

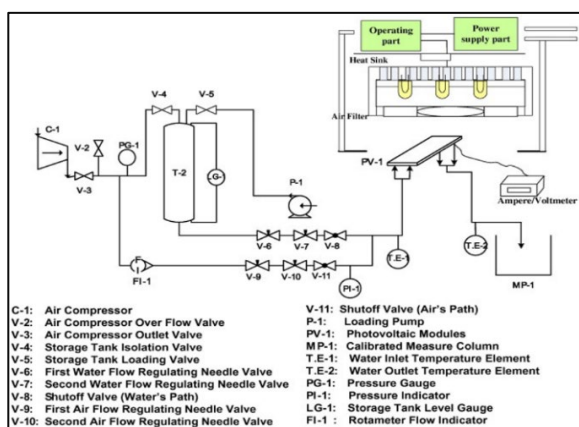


Fig. 8: Two-phase flow design for cooling photovoltaic cells using air and water ⁴²⁾

Another study of PV cooling was presented in 2019 by researcher *Nabil A.S. Elminshawy* ⁴³⁾ who examined, under high climatic conditions, the performance of a PV panel paired with a geothermal air-cooling system. The average cell temperature may be controlled using a geothermal cooling system that employs a PV module and an earth air heat exchanger (PV/EAHE), which enhances the performance of the PV module. A ground-to-air heat exchanger (EAHE) was employed in an experimental test for local circumstances to cool the surrounding air before being used to implement cooling the rear surface of the PV illustrated in Fig. 9. This brand-new alternative PV cooling technique includes blowing ambient air that has already been chilled across the rear panel surface. The temperature of the PV module was decreased from an average of 55 °C without cooling to 42 °C using pre-cooled air flowing at an optimal velocity of 0.0288 m³/sec across the PV module's back surface. Due to this, the efficiency of the energy generated and the solar panel increased by around 18.90% and 22.98%, respectively. Due to the proposed cooling system, the relative energy cost has been improved by 12%, which helps in avoiding the emissions of about 13,896 grams of CO₂ in the summer. During the hottest days of July, temperature measurements showed that PV modules without cooling (PVR) reached a maximum temperature of 60 °C. The recommended geothermal cooling configuration (PV/EAHE) and pre-cooled air rates of (0.0228, 0.02489, 0.0268, and 0.0288) m³/s resulted in module temperatures that were 8, 10, 11, and 13 °C lower than those of the reference module (PVR).

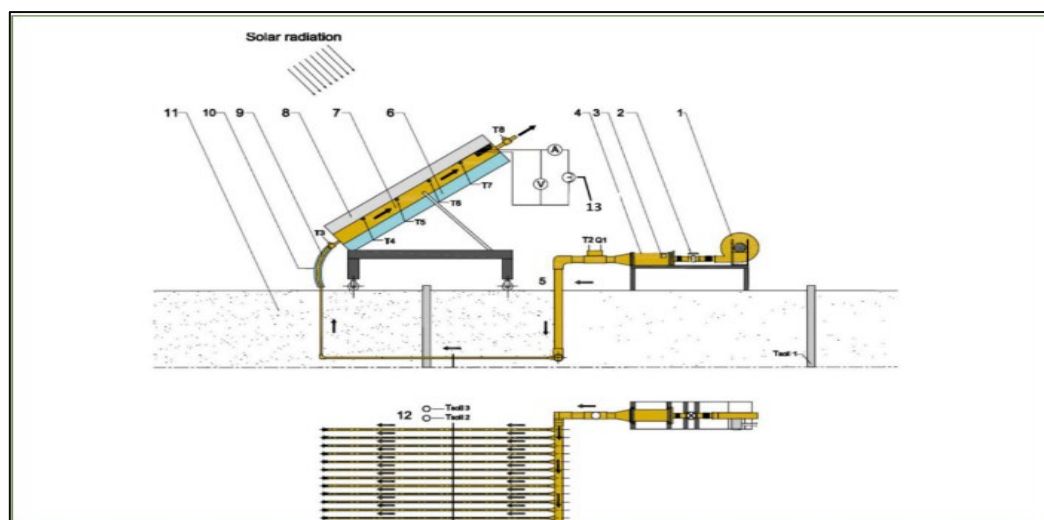


Fig. 9: Diagrammatic representation of the experimental test rig, air blower, temperature control, and control valve 4- warmer of air EAHE's 5-inlet, 6-insulation, 7- cooling ducts for air eight-PV module, 9- exit of pre-cooled air Insulation for 10 exit pipes, Temperature locations at 11 and 12 soils, Tsoil2 and Tsoil3, 13- DC lights and electrical loads ⁴³⁾.

Fig. 10 makes it abundantly evident that the conversion efficiency of the PV module has greatly increased as a result of the use of a thoughtful geothermal cooling system. When the pre-cooled ambient air is supplied to the (PVC) module at rates of 22.8×10^{-3} , 24.89×10^{-3} , 26.8×10^{-3} , and

28.8×10^{-3} m³/s, respectively, compared to an equivalent uncooled (PVR) module, it results in a 4.3%, 9.2%, 15.3%, and 23% percentage improvement in the average electricity conversion efficiency.

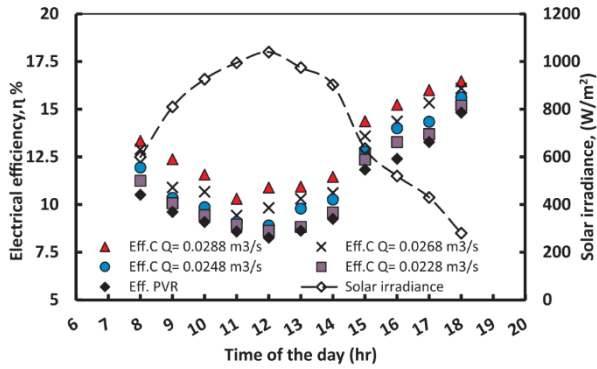


Fig. 10: In July and for different pre-cooled air flow rates, PV module conversion efficiencies without cooling ⁴³⁾.

The suggested Nabil A.S. et al. ⁴³⁾, cooling system provides for an electricity savings of approximately 36 kWh and will save an average CO₂ emission of around 13.9 kg CO₂ every summer season, improving the relative Levelized cost of energy by 12%. Table 1 compares the current study, which takes a 30-year economic life into account, to Baloch et al ⁴⁴⁾ findings. They used forced water passing through a heat exchanger with convergent channels at the bottom of the PV under study to perform PV back cooling. Table 1 shows that, when combined with geothermal cooling, solar modules significantly reduce the Levelized cost of energy when compared to alternative cooling systems. Despite using the same cooling channels approach as the current investigation, Baloch et al ⁴⁴⁾ 's lower PV output power is what caused the difference in LCE values between the two studies.

Table 1. A contrast between the Nabil A.S. cooling system and other ⁴³⁾.

References	N. (economic life)	Year	Energy Levelized (\$/kWh)	cost (US)
Nabil A.S. et al. ⁴³⁾	30		0.71	
Baloch et al. ⁴⁴⁾	30		1.57	

Researcher Rifat Ara Rouf et al ⁴⁵⁾ presented an article that explains how to appropriately use the acquired thermal energy to operate a traditional two-bed solar absorption system in order to create optimal cooling energy and long-term sustainability. The incremental solar thermal modules may increase heat collecting capacity up to 8641 GJ / 75.7 m² collector area. The expanded storage tank offers backup for 14-hour working days. So, intelligent operating settings may provide a greater peak cooling capacity of 16 kW / 2.2 m³ a comfortable and continuous cooling effect over a substantially longer period of time and of the heat storage tank. On the other hand, the proper management of the collected energy may turn into a benefit factor that leads to an improvement in the economic situation. Furthermore, it minimizes CO₂ emissions while conserving basic energy and power. Fig. 11 shows the diagram of the heat storage system and the

solar absorption cooling system with a direct solar connection.

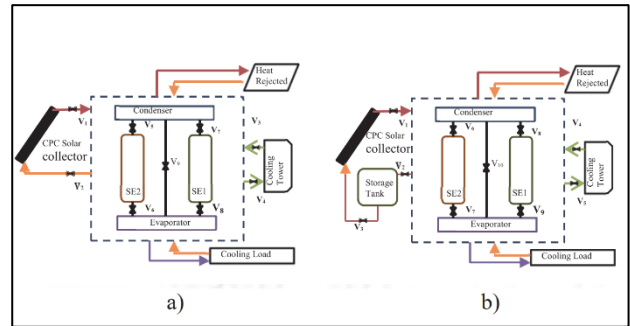


Fig. 11: Solar adsorption cooling system schematic diagrams a) with direct solar connection and b) with heat storage ⁴⁵⁾

Fig. 12 demonstrates that from 12.0 to roughly 18.0 hours, the temperature ranges from 10 °C to 9 °C. There are minor differences in the generation of cooling and energy collection as a result of these changes in the operating circumstances. Once the adsorbent is saturated or depleted from desorption, adding more heat or extending the cycle duration has little effect on cooling the output. Instead, improved cooling capacity and a lower cooling impact can be observed when this cycle of adsorption-desorption is expedited ⁴⁵⁾. Table 2 displays the total energy gathered and the total cooling produced in one day for various scenarios.

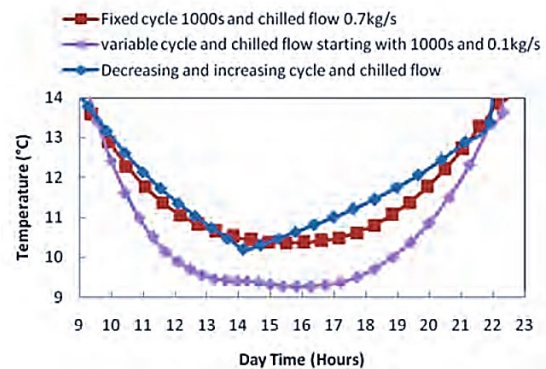


Fig. 12: Comparative chiller evaporator output with 2.197 m³ of storage tank volume ⁴⁵⁾.

Table 2. Energy allocation for various tank volumes ⁴⁵⁾.

Tank volume m ³	Total cooling Produced (MJ)	Total Heat used (MJ)	Total Heat collected (MJ)
N/A	306.00	647.02	646.70
0.343	330.72	658.87	679.59
1.00	365.03	722.15	785.78
2.200	379.44	748.42	864.10

An experimental study of the effects of air blowing and radiation intensity on PV performance was conducted by M.S. Naghavi ⁴⁶⁾. This study aimed to evaluate the effect of natural convective heat capture from PV on the gap between panels and the surface. Experimental and

numerical studies were conducted to examine how the natural air circulation underneath five vertically stacked PV panels affected the results. The study was limited to measuring air inlet or outlet temperatures as well as the temperature of PV panels. Investigations were also conducted into the solar radiation intensity and the separation between solar panels and rooftops. According to experimental and numerical investigations, the mean temperature of the PV array with no air gap increases by 12–5 °C over one with an air gap of more than 200 mm when the radiation level hits 1000 W/m² and the air gap rises to 250 mm. PV panel efficiency in Standard Test Conditions is 18.04%. But when the spacing is 0 mm, it decreases to 14.17% and increases to 15.01% when the spacing is 200 or 250 mm. According to CFD simulations, the surface temperatures of panels are essentially consistent. The CFD model closely mimics the experimental data. Fig. 13 shows the general scheme that was adopted to design the central composite to improve the performance of PV. In addition to many previous studies that dealt with PV cooling for various technologies,

^{1,47–56)} the summary of the different cooling types of photovoltaic cells conducted by previous researchers from 2012 to 2021 is reviewed in Table 3.

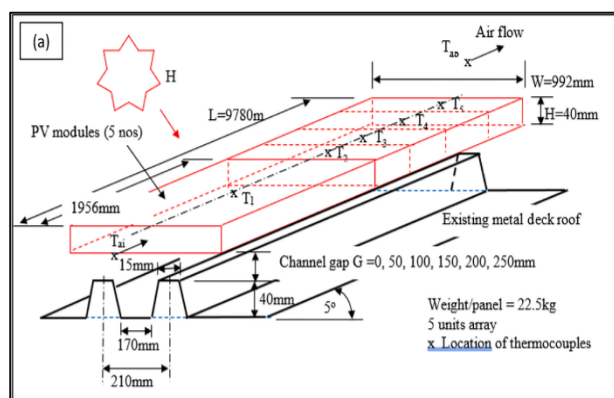


Fig. 13: Central Composite Design Usage Scheme for *M.S. Naghavi*,⁴⁶⁾

Table 3. Summary of previous studies of different cooling technologies for photovoltaic systems

Authors and Year	Cooling Technologies	Search Results and Features
Teo H, et al. 2012 ⁴¹⁾	Increase PV efficiency by using active cooling.	The efficiency of the PV cell without cooling reaches from 8% to 9%, while it is increased to 12-14% using cooling tubes (air). The work was done through simulation and experimental testing
Sheyda P, et al. 2013 ⁴²⁾	Cooling using a two-phase flow between gas and liquid	The results showed that the use of air and water as two-phase fluids in a hybrid system may significantly enhance the energy production of solar photovoltaic cells. Up to 38% of the energy produced
Wu S, Xiong C. 2014 ⁵⁷⁾	use this passive gadget to test the performance of the cells	Important design considerations for cooling systems are cost-effectiveness, design feasibility, and minimal energy consumption. The use of passive cooling increases PV efficiency by 8.3%.
Rifat Ara Rouf et al. 2016 ⁴⁵⁾	Solar adsorption cooling system	This essay concludes that appropriate integrated energy management is an important element in a growing economy. It may save around 9,324 BDT (US\$116.55) each year when cooling only one room. Furthermore, it minimizes CO ₂ emissions while conserving basic energy and power.
Makki A, et al. 2016 ⁵⁸⁾	In this work, a thermoelectric generator-integrated photovoltaic thermal (PV/T) absorber is presented and tested.	The results showed that integrating TEG modules with solar cells improved the performance of photovoltaic cells while utilizing waste heat, which leads to an increase in output power.
Popovici C, et al. 2016 ⁵⁹⁾	PV cooling using air-cooled heat sinks	The results, using air-cooled heat sinks, showed that the power increased from 6.97% to 7.55% compared to the base case for the photovoltaic panel.
Syafiqah, Z, et al. 2017 ⁶⁰⁾	Air- and water-cooling system	Applying the air- and water-cooling systems to the PV panels reduced their temperatures to 19.2% and 53.2%, respectively, according to the results from the ANSYS CFX and PSPICE programs.
Elminshawy, et al. 2019 ⁴³⁾	A geothermal cooling system that uses a PV module and an Earth Air Heat Exchanger (PV/EAHE)	Using pre-cooled ambient air on the rear panel surface resulted in improvements in PV-panel module output power and electrical efficiency of around 18.90% and 22.98%, respectively.
M.S. Naghavi 2022 ⁴⁶⁾	Investigating how natural convection is affected by the space between the panels and the roof.	Effective energy research reveals that using nano-hybrid PCM, hybrid PCM, and PCM-water hybrids to minimize carbon dioxide emissions to the atmosphere is more socially and economically cost-effective than using each technology alone.

3. Hybrid Solar Chimney PV

Researchers are presenting ideas and strategies for harnessing solar energy in a variety of diverse systems. Making a hybrid solar system is one way to improve the performance of solar systems. Where many researchers used the solar chimney to cool the solar cells (photovoltaic). Some researchers use Solar Updraft Towers (SUT) to cool photovoltaic cells using air known as "updraft technology." A solar updraft tower (SUT) is considered a non-concentrating power source. A SUT is also known as a solar chimney power plant (SCPP). Its working principle is based on the use of a solar collector to increase buoyancy force and an updraft column formed by a wind turbine. This technology's basic premise is to heat the ambient air and transform thermal energy into electric power.

In the north of Iraq (35.46 °N, 44.39 °E) the researcher *Abdullah Sabah Hussein*⁶¹⁾ focused on evaluating the performance of a revolutionary solar chimney design that incorporates a solar cell as a glass roof above the collector and a solar panel that is incorporated inside the collector. It is obvious that the optimal angle for generating energy is 45°. Additionally, it is asserted that the 45-panel angle, out of the three angles examined (30°, 35°, and 45°), provides the system with the most efficiency. The results showed that the photovoltaic/solar chimney varied from 8 to 13 percent. On an average day, it was found that the solar collector's air temperature rose by a maximum of 275-275 K. The chimney entrance was the ideal location for a wind turbine installation since it had the highest air velocity, 64 cm/s, which was measured there. Except around midday, when solar panels get fizzy in temperature and their electrical efficiency drops owing to this. Electrical efficiency follows solar radiation.

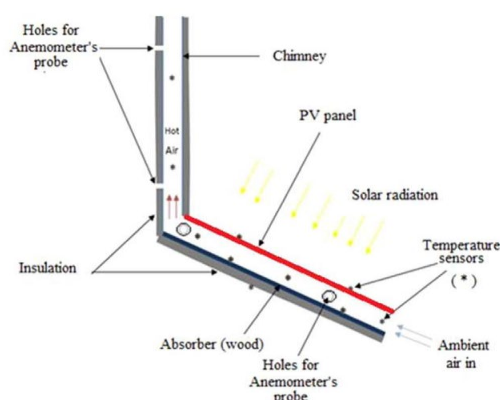


Fig. 14: Hybrid Solar Chimney PV⁶²⁾

Fig. 14 shows the diagram and photograph adopted by researcher *Omer K. Ahmed*⁶²⁾ in the design model, where the chimney was attached to the end of the solar cell, where it was installed on a cylindrical body attached to its chimney end. When temperatures rise, an upward current is formed inside the chimney, known as an updraft, that

works to draw air from the cylindrical body, and through a change in mass, a heat exchange occurs that reduces the heat of the solar panel increases the efficiency of the photovoltaic cell.

Fig. 15 depicts the temperature variation of two solar cell designs (A and B) when they were tilted at a 45-degree angle with the horizontal line. It was observed in the two models that, from the start of the test until it reached its peak temperature at noon, the solar cell's temperature and solar radiation values rose. The drop in solar radiation and the rise in afternoon heat losses caused the temperature of the cell surface to subsequently start to fall.

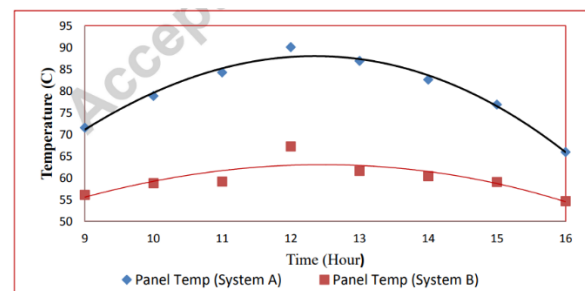


Fig. 15: Temperature comparison for two kinds of solar panels at a 45-degree angle⁶²⁾.

*Siamak Jamali*⁶³⁾ presented a study on a new system for cooling the STPV system with updraft technology in 2018. The suggested theoretical model is based on the energy balances of three primary components: Earth, Air, and STPV. It is computed accurately for each heat transfer in the system and the findings are compared to current experimental data on solar chimneys in the literature. It was emphasized that the suggested system's efficacy depends on both structural factors and radiation intensity. After conducting practical experiments, the researcher proves that the new design shown in Fig. 16 had reduced the STPV by up to 15% of the panel temperature, which led to an increase in the PV efficiency by 29% at the radiation intensity of 500 W/m². These results obtained by the researcher were in great agreement with the previous literature.

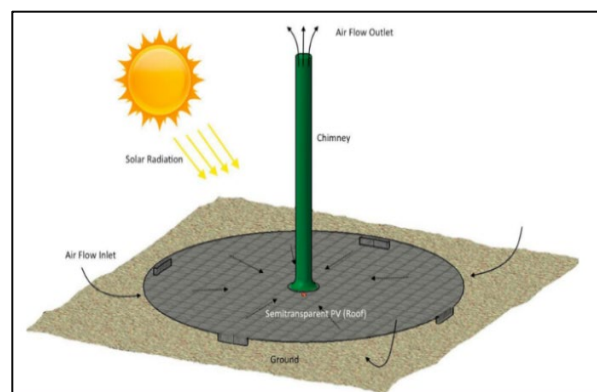


Fig. 16: The general structure used by the researcher Jamali⁶³⁾

*Siavash Haghighat*⁶⁴⁾ developed a hybrid solar system, including novel hybrid photovoltaic panels and solar chimneys that cool the PV panels using the airflow created underneath the solar chimney collector. The air beneath the collector is heated using thermal energy from the solar panels. In this work, the location and width of the photovoltaic panels in the solar chimney were investigated as two key characteristics. Four unique hybrid PV panel and solar chimney combinations with varying widths were modeled in total (70, 50, and 30 cm). Instead of using a clear collector, the best results were obtained by combining PV panels with solar chimneys. In comparison to the typical PV panel temperature of the solar chimney's non-hybrid mode, the study's investigations showed that the solar panel temperatures decreased by 5 °C. This decrease is caused by the airflow velocity, which reached its maximum speed while decreasing by 0.2 m/sec when compared to the clear collector, and is due to a 1% improvement in the efficiency of hybrid solar panels when compared to non-hybrid cells. Fig. 17 shows the structure diagram used by *Siavash Haghighat*⁶⁴⁾.

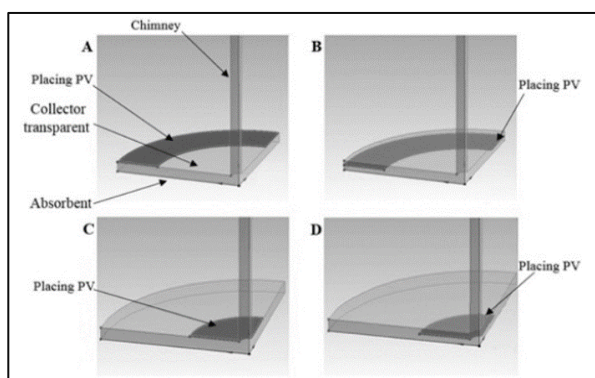


Fig. 17: Scholar *Siavash Haghighat* Scheme with Suggested Sites for PV⁶⁴⁾.

Huang, et al. (2020)⁶⁵⁾ studied provides a crossbred solar chimney and PV-panel unit for the special solar energy air cleaning system. Experiments reveal that installing solar panels in place of (50 to 60) % of the acrylic glazier on the collector top only results in a 14% reduction in heat airflow average while generating significant electric power production. absorption fans may be operated with the electrical energy produced by solar panels to increase air intake in a wide range of systems. The collector's ability to absorb solar energy may be significantly increased by adding photovoltaic panels. It has the ability to raise the quantity of air purification or decrease the area of land required. In Fig. 18, the clean sun chimney device is depicted, and Fig. 19 shows the schematic diagram of the system used.



Fig. 18: System of solar chimneys⁶⁵⁾

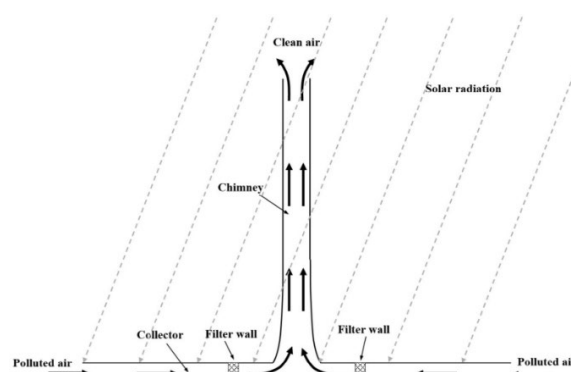


Fig. 19: Schematic of solar chimney⁶⁵⁾

The turbine and PV power output are displayed in Fig. 20. The overall total power production of the two hybrid systems is 53 and 57 times greater than that of the solar chimney system. The hybrid system that has PV panels on top of the collector produces the most electrical energy, because the collector's top-mounted PV panels have superior heat dissipation. The air movement beneath PV panels creates forced convection cooling in addition to the heat dissipation from the top of the PV-panels to the environment. Since the bottom surfaces of the PV panels are in contact with the ground and the air flow of the collector cools the top surfaces of the PV-panels, some of the heat is transmitted to the soil layer. The top and bottom PV panels expected average temperatures are 50.01 °C and 67.32 °C, respectively⁶⁵⁾.

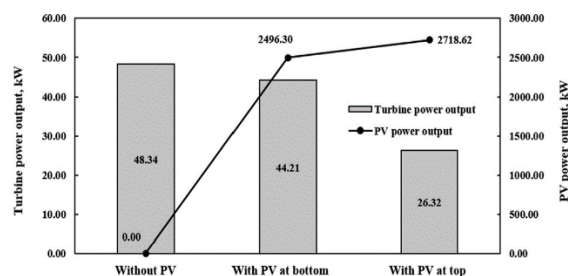


Fig. 20: Comparison of the PV and turbine power outputs at a distance of 40 meters⁶⁵⁾.

Hassan, et al. (2021)⁶⁶⁾ presented research on using and without solar panels to see how they affected the functioning of the hybrid solar chimney. Six cells were put between the collector's base and the glass cover, allowing the collector to move freely. The air circulates in and out of the cells; it is also demonstrated that when employed, the speed is increased as well as the efficiency of the solar collector and PV unit. The energy flowing out of the collector hits 1.8 m/s. According to practical results, the smokestack base is an appropriate site for the turbine because the air is cooler there. The velocity is higher in this area than in others, and during the day, the air velocity rises until it reaches its peak at 1 p.m. A prototype model was built to examine the performance of this solar photovoltaic chimney in the Iraqi city of Kirkuk, as shown in Fig. 21.

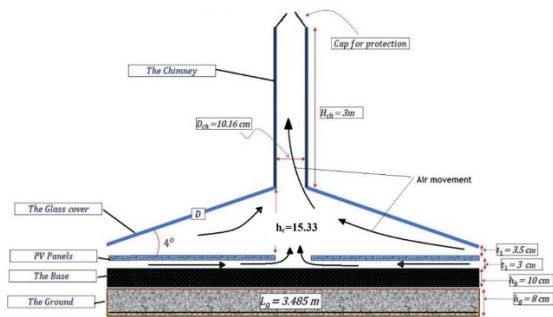


Fig. 21: The experimental model's dimensions⁶⁶⁾.

The daily variation in electricity efficiency is seen in Fig. 22. It should be observed that the electrical efficiency change has a concave upward contour. Due to the low temperature of the solar cells in the early morning hours in each of the months under consideration, high-efficiency values are seen. 17.8% was the greatest electrical efficiency value ever recorded in December. This trend is typical and has been shown in other studies looking at PV/T solar systems, such as⁶⁷⁾. Fig. 23 depicts the daily variation in thermal efficiency on an hourly basis. Due to the high levels of solar radiation, February had a greater thermal efficiency than the other months; around midday, this efficiency peaked at 68%. In contrast, December had the lowest value for thermal efficiency during the day, which is consistent with the findings from⁶⁸⁾.

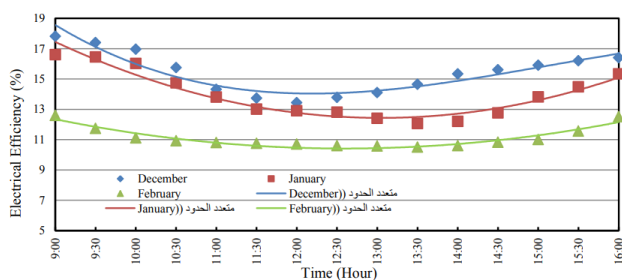


Fig. 22: The variation in electrical efficiency on an hourly basis throughout the day⁶⁶⁾.

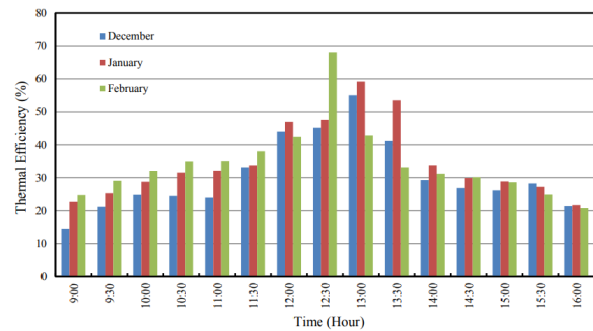


Fig. 23: the varying thermal efficiency on an hourly basis throughout the day.

Ajeet Pratap Singh⁶⁹⁾ studied a hybrid chimney-powered solar-PV plant and investigated the feasibility of using both PV modules and an HSCPP as a single unit in this research. The high ambient temperature overheats PV modules in a buoyancy-driven greenhouse system, lowering electrical conversion efficiency. A numerical model for different collector duct and solar chimney designs that have been experimentally proven is used to study the cooling of PV panels and the power generation of turbines. Diverting the chimney up to its maximum static pressure recovery limit affects power generation, although the PV module only slightly improves electrical efficiency. The poorest turbine and PV module performance is seen when the collector duct is converging alone. However, a 7% improvement in PV panel efficiency was seen when the converging duct and diverging chimney were linked. About 80% of the collector area, measured from the chimney axis, is most effective for cooling the PV module when it comes to temperature reduction. An energy-efficient hybrid solar chimney system design map based on PV panel efficiency has been demonstrated. Fig. 24 shows the structure and scheme used in the search⁶⁹⁾.

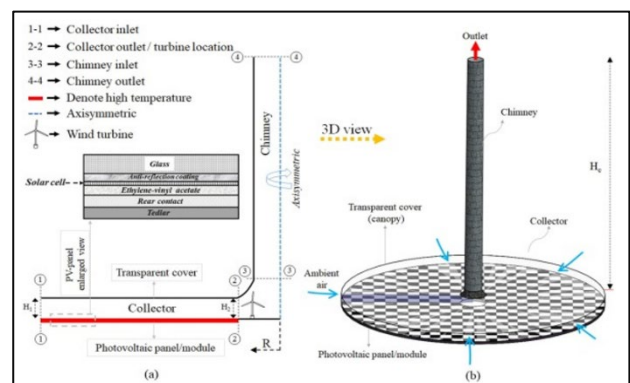


Fig. 24: The design and general structure used by the researcher Pratap Singh A,⁶⁹⁾.

Ali A. Ismael⁷⁰⁾ 2021, contributed to the Performance Evaluation of the Updraft-based Air Tower Power Plant. The examination and investigation of this research, which was conducted at the University of Technology in Iraq, employed the ANSYS software. The solar air heater in this

article is constructed on a double-transparent top layer to generate the greenhouse effect and catch solar energy, which creates the flow of hot air to the power-generating component. ANSYS software was used to solve Navier-Stokes equations and integrate power equations with the discrete radiation (DO) model in order to simulate and evaluate the impact of the proposed solar air heater's various transparent skin geometries on tower power plant performance in various operational parameters. The assessment's findings show that improving both the quantity and area of the collector's solar skin air heaters improves system performance. Fig. 25 shows the scheme adopted by researcher *Ali A. Ismaeel*⁷⁰⁾ in the ANSYS program. The velocity findings were predicted statistically, and the solar intensity presentation ranged from 50 to 950 W/m² with increments of 100 W/m². As can be observed in Fig. 26, at 950 W/m² solar radiation magnitude, the maximum velocity values that were determined for the three instances named "normal," "Model-B, and "Model-A" are 2.8, 3.2, and 3.4 m/s, respectively. These discoveries were discovered around the chimney's base.

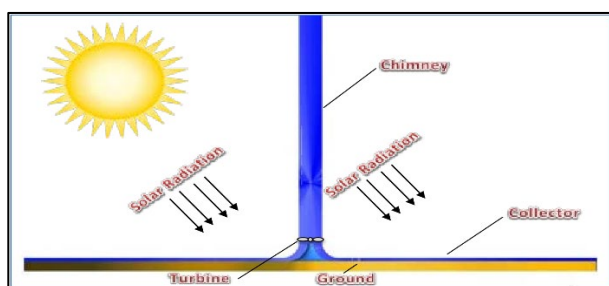


Fig. 25: Updraft tower schematic design for a solar power plant⁷⁰⁾.

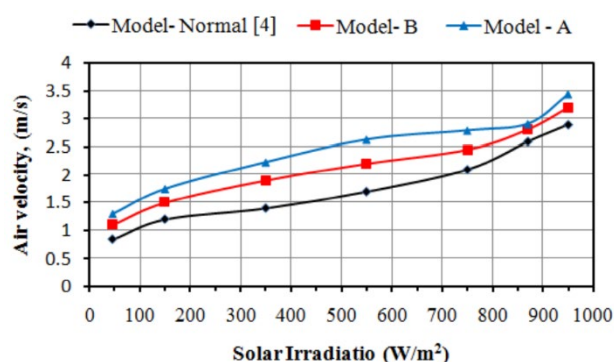


Fig. 26: Comparison of the Regular Model B and Model-base A chimney air velocity⁷⁰⁾.

In 2021, Ajeet Pratap Singh⁷¹⁾ proposed a new model for HSC-PV, where the efficiency of the solar chimney was improved by a number of previous designs. So, in this study, the airflow velocity Ψ at the turbine position was improved in order to enhance the turbine power generation. The present work shows a numerical analysis of an HSCPP consisting of a PV-Panel at the bottom of

the collector and a bell-mouth opening integrated into the inlet of the collector shown in Fig. 27. Designs combined with the bell-mouth design inlets increased flow velocity by 71% and lowered the PV panel temperature by 8-12°C. The turbine power output is improved by more than 200% due to the higher flow velocity.

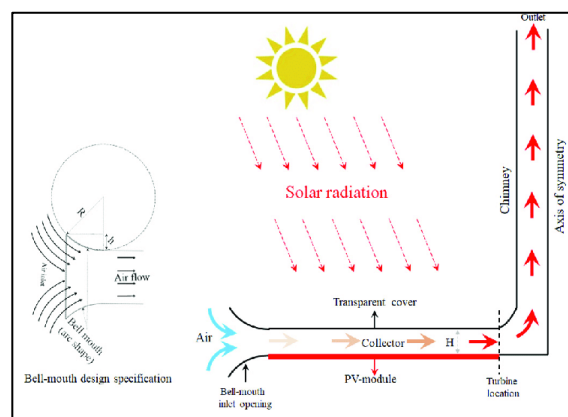


Fig. 27: Illustrative diagram of HSC The left figure is showing the bell-mouth design specification⁷¹⁾

⁷²⁾ A hybrid small-scale HSCPP was investigated experimentally and numerically. A solar collector, a chimney, and a convergent nozzle are part of the experimental model. The collector's convergent nozzle was used to increase chimney airflow. Experimental data were compared to the results of computer simulations of airflow and heat transfer. A hybrid solar system is more than two orders of magnitude more efficient than a regular solar chimney and 18% more efficient than a stand-alone PV panel. With a chimney height of up to 8 meters, Fig. 28 shows the model. In theory, increasing the size of a device would lead to an increase in output power and LCOE. In addition to other studies, Hybrid Solar Chimney studies dealt with⁷³⁻⁸³⁾ of them, while are listed Table 4 summarizes and compares a set of studies and results from 2018 to 2021 for Hybrid Solar Chimney PV.



Fig. 28: In-field testing of a hybrid solar chimney experimental setup with measurement equipment⁷²⁾

Table 4. Summarizes studies about Solar Chimney

Authors and Year	Objectives	PV Arrange method	Outputs and Results
Sabah Hussein A. 2018 ⁶¹⁾	PV cooling for energy production	PVC is fixed on an insulated aluminum box	It has been established that 45° degrees are the ideal angle. The PV/SOLAR chimney's efficiency ranges from 8% to 13%. The solar collector's solar collector experiences a maximum rise in air temperature of 2–3 °C.
Liu Q. 2018 ⁸⁴⁾	Electric power generation and PV cooling	It is installed on the surface of the collector around the chimney	Without cooling, the PV power capacity drops by 28.71%. The airflow cooling effect resulted in a loss of 11.81% of the average power capacity. The overall PV-related power contribution improves by 4.72% when PVT power is added.
Jamali S. 2018 ⁶³⁾	New Solar Chimney System for STPV System Cooling	Using the STPV as the Roof of the solar chimney	Lower the average STPV temperature by up to 15 °C. Energy output increased by more than 29% at the solar radiation intensity of 500 W/m ² .
Haghighat S. 2019 ⁶⁴⁾	Locating PV in the solar chimney for cooling	The best location is 50 cm for the hybrid PV panels instead of the transparent compound	The best result was reached by placing 50 cm of solar panels, as the temperature was reduced by 5 °C from the average temperature of the PV, increasing the efficiency of the PV system by 1%.
Salari A. 2020 ⁸⁵⁾	Enhance its efficiency and extend the performance of a conventional solar chimney (SC) with PV	Installed over homes or buildings with a certain technology	Prove that SC-PV-PCM is superior to other systems and is the best choice for residential buildings, and the SC-PV system is shown to be the best choice for office buildings in a subtropical environment.
Elghamry R. 86)	Building cooling and ventilation using new combinations of solar chimneys	Installed over homes or buildings	This paper demonstrates their potential to reduce room temperature by up to 3.5 °C. At a 30° inclination angle, the maximum PV output power inside the chimney is 70% of the maximum PV output power outside the chimney, which is 120 W/m ² .
Pratap Singh A. 2020 ⁶⁹⁾	Possibility to integrate a photovoltaic module into the (HSCPP)	the chimney axis is most effective for cooling the PV-panel	Demonstrating the increased efficiency of solar panels (about 7%) And, with a continuous temperature drop of 283-285K, roughly 80% of the collector area measured from the chimney axis is the most efficient zone for cooling the PV-panel module.

4. Solar Vortex Engine

One method that has drawn the interest of academics in the field of renewable energy is solar vortex generation (SVG). Where a short vortex column, in addition to a solar collector that warms the air and has bottom bases to let air enter, has taken the place of the tall chimney construction. In 1982, a prototype solar chimney power plant was built in Manzanares, Spain, and useful information was gathered from Haaf et al^{87,88)}. These data were collected by other researchers for further study and development of solar vortex engine technology, In 1999, it was proposed by *Louis M. Michaud*,⁸⁹⁾ the vortex engine or atmospheric vortex engine (AVE) idea, attempt to replace massive physical stacks with an air vortex formed by a shorter, less costly vortex. The AVE creates a vortex at ground level, comparable to a naturally occurring water tap.

The application was suggested by *Louis M. Michaud*,⁸⁹⁾ and *Norman Louis*⁹⁰⁾. The rising solar power tower of Fig.

29 is the subject of his patent claims, which seek to provide a less-priced substitute. In this application, heat is produced by a large area of land heated by the sun and covered with a transparent surface that traps hot air, similar to a greenhouse. By deflecting the vortex at an angle with respect to the tangent of the outer radius of the solar collector, a vortex is created. In order to catch useful energy, it is predicted that the solar collector's minimum diameter must be more than 44 m, which *Norman Louat*⁹⁰⁾ came up with. Similarly, removing the clear cover is suggested. Under this proposal, the chimney would be filled with warm seawater or air from the Earth's surface. In this application, the design strongly resembles a dust devil with a wind turbine in the center.

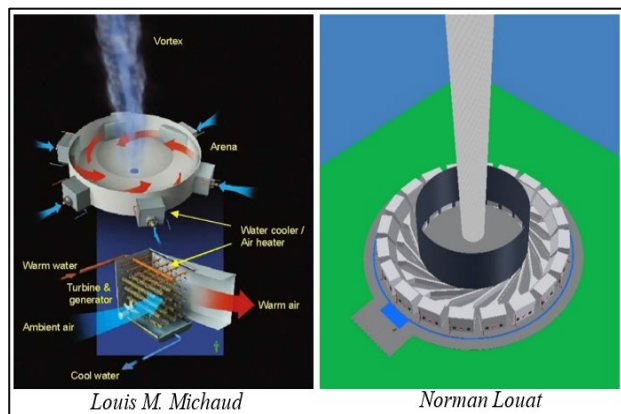


Fig. 29: Illustration of a vortex motor ^{91,92)}

Mark W. Simpson ⁹³⁾ presented a study of vortex power generation. Stationary columnar vortices are generated and maintained by a steady inflow of heated air flowing between a set of fixed ground-mounted vertical vanes. Utilizing the rotational and vertical flow induced by an "anchored" vortex, electricity is produced by powering a vertical-axis wind turbine with an electric generator. The anchored vortex is supported by hot air close to the solar-heated ground plane. This novel method of solar energy collection makes it possible to use solar-heated air in arid regions to generate energy at low cost, high volume, and with sustainability. In meter-scale laboratory tests, it has been demonstrated that strong buoyancy-driven vortices may develop and persist over a thermally controlled ground plane. Using stereo PIV, the current work focuses on the basic mechanics of columnar vortex generation, development, and dynamics, with special attention to scaling and the evaluation of the available mechanical power. It is possible to vary the buoyancy flux, which is connected to the pace at which airflow absorbs sensible heat, as well as the vortices' strength and size, substantially. Recent outdoor testing has demonstrated the continuous rotation of the turbine with significant kinetic energy extraction from the column vortex in both the presence and absence of crosswinds. Fig. 30 shows the design adopted by researcher Mark W. Simpson ⁹³⁾ to configure the vortex motor.

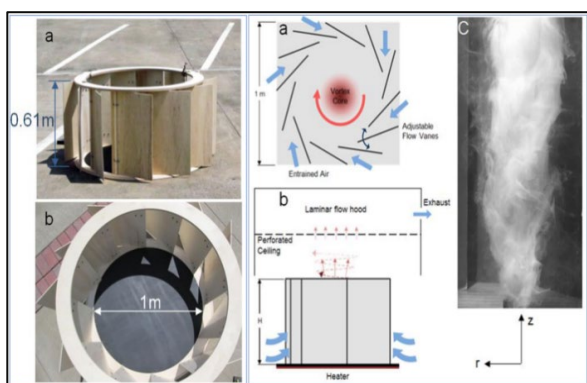


Fig. 30: General Structure of a Vortex Engine Design by Mark W. Simpson ⁹³⁾

Fig. 31 (at $z = 10$ cm) illustrates the changing of the vortex properties (Reynolds numbers $Re = \Gamma/2\pi\nu$ and R) with surface temperature ($T_s = 50$ – 150 °C). These findings indicate that the amplitude of the vorticity within the core grows noticeably, along with the angular momentum of the core fluid, even though the typical radius of the vortex and Re actually decreases with the buoyancy force. The capacity of the surface to convectively heat the entrained air in the laboratory setting is constrained by the surface's constrained horizontal extent, a restriction that is manifestly absent in nature ⁹³⁾.

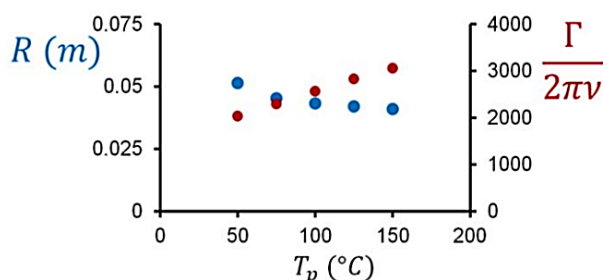


Fig. 31: Surface temperature has an impact on the core Reynolds number and characteristic radius of vortices ⁹³⁾.

Abdullah Mohiuddin and Eray Uzgoren ⁹⁴⁾ presented a study novel gadget that has been designed to produce power from solar energy by simulating dust devils. The CFD model was created to investigate the influence of geometric factors on the vortex in a controlled setting and to investigate its potential as an energy conversion device. The effects of vane height, vane number, vane width, and vane angle on the mass flow rate of the proposed system were examined. Following the investigations, the researcher proved that at blade angles greater than 30 degrees, vortex stability and torque strength improve. Large vane angles increase swirl and, as a result, vortex stability at high air speeds away from the vertical centerline, offering greater torque output opportunities. The space between the vanes is reduced when the optimal vane width is 1.4 R , and the minimum vane height is 1.3 R and 1.2 R .

The numerical simulations of the fundamental flow model are depicted in Fig. 32 using OpenFOAM, an open-source finite volume-based CFD software. The basic flow geometry shows a circular plate heated at an elevated temperature surrounded by an unheated floor; neither the round hot plate nor the floor is enclosed. The heated plate is surrounded by flat plates (referred to as vanes throughout the text). This research focuses on vertical vanes because they drive entrained flow away from the center, creating a vortex. In numerical testing, vane width, height, vane angle, and heated plate radius are all evaluated.

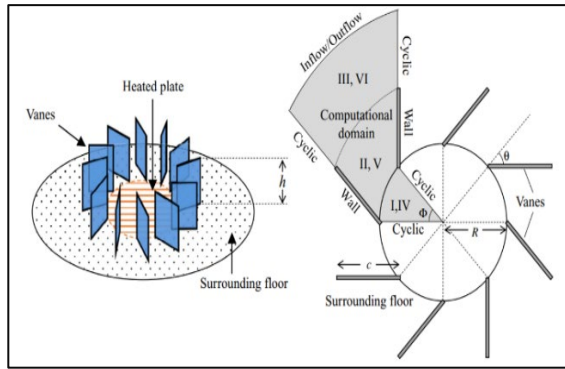


Fig. 32: General Structure of Flow Geometry, Arithmetic Domain and Boundary Conditions ⁹⁴⁾

Ali A Ismael⁹⁵⁾ presented a study on the improvement and development of the solar vortex power generation system conducted at the University Petronas in Malaysia. The study mainly targeted five stages to improve the absorption of solar energy and accelerate the vortex. The process involved raising the flow guide's height, applying a metallic powder-supported black enamel coating to the vortex generator's surface, installing air-guided channels inside the solar air collector, adjusting the vortex generator's vane orientation angle, and finally inserting a conical guided wall into the vortex generator's core.

In addition, all of the recommended modifications in the study methodologies were successful in increasing the amount of the cumulative thermal impact, regulation of airflow, rotational energy, and rising air motions inside the SVPG system. Therefore, as compared to the normal model, the average aerodynamic strength, useful heat gain, and air mass flow have been enhanced by 55%, 42%, and 26.11%, respectively. Fig. 33 shows the experimental model of the Solar Vortex Power Generator (SVPG).

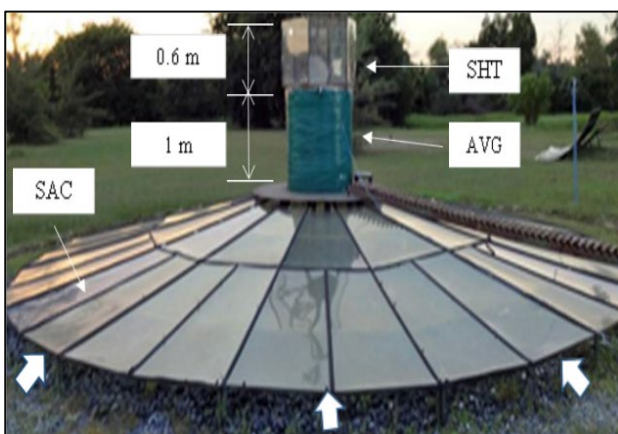


Fig. 33: Solar Vortex Power Generator Experimental model ⁹⁵⁾

An artificial air vortex generator and two solar air collectors make up the model, which was used to measure air mass flow, heat gain, and air kinetic energy in an actual laboratory setting. To remedy a setback in the prior design,

it was a success. Using both numerical modeling and experimentation, the model shown in Fig. 34 was developed and refined. A piece of software created for profit, the vortex generator's performance is monitored and predicted using ANSYS Fluent in a variety of engineering processes and parameters. The speed at which the vortex generator is activated is critical to its performance, according to simulation data. The vortex's speed rises by 42 percent as the flow speed increases from 0.5 to 0.8 m/s. Simulated flux hole layouts for vortex generator setbacks were also established during this time.

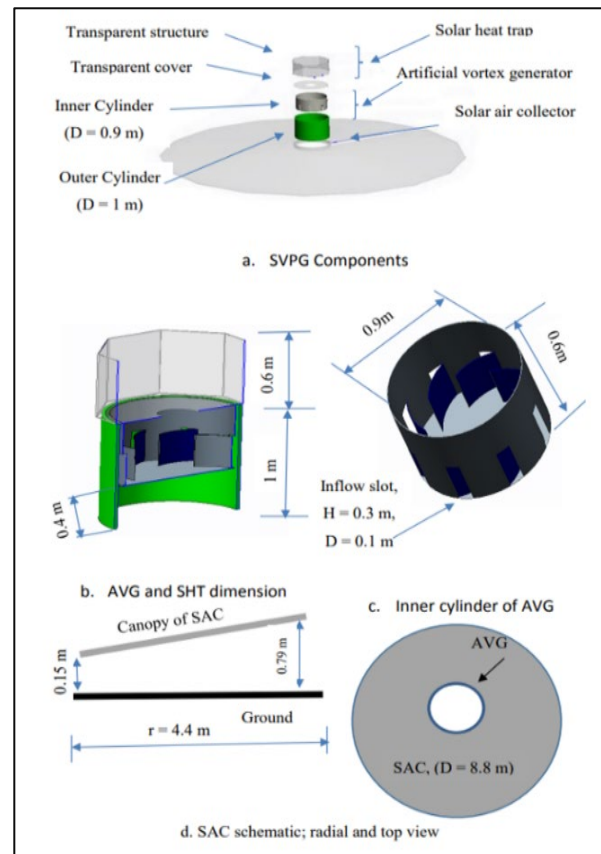


Fig. 34: Schematic of SVPG components ⁹⁵⁾

Researcher Abdullah Mohiuddin ⁹⁶⁾ worked in the solar swirl engine (SVE) that operates on the same basic idea as the SUT plant. A three-dimensional computer model of SVE was explored in this work to analyze flow characteristics and power potential. The effects of increasing the number of air entry slots (AESs) to 6, 7, 8, 9, 10, 11, and 12 as well as shifting the turbine's location were studied and optimized. In order to solve the governing equations, a turbulent model with a renormalization group (RNG) k- ϵ was used. Flow variables such as velocity, temperature, and dynamic pressure were calculated for the ideal SVE with 8 AES, resulting in, respectively, 1.42 meters per second, 311.1 degrees Kelvin, and 1.58 pascals. In order for the turbine to extract the greatest amount of energy, the ideal height for the turbine was determined to be 70.2 cm from the

bottom plate (10 cm from the top plate). The theoretical power was 3.45 W, but the actual power produced by the turbine at 0.702 m was 2.3 W. This was the case for the optimal situation, which had an AES of 8. According to the findings of the research, SVE has the potential to serve as an alternative to the chimney in solar updraft tower (SUT) power plants that generate energy. Fig. 35 shows the general design of the proposed model

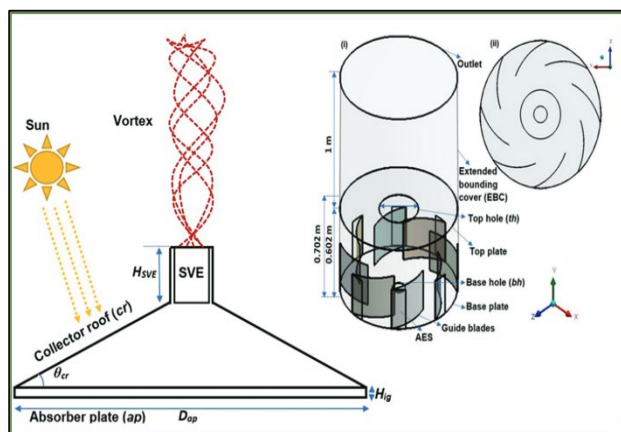


Fig. 35: A diagrammatic representation of the solar vortex engine (SVE) with EBC and top view of SVE ⁹⁶⁾

The equation ($\mu_t = \rho C_\mu k^2/\varepsilon$) was used to determine the change in vorticity magnitude along the SVE diameter, which is seen in Fig. 36 ⁹⁶⁾. In comparison to other heights, the vorticity magnitude was greatest at 0.702 m. Additionally, near the SVE's center, the vorticity was at its highest at all heights. Due to the frequent occurrence of a decrease-increase pattern in curves, the instability of vorticity is greater for all curves. As the warm air is struck on the curved guide blades, which were put at eight sites close to AES, and enters the system, it signifies that the guided blades are effective for the system. Inside the SVE and EBS regions, it generates adequate vorticity. The highest vorticity was measured at 0.702 m and was 73.9 s ⁹⁶⁾

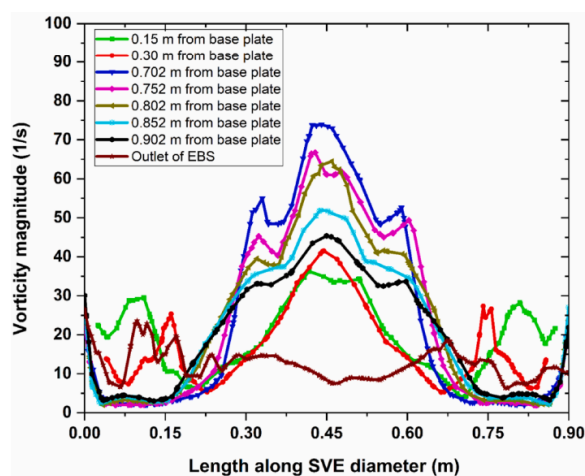


Fig. 36: Along the height of SVE, the vorticity profile ⁹⁶⁾

H. Al-Kayiem et al. ⁹⁷⁾ used an Al_2O_3 -in-black paint coating to improve the (SVE) system. Using a designed solar air heater with five compartments, the photothermal enhancement of four separate 5% wt metallic powder-in-black paints was studied experimentally. Each compartment included identical 110x15 cm aluminum absorbers designated as uncoated, black enamel painted, Al_2O_3 in black paint, CuO in black paint, and Al_2O_3 -CuO in black paint. and one of the most notable outcomes achieved is:

- ❖ The small-sized particles had better dispersion and uniform coating development, resulting in a more efficient conversion of solar light into heat.
- ❖ The heat conductance of the black enamel coating was enhanced by roughly 8.0 percent with a 5% weight. dispersion of the Al-in-Black coating.
- ❖ When compared to the unpainted absorbent, SAH had a 51.0% increase in thermal efficiency and a 28.5% rise in air temperature.
- ❖ The vortex generator's surface is coated with Al_2O_3 -in-black paint, which boosts the quantity of heat acquired by flowing air by 17.4 percent.

Fig. 37 shows the general design that researcher Hussain H. Al-Kayiem ⁹⁷⁾ relied on in the research and the main materials used in the research, which are: * Al_2O_3 powder; * CuO powder; and * Al_2O_3 -CuO mixture powder. Fig. 37 shows the general structure and some details of the proposed model used to achieve this study. In addition to other studies ^{94,98-106)}, listed in Table 5 studies about the Solar Vortex Engine studies have a summary of a set of previous studies for SVE from 2005 to 2020 of the place and objectives that the researcher seeks to achieve.

On the other hand, Table 6 presents a collection of research that looked at the number of slots (SVE) utilized for a group of prior studies from 2005 to 2020. Additionally, the location where the work was done and the design of the guiding vanes employed in the study.

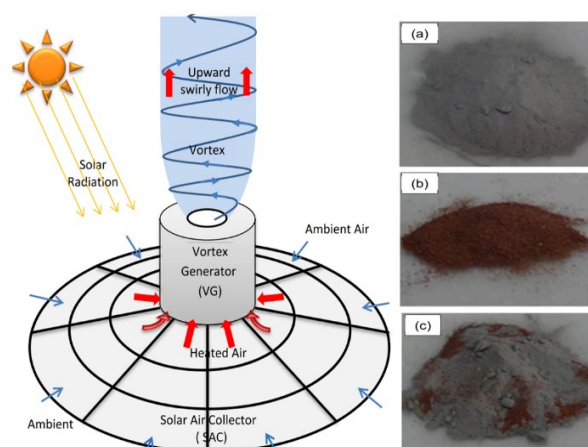


Fig. 37: Design the model with the materials used a- Al_2O_3 , b- CuO, and c- mixture powder ⁹⁷⁾

Fig. 38 depicts the variance in solar collector efficiency for various plate coating scenarios determined at varied sun irradiances. Thermal efficiency rose as solar radiation increased. The estimated thermal efficiencies of the SAH for the instances of Al_2O_3 -in-black paint, CuO -in-black paint coating, Al_2O_3 - CuO -in-black paint, and regular commercial paint, respectively, were 31%, 26%, 28%, and 28% at the maximum solar irradiation of 1040 W/m^2 . In comparison to the noncoated absorber, all painted absorber test cases both with and without additives displayed improved photothermic performance in the air collector ⁹⁷⁾.

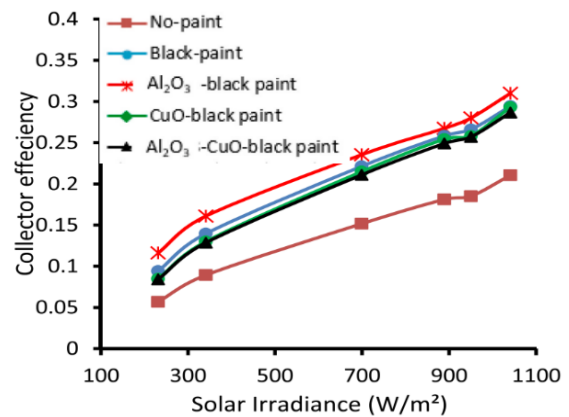


Fig. 38: Efficiency varies for different coatings at varied sun irradiances for solar air heaters ⁹⁷⁾.

Table 5. Summary of studies on the design and objective of the Solar Vortex Engine

Authors and Year	Search Execution Site	Objective of study
Louis M. Michaud, 2005 ¹⁰⁷⁾	American Meteorological Society	An engine consisting of a controlled tornado-like vortex is proposed
Nikitin Albert (RU) et al. 2007 ¹⁰⁸⁾	Russian Federation Federal Service for Intellectual Property, Patents	Invention patent, Power generation through the model
Simpson M, et al. 2013 ⁹³⁾	Technology Institute of Georgia USA: Atlanta, Georgia	The purposeful creation of vertical vortices caused by buoyancy is used to generate energy from the thermally stratified air layers above the solar-heated earth.
Mohiuddin A, et al. 2016 ⁹⁴⁾	Middle East Technical University Northern Cyprus Campus, Mersin 10, Turkey	Using a system that replicates dust devils, computational research was done to examine the effects of vane width, vane height, the number of vanes, and vane angle on the proposed device's vertical flow rate.
Hussein Al-Kayiem, et al. 2016 ¹⁰⁹⁾	College of Engineering, Al-Nahrain University, Iraq	Simulate and analyze a new solar updraft power system, named Vortex Generation Engine (VGE), to understand the artificial vortex
Ali A Ismaeel, et al. 2017 ¹¹⁰⁾	University of Technology, Baghdad, Iraq	The solar vortex power generation (SVPG) system was built to test the introduced system for the swirl air generator.
Ali A Ismaeel, et al. 2017 ¹¹¹⁾	University Technology PETRONAS, Malaysia	This paper was used to simulate the influence of inflow slot size on the vortex updraft velocity.
Ali A Ismaeel, et al. 2017 ¹¹²⁾	Universiti Teknologi PETRONAS, Malaysia and University of Technology, Baghdad, Iraq	presents and discusses a computational fluid dynamics (CFD) simulation of an artificial vortex air generator.
Pritam Das, et al. 2020 ⁹⁶⁾	India's National Institute of Technology Warangal	To assess the flow parameters and see the flow and vortex production inside the domain, a 3D model of SVE with an external boundary structure (EBS) was created.
Pritam Das, 2020 ¹¹³⁾	India's National Institute of Technology Warangal	For the purpose of assessing the flow parameters and power potential, a 3D computer model of SVE was investigated. The impact of air entry slot availability (AES). The best scenario (8)

Table 6. Previous studies about the number and shape of Guide Vane for SVE

Authors	Year	Where (Location)	Guide Vane Numbers	Guide Vane Shape and Angle
Louis M. Michaud ¹⁰⁷⁾	2005	American Meteorological Society	21	Curve
Nikitin Al'bert (RU) et al. ¹⁰⁸⁾	2007	Russian Federation Federal Service for Intellectual Property, Patents	6	small angles
Simpson M, Pearlstein A, Glezer A ⁹³⁾	2013	Georgia Institute of Technology Atlanta, GA, USA	12	Flat (30°)
Mohiuddin A ¹¹⁴⁾	2016	Middle East Technical University	12	Flat (25°-40°)
Mohiuddin A, Uzgoren E, ⁹⁴⁾	2016	Northern Cyprus Campus, Turkey	6, 12 and 18	Flat (30°)
Hussein Al-Kayiem, A. T. Mustafa, ¹⁰⁹⁾	2016	College of Engineering, Al-Nahrain University, Iraq	8	Curve (25°)
Ali A Ismaeel, Hussein Al-Kayiem ¹¹⁰⁾	2017	University of Technology, Baghdad, Iraq	8	Curve (15-25°)
Ali A Ismaeel, Hussein Al-Kayiem ¹¹¹⁾	2017	University Technology PETRONAS, Malaysia	8	Curve (25°)
Ali A Ismaeel, Hussein Al-Kayiem ¹¹²⁾	2017	Universiti Teknologi PETRONAS, Malaysia and University of Technology, Baghdad, Iraq	8	Curve (25°)
Pritam Das, V.P. ⁹⁶⁾	2020	India's National Institute of Technology Warangal	8	Curve (15°-25°)
Pritam Das & Chandramohan V. P ¹¹³⁾	2020	India's National Institute of Technology Warangal	Use 6 to 12 to prove that 8 is better	Curve (25°)

5. Abstracts and Setbacks Extracted from this Researcher

After reviewing photovoltaic cooling technologies and Hybrid Solar Chimney PV technologies, as well as studies that presented eddy simulation and artificial eddy generation methods for power generation using the Solar Vortex Engine (SVE) system to assess the strengths and setbacks of each system, it is possible to determine the direction to take in order to develop an efficient PV cell cooling system. The results of the evaluation can be summarized as follows:

► Solar cells do not store energy when the sun shines over them. Because it is a reliable and tested product, it has a long lifespan. However, higher panel temperatures result in less efficient cells and shorter PV life.

► All cell cooling technologies increase the life of the cell by reducing the temperature of the plate, which leads to higher efficiency and thus more energy produced.

► High PV temperatures, cause a slight increase in current and a significant decrease in voltage. This in turn reduces the output power produced as well as the life of the photovoltaic cell.

► Previous studies demonstrated that the cooling of photovoltaic cells using the passive mode is weak compared to the active mode. Therefore, this study seeks to raise the efficiency of the passive cooling system and reduce the energy consumed by the active system.

► There is a limit to the length of the chimney.

► The efficiency of the solar chimney is very low, not more than 2%.

► Difficulty cleaning and maintaining the PV panel, especially in large-scale plants.

► All previous studies of the Vortex Engine prove that SVE is an alternative to the Hybrid Solar Chimney because it is less expensive, offers better performance, and solves problems in the chimney system.

6. Proposed Model

A new model of Solar Vortex Engine has been proposed, which is an alternative system to Hybrid Solar Chimney PV and improves the performance of solar cells. The new system solves and addresses the problems and setbacks of the previous system. The proposed Hybrid Solar Vortex Engine PV (HSVE.PV) system consists of the Influence of the Inflow Guided Baffles attached to the back of the PV, a chimney, a heated glass surface, eight Guide Vane,

and an intake pipe extending to connect to the Guided Baffles. Fig. 39 shows a diagram of the proposed model with its main parts and how to link it with PV.

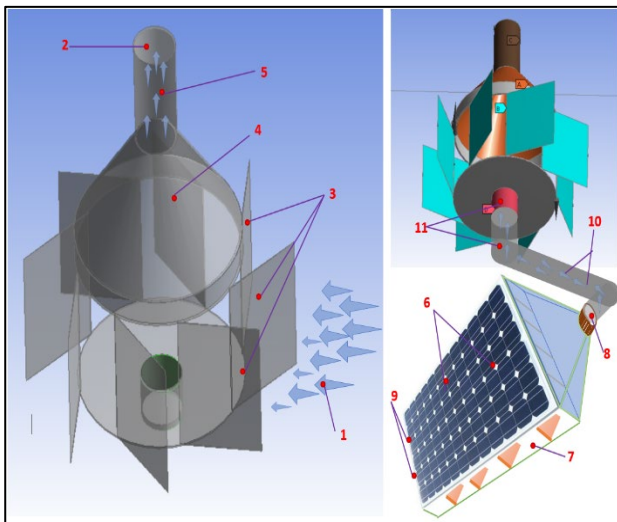


Fig. 39: Schematic diagram of the Proposed Model (HSVE.PV), 1- air entry, 2-air out, 3-Guide Vane, 4- Glass Surface, 5- Chimney, 6- PV, 9/7- Air entry through the Inflow Guided Baffles, 10/8- Air flow through the tube, 11- air Intake Tube from PV

To save costs and increase production capacity, more than one photovoltaic cell can be connected to a single SVE system that cools the cells simultaneously, as shown in Fig. 40.

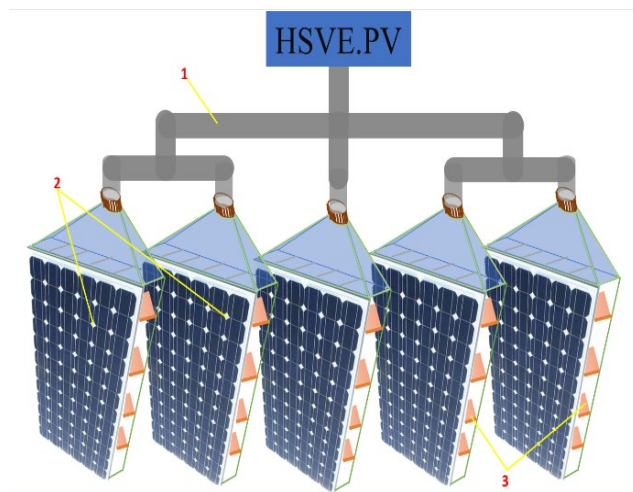


Fig. 40: A set of photovoltaic cells connected to the SVE system, 1- intake tubes, 2- photovoltaic cells, and 3- Guided Baffles

7. Conclusions

In the present time, the concept of PV cells is one of the most important ways to benefit from solar energy and convert it into electrical energy. However, the setback of

PV cells outcomes is a decline when the cell temperature and solar radiation are upgraded. Thus, absorbing the heat generated by the PV cell and lowering its temperature is important and necessary. A detailed literature review of cooling technologies in PV cell systems has been summarized and introduced in this paper. The review discusses the ideas and existing cooling methods proposed by researchers that utilize air, liquid, and hybrid methods. Then, the review focused on hybrid PV-solar chimney systems, which depended on air updraft motion in the chimney for PV cell cooling. The review evaluation revealed that there are two obstacles for wide the hybrid PV-solar chimney application.

First: there is a limit to the length of the chimney.

Second: the efficiency of the solar chimney is very low. Therefore, a group of previous researchers examined and tested to establish swirling air updraft motion as an alternative system for the chimney, and the new system is called the solar vortex engine (SVE). The CFD, experimental, and exciting models of SVE were also reviewed extensively. Nevertheless, no one suggests applying the SVE idea to PV power systems. Hence, this critical review paper proposes a new model of vortex engine arrangement that utilizes solar energy input for air updraft generation and creates a hybrid PV-SVE system.

Acknowledgment

The authors express their thanks to the University of Technology/ Department of Electromechanical Engineering/ Energy Branch for technical support in conducting this paper.

Nomenclature

<i>PV</i>	Photovoltaic
<i>SVE</i>	Solar Vortex Engine
<i>DC</i>	Direct Current
<i>PN</i>	Photodiode
<i>PVT</i>	Photovoltaic-Thermal
<i>PV / T</i>	Hybrid Photovoltaic-Thermal
<i>EAHE</i>	Earth air heat exchanger
<i>PVR</i>	Personal Video Recorder
<i>CFD</i>	Computational Fluid Dynamics
<i>SUT</i>	Solar Updraft Tower
<i>SCPP</i>	Solar Chimney Power Plant
<i>STPV</i>	Solar Thermal Photovoltaic
<i>HSCPP</i>	Hybrid solar chimney Power Plant
<i>LCOE</i>	Levelized Cost of Energy
<i>SVG</i>	Solar vortex generation
<i>AVE</i>	Atmospheric Vortex Engine
<i>PIV</i>	Particle Image Velocimetry
<i>SVPG</i>	Solar vortex power generator
<i>SHT</i>	Solar heat trap

<i>SAC</i>	Solar air collector
<i>AVG</i>	Artificial vortex generator
<i>RNG</i>	Renormalization group
<i>HSVE.PV</i>	Hybrid Solar Vortex Engine PV

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