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A STATE OF ART REVIEW ON THE RECENT DEVELOPMENTS IN SOLAR AIR HEATING TECHNOLOGY

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ABSTRACT
The sun is an incredible and renewable resource that has the power to fuel life on earth and provide clean, sustainable energy to all of its inhabitants. In fact, more energy from the sun reaches our planet in one hour than is used by the entire population of the world in one year. The sun's energy can be converted into electricity through solar photovoltaic (PV) modules (photo = light, voltaic = electricity). With the escalating expense of traditional energy sources, it's important to have access to alternatives like solar air heating technology, which uses only pure, renewable energy. It is possible to heat air using the "solar air heating systems" by absorbing the sun's thermal energy and recirculating the resulting air within a structure. In this paper, a literature survey has been conducted to study the developments in the field of the solar heating technology while covering the different principles of the same.
Keywords: solar photovoltaic, solar air heating technology, renewable energy, solar air heating systems, thermal energy,

INTRODUCTION
PV modules absorb sunlight and convert the energy into a usable form of electrical current. The sun shines all over the world, making solar electricity viable anywhere. Because solar can be paired with batteries for energy storage, solar electric systems can be independent of the utility grid, making them cost-effective for remote locations. Solar modules have no moving parts making maintenance costs low, and they are highly reliable with a long service life of 25+ years of guaranteed electricity. Solar electricity relies on the sun as its fuel source, so there is no need to drill for petroleum-based fuels, refine them, or deliver them to the site.
The design and installation of PV systems on a large scale enable us to move away from other polluting and unsustainable energy sources. Since the solar industry is growing, that means that the need for skilled workers is also growing! Remote Energy (RE) is a 501 (c) (3) for-impact organization that trains women and men worldwide to harness the power of the sun and develop the technical PV design and installation skills required to bring clean power and positive change to their communities. Technician training programs provide the growing workforce with the practical skills needed to be competent and competitive. Solar educator training programs empower local trainers with curriculum, mentorship opportunities, and the skills needed to meet current, regional training requirements.
Devices that heat air are called "air heaters". All varieties of radiant as well as space heaters are included, as well as items for use with forced air. Products that use forced air technology regulate the temperature of the air by continuously recirculating it over a heater. The air runs through the heater, picking up heat as it goes, and then blows out hotter than when it went in. Radiant heaters work by sending out waves of heat from a central point to warm whatever is in close proximity to it. A "free-flowing convection cycle" is formed due to the temperature difference, that warms the surrounding air. Self-contained and capable of using either fuel or electricity, space heaters are portable heating units. By definition, convection is the transport of heat across a fluid or other media. The fluid or the medium generates a forced or free-flowing convection current. In the forced flow convection, a fan or pump is used to circulate the medium. The convection cycle in the free-flowing systems is driven entirely by temperature as well as density gradients. "Solar Air Heating" using solar energy is one of the most cost-effective options available. The federal tax credit of 30% makes solar air heating economically viable in as little as 1–4 years.

LITERATURE REVIEW
[1] (Uzakov et al., 2021) proposed a "solar air heater", in order to keep the temperature of the heated air consistent in drying plants as well as "air heating systems". The article details the findings of an experimental study of installation's operating modes in natural as well as the climatic conditions of Karshi. The installation included a solar air heater, a storage tank with a "spiral-type heat exchanger" for accumulating the heated air, as well as a parallel hinged reflector to maximise the use of the solar radiation. Experiments performed in June on the heat carriers (air up to +65 °C & waste oil up to +75 °C) confirmed the solar air heater's excellent energy efficiency in the heating mode. The developed

installation's thermal balance is analysed. Analysis of how the installation's thermal power varies with the values of the most important heat engineering parameters.

[2] (Patel & Lanjewar, 2021) experimentally analysed the "Solar air heater" (SAH) ducts with the roughened surfaces in the pattern of gap in the V-geometry with the symmetrical gap as well as the staggered elements as the turbulence promoter to improve the thermo-hydraulic performance. "The investigation encompassed duct aspect ratio (W/H) of 12, relative roughness pitch (P/e) of 10, relative roughness height (e/Dh) of 0.043, angle of attack (α) of 60o, ratio of staggered rib position to pitch (P'/P) of 0.4, ratio of gap width to rib height (g/e) of 4, ratio of staggered size to rib height (r/e) of 4, number of main gaps (Ng) of 4, relative gap size of additional gap in symmetrical rib elements (g'/e) of 0.5-2, relative gap position of additional gap in symmetrical rib elements (d/w) of 0.25-0.85 and Reynolds number ranging from 4000 to 15,000". As an additional step, the suggested roughness geometry's results have been compared to those of previously published geometries. Maximum increases in the "Nusselt number (Nu) and friction factor (f)" over the smooth plate are found to be 2.51 & 2.70 times, respectively, for g'/e = 1 as well as d/w = 0.65. The highest possible "thermo-hydraulic performance" (THP) is 1.82 at g'/e = 1 as well as d/w = 0.65.

[3] (S. Kumar et al., 2021) studied heat exchangers like a "solar air heater" (SAH) that may harness the sun's rays and turn them into usable heat for the home. However, the low thermal-performance of the SAH is a result of air's weak thermal conductivity. Roughness is a powerful tool for boosting SAH efficiency. This article examines the impact of various factors on the "exergy efficiency" of a SAH using two distinct roughness geometries: semicircular & square. The solar air heater's flow path is a right triangle with equal 160-mm-long sides. It has been shown that the "exergetic efficiency of the SAH" may be improved by adjusting the Reynolds number and the roughness parameters (e/D and p/e, respectively). The exergetic efficiency of the semicircular ribbed SAH is found to be 26% greater than that of the square roughness at e/D & p/e values of 0.04 & 10, respectively. A SAH's exergetic efficiency, which takes into account both the quality of the useable energy and the pumping power required, makes it an appropriate design consideration. In addition, we create the design plots and provide suggestions for creating a highly effective solar air heater based on the data we gathered.

[4] (Kalash et al., 2020) conducted experimental and computational fluid dynamics research on the efficiency of the "double-pass solar air heater" . Ten metal tubes were used to construct 3 "double pass solar air heaters" for the experiments. All of the walls including the bottom base are insulated with 25 mm of Aluminum glass wool. The tests were conducted using one of three different setup types. The duration of the trials spanned the whole daylight hours. The design of the model utilised in the numerical studies was created in SolidWorks, while the simulations were carried out in Ansys Fluent. Both temperature & solar flux were found to rise gradually throughout the morning before levelling out around midday. The amount of energy stored steadily rises during the day and falls over the night. It was also discovered that the air velocity created vortices in the collection.

[5] (Hassan et al., 2020) tested the effectiveness of a novel "tubular solar heater" (TSAH) in the lab. Instead of using a flat absorber plate, as is typical with FSAHs, these heaters have parallel tubes facing in the same direction as the airflow. To examine the effects of changing the airflow rate through the SAHs, 2 SAHs (a FSAH & a TSAH) are built with identical dimensions & materials except for the absorbers. Researchers found that the TSAH outperforms the FSAH in terms of efficiency, outlet air temperature, output power, and peak heat loss. Furthermore, the given TSAH is proven to be more efficient than the previously examined SAHs designs. Compared to the FSAH, the temperature of the output air ffrom the SAHs may increase by up to 13.2 °C with TSAH when the air mass flow rate into the SAHs is 0.025 kg/s. At air mass flow rates of 0.075, 0.05, & 0.025 kg/s, respectively, the average daily efficiency of TSAH is about 83.6%, 76.3%, & 59.8%, representing increases of 132.6%, 58.6%, & 43.5% over FSAH. When comparing TSAH to FSAH, daily top heat loss is reduced by around 10%.

[6] (Arunkumar, Vasudeva Karanth, et al., 2020) studied the uses for solar air warmers in the home, workplace, and other settings are many. Because of solar air heaters' poor thermal efficiency, scientists have been working to boost the devices' performance by developing artificial flow modification methods for use in the flow field. Because of this, the laminar sublayer just below the absorber plate will be disrupted, leading to an increase in air turbulence. The absorber plate's heat-transfer efficiency improves as a consequence. This paper examines the role that turbulators of varying shapes had in enhancing the thermal performance of the air heaters by various researchers. Many factors, including design, geometry, flow conditions, absorber temperature, heat transfer rate, and "thermo-hydraulic enhancement factor", have been explored at length. Final thoughts are offered, and suggestions are made about how solar air heater performance might be further improved in the future.

[7] (Jia et al., 2019) recommended the spoiler's spiral form rather of the traditional serpentine form as a novel design for solar air heaters. This study presents experimental research on the operation of spiral solar air heaters (SSAH),

covering topics such as heat collecting efficiency, inlet/outlet temperature differential, irradiance, and air volume. According to the tests, the effectiveness of heat collection is directly linked to irradiation at a constant flow, and the temperature differential between the intake and output is linearly related to irradiation. Finally, the normalised temperature allows us to calculate the heat loss coefficient of the SSAH, which comes in at 5.69Wm2 K1. This kind of solar air heater has a better heat collecting efficiency than the regular and serpentine SAH.

[8] (A. P. Singh & Singh, 2018) detailed their research into a variety of curved solar air heater designs, all of which demonstrate considerable improvements in heat transmission. Based on the work of Moummi, N., Mahboub, C., Brima, A., and Moummi, A. (2015), we have used their original design. Testing a novel solar-powered air warmer concept. Incorporating potential design improvements to further explore the pathways for thermal efficiency enhancement features, as published in International Journal of Green Energy, 13, 521-529. Mahboub et al.'s published findings first established the accuracy of the CFD model. It was found that the Nusselt number rises dramatically if a secondary vortex forms close to the absorber wall. New relationships between the friction factor and the Nusselt number have been derived as a function of the Reynolds number and other geometric characteristics, such as the ratio of the height of the grooves to the distance between them. It is believed that the information offered in this study on the Nusselt number (Nu), outlet air temperature (To), thermal efficiency (ηth)), and friction factor (f) would aid researchers and industry in creating more effective designs of solar collectors.

[9] (Sharma & Mundari, 2017) predators prompted the development of new methods to preserve food and agricultural goods, solar drying (open sun drying) is the oldest method employed. The prolonged drying time and the need to shield the product from the elements and potential. One such cutting-edge method to achieve the same goal is the solar air heater-dryer arrangement. This study reviews a variety of international research on sun drying. Researchers have tried a variety of configurations and techniques in order to increase efficiency, including painting absorbers black, switching between natural as well as forced convection, using the unconventional absorbers such as spiral absorbers along with the ETC tubes as absorbers, studying the impact of recycling some of the air from the outlet and the artificial roughness of the absorber, employing dehumidifier beds to decrease drying air humidity, employing porous media for absorber, and configuring based on air flow. This review article covers every study and its findings.

[10] (Jamal-Abad et al., 2016) looked on the interaction between convection and radiation in a solar air-heater including a porous substance. We explain how the shape parameter (s), the Forchheimer number (F), and the radiation parameter (z) of porous media affect the collector efficiency. The Nusselt number, temperature and velocity are dimensionless quantities for which approximate analytical solutions are produced by the perturbation technique. Rosseland approximation modelling has been used to simulate the radiation heat transfer. A good agreement has been established between the analytical solutions with earlier efforts, and we give a discussion of the solution's correctness and limiting instances. An increase in the radiation parameter led to a considerable rise in the collector's effectiveness, as shown by the findings. An increase in the form parameter of the porous medium also results in a higher collector heat removal factor.

PRINCIPLES OF SOLAR AIR HEATING SYSTEMS

Solar air heaters can be broadly classified under two categories:

(1) First type has nonporous absorber in which air stream does not flow through the absorber plate. Air may flow above and/or below the absorber plate.

(2) Second type has a porous absorber in which air stream flows through the absorber plate.

1. Non-porous Type solar air heater

The simplest type of nonporous solar air heater is the one which consists of a bare metallic plate, the top of which is suitably blackened. Another plate, the rear of which is insulated, below the absorber plate is used to form the duct for air flow. The incident solar radiation on the blackened surface gets absorbed and the resulting heat is partially transferred to the flowing air within the duct.

The main disadvantage of this type of solar air collector is high thermal losses to the ambient due to convection and radiation. Therefore, the alternative designs have been developed where these type of thermal losses are reduced. The convective losses can be reduced by covering the absorber plate with one or more transparent covers, usually called glazing. Such solar air heaters are shown in Figures 4.2 and 4.3. In the solar air heater shown in Figure 4.2, the air flow duct is between the glazing (glass cover) and the absorber. The flow of the air is above the absorber. On the other hand, the air flow is below the absorber in the solar air heater shown in Figure 4.3. The selective coatings may be applied to the absorber to reduce the radiative losses.

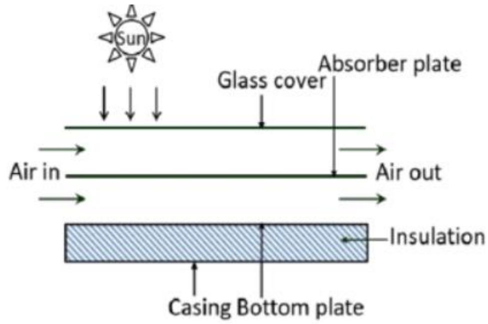

Figure 1 Non Porous Solar Air Heater

The main disadvantage of nonporous solar air heater is the low transfer between air and the absorber plate. The heat transfer can be increased by roughing the surface of the absorber at the rear, by adding fins or by making the absorber plate vee corrugated.

An important drawback of the nonporous absorber plate is the necessity of absorbing all incoming solar radiation over the projected area from a thin layer over the surface, which is of the order of few microns. Unless selective coatings are used, radiation losses from the absorber plate are excessive, and therefore the collection efficiency is difficult to be improved. The pressure drop along the duct formed between the absorber plate and the rear insulation is also prohibitive in nonporous absorbers. Any effort to increase the heat transfer between the absorber and flowing air stream such as adding fins or enlarged corrugations results in increased pressure drop across the collector. More fan power is therefore required to maintain the same air flow rate through the heater.

2. Porous type solar air heater

The second type of air heaters has porous absorber which may include slit and expanded metal, overlapped glass plat absorber and transpired honeycomb. A porous absorber shown in Figure 4.6 overcomes some of these problems in following way:

(a) The solar radiation penetrates to greater depths and is absorbed gradually depending upon the porosity of the absorber. The incoming air introduced from the upper surface of the matrix is first heated by the upper layers. The air stream gets heated while traveling through the matrix layers. The lower matrix layers are hotter than the upper ones resulting into better heat transfer from the matrix.

(b) The pressure drop for the porous matrix is usually much lower than the nonporous absorber.

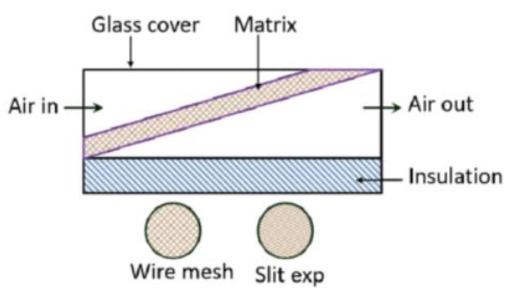

Figure 2 Porous Solar Air Heater

The solar heater with porous type of absorber has the following advantages:

- Solar radiation penetrates to a great depth and is absorbed along its path. Thus the radiation loss decreases. Air stream heats up as it passes through the matrix.
- The pressure drop is usually lower than the non-porous type.
- It may be noted however, that an improper choice of matrix porosity and thickness may cause reduction in efficiencies as beyond an optimum thickness, matrix may not be hot enough to transfer the heat to air stream.
- Wire mesh porous bed formed by broken bottles and overlapped glass plate are some examples of porous type absorbers used in Solar air heaters.

Solar Air Heater Advantages

- The need to transfer heat from working fluids to another fluid is eliminated as air is being used directly as the working substance. The system is compact and less complicated.

- Corrosion is a great problem in solar water heater. And this problem is not experienced in solar air heaters.
- Leakage of air from the duct does not create any problem.
- Freezing of working fluid virtually does not exist.
- The pressure inside the collector does not become very high.
- Thus air heater can be designed using cheaper as well as lesser amount of material and it is simpler to use than the solar water heaters.

Solar Air Heater Disadvantages

- Air heaters have certain disadvantages also the first and foremost is the poor heat transfer properties of air. Special care is required to improve the heat transfer.
- Another disadvantage is the need for handling large volume of air due to its low density.
- Air cannot be used as a storage fluid because of its low thermal capacity.
- In the absence of proper design the cost of solar air heaters can be very high.

CONCLUSION

The applicability of the solar air heater depends on various factors like high efficiency, low fabrication cost, low installation and operational cost and some other specific factors regarding specific uses. Extensive work in solar air heaters has been done. Various geometries have been proposed and their theoretical investigation is carried out. But it needs commercial exploitation. This paper covers the literature survey on the ongoing researches for the enhancement of the efficiency of the solar air heaters by using various techniques. The main principles of operation of porous as well as non porous type solar air heaters have also been discussed.

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