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Performance of solar stills integrated with PV/Thermal solar collectors: A review

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ABSTRACT

All Earth's life forms depend heavily on water. Despite the critical importance of fresh water in the modern world, water pollution caused by industry and increasing urbanization has significantly reduced the amount of pure water available on Earth. Changes in global climate and seasons also contribute significantly to the depletion of fresh water resources. Population growth over the past few decades has increased the demand for safe drinking water. Multiple water-borne diseases can result from drinking contaminated water, and depending on the level of pollution, this could even be fatal. There are several ways to purify polluted water, but solar distillation is the most cost-effective and environmentally friendly option because it mimics the hydrological processes seen in nature and can be powered by the sun alone. Solar stills provide drinkable water and don't call for any special expertise to operate or maintain. An integrated PV/T solar still is a welcome solution for distant locations that already struggle with access to safe drinking water and dependable electricity. According to research, a passive solar still produced 2–5 kg/m2 of fresh water daily whereas an active solar still connected to a PV/T collector could produce 6–12 kg/m^2 of fresh water daily. In this paper, we provide a complete investigation of the solar still coupling and PV module coupling levels at the moment.

1. Introduction

Water on Earth is 96.54% of salt water, while only 2.53% is fresh water [1], and only _0.36% of the fresh water is drinkable [2]. Overpopulation and increased industrialization have put pressure on formerly adequate water sources. Desalination is seen as a viable option to meet the growing need to fresh water. Total capacity, of the global is around to (60) million, m3 /d [3], and there are currently (14,451) desalination plants operating, as reported by the [22nd GWI/ IDA] Desalting Worldwide Plant Inventory. Multi-Stage Flash (MSF) distillation, Multi-Effect Distillation (MED), and Vapor Compression (VC) are examples of thermal technologies; Membrane technology examples include Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF), and Reverse Osmosis (RO). Commercially, MSF, MED, and RO are implemented in significant capacity in cities because they consistently have excellent efficiencies relative to electrical power usage. Villages of the north and west in China, as well as islands of the East and South Seas China, are too far off from major population centers to benefit from these technologies. Solar stills have the potential to be used in such locations to supply clean drinking water. To begin, there is a severe dearth of electrical energy, and the use of any electrical infrastructure is highly discouraged. Second, the sun provides a plentiful source of energy. For instance, in the north and west of China, the average annual solar radiation is greater than 6000 MJ/m2 /y.

And finally, solar stills are inexpensive, simple, and environmentally friendly to use. In addition, the populations and pure water demand are low enough that solar stills could meet the need, despite their lower productivity compared to electricity-driven desalination methods. Fifth, solar is projected to continue to combine with photovoltaic & thermal systems (PV/T) [4] ,or concentrated solar power (CSP) plants, as more and more photovoltaic and plants thermal are used, in these areas. According to Kumar and Tiwari [5], the cost of filtered water generated by passive solar was still (_$0.014/kg) for a system with a (30) year life duration.. Additionally, A solar distillation facility with a capacity of less than 200 kg/d was suggested. it more cost-effective than other plant types. Due to its low efficiency, solar still has not been widely used. Two of the biggest obstacles to developing solar stills are increasing production and making them more adaptable to various climates. Many scientists have contributed to the process of optimizing or rebuilding structures; most of their efforts have been put to the test in the laboratory. The history and developments of solar stills have been summarized by a number of academics [6-9]. Structure modifications and their impact on productivity and efficiency were the topic of research by Kabeel and El-Agouz [6] and Velmurugan and Srithar [7]. Energy transfer equations for the distillation process were presented, and solar stills were characterized by Kaushal and Varun [8]. For anyone interested in learning more about active solar distillation, Sampathkumar et al. [9] wrote a comprehensive and in-depth overview. The goal of this work is to classify solar stills into six types according to design guidelines and to expound on the attributes of each guideline from the perspective of increasing solar still production. Climate-specific recommendations for optimal building design are provided. In order to have a full picture of solar stills, it is necessary to analyze the most basic mass and heat transmission processes. Figure 1 [10] displays the various solar still distillation classifications. There are two basic kinds of solar stills: dynamic and static. In passive stills, the water in the basin is heated directly, eliminating the need for any additional heating sources and allowing distillation and heat collection to take place within the same apparatus. . There are two main types of passive solar stills, the traditional ones and the efficient ones. Water in active solar stills is heated directly, However, It also receives preheated water through an indirect channel that is heated outside, such as hot water accessible from a solar collector, heater, and a recirculation of outgoing water, in order to improve the water temperature in the basin and so boost the evaporation rates. Separate types of active solar stills include those that use waste heat as their primary energy source, those that rely on solar collectors (such as concentrators and flat plates), and those that use a combination of the two. The first known usage of stills was in 1551 by Arab alchemists, who were quickly followed by other scientists and scholars such as Della Porta (1589), Lavoisier (1862), and Mauchot

(1869). A little mining town in Las Salinas, modern-day Chile, commissioned Swedish engineer Charles Wilson to construct the world's first conventional solar still plant. The first stills were just enormous basins used to collect and store the high-salinity fresh water (four times that of seawater) used to supply the mine employees and locals with the nitrate mining effluents. There is a wide variety of styles and materials used to create the earliest stills. Several factors, including latitude, sun angle, average weather, solar still design, and distillation methods, affect how much water can be distilled with a solar still. Very low operating costs are what make solar distillation a practical option [11].

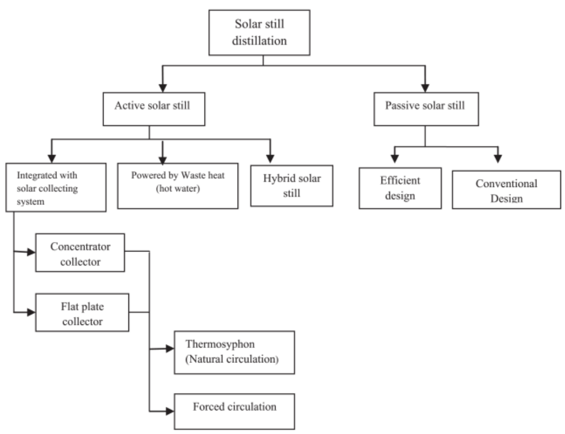


Figure 1: solar still distillation categories

2. Basin-type solar still productivity and the parameters that affect it

Figure 2[12] illustrates how ambient, operating, and design circumstances affect a solar still's output.

Operating conditions include water depth, different colors, still orientation, and input water temperature, whereas ambient factors involve temperature, isolation, and wind speed. Results appear to confirm that sunlight is crucial to this process. Kamal [13] showed convincingly that the outputs are highly sensitive to the source, which of this case is solar energy. temperatures and solar radiation have been shown to have a direct effect on still performance, as reported by Rahbar and Esfahani [14]. Aburideh et al. [15] conducted an experiment in the village of Bou Ismail-Algeria to investigate the impact of weather sun still on a double-slope plane; The outcomes demonstrated that incident sun radiation has a significant impact on production augmentation.

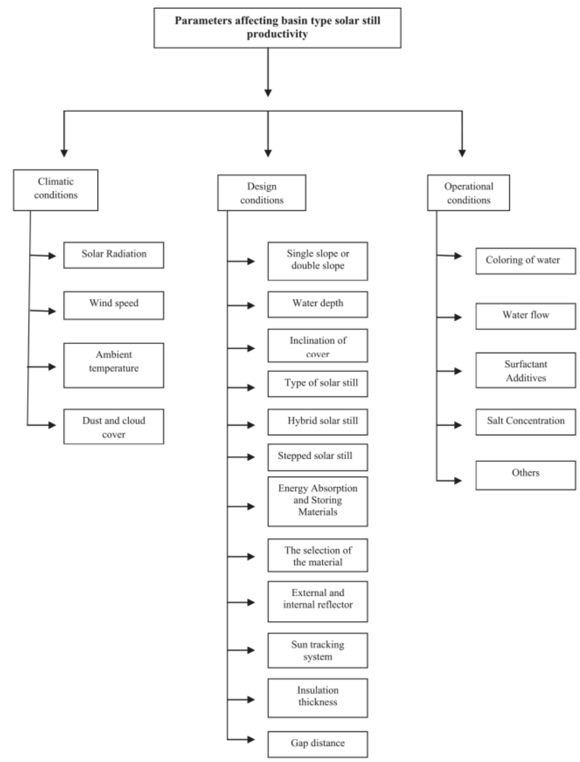


Figure 2: factors affecting the production of basin-type solar stills.

3.The process of a solar still and how it functions

Water that is high in salt content, such as saltwater, must be desalinized before it can be used in a solar still system [16]. In solar desalination, the evaporation and condensation process is used, just as it occurs in the hydrologic cycle. Energy from the sun is used in a green energy transfer process called a solar still to purify dirty water into drinkable water (as depicted in Fig. 1) [17]. At the outset, dirty water is poured into the solar still's basin. Light from the sun passes through a transparent yet condensing cover, raising the water's temperature to the boiling point, where it then evaporates. The slanted glass top became covered in water vapour., and the resulting droplets of pure, contaminant-free water slowly made their way downhill, where they were collected in a distillation trough. [18,19]. Consequently, the amount of energy produced by a solar still is totally reliant on the amount of sunlight that hits it [20]. Figure 3 is a diagrammatic representation of a basic basin-style solar still**.**

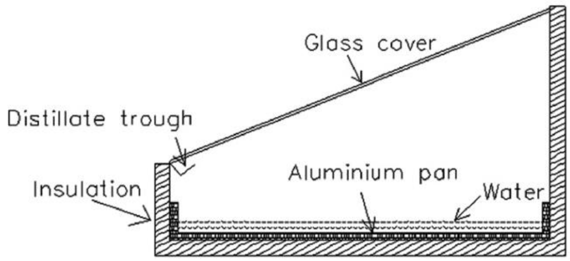


Fig. 3 : Flowchart of a straightforward basin-style solar still. Adapted from ref. with permission. [21].

3.1.Maintenance and troubleshooting

For optimal solar still performance, several measures must be implemented. Here are some of them:

First, scrub the toilet and flush it clean. Mineral salts and other impurities are left behind in the solar still basin as water evaporates. If the still is not regularly serviced and cleansed, these salts will accumulate to the point of saturation. Three times as much make up water as daily distillate is needed for proper still operation. The still's output of 2 litres of water would necessitate the addition of 6 litres of make-up water. The still dumps the extra 4 litres of water as make up water. To avoid salt buildup, the still basin gets a regular flush from the surplus make up water.

Second, keep the glass and condensate channel clean to maximise the solar distill's efficiency. Dust on the glass cover can block some of the sun's rays, limiting the device's performance. Vapor leakage can occur if glass is broken. When draining the basin water, it is also necessary to clean the condensate channel. Distillate, or another cleaning solution, can be used to clean glass [22][87].

4. Solar power generator containing a photovoltaic module

4.1.Flat plate collector

The internal heat transfer coefficient of a hybrid (PV/T) active solar still was experimentally investigated by Kumar et al.[23]. Fig. 4.a depicts the side view of a typical single slope passive solar still.(CSSPSS). It's constructed using GRP material, which is glass fiber reinforced plastic. The sloping slope of the condensing cover was 30 degrees with respect to the level of the ground below. In Fig. 4.b, we see the active solar hybrid from the side (HASS). Flat plate collector with integrated PV (FPC) and Dc generator pump are the three main components When forced circulation is used, a pump is used to circulate the water through the system .The CSSPSS and HASS trials were run all year long under the actual weather conditions experienced by Indian.

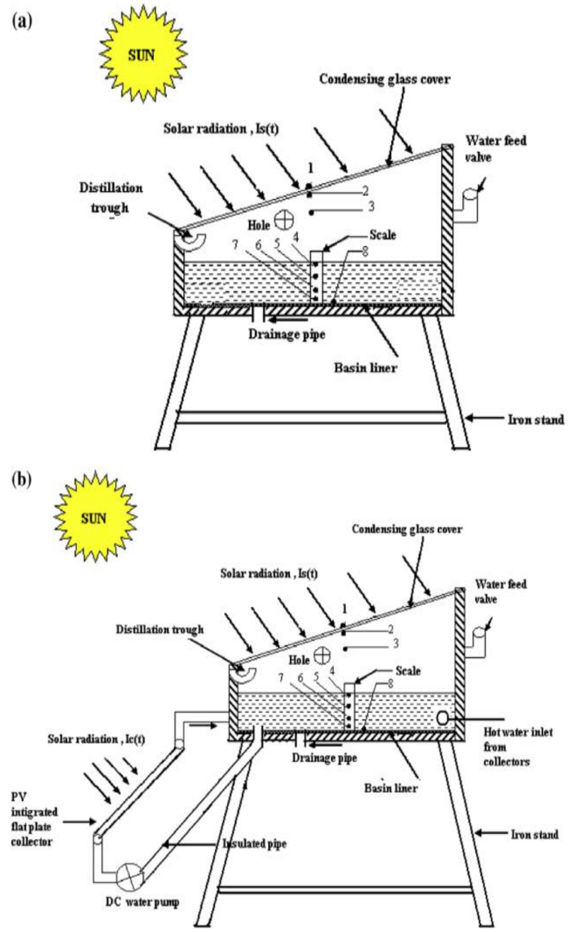


Fig. 4: (a) Single-slope passive solar still diagram, side view. (b) Schematic of a hybrid (PV/T) active solar still .[23]

Fig. 5: Photograph of experimental setup of hybrid (PV-T) active solar still [24].

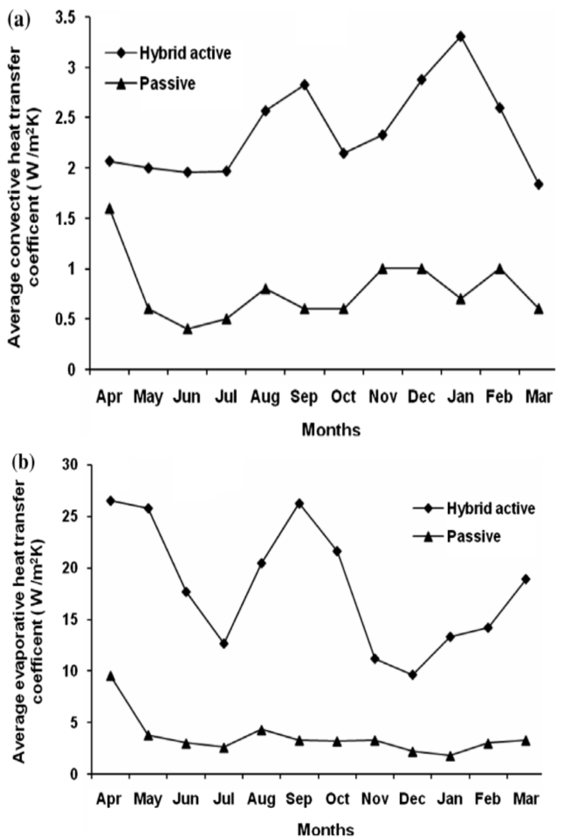


Fig. 6: average monthly change in comparison (a) convective (b) Evaporative heat transfer coefficient in passive and hybrid active solar stills of 0.05 m water depth [23].

The average convective heat transfer coefficient for CSSPSS and HASS at a depth of 0.05 m is shown to vary by month in Fig. 6.a.

Comparing CSSPSS with HASS, the average convective heat transfer coefficient is. For CSSPSS and HASS, the typical evaporative heat transfer coefficient at a depth of 0.05 m is shown to vary by month in Fig. 6.b. The average coefficient of convective heat transfer in (CSSPSS) is and in (HASS) it is. The annual mean value of the HASS's convective and evaporative heat transfer coefficient is found to be three to five times higher than that of the (CSSPSS). The characteristics equation for a single-slope solar still-FPC-PVmodule setup was obtained by Dev et al. [24]. Theoretical predictions were compared with experimental results. During the period in New Delhi, India, from April 2006 to March 2007, experiments were carried out in order to complete the characteristics equation of the Hybrid PV/T active solar still. The hybrid PV/T active solar still experimental set up is depicted in Fig. 5. This installation features a 1 m2 solar still with a 30 degree condensing cover and two 4 m2 FPCs that are 45 degrees off the ground. The DC motor that moves the still basin receives water from the collector is powered by a 75-watt photovoltaic panel that is built into one of the lower sides of the FPC. During non-sunny times, the pump is turned off to prevent heat loss from the opposite direction. At a water depth of 5 cm and with the pump working for 9 hours, HASS was shown to be 3.5 times more productive than PSS. A solar still can produce as much as 7.223 kg of liquid at its peak and as little as 2.006 kg at its lowest. Kumar and Tiwari [25] built and tested a single-slope photovoltaic thermal active solar still (HASS) and a single-slope passive solar still (PSS) in real-world climate. To compare HASS and PSS yields at a depth of 0.05 m during the year 2006-2007, see Fig. 7. In April of 2006, HASS and PSS fresh water production peaked at 7.22 kg and 2.26 kg, respectively.

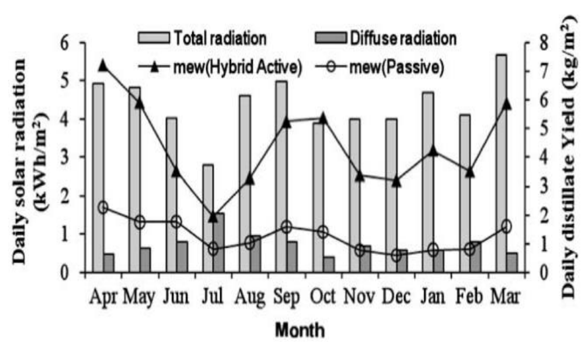


Fig. 7: yield comparisons of hybrid active and passive solar stills in various months between 2006 and 2007 at 0.05 metres of water depth [25].

Fig. 8: Monthly fluctuation of thermal and electrical efficiency for 0.05 m water depth for passive and hybrid active solar stills [25].

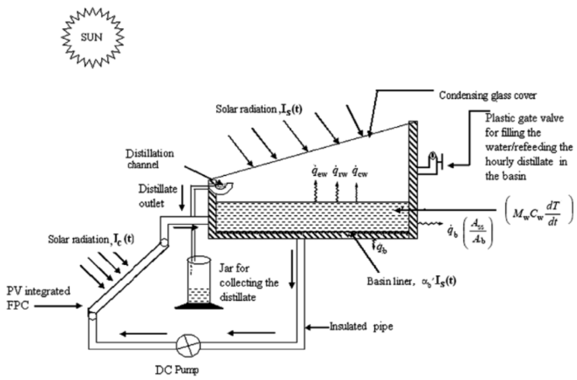


Fig.9: PV/T hybrid active solar still's schematic [26].

The number of collectors needed to integrate a PV/T hybrid active solar still was improved by Gaur et al. [21] by using energy and exergy equations.

It is made up of a solar still and a PVT coupled FPC (Fig. 9) To power the DC pump, a semi-transparent PV module serves as part of the PVT-roof. FPC's DC pumps can transport the heated water from the FPCs to the solar still. Fig. 10 is a schematic showing a series connection of PV/T collectors.

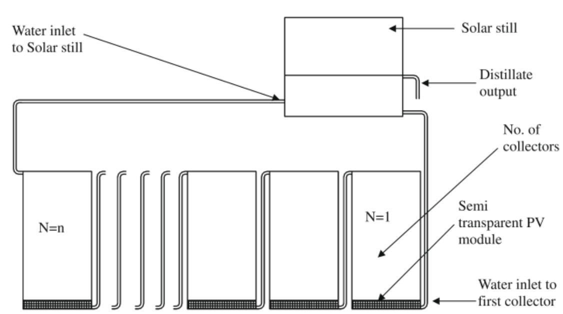


Fig. 10: Schematic diagram of PV/T collectors connected in series [26].

Ten tubes are spread out over a square meter of FPC space that is 45 degrees off the floor. PV module measuring 0.27 m 1.20 m with a 37 W output power is inserted into the bottom of the FPC. The DC pump can operate continuously for 24 hours on the daily power output of (0.22)kW h from the PV panels. Each PVT-FPC was found to have a net thermal gain of 3.662 kW h per day. Tests were run with 50 kg, 100 kg, 150 kg, and 200 kg of water in the solar still basin. Experiments showed that with only 50 kg of water in the still basin, the production increased significantly.

In Fig. 11, We can observe how a hybrid (PVT-FPC) solar still does daily yield and efficiency calculations in respect to the number of suns.

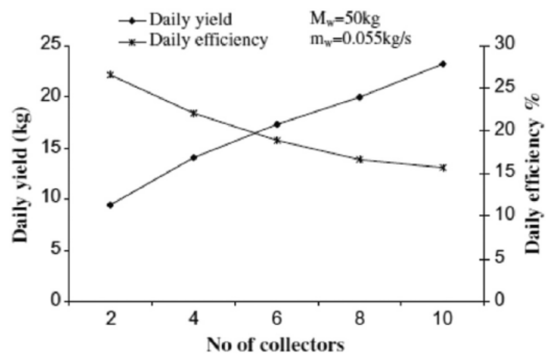
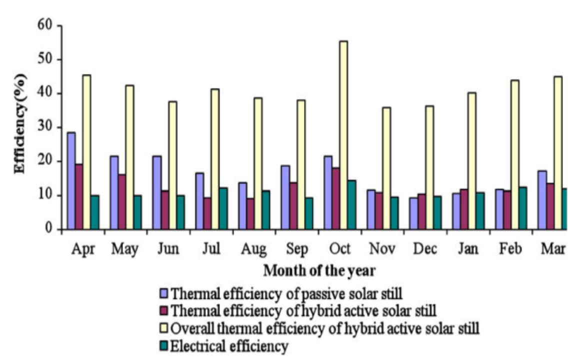


Fig. 11: Variation in efficiency and daily yield with collection count [26].

collectors for a mass flow rate of 0.055 kg/s, or 50 kg of water. The daily output increases along with the number of PVT-FPCs, but the, daily efficiency of solar stills drops. Because more FPC means more heat is lost to the environment, solar efficiency continues to fall as FPC numbers rise. The findings demonstrated that daily solar efficiency dropped by as much as 40% when going from 2 to 10 FPCs for the same amount of water. If the flow rate is 0.05 kilogrammes per second and the water mass is 50 kilogrammes, your daily yield will be 7.9 kg. It was determined that 50 kg of water and 4 FPCs provide the best performance from a hybrid active solar still. Kumar [27] discusses how a hybrid (PVT) active solar still is affected by factors including financial

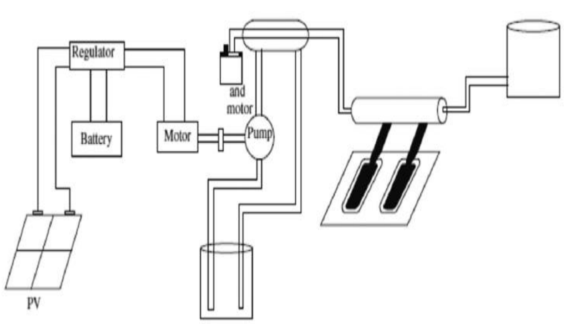


aid, tax reduction, price rises, and upkeep costs. For a 30-year Active Solar Still (ASS), he calculated an energy production factor of 5.9% and a life cycle conversion efficiency of 14.5% (the latter being the system's net energy productivity relative to the solar energy input over the course of its lifetime). Output of potable water by ASS costs 0.75 rupees per liter and 0.85 rupees per kilowatt hour of electricity.

The yield and efficiency of a hybrid PVT-FPC solar still are displayed against the number of collectors in Fig. 11 for a water mass of 50 kg and a mass flow rate of 0.055 kg/s. Although the daily efficiency of the solar system continues to decline, the daily production rises along with the number of PVT-FPCs. As FPC numbers increase, solar efficiency decreases because more heat is wasted to the environment. The results showed that after switching from 2 to 10 FPCs for the same volume of water, the daily solar still efficiency decreased by as much as 40%. Your daily yield will be 7.9 kg if you have a 50 kilogramme water mass and a flow rate of (0.055) kg/s.. It was determined that 50 kg of water and 4 FPCs provide the best performance from a hybrid active solar still.

Kumar [27] discusses how financial assistance, tax breaks, price increases, and maintenance expenses can effect a hybrid (PVT) active solar still. He calculated an energy production factor of 5.9% and a life cycle conversion efficiency of 14.5% for a 30-year Active Solar Still (ASS); the latter represents the system's net energy productivity in relation to the solar energy input over its lifetime. Production of potable water by ASS costs 0.75 rupees per liter and 0.85 rupees per kilowatt hour of electricity.

Thermosiphon [29, 30] and force circulation [31-33] are the two primary types. There are many parts that make up a flat plate collector, such as the glass cover [28, 34–36], absorber plate [37–39], air gap [40–43], riser pipe [44–48], frame, and insulation [49–51].



4.2. Collector with an evacuated tube.

With the help of a Super Heat Conduction Metal Vacuum Tube, Abdallah et al. [52] analyzed the efficiency of a solar still (SHCMV). Using a flat-plate photovoltaic system allows for constant operation. The proposed procedure for constructing a solar still is depicted in Fig. 12. All of the energy required by this system is produced by solar panels on the roof .the following components: a heat-pipe, a borosilicate glass tube, heat-collecting plates, a metal cover, a heat-exchanging end, and an aluminum safety-protection cap are the major components of a SHCMV tube. The efficiency and effectiveness of both the manufactured process solar still and the traditional solar still were tested experimentally.

SHCMV integrated solar stills produce 12 l/m2 /day, while traditional solar stills produce just 1 l/m2 /day.
A yield improvement of roughly 90% is expected with the suggested technology

Fig. 12: Schematic representation of the key elements of the built process [52]**.**

The new cogeneration technology for producing fresh water and power by incorporating PV module at solar still collector was researched by Yari et al. [53]. In this study, Using natural circulation, an Evacuated Tube Collector (ETC) is connected to a still basin., and semitransparent photovoltaic modules are installed above the solar still collector. As shown in Fig. 13, the innovative cogeneration PV integrated active solar still.

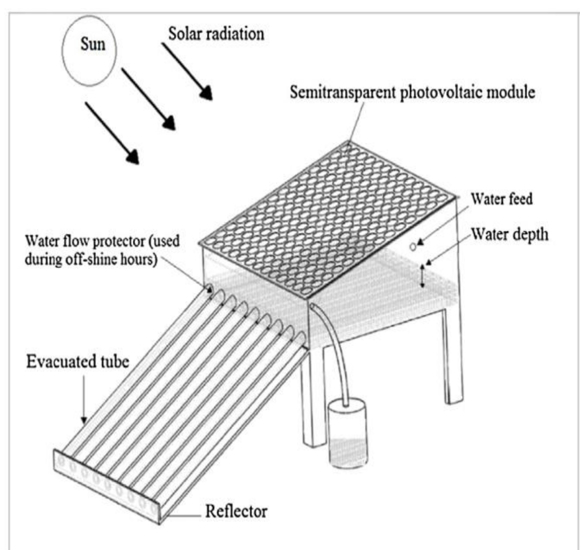


Fig. 13: Schematic diagram of a solar still integrated with ETC and semitransparent PV

module [53].

The daily electrical power output at a water depth of 0.07 m for six different types of PV modules is seen in Fig. 14. The results of these tests reveal that while an increase in solar radiation has a favourable effect, the temperature of the water in the basin and the quantity of tubes have no bearing on the operating temperature or electrical efficiency of the PV panels.. Maximum energy efficiency is 16.65% and maximum exergy efficiency is 6.86% for the Hetero junction utilising the Intrinsic Thin Layer (HIT) module, which, by combining 10 ETC and HIT(PV)modules, produces a maximum daily power output of 483.2 wh/m2.

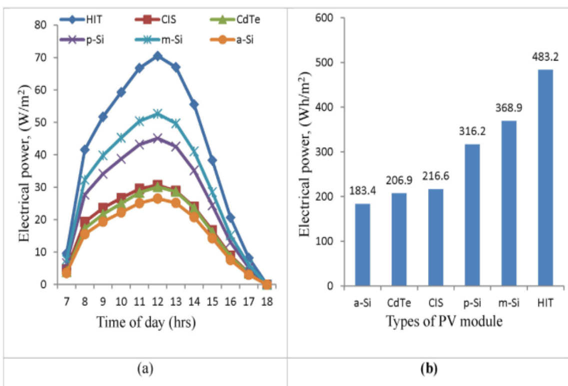


Fig.14: (a) six distinct PV modules with varying electrical output and d = 0.07. (b) For a PV module, a daily electricity supply [53].

Figure 15 depicts the system's daily fresh water yield for varying numbers of ETC groupings and water depths. It was determined that more tubes result in more fresh water being produced. At(30) ETC and a basin depth of 7 cm, the maximum daily fresh water yield was reported for PV integrated glass cover at 4.77(kg/m2.day) and for conventional glass cover at 5.89 kg/m2.day.

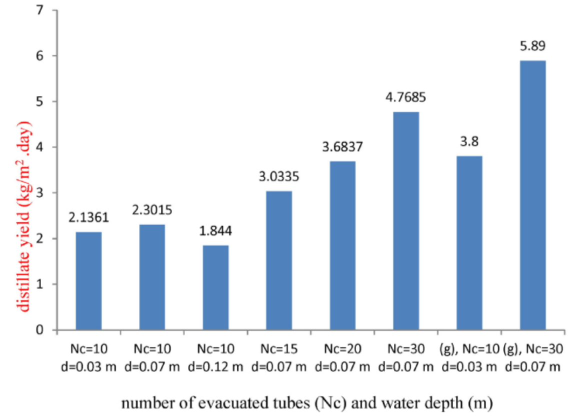


Fig. 15: How much distillation there is produced per day for various combinations of the number of evacuated tubes and the depth of the water for an HIT PV module [53].

4.3. New approaches

4.3.1. Desalination by concentrated solar thermal/photovoltaic systems.

Al-Nimr et al. [54] have theoretically modelled a distinct concentrated PV/T desalination system with an internal condenser and evaporator constructed of porous material. The technique suggested for PV/T desalination is described as follows: The focused solar intensity passes through the glass layer (A) and around the tubular system (B) while the PV cell produces power and rejects heat (Fig. 16). The heat that the PV cell rejects causes the water in the porous evaporator (C) to boil. When the vapour generated by the condenser and evaporator is sent to a second condenser, where the partial pressure between the plates causes the vapour to condense, water droplets are formed. Water droplets can move to a particular facet of the condenser by sliding with the aid of a little inclination provided when condensation occurs on the inner surface of the condenser. Using the thermosyphonic effect, cold water is pushed into the still, where it warms and flows to the cold storage tank, where its temperature is reduced and the cycle is repeated.

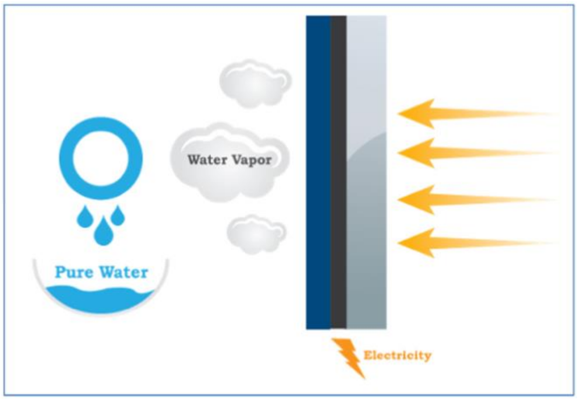


Fig. 16: Description of the PV/T system mechanism [54].

4.3.2. At the bottom of the basin, there is a PV/T cell attached.

The unique PV/T distillation system proposed by Al-Nimr et al. [55] comprises of a (PV/T) cell positioned at the basin's base that is paired with a solar basin stil. , To be treated, submerged beneath water (Fig. 17). A unique component of the system consists of fins mounted beyond the side wall.; these fins serve as a condenser. The setup of the innovative hybrid (PV/T) distillation system is depicted in Fig. 17. In addition to the revolutionary utilization of a PV/T cell immersed in water and a finned condenser located on the outside, The temperature of the water and the rate of evaporation are both raised by focusing solar radiation in the basin region with the use of an internal reflector. The proposed solution has the benefit of being both eco-friendly and multifunctional. It recycles water by distilling it and producing energy by means of PV/T cells. Water vapor is swiftly extracted from the basin using a fan installed above the water's surface, which then propels the vapor into a condensing chamber. The power from the submerged PV/T cell is used to run a fan, which increases condensation during the day. Because of this, the fan can run without an additional power source, and condensation occurs more quickly. The low pressure formed in the evaporation chamber thanks to the flow of water vapor from the evaporation chamber to the condensation chamber increases the evaporation rate. In addition, the temperature of the inner glass cover

(Fig. 17) is lowered by this procedure.

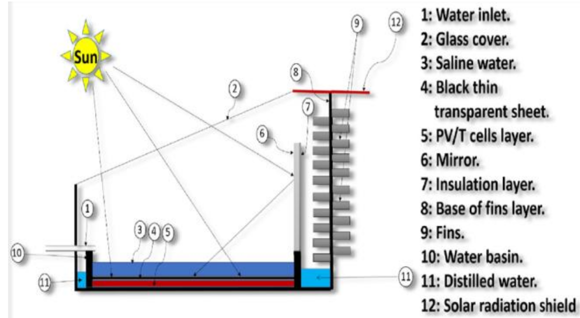


Fig. 17: An illustration of the parts of the solar PV/T distillation system [55].

4.4. Electrical heating

To create clean water in a sustainable manner, Ali-Riahi et al. [56] conducted trials on a solar still combined with an alternating current heater and a photovoltaic module.

Fig. 18: Photograph of experimental setup[56].

Conventional solar still plus (PV) heater (CSSPVH) daily fresh water production against conventional solar still (CSS). It has been discovered that (CSSPVH) can increase water productivity by a factor of six compared to CSS. Daily yields for (CSSPVH) and (CSS) are (5.7) and (0.9) kg/m2, respectively.

The integration of a 500-watt hater with a double-slope solar still is the focus of this study's research. There are six PV modules used to generate 1.5 kilowatts of power, and these are connected to four batteries that are each capable of holding 150 ah of power. (Fig. 18) By combining an AC heater and PV module, this system is superior because it can provide potable water in low-solar-radiation environments.

5. Ambient and operational factors

The effectiveness of a solar still as a distillation device is affected by both the weather and the way it is being used. Climate conditions primarily consist of temperature, the speed of the wind, and the strength of the sun , while operating conditions include cover angle, coating substance, and basin placement, brine depth, brine temperature difference from glass cover, insulation of solar still, etc. Because higher sun intensity causes brine to heat up, facilitating evaporation, its productivity improves with increasing solar intensity [57]. Thus, A cover might completely absorb sun light if it was angled at an angle equal to the local latitude. boosting output [58]. The coating of the basin also helps absorb solar energy, and certain materials can double as heat storage media, which is great for boosting output [60,59]. Black gravel with a size between 20 and 30 mm increased output by 19%, as shown by Nafey et al. [61]. Different researchers have reached different conclusions on the impact of environmental influences. It was reported by Voropoulos et al. [62] and disputed by Badran [63], who found that cooler temperatures helped boost productivity. In contrast to the claims of Badran [35] and El-Sebaii [64], discovered that productivity rose as wind speed rose, Nafey et al. Possible explanations for these variations include a larger rate of heat loss to the outside and a greater temperature difference between the brine and the glass cover. when the ambient temperature is lower or the wind speed is higher. Productivity is boosted by the former, but hindered by the latter. High production is guaranteed when there is only a thin layer of brine [57,65-67]. The heat capacity of a thin coating of brine is low, hence the brine evaporates quickly when the temperature rises.

Productivity was found to be 5.2 kg/m2 /d at a brine depth of _2 cm, and 4.5 kg/m2 /d at a brine depth of _8 cm, as reported by Nafey et al. [57]. Aybar et al. [69], who employed a slanted solar water distillation system, confirmed the findings of Tabrizi et al. [68] about the weir type cascade solar still, discovering that increased productivity was achieved with a reduced input water flow rate.

The temperature difference between the water in the still and the glass cover is crucial for distilling water. At temperatures over 37.C, more than 50% of the solar energy that enters the still contributes to the evaporation of brine [70]. A higher thebrine temperature than the glass cover creates a more productive environment [71-75]. With a temperature difference of 6.C, productivity was (0.1) kg/m2/h, and with a difference of 11.C, it was 0.85 kg/m2/h. Productivity was _0.8 kg/m2/h when the brine temperature was 70°C, while it was only _0.1 kg/m2/h when the temperature was 30°C [71]. Also crucial to a solar still are the insulating material and thickness [76,77-78]. According to Al-Karaghouli and Alnaser [52], the average daily production for the month of June in a non -insulated still was 2.46 kg/m2 /d, whereas the average daily production for an insulated still was 2.84 kg/m2 /d. Insulation, according to Khalifa and Hamood [78], can boost output by as much as 80%.

6. Improving the performance of the solar still

6.1. *Solar still with*Phase change materials *(PCMs) as a* Thermal energy storage materials *(TESM).*

Utilizing a TESM increased the production of a solar still [79]. It is in the solar still trays that you will find the TESM. In order to increase the efficiency of the heat transfer from the oil and wax to the water in the basin and to store heat energy throughout the day for later release at night, aluminium turnings were added to the paraffin oil and wax combination. In this way, the old amalgam served as a distinct category of PCMs[101]. Using a saline water supply flow rate of 0.40 L/min, maximum productivity of 0.851 L/m2 h was achieved. The addition of two hours of nighttime experimentation also resulted in an increase in hourly output of more than 0.05 L/ m2 h.

Summer and winter theoretical models for enhancing the solar still with and without PCM beneath the basin were created by El-Sebaii [80]. At various brine depths, the authors analysed how the amount of PCM affected daily, hourly, and overall output as well as the efficiency of the solar still. Based on the data presented, it was determined that the solar still produced around 9 litres per square metre per day (L/m2/d) and had an efficiency of around 85.3% with pure chloroform (PCM) during the day.

When using the solar still without the PCM, however, productivity dropped to around 5 L/m2 d. For shallower brine water levels on colder days, the solar still supplemented with PCM is more efficient.

Using PCMs (paraffin wax) as a heat storage medium, Kabeel and Abdelgaied [81] increased the efficiency of a solar still and the production of fresh water. For this reason, we built two identical solar stills and compared their performance with and without the use of PCMs. First is conventional solar still (CSS), and the other is a customised version of a CSS (CSS with PCMs). According to the results of the experiments, the productivity of the solar still was increased by 67.18% when PCMs were used, as the yield of freshwater was 7.54 L/m2 with PCMs and 4.51 L/m2 without them. In addition, the price of one litre of freshwater with PCMs was about $0.24 and the price without PCMs was about $0.252.

6.2. Sponge cubes used as *a* Thermal energy storage materials in a solar still (TESMs)

The impact of sponge cubes on solar still performance was studied by Abu-Hijleh and Rababa'h [82]. Sponge cubes significantly increased the surface area, which in turn enhanced the evaporation rate. When compared to standard solar stills, the output is increased by around 273% when sponge cubes are kept in the basin conventional solar still (CSS).

Cotton , jute , cloth, porous materials, and a sponge sheet were some of the many materials Murugavel et al. [83] tested in solar stills. According to the findings, black cotton fabric produces the best outcomes. To continue producing drinkable water long after sundown, El-Sebaii et al. [84] put a thin layer of a storage material beneath the basin plate of an active solar still and studied its performance.

6.3. A solar still using pebbles and sand as *a* Thermal energy storage materials *(TESM)*.

It was studied by Nafey et al. [85] how adding black pebbles and black rubber to a solar still affected production. They tested the solar still's distillation efficiency using black gravel of varying sizes (from 7 to 30 mm) and black rubber of varying thicknesses (from 2 to 10 mm) utilising brine quantities (from 20 to 60 L/m2). Using black rubber with a thickness of 10 millimetres and a brine volume of 60 litres per square metre enhanced production by 20 percent. To some extent, this is because black rubber has a poorer thermal conductivity than black gravel, allowing it to collect and release solar energy at a slower rate. Using black gravel with a size range of 20-30 mm also boosted productivity by 19% at a brine volume of 20 L/m2. This is because huge gravel sizes have the potential to absorb a lot of solar energy, making them ideal for this use case. A passive solar still with a free-floating absorber was the subject of El-[86][87] Bialy's experimental research. Two solar stills, one with and one without a floating absorber, were developed and built for this purpose. Two types of solar stills exist, the first being the conventional solar still (CSS) and the second being the customised still (CSS with floating absorber). The effect of water content and absorber plate type on SS performance was also studied. As seen in the findings, the adjustment yields substantial gains in output. Copper, stainless steel, aluminium, and mica were all used as good materials for increasing SS productivity by 17.2%, 15.2%, 20.1%, and 42.2.1%, respectively, thanks to the employment of floating absorbers

6.4. Solar still with aluminum filling as Thermal energy storage materials *(TESM)*.

To improve results, Abdullah [88] conducted an experimental study of active stepwise SS that included an air warmer and TESM (aluminium filling). The results showed that compared to CSS, stepped SS integrated with TES increased freshwater productivity by 53%, while stepped SS integrated with air heater and film cooling increased freshwater productivity by 112%. In addition, the daily efficiency for glass cooling, hot air, and TESM are 59%, 52%, and 55%, respectively, whereas the efficiency for CSS and stepped SS without any adjustments is around 34% and 48%; respectively[89].

Conclusion

In this study, we take a look at both traditional and innovative solar still designs. This review seeks to comprehend solar stills, the many varieties of which have already been the subject of extensive scholarly investigation. Future research is necessary for the commercially viable production of significant quantities of freshwater as solar still development continues. More study in this area will allow engineers to create a more efficient, high-performance ideal design. Passive solar stills are well-known for their inexpensive production and water-production costs as well as their straightforward design. However, their efficiency and productivity are lower. Thus, it has not been fully commercialized. The aforementioned issue has prompted the development of a plethora of active solar stills. For better evaporation and output, this setup uses an external source of thermal energy. In order to improve solar stills' designs and performance parameters, further research and tests are needed. As a species, we must ensure that this tool is both cost-effective and gentle on Earth. Enhancing the efficiency and output of solar stills requires a methodical investigation into their performance parameters[90]. The following inferences can be made from the preceding discussion: The availability of solar radiation is crucial for the generation of fresh water from a solar still and electrical energy from a PV panel. While higher wind speeds are beneficial for solar stills and PV panels, they can have a negative impact at the maximum speeds. Increasing the panel's temperature has a detrimental effect on its ability to produce electricity [89][100].

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