Title

Volume : 7

مجلة العلوم والتطـــبيقات الهـندسية

Journal of Science and Engineering Application

ISSN 2521-3911

Enhancement Water Production By Desalination Using Solar Energy: A Review

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Abstract:

It is known that energy is essential to life and economic growth. Energy is a foundation stone of the modern industrial economy. Energy provides an essential ingredient for almost all human activities, for example, without water, life as we know it would not be possible. Clean water or fresh water is rare in many low-density locations, and most of the time, there is no electrical grid connection or other energy source available, except renewable energy sources, which mostly pertain to solar radiation. Because desalination may turn salty water into a potable supply, it is a feasible solution to the issue of water shortage. Desalination is a reasonable answer for these areas' demands. Desalination systems and energy conversion are two distinct and independent technologies used in RE desalination. The actual issue with these technologies is determining the best economic layout and assessment of the integrated plants to make them profitable for isolated or desert areas. The conversion of renewable energy sources, such as solar, necessitates significant financial outlays, and despite extensive research and development, the technology is not yet sufficiently advanced to be used on a broad scale. With a focus on solar energy applications, this article provides an overview of the most significant advancements in the field of desalination using renewable energies, as well as the highlights that have been made in recent years.

Keywords: Desalination, Freshwater, Radiation, Solar, Renewable.

1. Introduction:

Even though water makes up over 71% of the earth's surface, it is difficult to supply fresh water to all of the demands of people, animals, and plants. Just 0.008% of all water is accessible surface freshwater; the majority of freshwater is found in aquifers, glaciers, and ice caps, making

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up around 2.5% of the overall water supply [1]. The problem of water scarcity has gotten worse due to industrialization and population increase. Currently, one-third of people worldwide experience extreme water stress, and this number is predicted to rise [2]. When the annual water supply falls below 1000 cubic meters per person, a water shortage arises [3].

Desalination is one of the most promising ways to address the water shortage. The process of extracting minerals and dissolved salts from salty water to create drinkable water is known as desalination. Total Dissolved Solids (TDS), which may range from 10,000 ppm for brackish water to 45,000 ppm for saltwater, can be used to categorize saline water [4]. However, the acceptable range for salt in drinkable water is between 500 and 1000 parts per million [5].

However, desalination is a labor-intensive process that uses around 10,000 tons of fossil fuel annually to generate 1000 cubic meters of water every day [6]. To meet the water demand, massive desalination facilities are anticipated to be built in the future. Regretfully, the traditional desalination method is not only environmentally harmful but also energy-intensive. The most efficient desalination systems available today use 7–10 kWh of primary energy to generate one cubic meter of water and release 3–4 kilograms of CO_2 [7]. Desalination procedures based on renewable energy sources will be more environmentally friendly for future water supplies because they don't harm the environment. Additionally, because these energy sources are free, the total cost of producing water will be extremely cheap. The desalination process powered by renewable energy has been under research and development for a while, and while some of them have found practical use, the majority have failed to commercialize because of the high capital costs and sporadic nature of renewable energy [8].

1.1. Desalination techniques:

Depending on the energy source, desalination systems can be categorized as thermal, mechanical, electrical, or chemical. Evaporation-condensation, filtering, and crystallization techniques are further classifications that rely on the desalination process. A few desalination methods, including forward osmosis (FO), membrane distillation (MD), membrane bioreactor (MBR), solar chimney, greenhouse, natural vacuum, adsorption desalination, and ion exchange resin (IXR), are still in the development stage. The most widely used desalination technologies are reverse osmosis (RO), multistage flashing (MSF), and multi-effects distillation (MED) systems.[9] The main forms of desalination used worldwide are depicted in Figure 1.

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Journal of Science and Engineering Application

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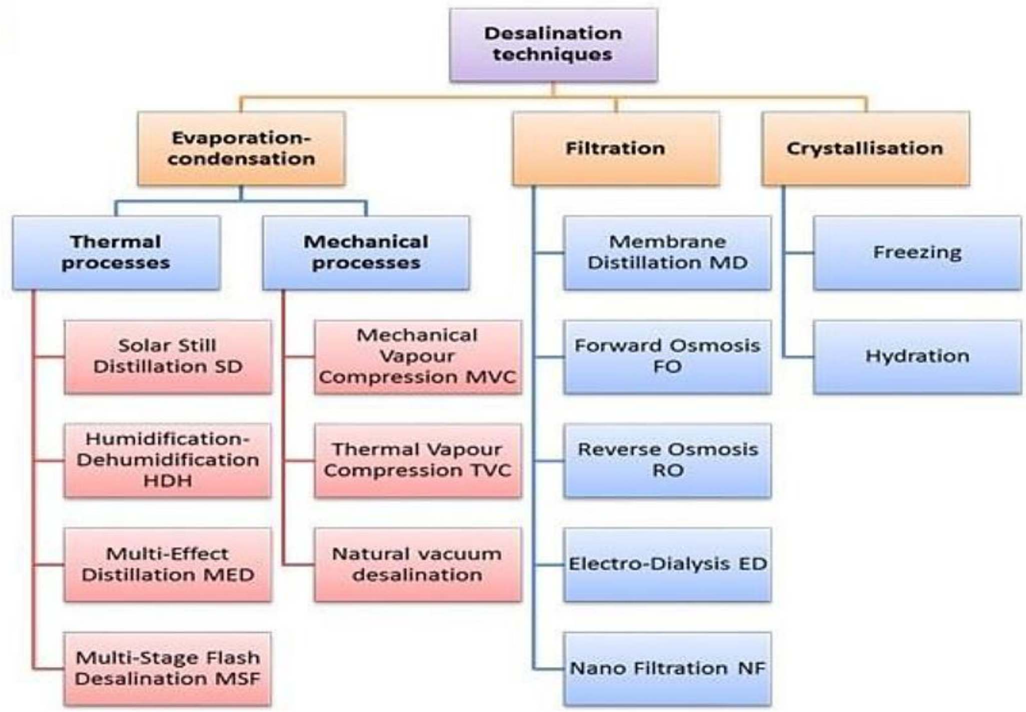

Figure 1: The main desalination processes [9].

1.2. Renewable energy desalination:

Desalination systems that rely on renewable energy sources can be broadly classified into three types: geothermal, solar (photovoltaics, or solar collectors), and wind. Water may be produced by combining these renewable energy sources with membrane desalination or thermal distillation technologies, as illustrated in Figure 2. In certain instances [10,11], These systems are linked to a traditional energy source (such as the local electrical grid) to reduce fluctuations in energy output levels and, in turn, water production [12]. Due to the high initial cost of the desalination unit, the cost of operating RO plants using renewable energy sources was shown to increase significantly (10.32 $\$/m^3$) [13].

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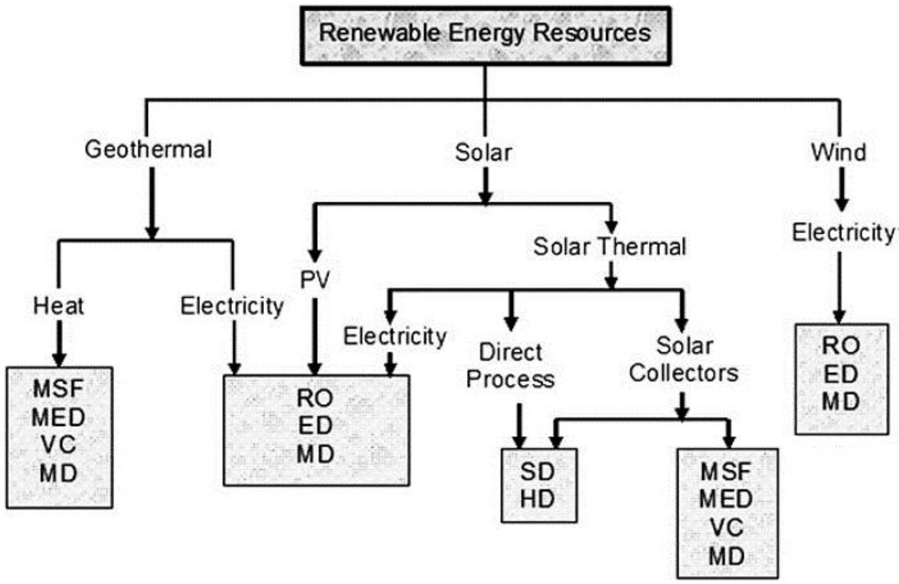

Figure 2: Water desalination methods combined with renewable energy sources [14].

1.3. Solar energy:

Many ancient civilizations revered the sun as a strong duty, and solar energy is the first form of energy that humans have ever employed. Food preservation by drying was the first known practical use. For a long time, researchers have examined solar radiation as a potential energy source and worked to transform it into a form that may be directly used [14]. The majority of energy comes from the sun. Photosynthetic processes were the initial source of wood, coal, oil, and natural gas. Because they are brought on by variations in temperature throughout different parts of the planet, even wind and tidal energy originates from the sun [15].

When compared to other energy sources, solar energy has several advantages, including being sustainable, clean, and pollution-free. Building heating and cooling, industrial and residential water heating, pool heating, refrigerator power, engine and pump operation, desalination of drinking water, electricity generation, chemical applications, and many more uses are all made possible by solar energy. Economic, environmental, and safety factors should all be taken into account when choosing an energy source. It is generally accepted that, if feasible, solar energy should be used in place of energy produced from fossil fuels because of its desirable safety and environmental benefits, even if the costs are somewhat higher [16].

Although solar energy shows promise for producing sustainable water, its principal use is hampered by its sporadic supply. Presently, under 1% of the world's desalination capacity is accounted for by the more than 130 desalination facilities that use renewable energy sources. Figure 3 displays the proportion of several processes [17].The application chart demonstrated that thermal desalination procedures powered by solar energy are being used extensively to generate fresh water, with photovoltaic-driven membrane systems coming in second.

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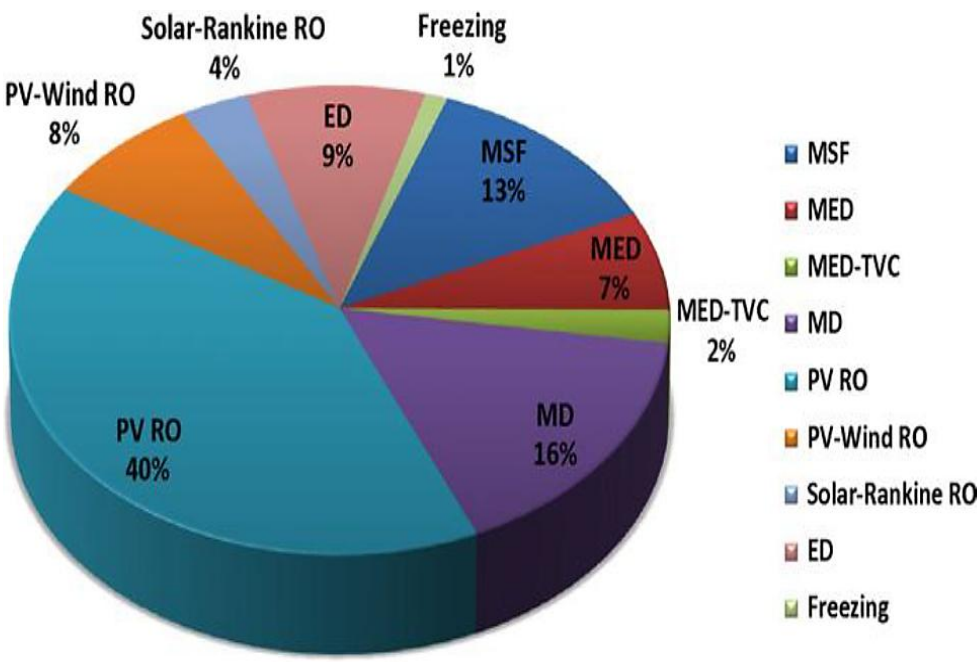

Figure 2: Share of different desalination processes operating with renewable energy sources [8].

1.4. Solar-powered desalination technologies:

Direct and indirect systems are the two main categories into which solar-powered desalination technologies fall. Direct systems are those in which the desalination and heat-gaining processes occur organically within the same apparatus. One of its most basic uses is the basin solar still, which captures solar energy that travels through a clear cover. The plant is divided into two subsystems in indirect systems: a system for desalination and a solar collector. The solar collector can be a solar concentrator, evacuated tube, or flat plate, for possible thermal desalination and solar energy combinations. Any of the previously mentioned distillation unit types—MSF, VOC, MED, and MD—that employ the evaporation and condensation principle can be attached to it. The RO and ED desalination processes are frequently driven by electricity generated by PV-powered systems [14].

Solar desalination with humidification and dehumidification is a potential process for producing fresh water, especially in remote and sunny locations. With the use of a complimentary, renewable, and environmentally friendly energy source, it has the ability to greatly increase the amount of fresh water available to humanity [18]. Simple, affordable, and efficient technology may be utilized to turn salty water into fresh water using solar energy, making it appropriate for small towns, rural regions, and those with extremely low-income levels [19]. For the supply of fresh water in lonely rural locations, recent advancements have shown that solar-powered desalination techniques are superior to alternatives like ED, RO, and freezing [20].

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Many academics are looking closely at solar energy-driven desalination technologies because of the potential for commercial use. Certain technologies are deployed for commercial use at certain sites, while other processes are still in the research and development stage [21]. The effectiveness of a hybrid solar-powered desalination system that uses single-stage flashing (SSF) dehumidification and air humidification was examined by Kabeel and El-Said. [22]. The hybrid HDH-SSF with solar air heater was determined to be the most cost-effective, producing up to 96 liters of water per day at a production cost of $12.53 per square meter. A combined solar thermal and photovoltaic (PV) collector as in figure 4 was developed by Chafidz et al. [23] to create an integrated solar-driven desalination system. According to the results, Test E generated the most water (99.6 L) when the following factors were present: strong solar radiation, low feed flow rate, greater thermal tank temperature, and heat pump use. The system generated distilled water with an average conductivity of 6.2 µs/cm. 69 L/h was the ideal feed flow rate.

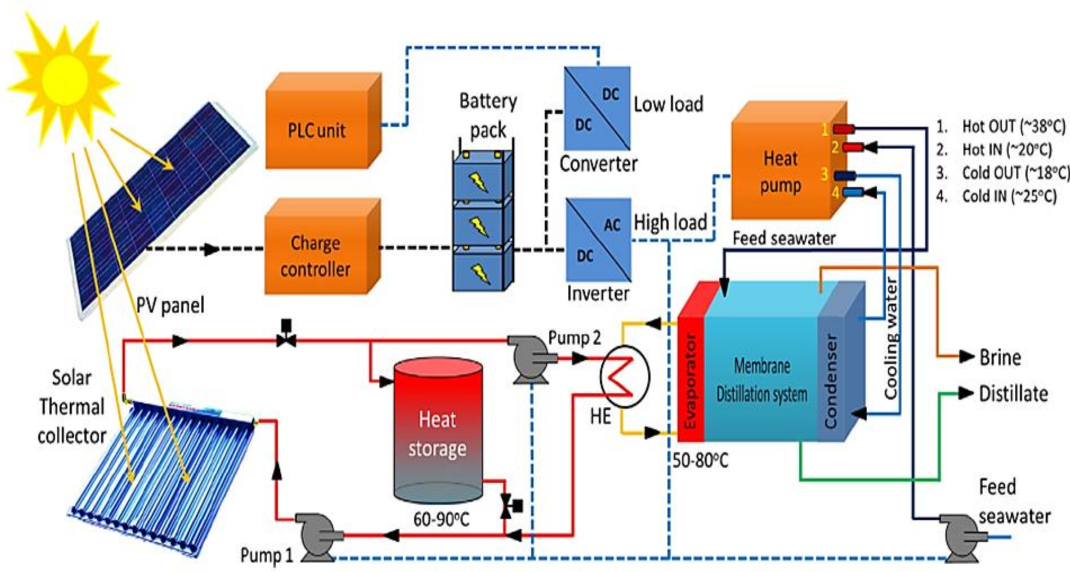

Figure 4: Simplified block diagram of the integrated solar-driven desalination system [23].

To increase water productivity in isolated settlements, a single slope solar still (DSS) has been designed by Eltawil and Omara [24]. The CSS productivity varied between 3 and 4 l/m2, according to the findings. Depending on the type of adjustment, the DSS productivity was 51–14.8 percent higher than the CSS. Productivity rose by 51% when an external condenser was used in conjunction with solar power. The DSS productivity increased by 56% and 82%, respectively, when circulating hot water was used in passive and active jets without condensers. A study to provide sustainable drinking water through solar domestic hot water systems by Kumar and Martin [25] was conducted. The pilot unit combines solar domestic hot water SDHW and Membrane Distillation MD techniques, generating 20 l/day of drinkable water and 250 l/day of domestic hot water for a single-family house/villa.

Bhardwaj et al. [26] showed how to effectively enhance the amount of filtered water produced from the stills by expanding the size of the condensation surface. It is found that solar stills may produce much purer water if the condensation surface area is increased. An increase in the condensation surface area can enhance water production by about 65%. A hybrid desalination system for small-scale Water production was designed by El-Said et al. [27] by utilizing a single-stage flashing evaporation unit (MSH-SSF) and a two-stage humidification-dehumidification unit together with a nano-fluid solar heater. The anticipated cost per m^3 was 6.43 US dollars, while the system's efficiency was 49.4%. To minimize excessive warm water loss during desalination, Sharshir et al. [28] offered a hybrid solar desalination system that uses four solar stills and a humidification-dehumidification system. The system increases the efficiency by 90% and the gain output ratio by 50% by reusing the warm drain water from the system to feed the solar stills. Additionally, the hybrid system generates a single solar still around 200% more than the traditional system does.

To produce chilled water, clean drinking water, and hot water for household use, Mohan et al. [29] designed a solar thermal poly-generation (STP) pilot plant. Cooling and desalination, generation, cogeneration, and solar cooling are the most important operations of the system. Summertime analysis of the system's performance revealed a 23% rise in energy use over solar cooling. To boost performance, a novel solar collector design with a simple distiller built into a cylindrical shape was examined by Bait et al. [30]. The findings demonstrated that the collector considerably raised the temperature of the basin water, resulting in a 31% rise in distillate quantities and a 40% increase in instantaneous efficiencies. It was expected that the collecting materials would cost 63 US dollars in total. The development of a novel solar thermoelectric generator distillation system that includes an internal condenser, porous evaporator, thermoelectric generator, and parabolic solar concentrator has been conducted by Moh'd et al. [31]. The results of the development and simulation of a steady state mathematical model showed that the output power ranged from 0.8 to 3.5 W for ambient temperature and solar radiation, the distillate ranged from 1.5 to 3 kg/day, the overall efficiency ranged from 15-20%, and the TEM efficiency ranged from 0.6 to 1.5%.

An experimental study on a solar thermal driven membrane distillation-based desalination system (SDMD) was carried out by Kabeel et al. [32]. According to this, the system's efficiency rose as the water mass flow rate increased, reaching around 49.01%. The daytime gained output ratio (GOR) was used to quantify thermal performance, and reached 0.49. Three solar-powered humidification-dehumidification (HDH) water desalination systems; single stage (SS), double stages (DS), and modified double stages (MDS) were studied by Fouda et al. [33] for hot and humid cities. The findings demonstrated that the MDS system outperformed the SS and DS systems by 86.7% and 34%, respectively, producing 350 kg of fresh water per day. The outcomes of Inclined Solar Panel Basins (ISPB) with and without Flat Plat Collectors were examined by Manokar et al. [34]. They discovered that active mode generated 46.87% and 6.6% of the daily production, respectively, whereas passive mode produced 4.3 and 7.9 kg. While active mode improved thermal, exergy, and daily yield efficiency, it reduced panel effectiveness.

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Al-harahsheh et al. [35] investigated water desalination using a solar still with phase change material (PCM) connected to a solar collector. The study found that the production rate of desalinated water is proportional to ambient temperature and hot water circulation flow rate. The unit produced 4300 ml/day.m^2, with 40% produced after sunset. An integrated solar distillation membrane prototype for the generation of thermal energy and drinkable water was the subject of an experimental investigation by Li et al. [36]. The findings demonstrated that a system with 40.2 m^2 of membranes and 1.6 m^2 of solar-absorbing surface could generate 44.5 kWh of heat energy and 44 L of drinking water daily at 45 °C. The effects of combining a flat plate collector, parabolic trough collector, and packed glass ball layer with the performance of traditional single slope solar still were investigated by Madiouli et al. [37]. According to the findings, the integrated solar still outperformed the conventional in terms of productivity by 172% and 203%, respectively, and had a higher freshwater production rate. The improved solar still costs $0.22 less per liter of water generated. A hybrid single-slope solar distillation and single-effect sun absorption cooling system was created by Sleiti et al. [38] to produce freshwater and cooling effects at the same time. When compared to traditional methods, the integrated system increases production by three times. With a cooling capacity of 20 kW and a COP of 0.85 at 500 W/m^2, the system managed to maintain a productivity of 10 kg/m^2.day. Models based on machine learning were used by Behnam et al. [39] to enhance the performance of solar-driven direct-contact membrane distillation systems. With a freshwater productivity gain of 35-77%, a GOR enhancement of 31-31%, a daily efficiency increases of 37-88%, and a 20% reduction in freshwater cost.

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A unique PV/T-distillation system was developed by Moh'd and Al-Ammari [40]. According to the findings, sun radiation is the environmental factor with the greatest influence. While falling wind speed or increasing ambient temperature have a good impact on still production, they have a detrimental impact on PV cell performance. A hybrid PV/T active solar still with a solar PV-powered Peltier system was created by Pounraj et al. [41]. The technology increased passive efficiency by 17% and thermal efficiency by 30%. The Peltier cooler and distillate-producing heater effectively used the solar PV power output, which was 32% greater than that of conventional PV. To produce more distillate water, Winston et al. [42] developed both a traditional passive solar still and a hybrid photovoltaic/thermal solar still by adding a nickel-chromium heater. The hybrid active solar's electrical and thermal efficiency was 25% greater. A solar still including a single basin-slope, photovoltaic cells, finned condensing chamber, and thermoelectric generators as in figure 5 was created by Moh'd et al. [43]. They examined system performance using a mathematical model. The distillation rate was raised by integrating fins through the condenser.

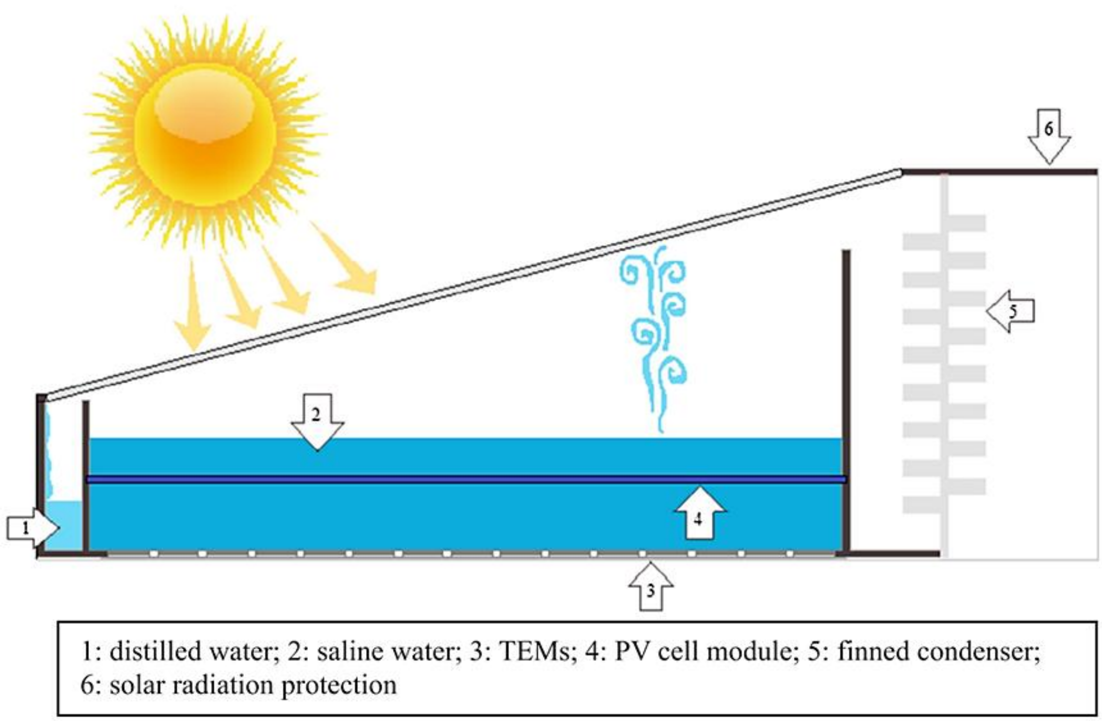

Figure 5 :A graphical sketch of the hybrid solar system, the system structure and its components [43].

To developed a solar-driven desalination system, Mahmoud et al. [44] used a hybrid solar still/two-effects humidification-dehumidification system, solar concentrator, and thermally cooled photovoltaic panels. Productivity declines as basin height and river rate increase, according to the study. However, the production of fresh water was improved by combining the solar concentrator with photovoltaic panels.

To enhance condensation in hot, dry regions, Al-Nimr et al. [45] developed a hybrid photovoltaics/thermoelectric cooler (PV/TEC) distillation system. With a 57.9% total efficiency and a 12.32% PV cell efficiency, the system produced 4.2 kg of distilled water daily. Zhao et al. [46] used direct contact membrane distillation (DCMD) and a photovoltaic module (PVM) to create a hybrid system. Compared to a single PVM, the results demonstrate a higher maximum energy efficiency (MEE) and power density (MPD). The effectiveness of a novel combination of single-slope solar still with a photovoltaic panel was investigated by Abd Elbar and Hassan [47]. The findings indicated that still production rose by 9% and 23%, respectively, when PV was integrated with a traditional solar still. The solution that used PV as a reflector was cost-effective and yet enhanced productivity by 3.2%. To improve condensation and evaporation, Balachandran et al. [48] examined traditional single-slope solar desalination stills (SSSDS) and suggested ones. They discovered that distilled water improved by 35% and 21%, respectively, when water film cooling was used over glass covers and hybrid natural fiber composite HNFC insulation.

The improvement of a hybrid solar desalination system through the use of porous material and saline water preheating is examined in the study by Abd Elbar and Hassan [49]. The freshwater yield and energy efficiency of the system were shown to increase when 40%, 50%, and 60% of salty water was preheated. Utilizing black steel wool fibers resulted in 17.8%, 13.7%, and 11.8% increases in the production of traditional stills, solar desalination systems, and solar desalination systems with 60% preheating, respectively. To create a unique cogeneration system, Elminshawy et al. [50] used membrane distillation and a cooled concentrator solar module. Up to 83% of solar radiation is converted into usable gain by the system, which also creates clean power and desalinates water. The device may lower carbon dioxide emissions and provide 19.58 m^3 of new drinkable water annually. By employing better evaporation and condensation processes, Ganesan et al. [51] increased the efficiency of a PV/T solar still, increased the output of distilled water, a nickel-chromium heater was installed, and an inorganic phase change material (PCM) was utilized for cooling. Even so, the PV/T solar system outperformed traditional systems with an overall thermal and electrical efficiency of about 12.5% and 11.5%, respectively.

The productivity of a conventional solar still (CSS) and a PV-coupled solar still (PVSS) with a 0.64 m^2 solar still basin area was examined by Badran et al. [52]. The findings demonstrated that the PVSS's productivity increased by over three times when in active mode, yielding six liters of distilled water. For co-generation of electricity and fresh water, Huang et al. [53], designed a novel hybrid system of a solar photovoltaic (PV) panel backside coupled with a multistage membrane distiller (MD). The hybrid system produced fresh water at a rate of 1.11 kg m-2 h-1 with four stages and generated 66.6 W m-2 of electricity under one sun with a resistance of 10 Ω. In order to collect freshwater without building a solar still, Abed et al. [54], propose and evaluate the use of a basic passive cooling method for a new hybrid PV/T system to produce distilled water, electricity, and hot water for homes. In comparison to the photovoltaic panel with desalination (PVWD), the cooling photoelectric panel with desalination (CPVWD) module produced the most water, around 65.73% more. It is discovered that the CPVWD module exhibits the maximum electricity efficiency.

Isah, et al. [55] investigated hybrid solar desalination systems' freshwater production, weather fluctuation, economic analysis, and system efficiency. author suggested a reduced cost and a distillate output of 6 L/m2.day. To increase the daily production of traditional basin-type solar stills as in figure 6, Saadi et al. [56] presented a novel stepped solar still. Fined that; the stepped solar still performed 47.18–104.73% better than the traditional. In contrast to the basic sun still, which had a payback time of 100 days and a cost of 0.0145 $/kg for distilled water, the stepped solar still had a payback period of 70 days and a cost of 0.01 $/kg.

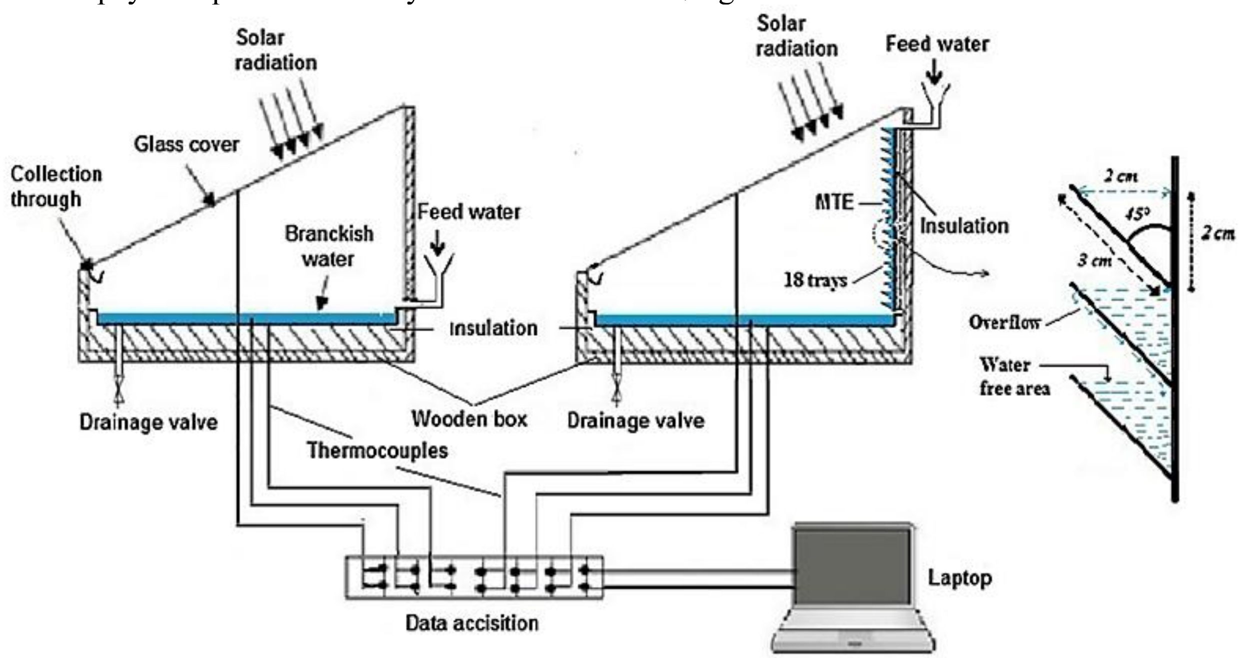

Figure 6: Schematic diagram of the experiment setup [56].

To increase water output, Kabeel et al. [57] created a tubular solar still (TSS) device that employs cover cooling. When tested at various depths and cooling flow rates, it produced 4.5 L/m^2 of productivity at lower water levels. The yield and efficiency rose by 31.4% and 32.6%, respectively, thanks to the TSS. Three solar still examples were examined by Yousef et al. [58], metallic wool fibers, hollow tubular pin fins, and conventional. According to the results, the upgraded stills' maximum energy efficiency increased by 42%, 45.5%, and 52.5%, respectively, and their daily cumulative distillate water production improved by 16% and 25% when compared to case 1. The average daily exergy efficiency was likewise raised by 14% and 23% by the redesigned stills.

The effectiveness of single-slope solar stills using phase change materials as thermal storage devices was investigated by Yousef et al. [59]. Five scenarios were tested. The findings demonstrated that while phase change material increased total production, it had a detrimental impact on freshwater productivity during the day. The best thermal performance was obtained in

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the case of pin finning based on phase change material. While nocturnal production decreased, steel wool fibers in the basin with phase transition material greatly increased freshwater productivity during the day. The effects of simultaneous thermoelectric heating and cooling on a solar still's performance were investigated by Shoeibi et al. [60]. According to the study, this alteration produced 76.4% higher efficiency and increased production by 2.32 times when compared to passive solar stills. Both the traditional and modified solar stills had the highest exergy efficiency of 1.48%.

The performance of a solar still configuration with a hydrophobic membrane installed on the surface for water production was investigated by Shirsath et al. [61]. They discovered that employing a membrane enhanced water production by 40–70%, as evidenced by the rise in dropwise condensation patterns across the condensing surface. The effectiveness of solar stills in conjunction with a parabolic trough solar collector (PTSC) was investigated by Hassan et al. [62]. High freshwater yields and a summertime maximum exergy efficiency of 1.34% were demonstrated by the results. The Solar still with heat sink condenser, coupled with PTC with forced water cooling (MSS + PTSC + FW) system was shown to be the most successful in lowering CO_2 emissions and to have the greatest performance-based energy-economic approach. A hybrid system employing HDH and six-wick stills was investigated by Abdullah et al. [63] in a variety of settings. 4 kg/min and 1500 rpm were the ideal water flow rates and fan speeds, respectively. Compared to the aspen pad, the cellulose paper demonstrated greater output. The GOR was 7.6 at 4 kg/min, and the condenser only increased distillate output by 16.6%.

Essa et al. [64] suggested a novel method of operation for the cords wick pyramid solar still (CWPSS), which draws water and maintains the wick moist by using a parallel top basin liner coated with jute wick cords. 35 wick cords produced the best results, increasing production by 195% and efficiency by 53% compared to traditional stills. The profitability of a modified, double-slope solar still in comparison to traditional solar was investigated by Elmaadawy et al. [65]. Modified double slope solar still with dispersed carbon black (CB) nanoparticles on the top of the second case combination MDSSS-III performed the best, improving yield, energy, and exergy efficiency, by 68, 50.6, and 146.3% in comparison to traditional solar still. To investigate how the performance of the hybrid solar still system was affected by electric heaters, basin water height, and concentrating solar collectors, Makkiabadi et al. [66] discovered that the system's effectiveness was much enhanced by the use of both electric heaters and concentrated solar heaters. The hybrid system's active mode produced 8178 mL/m^2 of fresh water.

To improve the performance of solar still, Sharshir et al. [67], experimentally investigated the use of graphite and copper oxide micro-flakes. According to the evidence, employing copper oxide and graphite micro-flakes increases solar still production by around 44.91% and 53.95%, respectively, as compared to traditional solar (without micro-flakes). Finally, the stills' daily efficiencies when using copper oxide and graphite micro-flakes with glass film cooling are 46% and 49%, respectively. The performance of the hybrid solar still was evaluated by Modi and Shukla [68], for the restoration of liquid desiccant and purification of saline water for three days in March

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and April. The study discovered that $CaCl_2$ in upper and lower basins produced daily water desorption with yields of 727.78 ml/m2 and 727.82 ml/m2, respectively, resulting in thermal efficiency of 16.74%, 25.39%, and 26.19%. To investigate a comprehensive hybrid distillation system of humidification and dehumidification (HDH) system performance, Abdullah et al. [69] designed, fabricated, combined, and experimented with six wick solar stills. The best distillate was generated by an HDH unit filled with an aspen pad at 4 kg/min. The average gained output ratio (GOR) increased from 2.5 for the HDH unit running only during the day to 4.5 for the identical unit operating both during the day and at night under 4 kg/min.

In comparison to indirect heating systems, Hassan, H. et al. [70] reported a study on a hybrid solar distiller employing salty water heating demonstrated notable increases in energy and exergy efficiency at varying water depths and a 71% reduction in freshwater production costs. Hassan et al. [71] evaluated how well a single slope solar still worked with an upgraded condenser and coupled with a parabolic trough solar collector (PTC). The modified solar still (MSS + SD + PTC) with sand inside the basin and PTC achieved the highest freshwater productivity, improving energy and exergy output by 113-14% compared to the conventional solar still system. The thermo-economic performance of single-slope solar still was enhanced by Kandeal et al. [72]. The greatest results were achieved by combining the ultrasonic foggers, which improved freshwater gain, energy efficiency, and exergy efficiency by 59.1, 65.5, and 63.8%, respectively, as compared to CSS.

Table 1 was shown the amount of water which calculated from previous studies.

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Table 1: Reported water amount	
Reference No.	**Water Amount**
[22]	Up to 96 l in August
[23]	69 L/h
[24]	The DSS productivity was 51–148% higher than the CSS, the external condenser with solar still production was 51% higher, and the CSS varied from 3 to 4 l/m^2.
[25]	maximum distillate of 27 l/day could be obtained in July and minimum production of 14.6 l/day
[26]	When the area of the condensation surface expanded by 7.5 times, the amount of water produced exceeded by more than 65%.
[27]	up to 112.5 kg/day
[28]	The daily water production of the conventional one, single solar still, four solars still, humidification-dehumidification, and hybrid system was 3.2, 10.5, 42, 24.3, and 66.3 kg/day, respectively.
[29]	While double stage cogeneration boosts daily output by 48% at the expense of residential hot water, the trigeneration mode, which integrates a single-stage membrane module, generates 4 l/h.
]30]	~ 2.77 kg/m^2, ~ 4 kg/m^2 for the passive and active targets
[31]	distillate range of (1.5–3) kg/day
[32]	Maximum productivity was 33.55 L/day.
[33]	MDS system (open mode) can produce fresh water of 350 kg/day and its freshwater productivity is enhanced by 86.7% and 34% than SS and DS systems, respectively
[34]	The maximum daily yield for passive and active stile is 4.38 kg and 7.9 kg respectively.
[35]	The unit was capable of producing 4300 ml/day.m^2
[36]	Produce ~3.2-4.8 L of drinkable water
[37]	Solar still integrated with PTC, FPC, and PLGB has a higher freshwater production rate of 6.036 kg/ m^2/day during summer and 2.775 kg/m^2 in winter.
[38]	Still productivity of 10 kg/m^2 per day
[39]	35.39–37 % increase in freshwater productivity
[40]	-
[41]	-
[42]	-
[43]	14% production enhancement when a finned chamber is used

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[44]	-
[45]	The maximum yield of the system was 4.2 kg of distilled water per day
[46]	-
[47]	PV and BSWF can increase CSS daily yield by 3.2%, 9%, and 11.1%, respectively, when used as reflectors and FAC, respectively, and by 12.5% and 10.96% in CSS with PV and FAC.
[48]	The conventional solar desalination still with thermos coil insulation yields 1.665 and 1.171 l/m^2/day, while the proposed still with water film cooling over glass cover and HNFC insulation yields 2.253 and 1.420 l/m^2/day
[49]	Solar desalination system with black steel wool fibers at 60% preheating achieves a maximum yield of 3.534 kg/m^2 day with an increase of 51.4% in comparison with conventional solar still.
[50]	The considered hybrid system can produce fresh potable water of 19.58 m^3 per year.
[52]	The yield in active mode (6 L) was more than triple that of the passive mode (1.4 L)
[53]	fresh water produced with a rate of 1.11 kg m^{-2} h^{-1} with 4 stages
[54]	Adding back or outer wick to the CPVWD increases the water productivity by about 65.73%
[55]	The distillate yield varies from 0.93 to 24.3 L/m2.day, with an average of 12.1 L/m^2.day. when modified system is utilized.
[56]	47.18–104.73% enhancement of productivity
[57]	the freshwater productivity reached its maximum value of 5.85 L/m^2.
[58]	In cases of hollow cylindrical pin fins and, the case of steel wool fibres, the daily cumulative production of distillate water was raised by approximately 16% and 25%, respectively.
[59]	Case 5 achieved the maximum accumulated daily water productivity about 25 % and a 9% increment in the total daily yield of freshwater.
[60]	Compared to the passive solar still, indicated that this modification improves productivity by 2.32 times.
[61]	enhancement of 40−70 % with modified device over that without a membrane.
[62]	The maximum daily yield of 9.45 kg/m^2 with an increase of 22% compared Traditional model.
[63]	Using cellulose and poplar pad as packing materials, the daily accumulated distillate water is around 70 and 62 L at a rate of 2 kg/min.
[64]	The maximum performance of cords wick pyramid solar still (CWPSS) was obtained when using the mirrors and fan at 35 wick cords, where the productivity rise reached 195% over the conventional CPSS.

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[65]	With regards to productivity, the modifications showed significant enhancements compared to CSS by 68, 53, and 46%, for the three cases perfotmed
[66]	In that condition (case 8), the yield of 8178 mL/m^2 was achieved much better than the base case (case 1), i.e., 3292 mL/m^2
[67]	The solar still productivity is enhanced by about 44.91% and 53.95% using the copper oxide and graphite micro-flakes, respectively.
[68]	In the upper basin, the daily water desorption from the weak CaCl2 solution was 1417.22 ml/m^2, 1253.88 ml/m^2, and 1368.74 ml/m^2, whereas in the lower basin, it was 757.22 ml/m^2.
[69]	The HDH unit packed with aspen pad produced higher output distillate under a water flow rate of 4 kg/min than that of 2 kg/min.
[70]	The daily freshwater of the direct heating system is 7.74, 8.38, 9.54, and 10.90 kg/m^2 at 15, 10, and 5 mm salty water depths, respectively.
[71]	The MSS + SD + PTC achieved the highest freshwater productivity of 4.65 L/m^2 in winter and 9.75 L/m^2 in summer.
[72]	Integrating the ultrasonic foggers produced the best results, increasing freshwater gain performance by 59.1% when compared to CSS.

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2. Conclusions:

Desalination using renewable energy sources is a viable and technically sound way to address the growing and stressful energy crisis and provide a long-term solution to the water shortage. Given the sharp rise in the cost of fossil fuels and the negative effects of burning them, such as pollution and climate change, connecting desalination facilities with clean, environmentally friendly energy sources is currently a critical concern. These technologies are specifically suited to supply fresh water in remote areas where there is currently a lack of water and electricity infrastructure. In many places with significant solar resources, socioeconomic growth is constrained by the lack of drinking water. Therefore, using solar energy for water desalination in nations with abundant solar energy in the Middle East and Africa is a promising solution for meeting water demand and would undoubtedly help to reduce carbon dioxide emissions through an environmentally friendly process as well as address the issue of water scarcity. The best method for rural and isolated places experiencing energy and water shortages is the solar still distillation (SD) system. The poor productivity of SD systems is their sole drawback, making them an expensive option. Therefore, further study is needed to improve the SD systems' productivity and performance.

The study's findings indicate that:

1. By expanding the area of the condensation surface, the still's water output rose.
2. Freshwater production increased more sharply in the trend of air sun heater collecting area variation than in the trend of water solar heater collecting area variation.
3. The system's productivity increased as the cooling water temperature decreased and the feed water temperature and flow rate increased.
4. In a profile that tracks the profile of solar radiation throughout the day, using solar collectors to heat air and water improves water production and recovery.
5. The active mode produces a greater amount of fresh water than the passive mode.
6. By supplementing the energy needed to run the unit constantly, the external solar collector increased the system's productivity.
7. When a parabolic trough collector, flat plate collector, and packed layer of glass balls are used in place of a typical solar still, the productivity and performance of the solar still are significantly higher.
8. Even after sunset, high freshwater productivity rates were sustained by the addition of oil to heat pipe evacuated tube collectors.

9. Freshwater productivity was increased by integrating an air-cooled condenser and oil-filled heat pipe evacuated tube collectors into the solar-powered Direct Contact Membrane Distillation system.
10. System productivity rises as the circulating air flow rate is decreased.
11. The productivity is greatly increased by using a solar concentrator.
12. More fresh water is produced along with improved electrical power output when PV/T panels are integrated and their cooling energy is recovered for heating the circulating air and preheating feed water.
13. In comparison to the aspen pad, the cellulose paper packaging material yielded better production productivity.
14. Higher water levels will not produce as much as running solar still at the lowest feasible height. This may be regarded as a useful guideline for improving solar still performance.

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Journal of Science and Engineering Application

ISSN 2521-3911

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Enhancement Water Production By Desalination Using Solar Energy: A Review

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Abstract:

It is known that energy is essential to life and economic growth. Energy is a foundation stone of the modern industrial economy. Energy provides an essential ingredient for almost all human activities, for example, without water, life as we know it would not be possible. Clean water or fresh water is rare in many low-density locations, and most of the time, there is no electrical grid connection or other energy source available, except renewable energy sources, which mostly pertain to solar radiation. Because desalination may turn salty water into a potable supply, it is a feasible solution to the issue of water shortage. Desalination is a reasonable answer for these areas' demands. Desalination systems and energy conversion are two distinct and independent technologies used in RE desalination. The actual issue with these technologies is determining the best economic layout and assessment of the integrated plants to make them profitable for isolated or desert areas. The conversion of renewable energy sources, such as solar, necessitates significant financial outlays, and despite extensive research and development, the technology is not yet sufficiently advanced to be used on a broad scale. With a focus on solar energy applications, this article provides an overview of the most significant advancements in the field of desalination using renewable energies, as well as the highlights that have been made in recent years.

Keywords: Desalination, Freshwater, Radiation, Solar, Renewable.