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Overview on Solar Pond

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ABSTRACT

Solar energy is a clean source of renewable energy and people around the world are getting numerous profits by the utilization of solar energy technology. Among various solar energy systems, a solar pond is a simple system that collects and stores heat for thermal and electrical applications. The solar pond's main components are heat extraction and storage. To create a solar pond with a salinity gradient, salt is introduced to the pond along with fresh water (SGSP). In addition, solar pond has the benefit of being its own thermal energy storage (TES). Hence, the aim of this paper is to provide an overview on solar pond, historical development and types of solar pond, Finally, the merits, demerits and applications of solar pond is discussed

Keywords: Solar pond, Salinity Gradient Solar Pond Heat Storage, Merits, Demerits, Applications.

INTRODUCTION

The term "solar pond" refers to any big, man-made body of saline water that may absorb and store solar energy and use it to generate heat and electricity indefinitely. In the early 1900s, a natural lake in the Transylvania area of Eastern Europe was discovered that was particularly well-suited to be used as a sun pond; nevertheless, research on the practical uses of solar ponds didn't begin until the late 1940s. Since then, there has been a worldwide increase in enthusiasm for solar pond research and construction. Notable solar ponds may now be found in the United States, India, and Israel (in El Paso, Texas) [1]. As a result of the solar pond's high production and maintenance costs compared to gas and a fossil fuel facilities, several projects have been scrapped. Global curiosity over solar ponds and their potential to provide renewable power remains high. During the day, the Sun warms the water in ponds and lakes, causing the warmer water to rise to the surface. Since the water evaporates and loses its heat to the air, the pond's water temperature remains constant [2]. On the other side, solar pond technology makes an effort to reduce heat loss by utilising salt, the concentration of which increases with depth. There are two distinct kinds of solar ponds, convecting and non-convecting. More often used, on-convecting solar ponds limit heat loss by blocking convection (the transfer of heat from one location to another by the flow of fluids) at the pond's base (lower convective zone) [3]. When the ground is completely covered with concentrated brine, the temperature at the bottom of the structure increases to roughly 100 °C (212 °F) as the sun's heat is trapped. The non-convective zone (the intermediate level) receives less salt than that of the convective zone. Water in the middle level cannot rise or sink because it is less dense than the water at the bottom and more dense than that at the top. Therefore, the intermediate level prevents convection currents and functions as an insulator, allowing sunlight to be trapped in the lower level. There is less salt in the upper convective zone, hence the water there stays chilly. At that point, fresh water is pumped in and salt water is drained. In the end, pipes submersed in the pond transport the heat from the ground up [4].

A convective solar pond is one that prevents heat loss not through convection but rather by preventing evaporation. The blackened bottom of a large water bag, foam insulation underneath the bag, and two layers of plastic or glass glazing on top of the bag all work together to allow convection while preventing evaporation. During the day, the water is heated by the Sun. Then, throughout the night, the heated water is transferred to the tanks. Solar ponds' ability to produce heat may be used in a variety of contexts and result in significant savings in terms of fossil fuel consumption [5] Various chemical, culinary, and textile goods can be manufactured with the use of the pond's extracted heat. In addition to heating greenhouses and swimming pools, the pond's heat may be utilised to warm cattle barns. The organic

Rankine cycle engine, which uses the heat to generate electricity, is a cost-effective and efficient way to transform solar energy into usable forms in rural areas. Through desalination, the solar pond can clean water for municipal systems, and it can also be used to dispose of brine left over from the offshore drilling process to obtain crude oil [6].

Solar Pond

Individuals may also use a solar pond as a collector if you don't need really high temperatures or your project. Applications in industry and agriculture at low temperatures, as well as heat and energy generation, water desalination, and more, are all possible with this versatile resource. It takes use of an elementary phenomenon to function. Hot water causes the lake or pond's surface to rise. Salt is put to a solar pond to act as a thermal mass, with the concentration of the salt increasing with depth. Due of its density, it remains on the ground, preventing the sun's warmth from escaping into the atmosphere. When the sun hits the water, the temperature can reach over 90°C, but the surface of the pond is often only around 30°C [7] .

There are three distinct layers of water in the pond:

- The upper layer, also known as the surface, or UCZ (Upper Convective Zone), is the warmest part of the atmosphere. It has barely any salt.
- The hot zone, or lower convective zone (LCZ), is located at the bottom of the water column (Lower Convective Zone). 70–85 ° C. The salt content is rather high. The power it provides comes mostly from the heat it produces.
- The separation zone is referred to as the "NCZ" (Non-Convective Zone). As one delves deeper into this region, the concentration of salt increases. Since the water above a certain layer is less dense due to its reduced salt content, that water cannot rise into the lower layer. Sunlight is trapped by the salt gradient, which also functions as an insulator.
- The acquired energy is of a somewhat low quality and can only produce temperatures of around 70–80 °C. Larger systems, on the other hand, may be constructed for far less money by utilising a membrane to cover the pond. While these solar ponds might be built anywhere, but are also most effective when situated near the ocean [8].

Working of Solar Pond

Solar pond containment entails making choices between several approaches for the pond’s placement, excavation, liner, insulation, and overall shape. When choosing a location, it's crucial to take into account the local geology, especially in regards to avoiding any potential subterranean aquifers. The pond is typically surrounded by a 3 or 4 m deep excavation. Building a wall of soil around the pond can reduce the need for extensive digging. The pond's leaky sides might waste a lot of salt solution and wasted energy. These consequences can be particularly severe in the event of porous soil, thus caution should be exercised while lining the bottom and sides. It is possible to employ synthetic materials such as butynol, nylex solid vinyl, ethylene propylene diene monomer, and ethylene propylene diene monomer as a membrane liner. The soil can be treated to make it impervious to hot brine solution as an alternative to using a liner. It is common practice to bury low-cost liners behind a compacted layer of soil [9]. The diagrams of a solar pond indicate the saline gradient and temperature is shown in **Figure 1.**

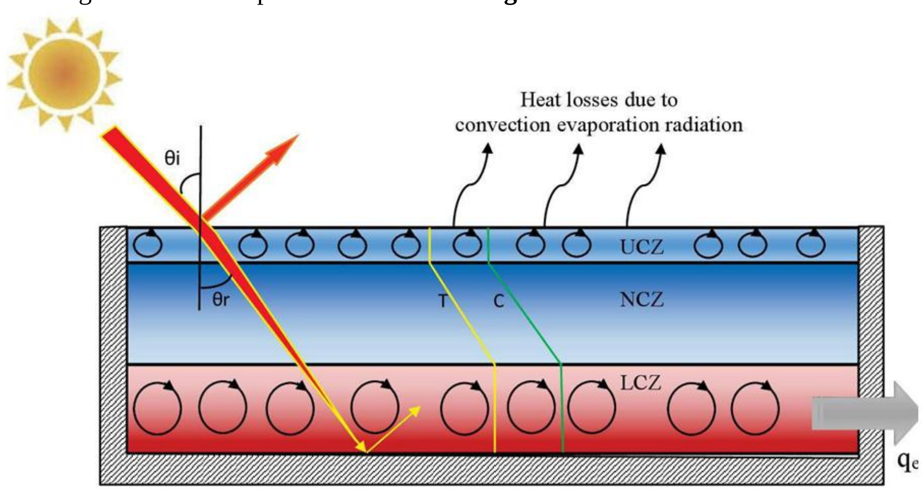

Figure 1: Diagram of a solar pond showing the temperature and saline gradient [10-12]

A pond's heating time can be sped up by installing thermal insulation on the pond's floor and walls, but this comes at a high price. The form of the pond is also crucial. Due of the low heat loss to the ground and the little amount of perimeter required for a given pond surface area, circular ponds are the most thermally efficient. Rectangular designs lack this benefit yet are often cheaper to build. Sidewalls that slope downwards significantly cut heat loss. From the perspective of structural stability of banks and edges, sloppy walls also are desirable; a 45° gradient has often been chosen [12].

Salt Gradient Solar Pond

SGSP combine solar energy collection with long-term storage. They're cheap and easy to make. Heat from these ponds might be used for desalination, power generation, process heating, room heating, and other industrial and agricultural uses. It is common for a solar pond to have a salinity gradient, with the resulting pond being divided into three zones. The uppermost layer is the upper convective zone or the surface zone (UCZ). The major gradient zone (MGZ), also known as the non-convective zone, is located in the centre (NCZ). Lower down is the storage zone, also known as the lower convective zone (LCZ) [13]. The bottom region consists of a convecting or temperature-stratified homogenous salt solution. Above it is the North Equatorial Zone (NCZ), which acts as a thermal insulator and features a salinity gradient. This means that there will always be less concentration in the water at the top compared to the water farther below. Low-salinity brine or fresh water forms a homogeneous layer at the surface. Due to the higher density of the hotter, saltier water at the bottom of the salinity gradient compared to the cooler, less salty water above it, convection is prevented in the gradient zone even when the heat is absorbed there in lower zone, provided the salinity gradient is large enough.

Water's optical and thermal properties make it such that energy from the sun that is absorbed in the lower zone can only be released by conduction, since the material allows through visible light but blocks infrared light. Water has a weak heat conductivity, but if the gradient zone is thick enough, it can, heat flows upward from the bottom zone extremely slowly. Water's high heat capacity and the solar pond's enormous volume make it useful as both a thermal collector and a long-term storage device, thanks to the gradient zone's insulating qualities [14, 15].

HISTORY OF SOLAR POND

We benefit much from solar energy, which has been effectively used by industry leaders to benefit humanity. Furnas examined a number of solar energy applications in 1955, including building heating, solar water heaters, air conditioners, sun drying, cook stoves, heat engines, PV cells, solar distillation, salt manufacturing, furnaces, and more [16]. **Figure 2** depicts the solar pond's historical growth.

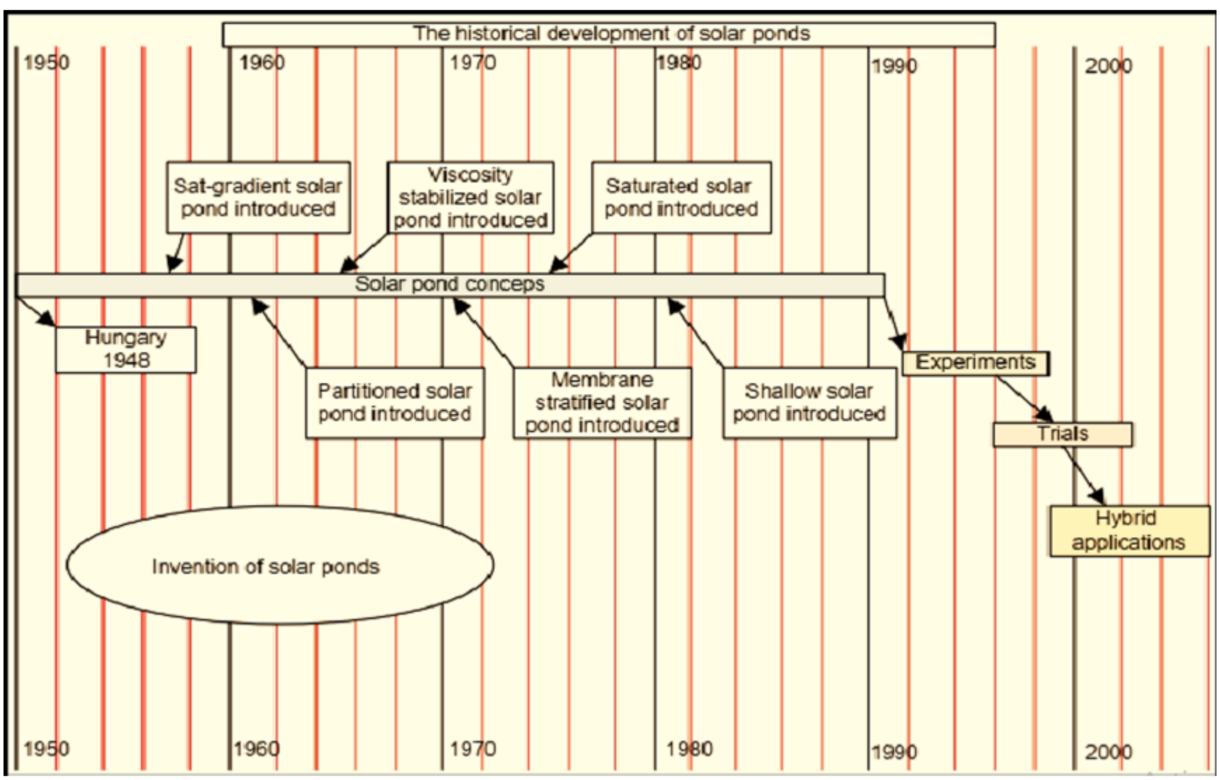

Figure 2: Historical evolution of Solar Pond [16, 18]

CLASSIFICATION OF SOLAR PONDS

Solar ponds may be broken down into two distinct types: convective and non-convective. A basic schematic **(Figure 3)** might be created to show the different kinds of solar ponds.

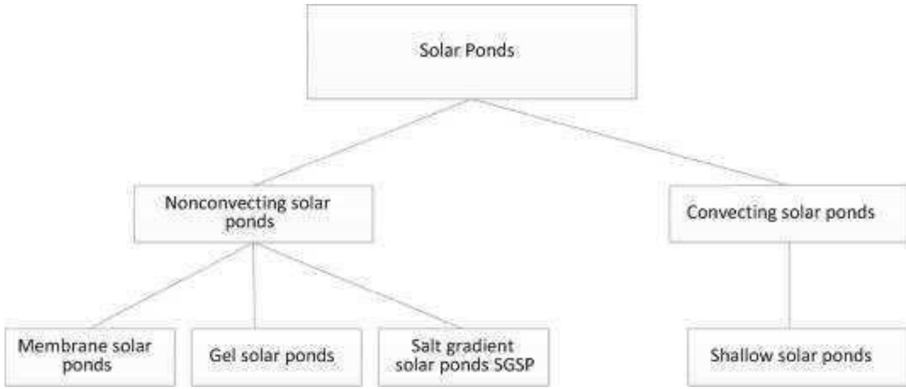

Figure 3: Solar pond diagram

Convective solar ponds

A convective solar pond, like the one in the shallows. The system consists of a big bag that blocks convection yet allows evaporation to occur. Black foam insulation lines the bag's bottom, and either plastic or glass sheets cover the top. Bagged water is heated by solar energy during the day, then transferred to a big heat storage tank at night to keep the heat in. A different variety is the large, freshwater lake. A thick coating of glass conceals the deep, salt-free pond below. Heat loss can be minimised when the sun isn't out or when it's night by installing insulation over the glass [19].

Non-convective solar ponds

Large, shallow bodies of water (about 3–4 metres deep) are positioned in a non-convective solar pond in such a way that the normal temperature gradient is inverted. This paves the way for the efficient collection of radiant energy (up to 95 C), storage of heat, and transportation of thermal energy, at temperatures 40-50 C above normal, from the system. There are three distinct varieties of non-convective solar ponds, distinguished by the layered structure maintenance strategies they employ. One example is the salt-water density-gradient pressure (SGSP) system. Membrane solar ponds, which can be either horizontal or vertical, are the other option. The third type is a solar pond made of polymer gel layers [20].

Salinity gradient solar ponds (SGSP)

This is where a solar thermal energy storage system, or SGSP, comes in handy. Solar radiation is used to heat water, which is then used to store sensible heat in thick saline water, which then produces a density gradient to inhibit convective heat transfer and stores thermal energy [21]. An example of an SGSP's schematic layout is seen in **Figure 4.**

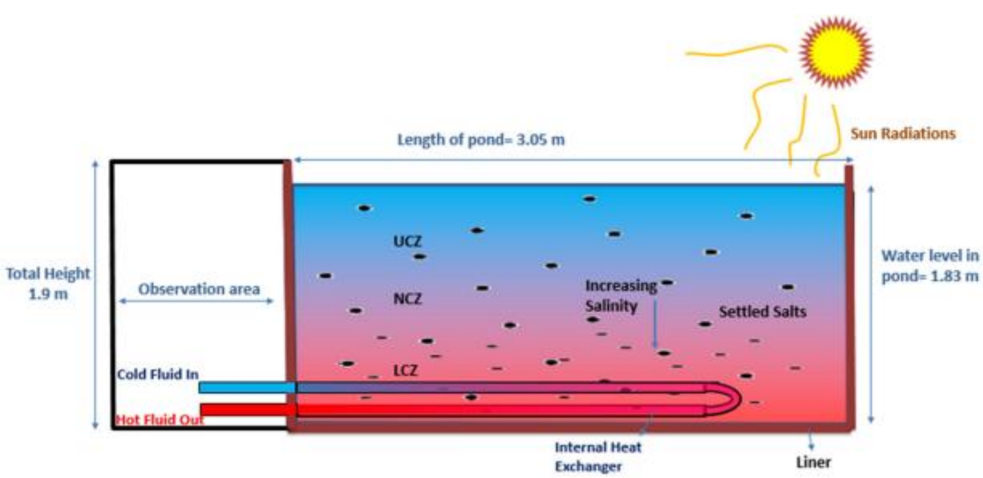

Figure 4: Schematic illustration of SGSP [21]

The core components of an SGSP are arranged in three distinct levels. There are three distinct layers in the atmosphere: the upper UCZ (Upper Convective Zone), the intermediate NCZ (Non- convective Zone), and the lower LCZ (Lower Convective Zone).

The UCZ is almost completely unsaline and maintains a temperature not too far from that of the surrounding ocean. Evaporation, wind mixing, flushing the surface, and nighttime chilling all contribute to the formation of this zone. This layer is often kept as thin as feasible (0.3 - 0.5 m) by employing wave-suppressing meshes or erecting wind-breaks in the vicinity of the ponds. The NCZ has a significantly more substantial gradient, taking up 1.5 m (or more than half) of the pond's depth. As one descends deeper into NCZ, one encounters higher average temperatures and a higher concentration of salt. The thermal insulation effect is provided by the vertical salinity gradient in NCZ, which prevents convection. Because of the pond's dark bottom, a temperature differential is created. The LCZ is characterized by relatively high salinity (20-30% by weight) and high temperature that remain relatively consistent. LCZ is a heat storage medium, and it is important that it be of sufficient size to deliver energy all through the year. It's often as thick as the NCZ (one metre). This material serves as a heat exchanger, heat sink, and heat extractor. There is a dark body at the bottom edge.

The bottom of the SGSP soaks up the vast majority of the sun's rays as they hit the surface. As a result, the thick salt layer gets hotter. Without the salt, the lower density water would ascend to the surface due to the buoyancy effect, and the two layers would eventually become homogenous. The pond's surface heat is quickly lost to the surrounding environment. However, in an SGSP, the heat cannot rise through the fresh water layer by natural convection because of the denser salt layer at the bottom. This causes the bottom layer to heat up to temperatures of up to 95 °C, giving the SGSP the benefit of being a novel energy trap with the capability of storing heat for extended periods of time. [21]. Recenly various thermal spray coatings are also used to increase the strength of material and increase the thermal conductivity [22-29]

Adhikari & Fedler (2020) [30] It has been looked into if there are two options for dealing with treated municipal wastewater: either discharging the treated water into a stream or reusing it for useful uses, including watering crops through land application. Effluent quality for land application systems is typically two to three times greater than that needed for stream discharge. Furthermore, popular sentiment is more positive toward wastewater reuse for irrigation than domestic reuse. It is common practise to employ a pond treatment system for reuse systems since it is cheap, efficient, and straightforward to set up. However, pond treatment systems lack clear design criteria, making it hard to choose an appropriate design technique. Pond-In-Pond (PIP) is the combination of two pond types (aerobic and anaerobic) and is recommended as the most suitable design plan for reuse purposes in this study. Computational Fluid Dynamics (CFD) Recent studies that analysed a flow-diversion mechanism, as well as data from operational PIP systems, suggest that this technology has promise for wastewater reuse. The average yearly effluent BOD produced by the investigated PIP system was around 40 mg/L. The different Zones of the SGSP is shown in **Figure 5**.

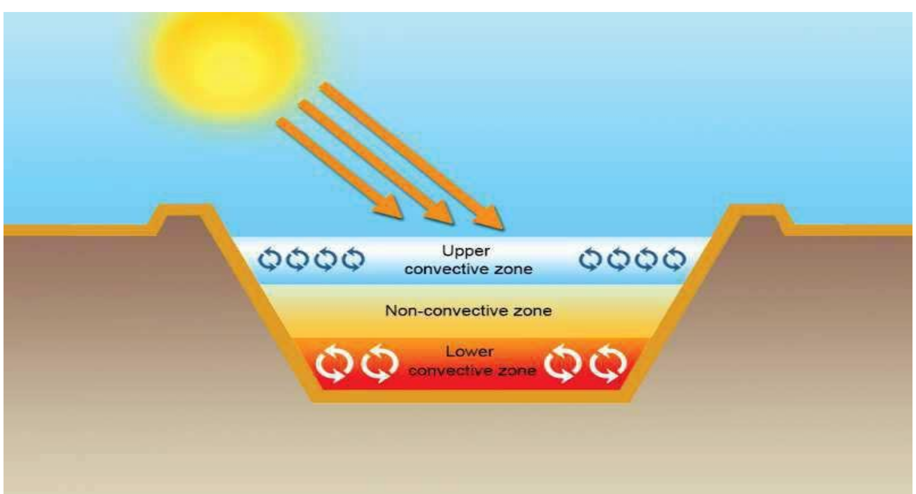

Figure 5: Zones of the SGSP

Contrasting on solar pond thermal efficiency between the bottom and surface zones exist due to water clarity, pond structure (especially the depth of the gradient zone), as well as the temperature differential (defined as the amount of solar energy incident on the pond surface divided by the rate at which heat is removed from the LCZ). High AT causes more heat loss at higher pond temperatures, reducing thermal efficiency. In contrast to the high temperatures (above 85°C) often required for electric power production, the thermal applications most suited to solar ponds have a lower operating temperature. The thickness of the storage zone is also a factor in the ponds' thermal performance (LCZ). The daily temperature swings in a solar pond are smaller when the storage zone is larger. A higher startup period might be expected at the pond with the greater storage zone thickness. For example, the El Paso solar pond has a 1.2 m gradient zone and a 1.35 m storage zone, the bottom temperature increased by around 1 °C each day at starting, and the LCZ saw temperature swings of 1-3 °C during the day and night [31, 32].

BENEFITS AND DRAWBACKS

There are several pluses to installing a solar pond. It may be used all year round, day or night, rain or shine, because of its built-in thermal energy storage. Rural locations in less developed nations, where large ponds may be produced, make the solar pond an especially viable alternative to fossil fuel technology. A solar pond can provide cheaper energy than the typical flat-plate solar water heaters seen in residences. The pond's ability to generate heat without the need of fossil fuels means it reduces emissions and helps preserve essential energy sources.

They can be constructed cheaply across wide regions, have a high storage capacity per unit of collecting surface, and are easy to use. It has been shown that solar ponds with a salinity gradient may provide consistent heat at temperatures between 50 and 90 degrees Celsius. The solar pond's greatest benefit is the low cost with which it can be set up. Creating a solar pond volume nowadays is not a particularly costly or time-consuming technique, but it is more practical to use in areas where the land structure is adequate. Heat storage can indeed be performed in a solar pond, an artificial pond or lake produced in areas with sufficient sun radiation. For maximum heat absorption, a solar pond uses transparent water to maximise the sun's beams. Moreover, the pond's base is often dark in colour to maximise the absorption of solar energy [33].

However, the solar pond isn't without its flaws. Since it needs a sizable plot of land, it may not be practical in urban settings. In addition to a lot of solar power, the pond needs a lot of salt water. Furthermore, while any competent engineer can build solar ponds, they still need regular upkeep. For instance, non-convecting ponds with accumulated salt must have it drained and replaced because of evaporation [33]

APPLICATIONS

Many diverse uses can benefit from the energy that solar ponds generate. "Larger ponds are proposed for industrial process heat, electric power generation, and desalination, while smaller ponds are utilized for space heating and cooling and residential hot water production." Because of their natural capacity for storing heat, solar ponds are becoming increasingly popular as a means of heating and cooling buildings and providing hot water for households. To yet, however, no such effort has been launched. Absorption chillers are used for cooling, and they are powered by waste heat. The 90°C needed for this purpose may be achieved steadily and simply from a solar pond throughout the summer [34]. However, the different applications of solar pond is shown in **Figure 6.**

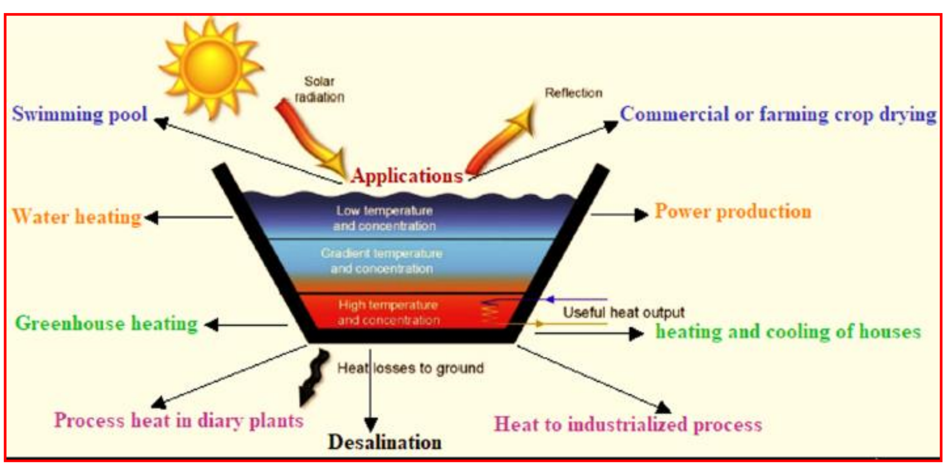

Figure 6: Diverse applications of solar pond [34]

CONCLUSION

The lengthy literature review led researchers to the conclusion that black painting the pond's inside walls increases the pond's efficiency. In order to increase the salinity in the solar pond, sodium chloride salt is favoured over other salts. In addition, with an increase in salt, the temperature in the LCZ also rises. In comparison to the natural brine used in the solar pond, the maximum temperature reached with artificial brine is greater. In particular in rural regions, the heat storage zone (HSZ) in SGSPs is perfect to execute desalination process without any energy charges. As far as overall performance metrics are concerned, HSZ should be properly developed. Non-convective zone (NCZ) and upper convective zone (UCZ) design considerations are crucial. The thicknesses of HSZ, NCZ, and UCZ should be tuned for maximum system performance.

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