Application of Sun Tracking Concentrated Solar Power (CSP) Technology with Parabolic Reflectors to Power an Electrolysis System for Yielding Green Hydrogen from Potable Water

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Abstract. Hydrogen energy, a clean and sustainable energy source, has received much attention recently. Water electrolysis combines the cathode's hydrogen evolution process with the anode's oxygen evolution reaction, which is a potential approach for producing hydrogen. High-grade energy is needed for advanced solar energy utilization technology such as electrolysis to provide the most compact, and efficient application. Electrical and thermal energy needs may be satisfied by concentrated solar power (CSP) technology. Utilizing CSP technology with parabolic reflectors has several advantages, including a proven track record of financial return on investment, a well-developed technology, and simplicity of integration with other renewable energy sources or fossil fuels. Given the world's current environmental status and the continuing degradation of fossil fuel supplies, the direct use of potable water as a medium for hydrogen synthesis has emerged as a hot research issue. Because of its availability in the Philippines and how it can be produced by desalinating seawater, immediate use of potable water as the medium for water electrolysis can minimize the cost of hydrogen generation. Research on yielding hydrogen gas as an alternative energy source by an electrolysis system powered by sun-tracking CSP with parabolic reflectors was thoroughly done to gather data. Results show that green hydrogen gas can indeed be yielded and can be more effective with the use of sun-tracking CSP.

1. Introduction

Daily, most use fossil fuels like firewood and coal, followed by petroleum gasses like LPG and kerosene. Although cheap and accessible, Fossil fuels emit an excessive amount of smoke that causes household air pollution (HAP)—the most significant health threat factor globally, according to the World Health Organization. On the other hand, petroleum gasses are expensive, less accessible, and toxic when inhaled. Both fossil fuels and petroleum gasses,

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aside from the downsides mentioned, are non-renewable sources, which means they are limited[1].

Hydrogen is the most basic and plentiful element in the universe, accounting for approximately 90% of the visible universe [2]. It is a valuable energy source for various reasons. The most significant factor is its abundant availability. While harnessing hydrogen requires many resources, no other energy source is as infinite as hydrogen. Unlike other energy sources, it has no chance of running out.

When hydrogen is used to make fuel, the byproducts are entirely harmless, meaning there are no known adverse effects[3]. It is a non-toxic substance that is uncommon as a fuel source. This aspect distinguishes it from other sources of energy, such as nuclear power and natural gas, which are very dangerous or difficult to harness appropriately. It also permits hydrogen to be utilized where other fuels are prohibited, indicating that it is eco-friendly and does not threaten the environment. It can destroy human health.

Numerous studies have been conducted on hydrogen production using an electrolysis system powered by solar energy through PV solar panels. However, this study aimed to assess the viability of improving the hydrogen yield from potable water by powering up an electrolysis system using sun-tracking concentrated solar power (CSP) technology using parabolic reflectors to maximize solar energy from the sun [4].

Advanced solar energy technology needs high-grade energy to generate the most efficient power with a small plant footprint and a short capital investment recovery period. Concentrated solar power (CSP) technology may satisfy electrical and thermal energy needsv[5].

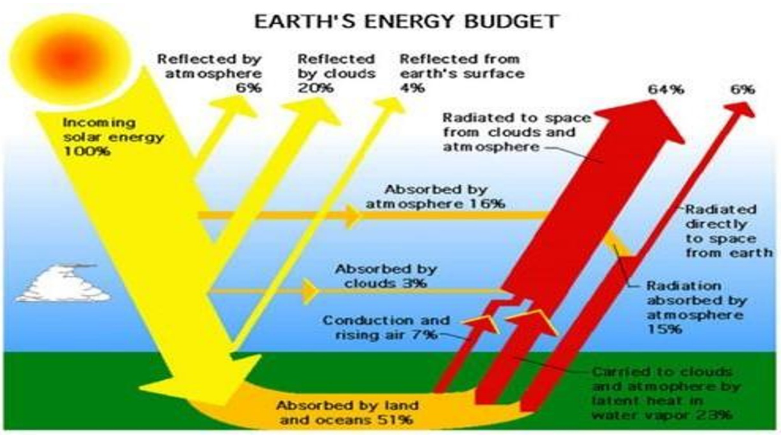

Fig. 1. Earth's Energy Budget [6]

The CSP roadmap came to the following conclusion based on a recent IEA report: with appropriate governmental backing, it is anticipated that by 2050, CSP will constitute 11.3% of the world's power consumption, with 9.6% coming from solar energy and 1.7% coming from backup fossil or biomass fuels. Moreover, thermal storage is an option for all CSPs [7]. With CSP technologies, medium- to high-temperature heat is produced when incoming sunlight is focused by mirrors or lenses on a relatively tiny target area. Convective and conductive heat losses are significantly reduced as a result of the increased thermodynamic efficiency and lower absorbent surface area produced by the increase in operating temperature and amount of heat collected per unit area [5].

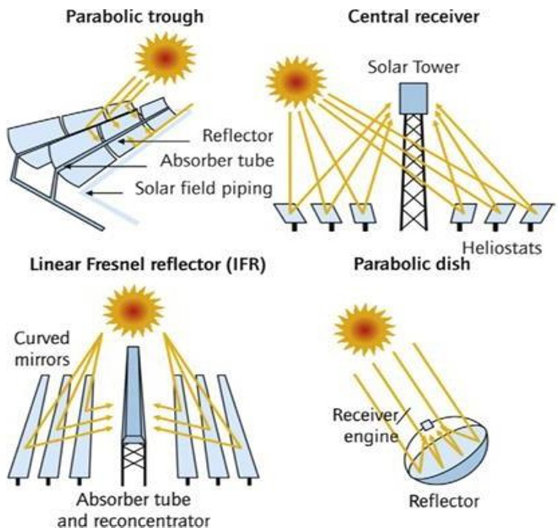

Fig. 2. Typical concentrated solar power technology [8]

Numerous previous studies have investigated sun-tracking control systems. In the area of passive solar tracking, offline sensor less DAST has been suggested. It was confirmed that by employing this technique, an additional 24.59% of solar energy was collected annually. The suggested system made use of a sun tracker with a simpler construction than a fixed PV system, which follows the sun more precisely while also having a lower production cost than sensor-based sun trackers. The solar position algorithm is used to compute the sun's vector. The sun-tracking error of this method was only 0.43, which is less than the error of the sensor less and sensor-based DAST that was employed [9].

2. Methodology

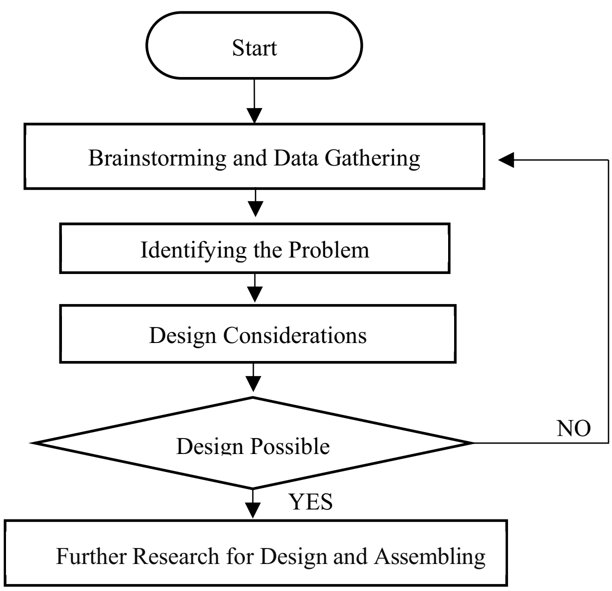

Fig. 3. Flow Chart

2.1 Brainstorming and Data Gathering

Multiple resources from existing journals and books were used to gather data and brainstorm further information on the application of sun-tracking concentrated solar power (CSP) technology using parabolic reflectors to power an electrolysis system for yielding green hydrogen as an alternative energy source, especially for cooking and other household uses.

2.2 Identifying the Problem

Small experimental tests of hydrogen yield via electrolysis and thorough research will lead to small stepping stones to determine further challenges and assess whether the study is viable and a promising solution to supplement the goal of utilizing renewable energy to generate electricity.

2.3 Design Considerations

The gathered data from thorough research and micro experiments will be analyzed and supplemented by further research from journals related to the study.

2.4 Design Possible?

After thorough data analysis, thorough research, and microe xperiments, the verification of identifying whether the design is plausible or otherwise will be performed. If this is plausible, further research on the design and application of these materials will be the next step for this study.

2.5 Possible design set-up

Sun-tracking concentrated solar power technology with a parabolic reflector will serve as the system's primary energy source. This CSP system will be further designed during the design and application of this study in future studies. From The CSP system, . Then, from the CSP system to the controller, it will be connected to the battery for energy storage. Then, the cables will be connected to the electrodes of the electrolysis container, particularly the anode and cathode, which will electrolyze the potable water that serves as the medium. The electrolysis process takes place to extract hydrogen. The design may be able to stop here, as it is already another study for the design of hydrogen storage. However, if it is used as an alternative to cooking fuel, then a tube will be connected to the bubbler to prevent backfire while extracting hydrogen. The ball valve controls the flow of hydrogen gas attached to the one-way check valve, which prevents reverse flow. The regulator is connected to the check valve because it maintains the hydrogen gas within the range of its limit. The burner will produce the flame to be used for cooking as an output.

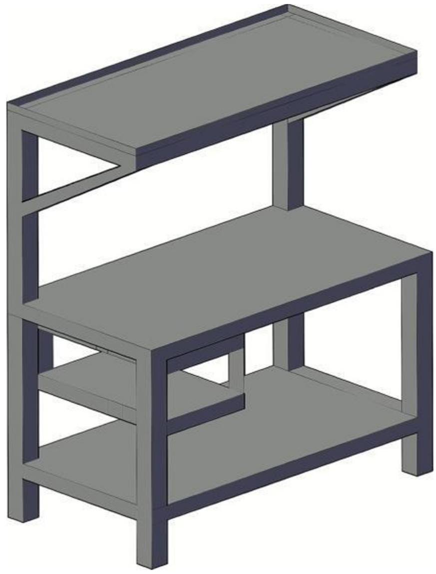

Fig. 4. 3D Layout of System Framing

2.1 Micro-Experimental Procedures

A micro experiment was performed to ensure that it is plausible to assemble an electrolysis system that can yield hydrogen before coupling it with the desired sun-tracking CSP technology.

1. Preparing the Electrolysis Chamber

Remove the container cover and drill two ⅛ diameter holes horizontally with a 5-inch gap. These holes are where the hydrogen hose will be placed. Two pieces of 225 mL were cut horizontally, and half of the pieces were kept with the cap. The two caps were 0n, and an ⅛ inch diameter hole was made. The hose, bottle domes, and a container cover were assembled. Align the holes of the bottle domes under the holes of the container cover and connect both with the hose. For the container itself, an inch was cut on both sides of the bottom of the container. This is where the electrode will slide out. Make sure that everything is
sealed to avoid leakage.

2. Assembling the electrode and settling it into the container

The electrodes are attached in such a way that they stand with a screw below to hold the electrodes. One electrode must be pushed out of the container for this to serve as the place where the battery clips are clipped. Two pairs of electrodes were made. One was for the anode, and one was for the cathode.

3. Assembling the bubblers

The two remaining bottles were grabbed, and two small holes were made in the cap. Fill it with water and insert two hydrogen hoses– one must be sunk in the water and one hose must not touch the water; these will serve as the bubbler. One was for oxygen, and one was for hydrogen.

4. Assembling the experimental electrolysis system

The container was filled with 8 liters of potable water. Seal the container. A container with a gasket is preferred for this experiment. The hoses were connected to the sunken hoses in the bubblers and sealed well. The battery clips were clipped to the naked outside electrode, with one clip on each side (anode and cathode). The battery was turned on for 3 minutes before the system was fully closed. After 3 minutes, 2 pieces of plastic were tied to each end of the bubbler's shorter hose to ensure no leaks. Wait for 1 hour to make sure that there is no hydrogen gas leaking. The plastic tied in the hydrogen gas bubbler should be fully secured. After doing so, electrolysis was stopped, and the plastic was removed to ensure no hydrogen gas leakage.

NOTE: The plastic will surely float if the yielded gas is hydrogen.

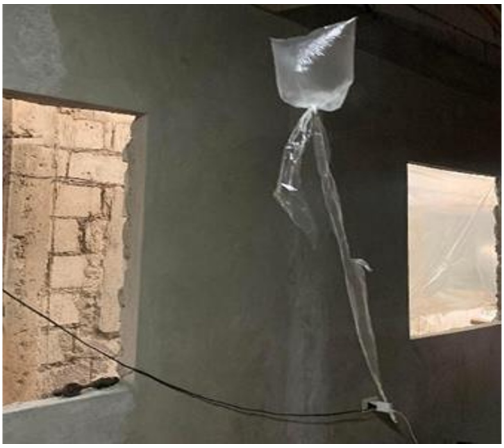

Fig. 5. Plasticity of Hydrogen Floating in the Air

To prove that the yielded gas is hydrogen, the inflated plastic is lit, and a small explosion occurs.

Fig. 6. Attempts to Burn Plastic with Hydrogen

2.2 Theoretical Volume of Hydrogen Produced in One Hour

$$v_H = \frac{no.of\ Coulombs}{no.of\ faradays * 96500\frac{Coulombs}{mole}} * \ 24dm^3 H_2 \qquad (1)$$

- V_H = Volume of hydrogen (dm^3)
- no. of Coulomb's = IT = Current in Amps*Time (in seconds)
- no. of Faraday's (F) = no. of moles of electrons required to produce 1 mole of hydrogen
- 96500 Coulombs/mole = Faraday's constant
- 24 dm^3H_2= no. of dm^3H_2 at room temperature and pressure

2.3 Energy Efficiency Formula

$$\eta_{energy} = [H(H2\text{-}) * V(H2\ experiment)]/[V * I * t] \qquad (2)$$

- η_{energy} = $energy\ efficiency$ = %
- H(H2) = Calorific value of hydrogen at 20°=11920 kJ/m^3
- V = Voltage = V
- I= Current =Ampere
- t = time = hour

2.4 Volumetric Efficiency Formula

$$\eta_{faradaic} = \frac{v_{H2\ experimental}}{v_{H2\ theoretical}} \qquad (3)$$

- $\eta_{faradaic}$ = $faradaic\ efficiency$
  = $volumetric\ efficiency$
- $V_{H2experiment}$ = $volume\ of\ hydrogen\ in\ the\ experiment$
- $V_{H2theoretical}$ = $theoretical\ volume\ of\ hydrogen$

3. Results

3.1 Hydrogen Yielding Through Electrolysis

Table 1. Parameters and Data for the Prototype

Parameters	Data
Time needed to charge Battery	3.3 hours
Minimum Voltage for Electrolysis	1.23 V
Voltage (Solar Panel, Controller, Battery)	12 V
Actual Voltage	12.49 V
Actual Ampere	2.8 Amps
Watts of Solar Panel	120 W
Ampere-hour of Battery	33 Ah
Ampere-hour of Solar Charge Controller	10 Ah

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3.1.1 Calculating the Volume that can be Produced

- $no.\ of\ Coulomb's = IT$
  $= Current(in\ Amps) * Time(in\ seconds)$
- $no.\ of\ Coulomb's = 2.8\ Amps * 1\ hour$
- $no.\ of\ Coulomb's = 2.8\ Amps * 3600\ seconds = 10080\ C$ no. of Faraday's = no. of moles of electrons to produce 1 mole of hydrogen
- no. of Faraday's=2 moles of electrons to produce 1 mole of hydrogen
- $96500 \frac{Coulombs}{mole} = Faraday's\ Constant$
- $24\ dm^3 H_2 = no.\ of\ dm3H2\ at\ room\ temperature\ and\ pressure$

$$v_H = \frac{no.of\ Coulombs}{no.of\ faradays * 96500 \frac{Coulombs}{mole}} * \ 24dm^3 H_2$$

$$v_H = \frac{10080\ \mu m}{2 * 96500 \frac{Coulombs}{mole}} * \ 24dm^3 H_2$$

$$v_H = 1.25dm^3$$

$$v_H = 1.25dm^3 * \left(\frac{10cm}{1\ dm}\right)^3$$

$$v_H = 1250cm^3 = 1.25L$$

$$v_H = 1.25L \text{ (every hour of electrolysis)}$$

3.1.2 Calculating the Energy Efficiency

H(H2)-Calorific value of hydrogen at 20°=11920kJ/m^3
V=Voltage=12.49 V I-Current- 2.8 Amps t-time=1 hour
V(H2 experiment) = 0.408 L

$\eta_{energy} = [H(H2-) * V(H2\ experiment)]/[V * I * t]$

$$\eta_{energy} = \frac{(11920kJ/m^3 * 0.408L}{12.49V * 2.8\ A * 1hr}$$

$$\eta_{energy} = \frac{(11920kJ/m^3 * 1000J/1kJ) * (0.408L * [\ 0.001m^3/1L])}{34.972W-h * [\ (1J/s)/W]}$$

$$\eta_{energy} = \frac{4863.36\ J}{34.972J - h/s * (3600s/h)}$$

$$\eta_{energy} = (486{\cdot}36\ J)/(125899{\cdot}2\ J)$$

$\eta_{energy} =$ **0.0386 = 3.86%**

3.1.2 Calculating the Volumetric Efficiency

Every 24 hours, 9.8 liters are produced.

$V_{H_2 experiment} = 9.8\ L\ /\ 24\ hrs = 0.408\ L/hr$

$V_{H_2 theoretical} = 1.25\ L/hr$

$\eta_{faradaic} = V_{H_{2}experiment} / V_{H_{2}theoretical}$

$\eta_{faradaic} =$ 0.408 *L/hr* / 1.25 *L/hr*

$\eta_{faradaic} =$ **0.3264 or 32.64%**

3.2 Sun-Tracking System

By ensuring that solar panels or concentrated solar power systems receive the most sunshine possible during the day, solar tracking may greatly increase the efficiency of these devices. Solar trackers maximize solar energy capture and lessen the impact of shadowing from nearby structures or other obstacles.

When the sun is directly overhead, solar panels and concentrated solar power systems are usually rated at their highest efficiency. Solar trackers assist in sustaining this state of maximum efficiency for longer stretches of the day by ensuring that solar energy systems are oriented in line with the sun's path. Solar trackers have the potential to boost the solar energy system's efficiency by as much as 40%. Moreover, on overcast days, solar tracking can increase the power output of concentrated solar power systems and solar panels. Even under less-than-ideal circumstances, solar trackers can increase solar energy capture by adjusting the angle of the solar panels or other solar energy devices to maximize the quantity of sunlight that reaches the ground [10].

3.3 Concentrated Solar Power Technology with Parabolic Reflectors

Researchers are interested in CSP technology since it is an effective renewable energy source for power generation. With a total solar-to-electricity efficiency of more than 16%, CSP technology can generate power with enormous capacity across large parts of the world. There are approximately 143 Concentrated Solar Power (CSP) installations worldwide. Of these, 114 are currently operational, 20 are no longer in use, and 9 are under construction with plans to start operating in 2022 and 2023. Based on the comparison, China, Spain, and the US are The three nations with the most CSP plants. With 51 projects constructed around the nation, all of which are operationally, Spain has a total installed capacity of 2.3 GW. Out of the four popular CSP technologies, parabolic trough collectors (PTCs) are the most widely used, with 91 projects. Solar thermal towers are second with 34 projects, followed by linear Fresnel reflectors with 16 projects, and there are only two dish projects, both of which are decommissioned. PTC technology was employed for almost 75% of the installed capacity. Moreover, it was discovered that, of all the technologies, the linear Fresnel reflector technique had the highest land utilization factor [7]

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The following tables are from the research journal [7]

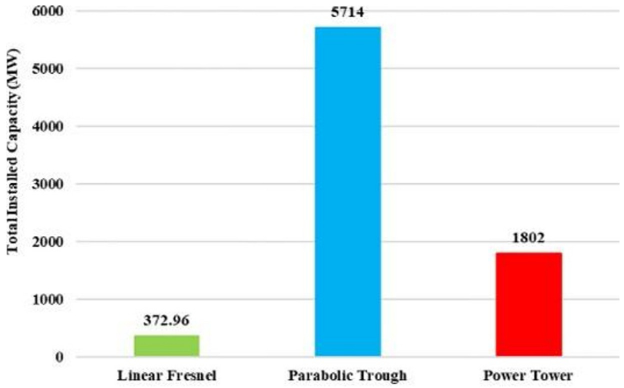

Fig. 7. Total installed capacity for each CSP technology

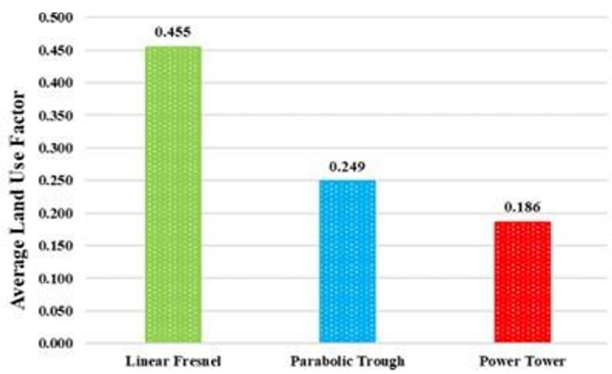

Fig. 8. Average land use factor comparison between the different technologies

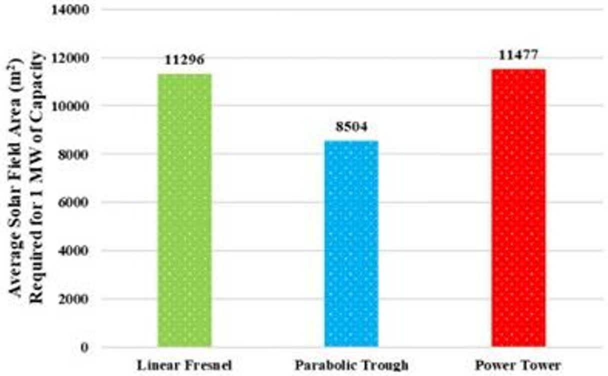

Fig. 9. Average solar filed required in (m^2) for 1MW of capacity for each technology

4. Discussion

4.1 Why are such studies relevant to students in our society?

Renewable energy is currently a major concern worldwide. Jobs, housing, food production, and climate change are all impacted. Energy is essential to life on Earth, and its affordability and cleanliness are more important than ever.

Clean energy has a significant impact on our lives, from its impacts on global warming to worldwide natural disasters. Debates are a vital background for many academic disciplines and today's classroom. All around us is energy. Both houses and schools run on energy. It supplies power, light, and heat. It cooks our meals, runs our computers, and fuels our cars. Since it is fundamental to students' daily lives, we should support their academic engagement.

However, lesson ideas might cover more than simply the presence and significance of energy. The importance of renewable energy sources also needs to be a top priority for students. Despite the advancements made by humanity in producing sustainable energy sources such as wind and solar power, energy still accounts for approximately 60% of greenhouse gas emissions worldwide and is one of the primary drivers of climate change.

Lastly, it is simple to take energy availability for granted. Large portions of the world's population live in areas without access to modern energy sources such as electricity. It is up to today's students to spearhead change and work toward universal access to affordable, sustainable energy.

5. Conclusion

- In regions where fossil fuels and gases are slowly becoming scarce, hydrogen can be generated using potable water (which can also be produced from desalinating seawater), and solar energy can be maximized through sun-tracking concentrated solar power technology.
- The electrolysis system design of this study has been innovated to take the already validated benefits of freshwater electrolysis from an expensive industrial-scale system to a low-cost, accessible, and resourceful approach. The concept of using solar energy with sun-tracking CSP technology to power a battery via the clipping of anode and cathode clips to stainless-steel electrodes was described in detail in this research. The resulting utterly accessible system design allows easy hydrogen yielding and a low-cost individual operating range, as the system does not require considerable money to produce hydrogen gas that can be used as a cooking fuel alternative and/or alternative energy for different uses.
- The energy and volumetric efficiency are also calculated. According to the calculated findings, the energy efficiency is 3.86%. The volumetric efficiency is determined, and the electrolysis process generates 32.64% of the theoretical volume.
- Compared to traditional plate collectors, CSP technologies provide several benefits, including the ability to operate at higher temperatures, more efficient systems, and less time to return their initial investment. Utilizing CSP technology with parabolic reflector systems offers the advantages of advanced technology, easy maintenance, and potentially cost-effective investment. Merging with other renewable energy sources or fossil fuels. This study thoroughly analyzes CSP technology in conjunction with a PTC system.
- A solar collector, reflector, or photovoltaic panel can be oriented toward the sun using solar tracking. A tracking mechanism ensures that the solar collector automatically tracks the sun's path across the sky and maintains the ideal angle to

maximize solar radiation. This is beneficial, especially with CSP, as both can maximize solar energy and convert it into another energy for daily use.

- Although this study confirmed that hydrogen has excellent benefits and can be an alternative energy source for cooking based on the specified parameters, there is still much room for improvement in future studies.

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