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Generating Hydrogen through Water Electrolysis Using Concentrator Photovoltaics

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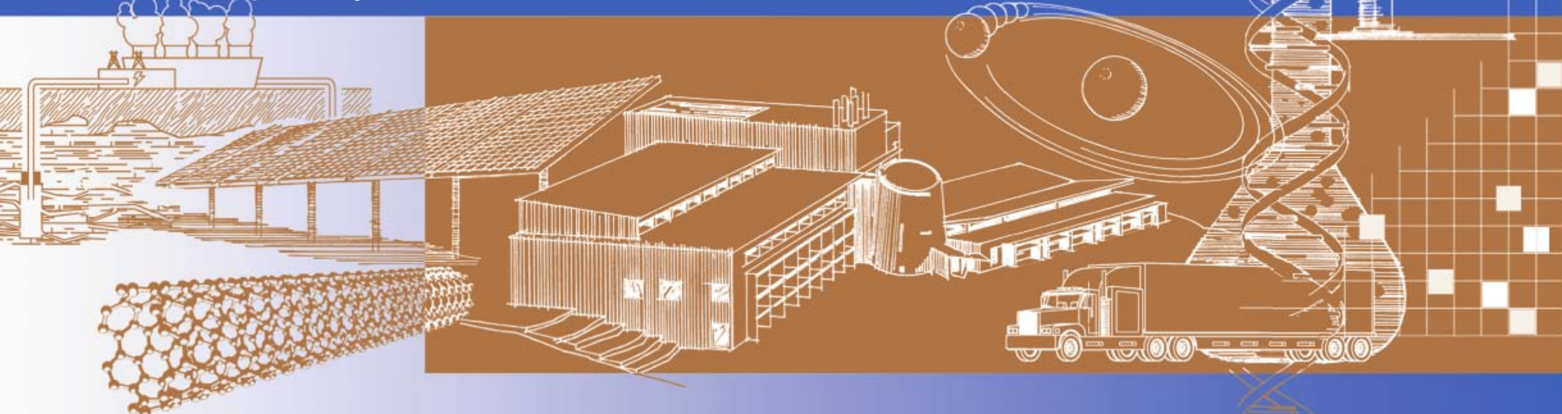

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Generating Hydrogen through Water Electrolysis Using Concentrator Photovoltaics

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ABSTRACT

Hydrogen can be an important element in reducing global climate change if the feedstock and process to produce the hydrogen are carbon free. Using nuclear energy to power a high temperature water electrolysis process meets these constraints while another uses heat and electricity from solar electric concentrators. Nuclear researchers have estimated the cost of hydrogen generated in this fashion and we will compare their estimates with those we have made for generating hydrogen using electricity and waste heat from a dish concentrator photovoltaic system. The conclusion is that the costs are comparable and low enough to compete with gasoline costs in the not too distant future.

1. Objectives

The goal for the PV Exploratory Research Project is highlighted in the beginning of the Solar Program Multi-Year Technical Plan by Secretary of Energy Spencer Abraham's challenge to "leapfrog the status quo" by pursuing research having the potential to create breakthroughs. More specifically, the project's objectives are to develop next-generation technologies and systems with the potential to create new high-value applications of solar energy in producing hydrogen fuel, generating competitive bulk power at central stations, desalinating water, or creating other products that are beyond present capability. The project is expected to create both disruptive technology advances and multiple incremental improvements. In this case, the PV Exploratory Research Project stumbled upon a potential breakthrough technology for generating hydrogen from water using only the heat and electricity from a concentrator photovoltaic system. We are exploring the potential for further developing this technology jointly with DOE's Hydrogen, Fuel Cells, and Infrastructure Technologies Program.

2. Technical Approach

Concentrating solar energy to produce electricity can occur at quite high solar conversion efficiencies. The highest efficiency for solar concentrator cells, as measured at NREL, is now above 37% for multijunction solar cells. In production, similar cells have efficiencies above 30% and are widely used for powering satellites. Solar Systems has measured a 40% boost in hydrogen production by stripping away the solar infrared radiation incident on concentrator solar cells and transporting it with a light pipe to heat a solid oxide electrolyzer cell operating above 1100˚C [1]. With today's solar cell technologies, it is therefore feasible to expect 50% conversion efficiency of solar energy to hydrogen through high-temperature electrolysis. A recent article provides a good theoretical understanding for the thermodynamics and electrochemistry of this process and confirms the potential for attaining 50% conversion efficiency [2].

Costs for high-efficiency CPV systems can be quite low. Recent studies predict system costs of \$0.85/W in large-scale production. These costs are comparable with those of today's wind energy systems, which generate electricity below 5 cents/kWh. And costs for hydrogen generated by wind-powered electrolysis are attractive enough, without a heat boost, to compete with the cost equivalent of gasoline. We expect that hydrogen produced by a CPV system through high-temperature electrolysis will be equally attractive, if not more so.

3. Results and Accomplishments

Using the heat and electricity provided by solar energy to produce hydrogen in an electrolyzer requires the use of several components. The following is a list and description of the four major components used in this hydrogen production system (See Fig. 1).

1. *Concentrator Photovoltaics (CPV):* This part consists of a small photovoltaic (PV) panel placed just outside of the focal point of a concave dish.
2. *Spectral Splitter:* Placed in front of the PV panel is a filter that is used to reflect infrared energy while allowing visible light to pass through to the PV panel.
3. *Light Pipe:* This device transfers infrared energy from the spectral splitter to the SOEC.
4. *Solid Oxide Electrolyzer Cell (SOEC) Stack:* This component of the system combines the heat from the light pipe and the electricity from the PV panel to separate water into oxygen and hydrogen molecules.

For this system to be effective, these components need to be implemented into a system that achieves high efficiency at competitive cost. Tables 1 and 2 show the results of our cost analyses and compare them with other analyses based on different financial assumptions. Taking in account the different assumptions in these analyses we conclude that the costs of CPV-generated hydrogen are comparable with those of wind- and nuclear-generated hydrogen and less than those of flat-plate PV hydrogen. Note that 1 kg of hydrogen is approximately the energy equivalent of 1 gallon of gasoline.

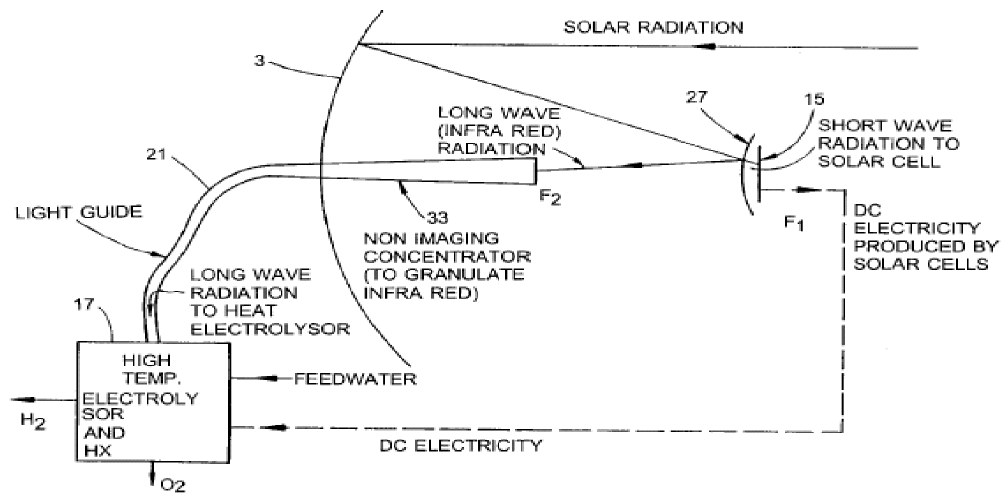

Figure 1. CPV/High Temperature Electrolyzer [1]

Table 1: System Cost Analysis

Component Cost (per kW)	Current Cost for a 1kW System	10MW System Est. Cost per kW (Yr. 2020)
CPV	$10,000	$800.00
Dichroic Filter	$500	$10.50
Light Pipe*	$990	$24.75
SOEC**	$2,000	$400.00
Unknown Costs	$5,000	$5.00
Total	**$18,490**	**$1,240**

*Prices quoted by CeramOptec
**Manufacturing costs quoted by Ceramatec, Inc.

Table 2: Cost Comparison

Process	Hydrogen Production Cost (per kg)
Gas Reformation [3]	$1.15
Wind Electrolysis [3]	$3.10
Nuclear Electrolysis [4]	$1.48
PV Flat-Plate Electrolysis [5]	$7.40
CPV Electrolysis	**$3.63**

4. Conclusion

This is a potential breakthrough technology for generating hydrogen from solar energy that is deserving of further study. In addition to repeating the experimental demonstration described in reference [1], we hope to develop a cost comparison using consistent financial assumptions to better determine the potential of this technology for generating clean hydrogen.

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[1] J. Lasich, "Production of Hydrogen from Solar Radiation at High Efficiency," United States Patent Number: 5,658,448, August 19. 1997.
[2] S. Licht, "Solar Water Splitting to Generate Hydrogen Fuel: Photothermal Electrochemical Analysis," J. Phys. Chem. B 2003, 107, 4253-4260.
[3] D. Mears, M. Mann, J. Ivy, M. Rutkowski, "Overview of Central H2A Results," *2004 US Hydrogen Conference Proceedings*, April 26-30, 2004.
[4] W. Summers, "Hydrogen Production Using Nuclear Energy," 15th Annual U.S. Hydrogen Conference Proceedings.
[5] L. Kazmerski, "PV Electrolysis," ASES Renewable Hydrogen Forum Proceedings, Oct 1, 2003.

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