Alternative and Renewable Fuel and Vehicle Technology

Docket Number: 08-ALT-1 ands AB118 Program

Survey of Project Concepts for the Alternative and Renewable Fuel and Vehicle Technology Program

Survey Provided by: Solar Hydrogen Energy Company
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Project Type: Fuel Production
Fuel/Technology: Hydrogen On-site By Photoelectrochemical Generation (solar direct water splitting – no fossil fuel required).
Development Stage: Application

1. R& D: Prototype No 6 is under development and expected to be commercially saleable.
2. Validation Testing: Outside testing documented efficiencies projected by NREL.

Concept: The US Department of energy in the publication: National Hydrogen Road Map (www.eere.energy.gov) lists "Direct Water Splitting Using Photoelectrochemical Processes" as an alternative hydrogen production process. This process is also listed on page 14 of "Hydrogen and Our Energy Future". Roxanne Garland at DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program directs the photoelectrochemical work.

Feasibility Established by the US DoE & Outside Testing Of Prototype

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL), *2002 Research Review* (page 13), cites that producing electricity from sunlight without the expense and complication of electrolyzers using photoelectrochemical process is expected to have 12.4% solar-to-hydrogen efficiency, which is more efficient than other photovoltaic approaches that produce only electricity. This report concludes: "This approach represents one possible long-term solution for the sustainable production of hydrogen."

It is anticipated that this **direct photoelectrochemical** solar hydrogen generator will operate at a solar-to-hydrogen efficiency of 12.4 percent, which is above certain other photovoltaic systems. Photovoltaic electricity to traditional electrolyzers making hydrogen, often demonstrate inefficiencies of 40% or

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higher, because of the high loss of operating electrolyzers. However, the process proposed here is **photolytic** or **photolysis** for generating hydrogen directly solely by renewable energy using solar and water.

Solar Hydrogen Energy Company received an outside testing laboratory report on their Prototype Number 3 that tested at the NREL expected efficiency percent of 12.4%. This was carried out at the testing laboratory in central California on a typical day of outside solar irradiance.

Specific Goals: Specific Goals to bring **direct photoelectrochemical** solar hydrogen generator technology to usefulness include:

- Design a module that will yield 1 Kg per hour. This has been calculated to have a face surface area of approximately 1 sq meter, 30" (76mm) x 52" (132mm) and approximately2' thick. This size is similar to a present day typical photovoltaic cell.

- Design to include low cost materials and low cost manufacturing technology so the completed product can be mass produced and sold on the energy market at low cost, keeping the over all energy cost down.

- Construct a module that will yield 1 Kg per hour. This has been calculated to have a face surface area of approximately 1 sq meter, 30" (76mm) x 52" (132mm) and approximately 2" thick. This size is similar to a present day typical photovoltaic cell.

- Obtain a solar tacking device that will increase solar exposure during the sun light hours.

- Secure outside testing of the completed solar-to-hydrogen hydrogen generating device.

- Document direct solar-to-hydrogen by photoelectrochemical solar hydrogen generator equipment set.

- **What are the key underlying technologies of this discovery?**

A photoelectrochemical reaction is created by solar exposure through a combination of lens and water to create at least a six sun solar concentration. This solar exposure on a photocell generates an electrical current that passes through an aqueous electrolyte which causes water to split into hydrogen and oxygen. The key technological feature in this system is the unique membrane system which completely separates the hydrogen and oxygen – no further separation of the two is required. The **most significant aspect and unique feature** of the present hydrogen generating system is that it requires only 1.3 volts direct current (VDC) to split water. 1.3 VDC is achieved in a number of ways

such as solar photovoltaics, low speed wind generators, or small stream hydroelectric turbines. The present system employs direct photoelectrochemical reaction with a unique sun concentration. Our patent application includes solar, wind, and hydroelectric systems. A multi-junction photo cell provides sufficient voltage to drive an oxidation-reduction reaction that produces hydrogen at the cathode and oxygen at the anode and each are emitted into completely separate channels and piped off for storage and use. **No follow-on separation of the two gases is required. No separate traditional electrolyzer is used.** This is not a system of traditional photovoltaic electricity-to-electrolyzer. An electrolysis reaction is created within the same case with an aqueous solution where concentrated solar light penetrates.

It is anticipated that this **direct photoelectrochemical** solar hydrogen generator will operate at a solar-to-hydrogen efficiency of 12.4 percent, which is above certain other photovoltaic systems. Photovoltaic power to traditional electrolyzers making hydrogen, often demonstrate inefficiencies of 40% or higher, because of the high loss of operating electrolyzers. However, the process proposed here is **photolytic** or **photolysis** for generating hydrogen, solely by renewable energy.

Plan to bring the project to completion: Milestone Schedule

The tasks are carried out by organized work efforts of employed staff including consultants, University consultants, and Principal Investigator, Research Director. A milestone chart is shown below identifying the series of tasks and their relation to each other.

Milestone Schedule - Tasks For Hydrogen Generation and Evaluation By Month

Month into study

1 2 3 4 5 6 7 8 9 10 11 12 .

>Desigh & Consulting using Systems Approach > Option For Extend Work<

>Multiphysics Modeling<

>Produce Engineering Drawings<

> Document Parts List < >Write Final Report<

>Define Measurement & Testing Parameters <

>Construct H_2 Generating Unit<

. >Carry Out Testing Procedure< .

Funding Needs: Funding for one year: Design costs by consultants and management; materials and supplies; machine shop work; labor to construct, in house testing; out side service testing; and report preparation : $300,000.

Expected Results: It is expected that through a California Grant that an "On-site Direct Photoelectrochemical Hydrogen Generating Unit" will be designed, constructed, and tested for its ability to yield 1 Kilogram of Hydrogen per hour.

Sustainability Goals and Standards: Compliance with CARB Standards

The proposed project leads to an operating product that is in compliance with the latest CARB standards, including 2007 standards, yielding numbers that are even lower than the compliance standards. The following Exhibit shows the air emissions of major generating pollutants per MWh. For solar, wind, hydro, and nuclear there are no NOx, SO2, CO2 or particulates by pounds per mega watts per hour. Since the PHG hydrogen generating system proposed in the present demonstration project employs only solar sources for splitting water, none of the above noted pollutants are expected to be emitted from an operating system.

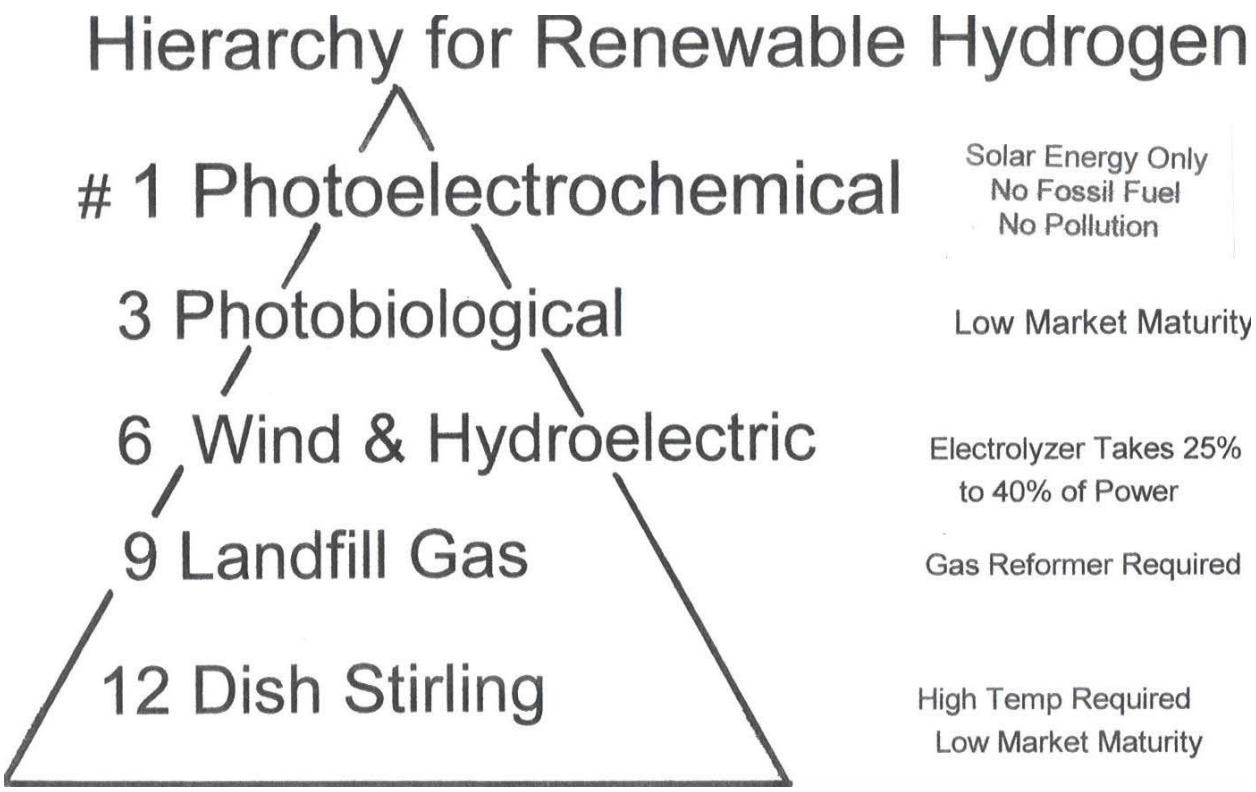
Exhibit 15: Air Emissions of Major Pollutants by Generating Technology per MWh Using Best Available Control Technology (BACT)

Plant Type	Heat Rate (HHV) Btu/kWh	NO_x Lbs/MWh	SO_2 (1) Lbs/MWh	CO_2 Lbs/MWh	Particulates Lbs/MWh
Coal	9,500	1.52	1.62	1,930	0.01
Combined Cycle	7,100	0.21	0.01	830	–
Gas Boiler	10,500	0.84	0.01	1,230	–
Combustion Turbine	11,500	0.58	0.01	1,345	–
Solar, Wind, Hydro, and Nuclear	None	None	None	None	None

SOURCE: U.S. Department of Energy, *Market-Based Advanced Coal Power Systems*, May 1999, and RDI Consulting analysis. Biomass not included in this table due to difficulties in finding reliable information.
(1) Based on 2000 average sulfur content in western coal plants of 1.3 lbs/mmBtu.

The proposed PHG system is a specific improvement over use of natural gas as fuel. For example, traditional motor vehicles are the single largest source of major criteria air pollutants and produce more than 60% of all carbon monoxide pollution. Natural gas contains less carbon than any other fossil fuel therefore using natural gas reduces, but does not eliminate exhaust emissions of: Carbon monoxide by 70%, non-Methane Organic Gas by 87%, Nitrogen Oxides by 87% and Carbon Dioxide by 20%. As such, natural gas vehicles are inherently cleaner, h**owever, the Honda FCX**, using hydrogen as fuel will only produce water and no other contaminants, thus exceeding California pollution regulations.

Environmental and Societal Impacts. This proposed work is a sustainable process using only water that yields neither CO_2 nor any other polluting or greenhouse emissions. Using hydrogen in fuel cells or combustion equipment also yields little or no CO_2 or other noxious elements into the environment. Implementing the system provides social justice yielding no air pollution or pollution to water sources yielding health benefits to humans and animals. Domestic dependency on oil is reduced, thus also reducing dependence on foreign oil coming into the United States. Financial performance is anticipated that with will repay investors in five to seven year pay out as capital cost for a household or small business unit is expected to be less than $20.000.


Hierarchy for Renewable Hydrogen
1 Photoelectrochemical
3 Photobiological
6 Wind & Hydroelectric
9 Landfill Gas
12 Dish Stirling
Solar Energy Only
No Fossil Fuel
No Pollution
Low Market Maturity
Electrolyzer Takes 25%
to 40% of Power
Gas Reformer Required
High Temp Required
Low Market Maturity

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