2008 Solar Annual Review Meeting

Session: CSP Advanced Systems
Company or Organization: Sandia National Laboratories
Funding Opportunity: Thermochemical Hydrogen Project

Nathan Siegel
Sandia National Labs, Solar Technologies Dept.

Sandia National Laboratories

Relationship to Solar Program Goals

This projects supports DOE/Solar's goal of developing advanced central receiver concepts

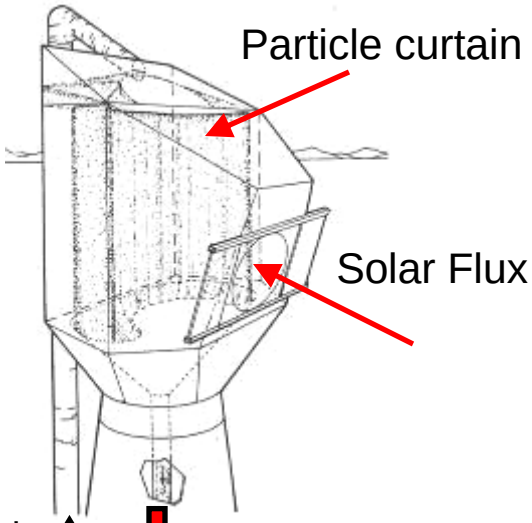
Project Description

Develop and demonstrate MW-scale hydrogen production technology based on a central receiver using solar power as the heat source by FY2014. This project will demonstrate thermochemical hydrogen production from water and solar heat and illustrate a hydrogen production technology that could also be used with nuclear energy. *Liquid transportation fuels may be manufactured from the product hydrogen and a carbon source using conventional methods.*

This project will leverage past efforts in the development of high temperature (>900 C) central receiver platforms as well as the development of thermochemical hydrogen production cycles currently supported by the Nuclear Hydrogen Initiative (NHI)

Solar Fuels Process Diagram

Solid Particle Receiver (SPR)



Hybrid-Sulfur Process

(1) $H_2SO_4 \rightarrow H_2O + SO_2 + 1/2O_2$

(2) $2H_2O + SO_2 \rightarrow H_2SO_4 + H_2$

Sulfur Iodine

(1) $H_2SO_4 \rightarrow H_2O + SO_2 + 1/2O_2$

(2) $2HI \rightarrow I_2 + H_2$

(3) $2H_2O + SO_2 + I_2 \rightarrow H_2SO_4 + 2HI$

Acid decomposer
Heat exchanger

Cold particles in (from storage)

Hot particles out

Hot Particle Storage

Cold particles (to storage)

H_2 fuel

O_2

e^-

SO_2 Electrolyzer

H_2SO_4

H_2O

H_2O, SO_2, O_2

Solar Fuels and the Sulfur Cycles

Advantages

The HyS and SI cycles have the potential to achieve hydrogen production at \$3/kg H_2 with a solar to H_2 annual efficiency above 22% (LHV)

The solid particle receiver includes thermal storage allowing around the clock operation of the fuel plant

A successful effort benefits the Solar, NHI, and EERE/Hydrogen programs

-**Solar:** A practical direct absorption central receiver

-**NHI:** Demo of a thermochemical cycle that works with high temperature reactors

-**EERE/Hydrogen:** Sustainable fuel production consistent with cost goals

Leverage Past and Current Work

An integrated SI loop is currently operating in batch mode at General Atomics

The sulfur dioxide electrolyzer is being developed by Savannah River NL

A prototype solid particle receiver was demonstrated on-sun at Sandia in February, 2008

Technical Approach

Solar Program

Solid particle receiver development

-Optimized receiver cavity
-High temperature operation/equipment
-Particle chemistry/durability

Particle handling and storage

-Storing and conveying particles

Hydrogen/Nuclear Program

SI or HyS process components

-Small scale SI system is complete, operating in batch mode
-Develop an SO_2 electrolyzer
-Demonstrate continuous operation for SI and HyS
-Develop appropriate heat exchangers

Hydrogen production system

-Select the best cycle based on operation and economic considerations
-Produce a system level design

Solid Particle Receiver Development

High Temperature Solar Interface

- Predicted operation at >1000 ^{o}C
- Demonstrated in excess of 300 ^{o}C
- Direct, efficient, solar absorption
- Cheap mass produced heat transfer and storage media
- Supports advanced power cycles
  - *-Ultra supercritical steam cycle (700^{o}C, 56% eff.)*
  - *-Brayton*

International Collaboration

- Solar hydrogen research consortia include:
  - -International Partnership for the Hydrogen Economy (IPHE)
  - -International Energy Agency (IEA)
- DLR (German Aerospace)
  - -Interested in hydrogen and advanced power cycles
  - -Currently working with Sandia to develop the solid particle receiver
- CSIRO (Australia)
  - -Interested in solid particle receiver collaboration

Prototype SPR On-Sun at Sandia

Major FY08 Activities

Planned Milestones

Milestone	*Requested FY08 Budget*	*Planned Start*
Solid particle receiver feasibility experiments	**$600K**	***Feb-Mar 2008***
Facility Layout and Safety Assessment	**$450K**	***July-Aug 2008***
Heliostat field upgrades	**$2.7M**	***May 2008***

FY08 funds total $2M

Funding will be used to support field upgrades – hardware and software

Field upgrades are needed not only to support this task, but also future work with the CSP FOA partners

The Solar Power Tower at the NSTTF – 32 years with no upgrades!

FY08 Progress Report

FY08 is the First Project Year

Solar Program Accomplishments

- Heliostat field hardware and software upgrades are underway

EERE/Hydrogen Program Accomplishments

-A prototype solid particle receiver was tested on-sun at power levels in excess of 2MW.

Nuclear Program Accomplishments

- *SI loop is built and operational*
- *Acid decomposer is working well*

Sulfuric acid decomposer system

Future Activities

FY09 Project Plan

Solid Particle Receiver Validation ($600K)

- Demonstrate high temperature (1000 ^{o}C) operation capability

Facility Planning ($450K)

-Assess the facility requirement for accommodating a MW scale thermochemical hydrogen production test.

Field Characterization and upgrade ($1M)

-Evaluate the quality of the heliostat field optics

-Upgrade the mirrors as required

Out years Project Plan

FY10-11 ($1.5M-FY10, $1.7M-FY11)

-Preliminary solar receiver and thermochemical system design, development of balance of plant components

FY12-13 ($1.6M-FY12, $2.3M-FY13)

-Go/No-Go on further development (FY11 or FY12)

-Detailed receiver design, preliminary thermochemical system design

FY14-FY15 ($2.7M-FY14, $1.9M-FY15)

-Construction and testing

Programmatic Issues

FY09 budget request for EERE Hydrogen production is $0

-"Hydrogen from natural gas available economically; Program has met critical path target of $3.00/gge;"

Nuclear hydrogen is funded in FY09

-Sulfur Iodine and hybrid sulfur work will continue

Receiver development will no longer be supported through the EERE/H2 program

Receiver development support through DOE/Solar is essential

-Allows this project to stay on track

-Addresses advanced power cycles

-Stimulates additional collaboration

Conclusions

This collaborative effort will lead to the demonstration of:

- *An integrated solar hydrogen production system*
- *A high temperature direct absorption central receiver*

Heliostat field upgrades are planned for 2008

- *These upgrades are greatly needed to support any testing at the Power Tower*

In 2009 we will increase the focus on:

- *Demonstrating the feasibility of the solid particle receiver*
- *Evaluating the facility/safety requirements of a MW scale solar H_2 demonstration on the Power Tower*
- *Additional field characterization/modification*

Receiver/process design work begins in 2010