



HYDROSOL-II

Thessaloniki, Greece

The HYDROSOL-II project has developed a thermochemical technology that produces hydrogen solely from solar energy and water, up to the pilot plant scale. This project and its predecessor, HYDROSOL, were both co-funded by the European Commission within Framework Programmes 6 and 5, respectively. Both projects demonstrate production of solar hydrogen via a two-step water splitting process. These are performed on monolithic honeycomb reactors, capable of developing high temperatures under concentrated solar irradiation and coated with active redox materials that are capable of water-splitting and regeneration.

In the HYDROSOL project, the technology was developed at the laboratory scale. The proof-of-concept and the capabilities of the technology were demonstrated, establishing HYDROSOL as the world's first, closed solar-only, thermochemical cycle in operation capable of continuous hydrogen production.

HYDROSOL-II aims to scale-up the technology on a dual reactor with a power level of 100kW/reactor, coupled on the solar tower facility of Plataforma Solar de Almeria, Spain. This demonstrates continuous solar hydrogen production within an optimized pilot plant.

Objectives

HYDROSOL-II's demonstration of a successful and efficient scale-up of a carbon-dioxide, emissions-free solar

hydrogen production process demonstrates the potential for mass production of solar hydrogen. A successful demonstration will narrow the gap between research and market implementation and show that using concentrated solar power facilities coupled with high temperature processes can be a viable way to produce large amounts of emission-free hydrogen at a reasonable cost.

Approach

An international consortium of experts in various areas has been involved in this project including Aerosol & Particle Technology Laboratory (APTL, Greece), DLR (Germany, concentrating solar technologies), Johnson Matthey (U.K., automotive catalysis), Stobbe Tech Ceramics (Denmark, ceramic manufacturing), and the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT, Spain, solar tower facilities).

The feasibility and scalability of solar hydrogen production by the HYDROSOL process and the stability of the redox/support assemblies was initially demonstrated by several solar test campaigns at the solar furnace facilities in Cologne, Germany. This is where multi-cyclic solar thermochemical splitting of water was successfully achieved on the dual chamber, or Conti, reactor, producing hydrogen by cyclic operation with a pair of coated monoliths exclusively at the expense of solar energy for up to 54 cycles in a row with the same redox coating. In addition,

Project Overview

What

HYDROSOL-II: Solar Hydrogen via Water-Splitting in Advanced Monolithic Reactors for Future Solar Power Plants

Who

A European consortium coordinated by APTL-Aerosol and Particle Technology Laboratory, CPERI/CERTH, Greece

When

Started: November 1, 2005
Completed: October 31, 2009

Participants

Lead Country
Greece

Partner Countries
Germany, Spain, Denmark, U.K.

Renewable Technology

Concentrated solar

Application

None - production demonstration only

Website

<http://www.hydrosol-project.org>

Contacts

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The thermochemical solar hydrogen plant at Plataforma Solar de Almeria, Spain, with the solar tower where the scaled-up HYDROSOL-II reactor is installed



the first successful cyclic solar hydrogen production tests with the 100-kW scale reactor were carried out in September 2008 at PSA, Spain. In comparison, further parametric studies currently in progress are showing that hydrogen production is possible on a solar tower under realistic conditions.

Within HYDROSOL-II, the Conti reactor was chosen as a starting point for the design of the pilot-scale reactor that consists of two adjacent, but separated, reaction chambers that represent a minimum array of modules suitable for the continuous production of hydrogen. Scale-up to 100 kW_{th} was implemented mainly by increasing the absorber surface. HYDROSOL-II is the largest pilot-scale project of its kind, the production target of the HYDROSOL-II reactor being around three kilograms of hydrogen per hour.

Accomplishments

The technology has currently reached the status of a pilot plant demonstration on a 100 kW scale, with the pilot solar hydrogen production reactor having been designed, built, installed, and operated on the SSPS-CRS solar tower facility of the Plataforma Solar de Almeria, Spain. The first hydrogen cyclic production tests were successfully carried out in September 2008, after exhaustive thermal qualification tests and implementation

of a practicable operational control strategy for the coupling of the solar field to the thermal requirements of the reactor for the two process steps. Further tests and parametric studies are currently in progress showing that hydrogen production is possible on a solar tower under realistic conditions and demonstrating the high potential of this particular thermochemical cycle technology for further scale-up. The achievements and the potential impact of the HYDROSOL project have been acknowledged by the global community with three major international awards "...in recognition of the outstanding scientific and technological achievements...":

- The Global 100 Eco-Tech Award at the Expo 2005, Aichi, Japan.
- The inaugural Technical Achievement Award of the International Partnership for the Hydrogen Economy in 2006.
- The European Descartes Research Prize 2006 for Excellence in Scientific Collaborative Research.

Lessons Learned

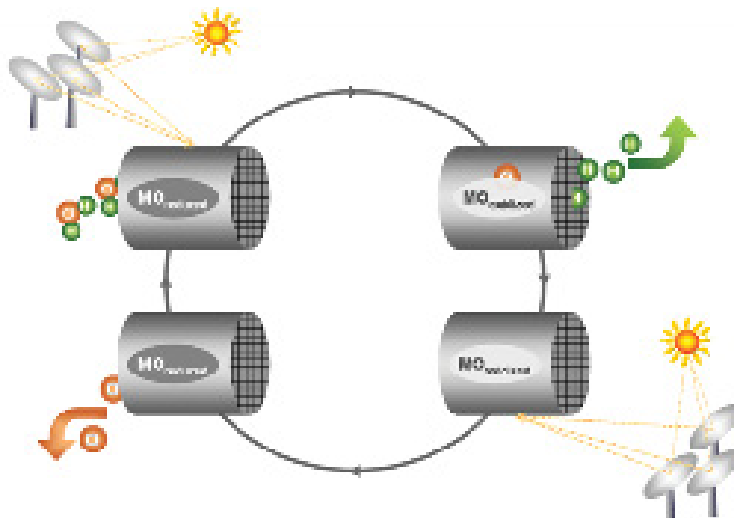
For effective commercialization of solar hydrogen production via thermochemical cycles, reactor concepts like the ones proposed and advanced within HYDROSOL-II seem to be the most promising. An example of this is

reactors that do not involve moving high-temperature reactor parts or circulation of hot solid particles. However, elaborate and robust control strategies compatible with industrial standards need to be further developed in order to effectively couple the operation of a solar field with both the heat requirements and the time scales of the HYDROSOL-II reactor operation steps. In addition, improvements on the reactor design, supported by detailed modeling and operation simulations, are needed to maximize the reactor's chemical and thermal efficiency and hydrogen yield per reactor volume.

Future Plans

Future plans include designing and building a HYDROSOL-technology-based, 1 MW solar demonstration plant, with the goal of producing renewable hydrogen that is cost-competitive with non-renewable methods. Activities will include the complete design of the whole plant--the solar hydrogen reactor and all necessary upstream and downstream units needed to feed in the reactants and separate the products--and the calculation of the necessary plant and hydrogen supply costs.

Right: Schematic of the two-stage, water-splitting/hydrogen production (top) and regeneration/oxygen release (bottom) HYDROSOL process



Below: Dual-chamber HYDROSOL-I (Conti) (top) and HYDROSOL-II reactors (bottom) operating under concentrated solar irradiation

