Hydrogen Details

During this century, the United States is expected to undergo a transition to a sustainable energy economy. Hydrogen has long been considered the ultimate energy carrier, a versatile fuel that converts easily and efficiently to other energy forms without the release of harmful emissions. The view of the U. S. Department of Energy (DOE) is that hydrogen and electricity produced from renewables will form the foundation for sustainable energy systems, displacing and eventually replacing fossil fuel resources. Hawaii became an early leader in the push to develop hydrogen as a fuel when, in 1980, U.S. Senator Spark Matsunaga introduced the first hydrogen legislation in Congress. In 1983, with a $50,000 appropriation from the Hawaii Legislature, HNEI established the Hawaii Hydrogen Program. In September 1985, HNEI was awarded a contract from the Solar Energy Research Institute (now the National Renewable Energy Laboratory) to establish the Hawaii Hydrogen from Renewable Resources Program.

During operation of this program and other subsequent hydrogen projects, HNEI's efforts have focused on developing core technologies for renewable hydrogen production, including direct solar and biological hydrogen production and gasification of biomass, and novel hydrogen storage technologies. In 1990, HNEI hosted the World Hydrogen Energy Conference, which drew 550 specialists from 31 nations. In 1996, DOE designated HNEI's program as a University Center of Excellence for Hydrogen Research and Education.

Photoelectrochemical Hydrogen Production [1]

Development of high-efficiency photoelectrochemical systems to produce hydrogen directly from water, using only sunlight as the energy source, is a major goal of the DOE Hydrogen Program. Since 1995, a number of photoelectrode configurations designed for high efficiency and low cost have been explored in HNEI's Thin Films Laboratory [2]. In 1997, a small scale reactor based on monolithically-stacked triple-junction amorphous silicon/germanium alloy (a-Si:Ge) thin film solar cells was used to demonstrate solar-to-hydrogen efficiencies up to 7.8%. These solar cells were modified with cobalt-molybdenum and iron-doped nickel oxide thin film catalyst coatings developed at HNEI. In separate tests, these thin-film low-cost catalysts were operated in KOH electrolyte for over 5,000 hours with no evidence of significant degradation.

Current efforts are focusing on a UH-patented unique 'hybrid' photoelectrode structure (see the full text of U.S. Patent 6,887,728 [3]), developed at HNEI, which combines a tandem a-Si:Ge solar cell monolithically series connected to a thick, photoactive over-coating of nano-structured metal oxide. In early testing, these devices have shown great promise for the development of long-life, high-efficiency hydrogen production systems. Working with key industry and academic partners, HNEI expects to successfully demonstrate solar-to-hydrogen efficiencies in excess of 10% and exceptional stability in a working version of the hybrid photoelectrode by 2015. For more information, click here [1].

Biological Hydrogen Production [4]

HNEI has carried out R&D on biological hydrogen production since the early 1990s. Initially, this project investigated the genetics of cyanobacterial (blue green algae) hydrogenases. A new R&D phase was initiated in 1996 to develop a microalgal indirect biophotolysis process, in which water is converted in separate stages into O2 and H2. The organism chosen for initial work on this project was a strain of Spirulina (Arthrospira platensis) already being commercially grown in Hawaii and used in the prior biohydrogen research at HNEI. Laboratory work confirmed that Spirulina produces H2 by dark fermentations, but not in the light.

The major part of the research carried out under this project from 1996 to 2000 was the operation and engineering studies of the photobioreactors. While this initial work demonstrated the ability to produce Spirulina in the reactors, an indirect biophotolysis process using cyanobacteria in the photobioreactors was not demonstrated.

Proposals for future biohydrogen research at HNEI aim to maximize the yield of H2 from endogenous substrates by dark fermentations in microalgae or by bacteria using exogenous waste substrates. Such processes could produce H2 fuel in small-scale amounts at acceptable costs in the near term, and larger quantities in the long term.

Hydrogen from Biomass[5]

Wet wastes and biomass have not been regarded as promising feedstocks for conventional thermochemical conversion processes because of the high cost associated with drying the material prior to entering the reactor. In the 1990s HNEI developed a process for hydrogen production by the catalytic gasification of biomass in supercritical water (water at high temperature and pressure). This "steam reforming" process produces a gas at high pressure (>22 MPa) that is unusually rich in hydrogen. The results of this work, conducted in the Renewable Resources Research Laboratory [6] between 1990 and 2001, are summarized in a series of peer-reviewed publications (Gasification of Biomass in Supercritical Water [7]).

Current efforts are focused on the thermochemical gasification of biomass. Operating at elevated temperature, the gasification process converts the solid biomass into a gas, while maximizing the chemical energy content of the product gas. The product gas can be (1) combusted for heat or power generation, (2) processed further via the water-shift reaction to maximize hydrogen production, or (3) upgraded and utilized as a synthesis gas to produce more easily transported fuels such as ethanol, methanol, or DME. Under the Hawaii Hydrogen Center for the Deployment and Demonstration of Distributed Energy Systems, HNEI is working with a number of industrial partners to explore the low-cost production of hydrogen from cellulosic biomass. Part of HNEI?s contribution to this project is in the areas of preprocessing biomass for improved reactor performance and product gas cleanup and conditioning.

Storage

While much of the early research on high-density storage systems was conducted under the auspices of HNEI, in 2000 this component was placed under the direction of the University of Hawaii's Department of Chemistry. The latest information on this area can be found at http://www.chem.hawaii.edu/UH_Chem/faculty/jensen.html [8].

In 2000, HNEI's mandate was broadened when the Hawaii Legislature passed a joint House-Senate resolution tasking the Department of Business, Economic Development & Tourism (DBEDT) to conduct a feasibility study to assess the potential for large-scale hydrogen use in Hawaii. HNEI, in collaboration with Sentech Inc., presented preliminary results to the Legislature in January 2001; the final report, "Nurturing a Clean Energy Future in Hawaii: Assessing the Feasibility of the Large-Scale Utilization of Hydrogen and

[9], was completed in June 2001 and revised in July 2004. The study identified areas where hydrogen and fuel cells have the potential to contribute to Hawaii's energy mix and developed a roadmap to develop this potential. One of the recommendations of the study was the development of public-private partnerships to develop the necessary hydrogen infrastructure. The formation of these partnerships was given additional urgency with passage of Act 283 by the 2001 Legislature, providing initial funding for the development of hydrogen partnerships in Hawaii. Our state energy office (DBEDT), with HNEI as the implementing partner, has been selected by DOE to develop a Hydrogen Power Park [10] in Hawaii. This project, which includes local and national industry elements as cost-share partners, will deploy and demonstrate an integrated hydrogen system comprising electrolysis for hydrogen production, hydrogen storage, and a grid-connected fuel cell. In August 2002, a Hydrogen Partnering Meeting, attended by DOD, DOE, industry, and local utilities, was held on the Big Island to provide additional focus and coordination. Additional partnering projects and proposals are under development (see Hawaii Hydrogen Partnerships [11]).

In addition to the efforts to develop hydrogen infrastructure, HNEI has begun an aggressive fuel cell testing and development effort for military and commercial sectors. The focal point of this effort, the Hawaii Fuel Cell Test Facility [12], is a collaborative effort of HNEI, UTC Fuel Cells and the Hawaiian Electric Company. Funding is provided by the Office of Naval Research through the Hawaii Energy and Environmental Technology Initiative [13].

In 2004, HNEI received funded from DOE for the Hawaii Center for Development and Deployment of Distributed Energy Systems [14]. This program involves augmentation of the Hydrogen Power Park, assessment of hydrogen fuels purity requirements for fuel cell applications, R&D of cost-effective renewable hydrogen production, and analysis of potential hydrogen and distributed energy systems for the Big Island grid system.

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DOE Hydrogen, Fuel Cells, and Infrastructure Technologies Program information can be found at: http://www.eere.energy.gov/hydrogenandfuelcells/index_html.html [16]

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Links:
[1] http://www.hnei.hawaii.edu/research/hydrogen/photoelectrochemical-hydrogen-production
[2] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/facilities/thin-films-laboratory
[3]
http://web41.its.hawaii.edu/www.hnei.hawaii.edu/sites/web41.its.hawaii.edu.www.hnei.hawaii.edu/files/page/2010/06/Paten
6,887,728 - Hybrid Photoelectrode.doc
[4] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/hydrogen/hydro-bio
[5] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/biocarbons#hydroprod
[6] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/facilities/r3lab

[7] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/hydrogen/hydro-gas
[8] http://www.chem.hawaii.edu/UH_Chem/faculty/jensen.html
[9]
http://web41.its.hawaii.edu/www.hnei.hawaii.edu/sites/web41.its.hawaii.edu.www.hnei.hawaii.edu/files/page/2010/06/h2_fue
[10] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/hydrogen/hydro-partner#powerpark
[11] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/hydrogen/hydro-partner
[12] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/fuel-cells/fuel-cell-testing
[13] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/fuel-cells/heet
[14] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/research-development/hydrogen/fuel-hydrocenter
[15] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/staff/richard-e-rocheleau
[16] http://www.eere.energy.gov/hydrogenandfuelcells/index_html.html
[17] http://www.hnei.hawaii.edu/term/hydrogen