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MEMORANDUM

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AUG / 3 1998

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DOE/GO/10170--717

TO: Neil Rossmeissl
Sig Gronich

FROM: Jon Hurwitch
Faith Klareich
Debbie Surek

DATE: March 4, 1997

RE: State Write-ups on EERE Funded Projects

We have completed approximately 43 write-ups on projects funded by the Hydrogen Program in FY 1997 as they appear in the latest draft of the FY1997 Annual Operating Plan (AOP). There are, however, a number of projects that are listed in the FY1997 spend plan for the Hydrogen Program that we were unable to directly crosswalk with the project descriptions in the AOP. Specifically, those projects are as follows:

Thermochemical Hydrogen Production
Photovoltaic Electrolysis
Ion Transport Membranes
Heat Pump R&D
Fuel Cell Integration
Fractional Analysis of Hydrogen Fueled ICE's
Refueling Station
Clean Corridor Management
R&D on Hydrogen rich fuels
Program Research and Development Announcement
Defense Program Conversion Management
Education
Industry Survey
Hydrogen Letter
Educational CD Rom
Biohydrogen and Climate Technology
System Comparison of Hydrogen to Alternative Fuels
Applying to EPAct

SNL
Miami
Contract through PETC
HNEI
LANL/Cambridge Assoc.
U. of Miami
ORNL
SNL
NRG
TBD
LLNL
Marcia Zalbowitz
NHA
Peter Hoffman
SEIA
J. Benemann
Miami

If you have other references or sources to the projects cited above and would like us to complete write-ups on them, please forward that information to us or direct us to those documents and we will proceed to write them. Otherwise, the 43 completed project write-ups will be submitted in both electronic form and hard copy by noon on Thursday, March 6.

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CALIFORNIA

In partnership with EERE and the Lawrence Livermore National Laboratory (LLNL), Texaco, Inc. is pilot testing the gasification of municipal solid waste blends to produce hydrogen gas. Texaco's research gasifier unit shakes-down one-ton/day samples, one sample of plastic/paper, and one sample including ash component. The pilot project was awarded \$400,000 and the data collected is being used to perform economic analyses of the overall process.

The Sandia National Laboratory is working with EERE to expand current state-of-the-art hydrogen storage and delivery system technologies by demonstrating an integrated engine-fuel storage-delivery subsystem that is fast, reliable, and safe. This \$198,000 effort is also developing and installing a hydride bed storage subsystem into a personal utility fuel cell-powered vehicle being developed for the City of Palm Desert in early 1997. This vehicle will produce greater range at lower weight than commercial batteries.

Enerscope, Inc. and Sandia National Laboratory are working together to develop a hydrogen-natural gas mixture that, when tested by the California Air Resource Board (CARB), will exceed all present and proposed standards for NO_x, CO, and NMHCs. A factory prepared CNG vehicle can be converted to run on HY-TEST fuel, a 70/30 by volume mixture of the two gases. This mixture can be an effective means of bridging the gap between a liquid-based fuel infrastructure and a gaseous hydrogen-based fuel infrastructure.

The Schatz Energy Research Center (SERC) at Humboldt State University is working through a \$696,000 cooperative agreement with EERE to develop a clean and sustainable transportation system for the City of Palm Desert. The project demonstrates the practical utility of hydrogen through the development of a fleet of 8 fuel cell powered vehicles, solar and wind powered hydrogen generating facilities, a consumer-ready fueling station, and a service center. The system holds the promise of a clean environment and an energy supply that is predictable, domestic, safe, and abundant.

Sandia National Laboratories is working through EERE in collaboration with researchers in Europe and Japan to demonstrate improved hydride storage materials for fixed site, infrastructure and transportation uses which are cost effective for a particular utilization application. This \$248,000 effort is developing lightweight, low temperature metal hydrides and performing engineering studies aimed at fabricating hydride storage systems for specific applications, as well as supplying materials used in the Palm Desert hydrogen project.

Clean Air Now is piloting an educational module on hydrogen energy with the L.A. Unified School District through a \$100,000 cooperative agreement with EERE. The program is exposing more than 2,500 middle school students to hydrogen technologies by developing and distributing teacher lesson plans, student workbooks, study guides, videos, and evaluation materials throughout the Los Angeles public schools.

The Sandia National Laboratory and Lawrence Livermore National Laboratory are working with EERE's Office of Utility Technologies and the Office of Transportation Technologies in a cooperative program to quantify and validate emissions and efficiencies using hydrogen fueled internal combustion engines. This \$248,000/\$123,000 project respectively is working with

EERE and the Los Alamos National Laboratory to develop a hydrogen fueled engine that drives an electrical generator for stationary electricity generation and series type hybrid vehicles.

The Lawrence Livermore National Laboratory is working with EERE to improve microsphere hydrogen storage bed technology and scale up the technology for industrial and commercial use. This \$198,000 effort is identifying optimal materials and processes that will improve the charge/discharge kinetics and minimize the cycle energy requirements.

The Lawrence Livermore National Laboratory is working with EERE to develop a rechargeable energy storage system to produce power and electrolytically regenerate its reactants using a single stack of reversible fuel cells. These reversible fuel cell systems are being designed for automobiles and could be ideal for convenient and rapid recharging, or for refueling from a high pressure hydrogen source to achieve driving ranges in excess of 350 miles.

COLORADO

EERE's National Renewable Energy Laboratory (NREL) is studying the feasibility of using biomass-derived hydrogen to replace the most common hydrogen production method of catalytic steam reforming of hydrocarbons. The process yields a zero net CO₂ impact. The \$350,000 project also identifies marketable by-products from the pyrolysis operation and improves catalyst formulation by optimizing the nickel content of the catalyst for processing biomass-derived oxygenates. The project's ultimate goal is to implement the concept at the regional level in an effort towards sustainable development.

In collaboration with the Hawaii Natural Energy Center and the Oak Ridge National Laboratory, EERE's National Renewable Energy Laboratory is developing a green alga capable of sustained hydrogen production in air for use in a direct water-splitting system. By applying genetic and molecular engineering techniques, NREL is selecting an oxygen tolerant hydrogenase and transferring that trait to an organism with projected high efficiency conversions to hydrogen, to develop a cost effective photobiological hydrogen production system from water.

EERE's National Renewable Energy Laboratory has discovered a unique type of hydrogen producing activity in a strain of photosynthetic bacteria that function only in darkness to shift CO (and H₂O) into H₂ (and CO₂). Through a \$350,000 field work proposal, NREL is scaling-up a bioreactor to determine if electrostatic binding of bacteria can be accomplished. The research will enhance mass transfer by a factor of 10 using innovative bioreactor concepts and/or moderately pressurized bioreactors.

The National Renewable Energy Laboratory in Golden is working with EERE to develop a system that combines a photovoltaic material and an electrolyzer into a single device that can be used to produce hydrogen. This direct conversion system reduces the costs of producing hydrogen via commercially available photovoltaic systems that are coupled with electrolyzers, by eliminating the high capital cost of the electrolyzer unit and reducing semiconductor processing required for connections and wiring. The \$285,000 effort concentrates on

improving tandem cell technology to offer greater utilization of the solar spectrum, thus maximizing conversion efficiencies.

The carbon nanotubes being developed at EERE's National Renewable Energy Laboratory promise compact, lightweight, convenient and cost-effective storage for use in future hydrogen storage systems. A \$220,000 field work proposal at NREL will produce ambient temperature adsorbents in a cost-effective manner that can store hydrogen at energy densities specified in DOE program goals, of 6.5 wt.% and 65 kg/m³.

As hydrogen emerges into the sustainable energy infrastructure, EERE's National Renewable Energy Laboratory is developing a low-cost fiber-optic chemochronic hydrogen gas detector suitable for use in hydrogen transportation applications. This \$285,000 effort is important to replace commercially available hydrogen detectors that are considered too complex, bulky and expensive for use in hydrogen-fueled vehicles, and that also may pose a possible hydrogen leak ignition hazard and are susceptible to electromagnetic noise interference.

A complete portfolio analysis of hydrogen technologies has been initiated by EERE's National Renewable Energy Laboratory to measure potential energy, economic, and environmental benefits in the context of national strategic goals and the overall Quality Metrics (QM) effort in EERE. This \$150,000 project estimates commercial penetration of hydrogen based energy systems in the utility sector, as well as market projections for hydrogen fueled vehicles.

The National Renewable Energy Laboratory is collaborating with Energetics, Inc. and the Princeton Economic Research Institute, both of Maryland, to assess and evaluate costs of renewable hydrogen processes compared to current technologies by completing process analyses for a number of key production and utilization technologies. Through this \$200,000 contract, NREL works closely with other DOE researchers to improve decisions by making process analysis an integral link between laboratory research and program planning.

CONNECTICUT

International Fuel Cells is partnering with EERE through a \$207,000 cooperative agreement to redesign the proven ONSI PC25 power plant technology to produce a hydrogen fueled 200 kW fuel cell power plant. This plant will provide a highly efficient, highly reliable approach for utilizing renewable hydrogen rich fuel sources, and can be grouped to provide multi-megawatt power stations of clean, efficient, reliable power.

DISTRICT OF COLUMBIA

The National Hydrogen Association, an industry trade group, is working through a \$247,000 cooperative agreement with EERE to determine opportunities in the market for the expansion of hydrogen. The NHA Annual meeting has drawn over 200 attendees yearly from the hydrogen community, including policymakers, industry, federal and local government officials, and others who are interested in the commercialization of hydrogen energy.

FLORIDA

The Florida Solar Energy Center is working with EERE to develop new membranes that will enable the operation of proton exchange membrane (PEM) electrolyzers at higher temperatures, thereby reducing the thermodynamic electrical energy requirement. This first-year cooperative agreement, funded at \$60,000, will lead to significant reductions in hydrogen production costs by substituting high-cost electrical energy requirements with low-cost thermal or process heat- derived energy.

EERE has awarded Solar Reactor Technologies (SRT), a Small Business in Miami, \$246,000 to commercialize a process for generating solar hydrogen combined with utility load-leveling. SRT will develop a reversible hydrogen/halogen fuel cell, using bromine as the halogen, that can be used in a hydrogen production/energy storage process, or used alone for energy storage on an industrial or utility scale. The cost of this commercial product can be borne by an electric utility and fully paid for by its use in load leveling.

The Florida Solar Energy Center, through a \$100,000 cooperative agreement with EERE, is developing a process to produce hydrogen using a dual bed photosystem consisting of two modules, with an aqueous solution pumped between them. This direct photoconversion system -- using the sun directly to produce hydrogen from water -- can be used to efficiently store solar energy as hydrogen while using an affordable collector.

The University of Miami is working with EERE to review safety publications to assess transportation safety issues using hydrogen fueled ICE's and to make recommendations for R&D needs. This \$80,000 cooperative agreement also assists in the implementation of the Palm Desert fuel cell project and investigates lean combustion severity.

The University of Miami is working with EERE through a \$50,000 cooperative agreement to develop improved methods of photovoltaic production of hydrogen. The University of Miami method generates high temperature steam, rather than water, in addition to electricity, to power an electrolyzer unit. By reducing the amount of electrical energy needed, the solar to hydrogen conversion efficiency is increased.

HAWAII

The University of Hawaii is working through a \$128,000 grant from EERE to develop processes for thermochemical conversion of wet wastes (which are abundantly available at negative cost throughout the world) without requiring the costly drying process. At high pressures, a carbon-catalyzed gasification process, using such solids as spruce wood charcoal, macadamia shell charcoal, or coconut shell carbon, effectively steam reforms biomass to a hydrogen-rich synthesis gas with efficiencies approaching 100%.

EERE has awarded the University of Hawaii \$296,000 in an international collaboration with Japan to establish and maintain a premier culture collection of tropical marine microorganisms able to generate hydrogen from water or organic substances. The University is constructing a two-stage sustainable bioreactor system using cyanobacteria, and developing an approach to screening algal strains based on optimal environmental ranges for the physiological characteristics of interest that can be used for process demonstration.

While solar cells from Solarex Corp. and other companies have demonstrated solar-to-hydrogen conversion efficiencies of 7.8%, fundamental materials issues effecting corrosion and photoelectrode stability in the devices remain. The University of Hawaii is addressing these issues through a \$200,000 cooperative agreement with EERE, in which they are demonstrating a stable catalyst interface, improving catalyst performance and lifetime in low-cost aqueous electrolyte, and developing reactor prototypes for long-term outdoor testing. The direct conversion of water to hydrogen represents a promising option for the large scale renewable production of hydrogen from water.

The University of Hawaii is developing an iron based non-classical hydride to replace rhenium for hydrogen storage in a \$178,000 grant through EERE. This catalytic system could be the basis for a low temperature, hydrogen storage system with available hydrogen density greater than 7 weight percent.

MARYLAND

Sentech, Inc. and Energetics, Inc., based in Maryland, are working with EERE to integrate all system study activities within DOE's Hydrogen Program by completing pathway analysis models which include production, transportation, utilization, reliability and safety data. These analyses assist DOE with decision-making and prioritizing research and development projects.

Sentech, Inc. is working through a cooperative agreement with EERE to develop information and educational products aimed at spreading public awareness of hydrogen energy. In 1996 Sentech produced a multi-media CD-Rom to teach middle school students about the uses of hydrogen as a clean, safe, and sustainable energy source that was displayed in Atlanta during the Summer Olympics. The current phase of the project is collaborating with industry sponsors to produce a CD-Rom that can be distributed and used in classrooms nationwide.

MASSACHUSETTS

The Massachusetts Institute of Technology (MIT) is working with EERE through an \$80,000 cooperative agreement to develop plasma technology that will improve processes for reforming hydrocarbon fuels to produce hydrogen-rich gases, without the use of a catalyst. The process minimizes the energy consumption and maximizes the hydrogen yields of thermal, non-catalytic processes.

MICHIGAN

Energy Conversion Devices, Inc. (ECD) has partnered with EERE to develop new metal hydrides for hydrogen storage at temperatures that can be used in commercial applications, such as with hydrogen internal combustion engines and PEM fuel cells. Alloys have been tested at more than 5 wt.% reversible hydrogen storage capacity in their unoptimized state. ECD continues this promising research through a \$221,000 EERE solicitation award with an emphasis on improving the alloy properties.

NEW JERSEY

Researchers at Princeton University are working with EERE on systems studies for hydrogen energy. In a \$100,000 grant, Princeton is assessing the value of blending hydrogen and natural gas in existing pipelines, and evaluating the infrastructure for hydrogen production from natural gas using central versus local reforming.

NEW MEXICO

The Los Alamos National Laboratory is collaborating with H-Power Corporation to develop a manufacturable, low-cost, high-performance hydrogen/air fuel cell stack technology for stationary generation of electric power from hydrogen. As part of this \$198,000 effort, LANL and H-Power is developing and demonstrating a prototype 4-5 kW unit, including hydrogen and air feeds and heat and water management auxiliaries.

The Los Alamos National Laboratory is working with EERE to provide industry and research laboratories with the modeling capabilities for hydrogen combustion and flow, as required for engine design and safety studies. This \$123,000 effort uses KIVA codes to investigate test cases for heavy-duty/light-duty applications fueled by hydrogen for near-term OTT requests.

To educate the public about hydrogen energy, Los Alamos National Laboratory has worked with EERE to develop a module on hydrogen energy that was presented at the 1996 National Educator's Workshop.

NEW YORK

INFORM, a non-profit environmental research organization, is working with EERE through a \$28,000 cooperative agreement to develop literature to support the transfer of information on hydrogen energy to the general public, including briefings for government officials, press releases for new reports, and analyses of policies and incentives to stimulate alternative vehicle fuel and transportation system development.

Under a cooperative agreement with EERE, Praxair and Alfred University are investigating hydrogen permeability through glass to determine if more advanced glass microspheres can be developed for hydrogen storage. Through a series of tests, measurements will be taken to characterize hydrogen permeability through various glass compositions. These investigations could provide information valuable to the development of cost-effective hydrogen storage technologies for a variety of end-use applications.

OKLAHOMA

The separation of water to form hydrogen and oxygen is an ideal source of hydrogen for energy needs, but requires a great amount of energy to achieve high hydrogen production rates.

The University of Oklahoma is working with EERE under a \$74,000 cooperative agreement to research the photocatalytic cleavage of water using a semiconductor photocatalyst to produce large amounts of hydrogen. This method is promising since the catalyst is a solid material and is relatively inexpensive, resistant to deactivation, nontoxic and safe to handle.

PENNSYLVANIA

Air Products and Chemicals, Inc. in Allentown is developing a novel process -- called Sorption Enhanced Reaction Process -- for the production of hydrogen by steam-methane reforming through a \$546,000 cooperative agreement with EERE. This process could markedly reduce the cost of hydrogen production by significantly lowering the operating temperatures, while producing conversion efficiencies currently achievable only at very high temperatures. Furthermore, the 98+% purity of the hydrogen produced eliminates the need for downstream purification. Such a system could accelerate interest in near- and mid- term energy applications for hydrogen, particularly in transportation.

SOUTH CAROLINA

Savannah River Technology Center (SRTC) is working with EERE to develop a new class of composite materials that will allow refineries to absorb and recover streams of hydrogen that are currently lost in the refining process. Current technologies used to recover these gases are very costly, thereby requiring refineries to acquire hydrogen through external sources. The materials under development at SRTC through this \$90,000 field work proposal will maximize the permeation of hydrogen absorbed on metal hydrides surrounded by a porous glass matrix, allowing the hydrogen to enter the composite and absorb reversibly onto the metal hydrides.

TENNESSEE

The Oak Ridge National Laboratory is working with the National Renewable Energy Laboratory and EERE through a \$248,000 field work proposal to develop a green alga capable of sustained hydrogen production for use in a direct water-splitting system. While it was commonly believed that two photoreactions were necessary for photosynthesis, ORNL has proven that photosynthesis can be performed with mutants of a green alga that lack a detectable level of one of the two light reactions, allowing maximum thermodynamic conversion efficiency of light energy into chemical energy by green plant photosynthesis. Hydrogen production performed by a single light reaction, as opposed to two, doubles the conversion efficiency from ca. 10% to ca. 20%.

The Oak Ridge National Laboratory is working with EERE to investigate advanced thermal management technologies for hydrogen storage. ORNL will work closely with its industrial partner, Materials & Electrochemical Research Corp. in the \$100,000 CRADA to further develop efficient, effective, and practical thermal management technologies for various storage options.

VIRGINIA

Directed Technologies, Inc. is working with EERE to analyze the value of hydrogen to accelerate the development of a refueling infrastructure. This \$125,000 effort is determining the refueling infrastructure requirements for hydrogen and hydrogen blends, and comparing the design and economics of production and fuel storage options for hydrogen refueling stations.

The following projects are not classified by state (not sure where the work is taking place):

Distributed Utility Associates is working with EERE to establish programmatic performance and cost benchmarks for hydrogen applications in utility systems compared with key conventional and competing alternatives to ensure that R&D investments are made for the most technically feasible and commercially marketable hydrogen applications. This \$75,000 project also assesses the payoffs of risk-taking and investing in hydrogen R&D for various market segments.

The Jet Propulsion Laboratory is collaborating with the National Renewable Energy Laboratory through a \$150,000 contract to develop a mathematical model of experiments that demonstrate hydrogen production from biomass in order to identify drivers of biomass fast-pyrolysis in the low temperature regime. These drivers are then used to control and optimize the process for maximum hydrogen production.

Tecogen Division of Thermo Power Corporation is working with EERE through a \$97,000 cooperative agreement to investigate a new approach for the transmission and storage of hydrogen. Tecogen's approach, using a metal hydride/organic slurry for high density hydrogen storage, is being studied through analysis and laboratory-scale experiments, and by demonstrating the critical steps in the process with bench-scale equipment.

A.D. Little is partnering with EERE in a \$221,000 solicitation award to develop a means for stationary storage of hydrogen that renders hydrogen fueling stations more economical. The process is based on steam reforming natural gas, separating hydrogen from that reformat, and storing the hydrogen to accommodate a non-uniform fueling demand using a low temperature metal hydride system.