

Final Report

Virginia-Maryland Hydrogen Technology Education Center (H2TEC)

Project Title: Virginia-Maryland Hydrogen Technology Education Center (H2TEC)

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Recipient: Virginia Polytechnic Institute and State University (VT)

Partners: University of Maryland – College Park (UMD)
Virginia Clean Cities Coalition (VCCC)¹

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1. Project Objective

The project objective is to provide learning opportunities in the area of hydrogen technology. These learning opportunities will include new courses for undergraduate and graduate students, short courses targeted to energy professionals, a seminar series to encourage information exchange, a variety of activities for public outreach, and curriculum development opportunities for K-12 teachers.

2. Background

A hydrogen-based energy infrastructure, which uses renewable and environmentally benign means for providing hydrogen as the fuel for transportation and distributed power generation, presents enormous technical challenges related to efficient H₂ production, reliable H₂ transport and storage, and optimal local power generation. Realization of this vision will require major advances in technology as well as major changes in our nation's approach to energy production, distribution, and use. These changes will require research and development by talented scientists and engineers and informed, knowledgeable decisions regarding research and development directions and public policy. To meet these needs, Virginia Tech and the University of Maryland, in association with their respective state energy offices, have established the Virginia-Maryland Hydrogen Technology Education

¹ Virginia Clean Cities was formerly known as Hampton Roads Clean Cities Coalition.

Center (H2TEC) as a distributed learning center for the DC/Maryland/Virginia region to enhance the understanding of policy makers, teachers of future scientists and analysts, and students at both the undergraduate and graduate level. The goals of this three-year effort include:

- Provide learning opportunities through courses, interactive projects, and simulations to prepare undergraduate and graduate students to contribute to H₂ technology development;
- Provide learning opportunities in seminars, short courses, and demonstrations for technical professionals who are participating in development, deployment, and policy making decisions related to hydrogen technology;
- Provide learning opportunities through interaction with the public and their representatives to foster familiarity and acceptance of hydrogen technology;
- Provide learning opportunities for young people and technical support for K-12 teachers so that future stakeholders will be prepared to participate in a hydrogen economy.

The project was initiated in fall 2004 with funding available for the first six months of the project. Unfortunately, additional funding for the project was never appropriated. To supplement the first six months of funding, project activities were supported where possible using internal funds and through collaboration with synergistic projects. Efforts focused on tasks that could be completed in the near term using available funds with less emphasis on tasks that required long term funding.

3. Patents

None.

4. Publications/Presentations

Publications Related to Hydrogen Technology

Bhargav, A., Pearlman, J.B., Shields, E.B., Palmer, G.S., Reihani, S.-A.S., Jackson, G.S., and Hearn, P, "PEM Fuel Cell System Modeling with Liquid Fuel Processing and Hydrogen Membranes", Proceedings of Proton Exchange Fuel Cells-XI Symposium, Electrochemical Society, Cancun, October 2006, *in press*.

Reihani, S.S. and Jackson, G.S. (2006), "Analysis of Low Temperature H₂ Combustion on Pd Catalysts with ILDM's", *Combustion Theory and Modeling*, **10**(1) 1-20.

Sukeshini, A.M., Habibzadeh, B., Becker, B.P., Stoltz, C.A., Eichhorn, B.W., and Jackson, G.S., (2006) "Electrochemical Oxidation of H₂, CO, and H₂/CO Mixtures on Patterned Ni Anodes on YSZ Electrolytes", *Journal of Electrochemical Society*, **153**(4) A705-A715.

Zhou, S., Varghese, B., Eichhorn, B.W., McIlwrath, K., and Jackson G.S. (2006), "Enhanced CO Tolerance for Hydrogen Activation in Au-Pt Dendritic Heteroaggregate Nanostructures", *Journal of American Chemical Society*, **128**(6) 1780-1781.

Presentations Related to Hydrogen Technology (UMD, VT)

Jackson, G.S., "Development of Fuel Cells: Distinguishing the Potential Breakthroughs from the Press Releases", at Venture Capital Session for Energy Technology at Dingman Center, Robert Smith Business School, University of Maryland, April 2006

- Jackson, G.S., “Hydrogen Economy Research from an Academic Perspective”, at Capitol Hill Hydrogen and Fuel Cell Caucus, Washington, DC, February 2006.
- Jackson, G.S., “Energy, Hydrogen, and Fuel Cells: What are the possibilities?”, Lecture to incoming freshmen in the Engineering College at the University of Maryland, April 2006.
- Jackson, G.S., “Patterned Geometries to Explore Electrochemical Oxidation Processes on Ni/YSZ SOFC Anodes”, invited presentation at Universität Karlsruhe, October 2005.
- Jackson, G.S., “Exploring Electrochemical Oxidation of H₂, CO, and CH₄ on Patterned Ni/YSZ SOFC Anodes”, invited presentation at ETH – Zürich, Switzerland, November 2005.
- Nelson, D.J., (2005), “Challenges for the hydrogen economy,” Virginia Hydrogen Economy Roundtable, Richmond, VA, August 19, 2005.
- Nelson, D.J., “Challenges for Hydrogen as a Transportation Fuel” at the Hydrogen Economy Panel, ASME International Mechanical Engineering Congress and Exposition, November 9, 2005, Orlando, FL.

Symposiums and Conference Sessions Organized

- Organized Symposium on Thermodynamics and the Design, Analysis, and Improvement of Energy Systems, 2005 ASME International Mechanical Engineering Congress and Exposition, November 5-11, Orlando, FL. Symposium featured 10 sessions 4 of which (18 papers) specifically addressed hydrogen or fuel cell systems.
- Chaired “Low Temperature Fuel Cell Technology,” session of the Advanced Energy Systems Division, 2005 ASME International Mechanical Engineering Congress and Exposition, November 5-11, Orlando, FL.

5. Activities Completed

The completed work for each of the scheduled tasks is described in the following:

Task 1: Develop interactive demonstrations and activities to support educational efforts

Renovated Virginia Tech’s hydrogen and fuel cell technology laboratories for graduate and undergraduate students. Completed safety improvements; added additional equipment capabilities; and improved functionality of laboratory.

Implemented a mechanical engineering senior design project (VT) for a hydrogen fuel cell auxiliary power unit (2004 – 2006). Offered undergraduate senior design project course to design and construct a hybrid electric vehicle which uses a hydrogen-fueled 2 kW PEMFC as an auxiliary power unit (APU) for vehicle accessory loads. The APU provides enough power for all of the vehicle’s 12 V power needs with plenty to spare for items such as televisions, small refrigerators, or other 120 V AC electrical devices. Also evaluated hydrogen as a fuel for a combustion engine or fuel cell for propulsion power.

Implemented a hydrogen fuel cell demonstration project (UMD). Using additional funding from Department of Defense and equipment donations, UMD completed the acquisition of an 8 kW fuel test stand, a 4 kW stack for operation on the test stand, and 2 AirGen hydrogen fuel cells for demonstration at UMD. The demonstration and test facility will be used for research on optimization of portable generators for a variety of applications and for demonstrations for visitors from the U.S. government.

Task 2: Develop and teach an advanced undergraduate course in hydrogen technology

Developed a three credit hour undergraduate course in hydrogen technology (VT). Course was developed and taught as a special studies course in spring of 2005 (16 students) and spring of 2006 (20 students). The class will be permanently added to the curriculum and taught as a technical elective once every two years.

Taught ME 4554 Advanced Technology Vehicles which incorporates a hydrogen technology component (VT). Course addresses a comparison of hydrogen with other transportation fuels and a comparison of fuel cell vehicle (FCV) technology with other advanced power technologies. Students often select hydrogen FCV's for their course design project (e.g. in 2004 10 out of 12 groups selected a hydrogen fueled FCV as their solution). Course was taught in fall 2004 (47 students) and fall 2005.

Task 3: Develop and teach a graduate course in hydrogen generation, storage, and distribution

Developed a one credit hour graduate seminar course, Science and Technology for a Hydrogen Economy, introducing issues in hydrogen technology (UMD). The course addresses the following topics: (1) advanced well-to-wheel analysis, (2) H₂-production from hydrocarbons and/or coal, (3) photocatalytic water splitting, (4) H₂ storage in complex hydrides, (5) PEM fuel cells, and (6) H₂ safety. The course was offered live at UMD and by distance learning at Virginia Tech.

Taught a 3-hour graduate course in Fuel Cell Systems which focuses on fuel cell science and technology and which includes modules on hydrogen production, storage, and distribution (VT). The course was offered in spring 2005 (17 graduate students) and spring 2006 (14 graduate students).

Introduced hydrogen technology into the engineering curriculum (UMD). Participated in the submission of a formal proposal for new Energy Systems Engineering program that incorporates a hydrogen and renewables track.

Established a new mechanical engineering graduate course on sustainable energy engineering. This course was co-taught by the UMD co-PI (Radermacher). The course looks at "well-to-wheel" issues for transportation and challenges for implementing sustainable approaches to stationary power generation. The course complements the one hour seminar course on Science and Technology for a Hydrogen Economy.

Provided graduate student fellowships (VT and UMD) to support graduate students conducting research in the area of hydrogen energy systems.

Task 4: Develop and teach a one-day short course on hydrogen technology

Taught (VCC) half-day short course, "Basics of the Hydrogen Economy". Prepared and taught a half-day short course on hydrogen technology which was offered September 13, 2005, at the greater Greater Richmond Convention Center, Richmond, VA.

Developed (UMD) system level modeling tools to support short course educational activities. A flexible component-based modeling architecture was developed to simulate fuel cell systems as well as hydrogen generation and storage systems. The work is being

developed in support of a project with the Army Research Labs (in Adelphi, MD) and Ballard Power Systems (Vancouver, BC). Numerous component models including gas-to-gas humidifiers, compressors, hydrogen membranes, water-gas-shift reactors, and condensers can be linked to a PEM fuel cell model for system level studies. The future development of a user interface will allow these tools to be used by short course students in system integration exercises.

Task 5: Host a bimonthly Hydrogen Technology Seminar Series

Initiated new lecture series at UMD focusing on energy solutions. Greg Jackson has organized a seminar series on forward looking energy solutions with broad publicity throughout the greater Washington, DC area. This seminar series is sponsored by the Engineering College at UMD and replaces the H2TEC Seminar Series for which funding was not made available.

Task 6: Develop a hydrogen energy advocate program for K-12 teachers

No work completed on this task due to incomplete funding.

Task 7: Host learning center open house activities

No work completed on this task due to incomplete funding.

Task 8: Provide briefings at meetings of government and industry associations

Provided briefings regarding the Virginia Hydrogen Network (VCCC). Briefings, presentations, and reports describing the Virginia Hydrogen Network were provided to government and industrial representatives as follows:

US DoE Hydrogen Learning Workshop, Annapolis, MD, September 8, 2004

MidAtlantic Hydrogen Coalition Inaugural Meeting, Baltimore MD, September 20, 2004

Presentations to General Motors and Air Products, October 2004

Presentations to members of the Virginia General Assembly (Delegates Welch and McDonnell and Senators Rerras and Bolling), November and December 2004,

Report to the Virginia Department of Mines, Minerals, and Energy, 2004.

Coordinated the Virginia Hydrogen Economy Roundtable (VCCC). Organized (VCC) and made presentations (VT and VCC) at meetings of the “Virginia Hydrogen Economy Roundtable” which is an on-going effort to promote awareness of hydrogen energy efforts and opportunities in the state of Virginia. The Roundtable effort included the establishment of a Legislative sub-group and the establishment of an Education Subgroup which is tasked with facilitating the development of a hydrogen curriculum in Virginia at the K-12 as well as at the college level. The Roundtable is sponsored by the Virginia Department of Mines, Minerals, and Energy. Forums for Roundtable meetings included:

Virginia Economic Development Partnership in Richmond, VA, August 19, 2005.

Virginia Hydrogen Economy Roundtable Legislative Subgroup Meeting, Richmond, VA, October 27, 2005.

Virginia Economic Development Partnership in Richmond, VA, November 19, 2005.

Provided briefings on hydrogen technology and development efforts to Virginia state legislators (VCCC). Provided information on hydrogen technology and on hydrogen activities in Virginia to state legislators considering Virginia House Resolution 711 which expresses support for hydrogen efforts in Virginia including “encouraging the colleges and universities in Virginia to develop curricula to train engineers, managers, and workers at universities and community colleges in the field of hydrogen-based energy.” Resolution was passed.

Provided consultation to congressional staff and legislators regarding the Hydrogen Liberty Bill (UMD). Presented scientific presentation at Liberty Bill Announcement by congressional representatives in Washington D.C.

Provided briefings on hydrogen technology to staff members of the Virginia congressional delegation (VCCC). Met to discuss hydrogen technology with staff from the offices of U.S. Rep. Thelma Drake and U.S. Sen. George Allen.

Made scientific presentation to Army Research Lab on the status of fuel cell system integration for portable PEM fuel cell applications (UMD).

Task 9: Provide display and educational materials for selected public forums

Participated in public presentations regarding hydrogen technology. Presented information to the general public at the following forums (in addition to technical forums identified under the Publications/Presentations sections in preceding Section 4):

Presented large seminar to incoming freshman on fuel cell technology and issues for transition to a hydrogen-based energy infrastructure at the UMD College of Engineering.

"Fuel Cell and Hybrid Electric Vehicles; Are they the Answer?", invited presentation by Doug Nelson at the Roanoke Higher Education Center, Roanoke, VA, November 5, 2004. Attendance was approximately 50 people.

Provided equipment displays at public forums. Displayed or demonstrated hydrogen technology equipment at the following public forums:

“Virginia Tech Future Truck,” display illustrating a hydrogen fuel storage system and a hydrogen IC engine was presented at the Roanoke Civic Center as part of the Association of Energy Conservation Professionals (AECP) Energy Fair, Roanoke, VA, December 3-4, 2004. Attendance was approximately 1,000 people.

Displayed a fuel cell APU designed by the Hybrid Electric Vehicle Team of Virginia Tech (HEVT) at the Association of Energy Conservation Professionals (AECP) Energy Fair, Oct. 21-22, 2005 in Roanoke, Virginia (VT).

Initiated development of a hydrogen refueling demonstration project (VT). Began procurement of equipment and assembly of the development of a hydrogen refueling demonstration project using funding from the H2TEC grant as well as funding from the Virginia Department of Mines, Minerals, and Energy.

FINAL REPORT

SPENDING SCHEDULE

Budget Category	Approved Budget Per Agreement	Project Expenditures
		Cumulative to Date
Personnel	\$17,150.00	\$16,226.15
Fringe Benefits	\$3,496.00	\$2398.88
Travel		\$0
Equipment	\$26,151.00	\$15,330.91
Supplies	\$500.00	\$12,214.79
Contractual	\$67,233.00	\$67,335.20
Other - Tuition	\$2,172.00	\$4,398.75
Other - Renovations	\$8,943.00	\$4,627.50
Total Direct Charges	\$125,645.00	\$122,572.18
Indirect Charges	\$36,044.00	\$31,939.86
Total	\$161,689.00	\$154,512.04
STAC Share	\$118,038.00	\$118,164.24
Cost Share	\$43,651.00	\$36,347.80

Cost Share Contributions Schedule

Funding Source	Approved Cost Share		Cumulative to Date	
	Cash	In-Kind	Cash	In-Kind
Virginia Tech	\$24,346	\$0	\$17,042.78	\$0
UMCP	\$19,305	\$0	\$19,305.02	\$0
Total	\$43,651	\$0	\$36,347.80	\$0
Cumulative Cost Share Contributions			\$36,347.80	