Overview of Hydrogen and Fuel Cells in Washington State

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Introduction

In recent years a number of hydrogen and fuel cell efforts have developed in the state of Washington. However, there has been no organized effort for our state or multi-state region. This is in contrast to a number of energy and economic development strategies in other states (California and South Carolina are examples). This paper documents various hydrogen and fuel cell efforts within the state and fits them into a broader national and international context.

Hydrogen and Fuel Cell Context

The developed countries of the world are embarked upon an aggressive, well-financed and deeply coordinated effort to switch from petroleum-based economies to hydrogen-based economies. Worldwide there is a full-court press to complete the research, development, deployment, codes, and standards. A hydrogen economy is viewed as the end game, coupled with major vehicle efficiency improvements and biofuels as intermediate steps to shift the world away from oil. Key nations in these efforts include the United States, European Union, Canada, Japan, India, China, Australia and many others www.hydrogen.energy.gov/international.html. The first nation to make the conversion to a hydrogen economy will probably be Iceland, using their geothermal energy for electrolysis-based hydrogen.

In the United States, milestones of progress are established in the U.S. Department of Energy's (DOE) *Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan* www.eere.energy.gov/hydrogenandfuelcells/mypp/. The strong research efforts have resulted in the milestones being met on time or early. For example, second generation fuel cell vehicles are now available, which are a major step forward. The General Motors fuel cell vehicle has traveled 300 miles without refueling. The Toyota Highlander fuel cell vehicle has made the Yukon Highway trip from Fairbanks AK to British Columbia including a cold-weather start of -22 degrees F.

In 2008, DOE shifted gears in its efforts from what was called "technology validation" to early adoption and market transformation. Codes and standards have progressed to the point of establishing solid permitting pathways for hydrogen fueling stations. Areas of research focus continue in the hydrogen storage and fuel cell stack component areas (see pages 27-30 of DOE's *Fiscal Year 2009 Budget-in-Brief* www.eere.energy.gov/ba/pba/budget_09.html.

An excellent perspective on the status of the development of the hydrogen economy was presented at the 2008 National Hydrogen Association Conference www.hydrogenconference.org by Larry Burns, Vice-President for Planning and R&D, General Motors. General Motors has implemented "Project Driveway" to place their vehicles in the driveways of the Los Angeles Basin. They are ready with the cars, and he called on energy companies to supply 50 prime location hydrogen fueling stations at 700 bar (10,000 psi) pressure.

Hydrogen Production

According to the *Hydrogen Fueling Infrastructure Assessment* by General Motors "a large hydrogen production site exists today near almost every major U.S. city" and "53 percent of the hydrogen produced in the United States is used in oil refineries, enough to fuel 13 million fuel cell-electric vehicles" (page 7, 2007). There are four major international industrial bulk-quantity gas producers: 1) Air Products, 2) Praxair, 3) Linde (BOC merged with Linde in 2006), and 4) Air Liquide.

Washington's five oil refineries need/use hydrogen for desulphuring oil. Hydrogen production is divided into two categories: 1) Refinery hydrogen production, and 2) Merchant hydrogen production for general sale. Ammonia (NH3) production facilities can also be used as a source for hydrogen production. Within the state, the following plants/capabilities exist relating to hydrogen (data from the *Hydrogen Data Book* hydrogen.pnl.gov/cocoon/morf/hydrogen/article/103):

- Air Liquide, Kalama WA (formerly MG Industries) – Merchant hydrogen production capacity is 290 thousand standard cubic feet (scf)/day.
- BP West Coast Products LLC, Ferndale WA – Refinery hydrogen production capacity is 128 million scf/day.

Hydrogen Potential

Regarding future potential in the state of Washington for hydrogen production, the following options are emerging as technology progresses:

- Hydrogen is already produced at the Moses Lake chlor-alkai plant owned by Eka chemicals. Separation/capture of the hydrogen is a key challenge. The governments of British Columbia and Canada have made a major investment in this technical area. Contact Sacré-Davey Group in North Vancouver (604) 986-0663. The Moses Lake facility is close enough (within a 200-mile radius) to supply captured hydrogen to the Seattle/King County metropolitan area.

- The King County molten carbonate fuel cell (1.5 MW) can be restarted with a fuel cell stack change-out. The fuel cell waste gas stream contains approximately 20-23 percent hydrogen. Air Products and Chemicals in partnership with FuelCell Energy is doing research on separating out the hydrogen (6/27/08 communication with Ed Heydorn of Air Products and Chemicals).

- Hydrogen can be produced through electrolysis using our state's wide range of renewable electricity resources.

- Hydrogen can be produced with digester gas from numerous dairies and waste treatment plants in the state, thereby supplying electrical energy, heat, and fuel for hydrogen vehicles.

Early Markets and Adopters of Hydrogen/Fuel Cell Systems

An area of early adoption of fuel cells is the forklift market. These systems currently rely heavily on batteries for their use indoors at warehouse facilities. Fuel cells offer a great improvement in performance, maintenance, and efficiency and are set to replace the battery market within a few years. Fort Lewis has signed up for approximately 80 fuel-cell-powered fork lifts for use on the military base.

The Federal Communications Commission has proposed new backup power telecommunications regulations (an 8-hour requirement for cell towers). These proposed rules were triggered by the disaster of Hurricane Katrina (cell towers had only one hour of backup power). Fuel cells provide an option for secure, long term, reliable backup power for communication systems during states of emergency. Other backup power needs, such as at airports and data centers, may also now consider fuel cells.

On January 1, 2009, portable electronic devices powered by hydrogen micro-fuel-cell technology will be allowed on all U.S. commercial aircraft. Canada already has authorized their use. This technology can extend the power life of portable devices by up to two weeks on a single charge.

Hydrogen/Fuel Cell Companies

There is a growing number of Washington-based hydrogen and fuel cell related companies that are establishing themselves in the world marketplace and finding specific niches and roles. The companies range from those selling fully commercial products to various stages of research and product development start-ups. Among them are:

- **ReliOn** is the strongest of Washington fuel cell companies www.relion-inc.com/default.asp. It is based in Spokane and is a spin-off of Avista Laboratories, Inc. ReliOn is an industry leader in the stringent backup power marketplace. They have developed a patented, modular, cartridge-based, proton exchange membrane (PEM) fuel cell technology. Products range from 300 watt to 12 kW in size. Currently, they are marketing a range of stationary fuel cells for emergency and backup power requirements, uninterruptible power supplies, digital power needs and a variety of off-grid power requirements. They serve private and public entities as diverse as telecommunications, energy, transportation, and government. Their PEM fuel cells are commercially available today. They have sold and delivered more than 1,450 kW of fuel cells in the U.S. and abroad. They have had three rounds of equity financing.

- **EnerG2** is a Seattle-based nanomaterials company with one of its key focus areas being hydrogen storage www.energ2.com/Default.aspx. Their technology uses nanocomposites to resolve hydrogen storage density issues (a remaining hydrogen economy technical challenge). EnerG2 works closely with the University of Washington's Department of Materials Science & Engineering. They have received a Washington Technology Center grant.

- **Genesis Fueltech** is a Spokane-based company specializing in methanol/ethanol reforming to produce hydrogen www.genesisfueltech.com/. The company is in the process of being acquired by Orient Venture Capital of Vancouver, B.C. This company is in the product development stage. Products being developed include portable/mobile applications up to the 500 watt power range and rack-mounted units from 500 watts to 5 kW for remote and telecommunications backup power.

- **Alumi-Fuel Power, Inc.** (formerly Hydrogen Power, Inc.) is a Seattle-based company that has gone through several name/structure changes. There is no current website. Their focus is to produce hydrogen from water, aluminum and a catalyst. Their goal is to produce a hydrogen battery.

- **InnovaTek** is a Richland-based company located at the Applied Process Engineering Laboratory www.tekkie.com/index.asp. One of its specialties is hydrogen production for portable and backup/emergency power. Gasoline, diesel or biodiesel are feedstocks used in a reforming process to make the hydrogen. The InnovaGen Fuel Processor is in the beta prototype stage of development. The system uses patented technologies based on advanced catalysts and micro-structured components. The company is developing fuel-processing technology that will support the market for renewable fuels and for the production of hydrogen. InnovaTek has received funding from the Washington Technology Center and works in cooperation with both Washington State University and the University of Washington.

- **Neah Power Systems** is a Bothell-based company focused on micro fuel cells www.neahpower.com/index.html. Their fuel cell uses a 400-micron porous silicon structure as opposed to a 10-micron polymer membrane, yielding a more powerful and longer lasting fuel cell. Market focus is on mobile power needs.

Hydrogen Safety

Washington has the premier hydrogen safety training course for first responders in the U.S. The Volpentest HAMMER Training & Education Center is located in Richland, WA www.hammertraining.com/. HAMMER stands for Hazardous Materials Management and Emergency Response. Since the facility first opened in September 1997, HAMMER has played an integral role preparing workers and emergency responders for high-risk tasks and the use of new technologies. It is a unique complex, combining more training on hazardous materials and emergency response than any other

facility in the United States. It has now added a hydrogen safety training course with live/hands-on experience.

On-line hydrogen safety training for first responders can be found at www.hydrogen.energy.gov/firstresponders.html.

Pacific Northwest National Laboratory

The Pacific Northwest National Laboratory (PNNL) has a very strong of hydrogen/fuel cell effort. This effort includes:

- **Hydrogen Safety** – PNNL supports the development of hydrogen safety best practices h2bestpractices.org/. In addition, PNNL supports the development of hydrogen safety codes and standards to ensure safe handling of the fuel and construction of storage and dispensing systems.

- **Solid Oxide Fuel Cells** – PNNL has a long history in developing this high temperature fuel cell www.pnl.gov/energy/fuelcells/sofc.stm. Gary McVay of PNNL serves as co-leader of the Solid State Energy Conversion Alliance www.netl.doe.gov/technologies/coalpower/fuelcells/seca/.

- **Hydrogen Storage** – PNNL is part of the Chemical Hydrogen Storage Center of Excellence. The following link is to a 2008 progress report on the status of the research www.hydrogen.energy.gov/pdfs/review08/st_5_aardahl.pdf.

- **Hydrogen Data and Analysis** – PNNL developed the *Hydrogen Data Book* hydrogen.pnl.gov/cocoon/morf/hydrogen/article/103 as part of the Hydrogen Analysis Resource Center for the U.S. Department of Energy hydrogen.pnl.gov/cocoon/morf/hydrogen.

Existing Fuel Cells

According to data from FuelCell 2000 www.fuelcells.org/, at least 12 fuel cells have been installed in various locations around Washington. ReliOn has produced 10 of these, and the other two are from UTC Power and Fuel Cell Energy. The uses range from backup power to converting biogas to electricity, heat and hydrogen.

Higher Education Courses

Several of the state's universities have developed courses in hydrogen/fuel cells. Examples include:

- **University of Washington** (Seattle) courses include Chemical Engineering 345, Introduction to Fuel Cells; Mechanical Engineering 430, Advanced Energy

Conversion Systems; and Mechanical Engineering 406, Corrosion and Surface Treatment of Materials (includes a section on hydrogen).

- **Central Washington University** (Ellensburg) developed a hydrogen/fuel cell course curriculum with funding from the Department of Energy/Bonneville Power Administration. The professor has passed away, but efforts are being made to recover the information.

University Research Efforts

A number of our state's professors are engaged in hydrogen/fuel cell research.

- **Washington State University** has several research efforts. Dr. Su Ha's research includes production of hydrogen from biofuels, development of a liquid organic fuel cell and a formic acid fuel, and magnetic resource imaging of mass transport of water and fuel in PEM fuel cells www.chebe.wsu.edu/~suha/. Dr Shulin Chen is researching dark fermentative production of hydrogen from high solids food waste (funded by the Washington Department of Ecology) bsyse.wsu.edu/bbel/Main/Research/Biodiesel.html. Dr Grant Norton's research includes the use of applied nanotechnology to enable the hydrogen economy. For example, research is being conduced on using nanosprings to store hydrogen in automotive fuel tanks research.wsu.edu/world_class/clean_energy.html.

- **University of Washington** has a number of research efforts. They are consistently part of the U.S. Department of Energy Hydrogen Program's Annual Merit Review and Peer Evaluation www.hydrogen.energy.gov/annual_review08_proceedings.html. Following are four recent examples. Dr. Karen Goldberg has focused on hydrogen storage using catalysts for ammonia borane depts.washington.edu/chem/people/faculty/goldberg.html and Dr. Oleg Prezhdo has focused on solar hydrogen production in combination with electricity production depts.washington.edu/chem/people/faculty/prezhdo.html. Kai Strunz has focused on analysis of hydrogen infrastructure with a high penetration of renewable energy www.hydrogen.energy.gov/analysis_repository/project.cfm/PID=140. In microbiology, Dr. John Leigh researches hydrogen metabolism in methanogens www.hydrogen.energy.gov/annual_review08_basic.html#posters.

State Hydrogen/Fuel Cell Laws

Washington State has several pieces of legislation that focus on hydrogen/fuel cells:

1. **Retail Sales Tax and Use Tax Exemptions**: RCW 82.08.02567 provides for a sales tax exemption for machinery and equipment for fuel cells that generate electricity (expires June 30, 2009) apps.leg.wa.gov/RCW/default.aspx?cite=82.08.02567. In addition, RCW 82.12.02567 provides a use tax exemption on tangible personal

property for generating electricity of more than 200 watts (expires June 30, 2009 apps.leg.wa.gov/RCW/default.aspx?cite=82.12.02567.

2. **Climate and Rural Energy Development Center of WSU**: RCW 28B.30.640 includes fuel cells within the definition of "clean energy" and the Center is tasked with "…programs and industries promoting research, development, or commercialization of fuel cells…" apps.leg.wa.gov/rcw/default.aspx?cite=28B.30.640.

3. **Net Metering**: RCW 80.60, the net metering law for customer generation, includes fuel cells as one of the "net metering systems" for up to 100 kW (see RCW 80.60.010 (10) apps.leg.wa.gov/rcw/supdefault.aspx?cite=80.60&full=true).

4. **Green Highway**: RCW 43.325 (expires June 30, 2016) establishes the Energy Freedom Program. Within this chapter, green highway zones are established and hydrogen fuel is included as an alternative fuel (RCW 43.325.010(2)) apps.leg.wa.gov/rcw/default.aspx?cite=43.325.010. In addition, alternative fuels refueling projects may be funded by grant or loan per RCW 43.325.020(4) apps.leg.wa.gov/RCW/default.aspx?cite=43.325.020. Demonstration hydrogen vehicle fueling stations may be funded by the green energy incentive subaccount of the energy freedom account per RCW 43.325.040(2)(c) apps.leg.wa.gov/RCW/default.aspx?cite=43.325.040.

5. **Capital Construction of State Facilities**: RCW 43.19.651 requires that, when planning for the capital construction or renovation of a state facility, state agencies consider fuel cell technology as a primary source of power for applications that require an uninterruptible power source. State agencies must also consider fuel cells when planning the purchase of back-up or emergency power systems and remote power systems apps.leg.wa.gov/RCW/default.aspx?cite=43.19.651.

6. **Public Agencies Aggregate Purchasing by the Department of General Administration**: RCW 43.19.663 requires the Department of General Administration to investigate aggregate purchase of fuel cells apps.leg.wa.gov/RCW/default.aspx?cite=43.19.663.

7. **Motor Fuel Quality Act**: RCW 19.112.010 includes hydrogen fuel within the definition of alternative fuel apps.leg.wa.gov/RCW/default.aspx?cite=19.112.010.

8. **Exemption from Retail Sales Tax**: RCW 82.08.809 exempts new hydrogen-fueled vehicles from paying retail sales tax if the vehicle meets California emissions standards and Washington Department of Ecology emissions standards apps.leg.wa.gov/RCW/default.aspx?cite=82.08.809.

The Hydrogen Highway

The hydrogen highway, which is planned to run the length of Interstate 5 (Canada to Mexico), is behind schedule in its implementation. Currently, 66 hydrogen fueling stations are operating in and around the San Francisco and Los Angeles area. Reasons for the delay include permitting difficulties, local challenges and requirements, the lack of fuel cell vehicles on the market to patronize new H2 fueling stations, and the lack of fueling stations for new hydrogen vehicles. In Washington State two fueling stations are being considered.

Conclusions and Recommendations

The hydrogen economy is beginning to unfold. It is time for Washington State to further consider its hydrogen/fuel cell policy and initiative framework. A number of other states have made much stronger and more focused efforts in this regard. The early steps described above pre-position us for a solid approach.

Additional Information and Background Materials

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy maintains a national Information Center. The Information Center answers general and technical questions on the subject of hydrogen and fuel cells. The toll free line is 1-877-337-3463 and is operated by the Washington State University Extension Energy Program in Olympia WA. Two staff members (Dave Sjoding and Erin Hamernyik) have expertise in hydrogen/fuel cells.

The Washington State University Extension Energy Program library maintains a collection of technical books and periodicals on the subject of hydrogen and fuel cells. A list of books can be obtained by contacting the library at (360) 956-2076 or the on-line catalogue can be searched at www.energy.wsu.edu/library/.

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