

# **NHA Conference and Hydrogen Expo 2009**

**Columbia, South Carolina, USA  
30 March - 2 April 2009**

**Volume 1 of 4**

**ISBN: 978-1-61567-404-6**

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© (2009) by the National Hydrogen Association  
All rights reserved.

Printed by Curran Associates, Inc. (2009)

For permission requests, please contact the National Hydrogen Association  
at the address below.

National Hydrogen Association  
1211 Connecticut Avenue NW, Suite 600  
Washington, DC 20036-2701

Phone: (202) 223-5547

Fax: (202) 223-5537

[info@HydrogenAssociation.org](mailto:info@HydrogenAssociation.org)

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2634  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

# TABLE OF CONTENTS

## VOLUME 1

### KEYNOTE SESSION 1: U.S. GOVERNMENT

|   |    |
|---|----|
| <b>The Energy Evolution - An Analysis of Alternative Vehicles and Fuels to 2100</b> ..... | 1  |
| <i>Mike McGowan</i>   |    |
| <b>Presentation to the National Hydrogen Association</b> .....                            | 31 |
| <i>Richard Carlin</i>   |    |
| <b>The DOE Hydrogen Program - Maintaining Momentum and Powering Early Markets</b> .....   | 52 |
| <i>Joann Milliken, Sunita Satyapal, Joseph Stanford, David Bogomolny</i>                  |    |

### PARALLEL SESSION 1

#### ANALYSIS: ALTERNATIVE TRANSPORTATION COMPARISONS WITH HYDROGEN

|  |     |
|--|-----|
| <b>Cost-Benefit Analyses of Alternative Light Duty Transportation Options for the 21<sup>st</sup> Century</b> .....        | 79  |
| <i>C. E. Thomas</i>  |     |
| <b>San Antonio International Airport: A Strategic Plan For Alternative Fuels</b> .....                                     | 240 |
| <i>Steve Clermont</i>  |     |
| <b>Transition Costs for New Transportation Fuels: A Comparison of Hydrogen Fuel Cell and Plug-in Hybrid Vehicles</b> ..... | 262 |
| <i>Joan Ogden</i>  |     |
| <b>Worldwide Hydrogen Bus Demonstrations: 2002-2007</b> .....  | 300 |
| <i>Lauren Justice, Bob Rose</i>  |     |

#### EDUCATION: TRAINING A WORK FORCE

|   |     |
|---|-----|
| <b>Hydrogen Energy Workforce Development - A Collaboration with the Center of Hydrogen Research</b> ..... | 334 |
| <i>Susan Winsor, Fred Humes, Scott Greenway</i>   |     |
| <b>First Responder Safety Training</b> .....  | 354 |
| <i>R. Paul Williamson, John Cornish</i>   |     |
| <b>Teaching Fuel Cell Technology an Embedded Curriculum Approach</b> .....                                | 377 |
| <i>T. C. Chandler, I. Ortiz-Hernandez</i>   |     |
| <b>Training Opportunities in Fuel Cells</b> .....   | 393 |
| <i>Jennifer Seger</i>   |     |
| <b>From The Schoolhouse to the Statehouse - Hydrogen Education Activities at SERC</b> .....               | 398 |
| <i>Jim Zoellick</i>   |     |

#### PRODUCTION: BIOMASS

|   |     |
|---|-----|
| <b>Green Hydrogen Production by Carbon Sequestration of LFG and Other Biomethane</b> .....              | 413 |
| <i>M. Jangbarwala, J. Jangbarwala</i>   |     |
| <b>Next Generation Co-Production of H<sub>2</sub> and Power from a High Temperature Fuel Cell</b> ..... | 432 |
| <i>Fred Jahnke, Pinakin Patel, Ed Heydorn, Frank Holcomb</i>  |     |
| <b>Optimization of BioHydrogen Production from Switchgrass by Mixed Culture Fermentation</b> .....      | 459 |
| <i>Joe N. Emily, Nazimuddin Mohammed</i>  |     |

#### STATE PROGRAMS

|  |     |
|--|-----|
| <b>Alaska Village Survival: Energy Independence via Renewables Firmed as Hydrogen in Anhydrous Ammonia</b> ..... | 476 |
| <i>Bill Leighty</i>  |     |
| <b>Engaging and Growing Stakeholders through Members and Partners</b> .....                                      | 564 |
| <i>Shannon Baxter-Clemmons</i>   |     |

|  |     |
|--|-----|
| <b>Texas Hydrogen Roadmap</b> .....            | 577 |
| <i>David Hitchcock, Marc W. Melaina</i>        |     |
| <b>Hawaii Renewable Hydrogen Program</b> ..... | 583 |
| <i>Mitch Ewan, Rick Rocheleau</i>              |     |

## **STORAGE: CHEMICAL, LIQUIDS, AND OTHER**

|   |     |
|---|-----|
| <b>NH<sub>3</sub> - The Other Hydrogen</b> <sup>TM</sup> .....  | 611 |
| <i>N. Olson</i>   |     |
| <b>The U.S. Hydrogen Program: Status and Performance Gaps of On-board Hydrogen Storage Technologies</b> ..... | 653 |
| <i>Ned T. Stetson, Carole Read, Grace Ordazm, Monterey Gardiner, Sara Dillich</i>                             |     |

## **KEYNOTE SESSION 2: INTERNATIONAL**

|   |     |
|---|-----|
| <b>Hydrogen Energy Roadmap of India</b> .....                               | 680 |
| <i>R. K. Malhotra</i>   |     |
| <b>Hydrogen Activities at UNIDO-ICHET</b> .....                             | 710 |
| <i>Mustafa Hatipoglu, M. Suha Yazici, Nejat Veziroglu, Matthew M. Mench</i> |     |

## **VOLUME 2**

## **PARALLEL SESSION 2**

### **ANALYSIS: TRANSPORTATION AND INFRASTRUCTURE**

|   |     |
|---|-----|
| <b>Building a Transitional Hydrogen Infrastructure Using Warehouses as Lighthouse Projects</b> .....  | 736 |
| <i>Paul Lemar Jr., Eileen Schmura</i>   |     |
| <b>Hydrogen Demand and Resource Assessment</b> .....  | 752 |
| <i>Witt Sparks</i>  |     |
| <b>Hydrogen Infrastructure Analysis Using HyPro</b> .....   | 772 |
| <i>Julie Perez, Brian James</i>   |     |
| <b>Modeling Investment Strategies in the Transition to a Hydrogen Transportation Economy</b> .....  | 795 |
| <i>M. Mahalik, C. Stephan, G. Conzelmann, M. Mintz, G. Tolley, D. Jones</i>   |     |
| <b>Industry-Wide Light Duty Hydrogen Vehicle Fueling Protocol up to 70MPa: Created by Math Modeling and Confirmed by System Testing</b> ..... | 833 |
| <i>Jesse Schneider, Ian Sutherland, Mike Veenstra, Mark McDougall, Andrea Lubawy, Steve Mathison, Steffen Maus, Frederic Barth, Bob Boyd</i>  |     |

### **INTERNATIONAL PROGRAMS 1**

|   |     |
|---|-----|
| <b>HycleS - A European-International Project on Carbon-Free Hydrogen Production</b> ..... | 870 |
| <i>Martin Roab</i>  |     |
| <b>Regional Initiatives to Develop Hydrogen Economy: Aragon Case (Spain)</b> .....        | 892 |
| <i>L. Romero, J. Mora, I. Aso</i>   |     |
| <b>Hydrogen Initiatives in India</b> .....  | 914 |
| <i>Narendra Kumar Pal, R. K. Malhotra, Anand Kumar</i>                                    |     |

### **PRODUCTION: NEW MICROBIAL TECHNIQUES**

|  |     |
|--|-----|
| <b>Electrolyte Effects on Hydrogen Evolution and Solution Resistance in Microbial Electrolysis Cells</b> .....           | 967 |
| <i>Matthew D. Merrill, Bruce E. Logan</i>  |     |
| <b>Increasing in Hydrogen Production Rate of Microbial Electrolysis Cells (MECs) by Reducing Electrode Spacing</b> ..... | 991 |
| <i>Shaoan Cheng, E. Lalauette, Bruce E. Logan</i>  |     |

|  |             |
|--|-------------|
| <b>Hydrogen Production from Glycerol by Fermentation or by Electrohydrogenesis using MECs .....</b>      | <b>1016</b> |
| <i>Priscilla Selembo, Bruce Logan, Joe Perez</i>   |             |
| <b>Hydrogen from Lignocellulose by an Integrated Fermentation and Microbial Electrolysis System.....</b> | <b>1038</b> |
| <i>Pin-Ching Maness</i>  |             |

**PRODUCTION: NUCLEAR**

|   |             |
|---|-------------|
| <b>Dependable Hydrogen and Industrial Heat Generation from the Next Generation Nuclear Plant.....</b> | <b>1060</b> |
| <i>C. Park, M. Patterson, V. Maio, P. Sabharwall</i>  |             |
| <b>Thermal Efficiency of the Copper - Chlorine Cycle for Hydrogen Production.....</b>                 | <b>1086</b> |
| <i>Z. Wang, G. F. Naterer, K. Gabriel, R. Gravelins, V. Daggupati</i>                                 |             |

**TRANSPORTATION: HYDRAIL**

|   |             |
|---|-------------|
| <b>Recent Canadian Advances in Hydrail and Nuclear Based Hydrogen Production.....</b> | <b>1105</b> |
| <i>G. F. Naterer</i>  |             |
| <b>The International Hydrail Conferences.....</b>                                     | <b>1132</b> |
| <i>Barry L. Burks, Jason Hoyle, Stan Thompson</i>                                     |             |
| <b>Why Hydrail?.....</b>  | <b>1158</b> |
| <i>H. S. Thompson Jr.</i>   |             |
| <b>Tomorrow's Solution - Today.....</b>   | <b>1175</b> |
| <i>Dale Hill</i>  |             |

**FOCUS ON SOUTH CAROLINA**

|   |             |
|---|-------------|
| <b>Savannah River National Laboratory: Hydrogen Programs.....</b> | <b>1196</b> |
| <i>Samit K. Bhattacharyya</i>                                     |             |

**KEYNOTE SESSION 3: TRANSPORTATION**

|  |             |
|--|-------------|
| <b>GM Powertrain Strategy - Electrification of the Vehicle .....</b> | <b>1218</b> |
| <i>Charlie Freese</i>  |             |
| <b>Keynote Session 3: Transportation .....</b>                       | <b>1271</b> |
| <i>Markus Bachmeier</i>  |             |

**PARALLEL SESSION 3**

**EMERGING MARKETS: TRANSIT**

|   |             |
|---|-------------|
| <b>Hydrogen and Fuel Cell Development in the Southeast .....</b>                                    | <b>1295</b> |
| <i>Dan Raudebaugh</i>   |             |
| <b>Hydrogen Bus and Heavy Duty Hydrogen Vehicle Fueling Testing.....</b>                            | <b>1316</b> |
| <i>Nico Bouwkamp</i>  |             |
| <b>Hydrogen Fueling Infrastructure and Fuel Cell Bus Demonstration Program in Columbia, SC.....</b> | <b>1331</b> |
| <i>Jason Hanlin</i>   |             |
| <b>Hydrogen Powered, Maglev Personal Rapid Transit .....</b>  | <b>1353</b> |
| <i>Paul Williamson</i>  |             |

**OUTREACH: THE HYDROGEN ROAD TOUR – PANEL DISCUSSION**

|   |             |
|---|-------------|
| <b>Hydrogen Road Tour 08 .....</b>                  | <b>1377</b> |
| <i>Thomas Korn, Werner Lehner, Markus Schneider</i> |             |

## **PRODUCTION: SOLAR THERMAL**

|   |      |
|---|------|
| <b>Development of a Sulfur Dioxide-Depolarized Electrolyzer for the Production of Hydrogen</b> .....            | 1421 |
| <i>David Hobbs, Hector Colon-Mercado, Mark Elvington, John Steimke, Tim Steeper, David Herman, Bill Summers</i> |      |

## **VOLUME 3**

|   |      |
|---|------|
| <b>Hydrogen Production Using Solar Energy based on the Hybrid Sulfur Thermochemical Cycles</b> .....                    | 1442 |
| <i>William A. Summers</i>   |      |
| <b>Solar Hydrogen Production through Thermochemical Water Splitting with Photocatalytic or Electrolytic Steps</b> ..... | 1466 |
| <i>R. Taylor, R. Davenport, A. T-Raissi, N. Z. Muradov, C. Huang, S. Fenton, D. L. Block</i>                            |      |
| <b>Solar Cadmium Hydrogen Production Cycle</b> .....  | 1503 |
| <i>Bunsen Wong, Lloyd Brown, Bob Buckingham, Roger Rennels, Yitung Chen</i>   |      |

## **STORAGE HYDRIDES**

|   |      |
|---|------|
| <b>Solvent-Free Synthesis and Hydrogen Sorption Properties of Ammine Metal Borohydrides</b> ..... | 1525 |
| <i>Douglas A. Knight, Gilbert M. Brown, Joachim H. Scheibel, Claudia J. Rawn, Jianming Bai</i>    |      |
| <b>Regeneration of Sodium Borohydride for Hydrogen Storage</b> .....                              | 1543 |
| <i>Chan-Li Hsueh, Chien-Chang Hung, Ming-Shan Jeng, Fangei Tsau</i>                               |      |
| <b>Reversibility Aspect of Metal Borohydrides</b> .....   | 1571 |
| <i>Ming Au, R. Tom Walters</i>  |      |

## **INFRASTRUCTURE: HOME FUELING**

|  |      |
|--|------|
| <b>70MPa Residential Hydrogen Fueling Appliance (RHFA) Feasibility Study &amp; Needs for Commercialization</b> ..... | 1588 |
| <i>Jesse Schneider, Tony Lindsay, Julie Cairns</i>   |      |
| <b>Feasibility of Home Hydrogen Refueling (HHR) System for Advanced Plug-In Hydrogen Vehicle Applications</b> .....  | 1615 |
| <i>Michael Pien, Steven A. Lis, Radha Jalan</i>  |      |
| <b>High Pressure Electrolyzer Based Hydrogen Home Fueler</b> .....   | 1642 |
| <i>Deborah Moss, Martin Shimko</i>   |      |
| <b>High Pressure PEM Electrolysis to Enabled Home Hydrogen Fueling</b> .....   | 1656 |
| <i>E. Anderson, L. Dalton, M. Schiller</i>   |      |

## **KEYNOTE SESSION 4: EMERGING MARKETS**

|  |      |
|--|------|
| <b>Hydrogenics Corporation</b> .....     | 1681 |
| <i>Daryl Wilson</i>                      |      |
| <b>Material Handling Equipment</b> ..... | 1728 |
| <i>William Ryan</i>                      |      |

## **PARALLEL SESSION 4**

### **EMERGING MARKETS: MATERIAL HANDLING**

|   |      |
|---|------|
| <b>H2 Fuel Cell Material Handling Equipment Program at Ft. Lewis, WA</b> .....                            | 1749 |
| <i>Jason Hanlin</i>   |      |
| <b>Material Handling Industry - Paving the Way for the Fuel of the Future, Today</b> .....                | 1766 |
| <i>Tom Joseph</i>   |      |
| <b>DLA's H<sub>2</sub> Demonstration Project at Defense Depot Susquehanna, PA - Lessons Learned</b> ..... | 1789 |
| <i>Ken Burt</i>   |      |

## **DELIVERY**

|   |      |
|---|------|
| <b>Fatigue Performance of Composite Overwrapped Pressure Vessels</b> .....                        | 1807 |
| <i>Vladimir M. Shkolnikov, Kevin L. Klug, Michael A. Olson</i>                                    |      |
| <b>Hydrogen Infrastructure: Demand Variability and Infrastructure Diversity</b> .....             | 1841 |
| <i>Christopher Yang</i>   |      |
| <b>New Polymer/Metal Pipe Technologies for Pipeline Connected Offboard Hydrogen Storage</b> ..... | 1865 |
| <i>James G. Blencoe</i>   |      |
| <b>Reducing the Cost of Hydrogen Fueling Insights from Delivery Modeling</b> .....                | 1903 |
| <i>Marianne Mintz, Amgad Elgowainy</i>  |      |
| <b>Deformation and Fracture Properties of Carbon Steel in High Pressure Hydrogen</b> .....        | 1918 |
| <i>Andrew J. Duncan, Poh-Sang Lam, Thad Adams</i>   |      |

## **FUEL CELLS: STATIONARY APPLICATIONS**

|   |      |
|---|------|
| <b>Isolated Hybrid Installation to Cover Single Family House Electrical Consumptions with Hydrogen Storage (IH2 Project)</b> .....        | 1939 |
| <i>Joaquin Mora Larramona</i>   |      |
| <b>Savannah River National Laboratory Regenerative Fuel Cell Project</b> .....  | 1955 |
| <i>T. Motyka</i>  |      |
| <b>The Influence of Building Location on Combined Heat and Power/Hydrogen (Tri-Generation) Cost, Hydrogen Output and Efficiency</b> ..... | 2005 |
| <i>Darlene M. Steward, Mike Penev</i>   |      |
| <b>Transportation and Stationary Power Integration with Hydrogen and Fuel Cell Technology (Combined Heat, Hydrogen, and Power)</b> .....  | 2033 |
| <i>J. Rinebold</i>  |      |

## **PRODUCTION: WIND**

|  |      |
|--|------|
| <b>Green Hydrogen from Wind and Solar: Design, Construction and One Year Operation of the IHER Project</b> ..... | 2065 |
| <i>Luis Correa Uson, Ismael Aso Aguiar, Leire Romero Elu, Ernest Burkhalter, Armando Herosilla</i>               |      |
| <b>NREL Electrolyzer Capital Cost Study</b> .....  | 2092 |
| <i>G. Saur</i>   |      |
| <b>Wind-to-Hydrogen Demonstration Project</b> .....  | 2129 |
| <i>Kevin Harrison, Gregory Martin, Todd Ramsden</i>  |      |

## **VOLUME 4**

|   |      |
|---|------|
| <b>Wind-Hydrogen Feasibility Study: Terms of Investment Analysis - The TOTAL and ENERTRAG Cooperation to Develop an Integrated Wind-Hydrogen Approach</b> ..... | 2153 |
| <i>C. Retzke, P. Mulard, M. Wenske</i>  |      |

## **SAFETY, CODES & STANDARDS: SAFETY & PERMITTING**

|   |      |
|---|------|
| <b>Further Experiences in Permitting and Safety of Intergrated Hydrogen Systems</b> .....                                 | 2181 |
| <i>S. Schoenung, M. Weeda, M. Argumosa, B. Simonsen, H. Iskov, J. Liinssen, I. Aso, A. Gardier, M. Giller, E. Stewart</i> |      |
| <b>Identifying and Engaging Stakeholders for Regulating Codes in South Carolina</b> .....                                 | 2214 |
| <i>Chris Daetwyler</i>  |      |

## **FOCUS ON SOUTH CAROLINA**

|   |      |
|---|------|
| <b>Driving Innovation in the Automotive Industry Cluster</b> .....          | 2228 |
| <i>Chris Przirembel</i>   |      |
| <b>SCRA - 25 Years of Collaboration Innovation and Implementation</b> ..... | 2245 |
| <i>Bill Mahoney</i>   |      |

## **KEYNOTE SESSION 5: INFRASTRUCTURE**

|   |             |
|---|-------------|
| <b>Global Energy Challenges, Future Mobility and Hydrogen .....</b> | <b>2266</b> |
| <i>Duncan Macleod</i>   |             |

## **HYDROGEN STUDENT DESIGN CONTEST WINNING TEAM**

|   |             |
|---|-------------|
| <b>Renewable Resources Mark Estill Student Life Centre .....</b>  | <b>2273</b> |
| <i>Rob Enouy, Andea Murphy, Adrienne Nelson, Tim Pasche, Chris Rea, Ankit Sharma, Neal Tanaka, Michael Fowler</i> |             |

## **PARALLEL SESSION 5**

### **INFRASTRUCTURE: FUELING STATIONS**

|   |             |
|---|-------------|
| <b>Costs and Operational Data for the Humboldt State University Hydrogen Fueling Station.....</b> | <b>2293</b> |
| <i>A. Allen, P. Lehman, G. Chapman , C. Chamberlin</i>  |             |
| <b>Hydrogen in Fuel Retail Stations.....</b>  | <b>2309</b> |
| <i>Anne Marit Hansen, Gerd Petra Haugom, Sigrun Luras</i>   |             |
| <b>Zaragoza Hydrogen Filling Station.....</b>   | <b>2356</b> |
| <i>Joachuin Mora Larramona</i>  |             |

### **TRANSPORTATION: VARIED PROPULSION AND INFRASTRUCTURE SYSTEMS EXAMINED**

|   |             |
|---|-------------|
| <b>Battery Fuel Cell Hybrids - A Marraige of Convenience .....</b>                        | <b>2370</b> |
| <i>James Horwitz</i>  |             |
| <b>The Establishment of the Hydrogen Economy .....</b>                                    | <b>2408</b> |
| <i>Jose Ignacio Galindo</i>   |             |
| <b>H2Motive Fuel Cell Motorbike with Portable Hydrogen Filling in Endurance Test.....</b> | <b>2446</b> |
| <i>J. Weigl, I. Inayati, E. Zind</i>  |             |
| <b>National Fuel Cell Vehicle Learning Demonstration Nears Full Deployment.....</b>       | <b>2498</b> |
| <i>Keith Wipke, Sam Sprik, Jennifer Kurtz, Todd Ramsden, John Garbak</i>                  |             |

### **INTERNATIONAL PROGRAMS 2**

|  |             |
|--|-------------|
| <b>A Scandinavian Approach for a Multinational Hydrogen Highway .....</b>                              | <b>2525</b> |
| <i>Vera Ingunn Moe, Ulf Hafselid</i>   |             |
| <b>Estimating the Cost of a Low Carbon Hydrogen Supply in United States .....</b>                      | <b>2559</b> |
| <i>Christopher Yang, Joan, Ogden\</i>  |             |
| <b>Case Study: Hydrogen Sweden - A Public-Private Partnership Facilitating Early Narkets.....</b>      | <b>2581</b> |
| <i>Magnus Karlstrom</i>  |             |
| <b>A Public-Private Partnership Preparing for Commercialization of Hyrogen in Transportation .....</b> | <b>2596</b> |
| <i>Vera Ingunn Moe</i>   |             |

### **PRODUCTION: FOSSIL**

|   |             |
|---|-------------|
| <b>Development of Dense Hydrogen Separation Membranes.....</b>                          | <b>2623</b> |
| <i>U. Balachandran, T. H. Lee, Y. Lu, C. Y. Park, S. E. Dorris</i>                      |             |
| <b>Metal Foil Reactor Enables Performance Benefits in Stream Methane Reformers.....</b> | <b>2641</b> |
| <i>William Whittenberger, Dennis Norton</i>   |             |
| <b>Development of a Non-Noble Metal Hydrogen Purification System .....</b>              | <b>2670</b> |
| <i>P. S. Korinko, George B. Rawls Jr., Kyle S. Brinkman</i>                             |             |



**SAFETY, CODES & STANDARDS: RELEASES AND MITIGATION**

**Achievements of the EC Network of Excellence HySage** ..... 2702  
*T. Jordan*

**Development of Uniform Harm Criteria for use in Quantitative Risk Analysis of the Hydrogen  
Infrastructure** ..... 2747  
*J. Lachance, A. Tchouvelev, A. Engebo*

**A Numerical Study of Hydrogen or Helium Release and Mixing in Partially Confined Spaces** ..... 2793  
*K. Prasad, W. M. Pitts, J. C. Yang*

**Author Index**